



Industrial Training Report  
On  
***“Reliability Enhancement of TSCR Funnel Slab Handling System through Digitalization”***  
At  
**TATA STEEL Ltd, Jamshedpur**  
Guided by  
**Mr. Biswanath Nath**

Submitted by  
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In partial fulfillment of the requirements for the award of the degree of  
**BACHELOR OF ENGINEERING**  
**IN**  
**ELECTRONICS & TELECOMMUNICATION ENGINEERING**  
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**CERTIFICATE**

This is to certify that Puval Mahato, student of Electronics & Tele-Communication Engineering from Jadavpur University, has done his project at Tunnel Furnace, LD 3 Department, TATA STEEL Ltd., Jamshedpur for a period of 4 weeks starting from 4<sup>th</sup> June 2019 to 2<sup>nd</sup> July 2019. His performance was up to desired standard.

The project work is entitled “Reliability enhancement of TSCR funnel slab handling system through digitalization”.

Mr. Biswanath Nath,  
Manager, Tunnel Furnace, LD-3,  
TATA STEEL Ltd.

## **ACKNOWLEDGEMENT**

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I would also like to thank other staffs of LD-3 for their valuable support and guidance.

I would also like to thank our parents for supporting us and providing us with various resources throughout the project. Lastly, I wish to express my deep sense of gratitude to all those who helped us directly or indirectly in completing this project. This Project would have not been successful without the help and assistance that I got, No matter how small.

Thank You.

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## **ABSTRACT**

The age of automation has brought a new meaning to the electronics. In the industries it means the completely automatic operation of the machine tool without human brain intervention, implying automatic inspection and possibly electronics integration and control of the various machining operations.

An insight into the various features of the working of the Tunnel Furnace in TSCR is given along with the working of remote I/O Devices and Siemens PLC System. PLC (Programmable Logic Controller) is an industrial digital computer which has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines or robotic devices, or any activity that requires high reliability control and ease of programming and process fault diagnosis.

A deep study has been made about the functioning of the PLC and its communication protocols with the remote I/O devices which takes the input of field devices. Also, there is a deep study about the digitalization initiative taken to increase the overall reliability of the Tunnel Furnace in TSCR.

## ABOUT THE COMPANY

### BACKGROUND:

Tata Steel (earlier known as Tata Iron & Steel Company or Tisco) was established in 1907. It represents the country's single largest, integrated steel plant in the private sector. The company has a wide product portfolio, which includes flat and long steel, tubes, bearings, ferro-alloys and minerals as well as cargo handling services. While in terms of size, Tata Steel ranks 34th in the world; it was ranked first (for the second time) among 23 world class steel companies by World Steel Dynamics in June 2005. With its plant located in Jamshedpur (Jharkhand) and captive iron ore mines and collieries in the vicinity, Tata Steel enjoys a distinct competitive advantage. The main plant at Jamshedpur manufactures 5 MTPA of flat and long products, while its recently acquired Singapore-based company, NatSteel Asia, manufactures 2 MTPA of steel across Singapore, China, Philippines, Malaysia and Vietnam. Apart from the main steel division, Tata Steel's operations are grouped under strategic profit centres like tubes, growth shop, bearings, ferro alloys and minerals, rings, agrico and wires

Company	Products	Established	Founder	Distribution	Production plants
Tata Steel	Finished steel	1907	J N Tata	Domestic & exports	India, Singapore, China, Philippines, Malaysia, Vietnam



TATA STEEL

## **PRODUCTS AND BRANDS:**

Products and brands Tata Steel's products include hot and cold rolled coils and sheets, galvanized sheets, tubes, wire rods, construction re-bars, rings and bearings. The products are targeted at automobiles, white goods, construction and infrastructure markets. In an effort to de-commoditise steel, the company has introduced brands like

- Tata Wiron (wire rods for farming and fencing segment),
- Tata Steelium (cold rolled steel for auto ancillaries and the general engineering segments),
- Tata Shaktee (corrugated galvanized sheets for rural house builder segments),
- Tata Tiscon (re-bars for individual house-builder semi-urban segment),
- Tata Pipes (pipes for individual house builder and farming segments),
- Tata Bearings (bearings for original equipment manufacturer and replacement market)

## **FINANCIAL ANALYSIS**

Financial analysis Increasing capacity and a recovery in the steel prices over the last few years have helped the company to increase its revenue. Its rich product mix (evinced through presence of high-grade value added cold-rolled products) as well as continuous improvement in operating efficiency (e.g. lowering of raw material consumption, coke rate, specific refractory consumption and business process reengineering) have contributed significantly to the improved operating margins of the company. While steel firms across the globe have been affected by rising input costs, the company has been able to leverage on its vertical integration by accessing raw material from its in-house mines and collieries. Rightsizing of its employees, along with a concomitant rise in employee productivity through emphasis on training, modernisation and automation has led to improved financials for the company.

## **Tata Steel's contribution in making "Made in India" global**

Steel is a capital-intensive industry and hence its profitability is dependent on its operating rates. Thus, producers need to maintain a minimum level of capacity utilization to recover fixed costs. With the Indian market having an inadequate demand for steel, Tata Steel was one of the pioneers in accessing the export market to improve its sales and realisations. Its cost-competitiveness in the international market has further helped it to improve its market share in the export market. Some of the markets targeted by the company included USA, Canada, China, South and Southeast Asia, Middle East and Europe. The major items of steel export include hot rolled coils and plates, cold rolled and galvanized products, wire rods and wires. While initially the company channelled its exports through its in-house Export Division, it currently exports through a group company, Tata International Ltd; having trading offices at Chicago, New York, London, Ukraine,

Turkey, Dubai, Saudi Arabia, Iran, Johannesburg, Kathmandu, Bangladesh, Colombo, Hong Kong, Thailand and Singapore.

Increasing trade co-operation through countries in the form of trade agreements has led Tata Steel to incorporate changes in its strategy. While exports currently constitute about 14 per cent of the turnover, the company has also started looking at overseas acquisitions / joint ventures to cater to lucrative markets by having appropriate production facilities in their vicinity.

### **Factors fueling Tata Steel's global initiatives**

Tata Steel maintains a cost advantage over most of its global peers due to its captive raw material resources. The company internally sources its iron ore needs and nearly 60 per cent of its coal needs. With the company embarking on capacity expansion, it is identifying new iron ore and coalmines to ensure that its backward linkages help it to maintain its cost competitiveness. To further build on its share in the global market, the company's has evolved a strategy of 'deintegrating' the value chain. While earlier the company adopted the strategy of creating vertical integration at a single manufacturing location, it is now adopting the strategy of split-location manufacturing facilities. This is based on the maxim that maximum value addition can be achieved by making semi-finished products (slabs / billets) at locations with proximity to raw materials and by finishing them at locations which are near to markets.

### **FUTURE PLANS**

The company intends to raise its capacity to 35 MTPA over the next 10-15 years. The capacity at Jamshedpur is expected to manufacture 10 MTPA, while the balance capacity will be built or acquired elsewhere in India and overseas, at an expected capital investment of US\$ 23 billion. The company has announced a 6 MTPA steel plant in Kalinganagar, Orissa, a 5 MTPA plant in Chhattisgarh, a 17 MTPA in Jharkhand and a 2.4 MTPA facility in Bangladesh. The funding will be done mainly through internal accruals and partially through debt funding.

## About the in-plant training

The Tunnel Furnace in TSCR is responsible for the transportation of slabs from caster to hot rolling mill for rolling. The Tunnel Furnace in TSCR is responsible for two main functions- Combustion and Material Handling. There are field devices along with water cooled refractory rolls which is driven by geared motors for the transportation of slabs. Failure of any of these devices and without having the knowledge of it beforehand could lead to unplanned interruptions and delays.

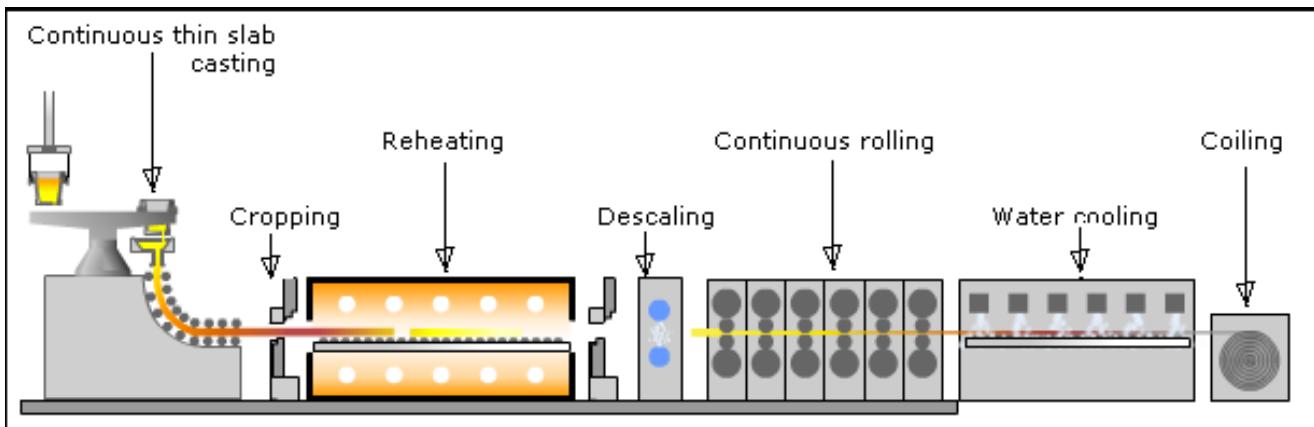
To detect the failures beforehand there is a digitalisation scheme proposed which would generate intelligent alarms along with notifications and order creation to avoid interruptions and delays. It is definitely a great step towards automation and the project is here is to study the digitalisation initiative taken to increase the reliability of the overall tunnel furnace in TSCR.

The project here deals with technology used in this initiative including both hardware and software to increase the overall reliability of the furnace.



TSCR TUNNEL FURNACE

## PLANT LAYOUT



### **REHEATING FURNACE:**

In steel plants reheating furnaces are used in hot rolling mills to heat the steel stock (Billets, blooms or slabs) to temperatures of around 1200 deg C which is suitable for plastic deformation of steel and hence for rolling in the mill. The heating process in a reheating furnace is a continuous process where the steel stock is charged at the furnace entrance, heated in the furnace and discharge at the furnace exit. Heat is transferred to the steel stock during its traverse through the furnace mainly by means of convection and radiation from the burner gases and the furnace walls.

The reheating furnace used in TSCR is Tunnel Furnace.

The Tunnel Furnace maintains and equalizes the temperature of the slabs arriving from the caster and delivers them to the rolling mill.

The tunnel furnace provides a buffer of up to six hot slabs, available for rolling when the mill is ready.

The furnace is roughly 675-foot long, divided into 11 zones. Natural gas burners maintain a temperature of 1800° F - 2100° F in the fired zones. A door at the rolling mill exit end of the furnace prevents heat losses, opening when it is time to roll a slab.

The furnace rollers can move slabs in either direction: toward the mill or back toward the caster.

The tunnel furnace is equipped with a furnace computer system that calculates slab temperature, controls heating profiles and tracks material through the furnace.

The interior of the furnace is 38'9" wide, fifteen feet from floor to ceiling, and 142' long. It is divided into eight zones for temperature control: preheat, top-and-bottom; heating, top-and-bottom; and soak, top-and-bottom, east-and-west. The preheat and heating zones combust a mixture of natural gas and preheated

combustion air with massive burners on the side walls of the furnace, both above and below the skids, to heat the slab nearly to its discharge temperature. Much of the preheating of the steel is achieved by the hot exhaust gases rushing past the slabs on the way to the 'recuperators' above the charge door. Whatever heat is left in the exhaust gases preheats the incoming combustion air to over 1000° F in these massive heat-exchangers. Conversely, in the heating zone the steel is primarily heated by the glowing-hot furnace walls. In the soak zone, numerous smaller burners seek to maintain a uniform temperature within the zones to equilibrate any cold spots in the slabs. Refractory dividers help to physically distinguish the zones, and thermocouple temperature sensors throughout the furnace interact with the automatic burner control systems to maintain the target temperatures in each zone.

## **PRIMARY DATA**

- Furnace Dimensions

### Line A

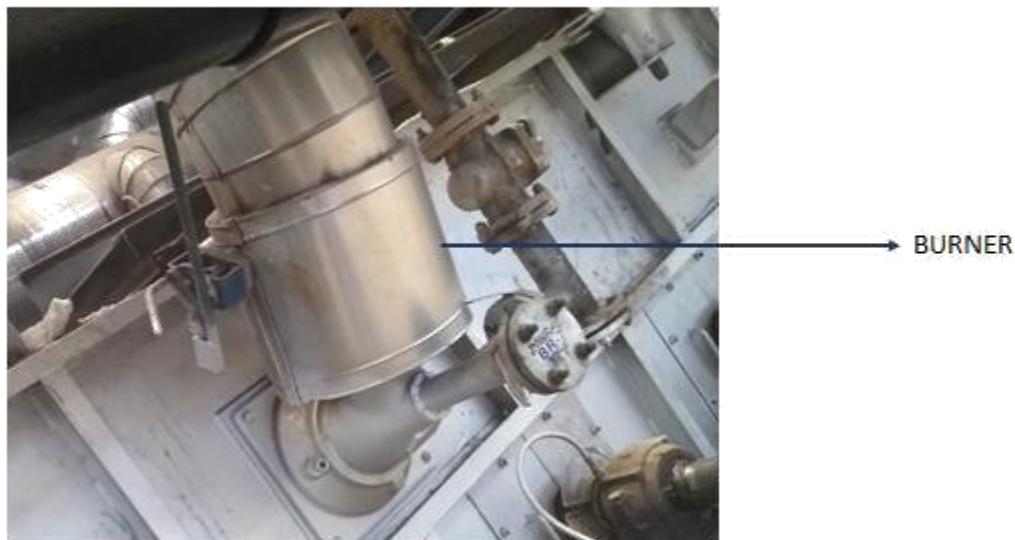
- Total Length:	238,750 <sup>1</sup> m	From Roll 001 to Roll 218
- Section 1 Length:	134,200 m	From Roll 001 to Roll 123
- Swivel Length:	51,750 m	From Roll 124 to Roll 170
- Section 3 Length:	51,700 m	From Roll 171 to Roll 218

### Line B

- Total Length:	234,693 m	From Roll 001 to Roll 214
- Section 1 Length:	182,500 m	From Roll 001 to Roll 167
- Swivel Length:	51,750 m	From Roll 168 to Roll 214

## EQUIPMENTS ASSOCIATED WITH TSCR TUNNEL FURNACE:(FIELD DEVICES)

- **BURNER** – The main function of the Burner is to heat the tunnel furnace so that the slabs rises upto its desired temperature-1200°C. It uses two gas pipes one for oxygen and the other for mixed gas and the quantity is supplied in desired proportion.



### BURNER PRESENT IN TSCR

- **PYROMETER** - A pyrometer is a type of remote-sensing thermometer used to measure the temperature of a surface. Various forms of pyrometers have historically existed. In the modern usage, it is a device that from a distance determines the temperature of a surface from the amount of the thermal radiation it emits, a process known as pyrometry and sometimes radiometry.



### PYROMETER

- **FLOW SWITCH**

Calorimetric flow switches, which are often also referred to as thermal flow monitors, use the physical laws of heat transport in flows. A distinction is basically made between two technical solutions: continuous and regulated heating.



#### **Continuous Heating:**

If the presence of flow in a piping system must be monitored, a calorimetric flow switch – also known as a flow monitor – is often used. A flow switch which is based on the calorimetric measuring principle consists of a measuring probe with two temperature sensors integrated into it (see illustration). One of the sensors is heated continuously with the aid of an integrated heating element (wire-wound) with a constant heating power and measures the temperature at the heating element. The second sensor determines the temperature of the medium in the pipe. Consequently, a temperature difference occurs between the two sensors, which is registered by the electronics. The higher the flow velocity of the medium in the pipeline, the smaller this temperature difference is. The basis for this is the cooling effect of flowing media. The molecules in the medium, which are flowing past the probe tip, collect “packages of heat” and transport them away. The more molecules flow past, the greater the cooling effect. The number of molecules passing by increases continuously with increasing flow velocity.

#### **Regulated Heating:**

The measuring probe is basically identical in design: There are two temperature sensors in the medium, one of which can be heated. In this technical solution, the heating power is regulated so that the temperature difference between the two temperature sensors is kept constant throughout. Consequently, as the flow velocity increases, the heating power must be increased in order to keep the size of the temperature difference constant. The applied heating power is thus a direct measure of the flow velocity in the medium.

- **RTD (RESISTANCE TEMPERATURE DETECTOR)**

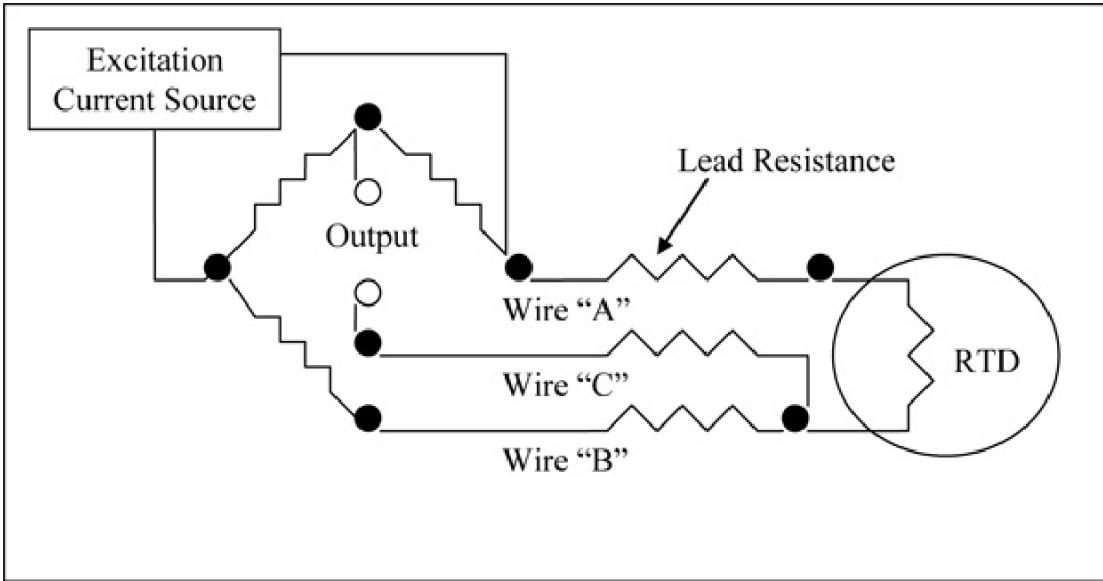
RTD stands for Resistance Temperature Detector. RTDs are sometimes referred to generally as resistance thermometers. Resistance thermometers, also called resistance temperature detectors (RTDs), are sensors used to measure temperature. Many RTD elements consist of a length of fine wire wrapped around a ceramic or glass core but other constructions are also used. The RTD wire is a pure material, typically platinum, nickel, or copper. The material has an accurate resistance/temperature relationship which is used to provide an indication of temperature. As RTD elements are fragile, they are often housed in protective probes. RTDs, which have higher accuracy and repeatability, are slowly replacing thermocouples in industrial applications below 600 °C.

RTDs work on a basic correlation between metals and temperature. As the temperature of a metal increases, the metal's resistance to the flow of electricity increases. Similarly, as the temperature of the RTD resistance element increases, the electrical resistance, measured in ohms ( $\Omega$ ), increases. RTD elements are commonly specified according to their resistance in ohms at zero degrees Celsius (0°C). The most common RTD specification is 100  $\Omega$ , which means that at 0°C the RTD element should demonstrate 100  $\Omega$  of resistance.

Platinum is the most commonly used metal for RTD elements due to a number of factors, including its (1) chemical inertness, (2) nearly linear temperature versus resistance relationship, (3) temperature coefficient of resistance that is large enough to give readily measurable resistance changes with temperature and (4) stability (in that its temperature resistance does not drastically change).

### **Why 3 wires RTD?**

In a 3 wire RTD configuration, Wires "A" & "B" should be close to the same length. These lengths are significant because the intention of the Wheatstone bridge is to make the impedances of wires A and B, each acting as an opposite leg of the bridge, cancel the other out, leaving Wire "C" to act as a sense lead carrying a very small (micro amperage range) current. With time).



#### RTD AND FLOW SWITCH IN TUNNEL FURNACE:



- **GEARED MOTOR:**

There are 216 motors in Line A and 218 motors in Line B. The maximum speed in which the motor can work is 1m/s.

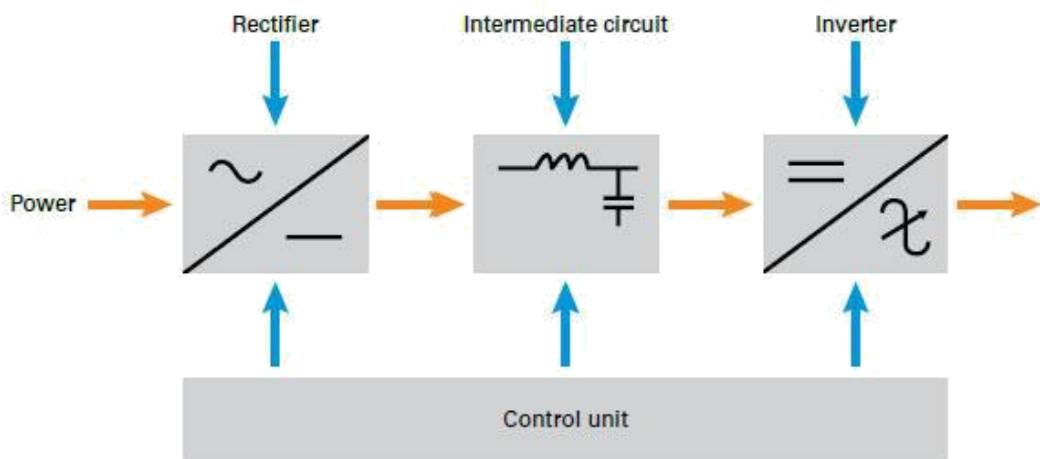
Roller motor is driven by **VVVF drive(Variab le Voltage Variable Frequency)** which in turn drives the wet rolls for the transportation of slabs inside the furnace.

VVVF DRIVE:

A variable-frequency drive (VFD) or adjustable-frequency drive (AFD), variable-voltage/variable-frequency (VVVF) drive, variable speed drive, AC drive, micro drive or inverter drive is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage.

### **Variable Frequency Drive Operating Principle**

Whilst there are a number of variations in variable frequency drive design; they all offer the same basic functionality which is to convert the incoming electrical supply of fixed frequency and voltage into a variable frequency and variable voltage that is output to the motor with a corresponding change in the motor speed and torque. The motor speed can be varied from zero rpm through to typically 100-120% of its full rated speed whilst up to 150% rated torque can be achieved at reduced speed. The motor may be operated in either direction.



**Rectifier:** The working principle of rectifier is changing the incoming alternating current (AC) supply to direct current (DC). Different designs are available and these are selected according to the performance required of the variable frequency drive. The rectifier design will influence the extent to which electrical harmonics are induced on the incoming supply. It can also control the direction of power flow.

**Intermediate circuit:** the rectified DC supply is then conditioned in the intermediate circuit, normally by a combination of inductors and capacitors to make the DC signal smooth.

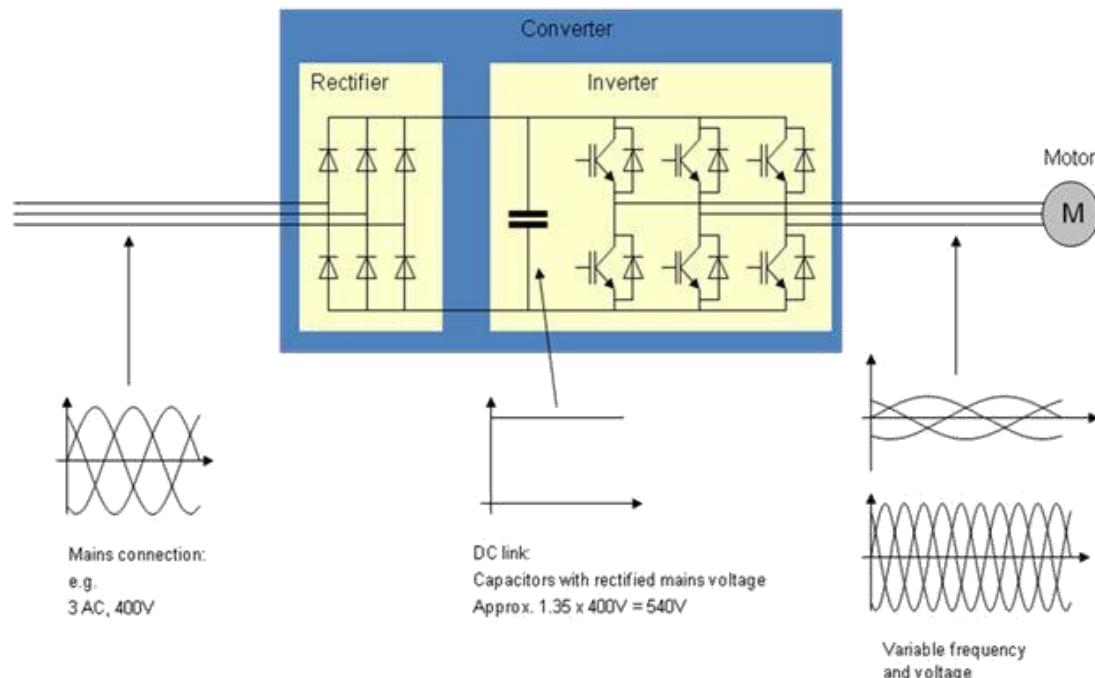
**Inverter:** The inverter converts the rectified and conditioned DC back into an AC supply of variable frequency and voltage. This is normally achieved by generating a high frequency pulse width modulated signal of

variable frequency and effective voltage. Semiconductor switches are used to create the output; different types are available, the most common being the Insulated Gate Bipolar Transistor (IGBT).

**Control unit:** The control unit controls the whole operation of the variable frequency drive; it monitors and controls the rectifier, the intermediate circuit and the inverter to deliver the correct output in response to an external control signal.

### **INTERNAL CIRCUIT DIAGRAM:**

### **Principle of a Converter**



- **WATER COOLED REFRACTORY ROLLS:**

TSCR Tunnel Furnace is a Roller Hearth type of reheating furnace consisting of 432 Water cooled refractory rolls (both line A & line B) driven by Geared Motors for transportation of the Hot slab from caster to Mill for rolling. The rolls consist of four tyres- spaced at certain distance apart made of cobalt for holding the slabs and helps in transporting further. The rolls are covered with a ceramic refractory coating since ceramic is a material which can withstand high temperature.

Inside the rolls there is an inlet pipe and outlet pipe for the continuous flow of cooling water so that the temperature inside the rolls doesn't get too high. In the outlet pipe **FLOW SWITCH** and **RTD** are present to determine the amount of cooling and rate of flow of water.



### REFRACTORY ROLLS

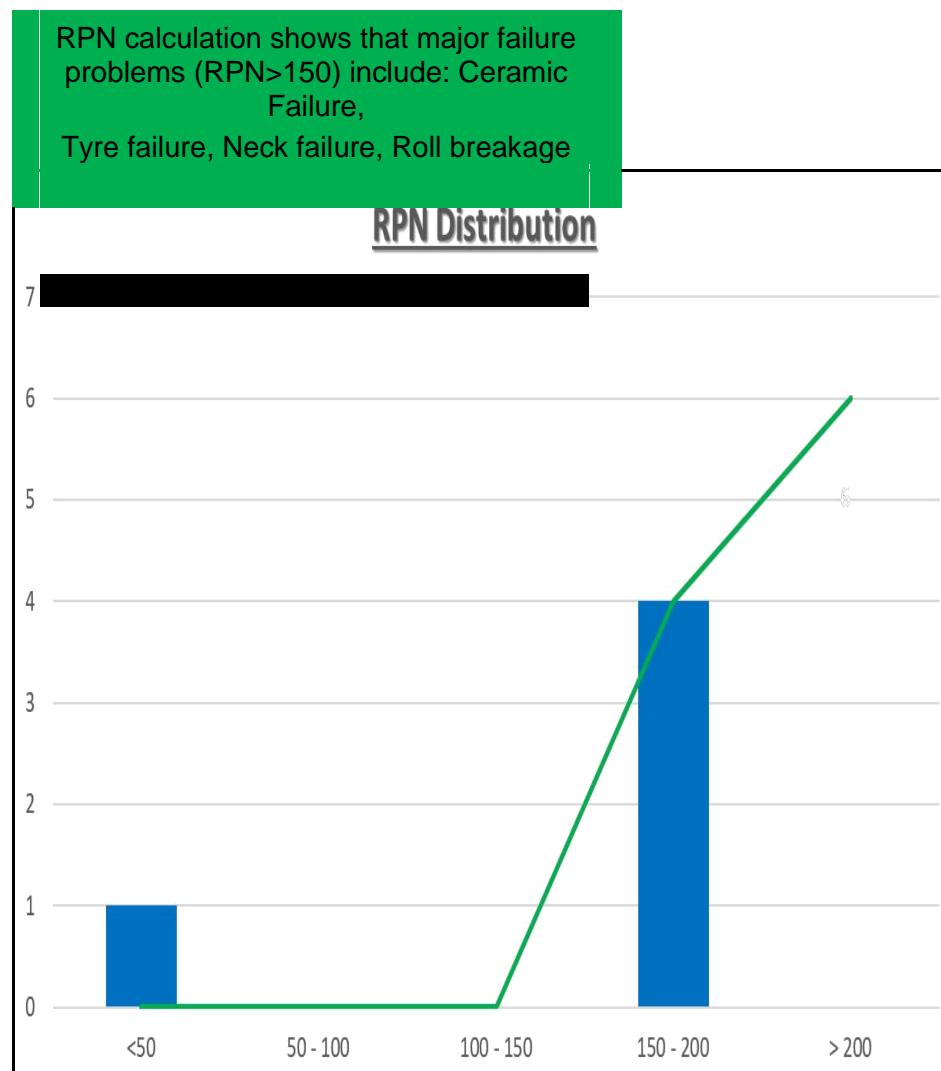
#### **FMEA (FAILURE MODE EFFECT ANALYSIS OF WATER-COOLED REFRACTORY ROLLS):**

ASSIGNING SOD number to calculate the Risk Priority Number (RPN):

Area	Assembly	Component	Failure mode/issue	Severity	Occurrence	Detectability	RPN	no.
Tunnel Furnace	Line A	Roll	Ceramic Failure	7	5	5	175	
			Tyre failure	7	5	5	175	
			Neck failure	6	5	5	150	
			Roll breakage	8	4	5	160	
			Power Supply Fails	2	5	2	20	

### **ISSUE CAUSE COUNTER-MEASURES:**

ISSUE/FAILURE MODE	CAUSE	SUB-CAUSE	COUNTER MEASURES
Ceramic Failure, Tyre failure, Neck failure, Roll breakage	Cooling problem, defects in material property, roll is not rotating, High temperature, Power failure	Water temperature, Motor tripped, Drive problem, Junk in roll	Flow switch and RTD monitor through Digitalisation, Motor current and speed checking through digitalisation



**RPN DISTRIBUTION GRAPH WITHOUT DIGITALISATION**

**CASE STUDY OF DAMAGED ROLLS-(INFORMATION GATHERED FROM INDUSTRY):**

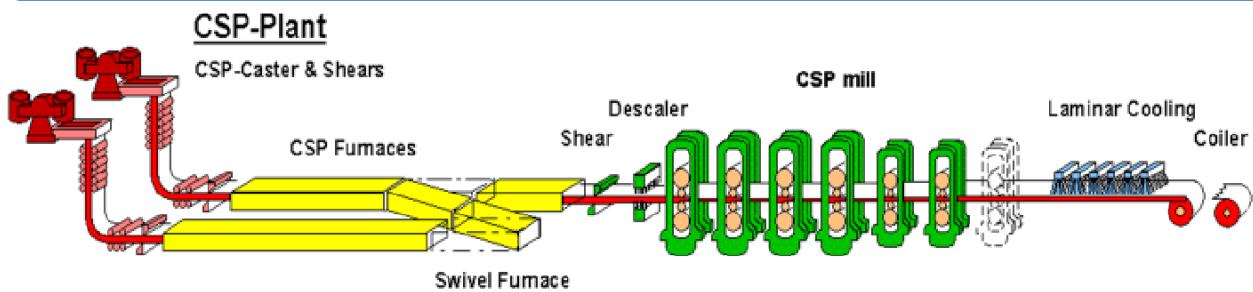
Line A 130 Roll Refractory 40 % damaged on 1st July 2015.	
Line A 166 Roll Refractory 10 % damaged on 23rd Nov 2017.	
Line A 197 Roll Refractory 50 % damaged on 23rd Jan 2016.	
Line B 132 Roll Refractory 20 % damaged on 18th Feb 2016.	
Line A 145 Roll Refractory 30 % damaged on 8th Dec 2015.	

**'THE MAIN AIM OF THE PROJECT IS TO REDUCE THE RPN NUMBER AS CALCULATED BEFORE THROUGH THE DIGITALIZATION INITIATIVES TAKEN SO THAT THE DETECTABILITY OF SEVERAL ROLL FAILURES BECOMES EASY AND RELIABLE.'**

## DIGITALISATION INITIATIVES:

### TSCR IEM Team-Digitalization initiatives at Tunnel Furnace

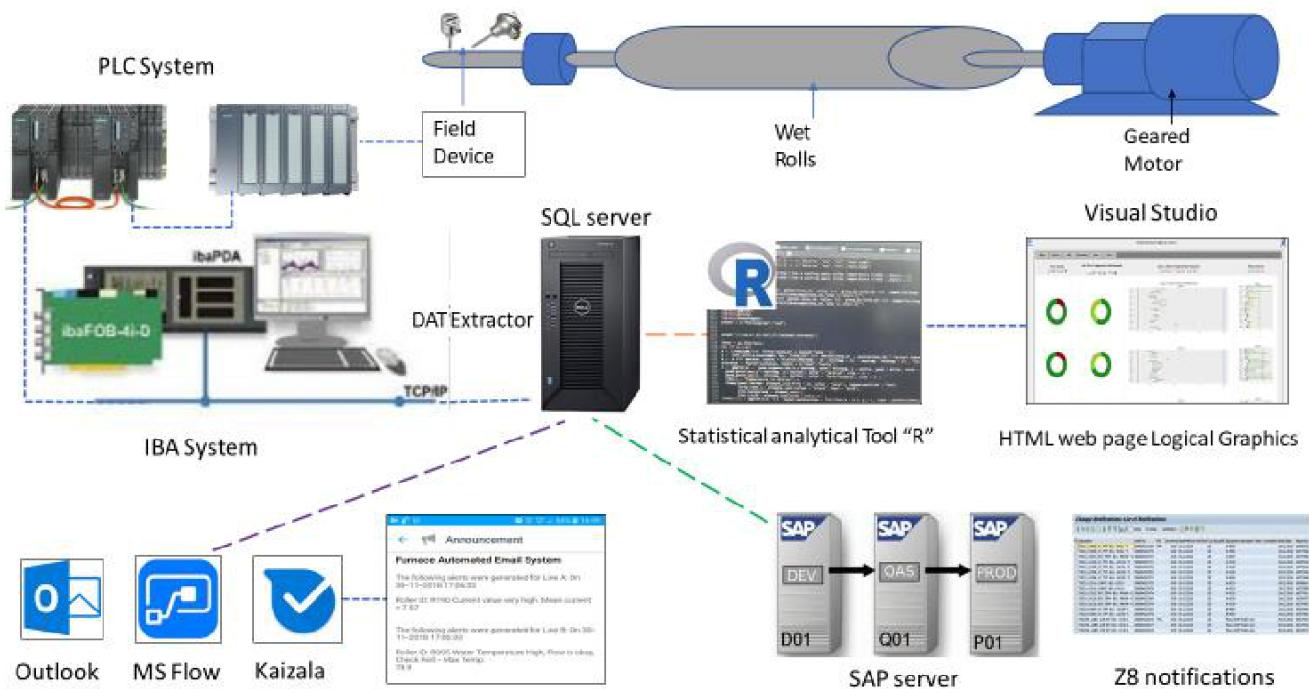
**Business Objective:** TSCR Tunnel Furnace is a Roller Hearth type of reheating furnace consisting of 432 Water cooled refractory rolls driven by Geared Motors for transportation of the Hot slab from caster to Mill for rolling. Frequent failures of the rolls and motors due to varied reasons lead to process interruptions, delays, high MTTR, opportunity loss, high spare cost. In FY18 there were unplanned roll change of 50nos @Rs5Lac with Heat loss delay of 8hrs and motor change of 5nos @Rs 1Lac.



**Challenges:** To use the existing resources to predict premature roll and motor failure.

**Meeting Challenges:** To use the existing field sensors and diagnostic analytic tools to generate intelligent Alarms so that we can take necessary actions beforehand to avoid unplanned interruptions and delays.

### Methodology: Digitalization Initiative



## METHODOLOGY OF DIGITALISATION INITIATIVE

From the figure Above we can understand the scheme of digitalization initiative taken at TSCR to predict premature roll and motor failures and generate intelligent alarms to take necessary actions beforehand.

As seen from the diagram the input signals from the field devices goes into Remote I/O device:

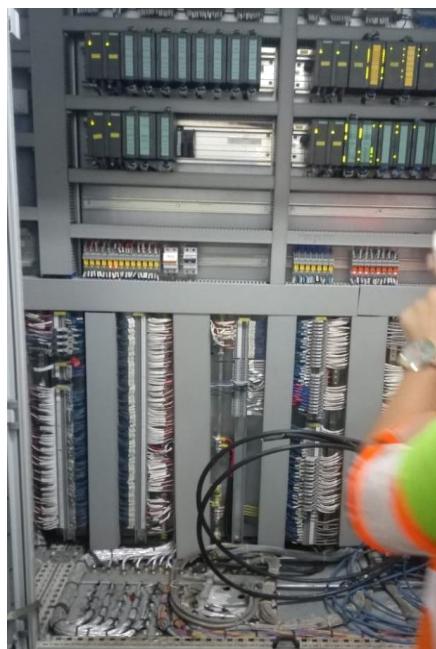
### **REMOTE I/O DEVICE:**

Modular remote I/O systems transmit process data from safe or explosion hazardous areas by connecting binary and analog sensors and actors to the control system via a bus interface. Remote I/O is the right choice when you want to put I/O modules close to the field devices. Due to the reduced wiring effort, you not only save cables, but also time, money, and work effort. Hence, remote I/O field units can be installed in a decentralized location inside hazardous areas while you easily control and monitor sensors and actors from the control room.

You can connect 4 mA ... 20 mA devices to remote I/O, including water flow transmitters, valve positioners, pressure transducers, or temperature transmitters. Devices such as thermocouples, resistance temperature detectors (RTDs), mechanical contacts, and visual or audible alarms may also be connected.

Our remote I/O systems are compatible with network protocols like:

- PROFIBUS DP
- MODBUS RTU
- MODBUS TCP/IP
- FOUNDATION Fieldbus H1



From there the signal goes into the PLC system S7400H which is in hot redundant mode and one the most important components of Tunnel Furnace Hardware Configuration.

### **PLC (PROGRAMMABLE LOGIC CONTROLLERS):**

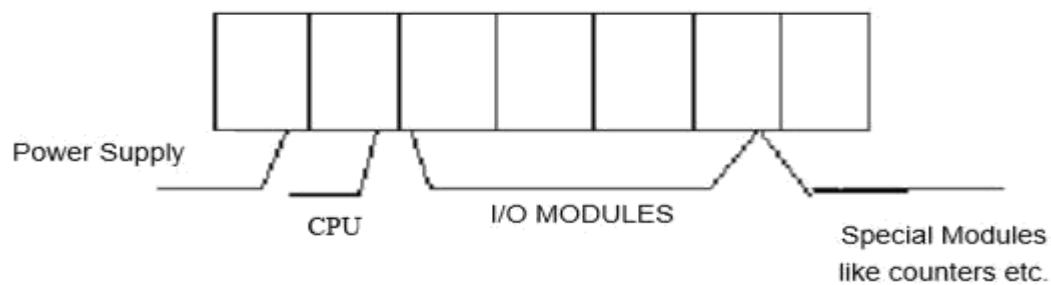
As the name suggests these are field programmable and more flexible than the normal relay logic which were being used. Time spent for the modification of the sequence will also be less since the modification is a software modification and not hardware modification. Also, PLC provide enhanced functions. These functions include counters, timers and Analog inputs and outputs. Counters and timers are available both in hardware version and software version. PLCs reduce the hardware connections since the actual logic is software, thus enhancing the reliability of the system it is also easy to connect peripherals like Computers, etc., for communication, data storage and display.

They have replaced the relay logic for the following applications-

1. Elevators
2. Washing machines
3. Process control
4. Special purpose machines etc.

### **HARDWARE CONFIGURATION OF A STANDARD PLC.**

All the PLC systems consists of a Power supply, CPU, input & output Circuits as shown in figure 3.1. These may be part of one unit or can be in modular form. In this description a PLC with back and module arrangement has been considered. Some of the PLC's will in addition provide counter modules, timer modules and analog Input and Output modules. These are mounted on a rack as shown below.



## **BLOCK DIAGRAM OF PLC**

### **FUNCTIONS OF DIFFERENT MODULES IN A PLC.**

#### **1. POWER SUPPLY MODULE**

This module normally receives 110V/220V single-phase supply as its input and converts the same into the required voltages for PLC functioning like 24V, DC, 15V DC etc., sometimes this unit also generates the 24V DC supply required for the Inputs.

#### **2. CPU (Central Processing Unit)**

- \* Processor
- \* Operating System
- \* ALU
- \* RAM for program memory, timers, counters, Relays, System data.
- \* Serial port
- \* Plug in memory module. Processor is the actual control equipment which works based on the operating system. As per the operating system it calls the control programmed in a specified manner and executes the same.

#### **3. Operating System**

Operating system is the executive program written by the PLC manufacturer which directs the functioning of CPU.

#### **4. ALU (Arithmetic Logic Unit)**

ALU is used for processing the data which is byte long and word long.

#### **5. RAM**

RAM stores the control program written by PLC user. It also contains data such as timer, counter, system data and working RAM area for holding the results of the logic.

## **6. Serial Port**

Serial port is meant for communication with peripheral devices such as Computer, Printer etc.

## **7. Plug in Memory**

Module Plug in memory module is used to store the control program and associated data in non-volatile memory.

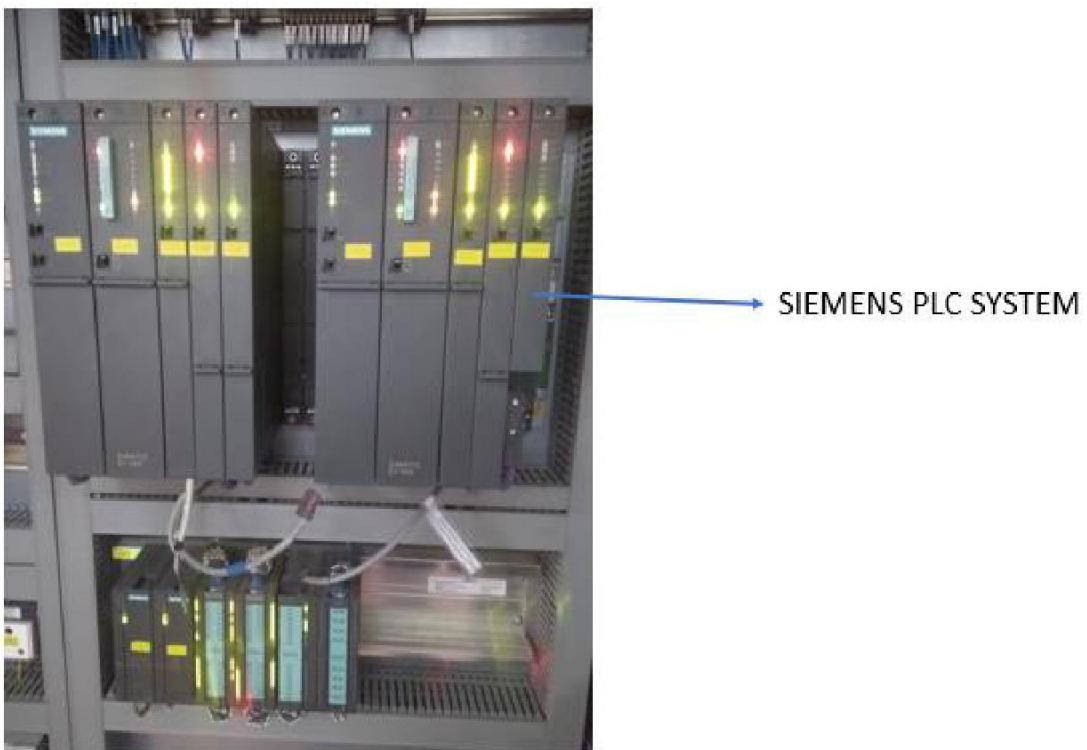
## **8. Input / Output modules Cards**

Depending on the marketing requirement various combination of I/O cards are supplied by the manufacturers. They are listed below.

### Digital Input Card

- \* Input voltage 24V DC, 38V DC, 110V AC, 220V Dc.
- \* Number of Inputs per card or per connector - 8/16/24/32/40/48.
- \* Current consumption will be normally within 20 milli ampere.
- \* Also, the inputs may have electrical isolation to take care of electrical noise.
- \* Normally these input units have built in delay to take care of the contact bouncing of the limit switches.

- \* Input voltage 24V DC, 38V DC, 110V AC, 220V Dc.
- \* Number of Inputs per card or per connector - 8/16/24/32
- \* Current rating - 200 mA/500 mA/1A/2A
- \* Built-in protection - Available in higher current modules.



## PROGRAMMING PLC'S

All PLC's need a control program which is written by OEM. This program can be written in different languages. They are.

1. Statement List
2. Ladder diagram
3. Control flow chart

**1. Statement List.** Language used in this case is Boolean language. Here each instruction in PLC is written as one statement along with the data shown below.

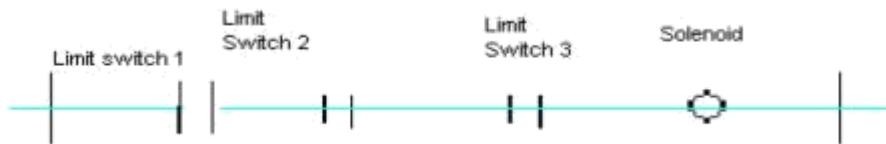
- Load I0. (Limit switch 1)
- And I1 (Limit switch 2)
- And not I2 (Limit switch 3)
- Write O1 (Solenoid 1)

In the above case 'I' stands for Input and 'O' stands for output.

This equation informs the PLC that if limit switch 1 and 2 are closed and if limit switch 3 is not operated then switch on Solenoid 1. To achieve the same function in case of a relay logic, the normal open contacts of limit switch 1 and 2 and NC contact of limit switch 3 were connected in series with coil of Solenoid 1 by wires.

## 2. Ladder Diagram

This is a symbolic representation of the control program in the normal relay logic form using signals of the limit switches. If the logic in statement list is written as ladder it will look as given below. This diagram appears as though the limit switches have been connected physically. Figure 3.2 explains a ladder logic diagram of a network.



**SIEMENS PLC SYSTEM**

PLC in tunnel furnace TSCR plays a very vital role in controlling the motor speed, current and generating intelligent alarms according to the logic written if one or more devices has started to malfunction.

There are two main functions of tunnel furnace and therefore two different PLCS are used-

- **Combustion or heating of slabs**

Preheating the slab up to the desired temperature, soaking it to ensure uniform heating until the core and finally to maintain it till discharge for smooth hot rolling. The tunnel furnace is about 240m long and the discharge temperature of slab for hot rolling is 1500°C. This functionality is being achieved by combustion PLC which is in hot redundant mode. The adequate temperature is being controlled by the ratio control between Mixed gas and combustion air. Three thermocouples per zone are there for temperature feedback. Each zone has broadly three controls in combustion PLC, i.e. Temperature control loop, flow control loop and furnace pressure control loop.

#### **Inputs to the PLC**

Gas Flow

Air Flow

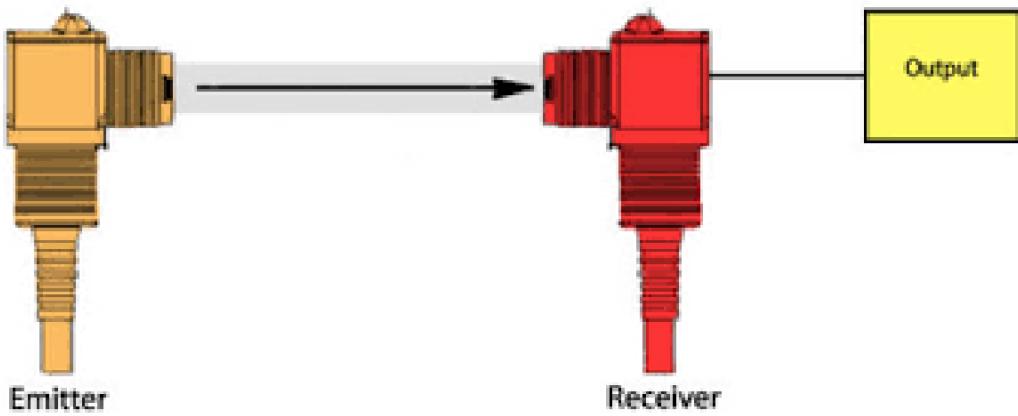
#### **Output from PLC**

Gas Controller Valve

- **Material Handling or Slab Handling**

To Transport the slab from furnace entry to discharge section and swivel operation, we have material handling PLC in hot redundant configuration. In order to track the slabs in efficient way we have photoeyes which confirms logical slab tracking and rectifying the integration error arising during handling.

A photoelectric sensor, or photo eye, is an equipment used to discover the distance, absence, or presence of an object by using a light transmitter, often infrared, and a photoelectric receiver. They are largely used in industrial manufacturing. A through beam arrangement consists of a receiver located within the line-of-sight of the transmitter. In this mode, an object is detected when the light beam is blocked from getting to the receiver from the transmitter.



### PHOTOEYE WORKING

The slabs are transported over water cooled rollers.

#### **Inputs to the PLC**

Flow Switch Status

RTD output

Motor Current

Motor Speed

#### **Outputs from PLC**

Flow switch regulator

Inverter which drives the motor

The following inputs/outputs helps in detection of faults in rolls and motors quite easily and it is regulated automatically.

**Following cases may arise-**

FLOW SWITCH	RTD	STATUS
Healthy	Working	The system is healthy. Rolls are cooled properly
Unhealthy	Working	Flow Switch is Faulty
Healthy	Not Working ( $\Delta T$ quite high)	Roll Breakage
Unhealthy	Not Working	Water Flow is not Ok.

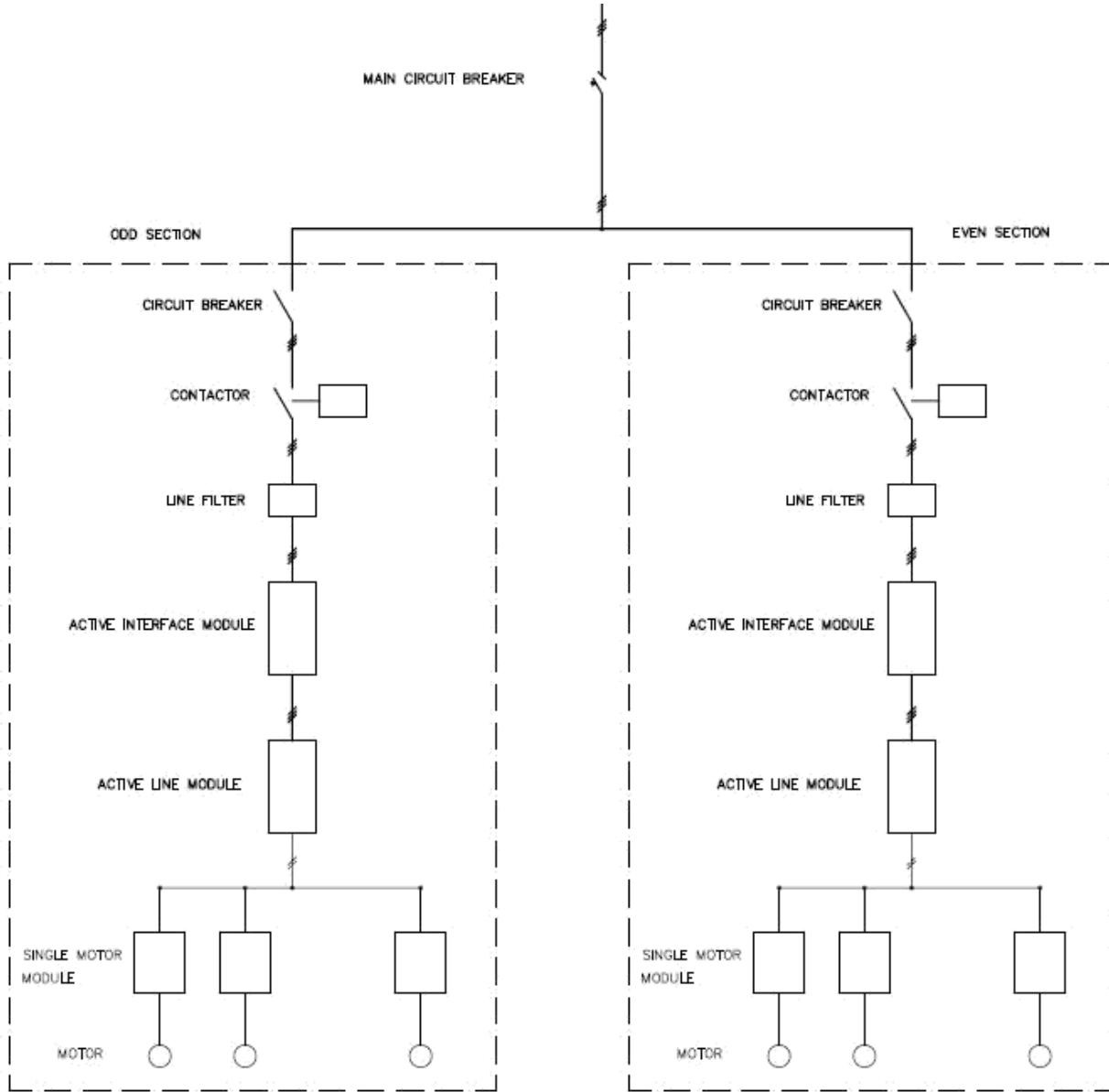
Input temperature of water is 25°C. The temperature of the water which comes out from the outlet pipe is measured through RTD. Then  $\Delta T$  is calculated. If  $\Delta T$  is within a certain range(20-30°C), then the cooling is proper inside the rolls. If  $\Delta T$  increases and the flow switch status is healthy as seen, then the cooling is not proper inside the rolls which means there is a roll breakage and has to be repaired immediately and the PLC generates an alarm. If  $\Delta T$  is less than the range then the water flow is reduced through the flow switch by the handling PLC. In this way flow switch and RTD is regulated by the handling PLC.

Motor Speed and motor current are also given input to the PLC by the remote I/O. There is a buffer upto 30 slabs in the tunnel furnace and the position of the slabs is identified by the photoeyes which are present in the tunnel furnace and their position is given input to the PLC.

Based on their position and current speed of motor, PLC decides whether to increase the speed of motor so that the slabs can be transported faster or to reduce the speed to avoid collision.

## ROLLER MOTOR VVVF DRIVE PANELS

Each Roller Motor of the 2 lines is driven individually by the respective inverter. The VVVF are grouped in Panels located along the plant near the driven Rollers. Each Panel is divided in 2 sections according to the following scheme:



- **Incoming Line Section** contains: Incoming Lines device, Section Switches, Contactor, DC Bus Supply/Breaking units, filters, auxiliary relays etc.

- **Inverters Section** contains: The Inverters to feed the rolls,

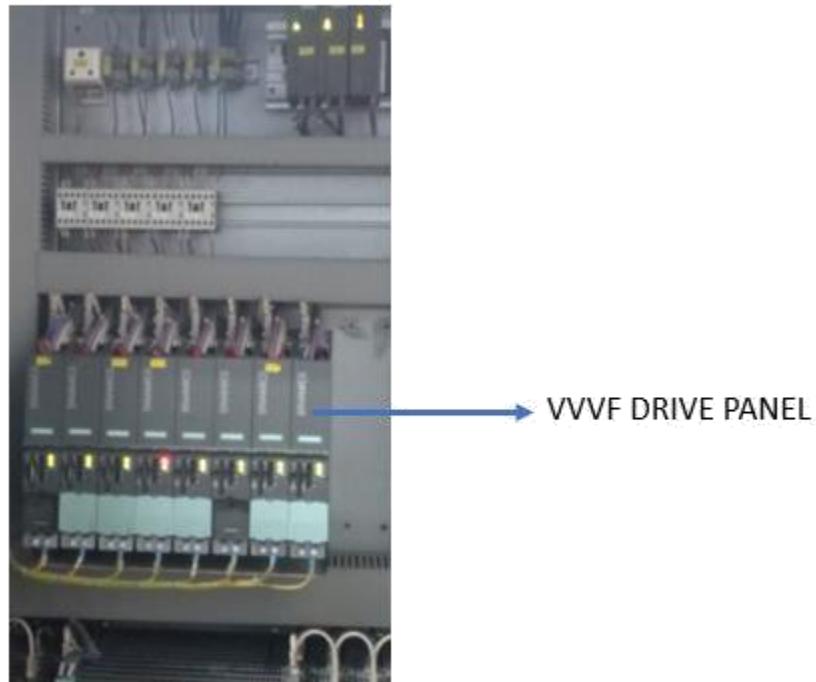
Normally each inverter is driven by the Handling PLC through the Profibus DP Interface.

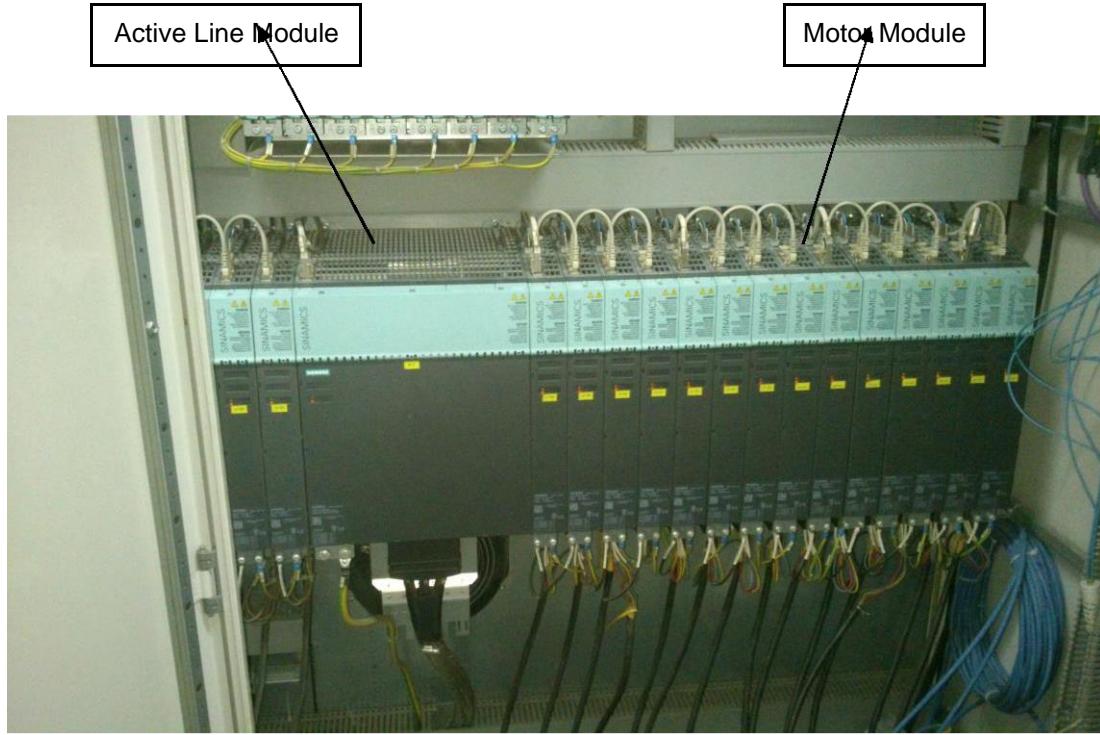
The use of Siemens SINAMICS family foresees that each power module is controlled by a Control Unit via Siemens “DRIVE CLICK” communication bus.

Each CU320 shall control up to 4 power modules (4 motors).

If the Handling PLC or the Profibus connection card fails, all the inverters of the Panel can be driven by the Combustion PLC through Hardwired Signals interface, in this case all the inverter of the same Panel will be driven at the same speed.

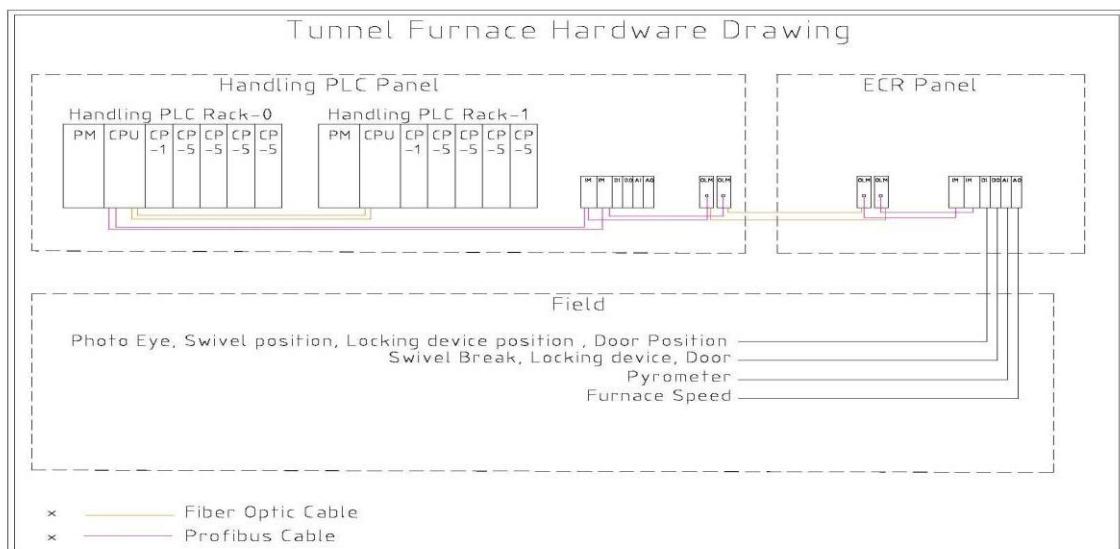
The combustion PLC will provide the DOs and AOIs for one drive, suitable adapters will provide the necessary quantity of Outputs for all the drives in the panel.





In this way the geared motor is controlled by handling PLC through VVVF drives which converts the incoming AC signal to DC using rectifier and back to AC according to our desired frequency by the use of inverter which ultimately drives the motor according to the frequency set depending upon the position of the slabs.

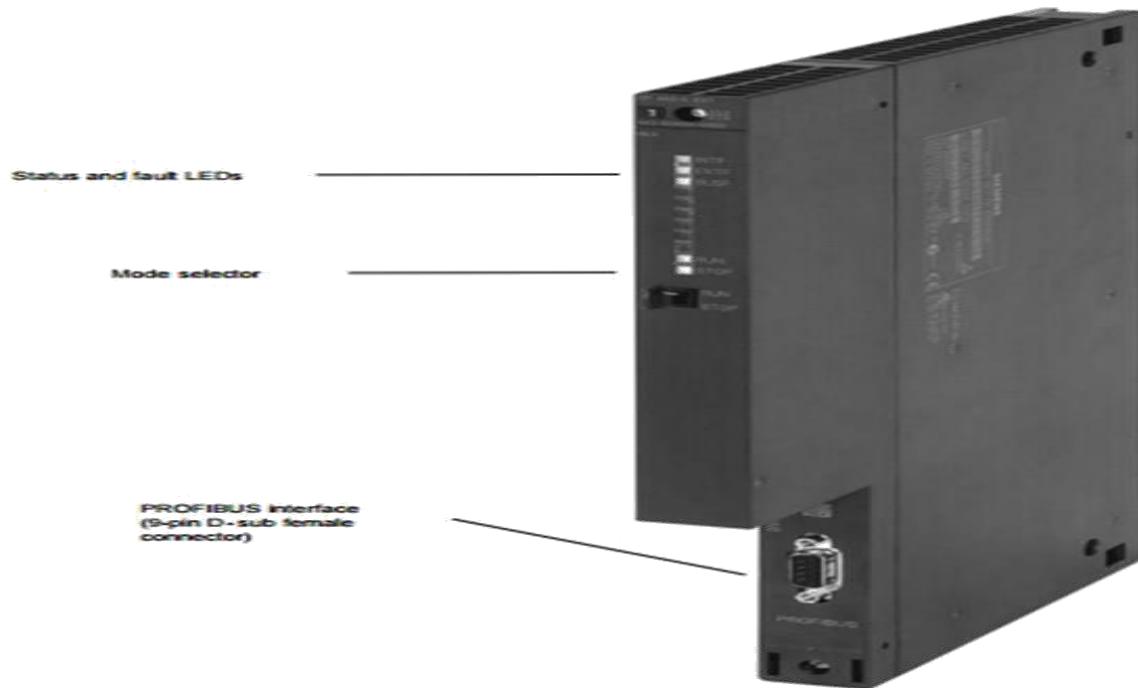
### NETWORK DIAGRAM



## COMMUNICATION PROTOCOLS USED:

- **PROFIBUS DP-(CP 443-5)**

The CP 443-5 Extended communications processor is designed for use in a SIMATIC S7-400 (standard) and S7-400H (fault-tolerant system) programmable controller. It allows the S7-400 / S7-400H to be connected to a PROFIBUS fieldbus system.



### PROFIBUS DP INTERFACE

#### **Characteristics of the DP Interface**

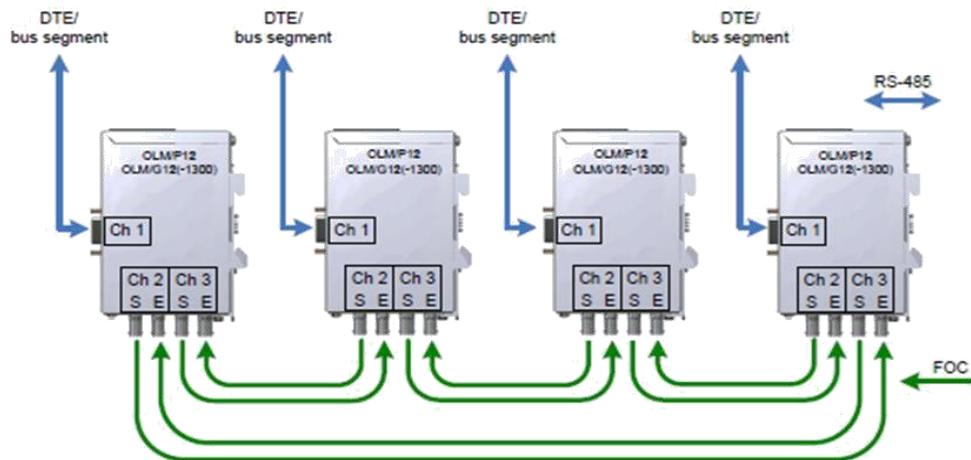
No special FBs or FCs are necessary for the DP mode. The interfacing to the distributed peripheral I/O is by direct I/O access or using SFCs/SFBs of the CPU. Maximum Speed achieved through this connection is 12Mbps and default speed is 1.5Mbps.

Characteristic	Explanation / Values
Number of DP slaves that can be operated	125
Max. size of the input area of all DP slaves	4 Kbytes
Max. size of the output area of all DP slaves	4 Kbytes
Maximum number of inputs per DP slave	244 bytes
Maximum number of outputs per DP slave	244 bytes
Max. size of the consistent area for a module	128 bytes

There is a lot of signal loss over long distance transmission so it is particularly used for short distance communication. We use OLM (uses fibre optic cable) for long distance communications as there is no signal loss.

- **OLM (OPTICAL LINK MODULE)**

PROFIBUS OLMs are designed for use in optical PROFIBUS fieldbus networks. They allow the conversion of electrical PROFIBUS interfaces (RS-485 level) into optical PROFIBUS interfaces and vice versa.



OLM RING TOPOLOGY

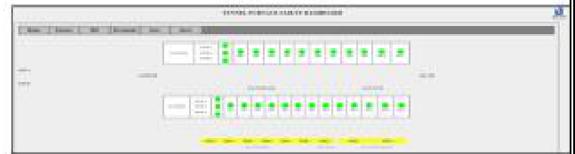
The interruption of one or both fiber-optic cables between the modules is detected by the OLM and the ring becomes an optical bus. If one module fails, only the DTEs connected to this module or the RS-485 segment are disconnected from the ring. The rest of the network itself stays functional as a bus. The problem is indicated by the LEDs of the two OLMs connected to the disrupted fiber-optic link and by the signaling contacts of these OLMs. The segmentation is canceled automatically as soon as both modules recognize that the segmented fieldbus (sub)network is no longer disrupted based on test frames that they send out automatically. The bus then closes again to form a ring.

## DIGITALISATION INITIATIVES (SOFTWARE USED)

### TSCR IEM Team-Digitalization initiatives

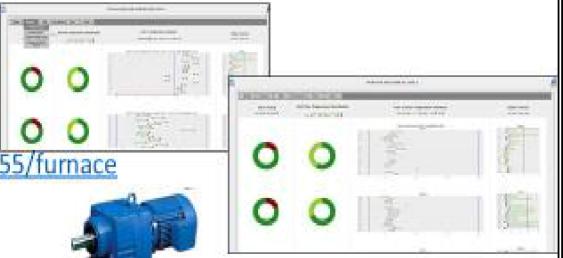
#### 1. Safety Dashboard:

- a) Tunnel Furnace CO Gas safe zones.
- b) Zonal Explosion Flap status.



#### 2. Predictive Analytics and Health monitoring of Capital Equipment:

- a) Geared Motor Health status.
- b) Wet Rolls Health status.



#### 3. Reports, Notifications and Alarms:

- a) Graphical reports are generated in web page <http://136.104.154.155/furnace>
- b) Intelligent alerts are generated via **Kaizala** messaging system.
- c) Integration with **SAP system** for notification and order creation



#### 4. Tools and Software used:

- a) IBA.dat extractor
- b) HTML programming.
- c) SQL server.
- d) R- statistical computing tool.
- e).net programming.
- f) Microsoft FLOW tool for Kaizala messaging services.

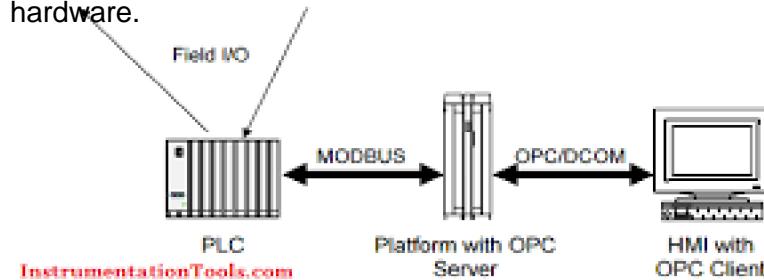
#### 4. Results and Way forward:

Using the alerts Mech team changed 8 Rolls and IEM 1 motor. In the future this will lead to Dynamic TBM

## OPC PROTOCOL:

OPC (Open Platform Communications) is a software interface standard that allows Windows programs to communicate with industrial hardware devices. OPC is implemented in server/client pairs. The OPC server is a software program that converts the hardware communication protocol used by a PLC into the OPC protocol.

The OPC client software is a program that connects to the hardware, such as an HMI. The OPC client communicates with the OPC server to receive data or send commands to the hardware.



## **SOFTWARES USED:**

- **HMI (HUMAN MACHINE INTERFACE)**

A Human-Machine Interface (HMI) is a user interface or dashboard that connects a person to a machine, system, or device. While the term can technically be applied to any screen that allows a user to interact with a device, HMI is most commonly used in the context of an industrial process.

Although HMI is the most common term for this technology, it is sometimes referred to as Man-Machine Interface (MMI), Operator Interface Terminal (OIT), Local Operator Interface (LOI), or Operator Terminal (OT). HMI and Graphical User Interface (GUI) are similar but not synonymous: GUIs are often leveraged within HMIs for visualization capabilities.

In industrial settings, HMIs can be used to:

- Visually display data
- Track production time, trends, and tags
- Oversee KPIs
- Monitor machine inputs and outputs

## **COMMON USES OF HMI:**

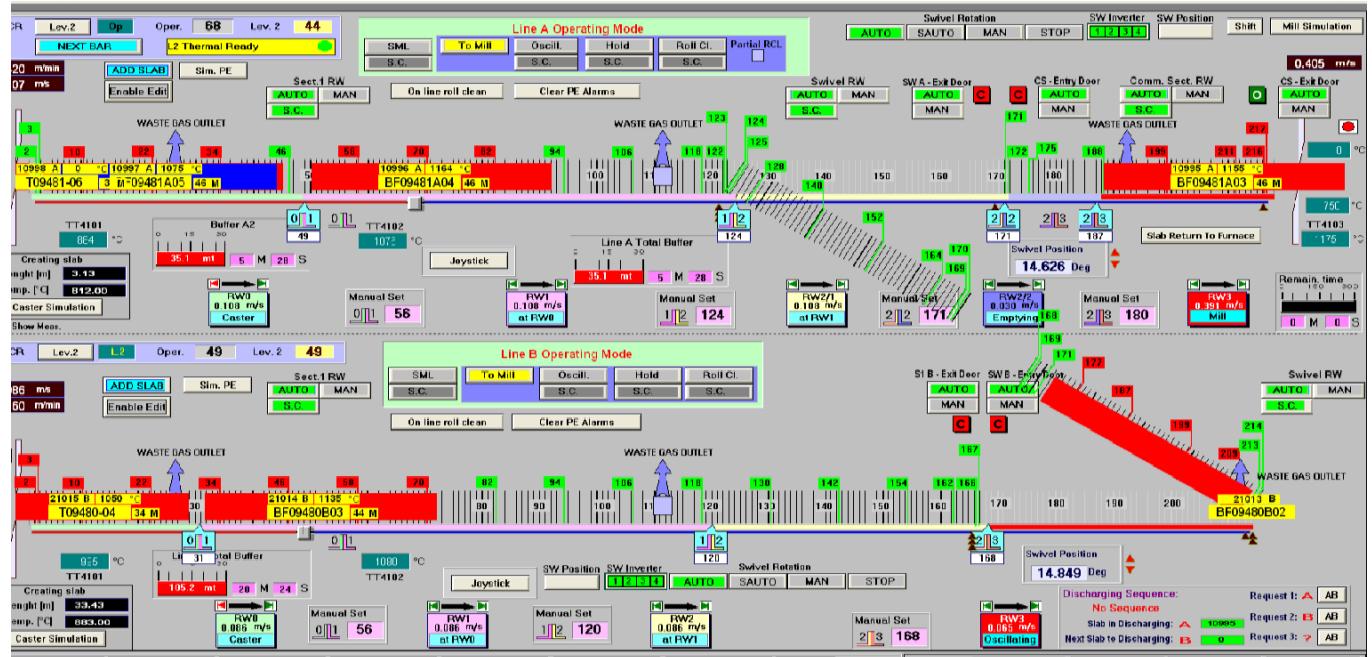
HMs communicate with Programmable Logic Controllers (PLCs) and input/output sensors to get and display information for users to view. HMI screens can be used for a single function, like monitoring and tracking, or for performing more sophisticated operations, like switching machines off or increasing production speed, depending on how they are implemented.

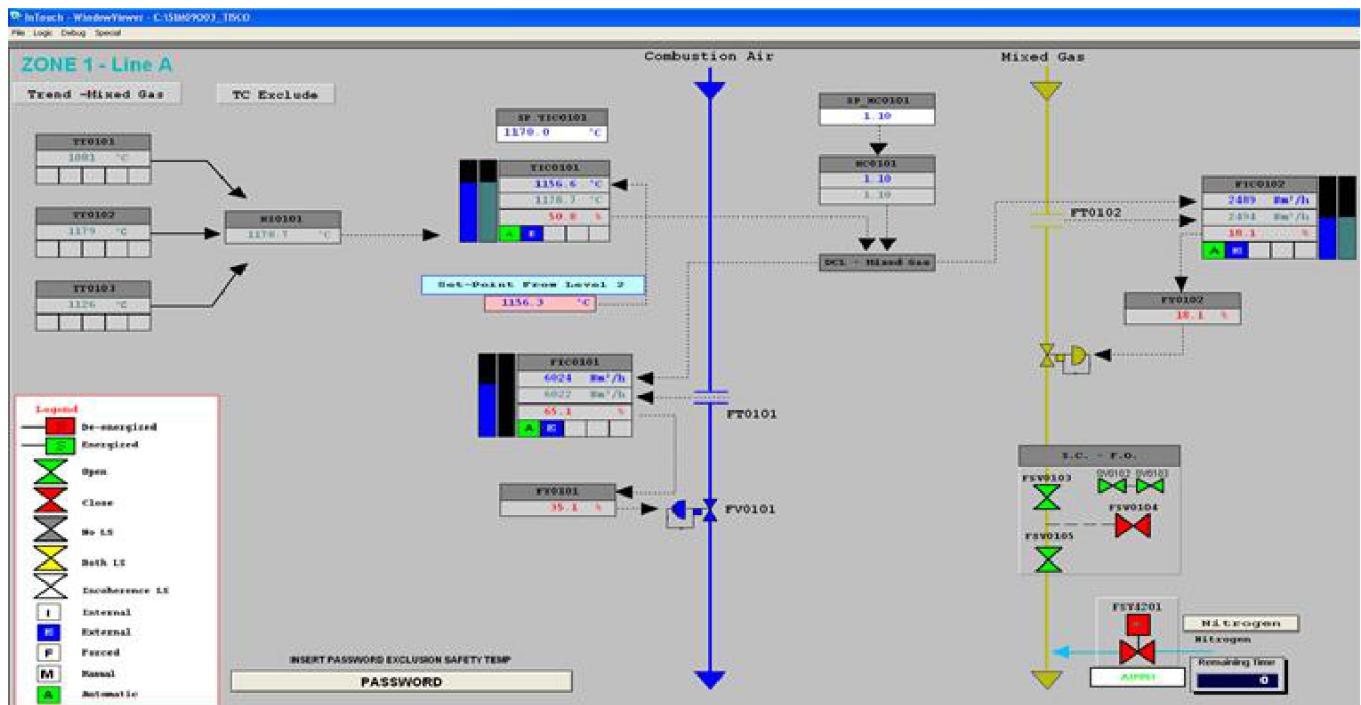
HMs are used to optimize an industrial process by digitizing and centralizing data for a viewer. By leveraging HMI, operators can see important information displayed in graphs, charts, or digital dashboards, view and manage alarms, and connect with SCADA and MES systems, all through one console.

Previously, operators would need to walk the floor constantly to review mechanical progress and record it on a piece of paper or a whiteboard. By allowing PLCs to communicate real-time information straight to an HMI

display, HMI technology eliminates the need for this outdated practice and thereby reduces many costly problems caused by lack of information or human error.

### SWIVEL ACTION BETWEEN LINE A & LINE B (AS Shown in HMI):





### TEMPERATURE CONTROL IN THE FURNACE AS SHOWN IN HMI

#### **DRAWBACK:**

Supervisory Control and Data Acquisition (SCADA) and HMI are closely related, and often referred to in the same context since they are both part of a larger industrial control system, but they each offer different functionality and opportunities. While HMIs are focused on visually conveying information to help the user supervise an industrial process, SCADA systems have a greater capacity for data collection and control-system operation. Unlike SCADA systems, HMIs do not collect and record information or connect to databases.

So, for DATA ACQUISITION a software named IBA Analyser is used which record and store the information.

- **IBA ANALYSER**

**'THE POWERFUL ANALYSIS SOFTWARE – FLEXIBLE AND FREE OF CHARGE'**

➤ **FLEXIBLE POWERFUL AND FREE OF CHARGE**

IbaAnalyzer is a very powerful tool for analyzing measurement data efficiently and without generating additional costs and deriving information from the analyses.

➤ **ANALYZING MEASUREMENT DATA**

Data can be analyzed either online during the measurement procedure or independently (offline).

➤ **COMPREHENSIVE DISPLAY**

The files and signal channels are managed in a comprehensive way due to a graphical surface.

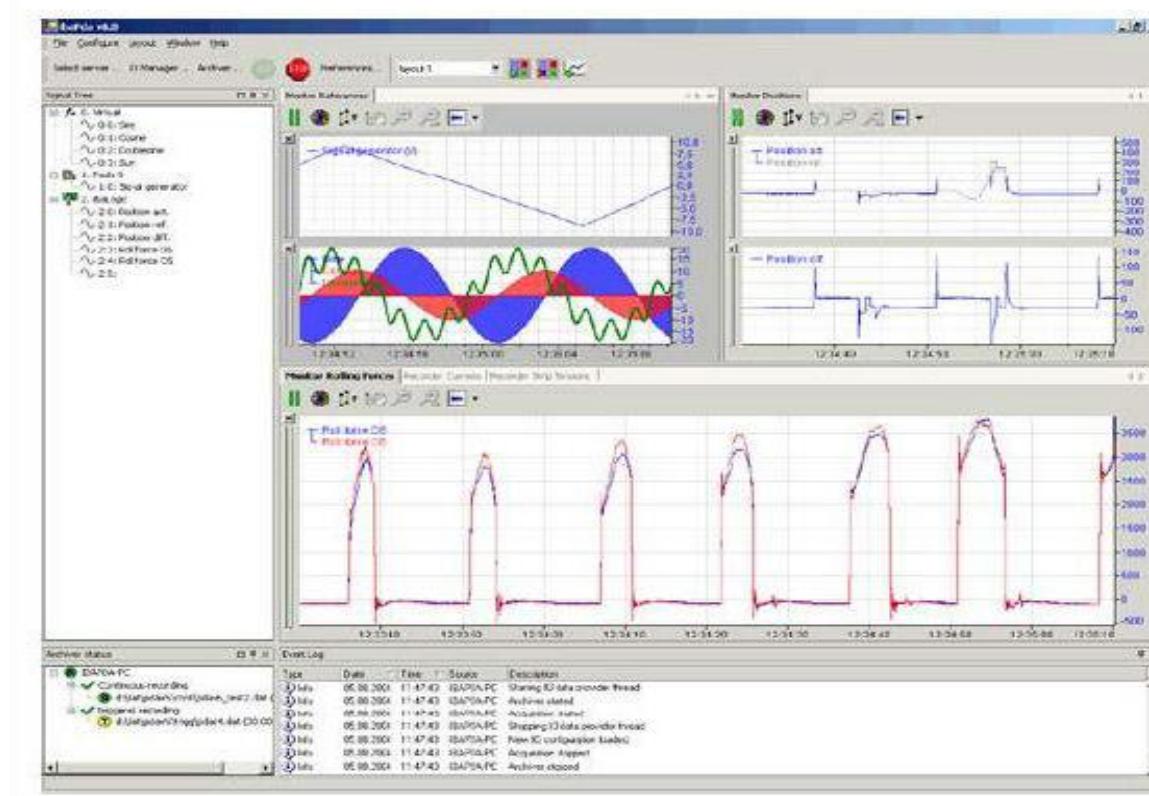
➤ **FORMULA EDITOR AND CREATION OF VIRTUAL SIGNALS**

For detailed analysis purposes, IbaAnalyzer offers a wide variety of mathematical functions that may be used besides for the common arithmetic and logical calculations.

➤ **FFT AND OTHER DISPLAY MODES**

Also, frequency analyses can be done in an easy way, using the recorded data.

SO IBA is a very useful software and is used to store the data collected – flow switch status, Motor and roll conditions and store it in the database for the further use.



- **IBA.dat EXTRACTOR**

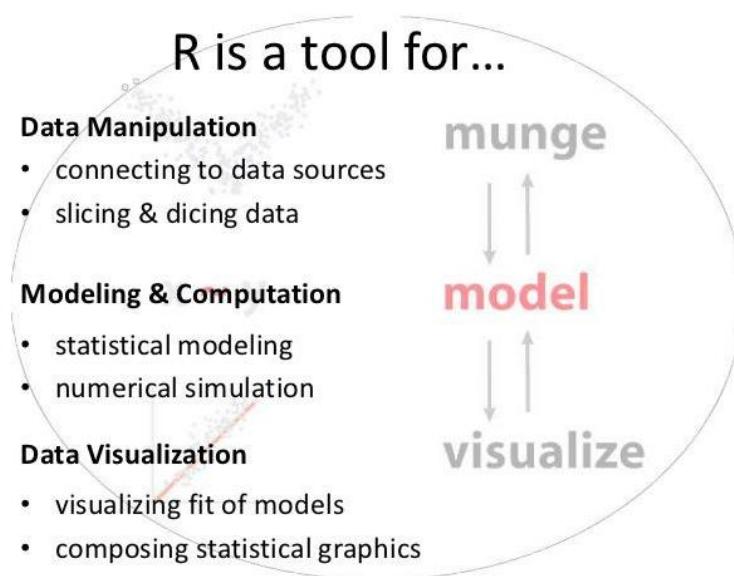
This tool is essential for collecting the data stored in the IBA analyser and sent it to the SQL server.

Microsoft SQL Server is a relational database management system developed by Microsoft. As a database server, it is a software product with the primary function of storing and retrieving data as requested by other software applications—which may run either on the same computer or on another computer across a network.

- **R STATISTICAL COMPUTING TOOL**

R is a programming language and free software environment for statistical computing and graphics supported by the R Foundation for statistical computing. The R language is widely used among statisticians and data miners for developing statistical software and data analysis.

R and its libraries implement a wide variety of statistical and graphical techniques, including linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering, and others. R is easily extensible through functions and extensions, and the R community is noted for its active contributions in terms of packages. Many of R's standard functions are written in R itself, which makes it easy for users to follow the algorithmic choices made.



- **HTML PROGRAMMING**

Hypertext Markup Language (HTML) is the standard markup language for creating web pages and web applications.

Web browsers receive HTML documents from a web server or from local storage and render the documents into multimedia web pages. HTML describes the structure of a web page semantically and originally included cues for the appearance of the document.

HTML elements are the building blocks of HTML pages. With HTML constructs, images and other objects such as interactive forms may be embedded into the rendered page. HTML provides a means to create structured documents by denoting structural semantics for text such as headings, paragraphs, lists, links, quotes and other items.



- INTEGRATION WITH SAP SYSTEM FOR NOTIFICATION AND ORDER CREATION

SAP ERP is an enterprise resource planning software developed by the German company SAP SE. SAP ERP incorporates the key business functions of an organization. The latest version (SAP ERP 6.0) was made available in 2006. The most recent Enhancement Package (EHP8) for SAP ERP 6.0 was released in 2016.

Business Processes included in SAP ERP are Operations (Sales & Distribution, Materials Management, Production Planning, Logistics Execution, and Quality Management), Financials (Financial Accounting, Management Accounting, Financial Supply Chain Management), Human Capital Management (Training, Payroll, e-Recruiting) and Corporate Services (Travel Management, Environment, Health and Safety, and Real-Estate Management).

Here it is used for notification and order creation and different jobs are entitled or listed through this server to respective personnel.

Change Notifications: List of Notifications													
	Description	Notif.No	PIS	Downtime	StartMalfunc	Malf.End	Typ	EquipAff	Equipment description	Descr.	Completion	Notif.Date	Report By
	TSCE_A_R055_W_TMP -B/L- 94.91- °C	300004327169	TFR	0.00	18.12.2018	Z8	A-R055				18.12.2018	63056753	
	TSCE_A_R055_W_TMP -B/L- 94.62- °C	300004327473		0.00	19.12.2018	Z8	A-R055				19.12.2018	63077368	
	TSCE_A_R024_RW_TEMP -B/L- 999.99- °C	300004327472		0.00	19.12.2018	Z8	A-R024				19.12.2018	63077060	
	TSCE_A_R198_W_TMP -B/L- 102.42- °C	300004327171		0.00	18.12.2018	Z8	A-R198				18.12.2018	63057018	
	TSCE_A_R198_W_TMP -B/L- 102.01- °C	300004327476		0.00	19.12.2018	Z8	A-R198				19.12.2018	63077640	
	TSCE_A_R206_W_TMP -B/L- 103.40- °C	300004327202		0.00	18.12.2018	Z8	A-R206				18.12.2018	63057026	
	TSCE_A_R206_W_TMP -B/L- 103.82- °C	300004327477		0.00	19.12.2018	Z8	A-R206				19.12.2018	63077648	
	TSCE_A_R214_CURNT -B/L- 8.02 A	300004327170		0.00	18.12.2018	Z8	A-R214				18.12.2018	63056814	
	TSCE_A_R214_CURNT -B/L- 8.01 A	300004327479		0.00	19.12.2018	Z8	A-R214				19.12.2018	63077898	
	TSCE_A_R125_RW_TEMP -B/L- 999.99- °C	300004327474		0.00	19.12.2018	Z8	A-R125				19.12.2018	63077421	
	TSCE_A_R139_RW_TEMP -B/L- 999.99- °C	300004327204		0.00	18.12.2018	Z8	A-R139				18.12.2018	63057675	
	TSCE_A_R139_RW_TEMP -B/L- 999.99- °C	300004327475		0.00	19.12.2018	Z8	A-R139				19.12.2018	63077491	
	TSCE_B_R004_W_TMP -B/L- 133.55 °C	300004327203		0.00	18.12.2018	Z8	B-R004				18.12.2018	63057040	
	TSCE_B_R004_W_TMP -B/L- 133.62 °C	300004327478		0.00	19.12.2018	Z8	B-R004				19.12.2018	63077662	
	TSCE-RS_LDB1_CUR_6M -B/L- 14.00 A	300004235316	TML	0.00	30.10.2018	Z8	ROLL SHOP ELEC AUX				30.10.2018	60617915	
	TSCE-RS_LDB4_CUR_6M -B/L- 15.00 A	300004235317		0.00	30.10.2018	Z8	ROLL SHOP ELEC AUX				30.10.2018	60617916	
	TSCE-RS_LDB3_CUR_6M -B/L- 17.00 A	300004235318		0.00	30.10.2018	Z8	ROLL SHOP ELEC AUX				30.10.2018	60619737	

#### SAMPLE Z8 NOTIFICATION

- **KAIZALA MESSAGING SYSTEM**

Kaizala is a mobile app that improves the way your business communicates and collaborates and get your work done out in the field. It's designed for large group communication, workflow management, reporting and analytics, and it's integrated with Office 365. Kaizala is an easy-to-use app, offering a simple and familiar chat interface.

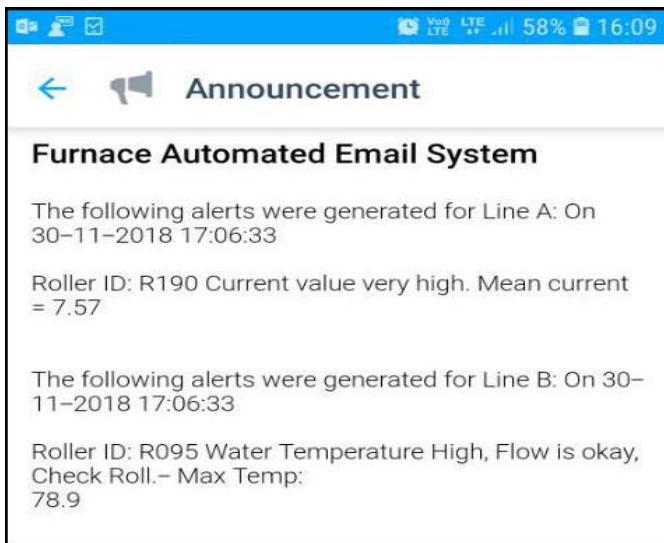
Microsoft Kaizala is a secure chat and messaging app that enables mobile users to send instant messages, Kaizala Actions, and attachments such as pictures, documents, videos, audios and more. Microsoft Kaizala also lets you get instant feedback from your users about anything you want. With the help of MS Flow, it lets your notification from outlook to Android.

BENEFITS:

- **Easier workplace coordination:** In a workplace full of remote and on-the-go employees, Kaizala makes it easier to manage your workplace. Coordinate everyday tasks with built-in actions that allow you to assign jobs, schedule meetings, and track performance. You can also build custom "Actions" based on your individual business needs with the Open API system
- **Connect with everyone easily:** Microsoft Kaizala makes it easier to communicate with large groups of workers inside and outside of your organisation. You can share photos, videos, text, documents and more with just a couple of taps, and get feedback from your employees and partners with surveys and polls. Additionally, setting up your users is easy – all you need is their phone number!
- **Make data-driven decisions:** With analytics built into its core, Microsoft Kaizala helps companies to make more informed decisions about the future of their business. You can get automated reports delivered straight to your business leaders, which support you to analyse the performance of your teams
- **Access Control and security:** The advanced Kaizala Management portal ensures that you have complete control over your actions and data. Your admins can control group memberships, remove users from groups in an instant, and even remotely wipe data from external devices

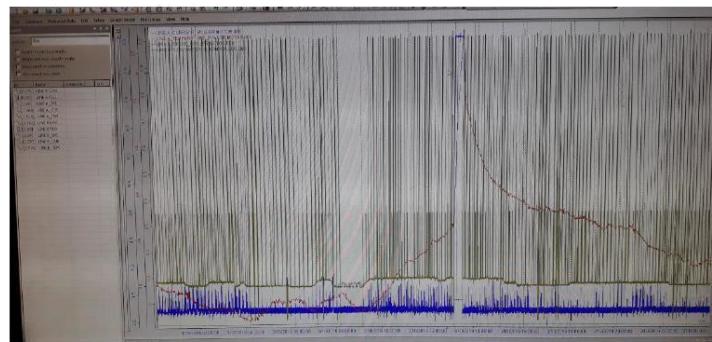
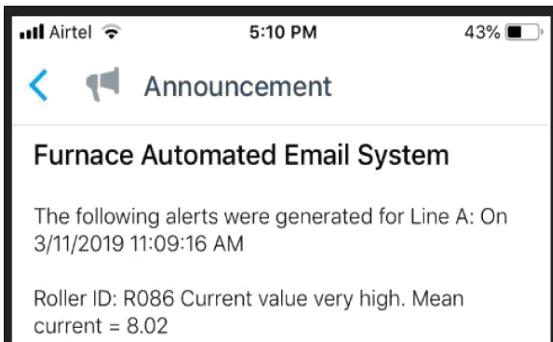


The use of this messaging APP helps us to create alerts and alarms if any of the field devices is malfunctioning so that necessary actions can be taken beforehand which increases the reliability of tunnel furnace which is also the main motive of this digitalization scheme.



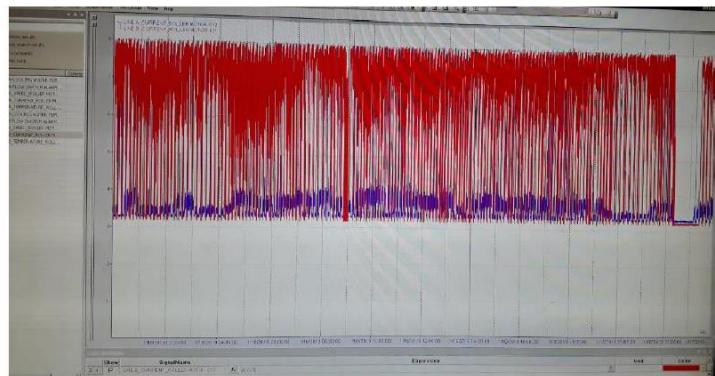
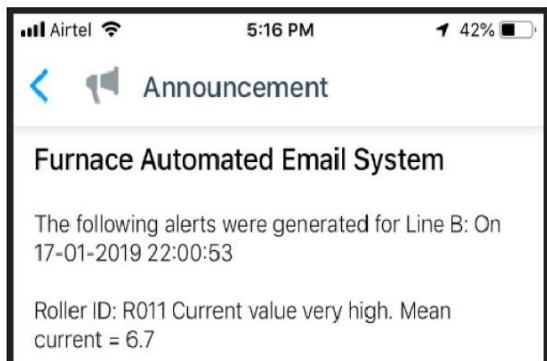
#### SAMPLE MESSAGE AS IT APPEARS IN KAIZALA

#### CASE STUDY:



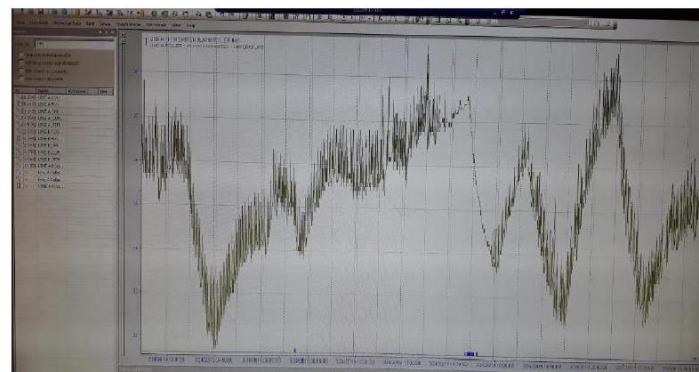
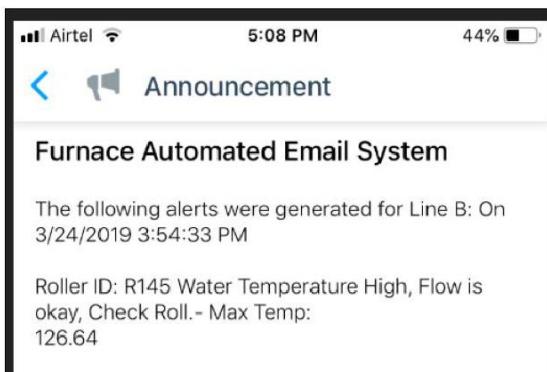
#### **High Current Alarm-Roller and Motor saved**

Instant high current alerts helped in saving a motor. It was found that the Roll was jammed. So Roll was changed in shutdown and found to be bent.



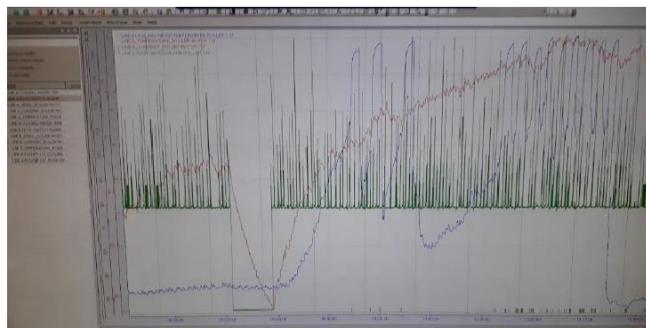
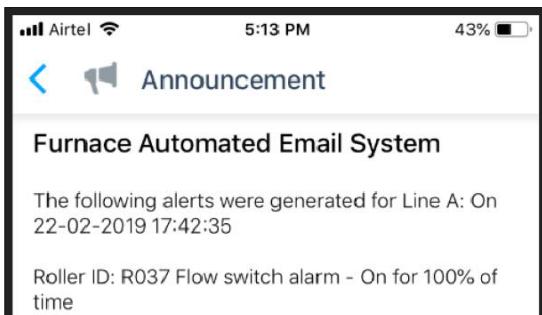
### **High Current Alarm-Motor saved**

Instant high current alerts helped in saving a motor. It was found that the adjacent motors were taking low current in comparison to it. So decoupled and roll leveling done to rectify the problem.



### **Cooling Water Temp Alarm-Roller saved**

Instant high cooling water temperature alerts helped in saving a roll. It was found that there was jamming in the rotary joint. So flushing was done to rectify the problem.



### **Cooling Water Flow Alarm-Roller saved**

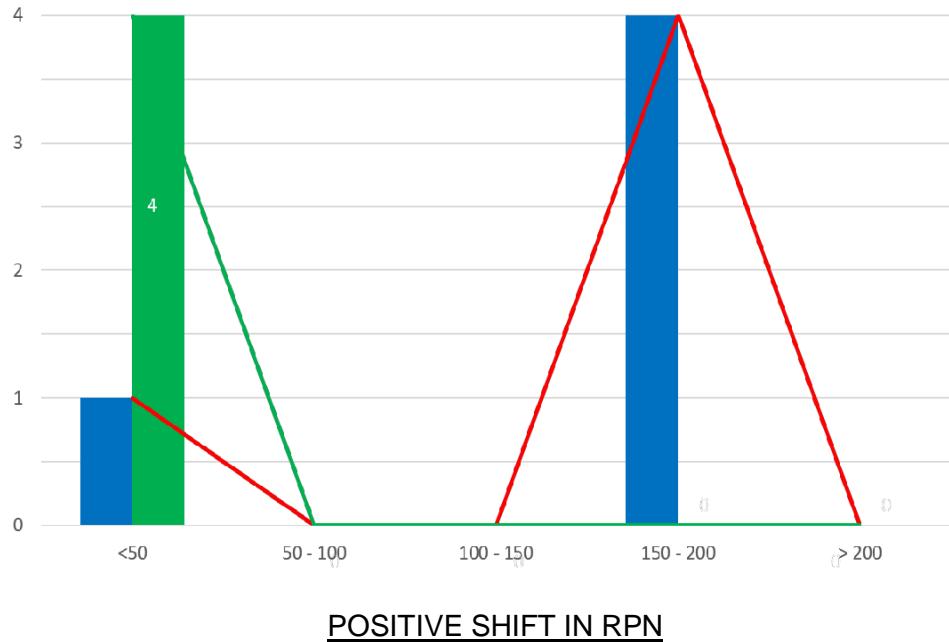
Instant low flow alerts predicted probable damage in roll. So Roll was changed in shutdown and found to be damaged ( Refractory damaged and roll punctured )

### **RESULTS AND WAY FORWARD:**

Taking the initiative for digitalization has made the error detection a lot easier and has increased the reliability of the tunnel furnace. With the help of this initiative the alarms are generated and failures are recognized beforehand. Thus this '**REAL TIME MONITORING SYSTEM**' is quite efficient and it has saved and detected a lot of failures in the TSCR plant beforehand thereby preventing uninterrupted delays and saving a lot of money (estimated around 1Cr.)

### **ANALYSIS OF RPN BEFORE AND AFTER THE DIGITALISATION INITIATIVE**

Area	Assembly	Component	Failure mode/issue	Before				After			
				Severity	Occurrence	Detectability	RPN no.	Severity	Occurrence	Detectability	RPN no.
Tunnel Furnace	Line A	Roll	Ceramic Failure	7	5	5	175	4	4	2	32
			Tyre failure	7	5	5	175	4	3	2	24
			Neck failure	6	5	5	150	4	3	2	24
			Roll breakage	8	4	5	160	4	3	2	24



### POSITIVE SHIFT IN RPN

We see that the detectability has increased after digitalization (so the number assigned is less) and so the Risk Priority Number (RPN) has decreased. We see the positive Shift in the RPN distribution graph after the digitalization initiative.

### CONCLUSION:

The Tunnel Furnace in TSCR is used for transportation of slabs from caster to hot rolling mill for rolling. The other function of the tunnel furnace is to preheat the slabs upto 1500°C for rolling. We have different field devices connected in the furnace and we also have rolls and motors for material handling and transportation.

These field devices along with motors and rolls are costly. Earlier when there was no digitalization, we could not detect their failures beforehand and when they failed to work, respective person needed to go to the field to replace the device.

But now due to the digitalization scheme necessary intelligent alarms are generated in the Kaizala app and there is an integration with the SAP system for notifications, order creation and necessary job scheduling.

Thus, due to this digitalization scheme the overall reliability of the tunnel furnace is increased.

### **LEARNING OUTCOMES:**

- Practical Application of Theoretical Learning
- Working Experience of Field Devices
- Knowledge of PLC Communication
- The World of Digitalization
- Internet of Things
- Knowledge of Kaizala Messaging App
- Problem Debugging and Diagnosis
- Easy and simple solutions of problems at hand
- Work Culture and team Ethics.

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