Generation and Transmission in Developing Countries

A panel session on Generation and Transmission System Planning and Improvements in Developing Countries was held during the IEEE PES 1996 Winter Meeting in Baltimore, Maryland. Panelists focused on the planning practices in deregulated power markets in developing countries, new realities in power development, proposals for developing hydro potential in Africa, Asia, and South America.

- Power Sector Restructuring and Expansion Planning, Manuel I. Dussan and Nelson de Franco
- Pressing Need of Developing Countries, Jose Malhaes da Silva
- Planning in a Deregulated Environment in Developing Countries: Cases of Bolivia, Chile, and Peru, Hugh Rudnick
- Power System Planning in Deregulated Environments: The Brazilian Experience, Marciano Morokowski
- Global Dynamics and the Potential for an Integrated African Grid, Bai K. Blyden

T.J. Hammons (University of Glasgow, Scotland, United Kingdom), chair or the International Practices Subcommittee of the Energy Development and Power Generation Committee, served as moderator. The following is a summary of each of the presentations.

United Nations Activities in Power System Planning

M. Willingham and Peter Mak

The role of the United Nations (UN) is primarily that of technical assistance rather than of developing projects. The United Nations Department for Development Support and Management Services (UN/DDSMS) energy projects have primarily been funded under the United Nations Development Program (UNDP). During the last 2 decades, hundreds of technical co-operation and preinvestment projects in energy involving hundreds of millions of dollars have been implemented. A roughly equivalent amount was provided by the recipient governments in the form of staff, facilities, and local operating costs. At this time, the department is executing 50 energy projects in 40 developing countries with annual delivery totaling approximately £7m. While the program in energy is the largest technical cooperation program in the energy field within the United Nations system, it is relatively small in view of the needs of the developing countries. The projects, however, do play an important catalytic role in many developing countries at an early stage of their energy development, particularly to strengthening of energy sector institutions through training, provision of experts, or acquisition of modern technology and equipment.

In the system planning area, the UN is addressing integrated electrical systems planning in developing countries based on a combination of technical, organizational, and economic factors in perspective planning, operational planning, medium-range planning, and long-range planning.

The main themes are forecasting and management capacity expansion, rehabilitation and power plant life extension, balancing supply and demand, and load management. Discussion is focused on technology transfer, finance and investment, and the environment. Program areas include promoting institutional changes for missing or outmoded infrastructure, assisting the investigation of relevant modern technologies, promoting marginal cost pricing instruments and mechanisms, long-term capacity-building through training of technical and management staff, and fostering demand-side management initiatives (including recommendations regarding regulation and privatization, as well as inventory of different approaches and solutions).

UN/DDSMS Programs

The United Nations Department for Development Support and Management Services programs and activities are designed to address programmatic concerns in the development of energy in development programs. The programs include the following.

Power System Expansion and Interconnection in People’s Republic of China. This study focuses on institutional, economic, and organizational aspects that limit the provision of clean, affordable, and reliable coal-based electric energy in the People’s Republic of China. It is considering the current status and projected growth of China’s electric networks, as well as
the primary technical, economic, and institutional constraints. It is also outlining programmatic initiatives and their implications for future UN System Programming.

Greenhouse Gas Emission Reduction in Egypt. This project is under consideration for funding by the Global Environment Facility. It has a proposed budget of £3.5m over 3.5 years. It is designed to assist the Egyptian Electricity Authority in reducing the long-term growth of greenhouse gas emission from electric power generation and from consumption of nonrenewable fuel resources. The objective would be achieved through activities based on energy conservation, as well as dissemination and implementation of the results of practical pilot projects and demonstrations of energy efficiency. The study comprises of five component tasks: loss reduction in the unified power system; load shifting and load management; energy conservation, co-generated power, and energy and engineering services.

Integrated Development of the Arab-Mediterranean Region. This proposed study will examine institutional aspects that affect the integrated development of the Arab-Mediterranean region as a major energy corridor for both electricity and natural gas resources. The Mediterranean basin is a potential crossroads for future energy trade between remote (primarily under-developed) energy producing countries and Europe. The future integrated electrical system will include utilities from over twenty countries, some of which include more than one utility. For the Arab region, neither of the two existing organizations include in their statutes any responsibility for the operation of an integrated grid network. The study will identify existing governmental statutory and legal conventions, security concerns, and relevant institutions for establishing appropriate political frameworks for cross-border energy projects.

Environmental Studies
There are three projects in China of special interest:

- New “city demonstration project,” aimed at controlling environmental pollution from coal combustion in four cities where pollution is at unhealthy levels. Mechanisms include: energy management and efficiency analysis for industrial facilities; individual training in energy planning and air pollution control; tours of appropriate technical facilities; instrumentation for supplementing environmental data; and development/purchase of software.

- A training institution for thermal power plant operators has been set up by the Ministry of Electricity to institute training programs in efficient power system operation. The project will provide the center with a thermal power plant simulator which will be used to train plant managers and staff in systematic maintenance procedures and improved operation routines to increase power system reliability and availability.

- A pilot project (£1.3m) on the modernization of a 200-MW fossil fuel generating unit is being implemented. It is possible that such modernization may ultimately be applied to all 112 Chinese-manufactured 200-MW units. This could reduce national coal requirements by 500,000 tonnes/year and save 2,240 MW of additional electric generating capacity that would otherwise have to be constructed at a cost of over £160m.

In Mozambique, the Electricity Supply Commission has been assisted in increasing operational efficiency and reliability of generation stations. Operational power plant capacity has been increased from 20 to 80 percent through intensive maintenance and operational improvements and the training of 220 technical staff in efficient power system operation.

Renewable Energy
The renewable energy program is examining satisfying rural energy needs by geothermal, solar, wind, and small-scale hydro. It includes resource assessment, technology transfer, and the training of technical manpower.

Geothermal Energy. In the development of geothermal energy, three major projects at the feasibility study stage have been executed in Chile, El-Salvador, and Turkey. The studies have led to the construction of geothermal-based power plants in several developing countries.

In Bolivia, a £6m geothermal feasibility study has been implemented in Laguna Colorado. Four deep exploration wells have been drilled and all are good producers. They can operate 2 x 4-MW back pressure turbines. Future development of the field will operate a 30-MW condensing type power plant.

In Tibet, a detailed geoscientific investigation in the Yangbajain Valley has been undertaken, together with reservoir and engineering studies of the Yangbajain geothermal field to optimize power generation at the existing plant in Yangbajain. Total project funding is £7m.

In Ethiopia, large-scale geothermal reconnaissance surveys resulted in the discovery of geothermal steam. A feasibility study has shown that it is economically viable to use the geothermal steam both for power generation and for industrial purposes. Total funding amounted to £3.3m.

In Kenya, following completion of a feasibility study for 15-MW power plants, three 15-MW units were commissioned in 1981, 1982, and 1984, respectively. A £2.3m project at the prefeasibility stage to extend geothermal exploration to new areas of the Kenya Rift Valley was completed in 1989.

The Philippines is the second largest producer of geothermal energy in the world with approximately 900-MW of installed capacity for power generation. Of three geothermal projects, two have focused on the assessment and management of geothermal reservoirs, while the third project examines the feasibility of the direct use of geothermal energy in agro-industry.

Solar Energy. In general, 70 percent of the people in developing countries have no access to electricity. A major problem facing governments in developing countries is how to meet future demand for basic electric service and to do so in a sustainable, environmentally acceptable manner. UN/DDSMS is promoting renewable sources of energy in rural communities for the provision of basic electrical services, and for lighting, broadcast reception, telecommunications, pumped water, medical refrigeration, and agro-processing.

The potential of solar energy in contributing to developing country energy supply is significant. Many projects and programs in solar energy application are being undertaken.

In Mongolia, a project is producing solar PV modules from imported silicon water for lighting kits for nomadic herdsman.

In Romania, the Research Institute for the Electrotechnical Industry is to manufacture solar photovoltaic modules.

In China, a £0.5m project has established a solar heating and cooling technique and is designing photovoltaic systems based on the special conditions of Western China.

Wind Power. Wind electric power generation is now proven and economically feasible in regions with favorable winds.

In China, a project designed and installed technically advanced wind power stations in Zhejiang and Fujian Provinces. These stations are: (a) providing practical experience in the operation and characteristics of different types of turbines, (b) being used for R&D in integration into electrical power systems, (c) providing a modest supply of electrical energy, and (d) assisting in the design and development of larger wind power systems.
Demonstration Facilities. Some of the largest projects involve demonstration facilities that package several new, renewable energy sources.

In Egypt, a £0.9m project is (a) testing and demonstrating solar and wind energy systems for selected remote coastal areas, and examining their socio-economic impact; (b) strengthening national capabilities through training programs; and (c) conducting a survey of market potential and capability of appropriate solar and wind energy equipment.

In Mongolia, two solar, wind, and biomass projects totaling £1.4m are establishing centers for renewable energy design for nomadic herdsmen and cattle farms in Steppe and Gobi.

In Syria, wind and solar energy surveys are being undertaken to furnish status and databases, and demonstration of wind electric, solar PV and biogas systems is taking place.

About the Panelists

Michael Willingham obtained a BS in mathematics from MIT, and a PhD in energy management and policy from the University of Pennsylvania. He has authored numerous technical and policy-oriented publications on fossil fuel utilization, emission controls, and environmental impact evaluation. Since 1991, he has been an advisor for energy and the environment for the United Nations, New York.

Kui-Nang P Mak is chief of the Energy Resources branch of the United Nations, New York. He has a BSEE (with high honors) and MSEE from the University of Illinois, Urbana Champaign, and a professional degree of industrial engineer from Columbia University, New York. He joined the United Nations in 1975, where he has been involved in energy development in developing countries. He became chief of the Energy Branch in 1990. He is a member of IEEE, SPE, and advisor to the New York Mercantile Exchange on Global Issues and the China Coal Preparation Association on technology transfer.

Power Sector Restructuring and Expansion Planning: Colombian Experience

Manuel I. Dussan and Neslon de Franco

Colombia is implementing an ambitious reform of its electric power sector based on: the creation of a competitive wholesale power market; unbundling of generation, transmission, and distribution activities; price deregulation for bulk energy sold to distributors and large users; open access to transmission and distribution networks; and creation of a semiautonomous regulatory commission (ERC). Main laws to support this reform were enacted in mid-1994, and most regulations were issued by mid-1995. The following is an overview of the main issues faced in Colombia in the transition from least-cost expansion planning to decentralized planning under a competitive market.

Colombia has ample hydro, coal, oil and natural gas resources to meet in the long-term a 5.5 percent annual growth of electricity demand in a power system with an installed generation capacity of about 10,000 MW (78 percent hydro). Still, Colombia experienced severe energy shortages during 1991 and 1992, caused mainly by extremely dry hydrological conditions, weak sector finances, a risky operation of the national interconnected power system, and a planning strategy that relied too much in large hydroelectric plants for power expansion. Electricity supply proved to be too vulnerable, and public opinion blamed the state, owner of all power utilities, for energy rationing. Subsequently, the state took the obligation to supply electricity and has taken actions to ensure that expansion plans include new generation capacity to meet future demand under extreme conditions of hydrology, plant availability, delays in commissioning new generation, etc, no matter that the combined event might have a very low probability of occurrence. In this process, reliability became a political issue in lieu of an economic concept to match supply and demand.

Competition and Reliability

The sector reform approved in 1994 substituted decentralized market-based investment decisions for centralized expansion planning. Under this new scheme, private and public firms would develop new generation projects reacting to opportunities to sell energy in the market (contracts to supply energy to distribution companies and large consumers, and energy sales in the spot market). One of the main concerns with this scheme was whether, in the Colombian case, market mechanisms could achieve optimal resource allocation.

The confirmation of large natural gas reserves in the country facilitated the application of decentralized planning because it provided a low-cost clean fuel for the economic development by private firms of medium-size generation units with low capital costs and short lead-times. Furthermore, the initial regulations, issued by ERC in 1994 and 1995, established the basic elements to support this new planning approach: transmission charges that reflect the costs imposed on the transmission grid by the user and provide an economic signal for the location of new plants; deregulation of wholesale power prices; obligation of distribution companies to purchase energy economically; establishment of a spot market and of mechanisms to handle long-term energy contracts between generators and suppliers; and provisions to include a capacity charge in the spot market.

The response of private capital for development of thermoelectric plants has been positive: 150 MW in operation, 1,050 MW under construction, 300 MW in negotiation, and there are initiatives to develop 13 additional plants with an installed capacity of about 2,000 MW, well in excess of what is needed to meet demand. Furthermore, an energy market is developing based on power purchase agreements (PPAs) between existing generators, distribution companies and large consumers.

However, the strategy to develop an energy market with the participation of private capital has not worked so well. The initial projects were developed under BOO schemes with PPAs backed by financial guarantees provided by the government, in order to reduce market risks for private investors and make these projects bankable. Development of new private projects with no direct government guarantees have been delayed due to difficulties in completing financial closing. The government, concerned about an increase in the risk of energy rationing due to delays in commissioning these projects, is promoting the development of other projects by state-owned generators, and is questioning whether the regulatory framework can ensure long-term development of power supply. Initiatives to develop independent private projects based in the market are discouraged and competition is limited to contracting BOO projects with state-owned generators as defined in the indicative plan.

Basically, it is argued that prices in the spot market are volatile and insufficient on average, to remunerate private investment in new thermal plants required to maintain a high reliability. Price volatility and remuneration of reserve plants are problems typical of a hydro-based generation system that could be handled by market instruments like long-term contracts and capacity charges. However, in Colombia these problems have been exacerbated by reliability concerns and widespread
Pressing Need of Developing Countries
Jose Malhães da Silva

Developing countries make tremendous efforts to open their markets, to become more competitive, and to attract foreign capital. They restrain their demographic growth so that their sparse domestic resources can be made better use of for reducing the major problem of these regions: POVERTY. National budgets increasingly assign priority to social issues, since this is a case where state action to provide the population with essential basic living conditions is irreplaceable.

At the end of this century, many developing countries find themselves in need of rethinking the role of the state. Some of its activities must be made more flexible and have to be decentralized; also, red-tape must be cut and, in certain cases, privatizing is essential. There is an absolute need to expand the participation of society.

An all-embracing analysis of the state’s role shows that major changes are taking place in the productive system, together with political and cultural upheavals which have in-depth impacts on the state-society relationship, particularly in connection with the capacity of governments to generate well-being and stake out development. Even industrialized nations are in need of increasing tax revenue to cover social welfare programs that, due to their scope, place ever greater demands on the state. On the other hand, the weight of the state apparatus raises the cost of public services which, in turn, leads to growing pressure by society for better and cheaper services. In view of this situation, delegating some of the government’s programs is both practical and sensible.

In this context, the capacity of a country to innovate is a major factor in making it competitive in the international market where the trade volume of services already greatly exceeds that of primary products.

New Era of International Cooperation

The developing countries are doing what they can. But action by industrialized countries, development banks, and multilateral agencies controlled by them must change. It should be conditioned upon the establishment of a new era of international cooperation. Developing countries need a significant increase in financial support in order to adapt to the needs of the longer term future.

Importance of Rural Energy

The supply of energy in rural areas is a basic condition for solving a number of problems: education, water and sanitation, transport, and technology in methods and equipment. At a time when the environment has become a general concern, pollution caused by the degradation of human life which is exacerbated by the distress of field workers should also be taken into consideration. In this respect, there already are clear signs that the capacity of large first-world cities to accommodate their own rural population and/or that from developing countries is on the verge of exhaustion. It is of fundamental importance to realize that improving the living conditions in rural environments is essential for building a more just and well balanced society which indirectly reflects on the developed world itself. Moreover, an exchange of experiences among developing countries should be encouraged.

Conditions for Sustained Development

In order to achieve sustainable development, it is essential that the local characteristics which dictate technical/environ-
mental solutions are clearly understood. Ecodevelopment should aim at social justice and respect of nature. It should strive for economic efficiency without, however, letting these concerns be an end to themselves.

If international organizations continue to deny third-world countries the funds they need for development, if developed nations do not improve their trade and investment relationship with them, it will be impossible to create conditions for sustained development.

Global policies and economic relations must be democratized in order to eradicate poverty on earth with minimal damage to the environment.

About the Panelist
Jose Malhães da Silva is executive director of the Brazilian Committee of the World Energy Council and assistant to the Board of Directors, FURNAS Centrais Elétricas S.A., the Electrorbras subsidiary for operations in the southeastern region of Brazil. In 1995, he was elected chair of the Developing Countries Committee of the World Energy Council for the period 1995-1998. He has been active in Brazil's energy sector for 25 years, during which he held various positions related to market forecast and economic studies for system expansion planning. He has made presentations on the Brazilian state reform of the electric sector and chaired international conferences throughout the world. He has a BSEE from the Federal University of Rio de Janeiro. He has taken graduate courses in economics and finance at the Centre d’Enseignement Superieur des Affaires (CESA-HEC) at Jouy-en-Josas, France.

Planning in a Deregulated Environment in Developing Countries: Bolivia, Chile, and Peru
Hugh Rudnick

Many developing countries have chosen to deregulate their electric power sectors, creating conditions for competition in generation and increasing participation by the private sector. In doing so, they have not only left in the past the traditional vertically integrated publicly owned utilities, but are also leaving back the government centrally determined generation-transmission expansion plans. Private investors are taking independent decisions according to their own assessments, and new generating plans and transmission lines are being built based on those assessments rather than those of the government bodies. This new environment creates significant challenges and poses many questions on how to reconcile the private and the public interests in the expansion of the electric power installations.

These challenges have been faced with novel ideas in South America, especially in Chile, where pioneer deregulations have been in place for several years. Chile started its deregulation process in 1978 with a new electricity law promulgated in 1982 (10 years ahead of the 1992 U.S. Energy Policy Act, which initiated a process to create market conditions in the U.S. electricity sector). Argentina followed with an aggressive process started in 1991, a new law approved in 1992, and a privatization process that still is going on. Several South American countries followed, with Peru 1993, Bolivia 1994, and Colombia 1994 promulgating deregulating laws in line with the Argentinean and Chilean initiatives. Brazil is undergoing a similar process, with international consultants now helping the government to reshape the industry.

Unlike the case of the telecommunications industry, in which changes in the industrial organization of the sector have been driven by rapid technological changes in equipment, there has been no technological breakthrough in the electricity sector. The forces behind change have either been political reform, regulation flaws, high tariffs, managerial insufficiency, or global economic crisis. Changes have taken place, for example, as a result of the failure of the state to adequately manage electricity companies, often with critical infrastructure deterioration, inefficiency in production and use, or plain company corruption. In other countries, the force behind has been the lack of public resources to finance the required investment for development (international banks conditioning loans to the start of deregulation processes). Chile made its changes as a result of political changes that brought free-market economists into the government, which took drastic actions to reduce the control of the state over the economy and increase the role of the private sector, creating market conditions where possible.

The Bolivian, Chilean, and Peruvian electric regulations have brought novel common ideas into the matter of planning in a deregulated environment. They correspond to countries with

Linking Renewable Energy Resources Around the World: A Compelling Global Strategy
Peter Meisen

Today, over two billion people in developing countries live without any electricity. They lead lives of misery, walking miles every day for water and firewood, just to survive. What if there was an existing, viable technology, that when developed to its highest potential could:

- Increase everyone’s standard of living
- Cut fossil fuel demand and the resultant pollution
- Relieve the population explosion
- Reduce world hunger
- Cut deforestation, topsoil loss, and spreading of deserts
- Enhance world trade
- Promote international cooperation and peace.

Over 2 decades ago, inventor, scientist, and mathematician, R. Buckminster Fuller proposed interconnecting regional power systems into a single, continuous world electric energy grid. While this global vision is still years away, technological advances over the past 2 decades have made the linking of international and inter-regional networks practicable today. In 1971, the United Nations Natural Resources Council corroborated these findings, but Cold War politics suppressed any real cross-border progress.

About the Panelist
Peter Meisen is a graduate of the University of California, San Diego. In 1986, he founded Global Energy Network International, a nonprofit organization conducting research and education on the interconnection of electric power networks between countries and continents with an emphasis on tapping remote renewable energy resources. He is an international authority on global issues of renewable energy; transmission and distribution of energy; quality of life and its relationship to electricity; the environment and sustainable development. In 1983, Meisen cofounded SHARE (Self Help and Resource Exchange), North America’s largest private food distribution program, currently serving over one million people each month in the United States, Mexico, and Guatemala.
very different populations, economic situations, and electricity consumptions, as indicated in Table 1.

The main components of the electric market reform, common to these three countries, have been:
- Wholesale market deregulation, with unregulated prices for large consumers
- Competition at the generation level with a centralized pool generation dispatch based on short term marginal costs
- Regulation in transmission and distribution with a competition by comparison scheme in distribution (either a yardstick competition model or a price-cap/efficiency index approach) and a transmission open access regulation with global allocation of network costs.

The Bolivian, Chilean, and Peruvian electric regulations have forced a evolution from pre-deregulation centralized planning by ENDA, ENDESA, and ELECTROPERU (the three previous state-owned vertically integrated electric utilities) to post-deregulation in which private investment and competition in generation gives place to the expansion being dictated by market considerations. In effect, there is no centralized planning, with each generation company or investor doing its own planning. These three countries have tried to reconcile the private and the public interests in the expansion of the system with the introduction of two novel ideas.

First, an indicative reference generation-transmission expansion plan is determined by the regulator every 6 months and used for regulating generation-transmission tariffs to small retail consumers. In practice, regulators have only provided indicative plans for generation investments, with only major transmission lines included, for the same reasons that planners worldwide have usually decoupled both planning problems. The indicative expansion plan is the one that minimizes investment, operation, and unserved energy costs and satisfies demand requirements in a given time horizon.

A long-term horizon is considered 15 to 20 years, modeling expected plant unavailability, and examining different hydrological conditions and different load growth rates. Proposals by private investors of new future generation units are considered as alternatives as well as potential ones assessed independently by the regulator. Different expansion plans are studied. The resultant indicative plan is not binding for the private sector although it is used by the regulator to calculate regulated tariffs (projected average future marginal prices, resultant from simulating operation with that expansion plan).

Second, an economically adapted transmission system is determined by the regulator. The Chilean 1992 electricity law provides a general definition: “an installation is economically adapted when it allows to produce a given quantity at the lowest cost.” Penalty factors based on adapted transmission systems are calculated by the regulator and are used to spatially distribute spot prices to main buses, starting from the load center spot price. The Peruvian 1992 legislation delimitates the definition by indicating that an economically adapted system is that electrical system where there is an equilibrium between energy offer and demand, seeking for reduced costs and maintaining quality of service.”

The Peruvian regulator not only is responsible for determining the adapted transmission system, but restricts the transmission owner, income based on that adapted system. The objective is to stimulate efficient investment, maintenance, and operation. Finally, the Bolivian 1994 legislation follows the Peruvian model. A similar concept is used in the three countries for the distribution regulation, where an economically adapted distribution “model” system is determined by the regulator every 4 years and used to calculate a “distribution value added term” used for the calculation of tariffs.

The economic adaptation notion used in these three countries relates to concepts formulated by Electrique de France economists back in 1949. The economic interpretation of an adapted transmission system (or adapted distribution system) requires therefore to optimize network development over time, a task not yet adequately solved by the state-of-the-art industry computer tools.

The results of these regulations have proved positive, particularly in the Chilean case, which has been in place for several years. This case has proved how adequate economic signals can stimulate enough private investment in generation-transmission to respond to high load growth rates, with the government being able to concentrate its initiatives and investment on other needy areas of the economy. The private sector, has, invested heavily in the expansion of the electric systems, with a significant participation by local private pension funds. The electricity business has in general been highly profitable, giving place to a previously unknown entrepreneurial diversification, with Chilean companies now controlling more installed generation capacity in other South American countries than within Chile.

After a long period during which the private sector closely followed the indicative expansion plan, it is now choosing to depart from it, bringing natural gas from Argentina into the country and planning to build more combined-cycle gas turbines than those indicated as necessary by the government. New transmission lines are also being built, independent of government central assessments. Significant electricity price reductions are projected.

**About the Panelist**

Hugh Rudaick was born in Santiago, Chile, and graduated as a civil engineer from the University of Chile. He received his MS and PhD degrees from the University of Manchester, UK.

He is a professor of electrical engineering at the Catholic University of Chile, and his research activities focus on power system economic operation, planning, and regulation. He has been a consultant with utilities and regulators in Argentina, Bolivia, Chile, and Colombia. He is a past-secretary of the IEEE.
Power System Planning in Deregulated Environments: Brazilian Experience
Marciano Morozowski

The Brazilian power sector is a large complex structure, has a high degree of integration, and includes federal, state, and private utilities and electric cooperatives. Centrais Eletrônicas Brasileiras S.A (Eletrobrais), a federal holding company and sector financing agency, coordinates sector expansion planning and operation of the power system in Brazil.

Eletrobrais has several regional subsidiaries (Chesf, Eletrosul, Eletronorte, and Furnas), which generate and transmit bulk energy for distribution by state government-owned and other utilities. Eletrobrais also holds the government’s majority interest in the Itaipu Binational Hydroelectric Plant and a majority interest in two distribution companies (Light in Rio de Janeiro, and-Escelsa in Espirito Santo) and in other distribution utilities. Some distribution utilities also own and operate generating plants.

In 1994, the installed generating capacity amounted to 48 GW, excluding Itaipú (91 percent hydro); its hydro-generation and imports totalled 267.5 TWh (95% hydro); sales were made to nearly 35 million customers and national electrification coverage reached a level of 87 percent. In the same year, per capita consumption was 1,470 kWh/inhabitant, about 25 percent higher than the Latin America country average.

Reform Description and Status

In recent years, the power sector institutional framework has been inappropriate for maintaining an adequate level of tariffs and financial performance. The system of national uniform electricity tariffs and the revenue-sharing mechanism which transferred revenues from the low-cost to the high-cost companies discouraged productivity, prudent investment, good financial practices, and efficient energy use and conservation.

As a consequence, the utilities lost their capacity to service their debts, pay suppliers, and complete power plants under construction: 17 power projects under construction, with a total capacity of about 7,000 MW, are now paralyzed or progressing slowly. In addition, the participation of cogenerators and independent power producers in public supply systems was discouraged or impeded.

To address this situation, the government and the sector authorities initiated reforms aimed to improve sector finances, increase private participation, encourage competition and productivity, and promote efficient energy use and conservation.

These and other recent measures will permit private sector participation in some of the suspended generating projects in order to complete the plans, and as suppliers in the bulk energy market to stimulate competition.

The new concession law will allow enhanced competition in the generation and distribution of electricity and increased private participation as concessionaires. Another law eliminated the existing legal limit (40 percent) of foreign ownership of the voting capital of privatized companies, included distribution concessionaires. Some state governments are considering privatizing their utilities, following the example of the distribution utility of the state of Tocantins, which became private in 1989.

The granting of concessions for hydroelectric projects remains constitutionally restricted to Brazilian companies.

The current privatization program extends to the two distribution subsidiaries of Eletrobrais (Light and Escelsa) and contemplates the sale of Eletrobrais and its subsidiaries shares to the public, albeit without relinquishing federal control.

Expansion Planning

The main reference for the strategic planning of the electric power sector is Plan 2015, which was elaborated in 1991-1992 and covers the planning horizon 1993-2015. This plan is based in four scenarios that consider electric energy demand yearly growth rates in the range 3.2-3.8 percent in scenarios 1 and 2, and yearly rates 5.1-6.7 percent in scenarios 3 and 4.

Last year’s 1995/2004 Decennial Expansion Plan has foreseen investment needs from £4000m to £5300m per year. About one-third is for electric power generation. In spite of that, the electricity industry autofinancing capability stands at about 2 billion dollars per year with the present tariff levels. As a consequence, there are 17 projects of about 6,745 MW of installed capacity (5,750 MW of hydropower) behind schedule.

Applying the new concession law of 1995, the government seeks to reduce the financing deficit for the electric energy expansion plan. Power utilities are presenting to DNAEE completion plans for their projects. The financial feasibility and the project cash flows of the 17 delayed projects are being carefully analyzed. Residual investments should include at least 1/3 participation of private partners. If plans are not approved, concessions will be revoked, while new concessions will be granted after public tendering or auctioning. A new Decennial Plan will be derived from those updated project implementation plans and from the government new concessions tendering schedule.

Partnership between government owned concessionaires and private companies has been pioneered in four hydropower projects: Ita (1,450 MW), Igarapava (210 MW), Dona Francisca (125 MW), and Serra da Mesa (1,200 MW).

Planning Structure and Challenges

Power system planning in a deregulated business environment poses new challenges to planners and investors, both public and private. These challenges are related to the planning process itself and to additional uncertainties due to competition between economic agents: producers, transporters, and big consumers. These challenges have been addressed in many countries (Chile, Peru, and Colombia, for example), by defining an “indicative plan,” that gives the marginal costs necessary to evaluate generation and transmission investment projects.

An important aspect, to be considered in the selection of the best method to generate the reference plan, is the structure of the planning function. Within an evolving decision making process this structure must comply with two conflicting objectives: decentralized decision-making without loss of quality of the expansion plan.

Therefore, besides the large R&D efforts still necessary to solve the rather complex management problem of existing systems, the electric energy sector will have to adapt the planning process and associated models to the new business environment, that will include, necessarily, a large amount of medium and small projects, in both supply and demand sides.

This adaptation will have to take into account recent progresses in power system optimization and simulation techniques, mainly in the area of integrated planning of generation-transmission-facilities. This is a particularly challenging problem in the countries that have unbundled the originally integrated, vertical organizational structures into several specialized utilities at the generation, transmission, and distribution levels.

It can be concluded that in Brazil there is a clear trend for increasing participation of the private sector in the electric power industry. New planning structure must reconcile government, utilities, and private investor concerns about the electricity...
supply industry. A new planning function must be devised, and the planning mechanics should be adequate to the new institutional structure of the electric sector and to the new organizational arrangement of the companies. A large R&D effort is necessary to adapt the planning process and models to the new business environment that will include a large amount of medium and small projects.

About the Panelist
Marciano Morozowski has a BSEE from the Federal University of Para, Brazil; a MSEE from the Federal University of Rio de Janeiro, and a DSc degree in systems and optimization from the same university. From 1973 to 1975, he worked as an analytical engineer in PTEL, a consulting company associated to Power Technologies, Inc. He developed professional activities in the areas of generation and transmission planning in the System Planning Department of Electrosul, 1976-1991. Since 1991 he has been a full-time teacher at the Federal University of Santa Catarina in the areas of system planning, reliability, and advanced computer techniques. He has authored 76 papers and a book on sparsity techniques.

Global Dynamics and the Potential for an Integrated African Grid
Bai K. Blyden

Global economic and environmental changes that have stimulated an interest in renewable energy sources also bring many challenges. These challenges in turn present engineers around the world with opportunities for innovative solutions. This presentation seeks to examine and make recommendations to support some of the past and current initiatives by African states and the international community towards this end. The challenges in harnessing the available potential are engineering, financial, and the sociopolitical reality on the continent. The suggested paradigm to address these issues revolves around the development of a Centralized Pool or target network which takes into account the above constraints to indicate development possibilities.

Design Basis Considerations
The following attributes are principal towards the issues being examined:
- Geography: the central and East African river basins, the Great Ruaha Rufiji basin, the Inga river basin, the Zambezi river basin
- Potential markets: Europe, SADC countries, North Africa, and the Middle East
- Generation and transmission issues and their performance attributes: load flow, dynamic stability, fault analysis (operational reliability)
- Sociopolitical reality
- Wars, drought, infrastructural and manpower deficiencies
- Global trends in energy management: deregulation
- Regional economic and cooperation, SADC, ECOWAS, etc
- Economics of power development
- Principal studies
- Africa-Europe, Zaire-Egypt
- Environmental preservation: deforestation, water resources management.

Hydro Electric Potential
The geography of the area under examination can be broken down into four groups of river basins.
- The Victoria and Albert Nile System, discharging into the Mediterranean
- The rivers discharging into the Indian Ocean
- The rivers discharging via lake Tanzania and the Zaire into the Atlantic Ocean
- The rivers of the Rift and Lake Rukwa system with no final outlet at all.

These four groups are geographical units in that they are the four drainage systems of East Africa. They also exhibit different water flow characteristics, which would determine the type of generating units possible.

The Inga basin development is more immediate, since the area is readily accessible and many detailed studies have been completed which include detailed transmission routes to Europe and North Africa.

The recommendation for examining all the four geographical units simultaneously and their potentials within the context of these two large initiatives stems from the following benefits:
- Enhancing system operational reliability and flexibility as a result of creating adequate spinning reserve, improved voltage regulation, contingency against vulnerable transmission lines and generation units
- Providing a streamlined and more energy efficient planning among the states by targeting the central pool as a revenue and energy source
- Establishing an integrated water management program and therefore improved flood control and the corresponding environmental benefits
- The benefits of coordinating infrastructural development such as access roads and communications to support access to the central grid
- An integrated and therefore relatively stable performance criteria and cost management base to attract investors
- Creating a common source of revenue and sharing the benefits of economies of scale for individual domestic programs related to the centralized pool.

The SADC countries bounded by this region have addressed the sharing of resources towards the wider goal of a free trade zone by the year 2000.

It is recommended, therefore, that integration be approached around a concrete model that can be examined by engineers, economists, and environmentalists worldwide.

Operational Reliability and the Target Network or Centralized Pool
As stated earlier, the focus of this presentation is to use engineering reliability as the focal point of reference to examine the delivery systems that can best satisfy the design basis considerations listed. An earlier study in 1983 discussed an option towards this end. Since then, advancements in HVDC transmission technology have created increased delivery possibilities, which the Italian study has dealt with in sufficient detail for this initiative. The Italian ENEL study evaluated the transfer of 30 GW over a 7000 km route at voltages of 600,750 and 1,000 kV. The Electricite de France-Lahmeyer International prefeasibility report for the Zaire-Egypt interconnection has also produced successful results.

This presentation adds to these initiatives by recommending that a centralized pool with a hybrid of ac and dc links and generation sources from many states be considered to enhance
the performance requirements for both these initiatives and others, for the following reason.

The large number of nation states that make up the load centers and their differences in demand/load profiles require much operational flexibility. Supply to Europe, for example, may require that generators, for the most part, operate to support a base load regime that would make them less prone to frequent regulation than less committed units from other areas that serve less demanding markets.

**Principal Studies**

At present, the Zaire-Europe, Zaire-Egypt, and ESHKOM of South Africa are the immediate principals based on their projected load growth demands and the efforts that have been made to date through studies and symposiums. Their proposals are looked at theoretically as phases towards the development of the central grid. Arguments supporting the design basis considerations will attempt to show the advantages of future ties to the central grid.

From both of the studies, ties to Europe and Egypt are radial in their design with reliability considered by having multiple transmission lines in parallel. The Inga study estimates 6 to 10 HVDC bipolar lines to deliver the full power of Inga. The reality of issues such as operational sabotage, weather conditions, seasonal variations of river flows, and future load growth demands may warrant the need for further flexibility on the supply side.

The routes from Inga to Europe and Inga to Egypt, for example, could be integrated with potential sources from East Africa through the Sudan as well as develop an independent route from that region to Europe and the North in general.

To this end, a hybrid mix of HVDC and HVAC may be necessary. The distances within the grid area are much less than the routes to Europe and North Africa, allowing for consideration of both types of interconnections. An HVDC link, for example, may have the operational advantage of precluding problems such as greater separation on voltage phase angles brought on by the loss of a principal system element which could cause generators to go out of synchronism. A HVAC interconnection on the other hand has the advantage of delivering large blocks of power even with a fault condition on one circuit. These are questions that will require specialized studies within the context of the operational reliability of the pool to meet the demands for the number of countries involved.

The same rationale applies to the other regions, where the Zambezi river basin with large plants such as Caborra Bassa with an installer capacity of 2,000 MW and with an additional potential for 1,000-1,700 MW can be integrated to serve the demands of a large market as South Africa and serving the role of maintaining system voltage levels and spinning reserve within the central grid.

**Operational Flexibility Versus Cost**

This mix of HVAC and HVDC to satisfy performance flexibility with it the added cost of the number of converting stations required at major interconnection points of the overall system. For example, ac interconnections linkages are suggested at the “crossing point” converter stations in North Africa to Europe. These interconnections would also require appropriately sized equipment to support their contingency requirements. However, reliability studies projected for operation over a number of years should show economic justification for the cost of these converting stations and additional transmission capacity when compared to the cost of down time under a heavy industrial base load condition.

**Deregulation as a Global Trend**

In many ways, the African states bounded by this region have the disadvantage of relatively weak power systems, poor maintenance, and many technical deficiencies. The advantages and opportunities are that their present status coincides with major global economic changes which have brought the potential of these countries to the forefront of global affairs. These global changes have also affected the manner in which large utilities of the industrialized countries operate with the trend towards deregulation domestically and expanding operations overseas. The World Bank and United Nations as institutional bodies are themselves encouraging many of the developing countries to move toward market-based economies and the deregulation of utilities as one the components.

An ongoing debate in the state of California is also appropriate for further study by the SADC countries and international bodies involved in the African development initiative. Edison, the large utility, supports the state’s commission to make regulatory and structural changes and creating what has been referred to as POOLCO, a privately owned company independent of the utilities and other generation suppliers that would dispatch the regional transmission and generation sources. This would allow the efficient use and expansion of the transmission system and provide transmission access to all buyers and sellers on non-discriminatory and transparent terms.

POOLCO would allow all generators to compete fairly in the regional market without concern about transmitting utilities favoring their own generation over that of competitors.

Further discussions of this debate on the merits of Direct Access can be found in what is known as the State of California’s Blue Book. A useful comparison to the English restructuring experience which resulted in the England-Wales region wide pool is also analyzed in the commissions report.

**Economics**

The discussion of economics and finance is brief, as much will result on the systems conceptualized to meet various country demands. This summary however acknowledges as a basis the estimates and justifications for project development examined by United Nations and World Bank economists.

**Conclusion**

The developmental initiatives in progress and the reality of the available potential can represent a turning point in the historical paradigm of economic relations between the industrialized nations and the “third world” represented by Africa in this case. It is particularly important for the African states affected, since the systems and structures involved in projects of this nature carry all of the developmental attributes desired by the organization of African Unity (O.A.U.) and the individual states themselves. These initiatives also represent the most ideal and practical platform for genuine “North-South” dialog as a result of the systems and structures that make it meaningful.

**About the Panelist**

**Bai Blyden** has worked as an engineer with the Sierra-Leone Construction Company, Sierra-Leone West Africa; as an engineer with Stone & Webster Engineering Corporation, New Jersey; and as a project engineer with Asea Brown Boveri, Fort Worth, Texas. He gained a MSEE from the Moscow Power Institute, Moscow, USSR in 1979.