

AMI Artificial Intelligence Developments for EAF Optimization in Nucor Steel Arkansas

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ABSTRACT

The amount of data available in the modern Electric Arc Furnace operation, has proven to have enormous potential for process analysis and improvement using the latest Artificial Intelligence tools and algorithms, as they have been implemented on a dedicated software recently developed by AMI, the SmartKnB platform.

SmartKnB is a graphic programming interface making it possible to develop solutions merging data acquisition, complex process logic and machine learning models. Its implementation in Nucor Steel Arkansas helped to improve EAF performance and increased refractory life for longer and safer campaigns by better controls of DRI feedrates, chemical energy and power inputs.

Keywords: Artificial Intelligence, Machine Learning, Smart Furnace, Chemical Energy, Optimization

INTRODUCTION

Nucor Steel Arkansas (NSA) has two furnaces with similar configuration, both have a 26 ft diameter and 150 tap ton capacity while maintaining a 75 ton hot heel. The capacity of the transformer is 81.496 MVA. The EAFs are limited to a potential of 950 V and a current of 140 KA. Each furnace is equipped with a top feed system with a capacity of 300 Ton/hr, which is used for DRI, carbon, lime and dolomitic lime.

The furnace is equipped with 4 PTI burners with a maximum flow capacity of 2000 scfm of oxygen and 300 scfm for natural gas; Figure #1 shows the position of the burners and the roof feeding.

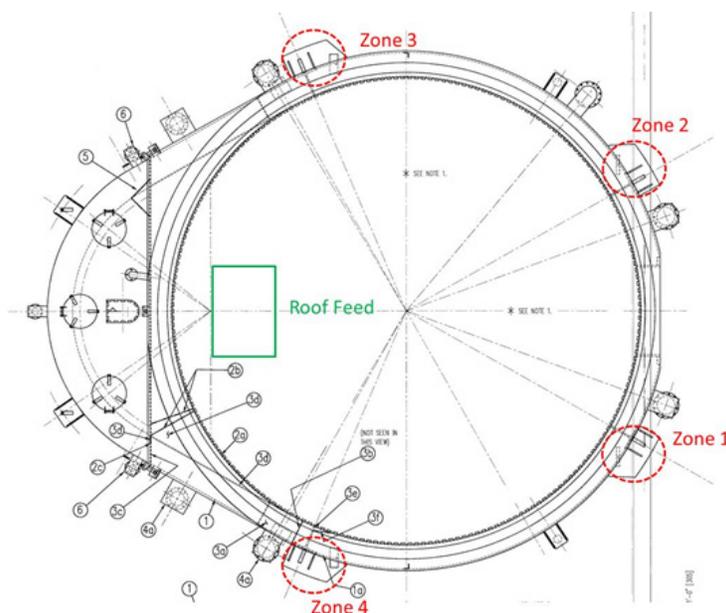


Figure 1. EAF layout diagram

The implementation of the SmartKnB platform in NSA was a continuation of the collaboration between AMI and Nucor that started with the implementation of the SmartFurnace^{1,2}.

DISCUSSION

The dynamic control of the SmartFurnace concept effectively manages the input of chemical and electrical energy in their Electric Arc Furnaces. Its main goal is to adapt and improve the production process based on specific requirements and limitations. The DigitARC PX3 Electrode Regulator, the SmartARC Electrical optimization module, the Chemical Energy, and the Continuous Feeding Module for DRI was implemented. The SmartKnB graphic programming platform, a new proprietary software developed by AMI, played a crucial role in integrating the SmartFurnace system into their existing network infrastructure to acquire the required data. This software offers flexibility in modifying and enhancing the program's functionality, contributing to the development and improvement of dynamic profiles.

The architecture of the AMI system, as depicted in Figure 2, showcases a comprehensive arrangement comprising two key hardware components. The first element is the Electrode Regulator cabinet, which communicates with the SmartFurnace server housing the essential optimization modules. After being

integrated into the NSA network, these devices facilitate efficient information exchange with the existing infrastructure, including PLCs and databases allowing the needed data flow.

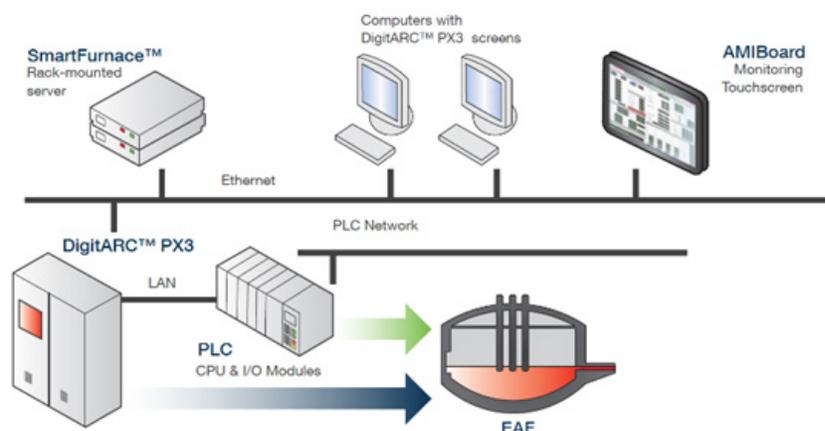


Figure 2. AMI EAF Optimization Technology.

1. DigitARC PX3 Electrode Regulator System

The electrode regulation system, implemented on both AC and DC furnaces, incorporates the cutting-edge DigitARC PX3 Electrode Regulator. This advanced system is engineered with a rapid closed-loop control mechanism and the execution of intricate algorithms, leveraging a dedicated CPU for swift data acquisition. A range of optimization tools and process monitoring features are integrated into the system such as arc stability calculation, noise filtering for the control signal output, and high-speed signal acquisition and logging.

To enable logging, diagnostics, and connectivity, an additional processing unit is employed. This dual setup facilitates prompt execution of the control program, ensuring zero delay in transmitting control commands to the proportional valves, providing dedicated input/output (I/O) capabilities for high-speed data logging, essential for both control operations and diagnostics, such as monitoring electrode arm pressure and position. A user-friendly graphic interface enhances user experience and simplifies system interaction.

The instrumentation employed in the Electrode Regulator system includes a Power Quality Meter which enables power distribution diagnostics and measurements of flicker and harmonics. Additionally, precise position sensors are installed to evaluate the behavior of electrode movements, enabling Electrode Tests. Changes observed in the test results over time can indicate variations in the hydraulic system's dynamics or mechanical issues, aiding in timely troubleshooting and maintenance.

2. SmartARC

The operation principle of the SmartFurnace system is the Dynamic Power Profile. In the case of SmartARC, this approach is used to control the electrical energy input in the furnace, ensuring optimal performance under varying steel grades and furnace conditions. The controlled variables include transformer and reactor taps, regulation mode, and current/voltage setpoints. The integration with the electrode regulator enables enhanced responsiveness and adaptability, resulting in more efficient process control.

Moreover, any available data in the PLC or database regarding raw material characteristics, equipment availability, or the overall process can be monitored to enhance the adaptability of the system. Specific control algorithms are developed to improve safety and efficiency, such as protections for Water Cooled Panels and refractory materials. This is achieved primarily by implementing better arc control to reduce radiation-related damage and continuously adjusting current setpoints.

3. Oxygen Module

The Oxygen module is designed to regulate the burners and oxygen lancing within the furnace. A dynamic program, tailored to specific steel grades is implemented, considering various heat conditions, particularly the stability of the electric arc and the estimation of the oxygen content of the steel. The Stability Factor, calculated by the DigitARC PX3 Electrode regulator, serves as a direct indicator of the efficiency of electrical energy input. The oxygen content of the steel is an estimation that uses Machine Learning, with this estimation the SmartFurnace system determines the precise timing and flow rate for the burners, and subsequently for the oxygen lancing.

4. DRI module

The DRI Control Module design has two main goals to achieve for the automatic DRI feed control: Optimize the time to start the DRI and Control the Steel temperature to avoid accumulation of un-melted DRI in the furnace. The DRI control module automatically starts the DRI feed based on energy consumption and arc stability. This feature has been very helpful to improve the furnace refractory life.³

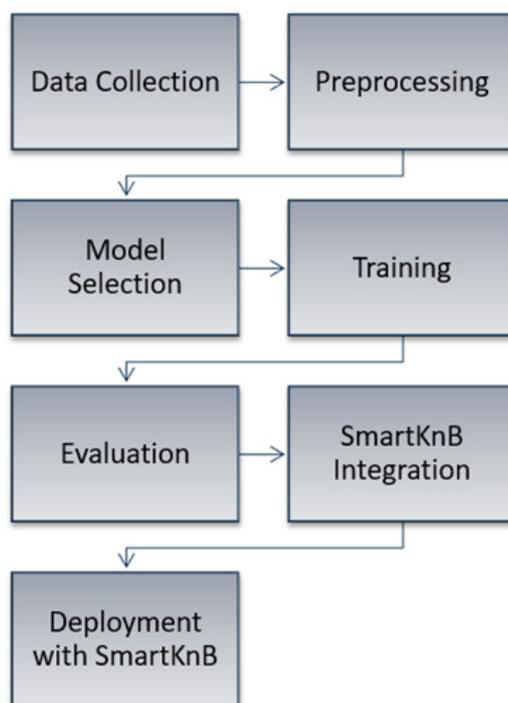


Figure 3. Machine Learning implementation process

ARTIFICIAL INTELLIGENCE PROJECT EXECUTION

The machine learning model process consists of several steps as outlined in the previous figure.

Data collection aims to gather information saved by SmartFurnace®; over a year's worth of data was collected from SmartFurnace logger, two years of data was collected (2022 and 2023).

Once the data was collected, preprocessing was conducted by selecting key features, cleaning those features for outliers, and creating new features.

After finalizing the dataset, various models were implemented to identify the best fit in terms of R-squared. Models such as LightGBM and XGBoostRegressor are among those used for training.

The evaluation was conducted by setting aside 20% of the data to test the model. By running the model with new data it hasn't previously seen, it was expected to achieve the same accuracy as during training. If this is the case, the model can be implemented online.

The online implementation was carried out using the SmartKnB platform. This system has a new UI capable of running machine learning models, among other powerful features. The best model was integrated into SmartKnB online.

Before deploying and closing the loop with the model, an analysis was conducted to ensure that the new ML estimation performs better than the previous estimation.

Figure 4 illustrates how using machine learning to estimate and adjust oxygen levels offers a more effective approach for achieving the desired endpoint. It shows that the total flow is managed to avoid high oxidation levels. Just before the sample was taken, the SmartFurnace burner profile increased the oxygen to meet the Oppm target.

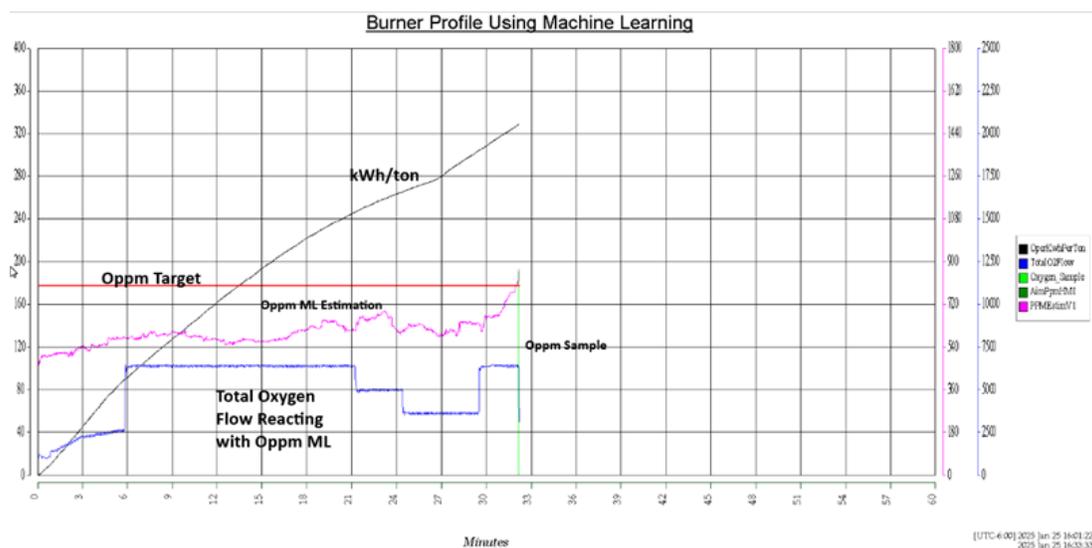


Figure 4. Machine Learning O2 ppm estimation and oxygen control

RESULTS

Using the machine learning module to predict Oppm has shown an improvement in accuracy of 40%, which is significantly better compared to traditional predictions.

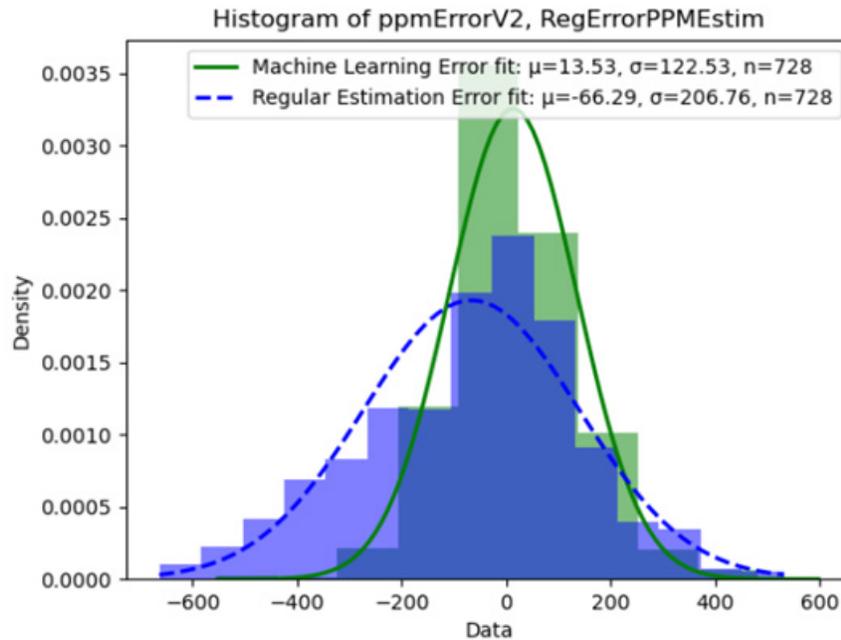


Figure 5. O2 PPM estimation error distribution

Figure 6 shows a 4% reduction in energy usage since activating the machine learning system, achieved by safely utilizing the carbon and oxygen of the burner and avoiding delays due to carbon blow down at the end of the heat and overshooting the oxygen content aims which could be detrimental to the refractory life.

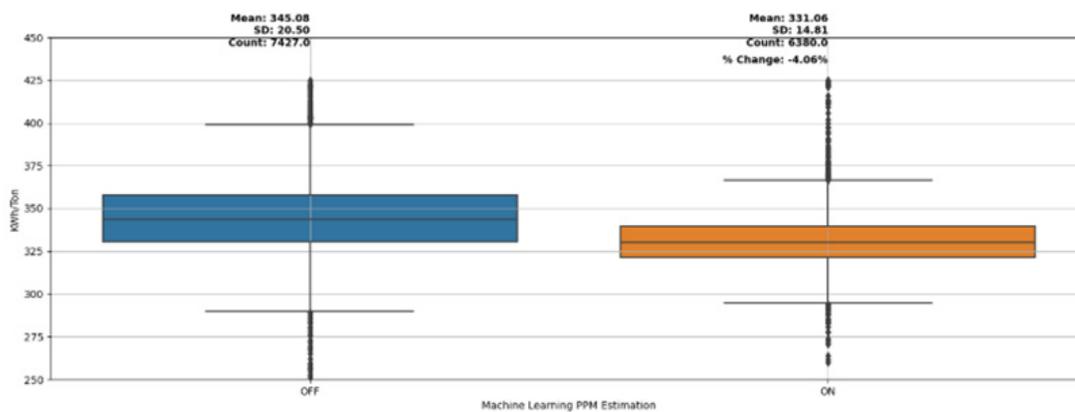


Figure 6. Energy savings due to ML logics

CONCLUSIONS

The utilization of an open and adaptable system for Electric Arc Furnace optimization brings numerous advantages by adapting the control parameters to specific conditions of the furnace at any given point.

As part of this project, a collaborative framework between NSA and AMI has been established with services dedicated to continuous improvement.

One of the advantages of the AMI system lies in its open platform, facilitating a transparent understanding of the system's operations and providing access to essential tools for data verification. Additionally, the support provided by AMI experts has helped maintain the performance and offers the opportunity for continuous improvement.

Machine Learning applications in oxygen control are the initial steps for a full Artificial Intelligence system, next steps are aiming to control end point of the heat including the continuous feeding of DRI.

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