Extensive automation upgrade at the JSW steel plant at Vijayanagar

JSW Steel Ltd is India's largest private sector steel company with an installed capacity of 14.3Mtpa, and its Vijayanagar plant is the first integrated steel plant to reach 10Mtpa capacity in a single location. In October 2013, JSW placed an order with Primetals Technologies for the installation of a comprehensive level 2 process optimisation system for 25 existing production facilities within the two meltshops including hot metal pretreatment stations, ladle furnaces, RH degassers, slab casters, ladle tracking system and shop supervisory system. Commissioning of the individual facilities started within 12 months of contract start.

Authors: Rudolf Hubmer, Josef Weiss and N Desai
Primetals Technologies and JSW Steel Limited

The JSW Group began steelmaking in 1982 when it set up the Jindal Iron and Steel Company with its first steel plant at Vasind near Mumbai. The next two decades saw significant expansion and several acquisitions, following the merger of Jindal Iron and Steel Co (JISCO) and Jindal Vijayanagar Steel Ltd (JVSL) in 2005.

Today JSW Steel has plants in six locations in India – Vijayanagar in Karnataka, Salem in Tamil Nadu, and Tarapur, Vasind, Kalmeshwar and Dolvi in Maharashtra. The global operations include a plate and pipe mill in the USA.

Today, with an installed capacity of 14.3Mtpa, JSW Steel is India's leading private sector steel producer. The plant at Vijayanagar, shown in *Figure 1* is India's first 10Mtpa steel plant at a single location and the fastest growing steel plant in India.

CONFIGURATION OF MELTSHOPS

The steel plant consists of two meltshops, SMS-I and SMS-II. The hot metal is produced in four blast furnaces and two COREX plants (C-2000 modules) and transported via torpedo ladles.

The individual plant units are shown in *Table 1*.

PROJECT CONFIGURATION

New level 2 automation systems were supplied by Primetals Technologies for 25 plant units. Two plant units, CC3 & CC4 in SMS-I, were also upgraded to have the same level 2 automation system on all the SMS-I continuous casting machines.

The scope of the project included not only the engineering, design, training and commissioning of the level 2 automation systems, including hardware, system software and application software for the abovementioned plant units, but also the installation of metallurgical process models for optimisation of the production process and level 1 modification. Additionally, a level 2 network for

Fig 1 **JSW meltshops**

Plant area	SMS-I	SMS-II
Hot metal	2 x 2 HMPT, 3 x HMDS	7 x HMDS
Primary steelmaking	3 x 135 t BOF	4 x 175 t BOF
Secondary steelmaking	3 x LF, 1 x RH	4 x LF, 2 x RH
Casting	4 x 1-strand slab caster	3 x 1-strand slab caster 1 x 8-strand billet caster 1 x 1-strand slab caster under construction

Table 1 **Plant units of SMS-I and SMS-II**
(HMPT: hot metal pre-treatment; HMDS: hot metal desulphurisation)

communication with all the involved automation systems, especially the respective level 1 systems, has been installed.

The use of the Primetals Technologies level 2 automation system allows plant management and operators to react flexibly and rapidly to changing input materials and to stabilise the production process. The operator is guided through the different steps of production to ensure consistent and reproducible operations.

The level 2 upgrade project included the entire hot metal treatment area of both meltshops, the three ladle furnaces and four continuous casting machines at SMS-I as well as the four ladle furnaces at SMS-II. Furthermore, a shop supervisory system and a ladle tracking system covering all areas of both meltshops have been implemented.

HARDWARE AND NETWORK CONFIGURATION

As part of the contract, a large amount of hardware and networking equipment was installed as illustrated in *Tables 2, 3, 4* and *5*.

As an example the layout of the new SMS-II network is shown in *Figure 2*.

System software The same standard for system software has been applied in both meltshops. The database servers are implemented as a hot standby system via Oracle Real Application Cluster technology, using an external disk array. The level 2 system is based on the main system software Microsoft Windows 2008 Server, MS Visual Studio .Net 2012 and Oracle 11g database.

Different level 1 interfaces to existing PLC systems from Rockwell, Schneider and Siemens have been realised.

PROCESS OPTIMISATION FUNCTIONS

All level 2 automation systems have the same basic concept. Beside the plant unit specific process model packages, the following functionalities are implemented:

- Plan data handling
- Process tracking
- Communication to existing automation systems
- Master data maintenance
- Reporting

Production planning and scheduling is performed by a high level production planning system. Whenever new planning information is available the data are sent to level 2 via the JSW heat tracking system. On the other hand, production and status information is sent to level 3 to enable proper updating of the overall production schedule.

Emergency dialogs are included so that the operator can manually enter information about heats to be produced.

Process data tracking This forms the core functionality of the system and provides tracking and storage of ▷

Quantity	Main hardware SMS-I
17	Application servers
3	Database servers
2	External disk arrays
39	Client stations, incl. metallurgist and development stations
8	Laser printers
12	15" colour LCD touch screen crane terminals
2	Large scale displays (60" colour LCD, 1920 x 1080 pixel)

Table 2 **Main hardware SMS-I**

Quantity	Main network equipment SMS-I
3	Layer-3 Ethernet managed switches
26	Layer-2 Ethernet managed switches
34	SFP Optical transceiver modules
2	Hardware firewalls
5	WiFi master access points incl. repeater
10	WiFi client receivers
6	Drums of Cat-6 UTP cables
10	Km of fibreoptic network cable

Table 3 **Main network equipment SMS-I**

Quantity	Main hardware SMS-I
14	Application servers
3	Database servers
2	External disk arrays
51	Client stations, incl. metallurgist and development stations
10	Laser printers
14	15" colour LCD touch screen crane terminals
2	Large-scale displays (60" colour LCD, 1920 x 1080 pixel)

Table 4 **Main hardware SMS-II**

Quantity	Main network equipment SMS-I
3	Layer-3 Ethernet managed switches
36	Layer-2 Ethernet managed switches
41	SFP Optical transceiver modules
2	Hardware firewalls
5	WiFi master access points incl. repeater
11	WiFi client receivers
7	drums of Cat-6 UTP cables
10	Km of fibreoptic network cable

Table 5 **Main network equipment SMS-II**

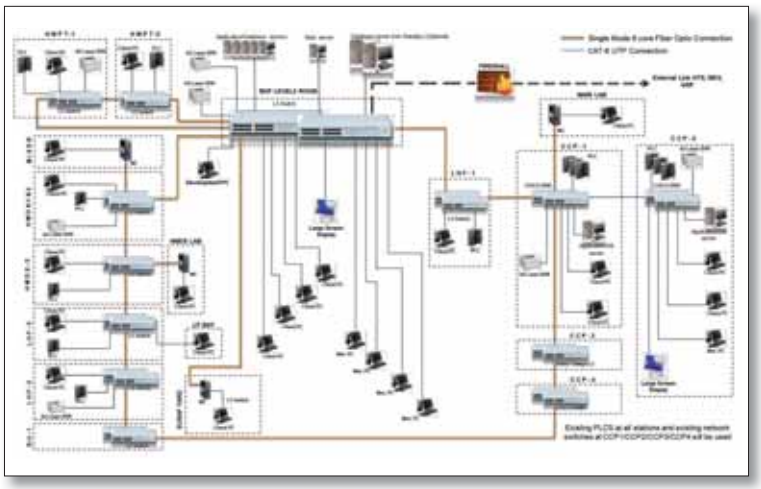

Fig 2 **Network layout of SMS-II**

Fig 3 **HMI screenshot at HMPT**

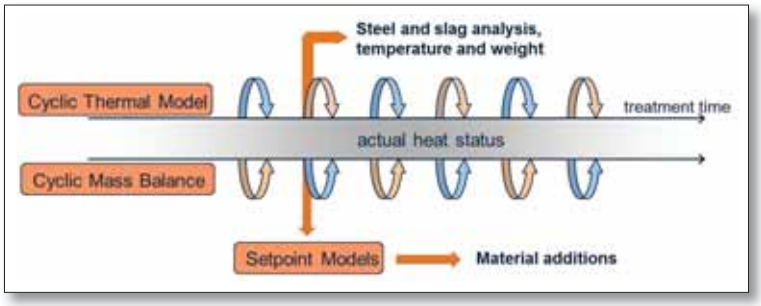

Fig 4 **LF Cyclic and set-point process models**

all gathered process data at the different plant units. Automatic data forwarding is properly implemented for all plant units.

Communication to existing automation systems The level 2 system of each plant unit has several communication partners, namely: laboratory, other level 2 systems, level 3 and different level 1 systems.

Master data maintenance Steel grades are basic input parameters for the level 2 system. Each order/heat is produced to meet a dedicated steel grade specification, which determines the end product. For the different plant unit additional data are needed (eg, end of treatment analysis). Depending on actual production different aims may be adequate. To cope with such situations, treatment schemes are introduced. For instance, in the hot metal pre-treatment injection schemes, oxygen blowing patterns and material addition patterns can be defined. These practices are maintained for each steel plant in a central place and deployed to the individual production units.

Reporting Reports are developed by standard reporting tools (eg, MS-Excel). The finished report is stored as Excel files with all the data within it, so the report data can easily be used for data evaluation later on. Additionally, the reports are available in pdf format for archiving.

HOT METAL PRE-TREATMENT (HMPT)

New level 2 systems are implemented at the two HMPT stations (each with two treatment positions) in SMS-I. There are three different possible treatment procedures: de-siliconisation , de-phosphorisation and de-sulphurisation. Equipment includes an injection device, O_2 lance, material bins and a sampling lance for temperature and steel samples.

From the user point of view there are two different process models, supporting these treatments:

- **Pre-calculation model** Calculation of oxygen volume, material amounts and process step durations based on hot metal analysis, hot metal temperature, treatment schemes and aim analysis (Si, P, S) at the end of the treatment. The calculated material and gas set-points can subsequently be sent to level 1.
- **On-line model** Cyclic calculation of analysis, weight and temperature of hot metal and slag based on the actual online process data (injected materials, material additions, blown oxygen) received from level 1. No calculation of materials is performed.

Figure 3 shows the online window for a desulphurisation treatment at the HMPT station.

HOT METAL DESULPHURISATION

Similar to the HMPT there is a pre-calculation and an online model installed. The pre-calculation model performs a simulation of the complete heat and determines the injection rates and the amount of desulphurisation materials (carbide, magnesium, lime) as well as the duration of each injection step. These model results can subsequently be downloaded to level 1.

The pre-calculation model is started automatically at take-over of the heat and at defined process events (eg, temperature measurement, new hot metal sample received, aim sulphur content changed). Additionally, this calculation can be started manually during the treatment at the operator's request.

Mono-injection as well as co-injection desulphurisation practices are supported by the model. The corresponding injection schemes can be defined by the process engineer in the level 2 data base. The pre-calculation model uses these injection schemes as input for simulating the heat and calculating the injection material set points

A typical co-injection scheme is shown in *Table 6* where Pre-Phase, Co-Phase and Post-Phase denote the different treatment steps of the co-injection scheme. Dur. Min/Max defines the minimum and maximum allowed durations of the treatment steps. The precalculation model uses flow rate practices (Practice 1, 2 and 3) for its calculations. The Use flag indicates whether a certain flow rate practice should be considered by the precalculation model or not.

The precalculation model will employ all possible treatment schemes (mono- and co-injection), which are currently in use for simulating the heat. The list of model results, that is, calculated treatment times, material amounts and material costs are shown on the user interface. The optimum solution according the optimisation mode (cost, time or cost by available time) is pre-selected (see the green line in *Table 7*). From this list the operator can select the practice to be used in the desulphurisation treatment.

The green line indicates the optimum result (for time optimisation) pre-selected by the model. For each injection material, the availability, price and chemical analysis must be known and the process optimisation mode has to be specified before take-over of the heat.

The following optimisation modes are supported:

Cost optimisation If cost optimisation is specified, the pre-calculation model pre-selects the material cost-optimised model result to reach the aim sulphur content. Cost optimisation may lead to an increased treatment time if, for instance, the cheapest material has a lower desulphurisation efficiency.

Time optimisation If time optimisation is specified, the pre-calculation model pre-selects the most time-efficient (fastest) process route to reach the aim sulphur content. Time optimisation is the default mode.

Fig 5 **LF Online HMI**

Fig 6 **Caster online HMI**

	Pre-Phase		Co-Phase		Post-Phase	Use
Dur. Min [min]	1.25		1.00		1.00	
Dur. Max [min]	1.25		30.00		1.00	
	Flow CaO [kg/min]	Flow Ratio CaO:Mg	Flow CaO [kg/min]	Flow Mg [kg/min]	Flow CaO [kg/min]	
Practice 1	65	5:1	65	13	65	☑
Practice 2	70	5:1	70	14	70	☑
Practice 3	80	5:1	80	16	80	☑

Table 6 **Typical co-injection scheme (with injection ratio CaO:Mg=5:1)**

DES Practice Selection

Calculation			Materials Wt.[kg]				Step 01				Step 02	
Type	Ratio	Dur. [mm:ss]	CAD9F3 (CaC2)	MgInj	Price	S Tmt. End [%]	CAD9F3 (CaC2) Wt.	CAD9F3 (CaC2) Rt.	CAD9F3 (CaC2) Wt.	CAD9F3 (CaC2) Rt.	MgInj Wt.	MgInj Rt.
Co	8.3:1	10:52	450	47	18136	0.0098	38	50.0	388	50.0	47	6.0
Co	5.0:1	11:32	387	67	15597	0.0098	30	40.0	337	40.0	67	8.0
Co	11.9:1	11:32	483	36	19472	0.0098	25	50.0	433	50.0	36	4.2
Co	11.8:1	12:37	484	37	19489	0.0098	23	45.0	439	45.0	37	3.8
Mono	-	15:07	596		23999	0.0100	596	45.0				

Table 7 **Example of pre-calculation model results**

LADLE FURNACE

The new level 2 system has been implemented at the three ladle furnaces in SMS-I and the four in SMS-II. The automation system for the secondary metallurgical treatment station contains several process models, the purpose of which is the calculation and control of the ▷

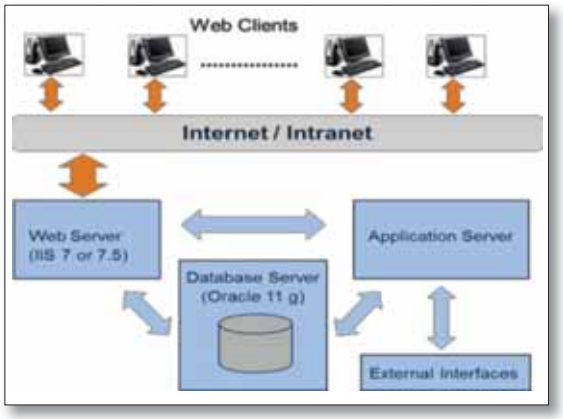

Fig 7 **Shop supervisory function**

state of the heat (weight of steel and slag and their temperature and composition) according to actual production conditions.

From a user point of view there are two models:

- **Pre-calculation model** which performs a simulation of the complete heat (starting from the current process step) and provides heating and material set points, which can be downloaded to level 1 subsequently.

- **Cyclic online model** which provides cyclic calculation of the status of heat (temperature, weight and analysis of steel and slag), taking into account chemical reactions and physical processes, as well as events like charging of materials and measurements.

The pre-calculation model is activated before heat start in order to perform a simulation of the complete LF treatment. Additionally, this calculation can be started during treatment at the operator's request or automatically after defined process events (eg, temperature measurement, or aim temperature modified). It covers specific set-point calculations such as temperature adjustment, alloying, deoxidation, desulphurisation, slag conditioning and inclusion modification.

During the treatment the state of the heat is calculated by cyclically running all models while updating them with actual process data. The results of these dynamic calculations can be observed in the trend viewer of the HMI online model application, both as up-to-date time and future predictions of the current treatment (see *Figure 5*). Hence, for each cyclic re-run of the models, an entire pre-calculation for the remaining treatment time has to be performed. Using this method the operator can conveniently observe the whole treatment, visually based on a simulation incorporating all new incoming actual data.

CONTINUOUS CASTING

The new CC level 2 system has also been implemented at the 4 continuous casting machines in SMS-I. A complete new installation was done on casters 1 & 2, while casters 3 & 4 have been upgraded and all casters in SMS-I run the same CC level 2 system version.

The basic functionality of the CC level 2 system is production plan handling as heat and slab tracking from the first announcement of a heat until the last slab has left the caster run-out area. Production events as well as quality-related information are tracked by the system.

A screen output example is shown in *Figure 6*.

The following additional features and process models are built within the new level 2 caster system at SMS-I:

Heat pacing For sequence casting the steelmaking process is synchronised with the casting process.

Equipment Expert Tracking and maintenance of the main machine equipment and their components.

Dynacs secondary cooling system Advanced process model for determination of the online temperature profile of the strand and calculation of the required water flow set-points.

Nozzle expert Monitoring of the condition of the secondary cooling system.

DynaGap – Dynamic gap optimisation Advanced process model for optimum strand gap and soft reduction at the optimum position.

Cut length optimisation Application of optimisation algorithms to cut as many prime length slabs as possible.

QE Quality Expert Quality control system for slab casting (data tracking and quality evaluation).

Caster simulator This is a script-based test tool for the caster level 2 system. The utility implements a simulation system for important level 1 signals and events required for processing a heat at the caster. This simulation program is used to test new or modified functions.

SHOP SUPERVISORY FUNCTIONS

The Shop Supervisory Function (SSF), a web-based application which gives a complete overview of the plant starting from the hot metal output of ironmaking units to the final product at the casters, was implemented for both meltshops. Its main function is to gather information from different aggregates through external interfaces, different stations through operator input and to display

the information in an organised way as online data and historical data. There is also long-term storage of historical data for reporting. Order information is displayed as-received from level 3 along with production status. Hot metal/steel/slag analysis result as received from different aggregates or from central laboratory is tracked heat wise and is displayed for online and history. Tracking of equipment based on number of heats or duration along with equipment master data are kept.

Figure 7 shows an overview of the SSF structure – a combination of SOA (Service Oriented Architecture) and N-Tier Architecture. The main difference between this and a client-server system is that the Web User Interfaces (HMIs) have no direct interaction with the database or with the Server tasks, rather, it communicates through the Windows Communication Foundation (WCF) Service.

The following applications are available in SSF Application (Process Web Explorer):

- Plant overview – live display of information for entire steel plant (with detail aggregate type view)
- Plant overview for large screen – live display slide show of information for entire steel plant
- Production schedule – live display of production schedule information
- Status overview – live display of information for heats, ladles
- Equipment tracking – tracking of equipments with status
- Ladle tracking live tracking of the steel ladles at all the aggregates or ladle preparation area
- Analysis viewer – live display of analysis and display of historical analysis
- Reports Viewer – Display of automatic generated reports and manual generation of reports in pdf and/or excel format
- Maintenance – ladle and equipment maintenance.

LADLE TRACKING

The Ladle Tracking System (LTS) is a web-based application which gives a complete overview of furnace charging ladles and steel ladles available and handling of crane jobs. Based on the information gathered from external interfaces and operator input from crane and/or other areas, the system tracks the ladles and displays information in an organised way as illustrated in *Figure 8*.

The ladle information for each ladle campaign and cycle is tracked and archived at cycle end for review/report.

The following are the highlights of the application:

- Overview of all ladles with tracked properties and events
- Crane operation handling (most of the crane job assigned automatically when ladle is in cycle)

Fig 8 HMI for steel ladle tracking SMS-I

- Auto job creation for cranes based on received interface messages and other logic
- Crane job management for ground operator (based on actual situation in case of emergency/out of cycle)
- Facility to assign charging ladle for converter along with route of ladle to have crane auto job
- Bay overview with available ladles and status for crane operator and ground operator
- Ladle inspection/maintenance/repair/prepare activity handling
- Steel ladle pouring operations (partial/full/distribution to multiple ladles etc)
- Thermal ladle condition evaluation
- Tracking of ladle life (campaign life, lining life, slag zone life, plug life etc)
- No client installation required
- Ladle history archival for reporting and viewing
- Crane job evaluation report
- Easy configuration of ladle properties and events
- Application compatible with all modern web browser (IE, Chrome, Mozilla)
- Can be upgraded to a full automatic ladle tracking system (Radar/RF ID based).

CONCLUSIONS

Primetals Technologies has successfully implemented new level 2 process optimisation systems for 25 plant units at JSW Toranagallu steel plant within the given time schedule. The start-up of all available aggregates was completed as per schedule in 26 days. Our long experience and the excellent cooperation with JSW have been the key factors for this success.

This major automation upgrade will support JSW in its strategy to stay on the leading edge of technical advancement and to further look for sustainable growth. **MS**

Rudolf Hubmer and Josef Weiss are with Primetal Technologies Austria GmbH, Linz, Austria. N Desai is with JSW Steel Ltd,Toranagallu, Karnataka, India.

CONTACT: rudolf.hubmer@primetals.com