An ABB SVC Light® rated at 13.2 kV, 0-64 Mvar (capacitive) has been installed at the Gerdau plant in Charlotte, N.C., USA operating an electric arc furnace (EAF) with continuous charging for scrap-based steel production. The EAF, rated at 30/33 MVA, as well as a ladle furnace (LF) rated at 18 MVA are taking their power from a 100 kV supply grid. The fast control of SVC Light will improve the power quality and particularly reduce the flicker levels generated. As a valuable by-product, improved productivity and decreased specific operating costs of the EAF can be attained. SVC Light is extremely well tested, with close to 15 years of track record as a flicker compensator.

The case
For many years, Gerdau in Charlotte has been operating an EAF of continuous scrap charging type in their industrial process. In this type of furnace, the cold scrap is fed into the side of the furnace from a conveyor system where it is immersed into liquid steel, with continuous melting taking place (Fig. 1). However, during recent years the surroundings of the steel plant have been developed into both a business and a residential area. Due to this the power utility has set up more strict requirements on mitigation of flicker. For the EAF operated with continuous scrap charging, the highest flicker peaks occur during the initial period when the EAF is started with cold scrap charged into a cold furnace, referred to as top charge. During that time, unless remedied, particularly annoying flicker can be expected.

Previously, the steel plant ran a conventional SVC, based on thyristor control. The main purpose of that compensator was to stabilize the AC bus voltage during EAF operation and keep up the steel production, but also to provide flicker mitigation. From a flicker point of view, however, the performance of a conventional SVC was no longer sufficient to meet the new requirements.
The EAF is fed from a double 100 kV sub-transmission circuit. Various scenarios for improved flicker mitigation were considered, such as re-conductoring the existing 100 kV lines, building a dedicated 3rd 100 kV line to the plant, or replacing the existing SVC with a STATCOM, a faster, more powerful flicker mitigating device than a conventional SVC. As a result, it was decided to dismantle the existing SVC and install a STATCOM instead, which was found to be the most attractive solution. ABB’s trade name for STATCOM is SVC Light, based on a three-level voltage source converter (VSC) design, utilizing IGBT (insulated-gate bipolar transistors) as switching elements. ABB was awarded the order and supplied an SVC Light to the steel plant, commissioned at the end of 2006.

Main circuit design
The SVC Light has a dynamic range from 0 to 64 Mvar capacitive reactive power and is directly connected to the 13.2 kV furnace bus, without any need for a special converter transformer. A single-line diagram of the furnaces and SVC Light are shown in Fig. 2. To minimize the amount of site work related to the SVC Light, all indoor equipment was pre-mounted in an enclosure and extensively tested before shipping. The enclosure contains the VSC including its DC side, the cooling system and the control room with corresponding cubicles.

The main component of the SVC Light, the VSC is rated at ± 32 Mvar. SVC Light operates with pulse-width modulation (PWM) technique, which leads to a very fast current response. The time response for a current order is in the order of one millisecond.

The SVC Light is employing ABB StakPak™ press-pack IGBTs. To provide mechanically robust series connection and to limit requirements on flatness tolerances, each of the sub-modules is equipped with a system of spring assemblies for each individual chip. Also the housing frame is part of the force absorbing system. The IGBTs are series connected to meet the total voltage requirement for the VSC branch. For the IGBT valves, cooling by means of de-ionized water is utilized, giving a compact converter design and high current handling capacity (Fig. 3). 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.

Three passive filters tuned to 2nd, 3rd and 25th harmonics are also part of the design. The VSC technology using forced-commutated switching of the converter valves generates some high frequency harmonics. The switching frequency, in this case 1620 Hz, is efficiently filtered by the high-pass filter connected close to the VSC.

The footprint of the SVC Light is small, approximately 15x30 meters including the new control building. It was important to be able to use the area where the old SVC was situated and also to use the existing circuit breakers. The breakers are of indoor air-break type, placed inside the existing control room.

Control system
The aim of the control is to:

- Mitigate flicker
- Limit unbalance between phases
- Control the power factor

For flicker mitigation, open loop reactive power control is utilized. For power factor control at the incoming feeder, closed loop reactive power control is employed.
The SVC Light control and protection system is based on the ABB MACH 2 platform, built around an industrial PC, equipped with high performance add-in boards. The fast current response from the SVC Light used for flicker mitigation depends on an extremely fast measuring and control system. These functions are implemented in one of the Digital Signal Processor (DSP) boards in the Main computer.

All measurement signals from the main circuit enter the MACH 2 system via special I/O frameworks. The signals are thereafter transmitted further to the main control and protection computer. The DC voltage measurement signals enter the MACH 2 via optical fibers to optical interface boards. The optical signals are converted to electrical pulses and transmitted to the DSP. One of the DSP boards is used for controlling the valves. The SVC Light system uses software protection included in the MACH 2 and one of the other DSP boards is dedicated for protection.

As flicker performance is of utmost importance, special focus has been put on continuous monitoring of the actual flicker levels. Consequently, a flicker meter has been implemented in the software of the SVC Light control and protection system. The meter monitors the voltage at the point of common coupling (PCC) and performs the full filtering and statistical signal processing of the data, which is then presented on the operator’s work station.

The Human Machine Interface (HMI) contains an industrial computer used as an Operator Work Station (OWS) and Sequence of Event Recorder (SER), Fig. 4. It also contains a keyboard, a screen, a LAN switch and a keyboard switch.

**Performance**

After commissioning the SVC Light, measurements were made to verify its performance. The EAF is operating in two distinct modes, operation with cold scrap (top charge) and during continuous feeding with pre-heated raw material. According to the measurements performed in the steel plant, the EAF generates very high flicker in top charge mode (in the range of \( \text{Pst} > 8 \)), while lower during continuous feeding. During scrap melting, the EAF also generates large reactive power variations, current unbalances between phases and harmonic currents.

The performance of the SVC Light was quantified during cold scrap melting, i.e., during high flicker emission by the EAF. The power quality parameters were:

- Flicker reduction
- Power factor correction
- Negative-phase sequence reduction
- Harmonic damping, including inter-harmonics.
The following performance guarantee was given:

Table I. Performance guarantee.

<table>
<thead>
<tr>
<th>Performance parameter</th>
<th>Guaranteed value</th>
</tr>
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<tbody>
<tr>
<td>Power factor</td>
<td>≥ 0.95</td>
</tr>
<tr>
<td>Flicker reduction factor (99%)</td>
<td>≥ 4.06</td>
</tr>
<tr>
<td>Total Harmonic Distortion (voltage)</td>
<td>≤ 2.5%</td>
</tr>
<tr>
<td>Individual Harmonics (voltage)</td>
<td>≤ 1.5%</td>
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</tbody>
</table>

The field tests have demonstrated that the performance guarantee has been fulfilled.

The flicker reduction by the SVC Light is illustrated in Fig. 5. The SVC Light reduces the flicker generated by the EAF by at least 5 to 6 times.

Negative-phase sequence generated by asymmetrical loads causes fatigue mainly in motors. To avoid disturbances to external devices connected in the vicinity of the steel plant, the SVC Light is utilized to reduce the negative-phase-sequence current generated by the EAF to a negligible value (Fig. 6).

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