STATCOM FOR GRID CODE COMPLIANCE OF A STEEL PLANT CONNECTION

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ABSTRACT

A recently commissioned steel plant in China comprises a very large electric arc furnace (EAF) for scrap based stainless steel production, fed from a local 220 kV grid.
*To fulfill the Grid Code, a STATCOM**) *was installed and commissioned in parallel with the EAF. The primary task of the STATCOM is to suppress voltage flicker to acceptable levels, but also to yield a high and constant power factor, as well as limit harmonic distortion and negative phase sequence components generated by the EAF.*
The paper elaborates on this application, giving some salient design features of the STATCOM as well as highlighting some key results of the implementation of the device for the given purpose.
Additionally, for the first time, a STATCOM based compensator has been modeled in an RTDS, Real-Time Digital Simulator.

INTRODUCTION

A newly commissioned steel plant in China comprises a very large electric arc furnace (EAF) for scrap based stainless steel production. Due to insufficient fault level of the 220 kV feeding grid, the plant cannot be started without corrective measures to ensure that the Grid Code is fulfilled with the EAF in operation. What is of concern is the maintaining of power quality in the grid.
To ensure sufficient power quality with the EAF in operation, a STATCOM*) was installed and commissioned in parallel with the EAF. The primary task of the STATCOM is to suppress voltage flicker to acceptable levels, but also to yield a high and constant power factor, as well as limit harmonic distortion and negative phase sequence components generated by the EAF.
Initially, a traditional SVC, i.e. an SVC based on thyristor control of shunt reactive devices, was considered for the task. It was found, however, that the flicker damping capability of such a device was insufficient for the purpose at hand, and a STATCOM, a device more potent for the purpose, was decided on instead.

The EAF is rated at 35 kV, 140 MVA, which makes it a very large installation of its kind in the world. The STATCOM is rated at 35 kV, 0-164 Mvar capacitive, continuosly variable, this also a very large installation.
The STATCOM (Figure 1) is based on a voltage source converter (VSC), built up of IGBTs (insulated gate bipolar transistors). A single converter is utilised, thereby avoiding all paralleling of devices. The converter is directly connected to the 35 kV EAF bus, without any need for a step-down transformer or other complex magnetic interfaces. As DC link, dry type, high voltage DC capacitors are utilized. This all ensures a simple and compact build-up. The STATCOM control scheme is based on pulse-width modulation (PWM), thereby ensuring minimum need for harmonic filtering.

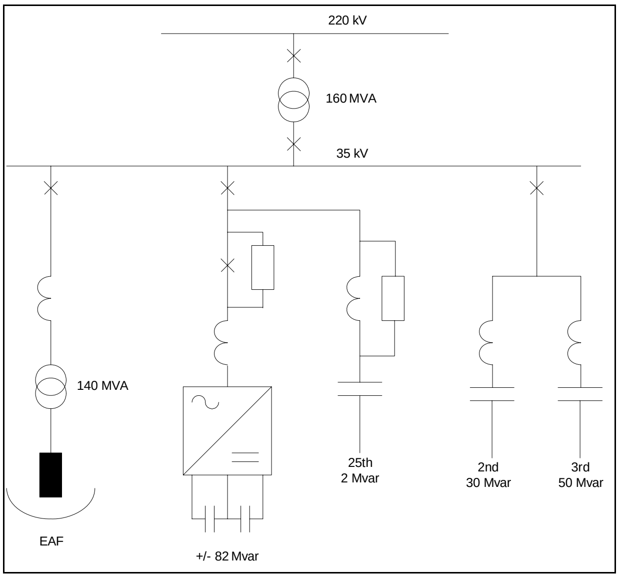

Fig. 1: Single line diagram, STATCOM and EAF.

RTDS

Developments in real time digital simulation technology have now made it possible to execute the demanding real time simulation of multi-level VSC converters with PWM switching frequencies in the order of 1.5 kHz. In the present case, a state of the art Real Time Digital Simulator (RTDS®) has been utilized to easily and conveniently

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*) Also known as SVC Light®

demonstrate the flicker improvement factor provided by the actual VSC controls under realistic system conditions.

SOME SALIENT DESIGN FEATURES

Voltage source converter

The central device of the SVC Light is the IGBT based VSC. In the present project the VSC rating is +/-82 Mvar and is realized with a converter directly connected to the industrial bus of 35 kV. To handle the voltage, the ABB semiconductors are series connected to reach an adequate total voltage rating. Each IGBT and diode component is built up in a modular housing comprising a number of submodules (in this project six), each containing a number of semiconductor chips (Figure 2). To provide mechanically robust series connection and to limit requirements on flatness tolerances, each of the submodules is equipped with a system of spring assemblies for each individual chip. Also the housing frame is part of the force absorbing system [1].

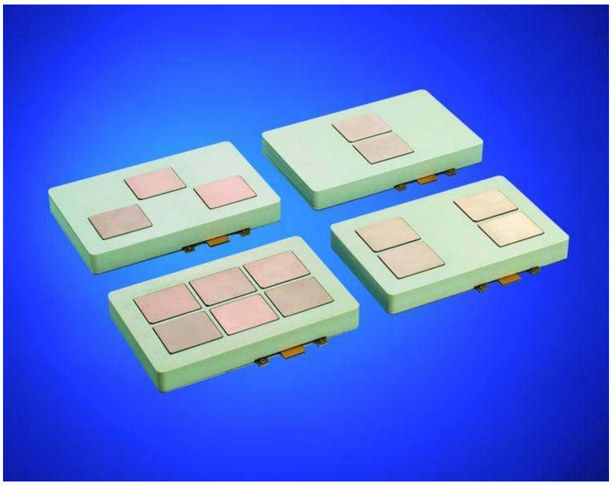

Fig. 2: StakPak™ press-pack IGBTs using 2, 3, 4 and 6 sub-modules for different current handling capacity.

Valve assembly

Water cooling is utilized by deionised water for the IGBT valves, giving a compact converter design and high current handling capacity. A compact design also reduces the loop inductance between the IGBT valves and the DC capacitors, which is beneficial from a loss point of view (Figure 3). IGBTs capable of handling close to 2000 A RMS are a reality today.

Fig. 3: Converter valve assembly.

DC capacitors

The DC capacitors are of compact, high voltage dry type design, particularly suitable for the application (Figure 4). By use of metallised film, insulated by means of polymers instead of impregnated materials, the capacitor gets a dry design, making it environmentally very friendly. In manufacturing, it requires neither impregnating fluids nor the use of paint solubles. It has high energy density, which together with its cylindrical shape enables very compact build-up of capacitor banks utilized in the VSC scheme.

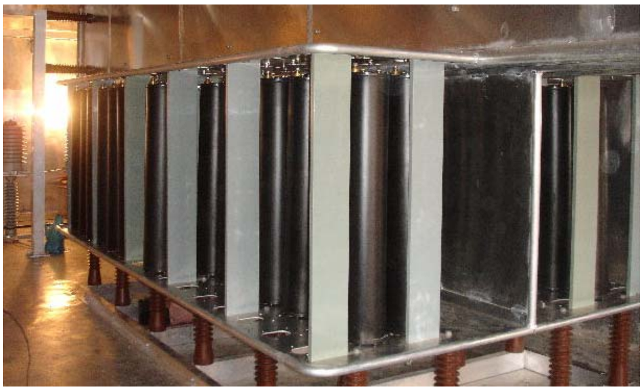

Fig. 4: DC capacitors for SVC Light.

Site views

A site view of the SVC Light is given in Figure 5. The concrete building closest to the camera is housing the VSC with IGBT stacks, cooling system, DC capacitors and control system. The tall building behind is the meltshop.

Fig. 5: Site view of the SVC Light.

In the roofed structure to the right, phase reactors, charging resistors and harmonic filters are located. A close-up is displayed in Figure 6.

Fig. 6: Harmonic filters.

SITE TESTS

After commissioning was finalized, measurements were undertaken to verify the performance requirements. Several parameters like voltage and current harmonics, power factor, voltage unbalance, voltage fluctuations and flicker level were to be evaluated against their respective specified limits. The results were satisfying in all aspects. In the following, some of the parameters specifically connected to the SVC Light performance will be treated more in detail.

Power factor improvement

The power factor of the load, i.e. the EAF and the SVC Light, was continuously above 0.995 or practically one, meaning almost 100 % complete reactive power compensation of the rapidly fluctuating load, and well above the contractual requirement of 0.95. This illustrates the benefit of a compensator with a rapid response. Figure 7 shows the power factor during one basket with a duration of about 20 minutes for both the EAF load alone as well as for the combination of EAF and SVC Light.

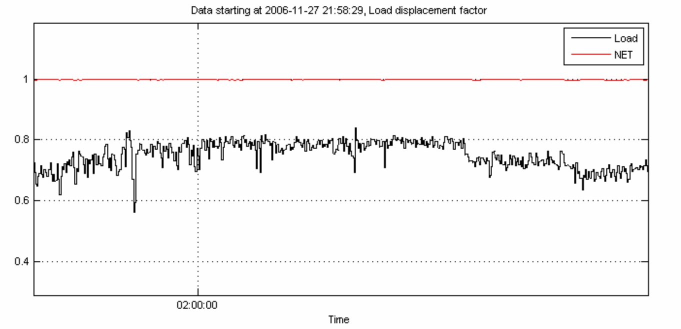

Fig. 7: Power factor improvement:
P.F. for the EAF alone (lower curve)
and for the EAF plus the SVC Light
(upper curve).

Flicker mitigation

Concerning flicker, data was captured for EAF operation both with and without SVC Light compensation as well as for background levels. From the data analysis, it turned out that the EAF while compensated by the SVC Light was not possible to detect above the background flicker. Figure 8 shows Pst data obtained from the whole measurement period. In the beginning, both the EAF and SVC Light are in operation. In the middle part of the plot, the EAF is operated stand-alone with increased flicker levels as a consequence. Finally, the last part of the plot covers the period for background flicker measurements.

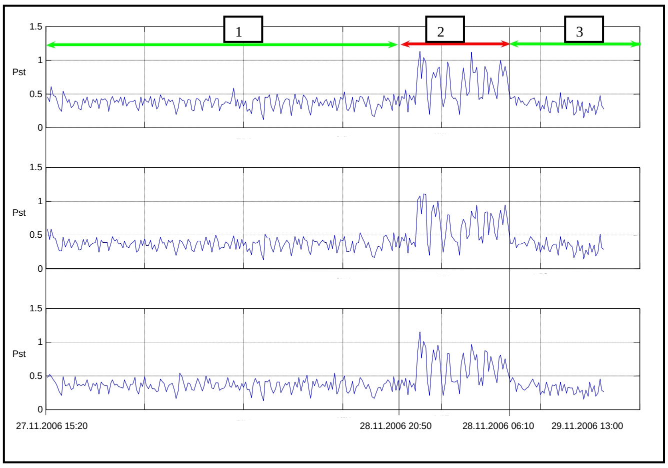

Fig. 8: Pst values from the test period.

As the flicker contribution from the EAF with the SVC Light in operation is below the background levels, the absolute Pst values cannot be used directly to determine the flicker mitigation efficiency. As an alternative, the indirect method is instead used [2]. In short, the method allows the whole process to be in operation while measuring the EAF current. Through a model of the step-down transformer, a virtual primary voltage is calculated as it would have been if only the EAF had been in operation. This voltage is then analyzed with the same algorithm as in a flicker meter and Pst values are obtained. With data from the same time, the flicker from the actual EAF operation with the compensator in operation is determined. By dividing the former flicker values with the latter, a value of the flicker reduction factor can be obtained. Figure 9 shows results from a typical 20 h period of EAF operation.

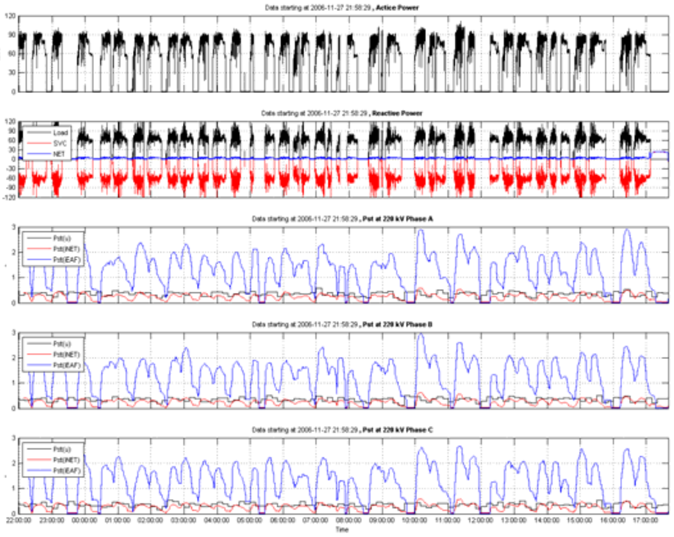

Fig. 9: Measurement data. For details, see text.

The first subplot shows the active power of the EAF. Subplot two shows the reactive power of the load (top curve) and the compensator (bottom curve). The middle curve, around zero Mvar, illustrates the efficiency of the compensator. Subplots three to five show the Pst values in the three phases. Each subplot shows the calculated Pst value obtained from only the EAF current as the large curve. The two lower curves originate from both the measurements (1 min-values) and from a commercial Pst meter (10 min-values) used for reference. The difference between the two latter curves is due to the different analysis period.

Using the data as above and calculating the improvement factor of the 95 % values results in an improvement factor between 5.3 and 5.5. This is in line with previous similar installations [3].

OPERATIONAL EXPERIENCE

In Figure 10, a melting cycle is shown, with SVC Light, and without SVC Light, and with the tap changer positions of the furnace transformer the same in both cases. It is clearly seen that the EAF bus voltage is improved with the SVC Light in operation. It is also seen that the full energy in the furnace is reached faster with the SVC Light in operation than without it. And likewise, the melting cycle is completed faster with SVC Light than without SVC Light. The time gain in the melting cycle indicates a more efficient melting procedure, which carries in it a potential for productivity improvements.

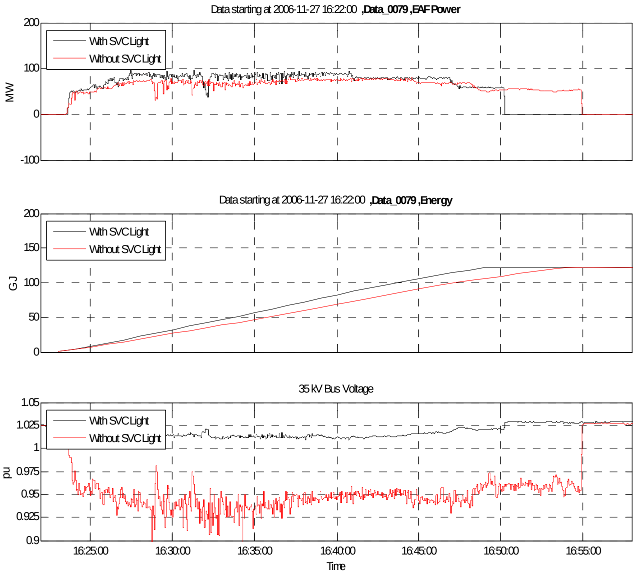

Fig. 10 (From top to bottom): Active power in the EAF; Energy developed in the EAF; EAF bus voltage.

CONCLUSION

A STATCOM has been commissioned at a steel plant in China. The purpose of the STATCOM (also known as SVC Light®) is to mitigate flicker emanating from the operation of a very large electric arc furnace. The task of limiting the flicker level to stipulated values at the 220 kV point of common coupling has been fulfilled, with the SVC Light yielding a flicker improvement factor of better than five.

Also, the power factor has been improved, and is very close to unity. Furthermore, requirements on harmonic limitation as well as on decreasing the unbalance between phases in the three-phase feeding grid have been fulfilled.

More efficient utilization of the EAF due to the SVC Light offers possibilities for productivity improvements.

Additionally, for the first time, a STATCOM has been modeled in an RTDS, Real-Time Digital Simulator.

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