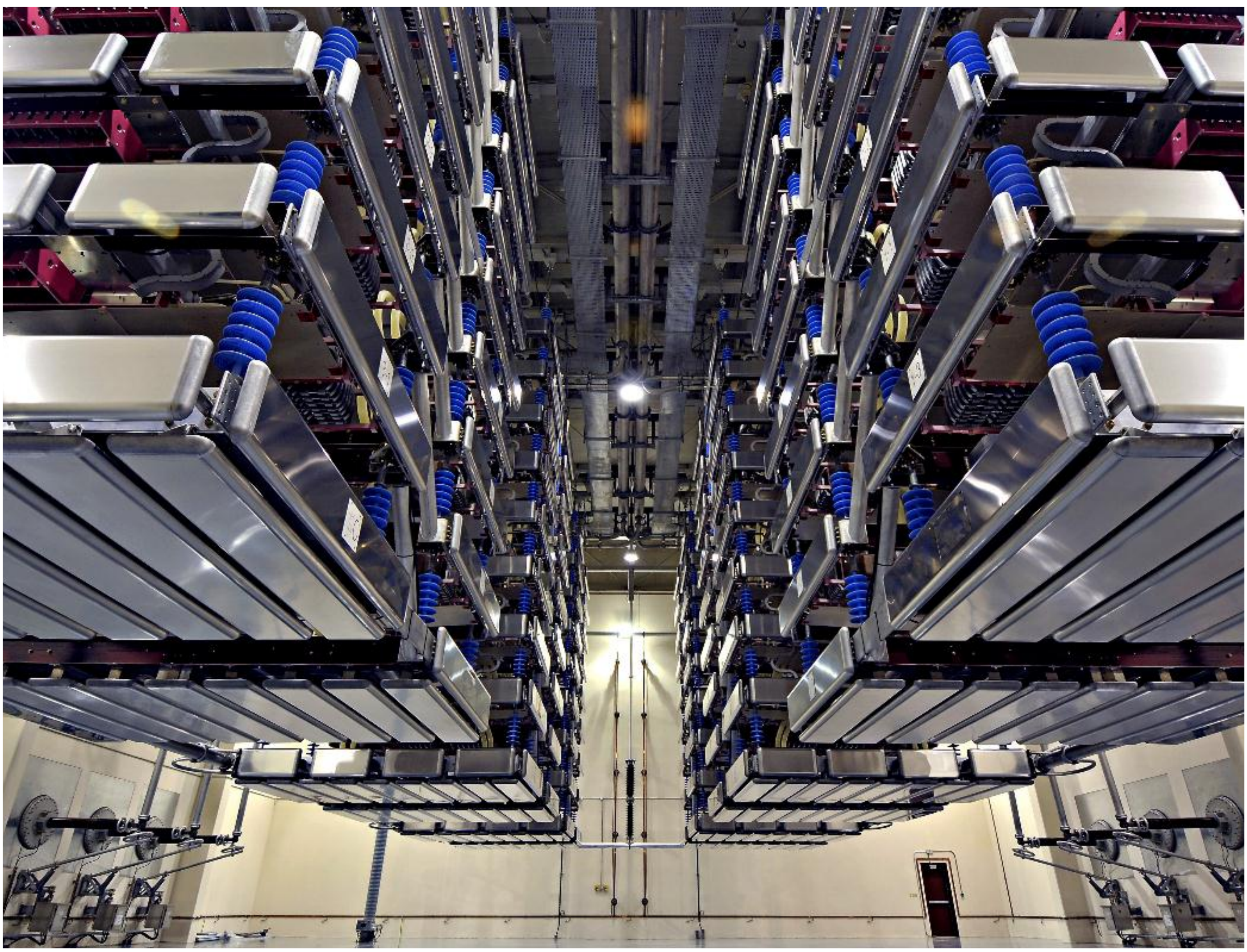
GE
Grid Solutions

GCCIA Phase 1
Making Interconnection in the Gulf a Reality

GE's interconnection of power grids between members of the Gulf States enables the sharing of electrical resources.



Imagination at work

Doha's substation in Qatar

Gulf Cooperation Council International Authority (GCCIA)

The GCCIA is an organisation formed in July 2001 with the primary objective to create an integrated and sustainable energy economy amongst the six Gulf States.

The aim is to create an interconnection of power grids between member states so that resources can be shared. The six countries include Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates.

The GCCIA Mission

To act in the interests of the people of the GCC Countries to provide reliable, competitive and sustainable transmission services.

Objectives of GCCIA

- 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 amongst the member states and strengthen collective electrical supply reliability.
- Deal with the existing companies and authorities in charge of the electricity sector in the member states and elsewhere in order to coordinate their operations and strengthen the efficiency of operation with due regard to the circumstances relating to each state.
- Apply modern technological developments in the field of electricity.

Panorama view of the Fadhili substation

Phase I
The GCC North Grid Challenge

Saudi Arabia runs its electricity transmission network at 380 kV, 60 Hz. The other five countries use 400 kV, 50 Hz. Based on the asynchronous nature of the states to be interconnected, the best solution was to add an High Voltage Direct Current (HVDC) interconnection. The Phase I system components linking the networks of Kuwait, Saudi Arabia, Bahrain and Qatar include:

- A double-circuit 400 kV, 50 Hz line from Al Zour (Kuwait) to Doha South (Qatar) via Ghunan (Saudi Arabia) with an intermediate connection at Al Fadhili (Saudi Arabia) and associated substations.
- A back-to-back HVDC interconnection to the Saudi Arabia 380 kV, 60 Hz system at Al Fadhili.
- A double-circuit 400 kV interconnection comprising overhead lines and submarine link from Ghunan to Al-Jasra (Bahrain) and associated substations.
- The control centre located at Ghunan is linked with each member country's national control centre and will ensure security, control interconnection access, perform frequency and interchange regulation, coordinate interconnection operation, and transaction recording and billing.

The Interconnection Project

The GCC interconnection grid has been planned in three phases:

Phase I	Phase II	Phase III
The GCC North Grid System interconnects Kuwait, Saudi Arabia, Bahrain and Qatar.	The GCC South Grid System will interconnect the independent UAE and Oman systems. (GCCIA is not involved in the Phase II execution).	Interconnecting the North and South GCC Grids, completing the shared energy connection between the six Gulf States.

Solving the Interconnection Challenge

The challenges presented by the interconnection of the GCC networks were ideally suited to the application of a High Voltage Direct Current (HVDC) scheme. Direct Current (DC) connection and transmission is used when Alternating Current (AC) transmission is not economical due to the distance, or impossible due to asynchronous frequencies.

As Saudi Arabia's network operates at 60 Hz and its Gulf neighbors are at 50 Hz, asynchronous AC interconnection was impossible. The only solution was to introduce HVDC into the grid.

The GE solution involved the creation of a 1,800 MW HVDC back-to-back link configured as three separate 600 MW substations. All three substations were built at the same location and constructed simultaneously. Each substation can operate autonomously or in a coordinated manner. This 3-pole HVDC converter interconnection substation is located next to Saudi Electric Company's existing Al Fadhili 380 kV AC substation.

One of the main functions of HVDC is to constantly look for the occurrence of a power generation loss in the interconnected networks. When a loss of generation is detected, the HVDC link injects power into the system and, through the use of frequency control, restores the system to normal conditions.

GE's Expertise From Evaluation to Operation

- Network feasibility studies
- Design and engineering
- Turnkey project management
- Energy Management Systems
- Market Management Systems
- HVDC and FACTS schemes
- Telecommunications
- Substation power electronics based on thyristor valves of up to 150 mm, 8.5 kV thyristors
- Installation, commissioning and testing
- Training and maintenance

Key Benefits

- By linking the asynchronous networks in the Gulf region, generation requirements are reduced in each system due to the ability to share spinning reserves
- The exchange of energy between member states will reduce costs for each country
- HVDC enables greater control; transmitted power can be "dialed up" and even modulated in response to inter-area power oscillations
- Increased system reliability, especially under emergency conditions
- HVDC functions as a fault "firewall". Faults cannot propagate in an HVDC network or in an AC network with HVDC interconnections.

GE's Grid Automation Solution End-to-End Innovation

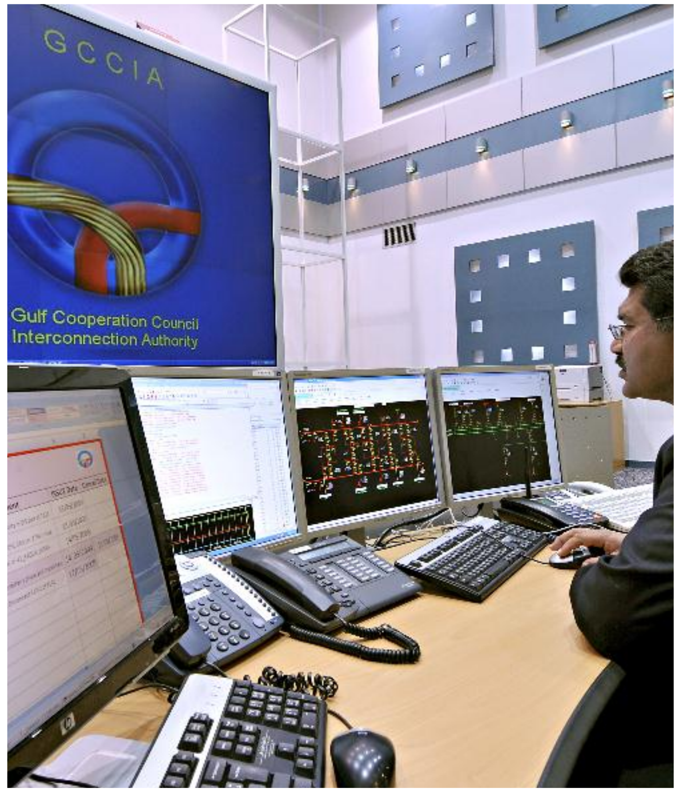
GE supplied the integrated energy management, control and protection system for the entire GCCIA network. This system included the construction of the building which hosts the load dispatch and control centre and the interconnection to the national utilities in each country.

The Energy Management System is based on GE's industry leading **e-terra**suite of products and applications including **e-terra***transmission* and **e-terra***generation*.

GE was responsible for the creation of the control and protection systems for the entire GCCIA substations network. All the available communications features were implemented and proven to work in a 400 kV transmission substation. GE provided MiCOM IEDs and substation automation solutions.

The GE configuration software, PACiS SCE , was the first commercially available IEC 61850 configuration tool. A telecommunication system was deployed connecting the GCCIA control centre to the substations and utilities' national control centres, designed to carry time-critical security services such as protection signals through DIP5000 equipment and IP-oriented data communications.

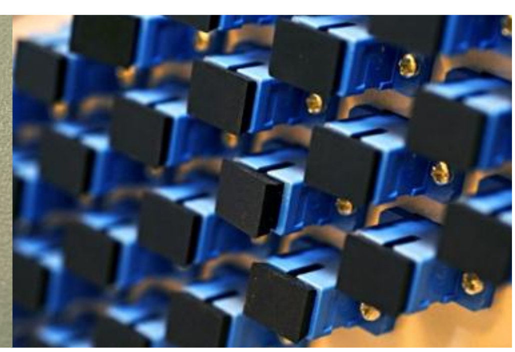
Due to many years of experience, GE took the leadership role in the GCCIA project team to ensure the project's success. Today, GCCIA has the most cost-effective transmission protection and control design in the Gulf area.



Environmental Challenges

The Gulf environment, which is very hot, dry and dusty, presented a specific challenge for the project. The converter substation is located in the desert, yet the valve hall requires high air quality for the HVDC thyristor valves. The valve hall air-conditioning is a closed circuit. Top-up air is heavily filtered before use and valve hall air pressure is maintained slightly positive to prevent the ingress of contaminants during the frequent sand storms.

The cooling equipment is the largest ever constructed for an HVDC installation due to the +55° C ambient temperature and the absence of fresh water for cooling. Parallel cooling for the thyristor valves is necessary to maintain temperature limits.



Efficient, Stable, Fully Redundant End-to-End Automation Solution

To effectively manage an interconnected network, a specific Energy Management System (EMS) is required, located in the Interconnection Control Centre (ICC), coordinating the seven dedicated GCCIA electrical substations and each GCCIA member country's control system.

A fully redundant and dedicated telecommunication system interconnects all the sites.

Each substation is managed through digital control systems to which are associated the relevant protections:

- Monitor and control of energy flows
- Dynamic reserve power sharing (spinning reserves)
- Trading support
- Energy accounting data for accurate billing between member countries

Digital Control and Protection Solution

The substation automation solution chosen by GCCIA is based on the mature IEC 61850 Ethernet PACiS and MiCOM IEDs. The requested high availability is ensured by a full redundancy at all substation levels including the gateways to the GCCIA SCA DA centre and emergency centre and the local control HMI PACiS OI.

All MiCOM bay computer C264 and Px40 protections (including the P740 distributed busbar protection) are directly connected on the IEC 61850 Ethernet network and work independently of each other.

Directly available in each substation, engineering workstation allows maintenance operators to adjust any parameters on-line and perform all postmortem analysis.

GE's Automation experts designed and engineered the system. The cubicle design, assembly, installation and commissioning had been carried out by GE's Dubai-based team. Competent and efficient project execution, combined with a close cooperation with all GCCIA involved contractors, has ensured on-time energization of the different North Grid System substations.

The PACiS & MiCOM solution ensures:

- Fully secured electrical network protection and control
- Redundant hot-standby communication to the SCADA
- Accurate and permanent monitoring of primary substation elements
- Detailed disturbance recording and analysis

Ghunan Control Centre - The Brain of the GCCIA Network

Situated 60 km in the middle of the desert, the control centre manages not only the energy trading and distribution between all the new GCC interconnected networks, but it is also the central communications centre for all existing network management systems in the six member countries.

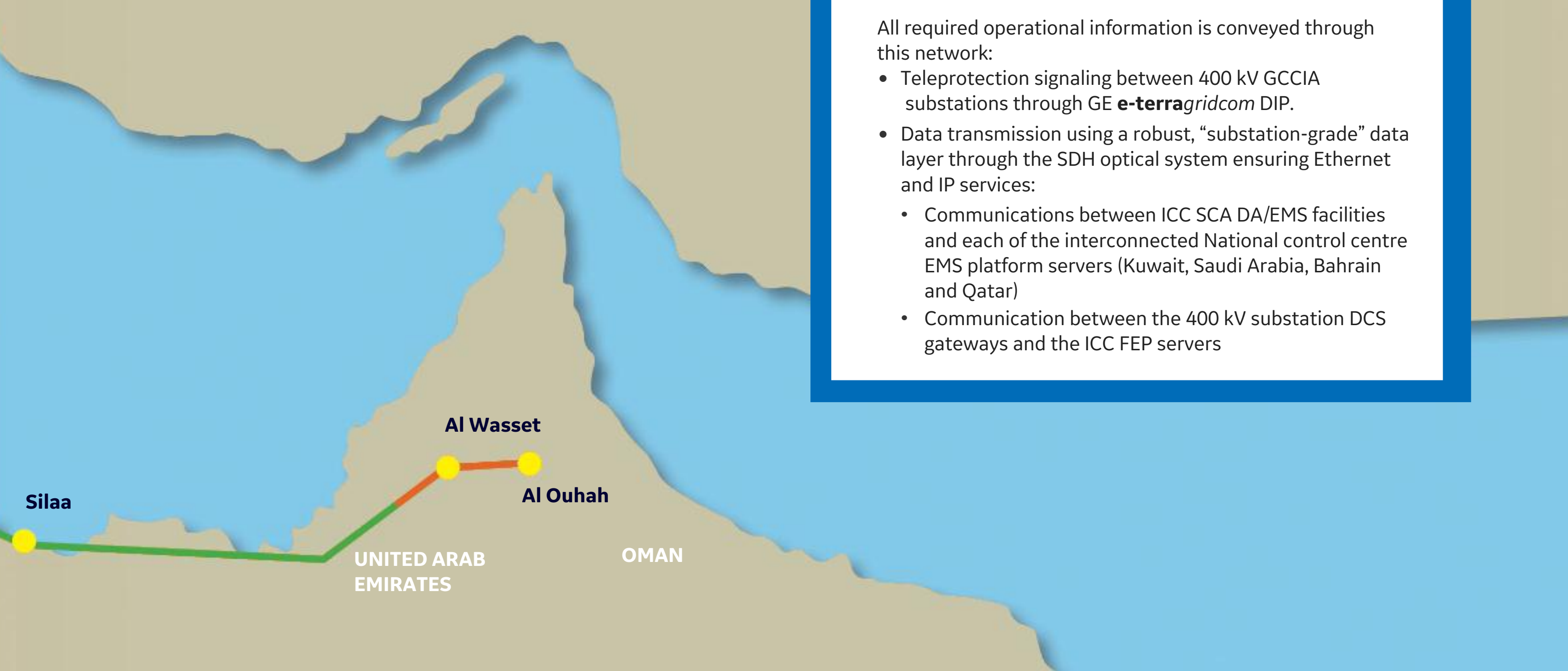
Telecommunication Solution

The telecommunication solution is based on a redundant transmission network:

- A core optical network using GE's SDH STM-4 (622 Mbps – upgradeable up to STM-16 2.5 Gbps) multiplexing equipment and optical amplifiers to cover long span links. The network is supervised through GE's NMS 5000 management platform and based on GE e-terra*gridcom* MSE 5010 SDH equipment.
- Back-up solution using digital power line carrier **e-terra***gridcom* T390.

All required operational information is conveyed through this network:

- Teleprotection signaling between 400 kV GCCIA substations through GE **e-terra***gridcom* DIP.
- Data transmission using a robust, "substation-grade" data layer through the SDH optical system ensuring Ethernet and IP services:
  - Communications between ICC SCA DA/EMS facilities and each of the interconnected National control centre EMS platform servers (Kuwait, Saudi Arabia, Bahrain and Qatar)
  - Communication between the 400 kV substation DCS gateways and the ICC FEP servers



Energy Management System

GE is a world leader in Energy Management Systems (EMS). The EMS suite of applications from our most recent **e-terra** platform product was deployed to coordinate the six member countries' power systems. Network security is managed by **e-terra**transmission and power management is managed by **e-terra***generation*.

The **e-terra** platform provides the following services to GCCIA:

- Load forecasting,
- Dynamic reserve monitoring,
- Interchange monitoring,
- Frequency regulation though a coordinated hierarchical AGC,
- Control of the HVDC link between Saudi Arabia (60 Hz) and the other states operating at 50 Hz.

HVDC Converter Transformers (1)

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:

- **1off 385.3 MVA, 380/97 kV, 60 Hz, Star/Star**
- **1off 385.3 MVA, 380/97 kV, 60 Hz, Star/Delta**
- **1off 380 MVA, 400/96 kV, 50 Hz, Star/Star**
- **1off 380 MVA, 400/96 kV, 50 Hz, Star/Delta**

HVDC transformers have to satisfy all HVAC requirements including special considerations relating to both high currents and high voltages. HVDC schemes are less common than HVAC ones and hence the specific HVDC technology must be carefully maintained.

The construction of HVDC converter transformers poses severe manufacturing challenges in terms of tight impedance control, AC and DC dielectric stresses and non-sinusoidal load current duty.

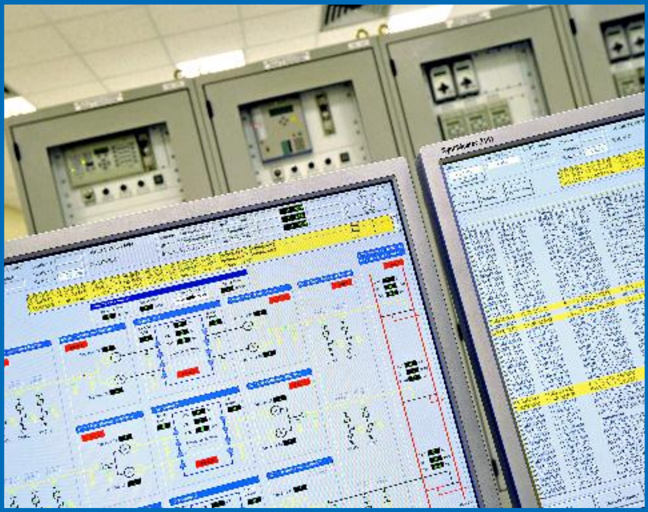
HVDC Control and Protection (2)

Each converter pole has a duplicated GE series V converter control and protection system to give the necessary power transfer control and provide protection to the converters and DC circuits.

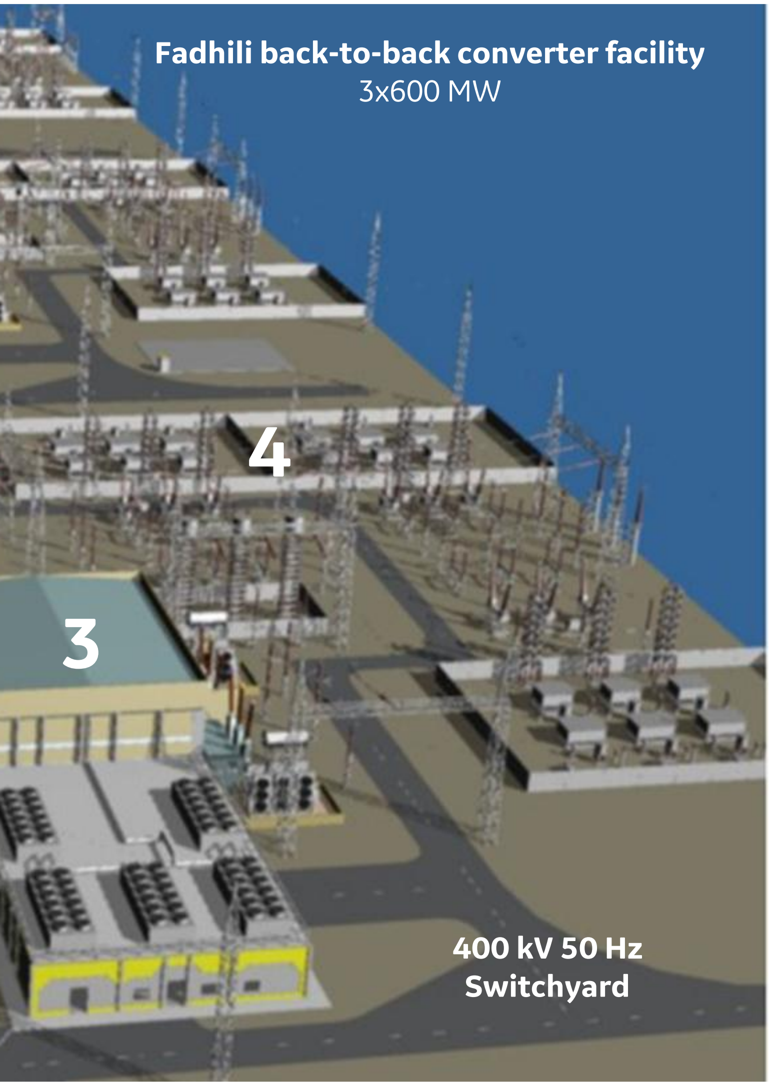
An overall duplicated series V master control with an integrated Human Machine Interface (HMI) allocates the required power to each of the poles and in addition interfaces to the GCCIA Interconnector Control Centre (ICC).

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, busbars and power cables. A transient fault recorder system is also provided.



Fadhili HVDC Substation



Switchyard (4)

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 GCCIA project, these filters are switched automatically using GE dead-tank circuit breakers, disconnectors 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.

Valve Hall (3)

At the heart of the converter substation are H400 series valves using 8.5 kV, 125 mm thyristors. The very high ambient temperature (up to 55°C) 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 90°C, the water-cooling plant required higher coolant flow rates than a standard HVDC link. The cooling pipe arrangement within the valve was changed to a parallel arrangement to increase the total flow rate into the converter. This required the largest water-cooling plant ever built for an HVDC installation.

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 purpose-built "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.

Facts & Figures

3,800,000 Hours of erection, testing and commissioning with no injuries

900 Construction and installation crew members

60 Testing and commissioning engineers and experts

9,500 Tons / 26,000 m^3
of equipment expedited from GE or supplier production sites around the globe.

Project Teams

To attain high quality turnkey project delivery objectives within 36 months, GE has created dedicated project teams.

Automation Project Management Team

The team was based in Al Khobar (Saudi Arabia) close to GCCIA and managed remote teams in Kuwait, Bahrain, Qatar and Dubai composed of GE locally based technical experts and engineers.

The team was supported by Automation Centres of Excellence in France (Massy, Energy Management Solutions and telecommunication solutions and Lattes, protection and control solutions) where dedicated teams of senior experts were also present on site to secure seamless project roll-out and the successive energization and go-live interconnection phases.

3 HVDC Dedicated Project Management Teams

They were created in France, UK and Saudi Arabia under supervision of the project direction mainly based in Paris.

Project direction was successively in the UK in the design stage and in Saudi Arabia in the site testing stage.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Imagination at work