Modernization and Upgrade of an SVC for an Electric Arc Furnace Application

Nucor Steel operates a bar mill production facility in Plymouth, Utah, with an electrical feed supplied by the electrical utility via a 138 kV transmission network providing power to two 33 MVA AC Electric Arc Furnaces (EAFs). To compensate for electrical disturbances generated by the EAFs, Nucor employed a -36/+72 MVAR Static Var Compensator (SVC) in 1980 (not supplied by ABB). In 1996, ABB replaced the existing control system with a more modern control system. In the early 2000s, Nucor began to experience complications with the SVC. At that time, Nucor commissioned ABB to perform a system study to investigate the power quality performance of the existing SVC and to make recommendations for modification.

System studies and recommendations

In 2005, ABB performed field measurements at the steel mill to analyze SVC performance and provide upgrade recommendations. A series of SVC sizes and topologies were explored. All simulations utilized updated SVC control algorithms and determined the SVC's impact related to power quality characteristics including flicker, reactive power balance, negative-phase sequence, and harmonics. It was found that during stages of melt with high flicker emission, the reactive power demand from the EAFs was well above the existing SVC rating. The limited capacitive SVC rating hindered the control system's ability to efficiently dampen flicker emitted by the EAFs. In order to achieve optimal flicker performance, it was recommended that the SVC be uprated to between 80 and 90 MVAR. The investigation also revealed poor damping of the 2nd harmonic in the system. The 2nd harmonic filter was not rated for the anticipated loads of the system. Therefore, it was recommended that the 2nd harmonic filter be modified or replaced to accommodate more MVARs. This would help mitigate the 2nd harmonic current levels and lessen the stresses on the existing 3rd, 4th, and 5th harmonic filters.

Conclusion, SVC upgrade

Ultimately, the client chose to upgrade and modernize the existing SVC with a new thyristor valve, cooling system, control system, and a larger, damped 2nd harmonic filter. This approach allows the client to upgrade the SVC in phases, with the provision available to replace the TCR and update the remaining harmonic filters if the size of the EAFs were upgraded in the future. Importantly, due to the fact that this was an existing steel mill installation, consideration had to be made for the construction time. The outage time available to perform the SVC construction was extremely limited. Additionally, the aging core components of the SVC (thyristor valve, cooling, and control) could be replaced with their modern counterparts, allowing for easier access to spare parts inventories and field service expertise.

Scope of supply

In 2006, ABB was awarded a contract to perform the upgrade of the SVC. The scope of the project included a new ABB MACH 2 SVC control system, a new thyristor valve including a new water cooling system for the valve and a new 2nd harmonic filter rated at 32 MVAR. Additionally, ABB was to perform the necessary engineering and the commissioning of the upgraded SVC. Civil and installation work for the modifications was taken care of by Nucor Steel, with ABB supervising the installation process. The single-line diagram of the upgraded SVC is displayed in Fig. 1:

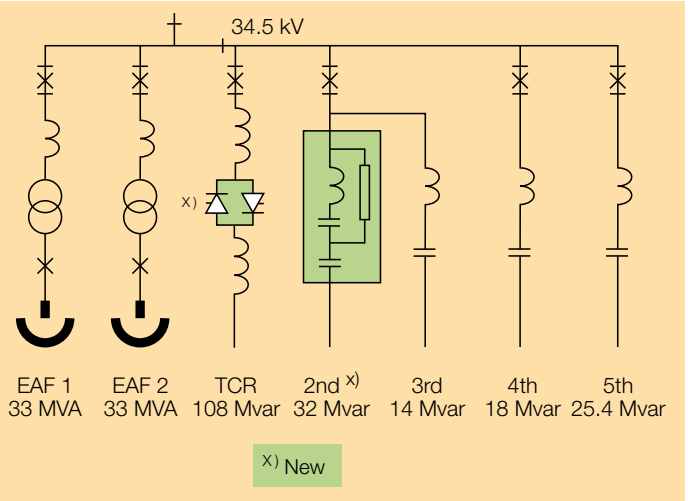

Fig. 1: Single Line Diagram of the upgraded SVC

Supply schedule

The promised delivery time of the equipment was set to be 12 months. From a planning perspective, it was very important to find a way to perform the upgrade with shortest possible outage of the SVC. To minimize the outage time, it was agreed that the new 2nd harmonic filter would be installed in a new

location, prior to starting the outage, instead of replacing it in the existing location. With this filter solution, an outage of 10 days was targeted to perform replacement of control, thyristor valve and cooling system as well as reconnect from the old to the new 2nd harmonic filter.

Provisions for the future

The new thyristor valve and cooling system have been rated for a higher TCR rating than what is required by the existing 108 MVAR TCR to accommodate a future upgrade of the plant that will require an increased SVC rating. When a higher rated TCR is required, the rating can be achieved by replacing the reactor coils only. This limits future investment and minimizes outage time in the future.

Technology employed in the upgrade

2nd Harmonic Filter

The new 2nd harmonic filter was designed as a C-type filter, consisting of a reactor and a capacitor connected in series in order to reach the required filter tuning. The capacitor comprises two groups in series, with a resistor connected across the tuning reactor and the first capacitor section. Configuring the filter in this manner results in the fundamental frequency current bypassing the resistor, thus reducing operating losses.

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 high power applications. The aim of the SVC is to control the power factor on the incoming line, stabilize the voltage at the furnace bus, and reduce the flicker at the point of common coupling (PCC). The automatic control system consists of an open loop phase-wise susceptance regulator and a closed loop susceptance regulator. All regulators are located in the MACH 2 computer.

Thyristor valve

The thyristor valve consists of three single-phase assemblies. The high power BCT (Bi-directionally Controlled Thyristors) are electrically fired, with firing orders communicated via optical light guides from the valve control unit. The valve employs series-connected 5 inch thyristors, water-cooled, together with associated snubber circuits, thyristor electronics, heat sinks and clamping arrangement. In the BCT, anti-parallel thyristors have been integrated on a common silicon wafer; therefore, only one thyristor stack is required per phase. With this arrangement, only half the number of thyristor housings and heat sinks are needed, improving reliability and minimizing maintenance.

Construction phase

The main targets of the construction phase were to minimize the scheduled outage and to cause minimal production impact. A preparatory site visit took place approximately one month prior to the planned outage. ABB provided a list of activities to the client that could be performed prior to the outage. The goal was to complete as much of the work as possible prior to the scheduled outage. After this joint review, the Nucor Steel crew had a few weeks to perform the preparation work.

Approximately one week prior to the outage, ABB's supervisor again joined the Nucor staff at site to finalize the preparation and plan for the outage. Partially dual working shifts were employed to minimize the outage time. Testing and commissioning work was performed in parallel with the upgrade installation to the greatest extent possible. A very short period was needed for the pure commissioning upon construction completion. With the detailed preparation done jointly by ABB and Nucor Steel combined with the shift work, the upgrade was completed and the SVC was back in service after only a 10 day outage, as scheduled.

Fig. 2: State of the art ABB thyristor valve, replacing the much larger original valve from 1980.

Main technical data of the modernized and upgraded SVC

Bus voltage	34.5 kV
SVC rating	18 MVAR inductive to 90 MVAR capacitive (-18/+90 MVAR)
Harmonic filters	2nd harmonic / 32 MVAR, C-type filter 3rd harmonic / 14 MVAR 4th harmonic / 18 MVAR 5th harmonic / 25.4 MVAR
Control scheme	Phasewise, open loop susceptance regulator, plus a three phase closed loop susceptance regulator.
Thyristor valve	BCT equipped, water cooled, with indirect light firing.

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