IMPROVED PERFORMANCE WITH MODERN AUTOMATION SOLUTIONS FOR ELECTRIC STEEMAKING[1]

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Abstract
The market for steel produced in electric steel plants continues to grow. And so do the demands on the steel producers. Optimum plant performance has to be achieved in a complex environment. Various targets such as flexible and cost-efficient production, optimum balance of raw material consumption, highest plant availability and sustainable product quality, as well as energy and mandatory GHG requirements have to be covered at the same time. Therefore a high degree of automation is required to ensure efficient and profitable steel production. Automation solutions throughout the entire electric steel plant, from stock yard to finished product, enable the producer to stay competitive in the volatile steel business. Proven solutions for power supply, drives, process control systems, advanced technological packages as well as state-of-the-art process optimization have been installed by Siemens VAI at numerous steel plants worldwide. Moreover new innovative packages, such as the EAF foaming slag manager, the on-line temperature measurement system RCB Temp or the holistic process model for EAF have been recently introduced to the steel market. This paper provides an overview about the innovative and benchmarking automation solutions for electric arc furnace and secondary metallurgy.
Keywords: Electric steelmaking; Process control; Process optimization; Automation solutions.

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1 INTRODUCTION

The market for steel produced in electric steel plants continues to grow, similar to the demands on cost-efficient production and productivity. Low consumption levels and efficient energy utilization have to be achieved.
The continuous efforts of the metals industry are driven by cost pressure and environmental regulations. Furthermore international agreements and national laws call for further reduction of pollution, energy consumption and CO2 emissions.
These market requirements must be met in order to ensure a competitive edge for the electric steel producer and to meet further demands like stricter emission limits or more challenging customer demands.
Meeting the above goals requires a maximum degree of modern automation solutions, combining technological, operational and automation expertise in all areas of the electric steelmaking, from energy supply and power control up to sophisticated dynamic process model applications.

2 ENERGY SUPPLY AND POWER CONTROL

Within the steel plant there is no production without power. That's why the distribution of electrical power is one of the basic preconditions for a safe and stable plant operation.
The correct installation of substations for high, medium and low voltage and the usage of well-designed distribution systems are the major keys to smooth production processes. High performance transformers, for example, are as important as the right switchgear solution for the various customer requirements.

2.1 Power Distribution and Compensation Systems

Short time voltage dropping or outages can cause high costs when they lead to production downtimes. Therefore, secure power supply via a well-designed and -equipped supply network is one of the prerequisites for successful plant operation. But most of all, the specific technological requirements of the production process must be considered during the conceptual design of a tailor-made power supply concept.
Large electrical loads in steel plants have a significant impact on the public electrical supply grid. The impact on power quality such as reactive power generation, harmonic voltage distortion, flicker and voltage variation frequently occur. Compensation systems do not only reduce the negative impact of typical plant loads to specified limits, but can also result in savings in energy costs – and can thus pay off quickly.
Siemens VAI has engineered, manufactured and successfully implemented numerous filter circuits and dynamic reactive power compensation systems (SVC and SVC PLUS).[(1)]

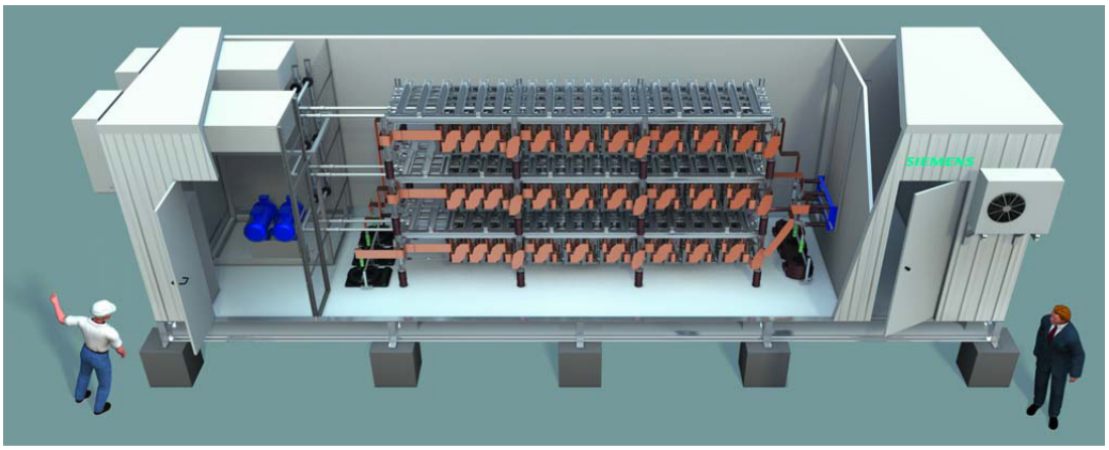

Figure 1. SVC PLUS arrangement inside container.

2.2 Furnace Switchgear

The SIMETAL Sivac-X furnace switchgear is especially designed for arc furnace operation with reliable and high frequent switching operations, even for the extreme requirements of ultra high-power arc furnaces. Simple operation is guaranteed at voltages of up to 40.5kV and load currents up to 4,000 A, and with the new current VCB as single circuit breaker for up to 4,500 A. Moreover, the long maintenance interval of 10,000 operating cycles allows for very low operating costs.

Figure 2. Furnace switchgear.

More than 30 years of experience in vacuum circuit breakers, as well as our in-depth knowledge of furnace switchgears, ensures smooth and reliable production without excessive over voltages or system failures.

3 EAF PROCESS CONTROL – LEVEL 1

The process control system SIMETAL EAF Control includes basic automation (level 1) and technological control functions to enable EAF steel production in an effective and safe way. A user friendly and redundant HMI configuration combined with the application of fail-safe state-of-the-art control devices ensure highest availability of the automation system. Typical features included are:

- **Adjustable profiles**
  The overall automation concept allows defining individual production schemes for transformer tap changer, reactor tap changer, electrode control curves, burners, RCBs (Refining Combined Burners) and injectors which minimize the operator actions.
- **Modular structure**
  Highly developed standard solutions make it easy to implement logic and communication to external systems like: Scrap yard, dedusting system, material handling, carbon / lime injection, FSM (Foaming Slag Manager), off-gas analyzer system and power plant.
- **System and process diagnostics**
  Diagnostic functions like condition monitoring, heat/day/month reporting and trend recording support trouble-free and reliable EAF operation.
- **Software simulation**
  All implemented functions are simulated according to specific operational rules. This covers e.g. hydraulic station, movements and process operations. The simulation of the complete heat cycle verifies the correct functionality of the automation software.

4 ADVANCED MEASUREMENT TOOLS

Today modern automation solutions also incorporate state-of-the-art measurement equipment. The typical measurement equipment, such as temperature/Celox hand lance is used as a standard tool for electric steelmaking.
In order to further improve the performance Siemens VAI has introduced unique measurement systems on the market:

- SIMETAL RCB Temp – contactless temperature measurement
- SIMETAL Lomas – continuous EAF off-gas analysing system
- SIMETAL LiquiRob – robot system for temperature & celox measurement and sampling.

4.1 RCB-Temp

The new contactless temperature measuring system, fully integrated into the RCB technology, provides a perfect method to predict the exact tapping time during power on. The measured temperature is evaluated with control models for repeatable results and a consistent process. The RCB Temp system (Fig. 3) includes three main functions:

- Burner mode
  During power-on times, RCB Temp can be used as a burner to preheat the scrap using various power settings.
- Lance mode
  As soon as the scrap is heated to the point where a reaction occurs between carbon, iron and oxygen, the system switches to lance mode to provide a supersonic oxygen stream.
- Temperature mode
  When a defined homogenization level of the liquid phase is reached, the system switches from lance to temperature mode and the temperature measurement cycle can start.

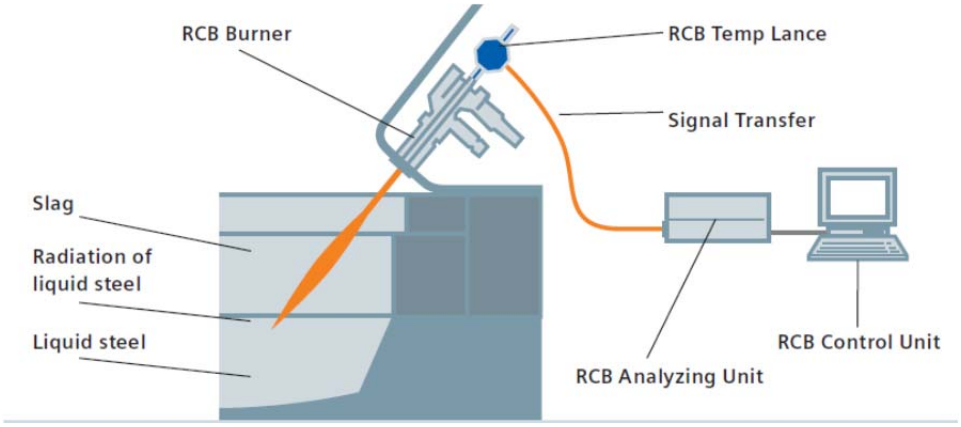

Figure 3. Scheme of RCB Temp system.

Based on this method there is no need of lances for temperature measuring. This results in a high level of safety for the operators and in reduced consumable costs. The energy consumption input decreases. This semi-automatic system allows an exact prediction of tapping with the following customer benefits:

- Increase productivity through power-off reduction
- Repeatable results for consistent process
- Decrease of operating and consumable cost
- Decrease energy consumption input with accurate tapping

4.2 EAF Lomas® Off-gas Analyzing System

A proven solution for EAF off-gas measurement is Lomas, which carries out fully automatic continuous gas analysis. The gas sampling device is placed in the water cooled primary EAF off-gas duct, as shown in Figure 4.

Figure 4. Lomas probe installation.

The off-gas is continuously analysed during power on time and during the power off time fully automatic sample probe purging and cleaning is performed. Therefore Lomas enables nearly maintenance-free operation, even under the very hot, corrosive and extremely dust-laded environment conditions at the sampling position directly after the EAF elbow. The Lomas system has been successfully installed more than 100 times in the converter area and just recently for the first time at the EAF at SDI Roanoke, USA.

5 FULLY AUTOMATIC ELECTRODE CONTROL

The overall performance of the EAF process is also strongly related to a well working electrode control system. SIMETAL Simelt is a fully automatic, end-to-end solution for electrode control in three-phase electric arc and ladle furnaces. It controls and dynamically adjusts the electric arc, ensures the most efficient use of electrodes and electric energy. The electrode control system can be integrated into any system environment and architecture. This technology has been successfully used in more than 300 applications worldwide.

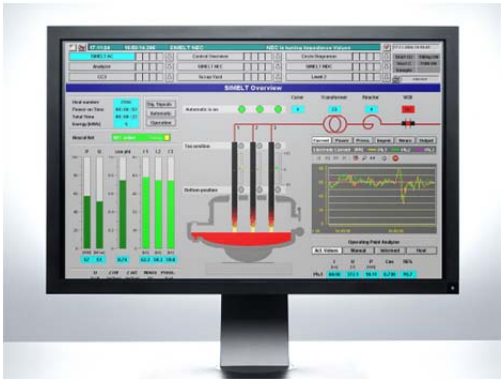

Figure 5. Main window of Simelt electrode control system.

Beside the basic AC module, the Simelt electrode control system also includes optionally a meltdown control (MDC) module as well as a neuronal energy control (NEC) module. For ladle furnaces and small EAFs (up to 50 t) the Simelt MICRO offers a high functional and reliable furnace operation at low investment costs. Simelt MICRO is based on the proven Simelt electrode control but using the new Simatic embedded controller as hardware base and the HMI is simplified by using WinCCflex visualization.

6 FOAMING SLAG MANAGER AND CONDITION-BASED SCRAP MELTING

6.1 Simetal SonArc FSM

SonArc FSM (Foaming slag manager) is an advanced add-on to the electrode control system enabling a fully automated foaming slag process. A combination of electrode current analysis and structure-borne sound analysis enables precise sectional and electrode related slag height detection. Thus not only foaming slag is indicated, but also height and distribution of the foaming slag in the furnace shell is shown in detail. By controlling and optimizing the carbon injection a uniform distribution of the foaming slag in all furnace sections is ensured.[2]

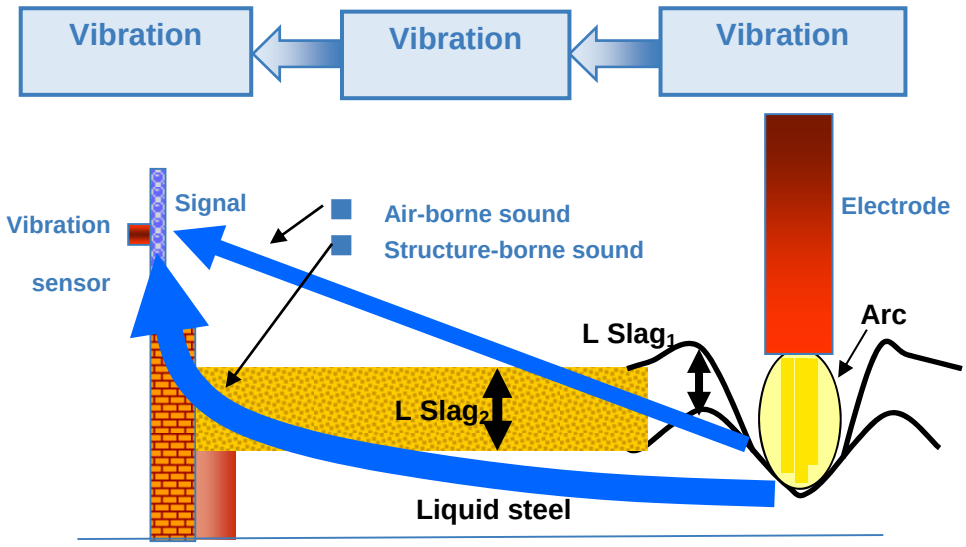

Figure 6. SonArc FSM - Principle of measurement.

Main benefits are:

- Controlled and optimized foaming slag process
- Reduced specific electric energy (up to 3%) and carbon consumption (up to 25%)
- Shorter power-on times, 1 min or even more time saving; increased productivity, 2% or more possible
- Reduced CO_2 emissions due to lower carbon and energy consumption, e.g. up to 10.000 t CO_2/year at 100 t EAF

6.2 Simetal SonArc CSM

SonArc CSM (Condition-based scrap melting) is a newly developed add-on to the foaming slag manager system. The FSM measurement devices can also be used to detect the state of the scrap melting process inside the furnace shell. The electrical operating point is adapted to the progress of scrap meltdown. Therefore, a smooth and standardized meltdown behavior is achieved under SonArc CSM operation. Furthermore, the system enables optimal charging of subsequent scrap baskets by signalizing the completed meltdown of the actual basket.

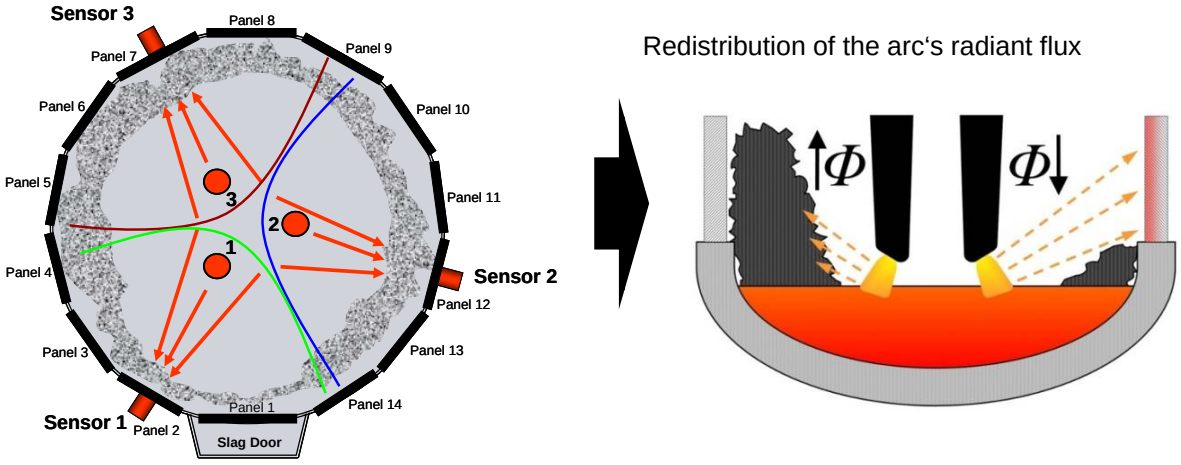

Figure 7. Process-oriented control of electric power.

Main benefits are:

- Standardized and controlled meltdown behaviour of scrap
- Reduced thermal loads at the furnace's water cooled panels
- Shorter power-on times
- Reduced specific energy consumption
- Reduced on-load tap changing of the furnace transformer
- Shorter tap-to-tap times and consequently higher productivity

7 PROCESS OPTIMIZATION

Further improvement of plant performance can be achieved by the implementation of a modern process optimization system including dynamic process models. SIMETAL EAF Optimization (level 2) is the ideal assistant for electric steelmaking in order to achieve cost-efficient and flexible production by intelligent usage of available energy and raw materials. The process optimization solution provides basic functionality such as process tracking, production plan handling, graphical user guidance and extensive reporting. A close connection to the EAF process control (level 1) ensures the proper signal processing and reaction by the EAF process models.
Steel Expert, the comprehensive group of metallurgical process models, features dynamic online optimization taking all process and quality-related data into account. The model results combined with technological instructions are forwarded as setpoints to the level 1 process control system to optimize the production process.[3]

7.1 Steel Expert Process Models for EAF

- **Steel Expert Prediction** performs a precalculation of the complete heat, tracing the defined melting practice. It gives a preview of the entire steelmaking process with regard to required electrical energy, process gases, alloys, slag formers and treatment times.
- **Steel Expert Charge** calculates all materials to be added to the melt - via baskets and bins - to reach the target steel grade specification.

- **Steel Expert Supervision** monitors cyclically the physical and chemical processes in the EAF and provides online information about steel and slag weight, analysis and temperature.

The amount of electrical energy necessary for melting the prepared and charged materials and for heating the steel bath up to tapping temperature is determined by Steel Expert Temp.
For stainless steel production, Steel Expert Reduction finally calculates the amount of reduction agents and the required reduction time.
In case of continuous DRI feeding, DRI Feed Rate Control dynamically controls the DRI feed rate targeting a constant steel bath temperature. The following figure shows the principles of the control.

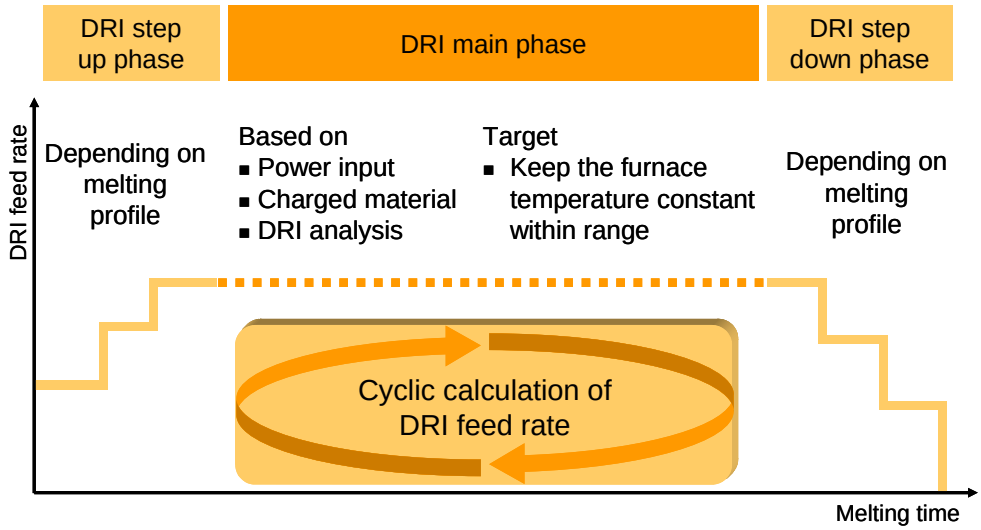

Figure 8. Principle of DRI feed rate control.

7.2 Additional Steel Expert Process Models for Secondary Metallurgy

In the steelmaking area several additional process models, specifically developed for the different treatment steps like deoxidation, desulphurization, inclusion shape control, heating/cooling and alloying are available.
All of the above process models feature:

- Cost optimization
- Considering linear and nonlinear constraints
- Considering hardenability requirements

The **Hardness Model** calculates the optimal target steel analysis with the aim that after alloying the steel is as close as possible to the aims of the given target specification and of given restrictions/conditions expressed in terms of the elements. The model can handle linear conditions as well as nonlinear conditions.

8 HOLISTIC PROCESS MODEL ENABLING CLOSED LOOP CONTROL

Today a significant amount of energy is generated by chemical reactions of fuel or gas, oxygen and carbon injected into the furnace. Thus the optimized on-line control of these input materials is a must to tap the full saving potentials. One of the developments in this way is the holistic EAF optimization system from Siemens VAI. This system is continuously monitoring the furnace off-gas analysis, the off-gas flow

and the slag level and controls the input of natural gas, oxygen (for refining and post-combustion) and carbon (for slag management).
It consists of four main parts (see Figure 9): The holistic process model (HPM) itself – a combination of algorithms and prediction strategies, the Lomas off-gas analyzing system, the SAM off-gas flow analyser and the FOX300 as slag foaming indicator.

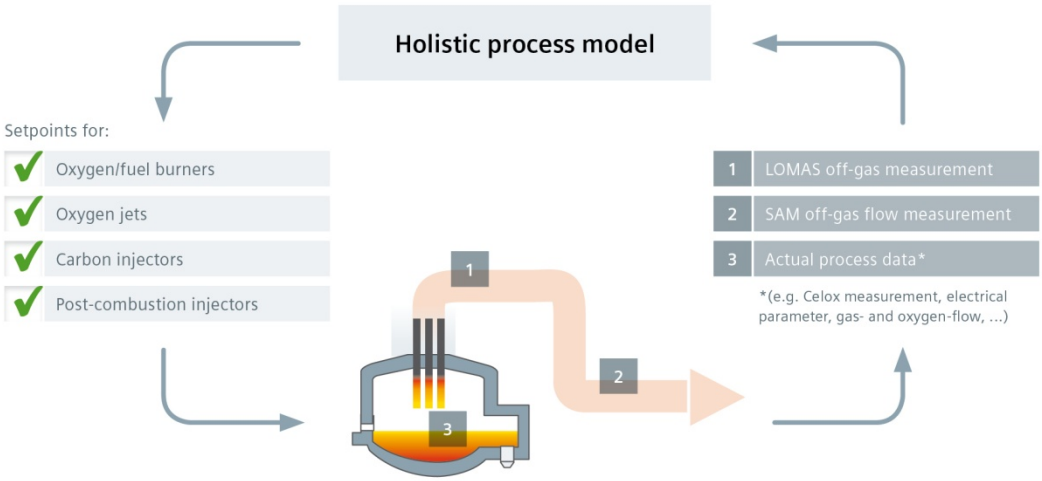

Figure 9. Closed loop control using process - and off-gas data.

This approach has proven to enable a closed-loop control of the oxygen and gas injectors, the carbon injectors as well as the post combustion burners. It takes actual EAF process data, the continuously measured Lomas off-gas analysis (CO, CO2, H2, O2 and CH4), the off-gas flow and the foamy slag index into account.
Such an “all-inclusive“ automation approach has shown significant advantages compared to usual, rigid melting diagrams and it allows to dynamically optimize the EAF production based on actual process conditions.
The main advantages are the minimized and efficient use of fossil and electrical energy, reduction of tap-to-tap time and an overall reduction of conversion costs.
Main benefits are:

- Minimized and efficient process-related use of natural gas, oxygen and carbon
- Saving of energy (electric and / or fossil fuel)
- Reducing of tap-to-tap time
- Increasing of transparency of the EAF process
- Increased process safety
- Fast start-up for high-quality

9 SUMMARY

It is a fact, that modern automation solutions, as described above, have a major impact on cost-efficient and flexible production. Numerous installations have proven that steel plant modernization with state-of-the-art automation packages provides a significant improvement of the overall plant performance.
Siemens VAI, which is part of the Siemens Industry Sector, is one of the world’s leading life cycle partners for the metallurgical industry and the leading software

house dedicated to the metallurgical industry. On the basis of our technological and automation expertise we are continuously searching for new solutions to further improve the electric steelmaking process.

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