

SmartKnB: Artificial Intelligence tools for EAF Optimization

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ABSTRACT

SmartKnB is an innovative programming platform engineered for advanced control of the Electric Arc Furnace (EAF) steelmaking process. By integrating diverse data sources—from sensor arrays and PLCs to historical logs and real-time imagery—SmartKnB enables the development, testing, and validation of sophisticated control algorithms in a modular, node-based graphic environment. As the core of AMI

SmartFurnace technology, all the control algorithms are implemented through SmartKnB. SmartFurnace is a comprehensive optimization system that dynamically adjusts electrical and chemical energy inputs based on real-time process data, improving process safety, efficiency and reduced emissions.

In addition, SmartKnB can be used to implement from traditional control methods to the most modern machine learning models. Including advanced image processing capabilities it can use pre-trained models facilitating automated image classification and anomaly detection—crucial for monitoring raw material issues and furnace conditions. Together, these integrated functionalities can contribute to enhance process efficiency, better energy management, and greater operational safety, allowing a smarter and more sustainable steel production

Keywords: : ELECTRIC ARC FURNACE, EAF, ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, PROCESS CONTROL, STEELMAKING PROCESS OPTIMIZATION

INTRODUCTION

AMI Automation is a technology company specialized in the development of advanced control systems for the steel industry. With decades of experience in the automation of Electric Arc Furnaces and other metallurgical processes, AMI has delivered tailored solutions that improve operational safety, process efficiency, and energy management. The flagship product of AMI for the steelmaking sector is Smart-Furnace, which integrates a series of intelligent modules, all developed and executed on the SmartKnB platform.

SmartKnB is a visual programming environment that enables engineers to build complex control algorithms using a modular, node-based interface. This tool is the evolution of the VisualKB tool also developed by AMI to implement advanced control logic in a graphic way. The principle is based on nodes that represent basic operations, mathematical functions, or entire control strategies of the EAF operation. This allows the development of a flexible control which can adapt to diverse production scenarios, including changes in raw material composition, process parameters, and production targets giving operational benefits.

The SmartKnB platform is compatible with common industrial protocols such as Modbus, OPC, and EthernetIP, making it suitable for integration with existing PLCs, sensors, and databases. Its REWL cycle (Read, Evaluate, Write, Log) ensures continuous synchronization between plant data and control outputs.

SYSTEM ARCHITECTURE

SmartKnB is structured around a visual programming platform in which users can create, test, and deploy control models using interconnected nodes. Each node represents a specific operation—arithmetic, logical, comparison, communication, or advanced algorithms like machine learning. This model-based architecture ensures that control strategies are transparent, easy to debug, and flexible to change.

The system operates on a cyclic execution framework called REWL, which stands for Read, Evaluate, Write, and Log. During each cycle, SmartKnB reads data from connected devices and databases, evaluates the control logic, writes output values to the plant, and logs process data for analysis. This framework ensures deterministic behavior, essential for reliable real-time control in industrial environments.

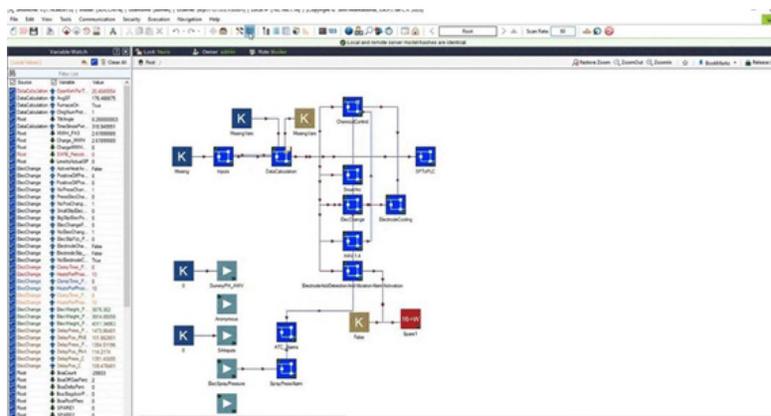


Figure 1. Programming platform overview

SYSTEM FUNCTIONALITY

AI And Machine Learning Integration

One of the key differentiators of SmartKnB is its ability to incorporate artificial intelligence and machine learning models directly into the control environment. Pre-trained models for classification, regression, and anomaly detection can be embedded via Python or C# nodes. These models enable tasks such as heat endpoint predictions, abnormal water vapor detection in the off gas, and raw material classification.

For example, in the module for abnormal water vapor detection, SmartKnB uses historical patterns and realtime signals to detect deviations indicative of water leaks or process anomalies. The IoBucket module integrates image processing to classify scrap types and estimate weights, improving material input tracking and control.

HMI Development And Interaction

SmartKnB includes an integrated HMI Builder, enabling users to create custom visualization interfaces linked to the control model. The builder supports indicators, graphs, gauges, progress bars, and input tools for variable manipulation. Each tool is associated with a node or variable in the model, ensuring seamless interaction.

For example, a furnace operator can monitor arc stability, slag chemistry, and off gas composition in real time, with indicators updating at every cycle. Custom buttons and sliders also allow safe parameter tuning within defined boundaries.



Figure 2. SmartKnB customized interface build

Visual Programming Environment

SmartKnB's user interface is built around a flowchart-style environment, where each node represents a discrete computational element. Users construct control logic by linking nodes representing constants, mathematical operations, comparisons, logical gates, or external communications.

This visual format reduces the learning curve for engineers unfamiliar with traditional programming languages. Nodes are color-coded by function category (e.g., arithmetic, boolean, comparison), and configuration of node parameters is accessible via context-sensitive dialogs. Complex logic can be grouped to simplify large models and enhance reusability.

Each SmartKnB model is composed of a tree of interconnected nodes. Nodes accept inputs, process internal logic, and produce outputs. The configuration process of the nodes include:

- Selecting variable sources (from communications, internal nodes, or global parameters)
- Mapping inputs and outputs through a graphical connector tool
- Using the Quick Connect interface for streamlined variable assignment

The modular architecture supports hierarchical design, where outputs from one composite node can feed into higher-level structures. Inputs and outputs can also be exposed to external devices through communication nodes or logged for historical analysis.

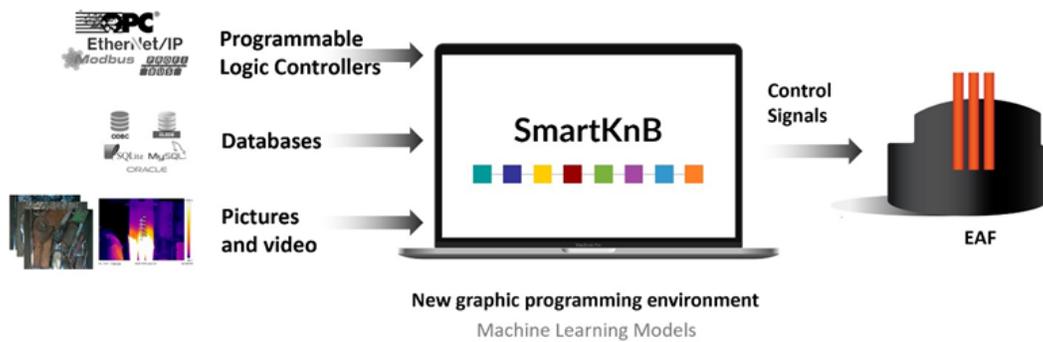


Figure 3. Sources of data of SmartKnB

Communication Interfaces

SmartKnB supports industrial protocols such as Modbus, OPC, and Ethernet/IP, allowing integration with most commercial PLCs and instrumentation. The communication framework includes:

- Devices: Logical groups that manage communication sessions with external systems.
- Read Nodes: Obtain values from sensors, PLCs, or other devices.
- Write Nodes: Send control signals or calculated outputs.
- Logger service: Stores selected variables in CSV or proprietary RPH formats for traceability and simulation.

The communication layer is designed to operate with low latency and high reliability, critical for real-time control in EAF environments.

Logger And Simulation Capabilities

SmartKnB includes a robust logging system that enables data collection and offline analysis. Users can define multiple loggers, each targeting a specific set of variables. The system supports both CSV and the proprietary RPH formats.

The RPH format is also used for simulation purposes. Engineers can simulate SmartKnB models using previously logged data, enabling safe testing of algorithm modifications before deployment. This feature helps identify issues early and reduces the risk of operational disruptions.

Image Processing And Computer Vision

SmartKnB incorporates image processing capabilities to enhance process monitoring and control. Through integration with machine learning nodes and external camera systems, the platform supports automated image classification and pattern recognition tasks directly within the control logic.

One key application is the IoBucket module, which uses camera input to identify types of scrap materials being charged into the furnace. The system can estimate weight, shape, and composition using computer vision algorithms, reducing the uncertainty in material input.

Additionally, SmartKnB's Python nodes can load and apply pre-trained models for tasks such as anomaly detection, slag foaming analysis, or water leak identification. By embedding vision models into the REWL cycle, SmartKnB allows real-time image-based decisions that enhance operational reliability and reduce human supervision.

SMARTFURNACE CONTROL MODULES

The most immediate application of SmartKnB was for the implementation of the AMI SmartFurnace optimization modules.

SmartARC

Optimizes transformer and reactor tap settings based on arc stability, scrap mix, and furnace stage.

Oxygen Module

Controls gas, oxygen, and carbon injection rates using electrical and process data.

Slag Optimization

Implements online mass balance to recommend flux additions targeting ideal slag chemistry.

Off Gas Analysis

Uses real-time off-gas data to enhance energy input distribution.

Raw Material Feed Optimization

Controls feeding timing and rate to prevent unmelted material buildup and improve thermal efficiency.

These modules are implemented as interconnected SmartKnB trees, which can be edited and extended as process conditions change.

CONCLUSIONS

SmartKnB represents a practical and robust solution for implementing advanced control strategies in the EAF process. Its visual, modular architecture enables rapid development and adaptation of control models, even in highly dynamic and demanding industrial environments. By supporting integration with standard communication protocols and legacy systems, it provides flexibility for deployment across a wide range of facilities.

The ability to embed artificial intelligence, machine learning algorithms, and computer vision tools directly into the control environment allows SmartKnB to address modern challenges such as process variability, material heterogeneity, and safety monitoring. From endpoint prediction and water leak detection to scrap classification and real-time HMI visualization, SmartKnB enhances the operator's capacity to maintain safe and efficient furnace operation.

AMI's continued development of SmartKnB, including the introduction of new nodes, tools, and visualization components, reflects a commitment to enabling intelligent, adaptive, and sustainable steel production. Through this platform, complex metallurgical processes can be better understood, controlled, and optimized using the latest advancements in automation and data analytics.

REFERENCES

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