Industry 4.0 – Plant Management- Concept to implementation in Steel Industry

Yatin Purandare, Chairman and MD, Vega Innovations and Technoconsultants

Overview

Integrated Steel Plants demand more and more seamless process integration as a part of extended automation – basically extending the automation carried out as part of Industry 3.0. The impact that raw material and process parameters have on finished product quality and productivity necessitates close monitoring and control to reduce rejections, wastage, and improve productivity by linking business and process automation in ways never done before. Industry 4.0 is the answer.

The basic Industry 4.0 technologies – Sensors, IIoT, WiFi, Internet, and Cloud – are well known. But building solutions that will survive the harsh environments of Steel Industry is the key. Special design and implementation considerations must be deployed, while delivering targeted business and operations benefits.

Vega's **intelleWORKS**™ implemented at a mini steel plant of 0.5 Mn TPA capacity, based on Industry 4.0 and integration with Business Automation, helped the customer derive a great value in quality, productivity, and efficiency.

In collaboration with the customer, keeping long-term goals in mind, the overall solution concept was arrived at with a vision to be the first Industry 4.0 compliant manufacturer in its class. The layered architecture was based on Data Acquisition, Data Processing, and Intelligence to optimise the processes. The modular nature of **intelleWORKS**™ enabled the customer to take a multi-staged approach to meet complete Digitalisation.

The architecture that drives Vega's solutions is as below:

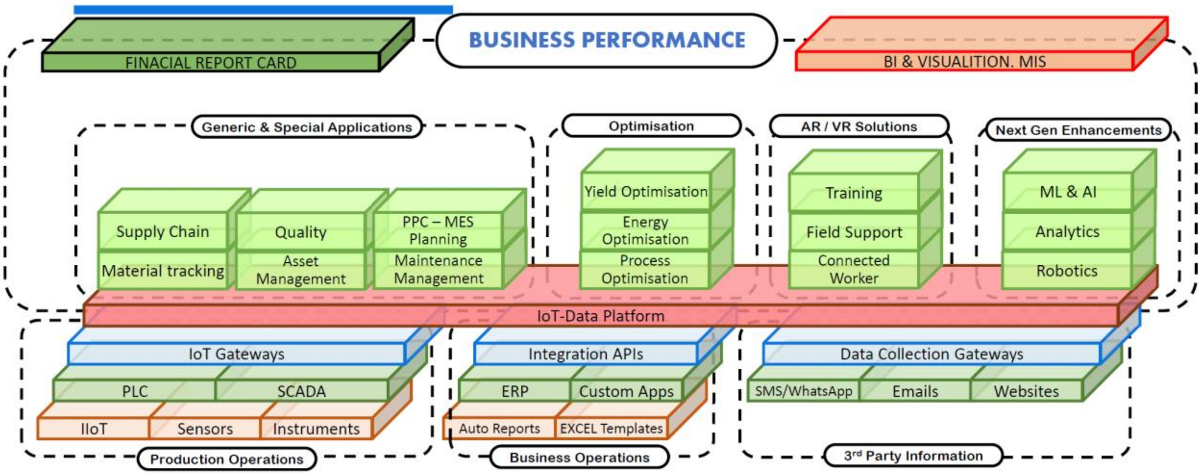


Figure 1 - Vega's Solution Architecture (Copyright Vega Innovations and Technoconsultants Pvt. Ltd.)

Data Acquisition

The first initiative is to collect plantwide data and bring it at a central place without manual intervention.

The primary purpose is to get visibility of Process Data across the plant. This gives the respective Process Owners information about their process's effects on downstream processes.

The second purpose is to do away with manual generation of daily reports and MIS. This process is digitalised to make it happen automatically and in Real Time. These Real Time reports, referred usually as Dashboards, are targeted for respective Process Teams to get the information delivered 'Anywhere' - on individual mobile devices.

Exception and Consolidated report per shift per day is automatically generated and published for the Managers to get the required inputs to help take corrective actions for the improvement.

Vega deployed **intelleVIEW**™ IoT platform to acquire data from each individual process automation systems, Sensors and IoT devices and third-party applications including web apps.

A representative list of daily reports as below, for each process independently and also consolidated at a plant level, are automatically generated.

- Production/ Productivity, Yield, Raw Material Consumption, Electricity Consumption - A quick information for Padta calculations.
- Electricity Consumed, Load Factor, Power Quality Parameters such as PF, Harmonics. Advance Report gives a drill down data at each section and equipment level.
- Process Disturbance - Idle Time, Process Delays, Cobbles. Advance Report gives a drill down data at each section and equipment level.

The immediate benefit is avoidance human errors, prevention of delays in getting information, and overcoming challenges of accessing information 'anytime, anywhere' due to mobility and Cloud based technology.

Material Traceability

The is the second initiative. The aim is to create a transparent quality process to increase customer confidence and satisfaction, make entire plant aware of the Finished Product quality parameters and use such information in individual and integrated process information. The modules of Vega's **intelleWORKS**™ helps customer achieve this.

Product Genealogy is a key demand by the Customers to understand the consistency of and traceability to the root level of finished product quality. Automation the existing manual process of generating records, gives the Customer confidence in quality management as well as adherence to international standards such as BIS.

Special design and implementation considerations must be deployed due to the very harsh nature of the manufacturing environment which is typical in steel making industry. For example, extremely high temperature scenarios near furnaces and on the surface of the ladle required special protection designs to avoid burnouts of the sensors and IIoT devices. Different IIoT devices communicated within the plant premises using Wi-Fi.

The software consists of a core application hosted on cloud with few small modules deployed on-premises for some localised interaction with legacy machines and equipment for data collection.

Approach

The solution divides the manufacturing process, from the point of digitalization, into five areas.

1. Melting
2. Ladle tracking
3. Casting
4. Rolling
5. Bundling

Melting

The solution involved interfacing with PLCs supporting the furnace operations and deploying additional sensors and IIoT devices to identify start of the heat, end of heat, slag-off events, and tapping events. It also involved creating traceable identifications for heat samples, linking spectrometer testing results to the samples and to the heat.

A QR/Bar code Label on the finished Product allows the customer to trace-back the product up to Heat Data for Chemistry, Grade, and mechanical properties.

A Scrap and Sponge Iron input management software **simpliRECYCLE**™ is installed for Scrap Process House along with batching, gradation and internal transport after grade weighing to Furnace charging platform. This cumulative tonnage per day is used for Melt yield calculations.

The Induction Furnace Level 1 automation is integrated with **intelleTRACE**™ to generate a HEAT NUMBER, plot all relevant data of power consumption, stage wise temperature measurement, slag removal time and various chemistry samples for the given heat. Direct integration with Spectrometer through bar coded heat samples (Lollipops) allows to track the heat chemistry per furnace and crucible.

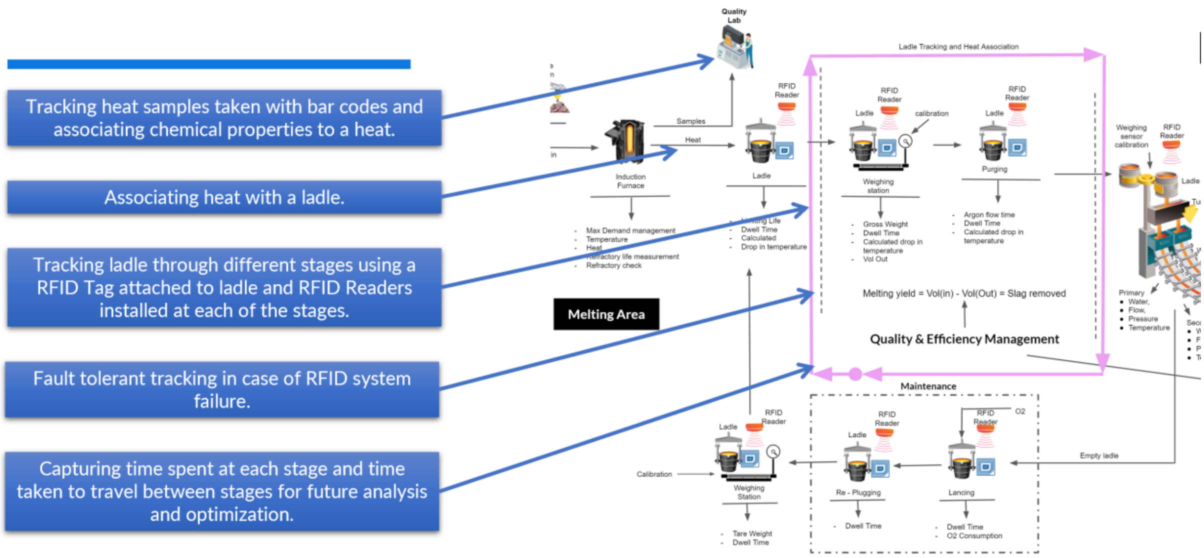


Figure 2 - Heat identification and ladle tracking

Ladle Tracking

Ladle tracking helps in

- Identifying the heat's journey accurately from furnace to caster
- Acquiring accurate timestamps for ladle arrivals and departures and accurate transit times, which are useful for crane logistics analysis and planning in future
- Calculating heat losses for waiting time, and correct temperatures for tapping and heating
- Assigning steel weight, remaining weight, and tare weight to the ladles, which is important for mass analysis

Passive RFID tags are fixed on ladles using a specially designed RFID Protection Armour. RFID Sensors housed in its own protection housing, leveraged these RFID tags to track position of the ladles. Due to the tags, each ladle gets a unique Identification number. The RFID sensors in furnace area are housed in a specially designed protective cover build using a special material. Even with the protection armour, the RFID tags could be damaged by direct splashes, collision hooks of crane, etc. Thus, the protection armour is designed for fast and simple exchange of the protection armour containing tag. New tags are automatically recognized by the software and the complete process of changing and detecting a new tag is quick. IIoT in other areas were deployed as required. For example, at the weighing station where the ladle is weighed before going to furnace for tapping and after the molten metal is tapped into the ladle is one such position in the process.

The software application is also able to determine whether the ladle took a break in the journey at a purging station and the temperature drop due to waiting at the purging station. Appropriate alarms are provided if the wait starts going near acceptable lower limit. This ensures that the ladle arrives at casting station with metal at acceptable temperature.

The tap-to-tap time monitoring and calculations of number of heats enabled to derive at refractory life management model.

The tapped heat is transferred to a ladle with unique ID to ensure predictable travel from tapping to caster platform through weighing and purging stations. The Ladle idle time is reduced by sequencing Heat with Casting demand with optimised Load Factor.

The unique ID of ladle carries heat data such as Chemistry to the casting platform and the weight data gives molten material weight of the heat. The accumulated molten metal weight and input raw material weight on daily basis helped to understand Melt Yield and Calibrate the grade mix for optimum yield and power consumption.

The Ladle transferred to Caster platform transfers heat data to casted billet. The weighing system on casting platform is used to measure the flow rate of Ladle and generate Ladle demand to achieve seamless and break-less casting.

The ladle is identified using its RFID at the casting station once it arrives there. This provides input for volume of molten metal. Accessing weight data using weighing sensors on casting station, through IIoT connected to it, flow rates are determined. Combining this information with configurations of casting station's subcomponents like tundish and casting strands, the software application can associate heat number to each billet. For this the application additionally leverages ability to identify billet cutter activities through the interface with existing PLC that controls the cutters.

Casting

The Caster Level 1 system along with additional IoT devices and sensors, is integrated with **intelleTRACK**™ to get the Casting parameters for a given Heat and relate the Heat and Casting data to individual billet. The Casted billet chemistry was linked through Spectrometer integration and by creating UID through Bar Code for each billet sample.

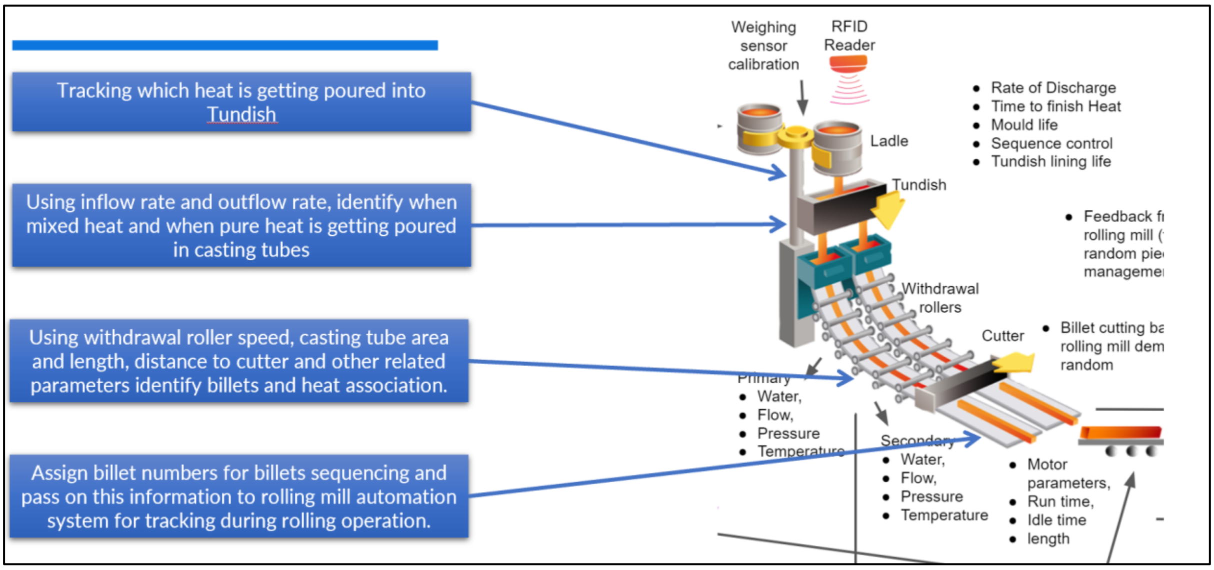


Figure 3 Tracking at caster

Using the sensors deployed across the conveyors transporting billets coming out of caster, the application can determine whether the billet has moved into rolling mill for hot rolling or has been moved to a cooling bed for future use. A barcode label creation for billet moved to cooling bed is available as option. When the cooled billet is to be reused or if billets purchased from outside are to be used, they are passed through a reheating furnace. The barcode labels provide identification so billets going through the reheating, which is a useful information for further sequencing.

Using sensors, the application determines whether a billet has arrived straight from caster (hot rolling) or it has come from reheating furnace. A unique billet number is assigned to it and the appropriate heat properties are associated with this billet number. This billet number is then handed over to the Rolling Mill Automation System.

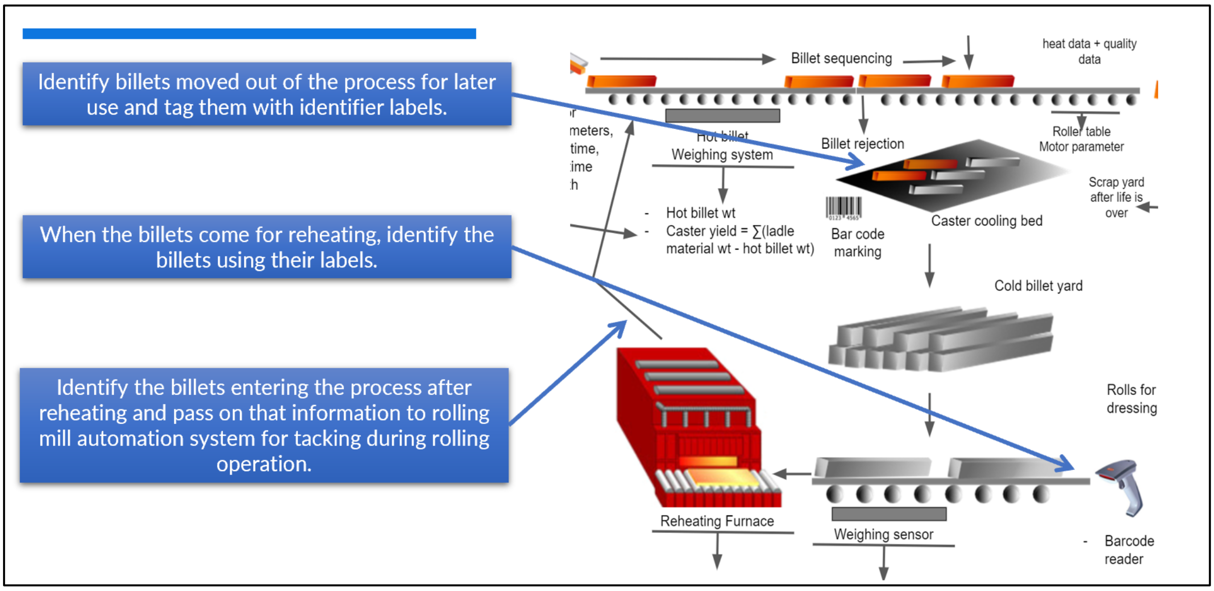
Reheating

The Reheating Furnace (RHF) controls are integrated to learn when and which islets are progressed to the Mill from RHF. The chemistry for such billets is tracked through Furnace Tracking software. The Heat Data for the billet is passed to **intelleTRACK**™ when the billet is ejected.

The tracking of Caster Billet and RHF billet is traced throughout the transfer path up to rolling mill.

The Casted and RHF billet is Tracked throughout in rolling and downstream processes till bundle formation along with Process Parameters and Quality Control Laboratory Data for each sample.

A consolidated data of the finished product/ products is captured, and a Bar Code label is generated for each bundle.



Rolling

The rolling mill automation system, in addition to its primary function, tracks the conversion of billet into bars. So, when finally, the bar comes off cooling bed, the Tracking application knows which billet the bar belongs to and hence knows its genealogy information like heat number it belongs to and its chemistry. The tracking application also interfaces with quality system to capture the mechanical quality test related data for the bars.

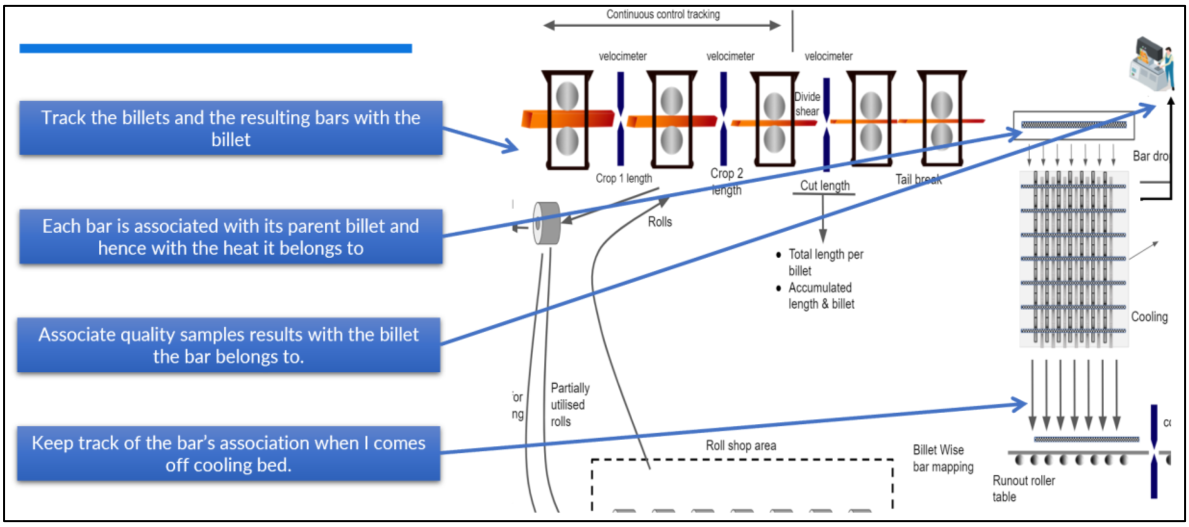


Figure 4 Tracking in Rolling Mill

Bundling

The tracking application interfaces with PLC of bundling automation system. The application receives bundle identification number, and which bars the bundle is made up of from bundling automation system. Based on this the tracking application prints a label with QR code which is attached to the bundle. Scanning the QR code gives required technical and commercial information. This QR code is useful while identifying bundle in the yard for dispatch and by the dealer / end customer to identify bars chemistry if required.

A mobile application will help dealers to scan the QR Code and instantly get chemistry details and any other details required.

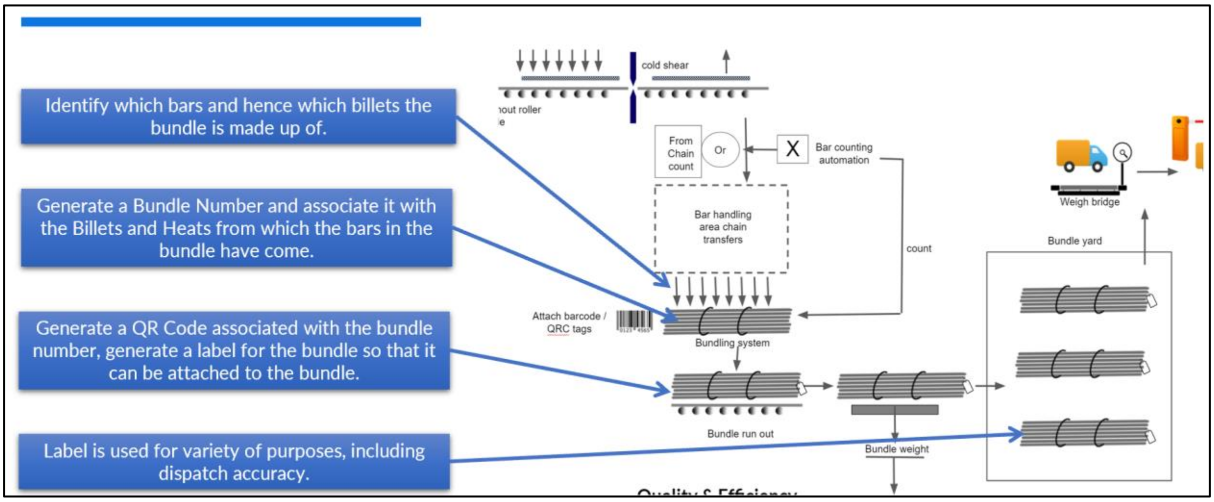


Figure 5 Tracking during Bundling

Process Optimisation

The third initiative is to identify areas of continuous improvements in Productivity, Quality and Efficiency. Then each of these areas to be embarked upon as projects.

Billet Sequencing - Machine Learning and Artificial Intelligence

Purpose is to improve Hot Metal Consumption in Hot Rolling or Integrated Steel Plant.

The data collected from Caster, Reheating and idle time report gives the present productivity and hot metal consumption. With purpose of feeding the rolling mill with 3-7 secs billet to billet gap needs Machine Learning and Artificial Intelligence to define the Casting Billet Cut Length, Casting Speeds, Transfer Roller Tale and Chain Speeds and introduction of RHF billet whenever the expected Mill Idle time is more due to unavailability of casted billet.

The solution is designed to

- Maximise the use of Casted billet to get better hot metal consumption and thus reduce the cold billet generation and its reheating cost
- Use of billets in sequence to get the best through put from Rolling Mill and thus increase Rolled Production.

Operator Less Bar Handling

This involves cooling bed Robotic Control after shear with Machine Learning and Artificial intelligence.

Purpose is to reduce the Cobbles from Shear to Cooling Bed as the parameter settings here are completely operator dependant and need a continuous calibration. This demands high skill of operator else results into a greater number of cobbles due to mishandling of braking and uneven parking.

Vega used a solution based on tracking of billet under rolling, length data pre and post optimisation and introduced special sensors with intelligent IoT system to regulate the parameters per bar such as start braking and breaking speed to achieve,

1. Parking on Cooling Bed in +/- 100 mm
2. Parking of Random Piece on Cooling Bed in +/- 150 mm
3. Zero Cobble in Shear to Tail rake Area
4. Zero Cobble on Cooling Bed
5. Avoid accident situation of non-braking of Random

The Solution resulted in,

1. Improvement of Yield as the Cobbles in the area are eliminated.
2. Improvement in Rolling Mill Up Time
3. Increased Operational Speed to increase the productivity as Bar Handling is not dependant on operator which was a bottleneck earlier due to operator limitation.
4. Consistency in operation.

Quality Management System -

Based on the collected data from various processes, linked with quality labs and finished product label, various quality reports are generated automatically and are attached to despatch details. Vega's **intelleQMS**™ software module compiles the data at various stages and generates various quality reports such as,

1. Raw Material and billet Gradation, Chemistry and inspection Report
2. BIS Report with reference to Lot No., Heat Number and Bundle Number.
3. Test Certificate per lot of despatch and attached to Auto Generated E-Invoice through **simpliDELIVER**™ module used for Logistics Management.

The above eliminates manual operation in data collation to publishing required data to the Customer. All the reports are shared along with Invoice in printed form and a Bar Code on the Invoice and/ or bundle enables user to download such reports from Web Portal.

The quality deviation or exception alerts are generated in real time for the Process Managers to take required corrective actions and avoid the rejections.

Energy Management System -

The **intelleVIEW**™ Plaform gathers entire Electricity Consumption Data of the plant with sampling rates of 3 secs. Each Process, Section, Equipment energy data is captured and is correlated with individual process production to get Consumption Per Ton Per Process.

Vega's **intelleENERGY**™ module helps to analyse many conservation aspects such as,

- The Load Factor Monitoring System allows the user to track trends and suggests the available time for shutdown without losing on the benefits of Load Factor maintenance.
- The Power Quality Data such as PF and Harmonics is generated at Plant, Process, Section and Equipment to understand weak links in the distribution system and take corrective actions to reduce the losses. Similarly, the data is further used to understand each equipment's operating factors with reference to the production and thus generates MIS for improvements in Energy Saving area.

Asset and Maintenance Management System -

One of the key aspects of getting optimum plant performance is PLF (Plant Load Factor) or PUF (Plant Utilisation Factor). The more the uptime of the equipment, more is the PUF resulting in higher productivity at the same cost. This needs a stringent meticulous and intelligent Maintenance Management.

Vega's **intelleASSET**™ and **intelleMAINTAIN**™ modules offer Asset Life Cycle Management and Centralised Maintenance Management without any Human Data Entry.

The Process Data collected in above processes is added with Equipment Data on its running, wear out, lubrication/ oiling cycles. The actual data is compared with the equipment specific Life Cycle, Maintenance Cycle data and necessary Alarms are generated. The Maintenance Teams get Alerts for actions to be taken for Preventive maintenance. For routine life cycle changes/ replacements, automatic Job Order creation for Maintenance teams linked with spare parts, tools availability through Inventory Management module **simpliSTOCK**™.

The collected data over a period is analysed through algorithms for Predictive Maintenance of each equipment and thus help to avoid emergency real downs. Historic records for real down help in timely maintenance.

Performance Management -

The ultimate requirement is to understand financial repercussions in terms of rejection, wastage, Yield Loss, Conversion Costs is the prime importance. The process data collected in **intelleWORKS**™ modules and business data extracted from **simpliWORKS**™ modules are integrated through **simpliREPORTS**™ module for getting preliminary Business Intelligence. User configurable Reports and Dashboards allows the customer to analyse the business and process to optimise the profitability.

Product mapping & pathway -

The mapping of the products below exhibits how this architecture can be realised in practice.

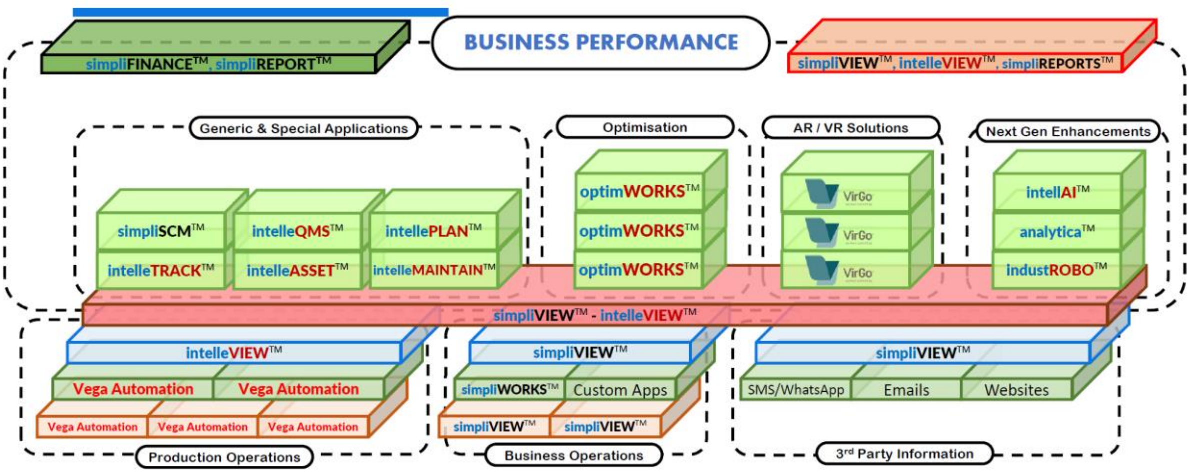


Figure 6 - Product mapping

Conclusion

The current state was siloed automation in each of the areas – Melting, Casting, Rolling and Bundling. The Industry 4.0 technologies applied properly has helped to connect theses silos in such a way that it is now possible to see them as part of single process.

Before this end-to-end digitalisation of the manufacturing process, there was lot of people intensity involved in connecting details and information of these siloed process areas. The resulting information was prone to errors and delays. With the tracking solution deployed, it has eliminated people interventions significantly for getting information. Additionally, enrichment of the information is done in near real time to show meaningful information as the process is progressing. Ability to respond to unforeseen events has improved significantly.

It is now possible to trace the product back to its chemistry records more confidently. It is now possible to do post-mortem analysis of different dimensions related to a particular heat easily and transparently. This has paved way for getting certifications required to enhance opportunities in the markets outside India.

Future Outlook

For the data being collected, at a meaningful point in future Big Data techniques and Analytics will be applied to arrive at patterns that corelate input material, process / equipment configurations and product quality. These patterns will help arrive at, using machine learning technologies, equipment configurations required for a particular type of input material and required product quality. These configurations can be directly fed into equipment if there are capable to receive it electronically or get the setting manually done by an unskilled worker using AR based Connected Worker solutions (for example, https://virgoinnovation.com/). This will eliminate uncertainty in the expected final product for a production campaign.

Yatin Purandare

Chairman and MD,
The Vega Group,
Pune, India