EAF Optimization Technology for Stainless Steel production with Dynamic Model applications

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Aperam Châtelet is a Stainless Steel producer based in Belgium. At the end of 2019, AMI was comissioned with the installation of the SmartFurnace Optimization Technology for their 160 ton EAF. The first step in the execution of the project was the installation of the DigitARC PX3 Electrode Regulator and the SmartARC Module, both for optimization of the Electrical Energy input in the EAF. The Dynamic Models were implemented attending the different needs of Austenitic and Ferritic grades, and focusing on consumptions of Electrode and Electrical Energy, and increasing productivity. A second step consisted on the control of the chemical energy input with the SmartFurnace Oxygen Module. This development was made with considerations in the Oxygen and Natural Gas control with the lance burners, according to scrap density, and the particular stainless steel grades. A development for the control of slag is the third step in the scope of this project, which is a cooperation between the Aperam, AMI Europe and AMI North America teams. Details of the technology used are presented in this paper, as well as results of the implementation.

KEYWORDS: ELECTRIC ARC FURNACES – STAINLESS STEEL - FURNANCE OPTIMIZATION

INTRODUCTION

The plant has an AC Electric Arc Furnace of 160 tons with a 8000 mm shell diameter. The furnace has a 140 MVA transformer with electrode size of 28 in. Additionally, the furnace has 3 sidewall burners used to improve the melting of scrap. The steel plant produces austenitic and ferritic grades in a 50:50 proportion.

CONTROL SYSTEM

The complexity of the stainless steel process demands many considerations in order to have optimal operation given the varying conditions in the furnace and raw material characteristics for the different practices and produced steel grades. The SmartFurnace concept for optimization developed by AMI consists of a modular dynamic control system, which keeps control of the EAF chemical and electrical energy input, with the objective to optimize the process adapting it to the actual production needs and constraints. For Aperam Chatelet, the AMI scope included the DigitARC PX3 Electrode Regulator, the SmartARC Electrical optimization module, and the Chemical Energy and Slag Modules development by both Aperam and AMI specifically designed for their stainless steel process. One important element of the installation was the VisualKB graphic programming platform. This proprietary AMI software allows not only to implement the complete SmartFurnace system and fully integrate it to the existing network infrastructure, but it gives the flexibility to easily add and remove parts of the program, to constantly adapt the functionality of the program. This software and its capabilities, designed to be a tool for development and continuous improvement, played an important role in building the dynamic profiles for melting scrap. Figure 2 shows the main screen of the platform.

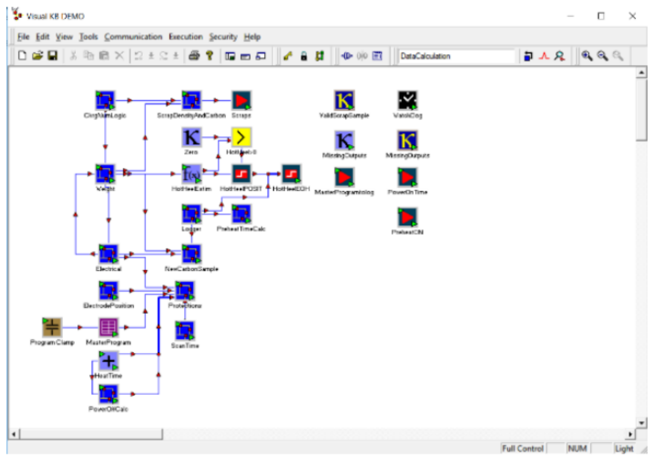

Fig. 2 – Graphic algorithms implemented in Visual KB.

Figure 3 shows the architecture of the AMI system, which in this case consists of two hardware elements. One is the Electrode Regulator cabinet, the second is the SmartFurnace server, where the optimization modules are implemented. These devices are integrated in the Aperam network to exchange information with the existing infrastructure including PLC's and databases.

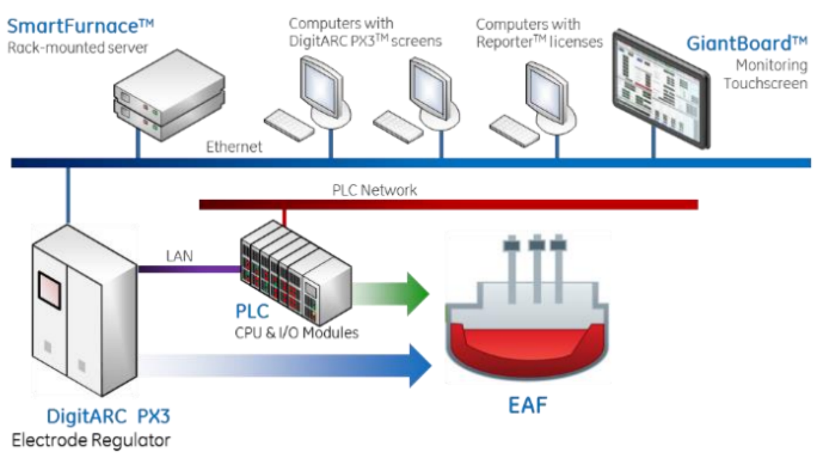

Fig. 3 – Architecture of the AMI System.

DIGITARC PX3 ELECTRODE REGULATOR

The electrode regulation system installed on both the AC and DC furnaces is designed with a fast closed loop control and execution of complex algorithms supported by a dedicated CPU that allows a fast data acquisition. Several optimization tools and process monitoring features are implemented, such as:

- Monitoring of Arc Stability for AC and DC EAF´s
- Control output filtering to eliminate resonance frequencies in the arm
- Advanced hydraulic 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

An additional processing unit is used for logging, diagnostics, and connectivity. This dual setup allows a fast execution of the control program with zero delay on the control commands sent to the proportional valves. It also provides dedicated I/O for high speed data logging used for both control and diagnostics like the electrode arm pressure and electrode position. It also includes a user friendly graphic interface.

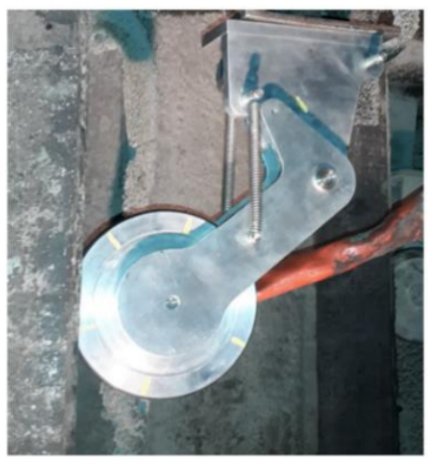

Fig. 4 – Powe quality meter (left) and electrode speed sensor (right).

Figure 4 shows some of the instrumentation of the Electrode Regulator. A Power Quality Meter allows power distribution diagnostics and measurement of flicker and harmonics. Additionally, with the installation of precise position sensors it is possible to evaluate the behavior of the electrode movements, making Electrode Tests. Differences in the results of the tests overtime may indicate changes in the dynamics of the hydraulic system, or mechanical issues.

SMARTARC

The main concept behind SmartFurnace is the Dynamic Power Profile as opposed to a fixed melting profile. In the case of SmartARC, this approach is used for controlling the electrical energy input in the furnace to achieve optimal performance for different steel grades and furnace conditions. The controlled variables include the transformer and reactor taps, regulation mode, and current/voltage setpoints. The capability of interacting directly with the electrode regulator enhance the response and adaptability for more efficient process control. The SmartARC system un Aperam takes in consideration the following process variables:

- Heat MWH
- Arc stability of each phase
- Statistical values of three phase currents
- Panel temperatures
- Primary voltage and current
- Steel grades

Additionally, any data that is available in a PLC or a database about characteristics of raw material, equipment availability or the process in general, can be used to increase the adaptability of the system. Specific control algorithms are developed for improving safety and efficiency, such as protections of Water Cooled Panels and refractory, mainly by having a better control of the arc, decreasing damages by radiation, and adapting the current setpoints continuously to prevent long arcs that might reach the walls or roof.

Oxygen Module
The Oxygen module was prepared to control the burners and the oxygen lancing. A dynamic program designed for the different practices of Austenitic and Ferritic grades was implemented, considering several conditions of the heat, particularly the stability of the electric arc and the composition of the charge.

The Stability Factor, calculated by the DigitARC PX3 Electrode regulator is a direct indication of the efficiency of the electrical energy input, so it can be used as a feedback for a dynamic chemical energy profile. With this calculation, the SmartFurnace system is able to determine the precise timing and flow for the burners, and later during the heat, to move on with the oxygen lancing.

Slag Module
The Slag Submodule determines the recommended fluxes that should be added to the furnace to achieve an optimal slag composition, and improve the slag formation process. This particular project was a joint collaboration of Aperam and AMI, implementing real time corrections with flux calculation logic implemented in the VisualKB programming platform. Using the extensive scrap chemistry, a model capable of correcting the amount of fluxes and alloys to reach the aim basicity-saturation and required steel composition was implemented, improving the consumption of material.

PROJECT EXECUTION
The project was executed in two consecutive stages with an individual evaluation procedure for each. The first stage consisted on only the DigitARC PX3 Electrode Regulator and SmartARC Electrical Energy Optimization System. Two sets of profiles were created for both steel grades, Ferritic and Austenitic. The objective was to test the performance of the electrical energy optimization for a longer period. This was accomplished during spring 2020, successfully concluding this stage.

A second part of the project consisted in the implementation of the Oxygen Module for control of burners and oxygen lances. Not only a dynamic program was implemented using stability of the arc and heat conditions to constantly calculate the optimal setpoints for gas and oxygen, but also a readjustment of the electrical energy control of DigitARC PX3 Electrode Regulator and SmartARC was made, to synchronize the complete energy input in the furnace.

Finally, as a third stage, a joint development between Aperam and AMI was executed for optimization of the slag control. The objective was to introduce a dynamic control of the lime feeding, and a recommendation of the charged fluxes based on the charge composition.

RESULTS

With the described system, Aperam Chatelet, had the following overall results in their operation KPIs, with the complete system:

- Power On Time: Reduction of 3.5%
- Natural Gas Consumption: Reduction of 7.5%
- Graphite Electrode Consumption: Reduction of 10.5%

Other reported benefits for longer term have included a reduce in the transformer tap change count per heat of 10%, a reduction of Electrode Breaks due to scrap cave ins and Non Conductive Charges of 23%, and with the Oxygen + Slag Modules calculations, a reduction in the Si% dispersion has been achieved.

These results have been observed without a negative impact in electrical energy consumption, refractory wear, or panel life.

CONCLUSION

The advantages of an open and flexible system for EAF optimization, gives the opportunity to adapt the control to the specific conditions of the furnace at any given time during the heat. After the conclusion of the project, a framework for collaboration between both companies has been implemented, including services aimed to continuous improvement, and new developments to enhance the functionality of the control system.

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