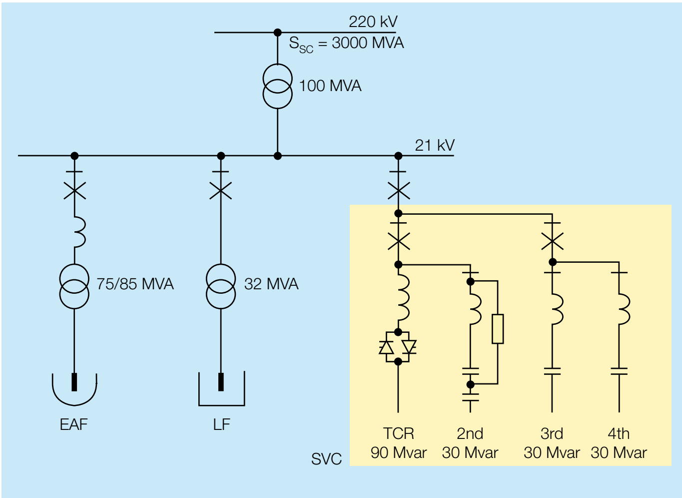
SVC for maintaining power quality in a 220 kV grid feeding a steel plant

Since 2002, Ferriere Nord S.p.a., a steel plant situated in northern Italy, has been operating an ABB static var compensator (SVC) in its electric arc furnace (EAF) based melt shop. The SVC was installed in order to mitigate flicker generated by the EAF; however, other benefits such as increased furnace productivity and decreased energy losses were also considered. The installation was part of a general meltshop expansion which also comprised the uprating of an existing EAF transformer from 55 MVA to 75/85 MVA. There is also a ladle furnace for refining in the plant, rated at 32 MVA.

The SVC has replaced an old saturable reactor which was operated in series with the EAF. By means of the SVC, the flicker severity factor at the 220 kV point of common coupling has been limited to $P_{st}(95) = 1.3$ with the EAF and ladle furnace in operation.



Single-line diagram

The SVC installation has also led to better furnace performance in terms of increased available power and lower electrode consumption.

The SVC is rated at 21 kV, 0-90 Mvar (capacitive). It has the following tasks:

- To keep a high and stable power factor at the point of common coupling, independently of the reactive power fluctuations from the furnace loads.
- To reduce the flicker at the 220 kV point of common coupling to acceptable levels.
- To mitigate the harmonic distortion generated by the furnaces.
- To stabilise the system voltage at the 21 kV furnace bus.

The SVC comprises the following main parts:

- A thyristor-controlled reactor (TCR) rated at 21 kV, 90 Mvar.
- A 2nd harmonic filter rated at 21 kV, 30 Mvar.
- A 3rd harmonic filter rated at 21 kV, 30 Mvar.
- A 4th harmonic filter rated at 21 kV, 30 Mvar.

By phase angle control of the TCR, the current through the reactor can be continuously controlled from zero up to the value given by the rated inductance of the reactor. The harmonics generated in the process are absorbed in the harmonic filters which are also part of the SVC.

Thyristor valve

The thyristor valve is of BCT type, i.e. equipped with bi-directionally conducting thyristors. In such devices, two thyristors are integrated into one wafer with separate gate contacts.

The two component thyristors in the BCT function completely independently of each other under static as well as dynamic operating conditions. Each component thyristor in the BCT has a performance equal to that of a separate conventional device of the same current carrying capability. The valve comprises only one thyristor stack in each phase instead of two, which offers considerable compactness of the valve design.

The thyristor valve is cooled by means of de-ionised water.

SVC control

The input signals to the MACH 2 control system are generated in current and voltage transformers that are located in different places in the plant. These are used by the control system for controlling, supervising and synchronizing purposes. The control system processes the input signals, calculates the phase-angle for triggering thyristors and converts them into control pulses for the TCR thyristor valve.

The MACH 2 control concept is developed to be insensitive to severe harmonics in the control inputs. It is an obvious requirement that the SVC must be insensitive to and does not amplify any harmonic resonant condition in the power system.

Performance

The SVC was designed to fulfil the following performance requirements at the 220 kV point of common coupling, with the furnaces as well as the SVC in full operation:

- Power factor, P.F. ≥ 0.95
- Voltage flicker, short term, P_{st}(95) ≤ 1.5
- Total harmonic voltage distortion, THD ≤ 1.5 %

In fact, the values measured during test runs of the installation not only fulfilled the demands, but actually surpassed them:

	Measured values	Required values
Power factor	0.99	≥ 0.95
THD	0.97%	≤ 1.5%
Flicker, P_{st}(95)	1.30	≤ 1.5

Productivity improvements

The SVC not only mitigates random voltage fluctuations at the point of common coupling, but also brings about a genuine increase in the RMS value of the EAF bus voltage. This provides higher active power in the furnace, which can be utilized to the benefit of the steel plant as follows:

- Shorter melting times
- Reduced specific electrode consumption
- Reduced specific energy losses
- Reduced wear of furnace lining.

The improvement of the power factor at the point of common coupling also enables a reduction of plant losses emanating from the flow of reactive power, and provides scope for more favourable power rates from the local utility.

These factors all offer potential for improving plant productivity and economy.

Increased productivity
By means of the SVC, the busbar voltage is stabilised to have an increased available power of 6-7% at the furnace in the given case. Due to this increased active power yield in the EAF, each tonne of scrap needs less time for melting. This can be used to increase the total production output of the plant. Alternatively, it can be utilised for additional flexibility in the production pattern, for instance, to simplify the meeting of peak demands.

Electrode savings
The graphite electrode consumption can be split into two constituents:

- Side oxidation, mainly dependent on tap to tap time.
- Tip consumption, mainly dependent on electrode current.

In the given case, electrode current remains the same, with the tap to tap time reduced. Reduction in side oxidation results, leading to reduced electrode consumption.

Loss reduction
With decreased tap to tap times, specific furnace losses, equal to losses per melt, decrease as well. Furthermore, as mentioned above, electric losses from the substation to the furnace are reduced, due to smaller flows of reactive power.

Refractory savings
Specific refractory wear, i.e. wear per melt, is reduced due to the shorter time spent for each melt. Furthermore, the more efficient and stable arcing in the EAF due to the SVC and series reactor also results in reduced refractory wear.

Main technical data:

Controlled voltage	21 kV
SVC rating	0-90 Mvar capacitive
Harmonic filters	2nd harmonic / 30 Mvar 3rd harmonic / 30 Mvar 4th harmonic / 30 Mvar
Control system	Phasewise, open loop susceptance regulator, plus a three-phase closed-loop susceptance regulator.
Thyristor valve	BCT equipped, water cooled, with indirect light triggering.

Performance with the SVC in operation:

Flicker, P_{st} (95)	1.30	Increased available furnace power	6-7 %
THD	0.97 %		
Power factor	0.99		

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