LATEST SMS EAF TECHNOLOGIES FOR SAFETY AND GREEN STEEL PRODUCTION

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The reduction of CO_2 emissions in steel production and conversion to green energy sources demands an efficient, dynamic, and flexible power supply for electric arc furnaces (EAFs). The increase of renewable energy resources leads to weaker grids, and stricter grid codes limit conventional EAF connections. The AURA family with IGBT-based power modules offers the requisite efficiency, dynamic performance, and power density for grid compliance as well as the transition to green steel. SMS employs innovative modulation technologies and control algorithms to optimize power transfer and minimize grid impact.
Alongside X-Pact AURA, SMS introduces two innovations that save energy, cut CO_2 and NO_x emissions, improve productivity, and enhance safety.
Condoor®: This automatic slag door, installed in over 50 locations globally, provides effective slag management with direct benefits including reduced power and electrode consumption, shorter process times, and optimized parameters such as carbon injection and flux consumption, for example. Combined with SCAD, it stabilizes cycle times and improves slag control, aiding alternative virgin iron sources in EAFs.
X-Pact Sampler: this equipment automates liquid steel measurements, enhancing safety by removing the need for operators to stay close to the furnace. The latest version features heat-armored protection, advanced automation software, and an Automatic Cartridge Exchange system that ensures greater reliability and less need for maintenance. It is suitable for use with new or existing EAFs, LDs, VDs, ladles, or tundishes, and can handle all typical manual measurements.

KEYWORDS: POWER GRID – SAFETY – EFFICIENCY – ROBOT SAMPLING– GREEN STEEL – OPERATIONAL RESULTS – SLAG DOOR - ENERGY SAVING

INTRODUCTION: HEADING

In view of the current steelmaking process shift from traditional routes to greener EAF based production, three cutting-edge technologies are set to play a major role in the years ahead.
At present, the EAF route accounts for over 29 percent of worldwide steel production, while 71 percent is covered by the integrated route. Europe, the US, and the Middle East are leading the way, with 45 to 95 percent of steel produced using EAFs [1].
Due to the increasing incorporation of renewable energy resources in power grids, which are becoming weaker, the efficient, dynamic, and flexible supply of power to electric arc furnaces is a must. Modular X-PACT Aura help steelmakers to deal with this challenging environment.
SMS group is also focused on enhancing the efficiency and safety of EAF operation with its Condoor® automatic slag door, designed to properly manage the slag, improve furnace performance, and ensure safe, automated operations in both new and existing furnaces. The X-Pact Sampler, combined with the Condoor, removes the need for operators to work in front of the furnace, contributing to a comprehensive safety concept in modern facilities.

AURA

The digitalization process in electrical steelmaking requires the use of accurate digital twins. In addition, grid code requirements are becoming more stringent, and, for example, user models and compliance studies are required for large industrial loads to ensure improved resilience in the public grid.
As a result, SMS decided to develop a complete power system including electromagnetic transient (EMT)

simulation and hardware-in-the-loop validation and testing, with the aim of identifying and analyzing improvements in terms of both EAF and grid-side performance [2, 3].
RTDS® allows modelling of the high voltage grid, the power conversion system, and the arc furnace using real power electronics controllers and an electrode regulator PLC, while simultaneously running µs-step size simulations lasting several hours.
The analysis is based on an existing 51-MVA DC-EAF – including 45-Mvar SVC with 45Mvar filter – working on a 100-percent scrap mix based on a three-bucket charge.
The X-Pact AURA power supply applies N-1 topology: thanks to the modularity of power conversion, full power is delivered to the EAF even if one power converter is out of service, increasing the system's availability to above 99 percent.
Figure 1 shows the single line diagram for the existing thyristor rectifier combined with SVC and AURA power supply.

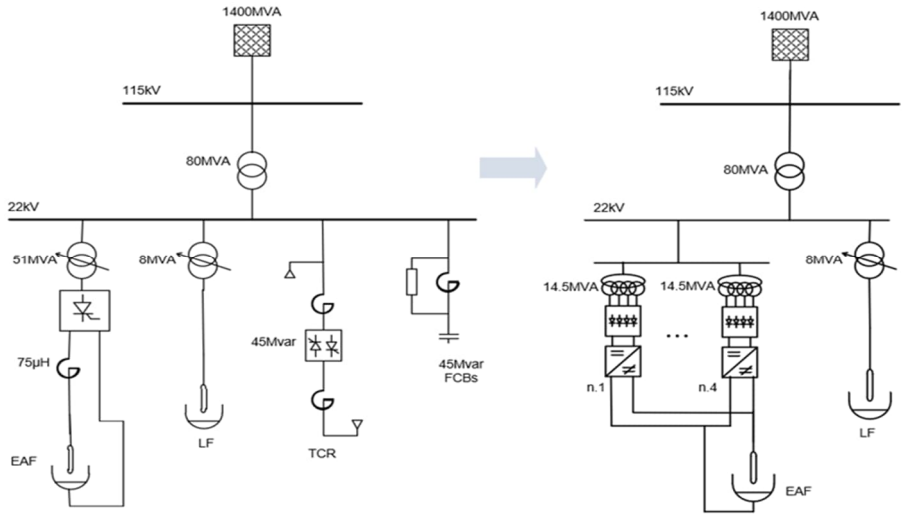

Fig. 1 – Basic schematic – traditional DC power supply (left), VS AURA power supply (right)

The relevant measurements were collected to build a detailed model of the arc furnace [4] and obtain a precise comparative study.
The measured scrap movement is replayed in the simulation model to reproduce the arc-length perturbations.
An accurate model of AURA power conversion is prepared down to IGBT switching level.
A number of recorded events are selected from the existing furnace for validation of the EMT model implemented in PSCAD™ and later in the HiL real-time simulator (RTDS®).
Figure 2 below shows the original recorded arc voltage and current (a), the laptop simulation result (b), and the RTDS validation (c).

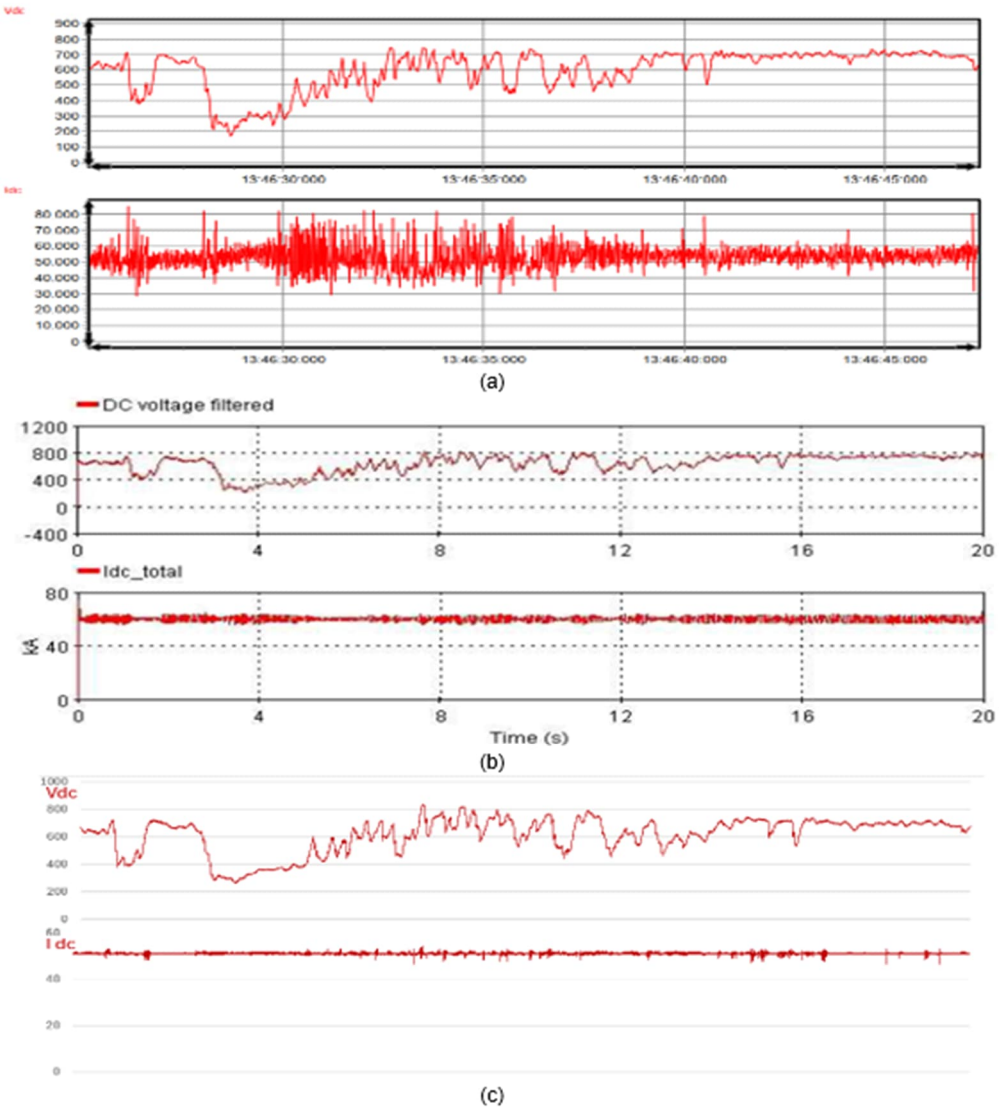

Fig. 2 – Arc voltage and currents: (a) recorded at site; (b) laptop simulation; (c) RTDS simulation

The effectiveness of control algorithms applied by the AURA power conversion system leads to reduced active and reactive power fluctuations on the grid side (Fig. 3), which in turn is reflected in significantly flicker reduction (Fig. 4).

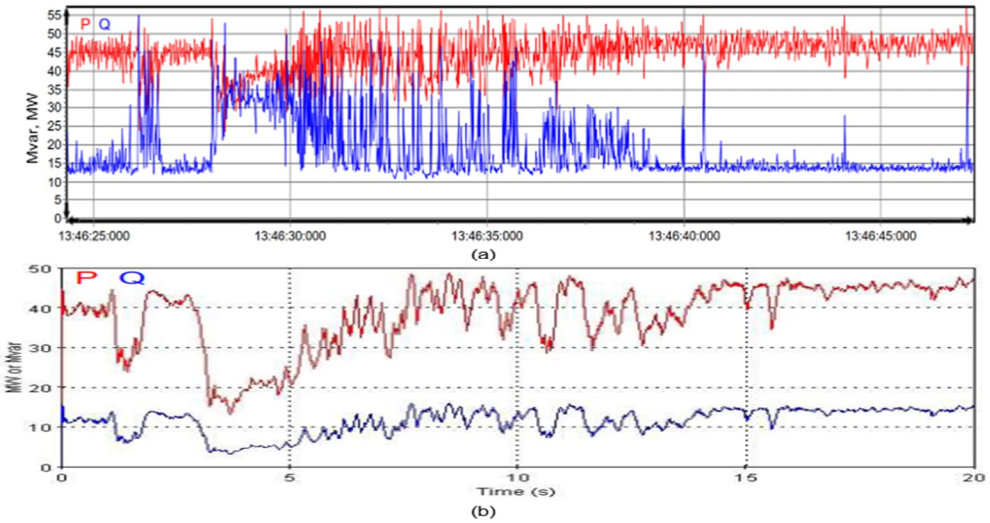

Fig. 3 – Active and reactive power at the EAF feeder: (a) recorded at site; (b) laptop simulation

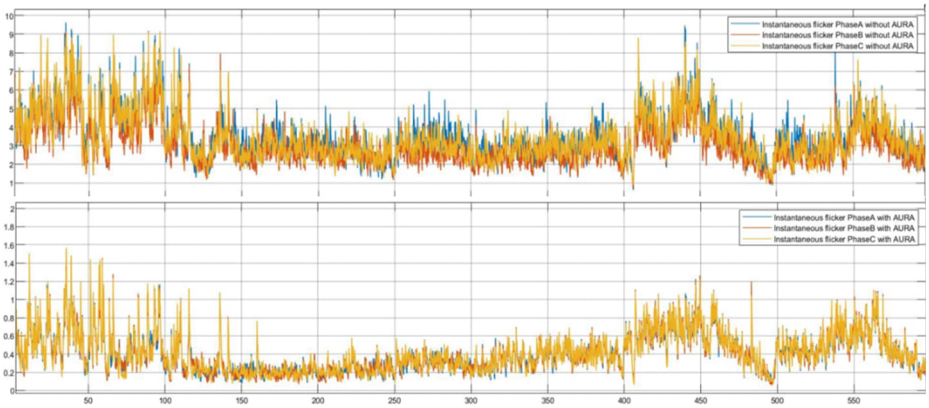

Fig. 4 – Instantaneous Pst at the EAF feeder: (a) recorded at site; (b) laptop simulation

Finally, long-term performances are obtained from complete heating RTDS simulations. A power quality analyzer (FLUKE 1770) is also connected to a simulator.

Tab. 1 – Performance results

PERFORMANCE RESULTS		
	Existing DC-EAF with SVC	X-Pact AURA power supply without SVC
Power Factor	> 0.99 (0.68 without SVC)	0.95÷0.96
$Pst_{95\%}$	3.9	0.6
THDi	<9%	<3%
THDv	<3%	<1%
Current unbalance	<28%	<1%
Average power to scrap	-	+10/15%
Energy consumption	-	-8/10%

THE CONDOOR®[5,6]

Handling and controlling the slag is no more an option for modern EAF.

One of the main constraints of the conventional deslagging process lies in the ineffective control capability,

which still depends on the operator's skill and judgment. With limited control over the slag flowrate due to its channel shape, accurately assessing any slag loss or retention is challenging. Metal may seep through "V" channels formed on the breast, and the quantity of metal in the slag pots suggests inaccuracies in the deslagging process.
Additionally, the openings on the conventional door allow air to enter the furnace or gases to emit from the furnace, depending on whether the EAF pressure is negative or positive. Reducing false air entry is essential for minimizing NOx emissions by limiting cold air exposure to the arc and burner combustion. Improved performance levels can be achieved for many EAFs by properly controlling air ingress.
Furthermore, various automatic machines and equipment units are positioned on the working platform near the EAF and encroach on the slag channel area, which complicates the flow of operations. For example, the slag channel must maintain a proper shape for the robot, sampler, oxygen lances, and carbon injection system: an incorrect sill profile could also result in malfunctions or unsuccessful operations, leading to thus in an increased power off time.
The Condoor® is the only solution capable of meeting all these challenges within a single equipment unit.
Developed by SMS group in collaboration with leading steel producers, it is a consolidated technological solution used in electric arc furnaces (EAF), which serves as the perfect valve for slag control and by sealing the door completely using a pusher that rests against the door tunnel.
The Condoor® features a robust two-axis design that allows the pusher to be moved along the channel (X axis) and vertically (Z axis), to control the door opening.
The Condoor® is fully automated and interfaced with the EAF automation system and is therefore perfectly integrated into the process; thanks to its automatic cleaning cycle, there is no longer any need for forklift cleaning that exposes operators to unnecessary risks.

1.1 Key technological features

Pusher

One feature that sets Condoor® apart from all other slag door solutions is the design of the pusher.
As the component most exposed to heat, radiation, and mechanical abrasion, it incorporates a sturdy water-cooled front panel, heavy steel structure, and embedded hydraulic cylinder, meaning it can push any jammed material on the sill as well as pull the slag for maximum cleaning efficiency. Moreover, the latest updates have resulted in a set of enhanced water-cooled panels that ensure superior lateral and bottom cooling. Such advancements have also simplified the manufacturing process as there are fewer installed components, maintenance is easier, and the need for spare parts is reduced. The Condoor® pusher has a pushing force of 24 tons, a pulling force of 16 tons, and an 800-mm stroke, so it works effectively in a variety of steelmaking processes, including for structural and stainless steels.
Based on the experience gained in more than 50 references currently in operation, the latest pusher design has reached full maturity, ensuring a longer operating time with no major maintenance work required for up to 1500/2000 heats.

Operational control

The Condoor® provides precise control over the door opening, allowing operators to select the optimal times for deslagging. By enabling remote operation, Condoor® enhances both safety and operational efficiency, reducing the need for manual interventions and other door cleaning equipment on the working platform.
The use of direct reduced iron (DRI), hot briquetted iron (HBI), or even hot metal (HM) in the EAF's charge mix produces larger volumes of slag compared to a scrap charge mix. Such EAFs must have sufficient flux to neutralize the acidic content brought in with the burden. In fact, DRI with a higher gangue content requires greater quantities of basic fluxes. Since different plants uses varying qualities of DRI/HBI, comparing process parameters such as flux consumption and liquid metal (LM) yield is quite a challenge. For example, within the MENA region, plants using 100-percent DRI/HBI have been observed to consume lime and dololime in quantities ranging from 25 to 120 kilograms per ton of steel, primarily due to differences in the gangue content and quality of the DRI/HBI.
Looking ahead, the industry recognizes that DRI pellets may struggle to meet global production requirements, leading to greater reliance on iron BF pellets (lower quality materials with a higher gangue content). As a result, effective slag management and control have become essential for modern EAF operations: they are no longer

optional.

Maintenance

The maintenance schedule is synchronized with the shutdowns already planned for the EAF, so there is no increase in downtime. In fact, as part of the weekly maintenance activities, the Condoor® is simply cleaned, visually inspected, and lubricated. At the end of each campaign the shell and Condoor® are taken together to the maintenance workshop, where the Condoor ® is removed and placed on a dedicated maintenance stand.

Fig.4 – Condoor® in operation

1.2 Production results

Described below are three cases studies showing the benefit of the Condoor® in a steelmaking plant.

1.2.1 First case study

One of the main benefits of the Condoor® is decreasing and stabilizing the power off time. In a reference plant in Asia, a remarkable six minute per heat reduction, averaged over 200 heats, was measured, leading to improved process consistency, with standard deviations down by 20 percent (refer to Fig.5).

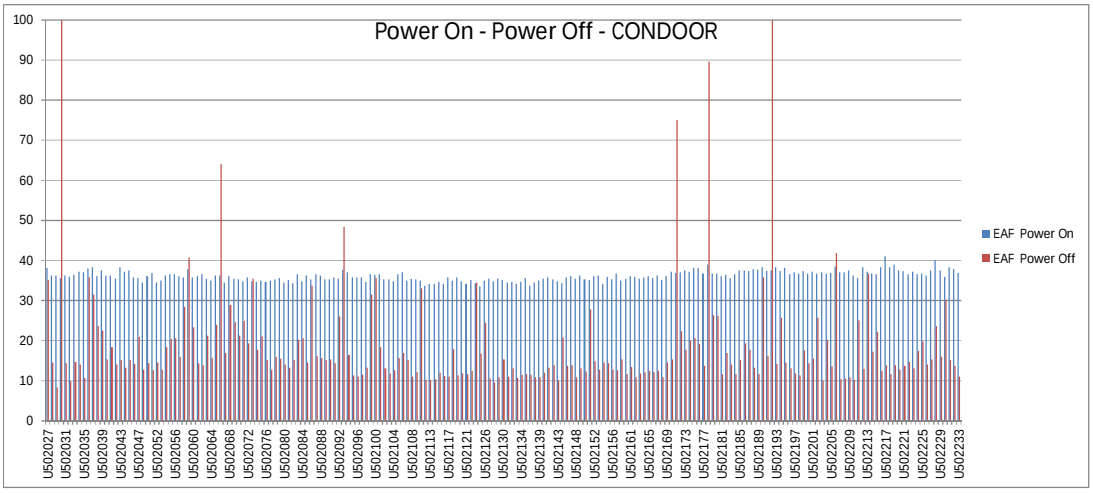

Fig. 5 – Power off time reduction over 200 heats with Condoor® (120-ton AC EAF)

1.2.2 Second case study

In a second reference plant[8], the power-off time was analyzed during an operating period of 18 months, involving more than 8000 heats: 1500 heats before and 6500 heats after installation of the Condoor®. The average P_{OFF} time was consistently reduced to 93.7 percent, corresponding to an increase in annual productivity of 1.15 percent.

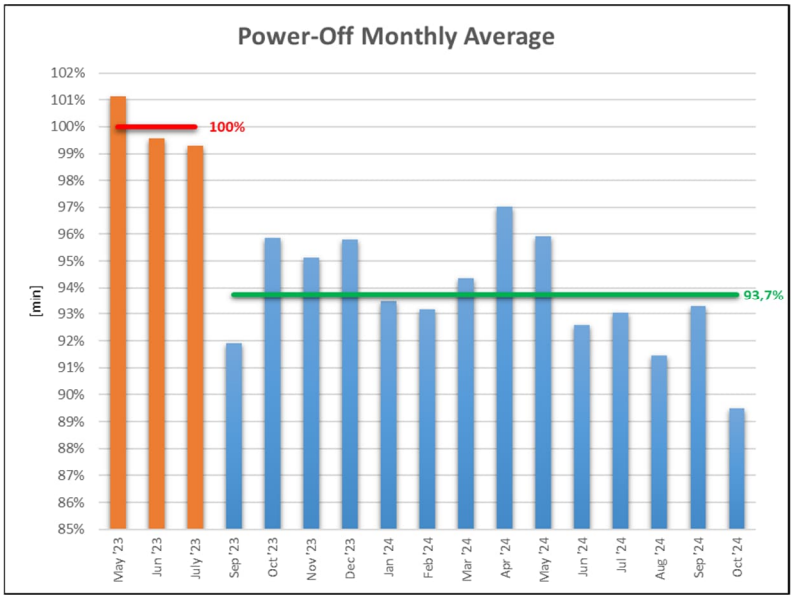

Fig. 6 – Power off time reduction over 6500 heats with Condoor® (140-ton AC EAF)

1.2.3 Third case study

The use of HBI in the process (50% scrap + 50% HBI charge mix) entails increased slag production. A conventional slag door is not capable of controlling the slag flow, leading to continuous deslagging throughout the whole process and thus poor efficiency levels.

By contrast, the Condoor® functions perfectly as a slag valve, retaining the slag inside the furnace, thereby increasing the retention time and overall yield. Accordingly, the deslagging time is reduced to ten minutes only.

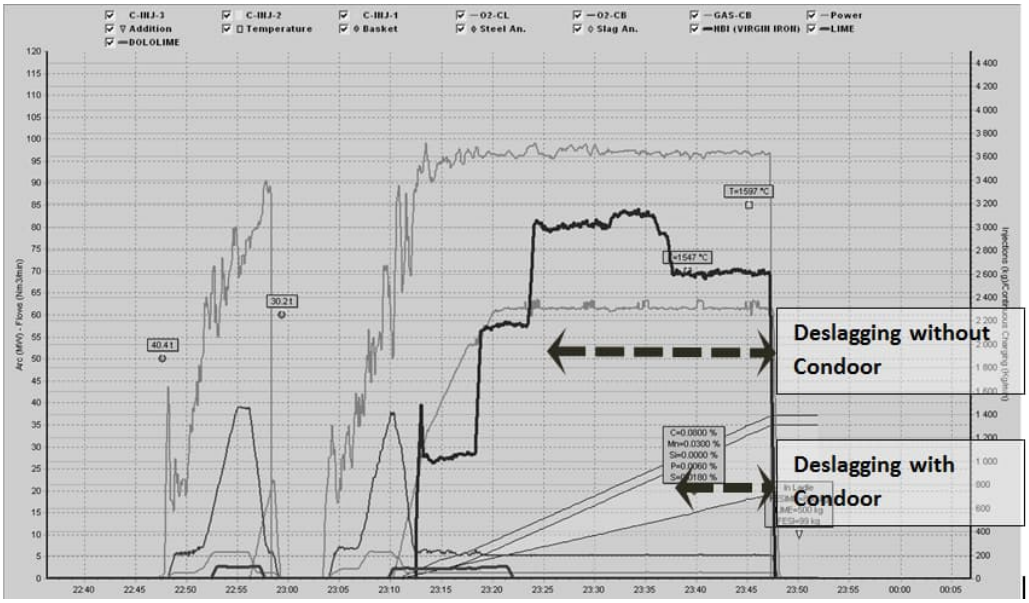

Fig. 7 – Deslagging time reduction during HBI process

X-PACT SAMPLER

X-Pact Sampler (Figure 8) is the robotic solution designed and built by SMS group to perform automatic measurements and sampling of liquid steel.

Today, operational safety in and around electric arc furnaces is one of the top priorities in the steelmaking sector. That is why SMS group developed the X-Pact Sampler, which eliminates the risks associated with liquid steel measurements taken by human beings in severe and hazardous surroundings. The system features safe, fully automatic operation, avoiding direct exposure of the operators to the liquid bath and ensuring better consistency in the measurement results. Moreover, the X-Pact Sampler does not require the process to be interrupted, as it can carry out the measurements during ongoing production.

The latest release of the X-Pact Sampler has been upgraded with improved heat shields, which are made with stainless steel covers that are designed to withstand the harsh environment of a steelmaking facility and can be used for EAFs, LFs, VDs, tundishes, or ladles. The new water-cooled lance ensures a longer lifetime and easier maintenance, with dedicated openings for quick disconnection and replacement of cables and hoses.

The new automation software has been smoothly integrated into the operator interface and troubleshooting procedures, is user-friendly, and is remotely connected to the main control room.

The system can be additionally equipped with the innovative Automatic Cartridge Exchange system, which can accommodate most probes available on the market today.

The flexibility of the X-Pact Sampler makes it ideal for new installations or revamps, as it can be adapted to almost any layout and is capable of handling all types of measurements normally performed by the operators themselves.

SMS robotic applications comply with the latest safety standards, such as the Machinery Directive and DIN EN ISO 10218. Accordingly, the working area of the X-Pact Sampler is fenced off and can be accessed through safety gates or radar safety barriers, which are interlocked with robot movements. Moreover, robot motion is safety certified, and its working range is safely limited.

The X-Pact Sampler is usually coupled with the Condoor, thus boosting the EAF's performance and operational safety in one go.

Fig. 8 – X-Pact Sampler

CONCLUSIONS

The X-Pact AURA power supply solution offers a range of considerable benefits – power factor, Pst, THD – compared to conventional EAF power supply technology.

Further, the use of RTDS enables both customers and SMS to exploit several intrinsic advantages: accurate performance prediction during the sales stage, and compliance studies during project execution. Moreover, the extent of on-site work activities is reduced thanks to the factory tuning of controllers and system de-risking, easy troubleshooting, and the availability of a ready-to-use digital twin.

Condoor® represents an innovative and reliable solution for slag management, emissions control, and operational safety in the steel industry.

The reported three case studies have shown a reduction and a consistency in power off time, as well as a decrease in electrical and electrode consumption.

X-Pact Sampler provides automatic, accurate, and reliable liquid steel measurements, and works in perfect harmony with Condoor ® to ensure safe, unmanned operations.

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