The Operation of the GCCIA HVDC Project and Its Potential Impacts on the Electric Power Systems of the Region

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***Abstract*—The Gulf Cooperation Council Interconnection Authority (GCCIA) has constructed and commissioned a 400kV interconnection grid between Kuwait, Saudi Arabia, Bahrain, Qatar and United Arab of Emirates (UAE), that includes 900 km of overhead lines, seven 400kV substations, a 1800MW three-pole back-to-back HVDC converter station and a submarine cable to Bahrain. This paper summarizes the design features of the GCCIA Back-to-Back HVDC station, illustrates both the technical considerations and physical characteristics of the project, and highlights the operational experience since its operation in 2009. Also, the paper provides some environmental aspects and personal recommendations, and sum up with illustrative conclusion over the covered topics.**

***Index Terms*—high-voltage direct-current transmission, interconnection, GCCIA, back-to-back HVDC, power system operation, grid connectivity, power system converters**

I. Introduction to GCCIA

A high level grid interconnection among the Gulf Cooperation Council (GCC) states was recognized beneficial to address the need of economic power transfer and achieve higher reliability and sustainable transmission services between the Gulf States. Eventually, the Gulf Cooperation Council Interconnection Authority (GCCIA) completed a 400kV Interconnection grid between six Gulf States members which are: Saudi Arabia, Kuwait, Qatar, Bahrain, United Arab Emirates (UAE) and Oman. Since Saudi Arabia's network operates at 60 Hz and the other Gulf States are at 50Hz, synchronous AC interconnection was not possible. Therefore, HVDC station was the only solution to interconnect the power grids of the member states [1], [2]. The project established three Back-to-Back HVDC each rated 600MW (1800MW total) convertor stations between the interconnected 50Hz 400kV systems of Kuwait, Bahrain, Qatar, UAE and Oman on one side, and the 60Hz 380kV system of Saudi Arabia on the other side. The HVDC station was constructed in Saudi Arabia connecting GCCIA 400kV 50 Hz Al-Fadhili substation to Saudi Electricity Company (SEC) 380kV 60Hz Al-Fadhili substation [1], [3], [4].

The GCCIA HVDC converter station was not only the biggest Back-to-Back station in the world (1800MW), but also introduced a unique feature which permits the sharing of reserves between the 60Hz and 50Hz power systems. The planning studies that were carried out to satisfy the GCC need for the interconnection of the independent GCC grids were based on the following objectives:

- Interconnect the member states' electrical power networks by providing the necessary investments for power sharing to anticipate power generation loss in emergency situations.
- Reduce the spinning reserves of each member state.
- Improve the economic power system efficiency throughout the member states.
- Provide cost-effective power sharing capabilities among the member states and strengthen collective electrical supply reliability.

II. Physical Characteristics of the Project

Figure 1. The geographical routes and layout of the GCC interconnection

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The GCC Interconnection is the biggest back-to-back HVDC station in the world with capacity of (3×600MW) 1800MW and it is the first of its kind in the region. The GCC HVDC main station is located in Saudi Arabia at Al-fadhili which is a desert area known for its sand storms and high temperatures during summer that could reach about +125 ℉. This extreme weather condition has enforced unique design for the station. Fig. 1 shows the geographical routes and layout of the GCC interconnection.

The project was implemented in three phases and has been divided into several work packages which are: substations, back-to-back HVDC converter station, submarine cable, overhead transmission line and a control center. The purpose is to enable a wide participation by international contractors in the implementation of the GCC project in an efficient and economic manner [4], [5]. Table I shows the work packages and the assigned contractors.

TABLE I. PROJECT CONTRACTORS

Work Package	Contractor
Substations	ABB
HVDC Station	Areva-Congelex
Overhed Transmission Line	NCC & MEEDCO
Cable	Prysmain – Nexans
Control	Areva-Congelex
Supervision	SNC-Lavalin

III. TECHNICAL CHARACTERISTICS OF THE PROJECT

The GCC HVDC project is a 400kV interconnection grid that includes 3300km (2100 mile) of overhead lines, seven 400kV substations, and 37km (23mi) of submarine cable to Bahrain. It allows power exchanges between Gulf States as shown in Fig. 2. Saudi Arabia and Kuwait each is able to export or import up to 1,200MW from the grid, while Bahrain, Qatar and UAE are able to trade 600MW, 750MW and 900MW, respectively. Oman has the lowest interconnector capacity at 400MW [6], [7].

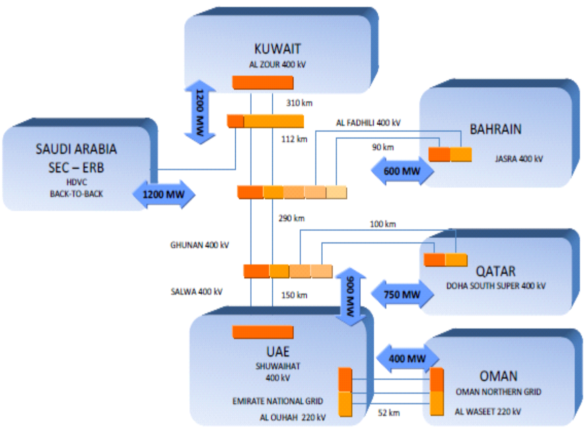

Figure 2. GCC interconnection configuration

The GCC converter station allows reserve sharing between the electrical power systems of participating member states. Also, it permits power transfer between the member states when such transfer has economic benefits. To achieve effective reserve sharing, the GCC HVDC project has implemented the Dynamic Reserve Power Sharing (DRPS) Control scheme which ensures 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. The HVDC converter facility also allows economic interchange of up to 1200MW of active power between the systems in either direction provided that the ability to effectively share reserve is not compromised. In order to ensure the availability of 1200MW of inter-system real power transfer capability, three independent 600MW back-to-back converters (poles) are installed and commissioned in 2009. Each pole is required to meet this power transfer level under specified system operating and environmental conditions. The key electrical parameters for dimensioning of the station are summarized in Table II [7].

TABLE II. HVDC STATION RATING PARAMETERS

Parameter	60Hz	50Hz
Nominal voltage	380kV	400kV
Max. continuous voltage	399kV	420kV
Min. continuous voltage	361kV	380kV
Max. 30 min voltage	418kV	
Min. 30 min voltage	342kV	
lighting impulse withstand level	1425kV	1300kV
switching impulse withstand level	1050kV	1050kV
Continuous frequency	60 ±0.5%	50 ±0.5%
30 min frequency	60 ±1.0%	50 ±1.0%
10 sec frequency	60 ±2.5%	50 ±2.5%
0.5 sec frequency	60 ±5.0%	50 ±5.0%

Each 600MW pole is identical and fully rated for power flow in either direction. This power rating is available under all of the system operating conditions listed in Table II. Each pole is designed to operate from a minimum power of 60MW (10%) to a maximum continuous overload of 660MW (110%). The latter figure is achieved when all transformer and valve cooling systems are available. These figures can be achieved over the complete range of system conditions listed in Table II. Continuous overload in excess of 660MW can be achieved at lower ambient temperatures. Short time overload capability, from 5 minutes to 30 minutes, is also available, the actual capability being dependent upon the prior operating regime of the converter station.

The GCC HVDC station consists of the following major components:

A. *AC Switchyard with Harmonic Filters*

HVDC converters consume reactive power and also generate harmonic currents. The AC systems have only limited capacity to deliver or receive reactive power and limited tolerance to harmonic currents. Harmonic filters are provided with all HVDC schemes to approximately balance the reactive power consumed by the converters as they are capacitive at fundamental frequency and they reduce the harmonic distortion to acceptable limits. For the GCC project, these filters are switched automatically using Alstom Grid dead-tank circuit breakers, dis-connectors and earth switches. As the converters generate high frequency conducted harmonics, PLC filters were added to block these harmonic currents from interfering with power line carrier communication in the AC networks. The switchyard is connected to the nearby GIS substations by underground 400 kV class XPLE cable. Table III shows the HVDC Filter ratings:

TABLE III. HVDC FILTER RATINGS

Converter End Frequency/Voltage Hz/kV	Number of Elements	Individual Elements size (MVAr)	Total MVAr per converter
50Hz/400 kV	2	130	397
	1	137	
60Hz/380 kV	2	180	360

B. Converting Transformers

Converting transformers (shown in Fig. 3) provide the galvanic isolation between the AC and DC systems and limitation of fault currents through the thyristor valves. Twelve transformers were supplied in total for this project consisting of four HVDC converter transformers for each of the three poles. Each pole is comprised of the following ratings: 385MVA, 380/97kV, 60Hz, Y/Y385MVA, 380/97kV, 60Hz, Y/Delta 380MVA, 400/96kV, 50Hz, Y/Y380MVA, 400/96kV, 50Hz, Y/Delta.

Figure 3. Converting transformer

C. Thyristor Valves and Controls

Each pole is arranged in pair of 12-pulse thyristor Graetz bridges per side, fed from two separate Y/Y and Y/Delta transformers. The thyristor valves are Alstom Grid H400 series valves which are rated at 8.5kV and have 125mm in diameter. Table IV shows the converter ratings.

TABLE IV. CONVERTER RATINGS

Power (MW)	DC link voltage (kv)	DC link current (A)
616	222	2776

The converter structure as follow:

- 12 thyristors per module, 3 modules in series per phase
- The 4 valves associated with each phase are mounted in a "quadrivalve" structure
- 3 "quadrivalves" create the 12 pulse bridges per converter
- Valves suspended from ceiling

HVDC converters need to be installed in a controlled environment with low levels of dust (converters have a tendency to act as an electrostatic precipitator and to accumulate dust on insulating surfaces). For this reason, the valves are installed in a "Valve Hall" with controlled temperature, humidity and dust levels and with a slight over-pressure to minimize dust ingress. These factors were particularly important on this project which, because of its desert location, is prone to high levels of external dust. The valve hall contains not only the valves but all equipment exposed to DC voltages. The only equipment located outside is AC equipment which is much less vulnerable to dust accumulation.

Each converter pole has a duplicated Alstom Grid series V converter control and protection system to give the necessary power transfer control and provide protection to the converters and DC circuits. An overall duplicated series V master control with an integrated Human Machine Interface (HMI) allocates the required power to each of the poles and in addition interfaces to the GCC Interconnector Control Centre (ICC). Control can either be in economic power transfer to permit trading of power between regions or when necessary in Dynamic Reserve Power Sharing (DRPS) mode to allow very rapid support of a region suffering loss of power generation. Master control also controls the reactive power exchanged between the converter station and the AC systems by switching harmonic filters and by controlling the thyristor triggering angles. Conventional protection is provided for the converter transformers, harmonic filters, bus bars and power cables. A transient fault recorder system is also provided [6], [7].

D. Cooling System

The very high ambient temperature on this project posed a significant challenge. Because the temperature of the valves' active part (the silicon in the thyristors) needs to be limited to 195 ℉, the water-cooling plant required higher coolant flow rates than a standard HVDC link. This required the largest water-cooling plant ever built for an HVDC installation.

Each one of the back-to-back converters has a single circuit valve cooling system to cool 6 quadri-valve assemblies. The valves are liquid cooled with 100% De-ionized Water. Due to the maximum outdoor ambient air temperature of 130 ℉ and +40 ℉ allowance for the heat exchanger, the maximum coolant inlet temperature to the valves in service is 140 ℉. Because of the very high maximum outdoor ambient temperature, it was necessary to use an efficient thyristor cooling technique, which is the parallel arrangement. The parallel cooling arrangement has 7 coolant paths and it directly provides each thyristor heat sink with coolant at the inlet temperature to the valve.

IV. Economics of the Project

The capital cost of the three phases of the project is US$1.1 billion, US$300 million and US$137 million, respectively. Also, it was agreed among the Gulf States to share the costs of the Interconnection in proportion to the reserve capacity savings as per Table V.

TABLE V. Cost Sharing of the Project

Country	Phase I	Phase I & III
Kuwait	33.8%	33.8%
Saudi Arabia	40.0%	31.6%
Bahrain	11.4%	9.0%
Qatar	14.8%	11.7%
UAE	-	15.4%
Oman	-	5.6%

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 payback 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 the attractiveness of the Project. Thus the analysis re-confirmed the economic viability of the Project.

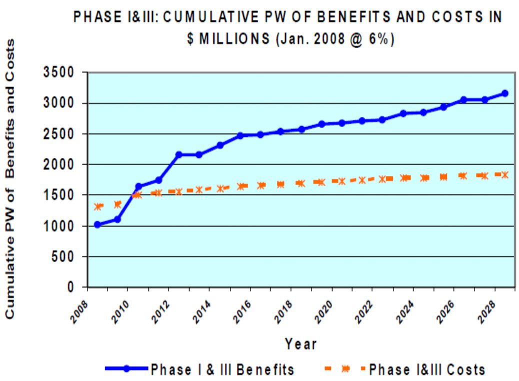

Figure 4. Project benefits and costs

Fig. 4 shows that upon the completion of phase 3 of the project, the cost saving rate of return after three years of operation is $3.35 billion [7], [8].

V. Operation of the GCCIA Project

A. Phases of the project

The HVDC interconnection of GCCIA was constructed in three phases:

Phase I: the interconnection of the northern part of the project. Saudi Arabia, Qatar, Kuwait and Bahrain had been interconnected by HVDC back-to-back converter facility, which also include:

- **A double-circuit 400kV, 50Hz line** from Al-Zour substation (Kuwait) to Ghunan substation (Saudi Arabia) with an intermediate connection at Al-Fadhili substation (Saudi Arabia).
- **A double-circuit 400kV, 50Hz** comprising overhead lines and AC submarine cable from Ghunan substation to Al-Jasra (Bahrain).
- **A double-circuit 400kV, 50Hz line** from Ghunan substation to Salwa substation (Saudi Arabia).
- **A double-circuit 400kV, 50Hz line** from Salwa substation to Doha South substation (Qatar).
- **An Interconnection Control Center (ICC)** located at Ghunan substation in Saudi Arabia.

Phase II: the work on phase two had been constructed in parallel in separate way from phase I. This phase concerned the interconnection of UAE and Oman national grids. It should be noticed that the interconnection of UAE internal grids had been finished earlier and wasn't involved as a part of GCCIA project.

Phase III: phase three was the jointing point of the two phases; the interconnection of the northern and southern parts of the project together to form GCCIA HVDC interconnected network.

- **A double-circuit 400kV, 50Hz line** from Salwa substation to Quwafiti substation (UAE).
- **A double-circuit and a single 200kV, 50Hz line** from Al-Quhah substation (UAE) to Al-Wasset substation (Oman).

Fig. 2 shows the block diagram of the three phases of the project.

To control and monitor the operation of the project effectively, GCCIA established a new interconnector control center equipped with supervisory control and data acquisition (SCADA) and energy management system (EMS) facilities in Ghunan, Saudi Arabia.

B. Operational Studies

In addition to conducting studies during the feasibility and planning stages of phase I, the GCCIA commissioned operational studies during the final construction stage of the GCC interconnection, prior to commissioning the interconnecting transmission lines. The responsibility of the planning and operational studies in the final stages of the project, before energization and synchronization, was done by RTE (Tractable Engineering and Elia). The studies work entailed various workshops, attended by GCCIA, the consultant consortium and representatives from the operations team, as well as visits to European control centers. The reliability of GCCIA interconnection has been a great interest since the beginning of the project. To ensure the flexibility of the power transfer, high and new operational standard were implemented.

In order to address collective electricity needs and achieve higher reliability and sustainable transmission services of the GCCIA, a high level grid interconnection amongst the states members was seen beneficial. However, the difference in the operating frequencies between Saudi Arabia's 60 Hz system and its neighboring states (Kuwait, Qatar, Bahrain, UAE and Oman) which operate at 50Hz. Thus, an idea of having AC interconnection was fundamentally excluded. The solution came in installing HVDC back-to-back system (1,800MW) converter station to connect the two frequency systems. The HVDC station was constructed in

Saudi Arabia connecting GCCIA 400kV 50Hz Al-Fadhili substation to SEC 380kV 60Hz Al-Fadhili substation. To ensure reliability of the system, three poles were installed in the converter facility; each one would have the ability to transfer up to 600 MW, where the third one is placed in case of emergency mainly [8], [9].

C. Modes of Operation

The main objective of the control scheme in HVDC is to perform the following:

- To provide effective reserve power sharing between the electrical power systems of participating Member States.
- To be able to be transfer 1200MW between the 50Hz to 60Hz systems fast enough to stabilize the interconnected systems following a critical loss of generation within either system through "Dynamic Reserve Power Sharing" (DRPS), as this term is going to ber introduced shortly in this report.
- To permit up to 1200MW of economic active power transfer between the Member States.

In order to satisfy the objectives highlighted above, the GCCIA HVDC was designed for three modes of operations as follows:

- **Hot Standby Mode***:* the Poles are kept energized from the AC (50Hz and 60Hz) grid, and, not scheduled for any power transfer and not activated for Dynamic mode of emergency sharing.
- **Economic Transfer (ET) Mode:** under this mode of operations, up to 1200MW of active power transfers between two frequency systems can be scheduled and implemented.
- **Dynamic Reserve Power Sharing (DRPS) Mode:** this mode of operations has contributed to the fact that GCCIA is a unique project; in this mode, power transfer is activated to achieve dynamic stability in either the 50 or 60Hz systems. The DRPS system is being used for the first time in the world in the GCCIA Project.

The HVDC converter station established at Al Fadhili in Saudi Arabia was not only the biggest Back-to-Back station in the world (3×600MW), but also introduced a unique feature which permits the sharing of reserves between the 60Hz and 50Hz systems The planning studies that were carried out to satisfy the GCC need for the interconnection of the independent GCC grids were based on the need to provide mutual support in the event of loss of generation in one network, permitting sharing and effectively reduction of individual reserve levels without compromising reliability. This mainly required rapid and automatic response to loss of generation in any country and the ability to rapidly change the direction of power flow to provide the necessary system dynamic support, through innovative control strategies for automatic reserve sharing.

D. Load Shedding

Harmonization of under-frequency load shedding (UFLS) is concerned with the high imbalance in active power as a result of sudden loss of generation, leading to a drop in frequency. This frequency drop can be corrected by suitable automatic load-shedding schemes. All member states had such schemes in place, but the interconnection of separate power systems required a harmonization of the existing UFLS schemes and the definition of common rules to be followed by each member state. When different power systems are interconnected, the solidarity principle automatically becomes the rule: The load is shed not only in the area where the imbalance occurs but also in the interconnected systems. This harmonization is required to minimize the shed load and fairly share the contribution of each member state. Two rules were recommended for the UFLS harmonization of the GCC system:

- The first UFLS threshold for the 50-Hz side (Qatar, Bahrain and Kuwait) is 49.3Hz.
- The first UFLS threshold of the 60-Hz side (Saudi Arabia) is set to 59.2Hz to keep a similar frequency range for the primary frequency control on both sides of the HVDC connections.
- No more than 200MHz between two UFLS stages.

VI. Environmental Aspects

One of the main challenges that faced the project is the environmental nature of the gulf area. The main converting station is placed in the heart of the desert in a very hot, dry weather with ambient temperature exceeding 125F. Due to the fact that the temperature of the valves' active part (made from silicon) are required to have a temperature limits up to 90 ℃, the water-cooling plant required higher coolant flow rates than a standard HVDC link. Thus, the cooling pipe arrangement within the valve was changed to a parallel arrangement to increase the total flow rate into the converter. This leads to the construction of the largest cooling system for an HVDC project ever [9].

Since the converter facility would be prone to high level of external dust and sand storms, the valves were installed in an air-conditioned room with heavy filters to insure the quality of the air from such particles.

A. Impacts of the Environment on the Project Operation

Since 2009 and up to now, many incidents have been occurred due to the severe weather condition which released alarms that sometimes caused non availability of the poles.

- **Transformer fan failure, tap-changer out of step and invalid tap code:** the recurrence of the sandstorms in Saudi Arabia has resulted in usual occurrence of "Pole not ready" due to failure of fans, tap changer out of step, and invalid tap code caused by dust ingress into circuit contacts.
- **Cooling plant alarms:** extreme outdoor ambient temperatures in summer and winter causes alarms related to temperature of the Valve cooling system inlet and condensation temperature on thyristor valve cooling that lead to tripping of Pole in some cases. Many tests are being conducted in the

moment by the manufacturer in order overcome the problem.

- **Valve Hall Ac Disturbance:** Alarms often received related to dust causing failure of the HVAC in the Valve hall and other sensitive equipment.

VII. Potential Impacts on the Power Systems of the Region

A. Regional Interconnectivity

There are much great potential that can be emerged by the interconnection of GCCIA with many regional grids which would result in successful cooperation in the area of electricity trade [9, 10]. Such targeted interconnections are as follow:

1). The Interconnection of Saudi Arabia National Grids: not until recently, Saudi Arabia had four separate grids that are not connected as shown in Fig. 5 which were; the Western grid, the Central grid, Eastern grid, and the Southern grid, with the exception of the interconnection between the Central and Eastern grids via AC overhead lines. However, after several years of comprehensive studies, the work on the interconnection of the internal Saudi grids has been taking place effective. The implementation of HVDC lines is essential in the completion of such interconnection. A bipolar HVDC link will be connecting the Central operating area with both the Western then Southern operating areas. The completion of the interconnection is planned to be completed by 2017.

Figure 5. SEC's four grids before the interconnection

2). Makkah-Riyadh HVDC Link: this project comes as a part of the Saudi Electricity Company (SEC) plans to interconnect its four operating areas into one national grid. The main goal is to connect Riyadh's grid to Makkah via 800km-long ±500kV dc link between Bahra Station (Western Operating Area) and Dharma Station (Central Operating Area). The capacity of this HVDC line is expected to be over 3,000MW.

In late November 2012, a contract has been signed between SEC and the Middle Eastern unit of Italy-based Centro Elettrotecnico Sperimentale Italiano (CESI) to provide assistance in the implantation of the project. CESI has established cooperation with Tractable Engineering for further consultations on this project. The completion of this line will complete the construction of a unified national grid.

3). Saudi-Egyptian HVDC Interconnection: a preliminary feasibility study has been studied to evaluate the possibility of an interconnection between Saudi Arabia western region grid and Egypt national grid. The purpose of this interconnection is to provide both Egypt and Saudi Arabia to necessary flexibility to trade energy in a commercial manner and exploit the differences in the peak hours between the two countries. The project basically will include a bipolar +/- 500kV, 3,000MW multi-terminals lines that pass through Tabuk (Northeastern city in Saudi Arabia) to Egypt via Sinai. The connection will include also 25Km AC submarine between Badur substation (Eastern Egypt) to Madinah substation (Saudi Arabia). The project was targeted to be constructed in 2011; however, it had been delayed to the political condition of Egypt. This interconnection will have a direct connection with GCCIA after the completion of the interconnection of the Saudi internal grids.

4). Saudi-Yemen Interconnection: due to the economic and structural development of the Southern region of Saudi Arabia, several studies have been conducted in order to strengthen the Southern grid. As Yemen has been recognized with intensive natural gas reserve, it is planned that they would depend more on natural gas to generate electric power. Thus, a feasibility study was completed in 2007 to assess the viability of the interconnection of the two areas, and a conclusion has been reached that such connection would be very beneficial for both sides. This connection would be directly connected to GCCIA HVDC system after the integration of the internal Saudi grids.

B. Global Interconnectivity

The interconnection of GCCIA to other regional and global grids has been taken into consideration seriously since the early stages of the project. Two feasibility studies are being conducting nowadays to evaluate the viability of the interconnection to both EJILST grids that includes Egypt, Jordan, Iraq, Lebanon, Syria and Turkey, and the Arab-Maghreb grids (includes Libya, Tunisia, Algeria, and Morocco). In case of such connection is to be completed, GCCIA would have a direct path to the European grid through the HVDC link that connects Morocco with Spain. Fig. 6 shows the targeted interconnection to GCCIA grid.

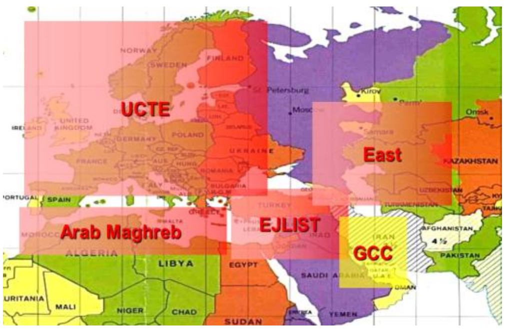

Figure 6. The potential global interconnection

C. Recommendation and Suggestions

The Gulf area is currently promising many renewable energy projects in the near future. For instance, Saudi Arabia has targeted to build concentrated solar systems, while UAE opened in 2009 the largest solar station in the world, Masdar City. Thus, we recommend that by integrating interconnection between these projects and GCCIA, a better and more reliable operation would result. Also the fiber optics system associated with Al-fadili stations is a very developed one, the largest for an HVDC system, thus we believe the telecommunication companies could ask for permission to use it which would allow benefits for the both sides.

VIII. CONCLUSION

The interconnections of the six members of the Arabian Gulf countries have been so far a very successful one and more than 250 loss-of-generation incidents have been resolved efficiently [11]. The idea of this project came before 30 years ago when multiple efforts had dreamed of having one interconnected network for all the gulf area countries. Yet after three feasibility studies, the project did not get the final approval until 20 years after the idea was firstly suggested. In this project, we tried to go cover all the aspects of GCCIA as a project in total. We started with a quick introduction on the project, followed by some extensive details on the physical characteristic and technical considerations that clearly illustrate the basic components of the project with the ratings of the equipment used. After that, we briefly discussed the economics of the project, which is mainly a governmental-paid, so that the participated utilities main job was to focus on other technical and operational issues, away from financial ones. The operation of the project have been clearly described along with the features that made GCCIA a unique project, such as the use of DRP control scheme for the first time in the world. In addition, some related topics to the project like defining the modes of operation, the load shedding followed in the project have been discussed for a better clarification of the nature of work. Proposed future plans of the project, which includes regional interconnection with Yemen, Egypt, would be completed successfully soon after the completion of the Saudi internal grid, which will give these countries a direct connection to GCCIA. Also, feasibility studies have been conducted to evaluate the benefits of a global interconnection between Europe and the mediterranian region [12]. The impacts that would result from implementing such large interconnection, which aim basicly to interconnect different continents, will be used hopefully to exploit the difference in peak load times and weather condition globally to reduce the overall power generation and to enhance the operation against the faults by taking the advantage of the capability of HVDC networks to operate more effecient against regular problems that face the Interconnected AC systems [13]. Finally, the paper concluded with suggestion and recommendation for this project based on some of what they had captured in this course. There is no doubts that GCCIA has been an effective project so far, and it have contributed sufficiently in the reliable, economic operation of the electric grid in the gulf area, which is known for having its load demand increasing significantly each year, and soon this project would be ready to play a major role in connecting both the western and eastern parts of the world, hopefully someday in the near future.

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