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in the Proceedings of the 2005 IEEE Power Engineering Society General Meeting, June 2005

"The Central African Power Pool (CAPP), the Economic Community of Central African States (ECCAS) and the New Partnership for Africa's Development (NEPAD),"
by B.K. Kalala,
in the Proceedings of the 2005 IEEE Power Engineering Society General Meeting, June 2005

"Technical Issues: Area Control Considerations in the WAPP and SAPP Areas,"
by W-J Lee,
in the Proceedings of the 2005 IEEE Power Engineering Society General Meeting, June 2005

"Hydropower and African Grid Development: A Rights Based Perspective"
by T. Hathaway and L. Pottinger,
in the Proceedings of the 2005 IEEE Power Engineering Society General Meeting, June 2005

"The Future of SAPP, WAPP, CAPP, and EAPP with INGA,"
by F.T. Sparrow, B.H. Bowen, and Z. Yu,
in the Proceedings of the 2005 IEEE Power Engineering Society General Meeting, June 2005

"African Power Pool Development: Accelerating the Technical Skills Factor,"
by B.K. Blyden,
in the Proceedings of the 2005 IEEE Power Engineering Society General Meeting, June 2005

Status, Plans of Action, Further Developments, and Recommendations for Power Pools in Africa

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***Abstract*—This paper focuses on power pools in Africa: status, plans of action, further developments, and recommendations. First, the Southern African Power Pool (SAPP) formation, current status, and future challenges are addressed. Then the Central Africa Power Pool (CAPP), the economic community of Central African States (ECCAS), and the New Partnership for Africa's Development (NEPAD) is examined. CAPP is a new sub-regional institution, created in Brazzaville in April 2003, under the auspices of ECCAS that is presently the focal point for discussions on regional power markets, particularly as the Ingar hydropower complex when developed could generate close to 40 GW. Security issues of power system interconnections in Africa are then reviewed. Also discussed is the current status and developments of the West Africa Power Pool (WAPP) and the East Africa Power Pool (EAPP). Also considered is Hydropower and African Grid Development in relation to a *rights-based perspective*. Finally, the future of SAPP, CAPP, WAPP, and EAPP is examined.**

***Index Terms*—African energy needs, African power pool policy, civil society, competitive electricity markets, continental network, dynamic stability, economic gains, human rights, hydropower, load carrying capability, power pool, power system margin, power system operation, real-time, rights-based approach, security, sustainable development, transient stability, transmission, voltage stability.**

I. Introduction

THIS paper considers the present status, plans of action, further developments, and recommendations in respect to Power Pools in Africa not presented in the literature in a convenient form heretofore. It is an update and follow-up to the paper on African Electricity Infrastructure, Interconnections, and Electricity Exchanges published in [1].

Interconnection of electric power systems of regions, states, and individual territories is acquiring a growing scale of importance in world practice. Projected development of regional power pools in Africa is an example. There are many benefits 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 of 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.

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II. Southern African Power Pool Formation: History and Future Challenges

Historically, electricity trading in Southern Africa started in early 1960 as bilateral trade after 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 Southern African Development Community (SADC) treaty to optimize 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 SAPP.

The past, the present, and the future of SAPP are now addressed. SAPP is transforming from a cooperative into a competitive pool.

A. Agreements That Govern Operation of SAPP

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

1) *Inter-Governmental Memorandum of Understanding*, which enables the establishment of SAPP;
2) *Inter-Utility Memorandum of Understanding*, which establishes SAPP's basic management and operating principles;
3) *Agreement Between Operating Members*, which establishes the specific rules of operation and pricing.
4) *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 nonoperating members since they are not connected to the other SAPP countries.

B. Resource Potential and Installed Capacity

The total installed capacity in SAPP is about 53 000 MW. Eskom of South Africa produces 80% of the total generation in SAPP (see Table I), and about 74% of the total energy produced in SAPP is from thermal stations.

Installed capacity of SAPP is given in Table I.

C. Operations of SAPP

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

D. Achievements of SAPP

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

- Mozambique-Zimbabwe 400-kV interconnector;
- Zimbabwe—Botswana-South Africa 400-kV inter-connector;
- Democratic Republic of Congo (DRC)—Zambia 220-kV interconnector.

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

E. Future of SAPP

SAPP is now developing a Spot Market with the assistance of NordPool Consulting through funding from the Norwegian Agency for Development (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 inter-connector;
- Mozambique—Malawi 330-kV interconnector;
- 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 DRC has 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 Inter-connector would also facilitate the interconnection to Eastern Africa. Africa can thereby utilize the diversity in resources and time differentials for the economic dispatch of the generating units.

F. SAPP Membership Review

A special Documentation Review Working Group (DRWG) was set up to review the SAPP documents so as to consider admitting Independent Power Producers (IPP) and Independent Transmission Companies (ITC) into SAPP. The proposed new composition of the Executive Committee is indicated in Fig. 1.

The proposed representation is as follows.

TABLE I
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**

*Most utilties have generating units that are old and cannot produce to their maximum capacity. As for the DRC most of their units are out on rehabilitaion.

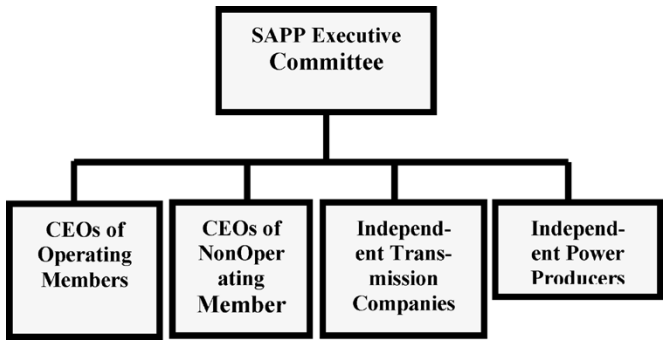

Fig. 1. Composition of SAPP executive committee.

- 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 Chief Executive Officers (CEOs) from government-owned power utilities that are operating members.

The overall proposed restructuring of SAPP is shown in Fig. 2. The restructuring of SADC has necessitated this. Also as SAPP is moving toward competitive markets, the Markets Subcommittee has been introduced.

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

A. CAPP

CAPP is a very new subregional institution, created in Brazzaville on 12 April 2003 under the auspices of the 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.

1) Mission and Vision: CAPP is assigned to: 1) promote power policies; 2) promote studies and construction of common

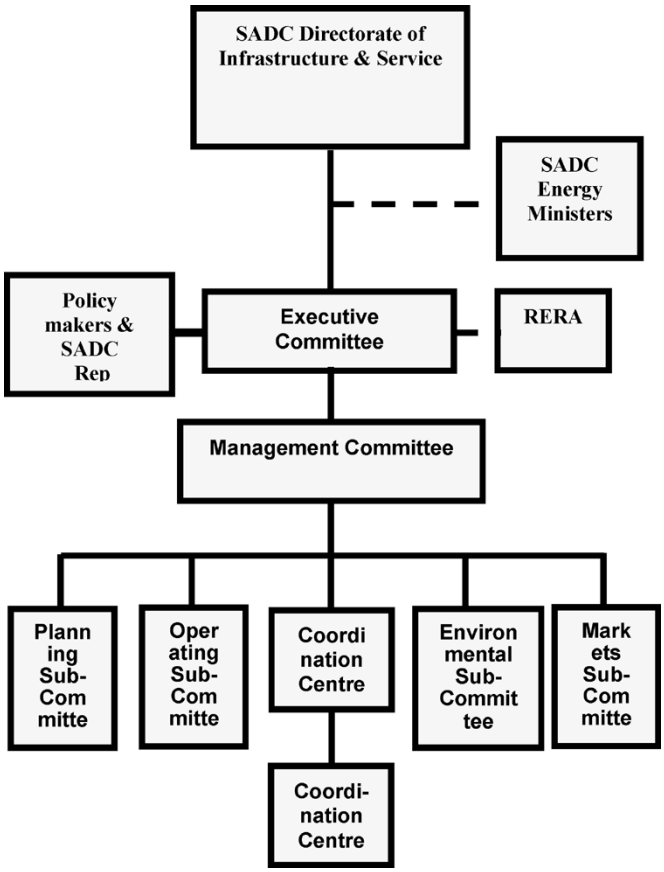

Fig. 2. SAPP management structure.

infrastructures and the organization of energy exchanges and the related services in ECCAS; and 3) 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's vision is to exploit the enormous hydroelectric potential of Central Africa estimated at more than 650 000 GWh (53% of the whole African potential) to satisfy all demands in electricity for households, states, and central African industry.

2) Members: Any public, private, and/or semi-public electricity supply enterprises of ECCAS member states may become a 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 include ENE-EP/EDEL (Angola), ELECTROGAZ (Rwanda), and REGIDESO (Burundi).

B. ECCAS

ECCAS was instituted in October 1983 in Libreville (Gabon) by 11 member states. These were 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).

TABLE II
ELECTRIC SITUATION OF AFRICA

Sub-Regions	Average Potential (GWh)	Power Production (MW)	Consumption (kWh/h)	Provisionally Needed (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%)

Source: CAPP, Brazzaville, Republic of Congo, June 2005

1) 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 as follows:

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

2) Immediate Perspectives: Planned for 2004 was the establishment of a zone of free exchange in the states of ECCAS with organization of the private sector, civil society, the feminine organizations, and academics so that they can contribute to achievement of the missions assigned to ECCAS. In addition, backing of capacities of the General Secretary of ECCAS was planned for implementation in the New Partnership for Africa's Development (NEPAD) in Central Africa.

3) Electric Situation of Central Africa: The electric system for the whole of Africa is shown in Table II.

In spite of its enormous hydroelectric potential, Central Africa is the least electrified sub-region in Africa.

4) Present and Future Inter-Connection Projects: These are indicated in Fig. 3.

5) CAPP Integration Projects: CAPP Integration Projects are summarized in Table III.

C. CAPP and ECCAS

To implement the Common Market of yesterday and to build the European Union of today, European states began the Common Market with what was the European Community of Coal and Steel (Rome, April 1951).

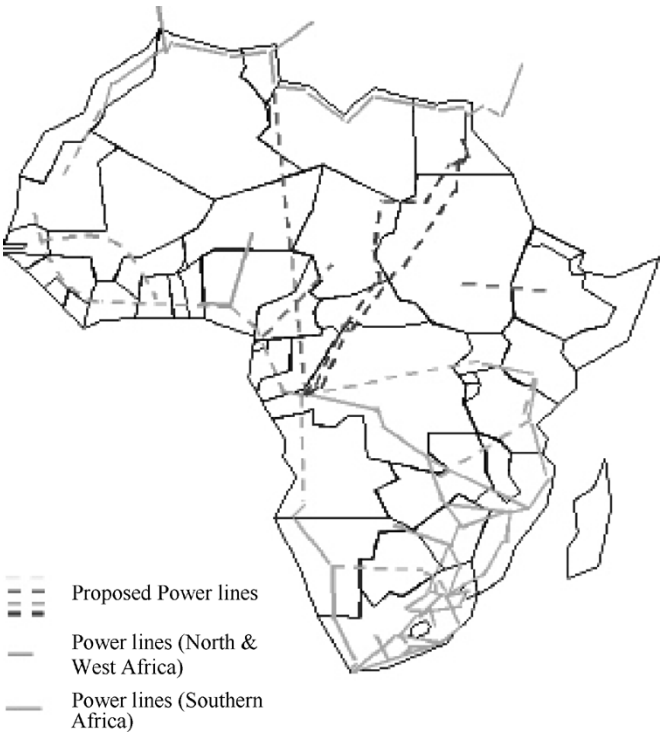

Fig. 3. Present and potential African grid.

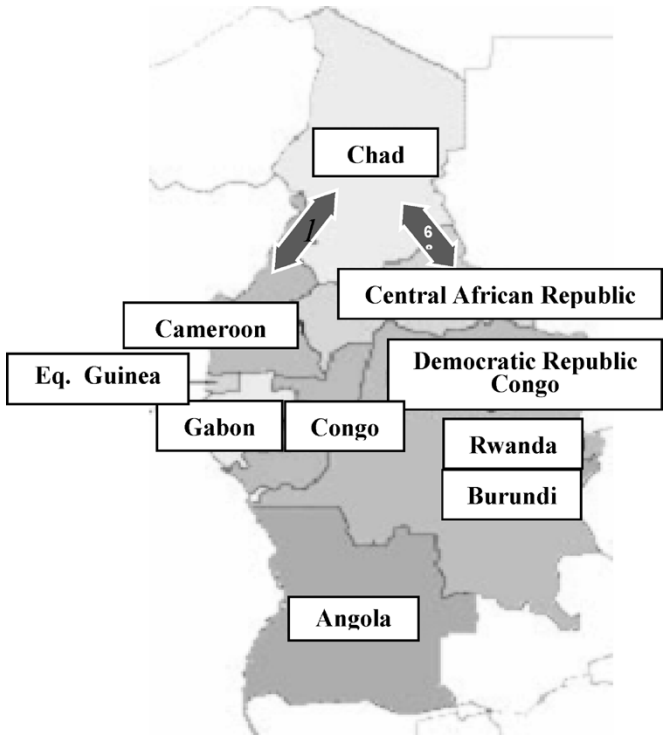

Fig. 4. Transmission interconnection projects between operating members.

TABLE III
CAPP INTEGRATION PROJECTS

Project	NAME OF PROJECT
1	Transmission Interconnection Inga (DRC) to Pointe-Noire (R.Congo) via Cabinda (Angola)
2	Planning of Grand Inga (DRC)
3	Backing of CAPP capacities
4	Interconnection of the electric networks of the ECCAS Member states (financed by a grant of African Fund for Development/FADB)
5	Implementation of Data Bank and Standards
6	Transmission interconnection between the electric Systems of CAPP and WAPP
7	Designing a master plan of investment and Development of an energy sector in Central Africa
8	Transmission interconnection between the electric Systems of CAPP and SAPP
9	Rehabilitation of hydroelectric power stations and Transmission Interconnections associated with the Member states of ECCAS
10	Institutional reform of state utilities of ECCAS Member states
11	Transmission Interconnections Inga (DRC)-Maloukou-Ouesso (RC) and Sangmelima (Cameroon)
12	The CAPP – COMELEC Interconnection (Inga-Assouan)
13	The Interconnection Cameroon–Chad
14	Setting up of the systems of information and communications integrated in the CAPP area

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

In March 2005, Eskom put in motion plans for a $50 billion project on the Congo River that is envisaged to meet the electricity needs of 13 southern African countries. It is hoped the project will begin by 2010. Eskom and utilities from Botswana, Namibia, Angola, and DRC will initially embark on rehabilitating two existing hydroelectric projects along the Congo River, which will produce about 9500 MW to 12 countries in southern Africa.

1) Transmission Interconnection Projects Between Operating Members: CAPP identified transmission interconnections projects between members, indicated in Fig. 4 and Table IV.

D. CAPP and NEPAD

1) Definition and Creation: NEPAD is a program of the African Union to fulfill its objectives of development by filling the gap that separates Africa from the developed countries.

During the Organization Summit held in Lusaka in Zambia in July 2001, the Millennium Action Recovery Plan (MAP) and those of the French-speaking nations, the *OMEGA* plan, essentially an infrastructure development plan, were merged and became the New African Initiative (NAI).

During the summit held in Abuja in October 2001, NAI became the New Partnership for the Development of Africa (NEPAD) dealing with good political governance, good economic governance, infrastructures, energy, agriculture, health, education, environment, new technologies for information and communication, and access to markets.

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

TABLE IV
PRESENT AND FUTURE INTERCONNECTION PROJECTS

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

Of all goods produced by Africa, hydroelectricity is the only one that is commercial, strategic, and nonpollutant that the subregion is able to produce and export to all Africa and toward a part of Europe and the Middle East without border hindrances.

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

E. Present Situation of Projects and Immediate Perspectives

1) Integration Projects: These include the following:

- launching of the interconnection of power grids of ECCAS member states financed by the African Development Bank and launching the "*Design of a Master Plan for Investment and Development of the Energy Sector in Africana Sub-Region*" financed by the organization United States Aid for International Development (USAID);
- requests for financing are submitted to other international financial providers;
- projects of institutional support;
- projects for electrification between members states;
- other requests for financing are to be submitted.

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

F. Mode of Execution of CAPP Programs

To achieve its missions, the CAPP Permanent Secretary adopted the method VIP:

V vision = picture of what one wants to be and to have;
V view = diagnostic (demand/offer);
V values = hierarchies objectives;
I influences = strategies or modes of actions;
P projects = actions or projects.

The method VIP enables one to precede by defining power politics, the setting up of programs of temporal and spatial actions, and scheduling of efficient actions to reach objectives necessary for the satisfaction of individual and collective power needs hierarchies.

G. Challenges

The challenges are

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

IV. TECHNICAL ISSUES: AREA CONTROL CONSIDERATIONS IN THE WAPP AND SAPP AREAS

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. 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. 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. 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. Interconnecting ac networks will increase complexity of the system that may increase system reliability, security, and impact stability due to the interactions of equipment and control actions. This section uses development of the West Africa Power Pool (WAPP) and SAPP to discuss area control considerations in this cross-countries interconnection utility grid [2].

A. WAPP and SAPP

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, Equatorial Guinea, Gabon, Rwanda, and São Tomé & Principe), West (Benin, Burkina Faso, Cape Verde, Ivory Coast, 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. 4 shows the present and potential African grid. Among them, the southern region has progressed further than any other in interconnecting its electricity grid, and the west region formed an alliance in 2000 and developed an implementation plan that will be staggered over a period of more than 20 years. They are good examples to examine the past and future energy integration activities among African countries.

1) West African Power Pool [3]–[5]: In September 2000, national electricity sector officials from 14 countries of the Economic Community of West African States (ECOWAS) working to create a regional market for electricity adopted 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.

ECOWAS countries have been divided into two main zones: Zone A includes Benin, Burkina Faso, Ivory Coast, Ghana, Niger, Nigeria, and Togo; and zone B includes Cape Verde, 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 Ivory Coast and Ghana have been identified as the main prospective exporters of electricity in the region during implementation of Phase 1.

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 B. Some national transmission lines will be reinforced for 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 center and the panel of independent experts on 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 construction of the coastal line from Ikeja West (Nigeria) to Abobo (Ivory Coast). 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 coordination 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 coordination center to strengthen the existing financial function. This phase will carry out the implementation of the regulatory regime defined in Phase 1.

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): Phase 4 will focus on the consolidation of actions to make existing entities and instruments fully operational.

B. Area Control Consideration of an Interconnected System [1], [6]–[10]

1) Financial Issues: 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 on anticipated transfers over the lines and requires engineering and economic analyzes. 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 the desired power transfers. Investments in transmission facilities have historically been funded by the utilities.

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 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.

2) Technical Issues: Interconnection enhances the ability to import power when there is a shortage due to extreme weather or generator outages. An interconnected ac network will increase complexity of the system that is subject to various reliability, security, and stability problems due to interactions among the increasingly prevalent generator automatic 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 on August 14, 2003. It took only 9 s 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 1) voltage stability, 2) dynamic/transient stability, and 3) cascading failure and protection coordination.

V. Hydropower and African Grid Development: A Rights-Based Perspective

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.

A rights-based approach to Africa's energy planning, specifically hydropower and grid development, can improve 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. The current trends and impacts of hydropower and grid systems on African civil society, the allocation of benefits and costs of hydropower and energy grids, and the criteria for a rights-based approach to decision-making in grid expansion are explored in [11]–[16].

A. Rights-Based Approach

A rights-based approach is a conceptual framework that integrates the norms and principles of the international human rights system into plans, policies, and processes of development 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 upon rights-based approach, an emerging consensus is forming on the key basic elements, including public participation and empowerment.

B. Hydropower and African Grids

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 noncommercial 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. 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.

Reservoirs of hydropower dams often displace thousands of people. The Kariba Dam shared by Zimbabwe and Zambia displaced 57 000 in the 1950s. Currently, the Merowe Dam is displacing 20 000 villagers in Sudan without receiving proper compensation.

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. There is little discussion occurring about how to develop the demand in rural areas for this type of project. With 52 generating units, it would be the largest hydropower project worldwide. Including transmission, it would cost an estimated $100 billion.

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 400-MW Bui Dam in Ghana.

C. 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, and 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.

Across Africa, 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.

D. Using a Rights-Based Approach

Utilizing a rights-based approach can bring more effective, sustainable, rational, and 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. Local participation and ownership help safeguard against harm done by development projects and will promote sustainability of the solutions found.

In summary, 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

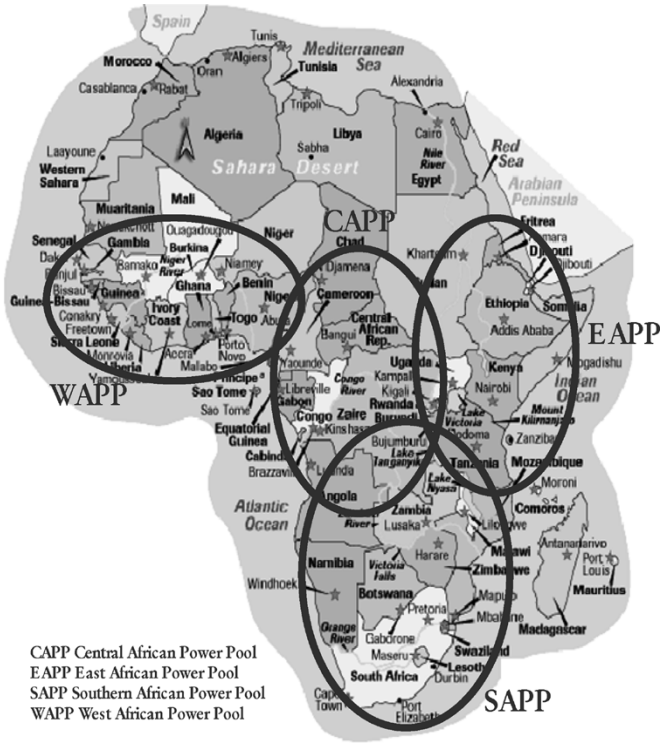

Fig. 5. Africa regional power pools: CAPP, EAPP, SAPP, and WAPP.

that appropriate decisions are made to promote African energy development for those who need it most.

VI. Future of SAPP, WAPP, CAPP, and EAPP

As discussed, SADC created SAPP in 1995, and ECOWAS created WAPP in 2001. Each of these two power pools covers a very extensive area, including 12 countries in the former and 14 in the latter (see Fig. 5).

CAPP was created in 2003, and there is discussion in East Africa of an East African Power Master Plan. These regional initiatives for improving trade among states all depend on new international transmission lines being built. Where 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?

A. Continental Transmission Networks

Major utilities in Africa are planning for a continent-wide transmission network. These are very long-term ambitious plans, and in several cases, the major lines being considered are still ideas and in an embryonic stage of development. Lines from Central Africa to Egypt and North Africa will require massive investments, although initial studies have already been conducted. The enormous hydropower potential on the River Congo is an attraction to utilities all over Africa. The western corridor line for transmission from the DRC to South Africa, through Angola and Namibia, is being studied by Eskom and member utilities of SAPP.

Drawing upon the experiences of the U.S., it was the formation of the North American Electric Reliability Council (NERC) in 1965 that ensured compliance with guidelines for providing overall reliability and system security. In the 1990s, wholesale trade in electricity was promoted and the Federal Energy Regulatory Commission (FERC) established procedures to ensure the availability of nondiscriminatory transmission access. The U.S. has a three-region national transmission network.

TABLE V
Sub-Sahara Regional Generation Totals

Power Pool	Total Existing Generation (MW)	Sub-Sahara Generation (%)
CAPP	4,561	8%
EAPP	3,092	5%
SAPP	42,011	72%
WAPP	8,579	15%
Total	58,243	

The U.S. has the Eastern Interconnect (the largest), the 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. Each regional grid operates as a single large utility with a common set of operating rules.

The total electricity generating capacity of Sub-Sahara Africa is about 6%–7% (see Table V) of the total capacity of the United States (983 GW). With Africa having a much larger area and smaller generating capacity, a major justification for promoting such a large grid, with expensive long transmission lines, is to distribute the enormous hydropower potential of the River Congo to the north and south of the continent. Supply of the Congo hydro to West and East Africa will provide cheaper power supplies to both regions.

VII. African Power Pool Development: Accelerating the Technical Skills

Paradigms to help develop and effectively share the necessary technical skills sets involved in the growing African energy development sector represented by various regional pools are now discussed [17]–[24]. The thesis is 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 SAPP, WAPP, CAPP, EAPP, and interconnection initiatives in North Africa with ties to the Middle East. Details of the Knowledge Engine [17], the EPRI Road Map Initiative & Strategic Science & Technology (SS&T), the status and goals of the Association of African Universities (AAU) and the African Virtual University (AVU) are now examined.

A. Existing Programs and Initiatives

1) EPRI & SS&T: As part of the Road Map Initiative discussed in reference [17], 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 examined in the present status of ICT Programs in Africa [18].

1) Improved Transmission Capacity, Grid Control, and Stability
2) Maintain and Strengthen Portfolio of Generation Options
3) Accelerated Development of Carbon Capture and Storage Technologies
4) Creation of the Infrastructure for a Digital Society
5) Improved Methods for Communicating and Applying Scientific Knowledge
6) Improved Power Quality and Reliability for Precision Electricity Users
7) Increasing Robustness, Resilience, and Security of Energy Infrastructure
8) Advances in Enabling Technology Platforms
9) Exploiting the Strategic Value of Storage Technologies
10) Transformation of Electricity Markets
11) Ecological Assessment Management
12) High-Efficiency End Uses of Energy
13) Maintaining and Improving Water Availability and Quality
14) Global Electrification
15) Development of Electricity-Based Transportation Systems.

The power pool development programs [20] 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 above, further examination of the societal impact brought on by current and planned development should yield the strategic direction for human capital development on a domestic and international level.

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