Ref. Ares(2024)2340902 - 28/03/2024

iSteel-Expert

Deliverable 1.3
List of KPIs

	Name	Date
Prepared by:	Renato Girelli	05.03.2024
Checked by:	All (coordination meeting)	28.03.2024
Approved by:	All (coordination meeting)	28.03.2024

Project co-funded by the Research Fund for Coal and Steel (RFCS)

G.A. 101112102

The information and views set out in this document do not necessarily reflect the official opinion of the European Commission. The European Commission does not guarantee the accuracy of the data included in this document. Neither the European Commission nor any

person acting on the European Commission's behalf may be held responsible for the use which may be made of the information contained therein.

Project details

Project Name	**Remote expert virtual system enhancing human management capabilities and favors preservation, transfer and continuous evolution of knowledge for steelmaking operation**		
Project Acronym	iSteel-Expert		
Project No.	101112102	Duration	36 months
Project Start Date	01.07.2023	Project End Date	30.06.2026

Document details

WP:	**1**	**WP Leader:**	**SIDER**
WP Title:	Definition of the current signals, installation of the new sensors & definition of system KPIs and procedures		
Task:	1.4	Task Leader:	TENOVA
Task Title:	Elaboration of functional KPIs and KPIs for final system assessment		
Deliverable No.	1.3		
Deliverable Title	List of KPIs		
Dissemination level	PU		
Written By	TENOVA		
Contributing beneficiary(ies)	ALL		
Approved by	ALL		
Status	Final draft		
Date	28.03.2024		

Document history

Vers.	DATE	AUTHOR / REVIEWER	NOTES
0.1	05.03.2024	Renato Girelli	Preparation of initial version
0.2	20.03.2024	Franco Amadei	Review and update
1.0	28.03.2024	Renato Girelli	Final Draft
1.1			
1.2			

iSteel-Expert - Electrodes status KPIs

the KPIs on electrode status (consumption) and control, provide essential feedback on electrode cooling system and electrical profile control

No	Name	Electrodes consumption
1	Usefulness	Electrodes consumption is a key indicator of the efficiency of the furnace run control (electrodes regulation, electrodes cooling, scrap feeding, slag foaming, furnace pressure)
	Unit of Measure	Kg per ton of tapped liquid steel & kg per ton of good billets & electrode tip shape (indicator of air ingress)
	Determination modality	Computation.
	Computation details	reference interval and required data: - last 100 heats - number of electrodes joining events (tracked based on post joining electrode push pressure increment) - weight of electrode segment (parameter) - tons of tapped liquid steel (from weighing system on ladle car) - tons of good billet (from Level 2) - per electrode phase, the number of jointings, alongwith the number of tips ranked with high side consume. At any new jointing operation (noticed based on the PLC signals on electrodes clamps status) the level of side oxidation of the electrode is ranked based on the shape of the electrode tip (normal or high side consume) assesed through the analysis of the focused images of the electrode's tip, from the EAF front operation floor camera.
	Assessed Base Line value	
	Remarks	
No	**Name**	**Heats between joining for electrode 1**
2	Usefulness	Electrodes unbalanced frequency of electrode joining is a key indicator of local criticalities to mitigate
	Unit of Measure	heats between two events of electrode joining
	Determination modality	Computation.
	Computation details	reference interval and required data: - heat of last but one electrode 1 joining - heat of last electrode 1 joining
	Assessed Base Line value	
	Remarks	
No	**Name**	**Heats between joining for electrode 2**
3	Usefulness	Electrodes unbalanced frequency of electrode joining is a key indicator of local criticalities to mitigate
	Unit of Measure	heats between two events of electrode joining
	Determination modality	Computation.
	Computation details	reference interval and required data: - heat of last but one electrode 2 joining - heat of last electrode 2 joining
	Assessed Base Line value	
	Remarks	
No	**Name**	**Heats between joining for electrode 3**
4	Usefulness	Electrodes unbalanced frequency of electrode joining is a key indicator of local criticalities to mitigate
	Unit of Measure	heats between two events of electrode joining
	Determination modality	Computation.
	Computation details	reference interval and required data: - heat of last but one electrode 3 joining - heat of last electrode 3 joining
	Assessed Base Line value	
	Remarks	
No	**Name**	**Electrodes regulation efficiency - Set Points versus Process Value**
5	Usefulness	The efficiency of the electrodes regulation is precondition for furnace best performance capacity. So the continuous monitoring of such key indicator allows for timely remedia actions.
	Unit of Measure	kA
	Determination modality	Computation.
	Computation details	reference interval and required data: - last 100 heats - process value versus set point of transformer secondary side electrical current: average and standard deviation, singly computed per each phase of the heat
	Assessed Base Line value	
	Remarks	

iSteel-Expert - Electrodes status KPIs

the KPIs on electrode status (consumption) and control, provide essential feedback on electrode cooling system and electrical profile control

No	Name	Electrodes regulation efficiency - Hydraulic system
6	Usefulness	The efficiency of the hydraulic component of the electrodes regulation is precondition for furnace best performance capacity. The hydraulic system efficiency is assessed based on the electrode quick rise performance, from still and with bypass valve open: ramp time, ramp end speed, valve opening time So the continuous monitoring of such key indicators allows for timely remedia actions.
	Unit of Measure	ms (millIseconds); mm/s
	Determination modality	Computation.
	Computation details	reference interval and required data: - last 100 heats - average values of ramp time, ramp end speed, valve opening time
	Assessed Base Line value	
	Remarks	
No	**Name**	**Electric power profile suitability**
7	Usefulness	to drive the electric run of the furnace with optimized power profiles is precondition for achieving the furnace best performance capacity. Up movement with mostly short displacements of the electrodes masts is key indicator of power profiles optimized for application in the diverse stages of the heat.
	Unit of Measure	mm
	Determination modality	Computation.
	Computation details	reference interval and required data: - last 100 heats - for each phase, average values of up displacement of the electrode mast in the diverse heat stages of the heats (up displacement determined by Electrode regulation system based on mast position encoder)
	Assessed Base Line value	
	Remarks	

iSteel-Expert - Slag quality KPIs

These KPIs are about the slag quality (foaming index, FeO content), the deslagging (amount of slag exiting the slag door) and the slag door condition (openness and cleanliness).
They are used to provide feedback on the oxidation of the charge material and effectiveness of the additives practice, operator compliance in terms of slag door control and cleanliness during the heat.

No	Name	Foaming index
1	Usefulness	Sostained and Consistent Slag Foaming is essential for maximazing the energy transfer and minimazing the arc radiation of the sidewalls.
	Unit of Measure	seconds (from foaming height divided by gas velocity); predefined slag appearance ranking (liquid, crusty, foamy)
	Determination modality	Computation.
	Basic Computation - references and	reference interval and required data: - heat by heat, foaming index average values in Consteel and Superheating stages, computed against -> foaming height (by correlating the level of electric current THD, computed by the electrodes regulation system TDR, and/or specific noice signatures from acoustic system, to correspondent threshold of foaming height) -> CO gas velocity (parameter values correlated to furnace relative pressure - heat by heat, ranked appearance of the slag in Consteel and Superheating stages (liquid, crusty, foamy) from analysis of the images provided by the slag door front and side cameras.
	Assessed Base Line value	
	Remarks	
No	**Name**	**deslagging extent**
2	Usefulness	Time and Extention of deslagging are important aspect of effective and well managed operative practice .
	Unit of Measure	kg/minute
	Determination modality	Computation.
	Basic Computation - references and	reference interval and required data: - heat by heat, average values in Consteel and Superheating stages, from continuous estimation based on camera images analysis
	Assessed Base Line value	
	Remarks	
No	**Name**	**slag door condition**
3	Usefulness	Time of slag door opening and closing in the stages of the heat, along with cleaning execution are important aspect of effective and well managed operative practice .
	Unit of Measure	for single status change interval, changing hour and duration
	Determination modality	status change detection through observation with time registration
	Basic Computation - references and	reference interval and required data: - heat by heat, detection of the open/close and cleaning status of the slag door during each stage of the heat, from continuous analysis of the images taken by the slag door front camera
	Assessed Base Line value	
	Remarks	Frequently, the actual open/close status of the slag door cannot just be confirmed by the status of the relevant limit switch which could not operate due to uncleaned slag door.

iSteel-Expert - Bucket charge KPIs

These KPIs on bucket charging operation (bucket position during charging, timing of the charging operation), are aimed to assess possible delays and the compliance of the operator with respect to the established procedures.

No	Name	Scrap Bucket unloading position
1	Usefulness	Properly carried uploading of the scrap from bucket, with the bucket placed in well centered position above the furnace, ensures quick unloading without delays due to roof closing difficulty because of pieces of scrap on the shell border.
	Unit of Measure	% of well centered positions
	Determination modality	Detection of well centered position of the bucket above the furnace, through analysis of the images taken by the EAF front operating floor camera, in roof open condition.
	Basic Computation - references and	reference interval and required data: - against a prefixed number of unloaded buckets, the percentage of the ones well centered
	Assessed Base Line value	
	Remarks	In a Consteel furnace, the furnace scrap charge from bucket is limited to the case of the first heat at the beginning of a new furnace shell campaign, to build the initial liquid heel, or for loading bulky processing residues from internal recycling.
No	**Name**	**Scrap Bucket unloading duration**
2	Usefulness	The whole duration of the furnace charge with scrap from bucket (from roof open to roof close) is a direct indicator of well performed bucket unloading operation.
	Unit of Measure	minute
	Determination modality	from roof open/close status events the duration of last bucket charge and, against a prefixed number of unloaded buckets, average duration
	Basic Computation - references and	reference interval and required data: - bucket by bucket, based on roof open/close status (Basic Automation signals) and detection of unloading bucket above the furnace (from images analysis) and/or increment of the furnace weight (from furnace weighing system)
	Assessed Base Line value	
	Remarks	
No	**Name**	**Roof closing issue after Scrap Bucket unloading**
3	Usefulness	Roof closing issue after bucket unloading is a direct indicator of either not well performed scrap unloading operation or early bucket uploading against furnace previous charge actual melting progress
	Unit of Measure	number of occurrence
	Determination modality	based on roof open/close status and roof opening/closing commands (Basic Automation signals), besides detection of the presence of pieces of scrap on the border of the shell or scrap which must be pressed, through the analysis of the images provided by the EAF front operation floor camera
	Basic Computation - references and	reference interval and required data: against a prefixed number of unloaded buckets, number of occurrence of roof closing issue due to presence of pieces of scrap on the border of the shell and number of occurrence of presence of scrap to press.
	Assessed Base Line value	
	Remarks	

iSteel-Expert - Fume system control KPIs

KPIs concerning the fume system control (amount of emission during the heat, abnormal emission event and high water vapour event), are aimed to assess the fume system draft efficiency and to identify abnormal events.

No	Name	Fume suction regulation
1	Usefulness	Fume suction regulation has a direct impact on energy and electrodes consumptions, as well as on the amount of dragged dust. The intensity of the suction is modulated against targets of relative pressure to achieve and keep inside the furnace in the different stages of the heat.
	Unit of Measure	mm of H2O column
	Determination modality	average values computation
	Basic Computation - references and	reference interval and required data: - heat by heat, average value of inside furnace relative pressure during each stage of the heat, from sampled measured values
	Assessed Base Line value	
	Remarks	
No	**Name**	**Fume emission intensity**
2	Usefulness	Intensity and duration of fume emissions in the stages of the heat are direct indicators of the efficiency of the system draft.
	Unit of Measure	predefined rating of the different fume emission levels (absent, low, normal, abnormal)
	Determination modality	fume emission intensity evaluation through analysis of the images taken by the EAF front operating floor camera. Based on plant signals, the high volume of dust resulting from fifth hole additives dropping will not be mistaken for fumes
	Basic Computation - references and	reference interval and required data: - heat by heat, rating of the fume emission in each stage of the heat - number of abnormal fume emission rated in each single stage in the last prefixed number of heats.
	Assessed Base Line value	
	Remarks	
No	**Name**	**High water vapor event**
3	Usefulness	water vapor high evolution is direct indication of abnormal water leakage, as the one from bucket wet scrap, compare to normal condition of water coming from electrodes cooling system, air moisture, burners CH4 combustion.
	Unit of Measure	predefined rating of the different levels of water vapor (absent, low, normal, abnormal)
	Determination modality	Level of white smoke presence in the fumes emission detected through analysis of the images taken by the EAF front operating floor camera.
	Basic Computation - references and	reference interval and required data: - number of water vapor evolution rated as abnormal in each single stage in the last prefixed number of heats.
	Assessed Base Line value	
	Remarks	Water vapor is an invisible gas, detectable with a thermal camera wotking in 6-7 µm wavelenght. But in condensing evolution it becomes a visible white smoke.

iSteel-Expert - Human and Equipment presence KPI

KPIs on human and equipment presence in the vicinity of the process are aimed to assess the human and equipment exposure during the phases of the process, compliance of the operator with respect to the established procedures, and timing of required activities.

No	Name	human&equipment exposure
1	Usefulness	frequency and duration of human and equipment presence in the vicinity of the furnace, during the process stages of the heats, that is, outside the scheduled furnace maintenance shutdowns, when there is no underway process, are direct indicator of equipment health (furnace and auxiliaries) and, indirectly, of the effectiveness of carried maintenace for keeping them in working order.
	Unit of Measure	occurances and duration
	Determination modality	any occurance of human and equipment presence in the vicinity of the furnace, during any process stage of the heats, has to be notified (HMI procedure), indicating reason (selected from a prefixed list) and duration.
	Basic Computation - references and	reference interval and required data: - heat by heat and stage by stage during the heat, notification of any occurence of presence in vicinity of the furnace - about a prefixed number of last heats, the total occurances of each reason type of vicinity in each stage of the heats.
	Assessed Base Line value	
	Remarks	The notification through HMI procedure of any occurance of human and equipment vicinity to the furnace will be complemented with AI applied to the analysis of the images from EAF front and back operative floor cameras, aimed at the automatic detection of human and equipment presence in the furnace area.

iSteel-Expert - Acoustic Emission KPIs

The KPIs concerning the acoustic emissions of the process are aimed to assess process status and progress, abnormal events, efficiency of electrical profile, status and efficiency of chemical injection system, status and efficiency of continuous charging control, status of critical water-cooled panels and circuits.

No	Name	AE process status and progress
1	Usefulness	Specific noise signatures are correlated to process status and process progress as well as to the running equipment (injectors, burners, oxygen lances). The applied acoustic technology allows to collect and mark such noise signatures both against normal and abnormal process and equipment condition.
	Unit of Measure	dB
	Determination modality	from the Power Spectral Density diagrams, from real time elaboration of the acoustic signals, the average amplitude of the components of the acoustic signals in the more significant ranges of frequency
	Basic Computation - references and	reference interval and required data: - heat by heat and stage by stage during the heat, registration of the average amplitude of the components of the acoustic signals in the more significant ranges of frequency, against status and run condition of the equipment
	Assessed Base Line value	
	Remarks	

iSteel-Expert - EAF vibrations KPI

The KPI concerning EAF vibrations is aimed to assess the process status and progress, the efficiency of electrical profile as well as to detect some abnormal events.

No	Name	EAF vibrations
1	Usefulness	Specific furnace vibration patterns can be directly correlated to the process status and process progress as well as to the running equipment (injectors, burners, oxygen lances) and specific events (bucket charge as an example). The vibration analysis through data processing of the vibration signals allows to collect and mark such vibration patterns both against normal and abnormal process and equipment condition.
	Unit of Measure	g rms^^2 (root mean square)^^2
	Determination modality	from the Power Spectral Density diagrams, from real time processing of vibration signals, the average amplitude of the components of the signal in assessed significant ranges of frequency
	Basic Computation - references and	reference interval and required data: - heat by heat and stage by stage during the heat, registration of the average amplitude of the components of the vibration signal in the more significant ranges of frequency, against status and run condition of the equipment
	Assessed Base Line value	
	Remarks	

iSteel-Expert - Consteel vibrations KPI

The KPI concerning Consteel vibrations is aimed to assess the working order of the equipment, the efficiency of the scrap feeding control, as well as to detect abnormal events.

No	Name	Consteel vibrations
1	Usefulness	Specific Consteel conveyor vibration patterns can be directly correlated to the status of running equipment. The vibration analysis through data processing of the vibration signals allows to collect and mark such vibration patterns both against normal and abnormal equipment condition (as an example, drop of cumbersome piece of scrap from the charging conveyor to the preheating conveyor)
	Unit of Measure	g rms^^2 (root mean square)^^2
	Determination modality	from the Power Spectral Density diagrams, from real time processing of vibration signals, the average amplitude of the components of the signal in assessed significant ranges of frequency
	Basic Computation - references and	reference interval and required data: - heat by heat and stage by stage during the heat, registration of the average amplitude of the components of the vibration signals in the more significant ranges of frequency, against status and run condition of both the furnace and Consteel conveyor
	Assessed Base Line value	
	Remarks	

iSteel-Expert - Consumption

The KPI concerning Electrical energy and oxygen consumption are aimed to assess the global efficiency and optimization of the furnace run, as well as to detect the abnormal condition from which come any increase of consumption.

No	Name	Electrical specific consumption
1	Usefulness	improvement of the efficiency and optimization of the furnace run are prerequisite conditions to minimize consumption and increase the metallic yield.
	Unit of Measure	kWh/ton of tapped steel & kWh/ton of good billets
	Determination modality	computation
	Basic Computation - references and data	reference interval and required data: - heat by heat, the electrical kWh counted by the Electrode regulation system divided by the tons of the tapped liquid steel - heat by heat, the electrical kWh counted by the Electrode regulation system divided by the tons of good billets
	Assessed Base Line value	
	Remarks	

No	Name	Oxygen specific consumption
2	Usefulness	improvement of the efficiency and optimization of the furnace run are prerequisite conditions to minimize consumption and increase the metallic yield.
	Unit of Measure	Nm3/ton of tapped steel & Nm3/ton of good billets
	Determination modality	computation
	Basic Computation - references and data	reference interval and required data: - heat by heat, the Nm3 of Oxygen, injected in lancing modality through the main line, counted by the Level 2 system, divided by the tons of the tapped liquid steel - the same against the ton of good billets
	Assessed Base Line value	
	Remarks	

No	Name	Oxygen activity
3	Usefulness	improvement of the efficiency and optimization of the furnace run are prerequisite conditions to minimize consumption and increase the metallic yield.
	Unit of Measure	ppm
	Determination modality	computation
	Basic Computation - references and data	reference interval and required data: - heat by heat, the Oxygen activity sampled before tapping. If additional oxygen is injected after the sampling , the measured ppm is updated considering the O2 Nm3/ton values when sampling and starting of tapping , available from Level 2 system.
	Assessed Base Line value	
	Remarks	

No	Name	Metallic yield
4	Usefulness	improvement of the efficiency and optimization of the furnace run are prerequisite conditions to minimize consumption and increase the metallic yield.
	Unit of Measure	unit-free
	Determination modality	computation
	Basic Computation - references and data	reference interval and required data: - heat by heat, the heat metallic charge (scrap from bucket + scrap form CONSTEEL) divided by the tons of tapped steel and then multiply by 1000.
	Assessed Base Line value	
	Remarks	

No	Name	Slag formers consumption
5	Usefulness	improvement of the efficiency and optimization of the furnace run are prerequisite conditions to minimize consumption and increase the metallic yield.
	Unit of Measure	kg/ton of tapped steel & kg/ton of good billets
	Determination modality	computation
	Basic Computation - references and data	reference interval and required data: - heat by heat, for each slag former (lime, dololime, carbon) the added quantity divided by the tons of tapped liquid steel.
	Assessed Base Line value	
	Remarks	

iSteel-Expert - GHG emission

The KPI concerning GHG emissions is aimed to attest the improvement of the efficiency and optimization of the furnace from which it derives a reduction of consumption and improvement of the metallic yield, with consequent parallel reduction of GHG emissions both of Scope 1 and Scope 2 kinds, according to the GHG emissions definition in the Greenhouse Gas Protocol.

No	Name	GHG SCOPE 1 emissions reduction
1	Usefulness	The reduction of GHG emissions is persued through the reduction of the consumption and the improvement of the metallic yield. So a KPI about GHG emissions reduction aims to attest the general benefit achievable through the improvement of the efficiency and optimization of both the furnace run and the furnace metallic charge management.
	Unit of Measure	kg of CO2/ton of tapped steel & kg of CO2/ton of good billets
	Determination modality	computation
	Basic Computation - references and data	reference interval and required data: - heat by heat, the consumption and metallic yield are compared to the ones of the assessed base line and the reduction of consumption and improvement of metallic yield translated into reduced amount of GHG emissions directly generated (from less carbon, less natural gas)
	Assessed Base Line value	
	Remarks	

No	Name	GHG SCOPE 2 emissions reduction
2	Usefulness	The reduction of GHG emissions is persued through the reduction of the consumption and the improvement of the metallic yield. So a KPI about GHG emissions reduction aims to attest the general benefit achievable through the improvement of the efficiency and optimization of both the furnace run and the furnace metallic charge management.
	Unit of Measure	kg of CO2/ton of tapped steel & kg of CO2/ton of good billets
	Determination modality	computation
	Basic Computation - references and data	reference interval and required data: - heat by heat, the consumption and metallic yield are compared to the ones of the assessed base line, and the reduction of consumption and improvement of metallic yield are translated into amount of GHG emissions avoided by the supplier of the reduced consumption (from less electrical kWh, less carbon, less oxygen, less scrap, less slag formers)
	Assessed Base Line value	
	Remarks	