

# SVC for flicker mitigation from a steel plant

Gerdau AmeriSteel Manitoba (GAM) located in Selkirk Manitoba Canada, operates two electric arc furnaces. One furnace (eccentric bottom tapped, EBT) is used for the melting of scrap steel and the other, a ladle furnace, for subsequent processing of the molten steel. In 2007, a Static Var Compensator (SVC), replacing an old synchronous condenser, was commissioned adjacent to the melt shop for reduction of network disturbances and for power factor correction.

Electric arc furnaces (EAFs) in general, represent troublesome loads on the feeding three-phase power supply, which is usually the public grid. During operation, an EAF when used for melting scrap such as GAM's EBT causes the following on the interconnected grid:

- Voltage fluctuations and flicker;
- Negative-phase sequence components in currents and voltages;
- Harmonics.

An SVC is an efficient means of mitigating the above mentioned threats to power quality in the plant as well as in the feeding grid. The outcome is a winning situation for all stakeholders:

- Compliance with the power quality standards specified by the grid company.
- Other consumers connected to the common grid are spared the nuisance of disturbances emanating from the steel plant.
- The steel manufacturer can operate the steel plant without infringing on operational agreements with the grid company.

The following are the tasks of the SVC:

- To parry the rapidly fluctuating consumption of reactive power of the furnace(s).
- Maintain a stable power factor at the Point of Common Connection (PCC), independent of the reactive power fluctuations from the furnace loads.
- Reduce flicker at the PCC to acceptable levels.
- Filter the harmonics generated by the furnace(s).
- Stabilize the system voltage at the load bus.
- Mitigate the voltage unbalance generated by the furnace(s).



Fig. 1: Gerdau AmeriSteel SVC.

## Main SVC design

The SVC is rated at 13.8 kV, 0-80 Mvar capacitive. The SVC is comprised of the following:

- A TCR (thyristor controlled reactor) rated at 80 Mvar
- A 2<sup>nd</sup> harmonic filter rated at net 27 Mvar
- A 3<sup>rd</sup> harmonic filter rated at net 26 Mvar
- A 4<sup>th</sup> harmonic filter rated at net 27 Mvar

A simplified single line diagram of the SVC is illustrated in Fig. 2.

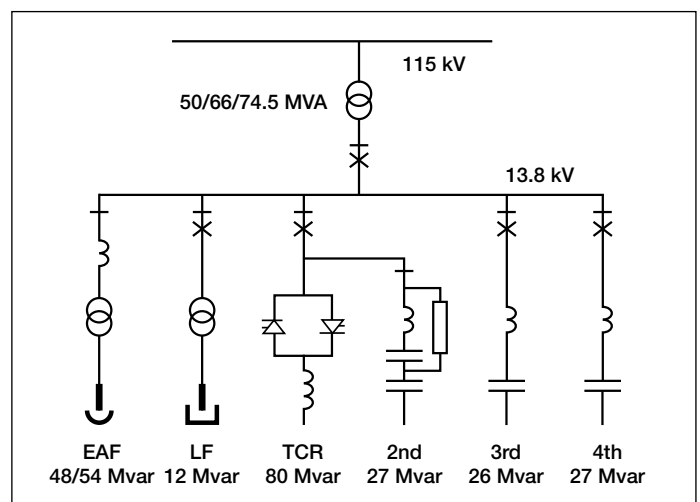


Fig. 2: Single-line diagram of the furnaces and the SVC.

By phase angle control of the TCR, the RMS value of the current through the reactor can be continuously controlled from zero up to the value given by the rated inductance of the reactor. Together with the capacitive reactance provided by the harmonic filters at 60 Hz, the total dynamic range of the SVC can be made capacitive. Thus, the overall dynamic range of the SVC installed at GAM is 0-80 MVar (capacitive).

Harmonics generated by thyristor control of the reactor current are absorbed within the harmonic filters.

### Thyristor valve

The thyristor valve consists of single phase stacks of anti-parallel connected Phase Controlled Thyristors (PCT). In parallel with the thyristors there are snubber circuits (series connected resistors and capacitors) to limit over-voltages at turnoff. The thyristors are electrically fired and the energy for firing is taken directly from the snubber circuits. The order to fire a thyristor is sent via optical fibers from the valve control unit. This type of system is called "indirect light firing". A thyristor control unit (TCU) converts the light pulses to electrical firing pulses and also performs protection and monitoring functions on each thyristor level. Between the thyristors as well as at the top and bottom of the stack there are heat sinks to remove the power losses from the thyristors. The thyristor valve is cooled by means of de-ionized water.

The thyristor valve is shown in Fig. 3.



Fig. 3: Thyristor valve.

### Basic Control Configuration

The main objective of the control system is to reduce flicker generated by the load and to improve the overall power factor.

The control system is based on the MACH 2 concept, which is a system of both hardware and software, specifically developed for power applications. The MACH 2 concept is built around an industrial personal computer (PC) with add-in boards and input / output (I/O) racks connected through standard type field busses like CAN (Controller Area Network) and TDM (Time Division Multiplex). Fig. 4 provides an overview of the different units constituting the control system, how they are interconnected and how the control system interfaces with the main circuit of the SVC.

### Control & Protection

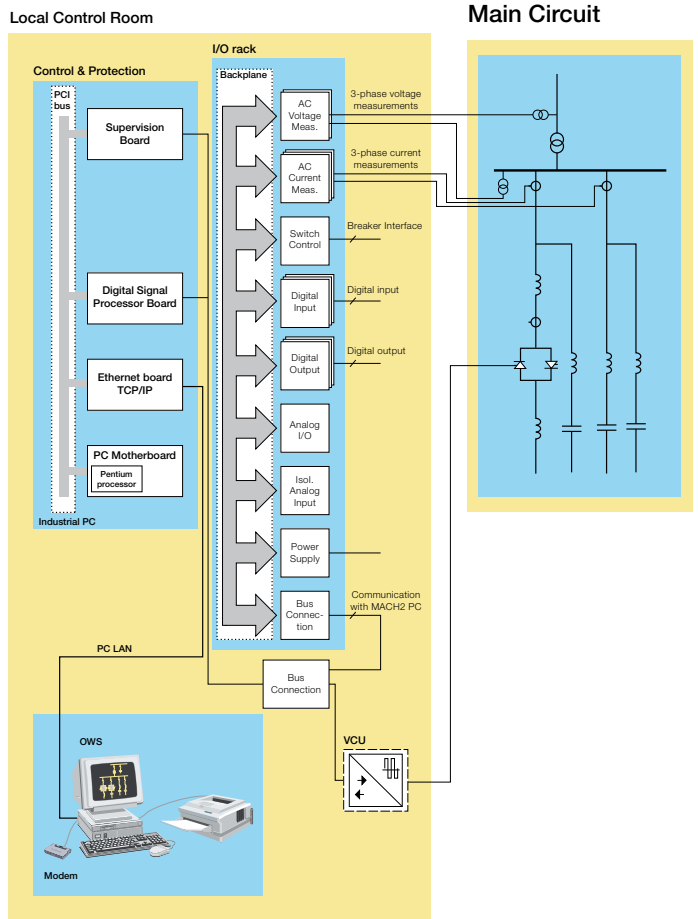


Fig. 4: MACH 2 SVC control and protection system.

The power system input signals to the control system are generated by current and voltage transformers that are situated in strategic locations of the plant. These input signals, sampled at a rate of 10 kHz, are used by the control system for controlling, supervising and synchronizing purposes. All measurement signals from the main circuit enter the MACH 2 system via special I/O-frameworks. These include circuit boards for galvanic separation, signal conditioning, sampling and pre-processing of data. (I.e. The MACH 2 control concept was developed to be insensitive to severe harmonics in the control inputs.) The signals are thereafter transmitted further via serial busses to the main control computer (MCP), using TDM for analog signals and CAN for digital signals.

The control system processes the input signals, calculates the phase-angle for triggering thyristors and converts them to control pulses for the TCR valve. These pulses are transmitted to the valve control unit (VCU) and from the VCU to the valve via optic fibers.

The SVC can be controlled from the SVC control room via an operator workstation (OWS) PC. As back-up to the OWS, there are two pushbuttons in the front of the control cubicle for SVC ON/OFF control. The SVC can also be controlled from a remote work station (RWS) PC installed in the GAM electrical supervisor's workroom. The communication between the MACH 2, OWS and the RWS PC's is performed via fiber optic or LAN network cables.

Included in the system is a human machine interface (HMI) which serves as the interface between the operator and the control system. The HMI function is performed by an InTouch application running on the OWS PC. The OWS communicates with the control system via the LAN using a SuiteLink protocol. Events, alarms and faults are time marked, recorded and stored in the OWS PC and displayed on the HMI screen.

A photographic view of the MACH 2 system is displayed in Fig. 5.



Fig. 5: Photographic view of MACH 2 control and protection system.

### Performance

The SVC was designed to fulfil the following performance requirements at the 115 kV point of common coupling, with the furnaces as well as the SVC in full operation:

- Power factor, P.F.  $\geq 0.99$
- Flicker reduction factor  $\geq 2$
- Voltage unbalance (99%)  $\leq 2.0\%$
- Total harmonic voltage distortion, THD  $\leq 2.5\%$

To ensure compliance with this performance specification, the parameters were measured after the SVC was operational. The performance measurements provided proof that the installed SVC meets or exceeds the specified performance.

### Productivity increase

Figures 6 and 7 show a typical heat and the total power and total energy used by the EAF and ladle furnace when the SVC is "off" (Figure 6) and "on" (Figure 7).

By comparing Figures 6 and 7 it can be seen that the power into the furnace increased from approximately 35 MW (SVC "off") to approximately 45 MW (SVC "on") at the same furnace operating taps. By integrating the input power over time to determine input energy for this example, 20 MWh of input energy is supplied in 45 minutes without the SVC, but in only 40 minutes with the SVC in operation. From this example it can be concluded that more steel can be melted during a certain time span as a consequence of the impact of the SVC, or, vice versa, the same amount of steel can be melted in a shorter time.

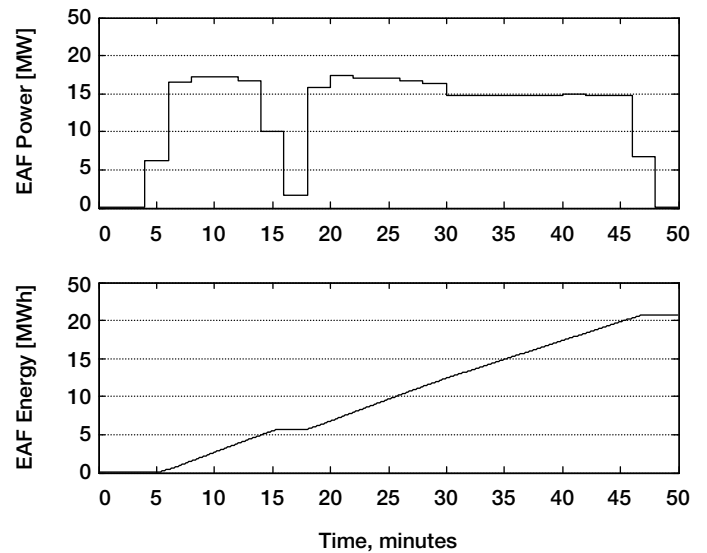


Fig. 6: Load power and energy without the SVC.

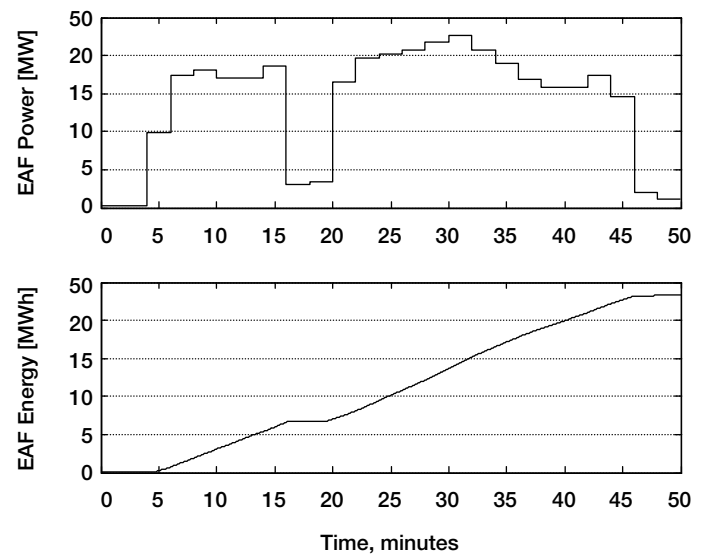


Fig. 7: Load power and energy with SVC.

### Flicker measurements

Fig. 8 illustrates the following for the operating case with the EAF "on" and the SVC "on":

- The network reactive power  $Q_{NET}$ ,
- The load reactive power  $Q_{LOAD}$ ,
- The SVC reactive power  $Q_{SVC}$ ,
- The furnace active power  $P$ ,
- The flicker (Pst)

By analysis of the flicker measurements, a flicker reduction factor exceeding 2.5 is obtained.

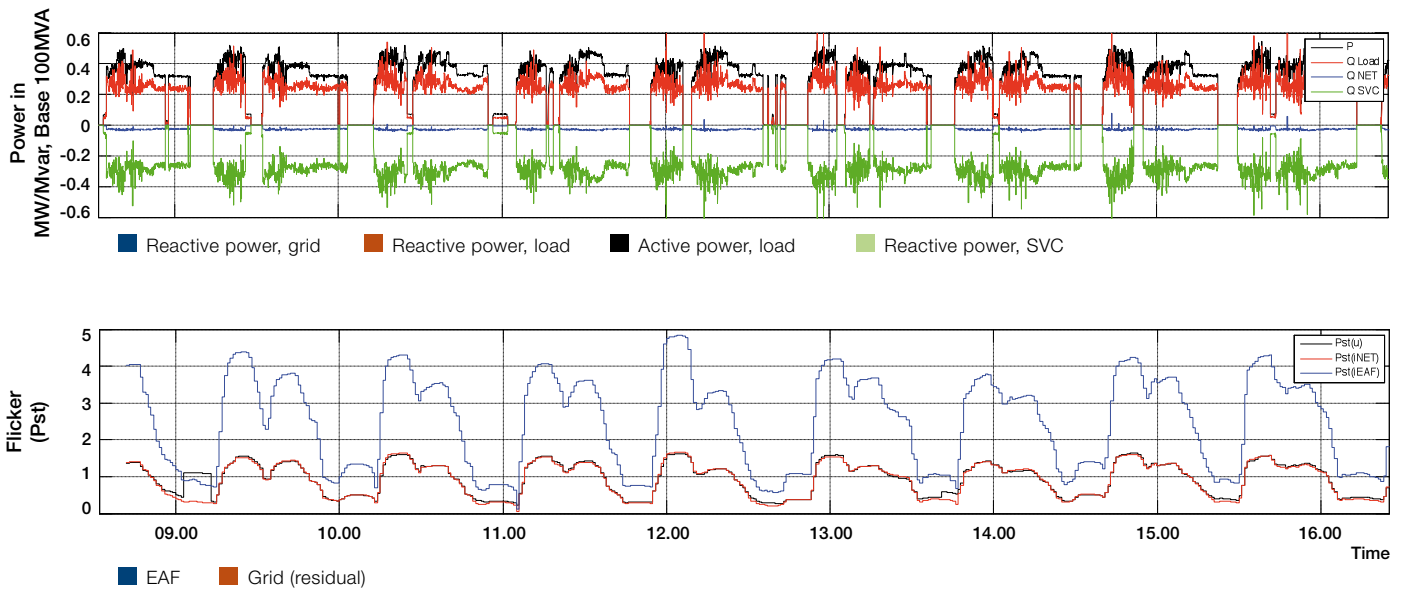


Fig. 8: Flicker measurements overview, SVC in operation.

## Main technical data

Bus voltage	13.8 kV
SVC rating	0-80 Mvar capacitive
Harmonic filters	2 <sup>nd</sup> harmonic / 27 Mvar 3 <sup>rd</sup> harmonic / 26 Mvar 4 <sup>th</sup> harmonic / 27 Mvar
Control scheme	Phasewise, open loop susceptance regulator, plus a three phase closed loop susceptance regulator.
Thyristor valve	PCT equipped, water cooled, with indirect light firing.

## Performance with the SVC in operation:

Flicker reduction factor	> 2.5
Power factor at the 115 kV PCC	≥ 0.99
Voltage unbalance at the 115 kV PCC	≤ 2.0%
THD at the 115 kV PCC	≤ 2.5%

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