Simulation-Based Training of Industrial Plant Operators: Steelmaking Case Study

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Industrial sectors such as steelmaking are increasingly challenged by workforce turnover, retirement of experienced personnel and reduced availability of long-term apprenticeship-based training. Operational knowledge that historically required years of supervised plant exposure must now be transferred within significantly shorter timeframes, while maintaining safety and operational consistency. In parallel, industrial companies face growing pressure to provide training environments capable of engaging younger generations accustomed to interactive digital technologies. Simulation-based training environments offer a potential solution by enabling accelerated, repeatable and measurable competency development within safe and controlled virtual operational settings.

This work presents a web-based simulation training platform designed to support operational readiness and competency development for Electric Arc Furnace (EAF) personnel through interactive process-oriented learning. The system integrates educational content, process visualization, interactive simulation and performance assessment within a unified modular architecture intended for industrial training applications.

Unlike conventional operator training simulators focused on high-fidelity replication of plant-specific Human Machine Interfaces (HMI), the proposed approach prioritizes conceptual understanding of process dynamics, operational sequencing, subsystem interaction and consequence propagation resulting from operator actions. The simulator therefore emphasizes operational logic and process comprehension rather than memorization of specific control interfaces.

The simulation environment reproduces the principal operational phases and subsystem interactions associated with EAF operation, including charging, slag handling, tapping procedures and material handling activities. The simulation logic is organized through finite-state process orchestration enabling coherent execution of complete heat cycles while maintaining user-driven interaction.

The training environment supports both guided demonstrations and fully interactive operational scenarios. Trainees can execute individual procedures or complete operational sequences while observing immediate and delayed consequences of their decisions. The platform additionally enables safe reproduction of hazardous or abnormal situations that would be difficult or unsafe to demonstrate in real industrial environments.

A dedicated analytics layer records user activity and training progression, including time spent in learning modules, execution duration, testing scores, response times, procedural errors and repeated scenario attempts. This information is aggregated into measurable indicators supporting evaluation of trainee progression and identification of operational weaknesses. The architecture therefore transforms training activities into a quantifiable process suitable for competency monitoring and continuous training improvement.

The proposed approach is designed to remain deployable in typical industrial environments while supporting modular adaptation to different operational contexts and training scenarios. The modular structure enables adaptation of the platform to different industrial facilities and operational contexts beyond EAF steelmaking.

The platform is currently under development within an industrial research project conducted in collaboration with steel industry partners. Ongoing validation activities focus on assessment of training effectiveness, analysis of learning progression and collection of industrial feedback regarding usability, realism and operational relevance.