Optimising the power system at Qatalum

Qatalum is Qatar's first aluminium smelter and started production in 2009. It was also the first smelter world wide ordering an AC/DC conversion substation able to be operated at 1750VDC. The rectiformer substations were handed over, for commercial use, to Qatalum in September and October 2009.

The rectiformer substation for Qatalum's pot line 1&2 was awarded on an Engineering, Procurement Construction (EPC) base to ABB Switzerland in June 2007. As engineering and management resources have been drying out for some time now, the traditional piece-meal project approach has been replaced by a larger package in integrated EPC solutions.

As power requirements in new smelters have reached more than 500MW per pot line, an optimised overall power system concept is important. The overall coordinated system approach eliminates cost overruns and guarantees on time delivery as well as the best technical solution.

When phase one of Qatalum is in operation, more than 1000MW need to be controlled and converted to DC power for efficient smelter operation.

At Qatalum, the power plant and the rectiformer station are two different EPC packages as the 220kV Gas Insulated Switchgear (GIS) is within the power plant scope and the 1500m 220kV cable runs are in the rectiformer substation package.

As the power plant EPC contractor has awarded the 220kV GIS with its latest control and protection system based on IEC61850 to ABB Switzerland, the substation integration and interface coordination was simplified and the overall system approach guaranteed.

Rectiformer bay

Traditionally the rectiformer units are arranged in line with the pot room front for efficient connection of the substation to the pot rooms. With the larger foot print required, as the unit rating has reached up to 200MVA in size, it was necessary to select a new arrangement with the rectiformers facing each other. This arrangement required an in-depth study of the forces applied to the DC collector bus bar as well as the effect of having different length of bus bars between the rectiformer and the pot room. After the rectiformer bays are installed and commissioned they were tested during the pre operation verification (POV), which also included the deluge fire fighting system.

EPC package scope

The rectiformer substation scope consisted of the following turnkey delivers:

Fig 1 Rectiformer Substation

Fig 2 Rectiformer bay during fire fighting system testing

Fig 3 220kV Cable Connection to the Regulation Transformer

- Overall system design, studies and performance calculations;
- 220kV cable runs and termination to the GIS and the transformers;
- 1750VDC/85kA Rectiformers;
- DC collector bus bar design, supply and installation;
- 70Mvar harmonic current filters operated of the regulation transformer tertiary winding. Each filter can be energised via a synchronised 33kV breaker;
- SCADA system;
- 33/0.4kV distribution for the substation;
- Fire detection and deluge system for the entire substation;
- Detailed civil works design and supervision;
- Interface to the 220kV GIS which ABB Switzerland supplied to the power plant PC package; and
- Substation controls and protection with the new IEC61850 protocol

Overall system integration and interface coordination with the other EPC package suppliers were major tasks on this project.

220kV cable installation

The cable routing to the two pot lines needed to be interfaced with several EPC package suppliers and needed to be integrated into the overall road concept. Cable-road crossing points needed to be put in place and cables laid into the ground well before other activities could start. With 10 feeders and an average cable length of 1500m the excavation of the cable trench alone was approx. 35 000m^3.

Fig 4 ABB's ELK-14, 300KV GIS

Fig 5 ABB FOCS installed at Qatalum

Fig 6 2000VDC Rectifier Design

220kV gas insulated switchgear

With the location of the power plant and the smelter within a close area it was possible to have a single GIS for the power plant and the smelter. The GIS on the one side directly connected the generator step up transformers and on the other side to the rectiformers. The interfacing of the GIS controls and protection is normally a very demanding task for the EPCM's engineers, ending up in a long lasting painful exercise. At Qatalum the GIS controls and protection as well as the rectifier control system was supplied by ABB Switzerland allowing a seamless interface.

DC measurement system

The fiber-optic current sensor – a simple loop of optical fiber around the bus bar – replaces the sophisticated head of the conventional DC current sensing system. The sensor integrates the magnetic field along the closed path described by the sensing fiber. As a result, the signal is independent of the particular magnetic field distribution and only determined by the enclosed current. All magnetic fields outside the fiber loop are of no influence. Sensor placement is therefore uncritical. The simplicity of the system reduces the time required for installation and commissioning to a few hours.

The sensor makes use of the Faraday effect in the fiber. The Faraday effect is the phenomenon that in a medium such as glass right and left circularly polarized light waves travel at different speeds if a magnetic field is applied along the propagation direction.

ABB's fiber-optic current sensor (FOCS) is a major progress in the technology of high current dc measurement in the electro-chemical industry. Besides its unprecedented performance it opens up new data acquisition capabilities for high dc current process lines. The installation of the FOCS allows retrofitting this new measuring system to already existing plants with little restrictions on where to place the measuring heads.

Rectifier design

After reaching 1650VDC at Sohar Aluminium, Qatalum specified 1750VDC as maximal smelter operation voltage. After conducting detailed rectifier design studies and type tests on ABB's standard rectifier design used for many years, only minimal alterations were required to make the design suitable for this HV DC application. The Qatalum rectifier frame design is made for 2000VDC with semiconductors and fuses fit for 1750VDC.

Fig 7 Rectiformer control system

Fig 8 Auxiliary power transformer

Rectiformer control system

The rectiformer station consists of five units with the possibility to add a sixth at a later stage. The rectiformer units can be controlled from the central control room via the System Control and Data Acquisition (SCADA)) system or from the master controller. The master controller as well as the SCADA system has been linked via fiber optic cable to the power plant for load control. This interconnection is required in particular during island operation as the power plant will not be connected to the Qatari utility grid.

Auxiliary power distribution

The rectiformer station has it own auxiliary power distribution which is fed from the smelter 33kV main distribution switch gear. Two redundant auxiliary power transformers are installed at the rectiformer station. The location was selected so that the redundant 400VAC cable runs are as short as possible and placed in such a way that they are not affected should a fault occur in one circuit.

The MNS low voltage switchgear system was designed and built to be the heart of any modern, highly automated motor control or power distribution system. The consistent application of the modular principle both in electrical and mechanical design as well as the use of standardised components allows its flexible and compact design. Depending on customer requirements, operating and environmental conditions at different designs levels are available.

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Power quality system

By going above 500MW per single pot line, power quality has become a demanding issue. Many different operation scenarios need to be covered to allow the smelter operation with no restrictions at the highest possible power quality. Power factor control and minimal harmonic current distortion are the two major parameters to be addressed. At Qatalum, the power quality targets have been set very high amongst the industry level – the highest world wide. These power quality levels can only be met by an overall system approach. For example: selecting a suitable transformer design and specific tolerances as such that the

Fig 9 400 VAC MNS Low Voltage Switchgear

Fig 10 33kV harmonic current filter

Fig 11 DC Collector Bus bar Installed at Qatalum

rectiformer and power quality equipment fit perfect together. A team consisting of a transformer, rectifier and harmonic currents filter expert simulated the power grid with the different operation points as well as the pot line operation behaviour and then selected the suitable parameters for the power quality system.

DC collector bus bar design

The DC collector bus bar and supports need to withstand forces created by a possible short circuit located anywhere on the bus system.

To calculate these forces the maximum short circuit current is calculated by means of simulations with different models. The overall system parameters and fault duration as well as the possible arc voltage are calculated and then used in the simulation software tool.

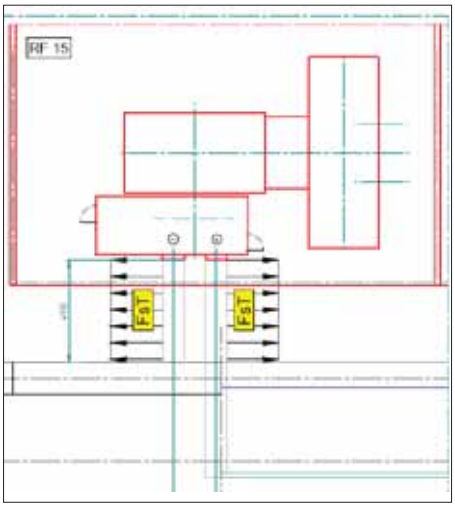

Fig 12 Rectiformer bus bar force calculation

The calculated currents are used to simulate the forces in respect to the bus bar arrangement. The forces in turn will be used to locate the supports and specify the bus bar support design.

Qatar's first smelter has set in many areas the most modern rectiformer substation bench marks in respect of a seamless interface between ABB electrification in the power plant and the EPC substation package. Environmental and power quality levels will be a new benchmark for smelters around the world. ■

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