36th European Modeling & Simulation Symposium, 038
21st International Multidisciplinary Modeling & Simulation Multiconference

2724-0029 © 2024 The Authors.
doi: 10.46354/i3m.2024.emss.038

Innovative Extended Reality and Simulation-based Training for Control Room Operators in Industry

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Abstract

Modern industrial plants are characterized by high level of automation, however, there are still numerous facilities which only partially benefit from it for various reasons. In this paper, the authors investigate existing training procedures for control rooms' operators in the old economy and analyze particular case study of Electric Arc Furnaces (EAF) operations. Finally, it is proposed a strategy to adopt simulation-based training solution for the plant operators with analysis of expected benefits.

Keywords: Simulation, Simulation-based Training, Electric Arc Furnaces

1. Introduction

Several centuries ago steelmaking played a crucial role in the industrial revolution and even nowadays the steel production is one of pillars of the modern society. During the centuries there were various technological advances and improvements which transformed the initially simple process based on charcoal burning into a series of much more complex ones, employing Basic Oxygen Furnaces, Blast Furnaces and Electric Arc Furnaces (EAF). Indeed, a strong demand of steel for construction of infrastructures and production of goods caused significant advances in terms of productivity and efficiency. Moreover, modern attention to the environmental impact and relative issues lead to growing interest in reduction of emissions and possibility to recycle scrap.

From this point of view, the very interesting type of furnaces are previously mentioned EAFs. Indeed, they could operate even using only scrap as feedstock and to take benefit of renewable electric energy sources with potentially lower CO_2 footprint. The core principle of EAF operation is heating of materials by passing strong electric current by means of inserted electrodes, while hot gases escaping from the main body of the furnace could be used to effectively preheat the material.

As with many other modern industrial processes, operation of EAF requires considerable skills, as the operator need to guarantee effective and safe operation of the furnace. Moreover, considering very high temperature in the main body of the furnace, there is only a limited possibility to accurately measure temperature inside or to take samples of the material, hence, experience and strong intuition are fundamental for the operation.

2. Electric Arc Furnace Operations

The control of EAF is a complex task which could be dangerous due to presence of molten metal and very high electrical demand.

The overall work cycle of EAF is composed of following main steps, repeated in a loop with duration of approximately one hour for each cycle:

1. Tap hole closure after casting.
2. Evaluation of residues in the body of the furnace
3. Start of the new casting process
4. Fusion of the loaded metal/scrap
5. Overheating and final decarburization
6. Preparations for casting
7. Casting into the ladle

Obviously each of these steps is composed of numerous routines, verifications, controls and actions. Moreover, there are separate processes for the furnace maintenance, startup and shutdown.

Detailed description of each step is found in various sources (Singh et al., 2020; Knapp et al., 2000) while its explanation is out of the scope of this paper.

3. State of the art

Simulation based training is used in various fields. In some cases, it is consolidated practice used for process optimization (Latorre-Biel & Jimenez, 2013), while in others it is still in emergent phase. Hereafter is presented a study of modern solutions, which employ simulation-based training of operators in different industrial contexts, while taking advantage of various technologies and techniques, such as Modeling and interoperable Simulation for Serious Games (MS2G), Virtual and Augmented Reality and Artificial Intelligence.

3.1 Training of Life Support Supervisors for Deep Water Diving

Underwater operations, such as the maintenance and servicing of underwater installations, cables, pipelines, as well as marine salvage and rescue operations, are vital part of numerous industrial fields. The challenging underwater environment is associated by various safety risks, especially important in case of deep-sea work, have prompted the development of various autonomous or remotely operated underwater vehicles (ROV), however, human intervention is still required in various cases.

A significant difference between operations in this field done now and several centuries ago are caused not only by technological advancements but by a better understanding of diving medicine. Hence, nowadays a multidisciplinary approach enables the efficient and safe execution of different underwater operations, due to more efficient prevention and treatment of human disorders that could occur in hostile conditions. This consideration is in line with overall industrial trends, which pay and more attention to safety of personnel, environmental sustainability, energy efficiency etc. (Bruzzone et al., 2020). Indeed, such advances allowed to perform operations even at depths (and consequently at pressures) which were impossible to achieve in the past due to the oxygen toxicity at high pressures, hence, other gas mixtures are used nowadays for breathing. In fact, diving medicine stands as one of very important pillars in sportive, military, and commercial diving. Obviously, in order to control and supervise such operations it is necessary to have well trained personnel, especially Life-Support Supervisors (LSS).

Due to safety and practical concerns, the most of relative training courses are conducted on empty saturation diving plants. This precaution arises from the critical nature of the field, where even a small error introduced by an inexperienced operator could lead to injuries for divers inside the plant as well as to damage of expensive equipment. Considering this, Simulation Team developed a Modeling and Simulation (M&S) based solution to address the training problem. Such a solution could significantly improve training activities, cut down training costs as well as to reduce risks. At this moment, only several solutions of this kind are known, however, they are focused mostly on the technical part of the plant operation, hence, the developed solution addresses also the problem of human behavior modeling including physiological reactions.

Indeed, application of modeling and simulation to various fields allows to significantly improve overall training efficiency, reduce its costs and associated risks. One of crucial considerations in this regard is related to management of abnormal and emergency situation. In fact, traditional training approach which is based on real equipment, often is limited to routine operation, omitting various possible undesired situations.

As mentioned, saturation diving poses significant dangers. Even routine operations could result in long-term negative consequences for the human body, especially during compression and decompression cycles. An additional challenge is that, in commercial diving, these operations often span several days, making it impractical to perform compression-decompression cycles for every work shift. Considering this, the common practice involves extending work activity by creating a controlled environment that allows divers to live in a special hyperbaric chamber between work shifts. This chamber replicates atmospheric conditions similar to those underwater in terms of pressure and breathing gas composition, hence eliminating the necessity of consecutive compression-decompression cycles.

Such hyperbaric plants are normally installed on a ship, barge, platform or even on shore, e.g. when a dam inspection is required. A typical plant contains a hyperbaric chamber, life-support systems, a submersible decompression chamber (referred also as a "Bell", due to similarity of the original form to a bell), a rescue chamber, and various auxiliary systems. The management of these facilities involves a team composed of technicians, assistants, and supervisors, with the principal role of ensuring the safety of divers played by the Life-Support Supervisor. In the past, training of LSS was performed on the real equipment, and only several physical-based simulators available. Considering this, Simulation Team creation of an innovative simulation model with particular attention to the physiological aspects of divers inside a virtual plant as well as to most common disorders typical for this kind of diving.

The created system has a modular architecture, enabling the reuse of individual components and the expansion of overall functionality by facilitating the introduction of additional models, data sources and sub-systems. Most important models of the system are:

- Model of the industrial plant processes dealing with gas physics simulation

- Model of human physiology and disorders

It is evident that these two models are interconnected and has reciprocal influences. The human physiology depends on the results of gas dynamic modeling, while the state of the atmosphere is highly impacted by physiological activities (e.g. breathing). Indeed, divers inside the chamber consume oxygen, produce carbon dioxide and heat, thereby affecting environmental conditions. Simultaneously, variations in temperature and gas concentrations have an impact on divers' behavior.

For illustrative purposes, following examples shows how the state of virtual humans could be assessed during the simulation.

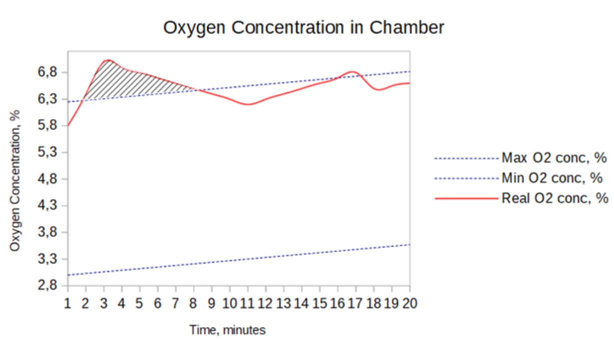

Figure 1. Evaluation of physiological indicators of virtual divers

In the figure the dashed continuous lines represent limits of acceptable oxygen concentration for an average person during the simulation; as absolute pressure changes during the run also the suitable for breathing air composition varies. At the same time, it is possible to observe continuous line which shows effective concentration of oxygen. When it is out of defined boundaries (dashed area), the product of value sampling time step and excessive concentration value forms a weight for evaluation of impact on the virtual divers.

For instance, hyperoxia occurs when the oxygen concentration in the chamber with diver exceeds limits, imposed by the absolute pressure. Hence, the simulator is required to calculate such limits in every single moment for every environment with divers, compare the limits with effective values and save these data for the analysis. In this particular example, the assessment consists of performing integration of difference between maximum acceptable and effective oxygen concentration, keeping track of exceeding value. Accumulated value, is used to estimate intensity of symptoms of this typical disorder. For instance, value near or equal to zero do not cause any symptoms, while big positive one could lead to a disorder. Similar approach could be applied to assess various parameters of an industrial plant.

Indeed, one of the key strengths of the solution is related to assessment of correctness of performed actions. Indeed, thanks to fully controlled virtual environment and modeled personnel, it becomes possible to track all actions conducted by trainee, evaluate automatically the consequences of actions and their impact on the industrial plant and on the personnel. Hence, it could be used to provide also a detailed report, especially useful for debriefing after the training sessions. Finally, automatic multi-factor assessment of the trainee provides opportunity to have an independent and detailed assessment of actions.

Another important consideration is assessment of correctness of operations. Indeed, apart from monitoring the effective impact of the trainee on the target system, it is necessary to ensure that all required steps were performed correctly. For instance, that the operator verifies periodically status of various systems and sub-systems, checks critical values etc.

With involvement of other partners and Subject Matter Experts (SME), it was possible to create a series of prototype of control panels, both virtual and physical, in order to allow interaction with the core models. Consequently, it led to creation o a full-scale training solution for LSS, capable to reproduce realistically the equipment as well as physics of the atmosphere and physiology of the divers.

The created models as well as final solution allow to simulate the training environment for LSS. It is evident that by providing this type of systems it becomes possible to mitigate and prevent various accidents by improving operator awareness and knowledge transfer.

The presented simulator includes different functions required to support the instructor in injecting simulated events and virtual malfunctions, load training scenarios and control performance during the training sessions.

This example illustrates application of the Modeling and Simulation to address problem of training of operators. Obviously, the same approach and concepts are applicable to numerous of industrial fields, including Iron and Steel. Indeed, simulation model of an industrial plant, coupled with realistic user interface and advanced monitoring and assessment tools, form a basis for training and assessment of personnel in various sectors.

3.2 Training of Portainer Crane Operators

Ports are vital hubs for global and regional trade, handling various types of cargo, including containers, raw materials and other assets and goods. Apart from different seaport characteristics, it is important to highlight the fact that ports are characterized by high risk, caused by presence of heavy and bulky equipment combined with often limited visibility, handling of dangerous goods and other factors. For example, even a relatively small crane capable to move a container could crash an obstacle, such as car or some other object, during the movement and do not even notice it. These considerations impose various limitations and requirements on the port procedures, as all relative operations need to be done ensuring safety of personnel and avoiding damages of equipment, goods and other assets (Bruzzone et al., 2023; 2011).

In order to maximize the safety and efficiency of operations in ports, either seaports and inland terminals and interports, it is fundamental that all personnel as well as anyone who has access to particularly dangerous areas, have sufficient preparation, is aware of risks and is capable to operate in order to avoid them. Obviously, such preparation requires adequate training, which could be difficult to provide without exposing persons to real risks. In particular, it could be very challenging to guarantee sufficient level of preparation for someone who never operated in such areas. Moreover, training of personnel responsible for handling of most critical equipment is even more difficult. Considering this, Simulation Team and SIM4Future created an innovative simulation-based training solution for operators in seaports, with particular attention to the case study of training of portainer operators; this type of cranes is used to load and unload big container ships and is typically biggest and heaviest machine in a port. While in typical training procedure a real crane is often used, nowadays it is convenient to employ simulation. Indeed, simulators that replicate real-world equipment with sufficient fidelity and in a controlled environment could be an efficient alternative, as simulators allow trainees to practice the operations in various scenarios, including adverse weather conditions, while avoiding any risk of real accidents. This helps build confidence and competence before actual on-site operations. At the same time, simulation-based training allows to address handling of abnormal and emergency situations by introducing relative scenarios, which could be difficult to achieve in case of training on real equipment. In general, it is possible to highlight following main aspects of training of operators:

- Safety of operation.

- Efficiency of operation.

- Compliance to norms and regulations.

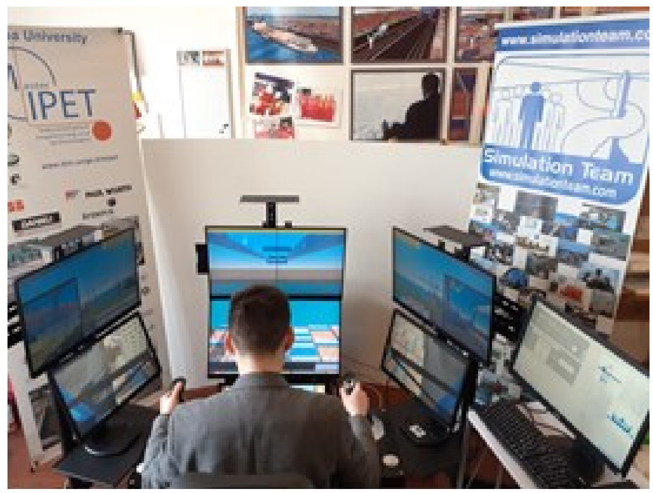

Figure 2. Training solution for heavy equipment operators.

When simulation-based training is used, it is necessary to provide sufficient level of realism and immersivity of the proposed environment, in terms of both physics and graphics of the environment as well as of control mechanisms (control room, cabin). Indeed, training must be performed in conditions which are based on the real world and provide realistic experience. In most of cases, crane control mechanisms must be represented by a high fidelity replica or by real control panels adapted to be connected to the simulator, providing proper Human-Machine interface, including joysticks, levers, buttons and other input mechanisms. At the same time, in case of crane operator training, acoustic and vibration outputs need to resemble as much as possible the experience of a real workplace. Hence, the solution is equipped with connection interface for surrounding audio as well as for motion platform, capable to introduce in the training all required vibrations, inclinations and even strikes.

The approach of automatic quantitative evaluation of trainees shown to be very useful. Indeed, it allows to perform assessment keeping track of every single action of the user, while requiring less attention from the trainer.

3.3 Utilization of Extended Reality to Support Training and Operations in Industry

As mentioned, the quantity and quality of information in industrial plants, generated from numerous data sources, provides numerous opportunities of improvement for different aspects of the plants' management, from performance and productivity improvements and up to enhancement of work safety. In this particular case study, it was addressed several aspects, while the main goal is to improve both safety and efficiency of production line operator. Indeed, this case study is related to operation of glass production line, with particular interest to glass furnace, Independent Sections (IS) machine, temper machine and quality control line. Hence, the aim of the W-ARTEMYS (Wearable Augmented Reality for Employee safety in Manufacturing sYStems) project is to provide the personnel responsible of the production line a series of portable and wearable tools, which could be used to improve situational awareness, help to identify malfunctions.

Indeed, information regarding overall systems' state could be used as warning about potentially dangerous conditions as well as to reduce time of response; furthermore, there are new additional functionalities, such as remote assistance: it turns possible to provide support to operators in front of the production lines by means of remote assistance from highly qualified personnel, available at any time in Headquarters; this functionality provides a new kind of service, useful to guarantee highly qualified remote support whatever is the distance between remote experts and on-site operators.

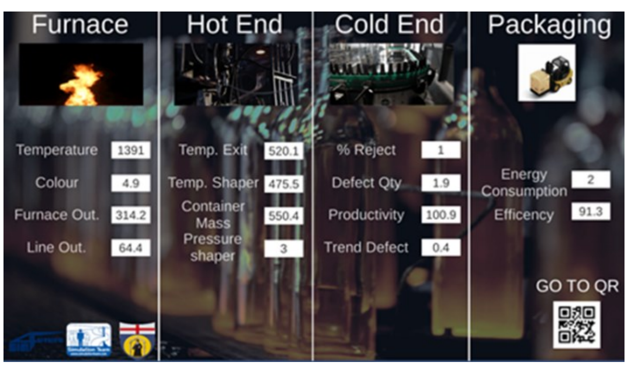

Figure 3. Mobile Dashboard for a glass production line.

To address such aspects, there are proposed portable, mobile and wearable solutions in order to assist operators in performing their daily duties and activities on the shop floor, along production lines and inside industrial plants. Moreover, the presented case study investigated possibilities to employ flexible solutions built over multiple platforms from Hololens to smartphones and tablets, which might be used not only to display information, but also to acquire and store data about interventions and information related to lesson learned.

Hololens is an Augmented Reality (AR) headset created by Microsoft, which allows to extend the vision of the real world by introducing in it various layers of additional information.

According to these considerations, the following objectives have been identified:

- To define Key Plant Indicators and most important risks faced by operators to be provided within the Mixed Reality (MR) in relation to machines and lines of interest.
- To develop innovative Software solutions able to integrate Industry 4.0 Equipment with Mixed Reality, Simulation and AI, developing also smart solutions for data acquisition, transfer, elaboration and visualization.
- To carry out experiments in order to validate the approach and estimate the potential of alternative solutions applied on site

As anticipated, this project focuses on testing of innovative solutions to support supervision and maintenance for industrial production line using MR technologies; special attention has been paid to use of Augmented Reality to highlight criticalities and boost performance during plant operations. Indeed, one aim of this project was also to evaluate efficiency of various types of wearable and portable hardware and software solutions, considering also limitations imposed by work environment as well as by the different kinds of production lines. Indeed, in some cases these environments could be characterized by excessive temperature, vibrations, high level of noise, dust or even presence of chemical agents. In particular, there were tested solutions that are flexible and portable on different platforms including smartphones, tablets and

Hololens.

Figure 4. Augmented Reality for onsite maintenance and remote

supervision support

Wearable and portable solutions, especially if incorporate Augmented Reality technologies, could be very useful to alert the shift managers and on-site operators about various events, such as malfunctions, errors or other abnormal behaviors which might require immediate intervention. In this way, it is possible to provide intuitive and quick access to the main plant indicators as well as to simplify and automatize rapid retrieving of information regarding specific machines and production parameters. For instance, it could be possible to immediately have a synaptic view of a machine by simply passing near it or by scanning a QR code or other type of graphical marker.

Indeed, to provide such functions it is necessary to integrate portable devices with other plant system and to let them know their position relative to the line and single machines. Depending on the particular requirements and limitations it could be possible to use Indoor Positioning System (IPS) or to attach QR "anchors" to machines and equipment of the plant. IPS is one of the most widespread approaches for positioning inside buildings and facilities. In fact, while it is common to use the satellite positioning outside, for example GPS, within an industrial plant or along a production line, usually, these signals turn to be weak, there are reflections and interference. To address such issue, nowadays there are various tools that allow to find the position using transmitters installed in fixed locations within the plant. For example, IPS based on Wi-Fi and Bluetooth signals allow to find the position with precision of a couple of meters even with minimum infrastructure investment, otherwise there are specialized and more precise systems that use UWB (Ultra-Wide Band) signals. Finally, in some cases, exact positioning respect to the production line is not required, hence, to avoid unnecessary investments it is possible to use simple QR codes.

Considering this, for the case study the target machines of the production line were equipped with such codes. Furthermore, many mobile and wearable devices are equipped with Inertial Measurement Units (IMU), which allow to keep tracking the position quite precisely even after the loss of direct code tracking. Regardless of exact positioning system, the main benefit is to have rapid access to relevant information with minimal manual actions required.

Finally, by transmitting the information about the operator location and activities to the control room, central office and/or engineering department, it is possible to improve efficiency of the remote supervision of operations. Indeed, the synchronization of wearable technology devices in this process allows to know exactly where an operator is located and even what he is looking at.

This approach could be further improved by creating a Digital Twin of the production line, or of the entire plant, and to move operators in this virtual world. In such case, remote supervisor could have access to all plant indicators in a virtual 3D environment and assist the operator on site, having the same vision of the plant (Virtual) as the on-site operator (Real).

Another important part is the data exchange infrastructure. For instance, in order to limit direct access to machines and to keep data acquisition efficient, simple, safe and consistent, it is preferable to have a single access point for such information, for example by providing a web API (Application Programming Interface) or database access. Such centralized approach avoids the redesign the data extraction modules for each different client device, which is a very important aspect considering the variety of access modes and data formats of typical production lines composed by multiple machines produced by different manufacturers. Finally, a centralized data source such as a database allows introduction of new functions as well as extension of existing ones, while the entire system could be easily adopted for other production lines and sites. Summarizing the proposed solution, the data is extracted and saved in a centralized database, periodically retrieved by the server and consequently sent to the clients. In this case, the server performs also data elaboration, analyzing the alerts and proposing possible explanations and corrective actions.

Indeed, the server's functionality could be improved by introduction of Artificial Intelligence module, which would allow, not only to indicate critical situations, but also to foresee them, reducing the risks both for operators and for the plant.

As mentioned, another important aspect of the project is to guarantee data confidentiality and security in general. Obviously, the maximum degree of security could be achieved if all the systems were isolated from one another, making however any kind of integration, centralization, control and remote maintenance impossible. Hence, compromises must always be made between security and efficiency. For these reasons the project employs only portable solutions capable to maintain high level of data protection. Starting from the proposed architecture it is possible to evaluate the most critical points in terms of data protection and access control.

For instance, considering that in proposed cases, the main server could have access also to some parts of the control system of production lines, it is clear the need to control access to sensitive data. Partially, this issue is addressed by the read-only access to the databases, which reduce drastically possibility of unauthorized modifications to the machines' configuration. In the same time, all but the database's port of the server must be blocked by the firewall. Another criticality related to cyber security is related to the use of wireless networks (Wi-Fi) as support solution for the new system. From this point of view, it is very important to provide high level of data protection and integrity control. For example, WPA2 protection must be used for connections, while all connected devices must operate within a secure VPN (Virtual Private Network) network. Obviously, portable devices must be forced to use only the dedicated wireless network as well as to block installation of unauthorized applications. Last, but not least, security aspects are strongly related to human factors.

In this project there were identified different possible use modes for these new systems in industrial plants. One is support of the operators on site, while another is the remote assistance to operator to solve particularly complex situation. Finally, another important use mode is the use of Mixed Reality Solutions to train operators.

These considerations lead to creation of a combined use of smartphone and Hololens to monitor state of the plant; vice versa headset and/or CAVE could be also used for remote assistance and training. For instance, it is possible to use a tablet to support operators during maintenance, providing them with data on machine alerts and action to be carried out/components to be checked.

Subject Matter Experts (SME) have been involved since the beginning and confirm their interest in these solutions.

Another project in which was studied utilization of immersive virtual environments for training is SISOM (SImulation SOlution based on virtual and augmented reality for Maintenance), in which various instruments, including CAVEs and portable devices were used (Bruzzone et al., 2017).

CAVEs have different strengths, but in this specific case the most interesting one is the capability to offer shared environment, available contemporary for multiple users. Indeed, traditionally CAVEs have a cubic structure, with images, creating visual part of virtual environment, shown of its sides. Images could be created using projectors of different types, either with classic direct view otherwise rear projection. The second type reduces significantly the number of components inside the CAVE. However, this solution has significant limit in exploitation as it requires a lot of space outside of the CAVE. For these reasons, it was developed a SPIDER (Simulation Practical Immersive Dynamic Environment for Reengineering), designed especially to be compact, while providing high versatility at relatively low cost. SPIDER utilizes direct view created by Super Short Throw Projectors, designed to project image on 2 meters width screens from distances around tens of centimeters. SPIDER and a CAVE in general could be used with various Input/output devices, such as motion platforms, motion capture systems, cockpit replicas etc.

In overall, virtual environments, either experienced via headset or virtual rooms, shown to be effective for explanation of processes, providing interactive guidelines for the user. Hence, this approach is fundamental for training of operators in industry (Possik et al., 2023).

Figure 5. Collaborative operation in shared virtual environment

3.4 MS2G

The innovative concept of MS2G (Modeling, interoperable Simulation and Serious Games) allows to develop interoperable, scalable and reusable simulators with benefits provided by combination of gaming elements with educational objectives, leading to engaging and efficient training experiences. Indeed, these serious games go beyond simple entertainment and serve a specific purpose, typically a skill development or knowledge acquisition. Hence, serious games benefit from gamification principles, which make the overall learning experience more enjoyable and motivating for trainees. The serious games require also progress-tracking mechanisms, in order to allow to learners and instructors to monitor individual performance, identify issues, and suggest ways for improvement. Finally, interoperable simulation allows creation of shared environments, created by coordinated execution of various simulators and models. For example, one model may be responsible for the crane itself, while others could govern operations of other assets and environmental conditions.

4. Regulations and Certifications

In various fields and industries, it is fundamental to complete a training course and to obtain relative certification in order to be allowed to conduct certain operations and activities. For example, in order to operate certain types of machinery or to pilot an airplane it is necessary to possess certain requirements, which must be formally proven by an authorized entity. At the same time, a similar approach could be encountered also in the everyday life, e.g. requirement to have driving license. Considering this and previously described advantages of simulation-based training, in some industrial fields have been introduced guidelines on the use of simulation, which indicate the qualities that a simulator need to possess in order to be suitable for the operator training. Hence, first a simulator is certified for some specific training course and consequently it is used to certify the operators. One of such examples could be IMCA (International Maritime Contractors Association), which provide detailed guideline on the use of simulation for training of different types of operators, e.g. Life Support Supervisors (IMCA, 2015). As an additional interesting detail, it is possible to note that IMCA authorizes to reduce duration of training courses by half in case a certified simulator is used, as simulation-based training is considered to be much more efficient in this field in comparison to traditional training procedures.

Another industrial plant in which certification is mandatory for positions with high level of responsibility are nuclear power plants. For example, according to United States Nuclear Regulatory Commission (USNRC) and Federal Authority for Nuclear Regulation (FANR), to act in role of Reactor Operators (RO) and Senior RO (ROS) it is necessary to obtain relative certification, with the training course partially done on simulator (USNRC, 2023; FANR, 2022).

Another example of industry-specific regulation in this regard is EASA (European Aviation Safety Agency) which governs use of simulation for training of pilots.

In some cases, regulators recognize different classes of simulators, which allows to formally distinguish between simulators based on their scope. Hence, to identify applicability of different simulation-based training solutions to specific goal. For instance, previously mentioned IMCA recognizes 4 classes of simulators A, B, C & S:

A. Full scope simulator with real-world operator interface for advanced training. This is the highest of relative classes and it requires that the trainee interacts with it by means of mock-ups of real equipment. Hence, simulator certified according to requirements of this class is necessary for training courses which are expected to be held on simulator only.

B. Simulator with comparable to real-world controls, coupled with simplified models suitable for basic training.

C. Simulator with limited realism for concept familiarization.

S. Simulator of some specific system, hardware or their parts for basic familiarization.

Hence, based on expected outcome of training course it should be possible to choose most suitable configuration of the system, adapt acquisition and/or development requirements. Similarly, authorities in different fields and in different countries adapt other types of classifications, even if the overall idea is mostly the same. For example, EASA distinguishes Full Flight Simulators (FFS), Flight Training Devices (FTD), Flight and navigation procedures trainer (FNPT) and Basic Instrument Training Devices (BITD), with several sub-levels for more fine-grain classification (EASA, 2018).

In overall, various certification authorities recognize importance and benefits of the simulation-based training and adapted their regulations accordingly.

5. Training of Operators in Iron and Steel Industry

Based on previous considerations, the authors started creation of an innovative training solution for EAF operators. In particular, it is decided to create a simulator of a control room operation, which should have following principal characteristics:

1. Be able to reproduce realistically principal control mechanisms available in a typical EAF control room. This includes virtual control panel and view from virtual arc furnace facility, coupled with videos registered on site (where applicable and available).
2. Contain a model of EAF operations (functions and logic, physics, basic chemistry, electrical consumption, thermodynamics etc) with sufficient for the scope of training precision.

Based on this consideration, it is proposed a following configuration for the first prototype version of the control panel

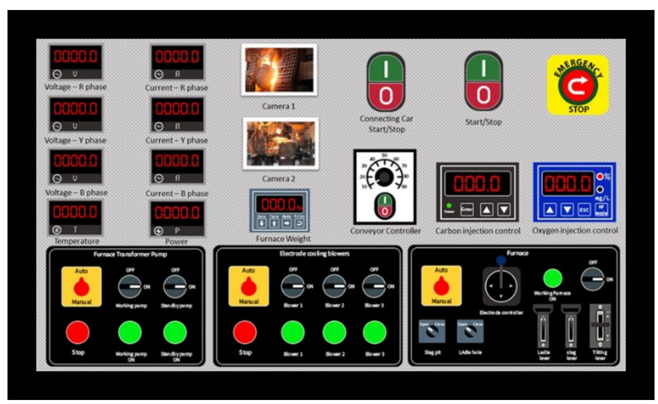

Figure 6. Preliminary prototype design for EAF control panel

Currently the project is in prototype development phase.

6. Conclusions

Simulation allows to overcome most of limitations typical for traditional training procedures of industrial plant operators and to offer opportunities which were difficultly achievable in the past. Indeed, it reduces costs of training and improves safety of human personnel and equipment during this procedure, permits to conduct effective assessment of trainees, introduce handling of emergency situations and abnormal conditions, equipment malfunctions. Moreover, in various fields it allows trainees to obtain required certification without even interacting with the "real" equipment.

In the field of Iron and Steel, the simulation could allow better knowledge transfer to the new operators, teach them to handle various scenarios and to prepare them to real world operations.

Acknowledgements

The presented research is carried out as part of iSteel-expert project (www.isteel-expert.eu). Project co-funded by the Research Fund for Coal and Steel (RFCS) G.A. 101112102

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