Know How and References

DC – EAF

Electric Arc Furnace

Salzgitter Steel AG
Preussag Stahl AG

EAF in the melt shop of Peine Salzgitter melting Scrap with a graphite electrode with a diameter of 800 mm. Foto: SGL Carbon

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Power, Control and Instrumentation System for the new DC electric arc furnace at the Peine steel plant of Preussag Stahl AG

Today: Salzgitter Steel, Germany

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Elpro GmbH, Berlin and AEG Berlin, delivered to MAN GHH, Gutehoffnungshütte AG all electrical supply and installed a complex, interlinked power, control and instrumentation system for the new electric steel making plant of Preussag Stahl AG in Peine. Individually, it comprises a higher-level power supply system including dynamic compensator for the DC electric arc furnace and ladle furnace, and an integrated control and instrumentation system for the electric steel plant. The operating and monitoring system interlinks the scrap supply and handling facilities, the flux and alloy supply equipment, the DC electric arc furnace and ladle furnace as the core elements, and diverse subsystems into one functional unit. The power, control and instrumentation system installed by Elpro and AEG for the new steel plant meets the production requirements.

The new electric steel making plant in Peine. In June 1994, MAN Gutehoffnungshütte (MAN GHH) AG Oberhausen received an order from Preussag Stahl AG Salzgitter for the supply of an electric steel making plant for their Peine location. This plant will involve a total investment of some DM 145 million. As early as December 1995, the first steps were taken to switch over from the oxygen steel making process to high-powered electric arc furnace metallurgy. The official inauguration on 24 May 1996 signalled the shutdown for the converter steel mill that had been in Operation for 30 years.
MAN GHH supplied a 100 t DC electric arc furnace and a 100 t ladle furnace as the core elements. Also included in the scope of supply were:

- dismantling and erection,
- construction,
- steel structures including soundproofing,
- dedusting equipment,
- cranes and transport vehicles for scrap and steel,
- electrical equipment and basic automation, as well as
- staff training and technical assistance.

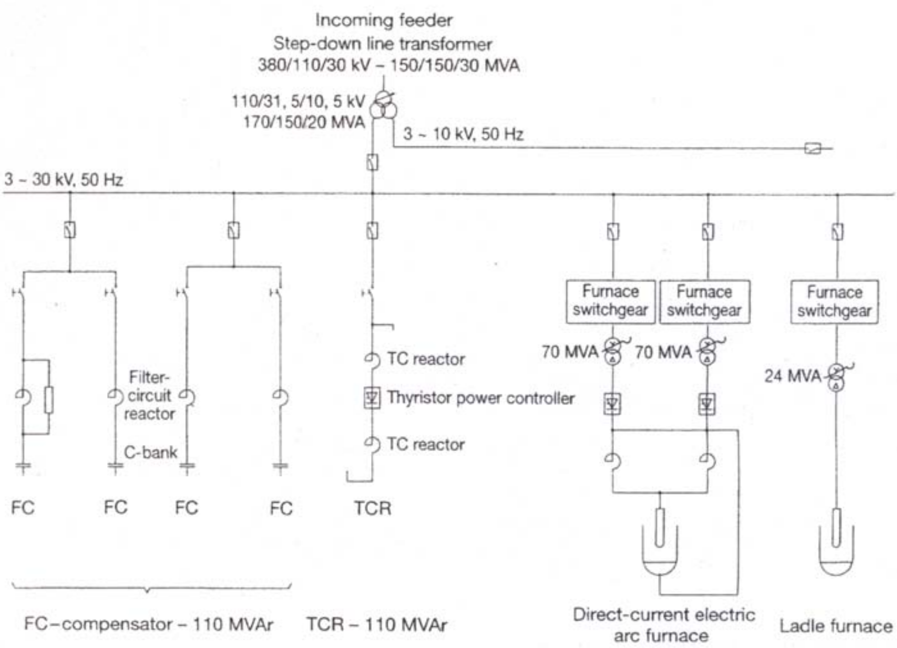
The close proximity of the Peine plant to residential areas meant that strict anti-pollution and anti-nuisance regulations had to be observed. Due to its many years of experience with environmental technology, MAN GHH was especially well qualified to implement these regulations. The same can be said of MAN GHH‘s DC electric arc furnace technology, which is acclaimed worldwide and which prompted Preussag Stahl AG‘s choice of supplier.
The DC electric arc furnace was developed by MAN GHH in the early 80s and the first furnace of this kind went into operation in the USA in 1985. There are now more than 30 furnaces working on the MAN GHH principle. Furnaces supplied by the Japanese licensee NKK Nippon Kokan achieved the breakthrough in Asia for this melt-down plant concept, which proved to be highly efficient from the very beginning Today, MAN GHH is a world market leader with its DC electric arc furnace.
The 100 t DC electric arc furnace has a transformer capacity of 2 x 70 MVA and is designed for a tap-to-tap time of 50 min.
Elpro GmbH, Berlin, was commissioned by MAN GHH to design, supply, erect and commission essential automation and electrical equipment. Elpro therefore assumed responsibility for the control and power technology of a complex, interlinked System.

Power supply system. Among the equipment and services supplied by Elpro were:

- a 110 kV outdoor switching Station,
- a 170/150/20 MVA three-winding transformer supplying 110/30/10 kV,
- a 30 kV switchgear System including a dynamic compensator with harmonics filter circuits as well as 10 kV and 0.5 kV distribution systems.

The steel making plant receives its electrical power from a 110 kV outdoor switching station as shown in **figure 1**. A three winding transformer is used to generate 30 kV and 10 kV voltages. A separate 30 kV indoor switchgear system feeds the DC electric arc furnace and the ladle furnace. Connected to the 30 kV bus bar are inductor-capacitors and static filter circuits with power of 110 MVAr (capacitive) and a dynamic reactive current converter TCR with a power of 110 MVAr (inductive). A 10 kV switchgear unit feeds the high-voltage motors driving fans. The 0.5 kV switchgear with 130 panels feeds the AC drives and all plant peripherals. One noteworthy feature is that the use of a three-winding transformer resulted in a highly cost-effective power supply system. Great care was taken to ensure magnetic decoupling of the 30 kV and 10 kV windings of this transformer in order to reduce the reactions on the System from the 30 kV to the 10 kV level. Due to the inherent current surges when firing the electric arc as well as the abrupt disconnection oncutting the electric arc, the elec-tric arc melting process causes reactions on the System. In the plant described, the system short circuit power at the 380 kV point of common coupling PCC was 19.6 GVA. Consequently, no reactions on system were to be expected.

Figure 1. Overview of the power supply system

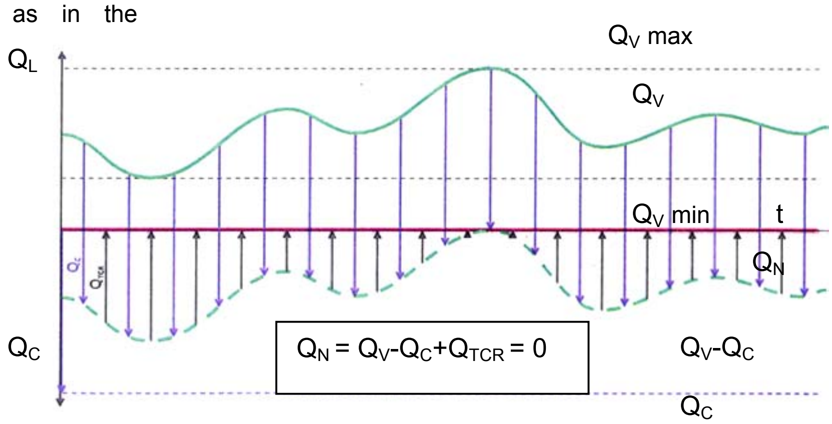


However, the short-circuit power in the 110 kV and 30 kV bus bars were only seven and four times higher than the rated power of the respective furnace transformers. Consequently, inadmissibly high voltage fluctuations were to be expected for the systems connected to the 110 kV, 30 kV, 10 kV and 0.5 kV switchgear, unless appropriate precautions were taken. The specified maximum voltage deviation of $\Delta U < -10\%$ could therefore not have been reliably observed and it was necessary to improve the voltage stability or the quality of the power by dynamic reactive current compensation. This measure is based on the theoretical premise that system perturbations have to be compensated in the harmonics range as well as in the fundamental wave reactive current. The term reactions on the system stands for the whole of the deviations from voltage, which is measurable at the PCC. Special computation programs were used to perform the variant calculations including harmonics analyse, in order to design the dynamic compensation system. The results of additional measurements taken on a comparable furnace were incorporated into the calculations.

The dynamic compensation system installed comprises:

- inductor-capacitor banks,
- filter circuits, and
- a TCR thyristor converter for dynamic reactive power compensation.

The inductor-capacitor units consist of the series connection of capacitors and inductors to form a series resonant circuit.
The resonance frequency of this circuit is chosen below the lowest frequency of the characteristic converter harmonics so as to act inductively for all harmonic currents, thus reliably preventing the occurrence of resonant conditions. The capacitors also compensate the inductive reactive power levels in the furnaces by a constant amount Qc. The filter circuits are also connected in series, but their resonant frequency is exactly tuned to the characteristic harmonics.



QC = Leading reactive power (capacitive) QN = Reactive power obtained at system
QV = Reactive power of loads QL = Lagging reactive power (inductive)
Q_{TCR} = Lagging reactive power with TCR circuit

Figure 2. Compensated for- and non-compensated-for reactive power characteristics as a function of time

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They short-circuit the harmonic currents so that the PCC voltage contains only very small portions of undesirable frequencies. In order to limit the number of exactly tuned filters, for cost reasons, and to compensate for intermediate harmonics, selected filters with damping reactors were installed as high-pass filters. The TCR reactive power converter stabilizes the voltage dynamically by adding the required compensatory inductive load in a controlled manner to the fixed capacitive load of the capacitor banks and filter circuits. The fast-response control System determines the duration of current flow by means of air core reactors. This allows dynamic adjustment of the inductive reactive power Q_{TCR}.The obtained reactive power compensation is clearly illustrated in **figure 2**. The fluctuating inductive reactive power Q_V of the furnaces is shifted into the capacitive range by capacitor banks with their constant capacitive reactive power Q_C However, the reactive power will continue to vary as a function of time (dashed curve Q_V - Q_C. If one controls the reactive power converter in such a manner that the sum of Q_V - Q_C + Q_{TCR} becomes zero at any instant of time, then the line-side reactive power Q_N also becomes zero and the bus bar voltage is thus maintained at an approximately constant value. The variation of voltage with time at the 110 kV and 30 kV levels with and without dynamic compensator units can be read off from the measurements recorded in **figure 3**. These show that the specified constant sine wave voltage is achieved by the dynamic compensation unit.

Measurements obtained from the working plant show a characteristic voltage curve virtually free of harmonics and a system without excessive compensation in any operating condition. This clearly confirms the aptness of the system design.

Elpro was able to draw on its long-standing experience and special expertise gained in the design of compensation units for rolling mills. Over the years, the enterprise has designed and supplied more than 50 large-scale plants with a great number of converter drives and compensation units for systems with a high incidence of harmonics.

Structural particularities of the compensation unit. Filter circuit reactors generate very strong electromagnetic fields. Consequently, this equipment is usually installed outdoors as far as possible from the buildings in order to prevent magnetic flux in structural elements. Due to the Peine plant’s location, this was not possible, and all filter circuit equipment and the reactors in the inductive reactive converter had to be installed in a very confined space in the upper storey of the switchgear building. The building itself had to conform to special regulations.

Operating and monitoring system. The operating and monitoring system built by Elpro and based on MAN GHH process expertise integrates scrap supply and handling facilities, the flux and alloy supply equipment, the DC electric arc furnace and ladle furnace as the core elements, and diverse subsystems, such as wire feed,
lime/carbon injection, lance manipulators and auxiliary equipment, including
the dust filter unit. into one functional unit. The scope of supply includes

- the entire process control, operating and monitoring level,
- instrumentation,
- load monitoring for all main power consumers,
- basic automation for scrap supply and handling, water management and operating fluid supplies, the bin charging system, charging equipment, and the dedusting unit. The software for the basic automation for the DC electric arc furnace and the ladle furnace was provided by MAN GHH. The integration into the control was carried out by Elpro.

The Operation and monitoring system serves to operate, visualize and control the process.

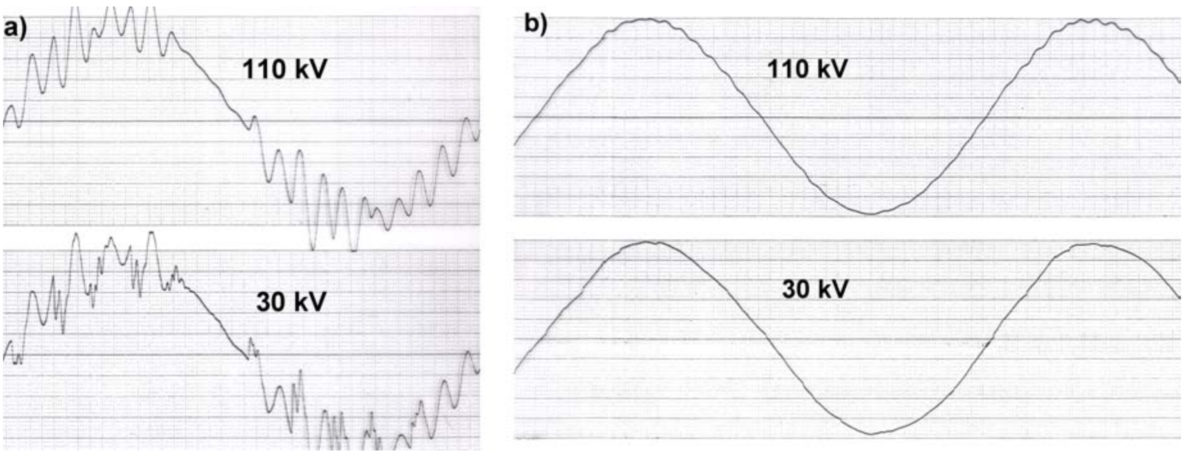

Figure 3. Oscillograph measurement record of voltages of 110 and 30 kV
a) excluding and b) including compensator

As illustrated in **figure 4**, it essentially comprises:

- nine Coros LS-B operating and monitoring stations fitted with 14'' TFT and 20'' conventional CRT monitors, keyboards and mouse installed in the control room desks and in the E-stations (a tenth station is in preparation),
- a SINEC H1 data bus,
- 15 SIMATIC PLCs for process-related tasks, with numerous subsystems connected via serial interfaces (e.g. weighing and radio control systems).

Despite the strong electromagnetic fields affecting the control rooms, the TFT monitors supply undistorted images.

The Operator stations were set up as follows:

Control room	No. of Operator stations
Electric Arc Furnace	3
Ladle Furnace	2
Scrap Yard	1

E-Stations	No. of service points
Electric Arc Furnaces	1
Filters, Operating Media	1
Scrap	1

Each Operator station can take over the monitoring functions for the specified section of the automated System and the operating functions for the associated plant systems. The three operator stations in the electric arc furnace control room are i.e. each Station can take over the functions of the therefore designed as identical and redundant units, other two. Under normal operating conditions, station 1 is used to operate the furnace. Station 2 is mainly used to monitor the furnace roof temperature and other significant temperature data as well as to control lime and carbon injection. Station 3 is used for charging. This concept allows the operators to use the monitors flexibly. The maintenance technician also receives his information from each operator station.

A PC network was prepared to provide the necessary metallurgical data for the operation and monitoring system. The PC network will perform calculations and supply the process control command signals. It is connected to the process control system SINEC H1 bus via a server PC.

Process visualization is achieved by dynamic process control images showing the current operating states of drives and valves as well as measurement and feedback data. The operating states are identified by colour codes symbols. In order to comply with the priority demand of rapid visualization, process data is preprocessed in the operator Station and stored for ready access. Depending on the amount of information to be displayed, charts and diagrams will appear on the screen within 0.5 to 3 s. Any malfunctions are signalled to the operator by a buzzer and by a change in colour of the corresponding symbol. The failure cause is recorded in a system log. Error messages are linked to measured value group images or actuator status images which can he called up.

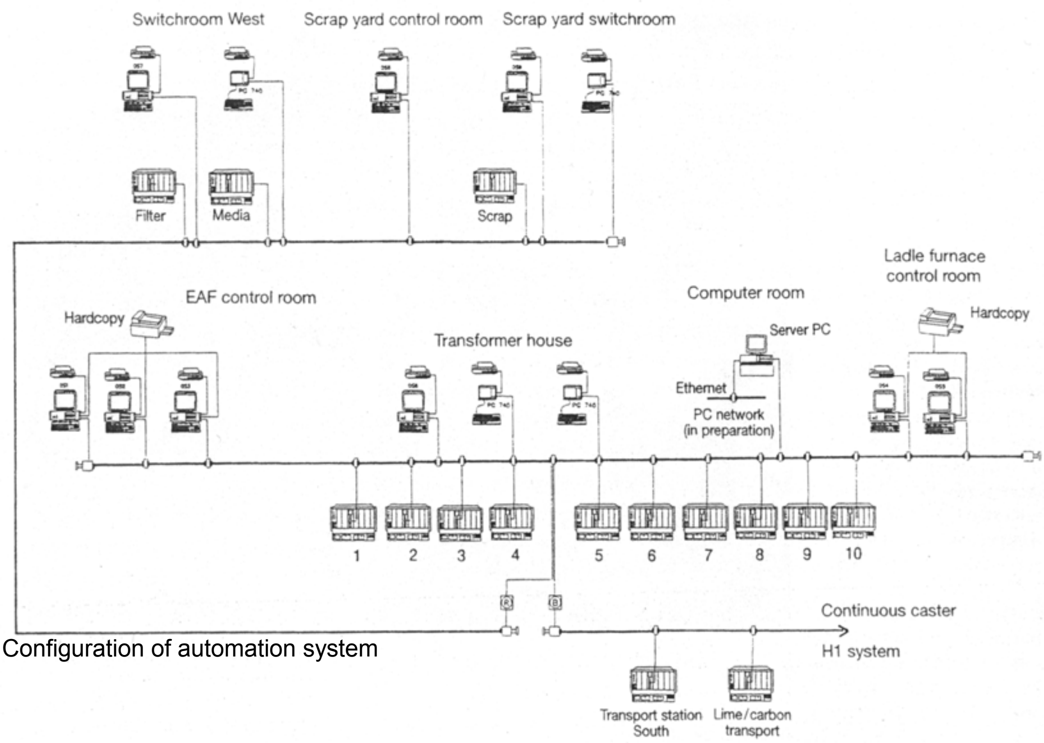

Figure 4. Configuration of automation system

1. Electric arc furnace
2. Ladle furnace
3. Bin charging system
4. Charging equipment
5. Burner nozzle
6. Lime/carbon injection system
7. Wire feeding machine
8. Auxiliary equipment
9. Load monitoring system
10. Refractory materials

according to image hierarchies for closer inspection Actuator status images are flow charts for each drive, indicating inputs and outputs, interlocks and the possible malfunctions. These are provided for use by the maintenance technician. All malfunctions and process events are logged along with the time, plant identification and a note on the cause.
An example of operation is given in **figure 5** showing the DC electric arc furnace at work with its operating panels.
The operating modes provided for process Operation are:

- automatic,
- semi-automatic,
- manual,
- local,
- maintenance and
- emergency shutdown.

Taking scrap supply as an example the modes mentioned above can be explained as follows: In automatic mode, the scrap ferries are remote controlled by the operating and monitoring system and guided by radio signals to the scrap crane. Maneuvering and loading of the scrap boxes is done manually from the crane control cabin. Radio data transmission is used to transfer the specified weights and scrap quality to a display in the scrap crane. Once the PC System has been finalized, this loading specification will be sent by the PC system to the operating and monitoring system. The specifications and formulations can then be stored and called up from the files in the archive data manager or modified as required. The PC system is not accessible in semi-automatic mode. The necessary commands, i.e. loading specifications, are entered in the process control system by the operators. Unlike the automatic and semi-automatic modes the operator must activate and deactivate all equipment individually in manual mode.
Generally speaking, the following tasks and functions are executed by the operating and monitoring system for all plant components:

- Start and stop of plant component groups from various initial operating states,
- operation, open-loop and closed loop control, display and monitoring of functions and equipment states,
- display and archiving of all vital current process data and operating states,
- display and logging of vital process data, process warnings and error messages.
- event reports including operator intervention, e.g. activation / deactivation or parameter adjustment.
- process control, blocking, adjustment and processing of algorithms as well as data management, acoustic and optical signaling executed via the 15 PLCs with their software,
- recording of the operating media and substances consumed per melt with data logging,
- indication of malfunctions in the control system (diagnostic charts) for all operator stations and the PLCs.

A load monitoring function was implemented in one PLC for the special task of limiting power consumption to the permissible maximum level for the billing period.
The software for all 15 PLC units was engineered in compliance with a global architecture. This was based on Preussag Stahl AG processing specifications and a module concept developed by Elpro GmbH. This object oriented module concept consists of software modules for equipment such as drives, valves, clacks measuring points, control loops, as well as the associated imaging modules for visualization and operation. This harmonized architecture is an essential prerequisite for maintenance and diagnostics in the PLC units. The observations made and experience gained during plant commissioning were applied as necessary and will be incorporated into future projects.
The power, control and instrumentation System installed by Elpro for the new steel making plant works as an integrated system and meets the production requirements.

Figure 5. EAF at work.