EAF Process Optimization in OEMK with AMI SmartFurnace technology

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With the requirements of the highly productive Electric Furnaces in OEMK, in Stary Oskol, Russia, and the necessity to adapt to the variability in raw materials and furnace conditions, an agreement was reached to install the latest AMI SmartFurnace technology in all four Furnaces. With state-of-the-art technology, the latest AMI SmartFurnace system, featuring optimization tools like the DigitARC PX3 Electrode Regulation System, and the latest modules for Electrical and Chemical energy control, have helped improve the operation in three furnaces as of April 2021, with the fourth one planned in June of this year. With this technology, the interaction between electric power and burners, coal & oxygen injection, and the feeding of DRI, is managed by the Electrical, Chemical and DRI Optimization modules, which provide a flexible and open platform with artificial intelligence tools, for the implementation of dynamic modelling of all energy sources in the EAF process.

KEYWORDS: EAF OPTIMIZATION – EAF CONTROL SYSTEMS – ELECTRODE REGULATION – DRI FURNACES – EAF CHEMICAL ENERGY INPUT

INTRODUCTION

The optimization of the steelmaking process can have radically different approaches depending on the specific conditions of a steel plant in a specific period of time. When the main objective is cost reduction, the optimization can be focused on decreasing the consumptions of electric power, oxygen, carbon, natural gas, etc. by affecting the production at minimum. If the objective is to increase production, the strategy must be different, considering other factors such as the electric power equipment including the transformer, reactor and constraints of the power line. For the OEMK plant in Russia, an additional challenge comes from the usage of DRI. The variations in the raw material characteristics have a direct impact on the performance of the furnace, so the DRI analysis and a close observation of the reaction of the furnace is critical to have optimal operation.

No matter what the main drive is, the main goal of the optimization task usually is to find the balance point of the needed trade-offs to maximize the benefits in every heat, and to have a system with the flexibility to adapt the operation when the conditions change.

PLANT AND PROJECT DESCRIPTION

The JSC "Alexey Ugarov" OEMK plant is a steelmaking facility, part of the Metalloinvest group, located in Stary Oskol, in the Russian Federation. Started in 1984, and in 2020 the plant more than doubled its designed capacity by producing 3.5 million tons per year of crude steel, with long products, square and pipe billets.

JSC OEMK "Alexey Ugarov" is also the only integrated plant in Russia that carries out direct iron reduction and smelting in electric arc furnaces. Its capacity is 3.5 million tons of metallized pellets per year, at all four metallization plants.

	EAF 1	EAF 2	EAF 3	EAF 4
MVA Transformer	105	105	105	105
Total Charged Tons	175-180	175-180	175-180	175-180
Total Scrap Tons	45-50	45-50	45-50	45-50
HBI in Scarp Tons	10-20	10-20	10-20	10-20
DRI Usage Tons	125-130	125-130	125-130	125-130
Feed Capacity Ton/h	3	3	3.1-3.2	3.1-3.2
# Burners with Carbon Injectors	2	2	3	3

By 2007, all four furnaces had the then latest AMI DigitARC+ Electrode Regulator, and latest versions of the SmartFurnace optimization Modules at the time. In 2018 conversations started for upgrade of all the existing AMI technology to the latest versions. In May 2019 a contract was signed for EAF #3, for execution in October of the same year and after a successful conclusion there, a contract was signed in March 2020 for upgrading of the rest of the furnaces. As of April 2021, projects in EAF #2 and #4 have been concluded successfully, and the last EAF shall be revamped in June 2021.

AMI SYSTEM DESCRIPTION

The SmartFurnace EAF Optimization system consists of a series of interacting entities. The DigitARC PX3 electrode regulator, together with the Electrical and Chemical energy supervisory control application, provide an integral optimization solution of the furnace operation parameters, interconnected to the PLC's through the process network using proprietary drivers, and to the electrode and fluxes actuators. This interaction as installed in OEMK is described in Figure 1.

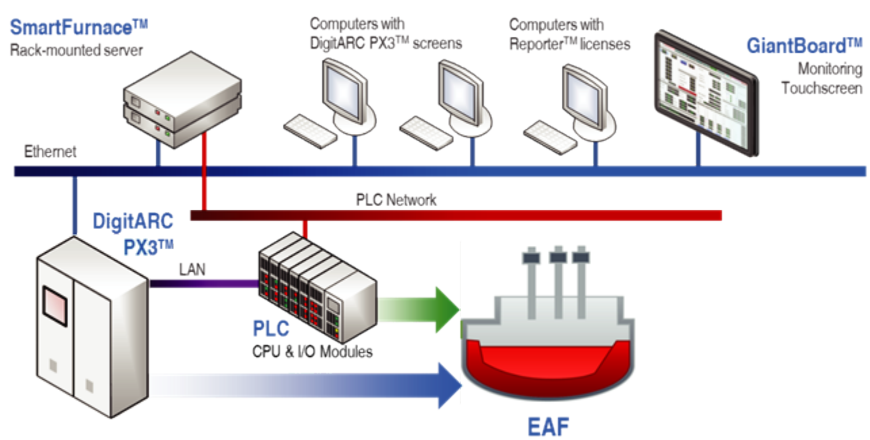

Fig. 1 – SmartFurnace System Architecture in OEMK

DIGITARC PX3 ELECTRODE REGULATION SYSTEM

The AMI electrode regulator available for AC and DC furnaces is capable of a fast close loop control and fast execution of complex algorithms supported by a dedicated CPU that allows a fast data acquisition to be used for several optimization tools and process monitoring features, including:

- Monitoring of Arc Stability for AC and DC EAF´s
- Control output filtering to eliminate resonance frequencies
- Advanced proportional valve tests
- Preemptive Cave In and a Dynamic Non Conductive Charge detection
- High speed acquisition of Electrode Speed and Electrode Hydraulic Pressure
- Regulator and furnace performance reports

All these features are significant improvements compared to the capabilities DigitARC+ Electrode regulator, installed in 2006 and 2007, due to availability of new technology, and the experience of AMI since that time to the present.

SMARTFURNACE MODULES

The optimization task consists of finding the balance among all the parameters considering specific production goals that might change over time. SmartFurnace is designed to provide a robust and flexible solution to adapt the furnace operation to the actual situation of scrap quality, mix, steel grade, practices, furnace conditions, etc. The modular design of the system gives the possibility to provide a tailored optimization solution to the specific needs of the client, allowing to add them gradually as they are needed. The subsystems that are part of the installation in OEMK are SmartARC, Oxygen, DRI, and Slag Modules. The base of SmartFurnace is the VisualKB platform, an Expert System graphic programming software developed by AMI.

SmartARC

Using dynamic Power Profiles, SmartARC system adapts to the current heat conditions changing the electrical parameters that provide the flexibility to the operation in order to achieve optimal performance. These parameters include the transformer and reactor taps, regulation mode, and current/voltage setpoints. SmartARC allows to have EAF optimization tools like:

- Cross Arc detection
- Furnace roof and Water-Cooled Panels protection
- Balance control
- Refractory protection

Oxygen Module

The C and O2 flow control is done with this module. In order to do so, the bath current oxidation is estimated using the injected oxygen value, and the estimated oxygen demand of the furnace reactions. With these statistical calculations, the system is able to determine the precise moment to start and stop the Oxygen lancing. A precise control of the oxidation and carburization minimizes the delays at the end of the heat to correct the steel carbon content and decreases the FeO levels in slag.

Slag Module

The Slag Submodule determines the recommended fluxes that should be added to the furnace to achieve an optimal level of MgO saturation in the slag, based on the chemical analysis. This condition promotes the formation of foamy slag, arc stability, and protection of the refractory. The estimations of the system allow minimum FeO contents in the slag and lower energy losses in the slag formation process.

DRI/HBI Feeding Module
This module controls the feeding rate of DRI considering the conditions of the heat and the chemistry of the DRI. A controlled feeding helps improve the energy usage efficiency, allowing an interaction with the electrical profiles adapting to the reaction of the Furnace to the charge material, and optimizing the speed of feeding to achieve the complete material charge without affecting the heat time and the power input. When the composition or metallization of the DRI changes, or the quantity of DRI used on a particular heat, the contribution of Carbon into the bath may change considerable and is very dependent of the DRI rate used and the heat stage. These variations of DRI request a coordinated control of the Carbon Injection.

SMARTFURNACE IMPLEMENTATION RESULTS
In all three furnaces that have the system installation so far, there were two KPIs that were evaluated, Electrode Consumption and Carbon Injection. The evaluation consisted in running each furnace for one month and calculate the average Electrode and Carbon consumptions using every single heat. The idea was to test the performance of the system under real working conditions rather than restricting the test to a few heats with controlled conditions. The result of the implementations so far have been:

	EAF 2	EAF 3	EAF 4
Electrode Consumption	3%	3%	3%
Injected Carbon	4%	4%	4%

Other benefits such as reducing electricity consumption have been observed. These results are obtained without the deterioration of the remaining furnace performance.

In SmartFurnace, a PID controller is implemented to improve the control of carbon injection from the Burners. Before implementation, the control was carried out by regulating the pressure and for different carbon fractions the task did not always coincide with the real flow rate.

One advantage of the project schedule in OEMK is the experience gained on sequential installations in the furnaces is that opens the possibility to test different control approaches in the implementation of the system, and it is possible to compare the performance between them. The result is that the control algorithms running on the first furnaces can be updated with improved features tested in the newer installations. At the end, the objective is that OEMK has the latest version of the SmartFurnace control algorithms.

CONCLUSION

With the variables involved and the many elements that interact in the OEMK furnaces it might be difficult to adjust and evaluate to a wide extent the performance of a complex system such as SmartFurnace. Benefits such as life of the refractory, better working conditions of the transformer, all power equipment may not be reflected immediately but rather in a longer term, which all come from a more efficient use of the energy input. Furthermore, with the collaboration with OEMK, the presented improvements have proven to be consistent.

REFERENCES

G. FERNANDEZ, I. VALDEZ, S. GONZALEZ, J. VILLEGAS; Using SmartFurnace and ZoloScan laser off-gas information to optimize DRI melting at Nucor Hickman. AISTech (2016).

F. MARTINEZ, G. FERNANDEZ, Technologies for EAF Energy Optimization, Proceedings, EEC Conference, Venice (2016).