Progress Report on the Gulf Council (GCC) Electricity Grid System Interconnection in the Middle East

Adnan Al-Mohaisen, Luc Chaussé, *Member, IEEE,* Satish Sud, *Member, IEEE*

Abstract – This paper describes the strategy adopted for implementation of the interconnection between the Gulf States (Kuwait, Saudi Arabia, Bahrain, Qatar, UAE and Oman) to ensure a competitive price for the project. This paper also describes the progress in the implementation and the issues which have had to be faced to date. In parallel, activities are being carried out to define the organizational structure of the GCCIA and the interconnection agreements which will provide the framework for the operations.

Index Terms – interconnection, grid systems, HVDC back-to-back converter, 400 kV transmission, GIS substations, submarine cable, project financing, project implementation.

I. INTRODUCTION

Recognizing the benefits of interconnection of their power grids, the six Arab states of Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates (UAE) and Oman, it was decided to build 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 interconnection was justified based on reserve sharing between the systems but once built will provide the opportunity for trading electricity between the member countries.

After investigating different options for financing the Project, it was decided to finance the Project with funds from the member countries.

For implementation, the project was broken into discrete contracts which allowed a number of prequalified International contractors to participate in the implementation of the project. The contractors will work concurrently but independently from one another. The proposed implementation strategy for the Project enabled wide participation by International contractors in the shared implementation of the GCC Project in an efficient and economic manner.

Adnan Al-Mohaisen, General Manager of the, GCC Interconnection Authority (GCCIA) P.O. Box No. 3894, Dammam 31481, Kingdom of Saudi Arabia, Email: ceo@gccia.com.sa

Luc Chaussé, Project Director, Transmission & Distribution Division, SNC–Lavalin Inc. Email : Luc.Chausse@snclavalin.com

S. Sud, Vice President, Transmission & Distribution Division, SNC–Lavalin Inc., 455 Rene-Levesque Blvd. West, Montreal, Canada, Email: Satish.Sud@snclavalin.com

In 2005 requests for Tenders were issued to pre-qualified tenderers for the major work packages: Transmission lines; GIS substations; HVDC Back-to Back; Submarine cable and the Control Centre including protection and telecommunication. Tenders were received and analyzed and contracts were awarded in November 2005. The Project schedule calls for the Interconnection to be in operation by early 2009.

II. THE INTERCONNECTION PROJECT

The electrical grid system interconnection between the GCC states is shown diagrammatically in Figure 1.

FIGURE 1
APPROXIMATE ROUTE AND LAYOUT OF THE GCC INTERCONNECTION

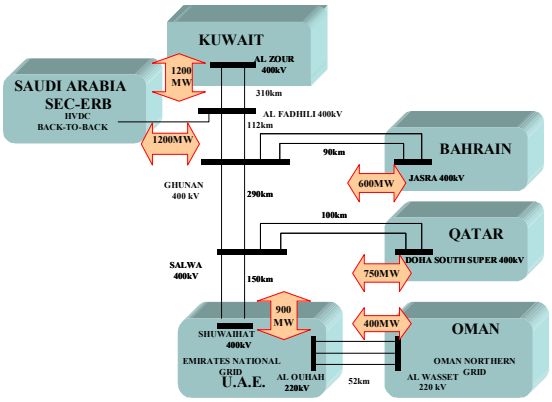
The capacity of the Interconnection to each of the countries is given in Table 1:

TABLE 1
SIZE OF INTERCONNECTION TO EACH GCC STATE

System	Size (MW)
Kuwait	1200
Saudi Arabia	1200
Bahrain	600
Qatar	750
UAE	900
Oman	400

A conceptual diagram of the Interconnection Project is shown in Figure 2.

FIGURE 2
CONCEPTUAL DIAGRAM OF THE INTERCONNECTION SYSTEM



The Interconnection Project will be implemented in three phases and consists of the following principal elements:

Phase I: Interconnection of the Northern Systems (Kuwait, Saudi Arabia, Bahrain and Qatar) to be completed in early 2009

- 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 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.

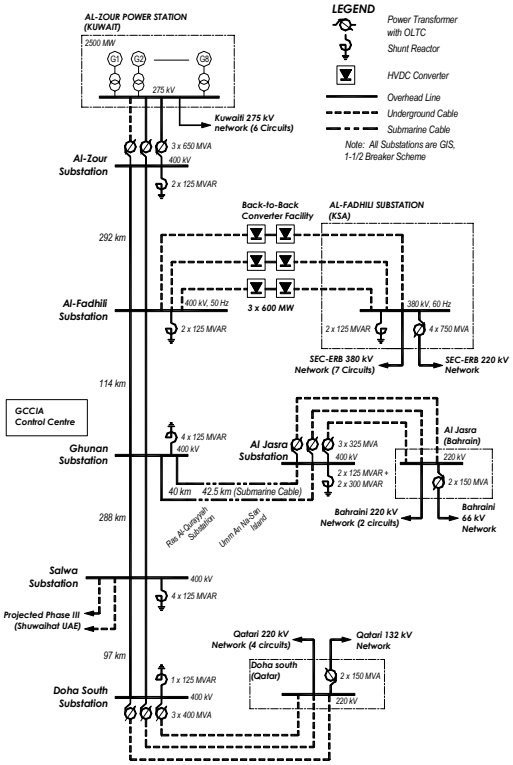
Phase II: The internal interconnection of the Southern Systems (UAE and Oman) to form the UAE National Grid and the Oman Northern Grid (GCCIA is not involved in this Phase).

Phase III: Interconnection of the Northern and Southern Systems in 2010.

- A double circuit 400 kV line from Salwa to Ghuwaifat (UAE) and associated substations.
- A double and a single circuit 220 kV line from Al Ouhah (UAE) to Al Wasset (Oman) and associated substations.

A simplified single line diagram of the system is shown in Figure 3.

FIGURE 3
SIMPLIFIED SINGLE-LINE DIAGRAM OF THE INTERCONNECTION – PHASE I



III. IMPLEMENTATION STRATEGY

The GCC Interconnection, Phase I comprises the installation of six (6) high voltage interconnected substations plus a back-to-back HVDC terminal interfacing with four (4) existing substations which belong to the national networks of the respective member Countries. These are concurrently required to effect the exchange of power between the power systems of Kuwait, Saudi Arabia, Bahrain and Qatar.

A Control Center for the GCC Interconnection, which is also capable of communication with the National or Regional Centers of the Member Countries, will also be installed and, when eventually completed, the interconnected substations will be suitable for operation in a coordinated and stable manner through this Control Center. The Center will provide the remote control and monitoring of the substations which will be suitable for unattended operation.

The design and installation of the interconnection facilities: substations, transmission lines and submarine cables, will provide for uniformity and compatibility of functions and allow efficient operation as an independent network, of all the corresponding elements of the interconnection system.

For implementation purposes, the project was broken into discrete contract packages which allowed a number of pre-qualified International contractors to participate in the implementation of the project. The contractors will work concurrently but independently from one another. The proposed implementation strategy for the Project enabled wide participation by International contractors in the shared implementation of the GCC Project in an efficient and economic manner.

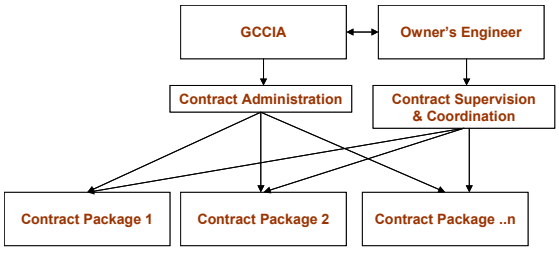
Thus, the request for Tenders for the six (6) contracts for GIS substations, one (1) for a back-to-back HVDC station, four (4) contracts for transmission lines, one (1) contract for submarine and land cables were separately issued.

Bidders were allowed to offer combination bids for more than one of the packages and offer combination discounts. To qualify, however, individual bids had to be made and the advantages of combination were evaluated on receipt of bids.

Additionally, a global contract, for the Control Center complete with overall system control and protection, was issued separately. This strategy enabled the selected contractor to offer one fully integrated protection, control, monitoring and communication network based on the latest LAN/WAN network philosophy and using the appropriate network protocols for data access between the stations and the Control Center as well as interchange of data between the GCCIA and the EMS dispatch centers of the different countries. These modern network functions will enable full data retrieval for fault, maintenance and defect analysis at a number of locations to ensure that all aspects of the GCC network are kept in top working order at all times.

The management of the EPC contracts is shown schematically in Figure 4.

FIGURE 4
IMPLEMENTATION STRATEGY – FUNCTIONAL RELATIONSHIPS



Invitations to tender were issued by the Engineer. Tender documents were based on FIDIC Conditions for Plant and Design Build.

For the GIS substations only the original GIS manufacturers were pre-qualified for the tendering process. Of the seven companies pre-qualified, five presented tenders for either all or some of the GIS substations.

For the back-to-back HVDC station, three tenders were received.

For the transmission line lots, twenty three companies or joint ventures were pre-qualified. Of these, nineteen presented tenders (either as pre-qualified, or jointly with others).

For, the submarine and land cables, three tenders were received.

For the Control Centre, protection & SCADA and telecommunication system, four tenders were received.

The tenders were evaluated for technical conformance to the specifications and then a commercial evaluation was performed. During the tender evaluation process, numerous requests for clarifications were sent to the Tenderers to complete the information of their Tender. When Tenders included deviations to the requirements, either explicitly or implicitly they were systematically requested to withdraw any discrepancy at no extra cost. If not withdrawn, minor departures were penalized through equalization factors, whereas major deviations led to rejection of the Tenders.

The lowest evaluated Tenders, taking into consideration combination discounts, were then recommended for award of contract. The results of this evaluation process were as follows:

TABLE 2
RESULTS OF THE EVALUATION PROCESS

Description	Tenderer	Price M$US
Six (6) GIS Substations	ABB	222
Back-to-Back HVDC Converter	Areva–Cogelex	206
Overhead Transmission Lines:		
B1 – Al-Zour –Fadhili	National Contracting Co	95
B2 – Al-Fadhili – Ghunan	HEC–MEEDCO	40
B3 – Ghunan-Salwa & Ghunan – Ras Al Qurayyah	HEC–MEEDCO	107
B4 – Salwa to Doha	National Contracting Co	38
Submarine and Land Cable	Prysmian/Nexans	343
Control Centre, Protection & Telecommunication	Areva/Cogelex	28
Total		1079

The six GIS substations were awarded to ABB. The back-to-back HVDC facility was awarded to Areva-Cogelex. National Contracting Company was awarded the two overhead transmission line packages (Al Zour to Fadhili and Salwa to Doha) straddling the borders Kuwait/Saudi Arabia and Saudi Arabia/Qatar. HEC-MEEDCO was awarded two overhead transmission line packages in Saudi Arabia (Al Fadhili to Ghunan and Ghunan to Salwa & Ghunan to Ras Al Qurayyah). The submarine and land cable from Saudi Arabia to Bahrain (Ras Al Qurayyah to Al Jasra) was awarded to Prysmian/Nexans. The Control Centre, protection and telecommunication package was awarded to Areva-Cogelex. The overall supervision of the Project, and to act as Owner's Engineer, to assist the GCC Interconnection Authority, was awarded to SNC-Lavalin.

In view of the proposal to package the project into several discrete contracts GCCIA's Engineer will have to carry out the following critical duties:

- Ensure the contract limits and interfaces are well specified.
- Ensure that the documentation of the contractors are consistent and cross referenced.
- Supervise the testing and commissioning of the individual substations as well as the interconnected systems.
- Supervise the individual contract schedules to assure meeting the overall project schedule.
- Facilitate the coordination between the individual contractors and the GCC member utilities. In particular, ensure that the interfaces at the GCC member 's interface stations and the data transfer necessary at those points are correctly engineered and implemented.
- Establish the overall control philosophy for the joint operation of the interconnected networks.

IV. PROGRESS ON IMPLEMENTATION

A description of the packages and the progress to date on the implementation is given below:

A. GIS Substations

Al Zour substation (Kuwait) consists of 400 kV GIS complete with three 650 MVA power auto-transformers 400/275 kV to interconnect the GCCIA network with the existing Al Zour 275 kV GIS Substation. Issues that had to be resolved were related to interfacing with the existing substation the exact location of the new GCCIA substation and the permits required to confirm the land use.

Al Fadhili substation (in Saudi Arabia) is a 400 kV GIS switching substation, which will interconnect Al Zour and Ghunan, as well as feed the 50Hz side of the HVDC back-to-back frequency converters. The 60Hz side of these converters will be connected to the existing Al Fadhili 380kV GIS substation. Issues that had to be resolved were related to the interfacing with the existing substation.

Ghunan substation (KSA) is a 400 kV GIS switching substation, that will connect Al Fadhili, to Salwa and to Al-Jasra substations.

Salwa substation (Saudi Arabia) is a 400 kV GIS intermediate switching substation between Ghunan (Saudi Arabia) and Doha South (Qatar) substations. This substation will further interconnect the transmission to Ghuwaifat (UAE) in Phase III of GCCIA interconnection project in the future. It was decided to equip the GIS substation for the future extension as part of Phase I.

Doha South substation (Qatar) consists of 400 kV-GIS with three 400 MVA power autotransformers, 400/220 kV to interconnect the GCC network with the existing Doha South 220 kV substation. Issues that had to be resolved were related to the interfacing with the existing substation and to adapt the design to the limited amount of space available.

Al Jasra substation (Bahrain) is a 400 kV GIS substation complete with three 325 MVA power autotransformers, 400/220 kV that will interconnect the GCCIA network with the existing Al Jasra 220 kV GIS substation.

B. HVDC Back-to-Back Converter Facility

The basic objective of the converter facility is to allow reserve sharing between the electrical power systems of participating member states (systems at 50 Hz and 60 Hz) and, as a secondary objective, to permit power transfer between the member states where such transfer has economic benefits.

To achieve effective reserve sharing it has been shown that up to 1200MW of active power will be able to be transferred from 50Hz to 60Hz systems and vice versa with sufficient speed of response and accuracy of control to stabilize the interconnected systems following the established critical loss of generation event within either system.

Provided that the ability to effectively share reserve is not compromised, the converter facility shall also

allow economic interchange of up to 1200MW of active power between the systems in either direction.

In order to ensure the availability of 1200MW of inter-system real power transfer capability, three independent 600MW back to back converters will be installed.

Work is progressing on the detailed design studies for insulation coordination; HVDC converters reactive power capacity; converter transformer design; network harmonic impedance calculation and filter design. An issue was obtaining the necessary network data from the utilities.

C. Overhead Transmission Lines

The 400 kV overhead lines will be on double circuit towers with two (2) optical ground wires (OPGW). Each phase will consist of four (4) conductor bundles and the number of insulators was chosen to assure satisfactory performance in the prevailing environmental conditions.

The first section of the overhead transmission line is located in two different countries: Kuwait and Saudi Arabia. From the existing generation station at Al Zour in Kuwait, the transmission line will go to Al Fadhili in Saudi Arabia, a distance of 310 km (about 62 km are in Kuwait).

From Al Fadhili, the overhead transmission line will depart southward to Ghunan a distance of 112 km.

From the Ghunan substation, the overhead transmission line will depart southward to link with the Qatar network near the Salwa substation. The estimated distance from Ghunan to Salwa is approximately 255 km.

From the Salwa substation, the overhead transmission line will depart towards the Doha South Super substation in Qatar. The estimated distance from the Salwa substation to Doha South is about 97 km.

From the substation located at Ghunan, there is also an overhead transmission line to Ras Al Qurrayyah at the gulf shore, a distance of about 36 km, where it will connect to the submarine cables to Bahrain.

Given the prevailing environment (line close to the sea coast and in desert conditions) it was decided to coat the insulators with silicone and to remove the envisaged built in line washing facilities. This should reduce the operation and maintenance costs. Special attention also has to be paid to the concrete mix for the foundations because of the presence of a high salt content in the soil (Sabkha). The transmission line routes have been surveyed and the design is being finalized. Figure 5 shows a tower being tested.

FIGURE 5
TOWER TESTING SITE

D. Submarine Cables

The system includes two (2) 400kV alternating current cables (2 groups of 6 cables) and related ancillary equipment that shall be capable of reliably transmitting 650 MVA of electrical power from an overhead line outdoor termination (pot-head) at a coastal substation at Ras Al Qurrayah in Saudi Arabia to an SF6 termination at the Al Jasra 400 kV substation in Bahrain. The cables will be Oil-filled (SCFF) and the operating frequency is 50 Hz. The cable systems will require the construction of approximately forty-one (41) km of submarine cables (armoured) and approximately seven (7) km of underground cable (non-armoured).

Two (2) fibre optic cables will be installed which will be utilized for communication purposes in connection with the protective relaying, controls and monitoring equipment.

E. Control, Protection, SCADA and Telecommunication:

The system of Control, Protection, SCADA and Telecommunication for the GCCIA will form part of a single work package in order to provide compatible equipment and systems for the whole GCCIA 400 kV interconnection network. Equipment will be implemented in all substations of the project namely, Al-Zour, Fadhili, Ghunan, Salwa, Ras al Qurrayah, Al-Jasra and Doha South. This work package will also include the supply and installation of a new GCCIA Interconnection Control Center (ICC) SCADA/EMS system which will be located at the site of the new Ghunan substation. The IEC 61850 protocol will be used for the communication.

V. PROJECT SCHEDULE

The update of the technical and economic feasibility of the Project was completed in early 2004. Approval for the method of financing of the Project was received in May 2004. In early 2005 Tender documents were issued to contractors pre-qualified for the different work packages. Tenders were received in June 2005 and contracts were awarded for project execution in November 2005. The Project should be in operation by early 2009.

VI. OTHER GCCIA ACTIVITIES

The other activities being carried out are the Management Consultancy mandate to define the organization of the GCCIA and to prepare the Authority for the Operations and Trading phases. A mandate has also been given to develop the Legal Framework which will govern the ownership and operations of the interconnection. Interconnection agreements for Energy Trading and Reserved Sharing will be prepared.

VII. CONCLUSIONS

This Project has been under study since the mid-eighties and involved the agreement and participation of six GCC countries. The process from study to implementation was a fairly protracted one as it involved: demonstrating the technical and economic feasibility; agreements between the countries; creation of the GCC Interconnection Authority; agreements on cost sharing and financing of the Project. All these hurdles were overcome and the Project is finally being implemented. The implementation strategy adopted was to divide the Project into work packages and to go out for International Competitive Bidding. There was a large response to the request for Tenders and the GCCIA was able to get competitive prices for the various packages. Contracts have been awarded and work is in progress on the detailed designs by the Contractors. The design review process by the Engineer is well underway. Site preparation work has now commenced and the Project is targeted to be completed on schedule.

VIII. REFERENCES

[1]. J. AL-Alawi, S. Sud and D. McGillis, "Planning of the Gulf States Interconnection". *IEE, Fifth International Conference on AC and DC Power Transmission*, Conference Publication Number 345, pp. 38-43, September 17-20, 1991.

[2]. J. Al-Alawi, S. Sud and D. McGillis, "Planning and Design of the Gulf States Interconnection". *Power in the Gulf, Middle East Electricity Conference*, pp. 49-68, January 13, 1992.

[3].D. McGillis and S. Sud, "Power Systems Interconnection Planning and Experience", *Power Technology International 1993,* pp. 43-50.

[4].J. Al Alawi, S. Sud and D. McGillis, "Planning and Design of the Gulf States Interconnection". *IEEE, Panel Session: Middle East Policy on Electricity Infrastructure, Interconnections, and Electricity Exchanges*, San Franciso, USA, July 24-28, 1994.

[5]. S. Sud, D. McGillis and Sami Abdulghani, "Guidelines for the Planning and Design of Power System Interconnections", *Role of Electricity in the Development of Arab Countries, Cigre First Regional Meeting of Arab Region*, January 21-23, 1995.

[6]. A.M.H.A. Karim, N.H. Al Maskati and S. Sud, "Status of Gulf Co-Operation Council (GCC) Electricity Grid System Interconnection", *IEEE, Power Engineering Society Energy Development and Power Generation Committee, Panel Session: Status of International Interconnections and Electricity Deregulation in Africa*, Denver, June 6-10, 2004.

[7].A. AL-Mohaisen and S. Sud, "Update on the Gulf Co-Operation Council (GCC) Electricity Grid System Interconnection", *IEEE, Power Engineering Society 2006 General Meeting, Panel Session: Africa – Integrated Gas and Electricity Transmission Planning in Power Generation and Energy Development Benefits, and Developments in HVDC Engineering Technology in Harnessing Large-Scale Hydroelectric Sites for Interconnected Regional Power Systems – 06GM0385*, Montréal, Québec, Canada, June 18-22, 2006.

IX. BIOGRAPHIES

Adnan Al-Mohaisen graduated from King Saud University in Riyadh, Saudi Arabia in 1976 with a bachelors degree in Electrical Engineering. Upon graduation he was among the first to be hired in the Royal Commission for Jubail & Yanbu. Thereon, he worked in various positions and in 1980 managed to attain, by scholarship, a Masters degree in Electrical Engineering (Power Systems) from the University of Missouri in 1981. During the 29 years that he was with the Royal Commission for Jubail & Yanbu, Adnan held 3 senior positions of Deputy Director General in the Planning & Projects, Community Services and Public Services areas. In late 2004, Adnan was nominated to become General Manager for the GCC Interconnection Authority in which he took the position in January 2005. Adnan also headed and participated in various committees in the Royal Commission and other public organizations. Adnan has also participated in management and career development courses from various reputable universities, such as the University of Chicago and the University of Southern California and the University of New South Wales in Australia.

Luc Chaussé graduated from École Polytechnique de Montréal, Québec, Canada in 1974 with a Bachelor Degree in Electrical Engineering. He is the Project Manager for the GCC Interconnection Project. During the 32 years of his career, he has been involved with manufacturers, contractors and consultants in transmission network projects as well as in thermal nuclear and gas turbine projects in Canada and overseas. He has developed a solid basis in the technical design of the electrical facilities namely with respect to automation, SCADA, protection, HV apparatus and telecommunication. He has been leading various major projects and managing turnkey contracts on both the client's and the contractor's sides. He has an extensive experience overseas with projects in Middle East, Africa and South America where he spent many years as an expatriate for on-site supervision of works. He is a member of the Order of Engineers of Québec and of the Institute of Electrical and Electric Engineers.

Satish Sud graduated with a B.Tech. (Honours) in Electrical Engineering from the Indian Institute of Technology, Kharagpur, India and obtained his M.Sc. in Engineering from the University of Manitoba, Winnipeg, Canada. He is Vice President in the Transmission and Distribution Division of SNC-Lavalin. He is an electrical engineer with over 36 years of experience and is responsible for the development and management of the Power Systems Group which undertakes electrical transmission and distribution projects, electrical system and energy studies, master plans, power sector reform and restructuring studies, and economic and financial studies. He has directed numerous electrical

generation, transmission planning and system design studies, both in Canada and overseas. He was the project manager for the planning studies to determine the techno-economic feasibility of various interconnection projects where both AC and DC alternatives were considered. He has also developed master plans for electrification and national energy plans for several countries. Some of the countries in which he has participated in planning studies and/or projects are: Canada, USA, Honduras, El Salvador, Nicaragua, Panama, Guyana, Argentina, Peru, Senegal, Mauritania, Mali, Guinea, Ivory Coast, Cameroon, Niger, Nigeria, Benin, Togo, Rwanda, Tanzania, Botswana, Zambia, Zimbabwe, Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates, Oman, Iraq, China, India, Philippines, Indonesia, Vietnam and nine countries of south eastern Europe. He is a member of the Order of Engineers of Quebec, Institute of Electrical an Electronic Engineers and the Institution of Engineering and Technology (Fellow).