September 15, 2005

IEEE POWER ENGINEERING SOCIETY
ENERGY DEVELOPMENT AND POWER GENERATION COMMITTEE

PANEL SESSION: AFRICAN REGIONAL POWER POOLS: STATUS, PLANS OF ACTION, FURTHER DEVELOPMENT AND RECOMMENDATIONS

Tom Hammons, Pat Naidoo and Bai Blyden

IEEE 2005 General Meeting, San Francisco Hilton Hotel, 12-16 June 2005
Wednesday June 15, Room Pending, 9:00 a.m.-1:00 p.m. and 2:00 p.m-6:00 p.m. (First Part).

Sponsored by: International Practices for Energy Development and Power Generation Subcommittee

Chairs: Tom Hammons, University of Glasgow, Scotland, UK.
Pat Naidoo, ESKOM, South Africa
Bai Blyden, BBRM Investments, LLC, USA

Track1 Understanding and Responding to System-Wide Events
Track 2 Securing New Sources of Energy

INTRODUCTION

On behalf of the Energy Development and Power Generation Committee, welcome to this Panel Session on African Regional Power Pools: Status, Plans of Action, Further Development and Recommendations

The Panel Session 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. The panel will therefore 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 as previously recognized by this body is acquiring a growing scale of importance in world practice. Examples of this influence and studies to date will be presented. Presentations will continue to 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 panel seeks to follow the paradigm of the EPRI road Map initiative that contemplates challenges of the 21st century.

Africa 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 Session presents some results of studies in this area at this time.

Panelists and Titles of their presentations are:

1. Lawrence Musaba, Coordination Centre Manager, Southern African Power Pool, Harare, Zimbabwe, Pat Naidoo, Senior General Manager of Transmission Company, ESKOM, Johannesburg, South Africa, and Alison Chikova, System Studies Supervisor, Southern African Power Pool, Harare, Zimbabwe. The Southern African Power Pool Formation: History and Future Challenges
2. Bai K Blyden, Engineering Consultant, BBRM Group, LLC, Elk Grove, CA USA. African Power Pool Development: Accelerating the Technical Skills Factor
3. Mo-Shing Chen, Professor Emeritus, University of Texas at Arlington, TX, USA. Security Issues of Power System Interconnection
4 Bruno Kapandji Kalala, Permanent Secretary, PEAC. CAPP, NEPAD and ECCAS
5. Wei-Jen Lee, Director, Energy Systems Research Center, The University of Texas at Arlington, Arlington, TX, USA. Technical Issues: Area Control Considerations etc in the WAPP and SAPP Areas
6. Ahmed Faheem Zobaa, Cairo University, Egypt. Southern Africa Power Pools and Southern African Development Community—An Overview
7, Terri Hathaway, International Rivers Network, Berkeley, CA, USA. and Lori Pottinger, Editor World Rivers Review, Director Africa Program--International Rivers Network, Berkeley, CA, USA. Hydropower and African Grid Development: A Rights Based Perspective
8. F.T. Sparrow, Director, Power Pool Development Group, Purdue University, West Lafayette, IN, USA and Brian H. Bowen, Potter Engineering Center, Purdue University, West Lafayette, IN, USA. The Future of SAPP, WAPP, CAPP, and EAPP
9. Stephen. M Gehl, Director Strategic Technology & Alliances, Electric Power Research Institute, Palo Alto, CA, USA. Targets and Technologies for African Electrification (Invited Discussion)
10. R.T. Mochebelele, Advisor Infrastructure, NEPAD Secretariat, South Africa. New Partnership for Africa's Development (Invited Discusser)
11. John Ayodele. West Africa Power Pool (WAPP) as a Tool for Regional Integration—Options on the Global Energy Market (Invited Discusser)

Each Panelist will speak for approximately 20 minutes. Each presentation will be discussed immediately following the respective presentation. There will be a further opportunity for discussion of the presentations following the final presentation.

Tom Hammons, (University of Glasgow, UK), Pat Naidoo (ESKOM), and Bai Blyden (BBRM Investments, USA) have organized the Panel Session.

Tom Hammons, Pat Naidoo and Bai Blyden moderate the Panel Session.

The first presentation is on The Southern African Power Pool Formation: History and Future Challenges It has been prepared by Lawrence Musaba, Coordination Centre Manager, Southern African Power Pool, Harare, Zimbabwe, Pat Naidoo, Senior General Manager of Transmission Company, ESKOM, Johannesburg, South Africa, and Alison Chikova, System Studies Supervisor, Southern African Power Pool, Harare, Zimbabwe. Pat Naidoo, Lawrence Musaba, and Alison Chikova will present it.

. Historically, electricity trading in Southern Africa started in the early 1960s as bilateral trade after the commissioning of the Kariba Hydro Power Station situated on the border between Zambia and Zimbabwe. The great hydro potential of the Zambezi River gave rise to the commissioning of more plants. This saw the extension and more bilateral electricity trading arrangements being put in place.

The Southern African Power Pool (SAPP) was created in April 1995 through the SADC treaty to optimize the use of available energy resources in the region and support one another during emergencies. At the time of creation, the SADC governments agreed to allow their national power utilities to enter into the necessary agreements that regulate the establishment and operation of the SAPP. This will be discussed in the presentation. Highlighted will be the resource potential and installed capacity of SAPP, the operations of SAPP, the achievements of SAPP, and a membership review of SAPP.

Lawrence Musaba is the Co-ordination Centre Manager for the Southern African Power Pool. He is an IEE Member and Chartered Engineer.
Pat Naidoo is the Senior General Manager for Eskom Transmission, South Africa.
Alison Chikova is the SAPP Supervisor System Studies. He is a Chartered Engineer and a Member of IEEE and IEE.

The second presentation is entitled: African Power Pool Development: Accelerating the Technical Skills Factor. It has been prepared by Bai K Blyden, Engineering Consultant, BBRM Group, LLC, USA. Bai Blyden will present it.

This presentation attempts to recommend paradigms to help develop and effectively share the necessary technical skills sets involved in the growing African Energy development sector represented by the various regional pools. The study is a follow up to a previous presentation focused on the opportunities the planning of these initiatives, present directly and indirectly. African Policy makers can effectively leverage the information mass created by planning of some of the energy development programs by integrating with various academic curricula within the framework of the growing field of knowledge management. The focus is on the South African power pool (SAPP), West African power pool (WAPP), Central African Power Pool (CAPP), East African Power Pool (EAPP) and interconnection initiatives in North Africa with ties to the Middle East

Bai K Blyden is Engineering Consultant, BBRM Investments, LLC, USA. He received the degree of MS.EE from Moscow Energetics Institute in 1979, specializing in Power Systems, Generation and Industrial Distribution Systems with a minor in Computers. He is currently a Project Manager with the Cummins Power Generation Group responsible for Distributed Generation CoGen projects in California where he resides. He has worked on over thirty power plants and their associated interconnections throughout his career in various capacities of Electrical Systems design, operations planning, management and construction. He has held consulting staff positions with various Utilities such as TVA, PG&E, The New York Power Authority, Entergy and TXU. He has lectured extensively on African Energy Development issues to Institutions and more recently to Investment groups. He is an early advocate of an Integrated African Grid and presented a conceptual framework and technical analysis for a centralized African Power pool with links to North Africa at the first IEEE Region 8 conference held in Nairobi, Kenya, December 1983.

The third presentation is on Security Issues of Power System Interconnection. It has been prepared and will be presented by Mo-Shing Chen, Professor Emeritus, University of Texas at Arlington, TX, USA.

Voltage stability, transient stability and dynamic stability studies are three approaches to power system security studies. For evaluation of the synchronous interconnection of the African regional power pools interconnection, security issues should be taken care of before any economic analysis is done. Power system security studies have been used in industries only in time of planning. This presentation will address a future real time security system that is in operation for deregulated power pools. Transient stability, dynamic stability, and voltage stability are included in the topics that will be addressed.

Dr. Mo-Shing Chen is an IEEE Fellow. Currently he is Emeritus Professor of Electrical Engineering at University of Texas at Arlington. He was recipient of the first Edison Power Engineering Educational Award. He has published more than 100 papers in IEEE and other professional journals

The fourth presentation is on the Central African Power Pool (CAPP), the Economic Community of Central African States (ECCAS) and the New Partnership for Africa's Development (NEPAD)**.** Bruno Kapandji Kalala, Permanent Secretary of PEAC, will make it

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The next (fifth) presentation is on. Technical Issues: Area Control Considerations in the WAPP and SAPP Areas. It has been prepared and will be presented by Wei-Jen Lee, Director, Energy Systems Research Center, The University of Texas at Arlington, Arlington, TX, USA

With a population of 13.4% of the world but only consumes 3% of world energy, Africa desperately needs cheap and clean energy for economic development and modernization. The Survey of Energy Resources conducted by the World Energy Council (WEC) in 2004 shows that Africa has more than enough energy to satisfy all its energy requirements. The resources are not evenly distributed within the continent. It is important to have cross-border interconnection of electricity grids and gas pipelines networks and joint development of new electrical generation projects to make the energy accessible to the general public. However, interconnecting AC networks will increase complexity of the system that may impact system reliability, security, and stability problems due to the interactions of equipment and control actions. This presentation uses the development of West Africa Power Pool (WAPP) and Southern Africa Power Pool (SAPP) to discuss area control considerations.

Wei-Jen Lee is Director, Energy Systems Research Center, The University of Texas at Arlington, Arlington, TX, USA.

The sixth presentation is entitled: Southern Africa Power Pools and Southern African Development Community: An Overview. Ahmed Faheem Zobaa, Cairo University, Egypt, will present it.

The Southern Africa Power Pool (SAPP) formed in late 1995 and the memorandum of understanding that was signed in December 1996 has guided its operations. SAPP includes twelve southern African power utilities, namely: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe and Zaire (now DRC). The main objectives of setting up the power pool are to ensure that all member utilities: co-operate and co-ordinate in the operation of their systems to minimize costs while maintaining reliability; fully recover costs; and share equitably in the resulting benefits. The Southern African Development Community (SADC). Member-states are Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. This presentation presents an overview of SAPP and SADC including status, plans of action, further development and recommendations.

Ahmed Faheem Zobaa received the B.Sc. (hons.), M.Sc. and Ph.D. degrees in Electrical Power & Machines from Cairo University, Giza, Egypt, in 1992, 1997 and 2002.

Currently, he is an Assistant Professor in the Department of Electrical Power & Machines, Faculty of Engineering, Cairo University. He regularly reviews papers for eight IEEE Transactions especially IEEE/PES transactions and seven journals in his areas of interest. He is author or co-author of many refereed Journal and Conference papers. His areas of research include harmonics, compensation of reactive power, power quality, photovoltaics, wind energy, education and distance learning. Dr. Zobaa is a member of the IEEE Power Engineering / Industry Applications / Industrial Electronics / Power Electronics Societies, the Institution of Electrical Engineers and the International Solar Energy Society.

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The seventh presentation is entitled: Hydropower and African Grid Development: A Rights Based Perspective. It has been prepared by Terri Hathaway, International Rivers Network, Berkeley, CA, USA. and Lori Pottinger, Editor World Rivers Review, Director Africa Program--International Rivers Network, Berkeley, CA, USA. Terri Hathaway will present it.

Many political and economic entities involved in planning Africa's energy development, specifically hydropower and regional grids, are promoting poverty alleviation and sustainable development as key goals, but utilizing strategies to promote infrastructure that will undermine these goals. Project planning under NEPAD and other bodies continues to lack transparency and civil society participation, resulting in projects that are not meeting the needs of the greater population. A rights-based approach to African grid development would promote people centered decision-making that would ensure human rights are promoted and protected, and equitable and sustainable development occurs. In the presentation these aspects will be critically evaluated and discussed.

Terri Hathaway is a campaigner with the Africa Program at International Rivers Network (IRN), an international non-governmental organization based in Berkeley, California. IRN supports local communities working to protect their rivers and watersheds. It works to halt destructive river development projects and encourages equitable and sustainable methods of meeting needs for water, energy and flood management.

The eighth presentation is entitled: The Future of SAPP, WAPP, CAPP, and EAPP. F.T. Sparrow, Director, Power Pool Development Group, Purdue University, West Lafayette, IN, USA and Brian H. Bowen, Potter Engineering Center, Purdue University, West Lafayette, IN, USA has prepared it. Professor F.T. Sparrow will present it

Vital new transmission lines are high on the agenda of energy planners in the various regions of Africa. These lines are identified within the power pools of Southern Africa and West Africa. The Central Africa Power Pool is in the process of identifying these lines, as also is the East Africa region. What are the economic gains from these new lines and what are the plans for a continent wide network? The power pool modeling at Purdue University is helping utilities across Africa to answer these questions. This presentation outlines some of the transmission modeling issues that are being considered at Purdue and with colleagues across Africa.

F.T. Sparrow has been Professor of Industrial Engineering and Economics at Purdue University since 1978. He has a Ph.D. in economics and operations research from the University of Michigan. He is Director of the Purdue Power Pool Development Group (PPDG) and Center for Coal Technology Research (CCTR) with his interdisciplinary interests focusing on energy modeling and analysis. Honored as a Ford Foundation research professor, he is also a consultant to various agencies and utilities.

Brian H. Bowen is Associate Director of the Power Pool Development Group, PPDG, at Purdue University, where he received his Ph.D. in industrial engineering. Before his association with Purdue University he worked in West Africa and Southern Africa for 17 years in engineering education and on energy (UK contracts). His research interests are in economic development and power pool cooperative infrastructures.

The ninth presentation is by Stephen M. Gehl, Director of Strategic Technology & Alliances, Electric Power Research Institute (EPRI), Palo Alto, CA, USA. It is entitled 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 their well-being. 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 presentation 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. The discussion describes 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.

It also describes 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, 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 will provide a balanced portfolio of generation options that will be robust over a range of country-specific conditions.

Finally, the presentation discusses grid options, from large, long distance transmission systems to local "minigrids" for village power solutions.

Stephen Gehl has over 25 years of experience in defining technology responses to the issues and opportunities of the electric power industry. Currently, he is the Director of Strategic Technology at the Electric Power Research Institute. He leads the Electricity Technology Roadmap initiative. The Roadmap is a guide for strategic technology development efforts in the electricity industry. In this capacity, he has worked with over 200 organizations, both domestic and international, to define electricity-related business and societal needs and aspirations and the technologies that will allow us to attain these aspirations.

The penultimate presentation is given by R. T. Mochebelele, Advisor, Infrastructure, NEPAD Secretariat, South Africa. It is entitled: New Partnership for Africa's Development. It is an Invited Discussion.

The West Africa Power Pool Program (WAPP) is a means by which the utilities in the member countries of the Economic community of West African States, ECOWAS, decided to come together to pool the electricity resources together for cheaper and quality electric power to their citizens. This is examined in the presentation.

The final presentation is also an invited discussion. It is entitled: West Africa Power Pool (WAPP) as a Tool for Regional Integration: Options in the Global Energy Market. John Ayodele will make it

The West Africa Power Pool Program (WAPP) is a means by which the utilities in the member countries of the Economic community of West African States, ECOWAS, decided to come together to pool the electricity resources for cheaper and quality electric power to their citizens

The 14 countries of ECOWAS have agreed to integrate their electric Systems so that cheaper power can flow in either direction. This will allow poorer countries with no recourses to embark on capital-intensive hydro/thermal power plants to be able to import power form other countries with reserve power.

However, as will be seen in this presentation, many challenges face the Pool System, from institutional setup to pricing and wheeling charges. Above all, building the bridges that will allow electric currents to flow, the funds required, and how utilities will contribute and pay for services with little internally generated recourses. In other words, the financing options which will include private investment participation, donor agencies, government funds etc, must be pooled to ensure that lines and substations required for pooling of National Electricity Systems are met.

The USAID funded a Regional Transmission Study to develop a master plan for the future development of the Regional Transmission development over a period 2004 – 2020. The study was done in close collaboration with WAPP Utilities, the World Bank and lenders. USAID had earlier commissioned the Purdue University Power Pool Development Group to produce a Long-Term Expansion Model for a 20-year planning system for energy and reserve trade between the countries with autonomy constraints.

The fact that there are about 5_currencies in the monetary system will not help the scenario and consequently, the efforts of the ECOWAS Executive Secretariat is to try to integrate the currencies into a single unit currency, the ECO. This will in no small way assist in this integration program.

This presentation will also summarize efforts made to date, the donors and various governments and will give an insight to the status and the way forward for WAPP.

PANEL SESSION SUMMARIES

0. PANEL SESSION INTRODUCTIONS

The Panel Session 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. The panel will therefore 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 as previously recognized by this body is acquiring a growing scale of importance in world practice. Examples of this influence and studies to date will be presented. Presentations will continue to 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. The effort to limit GHG emission is one such major benefit as is system operational reliability and quality of supply. Modeling developing regional grids remain core to the strategy of wider institutional integration, and in particular academia where core analytical skill sets critical to knowledge base economies reside. Therefore, the power pools as case studies in academic curricula and integrated with global 'lessons learned' allows for the creation of dynamically linked knowledge bases and their resulting derivatives to engineering in society. The panel seeks to follow the paradigm of the EPRI road Map initiative that contemplates challenges of the 21st century.

Africa, Asia and the Middle East are very favorable regions 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 Africa, European and Middle Eastern Electricity interconnections and efforts to improve efficiency and limit GHG emission and bridging the digital divide are very important problems.

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Power Pool, Harare, Zimbabwe. The Southern African Power Pool Formation: History and Future Challenges (Paper 05GM0505)

2. Bai K Blyden, Engineering Consultant, BBRM Group, LLC, Elk Grove, CA USA. African Power Pool Development: Accelerating the Technical Skills Factor (Paper 05GM1057)
3. Mo-Shing Chen, Professor Emeritus, University of Texas at Arlington, TX, USA. Security Issues of Power System Interconnection (Paper 05GM0391)
4 Bruno Kapandji Kalala, Permanent Secretary, PEAC. CAPP, NEPAD and ECCAS. (Paper 05GM1065)
5. Wei-Jen Lee, Director, Energy Systems Research Center, The University of Texas at Arlington, Arlington, TX, USA. Technical Issues: Area Control Considerations etc in the WAPP and SAPP Areas (Paper 05GM0507)
6. Ahmed Faheem Zobaa, Cairo University, Egypt. Southern Africa Power Pools and Southern African Development Community—An Overview (Paper 05GM0038)
7, Terri Hathaway, International Rivers Network, Berkeley, CA, USA. and Lori Pottinger, Editor World Rivers Review, Director Africa Program--International Rivers Network, Berkeley, CA, USA. Hydropower and African Grid Development: A Rights Based Perspective (Paper 05GM0884
8. F.T. Sparrow, Director, Power Pool Development Group, Purdue University, West Lafayette, IN, USA and Brian H. Bowen, Potter Engineering Center, Purdue University, West Lafayette, IN, USA. The Future of SAPP, WAPP, CAPP, and EAPP (Paper 05GM0597)
9. Stephen. M Gehl, Director Strategic Technology & Alliances, Electric Power Research Institute, Palo Alto, CA, USA. Targets and Technologies for African Electrification (Invited Discussion) (Paper 05 GM 0874)
10. R. T. Mochebelele, Advisor Infrastructure, NEPAD Secretariat South Africa. New Partnership for Africa's Development (Invited Discussion).
11. John Ayodele. West Africa Power Pool (WAPP) as a Tool for Regional Integration—Options on the Global Energy Market (Paper 05GM1083) (Invited Discusser)

1. THE SOUTHERN AFRICAN POWER POOL FORMATION: HISTORY AND FUTURE CHALLENGES (PAPER 05GM0505)

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

Abstract

Historically electricity trading in Southern Africa started in the early 1960 as bilateral trade after the commissioning of the Kariba Hydro Power Station situated on the border between Zambia and Zimbabwe. The great hydro potential of the Zambezi River gave rise to the commissioning of more plants. This saw the extension and more bilateral electricity trading arrangements being put in place.

The Southern African Power Pool (SAPP) was created in April 1995 through the SADC treaty to optimize the use of available energy resources in the region and support one another during emergencies. At the time of creation, the SADC governments agreed to allow their national power utilities to enter into the necessary agreements that regulate the establishment and operation of the SAPP.

The past, the present and the future of SAPP would be addressed in this paper. SAPP is transforming from a cooperative into a competitive pool.
Keywords**:** Power Pool, Competitive Markets

1. Introduction

Four agreements govern the operation of SAPP, including bilateral trading. These agreements are:

1) The *Inter-Governmental Memorandum of Understanding* which enables the establishment of SAPP;
2) The *Inter-Utility Memorandum of Understanding*, which establishes SAPP's basic management and operating principles;
3) The *Agreement Between Operating Members* which establishes the specific rules of operation and pricing; and
4) The *Operating Guidelines*, which provide standards and operating guidelines.

The Pool is comprised of twelve SADC members' states of which nine are operating members. Angola, Malawi and Tanzania are non-operating members since they are not connected to the other SAPP countries.

2. Resource Potential and Installed Capacity

The total installed capacity in SAPP is about 50,000MW. Eskom of South Africa produces eighty percent of the total generation in SAPP and about seventy four percent of the total energy produced in SAPP is from thermal stations. See Table 1.

3. Operations of SAPP

The major activities of SAPP are carried out through various Sub-Committees, which include the Executive, Management, Operating, Planning and Environmental Committees.

Table1. SAPP Installed Capacity

Country	*Utility*	*Installed Capacity [MW]*	*Net Capacity [MW]*
Angola	ENE	742	590
Botswana	BPC	132	120
Lesotho	LEC	72	70
Malawi	ESCOM	305	261
Mozambique	EDM /HCB	2,382	2,250
Namibia	NamPower	393	390
South Africa	Eskom	42,011	36,208
Swaziland	SEB	51	50
Tanzania	TANESCO	591	480
DRC	SNEL	2,442	1,170
Zambia	ZESCO	1,632	1,630
Zimbabwe	ZESA	1,990	1,825
TOTAL		**52,743**	**45,044**

4. Achievements of SAPP

The volume of bilateral electricity trading has been increasing mainly due to the commissioning of the following interconnectors:

- Mozambique – Zimbabwe 400 kV interconnector
- Zimbabwe - Botswana-South Africa 400 kV interconnector
- DRC - Zambia 220 kV interconnector

In April 2001, SAPP introduced the Short Term Energy Market (STEM) to complement the bilateral trade. This market is now 5 % (approximately 144 - GWh per annum) of the total trade in SAPP in term of the volumes traded. The SAPP successfully opened the Coordination Centre in Harare 2000. This is where central coordinating issues are carried out including the administering and management of the STEM

5. The Future of SAPP

SAPP is now developing a Spot Market with the assistance of NordPool Consulting through the funding from NORAD. Competitive trading arrangements are to be put in place. One of the major objectives is to have the following transmission interconnectors commissioned:
Zambia – Tanzania – Kenya 330 kV interconnector

- Mozambique – Malawi 330 kV interconnector
- The Western Power Corridor that aims to interconnect Inga in DRC to Angola, Namibia, Botswana and South Africa.

Major transmission constraints have been noted between Zimbabwe – Botswana and South Africa. This is due to the geographical locations of the countries where major trading is from South to North and vice versa depending on time of day. Utilities have entered into different peak and off peak contracts.

The Grand Inga site in the Democratic Republic of Congo (DRC) has got a hydro potential of close to 40 000 MW. It is the desire of the DRC to develop this site to its full potential for the benefit of Northern and Southern Africa. The realization of the interconnection of DRC to the Northern countries would mark the beginning of an interconnected African Grid. The Zambia – Tanzania – Kenya Interconnector would also facilitate the interconnection to Eastern Africa. Africa can utilize the diversity in resources and time differentials for the economic dispatch of the generating units.

6. SAPP Membership Review

A Special Documentation Review Working Group (DRWG) was set up to review the SAPP documents so as to considered admitting Independent Power Producers (IPP) and Independent Transmission Companies (ITC) into SAPP. Figure 1 is the proposed new composition structure:

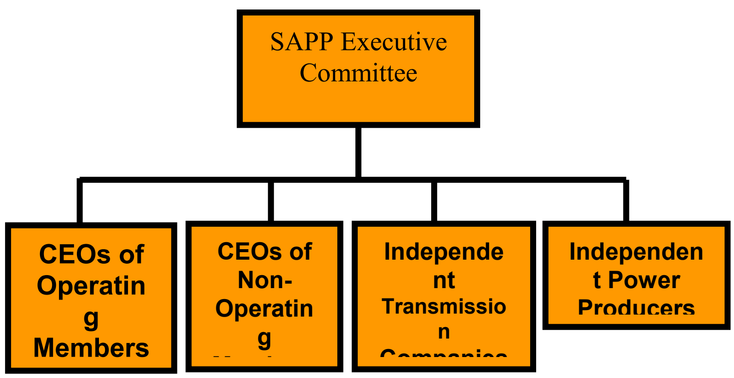


Figure 1. Composition of Executive Committee

The proposed representation is as follows:

- One representative from each operating member, one from each non-operating member, one from each ITC and one from each IPP.
- Each member will carry one vote.
- Chairmanship will be restricted to the CEOs from Government owned Power Utilities that are Operating Members.

The overall proposed restructuring of SAPP is shown in Figure 2. The restructuring of SADC has necessitated this. Also as SAPP is moving towards competitive markets the Markets Sub-Committee has been introduced.

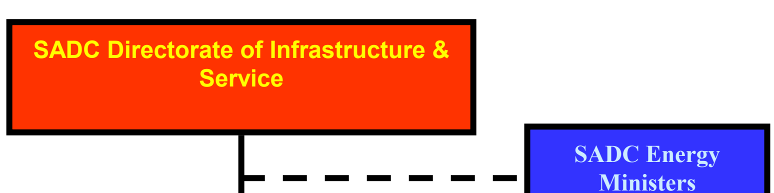


Figure 2.: **SAPP Management Structure**

Biographies

Lawrence Musaba is the Co-ordination Centre Manager for the Southern African Power Pool. He is an IEE Member and Chartered Engineer. Contact details are as follows:

Pat Naidoo is the Senior General Manager for Eskom Transmission, South Africa.

Alison Chikova is the SAPP Supervisor System Studies. He is a Chartered Engineer and a Member of IEEE and IEE. Contact details are as follows:

2. AFRICAN POWER POOL DEVELOPMENT: ACCELERATING THE TECHNICAL SKILLS FACTOR (PAPER 05GM1057)

Bai K Blyden, Engineering Consultant, BRM Group, LLC, Elk Grove, CA, USA

Abstract

This paper attempts to recommend paradigms to help develop and effectively share the necessary technical skills sets involved in the growing African Energy development sector represented by the various regional pools. This study is a follow up to a previous presentation focused on the opportunities the planning of these initiatives present directly and indirectly. The thesis being that African Policy makers can effectively leverage the information mass created by the planning of some of these energy development programs by integrating with various academic curricula within the framework of the growing field of knowledge management. The focus is on the South African power pool (SAPP), West African power pool (WAPP), Central African Power Pool (CAPP), East African Power Pool (EAPP) and interconnection initiatives in North Africa with ties to the Middle East

Definitions

Ba can be thought of as a shared space for emerging relationships. **Ba** provides a platform for advancing individual and or collective knowledge. (Ref.1a)
AAU-The Association of African Universities. (Ref.1b)
ICT-Information, Communications, Technology
AVU-African Virtual University
EPRI-Electric Power Research Institute
SST –Strategic Science & Technology
COREVIP-Conference of Rectors, Vice Chancellors and Presidents of the AAU

Introduction

This paper serves as a follow-up to IEEE Africa Panel Session 2004, Denver, ref.8 where several recommendations associated with development in the energy sector and the spin offs for human capital development were introduced. Details of the Knowledge Engine (Ref.6), The EPRI Road Map Initiative & SST, the status and goals of the Association of African Universities and the African Virtual University will be examined in proceeding paragraphs.

Existing Programs and Initiatives

EPRI & SST

As part of the Road Map Initiative discussed in Ref.6 EPRI has adopted a strategy whereby SS&T provides the strategic resources for EPRI's integrated R&D planning process, helping connect the specific technical objectives of EPRI's sector programs with the broad societal goals defined by the Road Map. SS&T concentrates on a set of 15 *limiting challenges* representing critical issues and opportunities facing the electricity enterprise and society along with the associated gaps in knowledge and technological capability. The limiting challenges link the destinations identified by the Road Map with the objectives of EPRI's sector programs. The *15 limiting challenges* listed below shall serve as 'guide posts' for integration as we examine the present status of ICT Programs in Africa ref.2

- Improved Transmission Capacity, Grid Control, and Stability
- Maintain and Strengthen Portfolio of Generation Options
- Accelerated Development of Carbon Capture an storage Technologies
- Creation of the Infrastructure for a Digital Society
- Improved Methods for Communicating and Applying Scientific Knowledge
- Improved Power Quality and Reliability for Precision Electricity Users
- Increasing Robustness, Resilience, and Security of Energy Infrastructure
- Advances in Enabling Technology Platforms
- Exploiting the Strategic Value of Storage Technologies
- Transformation of Electricity Markets
- Ecological Assessment Management
- High Efficiency End Uses of Energy
- Maintaining and Improving Water Availability and Quality
- Global Electrification
- Development of Electricity-Based Transportation Systems

Association of African Universities

The association of African Universities is an international NGO set up by the universities in Africa to promote cooperation among themselves and between them and the international community. The AAU maintains the following objectives Ref. 1b

- To promote interchange, contact and cooperation among university institutions in Africa;
- To collect, classify and disseminate information on higher education and research, particularly in Africa;
- To promote cooperation among African Institutions in curriculum development, and in the determination of equivalence of degrees;
- To encourage increased contracts between its members and the international academic world;
- To study and make known the educational and related needs of African university institutions and, as far as practicable, to coordinate the means whereby those needs may be met;
- To organize, encourage and support seminars and conferences between African university teachers, administrators and others dealing with problems of higher education in Africa.

"*The association is committed to work closely with the AU and to develop structures through which to effect cooperation with the AAU. The conference of Rectors, Vice Chancellors and Presidents (COREVIP) of the Association of African Universities (AAU) declared at the 2003 meeting in Mauritius its Vision and Strategic plan for the next decade ids for the AAU to be "an association of choice for higher education institutions throughout Africa, and the voice of the African Higher education community*" Ref.1b

African Virtual University

The AVU is another institution targeted in this study as a strategic platform from which to 'extract' and develop talent for the African Energy development sector. The following excerpt serves to describe its current status and some of the local challenges.

*"The **African Virtual University,** based at Kenyatta University, in Kenya, and financed, at least for now, by the World Bank. Participating universities across the continent, numbering more than 20 and*

growing, offer live and videotaped courses via satellite. During the live broadcasts, students can communicate with instructors via e-mail and fax, and sometimes by telephone.

The courses are mainly in mathematics, science, and information technology, says William Saint, a senior education specialist at the World Bank. "The idea is to cover subject areas where there are shortages," he says. "In extreme cases, some universities that have lost key staff cannot offer courses required for a degree. The African Virtual University can fill in those gaps."

Educators in Africa speak in ambitious terms about using distance-education technology to solve one of their most pressing problems: the overwhelming increase in demand for higher education.

The idea of high-school graduates from rural Tanzania or Togo pursuing postsecondary education through a village "Internet cafe" may seem far-fetched. But why not? asks Paul West, director of the Center for Lifelong Learning, at Technikon S.A., a South African distance-learning university. "With satellites instead of telephone lines, and solar-power generators instead of electricity, it's possible," he says.

Other experts, however, keep their enthusiasm in check. They point to the high costs not only of buying the right technology, but also of maintaining it with trained personnel. "Distance education is not going to solve all the problems" of African higher education, says Ms. Levey.

Confronted by an often bewildering and intoxicating range of options, Africa's university leaders say they must pick and choose with a clear sense of vision. Planning is key, they agree. "If each of us does not have strong policies on technology, we will just go in circles," says Sharon Siverts, vice-chancellor of the University of Botswana. She and other campus officials have called on the Association of African Universities to draft guidelines that institutions can use in developing strategic information-technology plans.

In addition to increasing their technological capacity, African academics are being urged to develop more local content for the Internet. According to Mr. Jensen, the South African researcher, only 0.022 per cent of all sites on the World-Wide Web last year were based in Africa.ref.3

Challenges and Solutions

The following excerpt is appropriate in identifying some of the current challenges and solutions to integrating the Knowledge Engine recommended under this study.

"A survey by the Association of African Universities in 1998 found that 52 of the 232 academic and research institutions responding had full Internet connectivity, while the 180 others had access that was "inadequate."

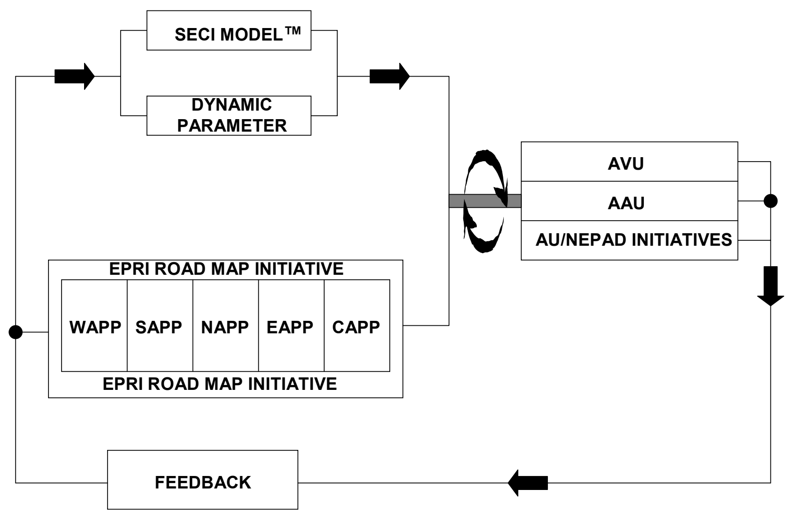
Many African universities are facing severe financial crises. In some countries they have been overwhelmed by sharp declines in government support and an exponential increase in demand for higher education. The dire lack of funds and the competition for scarce resources have simply made it impossible for many institutions to tap into the technological revolution. "My department doesn't even have a photocopier," says a professor at the University of Nairobi, in Kenya.

The limited degree of university Internet connectivity mirrors larger trends on a continent where most countries lag far behind much of the world in exploiting the potential of information technology for their people.

Out of a total population of 750 million people, Africa has only about one million Internet users -- and 85 to 90 per cent of them live in South Africa, according to Mike Jensen, an independent consultant *based in South Africa who specializes in Internet issues in Africa. He maintains a site on the World-Wide Web (http://www3.sn.apc.org/africa) that is dedicated to the subject. Subtracting South Africa from the equation, the figures show one Internet user for every 5,000 people in Africa, compared with one user per every 38 people worldwide, and one per every five people in Western countries.*

Conclusion

THE KNOWLEDGE ENGINE ™



The application of the Knowledge Engine to the AAU and AVU Infrastructure is but another instance of **(Ba)** by which the fast pace of information importance and knowledge management can serve in a dynamic role to accelerate development while recognizing the challenges of Basic infrastructure inadequacies.
The Power pool development programs (ref.7) strategically mapped against the *15 limiting challenges* delineated under the EPRI program casts the 'widest net' for developing 'Local Content'. Connecting the various institutions through a dedicated INTRANET developed from the minimal infrastructure recommendations discussed in previous paragraph Further examination of the societal impact brought on by current and planned development of these should yield the strategic direction for human capital development on a domestic and international level.

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BIOGRAPHY

Bai K Blyden, Engineering Consultant, BBRM Investments, LLC, USA. Bai Blyden received the degree of MS.EE from Moscow Energetics institute in 1979. Specializing in Power Systems, Generation and Industrial Distribution Systems with a minor in Computers. He is currently a Project Manager with the Cummins Power Generation Group responsible for Distributed Generation CoGen projects in California where he resides. Mr. Blyden has worked on over thirty power plants and their associated interconnections throughout his career in various capacities of Electrical Systems design, operations planning, management and construction. He has held consulting staff positions with various Utilities such as TVA, PG&E, The New York Power Authority, Entergy and TXU. He has also been a Project Engineer for major AE firms in the Power industry including Bechtel, Asea Brown Boveri, Stone & Webster and Dravo/Gibbs & Hill. While at ABB Mr.Blyden successfully led engineering teams that prepared Kansas Gas & Electric 950 MW Wolf Creek Nuclear Plant and Georgia Power's 2 x 1215 MW Plant Vogtle for Nuclear Regulatory Commission Electrical Distribution Safety Functional Inspection audits (EDSFI). He most recently served as a Project Manager on the CALPINE California Emergency Peaker Program which planned and managed the construction of eleven (45 MW) emergency GE LM6000 gas turbine Peaker units around Silicon valley during the 2001 CA Energy Crisis. He is a member of the IEEE International Practices Subcommittee and serves as consultant to GENI (Global Energy Network International). Bai Blyden is the author of several papers on African Energy Development published in various IEEE publications (1983-2004). He introduced the theoretical concept of a 'Dynamic Parameter', which he presented at MIT and at the IEEE Systems, Man and Cybernetics society conference, 1992 relating to Expert Systems and Artificial Intelligence applications for Power Plants. He has lectured extensively on African Energy Development issues to Institutions and more recently to Investment groups. Mr. Blyden is an early advocate of an Integrated African Grid and presented a conceptual framework and technical analysis for a centralized African Power pool with links to North Africa at the first IEEE Region 8 conference held in Nairobi, Kenya, December 1983.

3. SECURITY ISSUES OF POWER SYSTEM INTERCONNECTION (PAPER 05GM0391)

Mo-Shing Chen, Professor Emeritus, Energy Systems Research Center, University of Texas at Arlington, TX, USA

Abstract

Voltage stability, transient stability and dynamic stability studies are three approaches to power system security studies.
For evaluation of the synchronous interconnection of the African regional power pools interconnection, security issues should be taken care of before any economic analysis is done. Power system security studies have been used in industries only in time of planning. This paper will address a future real time security system in operation of a deregulated power pools.
Keywords: Voltage stability, transient stability, dynamic stability, real-time, security, power system operation, power system margin

1. Introduction of Stability

Stability is categorized as synchronous or angular stability and voltage stability depending on the quantities in which one is interested. Synchronous stability is focused on rotor angles or frequencies of generators and voltage stability is focused on bus voltages. Depending on the time-period one is observing, stability can be categorized as transient stability and dynamic stability. The observed time-period for transient stability is about a couple of swings after the disturbance. That of dynamic stability is normally 1 to 6 seconds after the disturbance. However, if necessary, the simulation time can be longer than 10 seconds. Table 1 summarizes different categories of stability.

Table 1 Categories of Power System Stability

	Transient Stability	**Dynamic Stability**
Synchronous Stability	Observe transient response (1 Swings after disturbance) of generators	Observe dynamic response (1~6 Seconds after disturbance) of generat
Voltage Stability	Observe transient response (1 2 swings after disturbance) of bus voltages	Observe dynamic response (1~6 Seconds after disturbance) of bus voltages

2. Transient Stability

For transient stability, one is interested in the system ability to survive a large disturbance, such as a fault, or a sudden change in generation, load, or system configuration, without a prolonged loss of synchronism. In this part, people just look at the rotor angle behavior of generators after the disturbance. The system is said to be stable in transient state if the rotor angle separation between any two machines tends to keep in a certain range after the disturbance. On the other hand, the system is transient unstable if the rotor angles keep running away.

Figure 1 illustrates the stable and unstable cases during a transient period for a four-machine system. Figure1 (a) is stable case because the difference between any two-rotor angles is within a certain range though the rotors are speeding up. Figure 1(b) shows generators separated in two groups and their rotor angles continue to drift apart. Therefore, (b) is unstable case.

2. Dynamic Stability

Dynamic stability is the ability of a power system to return to its initial state or reach another steady state nearby after a small disturbance. Dynamic stability of a system can be understood by looking at the damping of the system oscillation, which can be triggered by either an unexpected disturbance, or a regular operation of the power system. The oscillation should die out in several seconds after the disturbance for a strong system, Figure 2(a). If the oscillation is decaying slowly, Figure 2(b), then the system has bad dynamic characteristics. If the system has a lasting oscillation, Figure 2(c), or even diverging oscillation, Figure 2(d), the system is dynamically unstable. The poor damping of the oscillation signals a narrow stability margin of the power system. With this small margin, the system operators must be very careful when they are executing the system operations because the operation criteria might not apply. The same operation might drive the system to an unstable area though it was good yesterday.

In a power system, it may be stable during transient period but unstable during dynamic period, as shown in Figure 3.

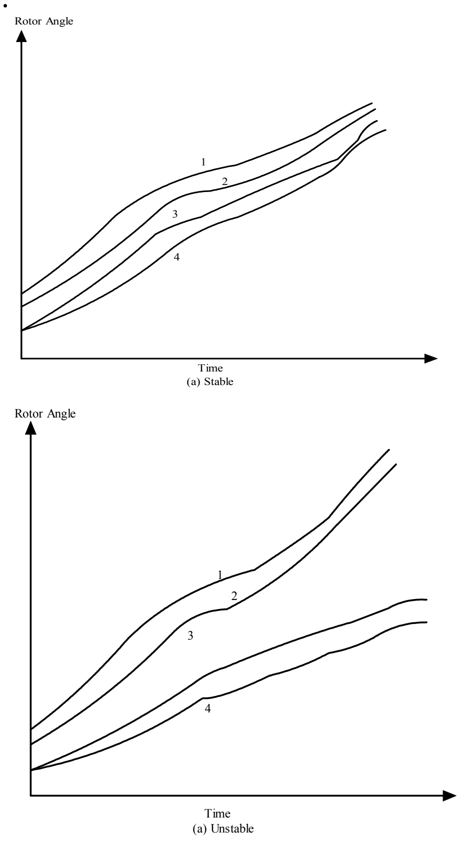
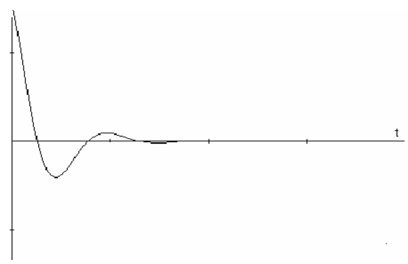
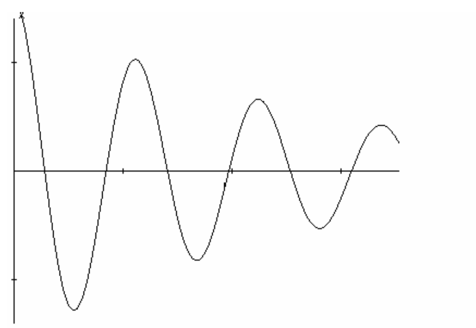


Figure 1. Rotor Angle Behavior during a Transient

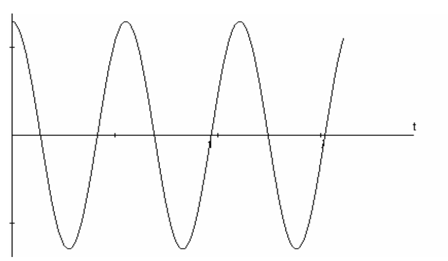
Both of two generators speed up after the fault and one would say that the system is transient stable from the first swing of rotor angles. After the first swing, the rotor angles begin a divergent oscillation, which is unstable. One of the phenomena of dynamic stability problems is the oscillation. The frequency of the oscillation is between 0.2 and 10 Hz. Thus, this oscillation is called low frequency oscillation since its frequency is low compared to system frequency.



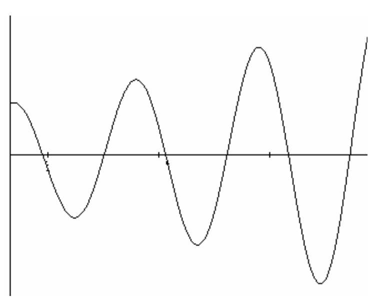
(a)



(b)



(c)



(d)

Figure 2. Oscillations

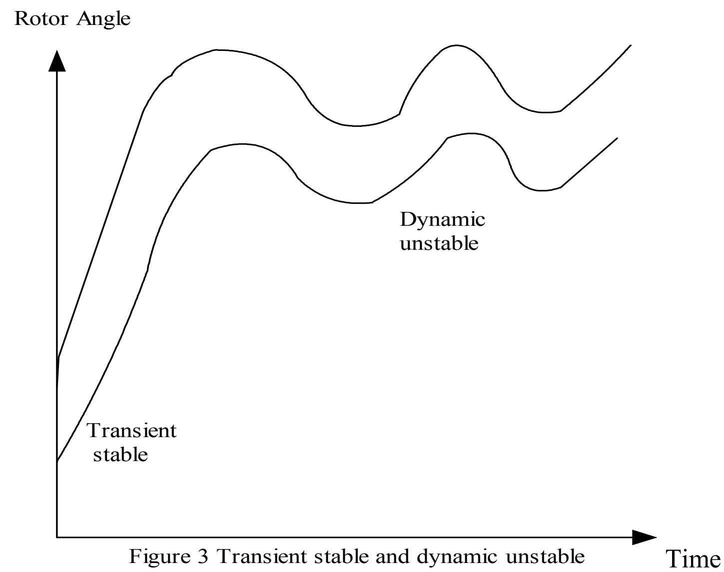
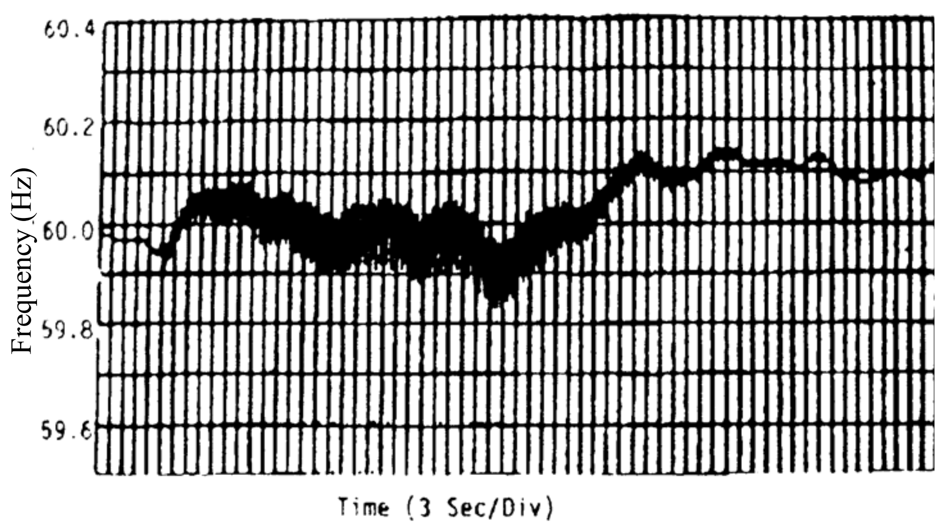


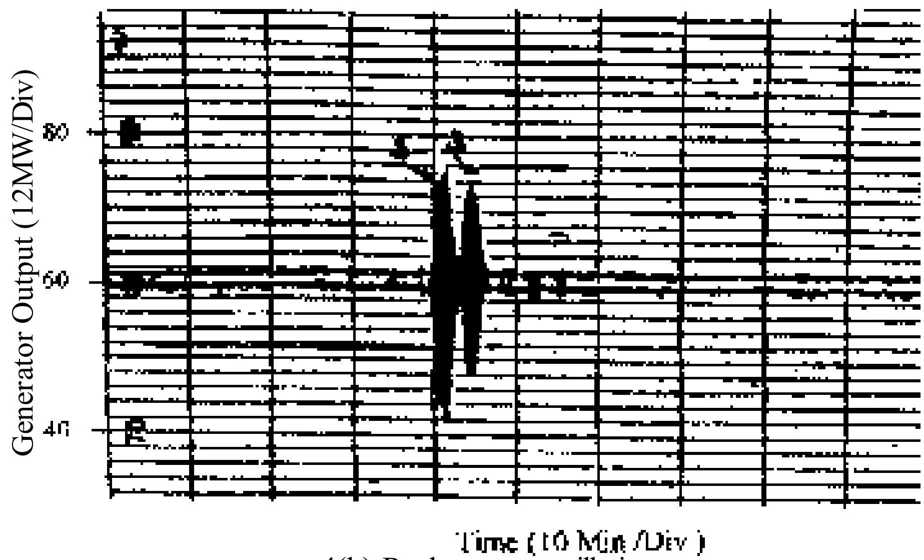
Figure 3 Transient stable and dynamic unstable

System oscillation is often found in an interconnected system. Power oscillation begins when the power flow on the tie line linking two areas in the system increases to some level. The oscillation disappears if the power flow is reduced. Therefore, the transmission capacities of tie lines are subject to a stability limit and, unfortunately, the stability limit is normally lower than thermal limit.

System dynamic characteristics are changing not only with system expansion, but also with system operation. The power system might have spontaneous low frequency oscillation without any known specific disturbance if the system is operating near the dynamic stability margin. Actually, there must be some but not special disturbance. Because the system is near the margin, this disturbance happens to drive the system to an unstable area and triggers the spontaneous oscillation. Once the disturbance disappears, the oscillation will be decaying slowly. Figure 4 is the example of a spontaneous low frequency oscillation observed on April 1991 in a power system. The oscillation frequency is about 0.8 Hz. Figure 4(a) is the system frequency oscillation and 4(b) is the real power oscillation of a nuclear unit.



4(a) System Frequency Oscillation



4(b) Real power oscillation
Spontaneous low frequency oscillation

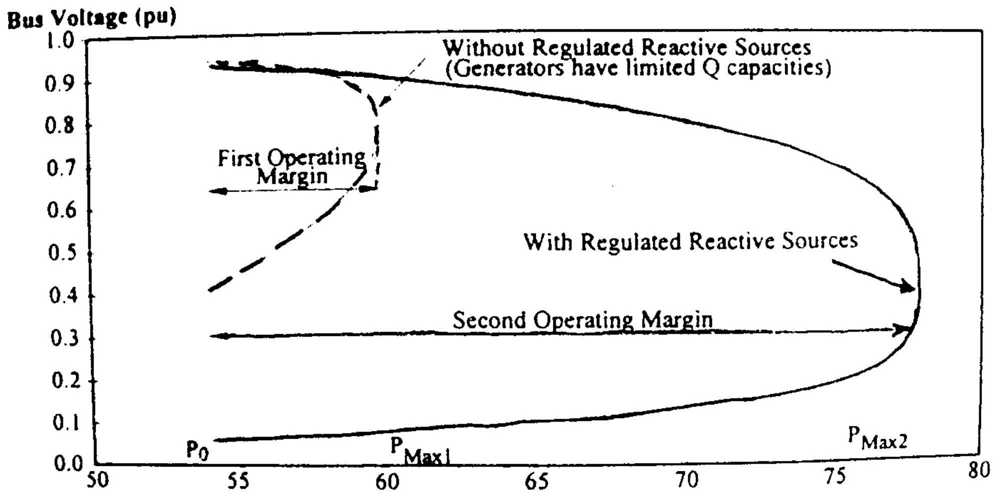
Since the power system is always subject to small disturbances, dynamic stability is essential for system operation, particularly if the system is operated at a tight dynamic stability margin.

4. Voltage Stability

Power system shall be operated securely not only in usual conditions, but also when there exist disturbances. The power system is stable when the system is able to restore to its initial condition or reach another steady state, which is acceptable in terms of operational standards after experiencing a disturbance. For voltage stability, the system should be able to keep the magnitudes of bus voltages when experiencing the disturbance.

Power failures caused by voltage instability, or so called voltage collapse, that led to power system blackouts have been reported in many countries, such as Sweden, France, Japan and the United States of America (including Aug-2003 Blackout). The affected area, because of voltage instability, can be metropolitan or nation wide. The effects are not only in power interruption to customers, but also in mass transportation and industrial manufacturing. The losses to the power utility are in both finance and customer service.

Voltage collapse is generally caused by increasing load and the deficient reactive power supply. It is a combinatorial problem affected by both system and load characteristics. The power-voltage characteristics of a power system are represented by a P-V curve. In the Figure 5, one of the P-V curves represents the present system, which has limited reactive sources. The other curve shows the PV curve with plenty of regulating reactive source devices.



System Load (GW)

Fig 5 PV curve of a power system

It is clear from the figure that the degree of stability cannot be judged based on how close the bus voltage is to the normal level. The power industry is basically just using the magnitude of bus voltage as a measurement of voltage stability.

5. Today's Congestion Management

- Only check the thermal limit
- Real-time limit is not there
- No voltage stability limit
- No transient stability limit
- No dynamic stability limit
- The responsibility of system congestion due to single contingency is not clear

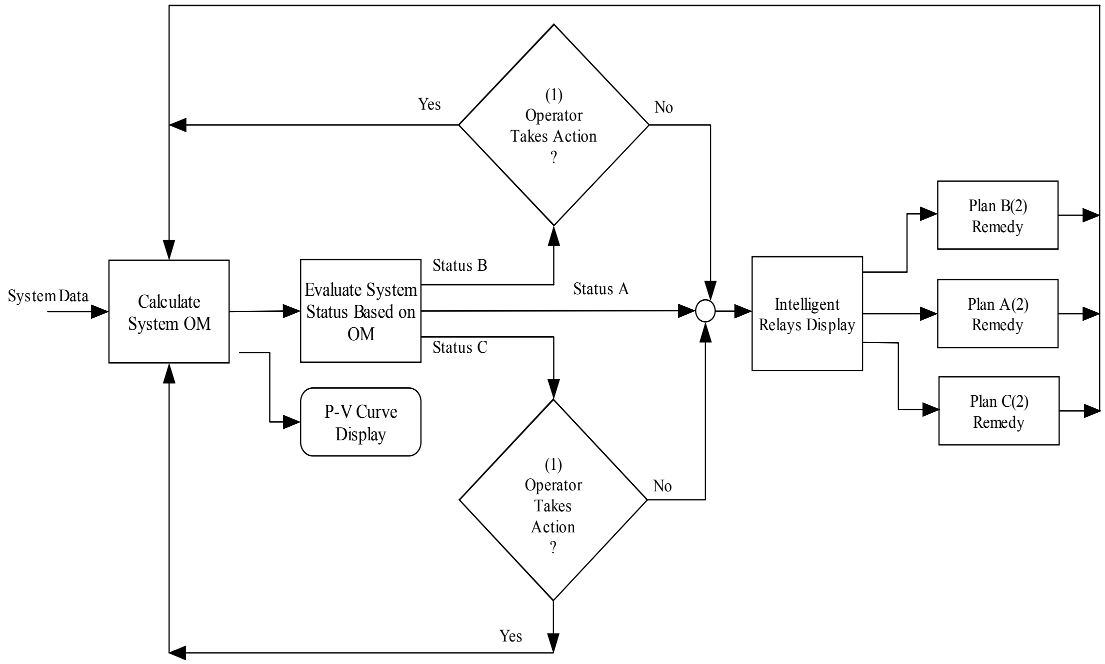
If we study the detail story of the august 2003 U.S. blackout, the security issues of power system must be handled at different approach.

6. Conclusion

Today's control room, the power system operator does not know the system margin. All utility's operation control system should provide the following:

- Real-time data of system margin
- Operator is **informed** and **involved**
- System identifies weak bus (es) of system
- Dynamic load-shedding (if necessary)
- An intelligent system should be installed **immediately** at all ISO facilities

A conceptual design of an intelligent system is shown below.



No

te: (1) Preventive actions include Re-dispatch, Shedding interruptible loads, Shedding weak bus loads, etc.
(2) Plans A, B, C remedies

Figure 6. Conceptual Design of an Intelligent Control-Room Operating System

Biography

Dr. Mo-Shing Chen is an IEEE fellow. Currently he is Emeritus professor of Electrical Engineering at University of Texas at Arlington. He was recipient of the first Edison Power Engineering Educational Award. He has published more than 100 papers on IEEE and other professional journals.

4. THE CENTRAL AFRICAN POWER POOL (CAPP), THE ECONOMIC COMMUNITY OF CENTRAL AFRICAN STATES (ECCAS) AND THE NEW PARTNERSHIP FOR AFRICA'S DEVELOPMENT (NEPAD) (Paper 05GM1065)

Bruno Kapandji Kalala, Permanent Secretary, PEAC

The Central African Power Pool (CAPP), The Economic Community of Central African States (ECCAS) and The New Partnership for Africa's Development (NEPAD)

I. The Central African Power Pool (CAPP)

a) Definition, Mission and Vision.

The Central African Power Pool (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.

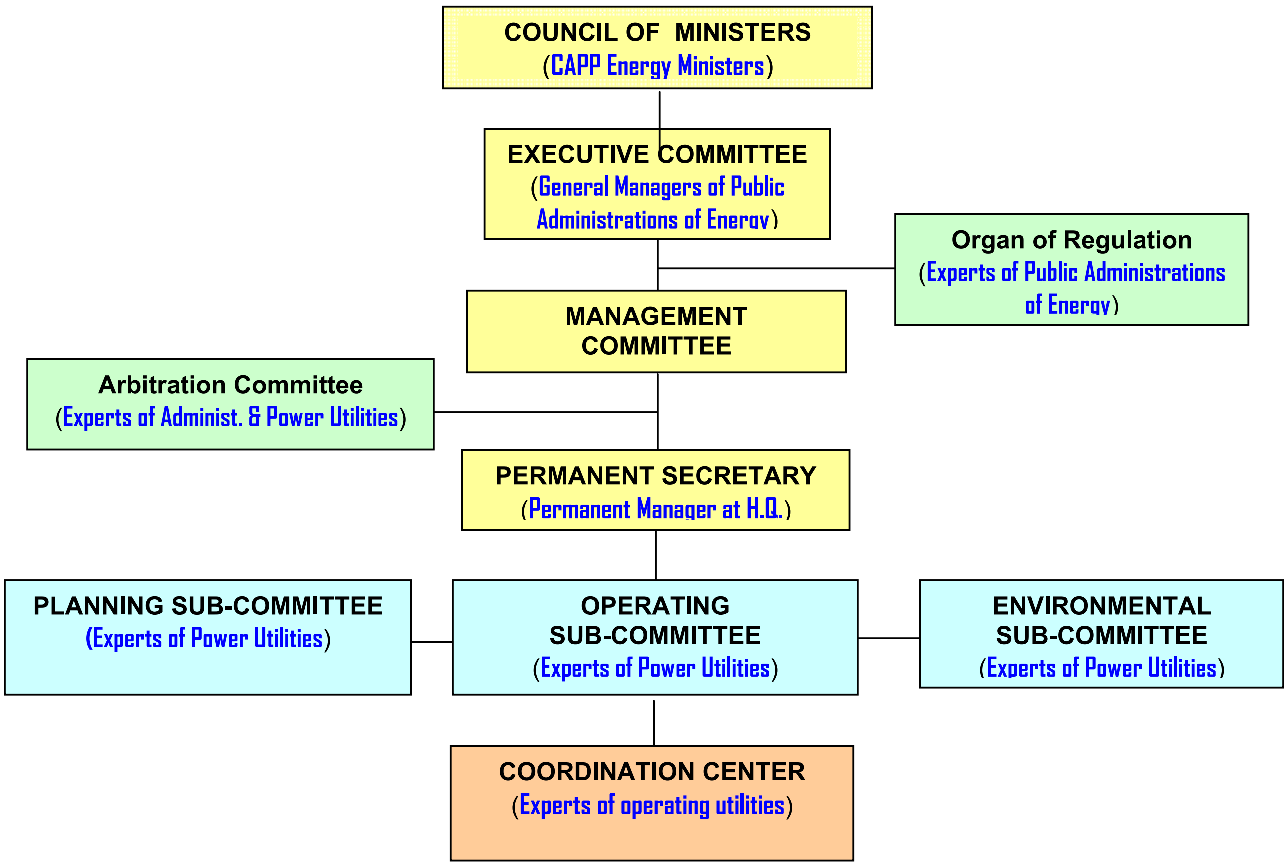
b) Members

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).

c) Structural Organs and Organization Chart



II. Economic Community of Central African States (ECCAS)

a) Introduction: ECCAS has been 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:

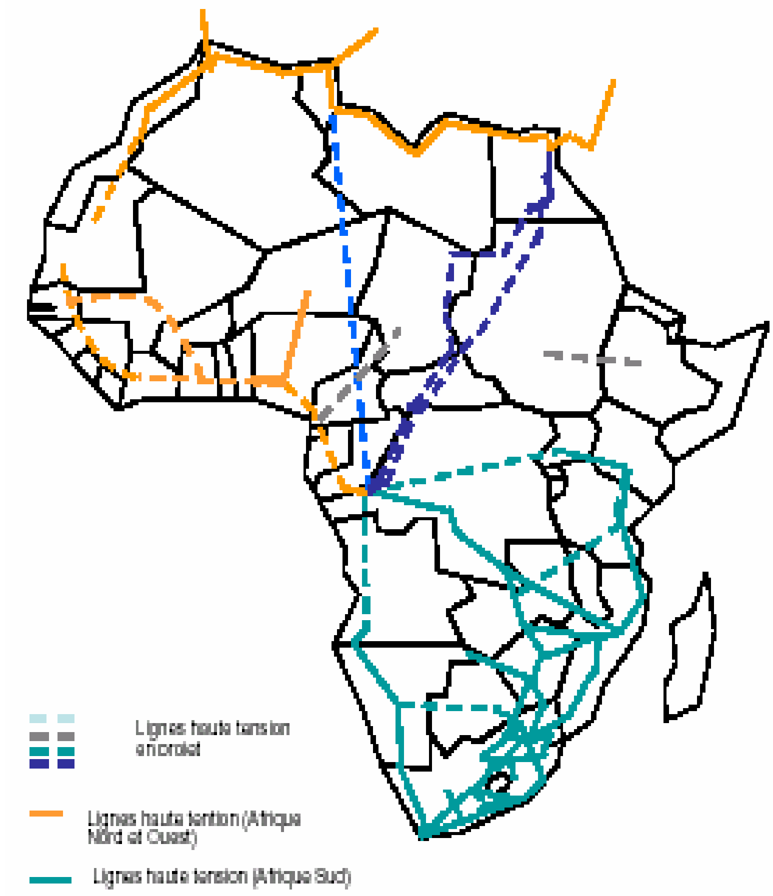
It was planed to establish in 2004 a zone of free exchange of the ECCAS and to organize the private sector, the civil society, the feminine organizations, the academic so that they can contribute to the achievement of the missions assigned to ECCAS. In addition, a backing of the capacities of the General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

d) ***Electric Situation of 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, the central Africa is the less electrified sub region in Africa.

e) Present and Future inter Connection Projects



f) CAPP Integration Projects

N	P R O J E C T S
	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.

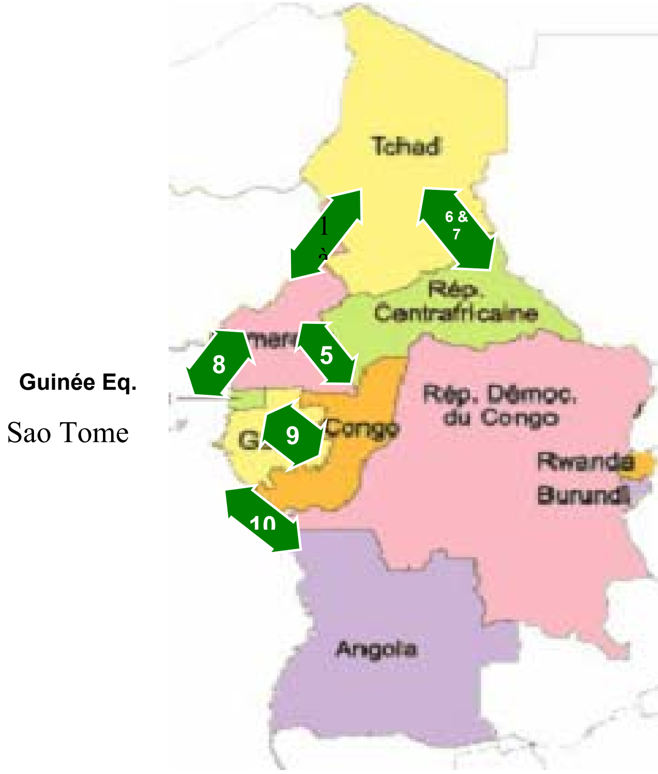
III. CAPP and ECCAS

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 listed below



N°	Name of the Project	Countries concerne
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	RCA RDC
07	Electrification of MOBAYE, KONGBO, ALINDAO, KEMBE	RCA RDC
08	Electrification of KYE-OSSI (AKOMBANG)	Guinea Equat. Cameroon
09	Electrification of MEDJENG	Guinea Equat. 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

IV. 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 MAP and OMEGA plans were merged and became the New African Initiative (NAI).

During the Summit held in Abuja in October 2001, N.A.I. 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.

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.

V. 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 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, we 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.

VI. 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.

VII. 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.

5. TECHNICAL ISSUES: AREA CONTROL CONSIDERATIONS IN THE WAPP AND SAPP AREAS (PAPER 05GM 0507)

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Abstract: With a population of 13.4% of the world but only consumes 3% of world energy, Africa is desperately needed cheap and clean energy for economic development and modernization. The Survey of Energy Resources conducted by the World Energy Council (WEC) in 2004 shows that Africa has more than enough to satisfy all its energy requirements. However, the resources are not evenly distributed within the continent. It is important to have cross-border interconnection of electricity grids and gas pipelines networks and the joint development of new electrical generation projects to make the energy accessible to the general public. However, interconnecting AC network will increase the complexity of the system that may increase the system reliability, security, and stability problems due to the interactions of equipment and control actions. This paper uses the development of West Africa Power Pool (WAPP) and Southern Africa Power Pool (SAPP) to discuss area control considerations in this cross-countries interconnection utility grid.

INTRODUCTION

The availability of cheap and clean energy is a crucial for economic development and modernization. This is particularly important in Africa, a continent where the majority of people are still dependent on fuel wood for their energy requirements. With a population of 13.4% of the world and a land area of 15%, Africa has only 2% of the world's industrial capacity. Its per capita income is only 15% of the world average and only consumes 3% of world energy. The Survey of Energy Resources conducted by the World Energy Council (WEC) in 2004 shows that Africa has more than enough to satisfy all its energy requirements. These include 7.1% of the world's known oil reserves, 7.5% of those for gas, 10.6% of the coal and 13% of the hydro. However, the resources are not evenly distributed within the continent. For example, Oil and natural gas are found mainly in the northern and western parts of the continent. Gas usage is limited. Egypt and Algeria produce 98.5 billion cubic meters of Africa's total production of 116.8 billion cubic meters. Almost 96% of the coal is produced in South Africa, Hydro is concentrated mainly on the Congo, Nile, Niger, Volta and Zambezi rivers. Therefore, regional cooperation and integration through energy pooling and cross-border energy trading would help economic development of the continent. This can be achieved through promoting cross-border interconnection of electricity grids and gas pipelines networks and the joint development of new electrical generation projects. However, interconnecting AC network will increase the complexity of the system that may increase the system reliability, security, and stability problems due to the interactions of equipment and control actions. This paper uses West Africa power Pool (WAPP) and South Africa Power Pool (SAPP) areas as examples to discuss the area control considerations while performing system integration [1, 2].

WAPP AND SAPP

According to the geographical location, the continent of Africa can be divided into North (Algeria, Egypt, Libya, Morocco, Western Sahara, and Tunisia), South (Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe), Central (Burundi, Cameroon, Central African Republic, Chad, Congo-Brazzaville, Democratic Republic of Congo (Kinshasa), Equatorial Guinea, Gabon, Rwanda, São Tomé & Principe), West (Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo), and East (Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Seychelles, Somalia, Sudan, Tanzania, and Uganda) regions. Fig. 1 shows the present and potential African grid. Among them, southern region has progressed further than any other in interconnecting its electricity grid and west region has just formed an alliance in 2000 and developed an implementation plan that will be staggered over a period of more than 20 years. They are the good examples to examine the past and future energy integration activities among African countries.

West African Power Pool [3, 4, 6]

In September 2000, the national electricity sector officials from 14 countries of the Economic Community of West African States (ECOWAS) working together to create a regional market for electricity by adopting a Memorandum of Understanding (MOU) for the West African Power Pool (WAPP). The full implementation of the WAPP project will be staggered over four phases over a period of more than 20 years. Each phase comprises an institutional development component and an infrastructure component.

The ECOWAS countries have been divided into two main zones: Zone A includes Benin, Burkina Faso, Côte d' Ivoire, Ghana, Niger, Nigeria and Togo, and zone B includes Cape Verde, the Gambia, Guinea, Guinea Bissau, Liberia, Mali, Senegal and Sierra Leone.

Phase 1 covers most of the zone A countries (except Niger, Nigeria and Togo) and Mali from zone B. Benin, Burkina Faso, Mali, and Togo have been identified as the main prospective importers of electricity due to high generation costs, while Côte d' Ivoire and Ghana have been identified as the main prospective exporters of electricity in the region during phase 1 implementation.

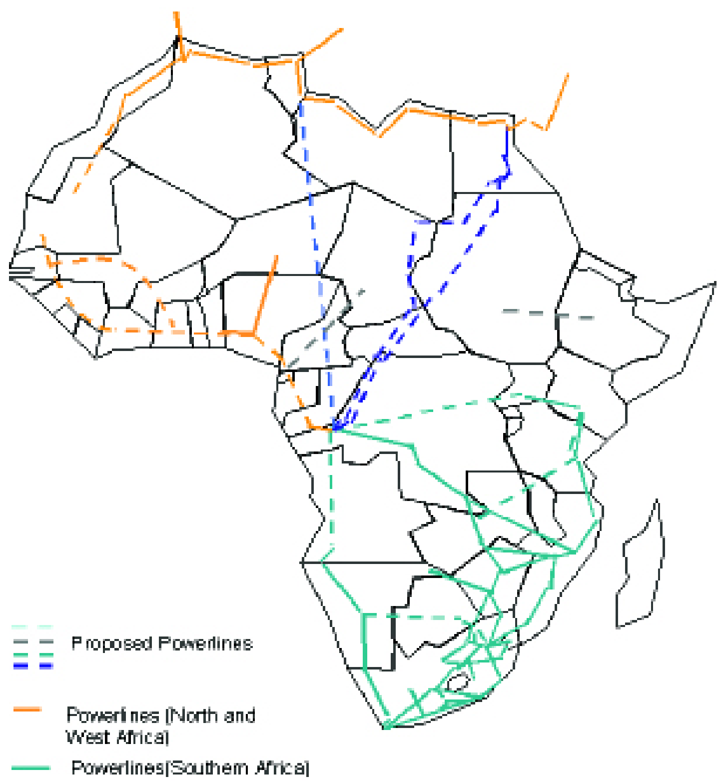

Figure 1. The Present and Potential African Grid.

Phase 1 (2003 – 2006)

This phase focuses on technical assistance, capacity and institutional building to develop an efficient regional power market along with the implementation of priority interconnection lines.

The priority interconnection lines will be built to link the countries between zones A and zone B. Some national transmission lines will be reinforced for the reliability and stability of the regional networks.

This phase will also establish the energy protocol that can be adopted by all ECOWAS member states. In addition, new institutions like the WAPP regional information centre and the panel of independent experts in regulations will be created. Dispute resolution functions and financial settlements will be strengthened. Individual country legislation, including regulations, will be reviewed, and the most appropriate long-term regulatory regime for the WAPP will be defined.

Phase 2 (2007－ 2012)

This phase will increase Nigeria' s involvement through the construction of the coastal line from Ikeja West (Nigeria) to Abobo (Côte d' Ivoire). Sikasso (Mali) will be connected to Manatali through Bougouni (Mali). Ghana and Burkina Faso will be interconnected and some national transmission lines shall be strengthened.

The executive board and the WAPP co-ordination center along with other entities will be created in this phase. A technical and operational function as well as a full commercial function would be added to the co-ordination center to strengthen the existing financial function. This phase will carry out the implementation of the regulatory regime defined in phase1.

Phase 3 (2013－ 2018)

While investing in regional generation and the strengthening of transmission networks, the regional legal and regulatory regimes for contracts would be strengthened in this phase. Based on regional resources, least-cost power generation investment strategies will be established. Additional interconnections with other regional networks, such as Senegal-Gambia, Guinea-Sierra Leone, Guinea-Mali, and Guinea-Liberia, would also be carried out.

Phase 4 (2019 – 2023)

The phase 4 will focus on the consolidation of actions to make exiting entities and instruments fully operational.

Important steps have been taken to promote investor security and permit investors to realize economies of scale by producing for a larger regional market. For example, the ECOWAS Energy Protocol provides a legal framework for energy sector investment and trade guaranteeing such promising key principles as “open access” and “free trade” within West Africa. The creation of the first of the permanent WAPP bodies, the ECOWAS Energy Information Observatory, serves as a focal point for both system operation and a source of information for interested investors. Consistent with the NEPAD emphasis on infrastructure and poverty reduction, the WAPP is addressing the needs of the poorest member states by bringing to greater maturity a half-dozen priority projects within Zone B of the WAPP. Finding foreign and local investors to finance these projects is now an immediate concern. The expected fast rates of growth in electricity demand by industry, services and consumers throughout the region could be one of the most appealing aspects of the WAPP for foreign and local investors. Yet energy sector investment in West Africa is hampered by the relatively discouraging overall investment climate, as evidenced by such factors as risk, credit-worthiness, and the ease of doing business. The WAPP's recent steps towards improving security for energy sector investment represent important progress, but there remains substantial room for improvement.

Southern Africa Power Pool [5 - 6]

The Southern African Power Pool (SAPP) was created in 1995 with the aim to provide reliable and economical electricity to consumers in SADC member states. The initiative developed from the complimenting the strengths and weaknesses of individual power sectors in Southern African countries. They include disparities in resources, production and consumption, as well as technical and human resource capacities. SAPP comprises of 12 of the 13 member states of SADC and nine of these are operating members. Since its inception, the grouping has been evolving from emphasis on policy and planning cooperation and resource sharing, to include competitive power trade, with electricity trade in 1999 valued at over US$150 million, making electricity an increasingly important commodity in the region.

Although SAPP aims at providing the end user with choice of supply, the issue of choice of supply is of secondary importance since over 70% of the region's population do not have access to electricity. In addition, there are wide disparities in access to electricity. For example, up to 67% of South Africans have access to electricity (Karekezi, 2003) while only 6% of Malawians have access to electricity (Potani, 2002) and in Lesotho, about 4% of the population has electricity. Closely related to the issue of access to electricity and affordability is the challenge of electricity pricing and subsidies. Governments in the region (and elsewhere) have traditionally priced electricity below costs of supply in efforts to yield social gains and make electricity affordable to poorer sections of the society. In terms of regional trade, the existence of subsidies, which vary from country to country, result in unequal pricing and can lead to distorted trade. Although, analysis of subsidies in most SADC countries has shown that subsidies are captured by the non-poor (Dube, 2003), pricing electricity at cost-plus levels may make integration less attractive and may further prevent the poor from gaining access to electricity.

Electricity demand in SADC is set to increase at an annual rate of between 4% and 5% for the next few years. Increasing demand and the large proportion of persons without access to electricity mean that major investments, in both infrastructure and human resource capacity development will be required in the next few years. The challenge is then for the region to develop a legal and regulatory framework that provides incentives for attracting investors in the African power sector. Furthermore, incentives in the power sector often entail tax rebates or breaks and policy makers in power sectors will have to justify the opportunity costs and convince revenue services that foregoing these sources of government finances will yield greater economy-wide benefits.

The power sector reforms and regional integration have compounds the technical and human resources capacity problem because it introduces a more complex level of operations. The SAPP is now evolving from a cooperative to a competitive pool. Power trade continues to increase steadily annually at an average of 20%. The value of the electricity traded in 1999 was over $150 million. A short-term energy market (STEM), which started live trading in April 2001, utilizes the Internet to conduct trades. The STEM is a spot market of non-firm electricity contracts. Technical know-how in commercial operations of power utility is another challenge since most utilities have operated on non-commercial basis. Furthermore, there is need for developing capacity for planning, maintenance coordination, standards development and regulation.

AREA CONTROL CONSIDERATION OF AN INTERCONNECTED SYSTEM [7 – 12]

Financial Issues

In general, synchronous interconnection must be accomplished through multiple large capacity transmission paths placed in service simultaneously. A thorough analysis of the optimal number of lines necessary to accomplish reliable interconnection depends upon the anticipated transfers over the lines and requires engineering and economic analyses. For those originally isolated systems, construction of new transmission facilities and improvement of existing transmission facilities would be necessary to provide the infrastructure to facilitate desired power transfers. Investments in transmission facilities have historically been funded by utilities. The facilities for interstate connection and the required infrastructure improvements may fall outside the traditional paradigm of transmission funding by utilities. The investment for the construction of the required facilities must have a reasonable expectation of recovering the associated costs from their customers or users of the facilities. The issue of providing the necessary economic incentives for construction of new transmission facilities in an environment where transmission owners must provide open access is common to synchronous interconnection investments. However, incentive for cost recovery and profit for investment may defeat the purpose of interconnection to provide cheap and clean energy in Africa.

Dealing with local resistance to new generation and transmission facilities can add significantly to the time required to install facilities and their ultimate cost. A number of parties expressed concern that synchronous interconnection facilities would be particularly vulnerable to local challenges since the motivation for their construction was not to improve electric service to the impacted community. Citizens who are complaining about facilities believed to be unsightly or dangerous being built in their own neighborhood are seldom mollified by evidence of potential benefits to distant economies. Moreover, since synchronous interconnection may not be safely accomplished without the simultaneous availability of multiple transmission paths, a delay in the completion of a significant part of the connections might delay the effectuation of entire undertaking.

Synchronous interconnection could impose additional operating cost on utilities and other owners of electric generating facilities. In order to maintain reliability, generators may have to adjust operations to accommodate those of utilities elsewhere on the interstate grid. The magnitude of these additional costs is difficult to quantify due to uncertainties over the operating characteristics of the interconnected grid. Any additional operating costs caused by synchronous interconnection raise two issues. First, the additional operating costs must be offset against estimates of gains from trade considered as benefits from synchronous interconnection. Second, there must be some mechanism for beneficiaries of power flows to compensate those entities that are forced to bear additional costs to accommodate those flows. Though initial evaluations suggest that any additional operating costs are probably not very large, there is considerable uncertainty and controversy over the significance of these costs and it would probably not be prudent to ignore them.

Technical Issues

Interconnection enhances the ability to import power when there is a shortage due to extreme weather or generator outages is a reliability benefit. However, interconnect AC network will increase the complexity of the system that is subject to various reliability, security, and stability problems due to the interactions among the increasingly prevalent automatic generator voltage and speed controls, system frequency, tie line flow, and critical bus voltages. The analysis of system dynamic performance and the assessment of power security margin have correspondingly become more complex. This may threaten reliability and lead to wide area power outages. The social and economic cost of power outages, especially extended outages over a wide geographic area can be significant, as was learned in the Northeast blackout in August 14, 2003. It took only nine (9) seconds for the blackout to spread across Canada and several states in the US, effecting more than 50 million people. Some went without power for more than three days. Understanding the behavior and fundamental characteristics of the system are critical for secure operation.

The primary reliability threats in a transmission system are:

a) Voltage stability
b) Dynamic/Transient stability;
c) Cascading failure and protection coordination

Voltage Stability

The condition of voltage collapse can occur when the power requirement exceeds the transmission line delivery capability. When this occurs, a precipitous voltage drop accompanies any increase in load, and the voltage is not able to maintain at its desired range. The process of voltage instability is usually triggered by some form of disturbance, such as a line or generator outage, or other change in operating conditions, such as energy trading. In most cases, the situation can be mitigated by reducing load/power transfer, and/or by providing local reactive support. A though reactive resource planning is needed to avoid or mitigate possible voltage stability problems in an interconnected system. Additional investment in reactive power resources may be needed.

Dynamic/Transient Stability

The concept of system stability revolves around whether generator electro-mechanical oscillations follow a disturbance that affects system voltages, currents, and power flows, can be restored to a stable, steady, and secures operating condition within a reasonable time frame. The types of disturbances that can trigger stability problems include sudden load changes, equipment failure, generation rejections, and system faults.

Transient stability has to do with the ability of the system to remain stable for the first oscillatory swing after a fault. Dynamic stability is related to the longer-term ability of the system to remain stable after a disturbance. Inter area oscillation is very common problem for an interconnected system with long transmission lines. One may have to improve the infrastructure of the system and/or install the Flexible AC Transmission Systems (FACTS) devices to mitigate possible dynamic stability issues.

Cascade Failure and Protection Coordination

If the failure of equipment may trigger other events and cause other devices to trip out of service, the system is threatened by the possibility of cascading outages. As an example, the condition might be precipitated by a transmission line failure caused by a falling tree branch. In response to the outage, all remaining transmission line flows adjust to carry more loads. This may result in tripping another overload line and worsen the system situation that lead to system blackout. The interconnected system is more susceptible for this type of situation since the under frequency may not function properly. These cascading overloads are an obvious threat to secure system operation, and were the main reason for the spread of the Great Northeast Blackout in the 2003. Regular evaluate and update the protection scheme is necessary when expanding the interconnection networks.

CONCLUSION

The availability of cheap and clean energy is crucial for economic development and modernization in Africa. In general, Africa has more than enough to satisfy all its energy requirements. However, the resources are not evenly distributed within the continent. Therefore, different organizations are promoting cross-border interconnection of electricity grids and gas pipelines networks and the joint development of new electrical generation projects to make the energy accessible to the general public. However, interconnecting AC network will increase the complexity of the system that may increase the system reliability, security, and stability problems due to the interactions of equipment and control actions. This paper discusses financial and technical issues that related to the interconnection of cross-countries utility grid.

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6. SOUTHERN AFRICA POWER POOLS AND SOUTHERN AFRICAN DEVELOPMENT COMMUNITY: AN OVERVIEW (Paper 05GM0038)

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***Abstract*—** The Southern Africa Power Pool (SAPP) was formed in late 1995 and a memorandum of understanding, which was signed in December 1996, has guided its operations. SAPP includes twelve southern African power utilities, namely: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe and Zaire (now DRC). The main objectives of setting up the power pool are to ensure that all member utilities: co-operate and co-ordinate in the operation of their systems to minimize costs while maintaining reliability; fully recover costs; and share equitably in the resulting benefits. The Southern African Development Community (SADC). SADC member-states are Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. This paper presents an overview of SAPP and SADC including status, plans of action, further development and recommendations.

Index Terms– African electricity infrastructure, electrical energy resources, international electricity connections

I. INTRODUCTION

Regional energy trade, particularly electric power, is a high priority for the Southern African Development Community (SADC)-member countries. The disparities in energy resources and consumption provide a strong rationale for the integration of the sector and for the promotion of regional energy trade. The August 1995 Inter-Governmental Agreement creating the Southern African Power Pool (SAPP) confirmed the region's commitment to expanding electricity trade, reducing energy costs and providing greater supply stability for the region's 12 national utilities: Botswana Power Corporation (BPC); Electricidade de Mocambique (EDM); Angola's Empresa Nacional de Electricidade (ENE); Electricity Supply Commission of Malawi (Escom); South Africa's Eskom; Lesotho Electricity Corporation (LEC); Namibia's NamPower; Swaziland Electricity Board (SEB); the Democratic Republic of Congo's (DRC) Societe Nationale d'Electricite (SNEL); Tanzania Electric Supply Company (Tanesco); Zimbabwe Electricity Supply Authority (ZESA) and Zambia Electricity Supply Corporation (ZESCO). SAPP membership is recently restricted to national electricity utilities, although Hidroelectrica de Cahora Bassa (HCB) was granted temporary observer status to the three SAPP Sub-Committees (Planning, Operation and Environmental) in April 1998. At that time a moratorium was declared prohibiting any other non-utility members from joining while the SAPP considers the role in the region of Independent Power Producers (IPPs) and Independent Transmission Companies (ITCs), as well as implications of future utility scenarios such as unbundling and privatization.

This paper presents an overview [1]-[13] of SAPP and SADC including status, plans of action, further development and recommendations

II. ENERGY OVERVIEW

Overall Southern Africa is a net energy exporter. In 2001, the countries of Southern Africa collectively consumed (Table I) 5.4 quadrillion British thermal units (Btu) of commercial energy (1.4% of total world consumption) and produced 7.7 quadrillion Btu (2.3% of total world production). Also in 2001, the region generated 119.2 million metric tons of carbon dioxide emissions (1.9% of the world total). The region's dominant economy, South Africa,

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accounted for 85.1% (4.6 quadrillion Btu) of the region's energy consumption, 72.7% (5.6 quadrillion Btu) of its energy production, and 88.4% (105 million metric tons) of its carbon dioxide emissions.

TABLE I Total Energy and Carbon Dioxide Emissions, 2001

Country	Total Com Energy Consumpti (Quadrillion Btu)	Total Com Energy Prod (Quadrillion Bt	Net Energy E (Quadrillion Bt	Carbon Emissions (Million tons of carbo	D
Angola	0.093	1.608	1.515	3.59	
Botswana	0.069	0.025	-0.044	1.23	
Comoros	0.001	0.000	-0.001	0.03	
Democratic R of Congo	0.078	0.107	0.029	0.73	
Lesotho	0.004	0.000	-0.004	0.06	
Madagascar	0.033	0.006	-0.027	0.52	
Malawi	0.019	0.008	-0.011	0.22	
Mauritius	0.047	0.001	-0.046	0.88	
Mozambique	0.037	0.075	0.038	0.39	
Namibia	0.033	0.000	-0.033	0.50	
Seychelles	0.008	0.000	-0.008	0.17	
South Africa	4.600	5.593	0.993	105.18	
Swaziland	0.023	0.009	-0.014	0.32	
Tanzania	0.061	0.025	-0.036	0.72	
Zambia	0.089	0.085	-0.004	0.56	
Zimbabwe	0.242	0.158	-0.084	3.92	
Regional Total	5.437	7.7	2.263	119.02	

Commercial energy resources in the region are diverse, with significant reserves of coal, petroleum, and natural gas. Electricity in Southern Africa is generated through thermal or hydroelectric resources (with one nuclear facility in South Africa). Natural gas is becoming more significant to the region's energy sector as fields off Mozambique, Namibia, South Africa and Tanzania are developed.

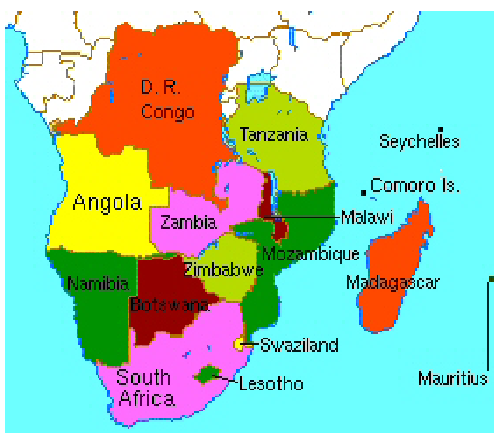

Figure1 SADC Members

Due to the region's relatively small urban population (approximately 25.4%), access to commercial energy sources is limited. The majority of Southern Africa's population still relies on the use of biofuel (wood and charcoal) as its primary source of energy. Biofuel accounts for approximately 75% of total final energy demand in the region. The countries with the highest rates of biofuel consumption are Tanzania, Mozambique, Zimbabwe, Zambia and Malawi.

SADC members, Figure 1, announced plans to elevate its energy technical unit (ETU) to a regional energy commission. The commission is being designed to facilitate regional integration in the energy sector. The ETU started its operations in April 2001 in Luanda, Angola.

III. SADC AND SAPP ELECTRICITY

Southern Africa's total installed electric generating capacity was 55,756 MW at the beginning of 2001, the majority of which was thermal Total electricity generation for the region in 2001 was 230.8 billion kilowatt-hours (bkwh). Net hydroelectric generation was 30.4 bkwh, with Zambia (7.7 bkwh), Mozambique (7.0bkwh) and the DRC (5.2 bkwh) being the largest generators. In 2001, total regional electricity consumption was 211.9 bkwh, led by South Africa's 181.2 bkwh (85.5%). Zimbabwe (9.8 bkwh, 4.6%), Zambia (5.5bkwh, 2.6%) and the DRC (3.8 bkwh, 1.8%) were the next largest electricity consumers.

Created in 1995, the SAPP aims to link SADC member states into a single electricity grid. The national utilities currently participating in the SAPP are Angola's Empresa Nacional de Electricidade (ENE), the Botswana Power Corporation (BPC), the DRC's SNEL, the Lesotho Electricity Corporation (LEC), Malawi's Electricity Supply Commission (MESC), Mozambique's Electricidade de Mocambique (EDM), Namibia's NamPower, South Africa's Eskom, the Swaziland Electricity Board (SEB), Tanzania Electric Supply Company (Tanesco), Zambia's ZESCO, and Zimbabwe's ZESA. SAPP's coordination center is located in Harare, Zimbabwe.

Eskom, South Africa's state-owned electricity supplier is a significant provider of energy to the African continent. It supplies more than 95% of the country's electricity. Around 74% of South Africa's electricity supply comes from coal-fired power stations (proven coal reserves are expected to last more than 150 years). The African continent's one nuclear power plant is situated in Koeberg, near Cape Town, supplying electricity to the economically important Western Cape province. It has a further active lifespan of about 30-40 years; at present there are no plans to expand nuclear energy.

The DRC has extensive energy resources, including hydroelectric potential estimated at 100,000 MW. The Inga dam alone, on the Congo River, has a potential capacity of 40,000-45,000 MW, sufficient to supply all of Southern Africa's growing electricity needs. Due to continuing political uncertainties and the resulting lack of investor interest, only a fraction of this amount has been developed at Inga. Total installed generating capacity was estimated at 2,473 MW in 2001. However, actual production is estimated at no more than 650-750 MW, largely because two-thirds of the turbines at Inga are not functioning. South Africa's Eskom, is currently involved in the rehabilitation of the Inga dam. The DRC exports hydroelectricity to its neighbor, Republic of Congo along a 220-kilovolt (kV) connection. The interconnection supplies nearly one-third of the electricity consumed in Congo-Brazzaville. Power from Inga is also transmitted to the Zambian grid along a 500-kV DC line from Inga to Kolwezi in southern DRC, and a 220-kV line from Kolwezi to Kitwe in northern Zambia. South Africa also imports DRC's energy output through the SAPP grid. In 2003, talks were also initiated to supply power to electricity-starved Zimbabwe.

In November 2003, BPC, Eskom, ENE, NamPower and SNEL formed the Westcor Power Project. The project's proclaimed aims are to provide low-cost, affordable and environmentally friendly electricity to ensure that economic development in the region is not constrained by capacity shortages. The first phase of the project will cost an estimated US $4 billion, according to a report by Eskom, and includes the building of a 3,500 MW Inga III hydropower station in DRC, with interconnections for about 1,864 miles of power transmission lines to supply the five Westcor countries. Inga III is the third of four hydropower plants due to be developed along the Congo River. A further phase - beyond Inga III - is Grand Inga, with a potential output of some 39,000 MW. The plan will eventually extend to building hydropower stations in Angola and Namibia. Depending on the outcome of the feasibility studies, the project is due to begin in 2010.

Mozambique's Cahora Bassa hydroelectric facility is located on the Zambezi River in the western Mozambican province of Tete. The power station's nominal capacity is estimated at 2,075 MW, and it currently supplies electricity domestically, as well as to Zimbabwe and South Africa. Hidroelectrica de Cahora Bassa (HCB), a joint venture between Portugal and EDM, operates Cahora Bassa. Currently, Mozambique is seeking funds to modernize the Cahore Bassa at an expected cost of US $40 million. The Mozambican government is also seeking investors for a second hydroelectric facility on the Zambezi River. The $1.3- billion Mepanda N'cua dam is be to built south of the existing Cahora Bassa dam. The new facility will have a capacity of 2,400 MW. The government expects construction to begin in 2005, and generation to begin in 2010. The Mepanda dam will also help to reduce the impact of floods in the Zambezi valley.

In June 2003, it was announced that HCB won the tender to supply Malawi with electricity for a 20-year period starting in 2004. According to the tender documents, the Electricity Supply Corporation of Malawi will be responsible for the transmission line from the dam town of Songo to the Malawian commercial capital of Blantyre, and will have to obtain the necessary funding. The cost is estimated at US $80 million. Work on the line began in late 2003 and is due to be completed in 2004. HCB will eventually supply Malawi with up to 300 MW of power, though it will initially begin supplying 100 MW. The two countries began work on the interconnection of their respective electricity grids, in 1998.

In 2003, Malawi has continued to experience frequent electricity shortages due to damage to the country's power stations caused by severe flooding, and as a result of the overall lower than expected water levels on the Shire River. Additional problems result from the continuing breakdowns in the country's power transmission network. The Shire River supports four Malawian hydroelectric plants, which account for the majority of the country's electrical output. The previously stated deal on the construction of the131-mile power-supply link from Mozambique's Cahora Bassa dam is designed to decrease the country's reliance on the Shire River hydroelectric plants. Currently, the lack of available resources prevents the project from moving forward. Additional work continues on the Kapichira hydroelectric power scheme that is designed to add 128 MW to the country's current capacity.

The Muela hydroelectric power station, build during phase 1A of the Lesotho Highlands Water Project (LHWP), opened in September 1998. The resulting electricity production ended Lesotho's previous dependence on imported electricity from South Africa and resulted in Lesotho's self-sufficiency in electric power. Fully operational since January 1999, the plant has a capacity of 80 MW, but this is due to increase to 110 MW when phase 2 of the LHWP goes ahead. Currently there are plans to privatize the operation of the plant, although no specific time schedule has been established.

In August 2003, it was announced that the Swaziland Electricity Board (SEB) and the European Investment Bank (EIB) had signed a $9.3 million loan agreement covering the construction of a hydroelectric power station at the Maguga dam on the Komati River. The total cost of the project is estimated to amount to $23.6 million, to be spent on purchasing two 2.5-MW turbines, two 11.3-MW generators and the construction of a 66-kV transmission line. The Maguga project forms part of the Swazi government's plan to reduce the importation of electricity from almost 100% of consumption at present to 80%. Most of the country's electricity is currently supplied by South Africa.

Botswana plans to provide electricity to 70% of the population by March 2009 and to the rest of its citizens by 2016. Currently, only 22% of Botswana's population has access to electricity. Botswana is continuing talks with Eskom and Nampower concerning the importation of additional electricity into the country. At present, nearly 60% of national demand is fulfilled by power imports, but Gaborone is keen to reduce this dependence, in part by developing its large reserves of (low-grade) coal. Through government funding, BPC is engaged in a major program to extend the electricity grid into rural areas, the largest phase of which was completed in early 2004. BPC plans to spend a total of $700 million to extend the company's transmission and distribution systems.

In March 2003, it was announced that a proposal to build a hydropower plant at Botswana's Popa Falls had been rejected on environmental grounds. Concerns centered on possible damage to the Okavango Delta, the country's premier tourist attraction. The Popa Falls project, which had the potential for 20-30 MW of power generating capacity, was strongly backed by Namibia's NamPower. Construction of the dam was due to start in mid-2004.

In January 2004, the South African government announced its intentions to encourage the private sector to move into power generation in the country.

In an effort to better deal with the issues of frequent blackouts and inefficiencies in the operations of the national water and power utility, Jirama, the Malagasy energy minister announced a new round of bidding open to private firms interested in operating the Madagascar company. The round is set for mid-April 2004.

About 50% of Namibia's electricity comes from its own generating sources. The remaining 50% is imported from South Africa. The main domestic electricity source is the Ruacana hydropower plant. The production level is cyclical, so imports from South Africa are needed to make up the difference between local demand and the periodic gaps in production from Ruacana. Over the last few years, total demand has outstripped the local generating capacity so that even when Ruacana is producing at full capacity, imports are needed to meet Namibia's domestic demand for electricity. The current import agreements between Namibia and South Africa are scheduled to expire in 2005, so Namibia is actively seeking alternative sources, including possible gas-to-electricity (GTE) supplies from the soon to be producing Kudu gas fields, as well as potential hydroelectric supplies from the Kunene River on the border with neighboring Angola.

In February 2004, Eskom of South Africa and HCB of Mozambique announced their refusal to renew contracts with the Zimbabwe Electricity Supply Authority (ZASA). The failures to conclude numerous supply agreements with its African neighbors, due to non-payments of previous delivery charges, has put Zimbabwe in a difficult situation of facing potential power blackouts. Zimbabwe currently imports about 35% of its electricity requirements.

Throughout 2003 and the early months of 2004, Tanzania's electricity supply has remained erratic due to the national grid's heavy reliance on hydroelectric power, which in turn was impacted by poor rainfall. Tanzania Electricity Supply Company (Tanesco) is considering the utilization of the gas to be supplied by the Songo Songo fields and the possibility of linking with the Zambian electricity grid as means of boosting power supply to the country.

Zambia has abundant hydroelectric sources and meets most of its energy needs from its own hydroelectric stations, which are operated by the state-owned and soon to be privatized Zambia Electricity Supply Company (Zesco). Zambia provides considerable electricity exports to its regional neighbors, especially Tanzania and Kenya, and in 2003, was actively seeking foreign investors from China and other countries to refurbish and upgrade its hydroelectric plants.

IV. REGIONAL GENERATION PROJECTS

The Congo River's huge potential for hydroelectric power may play an important role in providing power regionally (Central and Southern Africa), as well as exporting electricity to North Africa and even Southern Europe. The Democratic Republic of Congo (DRC) currently has 1,775 megawatts (MW) of electricity generating capacity at its Inga hydroelectric facility. The Inga hydropower station comprises a 351-MW plant (Inga 1), commissioned in 1972, and a 1,424-MW plant (Inga 2) which has been in operation since 1982. Inga is located approximately 150 miles (250 kilometers) from the DRC capital of Kinshasa. Inga, operated by the DRC's Societe Nationale d'Electricite (SNEL), domestically provides power to Kinshasa and other portions of western DRC. Inga also provides power to the neighboring Republic of Congo's (Congo) power grid along a 220-kilovolt (kV) connection. The interconnection supplies nearly one-third of the electricity consumed in Congo.

Inga also exports power to Southern Africa countries including Zambia, Zimbabwe 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. Zambia and the DRC are to upgrade their current 220-kilovolt (kV) regional interconnection to a much higher transmission level to allow other SADC countries to tap Inga's energy supplies. Zambia's Copperbelt Energy Corporation (CEC) and DRC's SNEL will undertake the upgrading project that includes construction of a new 220-kV line between Chingola in Zambia and Karavia near the southern DRC city of Lubumbashi. CEC officials stated that in addition to the new transmission line, the two countries would also repair the current 220-kV line to significantly raise the amount of hydropower that can be transmitted from DRC to Southern African countries.

Although Inga and Cahora Bassa are significant existing regional generating facilities, several other projects, with a regional focus, are being considered/developed. In April 2000, Angola and Namibia signed a bilateral cooperation agreement in the field of energy. The two countries are considering the development of a hydroelectric facility on the Kunene (Cunene) River that would provide electricity to both countries. Two possible sites for the dam are being considered, Baynes and Epupa Falls. Namibia favors the Epupa site while Angola prefers the Baynes site because it would enable Angola to renovate and regulate the Gove Dam, which is situated on a tributary of the Kunene River. The proposed facility would have a generating capacity of 360 megawatts (MW) and provide power to the Angolan, Namibian and South African grids.

In April 2002, South Africa's Deputy President Jacob Zuma and Swaziland's King Mswati III inaugurated the Maguga Dam. The Maguga Dam, Swaziland's largest public works project, will benefit both nations. The dam, the fourth largest in Southern Africa, will provide much needed irrigation water for agricultural schemes, create employment in tourism initiatives centered on the fresh water lake, and provide power from a hydroelectric plant. Swazi Prime Minister Sibusiso Dlamini stated the generating capacity from the proposed hydroelectric facility could meet 50% of Swaziland's electricity needs. This would lessen Swaziland's dependency on South Africa, where 90% of the country's electricity is imported from Eskom. The Maguga is the first of four projected dams intended to harness the Komati River, which flows into Swaziland's northwest sector from South Africa.

The Kafue Gorge Lower (KGL) hydroelectric station, south of the Zambian capital Lusaka, is expected to have a capacity of 750 MW. The Zambian government plans to export the vast majority of the power produced to Zimbabwe, Botswana and DRC. KGL, which is expected to cost $500 million, will be the second-largest generating facility in Zambia. The Kafue Gorge Upper power plant currently has a generation capacity of 900 MW. Construction is currently planned to start in mid 2003 and take five to seven years to complete.

In September 2000, Malawi President Muluzi inaugurated the $130-million Kapichira Hydro-Electric Plant. Officials from Escom stated that the commissioning of the new plant would add an additional 64 MW to the national power grid. By 2003, a further 64 MW will be added to the grid when Kapichira is completed.

V. REGIONAL TRANSMISSION PROJECTS

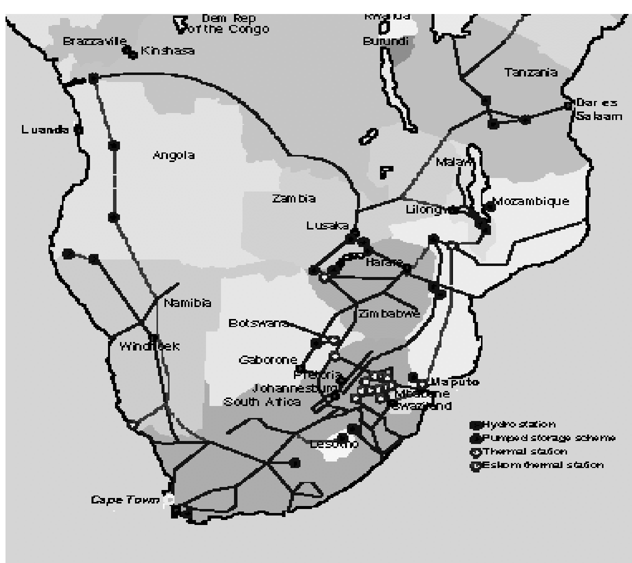

Figure 2 Southern African Grids

Figure 2 shows the Southern African grid.

A significant SAPP accomplishment was the completion of the Matimba-Insukamini interconnector linking Eskom and ZESA in October 1995. This interconnection initiated the first linkage of system operations between the northern and southern electrical systems in the Southern African region. The northern system is primarily composed of ZESA (Zimbabwe), ZESCO (Zambia) and SNEL (DRC), while the southern system is primarily Eskom (South Africa), BPC (Botswana) and Nampower (Namibia). The effect of the interconnections is that countries are able to source electricity in bulk and then redistribute it nationally at cheaper prices. Plans to connect the power grids of Angola, Malawi, and Tanzania with other SAPP member grids are in varying stages of development.

Zambia and the DRC are to upgrade their current 220-kilovolt (kV) regional interconnection to a much higher transmission level to allow other SADC countries to tap Inga's energy supplies. Zambia's Copperbelt Energy Corporation (CEC) and DRC's SNEL will undertake the upgrading project that includes construction of a new 220-kV line between Chingola in Zambia and Karavia near the southern DRC city of Lubumbashi. CEC officials stated that in addition to the new transmission line, the two countries would also repair the current 220-kV line to significantly raise the amount of hydropower that can be transmitted from DRC to Southern African countries.

In July 2000, the Motraco power supply project was completed. The 400-kV line crosses Swaziland and links Arnot via Barberton and Komatiport to Maputo, supplying power to BHP Billiton's Mozal Aluminum smelters. The project is a joint venture between EDM, Eskom, and SEB. The 400-kV line also provides additional capacity to Swaziland.

The Zambia-Tanzania Interconnection Project involves construction of 420 miles (700 kilometers - km) of 330-kV transmission line, 360 miles (600 km) on the Zambian side and about 60 miles (100 km) on the Tanzanian side. The proposed line will be able to supply up to 200 MW of power at an estimated cost of $153 million.

Namibia's and Botswana's electricity utilities, NamPower and BPC, have agreed to build a cross-border transmission line at a cost of $7.7 million. The 150-mile (250-km), 132-kV overhead transmission line will stretch from the Omaere electricity substation in Namibia to Charles Hill at the Namibia/Botswana border and from there to Ghanzi, in northwestern Botswana. The line is scheduled to be completed by September 2003.

Swiss firm ABB was awarded a $12-million contract to build the Van Eck-Kuiseb-Walmund 220-kV transmission line for NamPower in Namibia. The line will run from the Van Eck Power Station in Windhoek to the new Walmund Substation near Walvis Bay. The project is scheduled for completion in March 2003. In September 2002, ABB announced that it had secured a $32-million contract to build a transmission line in Mozambique. The 206-mile (343-kilometer) power transmission system would provide power to Mozambique's northwestern Niassa and Cabo Delgado provinces with power from Cahora Bassa. EDM awarded the contract, while the Swedish (SIDA) and Norwegian (NORAD) aid organizations provided financing.

In August 2002, Eskom announced it was undertaking a feasibility study on a $1-billion project to build a power transmission network to connect the power grids of several of its Southern African neighbors. The study would determine the viability of building an integrated power grid linking Angola, the DRC, Namibia and South Africa. Reuel Khoza, Eskom's chairman, said a memorandum of understanding outlining the potential scope of the project had been signed between the members of SAPP. Khoza stated that the signatories to the agreement were aiming at completing the feasibility by the end of the year.

VI. SAPP BILLING AND METERING

The region is moving forward towards greater regional energy trade and has already begun addressing the infrastructure needed to co-ordinate the trade. Energy trade among the SAPP members is set to increase in view of the annual electricity demand growth rate of 4-4.5%, but the process of pooling resources will see a continuous development and this will have its impact on energy price and billing mechanisms.

In the short term, the mode of energy trading among SAPP members will be a combination of the current bilateral energy agreements and the gradual introduction of a spot market. The situation may change as some of the agreements expire and the benefits of energy spot markets are demonstrated.

The mode of operation of the SAPP spot market has not yet been finalized, but it could take one of two recommended forms—power exchange or central dispatch with unit commitment. Each would have different impacts on billing and metering.

VII. ACTION PLANS

It is important to recognize that agreed-to plans must be capable of being realized. It is not ideal to put forward a suite of proposals that are unlikely, for a variety of reasons, to be achievable.

It is accordingly proposed that the following broad approach be followed:

- Focus be placed on the improvement of the performance of the power sector in each country;
- Promotion of / increase in cross-border trading to be identified and implemented;
- Regional plans be identified for the trading of electricity on a regional basis (such as SAPP);
- Inter regional trading opportunities be identified for implementation at an appropriate time.

The following action plans are therefore proposed-

- The conclusion of an ‘Energy Treaty’ (along the lines of the Energy Charter Treaty of the European Community) to be concluded at African Union level. The treaty will encourage co-operation in energy matters. It will essentially say that all countries will consider regional options when making decisions about their local energy needs/future needs;
- Establishment of an ‘African Forum of Power Utilities’ as a place where power utilities can foster cooperation;
- Acceleration of the activities of the African Forum for Utility Regulators as the forum for co-operation between African regulators (with the power sector being given special attention);
- Establishment of a Committee of African Energy Officials to facilitative the harmonization of a common and consistent legal and regulatory framework to promote cooperation in the power sector, as well as the harmonization of standards and specifications;

The idea is to learn from the initiatives already underway (such as SAPP), while continuing with bi-lateral and regional co-operation under the 'political umbrella' of an Energy Treaty, which will foster ongoing regional cooperation.

VIII. CONCLUSIONS

Energy demand among SAPP countries is set to increase, as is evident by the high electricity demand growth rate (4–5%), the setting up of the pool co-ordination center, the introduction of the spot energy market, and the introduction of new interconnections.

Energy trade in the short term has to accommodate existing bilateral trade agreements, but is likely to change its pattern on the expiry of the agreements. It is expected that the energy trade will shift towards hydropower for economic and environmental reasons. The change in energy trade patterns, coupled with the introduction of the spot market, will require an upgrade of the current billing and metering systems between utilities. This will enable the pace of trade between utilities to be speeded up. A systems upgrade will also facilitate the rapid transfer of trade data to the co-coordinating center for bill processing and settlement of payments. End users in the form of improved billing and metering services should feel benefits.

Electricity trade between African countries can be increased considerably. This will reduce total energy costs and increase energy security. Working together will boost trade and bring benefits to the economies of participating countries, and promote the socio-economic well being of their populations. But it is necessary to remove existing barriers to trade to achieve this, and action must be taken to introduce the reforms that are needed to attract investment.

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X. BIOGRAPHY

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7. HYDROPOWER AND AFRICAN GRID DEVELOPMENT: A RIGHTS BASED PERSPECTIVE (PAPER 05GM0884)

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Abstract

Many political and economic entities involved in planning Africa's energy development, specifically hydropower and regional grids, are promoting poverty alleviation and sustainable development as key goals, but utilizing strategies to promote infrastructure that will undermine these goals. Project planning under NEPAD and other bodies continues to lack transparency and civil society participation, resulting in projects that are not meeting the needs of the greater population. A rights-based approach to African grid development would promote people centered decision-making that would ensure human rights are promoted and protected, and equitable and sustainable development occurs.
Keywords: African energy needs, civil society, human rights, hydropower, rights-based approach, sustainable development

Introduction

Energy development is a vital piece to the foundation of modern communities. Most everyone agrees that the development of modern energy systems is a key step to Africa's future prosperity. Many of the existing bodies involved in African development state that poverty alleviation and sustainability are key goals. Yet they consistently employ processes to promote economic growth that undermines these goals.

A large proportion of African energy development occurring today is grid-based electricity development, which disproportionately benefits industry and urban communities without meeting the needs of the general population. Grid development is a significant tool, but it is not always the most effective response to Africa's energy needs. The energy needs must be critically assessed in order to appropriately determine when grid systems are the most effective solution.

Using a rights-based approach to Africa's energy planning, specifically hydropower and grid development, can improve the effectiveness and appropriateness of decisions made to solve Africa's energy needs.

Hydropower is a primary factor in the growth of national and regional grid systems across sub-Saharan Africa. This paper will explore: the current trends and impacts of hydropower and grid systems on African civil society; the allocation of the benefits and costs of hydropower and energy grids; and the criteria for a rights-based approach to decision-making in grid expansion.

Rights Based Approach

A rights-based approach is a conceptual framework that integrates the norms and principles of the international human rights system into the plans, policies, and processes of development in order to promote and protect human rights. The purpose of recognizing universal human rights is to allow people to flourish by promoting the realization of one's capabilities as a human being. Thus, development and human rights are both key strategies to the same goal: the promotion of quality of life, fulfillment of capabilities, and flourishing of individuals and communities. Some of the key priorities in a rights-based approach are: poverty elimination, promotion of gender rights, and self-determination. While there is no single, universally agreed rights-based approach, an emerging consensus is forming on the key basic elements, including public participation and empowerment.

The concept of human rights continues to be deepened into global laws, practices, and norms. Three key UN documents provide the foundation for international laws and practices on human rights: the Universal Declaration on Human Rights (1946), the International Covenant on Economic, Social and Cultural Rights (1966), and the International Covenant on Civil and Political Rights (1966). While the fundamental human right to development is rooted in the provisions of these documents, the UN nevertheless adopted the Declaration on the Right to Development in 1986, which explicitly defines rights-based development as a comprehensive, economic, social, cultural, and political process. The Declaration on the Right to Development states that every person is entitled to participate in, contribute to, and enjoy economic, social, cultural and political development.

In 1993, the World Conference on Human Rights affirmed the right to development by consensus. In 1995, the Copenhagen Declaration reaffirmed the link between human rights and development by establishing a new consensus that places people at the center of concerns for sustainable development, and by pledging to eradicate poverty and promote safe and just societies. Likewise, participating African states agreed at the World Summit on Sustainable Development in 2002 that human rights are part of the foundation to development.

Civil society is the arena of civic life that promotes action around shared public interests and values. It is an institution separate from government and the market, though institutional boundaries may sometimes be difficult to define. Civil society groups advocate and take action primarily for social development and public interest. Under a democratic framework, government and market institutions exist for the promotion of quality of life for members of civil society. Civil society should be viewed as an important key player in decision making about development because there are often social benefits and costs that are unrecognized by state and market institutions.

Hydropower and African Grids

African energy needs are indeed vast. Africa is home to 13% of the global population, but has the lowest energy consumption per capita of any continent. Most grid energy generation is in three countries: South Africa, Egypt, and Nigeria. Even then, a disproportionate amount of those using grid based energy live in urban areas. Vast disparities exist between grid energy available for commercial and non-commercial use. Grid based energy continues to be available overwhelmingly in urban areas, benefiting commercial use and those able to afford it. Concerns exist that financing grid-based development displaces resources available for energy development that could better promote poverty alleviation.

Hydropower is a significant source of existing and planned grid-based energy in Africa. Statistics are often used declaring that Africa's hydropower potential has gone virtually unexploited. While hydropower can generate significant electricity for grid systems and provide effective peak load power, hydropower projects are often proposed with overstated benefits and understated costs. Hydropower projects also have a history of poor implementation that has resulted in inequitable sharing of project costs and benefits. Beneficiaries of hydropower projects tend to live away from the hydropower site, and receive the grid based electricity, generally in urban areas or large towns. Those bearing the costs of hydropower projects may be directly displaced, have negative impacts to their livelihoods (such as fishing or agriculture), have increased health risks from water-borne disease, and face disruptions to social systems by temporary migration into the area during project construction. Those bearing the costs often do not benefit directly from the projects, or receive adequate compensation that recognizes all the social costs endured. Without genuine participation in the decision making process, communities often do not receive project benefits that outweigh their share of the costs.

Reservoirs of hydropower dams often displace thousands of people. The Kariba Dam shared by Zimbabwe and Zambia, displaced 57,000 in the 1950s. These are people for whom adequate compensation has never been granted, and whose lives and livelihoods were expensed for this addition to grid development. Currently, the Merowe Dam is displacing 20,000 villagers in Sudan without receiving proper compensation. They have been denied participation and genuine access to the justice system. In the past 50 years, some 40-80 million people have been forcibly resettled for large dams, and millions more face such a fate as we speak.

There are many current proposed hydropower projects across Africa. The largest is the NEPAD-backed Grand Inga scheme, which would be the core of a continental grid system. Over-simplified statements are made that if only Inga could be developed, the whole continent would be lit up. There is little discussion occurring, however, about how to develop the demand in rural areas for this type of project. With fifty-two generating units, it would be the largest hydropower project worldwide. Including transmission, it would cost an estimated cost of $10 billion. Grid development like Grand Inga contradicts the goals of small-scale sustainable energy projects that were discussed at the World Summit on Sustainable Development in 2002.

In the SADC region, there are many other projects proposed or underway. Mphanda Nkuwa in Mozambique is another NEPAD backed project that would fulfill the country's effort to attract energy intensive business. Significant hydropower development, such as Tekeze and Gojeb, is occurring in Ethiopia with expectations to export power. Other significant projects include the 520 MW Capanda Dam in Angola, the Kafue Gorge Lower Dam in Zambia, and the 400MW Bui Dam in Ghana.

Current plans to develop the African grid system include the promotion of regional transmission lines in order to develop power pools and numerous large-scale energy projects that will feed specifically into grid systems. The grid system, as currently planned, primarily benefits industry and wealthy communities in urban areas. There is virtually no benefit to rural areas, or the urban poor. Local industry and small business generally do not benefit from grid development to the extent that major commercial and industrial customers do. These large businesses, often foreign-owned, benefit from increased power generation, but often wield enough power to receive electricity at rates providing little profit margin for the government, if at all. In some cases, major end users pay rates subsidized by residential customers.

Power grids are not designed to reach the hundreds of millions of Africa's rural poor. Grid systems can create a greater divide between those with and without access, generally increasing the disparity between rural and urban areas. Mass grid development may even encourage greater urbanization, causing cities to develop at increased rates, leading to other negative economic impacts that cities must then address (such as increased water, sanitation and other infrastructure needs, increased crime, and increased spread of HIV and other disease). Many Africans live outside of the formal economy, living on subsistence and small enterprises that are often overlooked by development planners and policy makers. Designers of grid systems must be acutely aware of consumer demand and affordability. Whether in urban areas or in more distant communities, grid connection does not alleviate poverty for those unable to afford the electricity.

Economic Institutions

The stated goals of almost all major economic institutions in Africa are the same: poverty alleviation and sustainable development. NEPAD, the World Bank, the African Development Bank, all promote poverty alleviation as part of their missions. Similarly, economic communities, such as SADC, and ECOWAS, talk about sustainable development and poverty alleviation. However, these institutions are promoting economic strategies that do not promote poverty alleviation or other social goals. More importantly, they are marginalizing or excluding civil society's participation in these discussions and decision-making about concrete projects. This exclusion and lack of transparency not only undermines good projects, but also perpetuates poverty and the growing disparity of Africa's economic classes.

The New Partnership for African Development (NEPAD) has been described as a blueprint for Africa's self-determined economic propulsion out of poverty and toward sustainable development. NEPAD recognizes that half the Africa population lives on less than $1 per day, and that infrastructure is desperately needed to improve people's lives. However, NEPAD continues to be a top-down entity made up primarily of African elites with only token input from civil society. In a rush to promote foreign investment, economic growth, and NEPAD's political success, the body is virtually blind to the fact that its activities are in direct contradiction to its mission of African sustainable development.

Regional economic development planning and power pools are both gaining ground in Africa. More and more countries are receiving World Bank advisement to privatize their energy systems and promote competitive markets. Significant manipulation of market circumstances happens by those with the greatest market power: suppliers and major end-users. Civil society is rarely, if ever, in a position to benefit from the liberalized market.
Where there is supposed to be greater consumer power, industrial consumers wield the most power, often to the detriment of residential and small business users.

World Bank and IMF loans are regularly conditioned to include privatization of government enterprises and promotion of free market systems, including liberalizing capital markets, promoting market-based pricing and free trade. Unfortunately, these measures only move political economic powers from government bodies and politicians to private, often foreign, companies. None of these changes provides increased political economic power to civil society.

Across Africa, as with regions across the globe, there is a growing push to develop competitive markets and to move away from regulated energy monopolies. Environmental and social costs of a hydropower dam can vary greatly depending on the site, design and operation, but are almost always underestimated. One of the greatest costs of hydropower tends to be decommissioning, which is rarely, if ever, included in the cost of power projects. For these reasons, competitive markets can help pave the way for hydropower projects which are inaccurately determined to be "least cost" projects.

Eskom, the world's third largest utility, dominates Africa's power regimes and has developed its own internal NEPAD office, partly in hopes of securing more power projects for development. Eskom is assisting NEPAD with technology and resources, and is now in charge of developing continent-wide power integration systems. In order to make it look financially attractive, Eskom, NEPAD, and others must sell the package as being a great investment, with demand readily available. In order to promote Independent Power Producers, projects are often fast tracked without competitive bidding processes, often ending in generous financial agreements for the foreign companies. These un-transparent processes are regularly tainted by corruption.

Using a Rights-Based Approach

Utilizing a rights-based approach can bring more effective, more sustainable, more rational and more genuine development decisions. The inclusion of civil society in decision-making promotes transparency, which will likely decrease corruption. It will ensure that poverty alleviation happens, rather than poverty displacement, or even poverty generation. It will ensure appropriate solutions are found that fit the problems at hand because project analysis will be more complete. Most importantly, local participation and ownership of decisions helps safeguard against harm done by development projects, and will promote the sustainability of solutions found.

A rights-based approach allows for a positive transformation of power relations between various stakeholders involved in decision-making. There are four primary criteria to a rights based approach. First, it must include a linkage to human rights and accountability. Second, it includes equity of benefits and costs allocation. Third, it also includes empowerment and public participation, with attention to marginalized groups. And finally, it includes a transparent process. A primary concern over development projects in Africa is the external control of projects that affect internal peoples. Those within Africa need to be given decision-making control in their own development.

The World Commission on Dams (WCD) provides a framework toward rights-based decision-making of dams and development. The WCD's recommendations could help shift the decision-making paradigm in African grid development to ensure that the best development happens in the most effective way, and that everyone benefits.

Utilizing a rights-based approach can add economic value to development by promoting more effective, more sustainable, more rational and more genuine development decisions. The inclusion of civil society in decision-making promotes transparency, which will likely decrease corruption. It will ensure that poverty alleviation happens, rather than poverty displacement, or even poverty generation. It will ensure appropriate solutions are found that fit the problems at hand and stops unintentional harm that has occurred in poorly planned development projects. A human rights analysis can provide a more complete analysis by revealing additional concerns of the poor themselves, including the phenomena of powerlessness and social exclusion.

Conclusion

Development is not the end product. Development, specifically infrastructure, is a means to a better quality of life, higher living standards, and the fulfillment of human flourishing. However, good development must not only promote these goals, but must ensure equitable distribution of the benefits of development. Promoting a rights-based approach will ensure that appropriate decisions are made to promote African energy development for those who need it most

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8. THE FUTURE OF SAPP, WAPP, CAPP, AND EAPP WITH INGA (PAPER 05GM 0597)

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Abstract

New high voltage (HV) transmission lines are at the top of the agenda for many energy planners in the various regions of Africa. These lines are identified within the power pools of Southern Africa and West Africa. The new Central Africa Power Pool is in the process of identifying its new HV lines and the East Africa region is about to start. This paper looks at the centrality of the huge hydropower potential of the Grand Inga Project and the sensitivity of pricing electricity exports as they relate to transmitting power across Africa's proposed new HV lines.
Key Words: Transmission, economic gains, load carrying capability, African power pool policy, continental network.

Introduction

Capacity planning in Africa's power pools will be significantly affected by the proposed new HV lines. This paper considers the costs of interconnection across Africa and draws upon comparisons with HV line networks in other locations. The Southern African Power Pool (SAPP), West African Power Pool (WAPP), Egypt, and the East African 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. The Central African Power Pool (CAPP) and the Democratic Republic of Congo (DRC) have much to gain from exporting the potential hydropower at the right price.

Section 1 of this paper provides an introduction to Africa's power pools showing how each has an interest in the hydropower potential of Grand Inga. Section 2 outlines the North America experience with long-distance trading, and Section 3 discusses the creation of the CAPP. Section 4 considers investment and pricing of electricity exports, and Section 5 draws conclusions and recommendations for future electricity modeling in Africa.
Key Words: Economic gains, new HV transmission, African power pool policy, Grand Inga, electricity export pricing.

1. 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.

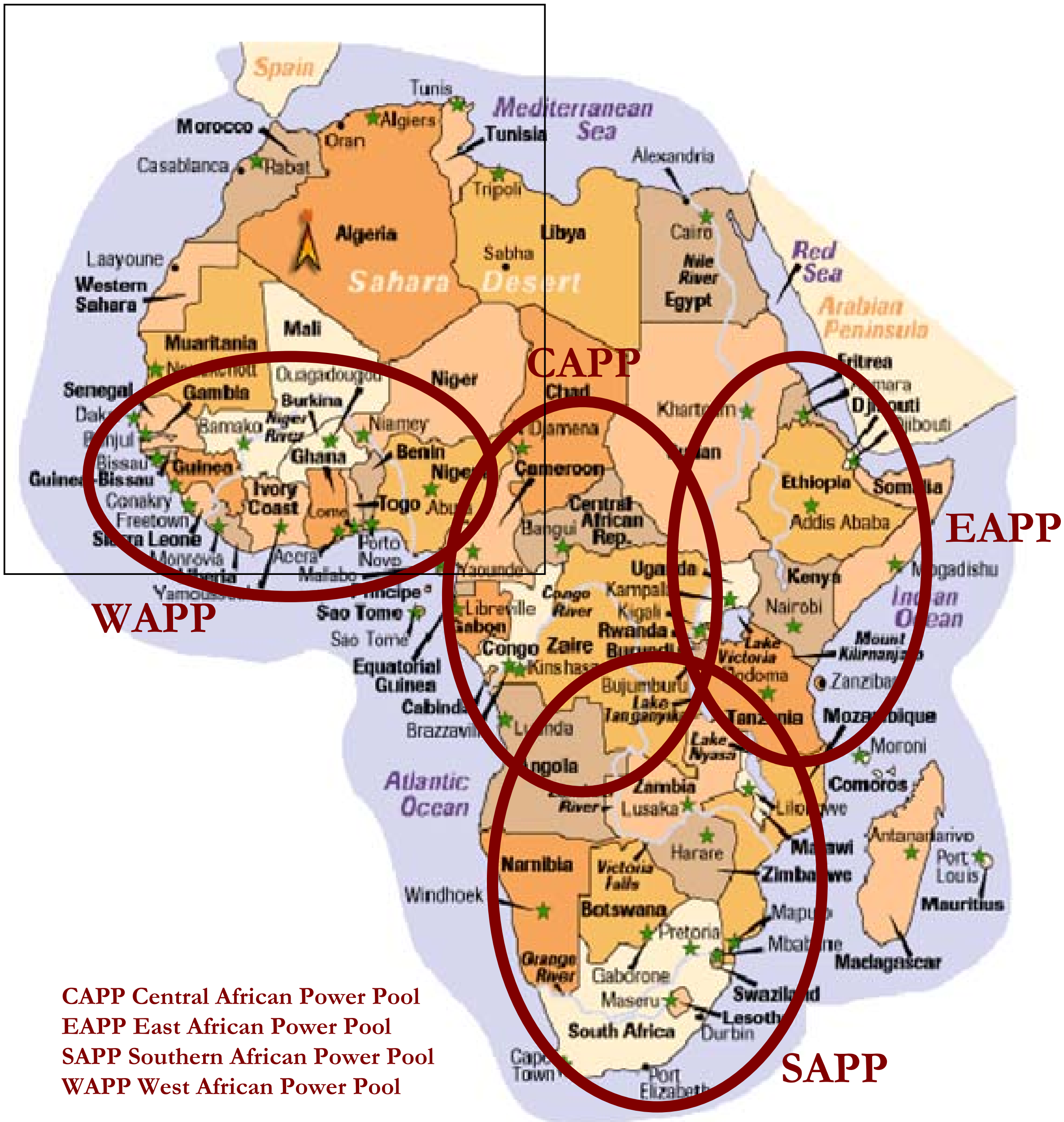


Figure 1. Africa Regional Power Pools, CAPP, EAPP, SAPP, and WAPP

The Southern African Development Community (SADC) created the 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 1).

Table 1. Sub-Sahara Regional MW Totals Reference*:* [1]

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 the 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 the SAPP with over 42GW of generation capacity (Table 1). 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.

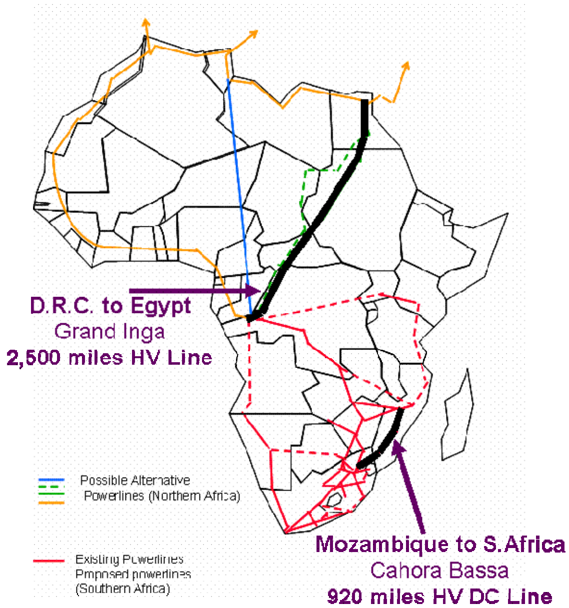


Figure 2. Long-Term Transmission Planning in Africa

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 2). 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 [2]. 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 2,500 miles.

Table 2. HV Transmission Lines in Africa and America Reference*:* [2,3]

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

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 2). 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.

2. Electricity Trading Between the North American Interconnects

Long distance electricity shipments in the U.S. were originally reserved for unexpected outages in generation. An interesting exception to this comes from the Canada's net flows of hydropower exports to New England and the west coast states. Net power flows between the three U.S. interconnections tends to be very limited. Canada's exports account for 5% to 10% of its total generation. In the case of CAPP these numbers will become reversed, with domestic consumption taking the 5% to 10% of Inga's total production, assuming new continent wide interconnections will be constructed.

In the 1990s the wholesale trade of electricity in the U.S. was promoted and the FERC (Federal Energy Regulatory Commission) established procedures to ensure the availability of non-discriminatory transmission access. It had been the formation of the North American Electric Reliability Council (NERC) in 1965 which ensured compliance with guidelines for providing overall reliability and system security. In Africa there is going to be need for a similar organization, as several countries will be involved with the proposed long HV lines.

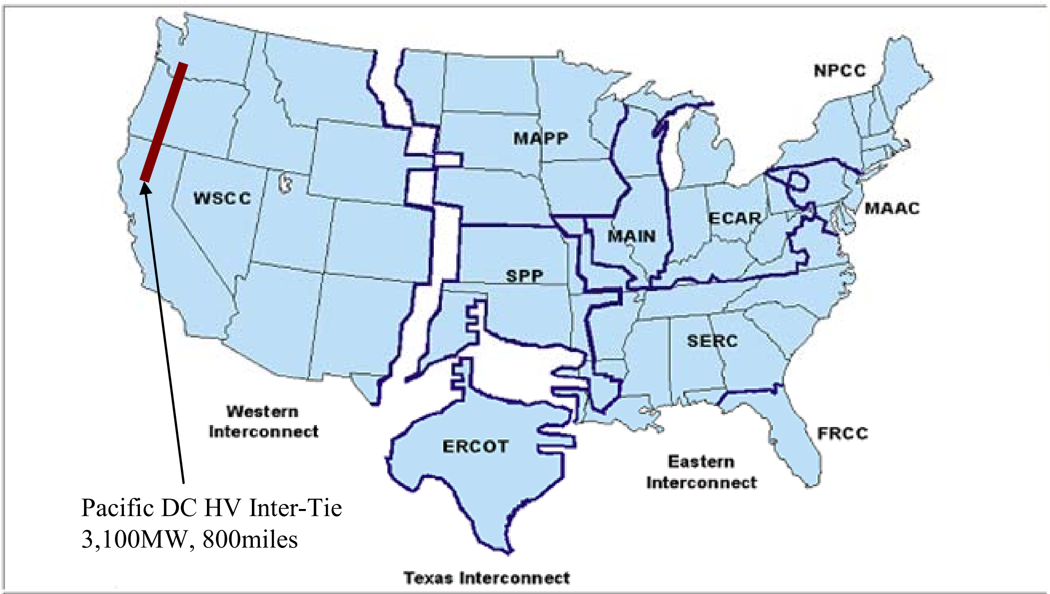


Figure 3. The Main Interconnections of the U.S. Electric Power Grid and the 10 North American Electric Reliability Council Regions

North America's three interconnected networks (Figure 3) are the Eastern Interconnect (the largest), Western Interconnect (second largest, west of the Rocky Mountain ranges) and the Texas Interconnect. There is very little load carrying capability between these three regions. Is it a technical problem or economics or simply no demand exists at present? Each regional grid operates as a single large utility with a common set of operating rules. The Texas System is not interconnected with the other two networks (except by certain direct current lines). The other two networks have limited interconnections to each other. Both the Western and the Texas Interconnect are linked with different parts of Mexico. The Eastern and Western Interconnects are completely integrated with most of Canada or have links to the Quebec Province power grid. Virtually all U.S. utilities are interconnected with at least one other utility by these three major grids. Mexico has a national interconnected grid with four regional divisions and about 23,500 miles of HV lines. It connects with the U.S. at several points over the border and in 2003 imported about 72GWh and exported 953GWh.

Table 3. U.S. High Voltage AC Transmission Mileage - Selected Years *Reference:* [4]

Voltage	1990	1999	Change
230kV	70,511	76,762	6,251
345kV	47,948	49,250	1,302
500kV	23,958	26,038	2,080
765kV	2,428	2,453	25
Total	**144,845**	**154,5033**	**9,658**

In the planning of Africa's new HV lines the control of the lines is to be an important issue. The FERC expects new regional transmission organizations (RTO) to improve power grid reliability while reducing discriminatory transmission practices, and increasing investments in the transmission infrastructure. The issue of exactly who will control the transmission of electricity under a nationwide system of RTOs needs resolving [5]. During this debate, in the 1990s, over 9,500 miles of new HV transmission lines were built in the U.S. giving approximately a 7% increase (Table 3).

Table 4. U.S. Electric Transmission Network - A Multi-Region Analysis Interregional Gross and Net Tie Line Transactions *Reference:* [6]

Interface	Peak Demand (MW)
NEPOOL to NYPP	27
NYPP to NEPOOL	888
Net, NYPP to NEPOOL	861
NYPP to MAAC	1,261
MAAC to NYPP	1,684
Net, MAAC to NYPP	422
MAAC to ECAR	969
ECAR to MAAC	3,908
Net, ECAR to MAAC	2,939
Total Gross Transactions (Four NERC Regions)	**8,737**

The early 21st century has seen less new HV lines being constructed and this is becoming of great national concern especially for the summer peaking seasons. At what level of administration is Africa to debate the construction and transmission controls of the inter-power pool interconnections? To date the HV lines have been limited to within the regional power pools.

Most electricity trade in the U.S. takes place not between the three interconnected systems but among the power pools in each interconnect. The main exception to this, as already noted, is in the case of Canada's exporting its hydropower. Major transfers of more than 3,900MW of peak demand moves between the two NERC regions ECAR and MAAC for example. Typical tie line transactions between U.S. power pools can vary between about 30 MW and over 3,000 MW (Table 4) but the lines are shorter than those being proposed for Africa.

Table 5. Capacity Limits for Electrical Transmission Lines Reference [7]

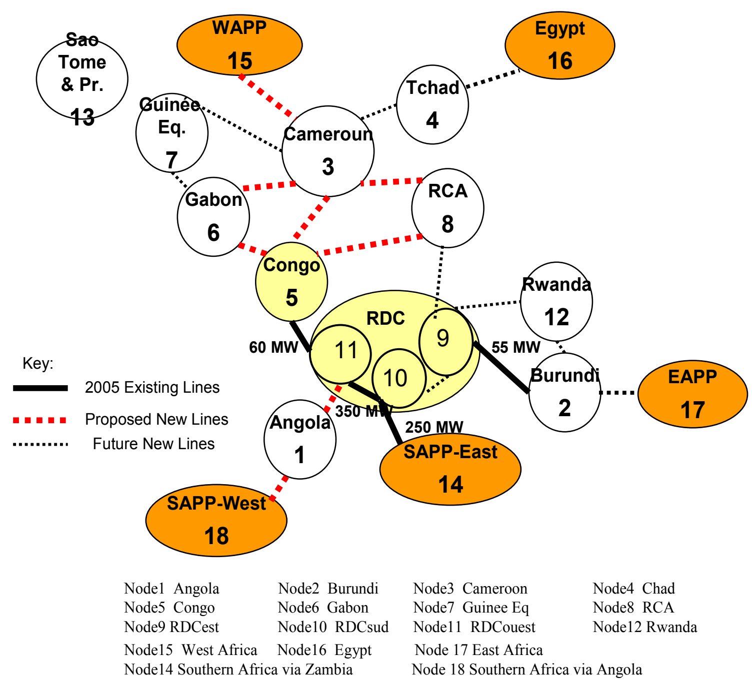
Voltage (kV)	Length (miles)	Maximum Capacity (GW)
765	100	3.8
	400	2.0
500	100	1.3
	400	0.6
230	100	0.2
	400	0.1

In the U.S. a 765kV line might carry 3.8 GW but it will only be 100 miles long (Table 5). Extra long lines as being considered in Africa will need further technical study and will be much more expensive. In the U.S. the transfer of 3,000MW over several hundred mile and more will normally involve several lines. Transmission lines, which are 1,000 miles, long or more, similar to the Mozambique to South Africa DC line, are special designs for which the capital costing and operating costs requires extra evaluation.

Exporting electricity from Mozambique's Hydro Cahora Bassa (HCB) to South Africa, and Canada's hydropower generation to the U.S. provides significant revenues to the exporting countries. In the case of DRC the export revenues could become substantial from building Grand Inga (Stages 1 and 2) with initial exports of 8,000MW (56,000 GWH/year). This could raise annual export revenues of $1.5 Billion or more once the full demand is being supplied.

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.

3. The Preliminary CAPP Model



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

Figure 4. 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 4 [8].

As Figures 1 and 2 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 [9,10]. The water cost was set at \$0.5/MWh which was the value stipulated by the SAPP some years earlier [11]. 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 4). 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 [12]. 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 [8] 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 4. 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.

4. 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.

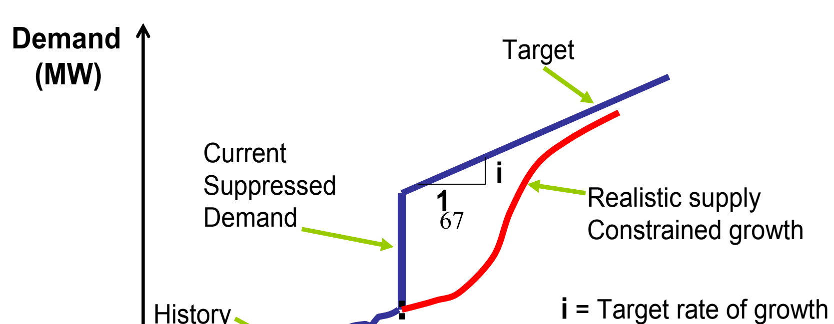


Figure 5. Electricity Growth Rate and Suppressed Demand

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 5). 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 8. World Total Net Electricity Consumption and Demand Growth Rates for 1993-2002 Reference*:* [13]

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%1.	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 8 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.

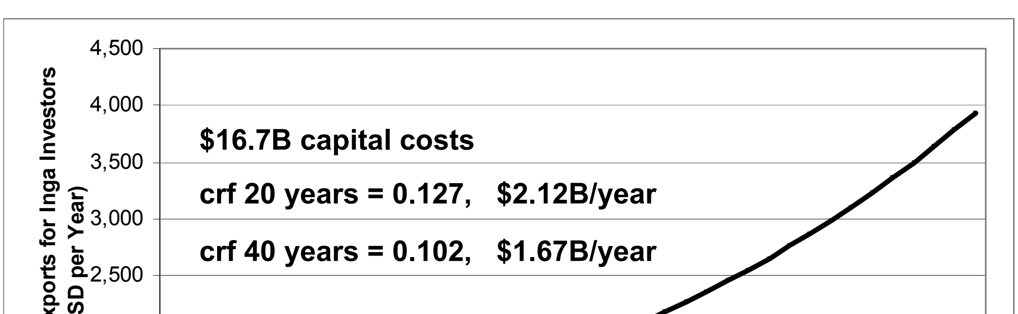


Figure 6. Net Revenues from Exports for Inga Investors With 2% and 4% Demand Growth (USD)

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.

Figure 6 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 6 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 6 also shows the most optimistic assumption with a 4% growth rate in demand being well in excess of historical rates as shown in Table 8. 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.

One very important last point: Over 40 years ago, Alan Manne, pointed out [14] that with economies of scale in construction and a given growth rate in demand, the higher the cost of capital, then "the smaller will become the optimal size of each installation" (p.637). Given the high cost of capital, due to the inherent risk of the hydro projects being considered because of their location, Manne's advice should be taken to heart by Inga promoters – they should look to smaller size projects.

5. Conclusions

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 but it is believed, by the authors, 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.

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9. TARGETS AND TECHNOLOGIES FOR AFRICAN ELECTRIFICATION. (Invited Discussion) (Paper 05 GM 0874)

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ABSTRACT

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 paper 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. The paper describes 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.

The paper also describes 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, 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 microturbines 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. Microturbines may offer the best combination of performance parameters for near-term application.

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.

The paper also addresses the challenges of introducing a modern electrification system to Africa, while limiting pollutants and greenhouse gas emissions, and assuring the affordability of the system.

Finally, the paper discusses grid options, from large, long distance transmission systems to local "minigrids" for village power solutions.

Introduction: 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.[1] 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.

The World Summit on Sustainable Development held in Johannesburg reaffirmed those goals and gave particular attention to the need for assuring a greater supply of modern energy services, notably electricity, to the entire world's population.[2] This report affirms and adopts that goal. For the benefits we envision, electricity will have to meet reasonable standards of quality and reliability be available for commercial, industrial and residential uses, be affordable, and cause minimal environmental impact. A diverse portfolio of generation options will be required, including advanced clean fossil, renewable, hydroelectric, and nuclear power sources, plus high-efficiency end-use technologies and applications to support both environmental and economic sustainability. Our vision for the 2050 global energy system is therefore one of worldwide new capabilities and opportunities for quality of life, dignity, and environmental sustainability, enabled by universally available electricity.

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.[4] 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 megajoules 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 megajoules per day threshold by 2050 to as little as 125 megajoules 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.

Table I: Roadmap Destinations	
Destination	**Summary**
Strengthening the Power Delivery Infrastructure	An advanced electricity delivery system that provides additi transmission and distribution capacity and "smarter" controls that sup dynamic market activity and the rapid recovery from cascading outa natural disasters, and potential terrorist attacks
Enabling the Digital Society	A next-generation power system that delivers the power quality reliability necessary for sophisticated digital devices and seamle integrates electricity systems with communications systems to produc "energy web" of the 21st century
Enhancing Productivity and Prosperity	New and far-reaching applications of the energy web that incr productivity growth rates across all sectors of the economy
Resolving the Energy/Environment Conflict	Clean, cost-effective power generation technologies combined workable CO_2 capture, transport, and storage options
Managing the Global Sustainability Challenge	Universal access to affordable electricity combined with environmen 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. Electricity also serves as the unique energy prime mover enabling technical innovation and productivity growth—the lifeblood of a modern society. One need look no further than rural North America in the 1920s and 1930s—regions that were transformed from economic backwaters through active rural electrification programs—to see the importance of electrification as the precursor to economic opportunity and well-being. Further, as electricity's share of "final energy" in the U.S. increased from 7% in 1950 to nearly 20% today, the energy required per unit of GDP dropped by one third. Such important achievements, which occurred throughout the industrialized world, remain elusive in the least developed world regions. Over the last 25 years, about 1.3 billion people have been connected to electric service, but even this achievement has not kept pace with global population growth. Today, the International Energy Agency estimates that 1.6 billion people lack access to electricity. To keep pace with the world's growing population, electrification must reach at least an additional 100 million people per year for at least the next 50 years. This is about twice the current rate of global electrification.

Setting Electrification Goals

Equally important as universal access to electricity is assuring adequate levels of electric service for those who have access. Our work 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 II 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[5], from a World Energy Council study of energy futures[6], 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. Even with major efficiency gains in the generation and use of electricity, the aggregate global requirements for electricity generation will still be prodigious. Therefore, a critical priority is the development and deployment of an advanced portfolio of clean, affordable, generating technology options—fossil, nuclear, and renewables—that reflects the diverse resource, environmental, and economic realities of the world, while enhancing efficiency and productivity throughout the energy supply chain.

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. Studies are urgently needed to quantify the value proposition of electrification under a variety of policy and technology scenarios. This information will play an important role in helping policymakers develop incentives as well as regulatory and market frameworks that will encourage private sector investment in electricity infrastructure for underserved areas. Also necessary are analytic tools that can improve this understanding and lead to development strategies specific to individual regions, to accommodate the differences in resources, human needs and cultural norms. The availability of these and other analytical tools will help avoid the mistakes that have occurred in recent African electrification initiatives. This body of work is beyond the scope of this paper, but significant problems in African electrification have arisen due to poor management practices, political corruption, counter-productive cross subsidies, ineffectual reform programs, among others.[7,8] These issues must be resolved to assure the success of electrification programs.

Table II. Global Electrification Prospects in Africa					
	GDP per capit (10^3 US $PPP year)	Primary Energ per capita (10 per day)	Electricity Consumption per capita (kWh per ye	Electricity (% 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

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. This report proposes some global goals and strategies, 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.

These questions require local and regional attention. Such analytical work must be done in a way that reflects appropriate local policies and the emerging new reality that electrification is increasingly funded with private capital and operated as a partnership between private firms and public institutions. In that emerging market, assessing the value equation requires attention to public values and policies as well as private incentives.

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. New higher power systems with intelligent metering that complement distributed and grid-based power may be required.

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. Note, however, that the markets for power in urban areas of the developing world dwarf the demand in rural areas. This suggests that there will be a continued role for central station generation in many developing countries that must necessarily rely on indigenous resources to control costs.

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 and capital cost of the generation equipment. Work is also needed to develop low-cost storage options—batteries, flywheels, and ultra capacitors for example—to deal with the intermittency problems of wind and solar power.

In many circumstances, power systems in developing countries will be designed to fill the needs of single users. However, village systems will probably require some version of a multiply connected mini-distribution grid, because simple radial distribution schemes will be unable to handle more than one generator on a system.

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. Other considerations include the need for standardization of voltage levels, interconnection standards, and safety measures such as current limiters. Finally, guidelines for the initial electrification of developing countries can speed the process by summarizing the case histories of other organizations and countries, recognizing that no single solution will suffice for all applications.

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. Urbanization in the more developed world stands at about 75%; in the less developed world it is only about 40%, so there is enormous potential urban migration in developing countries. The rate of migration may not be entirely independent of electrification; anecdotal evidence suggests that people in rural areas with access to electricity, and the opportunities it provides, experience less pressure to move to cities to find work.

Thus, while rural electrification may stem urban growth, we will still need a technology base for urban electrification, especially in the case of burgeoning "mega cities"—urban population concentrations of 10 million or more. We anticipate that urban electrification will include central station generation solutions, as well as the distributed options discussed above. The central generation technology will focus on fossil fuels (coal, gas, and some oil) in the near term, transitioning to low-carbon technologies (nuclear power, renewables, and sequestration of carbon emitted by fossil fuels). Distributed generation options will be used in the urban context, but their role will differ from that of rural applications. In cities, the high population density will place a premium on space available to support "horizontal" renewables, such as solar energy. Rooftop installations of photovoltaic systems will serve niche applications, but the small rooftop area per capita will limit electricity production. Fossil-fueled distributed generation will also play a role, but emissions of additional air pollution in urban complexes may add to an already heavy burden from automobiles, home heating, and cooking. The emerging drivers for urban electrification in the developing world are thus seen to be broadly similar to the issues in the OECD countries. However, one distinguishing characteristic of urban power plant programs is the need for flexibility in power plant design and operations so that the power supplier can quickly change business models to meet changing trends in population growth, electricity demand, and end-use technologies.

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. However, these advantages are mitigated to a degree by the relatively low efficiency and high emissions of some designs. In addition, purchasing today's technology may lock the purchaser into yesterday's solutions, and in the future it may be difficult to retrofit a more modern solution. 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.

The portfolio strategy offers the greatest flexibility and resiliency in meeting the uncertainties of the future, as well as the opportunity for different regions of the world to adjust the portfolio balance to suit their circumstances. A number of factors can shift the balance of the portfolio, including the availability and price of fuels, the pace of technological advancement, capital requirements, regulation, and policy. One critical factor will be the growing pressure to internalize the environmental costs of fossil energy, which will increase the relative importance and attractiveness of renewable and nuclear energy.

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 system would enable two-way flow of both power and communication. It could competitive markets for a range of distributed services. In the case of rural power systems, the lines between supplier and consumer blur and in many cases will disappear altogether. At a minimum, the consumer will dictate the nature and level of the services to be provided, and the rate of growth of the services. Ideally, the latter should initially keep up with the demand for new hook-ups, and then reflect the growth rate of the local economy.

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. Advanced and novel DER concepts under development include Stirling engines, various generating technology hybrids, flywheels, "ultra capacitors," and superconducting magnetic energy storage systems. Related R&D is addressing DER-specific power conditioning equipment. 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.

There is no single solution to the climate change conundrum. Activities on all nodes of the electricity value chain—from fuel extraction to power generation to end use—are contributing to the buildup of CO_2 and other greenhouse gases (GHGs) in the atmosphere, with a potential impact on precipitation and other important climactic factors.

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

1. Decarbonization, defined as reducing the carbon content of the fuel. Renewable generation, biomass, and nuclear power are the principal means for decarbonization. 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 dollar 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. As discussed earlier, 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. This means that at least initially, commercial production of hydrogen will probably rely on "free" or nearly free sources of primary energy. In Africa, this could mean tapping the large hydropower resources of East 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 of the electricity/hydrogen economy contemplates hydrogen providing as much as half of current US oil imports, half of all transportation fuel, and a sizeable fraction of US electricity generating capacity by 2050. Large, centralized hydrogen generation plants could be placed at network nodes or hubs to serve broad regions with both hydrogen and electricity. The nodes would store and deliver hydrogen, with smaller, distributed hydrogen plants at distribution feeders or hubs to help meet peak and intermediate loads.

This vision requires development of an energy infrastructure that can support expanded production, delivery, storage, and use of hydrogen energy. Construction of this infrastructure will require massive efforts and resources, resulting in evolution of the electricity/ hydrogen economy over two to three decades. Storage weight and volume reductions, mass production of fuel cells, construction of the necessary infrastructure, and expanded use of portable and distributed power generation devices will sustain the momentum toward an electricity/hydrogen economy. Early glimpses of this vision can already be seen in pilot programs underway in a few U.S. locations and several other countries. But there are formidable technological and economic challenges that must be addressed at every stage in the hydrogen energy chain, from production, to transport and local delivery and storage, and ultimately to end use.

The long-term vision for Africa is similar. 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.

The future large-scale use of hydrogen to carry energy is not without controversy. There are many unsolved barriers to the development of technologies and systems that would permit a viable electricity/hydrogen economy for 2050 and beyond. Acknowledging this uncertainty, we view hydrogen as a promising future possibility rather than an inevitable future. However, its potential value in energy efficiency, global emissions reduction, and energy resource conservation justifies serious study and development efforts.

Outlook for the Intelligent Power Delivery System

Although this paper focuses on the supply side of the electricity equation, 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. This will be true in developed and developing countries alike. It is important to remember that supply and demand in the electricity industry still rely on the same system design and much of the same technology in use since the dawn of electrification. This is a remarkable record of performance, but one that can no longer be sustained through merely evolutionary changes in the status quo.

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. Consequently, their cost and time requirements to offer commercial solutions will compare favorably with the developed world.

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.

The shorthand for this new system is the intelligent power grid, or “Intelligrid”, conceived of as an electricity/information infrastructure that will enable the next wave of technological advances to flourish. This means an electricity grid that is always on and “alive,” interconnected and interactive, and merged with communications in a complex network of real-time information and power exchange. It would be “self-healing” in the sense that it will constantly monitor its condition and self-correct at the speed of light to keep high quality, reliable power flowing. It could sense disturbances and counteract them, or reconfigure the flow of power to cordon off any damage before it can propagate. It would also be smart enough to seamlessly integrate traditional central power generation with an array of locally installed, distributed energy resources (such as fuel cells and renewables) into a regional network.

The smart, self-correcting power delivery system will become the conduit for greater use of productivity-enhancing digital technology by all sectors of the economy, leading to accelerated productivity growth rates. The power system will enable new energy/information products and services across the board, and reduce or eliminate the parasitic costs of power disturbances characteristic of the U.S. economy today.

To complete the picture, digital technology will also 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." The portal will provide both the physical and logical links that allow the communication of electronic messages from the external network to consumer networks and intelligent equipment. For consumers and service providers alike, this offers a tool for moving beyond the commodity paradigm of 20th century electricity service. It will complete the transformation of the electricity system functionality, and enable a set of new energy information services more diverse and valuable than those available from today's telecommunications industry.

The Intelligrid may appear to be a distant dream when compared with the near-term needs of African electrification. However, the ability of the developing world to leapfrog intermediate technologies may allow implementation of elements of the Intelligrid system as they become available. In particular, a wireless information network will be able to provide much of the communications support needed for a power system based on distributed energy resources. The hardware and software needed for distributed energy systems in Africa are already available. Implementation of a distributed Intelligrid will be limited by financial considerations rather than technology considerations.

Conclusion

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.

Increasing electricity supply will create the societal and economic "headroom" we need to address the global needs. Particularly important are the four linked goals of protecting earth's life support systems, improving human welfare, eliminating poverty, and stabilizing population. Only when the world's citizens have achieved a minimal quality of life will they have the will and resources to participate in the global economy.

Without this headroom, economic development will be sub marginal. However, economic headroom can catalyze growth and fulfill our aspirations of a global economy, enabled by digital-quality power and a new infrastructure that integrates electricity with the knowledge-based industries of the future.

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Biography

Stephen Gehl has over 25 years of experience in defining technology responses to the issues and opportunities of the electric power industry. Currently, he is the Director of Strategic Technology at the Electric Power Research Institute. He leads the Electricity Technology Roadmap initiative. The Roadmap is a guide for strategic technology development efforts in the electricity industry. In this capacity, he has worked with over 200 organizations, both domestic and international, to define electricity-related business and societal needs and aspirations and the technologies that will allow us to attain these aspirations. The Roadmap experience has been documented in more than 50 articles and papers in the trade and general press, and has led to several follow-on road mapping initiatives with other companies. In addition to the U.S.-based Electricity Technology Roadmap, Dr. Gehl led the development of an Energy Roadmap for the Netherlands, "Technology for a Sustainable Society". He recently completed a revision of the Electric Technology Roadmap, led Roadmap development efforts for the Malaysian utility, TNB, and is currently leading an effort sponsored by the Indian Oil Company.

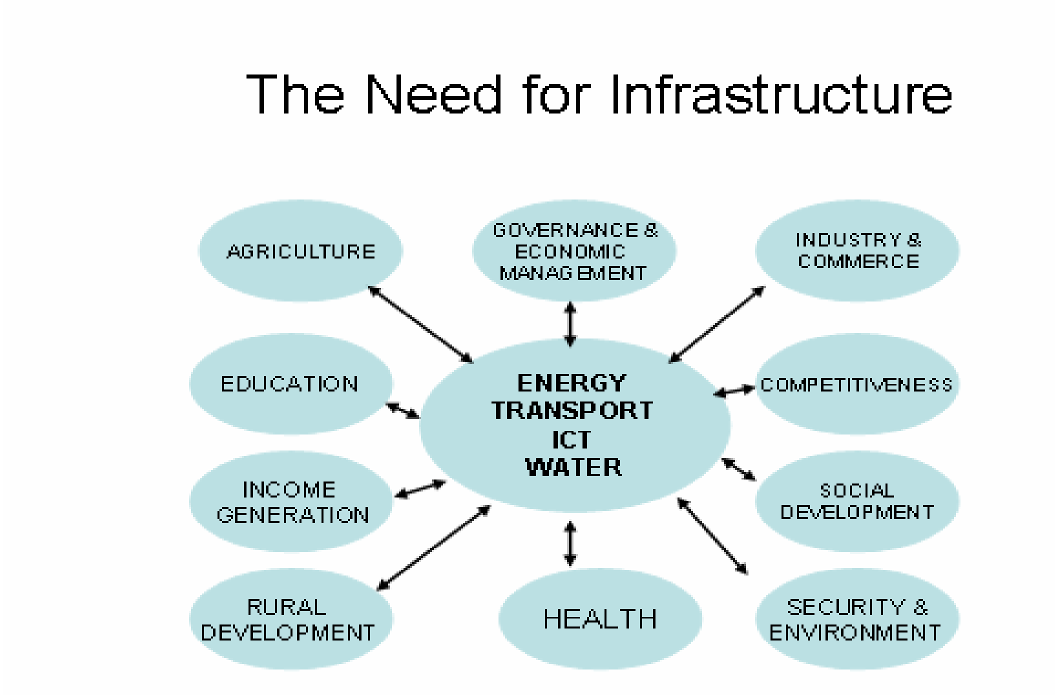
Previously, Dr. Gehl served as EPRI's Director of Strategic Synthesis with responsibility for developing EPRI's business and technology strategy. He also managed programs on fossil plant performance and nuclear fuels technology development.

Before coming to EPRI in 1982, he was a staff metallurgist at Argonne National Laboratory, where he conducted research on nuclear fuel performance.

Dr. Gehl received a Bachelor's degree in metallurgical engineering from the University of Notre Dame and a PhD in materials science and engineering from the University of Florida.

He is a member of Sigma Xi and The American Society of Mechanical Engineers.

10. R.T. Mochebelele, Advisor Infrastructure, NEPAD Secretariat, South Africa. New Partnership for Africa's Development (Invited Discusser)



WHY REGIONAL INFRASTRUCTURE

- Regional and International trade are central to economic growth and development.
- Efficient infrastructure network has the effect of generating new investments in other sectors.
- African countries, individually, are too small to generate economies of scale found in larger markets.
- Weak infrastructure linkages condemn the region to low competitiveness in the global market.
- Regional infrastructure leads to larger project sizes capable of attracting more private sector investments.

NEPAD CONTEXT IN INFRASTRUCTURE

- NEPAD aims at promoting regional integration in the continent to generate economies of scale.
- Bridging the infrastructure gap identified as an important element of promoting regional integration in Africa.
- Development of regional infrastructure is critical for sustaining regional economic development and trade.

APPROACH ADOPTED

The approach adopted by NEPAD in Infrastructure is two-pronged:

i) A short-term action plan (STAP) based on a survey of countries and RECs.
ii) A Medium-Long Term Action Plan/Strategic Framework, which is linked to and complements the short-term action plan. It will take up projects and initiatives that require more time for preparation and development as well as institute an enabling framework for future development of infrastructure

The NEPAD Infrastructure Short Term Action Program was endorsed by the Summit of AU in 2002.

THE ROLE OF NEPAD

NEPAD tasks to ensure the successful implementation of Short Term Action Plan:

- Mobilizing political will:
  - Facilitating the mobilization of resources.
  - a) Facilitating knowledge sharing, networking and dissemination of best practices
    b) among countries, RECs and technical agencies.
- Underpinning all NEPAD infrastructure programs is the objective of strengthening sector governance.
- The NEPAD program in infrastructure is not a new set of initiatives. NEPAD brings a new vigor to accelerate response to familiar problems and the implementation of tested policies and good practices.

TYPOLOGY OF STAP

STAP Projects and Programs are mainly of four types:

Facilitation – establishment of policy, regulatory and institutional framework to create a suitable environment;
Capacity Building initiatives to empower particularly the implementing institutions;
Physical/Capital Investment projects and programs; and
Studies to prepare new priority projects and Programs.

STAP PROJECTS/PROGRAM SELECTION CRITERIA

The STAP project selection process was guided by the following criteria:

- Projects that are at an advanced stage of preparation and that can be fast-tracked;
- Projects that support both a regional approach to infrastructure provision and regional integration;
- Projects that have stalled for various reasons and where NEPAD's intervention could be expected to make a difference;
- Initiatives that offer solutions to regional policy, regulatory or institutional constraints.

ENERGY SECTOR

Goal

To develop fully the energy resources of the continent in order to deliver affordable energy services to the various economic and social sectors - Power Systems Initiatives

Themes

i) Gas/Oil Transmission Initiatives
ii)Studies to Prepare New Initiatives
iii) Regional Capacity Building Initiatives
iv) Regional Facilitation Initiatives

NEPAD ENERGY FLAGSHIP PROJECTS

- Regional Pools and Inter-connections
- Greater Inga Integrator Study
- Establishing Regional Linkages for African Energy Commission
- West African Gas Pipeline
-

PROJECTS UNDER IMPLEMENTATION

- Electricity Master Plans for sub-regional interconnections in West, East and Central Africa
- West African Power Pool
- Southern Africa Power Pool
- Nigerian Benin Electricity Interconnection
- Mozambique-South Africa Gas Pipeline
- Electricity Networks Interconnection in Central Africa Study
- Kenya-Burundi-Rwanda-DRC Electricity Interconnection Study
- Morocco-Spain Electricity Interconnection
- Eastern Nile Power Trade Program Study
- Zambia-Tanzania-Kenya Electricity Interconnection
- Ethiopia-Djibouti Electricity Interconnection
- Benin-Togo-Ghana Electricity Interconnection
- Mozambique-Malawi Electricity Interconnection
(Kenya-Uganda Oil Pipeline and West African Gas Pipeline)

PROJECTS/PROGRAMMES STATUS

The Southern Africa Power Pool (SAPP)

In 1995, Southern African Development Community (SADC) signed the Intergovernmental Memorandum of Understanding establishing SAPP with the mandate of managing the co-operation in the electricity sector in Southern Africa. This formalization was a result of the regional evolution of the policy, planning and operational levels involving governments, power utilities and financial agencies for the last several decades.

The 12 members of the SAPP consist of the public utilities in the participating countries. These members have been tasked to create a common market for electricity in the SADC region and, in turn, allow their customers to benefit from the advantages associated with this market. All utilities participating in SAPP have equal rights and obligations, and have agreed to act in solidarity without taking advantage of one another. Members have agreed to share information and knowledge; be politically neutral; develop common planning and operating criteria and procedures; and to accept wheeling on behalf of other members when this is technically feasible.

The Secretariat is operation and is based in Harare, Zimbabwe

WESTCOR Power inter-connect (DRC – Angola – Namibia – South Africa)

The WESTCOR Steering Committee has been formed under the auspices of SAPP to initiate studies determining the viability of WESTCOR with source at INGA III. The WESTCOR Project is designed to investigate the feasibility of interconnection of the power systems of the Democratic Republic of Congo (DRC), Angola and Namibia and transmitting hydropower from DRC and Angola via Namibia to South Africa. Specifically, the study will make an assessment on interconnecting: the existing INGA Power Station (DRC) with the northern grid (Angola); Northern grid with central and southern grids (Angola); and the Angolan grid with the Namibian grid.

The objective of the study is to advance the preliminary study on DRCANSA carried out in July 1998 to feasibility level in order to assist in making investment decisions on the project. If implemented the interconnector would serve as an alternative route to transfer hydropower/gas power from DRC and Angola to the SAPP in general and South Africa in particular.

Project Status

An inter-governmental memorandum of understanding (IGMU) and the memorandum of understanding (MoU) have been signed paving the way for the project kick-start. The utilities of the countries concerned have formed a WESTCOR Joint Venture company registered in Botswana to develop the project and have agreed on equity contribution of 20% to enable financing of the project. The utilities have raised US$ 500,000 among themselves for the preparatory work on the project. The Development Bank of Southern Africa has shown interest in co-financing on this project. Other lenders need to be identified.

West African Power Pool

The West Africa Power Pool (WAPP) project will integrate national power grids of five coastal countries (Benin, Cote d'Ivoire, Ghana, Nigeria, and Togo) and three land-locked countries (Burkina Faso, Mali, and Niger). The project, as conceptualized, will be implemented in several phases. Phase 1 of the project is termed the West Africa Power Market Development Project (2002-2006) and comprises two components: Component A: critical infrastructure to expand cross border power trade; and Component B: Policy and capacity building.

Project Status

The World Bank is supporting the process to tune of about US$300 million, of which IDA could finance about US$100 million. With regard to the capacity building component, study tours to USA and Southern African Power Pools to kick start the process have been undertaken by the West Africa Power Pool Implementation Committee and the Working Group of Experts.

Greater Inga Integrator Study

The Grand INGA Integrator Study is intended to investigate the possibility of developing the hydropower potential at Grand INGA and transmitting the power to the continent's sub-regions (east, west, north, south and central). The study will also look into the wheeling of the power through the North African interconnection to Europe and the Middle East.

The objective of the study is to investigate the feasibility of developing the hydropower potential at Grand INGA to supply the sub-regions in the African continent and transmit the surplus power to neighboring continents.

Project Status

In order to facilitate the speedy implementation of this initiative, the NEPAD Secretariat and the ADB have held meetings with the authorities in the DRC to address the delay being experienced. ADB has earmarked US$ 10 million for the undertaking of the Greater Inga studies. Unfortunately, to date a formal request from the DRC has not been received by ADB.

Electricity Master Plans for Sub-regional inter-connections in West, East and Central

Energy resources in the sub-regions are characterized by an abundance of energy resources in some countries and scarcity in others. Whilst each sub-region in whole had abundant energy potential, the energy sector in individual countries is amongst the least developed. There is potential for strengthening the power systems within individual countries and between the countries, leading to the establishment of an East African Power Pool (EAPP), Western African Power Pool (WAPP), and Central African Power Pool (CAPP) along the lines of the Southern African Power Pool (SAPP).

The objectives of the Electricity Master Plan is to set, in stages the conditions necessary to optimize energy resources utilization, harmonize national energy development plans through interconnection of electric power systems and to ensure security of energy supply to Member States in the West, East and Central Africa.

Project Status

The Terms of Reference for the electricity inter-connectivity study have been prepared with the assistance from the African Development Bank (ADB). The World Bank has also shown interest in the project particularly in the ECOWAS region.

Some Interconnections Under Implementation:

Nigeria- Benin Inter-connection:

The objectives of the project are:
- To provide an alternate source of power supply to Togo and Benin;
- Reduction of power outages in Togo and Benin during drought years to limit economic and social hardships on the population of the two countries;
- Link the electricity grids of the sub-region thereby improving reliability of supply and optimizing production cost.

Projects Status

Financial resources to the tune of US $ 22.36 million have been secured with the ABD and contractual arrangements are in place. Project implementation is underway.

Kenya-Burundi-Rwanda-DRC: Electricity Networks Interconnection:

The objective of the study is to review the technical, economical and financial feasibility of the electricity interconnection projects between Kenya, Burundi, Rwanda and DRC.

Project Status

Financing to the tune US $ 2.95 million has been secured with the ADB and a financing agreement between the countries involved and ADB was signed on the 2nd July 2004.

Algeria-Morocco-Spain Electricity Interconnection:

The objective of the project is to increase interconnection capacity and imports of electric power, provision of least cost supply of electric power market and enhancement of the security and reliability of the transmission grid.

Project Status

The financial resources were secured by the ADB to the tune of US $ 97.28 million. The project is under implementation and so far more than half of the financial resources have been disbursed.

11. John Ayodele: WEST AFRICA POWER POOL (WAPP) AS A TOOL FOR REGIONAL INTEGRATION: OPTIONS IN THE GLOBAL ENERGY MARKET (Paper 05GM1083) (Invited Discusser)

ABSTRACT

The West Africa Power Pool Program (WAPP) is a means by which the utilities in the member countries of the Economic community of West African States, ECOWAS, decided to come together to pool the electricity recourses together for cheaper and quality electric power to their citizens

The 14 countries of the ECOWAS member States have therefore agreed to integrate their electric Systems together so that cheaper power can flow in either direction. This will allow poorer countries with no recourses to embark on capital-intensive hydro/thermal power plants to be ale to import power form other countries with reserve power. This is in line with the present delivery, more so that many of these counties are inter land with road and air transportation alternatives

However, as will be seen in this paper, many challenges face the Pool System, from institutional setup, to pricing and wheeling charges. Above all, the building of the bridges what will allow the electric currents to flow, the funds required and how the utilities will contribute and pay for the services with little internally generated recourses. In other words, the financing options which will include private investment participation, donor agencies, government funds etc, must be pooled together to ensure that lines and substations required for pooling of National Electricity System together are met.

The USAID funded a Regional Transmission Study to develop a master plan for the future development of the Regional Transmission development over a period 2004 – 2020. The study was done in close collaboration with WAPP Utilities, the World Bank and lenders. USAID had earlier commissioned the Purdue University Power Pool Development Group to produce a Long-Term Expansion Model for a 20-year planning system for energy and reserve trade between the countries with autonomy constraints.

The fact that there are about 5No currencies in the monetary system will not help the scenario and consequently, the efforts of the ECOWAS Executive Secretariat is trying to integrate the currencies into one unit currency, the ECO, will in no small way assist in this integration program.

This paper will also try to summarize the efforts made to date, the donors and the various governments and will try to give and insight to the status and the way forward for the WAPP.

Keywords: ECOWAS Integration Programs, Purdue Model, The Energy Observatory, Electricity Pricing Model and WAPP Stability

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