

Aid Finance for Nine Power Supervision and Control Systems Projects

an Evaluation of SCADA Projects in Nine Countries

**Lennart Königson
Geir Kaasa**

**Department for Infrastructure
and Economic Co-operation**

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**Lennart Königson
Geir Kaasa**

Sida Evaluation 03/25

**Department for
Infrastructure and Economic
Co-operation**

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Sida Evaluation 03/25

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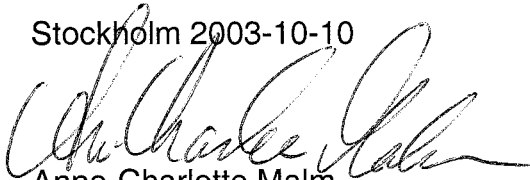
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PREFACE

The Evaluation of SCADA Projects in Nine Countries was carried out by Swedish Development Advisers in 2001. A seminar was arranged in November 2001 to discuss the conclusions presented in the draft report. Having received comments from Sida and from several consultants and ABB, Swedish Development Advisers submitted their Final Report in January, 2002.

Sida has, in a management response, concluded that the evaluation has provided plenty of fuel for thought, which has stimulated many useful discussions and contributed to the learning process. Many of the observations and conclusions relate to the proceedings between consultants/supplier and the buyer, in which Sida as a financier has a limited role. Sida has therefore found it appropriate to give the concerned consultants and supplier the opportunity to comment on the final report. These letters are attached as appendix 1 and 2 to the management response.

Stockholm 2003-10-10

A handwritten signature in black ink, appearing to read 'Anne-Charlotte Malm', written over the printed name.

Anne-Charlotte Malm
Head, Infrastructure Division
Sida

Department INEC	Division INFRA	Decision date 2003.06.17	Decision No. INEC/INFRA-474/03
Reporting Annika Johansson <i>[Signature]</i>		Reg. No. 2000-02345	
Approved by Head of INEC <i>[Signature]</i>		Signature <i>[Signature]</i>	
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Copy to Department/Division (orig) A. Johansson	Distr. (date/sign) 17/6 <i>[Signature]</i>
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Subject and decision

Management Response with Regard to "Aid Finance for Nine Swedish Hi-Tech Projects, an Evaluation of Aims and Outcomes of SCADA projects in Nine Countries"

Name of the Evaluation:	Aid Finance for Nine Swedish Hi-Tech Projects, an Evaluation of Aims and Outcomes of SCADA projects in Nine Countries
Country	Botswana, Ecuador, Jordan, Kenya, Lesotho, Pakistan, Vietnam, Zambia, Zimbabwe
Sector	Energy

DECISION

to approve the enclosed management response

Diarienummer:

Management Response to the Evaluation Report "Aid Finance for Nine Swedish Hi-Tech Projects, an Evaluation of Aims and Outcomes of SCADA Projects in Nine Countries"

1. Introduction

The evaluation comprises nine SCADA installations, of which seven were financed through concessionary credits handled by former BITS. Two of the systems were grant financed through former SIDA.

BITS and SIDA were operating under different mandates with each organisation having their own sets of guiding principles and routines for project assessment and decision. Since the merger of these organisations into Sida in 1995, principles and procedures for project selection have been under continuous development and are today very much streamlined. The evaluation was therefore launched with an awareness that conclusions may not necessarily have a bearing on the way Sida operates today. Still, the availability of nine developing country SCADA systems which had been in operation long enough to form the bases for an evaluation were considered as valuable reference material, with the ToR focused on technical and economical performance rather than the handling of the projects by SIDA/BITS.

Following the finalisation of the draft evaluation report, a seminar was arranged at Sida in November 2001, providing an opportunity for external parties earlier involved in the projects to comment on the findings.

2. Comments to main findings of the evaluation

Sida notes that the evaluation has found the nine projects to be highly successful with regard to implementation, operation and transfer of know-how. Since most of the systems have been successfully and reliably in use for many years after project completion, *Sida concludes* that the technology level as such has been appropriate in a developing country context and deemed useful for the operation of energy systems. This memo does not further deal with those positive aspects of the projects, since they do not call for further action by Sida.

Many of the observations and conclusions relate to the proceedings between consultants/supplier and the buyer, in which Sida as a financier has a limited role. Sida has therefore found it appropriate to give the concerned consultants and supplier the opportunity to comment on the final report (comments attached as annex 1 and 2).

Findings and conclusions of relevance for Sida's work have been compiled and commented upon under the headings below.

1. The role of the financier in the assessment of the SCADA projects

The evaluation points at a number of deficiencies in the handling of the projects by BITS/SIDA. The following weak points have been brought forward:

- Projects have not been justified through consistent problem analyses
- Insufficient assessment of the investments from a development perspective as opposed to commercial ambitions by other actors
- Low incentives for achieving cost efficiency and competitive pricing
- Insufficient financial and economic analyses before decision making

Since those findings belong to organisations which no longer exist, Sida has chosen not to seek to verify the correctness of the conclusions but rather to assess their bearing on the way those issues are handled today.

As for the situation today, *Sida notes* that all of the above areas are considered as key in Sida's assessment of new interventions. These issues are also subject to regular international discussion, where Sida takes an active part and seek to comply with best practise. Sida/INEC's project committees, where most projects are being dealt with at an initial stage as well as before a final decision is taken, are important fora to safeguard quality and compliance with best practise. *It is Sida's view* that this approach together with the current quality assurance mechanisms in place provides an adequate framework for dealing with infrastructure for economic development in a professional way, including the weak areas identified in the evaluation.

2. Financial and economic evaluation of SCADA systems after a few years of operation

In the cost-benefit analyses, the evaluator has chosen to restrict the "benefits" to those experienced by the operators of the SCADA systems. Based on these calculations, the evaluation arrives at the conclusion that the SCADA systems can neither be considered as having been financially nor economically justified.

Sida questions the validity of this conclusion with reference to the complexity of the benefits involved and related difficulties in quantifying them. Examples of benefits that occur at other levels, and therefore may not be experienced by the operators include:

- The role of SCADA systems in energy sector reforms. Most of Sida's partner countries are at some stage of sector reform, typically involving unbundling and commercialisation of generation, transmission and distribution as well as the establishment of independent power producers. In this context, a SCADA system plays a crucial role for the efficient handling of electricity transactions between the generation, transmission and distribution segments as well as for quality control purposes. Although it may be hard to quantify the SCADA system's marginal impacts on the benefits from power reforms, it is obvious that the economic benefits and the potentials for saving of public expenditures associated with such reforms in general are substantial.
- SCADA systems as a precondition for anything above "basic" power trade. Export/import of electricity requires monitoring of the quality of electricity as well as current information about the power system status. Regional power trade is an area of increased importance in many of the countries under evaluation, driven by the economic benefits of cooperation in the field of power supply. The Southern African Power Pool, the Coordinated Control Center in North Africa–Middle East as well as the emerging power trade within the East African Community are examples of such cooperation.

Energy sector reforms as well as regional power trade have been key ideas in energy sector policy development in Sida's partner countries during recent years. It can also be noted that to support these processes, SCADA systems have been regular components in most IFI financed sector programmes, as well as in investment programmes financed by developing country clients themselves. *It is Sida's view that*, in retrospect the financing of SCADA systems as such have been well in line with international best practise.

Further, the OECD guidelines on tied aid established in 1996 state that SCADA systems tend to be commercially viable and thus not eligible for tied concessionary financing in most countries. *Sida notes* that the result of the return calculations goes against the opinion of OECD.

Based on the same calculations, *the evaluation arrives* at the conclusion that the SCADA investments have yielded significantly lower financial and economic returns than alternative investments (e.g. in transmission or generation capacity) would have done. *Sida questions* the usefulness of such a

comparison, since a SCADA system also serves the purposes mentioned above which cannot be met by investment in transmission or generation capacity only.

3. Cost efficiency

The evaluation concludes that many of the SCADA systems have been much more expensive than the Norwegian SCADA systems used as a reference. *Sida has no independent view* on this, but notes that the model used for price comparisons has been seriously questioned by power sector professionals.

Sida is well aware of the difficulties related to the verification of competitive price levels in negotiated procurement of non-standardised technical equipment – SCADA system being one such example where all systems are unique with a corresponding uncertainty related to “fair pricing”. Today, Sida operates under a regulatory framework which strongly promote international competitive bidding, with the aim of safeguarding competitive price levels (see below on “tied aid”). *Sida is also aware* that from the buyer’s perspective, additional factors such as the availability of soft financing or different on-lending conditions suggested by individual donors may be weighted into the concept of “competitiveness”. In this respect, Sida seeks to promote donor harmonisation through various fora.

The evaluation further states that many of the preparatory studies for the investments lacked properly prepared financial and economic analyses. It is also claimed that many of the economic assessments were made by consultants with a clear interest in promoting more SCADA projects.

Sida shares the view that financial and economical analyses are of vital importance in the assessment of proposed investments. The concept of involving expertise independent from commercial actors in this work is fully in line with Sida’s standard procedures and is normally aimed at. At the same time, *Sida realises* that SCADA systems belong to a highly specialised field under rapid development, which efficiently reduces the number of experts with technical up-to-date knowledge fully independent of the SCADA business.

The evaluation also points at the lack of comparative analyses of alternatives. *Sida finds* this observation of limited relevance, taking into account the context and mandate under which BITS and SIDA were operating. In the case of BITS, the decision on financing was reactive, i.e. BITS got involved only after discussions between a competent buyer and seller had resulted in a contract. Consequently, it was not within the mandate of BITS to advice the purchaser not to proceed with a project or propose alternative investments. The former

SIDA, on the other hand, was operating in a wider sector context with a deep involvement already from the identification of possible interventions. This was often made as a part of a cooperation between multilateral financiers and donors based on a common analysis of the sector and a division of financing responsibilities for the most prioritised projects (as was the case in Zambia).

4. Tied aid

The evaluation brings forward a number of observations related to tied aid, which today mainly have a bearing on tied concessionary credits. The current overall framework for tied concessionary credits is largely the same as during the BITS period, while the international best practise has developed over time towards a stricter application of common agreements among financiers (such as the OECD Helsinki agreement) to prevent the use of tied concessionary credits in a way that markets are distorted.

For financing with tied concessionary credits, the projects should in principle be procured through an international competitive bidding procedure. Normally, Sida's offer is made for the financing of a specific tender from a Swedish company. In those cases where Swedish suppliers are awarded contracts, Sida's offer could be utilised for the financing of these parts of the projects.

The evaluation suggests that tied aid has led to non-competitive pricing of SCADA systems. In this context, it should be stressed that tied aid does not equal a non-competitive bidding process. On the contrary, most of the evaluated SCADA-projects have been procured in a competitive bidding procedure similar to the one described above. In a few cases, negotiated procurement has taken place with subsequent assessment of the price level. As mentioned above, the uncertainties associated with this process are larger than if competitive bidding is applied. *Sida fully agrees* with the conclusion that competitive bidding is one of the most efficient means to ensure a competitive price level. *Sida further notes* that Sida's current procurement rules prescribe competitive bidding irrespective of mode of financing.

Financing of investments through grants is by default untied today, with international competitive bidding as a rule.

"Increased export of Swedish made SCADA system" *is claimed by the evaluators* to be one of the objectives for BITS's operations, which is then used to measure the success of the projects. *Sida does not concur* with this assumed objective, which does not in a relevant way reflect BITS's broader objective of increased cooperation between Sweden and developing countries. This broader objective remains for concessionary credits today, but is

subordinated to Sida's overall goal to improve the living standard of the poor. The guiding principles for credit financing of investments have been further described in "Sida's policy for credit financed development cooperation".

Further, *Sida notes* that the attempts to evaluate buyer-seller relationships and the likeliness of future business for ABB fall outside the intended scope of the evaluation and *questions* whether the interview data collected from the current system operators is a relevant basis for far-reaching conclusions in this matter.

3. Implications for the future

The outcome of the evaluation suggests that the SCADA systems under study have performed well in the environment of a developing country and are being used in a sustainable manner (although only briefly touched upon in this memo). *It is Sida's view* that SCADA systems will continue to play an important role in the development of national and regional power supply systems. Although being a minor part of Sida's energy sector cooperation, it is reasonable to believe that Sida will continue to finance SCADA systems, when they are deemed appropriate in their sector context and in compliance with Sida's financing regulations.

Sida concludes that the evaluation has provided plenty of fuel for thought, which has stimulated many useful discussions and contributed to the learning process. As follows from the elaborations in earlier sections, *it is Sida's view* that Sida's current framework for project assessment provides the adequate means for a professional handling of the issues of relevance commented upon above. At the same time, the general movement towards international competitive bidding and un-tying of aid increasingly seen in Sida's cooperation programme contributes to promoting cost efficiency. Thus, *Sida does not consider* the outcome of the evaluation to call for any more specific actions to be taken.

SIDA
INEC / Infra
Annika Johansson
105 25 Stockholm

August 19, 2002

Dear Annika,

Re : Aid Finance for Nine Hi-Tech Projects

With reference to the titled project, SWECO jointly with SwedPower are pleased to forward our comments to the SDA report.

SDA has during execution of the work, approached us for initial input data and later for review comments which we have provided and commented to our best ability. Since the report is comprehensive we have, for obvious reasons, not been able to scrutinise and comment on all data in the report, but consider it essential to give the following general comments.

Choice of supportive area

SDA questions the priority between investments in SCADA or in primary power system for support. In the light of Sweden being a high tech country with a global reputation in using IT for efficient development and operation of the power industry, this conclusion seems questionable. It is important to keep in mind that the concerned countries approaches Sida for support in this specific area and that the priority has already been made earlier by themselves, often with support by others i.e. the World Bank.

The execution of the projects first phase (feasibility study) do not comprise the general analyse of the entire power industry and the priority of fields to support. The precondition is that a Network Management system is required.

Reformation

The Swedish support to the power industry by modern IT-tools has turned out too be extremely useful in order to support the reformation of the industry and consequently also protection of the environment. It has proved essential for a country to have Network Management systems in place to participate in regional co-operative work, since the character of electricity (production need to be made in the same moment as it is consumed) requires a continuous

supervision and control in order to function. The establishment of interconnections is always tied up with the existence of Network Management systems in each country to ensure no "export" of disturbances to neighbouring countries.

Both the South African Power Pool (SAPP) and the establishment of a Co-ordinated Control Centre (CCC) in North Africa – Middle East, can illustrate this fact.

The support of Swedish export

In the SDA report it is questioned if the Sida engagement in the area of Network Management systems has resulted in any Swedish export, apart for that financed by Sida.

As Consultants, we have during the last years managed to win a number of assignments, in international competition, within this area, financed by clients or third parties outside Sweden. The international interest for this relatively limited market has increased substantially the last decade due to the global trend of reformation and the insight of cost efficiency using IT in the power industry.

Sidas engagement in this area, since long, has actively contributed to the current success of Swedish project export. As illustrated by the fact that SWECO/SwedPower are currently involved in the following projects.

- Establishment of CCC in North Africa / Middle East, financed by Arab Fund
- NCC Sharja UAE, SCADA/EMS Load Dispatch Centre Implementation Project, financed by SEWA
- NCC Nigeria, SCADA/EMS Communication Study, financed by WB.
- NCC Kazakhstan, Transmission Rehabilitation Project SCADA/EMS part, financed by WB.
- AGOCO Libya, Messia Sarir Electrical SCADA System Study. Financed by AGOCO.

The few Swedish consultants with an international reputation within this area need to be viewed in the light of the relatively limited/specialised market and the limited number of international consultants in total. The successful international consultant firms within this area are less than 10. In order to manage this competition the conditions for numerous competitors in Sweden does not exists.

Investment costs

SDA states in their report that the investment cost for such projects in developing countries are substantially higher than compared to Sweden and indicates that this is due to non-competition. We have made a rough comparison of the costs for Swedish founded projects with similar projects in non-industrialised countries, financed by others and carried out by other consultants and suppliers.

The result shows a good conformity and that the projects financed by Sida is not more costly than others. This demonstrates, to our understanding, that it is not relevant to compare such projects in countries with long tradition and experience from IT-tools with projects in non-industrialised countries

International success

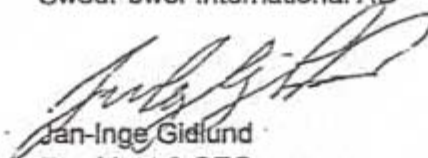
Both SWECO International and SwedPower International have been and is more and more involved in both IFI and Client financed SCADA projects. There is no doubt that our success depends to a significant degree on our experience and references gained from Sida financed projects. There is no way one can compete successfully on the international market without proven international experience in form of Company references and Employees CV's.

Yours sincerely,
SWECO International AB



Anders Ståhl
Vice President

SwedPower International AB



Jan-Inge Gidlund
President & CEO



Copy to

Sida
105 25 Stockholm

Dealt with by
John Pilling

Date
2002-08-23

Our Ref.

For the attention of
Annika Johansson, Programhandläggare
INEC/INFRA

Your date
2002-06-20

Your Ref.

Dear Sirs,

Aid Finance for Nine Swedish Hi-Tech Projects

We are pleased to submit our comments on the Report "Aid Finance for Nine Swedish Hi-Tech Projects" prepared by Swedish Development Advisors for Sida and dated January 2002.

SDA have produced a very comprehensive report on the nine SCADA projects financed by Sida and implemented by ABB. The issues raised by Sida in the Terms of Reference for SDA are important ones and ABB has worked closely with SDA for over a year to support them in their work. There are a number of points we should like to make too, as a supplement to the report:

General comments

An overriding goal for the international community's aid to poor countries is to pave the way for domestic and foreign commercial investments by means of institutional improvements aimed at market economy reforms. For the electricity sector, this means that SCADA/EMS systems are not just something "nice to have" but absolutely indispensable for the implementation of deregulation and privatisation. It is, therefore, surprising and disturbing that the SDA report, although impressively voluminous, lacks any reference to this fundamental observation. Had market reform aspects been adequately assessed, the overall conclusion would instead have been that Sida's support of SCADA has been particularly far-sighted and deserves corresponding recognition. These decisive merits relating the early introduction of SCADA do, of course, escape conventional financial analysis, a fact that is very clear from SDA's numerical exercises.

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Dealt with by
John Pilling

Date
2002-08-23

Our Ref.

Financial and Economic viability

In Chapter 7 SDA have presented the results of their financial and economic analysis. Unfortunately not all the figures used are included in the Report, which makes it impossible to fully verify their conclusions. There is an apparent contradiction that their study has found five of nine systems to have sharply negative rates of return although SCADA systems are generally accepted by the power industry worldwide and there are no western countries that manage their power networks without the help of them.

SDA have limited their study to only three benefits raised by those they interviewed and have chosen to ignore many others that could present a different picture such as savings in maintenance, losses and fuel, and postponement of major investments in network capacity enlargement.

Since SCADA systems are mandatory for the operation of complex electrical networks, particularly the deregulated and privatised networks of today, there is a tendency to sidestep the difficulties of quantifying and measuring the benefits as SDA have noted. It is analogous to the Utility telephone network, which everyone understands is essential, but which is also difficult to justify in a financial analysis.

This is particularly relevant in developing countries where networks are much less stable than those in industrialised countries and where there is a shortage of skilled personnel. The dilemma of the Utility in these countries is that even a well-qualified attempt to quantify SCADA profitability can fail due to subsidised tariffs, which are artificially low. The real SCADA benefit to society must utilise a higher value of power to attempt to quantify the cost of loss of power to hospitals, airports, offices and the like (typically ten times the actual Utility price)¹. In other words, what could be expressed as a loss-making investment on paper for the Utility is in fact an essential part of the network that improves the quality, economy and security of the electricity supply for the rest of society. It is like the investment in a fire station, which is, for the Municipality, a loss, but saves society lives and money.

Important environmental aspects are not mentioned at all in the SDA report – by optimising generation, for example, SCADA also helps to reduce harmful emissions including greenhouse gases.

Last but not least, SCADA helps developing countries to bridge the "Digital Divide", providing much needed experience for men and women in modern Information Technology. This aspect is not mentioned either in the SDA report, but is now of increasing importance as the electrical sector is reformed, unbundled and privatised. Today's "SCADA" does far more than just supervisory control: it must share data with electricity marketing organisations, independent power producers and neighbouring Utilities.

1. See, for example, Swedish State Power Board Report on Swedish Disturbance on 27-12-1983



Dealt with by
John Pilling

Date
2002-08-23

Our Ref.

Project Aims and Outcomes and The Project Initiation Process

In Chapter 3 SDA question whether the Utilities spending millions of dollars on major SCADA/EMS investments with the help of advisors like the World Bank, the Asian Development Bank, Électricité de France, Imatra Voima Oy, Mertz & McLellan and the Swedish State Power Board "could ... define their need for SCADA" and "could ... evaluate the benefits of something they knew very little if anything about"

And in Chapter 1 SDA have suggested alternative investments, which would have been better than SCADA, although in most cases the Utility had no SCADA at all. In each case the country concerned decided they needed SCADA; it was not something forced on them as SDA imply when they say that in most cases "... the owners' perceived influence over the process varied from low or limited to almost non-existent ..." The issue was what level of SCADA was appropriate rather than whether a transformer would have been better which is the solution to another problem.

SDA's comments demonstrate a regrettable lack of knowledge of the thorough and comprehensive approval process for major investments in the Utilities concerned. The decisions to place contracts with ABB were not taken until after the approval of a project committee, the consultant, technical and procurement management, senior management, the Board of Directors, the Ministry of Electricity and the Ministry of Finance. This process sometimes took over one year.

System relevance and cost

In Chapter 4 SDA have attempted to compare the cost of the nine SCADA systems studied with five systems in Norway and Sweden. Using a simplified model they have derived a cost per process point or process proportion, concluding that six of the systems studied were more highly priced than the Nordic systems.

SDA claim that an ABB SCADA specialist has reviewed their model and recommended modifications, which have all been taken into account. This is not correct. ABB have repeatedly stated that the SDA Model is grossly oversimplified and does not provide a sound basis for SDA's conclusions.

It costs more to provide a SCADA in Zimbabwe than it does in Sweden and the cost depends on the customer's needs and on existing conditions. SDA's model takes no account of the number of systems supplied in each country, software functions supplied (in particular non-standard functions which are project-specific developments), the ease of station access and planning of shutdowns required, the problems of documenting initial network status, transfer of technology, etc., etc



Dealt with by
John Pilling

Date
2002-08-23

Our Ref.

Promoting exports with Aid – is there sustainability?

In Chapter 6 SDA conclude that ABB's exports have not been strengthened permanently by the Swedish funding of SCADA projects. This is not correct either. Sida's support has substantially contributed to the leading position of ABB in the field of network management today. ABB's references include projects financed by multilateral organisations like the World Bank and the Asian Development Bank. The developments funded in the countries studied have been used elsewhere and, thanks to the good performance of the systems delivered and generally excellent customer relations built up over many years, there has been a steady stream of After Sales business following the initial system deliveries.

yours sincerely,

ABB Utilities AB

A handwritten signature in dark ink, appearing to read 'J. Pilling'.

John Pilling

Vice President, Export Sales

Aid Finance for Nine Swedish Hi-Tech Projects

An Evaluation of Aims and Outcomes of
SCADA Projects in Nine Countries

Part 1 The Report

For Sida
By Swedish Development Advisers AB
Gothenburg, January, 2002

Foreword and Acknowledgments

Aid projects are difficult to both design and implement. They are even more difficult to evaluate. A major reason is the fact that they involve many different parties with partly similar and partly different objectives. The outcome must meet at least some of the needs of those involved in order for the projects to serve its purpose. Different parties would therefore look for different outcomes of an evaluation and their incentive to contribute to the evaluation process would be contingent, in part, on the extent to which it would meet their objectives and serve their particular interests.

For this evaluation the Consultants have needed the help and assistance of a large number of parties to the nine projects under review. The relevance and correctness of the results are partly a function of the contribution offered by those parties. In order for the reader to make his or her own assessment of the relevance, completeness and correctness of this report the customary acknowledgements have been replaced by the Consultants' (subjective) assessment of the interest, accessibility and active assistance rendered by the key actors from whom the Consultants have solicited assistance.

Party	Role	Availability of staff	Access to data	Active assistance
Sida	Client	Moderate to low access to staff responsible for handling the projects	Complete access to all information available within Sida	Extensive assistance rendered by staff responsible for the evaluation
ABB	Supplier	Very good access to staff for interviews	Very good access to data in ABB files	Active assistance with respect to logistics, provision of data and with extensive comments on draft reports.
SWECO	Consultant	Moderate to low	Limited	Generous comments on draft report.
SwedPower	Consultant	Good – many staff members were interviewed by phone	Good – several documents were provided.	Help with data
IVO	Consultant	Good – former staff members were interviewed by phone	Very good – old documents were traced and sent to the Consultant	Active help in identifying additional information
BPC, Botswana	SCADA buyer	Very good	Good – BPC had prepared an extensive file for the evaluation	Help with data
CENANCE Ecuador	SCADA buyer	Exceptionally good	Complete access to all data that could be found	Active help in assessing benefits and verifying calculations
NEPCO Jordan	SCADA buyer	Good and very courteous	Full answers to all questions	Not requested
KPLC Kenya	SCADA buyer	Very good	Provided all requested information	Not requested
LEC	SCADA	Very limited	The evaluation had very	Not requested

Lesotho	buyer		low priority for LEC	
WAPDA Pakistan	SCADA buyer	No access granted	No data provided	Not requested
HCMC-PC Vietnam	SCADA buyer	Very good	Good access to data that existed within HCMC-PC	Helped actively in calculating benefits
ZESCO Zambia	SCADA buyer	Very good	Very good access to data	Helped supply extra data
ZESA Zimbabwe	SCADA buyer	Very good	Very good access to data	Helped supply extra data

In addition the Consultants have had the help of staff at Skagerack Kraft (formerly Vestfold Kraft), Buskerud Kraft, Jämtkraft, Borås Energi and Statnett, which has made possible a benchmarking analysis of considerable value for the evaluation. The Consultants would like to express particular appreciation for this assistance.

The Consultants' evaluation team has comprised Messrs Steinar Grongstad, Geir Kaasa (both from Norplan a/s), Lennart Königson, Jens Larssen and Helena Kästel (from Swedish Development Advisers ab). Project Manager has been Lennart Königson, who, with the assistance of Geir Kaasa, prepared this report. Jens Larssen and Helena Kästel assisted during the fieldwork, with research and with logistics and planning.

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Abbreviations

ARS	average RTU size
BITS	Beredningen för Internationellt Tekniskt och Ekonomiskt Samarbete
BPC	Botswana Power Corporation
CENACE	Corporacion Centro Nacional de Control de Energia
GDCC	Gaberone Distribution Control Center
HCMC-PC	Ho Chi Minh City Power Company
IRR	internal rate of return
KPLC	Kenya Power and Lighting Company
LEC	Lesotho Electricity Corporation
NCC	national control center
NEPCO	National Electric Power company
NPV	Net Present Value
NR	number of RTUs
plc	power line carrier
RCC	regional control center
RTU	Remote Terminal Unit
SC	System Category
SCADA	Supervisory Control and Data Acquisition
Sida	Swedish International Development Cooperation Agency
SIDA	Swedish International Development Authority (merged with BITS to become Sida in 1995)
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Corporation

Currencies and Measurements

Monetary values are unless otherwise stated in USD equivalents.
All measurements are metric.

Conclusions

Principal Findings

The Subject Matter

Two Swedish donor agencies have funded SCADA (Supervisory Control and Data Acquisition) systems for controlling power networks in a large number of developing countries. This evaluation covers nine SCADA systems that have been in continuous operation for five years or more. All have been funded in part by Swedish donor agencies. The systems under review belong to the national power companies in the following nine countries:

Botswana	Pakistan
Ecuador	Vietnam
Jordan	Zambia and
Kenya	Zimbabwe
Lesotho	

The SCADA hardware and software components for the nine projects were delivered by ABB while the systems' communication components were supplied by ABB associated or subcontracted companies. ABB has also been responsible for part of the know-how transfer components of the projects.

In total, approximately USD 150 million equivalent has been invested in these nine SCADA systems. Swedish aid has financed 55 percent of this amount, mainly by way of concessionary loans tied to purchases in Sweden. The customers, the national power companies in the countries concerned, have financed 14 percent and other donors the balance.

This evaluation has been commissioned by Sida. It seeks to evaluate the two objectives of the Swedish financial support for the projects; namely

- higher economic growth and development in the recipient countries, and
- increased exports of Swedish made SCADA systems.

Upsides and Downsides

The evaluation has found that the nine projects have been highly successful with respect to implementation, operation and transfer of know-how. With few exceptions the projects have been

- implemented and commissioned on time and within budgets,
- operated successfully and reliably for many years (up to 15 years at the longest), and
- accompanied by a comprehensive training and transfer of know-how program highly appreciated by almost all recipients.

The downsides are

- negative financial rates of return,
- low and for some projects negative economic investment return,
- high investment cost relative to system performance for a majority of the projects, and
- doubtful prospects for future Swedish SCADA exports to the nine countries concerned.

Implementation, Operation and Transfer of Know-how

Implementation appears to have been timely in all but one case (Pakistan¹). Cost overruns were few and in some instances there were investment cost savings. When overruns occurred the cause was usually delays during project preparation and procurement.

Three projects (Botswana, Vietnam and Zimbabwe) have encountered operational problems of some significance. In case of the two first mentioned the problems appear to have been poor system performance. This has, however, not impaired the basic functionality. The systems have been in continuous use and reliability has been high. In the case of Zimbabwe, the system that was specified by the national power company had inadequate capacity. This was subsequently amended.

Training has been provided by the supplier, through specially designed training assignments and by way of an annual training course in Sweden funded by a Swedish donor agency. Several of the operators have also been assisted in establishing local or in-house training facilities. The training efforts appear to have been quite successful and trained staff has, with few exceptions, remained with their original employers.

Objectives

Evaluations and Objectives

An evaluation should measure outcomes against objectives. In order to do so the evaluator has to answer the following questions:

- What were the objectives of the SCADA investments?
- Which were the options for achieving the objectives?
- Was the chosen measure the best and most cost effective option?

The two dominating reasons for funding the projects at hand with aid funds have been, on the one hand, economic development and, on the other, promotion of exports. The export objective follows from the fact that aid finance for the nine projects has been, for all intents and purposes, tied² and that there has been only one supplier – ABB. The economic growth objective should have been derived from a needs assessment in respect of the electric power sectors in the nine countries.

The early SCADA systems were developed in response to a very clear power sector need, namely that of reducing the need for staff in far away power plants and transformer stations. As SCADA systems evolved and developed it was found that they could also address a growing range of other power network issues such as fault finding in case of outages, optimization of transmission routing, economic dispatch, statistical analysis for maintenance purposes, etc.

Today's SCADA systems are, almost without exception, justified first and foremost by their capacity to reduce the duration of outages. Outage time is the period during which a network, or part thereof, is unable to deliver power to its users..

¹ Pakistan was the only country not visited by the Consultants and it has therefore not been possible to verify the stated reasons for the delay.

² Financing of the projects in Vietnam and Zambia was made with untied aid through negotiated procurement processes involving only ABB.

But proponents of SCADA systems correctly point to the fact that SCADA systems can deliver a broad range of benefits apart from outage reduction. However, the issue for this evaluation is not what SCADA could have achieved but rather WHAT IT DID PRODUCE and if it was THE BEST ALTERNATIVE for solving THE PROBLEMS FACED BY THE NETWORK at the time.

A logical problem solving framework, starting with problem formulation, continuing with alternatives, etc. as is shown in the graph to the right, has not been found for any of the nine projects.

Basic logical process	Analytical problem solving sequence
WHAT IS THE PROBLEM?	Quantify difference between current and desired results
WHERE DOES IT LIE?	Identify source/s of discrepancy between actual and desired results
WHY DOES IT EXIST?	Identify cause/s of discrepancy between actual and desired results
WHAT <u>COULD</u> BE DONE ABOUT IT?	Identify alternatives that could produce the desired result
WHAT <u>SHOULD</u> BE DONE ABOUT IT?	Evaluate alternatives and select the best

This evaluation has found that few if any of the preparatory studies contained clear descriptions of the problem/s to be solved and none of the documents discussed causes and alternatives. The focus has been on benefits – not on needs or problems to be resolved. In part, this may have been the consequence of multiple objectives. The development objective should have required BITS and SIDA to apply some version of the simplified logical framework shown above while the export objective dictated a different approach. It created a focus on the product rather than on the problem.

SCADA – an Export Potential to be Realized

BITS in particular, but also SIDA, have supported SCADA projects for the purpose of realizing the system's export potential. BITS' funds have been non-fungible, i.e. available only for financing the respective SCADA systems. With this objective and the restriction on the use of the aid funds there is no need to identify a problem and alternative solutions. SCADA becomes a solution looking for a problem that can serve as a basis on which the necessary economic justification can be founded.

The export objective

WHAT IS THE PROBLEM?	Low level of SCADA exports to poor countries
WHERE DOES IT LIE?	• Lack of awareness, • Lack of demand, • Heavy competition
WHY DOES IT EXIST?	• Lack of marketing • Lack of financing,
WHAT <u>COULD</u> BE DONE ABOUT IT?	• Arrange promotional courses • Arrange BITS financing
WHAT <u>SHOULD</u> BE DONE ABOUT IT?	Prepare technical study and economic project justification for aid financing

The export objective requires that obstacles, mainly lack of buyer finance and competition, be addressed. Concessionary financing would solve part of the financing problem and reduce competition. However, aid financing requires an economic justification, which makes it necessary to define scope, functions, cost as well as benefits. Guided by the export objective the problem solving process becomes a very different one. It makes the issue of alternatives superfluous. Difficulties in justifying the project can be handled by increasing the

economic value of the outage related benefits. As a rule, the economic assessments of SCADA projects argue that the extra power made available through improved power network control and management with a SCADA system should be given an economic value that equals the costs incurred by the users as a result of the loss of power through outages. This value is typically much higher than any tariff or market price of electric power. If this economic value is high enough it is possible to find an economic justification for almost any conceivable SCADA project.

A number of very comprehensive studies have been carried out in order to determine this value but the fact remains a single such value does not exist. It will differ from moment to moment, from country to country and from one user to another. The fallacy is that such values are seldom if ever used to evaluate alternative measures for reducing outages or generating any of the other benefits attributed to SCADA. This evaluation takes no stand as regards the “proper” economic value for power gained by way of outage duration reduction. It shows the internal rate of return for the value of electric power actually received by the respective power companies and discusses the probable rate of return for alternative investments that would serve the same or a similar purpose, i.e. reduce outages.

The Return on Investment

The cost benefit analysis used for the purpose of assessing the rate of return on the SCADA investments uses mainly *the current operators' own assessment* of the size and nature of the benefits that are rendered by their SCADA systems. There is general agreement among the projects' operators, supplier and consultants that the most important benefit to be derived from a SCADA system in a developing country is that of reduced outage time. In addition a SCADA system saves staff and may also create opportunities for more cost effective generation and transmission of power. These three benefits

1. decrease of outage time,
2. reduction of staff cost,
3. optimization of transmission and generation) have been assumed to correspond to the objectives of the investments.

They have been used in a cost benefit analysis of five of the nine SCADA projects³. Adequate data on outages have not been found for the remainder of the projects.

The five assessments show that the average internal rate of return on the investments has been very low irrespective of how the SCADA systems' contribution to increased network availability is valued. The projects are estimated to have *financial*⁴ internal rates of return of between –9 and –17 percent. The electric power gained by way of reduced outages must be given the values shown in the right column in the table below (*required revenue*) in order for the respective SCADA investments to yield an internal rate of return of 10 percent.

Country	Discounted financial rate of return (at actual revenue per kWh)	<i>Actual revenue</i> ⁵ (USD/kWh)	<i>Required revenue</i> for 10% IRR (USD/kWh)
Botswana	-17.2%	0.044	2.22
Ecuador	-6.8%	0.049	0.16
Vietnam	-16.0%	0.050	0.67
Zambia	-9.6%	0.027	5.18
Zimbabwe	-11.8%	0.029	2.20

The middle column shows the *actual revenue* per kWh sold by the respective networks. A comparison between *actual* and *required revenue* suggests that *actual revenues* are only a fraction of the revenue needed for rendering the projects financially viable with the possible exception of Ecuador⁶. *Actual revenue* per kWh would need to be 3.3 times higher in the case of Ecuador, 13 times higher in the case of Vietnam and over 50 times higher for Botswana, Zimbabwe and Zambia in order for the rate of return to equal 10 percent.

It should be noted that the return calculations do not take into consideration the optimization benefits that accrue over the long-term, as the power networks become gradually more and more complex. While these may eventually become substantial, the consensus among the operators of the five systems in respect was that, as of now, those benefits were still very small in their particular networks.

³ SCADA suppliers maintain that SCADA systems also deliver other benefits. This report takes no issue with this claim. It evaluates five specific projects for which the operators have specified the benefits derived under the particular circumstances that these systems are operated. These benefits may or may not be relevant for other SCADA systems.

⁴ Financial rate of return is that of the investing entity while the economic is that of society as a whole. The calculation of the financial return thus uses actual costs and revenues of the power company while the calculation of the economic rate of return is based on a hypothetical economic value derived from the benefits accruing to the users.

⁵ In the case of Botswana and Ecuador domestic power tariffs are market based while in Zambia and Zimbabwe they are determined by the government. Both national power companies are, however, required to be financially self sustainable.

⁶ The relatively low *required revenue* in the case of Ecuador is due to very particular and temporary circumstances and it is therefore not a representative value. In absence of these particular circumstances Ecuador's SCADA system would need an electricity value of USD 0.81 per kWh in order to yield a 10 percent IRR.

The Alternatives

The issue of alternatives is relevant mainly with respect to the problem of losses due to outages. Outages can be the result of a number of different factors. The review of the power sectors in the nine countries concerned that has been made in the context of this study, suggests that generating and transmission problems have been and continue to be the most common causes for outages. Adding generating capacity and/or improving the transmission system would therefore have served the same basic purpose as that of the outage reduction effect of SCADA, except that it would have addressed the most important cause while SCADA mitigates the symptoms.

Economic assessments of generation or transmission projects seldom if ever use the very high economic values for electric power that proponents for SCADA investments suggest are justified for the extra power that SCADA would make available. In case of SCADA investments in industrialized countries there is a logic behind this reasoning. It is that power networks outages in those countries seldom result from inadequate generating capacity or transmission system inadequacies. The argument of this study is that such a logic does not necessarily apply to developing countries.

With the values of power shown in the above table and used for calculating the internal rate of return for the SCADA projects, investments in improved transmission could be expected to yield positive returns in the range of between 20 and 30 percent. Similarly, seven smaller African power generating projects currently under construction in Southern and Eastern Africa can be estimated to generate returns ranging between 8 and 40 percent using a power value of USD 0.04 to 0.05 per kWh which is in line with that used for the financial return assessment of the SCADA projects.

This study therefore concludes that SCADA has not been a cost effective measure for reducing outages and delivering more power to consumers in five of the nine countries reviewed.

Development Aid or Export Promotion

This evaluation has concluded that none of the nine projects are likely to have resulted in export orders for ABB in the absence of aid. The cost, in the form of aid (on a grant basis) of creating an export market corresponding to USD 135 million in value for ABB's SCADA products⁷ and services, has corresponded to USD 37 million or 27 percent of the aggregate value of the deliveries. The rest of the financing has been on commercial or near commercial terms.

The comparison made in the course of this study suggests that total system asset costs for six of the SIDA/BITS funded projects have been considerably higher than the average for five Nordic SCADA project with comparable functionalities. In the case of the systems in Jordan and Zimbabwe the difference in cost as compared with the Nordic average was not higher than what could be explained by local conditions. A ninth project, the one in Pakistan, which could not be visited and for which the cost data is sketchy, may have had costs reasonably consistent with the higher range of the Nordic investment cost figures.

⁷ Part of the SCADA hardware was supplied by manufacturer associated with or subcontracted by ABB.

While there are several reasons why projects in, for instance, Africa cost more than in Sweden, the differences are larger than those factors can credibly explain. The fact that the two competitively priced SCADA systems represent two out of three that have been procured through fully competitive tendering processes is an indication that the pricing of the other projects may have been non-competitive⁸. The high costs may also have been the result of some over-design in terms of functions and system redundancy.

This comparison therefore suggests that a part of the USD 37 million in grant aid has benefited the supplier ABB by way of prices in excess of market prices prevailing at the same time in the Nordic countries. Factors that have contributed to this appear to have been:

- limited competition,
- insufficient comparative analysis of price quotations,
- over-design and excess redundancy, and
- incomplete and inconsistent economic and financial project appraisals.

The combined effect of these factors appears to be very limited contribution to economic development in spite of the fact that the projects themselves have been well implemented and successfully operated.

Is There a Contradiction?

SCADA systems are generally accepted by the power industry world wide as efficient means of improving the quality of technical management. Few western countries manage their power networks without the help of some kind of SCADA system. Yet this study has found five out of nine systems to have sharply negative rates of return. Can this apparent contradiction be explained?

The first observation is that SCADA systems were conceived and developed to meet the needs of the power sectors in industrialized countries. The issue of investment returns on SCADA systems in a developed as opposed to developing environment lies beyond the scope of this study. However, there are four factors that can explain, at least in part, the contradiction.

Staff reduction

SCADA systems were developed for the purpose of automation - to substitute men by machines. With the labor cost in industrialized countries even a small SCADA system can achieve costs reductions that could run into millions of US dollar annually. However, staff reduction has seldom if ever been a motive for SCADA investments in developing countries. None of the eight projects that were visited had installed SCADA systems for the purpose of reducing staff. Part of the reason is that staff cost is not nearly as large an item in most developing countries as in industrialized.

Optimization

Another factor is that of optimization. SCADA systems allow for a degree of fine-tuning and optimization, which is difficult to attain with a manually operated system, especially in the case of more sophisticated networks where there is a balance between supply and demand or, as is common, a generating overcapacity under normal load

⁸ ABB refers to its pricing policy not as market based but as "value based", i.e. related to the value it is assumed to create for the customer.

conditions. This is not the case in most developing countries. Many developing countries face a more or less constant excess demand for power, which results in extensive load shedding, frequent overload breakdowns and brownouts. Under those circumstances the scope for optimization is very limited.

In addition, most of the countries included in the review have relatively uncomplicated transmission networks with few alternatives for routing power to different consumption centers. This means in practice that there is little to optimize in case of transmission.

High investment cost

This report has concluded that, on average, the system investment and upgrading cost has been considerably higher in the nine countries concerned than what they appear to have been for systems with the same functionality in Sweden and Norway. In addition, the nine evaluated systems appear to have been somewhat over-designed and included more system redundancy than what is the norm in Nordic systems. The excess in investment cost as related to functionality has differed from project to project but in some cases it may have been 30 percent or more. With a 30 percent lower investment cost the rate of return would have been considerably better.

Value of lost power

The value of non-supplied power is a function of the security of supply that a system affords its customers. Where power outages and load shedding are common phenomena the value of non-supplied power will be low, perhaps not significantly higher than the tariff itself. In a country with almost 100 percent supply security loss of power will lead to large costs for society and its value is therefore high. In addition to having a much higher value of lost power, industrialized countries also have much better measures of what that value would be at any given time. There is either market information that makes it possible to determine the exact value or there are a number of sophisticated estimation models that serve a similar purpose. This makes possible much better return assessments for a SCADA investment.

Technically justifiable SCADA systems

The benefits to be derived from a SCADA system depend on the aggregate gains produced by the above factors. This in turn is contingent on the complexity of the system, which determines the amount of manual monitoring and supervision that would otherwise be necessary. On the basis of almost 30 years of SCADA operating experience the power industry in industrialized countries now knows reasonably well what level of complexity would justify a SCADA installation. In the subsequent chapters of this report this has been referred to as systems "*justified on technical grounds*". This suggests that the respective power system, had it been located in an industrialized country, would have been complex enough to justify an investment in a SCADA system.

Findings and Lessons

The following section summarizes the findings of the different sections of the report. It also contains some of the lessons the Consultants believe can be learnt from the nine projects at hand.

Evaluation aspects	Main findings	Some Lessons
Project Preparation	• A logical framework for the investment decision process starting with a definition of the problem to be solved appears not to have existed. • The preparatory studies lacked properly prepared financial and economic analysis that used a consistent analytical framework for all projects and for alternatives for achieving the investment purposes. This suggests that BITS and SIDA have not been sufficiently guided by their economic development objective. • Few of the nine projects appear to have been made subject to a thorough comparative analysis of investment costs. • Many economic assessments were made by consultants with a clear interest in promoting more SCADA projects.	⇒ The donor agency must assume responsibility for managing the preparatory work in such a manner that the development objectives, as opposed to commercial ambitions, become the defining parameters, for project scope and cost. ⇒ It is not reasonable to expect consultants to seriously question the viability of projects that may constitute part of their future market.
Project Initiation Process	• ABB, SwedPower and BITS have all played important roles in the initiation of the majority of the projects. The two projects where the customer has dominated the project preparation process appear to have been the most successful. • Few of the buyers viewed the consulting engineers as independent of ABB and/or Sida/BITS. • There appears to have been inadequate incentives for achieving cost-efficiency.	
System relevance and cost	• Most of the nine SCADA systems appear to be more sophisticated than required and they include an excess of back-up facilities (redundancy) • In six out of nine projects the investment costs have been considerably higher than those of comparable Nordic networks with ABB systems. • The complexity of the power networks in all countries but Botswana and Lesotho would have warranted SCADA systems had they existed in industrialized countries	⇒ Competent and resource-rich suppliers such as ABB need to be balanced by interests that promote cost efficiency and competitive pricing. This is of particular importance during the project initiation and preparation phase. The record suggests that such a balance has not been achieved in many of the projects under review.

Using the investment	• The buyers/owners have, by and large, been able to secure system objectives. All systems function with good reliability. • There has been little staff turnover and the staff is generally well trained and competent • Maintenance is a major problem caused in part by high spare part prices and slow after sale service. Several of the nine networks maintain that lacking after sale service on the part of ABB has prevented them from getting full use of their systems • The project versus process issue is moot. The relatively small differences in upgrading practices between Nordic and developing country systems are easily explained by higher prices and non-fungible aid funds.	Ensuring that hi-tech products and services developed for markets in industrialized countries meet the priority needs of a customer in a developing country is difficult but critical for the development impact of an investment. Networks in developing countries often face other problems that those for which hi-tech products are developed.
Aiding Sustainable Exports	• BITS and Sida funds have supported SCADA export efforts in several different ways. There is a need to examine if this leads to sustainable export markets for the industries concerned. • A number of buyer-seller relationships are strained and it appears that ABB has not been able to manage the "lock-in" and dependency aspects of the relationship with several of its customers in an optimal manner. • There is little to suggest that the projects and the tied aid have helped ABB create a sustainable market in the countries concerned. The two SCADA operators who have outgrown their old ABB systems appear to favor other suppliers. The best export business prospects continue to be aid-funded projects.	A donor agency that provides funding for a monopoly supplier needs to ensure that the monopoly is not used to the detriment of the aid objectives. It is probable that the pricing policy pursued by ABB has reduced the sustainability of the projects in that it has curtailed upgradings and restricted spending on maintenance.
Costs and Benefits	• SCADA systems cannot be justified, neither financially nor economically, by increased power supply due to reduction of outage time or by optimization of transmission and generation processes. All five SCADA systems for which return assessments have been made show negative financial returns. Three would require unrealistic electricity values in order to be economically viable. • The SCADA investments have yielded significantly lower financial and economic returns than alternative investments in better transmission facilities or higher generating capacity would have done.	Economic analysis of investment projects should, whenever possible, compare different investment alternatives.

Chapter 1 Project Aims and Outcomes

Introduction

Purpose of the Evaluation

Hindsight is of no value unless it creates insight. The report at hand is an exercise in hindsight for the purpose of learning from the experience gained that may be gained through nine projects to set up and operate automated power network control and management systems, also referred to as SCADA systems.

SCADA is an abbreviation of "Supervisory Control and Data Acquisition" which refers to automated remote control systems that collect data, transmit it to a central control unit where it is processed and/or stored. In later generation SCADA systems the central unit can also issue commands to a remote unit. There are many types of "SCADAs" and they are used to supervise and manage complex systems in different industries and sectors. The complexity of remote control systems vary from passive analogue systems to fully computerized digital systems for active control with software for optimizing flows and processes. The essence of all of those systems is, however, that of automation, i.e. replacing man by machines. Later generation systems designed for more complex network also serve the purpose of production and load flow optimization.

This study deals with nine power network "SCADAs". These projects were initiated during the period 1985 to 1995 and funded in part with Swedish concessionary loans and development grants. The Swedish International Development Cooperation Agency (Sida) has commissioned this evaluation.

The main objectives of the evaluation are, according to the Terms of Reference (see appendix 1), "to generate lessons and summarize experiences for possible application to similar projects in the future". The evaluation should in particular:

- evaluate if the scope of the projects and the chosen level of technology of the installed systems have been appropriate for the requirements of the power sectors in the concerned countries and whether or not the systems are sustainable; and
- determine whether or not the various SCADA installations have been financially and economically viable.

Swedish Development Advisers ab in association with Norplan a/s (both hereinafter referred to as the Consultants) was commissioned by Sida to carry out the study in November 2000. An Inception Report was produced in January 2001 and in the period March to June the Consultants visited eight of the nine projects.

This report summarizes the findings of the Consultants. Working documents and other relevant material is contained in a separate volume comprising 10 appendices.

Study Methodology and Implementation

The methodology used comprised four sets of complementary activities, namely

- compilation of a project data base (Project Fact Sheets) using information accessible in Sweden (principally in Sida's archives),

- verification of data collected in Sweden with Swedish actors (the supplier and the engineering consultants) and by way of Internet communication with SCADA operators in the nine countries,
- further verification of the Project Fact Sheets and gathering additional data through semi-structured interviews with relevant staff at the various power networks and SCADA control centers in eight of the nine countries, and
- benchmarking of technical and cost parameters of the evaluated projects with comparative data from SCADA installations in Norway and Sweden.

The study was carried out in two phases. Firstly, a desk study based on documents available in Sweden comprising:

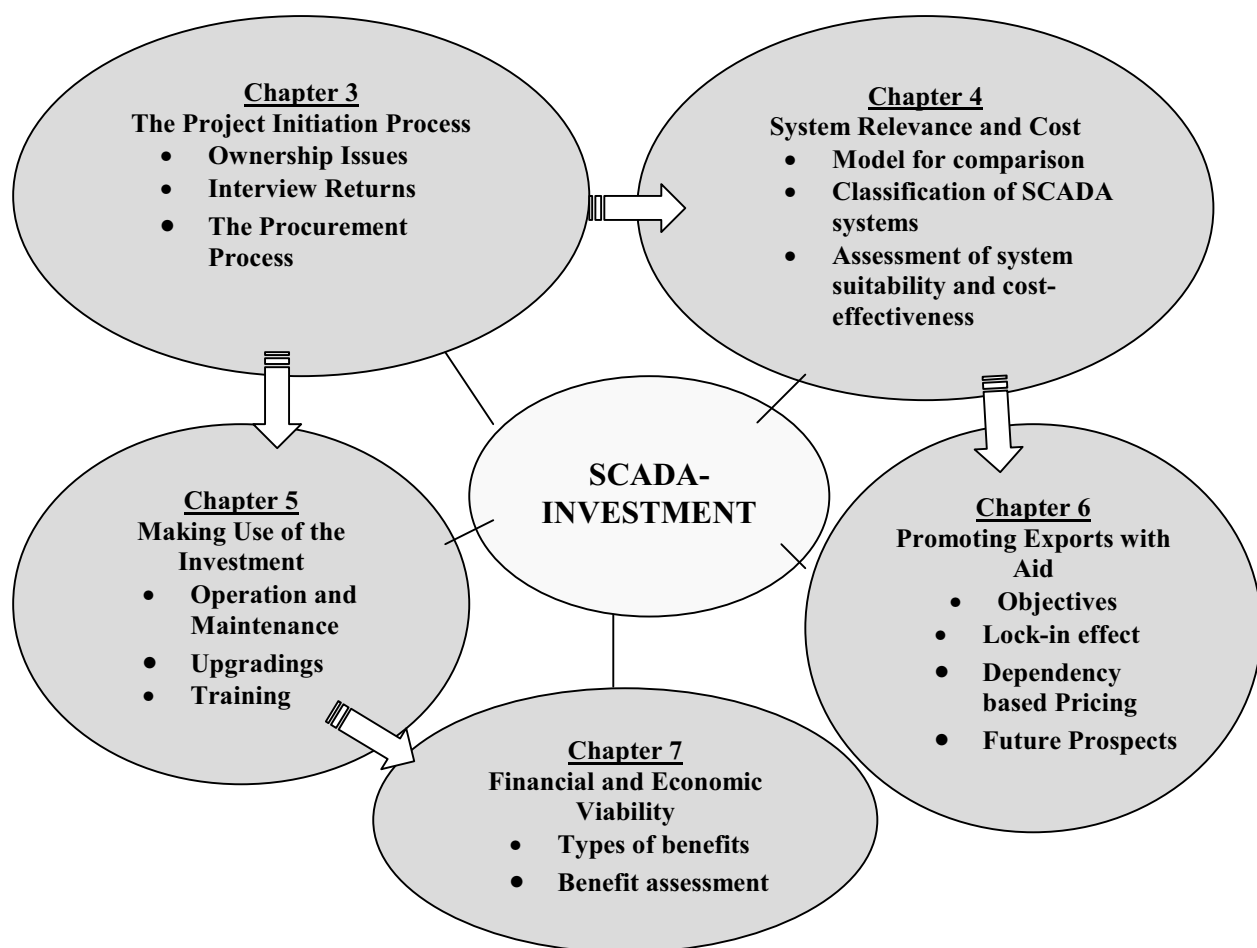
- Analysis of available reports and studies prepared by consultants involved in different stages of the nine projects,
- Compilation of statistics for the electricity sectors in the countries concerned (this and the preceding step were aimed at establishing baseline data on network needs and requirements),
- Analysis and compilation of economic and technical data related to the installed SCADA-systems, and
- Interviews with ABB staff responsible for the respective countries and others (mainly engineering consultants).

Secondly, field visits were carried out in all but one of the nine projects and countries. The Pakistani operator WAPDA, which was contacted directly and through both Sida, the Swedish Embassy in Islamabad and ABB's country representative, was not in a position to receive the Consultants.

The field visits were preceded by emailed information as to the aim of both the study and the visit as well as the methodology used and the information that was sought by the Consultants. The field visits consisted of semi-structured interviews using a set of questionnaires, which was common for all operators (see Appendix 4). This approach was used in order to ensure that the data and information collected would, as far as possible, be consistent and comparable.

Content of the Report

In order to respond to the need for identifying lessons to be learned the Consultants have focused the study on the five interrelated issues that are shown in the figure overleaf. Each of these aspects is discussed in separate chapters following upon Chapter 2, which describes SCADA and the Project Context in each of the nine countries.



Chapter 3 discusses the extent to which the project initiation process has been user or supplier driven. The hypothesis being that this is likely to impact on scope, relevance and cost of the system as well as on the use of the investment.

Chapter 4 deals with system relevance and costs as it seeks to determine the extent to which the scope and the chosen level of technology have been relevant for the buyers' needs and how the costs of the various systems compare with that of SCADA systems purchased by actors operating under market conditions.

Chapter 5 reviews the extent to which the buyers/operators have been able to use and maintain the systems. A comparison is made with the upgrading practices in Norway and Sweden in an effort to respond to the concern that developing country operators do not appreciate sufficiently SCADA systems character of process rather than projects. The training and know-how components of the projects are also examined.

Chapter 6 discusses the supplier-buyer relationship, which was a subject raised by virtually all interviewed operators in the eight countries that were visited. Aid is tied for the purpose of promoting exports. What have been the results?

Very few of the studies that preceded the SCADA investments under review included baseline data for subsequent assessment of quantifiable benefits. One reason is likely to have been the dearth of data as regards outages. This evaluation had to concluded that data to support cost benefit assessments could be found for only five out of eight

projects that were visited. The results of the financial and economic analysis of these five cases are, however, sufficiently consistent for the Consultants to conclude that they apply for all SCADA projects. The cost benefit analysis is presented in Chapter 7.

The Projects

Main Project Coordinates

The evaluation comprises the nine SCADA projects that are listed below. The table also contains some basic information on time of investment, type of system and current owner/operator⁹.

Countries	Year of investment	Type of system	Owner/customer
Botswana	1985	SINDAC 3	Botswana Power Corporation (BPC)
	1996	SPIDER 7c	
Ecuador	1992	SPIDER	CENACE
Jordan	1985	SINDAC 5	National Electricity Power Company Organization (NEPCO)
Kenya	1989	2 SINDAC 3	Kenya Power & Lighting Company (KPLC)
	1990	SINDAC 5	
Lesotho	1986	SINDAC 1	Lesotho Electricity Corporation (LEC)
Pakistan	1989	SINDAC 5	Water and Power Development Authority (WAPDA)
		SINDAC 3	
Vietnam	1991	PC-based interim system	Ho Chi Minh City Power Company (HCMCPC)
	1999	SPIDER	
Zambia	1996	SPIDER	Zambia Electricity Supply Corporation (ZESCO)
Zimbabwe	1985	SINDAC 5	Zimbabwe Electricity Supplier Authority (ZESA)
	1987	SINDAC 3	
	1994	SPIDER	

Eight of the projects are SCADA systems for the supervision of national networks and one (the one in the Ho Chi Minh City region in Vietnam) for supervision of a regional and urban transmission and distribution system.

Aggregate Project Cost and Sources of Financing

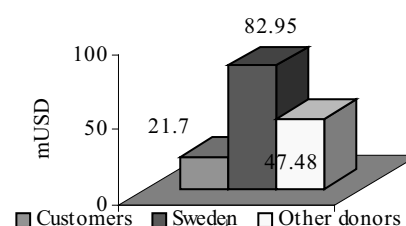
The amount of funds invested in the nine projects as well as the cost of the support rendered by Sida is shown in the following table (in USD million equivalent).

⁹ Because of power sector restructuring current owners/operators are not identical with original owners/customers in the case of Ecuador, Jordan, Pakistan and Vietnam. The reorganizations in those countries are not considered to have had any implications of relevance for this evaluation.

	Financing by client	Swedish financing	Other donors	Total	Grant portion of Swedish funding
Botswana	1.92	3.49		5.41	1.95
Ecuador	1.89	14.41		16.30	5.41
Jordan	5.84	8.00		13.84	1.72
Kenya	2.86	14.01	1.80	18.67	5.86
Lesotho	0.91	2.33	4.11	7.35	1.47
Pakistan	3.43	4.10	37.86	45.39	1.02
Vietnam	1.73	5.19		6.92	5.92
Zambia		11.96	3.71	15.67	11.72
Zimbabwe	3.12	19.46		22.58	4.82
Total	21.70	82.95	47.48	152.13	39.89

Close to USD 150 million¹⁰ has been invested in the nine systems over the period 1985 to 2000. This includes preparatory work by consultants (feasibility studies, design, specifications, procurement documents, etc.) and also hardware as well as software with installation, training¹¹ and various upgradings.

Of this amount Sweden, through two development cooperation agencies (SIDA and prior to 1995 BITS¹²), funded the largest part, some USD¹³ 83 million equivalent, which corresponds to 55 percent. The owners/customers financed 14 percent and other donors the balance - 34 percent. The grant portion of the Swedish funding amounted to USD 40 million, which corresponds to 26 percent of total funding.



Project Fact Sheets

Information on the project development and investment process along with other project information has been collated in Project Fact Sheets - one for each of the nine projects.

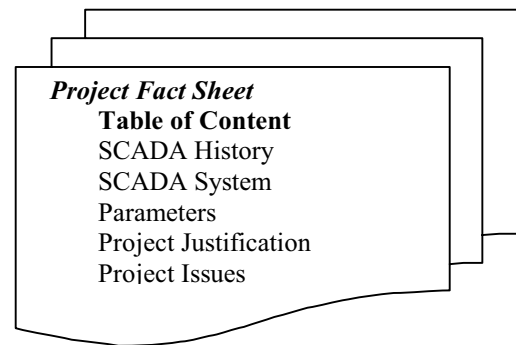
¹⁰Data on local costs have been difficult to find and it is probable that the total shown above is an understatement.

¹¹ Norad and SIDA have funded a training center in Zambia for the purpose of, among other things, SCADA training. This investment of approximately USD 8 million equivalent was intended to serve the training needs of many African countries and has therefore not been included in the SCADA investment total.

¹² Swedish funding for the concerned projects was initially provided by a specialized concessionary loan agency (Beredningen för Internationellt Tekniskt och Ekonomiskt Samarbete - BITS) and, in the case of grants, by the Swedish International Development Authority (SIDA). The two agencies were merged on July 1st 1995 and were thereafter called Sida (Swedish International Development Cooperation Agency).

¹³ Swedish funding in SEK has been converted to USD at the average exchange rate for the year preceding the commissioning of the SCADA system or the year when most of the consulting assignment was carried out. Details are given in Appendix 3. The exchange rate used in the contracts between ABB and the buyers do not always agree with the ones used in the Project Fact Sheets but this is unlikely to have but a marginal impact on the totals.

The Project Fact Sheets are enclosed in Appendix 3.



Purpose, Objectives and Achievements

The Essence of SCADA

The essence of a SCADA system is that of efficiency. SCADA makes it possible for fewer people to produce more and better electricity. It does this by providing supervisory control of a power network from a single control center. Remote Terminal Units (RTUs) at substations scan the voltages, currents, relays, etc. constantly and are polled regularly by the control center to give a continuously updated picture of the network. The control center operator is shown the raw data input from the stations which would otherwise be monitored by supervisory staff at the substation in respect. One control center operator can therefore monitor a large number of substations, each of which would otherwise need a full complement of monitoring staff. A SCADA system can also include Automatic Generation Control (AGC) for the control of frequency and a software module that can check the raw data for consistency and suggest alternative values where it detects wrong data.

In short SCADA is

- automated collection of data,
- transmission of data from the RTUs to a central processing and system management unit (control center),
- compilation and presentation of the data in a control center, and
- issuance of commands to the RTUs.

For less complicated power networks a SCADA system and its control center staff does what a trained staff complement located at different points of a power network would otherwise do. Its original purpose was to replace monitoring staff at a power network's control points with machines (RTUs). However, today's SCADA systems collect, transmit and process more information per unit of time than manual systems can do and it automatically checks the information and helps eliminate human errors.

The computing capacity of a SCADA system improves the scope for managing and controlling larger interconnected power network systems through fewer control centers. In the absence of a SCADA system, management of networks would require a hierarchy of control centers and each network would be smaller. In practical terms, software such as EMS and AGC allows for better optimization of respectively transmission losses and power production in large interconnected networks with many power production units.

Apart from reducing staff and shortening reaction time for some tasks, SCADA also reduces the risk for accidents since it decreases the staff's exposure to dangers near transformers and high voltage equipment.

For less complex power networks a SCADA system offer mainly two benefits, namely

1. *reduction of manning needs (labor savings) and*
2. *faster restoration of power in connection with outages (outage reduction).*

Even though developing countries have much lower labor costs than industrialized countries the former may still justify an investment in a SCADA system by the fact that well trained and experienced staff is in very short supply.

Beyond a certain point of network size and complexity it becomes impractical to manage without a remote control system in one form or another. Beyond this point a SCADA system would yield a third benefit, namely

For large, well-balanced and complex systems there is a third benefit to be gained, namely

3. *better usage of transmission and generating capacity (optimization benefit).*

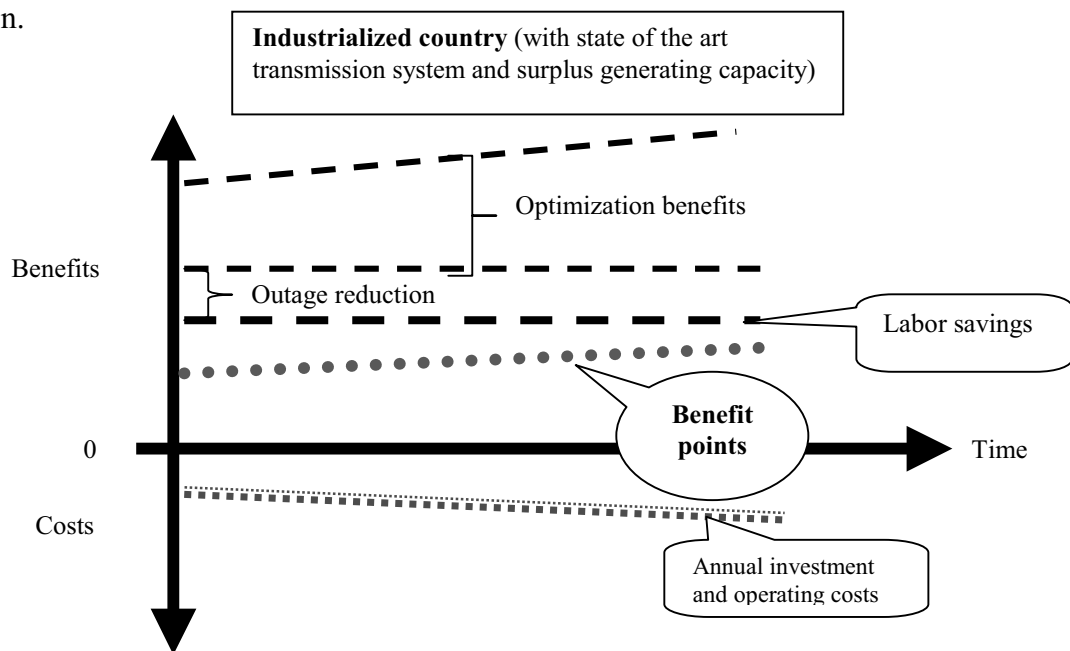
This optimization benefit would be with respect to reduced transmission losses, lower need for spinning reserves and fuel savings. It is not possible to determine exactly where on a scale of network size and complexity such a "benefit point" (where benefits exceed the cost of investing in and operating a SCADA) would be located. It would obviously be related to the cost of labor in the country in respect. In industrialized countries it is generally accepted that more complex networks that include high voltage transmission and generation would require such a large staff complement for supervision and data compilation that a SCADA system is warranted for the first two reasons alone. SCADA systems for networks of certain size and complexity have become industry standard in much the same manner as computers have become ubiquitous in offices.

For many developing countries the equation is likely to be quite different. Considerably lower labor costs would reduce the potential for benefits. Optimization benefits generated by a SCADA system are very seldom as important as those that can be achieved by improving weak transmission networks and increasing insufficient generating capacity. They would therefore accrue at a much later stage. This would tend to push the "benefit point" further away. However, in case outages are more common and of longer duration than in industrialized countries (which they normally are), reduction of outage time could partly compensate for the lower benefits derived from labor savings and optimization.

A fourth factor that impacts on the position of the point at which benefits would be positive would be the cost of investment and operation. The higher the investment cost and the higher the operating cost on account of, for instance, high cost of spare parts, the more distant the "benefit point".

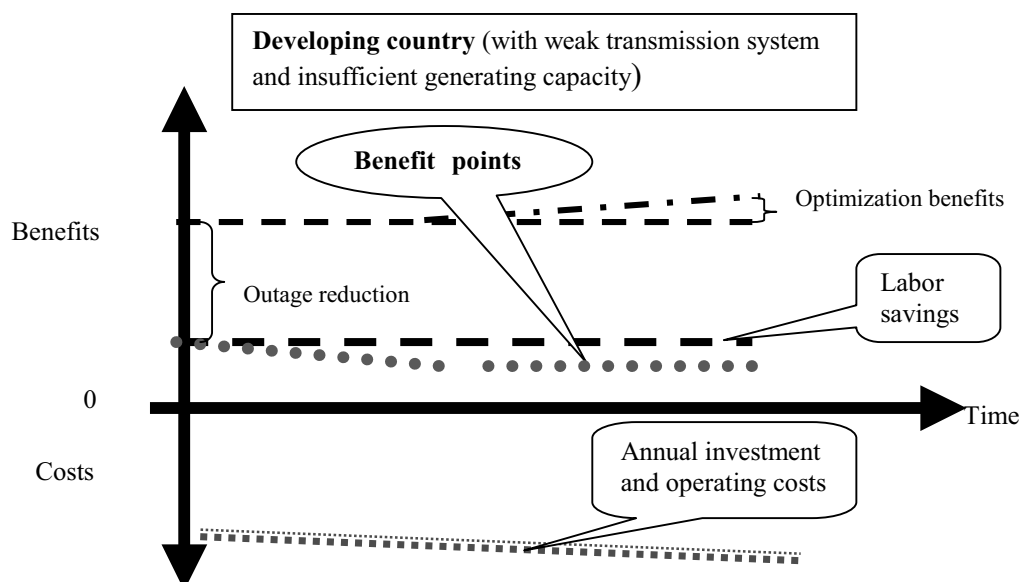
For a given network size and complexity the benefit point curve over time would be related to the four factors shown in the graph below, namely the sum of labor savings,

outage reduction and optimization benefits less the annualized cost of investment and operation.



In the above case the manning reduction alone would more than suffice for covering the annualized cost of SCADA investment and operation. Optimization benefits would accrue from the outset because the network is highly efficient and has surplus generating capacity. The latter is a consequence of complexity whereas the labor savings is more a function of network extension.

For a developing country the benefit point curve is likely to be different as it depends less on direct labor savings and more on outage time reduction. The latter is often a consequence of other imperfections in the system such as old and worn transformers, overloading of transmission lines and inadequate generating capacity.



The graph above depicts a case where the same SCADA system costs more on an annual basis because of higher investment cost and higher cost of maintenance. Although the sum of the labor savings and outage reductions may be the same as in the

case of the industrialized country, the higher costs reduce the benefit point curve. This also suggests that a higher degree of system complexity would be required to justify a SCADA system in a developing country than in an industrial.

Actors and Objectives

The four main categories of actors involved in the nine SCADA projects have been the nine owner/customer organizations in the recipient countries, the donor agencies (SIDA and BITS), the supplier ABB and the engineering consultants (mainly SwedPower and SWECO)¹⁴. Each of those actors has been guided by partly the same and partly different objectives. The following table summarizes the Consultants understanding as regards the actors' main objectives.

Actor	Principal objectives	Goal achievements
Developing country SCADA customers	1) Improved network management capability 2) Improved system reliability 3) Mastering of a new technology¹⁵ 4) Reduced operating costs	• By and large reliable and well functioning SCADA systems as well as trained staff • Improved network management capability.
SIDA/BITS	1) Deployment of aid funds in projects using the Swedish resource base. 2) Economic growth in the recipient countries 3) Swedish exports	• A steady flow of non-controversial and well managed aid projects, the economic benefits of which were unlikely to be questioned.
ABB	Exports to a new market segment, which would contribute to profitable growth of business volumes.	• An estimated USD 137 million of new SCADA business¹⁶ • Profit margins that are likely to have been significantly higher than those in industrialized countries.
SwedPower/SWECO	1) Profitable employment of consulting staff 2) Client satisfaction leading to more assignments 3) Development of a portfolio of SCADA reference projects for more SCADA related consulting assignments	1. A total of 29 consulting assignments at an estimated aggregate value of USD 5 million 2. Clients satisfied with technical competence and performance. 3. Achieved mainly by SWECO

¹⁴ BITS and SIDA merged in 1995 where after the organization is referred to as Sida.

The early systems were delivered by ASEA, which subsequently merged with its competitor Brown Boveri Corporation to form ABB.

SwedPower was, at the time the nine projects were prepared and implemented, owned by SWECO, Sydkraft and Vattenfall. Vattenfall, the Swedish State Power Board has since become the sole owner.

¹⁵ For some of the power networks, which already had SCADA systems, the third objective is likely to have been updating of staff competence.

¹⁶ For some of the nine projects, the communication part of the SCADA systems has been supplied by other firms under separate contracts. This appears to have been the case in Lesotho, Pakistan and Zambia. In other cases the communication part was included in ABB's contract. Communication equipment cost has varied from a low of 20 to a high of 60 percent of total contract value.

Summary

The table reflects both the differences and similarities with respect to objectives. The asymmetry is mainly with respect to price and profitability in the case of ABB, on the one hand, and economic growth in the case of SIDA/BITS as well as low investment and operating cost on the part of the customers, on the other.

The positive aspects of the projects are that many of the above listed objectives have been reached. This applies in particular to those shared by all actors. Thus

- all nine projects have been implemented and put into operation essentially as planned and within budget,
- all SCADA systems have functioned and delivered, if not all, at least a major part of the results they were intended to produce, i.e.
 - They have improved network management capabilities.
 - They have enhanced network reliability.
 - All have contained training components, which have enabled the network staff to master the new technology.

The more successful of the nine projects, from the customer's point of view, appears to have been the ones in Ecuador, Jordan and Zimbabwe. The systems in Botswana and Vietnam have suffered from defects that have limited their use and the SCADA SINDAC 1 system in Lesotho¹⁷ is deemed to have been the least successful in terms of use and benefits.

The negative aspects are that, in the majority of the cases, the investment in SCADA systems contributed little towards solving the customers' priority problems. Among those were large network losses and/or inadequate generating capacity. If the USD 200 million spent on SCADA could have been used for improved transmission capacity or enhanced generating capacity, then the financial and socio-economic benefits would have been much higher than the very modest returns the SCADA investments have yielded.

This evaluation has, however, concluded that the projects are nevertheless likely to have met several important BITS and SIDA objectives. They have been easy to administer, well executed, caused no or few problems and little controversy. This has, however, been achieved at a considerable cost. It is probable that the financing with tied aid funds has increased the aggregate investment cost of the projects considerably above that which would otherwise have been the case. The three factors that have contributed towards making the projects very costly are:

- limited competition,
- no or only perfunctory analysis of price quotations, and
- insufficient concern for cost efficiency (over-design and excess redundancy),

The following is a more detailed assessment of outcomes in relation to objectives for each of the actors.

¹⁷ Lesotho Electricity Corporation has since invested in a new SPIDER which has replaced parts of the old system. The new system is not included in this evaluation.

Outcomes

The Customers

The majority of the SCADA customers have been provided with well functioning systems. The records available with Sida and the information collected in the course of the site visits have revealed relatively few shortcomings. They have mainly been with respect to the systems in Botswana, Vietnam and to a lesser extent in Zimbabwe. Botswana Power Corporation (BPC) has experienced a series of difficulties including system crashes, which have resulted in system operators having to rely on field staff to relay information to the control center¹⁸. The upgraded system supplied to Ho Chi Minh City Power Company (HCMC-PC), which was commissioned in 1998, failed to meet the stability tests during the acceptance period.

In only two cases (Zimbabwe and Vietnam) were the systems inadequately dimensioned. For Vietnam this was due to particular circumstances over which the supplier had no influence and in the case of Zimbabwe the deficiency (due to incorrect customer specifications) was corrected by an upgrading project financed by SIDA.

The SCADA SINDAC 5 system in Jordan, which was commissioned in 1988, was replaced by a Ranger SCADA system in 1999. NEPCO told the Consultants that it had rejected the SPIDER alternative proposed by ABB because it lacked the flexibility needed by a rapidly changing power network such as that of Jordan. Ecuador is likewise planning to change to another make of SCADA system in the near future.

Timely implementation and high utilization rates

Implementation of the systems was, with few exceptions (mainly Kenya and Pakistan) timely and cost overruns were few and limited. All systems have been in operation since commissioning and some, such as the ones in Lesotho and Zimbabwe, have been running for as long as 15 years. The systems in Botswana and Jordan have been in operation for 12 and 11 years respectively.

Training has been provided for each delivered system by ABB in connection with system installation. In addition SwedPower (SWECO in the case of Zambia) has provided SIDA/BITS funded implementation support and training for all projects except the one in Zimbabwe. SIDA/BITS has also funded an annual training course "Power System Control and Operation"¹⁹ in which a total of 56 staff of national power companies in the nine countries has participated. The training and transfer of know-how has been highly appreciated by several network companies. Kenya and Zimbabwe are two cases in point. BPC in Botswana, the staff of which received training by ABB in 1994 and by SwedPower between 1995 and 2000, expressed some reservations. BPC staff was also trained at Zimbabwe Electricity Supply Authority's (ZESA) facilities in Harare. The NCC staff at HCMC-PC also felt that they did not get sufficient training in handling UNIX. ZESCO (Zambia Electricity Supply Company) also felt that more training would have been needed.

¹⁸ BPC submitted a report with a list of SPIDER defects, which the Consultants have forwarded to ABB.

¹⁹ This course, which was offered to senior power network staff from the early 1980s, was designed by Professor Torsten Segrell at the Royal Institute of Technology in Stockholm and managed under contract with BITS by ISO-SMG and subsequently by ÅF-SMG.

Most operators have achieved a high rate of system utilization. The software component, which is not in use in Kenya and Zimbabwe, is the EMS (energy management system), which is often not used by Nordic customer either. Both Ecuador and Jordan have achieved virtually full utilization of all aspects of the system. In some cases less than full utilization is due to imbalances between the SCADA systems' computing and communication components.

Benefits

Since the installation of the systems there have been few attempts to identify and quantify benefits by either of SIDA/BITS, the consulting engineers, ABB, or the operators. Nor have any evaluations sought to validate the assumption concerning benefits that were made in the appraisals or feasibility studies. The Consultants have found project evaluation reports only for the SCADA systems in Lesotho, Vietnam and Zimbabwe. They noted better response times, shorter outages and generally better quality of information but in no case was there a comparison of network performance before and after the installation of the systems.

The economic analysis of projects in this report is based on probable scenarios for quantifiable benefits for five cases (Botswana, Ecuador, Vietnam, Zambia and Zimbabwe). In the case of Kenya and Lesotho some conclusions have been drawn by inference. No data has been made available in the case of Pakistan. However, the real issue as regards benefits for the customers is not so much the inadequate return on the projects themselves but rather the fact that an alternative use of the funds by the networks would, in most cases, have yielded much higher benefits, both financially and economically.

The following table summarizes the Consultants' assessment of the degree to which

1. the customers have been able to make use of the systems, and
2. quantifiable benefits have been generated by the systems.

It also indicates alternative investments, which would have yielded maximum financial and economic return for the network at the time they installed the SCADA systems.

Country	Usage rate (%)	Comments	Quantifiable benefits	Comments	Alternative investment that would have responded to main network problem
Botswana	60	Some soft and hardware defects.	Marginal; mainly limited reduction of outage time in Gaborone and lower system maintenance cost.	A Nordic network comparable to that of Gaborone would manage without SCADA	Network losses of 8.4 % were due in large part to inadequate transformer capacity in the Gaborone distribution network
Ecuador	95	Short-term load forecast not used	Modest; staff reduction in substations, some reduction in outage time, reduced forced generation on account of insufficient capacity of major transformation station	System warranted from a technical safety point of view but economic merits limited	
Jordan	98	Fully utilized.	Modest; mainly staff savings in substations, outage time reduction, better frequency control for imports/exports.	Same as above	
Kenya	80	EMS never commissioned	Modest; some staff savings and outage time reduction.	Same as above but economic return lower because of inability to use entire system	Generating capacity is very limited. Imports from Uganda are the only source of extra power and this has not sufficed. Load shedding has been common.
Lesotho	50	Many software components incl. EMS not used	Negligible, some staff savings and limited outage time reduction	Network too small to justify SCADA	Extension of the Southern and Central lines and connection to the Mantsoyane mini-hydro plant
Pakistan	n.a.	n.a.	n.a.	n.a.	n.a.
Vietnam	60	Inadequate processing capacity.	Very small, only outage time reduction	Not economically justifiable. Manual control used in parallel.	Upgrading of old transformer stations was highest priority at the time the first SCADA investment was made.
Zambia	75	Limited EMS functions not used; one RTU was not commissioned	Small to modest; mainly staff savings and some outage time reduction station	System warranted from a technical safety point of view (due to mines) but direct benefits have been very low as there are many backup systems for the Copperbelt	Zambia has a very good power network and excess production. There is a need to rehabilitate of several old substations
Zimbabwe	80	EMS not used due to measurands instability	Relatively large; reduced outage time during national black-outs, manning reductions in most substations	Reduced outage time during a large number of national and regional black-outs has yielded the majority of the economic benefits	Inadequate generating capacity of 40 year old thermal plants and lack of maintenance of transmission facilities. Investments in more or improved generation would have yielded much better returns than SCADA.

It should be noticed that the above list of benefits refers only to those that can be quantified. In addition there are some that are intangible and non-measurable. They are discussed in Chapter 2.

SIDA/BITS

SIDA/BITS' most important objective should be that of economic and social development in the recipient countries. This would, however, have required a different logical framework and approach to the issue of project evaluation than the one that was used for the SCADA projects. The evaluations and appraisals that were made lack a definition of a project purpose other than that of the supply and installation of a SCADA system. This may have been the result, at in so far as the projects funded by BITS, of the non-fungibility of funds. However, it precluded consideration of other means and measures for achieving the benefits SCADA was supposed to deliver. The basic premise of an investment analysis is that of scarcity of capital and the need therefore to allocate it to the best yielding investments. An investment analysis should, whenever possible, be comparative²⁰. The internal rate of return (IRR) or the Net Present Value (NPV) is a measure by which different investment alternatives for achieving a given purpose can be ranked. These measures become meaningless if different assumptions are used for different investment alternatives. A very common error is to assume a vastly higher value of energy in the case of a SCADA investment than for other alternative power network investments serving essentially the same purpose. Such an analysis would answer the question of whether a SCADA investment in one country is more profitable than one in another country whereas the real investment choice instead is between different types of network investment in one and the same country.

The Consultants' review of available feasibility studies and project appraisals suggests, also, that the efforts to assess and measure the various projects' economic benefits were only perfunctory and that SIDA/BITS' own validation of the correctness and consistency of these assessments was cursory at best. Neither SIDA nor BITS appear to have taken notice of inconsistencies, logical errors and apparent arithmetical mistakes in the preparatory studies.

In the case of BITS a lack of focus on comparative economic analysis might have been the consequence of the organization's mandate, which was to finance Swedish deliveries to projects that would contribute to development. BITS' role was therefore not necessarily to finance the most needed investment for a given sector or customer in a developing country. This issue was left for the customer to determine.

The following table shows the incidence and nature of economic assessments in the documentation for the nine projects to which the Consultants have been given access.

²⁰ Only one of the preparatory studies of those to which the Consultants have had access stressed the importance of a comparative analysis. It was SwedPower's appraisal of the SCADA project in Kenya (Anders Bruse, et con.)

Country	Study	Comments
Botswana	Appraisal by Sydkraft	Cost benefit analysis for only half of the project • allocated 5% of total national losses to GDS project which represented half of the investment, • did not account for cost of extra production (a large part of Botswana's power is imported), • included both total investment, interest and repayments in cost stream, • assumed that the benefits would equal the value of increased sales of energy because of a 25% reduction in outages time, and • used USD 1.00/kWh as the value of non-supplied energy.
Ecuador	In-house study	not available with Sida
Jordan	No study or appraisal in Sida	BITS documentation contained no indication of an economic analysis of the project.
Kenya	IVO Project Document 1985 and SwedPower appraisal	No economic return calculation. "The new control system will give effective means to improve the overall economy of the company". SwedPower (Bruse et al) • equaled savings on account of reduced outage time to 5% of total network losses, as normally assumed by Vattenfall, • incorrectly discounted benefit stream (SEK 5 million during 15 years at 10% discount rate), and • did not account for cost of extra production (a large part of Kenya's power is imported).
Lesotho	Appraisal by Lars Hydén	No economic analysis but an estimate that the cost of imported power could be reduced by 1.8% corresponding to SEK 0.3 million per year. This would yield a rate of return of -20 % ²¹
Pakistan	ADB appraisal	Economic internal rate calculation for a project in which SCADA made up only a small part. No separate economic assessment of the SCADA investment.
Vietnam	SwedPower feasibility study	Assumed that • "the duration of outages could be brought down by approximately 20%". • value of savings would correspond to 10 times tariff • savings not reduced by cost of production.
Zambia	ESB feasibility study	The only detailed cost benefit analysis showed a positive NPV, but • contained two major arithmetical errors, • NPV after correction becomes sharply negative, and • cost of incremental power production ignored.
Zimbabwe	Short summary of benefits by ASEA	No record of a financial or economic assessment was found.

²¹ Assuming that other benefits (outage reduction and staff reduction) would cover operating and maintenance costs of the system.

Project preparatory studies exist in the case of Botswana, Zimbabwe and Jordan but the Consultants have not had access to those. A probable reason is that they have not been made available to SIDA/BITS either.

In only one of the nine projects was there a serious attempt at a cost benefit analysis, which included outage reduction as well as other possible benefits. This was a study for Zambia's SCADA system, which was carried out by an Irish consulting firm (ESB). It was, apart from a major logical error and some arithmetic mistakes²², by far the most ambitious of all the reports reviewed by the Consultant. This study suggested that the proposed SCADA investment would yield a surplus (NPV 1.085 for a 10 year economic lifespan and a discount rate of 10 percent). This calculation was, however, based on an apparent logical error. After correction for this the calculation yields a sharply negative rate of return. Given the thoroughness with which the balance of the report had been prepared, a more careful review might have alerted SIDA to what appears to have been a systemic erroneous assumption, namely that all SCADA projects are economically justifiable.

In all cases when studies have concluded that the projects are economically justifiable the reason has been an assumed very high value of lost or non-supplied energy. It is important to note that there exists no consensus as to the manner in which the cost to a society of non-supplied energy should be valued. The engineering consultants appear to have used this lack of consensus as a mandate for applying differing and entirely arbitrary values for which they presented no basis or justification. In most cases they have used values that have been derived from studies in industrialized countries where a kWh produces an infinitely bigger increment of GDP than in a developing country. The Consultants have concluded that those values, used for investment return calculations for alternative investments (in additional generating capacity or better transmission facilities, i.e. reduced losses) would have yielded very much higher returns than the SCADA investment.

ABB

The table below sets out the values (in USD million) of SCADA deliveries to the nine countries in respect and the grant financing of these deliveries.

		Delivery 1	Deliver y 2	Deliver y 3	Deliver y 4	Total ABB deliveries	Grant for delivery 1	Grant for delivery 2	Grant for delivery 3	Grant for delivery 4	Total grants for ABB deliveries
Botswana	SINDAC3		0.25	3.60		3.85			1.53		1.53
Ecuador		13.97				13.97	4.75				4.75
Jordan	SINDAC5	8.50	0.50			9.00		1.27	0.11		1.38
Kenya		16.15	0.16	0.11	0.19	16.61	5.57	0.05			5.62
Lesotho		2.58	0.10	0.62	3.70	7.00	1.65				1.65
Pakistan		44.55				44.55	1.02				1.02
Vietnam		3.08	0.17	2.62		5.87	2.13	0.12	2.62		4.87
Zambia			10.51	0.81		11.32	10.51	0.66			11.17
Zimbabwe		12.42	5.76	4.25		22.43	2.64	1.27	0.90		4.81
Total		92.75	25.45	12.51	3.89	134.60	28.27	3.37	5.16	0.00	36.80

²² On page 3 of section 15 of the report the consultant concluded that an 80 percent reduction of outage time would increase the supply of electricity by four times the total loss on account of outages.

The underlying detailed information for the above table can be found in the Project Fact Sheets in Appendix 3. It should be noted that the above cost data differs from that on page 15 in that it refers only to deliveries by ABB and associated suppliers (mainly communication equipment suppliers) whereas the latter comprise also other costs, mainly consulting services.

In the case of Botswana and Jordan the customers themselves financed the first deliveries. They are therefore not included in the totals. The deliveries included in the table are those that were aid funded and the ones that have followed upon the latter. The logic being that the subsequent deliveries, even if they were not aid funded, are likely to have been a direct consequence of the aid finance.

In all nine cases the major contractor has been ABB. For some of the countries the SCADA contracts were split into two parts, one for control center and RTU hardware and software and one for the communication system between the control center and the substations housing the RTUs. In some cases other parties in close collaboration with ABB supplied the communication part. In other cases ABB used a subcontracted firm to supply and install the communication system. The value of the communication part of the systems has varied between a low of 1.2 and a high of 67 percent of contract value.

The table thus suggests that aid has generated a total business volume of at least USD 135²³ million in the nine countries. The grant element or subsidy pertaining to this amount has corresponded to 27 percent. A pertinent question for this evaluation is who has been the main beneficiary of the grant element?

Market segmentation and pricing policy

A comparative analysis of the nine developing country SCADA projects and several Swedish and Norwegian ABB SCADA systems suggests that there exists a developing country market segment in which ABB's customers pay significantly more for the same products and buy considerably more sophisticated systems than in the Nordic countries. This market segmentation is likely to be a consequence, in part, of aid finance and of non-competitive or only partially competitive procurement practices.

ABB uses what it refers to as a 'value based pricing' policy. This implies that prices for individual contracts are related to the value a SCADA system or component conveys to the customer in respect. The consequence would be prices that varied from customer to customer depending on the benefits each one would derive from SCADA. Economic theory postulates, and reality has shown, that such a pricing principle cannot be upheld in a competitive market situation. It is only feasible where there is none or very limited competition. As a consequence, parts and service for the nine captive customers have been very highly priced. This has made it difficult for the operators to maintain the systems and it has probably also limited their ability to expand or modernize the systems without recourse to aid funding.

²³ Since this number includes only that for which records existed within Sida or, on occasion, with the customers (which was very rare) the real volume when spare parts, service, etc is included may well exceed USD 200 million.

Another possible consequence of the pricing policy might have been strained customer relations and a loss of future business. Two of the most successful SCADA operators (in Ecuador and Jordan) are switching to other suppliers but ABB for their new SCADA systems and they appear to do so without recourse to aid finance. All operators without exception expressed grave concerns about ABB's pricing policy.

SwedPower/SWECO

For SwedPower/SWECO the benefits have consisted of a steady supply of consulting assignments several of which have had a relatively long duration. The table below sets out the number of SwedPower/SWECO assignments of three different categories for which the Consultants have been able to find documentation.

	Project preparatory studies	Implementation or management support assignments	Training and technical assistance assignments
Botswana	1	1	
Ecuador	3	1	
Jordan	1	1	2
Kenya	3		1
Lesotho	1		1
Pakistan			2
Vietnam	3	1	1
Zambia	2	1	2
Zimbabwe	2		
Total no of assignments	16	5	9

The underlying detailed information can be found in the Project Fact Sheets.

The three main types of assignments are respectively project preparatory studies (which includes, design and specifications and tender evaluations) support during implementation or operation and training assignments. The first category is the largest in terms of numbers but the two latter are considerably bigger in monetary terms. The only country for which there is no record of SwedPower/SWECO having done any project preparatory work is Pakistan. In all other countries, the SwedPower/SWECO group was extensively used by BITS and SIDA, on occasion complemented by other consultants (see the Project Fact Sheets). It appears reasonable to conclude that while ABB has been the SCADA program's sole supplier SwedPower has been its privileged consultant. The records within Sida suggest that out of the 29 assignments awarded SwedPower/SWECO two were the subject of competitive tendering.

It is estimated that approximately USD 5 million in grant financing has been used to pay for the services of SwedPower/SWECO. Data on contract values did not exist for a number of the project preparation assignments. In these cases the Consultants have made conservative estimates (see the Project Fact Sheets). The breakdown (in million USD) is shown in the table below.

	Project preparatory studies	Implementation or management support assignments	Training and technical assistance assignments	Total (USD million)
Botswana	0.02		0.38	0.40
Ecuador	0.28			0.28
Jordan	0.06	0.10	0.18	0.34
Kenya	0.17		0.09	0.26
Lesotho	0.09			0.09
Pakistan			0.84	0.84
Vietnam	0.50	0.50		1.00
Zambia	0.26	0.60	0.36	1.22
Zimbabwe	0.15			0.15
Total	1.53	1.20	1.85	4.58

The cost of consulting services was normally funded in its entirety by grants.

The second objective of the SwedPower/SWECO group is likely to have been the development of a set of reference projects which would assist future marketing of their services in a relatively new but rapidly growing field. It appears that this aim has been achieved by SWECO. The company reports having won a number of World Bank funded SCADA related assignments.

SwedPower appears not to have been as active on the international consultancy market and may therefore not have benefited as much as SWECO from the experience gained.

Chapter 2 SCADA and Project Context

Why SCADA?

The Functions of SCADA

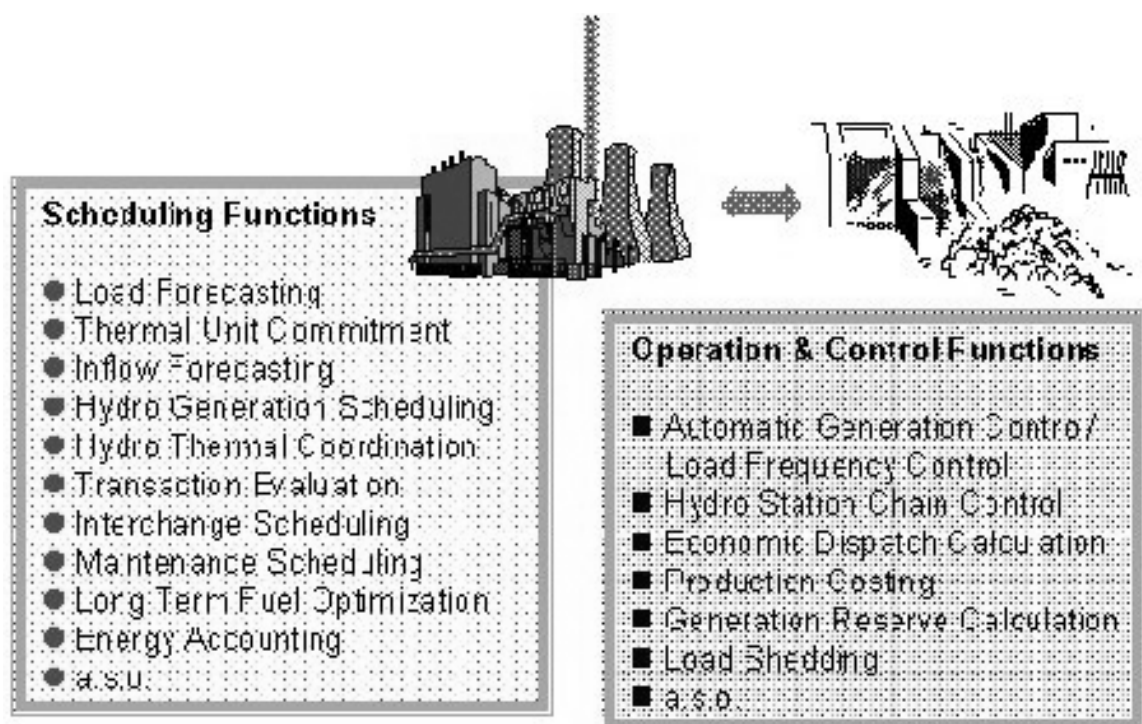
SCADA is a system that provides event triggered as well as programmed retrieval of process data from RTUs to a central control function. The RTUs would be located in substations and in power generating plants. Very large power consumers may also have RTUs. The RTUs of today are small computers that can send and receive signals by way of either the regular telephone lines, a dedicated telephone network (referred to as a power line carrier (PLC)) system or radio-based system.

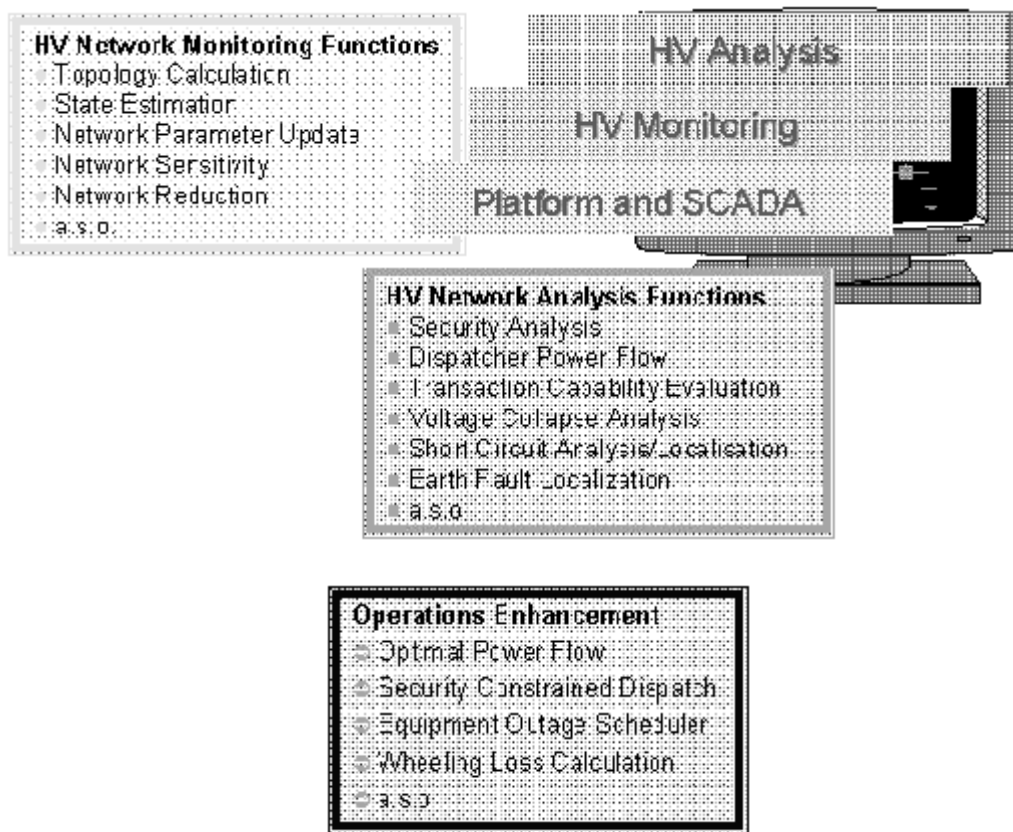
A SCADA system comprises essentially three parts:

1. the hardware - consisting of interlinked computers and remote terminals units,
2. the software - enabling the system to perform a number of functions, and
3. the communication network through which the control centers' computers and the remote terminals communicate.

SCADA systems have been in operation for far more than 30 years and both the hardware and the software have changed and improved dramatically during this period. The evolution of SCADA has been driven in part by the telecom and computer software and hardware development process.

The software of a SCADA system consists of a number of functions, essentially modularized application programs, the composition of which varies with the generation of SCADA system and with the complexity of the power system to be supervised and controlled. The following illustrations (taken from ABB's web site www.abb.se) show the main components of ABB's SCADA system.





Today there are relatively few manufacturers of SCADA systems for the power sector and most of them operate worldwide. The industry has gone through a concentration process as the major suppliers have bought their competitors. Thus ASEA, apart from merging with its SCADA competitor BBC, also bought several of the early Swedish SCADA firms such as Tekoma and Lyngsö as well as a number of international competitors including Bailey in the US. Today ABB, Siemens, Alstom, and Harris are among the largest SCADA companies in the world.

This evaluation deals with a number of different ABB SCADA configurations all of which belong to either the earlier SINDAC or the current SPIDER generation. The SINDAC version, of which there are 5 releases, was discontinued in the early 90s and since then there have been a total of nine releases of the SPIDER SCADA system.

The Benefits of SCADA

Proponents of SCADA claim that the system can deliver the following benefits:

- Reduction of staff,
- Reduced losses on account of faster restoration of power in case of outages,
- Improved reliability of power supply,
- Reduction of generation reserves,
- Reduced maintenance cost,
- Fuel savings,
- Reduction of technical losses,
- Improved staff training (by way of simulation), and
- Improved personnel safety.

SCADA systems help operators identify the location and reason for faults in a power transmission system. It also helps the operators optimize the operation of the systems generating capacity. SCADA furthermore generates a large amount of information on the day-to-day operation of power network which helps prevent faults, plan maintenance and schedule replacement of equipment.

The most common faults that might occur in the power network are:

- Lighting,
- Other natural occurrences (such as falling trees, wind, rain etc.),
- Manmade and external effects such as theft, vandalism, etc.
- Incorrect handling by staff,
- Failure of technical equipment, and
- Other incidences (e.g. faults occurred by other faults in the system).

These fault causes are described in Appendix 8 with specification of their underlying reasons, effects and the role of SCADA when they occur.

Staff reduction

SCADA is a remote supervision and control system, which makes it possible to reduce staff at substations and in generating plant. Staff reduction or elimination in remotely located installations was one of the factors that motivated the development of the early SCADA systems. The staff reduction effect of a SCADA system can be very significant and it often suffices for justifying the system in an industrialized country. For instance, an RTU in a substation would replace four shifts of supervision staff. A SCADA system would also reduce the number of analysts required in a control center and simplify record keeping and retrieval.

Outages

When a fault causes an outage there is a need for

- firstly, detection
- secondly, stabilization, and
- thirdly, restoration.

SCADA enables the operators to detect the location and nature of a fault quicker than otherwise. It also allows for a faster stabilization of the network. The amount of time gained can only be ascertained by comparing data on detection and stabilization, before and after the installation of a SCADA. Few operators have reliable such statistics.

Reliability of power supply

Because it allows larger networks to be managed from one and the same control center a SCADA system also makes it possible to use the full generation and transmission resources of such a system to maintain supply. For instance, in case of a fault in one transmission line a network manager with a SCADA system would be in a better position to use alternative routes than one without SCADA.

Maintenance

It is claimed that a SCADA system, because it delivers statistical data on the operation of the system on a continuous basis, facilitates maintenance planning and fault prevention. However, the data needed for this purpose can be collected and compiled without a SCADA system but it would require a large and well-trained staff.

Spinning reserves

A SCADA system makes it possible to co-manage large regional networks which, in the absence of computerized data processing, would be divided into smaller management entities. This allows for optimization of a larger number of generation units than otherwise. Together with computerized alarm functions this makes it possible to operate a network's generating plants closer to their maximum capacity, which in turn, reduces the need for reserve generating capacity, so called spinning reserve. This is important for systems that experience an increase in demand for electric power over a longer period of time.

Other benefits

The other benefits are of lesser importance and even more difficult to quantify. Fuel savings, for instance, have been estimated to correspond to less than 0.5 percent²⁴ but the basis for the estimate is very tentative. To some extent similar results could be achieved by competent monitoring by staff. The same applies for reduction of technical losses.

Development Context

Power Sector Development Indicators

The information regarding the development context in the project documents is limited. The focus in all projects concerned appears to have been on the technical aspects and in particular on the technical aspects of the SCADA systems themselves. Some project documents, but far from all, contain data on the status of the power network to be supervised by the proposed system.

An investment in a SCADA system has to be seen in the context of the country's electrification process. The four most factors commonly used for assessing the development status of a power network are:

- the complexity of the power network,
- the demand for electricity,
- network losses, and
- the prevalence of outages.

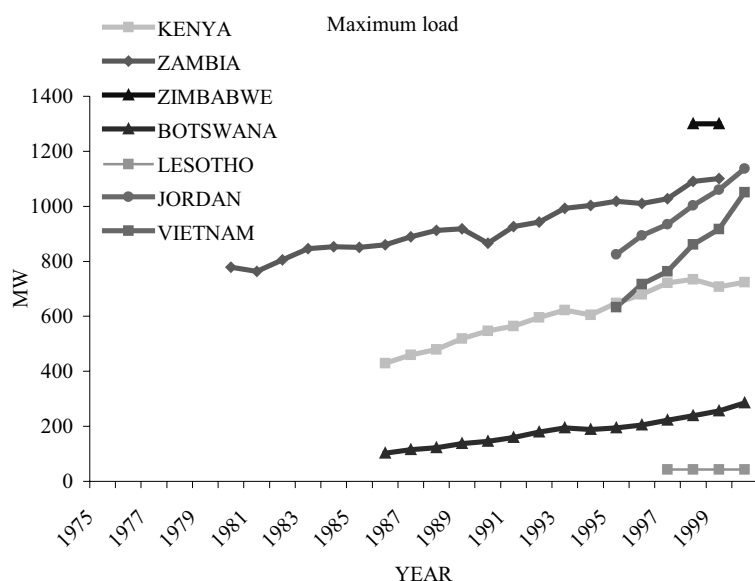
One indicator of the complexity of the system is the max load to which it is subjected. The demand indicator is the volume of produced and consumed electric power. System losses are normally defined as produced electricity, which is not delivered and/or paid for. Network losses comprise both technical and commercial losses, which are normally measured as a percentage of production and consumption. Extent of outages is a measure of the degree to which the productive capacity, which is lost because of transmission and distribution failures of one kind or another.

Maximum Demand

A gradual increase in max load suggests that the complexity of a power network has grown and the absolute level of the max load is a reasonably good indicator of the

²⁴ "Justification of Control Centres in Developing Countries", K. Lindström, CIGRE 310-05, 1989.

actual complexity of the system²⁵. The graph below shows the development up to year 2000 for seven of the nine countries. Data for Pakistan and Ecuador that covered a longer period was not available.



The changes in max load have been considerable in some countries such as Jordan and Vietnam (and probably also in Pakistan) while Zambia, Kenya and Botswana show max load curves with more modest growth.

The absolute level of the max load is such that the countries could be divided into three categories in terms of their system complexity. Botswana and Lesotho would thus have limited complexity; Kenya, Zambia, Jordan, Vietnam and Zimbabwe would be in a middle category while Ecuador and Pakistan (the latter had a peak demand of 3,026 MW in 1983) have systems with a complexity similar to that of many industrialized countries. These differences in complexity would call for different configurations of their SCADA systems.

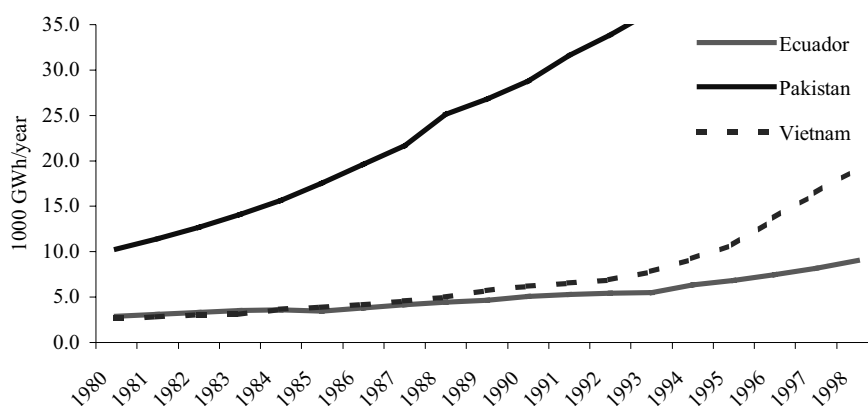
Consumption - Production

While there has been an increase in the demand for power in all countries included in the evaluation, the annual rate of growth over the last two decades has varied substantially. Three countries have experienced very high rates of growth of demand (at or above 10% per year) while two have had more moderate growth rates (around 5%) and another two very low or almost no growth at all. For Botswana and Lesotho data was available for only a part of the period. This data suggests however that both countries have had a high (9 to 11% pa) rate of growth (see separate graphs on pages 39 and 40).

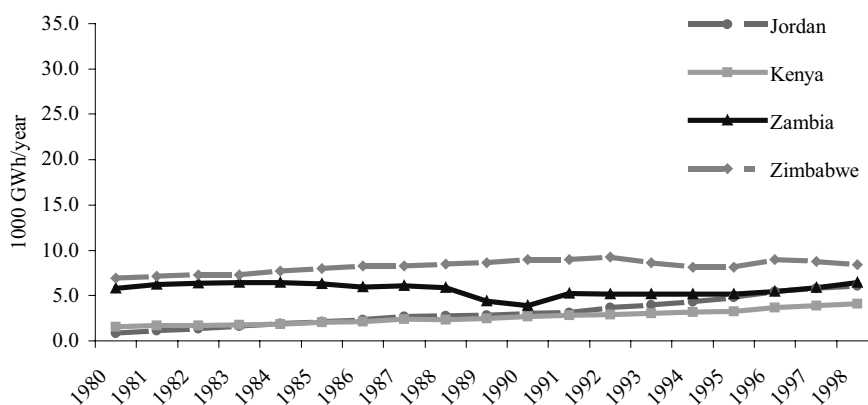
The following two graphs show the development in respectively the fast growing and the moderate to low growth countries.

²⁵ There are several other factors related to mainly generation, which also impact on the complexity of power networks. Wherever possible they are taken into consideration when the relevance of the systems is discussed in Chapter 4.

High Rate of Growth of Electricity Consumption



Moderate to Low Rate of Growth of Electricity Consumption



The table below compares the growth in electricity consumption (in percent per year) for seven of the evaluated systems with that of an equal number of OECD countries.

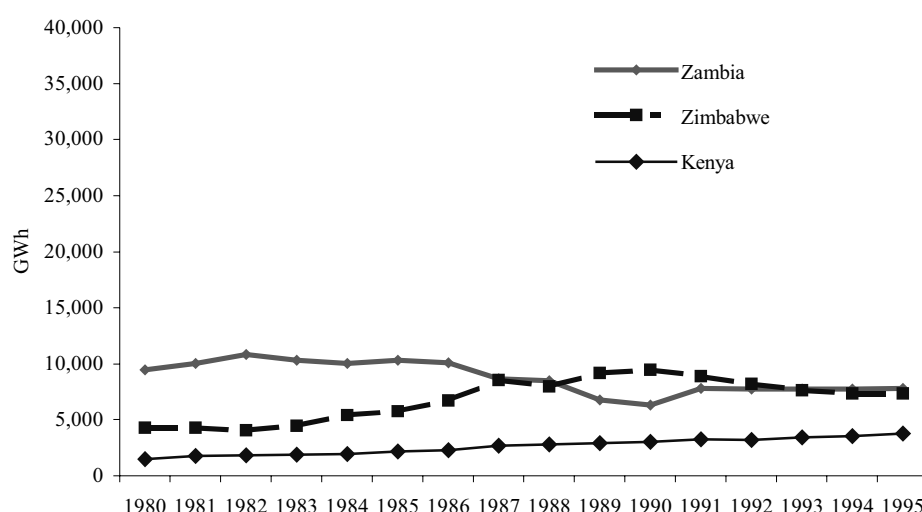
Developing Country	Rate of Growth of Consumption	OECD Country	Rate of Growth of Consumption
Ecuador	6.5%	Austria	1.9%
Jordan	11.7%	Finland	3.1%
Kenya	5.8%	France	4.4%
Pakistan	9.8%	Germany	1.2%
Vietnam	11.6%	Italy	1.9%
Zambia	0.5%	Netherlands	1.5%
Zimbabwe	1.2%	Sweden	2.9%

The majority of the networks that are evaluated differ from the OECD countries in that their growth of demand has been considerably higher. This suggests that they have faced different issues and problems than the OECD countries - one of keeping up with demand as opposed to optimizing production.

Production has matched consumption in most countries except for Pakistan and Vietnam. In the case of Botswana and Lesotho a substantial part of consumption is satisfied by imports. For Botswana this proportion has increased significantly during the 90s.

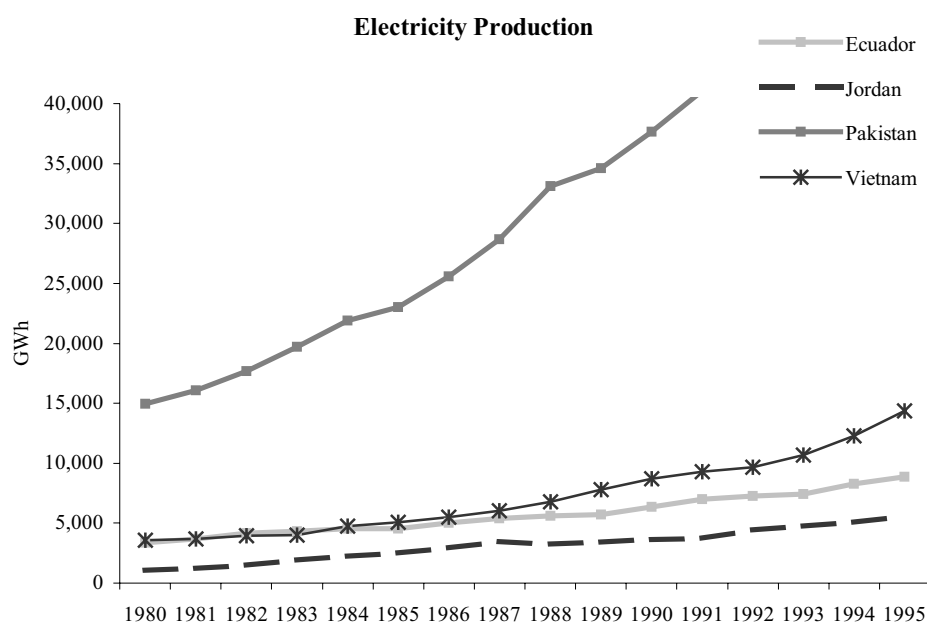
The following two graphs show, firstly, the moderate increase in power production in Kenya, Zambia and Zimbabwe, and, thereafter, the much larger increases in Ecuador, Jordan, Pakistan and Vietnam.

Electricity Production



The production of electricity in Zambia and Zimbabwe as well as Botswana (see separate graph on page 39) has stagnated during the 90s and in Kenya the annual increase has been relatively modest (on average 5% per year).

In the remaining five countries there has been considerable growth, in some cases quite substantial (Lesotho's growth, derived from a separate source of data, is shown in a graph on page 40).



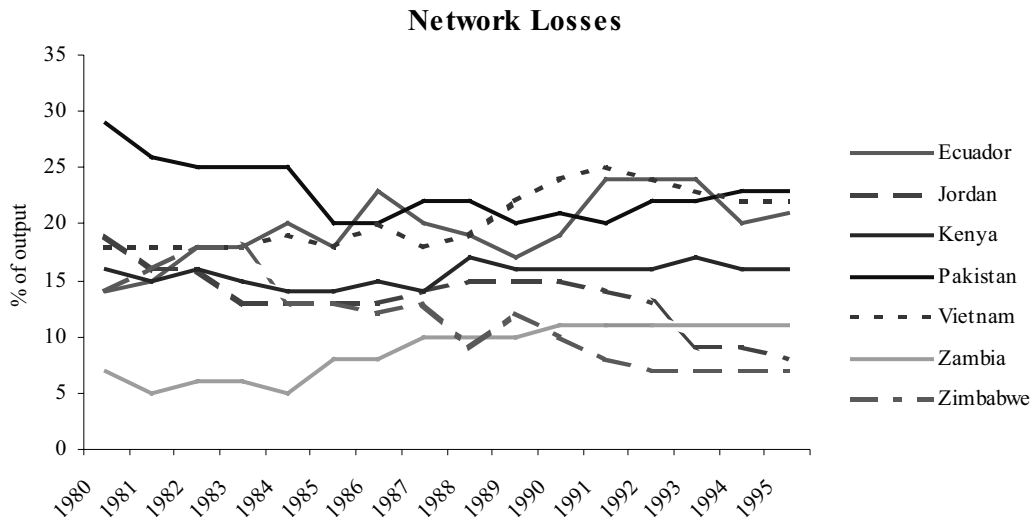
Country	Annual Growth in Consumption	Annual Growth in Production
Ecuador	6.5%	6.2%
Jordan	11.7%	11.0%
Kenya	5.8%	6.0%
Pakistan	9.8%	8.0%
Vietnam	11.6%	9.1%
Zambia	0.5%	-1.0%
Zimbabwe	1.2%	1.0%

As the complexity of the power network as well as the demand for power increases so does the need for more sophisticated means to manage and control the generation, transmission, and distribution of power in order to optimize efficiency. In some of the countries with rapid growth of demand optimization has, however, been a secondary issue as they have labored with a fairly chronic shortage of supply. In one case, that of Zimbabwe the situation has developed even though growth of demand has been sluggish. This is because of lack of investment in existing generating plants and their gradual deterioration.

Network Losses

Network losses, which comprise losses in both transmission and distribution networks and in the case of the latter both technical and commercial losses, have developed as follows for seven out of the nine countries²⁶.

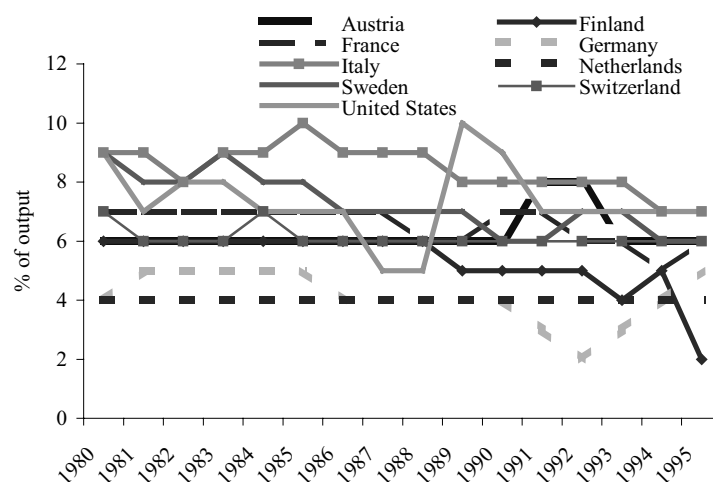
²⁶ Graph is based on World Bank statistics, which is unavailable for the full period for Botswana and Lesotho. It should be noted that it has not been possible to verify if the data refers to both technical and commercial losses in all cases. For losses above 20 % this is obviously the case.



The level of losses incurred by a system is one indication of its relative efficiency and, as a consequence, also of where its priority problem might lie. The graph suggests that the level of losses vary significantly from one country to another. There is one group of countries that have only rarely recorded losses of less than 20 percent while Zambia, Zimbabwe, Jordan and also Botswana (see page 39) have averaged less than half of this for several years. The analysis of the network losses for each country has not revealed any correlation between the installation of a SCADA system and the level of losses.

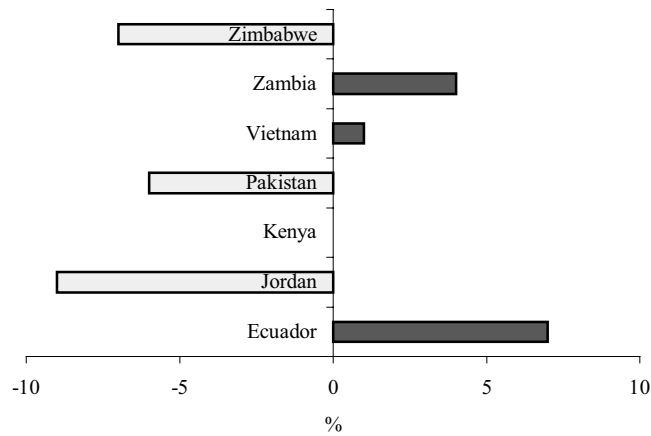
A comparable graph for a number of OECD countries shows a significantly different picture.

Network losses sample of OECD countries



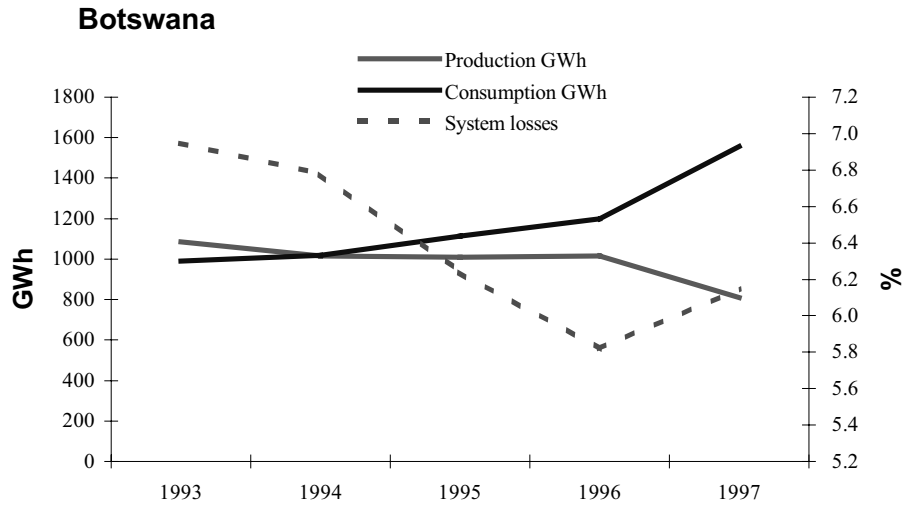
Network losses are considerably lower than in developing countries and they do not differ very much from one industrialized country to another. They also tend to change within a fairly narrow range. The graph below shows that this is not the case for the countries in our sample.

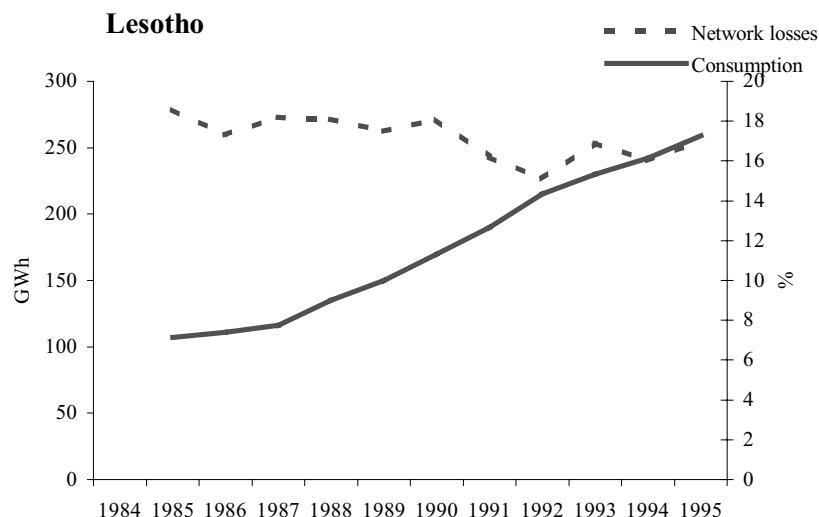
**Percentage Change in Network Losses during
the period 1980 to 1996**



Between 1980 and 1996 network losses increased in three countries (Zambia, Vietnam and Ecuador) and in the others they decreased at rates varying between 9 and 6 percent.

The graphs below summarize the data available for Botswana and Lesotho. It has been derived from different sources and may therefore not be directly comparable that for the other countries.





SCADA and Network Issues

Supply/demand imbalance is a particularly critical issue in Kenya and Zimbabwe although demand has been stagnant or only growing slowly. In both countries the power companies have had to resort to extensive and frequent load shedding. Pakistan and Vietnam have both had very rapid growth in demand but so far managed to also increase supply. High network losses represent a more critical problem in those countries. Botswana and Lesotho are both big importers and they are likely to continue to import for the foreseeable future. Expanding the network into sparsely populated rural areas has been the main issue. Ecuador, Jordan and Zambia have the best networks with relatively limited problems.

The following table summarizes the main issues facing the nine networks.

	High load	Supply/demand imbalance	High network losses	Outages	Economic dispatch	Export/import monitoring
Botswana			⊗	⊗		⊗
Ecuador	⊗				⊗	
Jordan						⊗
Kenya		⊗	⊗			⊗
Lesotho		⊗	⊗			⊗
Pakistan	⊗	⊗	⊗		⊗	
Vietnam		⊗	⊗	⊗		
Zambia				⊗		⊗
Zimbabwe		⊗		⊗		⊗
Total						

Project Justification

The following is a summary of the project justifications contained in the documentation on which SIDA/BITS based their approval of the projects. The table shows, for each project, which types of benefits were expected according to feasibility study or investment proposal.

	Staff reduction	Reduced reserves	Reduced transmissi on losses	Fewer and shorter outages	Improv ed power quality	Reduced maintenance cost	Fuel and water savings	Export/import optimization
Botswana	⊗		⊗	⊗		⊗		
Ecuador		⊗	⊗	⊗	⊗			
Jordan								
Kenya				⊗	⊗		⊗	
Lesotho		⊗	⊗	⊗	⊗		⊗	⊗ import
Pakistan		⊗	⊗	⊗				
Vietnam		⊗		⊗				⊗ distribution
Zambia	⊗	⊗		⊗			⊗	⊗ export
Zimbabwe		⊗	⊗	⊗			⊗	
Total	2	6	5	8	3	1	4	

Information on projects justifications for Jordan was not available to the Consultants.

All projects were intended to address the issue of outages, the reduction of which was also expected to yield the largest benefits. In six cases an additional justification for the investment was reduced generating reserves (in cases expressed as optimization of production). For five of the projects reduced transmission losses were also included among the intended results of the investment. Fuel savings, in a broad sense, has also been an objective for four projects. Power quality and staff reduction was only mentioned in respectively three and two cases.

In the course of the field visits the SCADA operating staff was asked to identify the extent to which these benefits had been realized and to quantify wherever possible the amount of benefits generated by their respective SCADA systems. Appendix 4 contains the questionnaires used for this purpose and Chapter 7 details the results.

Chapter 3 The Project Initiation Process

Looking Backwards

The issue of project relevance can be approached in two ways. One can either try to determine, ex-post, which were the principal issues and problems at the time the project in respect was conceived and relate those to the expected results. In the case of the SCADA projects this would call for an analysis and ranking of the network problems that faced each of the nine power companies some 10 to 20 years ago. These issues would then need to be related to the scope and level of technology of the SCADA systems. Although difficult to accomplish with accuracy and complete objectivity this analysis is attempted in Chapter 4.

It is also possible to seek the present owners' and operators' views on the extent to which the SCADA systems were designed to serve their power sector's priority needs. If complemented with an analysis of the factual circumstances surrounding the project initiation and procurement process, such a polling of subjective hindsight wisdom can offer some explanations as to why projects have not performed as planned or not been utilized as well as was expected.

The project initiation process is a particularly relevant issue for SCADA systems since these represent a technology that was new or recently introduced in the countries at the time the projects were conceived²⁷. They prompt the following questions

- Could the buyers define their need for SCADA?
- Could they evaluate the benefits of something they knew very little if anything about?

A buyer's ability to determine, independently of the seller, what he needs and what the proposed purchase will accomplish is one of the factors that determines how well the investment is used and consequently the benefits it yields.

Ownership Issues

The hi-tech nature of SCADA and its character of a new and largely untried technology in most developing countries give rise to three ownership issues:

1. Was SCADA a relevant solution for the problems facing the user organizations at the time the projects were conceived?
2. From which of the four main parties involved (e.g. owner, supplier, consultant, financing agency) did the driving force behind the project originate?
3. What were the choices offered the buyer in the course of the procurement process?

The Procurement Process

Did the buyer have a real choice between competing offers or were circumstances such that there was no real choice? If choice is limited an owner's sense of responsibility for and commitment to the project will normally suffer. A wholly

²⁷ Very basic SCADA systems existed in some of the countries concerned but none of these were anywhere near as sophisticated as the ABB SCADA systems that were subsequently installed. See appendix 2 for details.

competitive procurement process is typically user/owner driven, whereas a negotiated procurement tends to be more favorable for the interests of the supplier.

In order to respond to the issues of project ownership and relevance the Consultants conducted semi-structured interviews with the managers of the SCADA units and other senior staff in the eight user organizations that were visited.

Interview Returns

The interview results are summarized in the following table with respect of SCADA relevance, project sustainability, project initiative, and procurement process. The full interview results are attached in Appendix 5.

The SCADA relevance is studied and analyzed in respect of:

- main system issues at time of investment,
- SCADA functions, and
- suitability of SCADA scope.

There are two aspects that are evaluated in relation to project sustainability, namely:

- the technical component, and
- the competence of the operators.

The element of project initiative is divided into two categories.

- identification, preparation and initiation of the project, and
- actors' influence over the process.

Five aspects of the procurement process are included:

- type of bidding process,
- type of contract,
- users' reasons for selecting ABB,
- consulting engineer for design and specification, and
- Swedish consultant's perceived independence.

Summary of interview returns

	Botswana	Ecuador	Jordan	Kenya	Lesotho	Vietnam	Zambia	Zimbabwe
Relevance of SCADA functions	Limited to Good	High	High	Moderate to high	Low to Acceptable	Limited	High but not for EMS	Inadequate initially, high after upgrading
Suitability of SCADA scope	Very Good	Moderate - insufficient for future needs	Very Good at the time but insufficient at present	Moderate due to over-dimensioning	Limited	Moderate ²⁸	Very Good	Very Good
Project initiative	Owner's influence low	Owner's influence high	Owner's initiative high	Owner's initiative low	Owner's initiative very low	Owner's influence low	Owner's initiative low	Owner's initiative very low
Procurement process								
Type of bidding	Selective tender	Partly competitive	Competitive tender	Competitive tender	No competition	No competition	No competition	First competitive, second negotiated
ABB advantage	Supplier of existing system	Swedish financing	Swedish financing	Best Price/performance	Swedish financing	Tied aid	Swedish grant financing	Swedish concessionary loan

²⁸ Moderate suitability of scope is largely due to insufficient computing capacity resulting from US embargo on computer equipment.

Findings

Ownership and Relevance

From the interview responses it appears that the relevance of SCADA functions and the suitability of the scope was perceived by the respondents to have been best in the case of Ecuador and Zambia followed by Jordan and Botswana. Ecuador and Jordan were also the countries where the power companies felt they had had a high degree of influence over the project initiation process, i.e. a large degree of "project ownership".

The relevance of functions and suitability of scope is likely to also be a function of the design and specification process for which most projects have engaged external consultants.

- In both Jordan and Ecuador the power companies engaged and paid for their own consultants (a Brazilian firm in Ecuador and several British firms in Jordan) and carried out considerable in house assessments, prior to the involvement of BITS funded Swedish consulting engineers.
- In Ecuador the Government created a special SCADA development unit in the late 70s and it produced several studies and reports in the course of the following ten years.
- The power company in Jordan²⁹ established a first regional control center in the early 70s where after it prepared designs and specifications for a national control center with assistance of two British consulting firms. The center, built and equipped by Brown Bowery, was commissioned in 1983. In 1984 SwedPower was engaged to prepare specifications and tender documents for a new SCADA system.
- It is also appears that Jordan and Ecuador were the countries which have had the longest experience of SCADA systems and this has probably contributed to the fact that they had substantial influence over the project initiation process and that their systems met the needs.
- In Botswana the power corporation BPC carried out considerable in-house development work that included system specifications and tender documents.

In the other countries the owners' perceived influence over the process varied from low or limited to almost non-existent in the case of Lesotho for which there is no record of there having been a design assignment for a consultant.

The Image of the Consulting Engineer

In cases when the customer/user does not have a competent engineering staff to design, specify and procure SCADA system, the role of the consulting engineer becomes particularly critical. The interviews revealed that few of the respondents viewed the Swedish consulting engineers as independent of either SIDA/BITS or ASEA/ABB. The fact that only few of SIDA's and BITS' procurements of consulting services offered the buyer a choice³⁰, and that most of the projects were funded with tied aid appears to have added to the perception of a common Swedish interest being

²⁹ At the time Jordan Electricity Authority which has since been split into three entities, Central Electricity Generating Company, National Electric Power Company (the current SCADA operator) and Electricity Distribution Company

³⁰ With respect to procurement one respondent stated, "We were given a list from which to chose a consultant but there was only one name on the list".

served by consulting engineer, supplier and funding agency. A statement made by BPC staff reflects the attitude of several user organizations. *"We thought SwedPower was on our side. But ABB and SwedPower just switched hats with each other"*.

The documentation made available to the Consultants suggests that Sida/BITS assigned Swedish consulting engineers belonging to the same group (SwedPower/SWECO) to prepare specifications, appraise projects or evaluate bids, etc in seven out of nine cases (see Appendix 3 for further details). However, in several cases their assignments had been preceded by studies made by other consultants or, as in the case of Ecuador and Botswana, by in-house studies.

- Jordan Energy Authority (JEA) engaged two UK consultancies³¹ for design and evaluation.
- In Kenya, IVO, a Finnish company, provided design and specification services³².
- In Zambia, Sida funded the cost of a study prepared by an Irish consulting firm (ESB) and after which SwedPower was commissioned to appraise the study and SWECO to prepare specifications and tender documents.

The respondents from these five countries are also the ones that appear to have been most satisfied with system relevance and suitability of scope.

The Procurement Process

Jordan and Kenya were the two countries, which considered the procurement process for the system to have been competitive. The procurement process for the initial system in Zimbabwe, which involved a total of 28 tenders, was also highly competitive but it was followed by a negotiated contract for upgrading for which a consultant (Sydkraft International) concluded that prices were 60 to 70 percent higher than normal.

The procurement process in Ecuador was partly competitive. The first tendering process was competitive but it failed because of lack of funding. In a second round three suppliers were invited but only ABB submitted a tender along with an offer of Swedish concessionary financing for 85 percent of the contract value. The procurement process in Botswana, referred to as "selective tendering", can probably not be considered to have been competitive.

In summary it would appear that less than half of the procurements were seen by the owners to have been competitive, i.e. that there was a choice.

Without Funding - No SCADA

All but two respondents mentioned financing as the main competitive advantage for ABB. It is probable that this response was recognition of the critical importance of financing rather than an assessment of the price competitiveness of ABB's SCADA system.

³¹ Preece, Cardew and Rider and Kennedy and Donkin

³² BITS subsequently engaged SwedPower to appraise the project and IVO's study.

The interviews revealed that none of the countries were likely to have acquired ABB's SCADA systems at the time had they not had BITS or SIDA funding. The interviews did not raise the issue of price, partly because so many of the projects had not been subject to competitive bidding. Since external funding was necessary the issue of price is likely to have been of subordinated importance. This issue will instead be explored in the subsequent chapter.

Summary

The projects in Jordan and Ecuador appear to have been more successful than the others with respect to overall ownership and relevance. They are followed by the Zambian SCADA system, which received high marks for relevance and suitability.

The project in Lesotho appears to have been the least successful. This is corroborated by an early assessment of the project made by a Swedish consultant in 1988³³ (shortly after commissioning). Also low on the list is the project in Vietnam, which, because of an embargo did not receive the computers that the system required.

The following chapter will review relevance from a different perspective.

³³ Report by the Appraisal Mission regarding Possible Norwegian/Swedish Support to Improved Subtransmission and Distribution Networks in Lesotho, 19 July 1988

Chapter 4 System Relevance and Cost

The Need for a Model and a Measuring Rod

It is not possible to judge the relevance of a SCADA system without relating its features to some type of measuring rod. This chapter seeks to answer the question of whether the various SCADA systems were technically relevant and competitively priced by first creating a capacity measuring rod by which different SCADA systems can be ordered and, thereafter, comparing key aspects of the nine systems with those of three ABB systems in Norway and two in Sweden. The assumption being,

- firstly, that the Norwegian and Swedish networks represent competent buyers able to judge relevance of different versions and various components of the systems, and
- secondly, that they represent buyer behavior in a competitive market environment which forces the actors to maximize cost efficiency.

For the purpose of this evaluation the Consultants have designed a simplified SCADA Comparison Model. It deserves to be noted that this is only one of many different possible models none of which could take into account all the many features and differences of the soft and hardware products that has evolved over a period of close to 30 years.

It appears that no such model exists with either ABB or other engineering firms. At the Consultants' request, ABB's SCADA staff has reviewed the Consultants' model and recommended modifications, all of which have been taken into account. The Consultants have therefore concluded it is a reasonable basis for comparing different ABB SCADA systems. However, since it is a simplified model, which ABB also noted, its results must be considered indicative rather than exact.

The Components of the Model

This model distinguishes the SCADA systems that have been delivered to the nine countries according to scope and functionality. Each of the nine evaluated systems and the five Nordic are thereafter classified into different categories of functionality and capacity (the SCADA Classification Model). In parallel, a set of power sector parameters have been defined which identify the control and monitoring needs of different power network essentially by way of their complexity. Each of the nine as well as the five Nordic systems are defined in terms of the same power sector parameters.

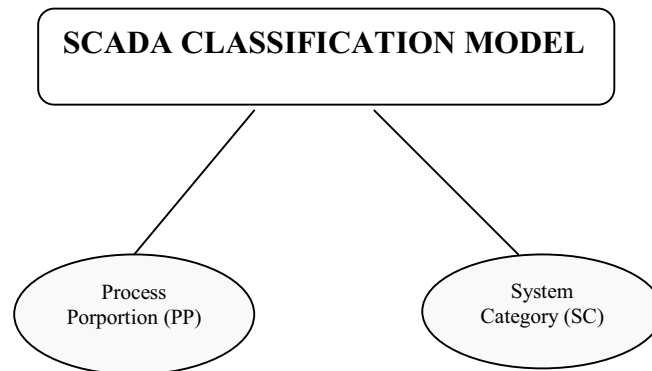
The model is thereafter used to determine

- a. the category of system that is used for different power sector parameters in, respectively, the nine evaluated systems and the five Nordic, and
- b. the cost per capacity and functionality indicator of each of the 14 systems.

Classification of SCADA-Systems

System Determinants

The Consultants have developed a SCADA classification model comprising two complementary measures of system scope and sophistication. These measures are hereinafter referred to as Process Proportion (PP) and System Category (SC).



The performance of SCADA systems with respect to processing speed and storage capacity has increased dramatically in the short span of two decades. The price related to performance has decreased in a similar manner as for computers. The most important factors that determine system costs as of today are:

- level of standardized contra system specific hardware and software components,
- extent of supplementary software for advanced power network operations, and
- reliability with respect to redundancy of central systems and telecommunications system.

Appendix 6 contains a list of the most common software application packages in ABB's SCADA systems. These applications and functions exist in most other SCADA systems as well.

Process Proportion (PP)

The systems that are evaluated in this study were commissioned at different times over a period of a dozen years starting in the mid-80s. The first SCADA systems based on standard PC computers and software appeared on the market in the early 90s but none of the systems in this study were PC-based³⁴. They were all specially designed for the particular user and comprised different hardware and software combinations. In addition they represented different software generations ranging from SINDAC 1 in the case of Lesotho to SPIDER in the case of Zambia and Zimbabwe.

A main parameter that has direct influence on system scope of supply and system cost is what this report has called "the process proportion". Since the essence of the system is to collect, transmit and process data between remote locations and centralized control facilities, the number of collection points and the volume of data compiled and

³⁴ The system for Vietnam was not intended to be PC-based, but became so because of a US embargo on computer equipment for Vietnam.

transmitted at each location determines to a significant degree the capacities required in different parts of a system. This aspect of a SCADA system has been a major system-dimensioning factor from the very first systems and up to the systems of today. The process proportion is a capacity factor, which determines:

- the processing capacity of the central system,
- the number of channels of the system's communication network,
- the number and capacities of RTUs, and
- the additional facilities and local control equipment in substations and power stations.

The PP measure does not take full cognizance of the difference in complexity and capacity between different types of communication systems for a SCADA system. Topography, the extension of the power network and the nature and capacity of the existing telecom net are factors that determine in part which communication solution is the most optimal for a given SCADA system. The cost of the communication part of a SCADA system can range from a low of 20 percent to a high of 40 to 50 percent of the total.

The Consultants have constructed a formula, using quantifiable system parameters, to calculate a composite value for PP for each of the SCADA installations included in the evaluation. Since the values of the PP indicator are relative rather than absolute three levels of PP have been defined, namely

Process Proportion (PP)	Process Points
Small	PP < 40
Medium	41 < PP < 80
Large	PP > 81

The PP value is based on the number of RTUs with a correction factor for the average RTU size for each SCADA system. The number of process points is the sum of the total number of commands, events/indications and measurements in each system. The sum of these items determines at which PP level the respective SCADA systems are positioned. The manner in which the PP has been calculated is described in Appendix 6.

System Category (SC)

The measure of the sophistication of a SCADA system is the capacity of the central software and hardware system and the capabilities of the communication system. This report refers to this as the System Category (SC). The details of the SC identifier are contained in Appendix 6. This report has placed the nine SCADA systems under review in one of three different SC categories, namely

1. Standardized,
2. Slightly Advanced, and
3. Advanced.

In each category there is a number of variations of SCADA-systems depending on alternative solutions related to the software, hardware, and telecom.

Standardized and slightly advanced SCADA systems are presently more or less the same. Slightly advanced systems belong to the period prior to the time when PC-based systems were introduced and they have now been superseded by the latter. These systems were based on the same software as the advanced systems, but they lacked the redundancy of the latter. The concept of redundancy is, in this context, used to depict a duplication of central or peripheral process equipment in a system. Telecom channels may also be redundant. The redundancy may be in the form of so called cold or hot stand-by facilities. The cold – hot difference refers to manual or automatic switching from one system to the stand-by system.

The systems belonging to the standardized category are based on Microsoft or similar software developed for a large number of different applications. Advanced SCADA systems are based mainly on UNIX operating systems and the supplier's proprietary software for data processing. Previously, these systems used so-called multi-user operating systems for real time processing.

Control Centers

A majority of the SCADA systems under review are national systems are used to manage and control national power networks. There are no or only very small difference in principal between the manner in which national as opposed to regional systems are managed and controlled. The added tasks of a national control center are monitoring of frequency control and dispatch for power import and export. For less complex national power networks these function do not require a very sophisticated SCADA system but modern SCADA system often incorporate automation of these functions as well. ABB's SPIDER system has concentrated these functions in what is called an AGC (automated generation control) module of software programs.

In less complex power networks, such as those that exist in the majority of the countries included in the review, load flow, in the case of export or import, can be monitored and controlled at the power exchange points between two national systems and reported to a central control facility by telephone on a regular basis or as the need arises. Monitoring of frequency and frequency time lag between networks can be done at the national control center using telecommunication facilities between local and national control centers, generation control facilities and relatively simple off-line IT programs. This would yield a result which is as adequate as that rendered by a more complex and more costly on-line and real-time SCADA system.

For some of the countries ABB delivered several control centers from which the whole system could be managed. Several control centers would add to the reliability of the system but it would also mean more hardware equipment and software components and more design and engineering work.

Classification of the SCADA systems to be evaluated

The SCADA systems included in the evaluation have been classified in accordance with their respective values for Process Proportion (PP) and System Category (SC). The values in the table below refer to the most recent ABB SCADA system installed in the respective countries in all cases but Lesotho. Also included in the table is the number of control centers.

SCADA System	Number of control centers	Number of RTUs	System category	Process proportion	System cost USD million	Corrected system cost USD million
Botswana SPIDER	2	36	Advanced 308	SMALL	4.99	4.99
Ecuador SPIDER	1	28	Advanced 308	SMALL	14.97	15.51
Jordan SINDAC	1	50	Advanced 302	MEDIUM	13.50	13.50
Kenya SINDAC	3	36	Advanced 308	SMALL	16.61	16.22
Lesotho SINDAC	1	20	Slight Advanced 204	SMALL	3.30	3.09
Pakistan SINDAC	3	108	Advanced 302		44.55	21.53
Vietnam Interim PC and SPIDER	1	40	Standardized 301	SMALL	3.25	3.25
Zambia SPIDER	1	24	Advanced 308	SMALL	11.32	10.99
Zimbabwe SPIDER	4	133	Advanced 308	LARGE	22,45	25.99

The cumulative investment cost (in thousands of US dollar) of the respective SCADA systems is shown in the second last column. The amounts cover the SCADA and telecommunication deliveries but do not include costs of consultants for project preparation, management support or training. The Nordic SCADA operators have had costs for both consultants and for training but probably not on the scale of the nine systems under review.

In case of Jordan the cost includes USD 4.5 million corresponding to the estimated purchase value of the old RTUs used in the ABB installed SCADA system. The cost estimate for Vietnam (HCMC-PC) is with respect to both the first and second phase. The reason being that the first phase was incomplete and is therefore, on its own, not well suited for comparison purposes. For those reasons the total investment for the respective systems therefore differ from the totals given in the table on page 15.

Because of the fact that the telecom components of the systems vary considerably in cost the investment cost used for the comparison between the Nordic and the BITS and Sida funded systems has been corrected to reflect a similar proportion of telecom cost for all systems where data on telecom cost has been made available. The details of the corrections are presented in Appendix 6. The last column of the above table shows the corrected values.

Power Sector Characteristics

There are important differences between the nine countries' power sectors. This implies that the requirements for the respective countries' SCADA would differ as well. There are several parameters that can be used for determining the networks' need for SCADA system capacity and functionality. The ones used for the purpose of this assessment are:

- maximum load,
- annual power production, and
- length of transmission lines.

Apart from the above listed power sector characteristics; the other factors that also influence the need for a SCADA-system are:

- amount of non-delivered energy (measured in system minutes),
- type of network,
- system operating framework,
- topography,
- desired level of security level of supply, and
- customer structure.

The latter factors, while relevant, play a lesser role than the former. They have not been included as quantifiable variables but are taken into account for the overall judgment of system relevance a sector needs.

Main Indicators of Sector Needs

The maximum load is a key indicator of the complexity of a system. It should serve as the most important determinant of the scope of functions of a SCADA system.

The volume of production is an indication of the potential for savings that the SCADA system could generate and it therefore indicates the level of SCADA system capacity.

The length of transmission lines is an important factor influencing the faults occurring in the system but it has a lower relevance than the other above-mentioned factors for the scope of the SCADA system. The length of the transmission lines has an influence on the costs for the telecom part of the installed SCADA system. Long distances between large supply centers may also lead to construction of several control centers.

Needs Indicators for the Evaluated Countries

The following table summarizes the status of the three parameters for each country at the year of the first investment of SCADA system.

Country	Production (GWh)	Max load (MW)	Length of transmission lines (km)
Botswana 1993	1100	190	1424
Ecuador 1992	7200	1827(1996)	7062 (1993)
Jordan 1985	2500	825 (1995)	3026 (1999)
Kenya 1989	2900	530	2610
Lesotho 1986	2	43 (1999)	700
Pakistan 1989	34600	5071 (1999)	3383 (1983)
Vietnam 1991	9300	632 (1995)	7700 (1991)
Zambia 1996	7800	1000	6200
Zimbabwe 1985	5700	1968 (2000)	4620 (1993)

Comment: The values are those prevailing at the time of investment or when not available the closest year. In these latter cases the year is put in brackets after the figure.

Appendix 7 contains a review of these parameters for each of the nine evaluated power systems.

Assessment of SCADA System Suitability and Cost Effectiveness

Comparison with Nordic SCADA Investments

The cost effectiveness of a system is normally assessed by relating its capacities and investment cost to that of alternative measures for achieving the same purpose. In the case of a SCADA system this is made difficult by the fact that each system is unique – it delivers features and functions that cannot be realized in any other manner. It is also difficult to assess the cost effectiveness by relating the investment cost to the value of the benefits since the latter are multidimensional and difficult to measure. This evaluation has chosen to seek an answer to the cost effectiveness issue by comparing the nine SCADA projects under evaluation with both each other and the five Norwegian and Swedish SCADA projects. The operating characteristics of the five Nordic networks are shown in Appendix 7

The following table shows the values of PP and SC indicators calculated for the five Nordic SCADA systems along with the number of control centers included in their systems. For all but Statnett³⁵ the investment cost figures are those incurred since the respective systems were initiated. In the case of Statnett the figures are in respect of a major replacement/upgrading project, which started in the late 90s. This amount has been increased by 50 percent in order to account for the RTUs that were retained from the previous system.

³⁵ Statnett is a national system for control of the Norwegian power network whereas all the other systems are regional.

SCADA System	Number of control centers	System category	Process proportion	Investment cost USD million equivalent
Borås Energi	1	SCADA 302	SMALL	0.70
Jämtkraft	1	UNIX 301	SMALL	2.08
Buskerud Energi	1	Standardized	SMALL	4.69
MINI-SCADA		104		
Vestfold Kraft	1	Advanced	MEDIUM	7.21
SPIDER		302		
Statnett	4	Advanced	LARGE	20.60
SPIDER		308		

Findings

The results of the assessment of the nine systems are summarized in the table overleaf in respect of the need for

- national SCADA,
- distribution SCADA system,
- multiple control centers,
- supplied functions, and
- System Category.

The relevance of the investment costs is assessed in relation to these elements Appendix 6 contains the details of the assessment of each system.

System assessment

	Botswana	Ecuador	Jordan	Kenya	Lesotho	Pakistan	Vietnam	Zambia	Zimbabwe
Need for national SCADA	Doubtful	SCADA justified on technical grounds	SCADA justified on technical grounds	SCADA justified on technical grounds	Not needed	SCADA justified on technical grounds	SCADA justified mainly because of high load factor in the	SCADA justified on technical grounds	SCADA justified on technical grounds
Need for distribution system SCADA	Very small Manual control system would have been sufficient	n.a.	n.a.	Nairobi distribution system did not necessarily need the regional SCADA system	Not needed	n.a.	distribution system for Ho Chi Minh City.	n.a.	Harare and Bulawayo SCADA systems for distribution not needed
Need for multiple control centers	Not needed	Only one exists	Only one exists	Three installed but only one needed	n.a.	n.a.	Only one exists	Only one exists	Four supplied max two needed
Need for supplied functions	Several applications have not functioned	Virtually all functions used	EMS used and system replaced with AGC system	EMS never installed		n.a.	Some statistical functions never used; Phase 2 failed stability test and software is malfunctioning	Load forecast function never used	EMS never used
System Category Need	System had 308 whereas 302 would have sufficed	SC 308 is justified	SC 302 well suited	SC 308 was supplied but 304 would have been enough	-	SC 302 appears under dimensioned	SC 301 is adequate	SC 308 was installed. SC 306 would have sufficed	SC 308 supplied for national system. 306 would have sufficed

The Need for SCADA

If the standards normally applied in industrialized countries would be used all but two of the nine SCADA systems would be justified on purely technical grounds by the complexity of the respective power networks. Lesotho's network was and still is too small to warrant a computerized remote control system. The same results can be achieved by having manually operated processes combined with automatic remote alarm and measurement handling. Botswana is a border case. Botswana's own system is too small and uncomplicated to warrant a SCADA system but it imports a large part of its power needs and wheels power from South Africa to Zimbabwe. This increases the utilization of its transmission net but the monitoring of this power can be handled as efficiently with much less sophisticated systems than the SPIDER system that was installed in 1996. There is likewise little to be gained by way of better frequency control since Botswana has a very small internal generating capacity in relation to that of South Africa.

In the Nordic countries, small and medium distribution networks (up to about 300 MW load) have been managed and controlled without SCADA systems up until the middle of the 90s. Monitoring and control has been based on telephone and on local switching and measuring of load flow. A distribution system operator has kept records of breaker positions on single line diagrams of the network from a centralized control center. Simple alarm systems for monitoring of supply outages have been common.

Five of the nine systems under review included SCADA sub-systems for monitoring a regional or city transmission and distribution system. Those sub-systems are, by and large, deemed to be superfluous. It is noted that no region or city in the Nordic country with loads similar to those of Nairobi, Harare or Gaborone would have invested in a SCADA system at the time this was done in four of the five countries concerned. The only case where this investment could be justified was that of Ho Chi Minh City in Vietnam. Today, with less costly systems and so called Mini-SCADAs, SCADA investments in distribution networks are likely to yield benefits more commensurate with their costs.

Redundancy and Function Oversupply

There appears to have been an excess of redundancy in the form of several control centers in one and the same country. The Consultants have concluded that extra control centers in Botswana, Kenya and Zimbabwe are unlikely to have added value to the respective power sectors. For the telecom part of the systems, the large size of some of the power systems could be deemed to justify redundancy. Growing distances lead to growing risk of communication breakdowns. However, it deserves to be noted that the power networks in both Kenya and Zimbabwe have no redundancy, i.e. reserve capacity, whatsoever when it comes to power generation. On the contrary – Zimbabwe's generating capacity is so old, worn and inadequate that the country is balancing precariously on the brink of major blackouts whenever demand surges.

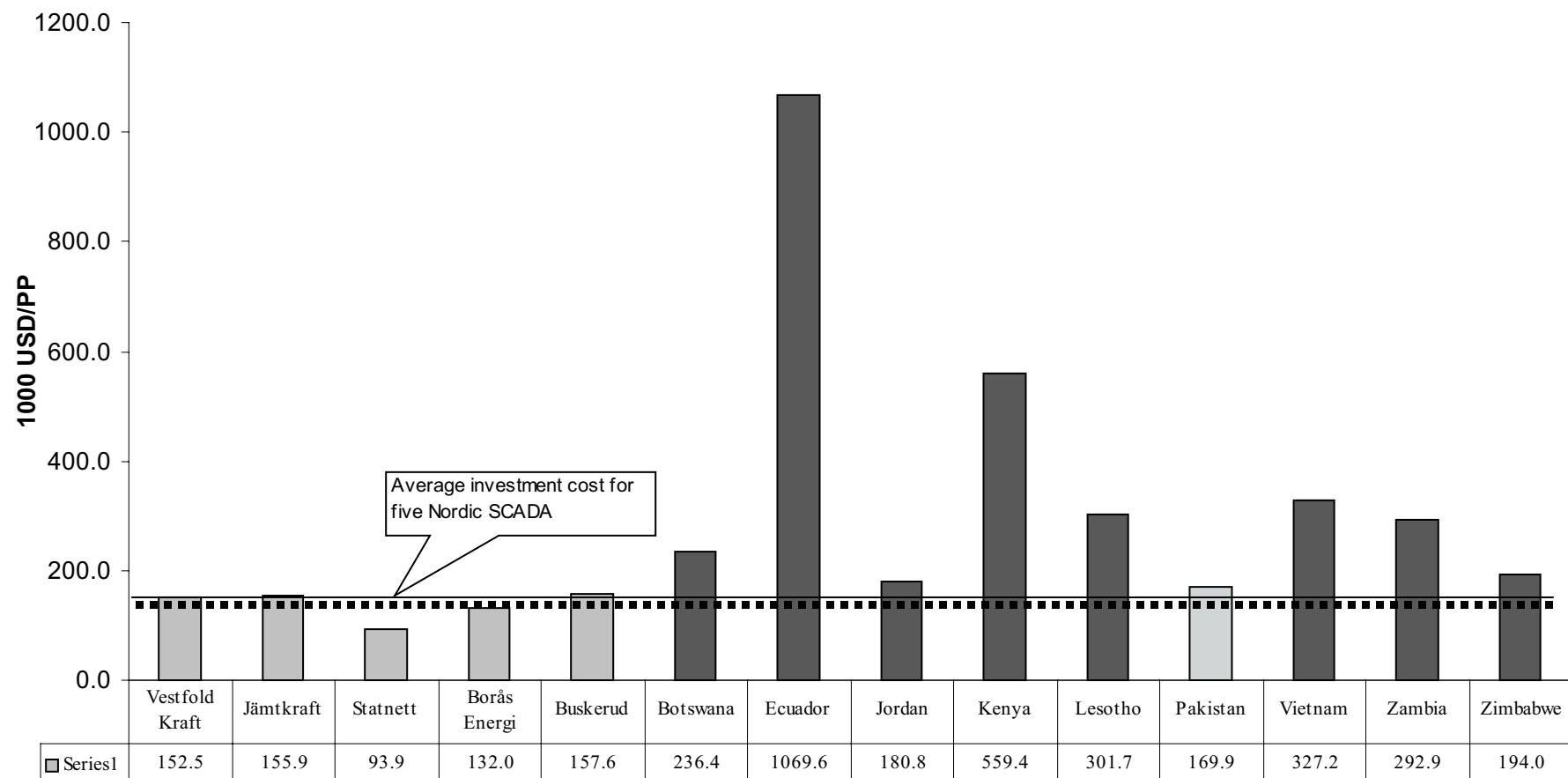
The evaluation also included a review of the question of whether or not there was a System Category or function over supply. The conclusion was that this appeared to be the case in at least three of the nine countries (Kenya, Lesotho and Zimbabwe) but that two countries might have adequate system category, namely Pakistan and Vietnam.

The function oversupply was particularly apparent in the case of the EMS software. Only two of the five systems with EMS appear to have used this costly software. Some have not even commissioned it. Other features of oversupply were the SCADA versions themselves. Most of the systems would have performed equally well with a somewhat lower degree of system sophistication.

The Investment Cost Issue

The final parameter that was evaluated was investment cost. A total of 14 projects have been compared – the nine under review and five Nordic projects ranging from small to medium and large. The PPs were calculated in the same manner for all 14 projects and the investment cost over time was converted to US dollar at the average annual exchange at the time the investments were made³⁶. The investment cost for the SIDA/BITS financed projects only includes the cost of deliveries by ABB and associated companies, not the cost of the many consulting inputs SIDA/BITS has financed. The investment cost has also been corrected for variations in the scope and cost of the telecom component where available data made this possible (in seven out of the 14 cases). The investment costs (in US dollar) were totaled up and divided by the PPs of the respective system in order to serve as a price/performance measurement. The details to how the PP comparison has been made are shown in Appendix 6. The graph overleaf shows the SCADA investment cost in US dollar per PP for each of the 14 SCADA systems.

³⁶ In the case of Norwegian Statnett the investment cost is that of a major replacement and upgrading project started in the late 90s.



Investments/PP

N.B. The estimate of the investment ratio in the case of Pakistan is indicative.

The Nordic projects display a relatively large consistency in terms of the investment cost per PP. It varies from a high of USD 158 to a low of 93³⁷ with the lower value being for a very large system, i.e. an economy of scale effect. The Sida funded projects, on the other hand, show huge variations. Three of the nine Sida funded SCADA systems show PP unit costs that are less than 1.5 times as high as the Nordic average. The SCADA system in Pakistan with USD 170 per PP is the lowest among the evaluation projects followed by the project in Jordan with US dollar 181 per PP and Zimbabwe with USD 194 per PP.. All three are relatively large system. The one in Pakistan is very large but the investment cost data for this system is much more uncertain for the other systems.

The procurement process for the systems in respectively Pakistan, Jordan and Zimbabwe appears to have been fairly competitive. In the case of Zimbabwe this applies to the first installation but not to the two subsequent. All other systems but those three were either more costly or very much more costly than the Nordic systems. The SCADA installations that were procured with little or no competition, such as the ones in Ecuador, Lesotho and Vietnam have PP unit costs considerably above those of the five Nordic SCADA systems.

There are a number of other reasons, apart from the degree of competition, why costs differ for SCADA systems in the Nordic countries, on the one hand, and far away developing countries or emerging economies, on the other. The following are some (but not necessarily all) of those reasons:

- oversupply of functionality and too much redundancy,
- a larger part of design and engineering done by the contractor as opposed to the buyer,
- a relatively larger complement of spare parts,
- more training than for Nordic customers,
- costlier installation because of need to have staff out-stationed for longer period of time, d
- higher transport costs, and
- higher finance related cost, i.e. EKN premiums, etc.

For all cases where data has been available the investment cost has been corrected for unusually high proportion of spares and training, etc. as in the case of Ecuador. Detailed cost data from four of the Sida funded projects³⁸ suggest that training has not exceeded 5 percent of the total. Spare part cost appears to have ranged between a high of 9.3 percent in Ecuador and a low of 4.6 percent in Zambia. The EKN cost, where it applies, can however, be quite substantial. There is no record of an EKN cost for Ecuador but in Kenya it corresponded to 9.8 percent and for the second delivery to Zimbabwe (the Bulawayo RCC) it equaled 7.6 percent of contract value. Transportation cost, on the other, hand accounts for a very small proportion (1.4 percent in Ecuador and 3.2 percent in Zambia).

It therefore appears as if the above-mentioned costs, while not insignificant, cannot by themselves explain the high cost per PP for a majority of the projects under review.

³⁷ Since the Statnett investment cost figure was for a replacement project (which yielded a USD 54/PP ratio) the investment cost has been increased by 50% to take into account facilities of the previous system used with the replacement, i.e. buildings, a large number of RTUs, communication network, etc. The result was a USD 80/PP ratio.

³⁸ Ecuador, Kenya, Zambia and Bulawayo RCC in Zimbabwe

The following table shows how the different SCADA systems' investment cost per PP deviates from a benchmark which has been assumed to be an average of those of the four Nordic SCADA systems, i.e. USD 138 per PP. It also sets out the probable reasons for deviations from the benchmark value.

Country	USD/PP value	% deviation from bench mark	Comments
Botswana	236	171%	Selective tendering appears to have yielded a moderately high cost per PP
Ecuador	1070	773%	Extremely high cost per PP possibly due to limited competition and very sophisticated computer facilities
Jordan	181	131%	Competitive procurement and relatively large proportion of buyer financing are likely reasons for moderate PP cost
Kenya	559	404%	High PP cost in spite of relatively competitive procurement. Oversupply (several control centers) may have contributed to high cost
Lesotho	302	218%	No competition and oversupply probable cause of high cost
Pakistan	170	123%	Competitive procurement and economy of scale appears to have yielded competitive cost (Note – weak database).
Vietnam	327	236%	No competition, and oversupply likely reasons for high cost
Zambia	293	212%	Limited competition, some oversupply and costly and engineering main likely reasons for PP cost
Zimbabwe	194	140%	Highly competitive procurement (28 tenders) and large size of system for first installation is likely to have contributed to moderate cost.

The two causes of particular concern are those of oversupply and high prices because of limited competition. Both are difficult to substantiate and may easily be questioned. However, interviews with the buyers suggest that they are perceived as having been very important. The following table summarizes what, with the benefit of hindsight, the buyers think of the prices and the relevance of the scope of delivery.

What the Buyers Say

In the course of the field appraisal the operators were asked to comment on the relevance of their SCADA system and what, with hindsight, would have been their preferred choice if they had funded the systems with their own funds. It appears that the existence of tied aid has played an important role in expanding the scope of delivery beyond that which would otherwise have been procured. The table below summarizes the operators' views.

Stated reasons for high cost of SCADA system

Country	Comments
Botswana	Availability of Swedish financing. In the absence of BITS financing BPC would have bought fewer RTUs
Ecuador	ABB was the only offer with financing and INELEC bought a more sophisticated system than they would otherwise have done.
Jordan	Availability of concessionary financing. In the absence of BITS finance JEA would have invested in a less expensive and less advanced system offered by BBC.
Kenya	In the absence of donor finance KPLC would not have bought as many control centers or the EMS. KPLC also claims that comparisons it has made suggest that prices for SCADA systems are much higher in developing than in industrialized countries. KPLC believes that there exists a certain amount of price collusion among major suppliers
Lesotho	There was no assessment of cost for the first SCADA project. For the second (which did not receive Swedish funding) Sydkraft International considered "the cost to be reasonable and in line with similar equipment offered for India and Zimbabwe".
Pakistan	No comments were available.
Vietnam	No comment as to relative cost of investment. The consultant determined scope of delivery. It was considered reasonable and subsequent problems mainly due to embargo.
Zambia	ZESCO wanted to use the opportunity of SIDA financing to replace the existing Harris system while low demand for power from the Copperbelt area would have suggested that this should not have been a high priority.
Zimbabwe	First SCADA scope (1985) was inadequate but price was considered competitive. Scope of delivery for the 1994-95 upgrade was good except for EMS but price was very high. Purchase of Harare ACC could have been postponed.

Tied Aid and Project Cost

A large number of studies have concluded that tied aid increases project cost by an estimated 25 percent³⁹. The findings of this evaluation are consistent with this observation. They suggest that tied aid affects the behavior of both the supplier and buyer. The effect of tied aid appears to be twofold in that it increases cost by:

- decreasing competition, and
- expanding the scope of supply.

Of the four parties normally involved in an aid funded project, the buyer, the supplier, the consultant and the aid agency, the consultant would be the party responsible for limiting the scope of supply to that which is cost efficient and justifiable by industry standards. The buyer would wish to make maximum use of the funds since they are not fungible, i.e. cannot be used for any other purpose. The supplier would obviously wish to sell as much as possible at the

³⁹ See for instance "Assessing Aid", The World Bank, 1998

highest possible price and the aid agency is often subject to spending pressures. Irrespective of how strong a professional commitment the consultant would have to cost efficiency the risk that the interests of the other three parties would dominate is apparent. This is what appears to have been the case in several of the projects under review.

Comparing Costs

ABB has a pricing policy referred to as value based pricing. This implies among other things that there exists no price list for individual items or components with which to compare the prices included in the various contracts for the nine projects. A few comparisons have, however, been made.

Botswana

ABB's price for a RTU was Pula 500,000. According to BPC the same RTU could be bought, in South Africa, for Pula 100,000 equivalent.

Kenya

In the period 1992 to 1996 KPLC bought three C400 RTUs for the prices shown below:

	1992	1995	1996
C400 RTU from ABB Sweden	SEK 935,000	USD 108,495 (SEK 773,570 equiv)	SEK 1,329,300

At the same time ABB Sweden supplied the C400 RTUs to Norwegian customers for a maximum price of NOK 280,000 (USD 40,000 equivalent).

An evaluation of the SCADA project in Kenya noted that the normal price paid by Vattenfall for a similar system was SEK 75 to 80 million (approximately USD 9⁴⁰ million) while the contract value exceeded USD 16 million (CHF 24.4 million plus KES 10 million).

Vietnam

In 1989 SwedPower estimated the cost of the SCADA system for the Ho Chi Minh City region at USD 1.5 million including a high capacity main computer. The cost of the partial system, which did not include the specified main computer but a PC instead, was USD 3.0 million.

Zambia

The cost estimate for the SINDAC system in Zambia, made by the consultant ESB, was USD 6.6 million as compared to a final ABB contract value of SEK 75 million (USD 10.51 million at 1995 exchange rate). In US dollar terms the contract value was 59 percent higher than consultants' estimate⁴¹.

Zimbabwe

A Project Review Report in respect of the 1994-95 upgrading of Zimbabwe's SCADA system (made by Sydkraft) noted that "prices quoted [by ABB] especially for the hardware appear to be

⁴⁰ The exchange rate at the time of the study was approximately SEK 8.50/USD.

⁴¹ In Swedish Kronor the final cost exceeded the estimate by 76 percent since the Swedish krona declined from 6.45/USD to 7.13 in the period 19989 to 1995.

roughly 60-70 percent too high compared to the prices of the corresponding products from other suppliers⁴²."

The role of the consultants

This evaluation has noted that cost comparisons, apart from the one for Zimbabwe that was referred to above, were lacking in most of the project feasibility and appraisal reports that have been made available to the Consultants. The most thorough cost estimates were found in the ESB and IVO studies for respectively Zambia and Kenya.

Country	Study	Comments
Botswana	Appraisal by Sydkraft	No cost comparisons were made
Ecuador	In-house study	Not available with Sida
Jordan	No study or appraisal in Sida	BITS documentation contained no indication that cost comparisons had been made.
Kenya	IVO Project Document 1985 and a SwedPower appraisal	The IVO study contained a detailed cost estimate, which was approximately a tenth of the eventual contract value. SwedPower's study stated, on the one hand, that ASEA prices were in line with those offered to the Swedish National Power Board, and on the other that a normal price for a similar system bought by the Swedish National Power Board would correspond to USD 9 million while the KPLC system cost USD 16 million.
Lesotho	Appraisal by Lars Hydén	A very brief assessment that contained no analysis of project cost
Pakistan	ADB appraisal	No comparison of costs appears to have been made.
Vietnam	SwedPower feasibility study	A rough estimate of project cost in the order of USD 1.5 million (SEK 10 million). The value of the contract was USD 2.8 million, which covered only part of the original project.
Zambia	ESB feasibility study	Contained a detailed cost estimate, which was approximately 40 % lower than the corresponding contract value.
Zimbabwe	Short summary of benefits by ASEA	No record of a cost comparison was found but procurement process for first SCADA system was highly competitive. Sydkraft made cost assessment of the upgrading.

⁴² ABB reports that this statement has since been withdrawn. However, no documents to that effect exist in Sida's archives.

Chapter 5 Making Use of the Investment

The System Utilization Process

This section deals with three aspects of what has been termed the System Utilization Process. They are, firstly, the operation and maintenance of the system, which is described for each country and operator, secondly the aspect of system upgradings and thirdly, training.

It is suggested that operators in developing countries have less appreciation of the need for upgradings than their counterparts in industrialized countries and that developing country SCADA owners should gain a better understanding of the systems' character of ongoing processes rather than projects with distinct beginnings and ends.

There has been a lot of training and transfer of know-how throughout the SCADA investment processes and in each and every one of the nine countries. With few exceptions the result appears to have been good. To the extent that there has been complaint it is mainly that there has not been enough training.

Operation and Maintenance

Overview

This section summarizes the Consultants' impressions of the operational and maintenance status of seven of the nine SCADA operations under review. These impressions were gained during relatively short three to four day visits and are therefore not complete. They are based mainly on statements made by the staff, which, in most cases, were taken at face value and not verified because of the limited time available. In the Consultants' view, however, the staff made every effort to present as an objective and true picture as possible.

All SCADA systems that were visited were well staffed and appeared to be competently operated. The very best appeared to be the ones in Ecuador, Zimbabwe and Jordan. With a few notable exceptions the spare part situation was good and there were few examples of equipment or facilities not used.

There had been and were still problems with some of the systems, notably in Botswana, Vietnam and Zambia while those in Zimbabwe had been solved.

The following is a brief description of the operational and maintenance situation of seven of the nine systems. The Consultants gained very limited access to the SCADA facilities in Lesotho and the SCADA system in Pakistan could not be visited.

Botswana

BPC's SCADA system has had good reliability. The national and city control center is well staffed and the staff appears competent and dedicated.

The main problem has been and continues to be maintenance and cost of spares. There have also been a number of operational problems, which have not been solved in spite of repeated requests

for assistance directed to both ABB and SwedPower. The fact that some distribution feeders give inaccurate measurands have forced BPC to retain a larger number of field operators than what would otherwise have been necessary. Other problems have been with respect to the data-engineering tool, the picture-editing tool (which has crashed on several occasions), the RCS application (also crashing occasionally and the unstable NCC to GDCC (Gaberone Distribution Control Center).

Ecuador

The SCADA system at CENACE has had a high reliability. The NCC is housed in a building located at an earthquake safe location outside of Quito and it is well staffed by approximately 35 persons all of whom have requisite formal education and training. There has been some staff turnover but a large number of staff members trained by ABB in connection with the installation are still with CENACE.

The spare part situation is good and no part of the system is out of operation because of lack of parts. Part of the NCC terminals was being replaced at the time the Consultant visited CENACE.

All software except for the short-term load forecast is in use. The EMS and the AGC are both used and the SCADA system in its entirety is used primarily for dispatching, especially during the dry season when several hydro reservoirs run dry. It is also used for monitoring the forced generation of Guayaquil during the dry season

The current operator of the Ecuadorian NCC and SCADA system is a regulatory and market making entity, CENAC, which supervises the market actors and ensures that deliveries are made and capacity is kept. CENACE has both a technical supervisory role and a financial function. Its SCADA system is used only for the former and only for supervisory and regulatory purposes. CENACE is not an operator of either nets or generating capacity and it cannot issue commands. This is done by the operators themselves using, as the case may be, their own remote control systems.

Jordan

The NCC operated by NEPCO appears to be very well staffed and competently managed. There has been little staff turn over.

The ABB SINDAC system installed in 1986-87 by JEA (the predecessor of NEPCO) has worked. All functions that the system had (including an early version of EMS) were installed and operated. The system had satisfactory reliability and availability. There had been no serious maintenance problems although the system was becoming old and spare parts were gradually more and difficult to access and quite costly.

Towards the mid 90s the SINDAC system started to be inadequate for the needs of Jordan, which had started to wheel substantial amounts of power between Egypt and Syria. The SINDAC system could not be expanded any further as all extra functions were fully utilized. NEPCO considered but rejected the SPIDER system proposed by ABB as too inflexible and not open enough. NEPCO wished to avoid the "lock in" to one and the same supplier.

Instead NEPCO chose the SCADA system RANGER from an American supplier Bailey.⁴³ NEPCO's technical staff concluded that the SPIDER system is ill suited for national networks but better suited for smaller and less complicated networks. They also maintain that SPIDER is well suited for mature and stable networks that do not grow or change very much. SPIDER is not well suited for developing countries.

NEPCO has estimated that approximately 40 percent of the previous SINDAC investment has been retained in combination with equipment of the new RANGER system.

Kenya

The SCADA system in Kenya has so far performed well and operated with a high degree of reliability and availability. The system is well manned and the staff is well trained but there has been a certain staff turnover. In the period 1992 to 94 two persons retired and three left to among others ABB.

KPLC reported that the basic functions of the EMS were not used but that parts of the software such as gross measurement error analysis, state estimation, contingency analysis, operator's flow analysis and symmetric short circuit analysis was operated. One of the system's 36 RTUs was never commissioned, reportedly because of problems with the telecom system to the substation in respect.

The main problem is maintenance. The hardware of the system, being 12 years old, is close to the limit of its technical life. In addition the spare part situation, as of March 2001 was quite alarming mainly because of lack of funds. Ordering and shipment of spares was also said to be time consuming.

KPLC has no support contract with ABB although the support provided by ABB was appreciated. The high cost was the major issue.

Vietnam

A different company than the one that bought the first SCADA system in 1992-93 operates the SCADA system in Ho Chi Minh City. Ho Chi Minh City Power Company (HCMC-PC), established some five years ago when Power Company 2 (PC2) was split into different units, took over the responsibility of supplying the greater Ho Chi Minh City area with power. HCMC-PC operates a regional transmission network and a city distribution network with 900,000 subscribers but has no generating plants. The first interim SINDAC system was replaced by a SPIDER system in 1998 when the existing network of 33 RTUs was complemented by another 16 units of which only seven had been installed by early 2001. Additions were also made to the UHF radio communication system, which had experienced problems of interference from high buildings in the center of Ho Chi Minh City.

The control center has a staff of 44 persons of which 15 are SCADA operators. There has been considerable turnover of staff. Only one of the nine staff members who were trained by ABB in the early 90s is still working with the SCADA system. The eight persons trained in connection with the second SCADA installation are required to stay with HCMC-PC for five years.

⁴³ which company has since been acquired by ABB

Maintenance has been the major problem. The control center staff claims that they cannot handle restoration and software faults on their own and that the center therefore has to rely on ABB staff from Sweden who visits Vietnam only infrequently and with considerable delays. With better training and better access to source codes the extra cost and long delays could be avoided.

HCMC-PC has also faced difficulties with spare parts because of changing state regulations as well as long delivery times.

Zambia

The SCADA system in Zambia has had a high operational reliability. Total down time of the system since 1996 has been 29 hours and 15 minutes but this has not affected all computers simultaneously. The central functions are well staffed by approximately 40 persons. There has been very little staff turnover (since 1996 only one person) and the operators are experienced. The NCC can also draw on experience staff from the two RCCs.

Previous problems with the telecommunication system appear to have been solved by way of a new system installed in 2001.

The load forecast software has been commissioned but was not running. This was said to be due to data acquisition problems that may be resolved by the new communication network. AGC performs well and in frequent use. It is used for import/export monitoring, for frequency control and for control of power generation at Kafue Gorge power station.

One RTU at Kabwe has never been commissioned due to radio link problems.

The main operational issue is maintenance and replacement of worn-out batteries at the substations. Disruptions of parts of the remote control operation may be the result if there is an outage that affects a substation without adequate battery backup power.

Zimbabwe

Zimbabwe's SCADA system has a high operational reliability. The two control centers are well staffed with a total of approximately 100 persons. There has been almost no staff turnover with respect to power system operators. Just one person has left since 1997. All SCADA operators have, on average, several years' experience.

The spare part situation is good and no part of the system is out of operation because of lack of parts.

The EMS software was commissioned but not running due to instability and sensitivity problems in measuring values. AGC, on the other hand, performs well and is in active use. It monitors imports, system frequencies and is used for control of power generation of the Kariba South plant.

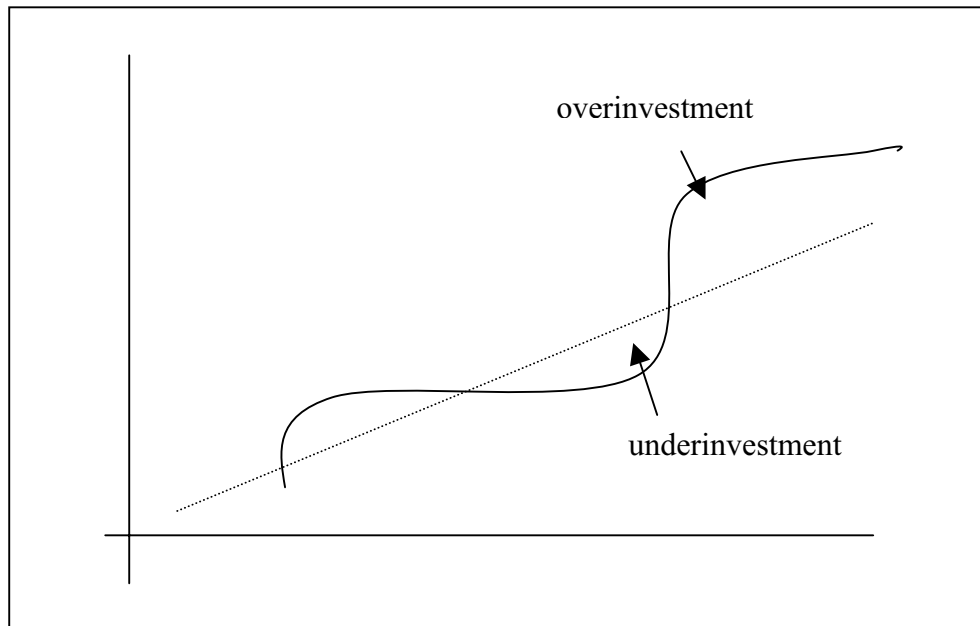
ZESA was the only operator to have access to the source code for SCADA and EMS/AGC software. This makes them relatively independent of ABB's support and has contributed to an in-

house development of programming skills, which are quite unique among all the eight operators that were visited.

Upgradings

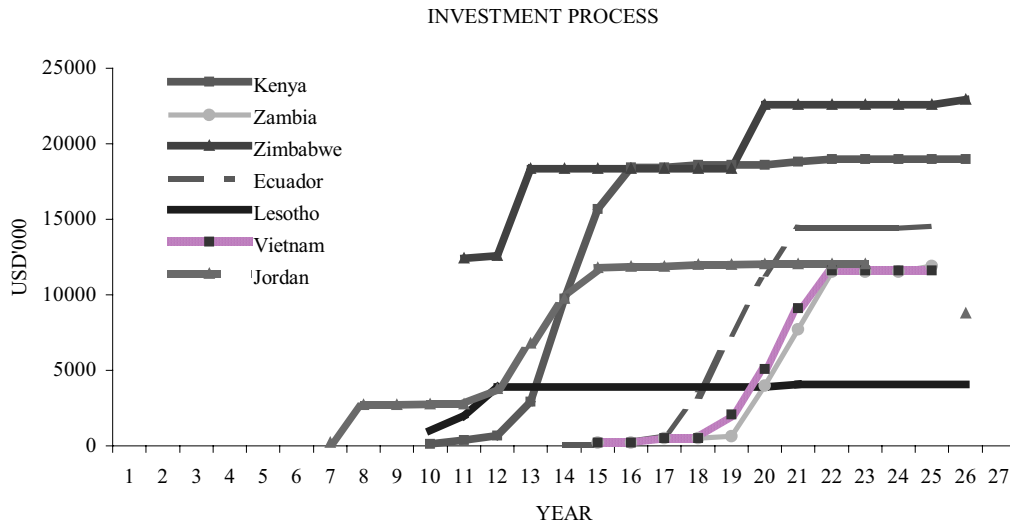
Is Process versus Project an Issue?

It has been suggested that the process versus project issue is particularly important in the case of SCADA investments. Developing country SCADA owners, it is claimed, has insufficient appreciation of the fact that a SCADA system, in order to best serve its purpose, should be frequently upgraded so as to provide maximum performance at all times. A gently sloping investment curve would indicate that the system is maintained and upgraded frequently while an "frog-leaped" and uneven curve suggests that there are periods when the operator has been over-invested, i.e. has a system with capacity beyond the need at the time, and other periods when the system is less than optimal. This interpretation of the investment curves is corroborated by the findings of the relevance and cost analyses, which suggest that most systems might have been over dimensioned at the time of investment.

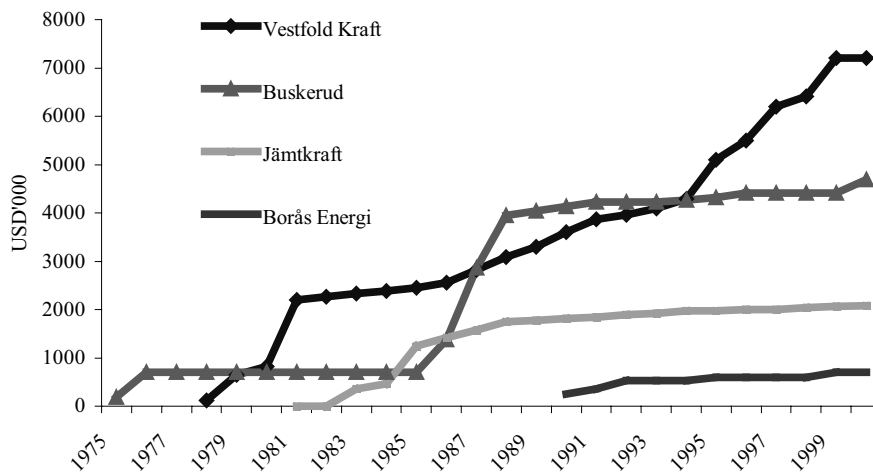


The Consultants have not found much evidence in support of this notion. There are possibly some differences but they do not appear to be substantial and the different service and price levels that appear to exist on respectively developing and industrialized markets can easily explain them.

The two graphs below show SCADA investment processes for respectively seven of the nine evaluation projects and for four Nordic SCADA operators. The curves show the accumulated amount of funds spent on the systems.



The seven SIDA/BITS assisted projects show investment curves characterized by few and large investments interspersed by long periods with no or very little investment activity.



The investment processes in the case of the four Nordic operators gives an impression of having been somewhat more even but they also have distinct investment humps. It appears that the differences are not as large as have been claimed and the differences that exist are probably a consequence of factors that have to do with pricing and service. This evaluation has concluded that spare parts and upgrading hardware and software is considerably more costly in a developing country. Another factor, which should dampen the desire to invest in a developing country, is that the tangible financial benefits in the form of reduced staff costs are nowhere near as large as in for instance Norway and Sweden.

Another important reason is likely to be aid funding in itself and the in particular funding with tied or non-fungible aid. Since these funds are often made available for a particular purpose there is a strong incentive for the recipient to use as much of it as possible irrespective of whether or not this is cost effective.

A closer examination also suggests that power companies in the Nordic countries tend to operate their systems for 10 to 15 years where after they invest in new generation equipment. The Statnett project that was discussed in the previous chapter, is an example of this, Vestfold Kraft and Jämtkraft are others. The record suggests that the owner/operators of the nine SCADA projects that are being evaluated have changed and upgraded with shorter intervals than in the case of the sample of Nordic operators used for bench marking.

Training

There have been essentially four types of training activities for SCADA staff and operators.

Training has been provided

- by the supplier ASEA/ABB both in Sweden (occasionally also in Norway) and on site,
- by consultants (mainly on site),
- through the Power System Control and Operation course in Sweden and
- by way of in-house training courses run by the operators.

The Consultants very strong impression is that the SCADA systems in many of the countries that were visited were characterized by a culture of training. This was particularly well articulated in Botswana, Ecuador, Jordan, Zimbabwe and Zambia.

The table overleaf sets out the training courses that have been funded by BITS and SIDA.

TRAINING By the supplier				By consultants			By SIDA/BITS
Country	Year	Contractor	Comments	Year	Assignment	Contractor	Power System Control and Operation Course
Botswana	94	ABB	Could have been better	95-00	Implementation support	SwedPower	4 participants in 12 courses
Ecuador	94	ABB	Very Good	91-95	Implementation support	SwedPower	9 participants in 12 courses
Jordan	88	ASEA	Very good	90	Management support	SwedPower	
				92	Training	SwedPower	9 participants in 12 courses
					Training	SwedPower	
Kenya	89	ABB	Excellent	95	Training	SwedPower	7 participants in 12 courses
Lesotho	87	ASEA	No comment	88-90	Training	Eggen Norplan	3 participants in 12 courses
Pakistan	89	ABB	n.a.	90	Training	SwedPower	2 participants in 12 courses
				98	Training	Svenska Kraftnät	
Vietnam	92	ABB	Good but lacking in UNIX	91	Implementation support	SwedPower	8 participants in 12 courses
				96	Technical assistance	SwedPower	
Zambia	95	ABB	System design and system operation training not satisfactory	90	Kafue Training Ctr Phase 1	SwedPower/Norplan	
				93	Implementation support	SWECO	7 participants in 12 courses
					Kafue Training Ctr Phase 2	SWECO	
Zimbabwe	85	ASEA	Excellent				
	87	ASEA					7 participants in 12 courses
	94	ABB					

The following table summarizes the operators comments as regards training.

Country	Comments
Botswana	"Training is an ongoing process. To that end BPC would like see its resources better utilized", primarily training for detailed SCADA system troubleshooting
Ecuador	Fully satisfied with the training provided by both ABB and SwedPower. (CENACE runs regular training courses on its own premises)
Jordan	Satisfied with the training.
Kenya	Very satisfied with the total training package from ABB
Lesotho	No comment (Lesotho appears to have had more training than any of the other operators but the result has not been as good)
Pakistan	n.a.
Vietnam	Critical, "training does not meet demand. Due to limit of expenses, many items of training program had been cut off to fit the budget from Sida".
Zambia	The personnel at NCC were not fully satisfied with the training in the SCADA system design and system operation facilities. This training was conducted by ABB during the implementation period and could have been better.
Zimbabwe	The training of SCADA personnel and power system operators has been completed to ZESA's full satisfaction". The staff in both fields is very skilled. NCC staff has been trained also in software design and maintenance, which is greatly appreciated.

The table below sets out the number of participants from the nine countries to the Power System Control and Operation course in the period 1985 to 98.

Year	85	86	88	89	90	91	93	94-1	94-2	96	97	98	Total	%
Botswana			1				1	1				1	4	7%
Ecuador	1	1	1	1	2	1	1				1		9	16%
Jordan	1	1	1	1			1	1		1	1	1	9	16%
Kenya	1	2	1	1							1	1	7	13%
Lesotho					1				1	1			3	5%
Pakistan					1	1							2	4%
Vietnam							1	2		1	2	2	8	14%
Zambia	1		1	1		1	1	1	1				7	13%
Zimbabwe	1	1	1				1		1	1		1	7	13%
Total from 9 countries	5	5	6	4	4	3	6	5	3	4	5	6	56	100%
Total no of participants	20	20	22	18	18	20	25	23	26	25	25	26	268	

A total of 56 persons from the nine countries received training through this course. They accounted for some 20 percent of all the participants. The cost of this training has not been included in the cost for the SCADA projects.

On the whole it appears that the training has been successful and that it has made a lasting impression on several of the organizations concerned. Total cost of training is estimated at approximately USD 4 million.

Chapter 6 Promoting Exports with Aid - Is There Sustainability?

Swedish Objectives

A substantial part of the Swedish funding for the SCADA projects has been in the form of tied aid in the form either of concessionary loans or grants. The concessionary loans and grants provided by BITS were tied by definition whereas SIDA grants, used to fund the SCADA systems in Vietnam and Zambia, could in principle have been used for purchases outside of Sweden. It appears that this was never contemplated, however⁴⁴.

An important reason for tied aid is a desire to favor the interests of national supplier/s and consultants. In the case of the SCADA projects at hand, these interests were represented by ABB, the sole Swedish supplier of SCADA systems⁴⁵, and the SwedPower/SWECO group. BITS supported the export ambitions of ABB and SwedPower/SWECO not only by direct funding but also through the abovementioned Power System Control and Operation course, which introduced many power company senior officers to Swedish SCADA competence and indirectly served to strengthen the Swedish position in the international market for SCADA systems. This course, consulting services by SwedPower/SWECO and SCADA systems delivered by ABB and tied aid finance by BITS were recognized as components of an effort to promote Swedish know-how in the export market.

The result to date has been the business volume of SwedPower and ABB, a total of about USD 180 million as noted in an earlier chapter. The issue of this chapter is to examine the present and possible future results of these efforts. Has the combined efforts of aid agencies, consultants and ABB resulted in a sustainable export market for ABB's SCADA and SwedPower's power sector know-how?

Is the Customer Always Right?

Customer Feedback

A relevant question for this evaluation must therefore be whether or not the strengthening of the market position of ABB and SwedPower/SWECO is likely to be permanent. The answer to this issue was sought by way of two indicators used in the interviews with senior staff of the eight SCADA operators that were visited. All interviews were semi-structured and the Consultants have, as is customary, interpreted the results.

The two indicators were:

- firstly, the operator/owners description, on a scale of strained, good, excellent, of three dimensions of the supplier relationship and one with respect to the Swedish consultant (SwedPower or in the case of Zambia, mainly SWECO), and

⁴⁴ In the case of Zambia SIDA funded a SCADA feasibility study carried out by a foreign consultant – ESB if Ireland. For all subsequent consulting work that was funded by SIDA Swedish consultants were chosen.

⁴⁵ At the end of the 80s there were several other Swedish SCADA companies, albeit relatively small and without developing country experience.

- secondly, a review of the eight SCADA operators' supplier preferences in the course of recent, ongoing or planned procurements of SCADA goods and services.

The following table summarizes the customers' responses.

Status of buyer – seller relationship									
	Botswana	Ecuador	Jordan	Kenya	Lesotho	Pakistan	Vietnam	Zambia	Zimbabwe
ABB									
General	☹	☺	☺	☺	☺		☺	☺	☺
Commercial									
Local	☹	☹	☺	☺	☺	☹	n.a.	☺	☺
representation									
Technical	☺	☺	☺	☺	☺		☺	☺	☺
staff relation									
SwedPower/ SWECO									
General	☹	☺	☺	☺	n.a.		☺	☺	☺

☹ = Strained, ☺ = Acceptable, ☺ = Excellent

If one accepts the credo that the customer⁴⁶ is always right it appears that the buyer – seller relationships range between strained and acceptable as regards general commercial matters and local representation but good to excellent when it comes to technical matters. A frequent complaint was long response time and exorbitant or very high prices for both parts and services. Many owners stated that ABB's lack of timely response suggested that they do not represent a priority for ABB. There was also a widespread feeling that ABB made excessive use of the operators' dependence on ABB for parts by way of very high prices and slow deliveries.

The eight visited power companies were also asked to indicate how they looked upon ABB's and SwedPower's competitive position with respect to recent, ongoing or planned procurements. The following is a summary of the responses.

⁴⁶ It should be recognized that the setting of an evaluation by a Swedish consultant of a Swedish aid funded project with Swedish suppliers is such that completely objective answers might not always be given.

ABB's and SwedPower's competitive position in current procurements

	Botswana	Ecuador	Jordan	Lesotho	Kenya	Vietnam	Zambia	Zimbabwe
ABB	Is unwilling to invite ABB for future system renewal	Will chose other system but ABB in ongoing procure-ment	Has chosen other system but ABB for system renewal	Awarded recent upgrade to ABB	Questions re ABB's pricing principles	Has chosen other system but ABB for new central transmission SCADA project	ABB has received new aid financed order for micro-SCADA	ABB short-listed for new small system – due in part to lock -in
Swed-Power	Swed-Power unlikely to be invited	Swed-Power not short listed for system renewal procure-ment	Swed-Power not invited	n.a	n.a	n.a	n.a	Swed-Power engaged for other projects

In spite of a good technical standing it appears that ABB has had limited success in its efforts to continue the business relationship beyond the one financed with aid funds. When procurements have been funded by the operators themselves or, as in the case of Vietnam through a World Bank loan, ABB has not been deemed to be competitive.

The "Lock in" Dilemma and "Dependency Based" Pricing

"Lock-in"

There are several possible explanations for the modest appreciation that ABB appears to be enjoying among the eight customers that were surveyed. For products such as SCADA there is a system dependence, often referred to as the "lock in effect" which is similar to that of a temporary monopoly. Customer "lock-in" is the norm in the information economy, because information is stored, processed and communicated using a system of multiple pieces of hardware and software and because substantial investment in specialized training is required in order to use individual systems. In economic and financial terms the "lock-in effect" could be said to be a consequence of durable investments in complementary assets specific to the brand of system and to assets (tangible and intangible) that have different economic life spans. This means that there is no given time when to start using a new, incompatible system. For the supplier this creates the semblance of a monopoly and this is how, for instance, ABB's representative in Pakistan described his position vis-à-vis the client WAPDA and how many of the SCADA owners characterized their relationship with ABB. The customer has nowhere else to turn so the need to provide prompt service at a competitive price does not appear to be particularly urgent.

"Value Based" or "Dependency Based" pricing?

ABB's "value based pricing" means that there is no price list common to all customers for many of the parts and services of the systems. Instead ABB seeks to price products and services in relation to the value those confer to the customer. Such pricing methods are felt by SCADA

owners to be a "dependency based" pricing method. The operators feel that they are charged as much as they can be expected to tolerate. The same part or service features can therefore vary considerably in price from one country to another depending on the options that are available to the customers, i.e. the degree of competition.

Future Prospects

"Lock-in" is common for information systems such as SCADA and managing the relationship is difficult for both buyers and sellers. The "lock-in" effect is seldom a lasting market characteristic. There are strong incentives for both customers and competitors to circumvent the barriers. The emergence of more open standards for SCADA systems is already affecting the market. A number of the interviewed SCADA owners are planning to acquire more open systems and NEPCO in Jordan has already done so.

ABB's position as a supplier to these owners is shown in the following table.

Owners	Future Prospects	Comments/Reasons
Botswana	Limited	Disappointment due to: • Highly priced support, spare parts etc. • Number of Issues not solved during guarantee period • Frustration because of the monopoly situation caused by lock-in
Ecuador	Limited	Not included among three short-listed bidders for new system Complaints about dependency-based pricing
Jordan	Limited	Lost a contract in 1999 when NEPCO contracted another supplier (Bailey) for a Ranger system Reasons: Open system and better price
Kenya	Moderate	Good relation with local representative but skepticism re pricing system
Lesotho	Good	Awarded a contract for 1999 investment in a Spider system funded by other donor organization
Pakistan		No information
Vietnam	Limited	Recently procured and World Bank funded SCADA system awarded to French group ⁴⁷
Zambia	Moderate	Recently purchased Micro-SCADA for distribution from ABB with aid-finance from Finland. Privatization may change procurement prospects since there will be less aid.
Zimbabwe	Moderate	ABB one of several possible suppliers for the up-coming Bulawayo-RCC project.

⁴⁷ Sida has reported that the French contract is reported to have been due to France providing tied aid.

Chapter 7 Financial and Economic Viability

General

Type of Benefits

The Consultants have been provided with adequate data for a financial and economic viability assessment of five of the nine projects. The methodology used for the assessment is that of cost benefit analysis. The benefits that have been included are those that the operators of the five systems listed as the most important. They are

1. Outage time reduction and blackout time reduction
2. Optimization benefits with respect to both transmission and generation, and
3. Manning reductions.

SCADA suppliers maintain that SCADA systems also deliver other benefits (see page 31 above). This report takes no issue with this claim. It deals with five specific projects for which the operators have specified the benefits derived under the particular circumstances that these systems are operated. These benefits may or may not be relevant for other SCADA systems.

Outages

Outages can either be unplanned (involuntary) or planned, the latter being shut downs for maintenance or outages because of load shedding. For those a SCADA system plays little or no role. SCADA generates benefits in the former time gains mainly in case of involuntary also referred to as unplanned or forced outages. There are three causes by which most power companies classify and record outages. They are:

- Unplanned externally caused (from the distribution network),
- Unplanned generation caused, and
- Unplanned transmission caused.

There are three phases to the power restoration process in the case of involuntary outages. They are as follows:

1. detection
2. stabilization and
3. restoration

A SCADA system offers the operators in the central control office a faster and more complete overview than what is possible with a manual system. This allows for faster detection, faster rerouting or disconnection or other measures need to stabilize the network. Restoration time, however, is not shortened significantly in case stations are manned.

Optimization

For most of the system under review optimization as defined above (see page 17) was not considered relevant. The same was the case for many of the other benefits that proponents of SCADA systems claim exist (e.g. better frequency control in case of exports/imports, longer equipment life, better capacity utilization, etc.). One reason might be that they are likely to be mirror effects of the manning reduction benefit. The staff who, in the absence of a modern

SCADA system, would man substations, power plants and a number of local control centers would do many of the things the SCADA system does, albeit not as fast and not always as accurately.

Furthermore, most of the operators interviewed by the Consultants would suggest that there is a wide range of SCADA solutions rather than a "with and without" SCADA choice. A SCADA system can be very simple and quite inexpensive. It can also be highly sophisticated and very expensive. Many of the things done by a sophisticated integrated SCADA system can be done off-line with the help of stand-alone PC computers. A simple and inexpensive SCADA system produces many of the benefits derived from a much more sophisticated. In some instances, depending on the sophistication of the operators, the complexity of the system to be supervised, the more complex system may not yield any measurable extra benefits at all.

Manning reductions

Manning reductions have not been a priority for any of the five networks that were visited and none of them had made any attempts to follow up the manning consequences of their SCADA systems. In some instances (Zimbabwe, Vietnam and Lesotho) operators maintain that there have been no staff reductions at all. In the case of staff reduction the Consultants have chosen to differ with the operators. It is probable that SCADA results in manning reductions over time even though there is no policy for achieving such a purpose. This is likely to have particular relevance for fast growing networks. The Consultants have therefore assumed, for all five systems that are evaluated, that a gradually growing number of transformer stations will be automated and that this will result in manning reductions corresponding to one shift of five persons less one who will be retained for maintenance duty. The estimates of benefits from manning reductions are likely to err on the generous side rather than the opposite.

One of the other benefits is, however, real but very difficult to quantify. That is the increased occupational safety for the staff. Power networks house many dangerous workplaces and SCADA helps reduce the extent to staff needs to be exposed to safety risks.

The value of electric power

What follows below is a simultaneous financial and economic assessment. For the projects at hand the only significant difference between the two types of assessment lies in the value of the energy provided as a result of reduced outage time. There is no objectively correct economic value for electric power. For this reason the internal rate of return calculations have used a range of electricity values. The base case is the average revenue per MWh of the network in year 2000. This is the financial value. The cost benefit calculations are carried out for multiples of this base case value, 2, 3, 5 and 10 times this value in order to provide a return range which would cover the likely economic value of the electric power gained as a result of SCADA.

Cost Benefit Analysis

The analytical tool that has been used is that of a cost benefit analysis. A set of annual benefits has been calculated for the estimated life of the investment. Together they make up the benefit stream. Annual costs as well as the investment cost make up the cost stream, which reduces the benefit stream to produce a net benefit stream. The items included are the ones shown in the table below.

Summary of benefits

Value of reduced non-supplied energy (USD'000)
Savings due to reduced manning levels
Residual value
Total benefit stream

Summary of costs

Variable production cost of extra delivery
NCC staff cost
Maintenance cost
Investment cost
Total cost stream

Net benefit stream

The net benefit stream has been discounted to produce the internal rate of return. In addition a net present value has been calculated for each benefit and cost item and for the net benefit stream in order to avoid having conflicting rates of return.

Basic Assumptions applied for all cases

The following are the basic assumptions common for all five cases:

- The investment lifetime is assumed to be 15 years
- A residual value of 15 percent of the original investment has been added to the benefit stream at the end of the 15-year period.
- All benefits and costs have been denominated in US dollars and the projections assume current prices until 2000 and constant prices thereafter.
- The operating costs comprise variable cost for the additional power (which cost differs from country to country), net cost of staff increment resulting from the installation of SCADA (assumed to correspond to 25 percent of staff cost of NCC and RCC facilities⁴⁸) and cost of maintenance (at 3 percent of the investment value annually unless actual costs exist).
- The calculations have treated the value of the incremental energy as a variable. The five network's actual revenue per kWh has been used as the base for calculating a financial investment return. An economic IRR has also been calculated for multiples (2 times, 3 times, 5 times and 10 times) of this value.

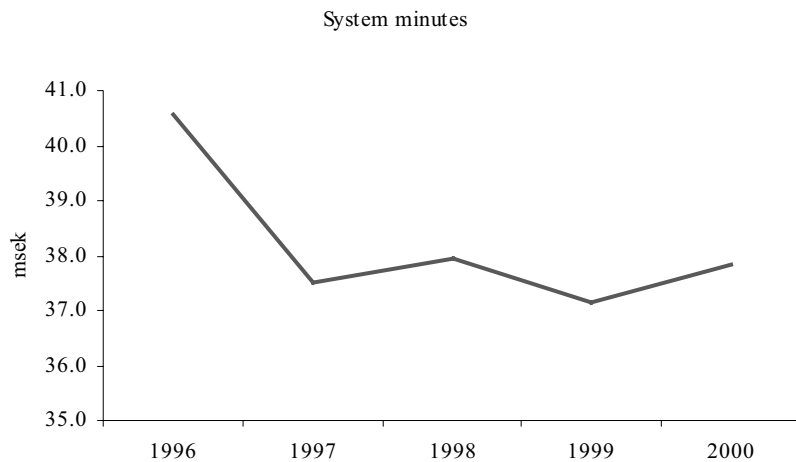
The Five Cases**Botswana – Low Level of Outages in a Mainly Urban Network**System minutes and system losses

"System minutes" is a concept, which places a value to annual outages in a system. It is a composite measure of the loss of power in a system over a year. It may refer to losses on account of both planned and unplanned outages, outages in generating plants or in the transmission

⁴⁸ In the case of Ecuador the SCADA staff cost is assumed to be 50 percent of the total CENACE staff cost since CENACE's control center is non-operational. The respective plant operators most of whom operate their own SCADA systems handle actual management of the generating plant and the transmission network.

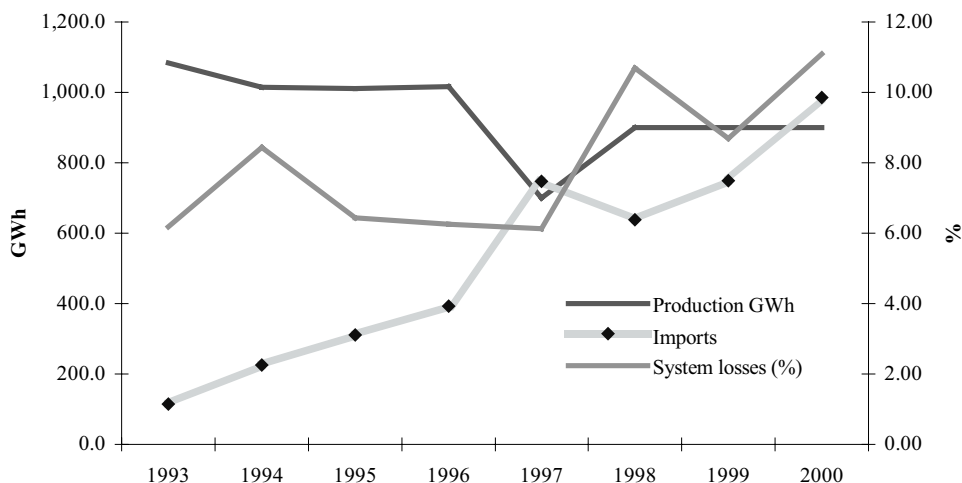
network. It is defined as the power lost (in MWh) times 60 divided by maximum demand (in MW) for the year in respect. Unless otherwise stated system minutes apply to involuntary outages. A normal level of system minutes for Scandinavian networks would be around 10 minutes. Developing countries often have well over 100.

The following graph, showing involuntary outage system minutes, summarizes the outage statistics made available by BPC.



Botswana's system minutes have fallen from 40 in 1996 to a current level of around 38. This is quite low by African and developing country standards and it would suggest that the country has a good network and few faults.

Botswana's statistics on system losses (the difference between production and consumption) also suggest that the network is well maintained and relatively efficient. Aggregate system losses of around 6 percent are low by developing country standards.

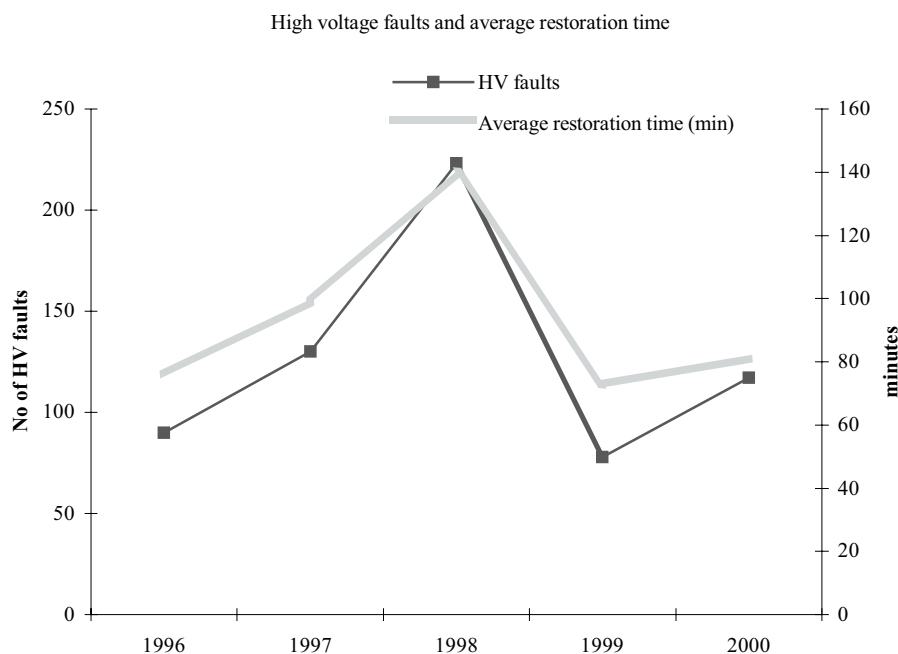


The above graph shows how system losses have varied. It also illustrates the fact that Botswana is a large net importer of power and that imports have grown rapidly in recent years.

This suggests that the benefits Botswana can derive from its SCADA system are mainly with respect to outage reduction and lower staff cost as a consequence of substation automation. Since Botswana produces little energy by itself there is little or no scope for optimization with respect to generation. The statistics for system losses show an increasing trend since the installation of the upgraded SCADA system in 1994/95, which suggests that there have been no transmission optimization gains.

Outages

The largest part of the outage reduction gains, in the case of Botswana, is with respect unplanned faults in the Gaborone district transmission network. Most of the substations in this network are manned and faults can therefore be addressed relatively quickly also in the absence of a SCADA system.



Available statistics suggest that the average outage time is less than 1.5 hours. Since most outages take place in the relatively densely populated Gaborone district detection is likely to be comparatively prompt. Stabilization in such a small network as the one for Gaborone is seldom very time consuming. It has therefore been assumed that outage time reduction by way of SCADA may reduce the average outage time by an average of ten minutes, or by around 12 to 13 percent.

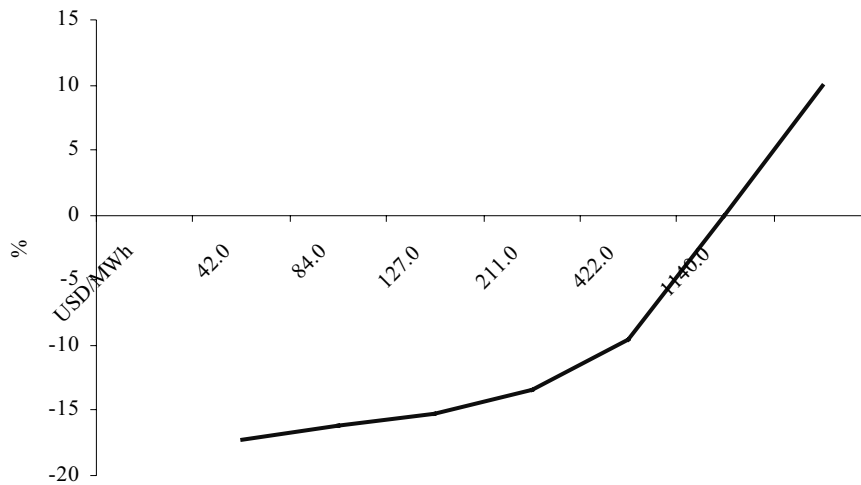
Reduction of staff cost

BPC's SCADA system has a total of 36 RTUs of which 14 are located at substations in the Gaborone district. Some staff reduction has taken place, mainly in the form of abolishment of a

night shift. For the purpose of the calculations it has been assumed that the staff is reduced by the equivalent of one three shifts team per year starting in 1999.

Other assumptions

The variable cost for the additional power is set at USD 0.037 per kWh, which is what Botswana currently pays for South African bulk power. The value of the energy that is being produced and sold as a result of shorter outage time is treated as a variable.



At the average current revenue, which is the equivalent of USD 0.042 per kWh, BPC's SCADA investment would yield a return of -17.2 percent. At a power value of USD 1.140 per kWh the SCADA investment would have an IRR of zero and the return increases thereafter with increasing electric power value to reach 10 percent at a power value of USD 2.20 per kWh.

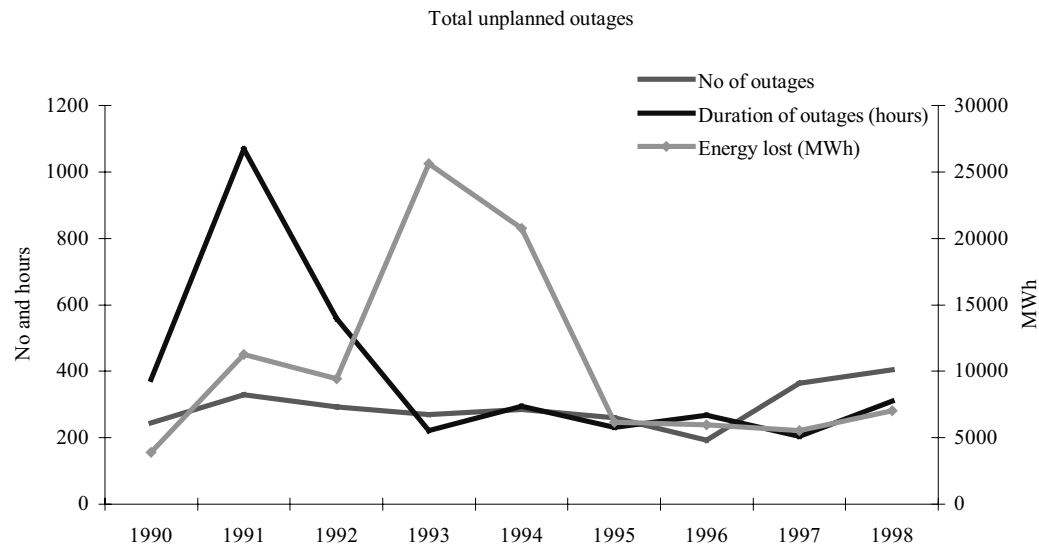
Ecuador – A Very Special Case

The SCADA operator in Ecuador, CENACE, identified three quantifiable benefits generated by its SCADA system, namely:

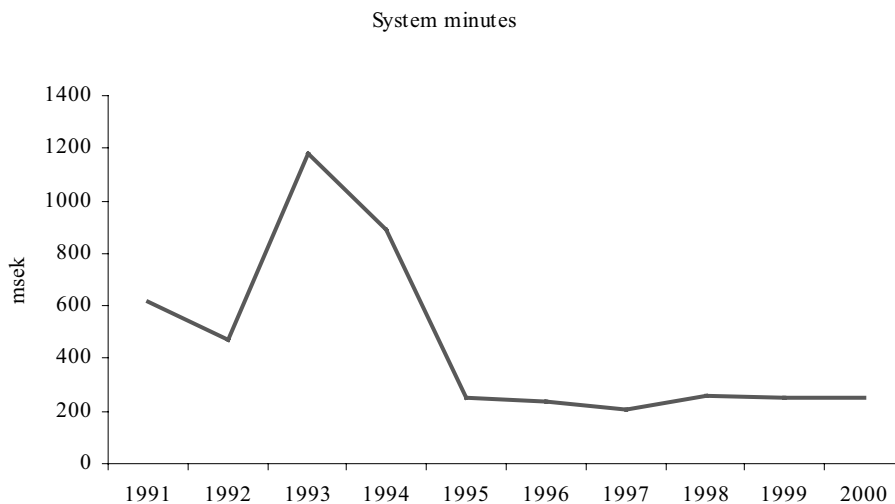
- outage time reduction,
- optimization, which consists of increased load on a large transformer station for Guayaquil (Trinitaria) during five months of the year (when power supply from a hydropower plant is unavailable), and
- substation manning reduction.

Outage reduction

The graph below shows total number of unplanned outages in the Ecuadorian power network since 1990. The SCADA system became operational in late 1994.



The statistics suggests that the level of unplanned outages stabilized in the period after the installation of SCADA. The number of system minutes in Ecuador fell from a high in the range of 600 to 1000 to a low of slightly more than 200 at around the time when the SCADA system was installed. This decline coincided with an expansion of the transmission network.

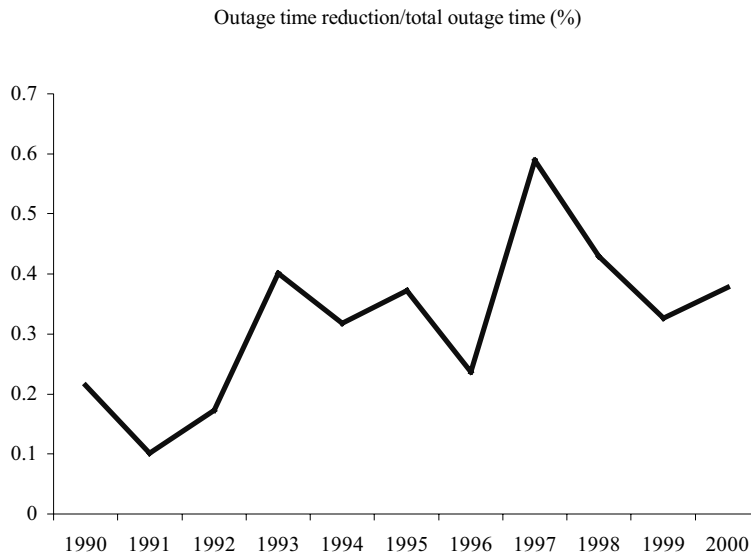


CENACE's technical staff estimated the outage reduction to correspond to an average of 20 minutes per involuntary or unplanned outages. They distributed the savings as follows:

detection	8 min
stabilization	7 min
restoration	5 min
Total	20 min

For the purpose of the investment return assessment it was assumed that the system minutes would decline slightly to around 200 per year and that the effect of SCADA would be a reduction of the loss by the equivalent of 30 system minutes or 15 percent.

A consequence of the assumption that SCADA has reduced restoration time by 20 minutes is that the outage related reduction of non-supplied energy varied between 10 and 50 percent of total non-supplied energy. This is shown in the graph below.



The increase in the curve is a consequence of the gradual decline of total non-supplied energy. This might suggest that 20 minutes would be on the high side for the longer term.

Optimization

CENACE suggests that SCADA enables the power network in Ecuador to operate the 375 MW Trinitaria substation at full capacity (as opposed to 350 MW) during five months of the year when power for Guayaquil has to be provided by a thermal plant. The net effect is an additional 20 GWh per year, which would otherwise have to be saved by way of load shedding. Political disagreements were said to be the reason why transformer capacity has not been increased. Given the fact that an investment in a transformer would have a very short pay-back period the investment return projections assume that an increase in transformer capacity would take place over a period of four years starting in 2001. The increased energy consumption made possible by SCADA in the case of Trinitaria is accompanied by an increase in direct production cost, mainly fuel for thermal plants.

Another optimization benefit that SCADA is often credited with is reduction of transmission losses. The statistics for losses in Ecuador show, firstly, that losses, both transmission losses and distribution losses, have been quite small – 4 and 5 percent respectively. Secondly transmission losses show a slightly increasing trend since the time the SCADA system was taken into operation. This suggests that there are no optimization benefits for transmission in the case of Ecuador.

Staff reductions

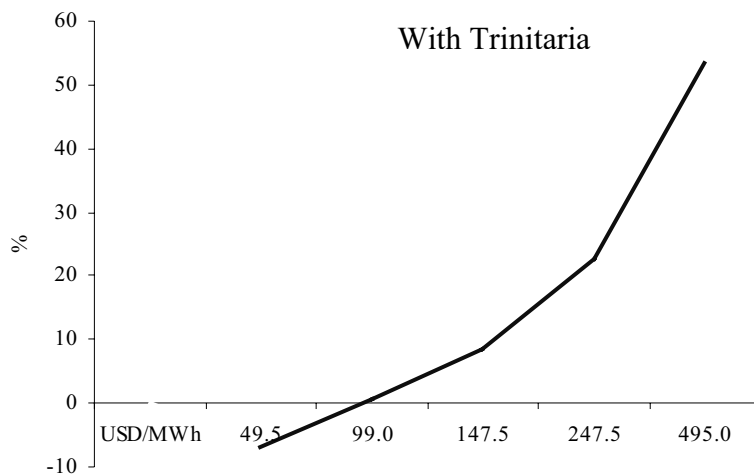
CENACE's SCADA system comprises 28 RTUs for the same number of power plants and substations. This would enable CENACE to gradually reduce field staff and the projections have assumed that one substation a year would be automated and that each would reduce the labor force by five operators of which one would be retained for maintenance.

Other assumptions

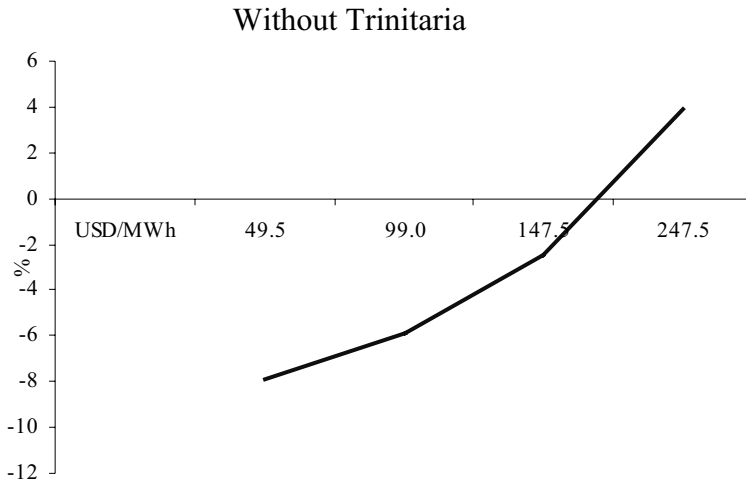
The variable cost of the power that is being produced and sold as a result of shorter outage time has been calculated on the basis of actual cost for different sources of power. Hydroelectric power accounts for approximately 65 percent of the generating capacity in Ecuador and its low variable cost brings down the average to USD 0.01 per kWh. In case of the Trinitaria gain the variable cost of production, mainly thermal, was reported to be USD 0.04 per kWh.

As it can be argued that the Trinitaria optimization gain is an anomaly resulting from the particular political situation in Ecuador the IRR has been calculated both with and without the Trinitaria gain. Because of the relatively high variable cost for the thermal plants that generate the extra power the difference is not very substantial.

The graph below shows how the IRR rates with Trinitaria at different values of electric power.



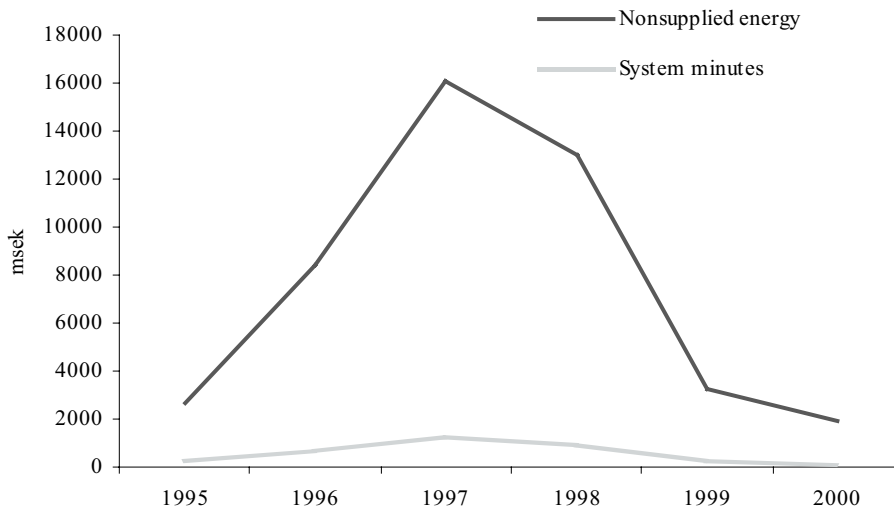
Without the Trinitaria gain the IRR curve for different electricity values would look as follows:



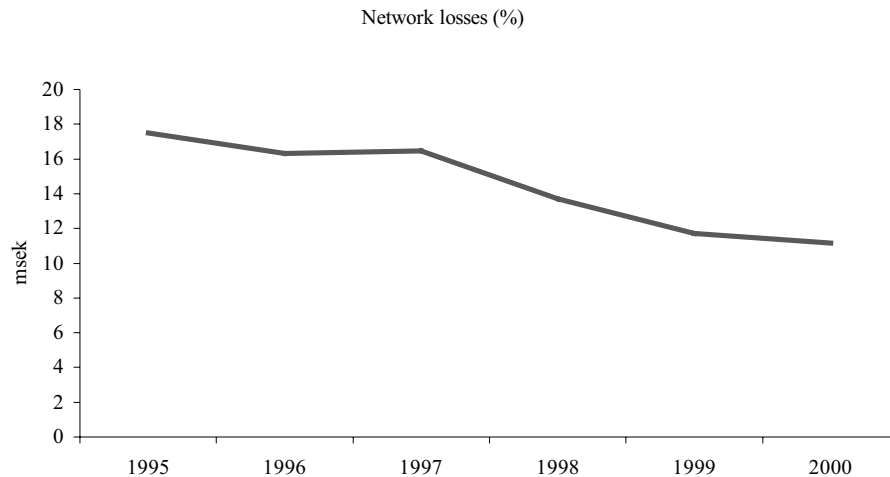
The calculations suggest that CENACE's SCADA system would yield a return of –6.8 percent (-10.2 without Trinitaria) at an energy value equivalent of the current average revenue per kWh (USD 0.0495). The value would have to increase to USD 0.12 (0.34 without Trinitaria) in order for the return to be zero percent and USD 0.16 per kWh (USD 0,81 without Trinitaria) for a 10 percent return.

Vietnam – Very Many Short Outages

HCMC-PC's outage statistics covered the five-year period since the company was created in 1995 to 2000. It was used to calculate system minutes for involuntary outages and a likely level of outage reduction achieved by way of SCADA. The graph overleaf shows how involuntary (unplanned) outages have affected non-supplied energy and system minutes since the introduction of the SPIDER version of SCADA in 1995. Statistics for the period prior to 1995 could not be found within HCMC-PC.



Network losses declined considerably after the SPIDER SCADA system was installed but this was considered to be a consequence of a large World Bank funded investment in transmission network improvements, which took place in the period 1995 to 97.



Benefits

The benefits accruing from SCADA in the case of Vietnam are mainly two: outage reduction and staff reductions. The staff did not consider it likely that there had been any transmission optimization and HCMC-PC does not operate any power plants where optimization could otherwise be a possibility.

The staff at the HCMC-PC control center considered that SCADA would reduce restoration time by five minutes, on average. This would yield a reduction of non-supplied energy ranging between 14 and 8 percent, which is consistent with the effect of outage time reduction as estimated by CENACE. After having reviewed time saving estimates of the other networks the Consultants felt, however, that the HCMC-PC's estimate risked being too conservative. The cost benefit projections therefore use an average of 10 minutes reduction per outage.

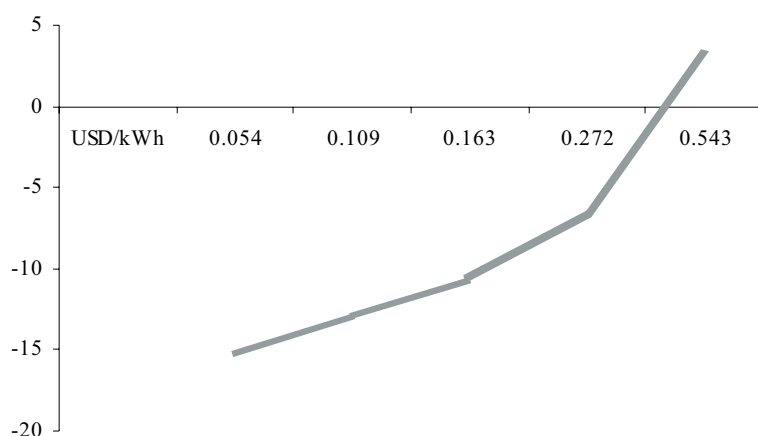
There has also been a certain reduction in substation personnel as a result of SCADA. The manning reductions at the substations during the last four years were estimated to correspond to six substations or an average of 1.5 stations per year each having staff of five persons on three shifts⁴⁹.

Other assumptions

The variable cost for producing the extra power has been assumed to correspond to USD 0.018 per kWh, which reflects the fact that Vietnam has a high proportion of thermal power.

The graph below shows the IRR of return for different energy values. The latter has to reach USD 0.43 per kWh in order for HCMC-PC's to yield zero rate of return. A 10 percent IRR return would require an electricity value of USD 6,73 per kWh.

⁴⁹ It deserves to be noted that the automation of substation seldom results in lay-offs. Staff has instead been transferred to maintenance units, which has had a positive effect on network losses.

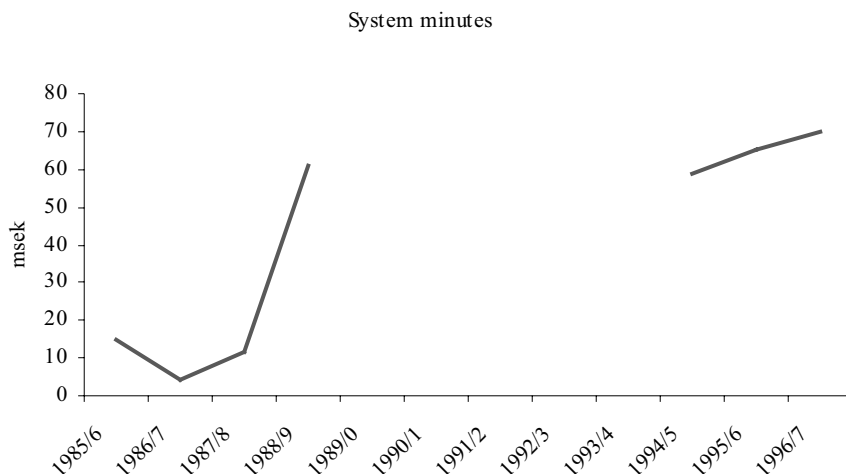


The calculations have also been tested for the eventuality of HCMC-PC being able to reduce outage time by the same period as CENACE, i.e. 20 minutes per outage. In this case the energy value yielding a zero rate of return would be USD 0.29 per kWh. In view of the fact that substations in Ho Chi Minh City are much more accessible than they are in mountainous Ecuador the difference in outage time reduction appears well warranted, however.

Zambia – a Good Network with Few Outages

Outage reduction

Data on outages and non-supplied energy exist for two periods, the latter part of the 80s and two years in the middle of the 90s.



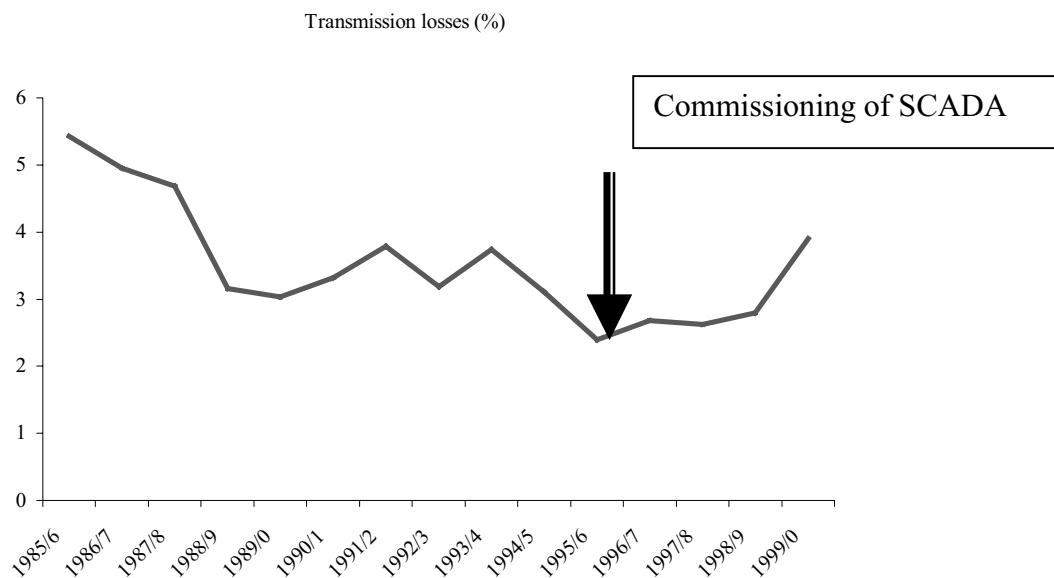
This data has been used to define an outage time reduction scenario based on a reduction of restoration time similar to the one used in the case of Ecuador, i.e. 20 minutes per outage. Zambia, with its large and relatively modern high capacity transmission network has several similarities with Ecuador. With this assumption and the scattered data that is available, the outage reduction achieved by SCADA should correspond to approximately 15 percent of total non-supplied energy due to unplanned outages.

In addition to the regular outage reduction benefits, Zambia is also likely to have benefited from its SCADA system in connection with regional blackouts. There have been a total of five local blackouts between 1994 and 97. A SCADA system provides a network overview, which is particularly valuable when a network is down. The assumption that has been used for the purpose of the cost benefit analysis is that SCADA has enabled the operators to save as much time as the duration of the blackout itself. Since the load that is lost is very large the resulting number of MWh becomes very large as well.

The available statistics on system minutes and non-supplied energy due to transmission faults is unlikely to include power lost because of blackouts. The gain in connection with blackouts, would, under the assumptions made, have corresponded to 65 percent of the total energy saved during the first three years of the running of the SCADA system.

Optimization benefits

The logical place to look for optimization benefits would be with respect to transmission losses. With the overview given by SCADA, the operator should be able to use the best routings at all times. However, the transmission loss statistics for Zambia do not suggest that the SCADA investment has assisted ZESCO in reducing transmission losses.



Staff reductions

Zambia has reduced the manning of approximately half of its substations but kept a full complement of staff in all power plants. The benefits therefore include the savings due to this reduction at the current remuneration levels for power sector staff in Zambia.

Other assumptions

The variable cost of the extra power that is produced as a consequence of SCADA related time gains has been assumed to be only USD 0.005 per kWh since Zambia produces electric power mainly from hydroelectric plants, which are characterized by high fixed costs but low variable.

This causes the Zambian IRR curve to be very flat. The IRR values are therefore shown in the form of a table instead.

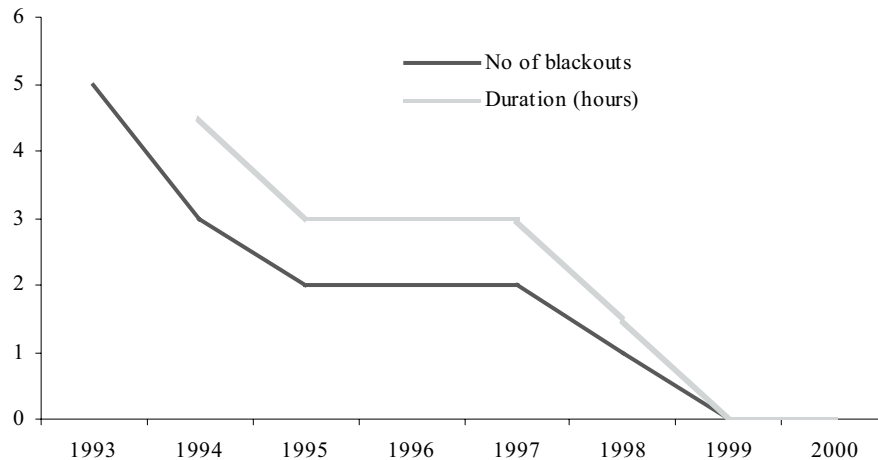
	%		USD/kWh
Internal Rate of Return of	-9.6	at an energy value of	0.027
Internal Rate of Return of	-9.4	at an energy value of	0.054
Internal Rate of Return of	-9.3	at an energy value of	0.081
Internal Rate of Return of	-9.1	at an energy value of	0.135
Internal Rate of Return of	-8.5	at an energy value of	0.270
Internal Rate of Return of	0.0	at an energy value of	2.457

Zimbabwe – Few Outages but Many Blackouts

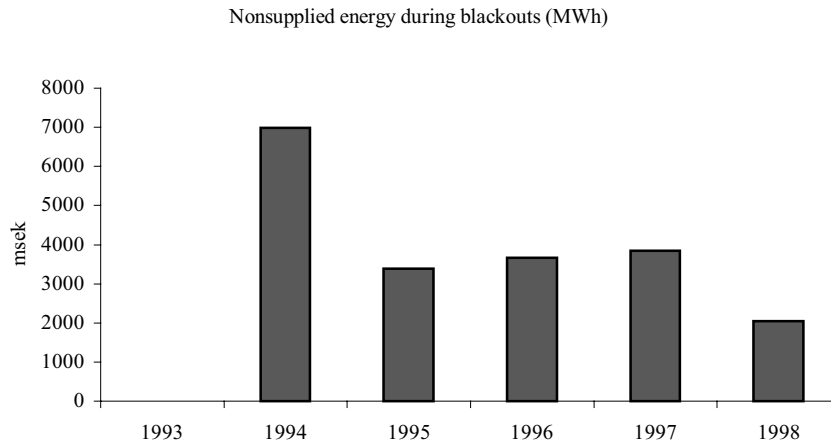
Zimbabwe's power plants are old and partly very worn and this has been a major cause of a number of very severe nationwide as well as regional blackouts over the last five to six years. There exists reasonably good statistics for these occurrences but regular outages have not been as well documented. A major analysis of outages, lost energy and system minutes was done in 2000 and this, together with the data on blackouts have served as a basis for assessing the benefits derived by Zimbabwe from its SCADA system.

Blackouts and outages

The frequency and estimated annual duration of blackouts in the period 1993 to 99 are shown in the graph below.



Since the load is very large, the loss of electricity (also called the amount of non-supplied energy) becomes very large. The subsequent graph shows an estimate of the total amount of non-supplied energy annually that has been the result of the blackouts. In 1994, this is estimated, on the basis of the capacity of the transmission lines that were down, to 7 GWh. The biggest single blackout took place in 1996 when the entire country was without electric power for several hours during two consecutive days.



As a consequence of the 1996 blackouts a number of measures were taken which have made it possible to avoid further blackouts since 1998. The projections made for the purpose of the investment return calculation assume that blackouts will be avoided also in the future.

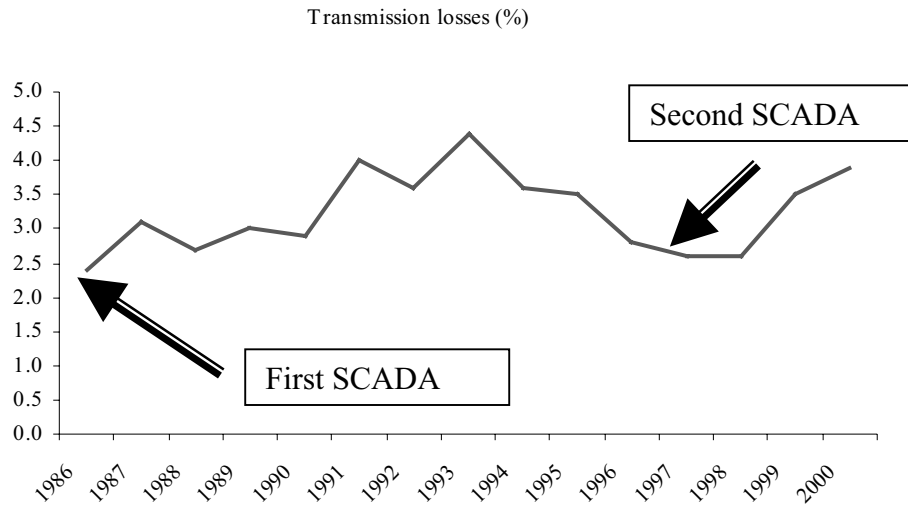
Because of its acute lack of generating capacity, Zimbabwe resorts to extensive load shedding on a regular basis but the outages, which are of relevance for the SCADA systems, are only the involuntary or unplanned.

The assessment of outage time reduction resulting from SCADA is based on the assumption that the system minutes in Zimbabwe have averaged 80 per year during the 90s. This is consistent with the limited data that exists and which suggests that Zimbabwe have few system minutes on its network apart from the blackouts. This is also consistent with the relatively modest transmission losses that ZESA has reported.

On the basis of this assumption and using the same time gain as has been applied for Ecuador and Zambia, the SCADA system yields an average annual reduction of non-supplied energy (due to transmission related involuntary outages) of approximately 400 MWh. This can be compared to the 7,000 MWh estimated to have been lost on account of blackouts in 1994.

Other benefits

The graph below showing transmission losses does not support the claim that SCADA generates optimization benefits for the transmission network and such benefits have therefore not been included in the calculations.

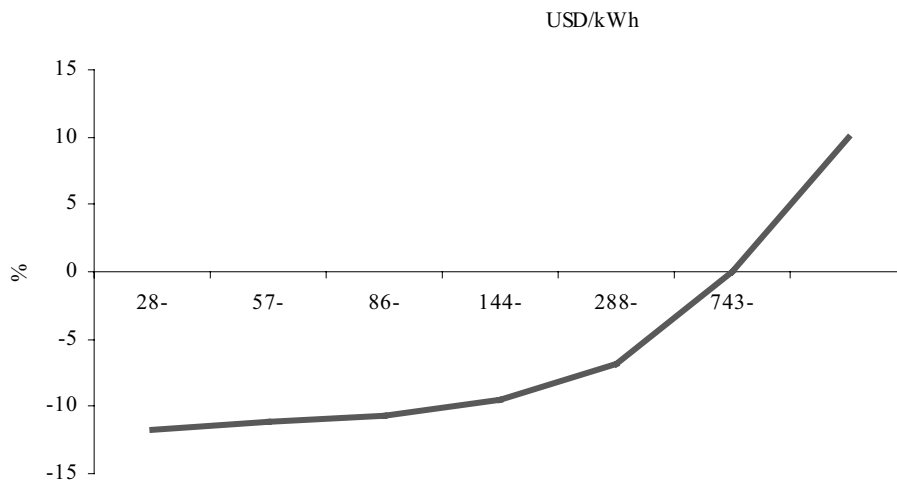


ZESA has, however, automated an estimated 80 of its approximately 110 RTU equipped substations. This has been taken into account in the investment return calculations.

Other assumptions

The variable cost of the extra power has been set at USD 0.017 per kWh, which was the transfer price within the SAPP (Southern Africa Power Pool) during the greater part of the 90s.

The graph and table below show the IRR values for different electricity values in the case of Zimbabwe.



	%		USD/kWh
Internal Rate of Return of	-11.8	at an energy value between	0.028-0.0385
Internal Rate of Return of	-11.2	at an energy value between	0.057-0.077
Internal Rate of Return of	-10.7	at an energy value between	0.086-0.115
Internal Rate of Return of	-9.5	at an energy value between	0.144-0.192
Internal Rate of Return of	-6.8	at an energy value between	0.288-0.385
Internal Rate of Return of	0,0	at an energy value between	0.743-0.993

Financial and Economic Conclusions

Financial Aspects

The following table summarizes the financial and economic assessment. The five projects for which an analysis was possible all show sharply negative rates of return at an electricity value of USc 5 per kWh. As this value is at par with higher revenues (those of Ecuador and Vietnam) the implication is that all projects are likely to consume funds and liquidity.

	USD 0.05/kWh	USD 0.10/kWh	USD 0.20/kWh	USD 0.30/kWh	USD 0.40/kWh	Current revenue per kWh (USD)	Network rate of return 98/99 ⁵⁰
Botswana	-17.0	-15.8	-13.6	-11.7	-9.9	0.042	7.8
Ecuador with Trinitaria	-6.7	0.9	16.2	29.9	42.3	0.049	
Ecuador without Trinitaria	-10.2	-7,9	-4.1	-1.0	1.7	0,049	
Vietnam	-16.2	-13.7	-9.2	-5.1	-1.1	0.054	n.a.
Zambia	-9.5	-9.2	-8.8	-8.4	-7,9	0.027	3.1
Zimbabwe	-11.4	-10.4	-8.4	-6.6	-4,9	0.029	7.4

The last column shows the estimated network rate of return on assets for 98/99 in the case of three of the five countries. These rates, based on the current revenue per kWh, are far above those estimated for the SCADA systems.

Botswana has a relatively low level of outages, low load as well as short average outages durations. Labor cost reduction is therefore a relatively more important benefit for BPC, which explains the fact that the rate of return changes only moderately with changing power unit value.

CENACE's SCADA investment shows the best rate of return of all the five cases. This is largely a consequence of the optimization benefit due to the inadequate Trinitaria transformer in Guayaquil. The obvious alternative to a SCADA investment in the case of Ecuador would therefore have been a new transformer for the Trinitaria substation. This is discussed in a subsequent section. Without the benefits of the optimization of Trinitaria the IRR rate for Ecuador would decline substantially although it would still be superior to that of the other four systems. This is a reflection of the fact that Ecuador has a high maximum load and that outages, when they occur, lead to large load losses.

⁵⁰ Source of the rate of return data for the African countries is Southern African Power Pool Annual Review Report for April 1997 to March 1999.

Vietnam has the highest average revenue per kWh and a relatively large number of unplanned outages. The maximum load in the Ho Chi Minh City regional network is also relatively high. This combines to reduce the effect of a high investment cost at higher multiples of the kWh value.

ZESCO in Zambia has also a relatively low return on its SCADA investment. This is a consequence of a relatively low load in the areas where the SCADA system can reduce outages. Outage reductions in the Copperbelt would have yielded a higher return but those systems already exist.

Zimbabwe's return on its SCADA investment is similar to that of Zambia's mainly on account of the large volume of power assumed to have been gained in connection with the many and extended blackouts. A major reason for the blackouts has been the inadequate capacity of some of Zimbabwe's 40-year-old power stations. Kenya is facing partly the same situation as Zimbabwe. It has a large power network with inadequate generating capacity, many and frequent loadsheddings and probably a fairly high level of outages. It is probable that Kenya's SCADA system would show a return figure that is similar to that of Zimbabwe.

It appears that the IRR percentages for Botswana, Ecuador (without Trinitaria) and Zambia are the most relevant. For the two other countries SCADA has served to alleviate the symptom but not the cause of network defects. Notwithstanding SCADA, those countries must, eventually, invest in better transformers and more generating capacity. The benefits attributable to SCADA would then decrease.

Alternative Investments

The main reason for the very low returns is the low productivity of SCADA investment in terms of increased power supply. A SCADA system produces very few extra kWh per invested dollar. This is illustrated in the following table, which shows, in the fourth column, the approximate investment cost per kWh of power "produced" by the SCADA system in the form of reduced outage time. Except for the particular case of Ecuador, one thousand dollars in investment will yield from a low of about 16 to a high of 126 kWh annually in extra power over the long term.

	Inv cost mUSD	Annual "production" GWh/yr	Annual kWh/USD'000 of inv. cost	Total kWh "produced" during 15 years
				5,671.9
Botswana	5.41	0.35	69.89	176,980.2
Ecuador	16.63	0.98	709.48	
Vietnam	13.84	0.96	126.93	17,975.7 4,012.3
Zambia	11.95	0.29	27.94	
Zimbabwe	22.5	0.45	16.53	5,579.4

The major reasons for outages are insufficient generating capacity and transmission system faults. The alternatives to SCADA that serve the purpose of reducing outages are therefore new or

extended generating capacity or transmission network rehabilitation or upgrading. The cost efficiency of the SCADA investments have therefore been compared to those of actual generating and transmission projects in Eastern and Southern Africa.

Generation projects

The total investment cost, output, likely production and the investment cost per kWh produced annually for seven small to medium sized generation projects is shown in the following table⁵¹.

	MW	Inv cost mUSD	USD/kW	Assumed utilization rate ⁵²	Production GWh	Annual kWh/USD'000 of inv. cost	Est IRR over 15 years
Ubungo	34	18	529.4	0.5	148.9		24%
Hwange upgrade	84	130	1547.6	0.7	515.1	180355.6	8%
IPTL	100	150	1500.0	0.7	613.2	73000.0	9%
Dar es Salaam	50	24	480.0	0.5	219.0	61320.0	27%
Kapichira 2	64	38	593.8	0.8	448.5	95812.4	41%
Lower Fufu	45	59	1311.1	0.8	315.4	95813.2	17%
Kariba South	150	100	666.7	0.8	1051.2	136266.1	36%

The two last columns show respectively the output per dollar of investment and the estimated IRR for each of the projects. One US dollar of investment in a generating plant would thus produce over 50,000 kWh per year while a SCADA would produce less than 100 kWh yearly per US dollar invested. The estimated IRR, assuming a power value of USD 0.04 to 0.05 per kWh would range from a low of 8 percent to a high 41.

Transmission

A recent study of transmission rehabilitation in Zambia⁵³, for the purpose of reducing outages, concluded that the IRR, assuming an electricity price of USD 0.027 per kWh, would correspond to 20.1 percent. At this value for power the SCADA project in Zambia would yield a return of –13.9 percent. Zambia's SCADA system would need to generate 450 times more extra power than what the projections assume in order to yield an investment return commensurate with that of the transmission rehabilitation project.

The same applies for Ecuador. The power industry in Ecuador would need to invest a maximum USD 2 to 3 million to replace the Trinitaria substation with one that could handle the load. Under the same assumptions⁵⁴ as have been used for the SCADA assessment such an investment would yield a minimum discounted rate of return of 11 percent. This compares with the IRR of –10.2 for the Ecuadorian SCADA systems without the Trinitaria benefit.

⁵¹ Source: SAPP Annual Review Report April 1997 – March 1999

⁵² The four first plants are thermal and the smallest will be used for peak power. The hydroelectric plant have been assumed to be base load plants.

⁵³ Transmission system Rehabilitation Project Cost-Benefit Analysis, Norconsult August 1997

⁵⁴ The current power supply increase to Guayaquil (20,000 MWh annually) made possible by SCADA has been assumed to grow at an annual rate of 3% and the net value of the power would be USD 0.09 per kWh (the current difference between average revenue and variable cost). Since a transformer would allow for a larger power supply than the current SCADA optimization these would be minimum values.

The conclusion is therefore that the notion that SCADA projects can be justified by their reduction of outage time does not apply to five of the nine SCADA investments under review. This would have required huge outages if not a steady stream of blackouts and kWh values that do not appear to have existed in the five countries that this study have analyzed.

Summary of Cost Benefit Analysis

The following table summarizes the net present value of the individual cost items as well as the benefit and cost streams of each of the five projects. All figures are in USD thousand equivalents at constant prices. The discount rate used for the net present value calculation is 10 percent and the period is 15 years.

Summary of benefits (USD'000)	Botswana	Ecuador	Vietnam	Zambia	Zimbabwe
Value of reduced non-supplied energy	110.3	5,754.2	581.9	51.0	297.2
Savings due to reduced manning levels	236.4	1,083.0	387.7	1,023.5	1,345.2
Residual value	160.6	394.4	225.9	370.5	723.6
Total benefit stream	507.2	7,231.6	1,195.5	1,445.0	2,366.0
Summary of costs					
Variable production cost of extra delivery			143.5	11.4	170.8
Control center operating cost	94.6	468.0	78.2	60.9	527.9
NCC and RCC staff cost	195.7	2,409.1	50.1	406.1	550.7
Maintenance cost	787.4	956.2	1,263.9	136.9	546.7
Investment cost	5,100.0	16,080.0	6,290.9	10,565.0	19,037.0
Total cost stream	6,177.8	19,913.4	7,826.6	11,180.3	20,833.1
Net benefit stream	-5,670.6	-12,681.8	-6,631.1	-9,735.3	-18,467.1

The above table shows that, at the actual electricity revenue, the discounted net benefit stream will be negative, i.e. costs will exceed benefits for all five analyzed projects. The excess of costs over benefits will result in a financial deficit that is larger or almost as large as the investment itself. It should be noted that this does not take into account the debt service on the loans taken up to finance the systems. From a purely financial point of view the analysis suggests that the five networks will have to pay twice for their SCADA investment.

Aid Finance for Nine Swedish Hi-Tech Projects

An Evaluation of Aims and Outcomes of
SCADA Projects in Nine Countries

Part 2 Appendices

For Sida
By Swedish Development Advisers AB
Gothenburg, January, 2002

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Appendix 1 Terms of Reference

TERMS OF REFERENCE

EVALUATION OF Sida SUPPORTED INSTALLATIONS OF SCADA SYSTEMS IN LOAD DISPATCH CENTRES

1. BACKGROUND

- 1.1** The Swedish International Development Agency (Sida) and its predecessors SIDA and BITS have financed various types of SCADA (Supervisory Control and Data Acquisition) systems in the following nine developing countries:

Botswana	Kenya	Vietnam
Ecuador	Lesotho	Zambia
Jordan	Pakistan	Zimbabwe

In addition, there are some Sida-financed SCADA-systems not yet commissioned but in various states of implementation. They are not to be included in the evaluation.

- 1.2** Up to mid-1995 the Swedish financing was channelled through BITS for concessionary credits and through SIDA for grants. After 1st of July 1995 the Sida-financing has been handled by the Infrastructure & Economic Cooperation Department (INEC).
- 1.3** The financing has been based on reviews by consultants regarding the feasibility of the systems and, in some cases, consultants have assisted the borrowers during the design, procurement and implementation stages.
- 1.4** The systems have been installed in (power) load dispatch centres to facilitate the efficient operations of the power systems as SCADA provides the operating staff at the dispatch centres with instant information on such data as status of circuit breakers, loading and voltages profiles and fault scenarios. Thus, one important role of a SCADA system is to facilitate a rapid restoration of the power system after a disturbance.
- 1.5** All the SCADA systems financed by Sida (and BITS/SIDA) have been delivered by ABB. Most of them have been in operation at least 4-5 years thus making it appropriate to evaluate the concerned investments.

2. PURPOSE OF THE EVALUATION

2.1 The objectives of the evaluation are (i) to describe and evaluate some of the projects in detail by desk reviews and field visits and some through desk reviews only and (ii) to analyse the results of the evaluation in order to generate lessons and summaries experiences for possible application to similar projects in the future. Issues to be taken into consideration are among others: how the facilities have been used, to what extent the outages of the electricity supplies have been reduced, efficiency improvement, external factors interfering with the system, reliable statistics of faults and remedies etc. The evaluation shall in particular:

- i) evaluate if the scope of the project and the chosen level of technology of the installed systems has been appropriate for the requirements of the power sector in the concerned countries and whether or not the systems are sustainable; and
- ii) determine whether or not the various SCADA installations have been financially and economically viable.

3. ASSIGNMENT

3.1 The evaluation shall comprise but not necessarily be limited to the following aspects:

- identification, preparation and procurement (including type of contract) of the projects;
- implementation of the projects including assessment of the works/ installations and of the purchasers' involvement;
- costs as estimated and actual;
- organisational aspects;
- operational experiences and routines of the projects including the utilisation of the systems as planned and actual;
- established programs for maintenance and availability of maintenance facilities including spare parts;
- availability of qualified operational staff including assessment of the training and of the transfer of know-how during project implementation;
- assessment of the suitability of the selected technology and the sustainability of the projects; and
- quantification of the benefits of the projects as planned and actual including assessment of the economic and financial results.

4. METHODOLOGY, EVALUATION TEAM AND TIME SCHEDULE

4.1 The evaluation will commence by a review of the information available in Sweden (with Sida, the manufacturer (ABB), consultants etc.). The findings shall be presented in an Inception Report. Sida will review the findings and recommendations of the

Inception Report and, in consultation with the consultant, determine which projects that will be selected for field visits. It is anticipated that the visits will be limited to the following four countries: Botswana, Ecuador, Jordan and Zambia. It is anticipated that the Consulting Team will spend 1 – 1.5 weeks in each country to be visited.

- 4.2 The concerned authorities in the countries with projects selected for detailed reviews will be contacted before the field visits take place. The consultants will be responsible for these contacts but will be assisted by the Sida Headquarters and the concerned Swedish embassies as required.
- 4.3 The preliminary findings of each field visit shall be discussed with the concerned authorities and Sida representatives in the country at the end of each visit.
- 4.4 It is anticipated that the evaluation will be carried out by an expert familiar with the operations of the concerned systems and by an economist with experience in establishing the economic and financial benefits of similar projects. One of the experts shall act as Team Leader and the Team Members shall not previously have been associated with the projects subject to the evaluation.
- 4.5 The assignment is expected to commence in November 2000, and to be completed in March/April 2001.

5. REPORTING

- 5.1 The Inception Report is to be submitted to Sida not later than four weeks after the commencement of the evaluation. The Inception Report shall detail the criteria proposed to be used for establishing technical, financial and economic viability of the projects. It should be anticipated that Sida would present its comments within three weeks of the receipt of the Inception Report.
- 5.2 A Draft Final Report shall be presented to Sida within three weeks of the completion of the field visits. The Final Report shall be submitted within three weeks of the receipt of the comments of Sida on the draft Final Report. All the projects shall be included in the reports, thus also the ones only subject to desk reviews. It is understood, however, that the extent of the evaluation of these latter projects will depend on the information available in Sweden. In addition, the report shall include an overall analysis of the results of the projects with summarising of lessons and experiences for possible application to similar projects in the future.

5.3 5.3 The reports shall be written in English and the format and outline of the Draft Final Report and the Final Report shall follow the guidelines in the attached "Sida Evaluation Report - A Standardized Format" (Annex 1). Sida shall be provided with four copies of the Inception Report and of the Draft Final Report and with 10 copies of the Final Report. Word for Windows or a compatible programme shall be used and a diskette version of the Final Report shall also be provided. The Final Report shall be presented in a way that enables publication without further editing. Subject to decision by Sida, the Final Report will be published within the Sida Evaluation Series.

5.4

5.5 5.4 The assignment includes the production of a Newsletter Summary following the guidelines in "Sida Evaluation Newsletter-Guidelines for Evaluation Managers and Consultants" (Annex 2) and the completion of a Sida Evaluations Data Work Sheet including Abstract (Annex 3). The draft and final Newsletter Summary and Data Work Sheet including Abstract shall be submitted simultaneously with (but separately from) the Draft Final and Final Report.

Appendix 2 Study Approach and Methodology

A broad based approach

The Consultants' approach was to try to create the broadest possible base for the evaluation by visiting and assessing, on site, as many of the nine projects as possible. This, it was felt, would give Sida as well as the participating power companies a sounder basis for judging the issues related to SCADA investment and their financing with aid funds.

The four sets of complementary activities comprised by the methodology are described below.

Four Components to the Methodology

The web site

Since virtually all of the nine SCADA projects have access to the Internet and several have their own web sites, the Consultants created a 'project web site on SweDevelop's own home page through which information could be both disseminated and collected. Each of the SCADA owners were given passwords which enabled them to access the files and other documents relating to the evaluation and to comment, correct or amend the information collected as regards their own operations.

Project data base

The Consultants made extensive searches for data and information on the projects in Sida's files and archives, which yielded data on all projects except the one in Jordan. ABB also lent considerable assistance by making time available for interviews and meetings and by perusing the ABB archives. The search for information within Sida and ABB was complicated by the fact that several of the projects were supported by a concessionary loan agency (BITS), which has since been merged with Sida. Another important aspect is the fact that the systems have probably been partially modified and/or extended by the operator without support from Sweden. This implies that the information obtained in Sweden shows only part of the total picture.

The data collection within Sida and through ABB resulted in a set of nine Project Fact Sheets, which tabulated both the sequence and dates of the various project events in each country, investment cost data, main technical project components and investment justifications. The fact sheets were complemented by data for the respective countries' power sector. These fact sheets can be found in Appendix 3.

Field survey

The Project Fact Sheets made it possible to identify

- firstly, which information needed to be verified,
- secondly, which information was missing and would need to be sought elsewhere, and
- thirdly, the main purpose and justification for each project.

The result of this analysis was a set of documents used for collecting information from the nine organizations that own and operate the SCADA systems (the owners).

These documents were:

- firstly, a description of the information needs that was sent to all the owners,
- secondly, details of information required regarding the key parameters, and
- thirdly, an evaluation guide used by the Consultants during field work.

These documents are attached in the Appendix 4.

Benchmarking

ABB's main market for the SCADA systems has been and remains the industrialized countries and in particular the Nordic countries, where its system has gained a high market share. This in combination with the fact that the Nordic countries have one of the world's most market oriented and competitive electric power sectors, suggested that ABB SCADA systems operated by comparable Norwegian networks could be used as a benchmark reference for the projects under review.

The study was therefore extended to include a comparison between, on the one hand, the SCADA systems in the nine developing countries, all of which were bought and operated by state owned power companies¹, and on the other hand a total of five ABB systems in Norway and Sweden.

Study Implementation

The study was carried out in two phases. Firstly, a desk study based on documents available in Sweden was carried out, which resulted in an Inception report defining the objectives of the study and proposing an evaluation method. Secondly, the Consultants carried out fieldtrips to eight of the nine countries.

Each fieldtrip comprised the following elements:

- Interviews with SCADA responsible at the Power Company;
- Visit at and review of the National Control Center (NCC);
- Interviews with SCADA operators; and
- Discussions with ABB personnel at the local offices.

¹ The system in Ecuador has since become part of a regulatory agency that supervises privatized power companies. A similar process is reported under way in Pakistan.

Appendix 3 Project Fact Sheets

Botswana

Project Fact Sheet	Botswana Power Corporation
SCADA History	

Year	Activity	Contractor	Comments	Currency	Amount (million)	mUSD equivalent
1980	Study of remote control system	Consultant/ETS				
1981						
1982	Tdr docs	BPC-ETS				
1983	Offer and contract	ASEA				
1984						
1985	Inst SCADA	ASEA	SINDAC 3	Pula	3.10	1.14
1986						
1987						
1988						
1989						
1990						
1991	Upgrading study	Foreign consultant				
1992						
1993	Internal study & tdr docs	BPC-ETS	For Gaborone SCADA			
1994	1. Application to BITS 2. Appraisal 3. Inst SCADA & RTU ext	SwedPower ABB	For NCCU + GDS S. Rudefalk Addition of 4 more RTUs			0.02 0.25
1995	1. Offer 2. BITS approval TA+training	ABB SwedPower	Neg tdr From 95 to 00	SEK SEK	20,60 5.00	0.40
1996	Inst SCADA upgrad + S ext	ABB	NCC SPIDER	SEK	24.10	3.60
1997						
1998						

SCADA Project Funding (mUSD)

Xrate	Client	Swedish financing	Other funding	Total	Comment
2.71	1.14			1.14	
7.71	0.25	0.02		0.02 0.25	Grant 0.02
		0.40		0.40	Grant 0.40
6.70	0.53	3.07		3.60	Grant 1.53
Total	1.92	3.49		5.41	Grant 1.95

SCADA System Parameters									
Year	Installation	Control center	No of RTUs	No of networks controlled	No of commands	No of indicators/ events	No of measures	Telecom	Special software
1985	SINDAC 3		14		370	1300	360		
1994	Ext by 4 RTUs		4						
1996	SPIDER NCC		18	2	362	3551	540	PLC, radio, fiber	
	SPIDER 7 C /GDS	Dual hot/standby	14	3	179	1589	291	radio	

- Prior to 1985 BPC had a conventional remote control system with operating instructions transmitted by phone.
- The first SCADA (SINDAC 3) for the National Control Centre (NCC) – installed in 1985 - was designed for 4 power stations and 15 transmission substations
- Four RTUs, financed under a SADCC project, were added in 1994 to include Bulawayo, Francistown, Morupule and Gaborone South
- The 1996 NCC upgrade replaced the SINDAC 3 with a SPIDER 7C and added 14 RTUs. The original communication system was not replaced
- A Gaborone SCADA – SPIDER – with 13 RTUs linked with the NCC was part of the package installed in 1996

Project Justification		
First SCADA system	1. Reducing outages due to faults in the transmission network 2. Reducing transmission losses 3. Reducing staff requirements for 15 substations	
95 NCC upgrading	1. Reducing support cost	Ave between –90 and 95 SEK 1.3 pa
95 GDS	1. Reducing outages and outage duration in Gaborone distribution network Outage time reduction estimated at 25%	Loss 1.025 GWh/yr

Project Issues		
First SCADA system	1. What was the reduction in transmission related outages? 2. What was the reduction in transmission losses?	
95 upgrading	1. What is the support cost with the upgraded system? 2.The support cost for the NCC was estimated at SEK 0.7. What is the actual cost?	
95 GDS	1. Have the number and duration of Gaborone outages been reduced	

Other Project Data					
Item	Year	Value	Comments	Year	Value
Inst capacity MW		197		1997	132
Max demand MW				1997	223
Max demand in Gaborone	1993	42		1997	n.a.
Consumption (GWh)		991		1997	1189
No of subscribers BPC nationwide	1993	32,000		1997	38,000
No of subscribers in Gaborone3	1993	17,000		1997	n.a.
Length of HV net km	1993	1372		1997	2454
Network losses	1994	8.4		1997	6.4

Project Fact Sheet **INECEL and CENACE**

Year	Activity	Contractor	Comments	Currency	Amount (million)	mUSD equivalent
1974	Outline study of proposed National Control Center	IECO	(Brazilian Consultant)			
1975	Specifications					
1976						
1977						
1978	Installation	UNITEL	For Pisayambo project			
1979	Feasibility study	INECEL				
1980						
1981						
1982	Justification study	INECEL				
1983						
1984						
1985						
1986	Requirement Study	INECEL				
1987	Call for tdrs and offers	ASEA Siemens Ferranti,	4 of the tenders failed			
1988	First tdr eval	SwedPower	Bengt Leander 87-89	SEK	0.5 (est)	0.09
1989	BITS approval		SINDAC			
1990	Retender Second tdr eval BITS approval for new ABB offer	ABB SwedPower	Bengt Leander SPIDER	SEK	1.10	0.19
1991	Impl support, verificat contract	SwedPower	Bengt Leander 91-95	SEK	2.3	0.38
1992						
1993						
1994	Inst SCADA	ABB	SPIDER Bld etc	SEK S/ USD	78.18 84.54	13.75 0.67 1.00
1995	Project report	SwedPower	Bengt Leander			
1996						
1997						

Xrate	Client	Swedish financing	Other funding	Total	Comment
6.14		0.09		0.09	Grant 0.09
5.91		0.19		0.19	Grant 0.19
6.06		0.38		0.38	Grant 0.38
(7.71) ²	0.67 1.00 (est)	13.75		13.75 0.67 1.00	Grant 4.75

3

1998										
1999	Y2K support	ABB		SEK	1.0	0.12	8.27	0.12		0.12
2000	Basic support	ABB		SEK	1.0	0.1	9.66	0.10		0.10
							Total	1.89	14.41	Grant 5.41

Year	Installation	Control center	No of RTUs	No of measures	No of indicators	No of commands	Telecom	Special software
1978	UNITEL						Canadian PLC	
1992	SPIDER+EMS	Dual hot/standby	28	700	3477	500	PLC, fiber	EMS

- Prior to SPIDER, Ecuador had a small remote control system (UNITEL) for its Pisayambo project. This was installed in 1978/9
- The process towards a modern SCADA started in 1979 when INECEL was commissioned by the government to make a study and prepare specifications
- The first tendering process in 1987/88 could not be completed because of INECELs difficulties in raising finance for the project.
- In 1989 the winning company ABB was asked to retender

Project Justification		
SCADA system	1. Shorten outage duration 2. Reduce frequency variations 3. Reduce need for spinning reserve 4. Reduce transmission losses 5. Simulation of breakdowns to improve preparedness	Network losses corresponded to 21% Benefit/cost ratio estimated at 1.8 over 15 years

Project Issues		
SCADA system	1. What has been the reduction in no and duration of outages? 2. What has been the reduction in frequency variations? 3. What has been the reduction in required spinning reserve? 4. What has been the reduction in transmission losses?	

Other Project Data					
Item	Year	Value			
Inst capacity MW	1993	1800			
Max demand MW	1993	1100			
Consumption GWh	1993	5500			
No of subscribers	1993	n.a.			
Length of HV net km	1993	1827			
Network losses %	1993	21			

Jordan

Project Fact Sheet	National Electricity Power Company, Jordan
SCADA History	

Year	Activity	Contractor	Comments	Currency	Amount (million)	mUSD equivalent
1973	SCADA for greater Amman area	n.a.				
1974						
1975	Design study for new NCC	JEA+British consultant				
1976						
1977	Tdr docs	JEA				
1978	Contract for BECOS-10 system	BBC				
1979						
1980						
1981						
1982	Installation of BECOS-10					4.50
1983						
1984	1. Offer 2. Tdr eval & neg 3. BITS approval 4. Design and specs up-grade	ASEA SwedPower	Up-grading of NCC hardware+software RTU +EMS Bengt Leander 84-87	SEK	0.5 (est)	0.06
1985						
1986						
1987						
1988	SINDAC-5 installation BITS approval	ASEA	SINDAC + EMS Terminal upgrade and ext	SEK	52.25	8.50
1989	Installation of more RTUs, etc	ASEA	Circuit boards +6 RTUs	SEK	3.00	0.50
1990	Mgmt support etc	SwedPower	Thomas Melkersson 89-94	SEK	0.90	0.10
1991	Offer re SCADA upgrade	ABB	SPIDER			
1992	Training	SwedPower	NCC management /operation routines	SEK	0.88	0.15
1993						
1994	Training	SwedPower		SEK	0.25	0.03
1995						
1996						
1997		JEA+DSI				
1998						

SCADA Project Funding (mUSD)

Notes	Client	Swedish financing	Other funding	Total	Comment
	4.50			4.50	
8.28		0.06		0.06	Grant 0.06
6.14	1.27	7.23		8.50	Grant 1.27
6.45	0.07	0.43		0.50	Grant 0.11
6.45		0.10		0.10	Grant 0.10
5.81		0.15		0.15	Grant 0.15
7.71		0.03		0.03	Grant 0.03

1999	Sida eval of training component Installation of Ranger SCADA	Sida Bailey Network	EPRI-API (CIM) open system configuration									
							Total	5.84	8.00		13.84	Grant 1.72

Year	Installation	Control center	No of RTUs	No of measures	No of indicators	No of commands	Telecom	Special software
1988	SINDAC-5 + EMS	3 computers	44	18000	3000	1400	PLC	EMS
1989	Circuit board replac + RTUs		6					
1999	SINDAC replacement by Bailey Ranger system		14		8500	1000	New PLC, fiber	EMS

-
- Until 1982 Jordan had a conventional electromechanical remote control system based on telephone communication of data and operating instructions.
- The first SCADA system, a BECOS-10 with 34 RTUs, was commissioned in 1983. The cost shown for that system is that part of the total cost which NEPCO estimated was the value of the RTUs used also for the SINDAC 5 system installed in 1988.
- Between 1984 and 1987, SwedPower assisted Jordan Electricity Authority (JEA) in reviewing specifications, evaluating tenders and negotiating a contract for the upgrading of an existing NCC.
- The upgraded NCC, equipped with new hardware and software, was commissioned in 1985 with a SINDAC-5 EMS system. A total of 34 RTUs were kept and 10 new were added and EMS functions were enhanced. The value of the old RTUs was estimated by NEPCO to USD 4.50 million equivalent
- 6 of the old BECOS-10 RTUs were replaced and new circuit boards were installed in 1989
- In 1991 JEA entered into a cooperation agreement with SwedPower to train the NCC manager.
- During 1992, SwedPower conducted further training of NCC management.
- Between 1990 and 1994 32 JEA staff members participated in Sida funded training (BITS)
- In 1994 SwedPower conducted phase II of a training course for management of interconnected networks

Project Justification		
First BBC SCADA system	n.a.	
NCC upgrade with SINDAC-5	n.a.	
Terminal upgrade & ext	n.a.	

Project Issues		
SCADA system	n.a	

Other Project Data					
Item	Year	Value			
Inst capacity	1994	1150 MW	Zarqa 400MW, Aqaba 650MW	1999	1578 MW
Maximum demand	1994	825 MW		1999	1137 MW
No of subscribers	1994	673,000		1999	834,000
Length of transmission system	1994	2,790 km	400 and 230 kV	1999	3026 km
Transmission losses		1.6		1999	3.0%

Kenya

Project Fact Sheet	Kenya Power & Lighting Company
SCADA History	

Year	Activity	Contractor	Comments	Currency	Amount (million)	mUSD equivalent
1981						
1982						
1983						
1984	Specs & tdr docs	IVO		FIM	3.79	0.67
1985	1. Appraisal 2. BITS approval	SwedPower	Anders Bruse	SEK	0.1	0.01
1986						
1987	Ext specs & tdr docs	IVO		FIM	4.77	1.13
1988	Appraisal of ext	SwedPower		SEK	0.5 (est)	0.08
1989	1. BITS approval of escalation 2. Follow-up study 3. Inst SCADA NCC & 3 ACC	SwedPower ABB	Gunnar Frostberg SINDAC 3 & 5 +EMS	SEK CHF	0.5 (est) 24.40	0.08 16.15
1990						
1991						
1992	Final report NCC and 2 ACC Extension by 1 RTU	IVO	Final project costs	SEK	0.93	0.16
1993						
1994						
1995	Training Extension by 1 RTU	SwedPower		SEK USD	0.6 0.11	0.09 0.11
1996	Extension by 1 RTU			SEK	1.329	0.19
1997						
1998						

SCADA Project Funding (mUSD)

Note	Client	Swedish financing	Other funding	Total	Comment
			0.67	0.67	
		0.01		0.01	Grant 0.01
4.22			1.13	1.13	
6.14		0.08		0.08	Grant 0.08
6.45		0.08		0.08	Grant 0.08
	2.38	13.77		16.15	Grant 5.57
5.81	0.16			0.16	Grant 0.05
7.13	0.02 0.11 0.19	0.07		0.09 0.11 0.19	Grant 0.07
Total	2.86	14.01	1.80	18.67	Grant 5.86

SCADA System Parameters								
Year	Installation	Control center	No of RTUs	No of measures	No of indicators	No of commands	Telecom	Special Software
1989	SINDAC 5 EMS	NCC and NACC (National CC and distr. Nairobi)	24	1500	5700	1500	PLC, radio, fiber, pilot cable	EMS, AGC
	SINDAC 3	CACC (Coast area)	6					
	SINDAC 3	KCC (Kamburu)	6					
1990								

- An NCC and NACC with SINDAC 5 version of SCADA and 2 Regional Control Centers with SINDAC 3 versions were commissioned in 1990.
- EMS has never been commissioned
- The western part of Kenya, still has a separate SCADA system based on a BBC SCADA system (Becos 04) .

Project Justification			
NCC and RCC SCADA system	1. Optimization of production and reduction of network losses 2. Prevention and reduction of duration of outages 3. Increased voltage and frequency stability		
RCC for Western Kenya	1. NCC' power system calculations cannot be used without manual entering of data from Western region 2. Different systems complicates maintenance, upgrading and retention of competence		

Project Issues			
First SCADA system	1. Effect on network losses? 2. Effect on outages? 3. Effect on voltage and frequency stability		
Extension	1. Effect on staffing 2. Effect on Western region network losses and outages?		

Other Project Data

Item	Year	Value	Comments	Western region	Year	Value		Year	Value
Inst capacity MW	1984	550	400MW hydro		1989	702		1995	809
Maximum demand MW	1984	350		50				1995	
Consumption GWh					1989	2943		1995	3919
No of subscribers									
Length of HV net km					1989	2610		1995	7668
Network losses %								1995	15.0

Lesotho

Project Fact Sheet	Lesotho Electricity Corporation
SCADA History	

Year	Activity	Contractor	Comments	Curr ency	Amount (million)	mUSD equivalent
1982						
1983						
1984	1. Appraisal 2. Tdr eval 3. BITS approval	Lars Hydén NVE		SEK	0.05	0.01
1985						
1986	Inst SCADA	ASEA	SINDAC 1	SEK	17.01	2.38
1987	Training	ASEA		SEK	1.30	0.20
1988	Extension RTU	ASEA		SEK	0.65	0.10
1989	Training	Norplan		NOK	1.5	0.25
1990	Offer	ABB				
1991	1. Tdr eval 2. Appraisal of NCC upgrading	NVE Sydkraft	Gunnar Frostberg	SEK	0.5	0.09
1992						
1993						
1994						
1995	Inst of upgrade	ABB		SEK	2.50	0.32
1996	Extension	ABB	Extension of Faulty Circuit Boards	SEK	2.00(est)	0.30
1997						
1998	Inst of NCC	ABB	SPIDER			3.70
1999						

SCADA Project Funding (mUSD)

Xrate	Client	Swedish financing	Other funding	Total	Comment
8.28		0.01		0.01	Grant 0.01
7.13	0.35	2.03		2.38	Grant 1.01
6.35		0.20		0.20	Grant 0.10
6.14	0.10			0.10	Est
5.99			0.25	0.25	
6.06		0.09		0.09	Grant 0.09
7.85	0.16		0.16	0.32	
6.70	0.30			0.30	
			3.70	3.70	
Total	0.91	2.33	4.11	7.35	Grant 1.21

SCADA System Parameters									
Year	Installation	Control center	No of RTUs	No of measures	No of indicators	No of commands	No of objects	Telecom	Special Software
1985	SINDAC 1 för Maseru	RCC	11	154	189	64	32	PLC	
1998	SPIDER	NCC	9	562	904	112	56	PLC	AGC, SLF, EQS, LM

- Prior to 1985 Lesotho Electricity Corporation had no remote control facilities. All substations were manned.
- The first SCADA system was commissioned in 1986 and went operational in 1987. It was a SINDAC 1 system for supervision of the transmission net (33kV) in Maseru.
- In 1998 a SPIDER system was installed to serve the national transmission network. The system's interconnection with the SINDAC 1 is limited. The SPIDER system was financed by other donors than Sida.

Project Justification		
Original SCADA	1. Low capacity of net requires monitoring for load shedding purposes 2. Capacity cost for imported (ESKOM) power can be reduced	Load control could reduce cost by SEK 0.3/yr

Project Issues		
Original SCADA system	1. At the time of investment the consumption in Maseru was deemed too low to justify the investment. What has happened with Maseru consumption, outages and network losses? KOLLA	

Other Project Data								
Item	Year	Value	Comments	Year	Value			
Inst capacity MW	1988	44.2		1995	4828			
Maximum demand GWh	1988	135		1995	259			
No of subscribers	1988	8600		1995	13000			
Length of HV net (132+33kV) km	1988	890		1995	847			
System losses %	1988	18		1995	17.2			

Project Fact Sheet	Water and Power Development Authority
SCADA History	

Notes	Client	Swedish financing	Other funding	Total	Comment
6.45	2.59	4.10	37.86	41.96 2.59	Grant 1.02
5.91	0.84			0.84	Grant 0.84
Total	3.43	4.10	37.86	45.39	Grant 1.86

SCADA System Parameters									
Year	Installation	Control center	No of RTUs	No of measures	No of indicators	No of commands	No of objects	Telecom	Special software
1995	NCC SINDAC 5 2 RCCs SINDAC 3	1+2	108	6000	30000	2000		Micro-wave/singel ch radio	EMS

- Prior to 1995 WAPDA had no remote control facilities. All substations were manually operated.

Project Justification		
First SCADA system	1. Required to handle increasing and spreading load following from rehabilitation of old feeders and expansion of transmission and distribution capacity to match planned new generation capacity 2. Savings because of reduced transmission losses and outages 3. Reduced need for investment in system redundancy 4. Better coordination between two systems (WAPDA and KESC)	

Project Issues		
First SCADA system	1. Reduction in transmission losses 2. Reduction in outages	

Other Project Data				
Item	Year	Value		
Inst capacity MW	1983	5071		
Maximum demand MW	1983	3026		
No of subscribers				
Length of HV net km	1983	3800		
Network losses %	1983	25		

Vietnam

Project Fact Sheet	Ho Chi Minh City Power Company
SCADA History	

Year	Activity	Contractor	Comments	Curr ency	Amount (million)	mUSD equivalent
1987						
1988						
1989	Phase 1 1989-1993 Feas study of Phase 1	SwedPower	Jöran Vedin			0.05
1990	Tdr docs	SwedPower	Jöran Vedin			0.20
1991	1. Offer 2. Tdr eval 3. Impl support 4. Sida approval	ABB SwedPower SwedPower	No ICB Jöran Vedin 91 to 93			0.05 0.25
1992	Inst SCADA Phase 1	ABB	Interim SINDAC	SEK	17.88	3.08
1993						
1994						
1995	Up-grading	ABB	4 RTU	SEK	1.24	0.17
1996	Tech Ass	SwedPower		SEK	3.35	0.50
1997	Appraisal of phase 2	IVO				
1998	Inst SCADA Phase 2	ABB	SPIDER + 7RTUs	SEK	20.90	2.62
1999						
2000						

SCADA Project Funding (mUSD)

Xrate	Client	Swedish financing	Other funding	Total	Comment
		0.05		0.05	Grant 0.05
		0.20		0.20	Grant 0.20
		0.05 0.25		0.05 0.25	Grant 0.05 Grant 0.25
5.81	0.95	2.13		3.08	Grant 2.13
7.13	0.05	0.12		0.17	Grant 0.12
6.70		0.50		0.50	Grant 0.50
7.95	0.73	1.89		2.62	Grant 2.62
Total	1.73	5.19		6.92	Grant 5.92

Year	Installation	Control center	No of RTUs	No of measures	No of indicators	No of commands	Telecom	Special software
1993	Interim PC based SPIDER SCADA	1	21+12	550	290	543	6 channel UHF	none
1996	SPIDER	1	16	708	318	571		none

- Prior to 1993 PC2 had no remote control facilities for its Ho Chi Minh City district network. All facilities were manned. The district network level takes power from the HV transmission network for feeders below 66kV
- The district control center (DCC) for Ho Chi Minh City supervises 21 distribution stations with 110kV volts and less and part of the HV net in the Ho Chi Minh City area.
- Because of an American embargo ABB could not deliver a full SCADA system. A simplified "interim" SCADA system based on PC computers was therefore commissioned in 1993. The interim system has however, not been able to meet the full requirements of PC2.
- In 1995 PC2 was split in two parts, one regional and transmission and distribution and one for the Ho Chi Minh City. The latter was called Ho Chi Minh City Power Company (HCMC-PC) and it became the owner and operator of the Sida financed SCADA system.
- An upgrading project which included replacement of the SINDAC system with SPIDER and 16 RTUs (of which only 7 had been commissioned as of early 2001) was commissioned in 1996

Project Justification		
Interim SCADA system	1. Reduce duration of power (by 20% corresponding to a loss reduction of 1.1GWh per year) 2. Improve utilization of distribution network 3. Reduce need for investments 4. Relieve staff of need to produce statistics so that they can work with maintenance	

Project Issues		
Interim SCADA system	1. Effect on duration and frequency of outages? 2. Effect on investments? 3. Labor savings (HCMC operation was quite labor intensive)	

Other Project Data														
Item	Year	Value		Year	Value		PC2 only Year	PC2 only Value		PC2 only Year	PC2 only Value		HCM Dist Area Only Year	HCM Dist Area Only Value
Inst capacity MW	1991	2280		1995	4500		1988	474		1998	1850		1988	256
Maximum demand													1988	520
Consumption GWh	1991	9300		1995	14867		1988	2332		1998	10200		1988	1393
No of subscribers				1995	500 000									
Length of MV net	1991	7700					1988	1370						
Network losses %	1991			1995	26.8									
Estimated outage time hours	1991									1998	1348			

Zambia

Project Fact Sheet	Zambia Electricity Supply Corporation
SCADA History	

Year	Activity	Contractor	Comments	Curr ency	Amount (million)	mUSD equivalent
1978	Inst SCADA NCC	Jeumont Schneider	Eclipse S/2000 computers and J- S RTUs			
1979						
1980						
1981						
1982						
1983						
1984						
1985	Inst of SCADA for Lusaka	Harris				
1986						
1987						
1988						
1989	Feas study	ESB				0.23
1990	Kafue Train Ctr 1	SwedPower/ Norplan		SEK /NOK	23	
1991	1. Appraisal 2. Tdr docs, etc	SwedPower SWECO	Bengt Leander	SEK SEK	0.05 1.50	0.01 0.25
1992	1. Offer 2. SIDA approval	ABB	No ICB			
1993	Imp support	SWECO		SEK	4.50	0.60
1994						
1995	1. Inst of SCADA NCC 2. Kafue Training Ctr 2	ABB SWECO		SEK SEK /NOK	74.98 29.00	10.51
1996	Analysis of results	VINCO				
1997						
1998						
1999	Training	SwedPower	Hans Bjerhag	SEK	3.00	0.36
2000	Inst SCADA BCC	ABB		NOK	6.34	0.81
2001	Inst new telecom	Teamcom		NOK	27.04	2.90

SCADA Project Funding (mUSD)

Xrate	Client	Swedish financing	Other funding	Total	Comment
				?	
		0.23		0.23	Est
5.91					
6.06		0.01 0.25		0.01 0.25	Grant 0.01 Grant 0.25
5.81					
7.80		0.60		0.60	Grant 0.60
7.13		10.51		10.51	Grant 10.51
8.27		0.36		0.36	Grant 0.36
7.85			0.81	0.81	Grant 0.66
9.32			2.90	2.90	
Total		11.96	3.71	15.67	Grant 12.39

SCADA System Parameters									
Year	Installation	Control center	No of RTUs	No of measures	No of indicators	No of commands	No of objects	Telecom	Special software
1978	Data General+Jeumont Scheider	Eclipse S/2000	10	n.a.	n.a.	n.a.			
1996	SPIDER EMS	NCC	23	1513	8967	783		Fiber PLC Radio	Load forecast & AGC
2000	Emergency backup	BCC	1						

- The first SCADA system was commissioned in 1979. It linked two hydroelectric plants and seven transformer stations with an NCC. This system was kept in operation until 1995 but had limited availability and could not be extended. In addition, being a 16 bit system, it became progressively more difficult to service with spare parts.
- In 1996 a SPIDER EMS system was installed. It has since upgraded with another workstation. The system has also been Y2K secured.
- An emergency control center has been built in Lusaka with support of NORAD. ABB provided the software for this installation which was made in 1999.
- A contract for distribution control center for Lusaka was signed with ABB Finland during Dec 2000.

Project Justification		
SCADA SPIDER system	1. Achieve efficient utilization of existing production and distribution facilities (reduce reserves, increase fuel efficiency) 2. Reduce no of disruptions of production 3. Limit the duration of outages 4. Maximize the amount of energy that is exported and foreign exchange earnings 5. Reduce staff costs 6. Maximize revenues	

Project Issues		
SCADA SPIDER system	1. Has inadequate staff competence limited the usefulness of the installation? 2. Was staff training part of ABB's delivery and if so was it adequately supplied? 3. Have reduction in no and duration of outages been achieved? 4. Was staff cost reduced?	

Other Project Data								
Item	Year	Value	Comments	Year	Value			
Inst capacity MW	1991	2436			1,750			
Maximum demand MW				1995/96	1,000			
Consumption GWh	1991	6295		1996/97	6,848			
No of subscribers				1995/96	150,000			
Length of HV network km		9737						
Network losses		7						

Zimbabwe

Project Fact Sheet	Zimbabwe Electricity Supply Authority
SCADA History	

Year	Activity	Contractor	Comments	Curr ency	Amount (million)	mUSD equivalent
1980	Feas study	MerzMcLellan				?
1981	Tdr docs	MerzMcLellan				?
1982	Offer BITS approval	ASEA				
1983	BITS approval of cost increase					
1984						
1985	Inst SCADA SINDAC 5	ASEA	Incl DCC Harare	SEK	108.0	12.42
1986	1. Evaluation of NCC 2. Study for Bulawayo RCC 3. BITS approval	SwedPower Merz McLellan	Tommy Ohlson Bulawayo RCC	SEK	1.00	0.14
1987	Inst ACC Bulawayo	ASEAB	SINDAC	SEK	36.60	5.76
1988						
1989	Upgrade study	Pwr Tech Inc				?
1990	Appraisal	Sydskraft	Björn Sonnerup	SEK	0.07	0.01
1991	BITS approval	ABB				
1992						
1993						
1994	1. Inst SCADA upgrade 2. Proj Completion Rep	ABB ZESA	SPIDER EMS	SEK	32.8	4.25
1995						
1996						
1997						
1998						
1999						

SCADA Project Funding (mUSD)

Xrate	Client	Swedish financing	Other funding	Total	Comment
	?		?	?	
	?		?	?	
8.69	1.86	10.56		12.42	Grant 2.64
7.13	?	0.14	?	0.14	Est
6.35	0.61	5.15		5.76	Grant 1.27
	?		?	?	
		0.01		0.01	Grant 0.01
7.71	0.65	3.60		4.25	Grant 0.90
Total	3.12	19.46	?	22.58	Grant 4.82

SCADA System Parameters									
Year	Installation	Control center	Network controlled	No of RTUs	No of indicators	No of commands	No of measures	Telcom	Special software
1985	SINDAC5 Dual hot/standby	NCC and Harare	National grid	100	4000	11000	3000	n.a.	
1987	SINDAC 3	ACC Bulawayo	Distr 33kV	27	5000	60	8000	PLC	
1994	SPIDER EMS	NCC	National grid, transmission +33kV	106	25917	2927	4983	PLC, fiber, radio	AGC, SE, OLF, NC, VAR, mfl.

- Prior to the 1985 installation of a SINDAC system there existed a simple NCC system to control the transmission network, which was commissioned in 1978.
- The first ABB system was commissioned in 1985. It was a SINDAC 5 system, which included the distribution net in Harare.
- In 1987 (?) the ACC in Bulawayo was upgraded to a SINDAC 3.
- In 1994 the SINDAC system was replaced by a SPIDER (Release 1) system. It used the same RTUs as were installed in 1986. Currently the NCC is not using the EMS functions that were part of the 1994 installation.

Project Justification		
First ABB SCADA system	1. Optimize production (reduce need for redundancy, improve fuel efficiency) 2. Reduce transmission losses 3. Prevent or shorten outages 4. Improve voltage and frequency stability	
ACC Bulawayo upgrading NCC upgrading (94)	Insufficient data processing capacity due to network expansion Poor response time	

Project Issues		
First ABB SCADA system	Evaluation report claimed significant benefits in the form of postponed or reduced investment. Data?	
	The project evaluation stated that outages were significantly reduced following commissioning of the SCADA system. Data?	
	Data concerning improved power quality?	
	Lack of stability of the PLC impaired the system. How and when was this attended? How serious was the impairment?	

Other Project Data															
Year	1985/6	1986/7	1987/8	1988/9	1989/0	1990/1	1991/2	1992/3	1993/4	1994/5	1995/6	1996/7	1997/8 ³	1999	2000
Maximum demand MW					1538	1576	1608	1478	1554	1616	1744	1828	1950	2034	1986
Inst capacity MW									1,960						
Generated (GWh)					9361	8924	8237	7468	7535	7810	7323	7298	10055	7091	6996
Imported (GWh)					332	1144	2027	1214	2009	2312	3172	4013	7460	5275	5095
Network losses (GWh)															
Network losses (%)	12.0	13.0	9.0	12.0	8.7	10.7	9.9	11.0	11.9	10.7	10.8	10.8	11.3	12.8	13.2
Of which transmission					3.0	4.0	3.6	4.4	3.6	3.5	2.8	2.6	2.6	3.5	3.9
Consumption GWh	8303	8286	8500	8623	8852	8992	9248	7731	8412	9036	9365	10088	15534	10779	10493
No of subscribers									370,000						
Length of HV net km									4,620						6043

³ 18 months

Appendix 4 Evaluation documents

The following is the document sent to the SCADA operating entities for the purpose of soliciting their assistance in preparing information.

SCADA Evaluation Information Needs

Please find below some information as regards the aspects of your SCADA system that we believe would be relevant for the ongoing SCADA-evaluation that involves the nine following countries: Botswana; Ecuador; Jordan; Kenya; Lesotho; Pakistan; Vietnam; Zambia; and Zimbabwe.

The main purpose of the evaluation, commissioned by Swedish international development agency (Sida), is to evaluate the benefits that SCADA has delivered. More precisely, we would like to study whether SCADA has lead to reduced outages, reduced transmission losses, fuel savings, improved power quality and reduced maintenance. As the scope of the evaluation covers both technical and economic aspects of the SCADA installations, information would be needed with respect to a wide range of issues.

First of all, we are interested in technical specifications regarding the installed SCADA-systems. This comprises information on:

- Control center;
- Number of RTUs;
- Number of measures;
- Number of indicators;
- Number of commands; and
- Does the software comprise EMS or not?.

Secondly, we try to trace the *costs* of *and sources of finance* for the installation, support and training as well as the *year* for the project's different phases. This means that all studies effectuated (e.g. appraisal studies, feasibility studies, etc.) are of great interest. It is equally important to identify the different contractors involved.

Thirdly, we would like to have your views on the SCADA-system. The following issues are of interest:

- Identification of the most important issues to focus on in the evaluation according to you;
- Explanation of the main problems you have been confronted with related to the SCADA project; and
- Suggestions of the most relevant topics of interest to be addressed in an eventual future exchange of experiences between the countries concerned.

Fourthly, we are interested in taking part in your appreciations of cost figures related to:

- Socio-economic costs caused by power cuts;
- Wage cost for SCADA operators as well as for substation operators; and
- Energy tariffs.

If there were any investigation carried out regarding these matters it would be of great interest to the evaluation.

Fifthly, we would be very grateful if we could be given access to the power system's fault statistics. The years that are relevant are 2-5 years before the first SCADA investment up to now. More precisely, it concerns statistics on the following issues.

- Production
 - Number of outages
 - Total losses (kWh)
- Transmission/distribution
 - Number of outages
 - Total delivery losses (kWh)
- Peak load per year (MW)

Finally, we would like to revise already available statistics on technical losses (MWh) as well as on transmitted energy (GWh) per year and if necessary correct misleading information. The relevant years are the same as the aforementioned.

Details of information required regarding the key parameters

Technical SCADA Evaluation Parameters

SCADA system	Control-center	Network controlled*	Number of RTU's	Number of commands	Number of indications /events	Number of measurands	Telecom systems**	Special software*** (EMS, DMS, AGS)

- * 1. National Grid
 2. Transmission network
 3. Distribution level 1 (33 kV)
 4. Distribution level 2 (11 kV)

- ** 1. PLC (Power Line Carrier)
 2. Radio
 3. Fibers
 4. Pilot cables

- *** Seek for which parts of EMS, DMS, AGS that has been purchased

Hardware configuration

	Hardware configuration for each system	Give a <u>X</u>	Comment
	Number of work places		
	Single computer system		
	Double computer system, cold standby		
	Double computer system, hot standby		
	Single front end		
	Double front end		
	Mimic board		
	Single UPS (Get battery backup time)		
	Double UPS (Get battery backup time)		
	Emergency diesel generator		
	Air conditioning		

SCADA-system philosophy

Mark the square with an **X** if the control parameter is present in the SCADA system.

Control parameters	Power-station	Substation National grid			Substation Transmission Network			Substation Distribution level 1 (33 kV)		Substation Distribution level 2 (11 kV)	
		High-voltage	Middle-voltage	Low-voltage	High-voltage	Middle-voltage	Low-voltage	High-voltage	Low-voltage	High-voltage	Low-voltage
Circuit breaker indication											
Disconnecter indication											
Earth switch indication											
Circuit breaker control											
Disconnecter control											
Earth switch control											
Transformer voltage control											
Generation load control											
Generation start/stop											

Evaluation guide

1. Review available information (key figures) on:
 - Commands;
 - Indications/events; and
 - Measurements.
2. Review the compiled information on the costs, financier, engineer/consultant and supplier/contractor of the installation, support and training as well as on the year for the project's different phases. Find out if any additional studies have been carried out.
3. Find out power companies' (owners') views on the SCADA-system. Focus on:
 - Identification of the most important issues to focus on in the evaluation according to the owners;
 - Explanation of the main problems the owners have been confronted with related to the SCADA project; and
 - Suggestions of the most relevant topics of interest to be addressed in an eventual future exchange of experiences between the countries concerned.
4. Find out who the real initiator has been in the SCADA project's different phases. Is it the owners themselves that have been the driving force or is it the engineer/consultant or the supplier/contractor?
5. Ask for the owners' appreciations of cost figures related to:
 - Socio-economic costs caused by power cuts;
 - Wage cost for SCADA operators as well as for substation operators; and
 - Energy tariffs over year.

Have the owners carried out any investigation regarding these matters?

6. Study if the SCADA-systems have delivered the benefits that were expected?
This involves investigation of the five performance criteria:
 - reduced outages;
 - reduced transmission losses;
 - fuel savings;
 - improved power quality; and
 - reduced maintenance.
 - staff reductions as well as
 - reduction of need for generation and transmission reserves.
 - lower cost of imported power and more revenue in case of exported power.
7. Access the owners' power system's fault statistics and look at statistics concerning:
 - Production
 - Number of outages
 - Total losses (kWh)
 - Transmission/distribution
 - Number of outages
 - Total delivery losses (kWh)

- Peak load per year (MW)

Relevant years: 2-5 years before the first SCADA investment up to now.

8. Review and revise, if needed, already available statistics on:

- Technical losses (MWh) and
- Transmitted energy (GWh) per year information.

Relevant years are the same as the aforementioned.

9. Find out whether the SCADA system's full capacity has been used. If it hasn't, investigate why. In addition, study what happens when something in the system brakes down. How is the system maintained?
10. Study the privatization in the country regarding the power sector and ascertain whether there is a correlation or not with the existence of the SCADA-system and the process (with or without SCADA).
11. Study whether the installation and the eventual upgrading of the SCADA-systems have influenced the organization's structure? If the answer is yes, find out how it has been affected.
12. Ask for single line diagrams and figures on the power systems that are remote controlled. These should provide an overview of:
 - Production and transmission system parameters
 - Transmission lines and cables with voltage level and length
 - Power stations (hydro and thermal)
 - Substations (voltage levels, transformers, switch bays etc.)
 - Type of network (radial- or ringed network)
 - Distribution parameters
 - Distribution lines and cables with voltage level and length
 - Distribution stations (distribution transformers)

The overview should contain a specification of which parts of the network that are remote controlled as well as of strategies for remote control on the different network levels (remote switching possibilities, alarm and measurement handling, start/stop and control of power plants etc.). Additionally, if the SCADA system includes control water reservoirs and waterways it should equally be included.

Appendix 5 Interview Results

SCADA functions relevance, scope suitability, project initiative, and procurement process.

	Botswana	Ecuador	Jordan	Kenya	Lesotho	Vietnam	Zambia	Zimbabwe
SCADA Relevance								
Main system issues at time of investment	Large losses in Gaborone distribution network	Large variations in water availability and seasonal capacity shortages	Interconnected systems with Syria and Egypt	Rapid development in the primary power system. In sufficient capacity in existing SCADA	Lack of transmission capacity	Insufficient transmission capacity of lines and transformers	Need of improved supply security level related to needs of the mining industry. Lack of spare parts to the existing SCADA Impossible to add extra capacity and limitations due to report and data handling	Import/export Problems with old system's hard disk capacity to handle the amount of data
Relevance of SCADA functions	Limited to good	High	High	Moderate to High	Low to acceptable	Limited	High except for load forecast	Moderate

	Botswana	Ecuador	Jordan	Kenya	Lesotho	Vietnam	Zambia	Zimbabwe
Suitability of SCADA scope	Very good	Moderate – insufficient for future needs	Very good at the time but insufficient at present	Moderate due to over dimensioning EMS functions never commissioned Too many Control Centers SCADA in distribution network irrelevant at time of purchase	Limited	Moderate Inadequate computing capacity for installed functions (due to US embargo)	Very good Except for load forecast function	Very good However Over dimensioned Too many Control Centers EMS functions never used due to data acquisition problems. SCADA in distribution network not needed at time of purchase

	Botswana	Ecuador	Jordan	Kenya	Lesotho	Vietnam	Zambia	Zimbabwe
Technical aspects	Good Except for several unresolved operating problems	Limited System to be replaced entirely in 2002	Good Even though system has been replaced, 40 percent of the investment is still in use.	Limited Short System lifetime left on central systems. RTU's and Telecom in good condition	Limited Low availability of maintenance facilities such as spare parts. System attained its lifetime.	Limited Poor performance of newly installed up-grade	Good Apart from problems in operation of the initial telecom system	Good
Project Initiative								
Identification, Preparation, Initiation		The project was initiated in the early 1980s by INECCEL, which, on its own initiative, contracted several international consultants for design and procurement.	The project was initiated by NEPCO as they felt the need for a system to control and manage the transmission network. A British Consultant was hired to evaluate the need.	The procurement handling and modeling of the SCADA system was driven by the consultant IVO. Procurement through competitive tender	Project was initiated with very little involvement of the operator LEC.	The project was agreed with the national power company in Hanoi for implementation by HCMPC. Important objective was to introduce new technology.	A study by an Irish consultant (ESB) was the basis for a non-competitive tender. A project agreement between Sida, ZESCO and ABB was established with the help of SWECO.	The initial SCADA system was purchased through competitive tendering. The subsequent SPIDER system was a directly negotiated purchase.
Owner (%)	20	70	75	15	10	20	20	10
Supplier (%)	30	10	10	25	70	20	20	25
Consultant (%)	30	15	10	45		45	45	25
Sida/BITS (%)	20	5	5	15	20	15	15	40

Comments: The driving force in the initial phase is estimated in percentages according to information obtained through semi-structured interviewed with the SCADA-operators.

	Botswana	Ecuador	Jordan	Kenya	Lesotho	Vietnam	Zambia	Zimbabwe
Procurement process								
Type of bidding process	Selective tender	Partly competitive Initially competitive, at the end non-competitive	Competitive Bidding	Competitive Bidding	No competition	No Competition, only one bid	No Competition	Competitive bidding re first investment No competition re second
Type of contract	Turnkey	Lumpsum fixed price	Turnkey	Turnkey	?	Itemized Lump sum	Turnkey	Turnkey
User's reason for selecting ABB	Previous supplier	Only bidder with financing	Availability of Swedish concessionary financing	Best Price/ Performance. Availability of Swedish financing.	Availability of Swedish financing.	Supplier had to be chosen from Sida's list. Only ABB to chose from	Availability of Swedish grant financing	Availability of Swedish concessionary financing
Consulting engineer for design and specification	In-house engineering department and SwedPower	SwedPower	British engineering firm	IVO	Syd Kraft (Closely linked to SwedPower)	Consultant had to be chosen from Sida's list Only SwedPower to chose from	SWECO (Closely linked to SwedPower)	SwedPower
Swedish consultant's perceived independence	Very low independence, seen as closely linked to ASEA	Low independent of ABB	Independent	Low independence of ABB	?	Low independence Perceived to be closely associated with both ABB and Sida	Low independence of ABB	Low independence of ABB

Appendix 6 Technical SCADA Evaluation

Main software modules in a SCADA-system

The following table gives an overview of the most common software application packages in ABB's SCADA systems. Other SCADA contractors but ABB have approximately the same content in their software products. System category 1 (standardized) and 3 (advanced) may be equipped with modules for statistics and historical data collection and storage called Utility Data Warehouse (UDW).

Software Module	Explanation of abbreviation	Description
SCADA	Supervisory control and data acquisition	Remote operation and control of a process. Used for power production, transmission and distribution systems. Software for data administration, picture handling and display functions. Event and alarm handling, dynamic coloring and job management are common features.
DMS	Distribution management system	Used in distribution networks for network calculations and analysis, statistics on outages, load forecasting and load control strategies, remote meter readings and tariff switching, remote operation and setting of digital protection equipment, distribution system planning and trouble shooting.
EMS/AGC	Energy management system (for production). AGC-Automatic generation control	Stand alone EMS part for managing power production and water reservoirs, optimization of power unit allocations. Software installed in the national grid dispatch centers for load and frequency control for the total network.
EMS	Energy management system (for transmission network)	Remaining EMS software for network management including network calculations and analysis, load flow optimizing, contingency analyses, fault simulation, demand forecasts.
DTS	Dispatch training simulator	Training of power system operators
UDW	Utility data warehouse	Statistics and historical data collection and storage

Process Proportion (PP)

The (PP) identifier is based on the number of RTUs (NR) with a correction factor for the average RTU size (ARS) for each SCADA system. ARS is the ratio between number of process points (NPP) and number of RTUs. The number of process points is the sum of the total number of commands, events/indications and measurements in each system.

The correction factor is the ratio between the ARS and a normal RTU size (NRS). The NRS is set to 300 process points. Large substations in the transmission network and power plants are normally above the NRS value, while smaller substations in the distribution system are on the lower side of the NRS value.

The definition of PP is shown in the table below.

Process Proportion (PP)	Process Points
Small	PP < 40
Medium	41 < PP < 80
Large	PP > 81

Formulas:

$$ARS = NPP / NR$$

$$PP = NR * (ARS / NRS)$$

PP Process Proportion

NR Number of RTUs in each SCADA system

ARS Average RTU size for each SCADA system

NRS Normal RTU size (here 300 process points)

NPP Number of process points for each SCADA system

System Category (SC)

The SC measure is based on a description of the central system with software and hardware and a brief identification of the telecom system. The table on the next page gives an overview of this measure.

System category (SC)		(SC)	Software	Hardware	Telecom
1	SCADA Standardized Windows/ Windows-NT OS ABB-products: • MICRO-SCADA • MINI-SCADA	101	SCADA (standardized)	Single system	Single channels
		102	SCADA (standardized)	Single system	Redundant channels cold stand-by
		103	SCADA (standardized)	Redundant system cold stand-by	Single channels
		104	SCADA (standardized)	Redundant system cold stand-by	Redundant channels cold stand-by
2	SCADA Slight advanced Unix /Historical real-time OS ABB products: • SINDAC 1 • SINDAC 2 • SINDAC 3	201	SCADA (customer adapted)	Single system	Single channels
		202	SCADA (customer adapted)	Single system	Redundant channels cold stand-by
		203	SCADA (customer adapted)	Redundant system cold stand-by	Single channels
		204	SCADA (customer adapted)	Redundant system cold stand-by	Redundant channels cold stand-by
3	SCADA Advanced Unix /Historical real-time OS ABB products • SINDAC 3 • SINDAC 4 • SINDAC 5 • SPIDER	301	SCADA (customer adapted)	Redundant system hot stand-by	Single channels
		302	SCADA (customer adapted)	Redundant system hot stand-by	Redundant channels hot stand-by
		303	SCADA (customer adapted) + DMS	Redundant system hot stand-by	Single channels
		304	SCADA (customer adapted) + DMS	Redundant system hot stand-by	Redundant channels hot stand-by
		305	SCADA (customer adapted) +AGC	Redundant system hot stand-by	Single channels
		306	SCADA (customer adapted) + AGC	Redundant system hot stand-by	Redundant channels hot stand-by
		307	SCADA (customer adapted) + EMS + AGC	Redundant system hot stand-by	Single channels
		308	SCADA (customer adapted) + EMS + AGC	Redundant system hot stand-by	Redundant channels hot stand-by
		309	SCADA (customer adapted) + EMS + AGC + DTS	Redundant system hot stand-by	Single channels
		310	SCADA (customer adapted) + EMS + AGC + DTS	Redundant system hot stand-by	Redundant channels hot stand-by

SCADA system category 1 and 2 are today similar. The systems in category 2 can be regarded as mostly historical since they date way back before the PC-based system came to the market. These systems were based on the same software as the advanced systems, but without advanced redundancy.

Category 1 is stated as standardized as these systems are based on standard Microsoft software or similar developed for a large number of applications.

According to ABB, category 1's upper limit is set at about 10.000 process points, where process points are similar to the sum of commands, events/indications and measurements. This limit value is increasing rapidly.

Category 3 systems are today mostly based on UNIX operating systems and the contractor's own developed software for data processing. Earlier these systems were based on so-called multi-user operating systems for real time processing.

Power system parameters

The nine SCADA systems are benchmarked against comparable systems in Norway and Sweden along a range of parameters, which are tabulated below.

Power system parameter	Parameter value	Effect on SCADA system
Power network system controlled	Power production (P) Power transmission (T) Power distribution (D)	Affect choice of special software in the central system. The size of RTUs is often bigger in power stations than in substations.
Number of remote controlled units.	No	Number of remote controlled units is more or less similar to number of RTUs.
Length of transmission network	Km	Affect the costs for the telecom part of a SCADA system. May also affect the reliability of the telecom part.
Maximum (yearly) load in the network	MW	Important figure for the complexity of a power system. Also important for SCADA system benefit calculations.
Power export/import	Yes/No	Affect choice of special software in the central system.
Power system frequency control	Yes/No	Affect choice of special software in the central system.

The complexity of the power systems differs from one system to another. The complexity may go from small and simple isolated power networks to great interconnected and ring operated power networks. Two important issues for an interconnected system are the control of system frequency and the matter of import and export, which both have to be handled centralized.

In general, the complexity of a system stands more or less in proportion to the maximum load in a network, a parameter that is important regarding the network's development rate.

System Category and Process Proportion for the SCADA system

The key characteristics of the Sida financed SCADA systems under review and the five Nordic SCADA systems are shown in the table below.

	Number of CC's	Type of SCADA system	System Category (SC)	Process Proportion (PP)	figure
SIDA financed systems:					
Botswana	2	SPIDER	308	SMALL	21
Ecuador	1	SPIDER	308	SMALL	15
Jordan	1	SINDAC	304	MEDIUM	75
Kenya	3	SINDAC	308	SMALL	23
Lesotho	1	SINDAC	204	SMALL	1,5
Pakistan	3	SINDAC	304		
Vietnam	1	Interim PC- based SCADA	103	SMALL	6,4
Zambia	1	SPIDER	308	SMALL	38
Zimbabwe	4	SPIDER	308	LARGE	132
Bench marking systems, Sweden and Norway:					
Borås Energi	1	SINDAC 3	302	SMALL	
Jämtkraft	1	SPIDER 1	301	SMALL	
Buskerud Energi	1	MINI-SCADA	104	SMALL	30
Vestfold Kraft	1	SPIDER	302	MEDIUM	46
Statnett	4	SPIDER	308	LARGE	258

Vestfold Kraft and Buskerud Energi are regional transmission network companies in Norway. Statnett is the national transmission network company in Norway, and has the dispatch functions for the national transmission network, control of the system frequency in Norway and the control of import/export to the neighboring countries. Borås Energi and Jämtkraft are both regional transmission networks companies in Sweden.

Power system parameters

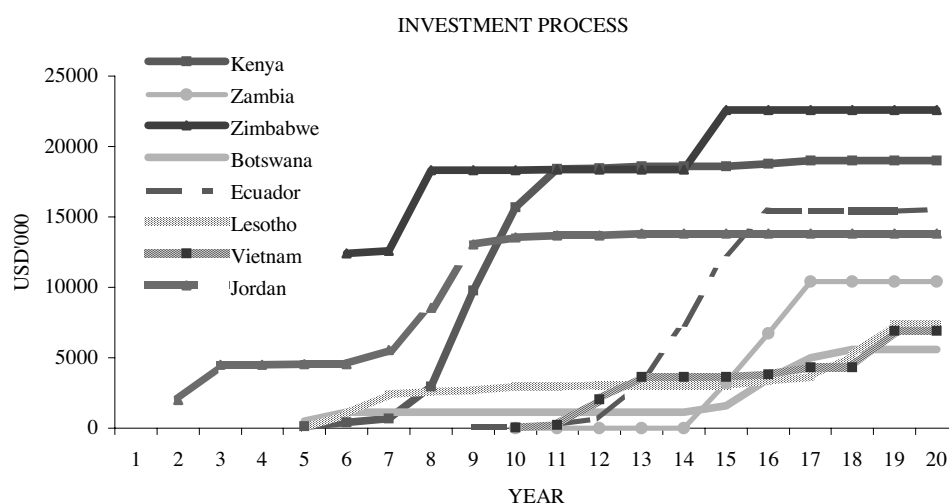
The following form gives an overview of the power systems that are controlled by the corresponding SCADA systems.

	Power network system control range*	Number of remote controlled units (RTUs)	Length of transmission network km	Max. load in the network in 1999 MW	Power export/import	Power system frequency control
SIDA financed systems:						
Botswana	T,D	32	2450	285	Yes	Yes
Ecuador		28		1815	Yes	
Jordan	P,T	48	2945	1137	Yes	Yes
Kenya	P,T,D	36	3619	708	No	Yes
Lesotho	D,T	11	700	43	Yes	No
Pakistan	P,T	24	n.a.			
Vietnam	D	33	3476	917		
Zambia	P,T	24	6160	1101	Yes	Yes
Zimbabwe	P,T,D	132	6043	1300	Yes	Yes
Bench marking systems, Sweden and Norway:						
Borås Energi	T,D	10	?	130	No	No
Jämtkraft	P,T,D	50	430	320	Yes	No
Buskerud Energi	P,T	37	490	857	No	No
Vestfold Kraft Nett	T	41	530	852	No	No
Statnett	P,T	112	9700	23700	Yes	Yes

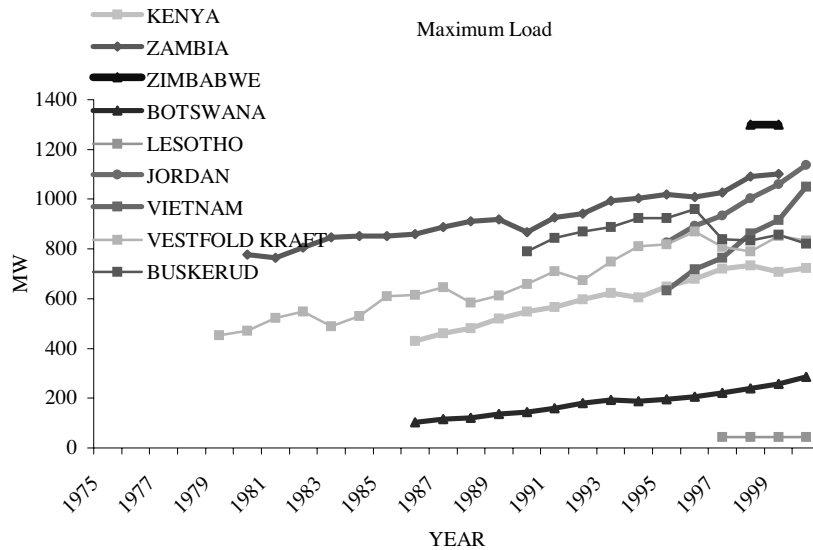
* P=Production; T= Transmission; D= Distribution

Benchmarking

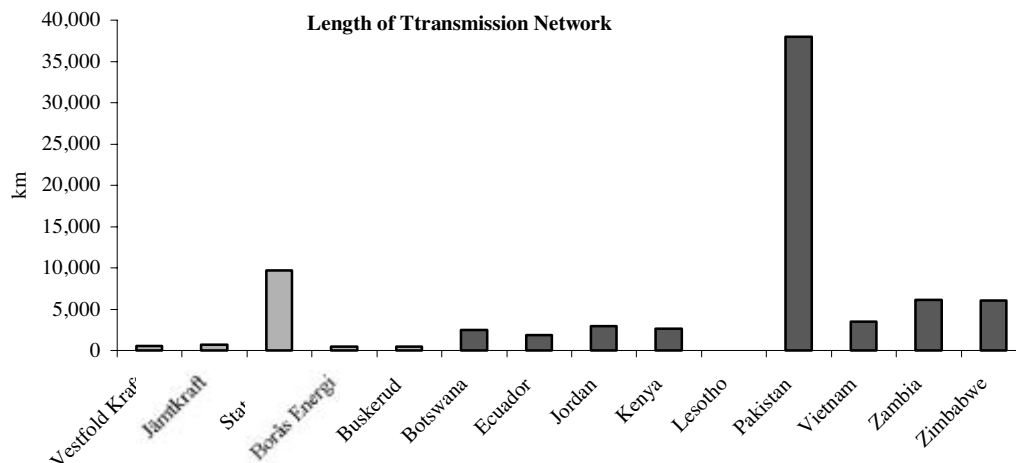
The different SCADA investments are compared. The cumulative investments curves of seven of the aid-funded projects, on the one hand, and the Nordic, on the other, are shown in the two graphs below.



The maximum load growth in each of the networks is comparable. The loads in Kenya and Zambia are nearly at the same level as the Nordic systems, while the one of Zimbabwe is between 1,5 and 2 times the load in Kenya.

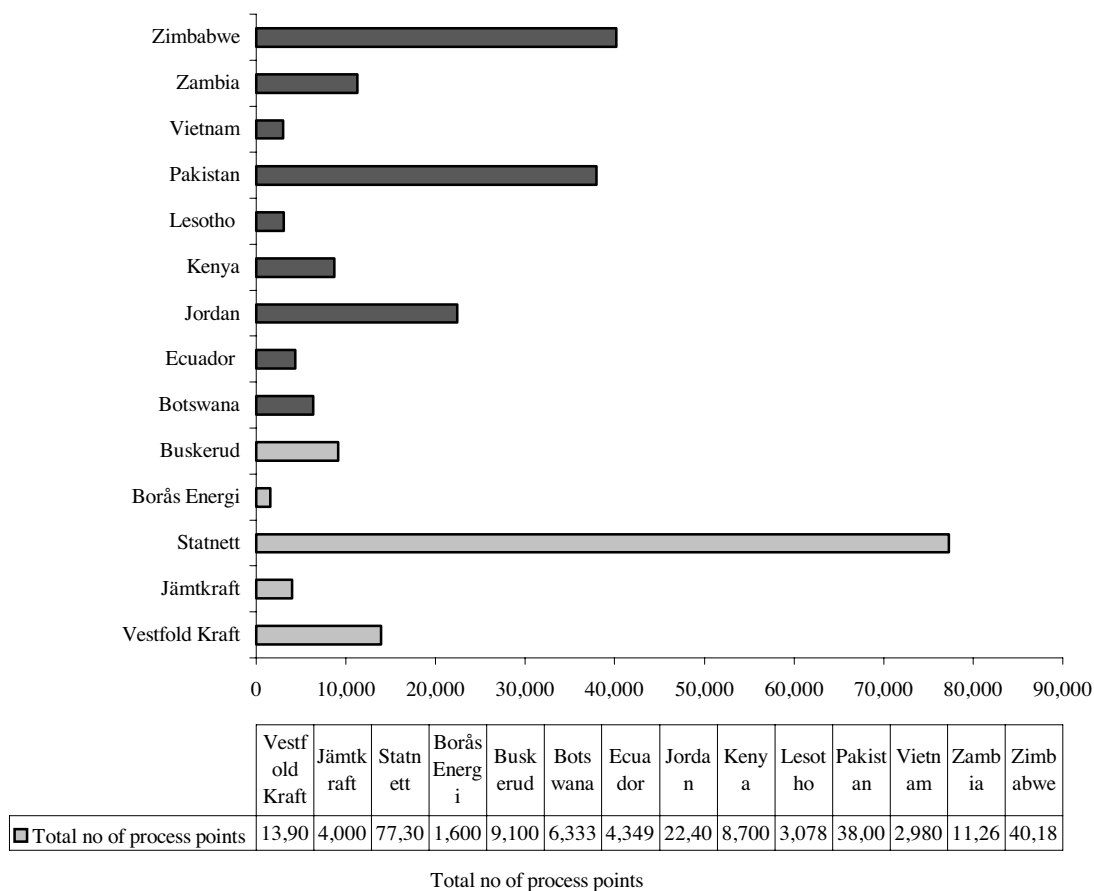


The graph below compares the length of the transmission lines.



As can be seen there is a huge difference in the length of overhead lines in the compared systems. The length of overhead lines regarding the systems in the nine developing countries is substantially longer than the ones for the Nordic networks, except from the one of Statnett. This implies higher costs for the telecom part of the SCADA system and in some cases the long distances between large supply centers may require construction of several control centers.

The SCADA systems' Process Proportions are shown below.



Investment cost per PP

The comparison of investment cost per PP for the different system is made complex by the fact that scope of delivery for the various systems has been different. One difference is likely to be with respect to consultancy services. The comparison is therefore only with respect to the deliveries by ABB and associated suppliers – not consulting services provided under separate contracts.

Another difference is with respect to the communication component. The comparison that is made below has sought to reduce the effect of different scope for the telecom components but data on the cost of the telecommunication component has not been found for all projects.

It is also probable that there are differences with respect to the supply of spare parts and training services under the ABB contracts. Where there is data to identify such differences the investment cost has been corrected accordingly.

In order to eliminate as far as possible the distorting effect of different scope of the communication component the investment cost for has been corrected for the systems for which data on the cost of the telecom has been available.

Data on the cost of the telecom component has been found in the case of two of the Norwegian system and six of the nine Sida funded systems. The most significant telecom component appears to have been in Pakistan⁴. In the case of Pakistan, ABB reports that the delivery included an entire telecommunication system with switchboards and associated equipment. On average the telecom component corresponds to 21 percent of the total investment cost for the six systems for which data exists. The average for five systems, i.e. excluding Pakistan, is only 14 percent. The two Norwegian systems have a telecom component cost that corresponds to, on average, 17 percent of total cost. The latter is the proportion that has been used for correcting the investment cost used for the purpose of the PP assessment. In case of a proportion of less than 17 percent, such as in the case of Zimbabwe, the total investment cost has been increased. In case of a telecom component proportion of more than 17 percent the total investment cost has been reduced. Those are highlighted in the table below.

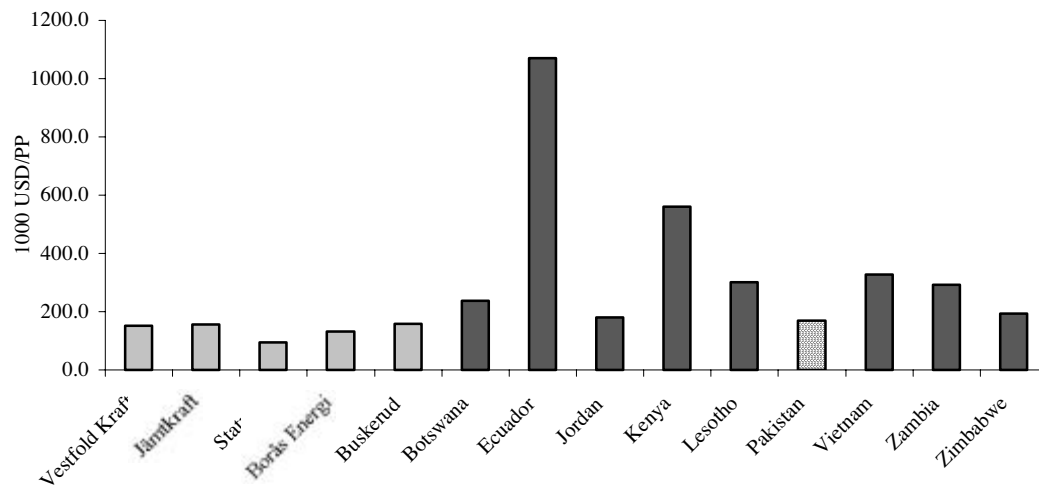
The table below shows the investment costs after correction. The highlighted systems are the ones for which data has made it possible to apply the correction.

	Investment cost (excl consultancy) (USD'000)	Telecom component (USD'000)	Proportion of telecom component (%)	Assumed average proportion of telecom component (%)	Corrected total investment cost (USD'000)
Vestfold Kraft	7.212	1,373.7	19.0%	17	7.064
Buskerud	4.687	704.0	15.0%	17	4.779
Jämtkraft	2.078	n.a.	n.a.	17	2.078
Borås Energi	704	n.a.	n.a.	17	704
Botswana	4.990	n.a.	n.a.	17	4.990
Ecuador	14.970	960.9	6.4%	17	15.506
Jordan	13.500	n.a.	n.a.	17	13.500
Kenya	16.613	3,213.8	19.3%	17	16.223
Lesotho	3.300	765.6	23.2%	17	3.095
Pakistan	44.550	30,597.0	68.7%	17	21.527
Vietnam	3.250	n.a.	n.a.	17	3.250
Zambia	11.319	2,245.0	19.8%	17	10.998
Zimbabwe	22.446	269.7	1.2%	17	25.992.2

The investment cost for the Ecuadorian system has also been corrected for its relatively large spare parts and training components.

This corrected investment cost has been divided by the number of PP points and the result is shown in the graph overleaf.

⁴ The reader should be aware of the considerable uncertainty that applies to data for the Pakistani SCADA system, which is due to the fact that Pakistan could not be included in the field visits.



Investments/PP

The average USD cost per PP value for the five Nordic SCADA systems was found to be 138. The table below sets out the actual USD per PP values and the deviation from the Nordic benchmark value.

	USD/PP	Deviation from benchmark
Vestfold	152	110%
Jämtkraft	156	113%
Statnett	94	68%
Borås	132	95%
Buskerud	158	114%
Nordic benchmark value	138	
Botswana	236	171%
Ecuador	1070	773%
Jordan	181	131%
Kenya	559	404%
Lesotho	302	218%
Pakistan	170	123%
Vietnam	327	236%
Zambia	293	212%
Zimbabwe	194	140%

Appendix 7 Country Specific Analysis of Main Project Parameters

Botswana

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Botswana	1,1 – (93)	0,9 – (93)	190	1424

The SCADA system in Botswana controls a relatively large transmission network with a low max load as well as the distribution network for Gaborone. This is done from two control centers for respectively the national and the Gaborone network. The current system is a SPIDER system with an SC corresponding to 308. PP is SMALL (value 21).

The low load in the transmission network makes the need for a SCADA somewhat questionable. However, the fact that Botswana meets a large part of its demand with imported power increases the need for the kind of monitoring and control that only a SCADA system can provide.

The distribution network in Gaborone would not need to be supervised and controlled by a SCADA system. Manual routines would have sufficed for such a small distribution network. There are few examples of distribution networks of the limited size and with the relatively low load that have SCADA SPIDER systems in Sweden or Norway. The low PP indicator suggests that the network could be controlled from one control center.

A system with an SC value of 302 would have been sufficient for covering the needs of the national transmission network. The EMS function has not been used.

The investment cost is higher than those found for similar systems in the Nordic countries but the discrepancy might be within a range that could be explained by other factors than non-competitive prices. Spare part cost has reportedly been considerably higher than what applies in neighboring South Africa.

Ecuador

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Ecuador	7,2 – (92)	5,4 – (92)	7062 – (96)	1827 - (93)

The transmission network in Ecuador is not particularly large but it has the highest maximum load of any of the nine countries. The max load is twice the level of the Norwegian regional networks. This suggests that the network has a degree of complexity, which justifies a SCADA system. There are also large variations in loads and several of the large hydroelectric power stations operate only during part of the year, which increases the need for a SCADA system.

Ecuador has a SPIDER system, which controls both production and transmission. The SC value corresponds to 308 and PP is in the SMALL category. The small PP suggests that one control center, with one to two persons on watch simultaneously, should be sufficient.

All the software is being used with the only exception of the short-term load forecast. The complexity of the system and the composition of production resources suggest that it makes sense to use both EMS and an AGC. An SC 308 would therefore be called for.

The investment cost is very high compared to that of similar systems in the Nordic countries, particularly in view of the low PP value (15).

Jordan

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Jordan	2,5 – (85)	2,0 – (85)	825 – (95)	3026 – (99)

The transmission network in Jordan is relatively large and has a maximum load which is similar to that of Zambia and the regional Nordic systems. This suggests that the network has a complexity, which warrants a SCADA system.

The Jordanian SINDAC system, which was intended to control and monitor production and transmission (but not distribution) was of an SC category of 304 and the PP was 75 (MEDIUM). This system would seem to have been well suited for the conditions at the time of procurement. There did not seem to exist a need to include distribution control capacity.

The central control and processing system has since been replaced in order to get an AGC function. This also appears justified by the need to monitor import and export of power and for monitoring of power frequencies.

The investment cost per PP is reasonable.

Kenya

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Kenya	2,9 – 89	2,5 – 89	530	2610

In Kenya a new SINDAC system of category 308 was commissioned in 1990. It included three control centers and replaced an old BECOS system. The system would manage both the national transmission network, the production units and the distribution network in Nairobi. Some 33 new RTUs were bought but several of the existing process units were prepared for remote control. The Process Proportion was SMALL, which indicates that the network could have been controlled from one control center.

In 1990 when this system was commissioned, Nordic operators used SCADA systems for only the largest distribution networks. Nairobi's distribution system at the time was not of a size that would appear to have required a SCADA control system. A SINDAC 3 with an SC value of 304 located at one control center ought to have met the needs for power system remote control in Kenya.

The EMS software package has not been installed.

The system's investment cost in 1990 was very high compared to similar systems in Nordic countries, especially in view of the SMALL PP.

Spare parts from ABB to the SCADA system in Kenya also appear to have been exceedingly costly. Between 1992 and 1996 the system was extended with three RTUs of type C400. The cost inclusive freight was in the range of USD 130,000-185,000 per unit. The RTUs were installed and commissioned by KPLC personnel. The corresponding cost in Norway for a medium equipped C400 was, at this time, around USD 45,000.

Lesotho

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Lesotho	0,0 – (86)	0,1 – (86)	20 - (86)	308 - (83)

The size of the transmission network in Lesotho is similar to that of the regional networks in Norway but the load is only about 5 percent of that of the three networks used as benchmarks. This implies that the system to be controlled is very simple and that it could easily be managed manually.

The investment cost can best be compared with that of the regional Norwegian networks and it seems extremely high given its low PP value.

Pakistan

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Pakistan	34,6 – (89)	26,8 – (89)	5071 – (99)	3383 - (83)

Pakistan was not visited and the information available as regards its system has not been verified on site. Cost data has been provided verbally by ABB and collected from a few appraisal documents. It is therefore difficult to pass judgment on the appropriateness of its system. However, the sheer size of the network in combination with the relatively high load factor indicates that the network would warrant a SCADA system with both EMS and AGC capacity. The SINDAC 5 system that Pakistan is supposed to have bought would have an SC value of 304 and it would not include AGC. If this is correct it is not improbable that the system was under dimensioned.

The investment cost estimate lacks precision. The system appears to have been made up of deliveries from two main sources: ABB in Sweden and EB/Nera in Norway. The ABB delivery contained both SCADA and telecom supplies while the Norwegian supply has been assumed to comprise only telecom equipment and services. The latter has not been verified and it results in a 67 percent proportion of telecom supplies which is far higher than for any other project. If this is correct the investment cost of the Pakistani SCADA project would be only 23 percent above the Nordic bench mark level which makes it the most reasonably priced of all the projects.

Vietnam

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Vietnam	9,3 – (91)	6,6 – (91)	632 – (95)	7700 – (91)

The network in Vietnam that is the subject of evaluation is that of the region of Ho Chi Minh City. This SCADA system was intended to control the transmission part of the Ho Chi Minh

City network, which is comparatively extensive and with a relatively high load factor. The high load factor, in particular, suggests a need for a SCADA system.

The SCADA system that was installed in 1995 was PC based and would be most appropriately described as a SC 103 system. PP has been estimated to correspond to SMALL (6.4) which would be low for the size of the network but which is partly compensated for by a relatively large number of RTUs.

In view of the fact that the system was PC based and since it has a low PP value it appears that the investment cost is very high. The large number of RTUs accounts for part of the excess cost but not all of it.

Zambia

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Zambia	7,8 – (96)	5,4 – (96)	1000	6200

The system in Zambia was commissioned in 1996. It is a SPIDER system of category 308 located in one control center. The new system replaced an old French system called ECLIPS S/200. This means that the process units were prepared for remote control. However, none of the old RTUs could be used in the SPIDER system, and 24 new were bought.

The transmission network in Zambia is interconnected with that of the neighboring SADEC countries and it both imports and exports power. This together with the complexity of the power system and the need for a high level of reliability for supply to the mining industry in the Copperbelt region, were the main justifications for the SCADA system.

Zambia's SPIDER system is installed in a National Control Center near the head office of ZESCO in Lusaka. The System Category (SC) is 308 and the Process Proportion is SMALL. A SPIDER system with an SC of 306 would have been better suited to the needs of Zambia at the time of the investment.

The concentration of the SCADA system to one control center for dispatch functions and power production and transmission system control seems reasonable.

There are between 40 and 50 total number of high voltage substations. Only 20 of the main substations have so far been incorporated in the SCADA system. The reason for this is mainly the high initial cost for smaller and less critical substations. The main goal for ZESCO has been to ensure a secure supply of power to the mining industry.

The load forecast software was installed but has not been used. This was said to be due to data acquisition problems. The AGC appears to work well and is extensively used. ZESCO has experienced problems with the telecommunication part of the system, which has been replaced with a new telecom system delivered by Teamcom Norway.

The cost of the Zambian SCADA system was higher than that of similar systems in the Nordic countries; especially in view of the low PP value and the fact that the central system was installed in only one control center. However, the discrepancy was not as large as in Ecuador, Kenya, Lesotho and Vietnam.

Zimbabwe

Country	Production GWh	Consumption GWh	Max load MW	Length of transmission lines km
Zimbabwe	5,7 – (85)	8,0 – (85)	1300 - (00)	4620 – (93)

Both the interconnection to neighboring countries and the complexity of the power system in Zimbabwe suggests that a SCADA system is technically justified. The first SCADA system was a SINDAC 5 system for the National Control Center in Harare. It was installed for the dispatch functions of the national grid, the control of the transmission network and the control of the distribution network in Harare. The system was upgraded to a SPIDER in 1994. In 1987 a SINDAC 3 system for the distribution system in Bulawayo was installed.

The SPIDER system at the National Control Center had an SC of 308 and the SINDAC system at the Regional Control Center in Bulawayo had an SC of 302. The PP for the total SCADA installation was in the LARGE category.

The Zimbabwean SCADA system appears to have been over-dimensioned. The performance parameters are very similar to those of the Zambian system but there is a large difference in the PP values. The explanation for this should be the SCADA control facilities for the distribution system in Harare and Bulawayo. These networks were not, at the time, large enough to warrant their own SCADA systems.

The EMS functions have been installed but never put to into operation. The reason was reported to be network instability and sensitivity problems in measuring values. The AGC, on the other hand, performs well and is in active use.

A SPIDER system with an SC of 306 located in two control rooms in the National Control Center would have been more appropriate for the need for remote control in Zimbabwe.

The investment cost per PP unit in the case of Zimbabwe is reasonably closer to the Nordic levels. However, it appears that the PP is too high for the needs of the Zimbabwean power sector.

Appendix 8 Faults in the network, their reasons, effects and restoration with SCADA

Faults	Reason	Effects	Restoration with SCADA
Lightning	Stroke of lightning on high voltage power lines and equipment	Normally passing faults but might lead to broken insulators, flashover in high voltage equipment and destroyed control equipment due to surge voltages	Automatic restoration from protection relays or manual restoration through the SCADA system. Normally possible without fault inspections. Short restoration time
Other natural occurrences	Falling trees, wind, rain/moisture, tree growth, pollution, salt, snow/ice, heat, animals, blockages of waterways	Permanent faults	Need inspection before restoration. SCADA gives indications on where the fault is located. Rerouting when possible. Less time in finding and locating the fault.
Manmade (external)	Vandalism, woodcutting, blasting, excavation, installation work, planes, boats, fire	Permanent faults	Need inspection before restoration. SCADA gives indications on where the fault is located. Rerouting when possible. Less time in finding and locating the fault.
Staff handling	Careless reprogramming of control and protection equipment after maintenance and testing, poor maintenance, wrong switching maneuvers, insufficient network control	Normally passing faults. However, they might lead to overload, surge voltages and production surplus/deficit.	Manual restoration locally or with SCADA. In general short restoration time
Technical equipment	Bad construction, incorrect settings on protection equipment, manufacturing defects, material defects, wrong erection, ageing, corrosion	Normally permanent faults	Inspection is needed before restoration. SCADA gives indication on the fault's location. Rerouting when possible. Less time in finding and locating faults.
Other incidents	Unknown or invisible Faults influenced by other faults in the network, design faults	Normally passing faults that are difficult to detect. They might lead to overload, surge voltages, production surplus/deficit	No inspection needed. Manual restoration through the SCADA system. Short restoration time

Appendix 9 Consulting engineers in nine Sida/BITS financed SCADA projects

Countries	Consultants involved during the entire project	Consultant responsible for design and specification
Botswana	SwedPower	SwedPower
Ecuador	SwedPower, Parsons (UK), Kema (Holland), Electrotech (USA)	SwedPower
Jordan	SwedPower	SwedPower
Kenya	IVO, SwedPower	IVO
Lesotho	Sydskraft, Norplan	Syd Kraft
Pakistan	Svenska kraftverk, EdF, SwedPpower	SwedPower
Vietnam	SwedPower	SwedPower
Zambia	SWECO, SwedPower, Vinco	SWECO
Zimbabwe	MerzMcLellan, Sydkraft, SwedPower	SwedPower

Appendix 10 List of persons interviewed, their title and respective organization

The following list includes the persons that the Consultants have interviewed during the fieldwork. In addition to those mentioned, there are as well a large number of operators who have contributed to the evaluation even though they are not mentioned in the list below.

Country	Title	Name	Organization
Botswana			
	Distribution Engineer Operation and Maintenance	Mr. Mapani	BPC
	Acting Chief Executive Officer	Mr. Moore	BPC
	Chief Engineer	Mr. Kaluji	BPC
	Operation manager	Mr. Makobe	BPC
Ecuador			
	IT Director	Mr. Játiva	CENACE
		Mr. Francisco	CENACE
Jordan			
	Managing Director Operation	Mr. Hammouri	NEPCO
Kenya			
	Service Manager	Mr. Mwangi	KPLC
	Technical and Slaes Engineer	Mr. Okoth	KPLC
	Chief Manager Information Technology	Mr. Johnson	KPLC
Lesotho			
	SCADA Transmission Manager	Mr. Ntlopo	LEC
	Operation Manager	Mr. Delaine	LEC
	Chief Engineer		LEC
Vietnam			
		Nuguyen Hong Thanh	HCMCPC
	Deputy Manager	Tran Anh Vu	HCMCPC
Zambia			
	Acting Managing Director	Mr. Chibulu	ZESCO
	Electro- Tech. Service Manager	Mr. Lwinindi	ZESCO
		Mr. Mwansa	ZESCO
		Mr. Chifwaila	ZESCO
		Mr. Sitwala	ZESCO
Zimbabwe			
	Transmission Service Manager	Mr. Rugoyi	ZESA
	Transmission Operation Manager	Mr. Chitembwe	ZESA
	Distribution Services Manager	Mr. Mutangadura	ZESA
	Principal Research Engineer	Mr. Dube	ZESA
	Grid Assets Manager	Mr. Nyachowe	ZESA
	Sales and Marketing Manager	Mr. Rafemoyo	ZESA
		Mr. Nyatanga	ZESA
	Senior System Engineer	Mr. Cipofya	ZESA

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