

# The iron ore mine at Malmberget: SVC for voltage support, power factor control and power quality improvement



An SVC came on line in 2013 at LKAB's underground mining facility at Malmberget in the north of Sweden, the second SVC for mining supplied to LKAB by ABB in just a couple of years. It is a turnkey installation, rated at 21.5 kV, 0-41 Mvar capacitive, and with all indoor equipment housed in a pre-fabricated container. Its purposes are stabilizing the feeding voltage to the mine during varying load cycles, power factor correction as well as power quality improvement in conjunction with planned extensions of the ore mining capacity. The SVC has been designed to cope with an ambient temperature span of -40 to +40 deg. C.

As space is scarce in the substation, the SVC is located some distance away and connected to the 21.5 kV mine bus via 600 m power cables, a well proven solution in cases like this.

The load to be compensated by the SVC consists of six mine hoists connected to the 21.5 kV bus, four AC converter hoists each rated at 3.99 MW and two 6-pulse DC converter hoists rated each at 8.15 MW, altogether 32.3 MW. The duration of a load cycle is approximately 70 s and consists of an acceleration phase, operation at full speed, and retardation. During this time the load varies strongly, causing voltage variation on the feeding bus as well as at the PCC (Point of Common Connection).

With the SVC in operation, a stabilization as well as increase of the mining bus voltage level have been established.

The SVC is designed to fulfil the following performance requirements with all six mine hoists accelerated simultaneously:

Power factor  $\geq 0.99$  at the 21.5 kV bus

Flicker, Pst (95%)  $\leq 1.0$  at the PCC

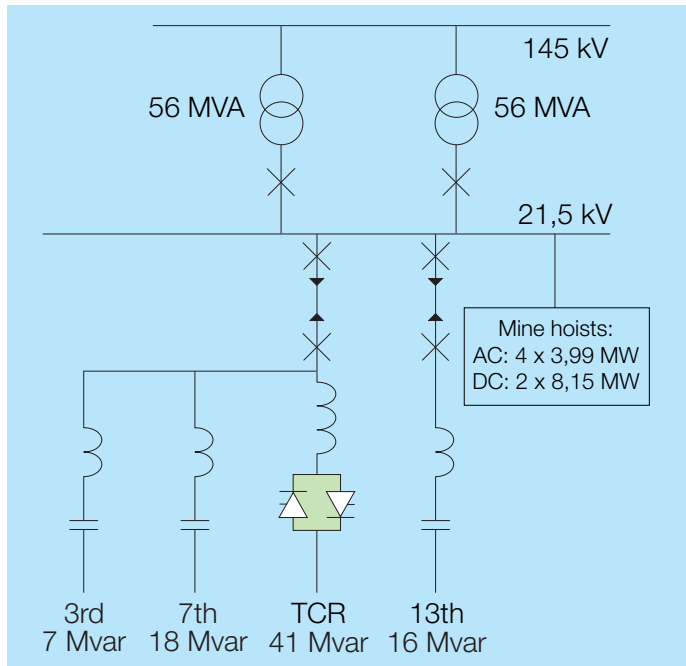
Max voltage variation caused by the hoists (95%) 1.0 % at the 21.5 kV bus

Total voltage distortion (95 %)  $\leq 1.5$  % at the PCC

Total current distortion (95%)  $\leq 5$  % at the 21.5 kV bus and the PCC

## Main circuit design

The SVC consists of a Thyristor Controlled Reactor (TCR) rated at 41 Mvar, 21.5 kV, in parallel with three Harmonic Filters tuned to the 3<sup>rd</sup>, 7<sup>th</sup>, and 13<sup>th</sup> harmonics. The total reactive power yield of the filters is 41 Mvar at 50 Hz, giving the SVC an overall control range of 0-41 Mvar capacitive, continuously variable.



Single line diagram, SVC

## Thyristor valve

The three-phase thyristor valve consists of three single-phase units. Each unit is equipped with a vertical stack of BCT (Bi-Directional Control Thyristors). A BCT is two anti-parallel high power thyristors integrated onto one single silicon wafer and assembled into a housing. In parallel with the thyristor, a snubber circuit (series connection of resistors and capacitors) is mounted. The thyristors are liquid cooled using de-ionized water with low conductivity as coolant. Nickel-plated aluminum heat sinks, providing double side thyristor cooling, also serve as electrical connection between the thyristors.

## Control system

The control system is based on the ABB 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 PC with add-in boards and I/O racks connected through standard type field buses like CAN and TDM.

There are two SVC control modes available:

- Closed loop control, based on power factor control or Mvar control;
- Open loop reactive power control

The SVC is mainly controlled from its operator work station (OWS) located in the SVC building.

## Reduced modes of operation

The SVC can be operated even with individual reactive power branches temporarily out of operation. The control system is then activated to perform according to the changed mode of operation.

Modes of operation:

- TCR, 3<sup>rd</sup> and 7<sup>th</sup> Harmonic Filters
- TCR and 3<sup>rd</sup> Harmonic Filter

## Main technical data, SVC

Controlled voltage	21.5 kV
Dynamic rating	0-41 Mvar (capacitive), continuously controlled
Harmonic filters	3 <sup>rd</sup> harmonic / 7 Mvar 7 <sup>th</sup> harmonic / 18 Mvar 13 <sup>th</sup> harmonic / 16 Mvar
Control system	- Closed loop control, based on power factor control or Mvar control; - Open loop reactive power control
Thyristor valve	Water cooled, BCT type thyristors, indirect light firing

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