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Ghana's Experience In Power Interconnections Within The Framework Of ECOWAS.

1. INTRODUCTION

The Economic Community Of West African States (ECOWAS) was established in 1975 to promote integration and economic co-operation between member states, leading to the establishment of an economic union in West Africa in order to raise the standard of living of its peoples. To achieve its aim, ECOWAS is committed to ensuring the harmonization of national policies and the promotion of integrated programs, projects and activities in a broad spectrum of economic sectors. One of the most important sectors is the energy sector which plays a very important role in the industrial and economic integration of the region. It is also widely recognized that, the availability of reliable electric power is vital for economic development.

Within the framework of ECOWAS co-operation in the energy sector, Ghana has actively been involved in the establishment of the West African Grid System (WAGS) by spearheading interconnections with two utilities in the neighboring countries of Togo, Benin and Cote d'Ivoire. She has also played a key role in making this co-operation in the electricity business a major success. All member countries of the interconnection; Ghana, Togo and Benin were also founding members of ECOWAS. This paper describes Ghana's experience in power and energy exchanges with neighboring ECOWAS countries.

The interconnection contract was negotiated by the first Ghanaian Chief Executive of VRA, the late Dr. E.L. Quartey, in the spirit of economic co-operation in the subregion. It was indeed this spirit that was recognized in the organization and creation of ECOWAS in Lagos on May 28, 1975. The agreement for the supply of power from Ghana to Togo and Benin was first signed in August, 1969 and the supply commenced in December 1972.

2. DESCRIPTION OF THE WEST AFRICAN GRID SYSTEM

The development of the West African Grid System (WAGS) started in 1969 when the Volta River Authority (VRA) of Ghana initiated its interconnection project with the Communuate Electricite du Benin (CEB) of Togo and Benin. The transmission interconnection links the Generating Station of Akosombo in Ghana through the Lome Substation in Togo, to the Cotonou Substation in Benin. It is a double circuit line operated at 161KV. The total length of the line is 290km comprising of 130km in Ghana, 75km in Togo and 85km in Benin.

Further expansion of the WAGS included an interconnection with Cote d'Ivoire, another founding member of ECOWAS. The two transmission networks of Ghana and Cote d'Ivoire are linked by an intertie between the Abobo substation (north of Abidjan) in Cote d'Ivoire and the Prestea substation in the western part of the Ghana network. The operating voltage is 225KV on a single circuit line of about 220km in length, comprising 145km in Cote d'Ivoire and 75km in Ghana.

A map showing the interconnected grid system is presented in Figure 1.

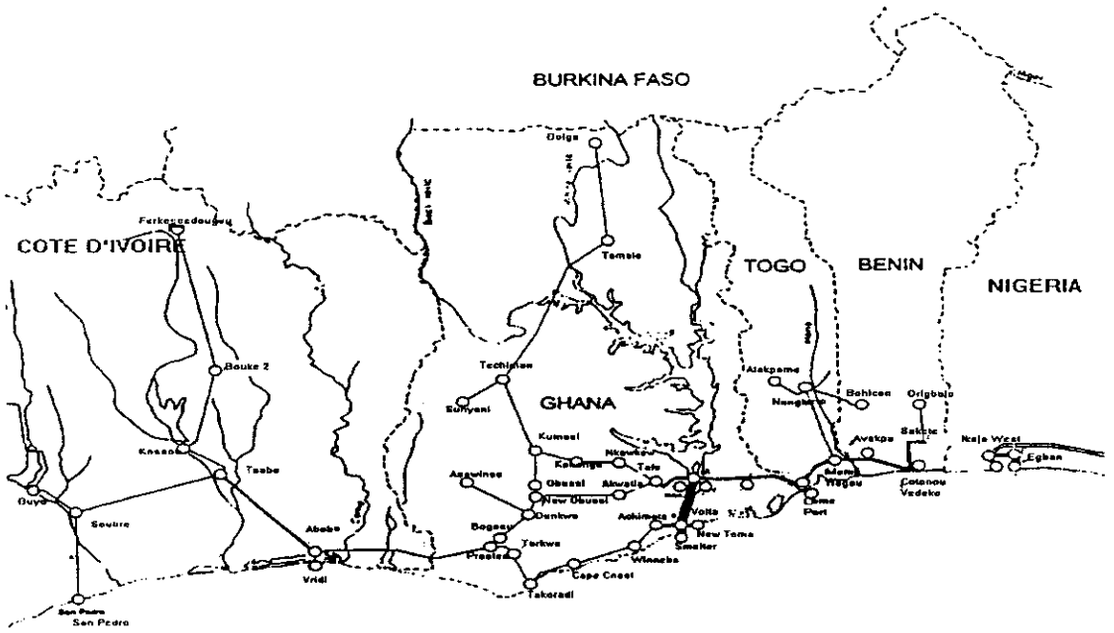

Figure 1

CHARACTERISTICS OF THE VARIOUS NATIONAL NETWORKS OF WAGS

2.1 Ghana Network (VRA)

The electricity network of Ghana has an installed capacity of about 1072MW derived from two hydro plants at Akosombo and Kpong in the Eastern Region. In addition there is a 30MW Diesel Plant at Tema in the Greater Accra Region. Current maximum peak load is about 850MW, with an average annual energy consumption of about 6,300GWh of which 2,760 GWh is consumed by an aluminum company, the Volta Aluminum Company (VALCO), in Tema.

2.2 Cote d'Ivoire Network (CIE)

The electricity network of Cote d'Ivoire has an installed capacity of 913MW, of which 599MW is generated from five hydro plants and 314MW from Steam and Gas Turbine Generating Sets located at VRIDI. The Hydro and thermal generating plants are situated in the southern, central and western sides of the country. The current peak load demand is 365MW and the average annual energy consumption is 2,300 GWh.

2.3 Togo/Benin Network (CEB)

The Togo-Benin network has an installed capacity of about 155MW of which 90MW is derived from a gas turbine in Togo and diesel generating sets in Togo and Benin. The remaining 65MW is generated from a hydro plant at Nangbeto also in Togo. The current peak load is about 120MW with an average annual consumption of 550 Gwh.

3. TYPES OF ENERGY EXCHANGES ACROSS THE WEST AFRICAN GRID SYSTEM

Different types of energy exchanges have been performed across the WAGS. These include one way transfers, two way sales and network pooling. One way sales have primarily served to provide lower cost energy from the hydro resources of VRA to Togo and Benin. Two way exchanges provide mutual support and assistance during system disturbances and emergencies. Another practice by the interconnected utilities is the pooling of generation resources of two parties and consequent co-ordination from one central point. Table 1 as appended shows the energy exchanges between member countries of WAGS. Various forms of exchanges as practiced on the WAGS are as listed below:

3.1 Guaranteed Supply

Under this type of exchange, energy supply is guaranteed by one party to the other for a specific period. Guaranteed supplies are billed monthly according to negotiated tariffs as is the agreement between VRA and CEB. Under this agreement, VRA is obliged to supply CEB with 50MW of continuous power up to the year 1997, except under force majeur conditions. This energy constitutes about 75% of the power requirements of Togo and Benin.

Guaranteed supply from VRA to CIE has varied over the years based on the annual inflows of water into the Volta Lake and the condition of the units at the Akosombo generating station. This one way sales arrangement is, however, changing due to the decreasing level of inflows into the Volta Reservoir coupled with the rapid increase in the Ghana domestic demand.

3.2 Opportunity Exchanges

Opportunity exchanges have involved the supply by VRA of relatively cheap hydro energy to CIE in lieu of the expensive thermal energy generated at VRIDI in Cote d'Ivoire. Also included in this facility is the supply by CIE of thermal energy to VRA to enable VRA meet its load demand during major maintenance of units at Akosombo Generating Station. Opportunity exchanges as practiced between VRA and CIE can be interrupted by giving an eight hour notice. Billing is according to negotiated tariffs ensuring that benefits are equally shared.

3.3 Storage

This type of exchange comes into play when the inflows during the rainy season are extremely high thus bringing about the risk of spilling by one party. The party whose reservoir is not close to spilling helps out by storing its counterpart's excess energy. Energy restitution is done on a 50% basis i.e. half of the stored energy is returned to the party who stored its energy. This facility has been used particularly in the Ghana - Cote d'Ivoire interconnection and more recently hydro energy from Nangbeto is stored in the Volta Lake.

3.4 Emergency Supply

Unscheduled energy is supplied by one party to the other on request during difficulties affecting the electrical power system of any of the parties. Energy so supplied is restituted at the same time of day and within 48 hours of the supply.

3.5 Inadvertent Exchanges

This is unscheduled energy recorded in favor of either VRA or CIE. This is mostly kept at the lowest possible level. Any such exchange recorded is restituted either at the end of the supply agreement or at any time agreed upon by the parties..

3.6 Network Pooling

This arrangement came into existence between VRA and CEB in 1993 when VRA requested CEB to rely more on its own generation and VRA's need to manage its capacity more frugally. This was because VRA was embarking on a retrofit of its generating units at Akosombo with an attendant loss of capacity. The operation of all the generation and transmission facilities of both networks were integrated, centrally controlled and coordinated at VRA's System Control Centre.

4. MANAGEMENT AND OPERATION OF THE INTERCONNECTED SYSTEM

Management and operation of the interconnected system have been achieved in a variety of ways. Separate Technical committees have been formed between VRA and CEB, and between VRA and CIE to take decisions on matters concerned with the technical management of each tie-line. The committees approve all operating instructions and technical studies undertaken on the tie-line. The committees also prepare protocols for energy exchanges and undertake negotiations on matters concerning power sales on behalf of the management of their respective utilities. These committees meet at least once a year. In the case of Ghana-Cote d'Ivoire interconnection, there is also an operating sub-committee which meets quarterly, alternatively in the two countries, to review or initiate tie-line procedures and rules, operating instructions, balance of energy exchanges and other issues affecting the smooth operation of the interconnection.

4.1 Ghana-Cote d'Ivoire Interconnection

The Ghana-Cote d'Ivoire interconnection is an intertie meant for exchange of power between the two systems. VRA, therefore, is obliged under contract to cooperate closely and work hand in hand with its Ivorian counterparts in the realization of the goals vis-a-vis the technical and economic management of the tie-line.

The peculiar situation of VRA, where it was supplying guaranteed energy to its exchange partner, CIE has enabled VRA to remain at the forefront of all activities in the technical and economic management of this tie-line. Effective technical management of the intertie has provided the following technical and economic benefits to both Ghana and Cote d'Ivoire.

a) Limited use of expensive thermal power plants in Cote d'Ivoire as a result of the availability of cheaper hydro energy from Ghana.

b) Either country can take advantage of the differences in commissioning dates for future hydro-electric power plants.

c) Either country has taken advantage of the differences in hydrology of the two countries.

d) A more stable frequency on supply lines has been experienced.

e) Better frequency controls with the aid of the Load Frequency Control (LFC), in service on the two systems and assisting each other mutually.

f) Emergency exchanges enable each party to limit load shedding in the event of major generation installation problems. Furthermore, the emergency exchanges facility allows quicker and less stressful trouble shooting.

g) The advantage of operating the two systems in parallel is that, by pooling spinning reserves, the two systems are able to reduce their combined requirements of spinning reserve.

h) More flexible coordination of maintenance activities on important generation and transmission equipment.

In addition to these benefits, the personnel of the two systems namely, VRA in Ghana and EECI-CIE in Cote d'Ivoire have closely cooperated to acquire a common dynamic know-how and experience in Technical Management of Interconnected Systems. Such expertise include techniques in the control of load, stability studies, effective communication, coordination and organizational activities and personnel training.

4.1.1 Level of Power Transfer

The two systems are closely monitored (especially the Ivorian network) to limit the level of power flow from Ghana to Cote d'Ivoire, in order to prevent total system collapse in the event of an automatic outage on the interconnected lines. Steps taken to limit power flow include:

- a review on the load shedding plan on the Cote d'Ivoire network to take account of the level of importation from Ghana.

- coordination of relay protection schemes on the two systems, and

- an elaboration of, and strict adherence to instructions for the operation of the tie-line concerning the Exchange Programs, Coordination of Maintenance and Load Frequency Control.

4.1.2 Stability of the Two Systems

VRA in collaboration with its Ivorian counterparts, and with the help of external consultants, have investigated the steady and transient state stability of the Ghana-Cote d'Ivoire Interconnected System in order to reduce unstable oscillations during fault situations or switching actions on either system.

4.1.2.1 Transient Stability

From recommendations made by the various studies on transient stability of the two systems, steps have been taken to reduce the fault time on the Ivorian network by the use of remote tripping methods. To improve transient stability conditions on the Ghanaian side, reinforcement of the transmission network has been undertaken.

4.1.2.2 Steady State Stability

In order to improve on the steady state stability of the two systems, the following actions have been taken in the short term.

- installation of protective devices to trip the tie line to avoid the major incidents occurring on either network;

- Limiting power flow in either direction to a maximum of 100MW in the event that the network (loop) is opened anywhere on the 161KV Ghanaian network.

Efforts are underway to install Power System Stabilizers on the generating units at Buyo in Cote d'Ivoire and Akosombo in Ghana. These steps will help render the interconnected system stable in steady-state under a wide range of operating conditions, in the long term.

4.1.3 Telecommunication Facilities

In order to ensure easy communication during operations, efficient telephone, fax and telex facility using Power Line Carrier (PLC) systems, have been installed between the Dispatching (Control) Centers in Abidjan and Tema.

4.1.4 Training

There has been constant interaction between the personnel of the two utilities to enhance their acquaintance with operations on both sides. To this end, programs are drawn yearly for the exchange of operators to enable operators in the VRA and CIE acquire working knowledge in French and English respectively.

4.2 Ghana-Togo/Benin Interconnection

The agreement signed in 1969 between the Governments of Ghana, Togo and Benin, required the Volta River Authority (VRA) to initially supply guaranteed continuous power of 25MW to Togo and Benin. This value was reviewed and increased to 50MW in 1971. To date, VRA has continued to be a direct supplier of guaranteed energy to Togo and Benin, which are represented by the Communuate Electrique du Benin (CEB). It is worth noting that in spite of the non-existence of a permanent Technical Committee to manage operations, there has been very close collaboration and cooperation between VRA and CEB in solving operational problems on the interconnected system. In other words, there has always been the will to work closely to improve existing cordial relations. The need to further reinforce the technical and economic operation in the sub-region prompted VRA to spearhead a new type of cooperation in September, 1992, whereby the generation and transmission facilities of the two systems were integrated or pooled, with the aim of jointly operating an Integrated System for mutual benefit. The generation facilities within Togo and Benin are operated by CEB's Coordination Center in Lome/Aflao as directed by VRA System Control.

In addition to the real-time operational functions ensured by the two dispatching centers, the technical management of the tie-line is ensured by Technical Committees and Technical Sub-Committees made up of personnel from the two participating systems. Day to day operations, including switching on, switching off, maintenance and repairs are the responsibility of each party. Each party is obliged to maintain its equipment in good running order. Directives for starting up or shutting down generating units is coordinated from the Tema System Control Center.

4.2.1 Procedures For Maintenance/Coordination

An effective coordination of the maintenance of the installations is necessary to achieve the reliability required by the pool. It is also necessary that maintenance schedules be optimized. Hence, annual, monthly, and weekly maintenance schedules of generation and transmission equipment are exchanged so that each party can plan effectively by taking into account the unit availability information of the other.

4.2.2 Communication equipment

These are similar to those between VRA and CIE. Efficient PLC telephone, fax and telex facilities have been installed between VRA System Control and the Lome/Aflao substation. The availability of efficient communication facilitates coordination in the day to day management of the integrated system and adherence to the laid down administrative and financial procedures.

5. FUTURE DEVELOPMENT OF INTERCONNECTIONS WITHIN WEST AFRICA

The present WAGS comprises only four ECOWAS countries out of the 16 countries which form the organization. Based on the successful experience of these countries, various studies and initiatives are underway to extend the interconnection among other member countries of ECOWAS. In all these initiatives Ghana continues to play a leading role.

Presently, an evaluation of a future Ghana Burkina Faso interconnection is being studied. The preliminary analysis performed indicate the technical feasibility of the interconnection at voltage levels of 161 kV and 225 kV. It is expected that the study on the interconnection would be completed before the end of 1995. This will pave the way for project development and implementation eventually including Burkina Faso in the West African Grid System.

Analysis into other interconnections between Ghana, Nigeria, Togo and Benin are also underway. Preliminary results indicate that connecting Nigeria to Benin would substantially increase the stability of the existing Cote d'Ivoire - Ghana - Togo - Benin system. The interconnection would also further help lower the cost of energy production within the subregion by utilizing the unused capacity in the Nigerian power system with their relatively low costs of production.

Recently an agreement was signed between the governments of Nigeria, Benin, Togo and Ghana for the construction of a gas pipeline from Lagos through Benin and Togo to Ghana. Gas from Nigeria would be used for electric power production and other industrial and commercial purposes in Ghana, Togo and Benin. Demand for gas has been based on data received from the interested countries and for Ghana, VRA's demand forecast for electricity was used. Close to 80% of the gas requirements would be used for electric power generation of which about 70% would be used in Ghana.

It is clear that Power Interconnections represent an ideal approach in consolidating the economic gains of the subregion. This is the conviction of ECOWAS and is a policy being vigorously explored by member states. Ghana's experience and success in power interconnections during the past twenty-two years of ECOWAS co-operation is a practical demonstration of the fact that power interconnections form a strong basis for economic and industrial growth within the ECOWAS communities.

Table 1: Energy Exchanges (GWh) Between WAGS Member Countries

Year	VRA Total Generation	VRA Total Export To		VRA Total Import From		VRA Net Supply To	
		CEB	CIE	CEB	CIE	CEB	CIE
1972	3,321	1	0	0	0	1	0
1973	3,872	99	0	0	0	99	0
1974	4,878	127	0	0	0	127	0
1975	3,948	136	0	0	0	136	0
1976	4,174	155	0	0	0	155	0
1977	4,394	189	0	0	0	189	0
1978	3,721	216	0	0	0	216	0
1979	4,631	299	0	0	0	299	0
1980	5,276	440	0	0	0	440	0
1981	5,341	472	0	0	0	472	0
1982	4,941	521	0	0	0	521	0
1983	2,548	492	0	0	0	492	0
1984	1,799	318	317	0	6	318	311
1985	2,996	448	309	0	73	448	236
1986	4,372	437	237	0	10	437	227
1987	4,676	412	114	0	15	412	99
1988	4,807	301	88	6	84	295	4
1989	5,231	338	193	8	17	330	176
1990	5,721	458	312	0	4	458	308
1991	6,190	365	453	6	0	359	453
1992	6,602	499	410	0	1	499	409
1993	6,313	330	91	0	31	330	60
1994	6,104	420	48	0	60	420	-12

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