EAF dynamic process optimization with AMI SmartFurnace Modules in Duferdofin Nucor

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The optimization task in the Electric Arc Furnace requires a very precise balance of the interaction between the chemical and electrical energy. With the increasing number of high productive EAF, the use of burners, coal injectors and oxygen injection in coordination with electric power play a significant role in improving the efficiency of the steel making process. Besides, with constant changes in demand, produced steel grade, and raw material quality among other constraints, the need for a system capable of adapting to the current operation conditions becomes critical. With this situation in mind, Duferdofin Nucor, a steel plant located in San Zeno, Italy, made an installation of the AMI technology in their Electric Arc Furnace during the summer of 2018. This paper describes how the AMI SmartFurnace system, featuring the DigitARC PX3 Electrode Regulator together with Electrical and Chemical Energy Input Modules, helped optimize the operation in Duferdofin Nucor, with results in efficiency and productivity. The details of this system are discussed and results of its functionalities are shown.

KEYWORDS: EAF, FURNANCE OPTIMIZATION – EAF CONTROL SYSTEMS – ADAPTIVE CONTROL – ARTIFIICAL INTELLIGENCE.

INTRODUCTION

The Duferdofin Nucor group is an Italian company specializing in beam production, mainly for the European and North African market. With four production units distributed around Italy, the San Zeno Naviglio plant in Brescia is where the group melt shop is located. This plant has a capacity of 800,000 tons per year of hot rolled long products, and is equipped with one Electric Arc Furnace, one Ladle Furnace, a Vacuum Degassing plant, and two Continuous Casting machines. The production consists of round, square, and rectangular sections and dog-bone semi-finished sections for rolling or direct hot rolling. Around half of the plant output is dedicated to special grades. The production line is then continued in the Pallanzeno and Giammoro rolling mills.

DUFERDOFIN NUCOR EAF

The plant has an AC Electric Arc Furnace with a capacity of 100 tons and a tapping size of 90 tons. It is an EBT layout with a 6300 mm diameter. For electric power, it is equipped with a 100 MVA transformer and electrode size of 600 mm, while for chemical energy it has three Oxy-Fuel lances, two Carbon Injectors, and 1 Lime injection point. The used raw material is mostly scrap in two to three buckets. Figure 1 shows the layout of the EAF at the moment of the system installation.

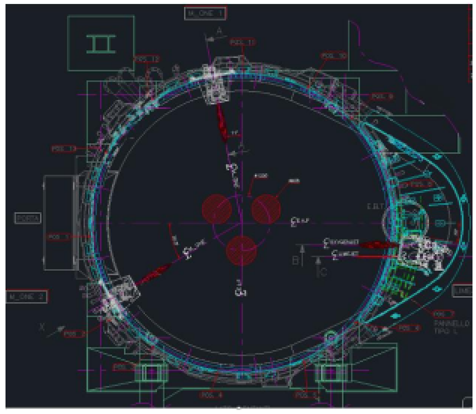

Fig. 1 – EAF Layout

CONTROL SYSTEM

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 make the process as efficient as possible, adapting it to the actual production needs and constraints. The AMI scope included the DigitARC PX3 Electrode Regulator, and the VisualKB development platform where the AMI SmartARC Electrical optimization module was implemented, a part of the SmartFurnace solution. This same programming platform was used to implement a Chemical Energy Control developement. This platform gives SmartFurnance artificial intelligence capabilities, complex decision making tools in a completely open programming environment, allowing customers to access the system and add specific functionalities as needed. Figure 2 shows the main screen of the platform.

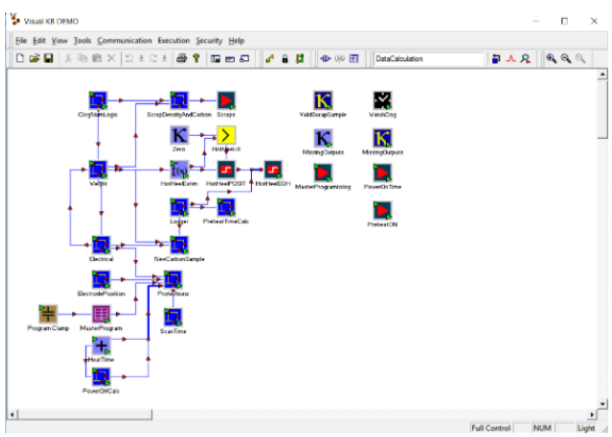

Fig. 2 – Graphic algorithms implemented in Visual KB

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 Duferdofin Nucor network to exchange information with the existing infrastructure including PLC's and databases.

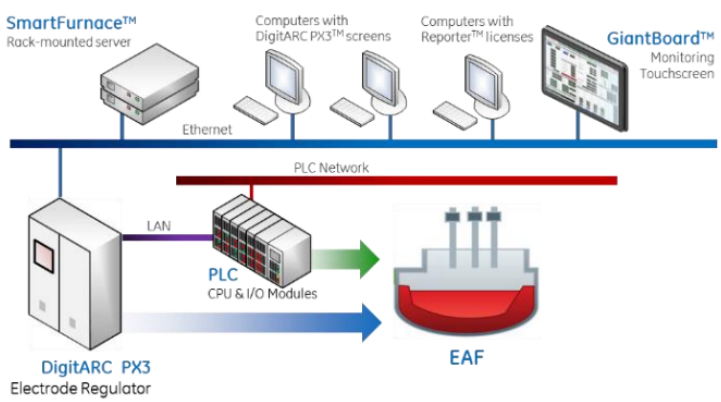

Fig. 3 – Architecture of the AMI System

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.

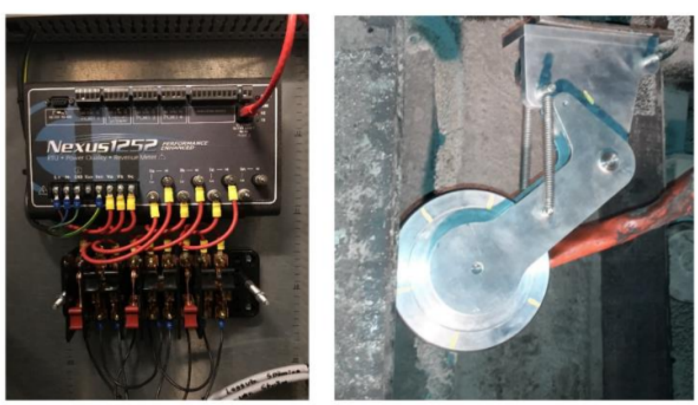

Fig. 4 – Power quaity meter (left) and electrode speed sensor (right)

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 according to the actual conditions of the heat, adding the flexibility to the operation in order to achieve optimal performance. 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 feedback used for closed control loop varies in source and characteristics, and is tailor made to each installation. A typical SmartARC system 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

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:

- Cross Arc detection, when the atmosphere inside the furnace becomes conductive due to carbon dust or steel fines this might produce arcing between phases which greatly affect Power Input and might cause arcing in panels.
- Water Cooled Panels and refractory protection, 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.

PROJECT EXECUTION

When the system testing started, the settings were the same as the original system in terms of electrical balance, transformer taps used and current levels. The maximum tap used was limited to prevent refractory wear around the area right in front of phase 2 which was caused by the current electrical balance in the furnace. This was a setting that was hardly changed since it have proven to be a source of problems in the past. After analyzing the electrical balance and the behavior in the furnace, the arc lengths were slightly increased in phase #2, but with less power.

After fine tuning, the refractory wear improved drastically in front of phase #2 and became even around the furnace even with longer arcs. This change allowed later to increase the transformer tap by two steps, increasing the secondary voltage by 60 volts. This was reflected later on a decreased electrode consumption and power on time. Regarding the chemical energy control developed jointly with the Nucor group, the original operation was a practice with a tendency to produce some extra oxidation in the steel.

The goal with this practice was to run with low energy consumption and avoid delays due to decarburization. Based on the carbon estimation module, it was very likely we were wasting some chemical energy with this type of operation. The chemical control module was then set with a new practice to limit the oxygen usage based on the oxidation estimation, and also to reduce natural gas usage when the scrap melting stage is most likely finished. With this new operation the furnace was able to run with the same energy consumption but less Carbon, Oxygen and Natural Gas. This also helped on the refractory wear and the electrode oxidation.

RESULTS

With the described system, Duferdofin Nucor the following result was quantified focusing on increasing productivity:

- Power On Time -5.9%

Besides the increase in output, other associated benefits included reduced refractory wear, and electrode consumption. These are sustained results over the period of 4 months. The Chemical Energy control development added benefits in the use of oxygen, gas and carbon as well.

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. As an example, with the addition of a 4th burner, the optimization task will continue as a joint cooperation between Duferdofin Nucor and AMI integrating the new equipment into the dynamic profile. Figure 5 shows the layout of the furnace with the new burner.

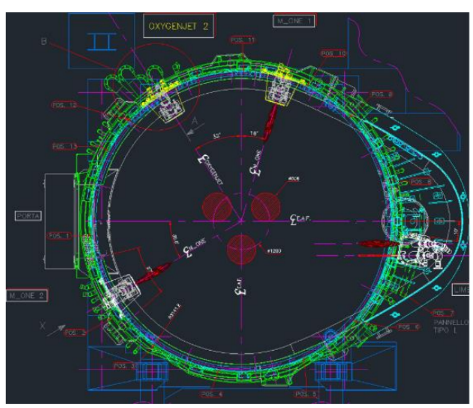

Fig. 5 – EAF Layout with the new burner

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