This paper reviews the present status and future prospects of international interconnections, infrastructure, electricity exchanges and deregulation in Africa from the viewpoint of generation and transmission development, deregulation trends and policies. Part 1 (ENERGIZE, March 2005) considered the case of the Southern Africa Power Pool (SAPP) interconnections in developing a competitive market for regional electricity cross border trading, while Part 2 (below) considers the Gulf Co-operation Council (GCC) Electricity Grid System and North African interconnections. The paper is an update and follow-up to a paper on African Electricity Infrastructure, Interconnections and Electricity Exchanges that was published in 2000 [1].

Recognizing the benefits of interconnection of their power grids, the six Arab States of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) undertook a study in 1990 to define an Interconnection Project and to determine its feasibility. The study recommended an AC interconnection of the 50 Hz systems of Kuwait, Bahrain, Qatar, UAE and Oman with a back-to-back HVDC interconnection to the 60 Hz Saudi Arabian system. The study concluded that the recommended Interconnection Project for the GCC countries was technically feasible as well as economically and financially viable. The Gulf Co-operation Council Interconnection Authority (GCCIA) has been established and given the mandate to proceed towards implementation of the Interconnection Project as recommended in the 1990 study.

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

Evolution of the power sectors in the GCC countries

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

Demand growth in the GCC countries

The demand in GCC countries as shown in Table 1 is expected to grow from 32,747 MW to almost 94,000 MW over the next 25 years.

Table 1: Demand growth up to 2028.

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

Table 2: Size of interconnection to each GCC state.

<table>
<thead>
<tr>
<th>System</th>
<th>Size (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuwait</td>
<td>1200</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>1200</td>
</tr>
<tr>
<td>Bahrain</td>
<td>600</td>
</tr>
<tr>
<td>Qatar</td>
<td>750</td>
</tr>
<tr>
<td>UAE</td>
<td>900</td>
</tr>
<tr>
<td>Oman</td>
<td>400</td>
</tr>
</tbody>
</table>

The Interconnection Project is comprised of the following principal elements:

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

The Interconnection Project comprises the following principal elements:

Phase I:

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

Phase III:

- A double circuit 400 kV line from Salwa...
to Shuwaihat (UAE) and associated substations.

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

The capacity of the interconnection to each of the countries is given in Table 2 and Fig. 2.

Cost of the interconnection project

The estimated cost of the Interconnection Project based on economic conditions of 2003 for Phase I and Phase III is $US1189-million and $US137-million, respectively.

Benefits of the interconnection project

The principal benefits that can be achieved through interconnection are:

- Interconnections result in the requirement for lower installed capacity in each of the systems (due to reserve sharing) while still supplying the load with the same (or better) level of reliability.
- Interconnections can permit larger and more efficient generating units to be installed on the individual systems.
- Interconnections enable systems to share operating (spinning) reserves so that each system can carry less spinning reserve.
- Interconnections enable interchange of energy between systems resulting in a lowering of total operating costs.
- Interconnections permit assistance from neighbouring systems to cope with unforeseen construction delays and unexpected load growth.
- Interconnections permit emergency assistance between systems to mitigate the effects of unforeseen contingencies such as catastrophic multiple outages.

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

The principal benefits due to the interconnection arise from the sharing of reserves between the systems and the consequential reduction in the installed generating capacity and associated operating and maintenance costs in the GCC countries. The capacity benefits to 2028 for Phase I are shown in Table 3.

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

Economic evaluation

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

Sharing of the costs of the interconnection project

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

Financing options for the project

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

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

The options of financing the project which was considered in the 1997 feasibility studies were five options as given in Table 4. The first and second option is based on full (100%) ownership of the project by the governments in which case the governments will be responsible for all costs associated with the project.

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

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

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

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

Next steps

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

Table 3: Generation capacity reduction benefit for phase I countries.

<table>
<thead>
<tr>
<th>Capacity Benefit (MW)</th>
<th>Isolated</th>
<th>Interconnected</th>
</tr>
</thead>
<tbody>
<tr>
<td>65%</td>
<td>1331</td>
<td>3380</td>
</tr>
<tr>
<td>33%</td>
<td>5066</td>
<td>29066</td>
</tr>
<tr>
<td>50%</td>
<td>3380</td>
<td>100%</td>
</tr>
<tr>
<td>17.5%</td>
<td>27017</td>
<td>26361</td>
</tr>
<tr>
<td>25%</td>
<td>3151</td>
<td>2988</td>
</tr>
<tr>
<td>50%</td>
<td>5060</td>
<td>35%</td>
</tr>
<tr>
<td>100%</td>
<td>4649</td>
<td>2049</td>
</tr>
<tr>
<td>35%</td>
<td>288</td>
<td>4649</td>
</tr>
<tr>
<td>79%</td>
<td>778</td>
<td>4507</td>
</tr>
</tbody>
</table>

Table 4: Financing options considered.

<table>
<thead>
<tr>
<th>Finance Options</th>
<th>Ownership</th>
<th>Sources of Finance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Government</td>
<td>Private sector</td>
</tr>
<tr>
<td></td>
<td>Capital</td>
<td>Private sector</td>
</tr>
<tr>
<td>Loans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>3</td>
<td>30%</td>
<td>25%</td>
</tr>
<tr>
<td>4</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>5</td>
<td>25%</td>
<td>25%</td>
</tr>
</tbody>
</table>

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

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

Status of international interconnections in North Africa

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

North African interconnectors

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

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

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

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

National Transmission Capacity (NTC) among the South-east Mediterranean Countries (SEMC) countries in 2003 is indicated in Fig. 3.

Jordan - Egypt red sea interconnection

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

More specifically the situation is:

- Tunisia - Libya: two lines at 220 kV (1 single circuit and 1 double circuit) have been completed. Permanent synchronization between the two blocs is subject to outcome of the testing phase that is envisaged will be completed in 2004;
- Syria - Turkey: a 400 kV line (Birecik-Aleppo) is now completed, but its exploitation will probably not take place prior to connection of the Turkish system to UCTE;
Turkey - UCTE: Turkey is presently interconnected with Bulgaria through two 400 kV lines.

Other developments: North - South HVDC connections

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

- Algeria - Spain: the feasibility study for a HVDC connection from Terga to Litoral de Almeria through a submarine cable (connection about 240 km) with a capacity of 2000 MW has been completed. The construction of 2000 MW of new generation (possibly CCGT) in Algeria – out of which 800 MW for local needs and 1200 MW for export - has been planned. Because of the difficulty in getting foreign investments, the project will be commissioned in two stages. At the beginning a bipolar HVDC link rated 1000 MW will be realized with marine electrodes for emergency current return;

- Algeria - Italy: the project of a potential interconnection rated 1000 MW between Algeria and Sardinia (Italy) is at a pre-feasibility stage. This project will be integrated with a second HVDC link, developed in two modules (500 MW + 500 MW), between Sardinia and Continental Italy.

Further envisaged HVDC links are relevant to Tunisia-Italy (2000 MW) and Libya - Italy (600–1000 MW). For these latter projects no detailed feasibility analyses have been carried out so far.

Future perspectives

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

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

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

References


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