October 29, 2005

SIXTH REGIONAL CONFERENCE OF THE NATIONAL COMMITTEES OF CIGRE IN ARAB COUNTRIES

ARAB COMMON MARKET FOR ELECTRICITY AND ELECTRICAL INDUSTRIES

PLENARY LECTURE: AFRICAN REGIONAL POWER POOLS: STATUS, PLANS OF ACTION, FURTHER DEVELOPMENT AND RECOMMENDATIONS

Tom Hammons, Chair International Practices for Energy Development and Power Generation IEEE,
University of Glasgow, UK

Cairo Marriott Hotel, Egypt, 21-23 November 2005

Sponsored by: Egyptian National Committee of CIGRE

INTRODUCTION

On behalf of the SIXTH REGIONAL CONFERENCE OF THE NATIONAL COMMITTEES OF CIGRE IN ARAB COUNTRIES and the IEEE Energy Development and Power Generation Committee, welcome to this Plenary Session on African Regional Power Pools: Status, Plans of Action, Further Development and Recommendations in Arab countries and Africa as a whole.

The Lecture focuses on the present status and future prospect of electricity infrastructure from the viewpoint of Generation and Transmission Development, Global Deregulation trends and policies, advances in Global Research and Development (R & D) and strategies to influence the integration into the Global transition to knowledge based economies in Africa. Discussed is targets and technologies for African electrification, international interconnections in North Africa, electricity grid system interconnection of the Gulf states, competitive markets for regional electricity trading in the Southern African Power Pool (SAPP), the Central African Power Pool (CAPP), the West African Power Pool (WAPP), and future of SAPP, CAPP, WAPP, and the East African Power Pool (EAPP), The presentation will evaluate and update models and policies that are near term, mid term and long term.

Interconnection of electric power systems of regions, states and individual territories is acquiring a growing scale of importance in world practice. Discussion will be focused on the projected development of regional power pools as a development strategy while taking into account the importance of distributed generation in this strategy. There are many benefits of this tendency that continue to be examined to influence development policies because of the so-called system effects that lead to improving economical, ecological and technological efficiencies of the joint operation of electric power systems. Modeling developing regional grids remains core to the strategy of wider institutional integration, and in particular academia where core analytical skill sets critical to knowledge base economies reside. The presentation seeks to follow the paradigm of the EPRI Road Map initiative that contemplates challenges of the 21st century.

North Africa and Africa in general is a very favorable region for electric power grid creation and using the above system effects on account of different levels of economic development in different countries of the region, different placement of fuel and energy resources, and consumers, etc. Therefore, the analyses of the present status and prospective trends of African Electricity interconnections and efforts to improve efficiency and bridging the digital divide are very important problems.

The Lecture presents some results of studies and views in this area. It is based primarily on Panel Sessions on African Electricity Infrastructure organized by the IEEE International Practices Committee of the Power Engineering Society in recent years.

1. TARGETS AND TECHNOLOGIES FOR AFRICAN ELECTRIFICATION

An essential strategic objective for the 21st Century is to provide all people with access to sufficient energy to achieve and maintain an acceptable quality of life. For reasons of global sustainability, including major improvements in resource conservation, environmental protection, economic opportunity, and health, the majority of that energy will in all likelihood be delivered as electricity by mid-century. Already some 1.6 billion people – one quarter of the world's population—have no access to electricity, and an additional 800 million people have limited access to electricity but still rely on traditional biomass fuels for cooking and heating. Africa provides a unique example of the promise and the problems associated with electrification because of its large rural population, the wide range of economical issues and cultural differences among its peoples, and the enormous social value of electrifying its 600 million inhabitants.

This Section discusses the issues associated with bringing electricity to the rural population (accessibility), providing an adequate supply of reliable power (availability), and providing power safely, with minimal impact on ecosystems and the environment (acceptability). All three factors must be satisfied if electricity is to have a significant effect on local economy and quality of life. Discussed are the results of an analysis indicating that an electric energy level of 1,000 kWh per person is needed to achieve electric services such as lighting, entertainment, refrigeration, public health, clean water, and basic education.

Also described are the technologies needed to generate the needed power and transmit the electricity from the point of generation to the end use location. Africa has abundant supplies of indigenous primary energy resources such as coal, especially in South Africa, hydropower, particularly in Democratic Republic of Congo, wind, and solar resources. These supplies, along with uranium and imported petroleum and liquefied natural gas round out the energy supply. The analysis indicates that combining central station generation in urban areas with distributed renewable generation in rural and urban locales can provide a balanced portfolio of generation options that will be robust over a range of country-specific conditions.

Distributed generation (DG) can help improve the reliability of the power system by allowing customers with critical load to bypass the central station and transmission grid. DG technologies include a wide range of options that run the gamut from diesel generators to micro-turbines to fuel cells. Diesel generators are cheap, relatively reliable, and represent a mature technology (little technology risk). However, diesels generally have high emissions, which makes them unsuitable in some applications.

Fuel cells in contrast are new and expensive, and there are questions about reliability in the field, at least for some designs. Fuel cells are probably not an option for early adoption, but anticipated technology advances should make fuel cells suitable for the longer term.

In many instances, DG technology can be directed toward strategic loads, such as industrial facilities, hospitals, etc. This approach will aid economic development, and will be complemented by introducing a basic level of electrification, as described previously.

Also addressed are the challenges of introducing a modern electrification system to Africa, while limiting pollutants and greenhouse gas emissions, and assuring the affordability of the system.

Grid options, from large, long distance transmission systems to local "mini-grids" for village power solutions are also discussed.

Global Energy System Vision

Over the next 50 years, universal access to at least a minimum level of electricity and related services can contribute to dramatic improvements in the quality of life (education, economic justice, public health and safety, and environmental sustainability) for the world's under-served populations. In 2000 the United Nations General Assembly adopted a comprehensive set of "Millennium Development Goals" to help create a more coherent worldwide focus on the truly pressing tasks for the coming fifteen years. Global electrification can greatly assist the effort to achieve those UN goals, such as halving the incidence of extreme poverty or reducing the waste of material resources.

What is needed is a global vision for realizing electricity's essential value to 21st century society, a plan to set strategic technological priorities, and an outline of the associated research, development, and delivery requirements needed to achieve this vision. In this context, EPRI's Electricity Technology Roadmap outlines a vision for the future based on broad stakeholder input to spur debate, consensus, leadership, and investment that will enable electricity to continue to fulfill its potential for improving quality of life on a global scale. The initial version of the Roadmap, released in 1999, describes a series of destinations for the power system of the 21st century[3]. A companion volume that supplements the initial report is now available. This report expands the original by identifying three comprehensive high-priority goals that are most essential to assuring global economic and environmental health. They are:

- **Smart power** – the design, development, and deployment of the smart power system of the future
- **Clean power** – the accelerated development of a portfolio of clean energy technologies to address climate change
- **Power for all** – the development of policies and tools to ensure universal global electrification by 2050.

These characteristics reinforce the Roadmap's original destinations and provide a basis for a new planned initiative to include a series of detailed recommendations for technology development.

Improving Efficiency of the Energy Supply Chain

As societies strive to improve access to modern energy services, they must also find ways to make the energy system more efficient. The efficiency of the full energy supply chain (extraction, conversion, delivery, and consumption) has only reached about 5%; therefore, large opportunities for improving efficiency remain at every stage in this chain. For example, using today's energy sources and technology, achieving universal supply of at least 210 mega-joules per day per capita by 2050 would approximately triple the current global rate of energy consumption. Fortunately, realizing technological advancements that are now visible throughout the energy supply chain could reduce the 210 mega-joules per day threshold by 2050 to as little as 125 mega-joules per day with no loss in economic productivity or quality of life potential. The efficiency of electricity generation, for example, now typically in the 30% range, could easily reach, on average, 50–60% by 2050, based on modest technology improvements over current practice. Even greater performance is possible if step function technology advances occur, as seems likely. For example, the emergence of low wattage lighting and appliances aimed at the developing world suggests rapid technological progress in household energy efficiency. Even the automobile is on the threshold of transformative change.

EPRI's Electricity Technology Roadmap Destinations are indicated in Table 1.

Table 1. EPRI's Electricity Technology Roadmap Destinations	
Destination	**Summary**
Strengthening the Power Delivery Infrastructure	An advanced electricity delivery system that provides additional transmission and distribution capacity and "smarter" controls that support dynamic market activity and the rapid recovery from cascading outages, natural disasters, and potential terrorist attacks
Enabling the Digital Society	A next-generation power system that delivers the power quality and reliability necessary for sophisticated digital devices and seamlessly integrates electricity systems with communications systems to produce the "energy web" of the 21st century
Enhancing Productivity and Prosperity	New and far-reaching applications of the energy web that increase productivity growth rates across all sectors of the economy
Resolving the Energy/Environment Conflict	Clean, cost-effective power generation technologies combined with workable CO_2 capture, transport, and storage options
Managing the Global Sustainability Challenge	Universal access to affordable electricity combined with environmentally sound power generation, transmission, and delivery options

Electrifying the World

As a practical matter, electricity must form the backbone for the transition to a globally sustainable energy system and the modernization process it enables. Electricity's ability to transform the broad array of raw energy and other natural resources efficiently and precisely into useful goods and services, irrespective of scale, distinguishes it from all other energy forms.

Setting Electrification Goals

Equally important as universal access to electricity is assuring adequate levels of electric service for those who have access. Work undertaken by EPRI suggests 1,000 kWh per person per year as a benchmark goal for minimum electric services—an essential milestone in the pathway out of poverty. This target is similar to the electric consumption in emerging modern societies that use a mix of fuels (some directly, others via electricity carrier) to satisfy their needs. It lies between very low levels of electrification (100 kWh per person per year) insufficient for measurable economic benefits and the 10,000+ kWh per person per year of the current U.S. economy. Achieving this target can help meet personal needs for basic lighting, communication, entertainment, water, and refrigeration, as well as provide electricity for the efficient local production of agriculture and goods and services.

In choosing the 1,000 kWh per capita per year goal, we are mindful that improved energy efficiency and complementary innovations would allow delivery of basic energy services using less electricity. Nonetheless, the benchmark reveals that, under current trends, perhaps 90% of the world's population in the next 50 years will be born into conditions that fall short of the 1,000 kWh goal. Based on country averages, about 3.7 billion people today live in countries where the average per capita consumption of electric power is below the 1,000 kWh threshold. Over the next 50 years, it is likely that another 3 billion people will be added in these electricity-deficient areas.

Table 2. Global Electrification Prospects in Africa					
	GDP per capita (10^3 US $PPP per year)	Primary Energy per capita (10^6 J per day)	Electricity Consumption per capita (kWh per year)	Electricity (% of Final Energy)	Carbon Emissions (MTC/yr)
2000					
Sub-Saharan Africa	1.7	70	840	7	140
3rd World	2.4	70	1,550	7	900
Industrialized World	28.0	650	7,300	18	3,200
2050 Reference Case					
Sub-Saharan Africa	2.0	90	900	10	400
3rd World	3.5	110	1,900	11	2,700
Industrialized World	39.0	690	11,000	3	2,950
2050 Electrified Case					
Sub-Saharan Africa	4.0	120	1,460	31	350
3rd World	5.3	130	2,930	31	2,300
Industrialized World	39.0	460	16,100	48	1,420

Table 2 presents anticipated trends in energy and economic statistics over the next 50 years for Africa and other parts of the globe. Actual data for the year 2000 are presented along with two projections, one representing a "business as usual" scenario and the other a world driven by sustained efforts to use electricity as the engine of economic growth in Africa and around the world. These data are derived from the US DOE Energy Information Agency International Energy Outlook for 2004, from a World Energy Council study of energy futures, and from other sources. Africa trails all other regions in economic growth, in energy and electricity growth, and in carbon emissions. Moreover, Africa attains the target of 1,000 kWh per person only in the electrified case. The extreme poverty of much of Africa is a key factor in limiting the pace of electrification, but the failure of reforms and other political issues also play a role.

Providing power to a global population in 2050 of 9 billion—including minimum levels of 1,000 kWh per person per year to the very poorest people—will require roughly 10,000 GW of aggregate global generating capacity, or three times the current level, based on today's technology. That corresponds with at least a 3% annual rate of increase in global electricity supply.

Crucial Issues in Global Electrification

To build the necessary momentum toward global electrification, research initiatives must address the whole electricity supply chain—from market policies through generation, transmission and distribution. In some cases, technology development will be required, but first some improvements in basic understanding are essential to meeting global electrification goals. The availability of these and other analytical tools will help avoid the mistakes that have occurred in recent African electrification initiatives. Significant problems in African electrification have arisen due to poor management practices, political corruption, counter-productive cross subsidies, ineffectual reform programs, among others. These issues must be resolved to assure the success of electrification programs.

Highest Priority Actions

The highest priority should be assigned to activities in two areas. First, additional research is needed on the "value equation"—the costs and benefits associated with universal electrification. Some global goals and strategies are proposed here, but work is needed to understand the implications of those global goals for particular localities and regions and to outline specific strategies for achieving the goals. For example, the goal of 1000 kWh per person per year will vary with local conditions (e.g., heating requirements) as well as the potential for increasing efficiency and the competition between electricity and other energy carriers.

Second, work is needed on specific technologies that will be essential to meeting the goal of universal electrification. Improvements across a broad portfolio of generation and delivery systems will be needed. Especially for service in remote rural areas there is a need to create or adapt relatively clean, low-cost, and readily deployable off-grid distributed generation options. For service in most other areas improvement of grid-based systems will be needed, with special emphasis on improving the reliability of distribution infrastructure.

Work on these topics will require attention to the interplay between technological capabilities, the goals that particular regions and localities may set for electrification, and demographic change. Low-power distributed generation may be adequate for achieving universal access to electricity. But if the goal is extended to include large consumption of high quality electricity then today's rural distributed generation systems may be unable to supply the level and quality of power demanded.

Outlook for Generation Technologies in Africa

The electrification of Africa offers the opportunity for a fresh look at designing a 21st century power system. For example, systems for the developing world are expected to rely on distributed generation for many applications, rather than the focus on central generation that is typical of countries that electrified during the 20th Century. Distributed designs may be the least costly and quickest way to get power to rural areas in developing countries using readily available indigenous resources. Distributed energy resources will also have a role in supplying the electricity needs of urban areas in developing countries.

The distributed generation portfolio for developing countries is essentially the same as for the developed world. Moreover, petroleum-based liquid fuels may have an advantage in rural settings, because of the high volumetric energy density and the potential for upgrading existing refineries and building new ones to refine coal and crude oil into clean fuels. Liquid fuels are also valuable because they can be used both for stationary power requirements and for motor fuels (e.g., synthetic diesel oil).

Renewables will have an especially important role in developing countries. In general, technologies addressing the needs of the developed world can be adapted for use in developing countries. Examples include solar photovoltaics, wind generation, and biomass. To use these technologies effectively in the developing world, technology advances are needed in several areas, such as reducing the capital and operating costs of the equipment, reducing maintenance requirements, and improving the efficiency of end-use technologies. End-use efficiency improvements can lead to substantial reductions in the power requirements. Work is also needed to develop low-cost storage options—batteries, flywheels, and ultra capacitors for example.

End-use technologies can also be designed to meet the needs of rural settings. Direct current end-use equipment—lights and power supplies for electronic applications—can be connected directly to DC generators, such as PV systems and fuel cells, without the need for AC inversion of the generator output, and conversion back to DC at the point of use.

Electrification of Urban Areas of Developing Countries

The demographics of electrification are changing as urban population increases. Today's rural population in developing countries is about 2.8 billion people, while perhaps 1.7 billion live in urban areas. The rural population is expected to remain approximately stable over the next three decades, and population growth in the developing world will concentrate in cities as people move from the countryside. By 2050, the urban population of the less-developed world may double. The pace of this urban shift is one of the many large uncertainties that make projections difficult.

Technology Portfolio

African power producers, transmission companies, and distribution companies have several options for introducing electricity and expanding its reach. There are two principal options. The first is to implement current technologies. The advantages of this approach are low initial cost, a reliable, proven technology, and technicians skilled in operation and maintenance requirements. A second class of power systems incorporates new technologies with higher efficiencies, better environmental performance, and lower life-cycle cost. Frequently, the superior performance and low life-cycle cost may be offset by a higher initial capital cost.

One key attribute of new technologies is the potential to address climate change concerns through the implementation of a portfolio of zero- or low- carbon emitting generation systems. In the African context, this suggests a growing reliance on distributed generation, fueled by natural gas or renewable primary energy sources, in addition to clean coal technologies and nuclear generation.

There is general agreement that we will have to continue to use coal as a fuel resource in South Africa. The issue here is the design of the next generation of coal plants. There is a significant opportunity to improve the environmental performance of coal by "refining" it into clean gaseous fuel or chemical feedstock. The gasification process can provide both high-efficiency power generation and hydrogen. This process is also amenable to carbon capture and sequestration.

Natural gas is also an option for African electrification. The reserves in Algeria and Nigeria can be tapped to provide fuel for gas turbines, and ultimately for fuel cells. Gas imports can supplement the indigenous reserves. Key technological issues include the need for liquefied natural gas (LNG) infrastructure for shipping and handling.

Distributed Energy Resources (DER), which includes generation, storage, and intelligent control, will become an integral asset in the African electricity supply system. As DER grows, it could fundamentally change the relationship between power supplier and consumer, and over time, the network architecture of the distribution system.

The portfolio of DER generation technologies includes reciprocating internal combustion (IC) engines (500 kW–5 MW), small combustion turbines (5–50 MW) and even-smaller micro turbines (kW-scale), and various types of fuel cells. Photovoltaics, small wind turbines, and other renewables are often considered DG technologies. Commercial DER storage technologies include batteries and capacitor banks. These technologies should find ready application in the African context. Implementation of these technologies in Africa will require substantial site-specific evaluations. "Ruggedized" equipment that resists breakage and has minimal maintenance and repair requirements is likely to capture much of the market for rural areas.

Mitigating Greenhouse Gas Emissions

Addressing potential global climate impacts is becoming an urgent priority for the energy industry and policymakers alike. This reflects the fact that atmospheric CO_2 concentrations have increased 33% over the last 200 years, and are continuing to increase. .

Changing from a global system where more than 85% of the energy used releases CO_2 to a system where less than 25% is released requires fundamental improvements in technology and major capital investments. A robust portfolio of advanced power generation options—fossil, renewable, and nuclear—will be essential to meet the economic aspirations of a rapidly growing global population.

Today's and tomorrow's complex climate issues will require a multidisciplinary carbon management strategy on three broad fronts:

1. De-carbonization, defined as reducing the carbon content of the fuel. Renewable generation, biomass, and nuclear power are the principal means for de-carbonization. However, some petrochemical processes are available that produce liquid fuels with a high hydrogen content that could be used in gas turbine generators.

2. Sequestration, which consists of removing CO_2 from the product stream at the point of production, is a commercially available technology, but reducing the high costs of the technology would probably be required to make sequestration a viable alternative in developing countries.

3. Efficiency improvements reduce the energy required to produce a given amount of economic output. Efficiency improvements can be found throughout the energy supply chain, from mining and transporting fuel, converting the fuel to electricity or other energy carrier, power delivery, and end-use efficiencies.

Developing countries, including African countries, pose a particularly difficult challenge in addressing climate issues. The economic development of these countries depends on expanding electricity consumption, and most low-cost generation technologies emit greenhouse gases. However, as technologies are deployed in coming decades, solutions that meet the needs of the developing world will almost inevitably become viable.

Outlook for the Electricity/Hydrogen Economy

Policymakers and the technical community are exploring approaches to use hydrogen as an energy carrier that complements electricity. Both hydrogen and electricity are clean at the point of use, are easily converted to one another, and can be derived from a variety of domestic primary energy sources. Potential uses include both stationary and vehicular power as well as energy storage. Hydrogen's greatest value appears to lie in scenarios driven by energy supply security and climate change, especially when used as a motor fuel, or in other distributed applications. In either case, hydrogen should integrate well with electricity. Electricity is more flexible and less costly, while hydrogen is easier to store and increases the capacity factor for expensive generation infrastructure.

However, as an energy carrier, hydrogen has one major drawback – the efficiency of producing hydrogen from water or a hydrocarbon, is extremely low using today's technology. In Africa, this could mean tapping the large hydropower resources of Central Africa or the solar resource of the Sahara desert as the primary energy for hydrogen production. Availability of hydrogen would reduce Africa's reliance on energy imports and contribute to the security of energy supply.

The long-term vision for Africa is that large programs will be required to design and build large-scale hydrogen production facilities, to transport and store hydrogen, and to develop end-use applications that are optimized for hydrogen.

Outlook for the Intelligent Power Delivery System

The ultimate force pulling the electricity sector into the 21st century may turn out to be the technologies of electricity demand—specifically, intelligent systems enabling ever-broader consumer involvement in defining and controlling their electricity-based service needs.

Historically, the power delivery issues of security, quality, reliability, and availability (SQRA) have been measured and dealt with in a fragmented manner. In the future, they will almost certainly become a highly integrated set of design criteria to meet the evolving power requirements of consumers. Fortunately, the suite of advanced technologies that can be used to improve the security of the power delivery system can also be used to improve power quality and reliability, and transform the power system to meet the needs of the 21st century. These technology developments will first be manifested in the industrialized world, but developing countries will be able to leapfrog many of the intermediate steps in the development process.

The result will be dynamic technologies that empower the electricity consumer, stimulating new, innovative service combinations emphasizing speed, convenience, and comfort, with different quality levels and types of electric power. A vigorous, price-sensitive demand response from an increasing class of consumers whose energy choices reflect both electricity prices and power quality will become an integral part of the electricity marketplace.

Digital technology will be able to open the industrial, commercial, and residential gateways now constrained by the meter, allowing price signals, decisions, communications, and network intelligence to flow back and forth through the two-way "energy/information portal."

In summary, Global economic growth will drive electrification, both in developed and developing countries. Almost without exception, the major technology trends depend upon an advanced electricity infrastructure. In Africa, widespread access to electricity will be a prerequisite for sustaining economic growth. Developing countries need clean, affordable electricity to grow their economies and meet the aspirations of their people. Thus, electrification will be a key factor in global stability.

2. STATUS OF INTERNATIONAL INTERCONNECTIONS IN NORTH AFRICA

Interconnections between neighbouring utilities are becoming increasingly vital for implementation of an open energy trading market and to increase the reliability of power systems. The power utilities of the Arab countries in North Africa and the Middle East have made considerable investments in extending transmission system interconnections and power-transfer corridors at various voltage levels to facilitate cross-border trading of electric power.

North African Interconnectors

Libya is a large country that shares borders with six neighbouring countries, four Arab states (Egypt, Sudan, Algeria and Tunisia) and two African states (Chad and Niger). Currently Libya is only electrically interconnected with Egypt at the east network boundary where energy has been exchanged through a tie line since the circuit was commissioned summer 1999. This interconnector was constructed as a double-circuit 220-kV line connecting Tobruk substation in Libya, approximately 150 km inside the border, with Salum Substation in western Egypt. The 220-kV transmission line extends 165 km and is capable for commercial trading of 200 MW in either direction. This line extends across the Egyptian desert another 350 km before it reaches areas of dense energy consumption and the load centres of the Mediterranean city of Alexandria. The overall length of the transmission line is 500 km.

The power system of the Egyptian Electricity Authority (EEA) is interconnected on the eastern boundary of the country with the Jordanian system through a 500-kV circuit that links the two countries via overhead lines and a submarine cable crossing under the Bay of Aqaba in the Red Sea. Jordan is electrically interconnected with Syria, whereas Syria is about to be linked with the eastern boundary of the European grid (UCTE) via Turkey.

Tunisia and Algeria border Libya's western boundary. Until now, there has been no power-system interconnections between these two countries. However, the Tunisian and Algerian power grids are interconnected with two links, and Algeria is interconnected at its western border with Morocco, which is connected with Western Europe via Spain.

The 400-kV AC link with Spain, comprising transmission lines and a submarine cable under the Straits of Gibraltar, connects Mellousa Substation in Morocco with Pinar del Rey Substation in Spain. The “missing link” is the Libya-Tunisia interconnection, which will close the loop of the Mediterranean Basin countries when commissioned.

National Transmission Capacity (NTC) among the South-east Mediterranean Countries (SEMC) countries in 2003 is indicated in Fig. 1.

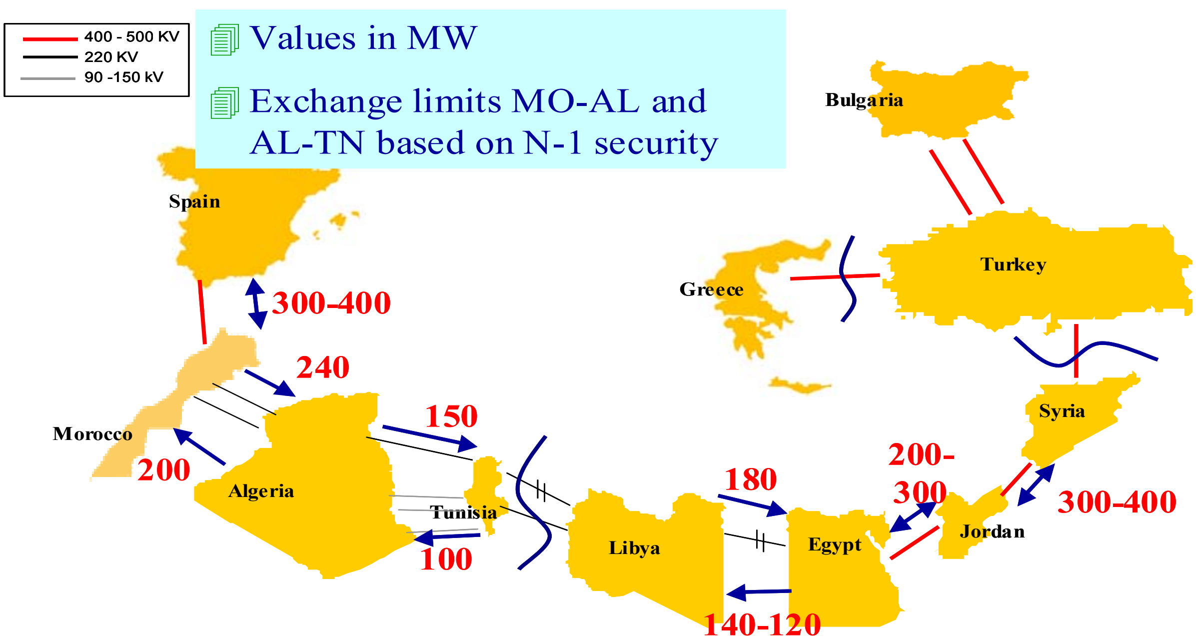


Figure 1. NTC Among SEMC Countries in the Year 2003

Jordan -Egypt Red Sea Interconnection

The development includes a 400-kV submarine cable that crosses the Gulf of Aqaba between Taba in Sinai and Aqaba in Jordan. This link, which is an important stage in the planned interconnection between Egypt, Jordan, Syria, Iraq and Turkey, will be the first electrical connection between Asia and Africa and will eventually lead to a grid loop extending all the way around the Mediterranean. Commissioning of this circuit was in 1997.

More specifically the situation is:

- Tunisia-Libya: two lines at 220 kV (1 single circuit and 1 double circuit) have been completed. Permanent synchronization between the two blocs is subject to outcome of the testing phase that is envisaged will be completed in 2004

- Syria-Turkey: a 400 kV line (Birecik-Aleppo) is now completed, but its exploitation will probably not take place prior to connection of the Turkish system to UCTE
- Turkey-UCTE: Turkey is presently interconnected with Bulgaria through two 400 kV lines.

Other Developments: North-South HVDC Connections

To enhance the possibility of electricity trading between SEMC and Europe, some South-North HVDC links are under study. The corridors under investigation are:

- Algeria-Spain: the feasibility study for a HVDC connection from Terga to Litoral de Almeria through a submarine cable (connection about 240 km) with a capacity of 2000 MW has been completed. The construction of 2000 MW of new generation (possibly CCGT) in Algeria – out of which 800 MW for local needs and 1200 MW for export - has been planned. Because of the difficulty in getting foreign investments, the project will be commissioned in two stages. At the beginning a bipolar HVDC link rated 1000 MW will be realized with marine electrodes for emergency current return
- Algeria-Italy: the project of a potential interconnection rated 1000 MW between Algeria and Sardinia (Italy) is at a pre-feasibility stage. This project will be integrated with a second HVDC link, developed in two modules (500MW+500MW), between Sardinia and Continental Italy.
- Further envisaged HVDC links are relevant to Tunisia-Italy (2000 MW) and Libya-Italy (600~1000 MW). For these latter projects no detailed feasibility analyses have been carried out so far.

Future Perspectives

Looking into the future, further steps are envisaged related to the extension of the Euro-Mediterranean synchronously interconnected system, namely:

- Extension to South: synchronous interconnection between Egypt and Sudan (220 kV line)
- Extension in the Middle East with the interconnections Syria-Iraq (400 kV line), Turkey-Iraq (400 kV line) and Jordan-Western part of Saudi Arabia (voltage level to be defined).

The Red Sea Cable Interconnection Project linking the electrical networks of Egypt and Jordan will operate with an initial interchangeable energy of 300 MW rising to 2000 MW at a future stage.

3. STATUS OF GULF CO-OPERATION COUNCIL (GCC) ELECTRICITY GRID SYSTEM INTERCONNECTION

Recognizing the benefits of interconnection of their power grids, the six Arab states of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) undertook a study in 1990 to define an Interconnection Project and to determine its feasibility. The study recommended an AC interconnection of the 50 Hz systems of Kuwait, Bahrain, Qatar, UAE and Oman with a back-to-back HVDC interconnection to the 60 Hz Saudi Arabian system. The study concluded that the recommended Interconnection Project for the GCC countries was technically feasible as well as economically and financially viable.

As recommended in 1990, the Gulf Co-operation Council Interconnection Authority (GCCIA) has been established and given the mandate to proceed towards implementation of the Interconnection Project as recommended in the 1990 study,

In light of the time that has elapsed since the 1990 study and in view of evolution of the power sectors in the GCC countries, it was decided in 2002 to update the 1990 studies and to re-confirm the feasibility of the Interconnection Project, carry out a Market study, prepare a plan for financing of the Project, develop the Agreements that have to be reached between the different countries, and prepare an implementation strategy.

Evolution of the Power Sectors in the GCC Countries

In 1990 all the power utilities were government owned and vertically integrated. Governments in the region have already embraced the need and accepted the benefits of private sector participation in the power sector. Since then, legislation has been passed in Oman, UAE., Qatar and Saudi Arabia allowing the construction and operation of private power (and desalination) plants. Bahrain is expected to embrace private sector participation in the power sector shortly. Most of the GCC countries are in the process of unbundling their power systems into generation, transmission and distribution entities. The presence of an Interconnection between the GCC countries will, in addition to enabling sharing of reserves thus reducing the generation requirements in each country, provide the opportunity for trading electricity between the member countries as well as eventually trading outside the GCC.

Demand Growth in the GCC Countries

The demand in GCC countries as shown in Table 3 is expected to grow from 32,747 MW to almost 94,000 MW over the next 25 years.

Table 3. Demand Growth up to 2028

Year	Kuwait MW	Saudi Arabia* MW	Bahrain MW	Qatar MW	UAE MW	Oman MW	Total MW
2003	7685	9910	1547	2308	9137	2160	32747
2008	10284	13945	2070	3184	12780	2662	44925
2010	11555	14745	2325	3387	14383	2824	49219
2028	27017	23210	4989	4649	29358	4558	93781

* The Saudi Arabia demand only includes the demand supplied by the SEC-ERB (i.e., the load in the Eastern Region and the firm exports to the Central Region)

Interconnection Project

The feasibility study recommended that grid system interconnection between the GCC states is feasible from all technical and financial considerations and recommended the project be carried out in three phases as shown diagrammatically in Fig. 2.

- **Phase I:** Interconnection of the Northern Systems (Kuwait, Saudi Arabia, Bahrain and Qatar) in 2008.
- **Phase II:** The internal interconnection of the Southern Systems (UAE and Oman) to form the UAE National Grid and the Oman Northern Grid.
- **Phase III:** Interconnection of the Northern and Southern Systems in 2010.

Figure 2: **Approximate Route and Layout of the GCC Interconnection**

The Interconnection Project for Phase II is internal interconnection of the Southern Systems (UAE and Oman) to form the UAD National Grid. The Interconnection Project for Phase I and for Phase III is comprised of the following principal elements:

Phase I:

- A double-circuit 400 kV, 50 Hz line from Al Zour (Kuwait) to Ghunan (Saudi Arabia) with an intermediate connection at Fadhili (Saudi Arabia) and associated substations.
- A back-to back HVDC interconnection to the Saudi Arabia 380 kV, 60 Hz, system at Fadhili.
- A double circuit 400 kV comprising overhead lines and submarine link from Ghunan to Al Jasra (Bahrain) and associated substations.
- A double circuit 400 kV line from Ghunan to Salwa (Saudi Arabia) and associated substations.
- A double circuit 400 kV line from Salwa to Doha South (Qatar) and associated substations.
- A Control Centre located at Ghunan.

Table 4. Size of Interconnection to Each GCC State

System	Size (MW)
Kuwait	1200
Saudi Arabia	1200
Bahrain	600
Qatar	750
UAE	900
Oman	400

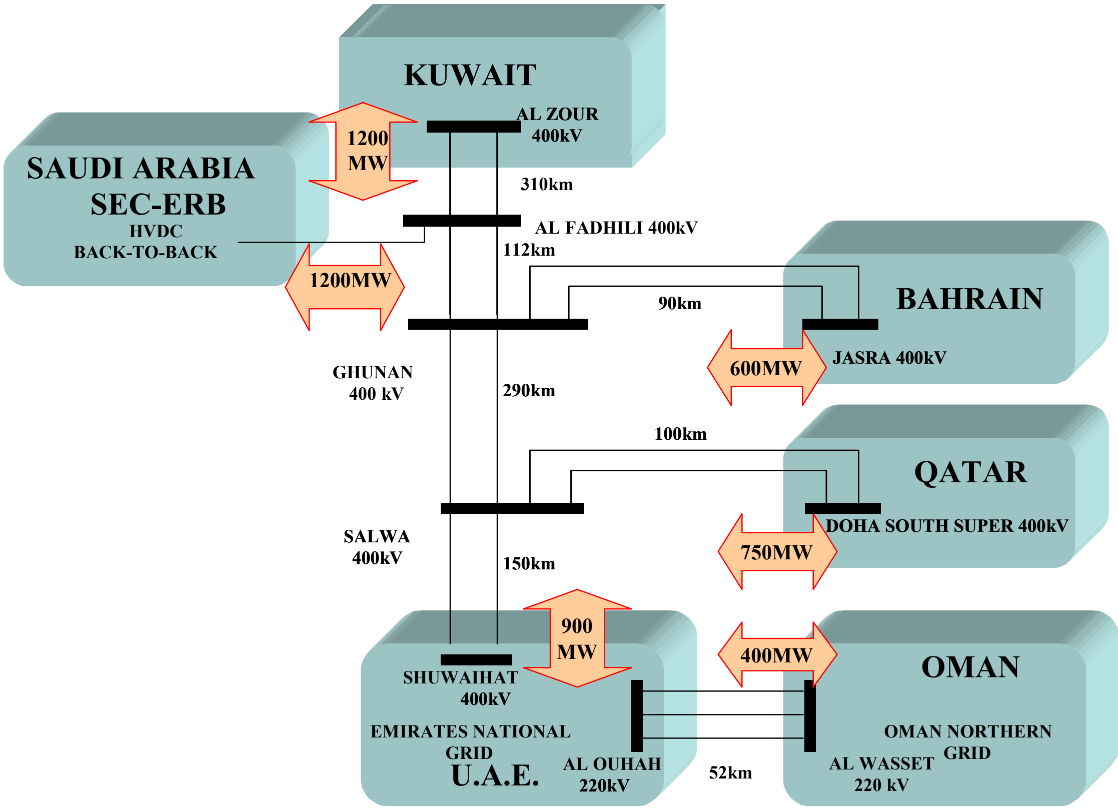


Figure 3. Conceptual Diagram of the Interconnection System

Phase III:

- A double circuit 400 kV line from Salwa to Shuwaihat (UAE) and associated substations.
- A double circuit 220 kV line from Al Ouhah (UAE) to Al Wasset (Oman) and associated substations.
- A single circuit 220 kV line from Al Ouhah (UAE) to Al Wasset (Oman) and associated substations.

The capacity of the Interconnection to each of the countries is given in Table 4 and Fig. 3.

Cost of the Interconnection Project

The estimated cost of the Interconnection Project based on economic conditions of 2003 for Phase I and Phase III is $US 1189 million and $US 137 million, respectively.

Benefits of the Interconnection Project

The principal benefits that can be achieved through Interconnection are:

- Interconnections result in the requirement for lower installed capacity in each of the systems (due to reserve sharing) while still supplying the load with the same (or better) level of reliability.
- Interconnections can permit larger and more efficient generating units to be installed on the individual systems.

- Interconnections enable systems to share operating (spinning) reserves so that each system can carry less spinning reserve.
- Interconnections enable interchange of energy between systems resulting in a lowering of total operating costs.
- Interconnections permit assistance from neighbouring systems to cope with unforeseen construction delays and unexpected load growth.
- Interconnections permit emergency assistance between systems to mitigate the effects of unforeseen contingencies such as catastrophic multiple outages.

In the present study the benefits due to reduced generation requirements as a result of reserve sharing were quantified. In addition, the opportunity for power trading between the countries was assessed.

The principal benefits due to the interconnection arise from the sharing of reserves between the systems and the consequential reduction in the installed generating capacity and associated operating and maintenance costs in the GCC countries. The capacity benefits to 2028 for Phase I are shown in Table 5.

It was also found that given the high differential between the price of gas and the price of crude oil (a ratio of almost one to four) there is significant potential for economy interchange between the countries. However, there is a lot of uncertainty in whether or not such savings can be counted on towards the economic justification of the Project. Nevertheless, the studies showed that there is an opportunity to trade and for countries to realize substantial benefits.

Table 5. Generation Capacity Reduction Benefit for Phase 1 Countries

Country	Load (MW)	Total Installed Capacity (MW)		Cumulative Benefit (MW)	Reserve (MW)	
		Isolated	Intercon-nected		Isolated	Intercon-nected
Kuwait	27017	30397	29066	1331	3380	2049
Saudi Arabi	23210	26361	24752	1609	3151	1542
Bahrain	4989	5782	5494	288	793	505
Qatar	4649	5427	5060	367	778	411
Total	59865	67967	64372	3595	8102	4507

Economic Evaluation

The economic evaluation of the Project showed that the benefit to cost ratio for Phase I of the Project is of the order of 1.5 and that the pay back period for the investment is less than four years. Given the small incremental cost of Phase III it is evident that implementation of Phase III would further improve attractiveness of the Project. Thus the analysis has re-confirmed the economic viability of the Project.

Sharing of the Costs of the Interconnection Project

It was agreed amongst the countries to share the costs of the Interconnection in proportion to the reserve capacity savings. Considering the time value of money and that capacity savings occur at different points of time, it was agreed to share the costs in proportion to present value of the capacity savings.

Financing Options for the Project

The financial analysis has re-confirmed the financial feasibility of the Project.

The various options of financing the total cost (capital and operational) of the project are being considered in detail in a separate study carried out by the Gulf Investment Corporation (GIC). The finance of the project can be partially or wholly provided from loans or with participation by the private sector, with or without contribution by the governments.

The options of financing the project which was considered in the 1997 feasibility studies were five options as given in Table 6. The first and second option is based on full (100%) ownership of the project by the governments in which case the governments will be responsible for all costs associated with the project.

The third option considers full ownership by the private sector. The last two options consider joint ownership with different percentage participation and ownership between governments and the private sector.

Table 6. Financing Options Considered

Finance Options	**Ownership**		*Sources of Finance*		
			Capital		
	Govern-ment	Private sector	Govern-ment	Private sector	Loans
1	100 %	-	100 %	-	-
2	100 %	-	35 %	-	65 %
3	-	100 %	-	35 %	65 %
4	50%	50%	17.5 %	17.5 %	65 %
5	50%	50%	25 %	25 %	50 %

There were various important issues when considering the finance options for the project:

- Government risks
- Enhanced efficiency of the private sector to carry out the project when compared to the government
- Cost of provision of finance by the government.

The GCCIA was set up as per the second option in which the government will be responsible to take 35 % of the cost of the project with the remaining 65 % provided from loans.

Next Steps

An implementation strategy has developed. Relevant agreements are being drafted to confirm the commitment of each of the countries to the Project. An information memorandum is being prepared to solicit financing for the Project.

In summary, the present studies have re-confirmed technical feasibility and the economic and financial viability of the Project.

Steps are now being made to take the Project to market and to work towards its implementation.

4. TOWARDS DEVELOPING A COMPETITIVE MARKET FOR REGIONAL ELECTRICITY CROSS BORDER-TRADING: THE SOUTHERN AFRICAN POWER POOL.

The competitive market for regional electricity cross-border trading for the Southern Africa Power Pool (SAPP) will first be considered as a case study for Southern Africa. Regional electricity cross border trading is governed by fixed co-operative bilateral agreements, generally of a long-term duration. The fixed power purchase agreements provide for the assurance of security of supply but are not flexible to accommodate varying demand profiles and varying prices. The pricing of electrical energy differs for periods of peak and off peak consumption. To explore further the benefits thereof, the sourcing and scheduling of electrical energy closer to the time of dispatch has been investigated. Research has shown that competitive bidding is one option for sourcing and securing supplies closer to real time dispatch. Using the experiences of SAPP as a case study, a competitive market framework for cross border electrical energy trading was developed. In April 2001, the market commenced trading with a few participants. With increasing participants and market confidence, the results of the first two years show that the model is robust and is a recommended framework for cross border short term electrical energy trading. The short-term energy market, designed to be day ahead, compliments the bilateral market and provides another technique for the pricing of electrical energy. With the addition of real time communications and energy management systems, the spot market for competitive bidding is the next step.

Routine activities that follow include scheduling, settlements and the monitoring of quality of supply. Further on, based on events, detailed investigations are conducted into inadvertent energy flows and major power system faults and disturbances.

For bi-lateral contracts, the pricing of electrical energy is negotiated and the outcome is generally based on the classical economics of supply and demand. At times of peak consumption, the price for electrical energy is generally higher. At times of off peak consumption, the prices are generally lower.

The off peak tariff in most countries is approximately 40 % of the peak tariff. This difference promotes new business opportunity. Hence, a new process is introduced for the pricing of electrical energy in the short term. The time-based differentiation in pricing arises from the physical constraint in that produced electrical energy must be instantly consumed. Storage of electrical energy is not practical. Energy banking and pumped storage schemes are the exceptions for electrical energy storage for a very small percentage of the total electricity generated.

The Power Pool Development Group at Purdue University has collaborated with electricity utilities in 26 countries of Africa in the development of regional long-term capacity expansion planning decision support tools. In the case of SAPP, the Purdue modeling team was in partnership with the SAPP Planning Sub-Committee and member utilities from the 12 countries that constitute the Southern African Development Community (SADC).

The Purdue Long-Term Expansion Model (LTEM) has been used in both the SAPP and WAPP policy planning. It is a 20-year planning system for energy and reserve trade between countries, which minimizes the present value of electricity generation costs, and generation/transmission capacity expansion costs subject to reserve and country autonomy constraints on the system.

Full technical details of the modeling are available. Modeling results for the SAPP and WAPP are available on the Purdue University Power Pool Development Group (PPDG) website.

Case Study for Southern African Power Pool

SAPP is a regional body that was formed in 1995 through a Southern Africa Development Community (SADC) treaty to optimize trading entities, the use of available energy resources in the region, and support one another during emergencies. The power pool's, Co-ordination Centre is located in Harare, Zimbabwe and comprises twelve SADC member countries represented by their respective electric power utilities.

SAPP is managed by the decision-making that occurs in the hierarchical structured committees illustrated in Fig. 4. Reporting to the Energy Ministers of SADC is the Executive Committee that is composed of the Chief Executives of the participating utilities. Reporting to the Executive is the Management Committee, which is composed of senior managers from the transmission system operations and energy trading divisions of each utility.

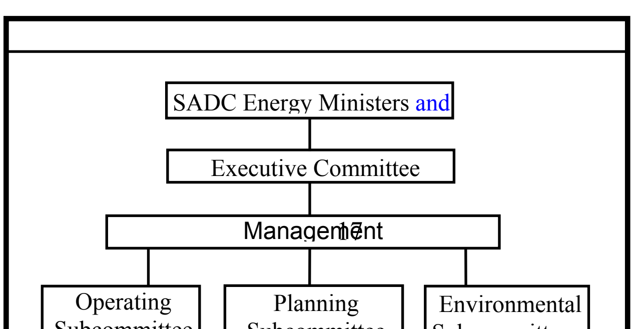


Figure 4. SAPP Structure

The Management Committee collates the proceedings of the sub-committees of Operating, Planning and Environmental, summarizes the proposals and recommendations and presents bi-annually a report to the Executive Committee. In the SAPP proceedings of 1999, the recommendation from the Operating Subcommittee to introduce a competitive market for short term energy trading was submitted and approved. The design and rules of the short-term energy market is now summarized. The results of more than two years of trading activity have been analyzed and are also summarized.

Design of the Short Term Energy Market

The goal of standard market design is to establish an efficient and robustly competitive wholesale electricity marketplace for the benefit of consumers. This could be done through the development of consistent market mechanisms and efficient price signals for the procurement and reliable transmission of electricity combined with the assurance of fair and open access to the transmission system.

For the Short-Term Energy Market (STEM) design, the following criteria was submitted as input:

i.) ***Transmission rights*** - Long and short-term bilateral contracts between participants have priority over STEM contracts for transmission on the SAPP interconnectors. All the STEM contracts are subject to the transfer constraints as verified by the SAPP Co-ordination Centre.

ii.) ***Security requirements*** - Participants are required to lodge sufficient security with the Co-ordination Centre before trading commences and separate security is required for each energy contract.

iii.) ***Settlement*** - Participants have the full obligation to pay for the energy traded and the associated energy costs. The settlement amounts are based on the invoices and are payable into the Co-ordination Centre's clearing account. It is the responsibility of the Participants (buyers) to ensure that sufficient funds are paid into the clearing account for the Co-ordination Centre to effect payment to the respective Participants (sellers).

iv.) ***Currency of trade*** - The choice of currency is either the United States Dollar or the South Africa Rand dependent on the agreement between the buyer and the seller.

v.) ***Allocation method*** - The allocation of available quantities based on the available transmission capability is by fair competitive bidding with equal sharing of available quantities to the buyers.

vi.) ***Firm contracts*** - Once contracted, the quantities and the prices are firm and fixed. There are currently three energy contracts that have been promoted in the STEM as follows: monthly, weekly and daily contracts.

To commence the design process, three working groups were tasked to detail the parameters for settlements (Treasury Working Group), the parameters for Trading (Trading Working Group) and the parameters of governance (Legal Working Group). The working groups were composed of specialists from the participating utilities. The work was conducted over one year.

The trading platform for the new competitive short-term market was designed locally. The platform employs a matrix for the solution of simultaneous linear equations. Analysis of the trading results and market performance are:

- Excess capacity prevails in the regional market, generally during off peak. Electrical energy prices are generally, on average, lower than that for the bilateral market.
- The number of market participants increased from four in the first year to eight as at May 2003.
- The average tariff of energy traded is in the range from 0.3 to 0.6 US c/kWh. The highest matched price was 1.45 US c /kWh.
- The offer prices tend to increase as the cold winter months are approached when the SAPP regional peak demand occurs. This behaviour concurs with the economics of supply and demand.
- Transmission availability determines successfulness of trade. Transmission congestion mainly on the cross border tie lines constrains trade.
- Opportunity for trading short term is available. The highest monthly revenue was equivalent to USD 380,000. The figure is projected to increase.

Post STEM Energy Market

The Post STEM energy contracts are concluded outside of the STEM market between participants through bilateral negotiations. Unallocated STEM bids and offers are published on the Internet and these offers and bids are available for hourly trading on the trading day.

This market started in December 2001 and is now about ten percent of the energy traded on the STEM. A higher tariff than the STEM is agreed and trading takes place the next day. Energy and Volume Traded in the Post STEM Energy Market is given in Fig. 5.

The working groups were comprised of specialists from the participating utilities. The work was conducted over a period of one year.

The results of the working groups are summarized in Table 7.

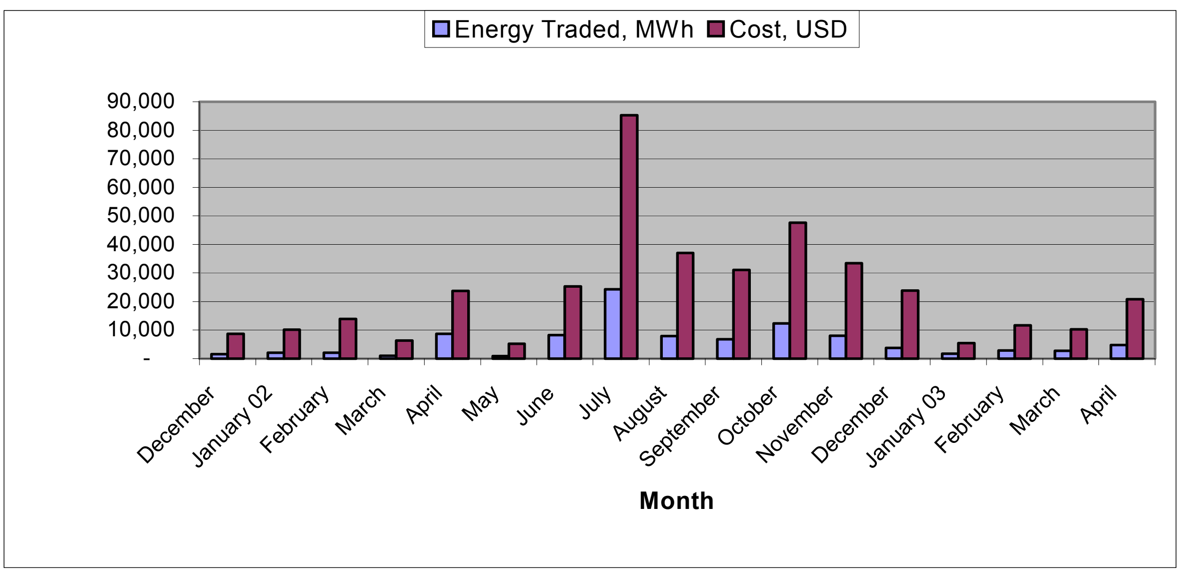


Figure 5. **Energy and Volume Traded in Post STEM Energy Market**

Table 7. Summary of Design Features for Short Term Energy Market (STEM).

Treasury Working Group	• Currency of trade. • Security of Payments • Clearing Institution & location • Settlement process
Trading Working Group	• Trading Platform • Wheeling Charges • Trading Rules • Daily Scheduling Procedures • Market Structure
Legal Working Group	• Governance documents • Regulatory Rules • Agreements

The outlook for the future regional market includes an increase in trend for deregulation and liberalization with private equity participation. Other countries have similar strategies and the net result will be an increase in interconnectivity and cross border trading. Large untapped run of the river projects is now emerging as potential new sources of regional energy, for example the Inga development in the Democratic Republic of Congo. The economic renaissance of the continent gathers momentum, supported by the policies and practices of NEPAD, the New Partnership in Africa's Development.

5. THE CENTRAL AFRICAN POWER POOL (CAPP), THE ECONOMIC COMMUNITY OF CENTRAL AFRICAN STATES (ECCAS) AND THE NEW PARTNERSHIP FOR AFRICA'S DEVELOPMENT (NEPAD)

The Central African Power Pool (CAPP)

a) ***Definition, Mission and Vision.***

CAPP is a very new sub-regional institution, created in Brazzaville on 12 April 2003 under the auspices of the Economic Community of Central African States (ECCAS).

CAPP presently is the focal point for discussions on regional power markets; member states of ECCAS rely upon CAPP for technical analysis of proposals for power sharing between member states.

CAPP is assigned to:

- Promote power policies
- Promote studies and construction of common infrastructures and the organization of energy exchanges and the related services in ECCAS.
- Develop regional power management and trading arrangements in Central Africa.

It aspires to become a major player in regional cooperation in the power sector.

CAPP vision is to exploit the enormous hydroelectric potentialities of the Central Africa estimated at more than 650 Thousands GWh (53 %) of the whole African potential, to satisfy all demands in electricity with the households, the states and the central African industry.

b) ***Members***

Any public, private, and/or semi-public electricity supply enterprise of ECCAS member states may become member of CAPP.

Present members of CAPP are AES-SONEL (Cameroon), ENERCA (Central African Republic), SNE (Republic of Congo), SEEG (Gabon), SEGESA (Equatorial Guinea), SNEL (Democratic Republic of Congo), EMAE (Sao Tome & Principe), and STEE (Chad).

Expected members: ENE-EP/EDEL (Angola), ELECTROGAZ (Rwanda) and REGIDESO (Burundi).

a) ***Structural Organs and Organization Chart***

This is shown in Fig. 6.

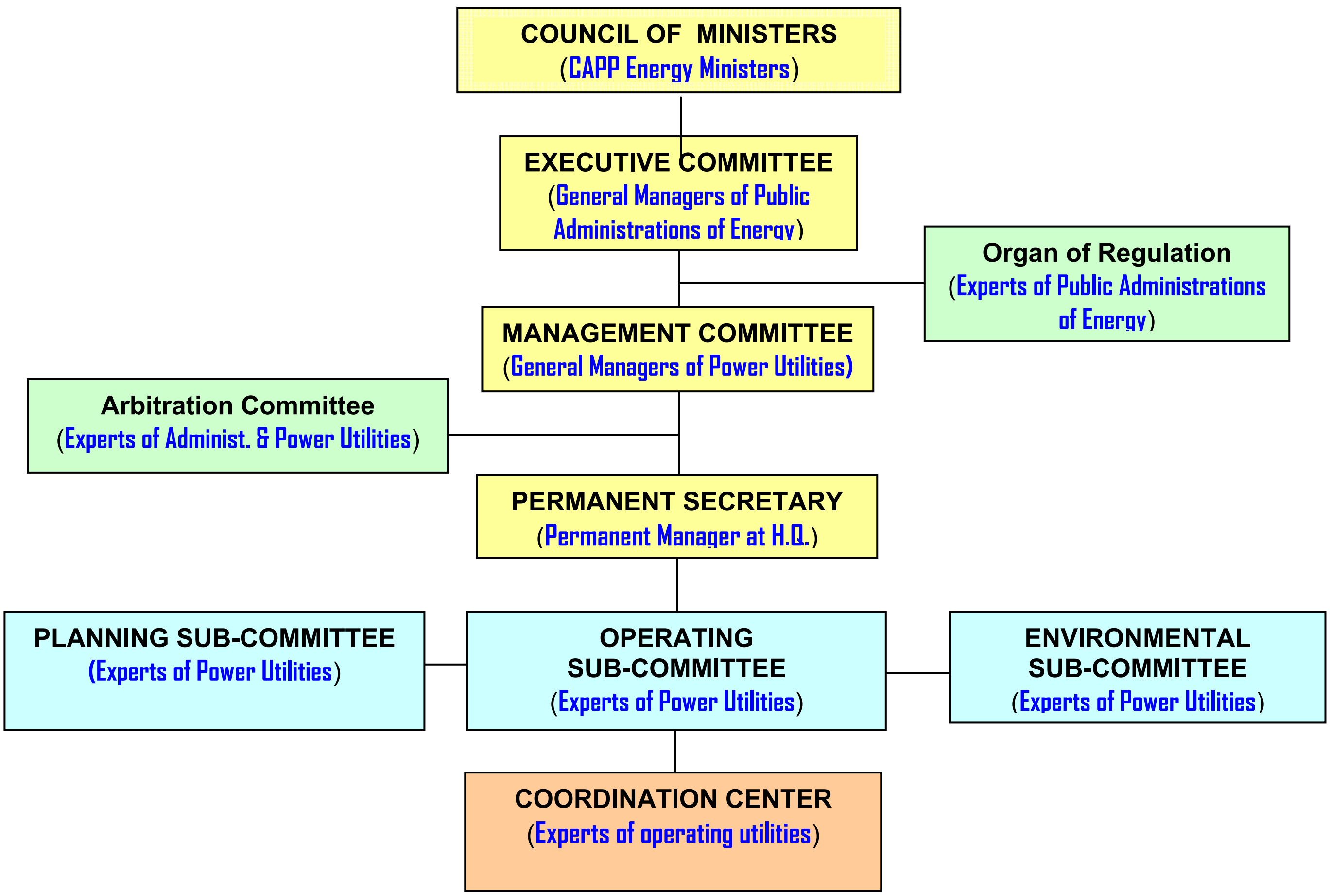


Figure 6. Structural Organs and Organization Chart

Economic Community of Central African States (ECCAS)

a) Introduction: ECCAS was instituted in October 1983 in Libreville (Gabon) by 11 member states which are Angola, Burundi, Cameroon, Central African Republic, Republic of Congo, the Democratic Republic of Congo, Gabon, Equatorial Guinea, Rwanda, Sao-Tome and Chad.

Its headquarter is situated in Libreville (Gabon).

b) Objectives: To promote and to reinforce a harmonious cooperation and a dynamic, balanced and auto-kept development in all domains of the economic and social activity to:

- the harmonization of the sectarian national policies in view of the promotion of the common activities, mainly in the domain of the industry, of the transportation and communications, the energy, agriculture, the natural resources, the trade, the currency and the finances, the human resources, the tourism, the training and the culture, the science and the technology;
- the progressive deletion, between the member states, of the obstacles to a common market and to the free circulation of people, goods, services, funds and to the right of establishment;
- the promotion and the peacekeeping, the security, the stability and the lasting development in Central Africa.

c) Immediate Perspectives:

It was planned to establish in 2004 a zone of free exchange of the ECCAS and to organize the private sector, the civil society, the feminine organizations, the academic so that they can contribute to the achievement of the missions assigned to ECCAS. In addition, a backing of the capacities of the General Secretary of the ECCAS has been planned for the implement of the NEPAD in Central Africa.

b) ***Electric Situation of Central Africa***

The Electric Situation in Central Africa is indicated in Table 8.

Table 8. Electric Situation in Central Africa

Sub-regions	Potential aver. in GWh	Power Prod. in MW	Consum. in kWh/h	Previs. needed in GWh(2005)
North Africa	41 000 (3.7%)	134 000 (33.2%)	739	209 300 (36.8%)
West Africa	100 970 (9.2%)	38 033 (9.4%)	143	50 546 (6.8%)
Central Africa	653 361 (57.7%)	10 537 (2.6%)	109	13 052 (2.3%)
South Africa	151 535 (13.8%)	208 458 (51.7%)	1 617	279 409 (49.,0%)
East Africa	171 500 (15.,6%)	12 281 (3.1%)	68	12 281 (3.0%)

In spite its enormous hydroelectric potentialities, Central Africa is the less electrified sub-region in Africa.

c) ***Present and Future Inter-Connection Projects***

Present and future integration projects are shown in Fig. 7 and Table 9.

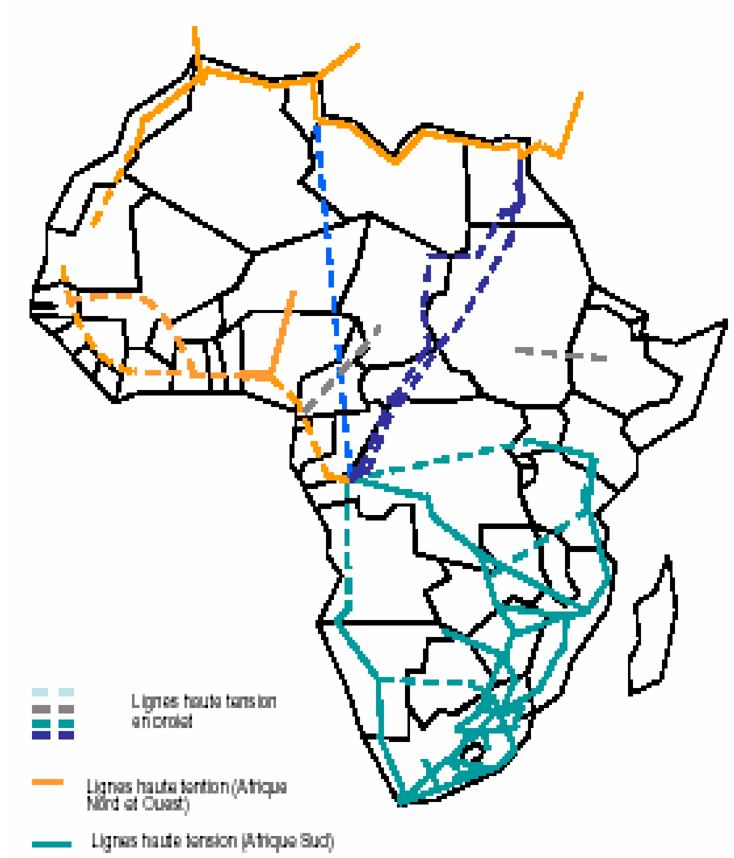


Figure 7. Future Integration Projects

Table 9. Future Integration Projects

N	PROJECTS
	Transmission Interconnection Inga (RDC) - to Pointe-Noire (R.Congo) via Cabinda (Angola),
	Planning of Grand Inga (RDC)
	Backing of CAPP capacities
	Interconnection of the electric networks of the ECCAS member states (financed with a grant of African Fund for Development/FADB)
	Implementation of Data Bank and Standards
	Transmission interconnection between the electric systems of CAPP and WAPP
	Designing a master plan of investment and development of the energy sector in Central Africa
	Transmission interconnection between the electric systems of CAPP and SAPP
	Rehabilitation of the hydroelectric power stations and Transmission Interconnections associated of the member states of ECCAS
	Institutional reform of the states utilities of ECCAS member states
	Transmission Interconnections Inga (RDC) - Maloukou-Ouesso (RC) and Sangmelima (Cameroon)
	The CAPP – COMELEC Interconnection (Inga - Assouan)
	The Interconnection Cameroon – Chad
	Setting up of the systems of information and communications integrated in the CAPP area.

CAPP and ECCAS

a) Introduction: To implement the Common Market of yesterday and to build the European Union of today, the European states began with the basis that was the European Community of Coal and Steel (CECA) in April 1951 in Rome.

In the same way the Central African states created CAPP in April 2003 as the basis of the sub regional socio economic integration for the power exchanges to overcome the shortcomings of the interconnections of the national electric systems.

b) Projects of Electrification between Operating Members

CAPP identified some transmission interconnections projects illustrated in Fig. 8 and Table 10 below:

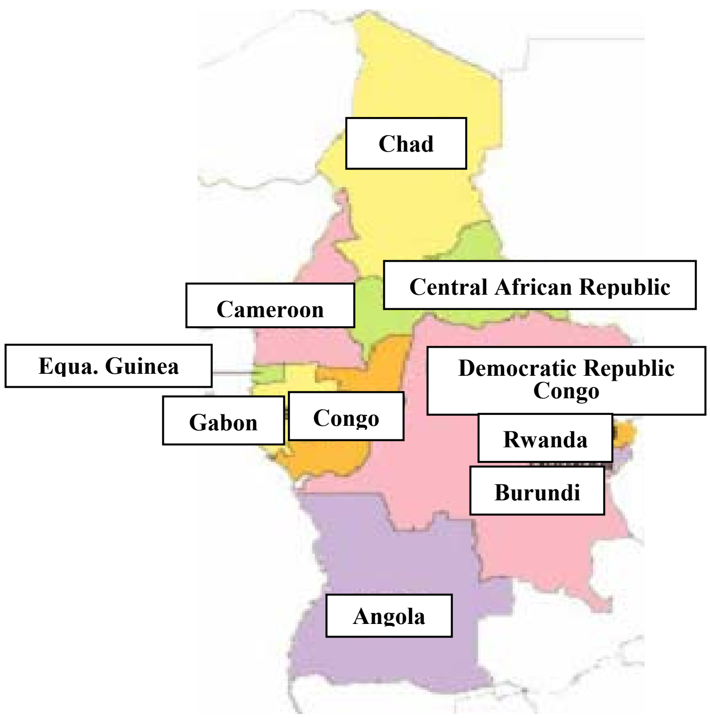


Figure 8. CAPP Transmission Interconnection Projects

CAPP, and NEPAD (New Partnership for Africa's Development)

a) Definition and Creation**:** The New Partnership for Africa's Development, NEPAD, is a program of the African Union to reach its objectives of development: to fill the delay which separates Africa from the developed countries.

During the organization Summit held in Lusaka in Zambia in July 2001, the Millennium Action Recovery Plan (MAP) and those of the French speaking Nations, the *OMEGA* plan, essentially an infrastructure development plan, were merged and became the New African Initiative (NAI). During the Summit held in Abuja in October 2001, NAI. became the New Partnership for the Development of Africa (NEPAD) dealing with: Good political governance, good economic governance, infrastructures, energy, agriculture, health, education, environment, new technologies of information and communication, access to the markets.

Table 10. CAPP Transmission Interconnection Projects

N°	Name of the Project	Countries concerned
01	Electrification of BONGOR	Cameroon Chad
02	Electrification of DATCHEKA, FIANGA & GOUNOUGAYA	Cameroon Chad
03	Electrification of LERE, PARA, RIBAO, MOMBOR0A & BINDER	Cameroon Chad
04	Electrification of KYE-OSSI, EBEBIYIN & MEYO-KYE	Cameroon Chad
05	Electrification of MBINDA et MAYOKO	Gabon Congo
06	Electrification of ZONGO	CAR DRC
07	Electrification of MOBAYE, KONGBO, ALINDAO, KEMBE	CAR DRC
08	Electrification of KYE-OSSI (AKOMBANG)	Equat. Guinea Cameroon
09	Electrification of MEDJENG	Equat. Guinea Gabon
10	Electrification of DIVENIE from Malinga station	Gabon Congo
11	Electrification of BAMBAMA from BOUMANGO station	Gabon Congo
12	Electrification of LEKETI and OKOYO from LECONI station	Gabon Congo

One of the most important objectives of the NEPAD is to guarantee the lasting development and the integration of the African continent.

From all goods produced by Africa, hydroelectricity is the only one, which is commercial, strategic and non-pollutant that the sub-region is able to produce and to export, in all Africa and towards a part of Europe and the Middle East, and without border hindrances.

Therefore, the CAPP, as organism of hydroelectricity promotion, constitutes necessarily a major asset for the internal and external economic integration and for the realization of the plan of action of the NEPAD in Central Africa.

Present Situation of the Projects and Immediate Perspectives

1. Integration Projects:

- The launching of the interconnection of power grids of ECCAS member states financed by the African Bank of Development, and the launching of the "Designing a master plan of investment and development of the energy sector in the sub-region" financed by the United States Aid for International Development (USAID)
- Requests of financing are submitted to other international financial providers
- Projects of institutional support
- Projects of electrification between members states
- Other requests of financing are submitted.

2. Perspectives: According to the contacts with the different partners, it was noticed that they have real opportunities to mobilize funds necessary to the realization of the common power projects. However, the obstacles must be raised to the level of the guarantees, of the political wills and to the level of the harmonization between the different African Power Pools.

Mode of Execution of the CAPP Programs

To achieve its missions, the CAPP Permanent Secretary adopted the method V.I.P.:
V: vision = picture of that one wants to be and to have
V: view = diagnostic (Demand/Offer)
V: values = hierarchized objectives
I: influences = strategies or modes of actions
P: projects = actions or projects

The method V.I.P. enable to proceed by the definition of the power politics, the setting up of the programs of temporal and spatial actions and the scheduling of the efficient actions in order to reach the objectives necessary to the satisfaction of the individual and collective power needs hierarchized.

Challenges

- To share the vision, to develop will to work in dialogue and to harmonize the sub regional policies of electrification of Africa
- To promote the Power Pools as basis of realization of the objectives of the NEPAD and the African sub regional Communities.

6. THE FUTURE OF SAPP, WAPP, CAPP, AND EAPP WITH INGA

The proposed new HV lines will significantly affect capacity planning in Africa's power pools. The costs of interconnection across Africa are now considered. It draws upon comparisons with HV line networks in other locations. SAPP, WAPP, Egypt, and the East Africa Power Pool (EAPP) have each expressed their interest in continental interconnection. The hydropower potential from the River Congo is a big attraction to regional planners and the key development project of Grand Inga (39GW potential, located 150km from Kinshasa) necessitates the planning of very long HV lines. CAPP and DRC have much to gain from exporting the potential hydropower at the right price.

The first Section provides an introduction to Africa's power pools showing how each has an interest in the hydropower potential of Grand Inga. The second Section outlines the North America experience with long-distance trading, and the third Section discusses the creation of the CAPP. The penultimate Section considers investment and pricing of electricity exports, and the last Section draws conclusions and recommendations for future electricity modeling in Africa.

African Power Pools and the Centrality of Inga

Over the past decade there have been major initiatives taken by African governments to improve reliability and reduce costs by promoting the development of regional power pools.

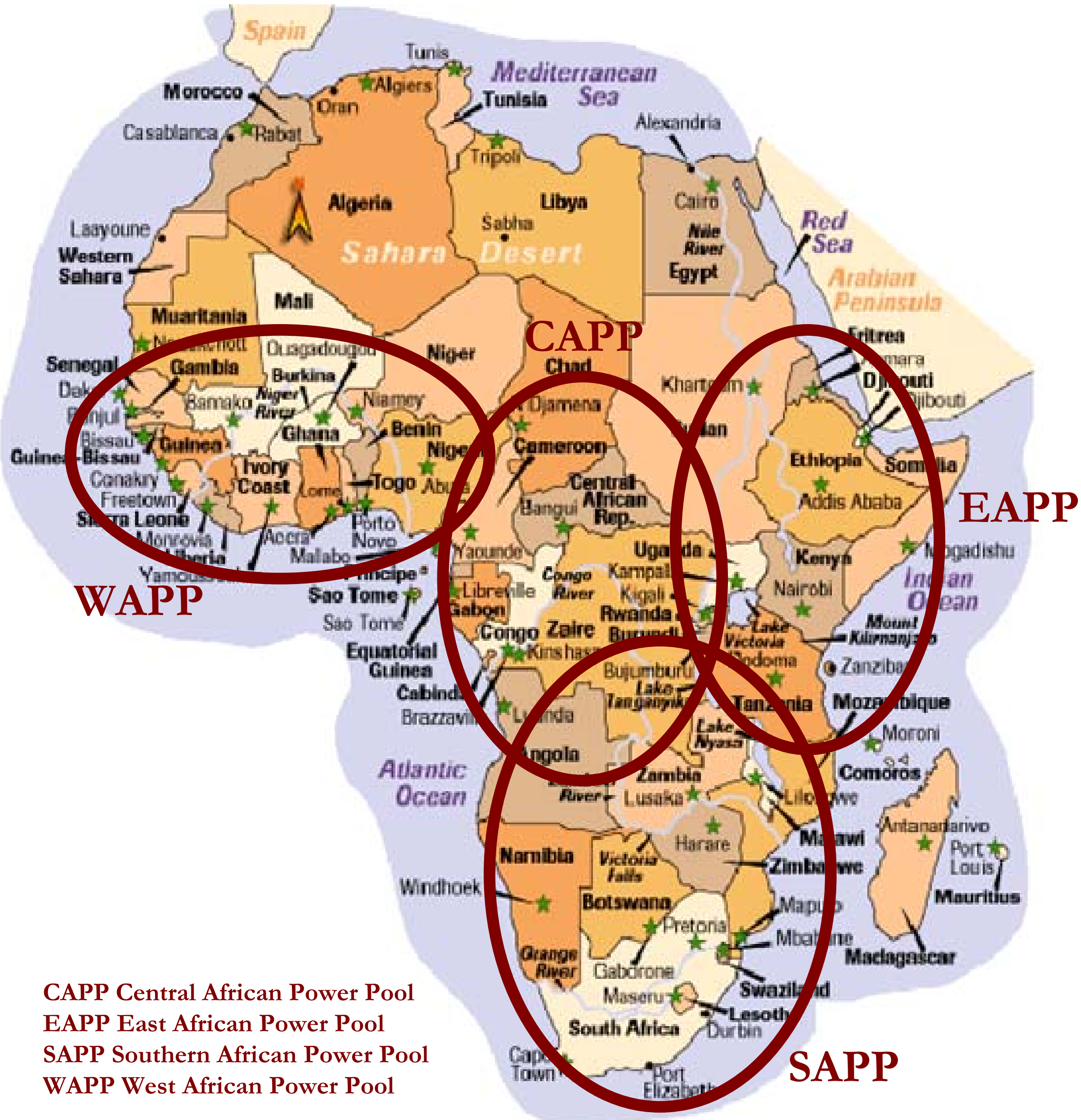


Figure 9. Africa Regional Power Pools, CAPP, EAPP, SAPP, and WAPP

SADC created SAPP in 1995 and the Economic Community of West African States (ECOWAS) created the WAPP in 2001. Each of these power pools covers a very extensive area including 12 countries in the first instance and 14 in the latter (Figure 9).

Table 11. Sub-Sahara Regional MW Totals Reference

Power Pool	Total Existing Generation (MW)	Sub-Sahara Generation (Percentage)
CAPP	4,561	8%
EAPP	3,092	5%
SAPP	42,324	72%
WAPP	8,579	15%
Total	58,556	100%

Most recently, CAPP was created in early 2005 and there is currently discussion for developing an EAPP. These regional initiatives for improving trade among states all depend on new international HV transmission lines being built.

Africa's largest regional power pool is SAPP with over 42GW of generation capacity (Table 11). Total electricity generating capacity of Sub-Sahara Africa is about 59GW (7% of U.S. total of 983GW). With Africa's much larger area and smaller generating capacity there is a question if such a large spread-out continental grid, involving expensive long transmission lines with large line losses can be economically justified. There is an ever-growing interest, in spite of the economic challenges, to transmit the enormous hydropower potential of the River Congo to the north, south, east and west of the continent. The Purdue modeling team has built models for SAPP and WAPP. A preliminary CAPP model has now been built and a proposal prepared for modeling the East Africa region. These modeling initiatives will provide top level planners with quantitative economic assessments of the new regional interconnections, demonstrating the magnitude of the gains from joint construction and trade.

What are the most critical new lines required in each of these four regions of Africa and how can the experiences of the United States and other large interconnected networks assist in the planning of a network across Africa?

The great hydropower potential of the River Congo, especially at Inga, can certainly play an important role in providing power regionally. Located at the heart of Africa (150km from Kinshasa) it is at the center of a future continent-wide power network (Figure 10). DRC-Inga currently exports and wheels power to SAPP countries including Zambia, Zimbabwe, Botswana and South Africa. Power from Inga is transmitted to the Zambian grid along a 500-KV direct current (DC) line from Inga to Kolwezi in southern DRC, and a 220-KV line from Kolwezi to Kitwe in northern Zambia. Viability of a second southern interconnection, from DRC to SAPP via Angola and Namibia, rests solely on expanding the generating capability of the Inga facility. Expansion of Inga 3 (3,500MW) coupled with the rehabilitation of Inga 1 and 2 can provide enough excess generating capacity that will justify the creation of an expanded regional electricity export scheme. The Western Energy Highway will connect DRC-Inga to Nigeria and WAPP, providing 1,000 MW of electricity. The fully implemented Grand Inga scheme will be the largest generating facility in Africa with 39,000 MW and feasibility studies indicate that it's interconnector to Egypt would be viable with the construction of the Northern Energy Highway, passing through Congo, the Central African Republic, and Sudan to Egypt, a distance of about 4,000 km.

There are striking differences in the amounts of HV transmission lines in Africa and North America. Sub Sahara Africa is about 2.5 times the size of the U.S. The SADC has an almost equal area to that of the U.S. Its 5,710km of international HV lines together with South Africa's 25,180km of HV lines amounts to 12% of the HV lines in the U.S. (Table 12). The high demand centers in Africa are mostly concentrated in the capital urban areas and are very widely dispersed making a marked difference with the much higher number of high demand centers in the U.S.

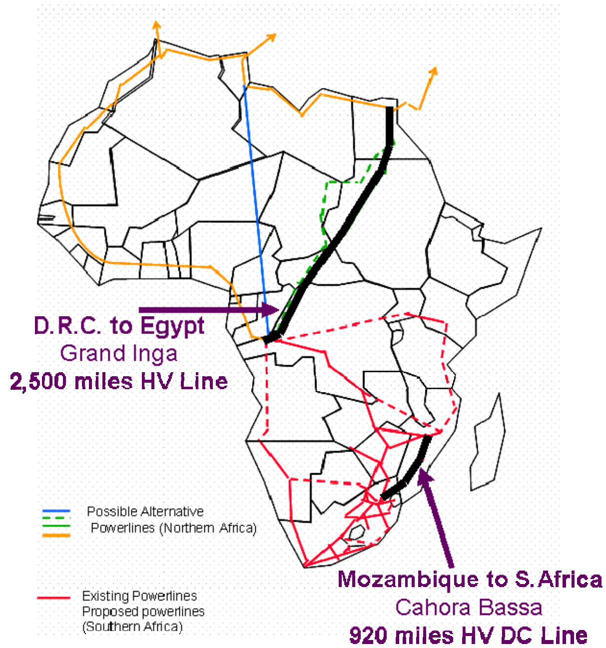


Figure 10. Long-Term Transmission Planning in Africa

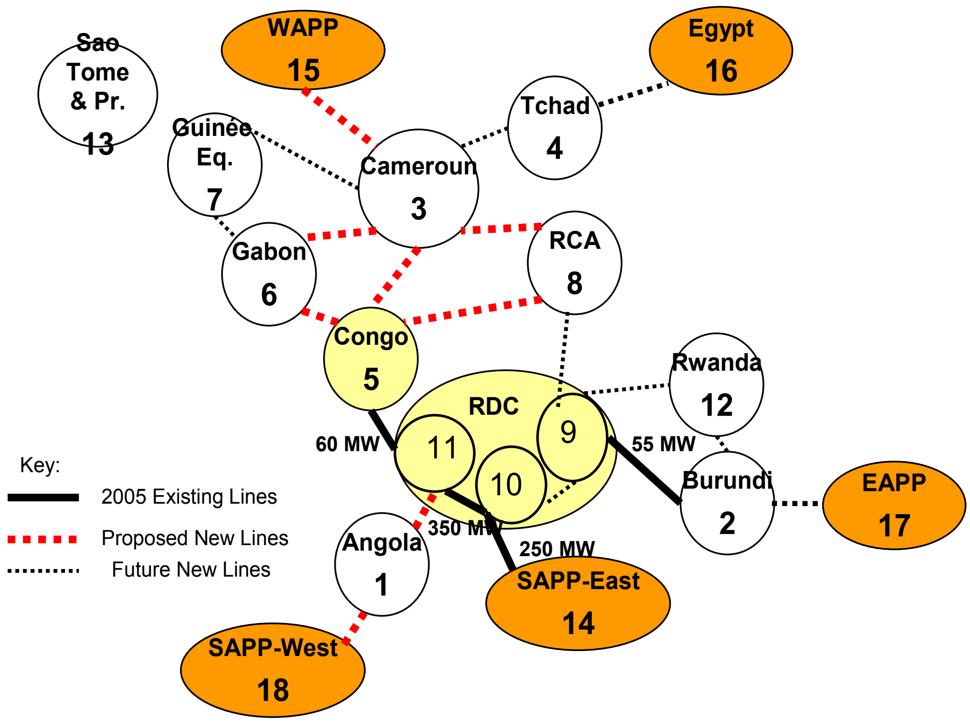
Table 12. HV Transmission Lines in Africa and America

Region/Country	Surface Area (1000 km^2)	HV Transmission Line Length Above 110kV (Km)
Sub-Sahara Africa	24,267	N/a
SADC	9,275	5,710
Rep. South Africa	1,221	25,181
Nigeria	924	11,000
U.S.A.	9,629	248,648
Canada	9,971	N/a
Mexico	1,958	23,500

In the planning of Africa's new HV lines the control of the lines is to be an important issue. The Federal Energy Regulatory Commission (FERC) expects new regional transmission organizations (RTO) to improve power grid reliability while reducing discriminatory transmission practices, and increasing investments in the transmission infrastructure.

In the case of Canada it is one of the world's largest producers of hydroelectricity, generating over 315,500 GWh (2002). Very similar to DRC it is estimated that Canada has 180 GW of hydroelectricity potential remaining, although only 34 GW is currently deemed economically feasible. The economic analogy of building more hydropower in Canada with the DRC's Inga might help planners in Africa. Export potential for sending power to the U.S. from Canada has the attraction of further massive energy revenues but the capital-intensive nature of new hydro capacity could overwhelm benefits from trading. This is an issue that confronts the Inga project. Correctly pricing Inga's electricity exports is going to be essential for the successful launching of the project as it looks towards providing mutual benefits to consumers in Africa's power pools as well as to DRC.

The Preliminary CAPP Model



Node1 Angola Node2 Burundi Node3 Cameroon Node4 Chad
Node5 Congo Node6 Gabon Node7 Guinee Eq Node8 RCA
Node9 RDCest Node10 RDCsud Node11 RDCouest Node12 Rwanda
Node15 West Africa Node16 Egypt Node 17 East Africa
Node14 Southern Africa via Zambia Node 18 Southern Africa via Angola

Note: RDC is French for DRC, similarly Tchad for Chad

Figure 11. The Preliminary CAPP Model - With 18 Nodes Including 5 Export Nodes

Recently, Purdue's Power Pool Development Group's (PPDG) long-term planning software has been utilized to explore the economic gains that could be expected from the future development of the CAPP with its' 10 connected countries as indicated in Figure 11].

As Figures 9 and 10 indicate, the central location of CAPP allows it to consider exports to each of the two major Power Pools already in existence, SAPP and WAPP, as well as possible sales to Egypt and EAPP. These export opportunities, along with the well documented advantages of common operation and expansion of the grid within the 10 country region, should make the establishment of CAPP a top priority for any Pan-African electricity generation planning project.

The model simultaneously cost minimizes expansions in both the generation and transmission sectors. The water cost was set at \$0.5/MWh which was the value stipulated by the SAPP some years earlier. For demonstration purposes initial export demands were set at 1,000 MW each for SAPP west, WAPP, and EAPP, 250 MW for SAPP east, and 4,000 MW for Egypt. A general growth rate was assumed of 5% for CAPP as well as at the export nodes of SAPP, WAPP, Egypt and EAPP.

The 18-node model provides an optimal planning strategy for new lines emanating from Inga (node 11, DRC west, Figure 11). It is a 20-year long-term capacity expansion and electricity trade model as developed over the past several years for the SAPP and WAPP. Unserved energy costs are set at \$140/MWh and unmet MW at $3M/MW. The unserved energy and unmet MW costs could be argued for being raised but these values have been used in SAPP and WAPP and were therefore employed in the preliminary CAPP model.

While the CAPP modeling report is still in draft form and cannot yet be released, it should come as no surprise that the model predicts the need for major transmission construction projects to serve the need for power flows within CAPP, and even larger investments in HV lines to allow power flows from the Inga sites to the five export markets shown in Figure 11. As the demand from Egypt, SAPP, WAPP, and EAPP increase, as well as demand within CAPP, then a portion of the larger expansion capacity envisioned at Grand Inga appears to be justified.

However, the CAPP data still needs careful compilation and validation, a task planned for the next phase of the project.

Investment and Electricity Pricing Issues

The determination of the electricity demand growth rates, demand forecast figures, and electricity prices are critically important in the planning process for new capacity. Improved forecast training in many countries of Africa, with more detailed data collection, will improve the determination of such critical numbers. The less industrialized nations frequently have problems with inadequate power supplies. These are reflected in the growth rates data as "hoped for rates" and do not provide satisfactory input data for planners.

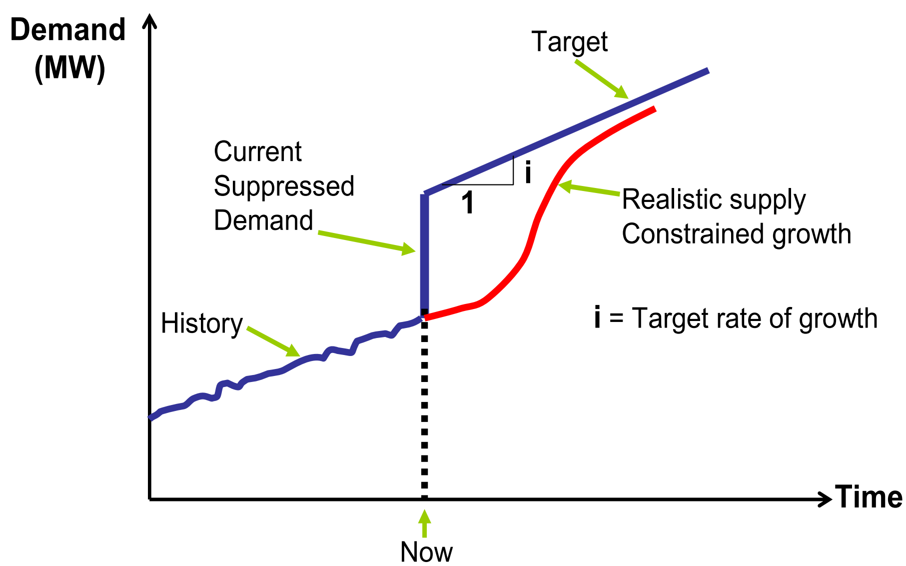


Figure 12. Electricity Growth Rate and Suppressed Demand

The problem with all the plans to utilize the enormous hydro power potential of the Conga lies in the fact that, unlike distributed generation projects having short construction times and small construction costs, centralized hydro projects require very large initial investments in dams and the transmission lines long before any project revenues are generated. The demand growth numbers for projects like Inga have significant affects.

A realistic model of constrained growth will improve the forecasting technique (Figure 12). The demand numbers significantly affect the attraction of suitable investments for the two Inga projects (Inga 3 and Grand Inga Stage 1) being modeled. The growth rates of 5% and more are often considered as reasonable but looking at the historic numbers for the instances of Egypt, Nigeria and South Africa this is higher than what has been happening.

Table 13. World Total Net Electricity Consumption and Demand Growth Rates for 1993-2002

Billion kWh	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Egypt	40.45	44.41	46.56	48.44	48.13	51.65	55.6
Nigeria	13.15	12.84	13.74	12.92	13.36	13.67	13.5
S.Africa	144.6	149.37	156.2	160.89	168.3	175.5	175

Growth Rates	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Egypt	9.8%	4.8%	4.0%	-0.6%	7.3%	7.7%
Nigeria	-2.4%	7.0%	-6.0%	3.4%	2.3%	-1.1%
S.Africa	3.3%	4.6%	3.0%	4.6%	4.3%	0.1%

Billion kWh	**1999**	**2000**	**2001**	**2002**
Egypt	60.59	66.86	72.93	75.58
Nigeria	13.83	13.11	16.13	18.43
S.Africa	178.14	183.76	185.90	189.36

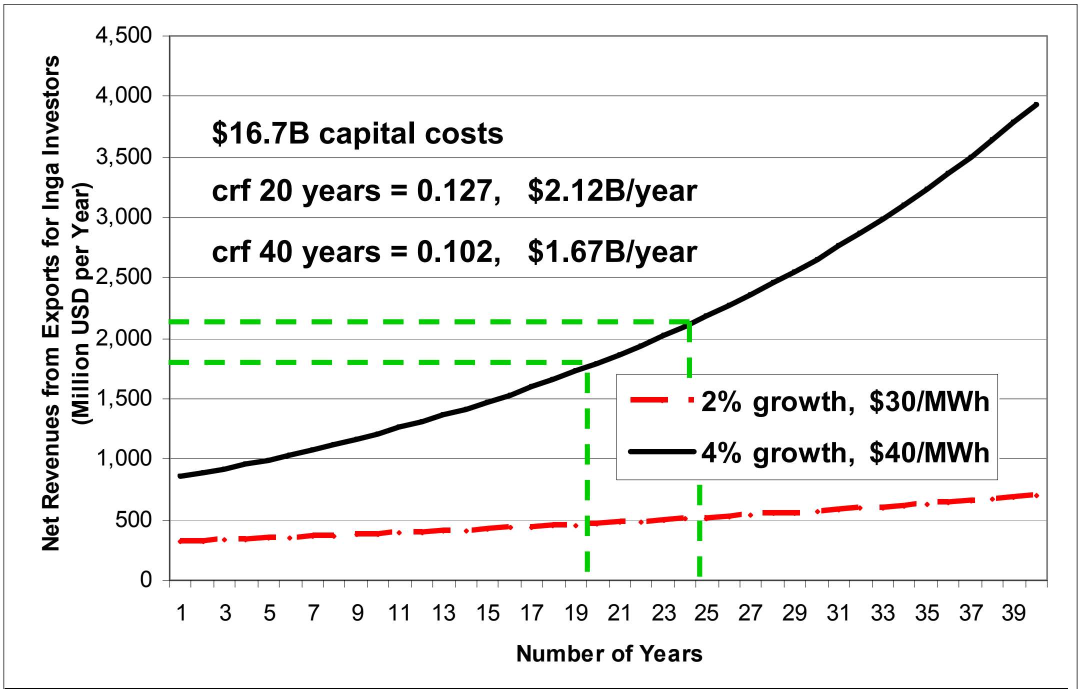
Growth Rates	**1999**	**2000**	**2001**	**2002**	**Total**	**Average**
Egypt	8.9%	10.3%	9.1%	3.6%	25.9%	**2.6**
Nigeria	2.4%	-5.2%	23.0%	14.3%	18.4%	**1.8**
S.Africa	1.3%	3.2%	1.2%	9%	14.4%	**1.4**

The average historic electricity demand growth rates for the largest national utilities in Africa over the past 10 years or more has been in the order of about 2%. This rate has been considered as a "low case" expansion scenario in the SAPP and WAPP. The numbers in Table 13 show the historic and average growth rates for these three countries.

Consider an illustration of the magnitude of the problem with having low demand growths. The two Inga hydro projects, the 3500MW Inga 3, and the 4000MW Grand Inga Phase 1 project – which are the driving forces behind much of the power pool activity in Africa - have estimated capital costs of roughly $4 Billion each. To this must be added the estimated transmission costs of $8.7 Billion to hook up the Inga sites to the export markets within SAPP ($1 Billion estimation at $1M/MW), WAPP ($1 Billion estimation), EAPP ($1 billion), and Egypt ($5.7 Billion). Thus the total upfront investment costs of the two Inga projects are in excess of $16.7 Billion.

Assuming a capital cost 10% and a project lifetime of 40 years, a range of $2.12 to $1.67 Billion dollars a year in returns to the investors must be assured for the projects to be financially viable. Further, all these export markets, each a functioning or planned power pool in itself, have local base load combined cycle generation construction options whose capital and operating costs are in the range of $30 to $40 per MWh (gas price range of $2.00 to $3.00 per MBtu), depending on the price of natural gas in these regions. These gas prices are reasonable estimates of current gas prices in Africa. If opportunities for LNG exports develop then these prices could increase. These domestic regional options will determine the maximum price these markets would be willing to pay for hydro electricity imported from the Inga projects. A further complication is that many of these regions already have capacity expansion projects on-going to satisfy near term needs for new capacity.

If we make the optimistic (for Inga) assumption that all projected growth in demand beyond 2005 in the four regions would be met by Inga power, as long as the price does not exceed the $/MWh range indicated above, we have the basic structure of a procedure to determine if the Inga projects make economic sense.



At $30/MWh & 2% demand growth the annual cost of capital does not break even with revenue from exports within a 20 year or 40 year planning horizon. At $40/MWh and 4% demand growth the annual cost of capital breaks even at 18 years (40 year horizon) and 24 years (20 year horizon)

Figure 13. Net Revenues from Exports for Inga Investors with 2% and 4% Demand Growth (USD)

Figure 13 shows the yearly net revenue stream available to the investors in the Inga projects assuming a range of demand growth rates from 2% to 4% in the four markets, using the base electricity consumption in 2005. The revenue stream, obtained by extrapolating the kWh figures in Table 8, is what remains as a return for investors, after having subtracted from the revenue estimates hydro operating costs of $2/MWh, and assuming no line loss. Also shown in Figure 13 are the annual required returns to the investors, assuming two alternative lifetimes for the Inga projects of 20 years, and 40 years, and capital cost of 10%.

Figure 13 also shows the most optimistic assumption with a 4% growth rate in demand being well in excess of historical rates as shown in Table 13. This results in the project yearly cash flows not covering the yearly-required returns until year 19, while the pessimistic assumption with a 4% growth rate results in the annual revenue stream equaling the required annual return only after 25 years have passed. Note that if the growth rate is 2%, the revenue stream never generates the required annual revenue stream during the lifetime of the Inga projects. Does this mean that the Inga projects should be abandoned? Not at all but it simply means that much more analysis must be done before any investor group will look seriously at Inga as a viable investment option with these export assumptions.

Comparative assessment to similar sized projects can always help if it were possible to obtain the growth and cost data involved. Certainly Mozambique's exports to South Africa are more appropriate for the Inga project than say Canadian hydropower to the U.S. The level of risk in North America is less and the cost of borrowing capital therefore reduced. High electricity growth rates elsewhere in the world make a major difference and China comes to mind. The huge Three Gorges project can be justified with the 8% to 10% historic growth rate but can the much smaller African growth rates justify the construction of such large projects?

Perhaps it is Egypt and the Mediterranean region with its large and growing demand for electricity that is the only obvious additional market for an enlarged Inga. If this is the case then the expansion costs of the DRC to Egypt line together with Inga, and the electricity export prices appear to be the first two most important issues for consideration. Secondly firm power contracts as well as wheeling rates will need to be agreed upon among all the players and stakeholders to secure adequate investments.

Without the Egyptian export gateway it is hard to justify the capacity expansions as growth rates as high as 4% or higher for many African countries are not taking place. The suppressed demand has to be remembered but still massive rural and urban electrification programs are required to take place to see the needed growth levels. These are some of the opportunities and challenges facing those energy planners promoting the substantial expansions for Inga and the inter-regional power grid of Africa.

In summary, the vision of a continent-wide HV power grid across Africa with Inga at the heart of the network has inspired African electricity planners for many years. The concepts and documented benefits of integrated African power pools, as demonstrated by the studies done by Purdue's PPDG for the SAPP and WAPP, support the impetus towards implementing the Pan-African HV network plan. Central to a strong future continental network are the creation of an efficient CAPP because of its location and the potential of Inga.

While the results of current work by PPDG support the general economic feasibility of the vision, this paper questions the approach taken by some supporters in their promotion of several very large projects, rather than a series of smaller ones. Both economic theory and industrial practice tell electricity planners that in situations, as in Africa, where capital costs are high and demand growth rates are low, it is best to forgo the scale economies present in constructing a few large projects, and choose instead to expand capacity slowly to allow the expansion in capacity to better match demand growth.

There might be enormous revenues and benefits from building Grand Inga and major new HV lines across Africa. However, it is believed that the time has arrived for a combined in-depth analysis of the three broad development scenarios referred to, (a) building Grand Inga for power exports to the Mediterranean, (b) building Grand Inga as a power source for all Africa, and (c) planning for massive urban and rural electrification. Each scenario holds great potential but each one needs to be considered within the complementary inclusiveness of all three scenarios combined, if sustainable development is Africa's goal.

7. POWER MARKETS IN EUROPE

In EU Europe there is growing a "single market" according to the legal situation, realisation 100 % by 2007. So far differences of market prices in different regions lead to increasing Cross Border Trading (CBT), for which the transmission systems were not designed. EU is happy because their target (greater than 10% of consumption across borders) is reached, but the Union for the Coordination of Transmission of Electricity (UCTE) is reporting on 11.5% CBT and complaining. This has been supported by transmission tariffs neglecting allocation signals as a political will. Work on fair CBT tariffs is going on.

In the *UCTE Issues New System Adequacy Report (Retrospect on 2004)* published in July 2005, it was reported that overall electricity consumption in mainland Europe increased by 1.7%, but this was less than in 2003 on account to mild weather conditions. Generation capacities increased by 4%: most of capacity developments were in combined cycle plants and renewable sources (up to 20%).

Although the retrospect shows sufficient generation capacities, two incidents leading to blackouts occurred in Greece and Luxemburg. Congestion in the Eastern part of UCTE was more severe than in 2003. Strong increases of wind generation in Germany led to high unscheduled flows on interconnections (*the full 'UCTE System Adequacy Retrospect 2004' can be downloaded from* http://www.ucte.org).

UCTE released recently its retrospective report on the adequacy of the electric systems in the 22-country region of mainland Europe extending from Portugal to Poland and from Germany to Greece. The results of the monthly survey show sufficient generation reserves for combined UCTE countries' remaining capacities. According to UCTE experts, some 5% are needed for secure operation, which was the case on reference days during 2004.

Non-hydro renewable generation in UCTE has once again increased, by more than 30%, mainly due to wind-power generation development. This strong evolution, noticed particularly in Spain and Germany, has a significant impact on transmission system operation and brings grids close to their limits.

International exchanges remain on a high level: on average, 11.5% of the UCTE countries' national consumption originates from imports from other UCTE countries.

The most significant event in UCTE in 2004 was the successful reconnection of synchronous zones 1 and 2 (on October 10 2004). UCTE is now a single synchronous zone.

Interconnection capacities in the period were also reinforced between Spain and Portugal, Hungary and Croatia, and between Germany and NORDEL through the Baltic cable.

Very bad weather conditions affected the Eastern part of UCTE in November 2004, especially Poland and the Czech Republic which lost their interconnection.

Unscheduled flows resulting from wind power variations stressed security limits on the interconnections between Germany, Poland, the Netherlands, Belgium and France and caused the curtailment or reduction of commercial contracts.

In summary, there is congestion at borders. Counter-measures for congestion management is a pressing topic at this time, together with market oriented methods and harmonisation. There are several power exchanges in operation trading roughly 20 % of total electricity trade. They play an important role in giving signals for market prices. Another problem is wind energy, not only Germany and Spain but increasingly for UCTE.

Concerning technical matters: since October 2004, UCTE is one large frequency zone including (again) SE-Europe that encompasses Bulgaria, Romania and the south western part of Ukraine as well as three North African countries Morocco, Algeria and Tunisia. The connection Tunisia -Libya is ready but not yet in use. .

Studies for future cooperation and interconnection of UCTE with UPS IPS (Russia) and Turkey (consequences for Med Ring) started in 2005.

8. ELECTRICITY MARKET DEREGULATION

Electricity market deregulation has been underway for about one and a half decades since the United Kingdom opened a Power Pool in April 1990. Some markets such as NordPool and New Zealand have been very successful, but others such as California and pre-NETA UK market have failed.

Some existing markets are:

- Pennsylvania-New Jersey-Maryland Interconnect (PJM)
- New York ISO (NYISO)
- ISO-New England (NE-ISO)
- Electric Reliability Council of Texas (ERCOT)
- Independent Electricity Market Operator (IMO) of Ontario
- Power Pool of Alberta
- New Energy Trading Arrangement (NETA) of the United Kingdom
- Nordic Power Exchange (Nord Pool)
- National Electricity Market (NEM) of Australia
- New Zealand Electricity Market (NZEM).

Proposed Markets include:

- Northeast Regional Transmission Operator (NERTO)
- California Market Design 2002 (MD02)
- Mid-West ISO (MISO)

The design of a competitive wholesale market is determined by two fundamental principles: 1) competitive and efficient energy trading, and 2) reliable operation of the grid. From the different market structures, it is evident that there are significant differences in the design of energy trading and in the ways to conduct security constrained economic dispatch. Some markets have a day-ahead market for spot trading and some markets just have a day-ahead or an hour-ahead scheduling process to facilitate real time operation. Most overseas markets adopt a zonal model, but a majority of US markets use a nodal model. If energy trading (primary bilateral vs. day-ahead spot market) and congestion management (zonal vs. nodal) are the most important market design elements, it is possible to construct four options (combinations) for analysis.

New Electricity Trading Arrangements Market of England--Example

The electricity Pool of England and Wales, which served as the market for electricity trading in England and Wales since March 1990, was replaced in March 2001 by the New Energy Trading Arrangements (NETA). The Office of Gas and Electricity Markets (OFGEM), which regulates the UK's electricity industry, says that wholesale has increased significantly under NETA. Its extension to Scotland, called the British Electricity Trading and Transmission Arrangements (BETTA), started in 2004.

England and Wales had a customer base of 29 million in 2000, representing an estimated population of 59.5 million. Demand peaked at 51,012MW on January 16, 2001. Total generating capacity in England and Wales in the winter 2000/2001 was 67,695 MW, giving the area a reserve margin of 33%.

During the operation of the Electricity Pool of England and Wales, fuel use for power generation changed dramatically. While nuclear energy fluctuated between 21% and 29% of the total and hydro held steady at a low level (less than 1%), the use of coal for power generation decreased substantially—from 65% down to 36%--while oil decreased from 11% to 2%. Natural gas picked up the difference, rising from less than 1% in 1990 to more than 33% in 2000.

In a 2001 report OFGEM cited fundamental weaknesses of the pool, including '*wholesale electricity prices that had not fallen in line with reductions in generators' input costs; a lack of supply side pressure and demand side participation; and inflexible governance arrangements that had prevented reform of the arrangement.*'.Arrangements under the Electricity Pool also kept wholesale prices artificially high.

NETA was designed to allow a variety of markets to evolve, including bulk OTC trading, standardized products, power exchange trades, options/swaps, other financial instruments, and spot markets. The terms of these markets can range from several years to within a day.

It was designed to improve electric competition by substantially altering the incentives of market participants. The first year operation showed that the market for long-term contracts had expired quickly which provided investors with much improved opportunities for hedging. On the other hand, the overall price reduction sent an adverse signal of hesitation for the investment intention of investors.

About 37% of domestic gas and 38% of domestic electricity customers have exercised their choice to switch providers. Switching rates are higher than in many other competitive markets in Britain and higher than achieved in any gas and electricity market anywhere else in the world.

In conclusion, potential areas of improvement in the NETA Market that are being addressed are:

- The major deficiency of NETA was a dramatic decline in energy from CHP units and an exit of investors from this sector

- Attempts of OFGEM to introduce a Code of Behaviour for market participants failed, although abusive behaviours such as the DEC game have not been significant problems in the UK since NETA began
- The smaller generators' said that one of the main obstacles preventing them from participating in NETA was the difficulty they faced in using consolidation services that allow smaller generators to aggregate their output to sell it more competitively.

ACKNOWLEDGEMENT

The author acknowledges contributions made by Lawrence Musaba (Coordination Centre Manager, Southern African Power Pool, Harare, Zimbabwe); Pat Naidoo (Senior General Manager of Transmission Company, ESKOM, Johannesburg, South Africa); Alison Chikova (System Studies Supervisor, Southern African Power Pool, Harare, Zimbabwe); Bai K Blyden (Engineering Consultant, BBRM Group, LLC, Elk Grove, CA, USA); Mo-Shing Chen (Professor Emeritus, Director Energy Systems Research Center, University of Texas at Arlington, TX, USA); Bruno Kapandji Kalala (Permanent Secretary, PEAC); Wei-Jen Lee (Director, Energy Systems Research Center, The University of Texas at Arlington, Arlington, TX, USA); Ahmed Faheem Zobaa (Cairo University, Egypt); Terri Hathaway (International Rivers Network, Berkeley, CA, USA); Lori Pottinger (Editor World Rivers Review, Director Africa Program--International Rivers Network, Berkeley, CA, USA); F.T. Sparrow (Director, Power Pool Development Group, Purdue University, West Lafayette, IN, USA); Brian H. Bowen (Potter Engineering Center, Purdue University, West Lafayette, IN, USA); Stephen. M Gehl (Director Strategic Technology & Alliances, Electric Power Research Institute, Palo Alto, CA, USA); Prof. Nkulu (NEPAD); Richard Claudet (Cummins Inc, USA); and John Ayodele (WAPP).

E N D