MELT EXPERT- A NEWLY DEVELOPED INDUSTRIE 4.0 BASED ELECTRODE CONTROL SYSTEM*

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Abstract
Industrie 4.0 is slowly but surely arriving in the melt shops. Furnaces are being equipped with more and more sensors, digital models are increasing the degree of automation, and information is being shared between different aggregates within the plant. Because the electrode control system plays a key role in electric steelmaking, it naturally assumes an important position in the melt shop's Industrie 4.0 strategy. In addition to reliable, state-of-the-art core regulation functionality, monitoring and reporting tools and the ability to communicate with other equipment are also required. Therefore, the latest generation of our electrode control system, the Melt Expert, was developed based on Industrie 4.0 design principles. Intelligent plant condition diagnostics, performance monitoring, and user-defined reporting are essential modules in this new system. With these functionalities, electrode control systems are developing into the information and control center of the furnace. A newly developed software app brings most relevant process information to mobile devices. This feature allows steelmakers to keep an eye on the performance of their equipment anytime and anywhere. This paper describes the new features of the electrode control system and shares our customers' operational experience. Our focus is on the practical aspects of plant status monitoring, KPI reporting, and diagnostic functionality as well as the improvements achieved.
Keywords: Industrie 4.0, EAF, electrode control system, condition monitoring systems.

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1 INDUSTRIE 4.0 AND ITS RELEVANCE FOR THE STEELMAKING INDUSTRY

Industrie 4.0 is the fourth industrial revolution after the mechanization, electrification, and computerization of production process lines.
The term Industrie 4.0 originated with a project in the German government's high-tech initiative, which aims to maintain Germany's leading manufacturing position.
The key idea behind this strategy is the increased customization of products under the conditions of highly flexible (mass) production. The necessary automation technology is improved by introducing methods of self-optimization, self-configuration, self-diagnosis, cognition, and intelligent support of workers in their increasingly complex duties.

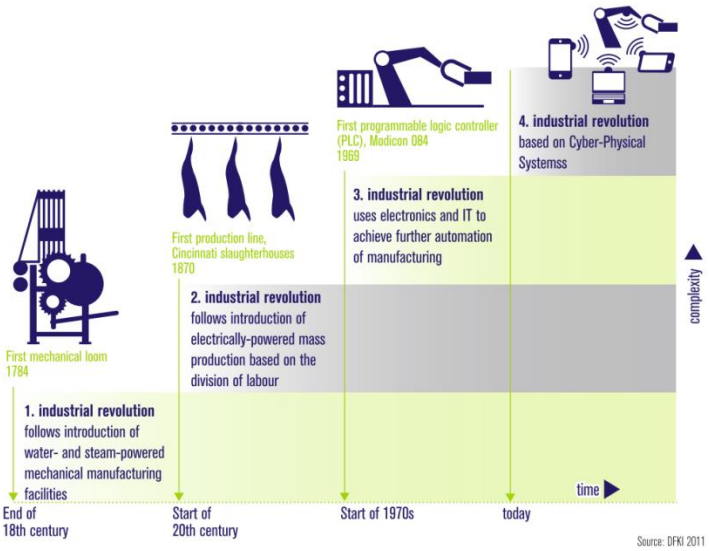

Fig.1 The evolution of the industry [1]

Although the concept of Industrie 4.0 was originally intended for the traditional manufacturing industry, it's becoming more and more important in other segments as well.

Steel plant status quo

In modern steel plants today, processes are executed fully automatically, and manual intervention is needed only in the event of malfunctions. This is one of the key factors in increasing plant efficiency and securing product quality.

The steel plant of tomorrow

The concept of Industrie 4.0 takes us one step ahead. Even normal production anomalies like electrical or mechanical breakdowns will be handled by the system itself by detecting the situation, stopping the aggregate, informing all other facilities in the plant about the expected delay, and contacting the maintenance team with a detailed report about the problem and the required repair work.

The path to the steel plant of the future

To prepare for the future, steel plants are already being equipped with more and more sensors for gathering precise information about the current status of the plant. Digital models are increasing the degree of automation, and they allow rule-based, autonomous decision-making. Crosslinking the various aggregates through level 2 and level 3 systems enables information to be shared throughout the plant. The development and implementation of the above-mentioned measures will be one of the pillars of tomorrow's steel production.

1. The six design principles for Industrie 4.0

The primary outcome of the German Industrie 4.0 Working Group was the definition of six design principles. These principles provide a guideline for the design and implementation of Industrie 4.0 scenarios.

Interoperability	All components communicate and interact with one another.
Virtualization	Linking the physical world to data and models stored in software creates virtual models of the physical world.
Decentralization	Decisions are made autonomously and locally as much as possible.
Real-time capability	Data is collected, analyzed, and interpreted in real time.
Service orientation	Services are offered to others and services from others are used.
Modularity	Components are flexible and adapt very easily to new requirements.

2. PRACTICAL IMPLEMENTATION OF THE DESIGN PRINCIPLES IN THE NEWLY DEVELOPED ELECTRODE CONTROL SYSTEM

Following the design principles of Industrie 4.0, and keeping the steelmakers' daily business in mind, a modern electrode control system needs to fulfill the following demands:

- Acquire more information about the process and the facility
- Act as a point of service (for humans and machines)
- Communicate with all facilities connected with the arc furnace
- Analyze and interpret the information acquired and provide findings to the arc furnace's superordinate systems (act as a cyber-physical system and be a part of a superordinate cyber-physical system)
- Make decisions locally or support other decision-makers (humans and machines) by providing refined information

With the development of the Melt Expert – the successor of the well-known market leaders Simelt and Arcos – the concepts of Industrie 4.0 have been incorporated and several principles from the strategy have been implemented.

Obtain more information

One of the key principles is the demand for more information. "Condition monitoring" is a well-known buzzword, but is not sufficient for Industrie 4.0. All available information must be utilized in order to acquire more knowledge about the state of the facility, the state of the process, and product quality. It is essential to derive key performance indicators in order to detect even slight changes in the production process and to begin countermeasures.

Fig. 2 Melt Expert key performance screen

Analyze and interpret information

By organizing the findings on different specialized screens on the HMI, the needs of diverse stakeholders (process engineer, hydraulics/mechanics engineer, electrical engineer, shift electrician) can be addressed.
But the electrode control system not only acts as an information server: It also offers special services for maintenance purposes. In this role, the electrode control system was designed for the special needs of the maintenance crew to assist them in examining the condition of the electrical and mechanical system during maintenance shutdowns. Fully automatic tests of the equipment can diagnose faults in high-current busbars, hydraulic valves and pumps, current and voltage measurements, and the rolls of the electrode lifting column. Detailed reports not only show the results of these measured parameters, they also interpret these results and provide recommendations for repairs. This reduces the need for human interpretation of the readings. For example, an automatic health check of electrical measurement equipment used to assess electrode current and electrode voltage describes the precise root cause of abnormal readings: “The grounding cable from arc furnace to electrode voltage measurement is broken!” This both saves time and allows for selective repairs.

Mobile communication

A newly developed app for mobile devices allows location-independent observation of the furnace from anywhere and at any time. Two target groups in particular are addressed.
Managers will receive a benchmark of the actual performance based on historical data evaluation (daily, weekly, monthly, and yearly reports).
With updated information available on mobile devices, decisions can be made quickly.

Inspection and maintenance work in the control room can be performed more conveniently because all the necessary data will be available on the app. For example, actuating signals, hydraulic pressure, electrode speed, and other values can be monitored on a mobile phone while making adjustments to the hydraulic aggregate.

Internet of Things concept

A newly developed signal condition unit specifically designed for the needs of the electrode control system reduces the complexity of the system and makes the hardware configuration of the system more flexible. Later upgrades will also be supported: for example, customer-specific extensions. This can be realized by utilizing the Internet of Things concept: Locally installed devices will measure analog signals and transfer the data to the electrode control system using Ethernet/TCP.
The output signals to the electrode lifting valves can also be controlled via an Ethernet/TCP remote IO device, which prepares the hydraulic valve stand for the Internet of Things.

Fig. 4 Multifunctional analog input module

3. NEW IMPLEMENTED FEATURES

The addition information enables the extension of the already comprehensive functionalities. Some of the most interesting features are briefly described below.

Online monitoring of high-current cables

Using Rogowski coils, the current from each high-current cable is measured and fed into the regulation system. The single-cable currents are compared with the electrode current and a dedicated model monitors the abrasion level of the cables. Abnormal distributions are recognized immediately and cable faults are detected at a very early stage. The main advantage is easy and risk-free installation with no breakers or switches in the high-current busbar, which results in a very cost-efficient setup.

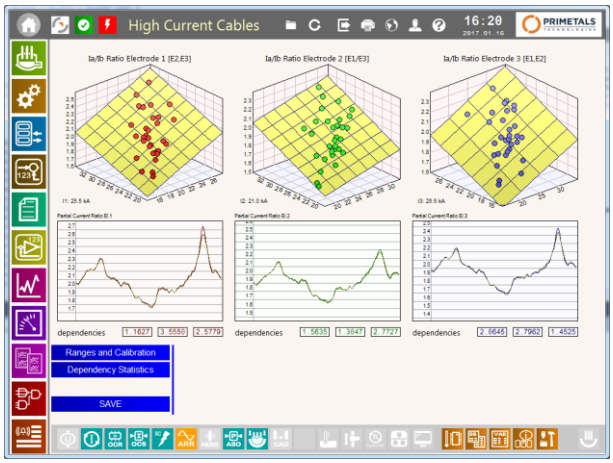

Fig. 5 Melt Expert high-current cable evaluation

Fully automated dip test

What is known as a dip test is typically performed to measure the reactance of the high-current system. During this measurement, the electrodes are dipped into the liquid steel bath and the system's reactance and resistance without the electric arc are measured and calculated.

The Melt Expert provides a fully automated sequence where the electrodes are immersed automatically to a specific distance and for a defined time. The automated procedure relieves the operator of handling the electrodes and guarantees reproducible results. Last but not least, safety is increased because the process is immediately stopped if the current exceeds the limits.

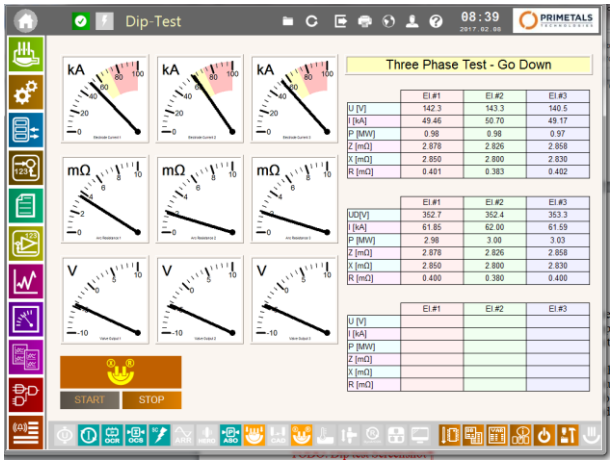

Fig. 6 Melt Expert high-current cable evaluation

Scrap classification

The charged scrap is automatically classified by using the information of the electrode mast position measurement systems. During the boring phase, the time and energy required for boring at a specific distance are recorded. The scrap composition is then classified based on these measurements (lighter scrap requires less time/energy than heavier scrap).
This information is used to adapt the parameter set of the regulation as well as for selecting or correcting the melting profile.

Electrode consumption evaluation

Using the hydraulic pressure measurement of the electrode lifting cylinder, the weight of the electrodes is calculated. This information is used to estimate electrode consumption.

Heating rate evaluation

The Melt Expert computes and logs the heating rate of the furnace. As long as there is not a lengthy idle time, material addition, or roof opening, the heating rate data is considered and stored in a report.

Power supply and phase rotation monitor

A constant power supply is essential for stable production conditions. Any fluctuation in the supply network influences the primary voltage and in turn the energy input into the furnace. Therefore, it is very important to be aware of changes in the supply circuit. The Melt Expert monitors the supply network and reports unusual fluctuations.
In addition, the phase rotation is checked periodically and automatically.

Fig. 7 Melt Expert system monitoring

Control-loop optimization assistant

A continuous review of the regulator's current performance and parameter adaptation to changing environmental condition are vital for maintaining a high performance. The optimization assistant quantifies the quality of regulation by judging the ability to maintain the set-point. This provides important information for the tuning and optimization process.

4. USER EXPERIENCE FROM FERALPI RIESA, GERMANY

Today the traditional demands on electrode control systems – like savings in energy and electrodes and the highest degree of reliability – are mandatory. To get the maximum benefit from the installation of a new electrode control system, first of all the new device must be technically capable. This means that the control algorithms need to be state-of-the-art and self-adaptable for the various melting stages. Secondly, and no less important, the electrode control system needs to provide feedback about current performance. Only with this information is a sustainable tuning process of the furnace possible.

The Melt Expert was installed in an electric arc furnace at Feralpi Riesa in Germany at the beginning of 2016.

In the first step, the existing electrode control system was replaced by the Melt Expert. The previous controller was kept as a standby solution.

In the second step, the measurement system was replaced by Rogowski coils and a fine-tuning of the regulation system was performed.

After one and a half years of operation, the following results have been observed.

First of all, and probably most important, significant reductions in energy consumption and power-on time have been achieved.

The effort for system maintenance has also been substantially reduced. Because a relevant date is available at the press of a button in the maintenance office, much less time is spent on inspections and routine checks.

Compared with the previous system, far more information is available. The intelligent evaluation of this data allows the actual condition of the furnace to be assessed. Creeping-in defects and wear can be detected at a very early stage, which makes maintenance more plannable.

Even though these effects can't be directly quantified in terms of monetary savings, the improvements in maintenance quality are substantial. The KPI evaluation of the electrode control system is an important approach, and will be intensified in the future at Feralpi Riesa.

5. SUMMARY

Primetals Technologies' newly developed electrode control system was developed using the design principles of Industrie 4.0. In addition to the core regulation functionality, many more features that deliver information about the process were implemented. By providing a comprehensive overview of actual performance and early warnings of creeping-in defects, the system creates a solid basis for keeping furnace performance at a high level.

A mobile app serves as a furnace "fitness tracker." Like the fitness apps that improve personal physical condition, it delivers key data on current performance and indicates approaches to keep performance high.

With more than 15 installations, the Melt Expert is now established in the market.

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