I. INTRODUCTION

The function of an electric power system is to provide electricity to its customers efficiently and with a reasonable assurance of continuity and quality. Electric energy is produced and delivered practically in real time and there is no convenient method to store it. This makes it necessary to maintain a continuous and almost instantaneous balance between production and consumption of electricity.

The delivery of secure, reliable power supply is a subject of intense interest today. This interest has been heightened since the major blackouts that occurred around the world in 2003. The August US/Canada blackout, the September blackout in Italy, and other blackouts in UK, Sweden and Denmark readily come to mind. These gained worldwide attention due to the fact that they were very unusual and affected large number of customers, in parts of the world where the levels of availability and reliability of electricity supply are relatively high. Reliability impacts the cost of delivering power to the customer and this in turn affects the level of development and living standards of the society. The cost estimates for the August 14, 2003 blackout in Northeast US/Canada are of the order of US$6 to $8 billion, with the event affecting an area serving about 50 million consumers. [1]

In Africa, power system blackouts are not uncommon, in fact are very frequent, but hardly attract wide attention. Customers incur real costs when interruptions occur and unreliable networks induce customers who can, to invest in their own generating capacity. This is very expensive, both for the customer and for the country. Power system reliability is therefore an important issue in Africa as unreliable networks impose a greater than necessary burden on an already impoverished population, coping with a deficient economic and social system.

II. ELECTRICITY ACCESS IN AFRICA

Access to modern energy forms is a basic human need. It is a prerequisite for economic, social and political development. Of the various forms of energy available, electricity is recognized as the type most convenient to use. In view of this, many developed countries have established stable infrastructure systems to support the supply of affordable, reliable electrical energy to support and sustain their social and economic development. As a result, access to electricity is almost universal in these countries.

One of the major challenges faced by African utilities is to increase access to electricity for majority of its population. Electrification rates are low and most of the population, especially in the rural areas, do not have access to modern forms of energy. It is estimated that almost 1.6 billion people in developing countries did not have access to electricity in their homes in 2002, representing a little over a quarter of world population and most of the electricity deprived areas are in South Asia and sub-Saharan Africa. [2]

Table 1 below shows the average electrification rates in selected regions of the world for 2002.

The table shows that sub-Saharan Africa lags far behind the world average in terms of access to electricity. Within sub-Saharan Africa, access varies from about 3% in Ethiopia to 100% in Mauritius. [2]
### Table 1: Electrification Access Rates – 2002

<table>
<thead>
<tr>
<th>Region</th>
<th>Access (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>35.5</td>
</tr>
<tr>
<td>North Africa</td>
<td>93.6</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>23.6</td>
</tr>
<tr>
<td>Middle East</td>
<td>91.8</td>
</tr>
<tr>
<td>Latin America</td>
<td>89.2</td>
</tr>
<tr>
<td>Developing Asia</td>
<td>68.7</td>
</tr>
<tr>
<td>China/East Asia</td>
<td>88.1</td>
</tr>
<tr>
<td>South Asia</td>
<td>42.8</td>
</tr>
<tr>
<td>OECD/Transition Economies</td>
<td>99.5</td>
</tr>
<tr>
<td>World</td>
<td>73.7</td>
</tr>
</tbody>
</table>

Source: International Energy Association (IEA), World Energy Outlook 2004

### III. POWER POOLING TO INCREASE ACCESS

In recognition of the importance of electricity to socio-economic development, many utilities in Africa, with the support of their governments are implementing schemes to improve electrical energy access. Some of these schemes include rural electrification, electricity sector restructuring, accelerated investment in electricity delivery infrastructure and power pooling and regional integration.

Africa is endowed with substantial energy resources, but their geographic distribution is uneven. Most of these resources are also yet to be developed. Besides, the various electrical utilities are in different states of network development and almost all, with the exception of a few, have inadequate resources to satisfy demand. Governments and utilities have recognized the need to provide a framework that encourages cross-border trading in electricity and the sharing of resources. Thus, the delivery of electricity is entering a new phase. Power pooling arrangements are being made all around Africa with the objective to provide the region with adequate, efficient, economic and reliable power supply. Power pooling aims at effective reduction in operating cost and increased reliability through coordinated exchange of power and energy. Electricity trade based on interconnected electric power networks will provide significant economic benefits for individual countries and the entire region. In summary, promoting regional cooperation and integration through power pooling and cross-border exchanges will help to minimize cost while enhancing reliability and security of supply.

As utilities in Africa interconnect their electrical power systems to pool resources for their common benefit and to increase access of their people to electrical energy, there is the need for more robust and stable systems to ensure that the objectives and benefits of power pooling are achieved. It is important to establish structures and effect policies to ensure interconnected systems are operated in a manner that will not negate the gains of pooling and sharing of resources. Access must not only be seen in terms of provision of resources, but also operating these resources to achieve the objectives which drove the need for investment, in the first place.

Even as interconnections present several advantages, they also increase the potential for large scale blackouts and hence unreliability. Unreliable systems are a hindrance to increased access and impose additional costs on electricity consumers. The hardships and economic costs associated with blackouts become even more important challenges as the society becomes increasingly dependent on the availability of high-quality and reliable power.

### IV. DEFINING RELIABILITY

Reliability is a measure of how well a system performs its expected function. Another system characteristic that is closely related to reliability is adequacy. A system is adequate if it has sufficient resources to perform its function. A system can be adequate but unreliable. However, if a system is inadequate, then it must also be unreliable. The North American Electric Reliability Council (NERC) defines power system reliability to be:
[The degree of performance of the elements of the bulk electric system that results in electricity being delivered to customers within accepted standards and in the amount desired. Reliability may be measured by the frequency, duration and magnitude of adverse effects on the electric supply. Electricity system reliability can be addressed by considering two basic and functional aspects of the electric system – adequacy and security].

Adequacy: - The ability of the electric system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.

Security: - The ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements.

A power system is unreliable if any of its component systems are inadequate. When a system has an insufficient degree of security, it becomes exposed to severe and in some cases catastrophic failures of the types commonly experienced by African utilities.

Ensuring reliability also depends, to a great extent, on the manner in which the power system is operated. Thus, considerable attention must be paid to the system operating function, to assure reliability of supply.

V. SYSTEM OPERATING FUNCTIONS

Providing reliable electricity supply begins with careful planning and design of the power system. It continues at the operating stage where, through control and coordination of production, electricity is moved across the network for delivery to customers by means of a distribution system.

The primary objective in power system operations is to provide sufficient generation continuously to match load at the lowest possible cost. This objective must be accomplished while maintaining system voltage and frequency within specified limits and providing for system security. Operating the power system to maintain reliability is a big challenge, even for an isolated network. The challenges multiply as systems are interconnected to each other for power pooling. The trend towards power pooling exposes the system to potential disturbances brought on by events and actions in neighbouring systems. New forms of stability problems may also arise and changes anywhere in the interconnected system could impact other points in the system.

The day-to-day monitoring and operation of the power system is handled by system operators. Therefore, from an operational perspective, system operators are responsible for achieving an efficient, economical and reliable delivery of power supply and a lack of coordination among utility operators can significantly impact the reliability of the power system.

With the increase in interconnections, there are a number of concerns that warrant policy attention and important issues that need to be addressed to ensure systems are operated to provide the level of reliability desired. Some of these reliability related issues and concerns are discussed below.

A. Planning & Capacity Expansion

Planners need to support a regional forum or organization with responsibility for assessment of long-term system requirements. This forum should also have the authority to develop and maintain criteria for system expansion and recommend system expansion plans for implementation.

B. Operator Training

As utilities move towards the use of power pooling to increase access, system operations get more challenging. The human resource base is the most important asset of any endeavour and maintaining reliability requires qualified, trained and skilled operators. In addition,
there is the need for continuing education
to ensure system operators are kept
abreast with changes in the power system,
advances in technology, etc. System
operators must have a profound
understanding of the system and
understand its dynamics. Most utilities
have facilities for training, to meet their
own local objectives and needs. Alongside
the move towards increased integration,
there is the need for improved training, to
ensure operators meet minimum agreed
performance standards and are brought to
the same level of knowledge and
understanding of the power system.
Training programs must be designed to
provide technical competencies relevant to
operations in a power pool environment.
Moreover, policies and structures must be
gearied towards establishing some form of
certification program for operators and
their support staff, as currently pertain in
parts of the developed world.

C. Rules Of Operation

Whenever different operational
approaches are used to assure reliability,
the result is the development of “seams”.
A seam basically means that contradictory
or inconsistent signals may take place
within an interconnected network. Such
seams will inevitably lead to decreased
reliability and efficiency. The complexity of
system operations and the characteristics
of the electricity network necessitate
considerable centralization in system
operating functions. A lack of coordination
among utility operators can significantly
impact the reliability of the bulk power
system. Rules of operation of the
interconnected grid must therefore be in
place to ensure proper coordination of
operations. Operating policies and rules
should clearly define the functions,
responsibilities and authorities of each
control area within the power pool, under
different operating conditions. It is also
important to promote communication and
cooperation among grid operators.

Some of the principal elements of
common operational rules are as follows:
• Procedures for agreements on long-
term exchanges, short-term
exchanges and emergency
exchanges, including rules for pricing
of energy, power and other services
including wheeling;
• Technical coordination and guidelines
including criteria for:
  o Load-frequency regulation
  o Voltage regulation
  o Reserve sharing and monitoring
  o Overload and stability control
  o Protective relays and load
  shedding coordination
  o Energy metering and accounting
  o Telecommunication systems
  o Common operational statistics
• Transfer capability limits
• Information systems, reporting
requirements and procedures
• Measures for system control during
disturbance situations
• System restoration procedures
• Communication among operators.
• Coordination of maintenance
schedules
• Data sharing requirements and data
exchange practices

Improved information systems and
operating procedures will enhance the
ability of system operators to anticipate
and respond to the operational
complexities associated with power
pooling.

Operational rules which are set must at all
times be adaptable to changing
circumstances and conditions. In addition,
procedures for modifications and updates
ought to be clearly spelt out.

D. EMS & Telecommunication Systems

Central to the reliable operation of a power
pool is the need for better set of tools for
monitoring and operation. The control
centre, with its Energy Management
System (EMS) is a critical component of
the power system operational reliability
picture. Supervisory Control and Data
Acquisition (SCADA) and EMS functions
and tools assist the system operator in his
effort to optimize the operation of the
power system, with respect to efficiency,
reliability, etc.
Currently, some utilities in Africa do not have functioning control centers. Where they exist, a great number of the systems are also outdated, using obsolete technology.

Mandatory standards for EMS system requirements and performance capable of meeting the needs of the integrated power pool must be specified for compliance by all utilities. Minimum technical requirements and technological standards for telecommunication systems and data exchange infrastructure and protocols must also be defined.

E. Reliability Standards

All members of the power pool must be encouraged to adhere to standards necessary to preserve the reliability of the interconnected power system. Operating standards are intended to keep the system secure. If they are violated, it means the system is likely inadequate and steps need to be taken to identify problems that may exist and rectify them.

The issue of regional reliability standards, who sets them and how they are set may be one of the most challenging aspects of maintaining reliability in an integrated power system. What is an acceptable standard? How would it be created and what would it address? Should there be one or several standards? Occasional power outages are an inconvenience for some and a disaster for others. Currently, there are local differences in how the power system behaves, the resources that are available and the reliability requirements of each country. The advantages and disadvantages of national and regional scope of standards must be addressed as part of decisions on how to structure reliability rules.

Well defined reliability standards will provide each utility with a clear view of what performance is expected in any situation. The benefits or otherwise of enforcing common reliability standards must also be considered and appropriate policies drawn up, as required.

VI. RELIABILITY ORGANIZATION

Following development of policies related to the operational issues discussed above, institutions and structures should be set up to implement and enforce them. Measures to track implementation of recommended actions in order to improve reliability must also be outlined. These points to the need for creation of a reliability organization or entity. Such entities may be formed first in sub-regional pools and then continent-wide, as interconnections increase.

Some of the functions of the reliability organization may include:

- Setting standards for reliable planning and operation.
- Coordinating the provision of services necessary to support reliable planning and operation.
- Monitoring, assessing and reporting on compliance with reliability standards and benchmarking with industry standards.
- Facilitating information exchange and coordination among utilities.
- Formulating standards for training and providing certification for operators and support staff.
- Defining minimum standards for EMS and telecommunication infrastructure.
- Serving as an independent source of reliability performance information.
- Defining and implementing sanctions for failure to achieve standards.

Most power pools have within their structures operating and technical committees, made up of representatives of member utilities. An argument could be made that the responsibilities of the reliability entity could be entrusted to these committees. However, the main issue is, will they be able to enforce decisions? Made up of member representatives, with their individual interests, will they be able to examine issues in a transparent manner, devoid of
bias and personal interests and reach decisions based mainly on the objective of providing reliable and economic supply of electrical energy? These issues must be debated and resolved within the regional pools. Whatever the solutions adopted, there is the need to set up an institutional framework for reliability management.

Massive investments are required in developing countries to expand the electricity sector. The IEA World Energy Investment Outlook – 2003 report states that global financial systems have the capacity to fund the investments, but will not do so unless conditions are right. A stable and reliable integrated power system, with well laid out policies, rules and institutional structures will send signals to the rest of the world that we are ready to deal with the issues retarding the economic progress of the continent. It will also give clear indications of our readiness to operate our power systems to meet widely accepted industry reliability standards and thereby help to attract the much needed investment into the sector, for the benefit of our people.

VII. CONCLUSIONS

Every electricity system requires a coherent set of policies, structures and rules to ensure reliable delivery of power to customers. Ensuring reliability depends on a mix of having the right policies, procedures, tools, etc.. Reliability can be achieved by implementation of policies that will enhance operation of existing networks.

The creation of an independent reliability organization is recommended. This will ensure improved levels of reliability and provide the mechanism needed to ensure systems do not export or import, as the case may be, unreliability as they interconnect with each other. The structures that are put in place will determine the level of success of regional integration. The setting up of a reliability body will guarantee that the benefits of power pooling are thereby derived.

REFERENCES