TECHNOLOGIES FOR EAF ENERGY OPTIMIZATION

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This paper describes the works and results during the optimization process of the EAF. Today, steel production requires the highest standards of operation in order to remain competitive, so the advantages of operation standardization and the flexibility provided by the DigitARC PX3 Electrode Regulation and the SmartFurnace to handle changing operating conditions are evaluated, while efficiently controlling the electrical and chemical energy input. Equipment reliability and robustness of the Control System design and the ZoloBOSS Laser Off Gas Analyzer are also part of this paper.

Keywords: EAF Optimization, EAF Control Systems, Abnormal Water Vapor Detection, 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. 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.

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 is described in Figure 1.

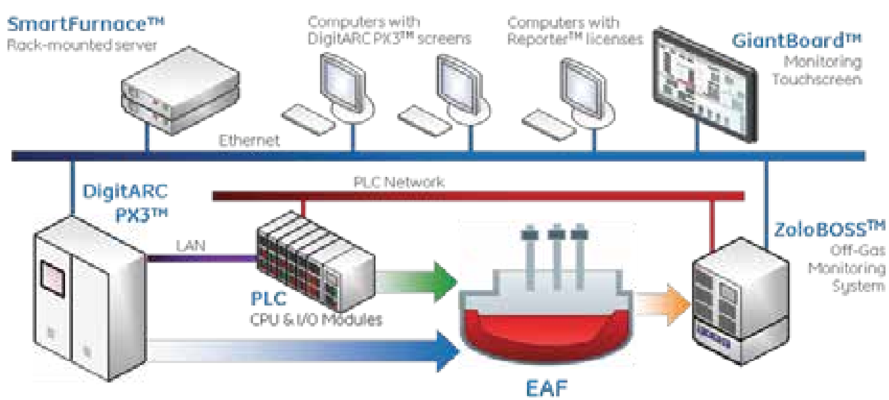

Figure 1. EAF Optimization System Architecture

DIGITARC PX3 ELECTRODE REGULATION SYSTEM

This 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

SMARTFURNACE MODULES

The optimization task consists on finding the balance among all the parameters considering specific production goals that might change over time. The optimization system 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. These subsystems are SmartARC, Oxygen, DRI, Slag and latest Off-Gas Modules. The base of these modules is the VisualKB platform, an expert system graphic programming software developed by AMI.

SmartARC

Using dynamic power profiles, this 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. This platform 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 submodule for slag control 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

In furnaces where continuous DRI/HBI feed is used, it is possible to integrate the module to control the feed rate considering the conditions of the heat. A controlled feeding helps improve the energy usage efficiency. The technology of this module has made it possible to adapt it to the control of continuous scrap feeding to furnaces with this charging method.

Off Gas Module

The latest integration to SmartFurnace is the module for off gas control, using the ZoloSCAN laser monitoring system, which detects the concentration of CO, $CO2$, $H2O$ and the temperature of the gases. With this information, it is possible to close the control loop of chemical energy, helping to optimize the use of carbon and oxygen. The $H2O$ monitoring can identify abnormal concentration of water in the furnace exhaust gas.

The tunable diode laser absorption spectroscopy (TDLAS) technology of this probe, has proved to accurately provide real time monitoring of the CO, $CO2$ and $H2O$ concentration at a speed that allows to close the chemical energy control loop. Laser transmitter and receiver heads with automatic alignment are installed on the duct, sending a single laser ray through optic fiber up to the duct gap, and returning to the control cabinet again by optic fiber [3]. The usual setup of the off gas probe is shown on Figure 2.

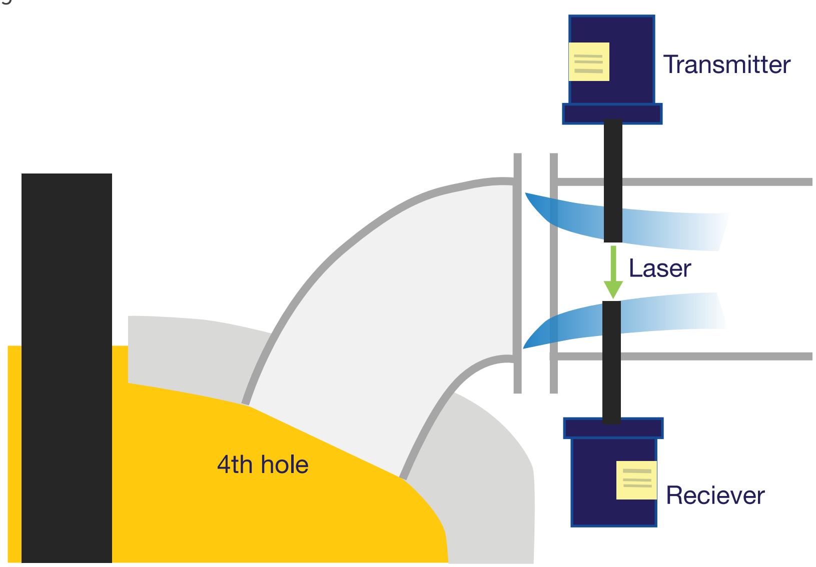

Figure 2. Usual setup of the ZoloSCAN Off Gas monitoring probe.

SMARTFURNACE IMPLEMENTATION RESULTS

ArcelorMittal Zaragoza

By the end of 2012, the electrode regulator and the optimization systems were implemented in a DC EAF in the ArcelorMittal plant in Zaragoza, Spain, together with an upgrade of the rectifier control with the objective to add flexibility to the process and being able to adapt it to variable market conditions and an expected increase of the energy costs [1]. The largest producer of merchant bars in the country, this plant produces Rear, Angles, Flats, U and UPN profiles. The furnace has the following characteristics:

- 7100 shell diameter
- 120 tapped tons
- Maximum 1100 V and 110 kA DC
- 4 RCB burners and 3 Carbon injectors

The strategy for the electrical energy optimization considered the relatively large width of the shell, allowing the use of longer arcs minimizing energy losses and reducing electrode consumption, but constrained to prevent damage to the water cooled panels and refractory wear. With the electrode position, energy consumption, and an accurate DC arc stability measurement using proprietary algorithms, a dynamic voltage set point program was developed.

After an exhaustive analysis of the chemical energy, it was determined that the variable with best correlation with the cost was the Carbon usage. With an accurate control of the oxidation, a reduction in the carbon injection was made reducing the operation cost. The control of lime injection also helped reduce the cost as better stability was achieved.

The results showed that the production cost is decreased as less oxygen and carbon is used. As better stability was achieved it was possible to increase the electric power input, decreasing the Power On time. The main reported results are:

- EAF electrical consumption reduced by 7%
- EAF gas consumption reduced by 4.5%
- EAF foaming coal consumption reduced by 35%
- EAF refractory bricks life increased by 15%

These results were achieved after 3 years of collaboration between ArcelorMittal Zaragoza personnel and AMI. The possibility of an open system such as this, allowed the client to be actively involved in the optimization of the furnace.

NorthStar Bluescope

Located in Delta, OH, in United States, NSBSL has two AC twin shell shaft furnaces with a single set of electrodes [2]. The use of preheated scrap together with the feeding of Pig Iron on a twin shell furnace added several controlled variables to the optimization task compared to standard EAF's. The control of the electrical energy was performed using the SmartARC module. The chemical energy automatic control was implemented with Oxygen, Slag and Off Gas modules.

During 2015, the installation of the ZoloSCAN probe for off gas monitoring was carried out to detect the concentration of CO, CO2, H2O and the temperature of the gases. This proved to be a challenge due to the nonstandard configuration of the exhaust duct of the twin shell. As the probe was located at the exit of the shaft, where most of the CO has already transformed into CO2, which had to be taken into consideration. Due to the characteristics of the gas extraction, a camera system was also installed to monitor the gas output through the roof. The location of the probe can be seen in Figure 3.

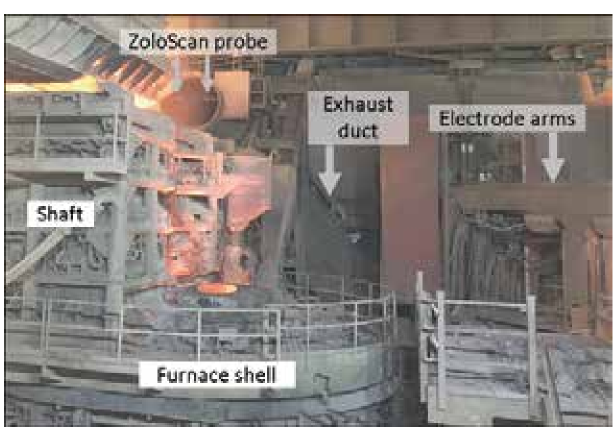

Figure 3. NSBSL Furnace

While the use of the Laser Probe with the Off Gas module helped to optimize the chemical energy input, a major objective of this installation was to monitor the water vapor inside the furnace. By using a complex algorithm that considers the H2O concentration of the off gas, its temperature, and the gas flow through the flow meter and the camera, the water vapor mass is calculated. Other variables such as the preheating time, damper position, natural gas consumption, duct temperature, pressure and moisture among others, must be considered in order to have an accurate estimation of the H2O vapor in the furnace. This information is used to create a profile of the typical water vapor found under normal circumstances. Figure 4 shows the predicted water vapor profile (red) and the actual measurement from the probe (blue). Figure 5 shows the detection of an abnormal level of water vapor. The Off Gas module triggered an alarm that indicated an actual water leak less than two minutes after its detection.

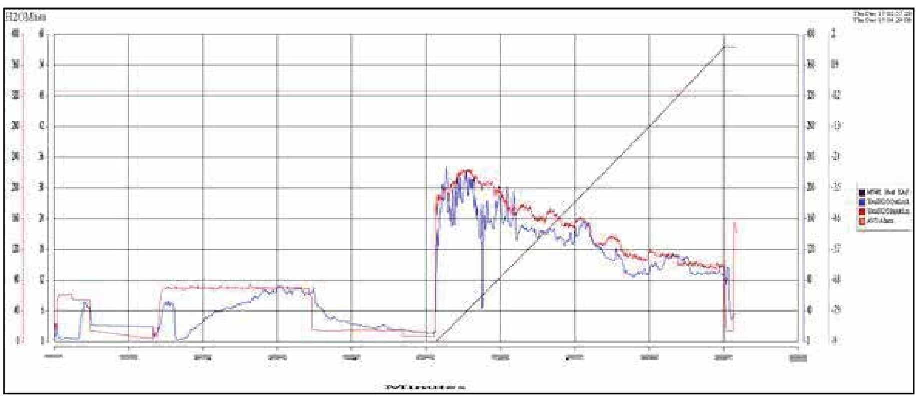

Figure 4. Predicted (red) Vs. measured (blue) water concentration.

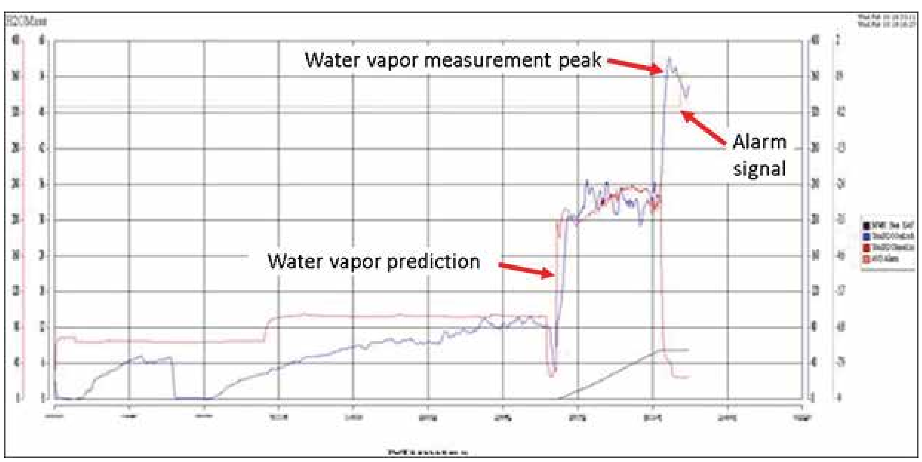

Figure 5. Detection of abnormal water vapor concentration levels

After the implementation of these tools, the obtained improvements in some of the performance indicators of the furnace are as follows:

- Power on Time: 5.2 %
- Yield [%]: 0.7 %
- Energy [kWh/ton]: 1.6 %
- Oxygen [nm3/ton]: 4.0 %
- Natural Gas [nm3/ton]: 5.3 %
- Lime [kg/ton]: 2.4 %
- Carbon [kg/ton]: -1.8 %

The ongoing cooperation between NSBSL and AMI is focused on improving the excess water vapor estimation and an overall optimization task.

CONCLUSION

The evaluation of performance improvement in the EAF is usually difficult to carry out. The variables involved and the many elements that interact in the furnace can have vastly different ways to be looked at, depending on the priorities of a certain furnace at a certain period, since priorities tend to change over time.

Arc stability is one of the main indicators to evaluate performance. In DC furnaces the measurement of arc stability by the optimization system is achieved accurately with proven technology in many installations around the world.

With improvements in the response of the system and the usage of chemical and electrical energy, by consequence other benefits such as life of the electrodes, refractory and hydraulic system, as well as the transformer, reactor and all power equipment have better working conditions.

New developments such as the Off-Gas module featuring the Laser probe with already many installations, have recently contributed to further optimize the EAF process.

REFERENCES

1)G. FERNANDEZ, J. ARRIBE and J. LAPORTA. Optimization of ArcelorMittal Zaragoza DC EAF using AMI SmartFurnace. 2nd ESTAD Proceedings. METEC, Dusseldorf, Germany (2015).

2)I. PEREZ, J. CARGILL, K. GRIESHABER and F. MARTINEZ. SmartFurnace and ZoloSCAN Laser Technology in NSBSL EAF Shaft Furnace. AISTech 2016 Proceedings. Pittsburgh, U.S.A (2016).

3)K. GRIESHABER and F. MARTINEZ. ZoloSCAN Laser Diagnostic System for EAF Leak Detection and Process Optimization. 2nd ESTAD Proceedings. METEC, Dusseldorf, Germany (2015).