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Digital Initiatives in Carbon Plant to Drive Quality, Reliability, Safety and Innovation

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Abstract: Carbon plant produces anodes for Aluminium Smelter as required in electrolysis process in Pot-room for Aluminium Production. In ADITYA Plant, anodes are supplied to both ADITYA and HIRAKUD Plants. A number of digital initiatives have been initiated to drive Quality, reliability, safety & innovation. These include: (i) Installation of Video Image Smoke & Fire Detection system (VISFD), (ii) Benchmarking study, (iii) Online Butt Weighing System in Aditya Rotary Shop (ARS), (iv) Anode Visual Monitoring System, (v) Online anode pallet temperature measurement, (vi) Digitization of logbooks, (vii) Development of VR (Virtual Reality) modules for critical equipment to improve skillset of manpower, and (viii) Wireless monitoring of Ball Mill in Green Anode Plant (GAP). This paper describes the benefits of these digital initiatives and how these have greatly improved reliability, greater monitoring, control & safety in carbon.
Keywords: Carbon, Anodes, and Digital initiatives.

I. INTRODUCTION

Manufacturing of anodes in aluminum smelter includes three stages, namely green anode production, baking of green anode and rodding of baked anode.

The basic principle behind most of the Modern-day aluminium smelter is “Hall-Heroult process” which was invented during 1886 by the American chemist Charles Martin Hall and French scientist Paul Heroult. The Hall-Heroult process consists of an electrolysis cell made of steel shell with inside insulated & refractory line. Inside this shell cathode blocks made of carbon material with steel collector bars are arranged in a fixed pattern bonded with some ramming paste. The anode is also made up of carbon materials which is immersed inside the electrolyte (cryolite bath). During electrolysis process, the anodes are consumed as the carbon in the anode reacts with the oxygen in the alumina. Molten aluminium is produced as per the reaction (1) and tapped out from the pot cells in regular intervals.

$$2\ Al2O3 + 3\ C = 4\ Al + 3CO2 \qquad (1)$$

The above reaction is a continuous reaction, so the carbon anode gets consumed regularly with a total consumption of 0.4-0.5 kg / 1 kg of aluminium metal produced.

From the above it is clear that a typical aluminium electrolysis process requires electrolytic pot cells, carbon anodes, alumina and electrical current. So, in any aluminium smelter the key production units are pot room, carbon plant & cast house.

The carbon anodes are made from a mixture of calcined petroleum coke, coal tar pitch, spent anodes (butts) and green scraps molded into blocks and baked in anode baking furnace at about 1100±20°C. An aluminium stem with iron stubs is then attached with the anode by pouring cast iron into the stub hole on the top of the anode block in order to have the electrical contact and physical support to the anodes in pot cells.

This paper will have a walkthrough of some of the digital practices followed in carbon plant to sustain quality, reliability, safety & innovation.

II. BRIEF DESCRIPTION

Aditya Aluminium, a unit of Hindalco Industries Limited is a part of Aditya Birla Group. Hindalco Industries Limited, metals flagship company of the Aditya Birla Group, is the industry leader in aluminium and copper. With a consolidated turnover of US$18 billion, Hindalco is the world’s largest aluminium rolling company and one of Asia’s biggest producers of primary aluminium.

Aditya Aluminium, situated at Lapanga, Sambalpur, Odisha is an ISO 9001/ISO 14001 certified company. The process and quality is registered in London Metal Exchange (LME). It consists of 360 KTPA smelter supported by 6 x 150 MW captive power plant. The plant is commissioned in 2014 with state-of-the-art technology from Rio Tinto Alcan-AP36S. With continuous process improvements, operational excellence along with in-house technical innovations Aditya Aluminium placed 1st in productivity among AP30 smelters operating <370 kA & 2nd most pure metal producer among 22 AP30 smelters.

Carbon produces anodes for aluminium smelter as required in electrolysis process in pot-room for aluminium production. Carbon plant consists of 3 Sections:

1) Green Anode Plant (GAP) producing two types of green anode of different dimensions,
2) Anode Baking Furnace, and
3) Anode Rodding Shop.

In ADITYA Plant Anodes are supplied to both plants ADITYA & HIRAKUD Plants.

A number of digital initiatives have been initiated to drive quality, reliability, safety & innovation.

III. BACKGROUND

Green anode plant is quite susceptible to fire hazards. In aftermath of the fire incident in green anode plant which happened in March 2019 it was the need for predictive/analytics for the proactively detect probable hotspot.

The raw materials in anode production contains inherent inflammable agents which can lead to fire.

- Four small fire and one major Fire incident happened in GAP, Aditya.
- Dense pitch fumes all throughout the plant.
- HTM Oil of temp 255°C recirculating in plant through pipelines.
- Heavy fire incident occurred in our sister units- Renukoot and small fire incident in Mahan.
- Large Fire incident occurred in other group of same business- Vedanta.

IV. CRITICALITY OF THE PROBLEM

Green anode plant is the heart of aluminium smelter process which provides consistent quality of anode for production of aluminium.

Any eventuality in GAP could adversely affect the pot-line operation.

- Single plant catering to the anode requirements of Hirakud & Aditya.
- Pot-line at stake for both Hirakud & Aditya smelters.
- Single line equipment with foreign OEMs.

Table-1: Problem solving approach

Problem / Concept Description	Approach	Result / Implementation Status	Value / Financial Benefits	Time Period
GAP is Highly Fire prone plant being the presence of dense pitch fumes and high temp HTM oil (~290°C). Following Fire incidents occurred in different units: • 4 times Fire incident occurred in GAP, Mahan. • In 2010 Fire in GAP, Renukoot • In 2019 GAP, Aditya & Vedanta fire occurred.	• Brainstorming on different technologies related to online temp. monitoring. • Identification of critical areas. • Creating of different zones within a single equipment for temp analysis & alarms. • Case studies of fire from different units & industries.	Completed in the highly fire prone areas: • Reject Paste Belt Conveyor. • Paste Feeder Room. • Hot Air Generator area. • HTM Building.	Tangible Gain: • Reviving cost of the plant approx **6 Cr.** Intangible Gain: • Equipment and Human safety enhancement. • Production loss.	Jan 22 to July 22 (7 months)

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A. *Video Image Smoke & Fire Detection System (VISFD)*

- Plant cross-functional team along with corporate digitization team made a detailed study of IR automation case studies. Its application in different industries, after which several discussions and brainstorming sessions were being executed along with M/S- FLIR and LAND looking into our application. As main challenge was the area is full of pitch fumes.
- The camera required for analysing the images and continuously monitor the pixels which are different from the fire & smoke, the analytical tool was required to identify the smoke and fumes (Fig. 2).
- Those digital images were transmitted to a model and if any fire is present then it will give the annunciation to control room for further action (Fig. 3).

B. *Benchmarking Study*

This is the first time IR automation along with AI dashboard is implemented in Green Anode Plant to mitigate fire safety in such a fire prone plant (Fig. 4 & 5).

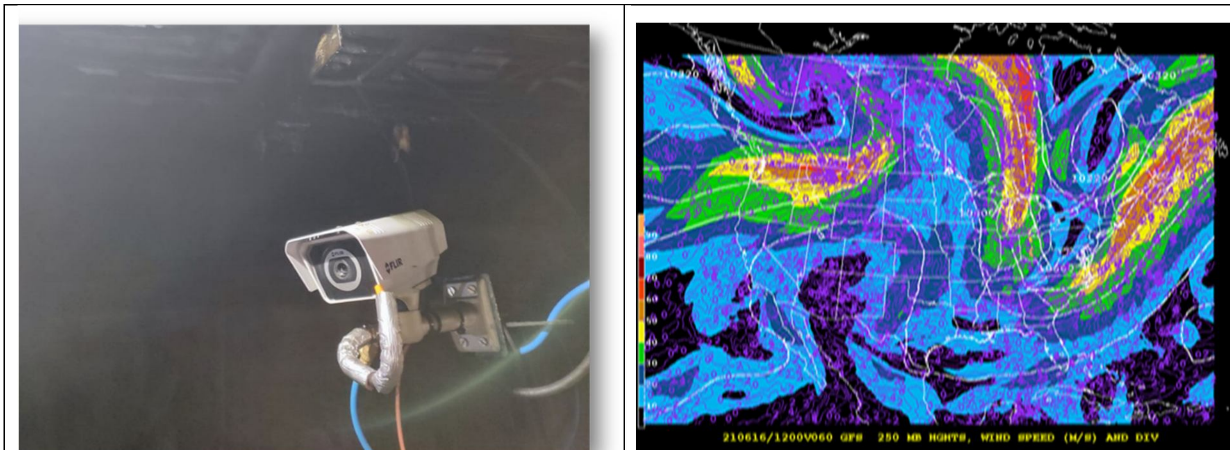

Fig. 1: IR camera for hot spot identification. AI Cameras & different zones identified by a single AI Camers.

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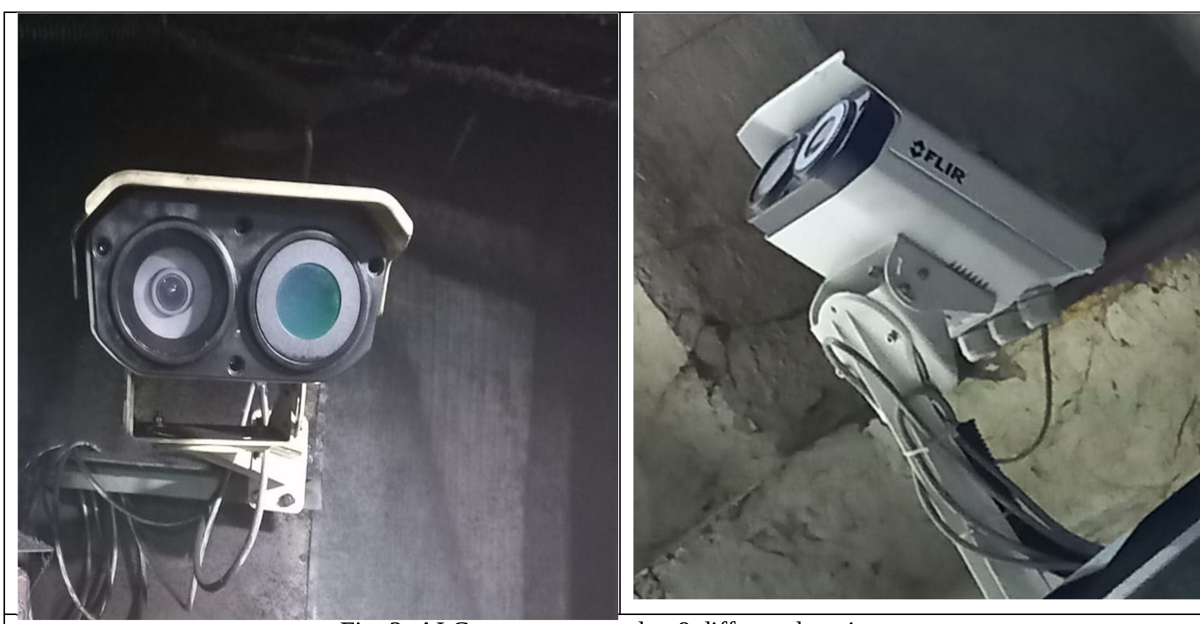

Fig. 2: AI Cameras mounted at 8 different locations.

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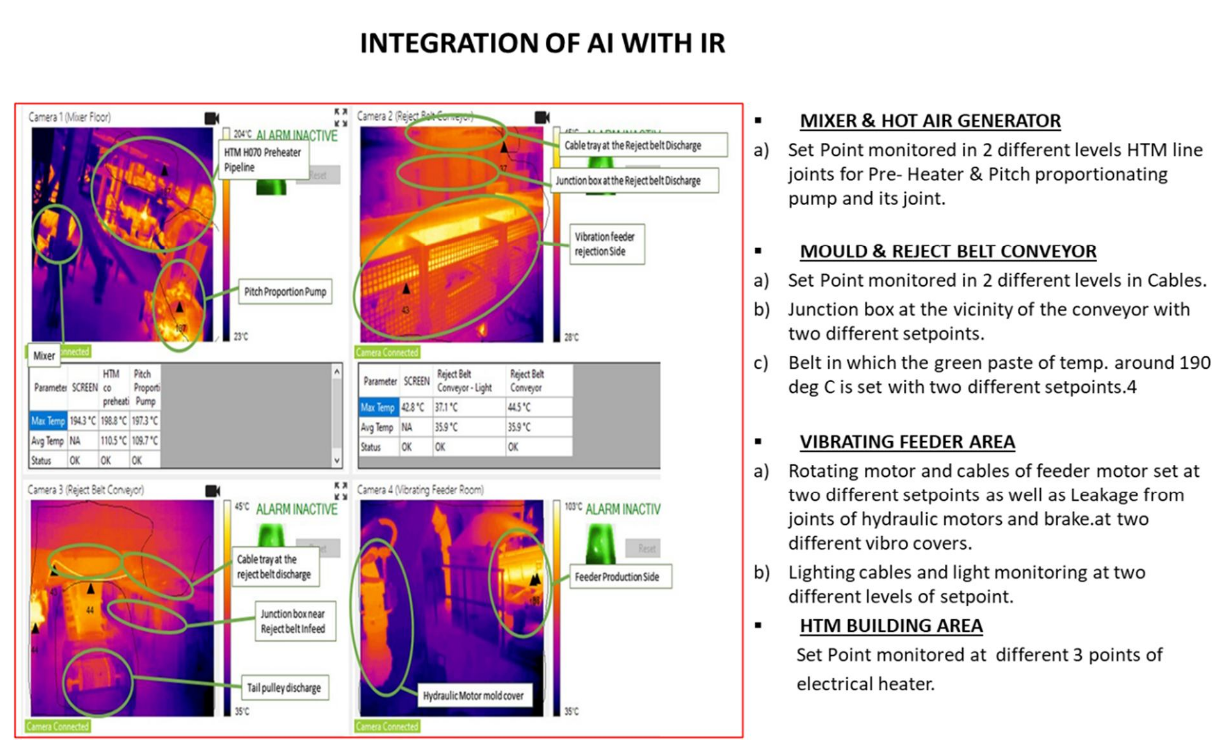

Fig. 3: AI Dashboard.

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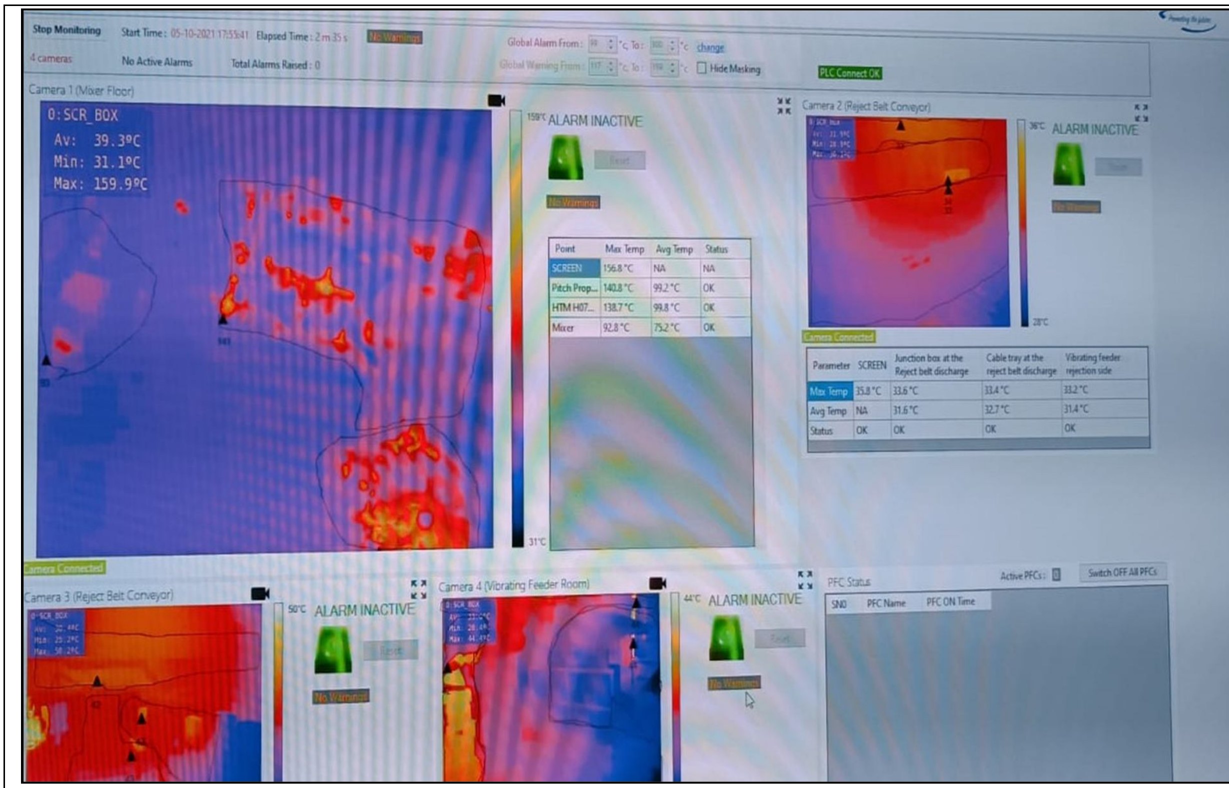

Fig. 4: Dashboard of each individual area with healthy condition and display of temperature with tropical notification.

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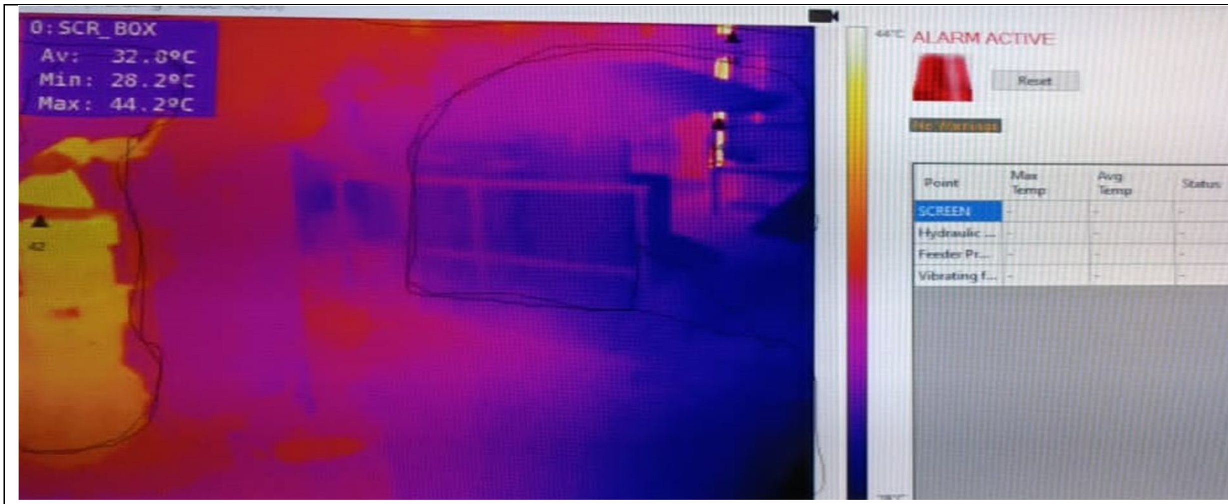

Fig. 5: Dashboard of each feeder area with alarm condition and display of temperature with tropical notification along with hooter activation.

C. Deployment of AI Enabled CBM solutions and Predictive Analytics for Critical Equipment at Aditya Rodding Shop (SMART ARS)

1) In anode rodding shop there are a number of rotating equipments but there was no online CBM solution for continuous monitoring of machine health.
2) Online CBM solution using IOT enabled vibration analysis/Oil Condition. monitoring was adopted (Fig. 6).
3) 24*7 remote diagnostic solution for rotating equipment.
4) Interactive DASHBOARD to analyze performance of equipment & provide solution with real time alerts for predictive analysis (Fig. 7).

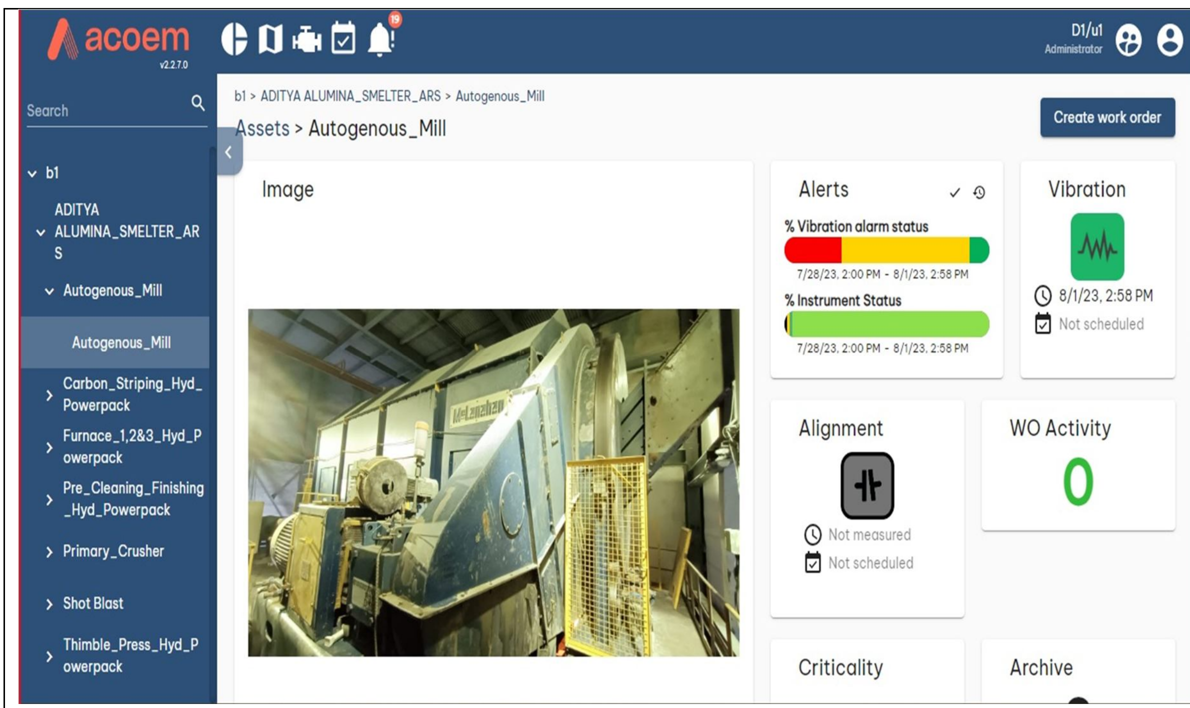

Fig 6: Dedicated DASHBOARDS for individual equipment.

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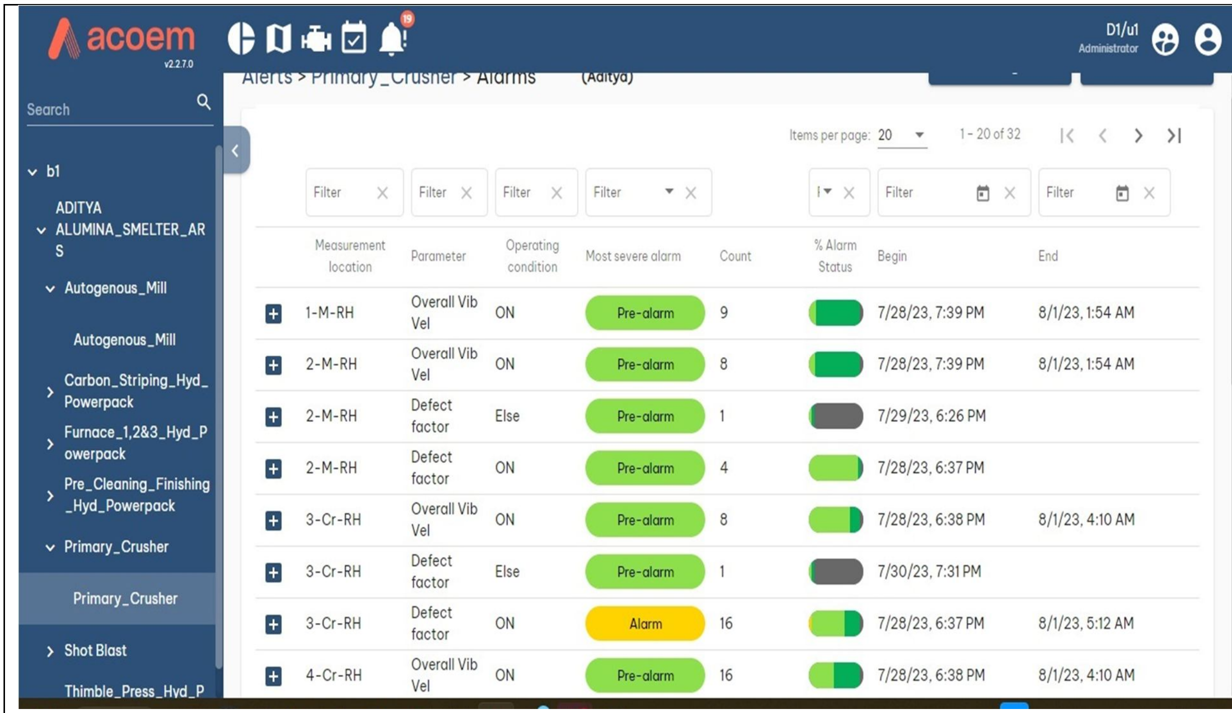

Fig. 7: Real Time DATA for Predictive Analysis.

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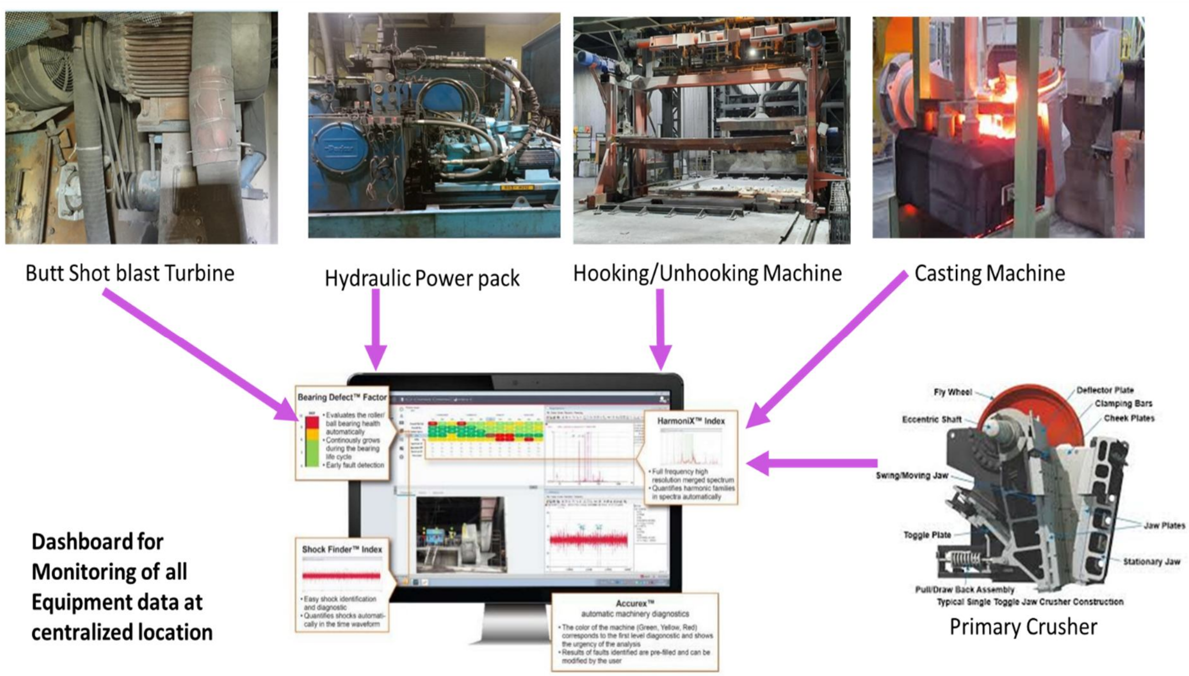

Fig. 8: Details of Equipment covered.

Benefits

- Prevent unscheduled downtime.
- Improve plant maintenance by improving the MTBF.
- Lower maintenance costs through predictive analysis.
- Enhance safety of machine & people.
- Prevent major failures.
- Maximize production output

D. Online Butt Weighing System in ARS

- The anodes which are sent for electrolysis, a part of it returns back to CARBON for recycling (BUTT) & usage back in the anode making process.
- Mounting of load cells in the Power & Free Conveyor track at 2 locations i.e after Shot Blast Machine & Thimble Press in Anode Rodding Shop to take the carbon weight with real time DATA transfer & logging in PLC. (Ref Fig 9 & 10)
- Real time checking of butt return from pot-room thus elimination of manual intervention & error.
- Monitoring of the performance of anode in pot-room.
- Monitoring of the net carbon consumption.
- Enhanced Safety due to elimination of man-machine interface.

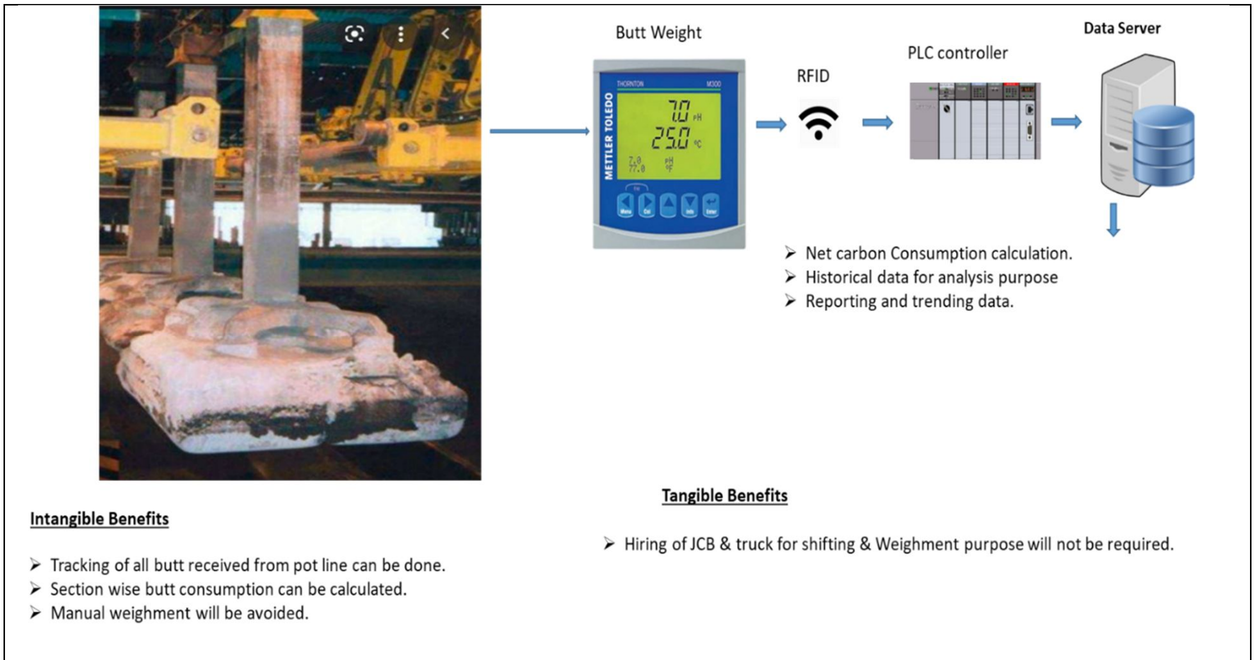

Fig. 9: Digital Architecture for Butt Weighing System.

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Fig. 10: Online Butt weighing system in P&F Conveyor in ARS.

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E. Anode Visual Monitoring System

- This project is initiated to strengthen and full proof the anode inspection mechanism for the 100% anodes produced at Green Anode Plant and Anode Baking Furnace.
- This Automated Anode inspection system is designed to capture images through AI Enabled Cameras at 2 designated points in conveyors for green & baked anode (Ref Fig. 11 & 12) and make an analysis of the physical abnormalities of anode. Based on which the anodes can be rejected and not to be sent to pot room. Thus, it ensures 100% sampling,100% defect tracking & 100% elimination of manual intervention.

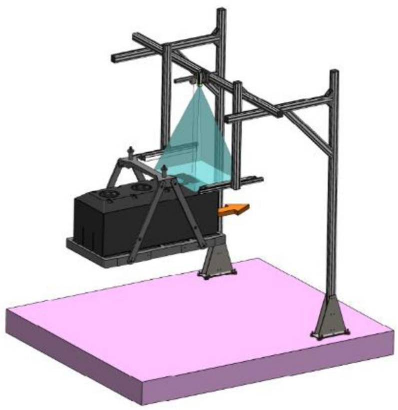	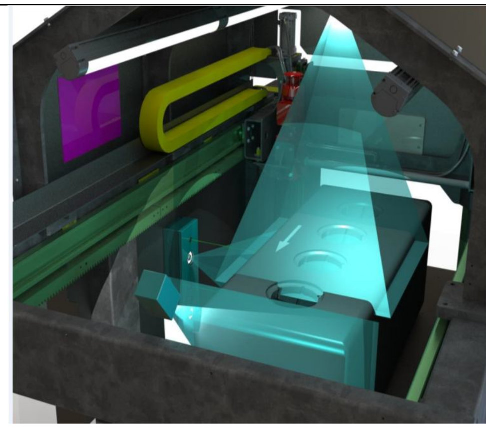
Fig. : Showing mounting of the camera in the P&F Conveyor	Fig. :Depicting the sample area scanned to detect abnormalities

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Below types of physical abnormalities will be detected in anodes through this online monitoring-inspection system:

- Damage in anode stub hole
- Cracks in anode surface
- Physical Deformation
- Broken corners
- Surface Segregation

Thus, 100% defect free anodes can be sent to Pot-room.

Fig. 11: Anode Visual Monitoring Station.

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Fig. 12: Anode Visual Monitoring Station & Dashboard.

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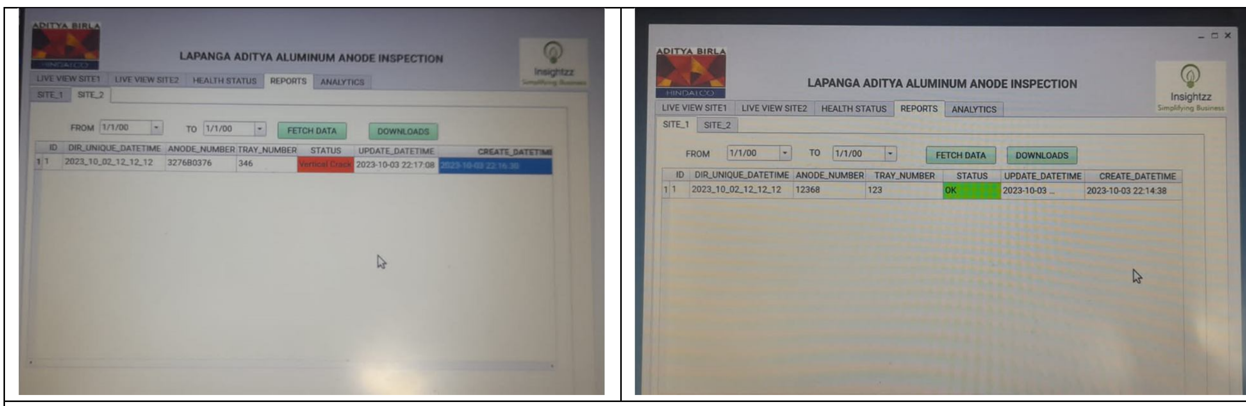

Fig. 13: Anode Visual Monitoring Dashboard with defect details.

F. Online Anode Pallet Temperature Measurement

- The Part of anodes which are returned back from pot-room (spent anodes) in pallets are cooled for 2 days in the storage area as per SOP to eliminate any fire hazard which may arise due to contact of hot bath from the spent anodes.
- To improve safety, online temperature measurement system (Infrared Camera) is installed in Anode storage area for measuring the temperature of the anode pallets which are returned from pot room.
- Real time display in central control room 24x7 (Fig. 14 & 15).

Fig 14: Pallet View from Central Control Room.

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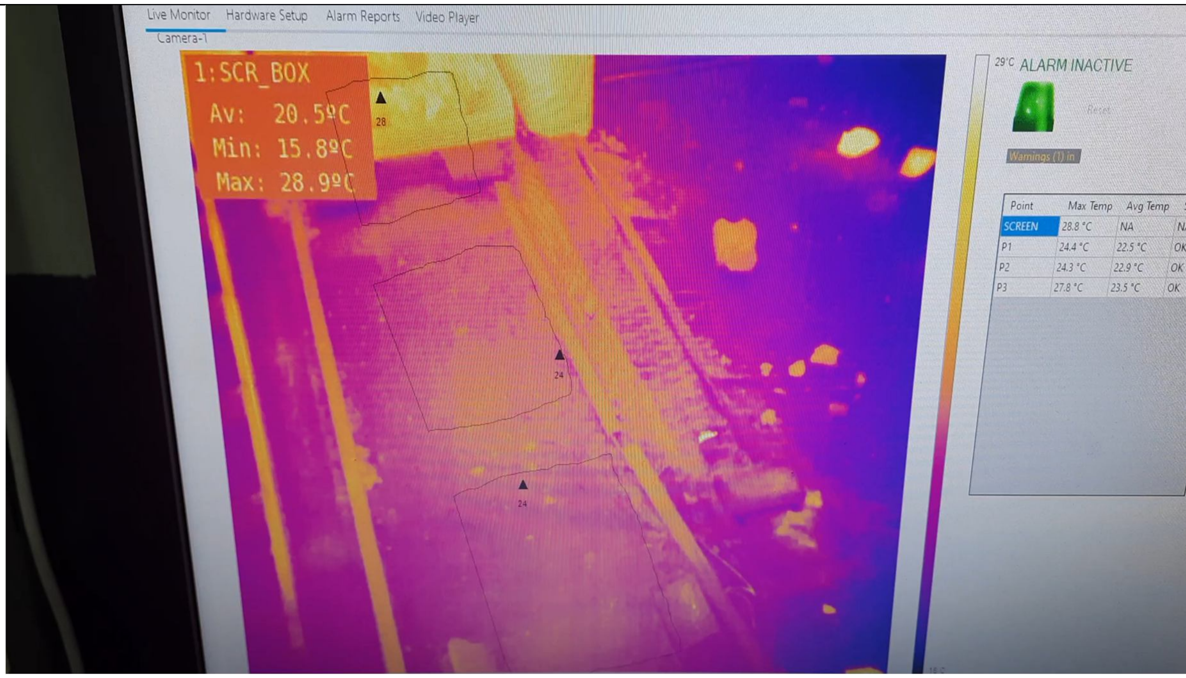

Fig. 15: Pallet Thermal View from Central Control Room.

Intangible Benefits

- Eliminate manual intervention
- Increase safety
- Decreasing turnaround time of temperature measurement
- Eliminates man machine interface

G. *Digitization of Logbooks*

- Reducing paperwork & availability of DATA 24x7 Online.
- Improving productivity by reduction in manual fetching & logging of DATA.
- Usage of ORACLE BI to automate the data acquisition & formulation of DASHBOARDS for enhancing data visibility & decision making (Fig. 16 & 17).

Fig. 16: Digital Dashboards for DATA Analysis.

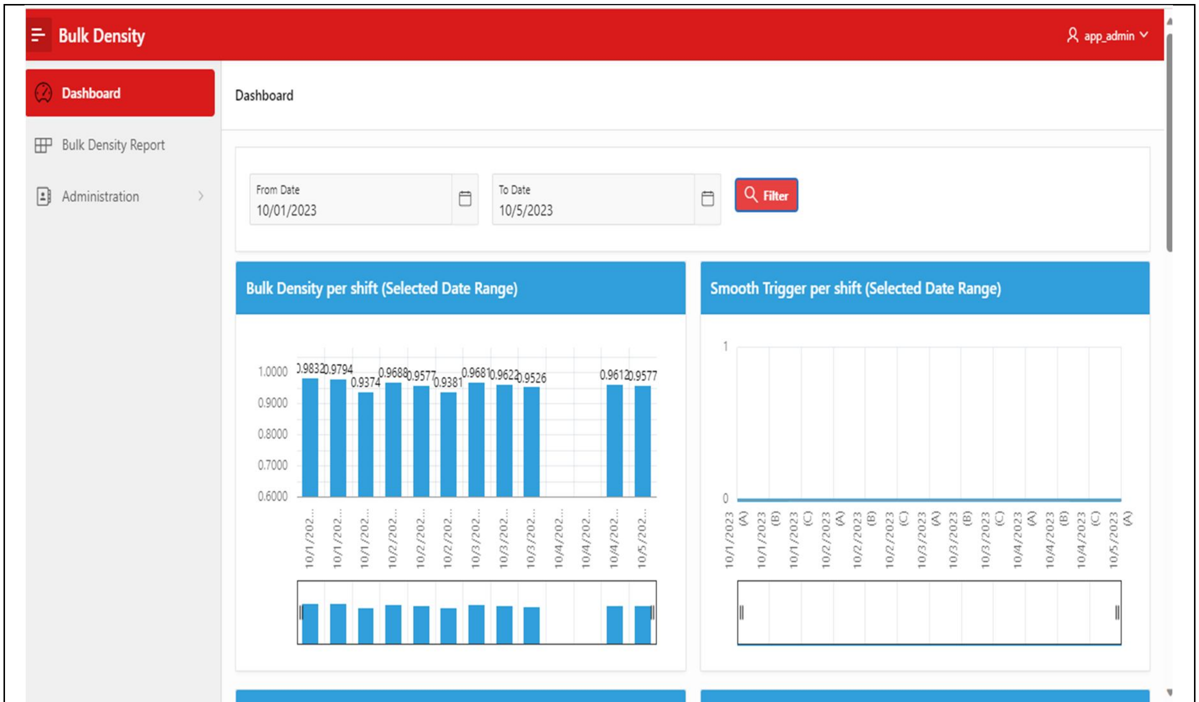

Fig. 17: Digital Dashboards with trends for DATA Analysis.

H. Development of VR (Virtual Reality) Modules for Critical Equipment to Improve Skillset of Manpower

- Developing people capability plays a vital role in an organization success
- CARBON plant consists of numerous critical equipment & in–depth knowledge is quite critical in ensuring continuous plant production & plant availability.
- Development of Virtual Reality Modules for Critical Maintenance activities for LIVE demonstration to the technicians & new joinees (Fig. 18 & 19).

Fig. 18: VR Kit: Oculus Rift Headset, with Sensors and controllers.

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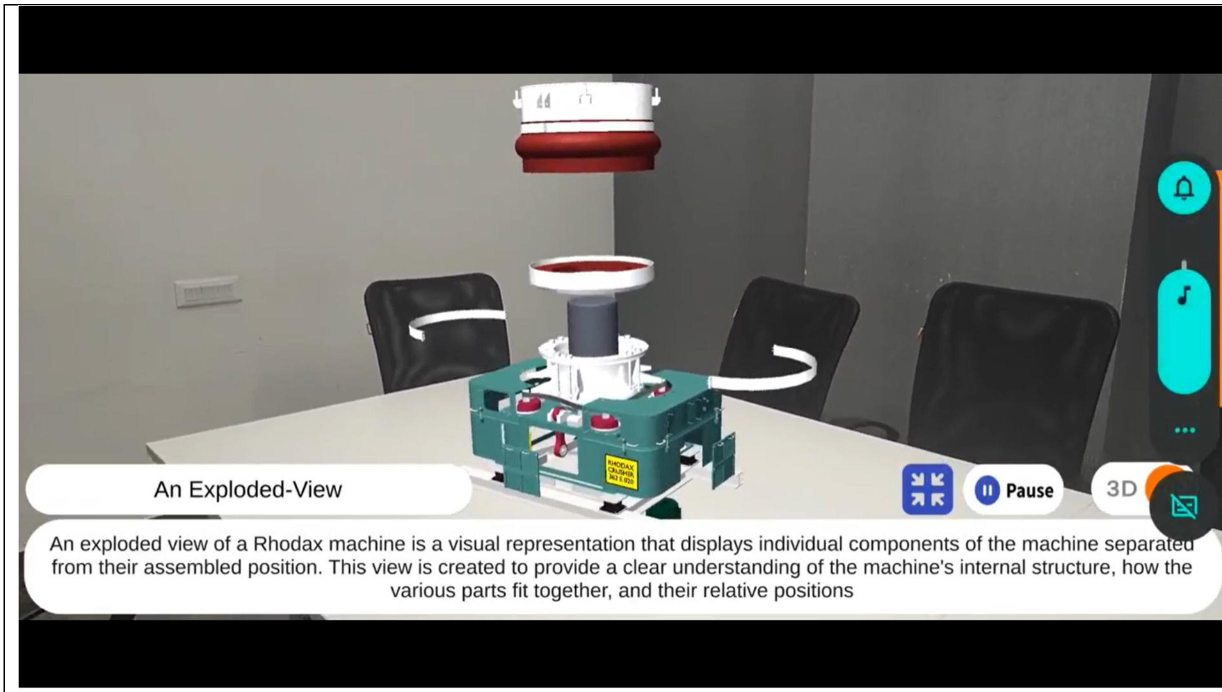

Fig. 19: VR Module for Rhodax Crusher in Green Anode Plant.

I. Wireless Monitoring of Ball Mill in GAP

- Ball mill is a major critical equipment in Green Anode Plant.
- Wireless sensors were mounted on the Gearbox, Motors, pinion, fluid coupling.
- Online CBM solution using IOT enabled vibration analysis with real time alerts in mobile & mail for taking prompt action.
- Interactive DASHBOARD to indicate the equipment behavior with prescriptive analysis (Fig. 21 & 22).
- This project has resulted in prediction of defects in ball mill alignment thus helped in pro-active diagnosis.

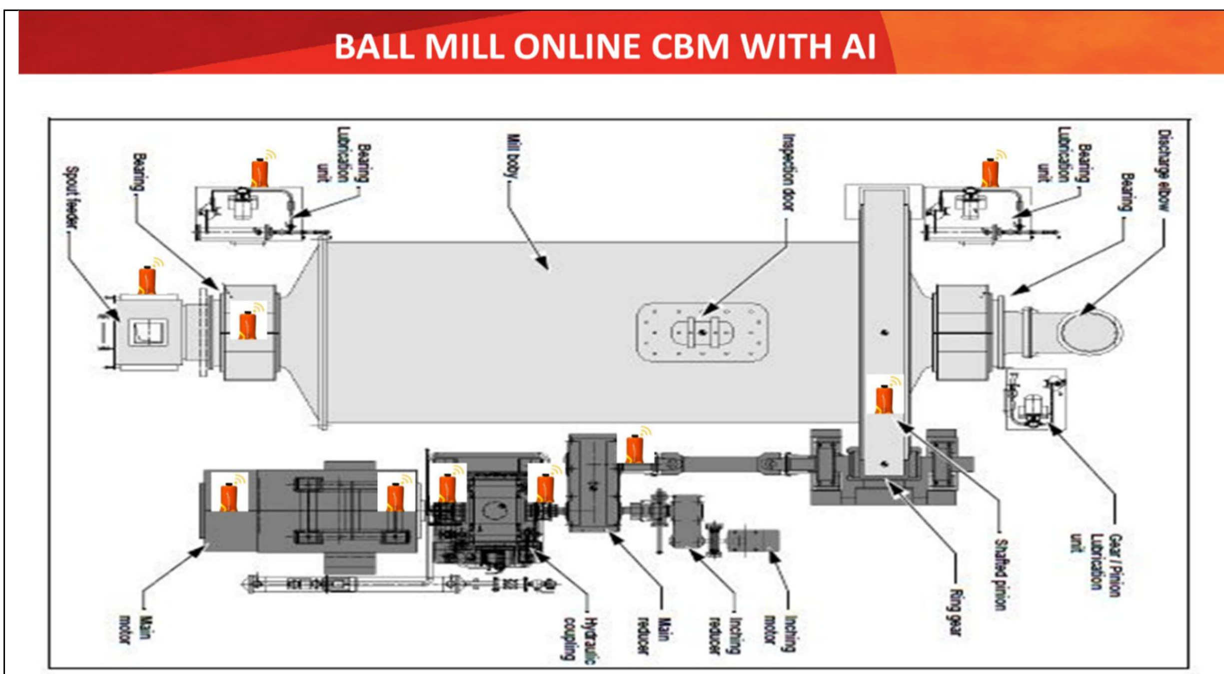

Fig. 20: Wireless Sensors mounting in Ball Mill in Green Anode Plant.

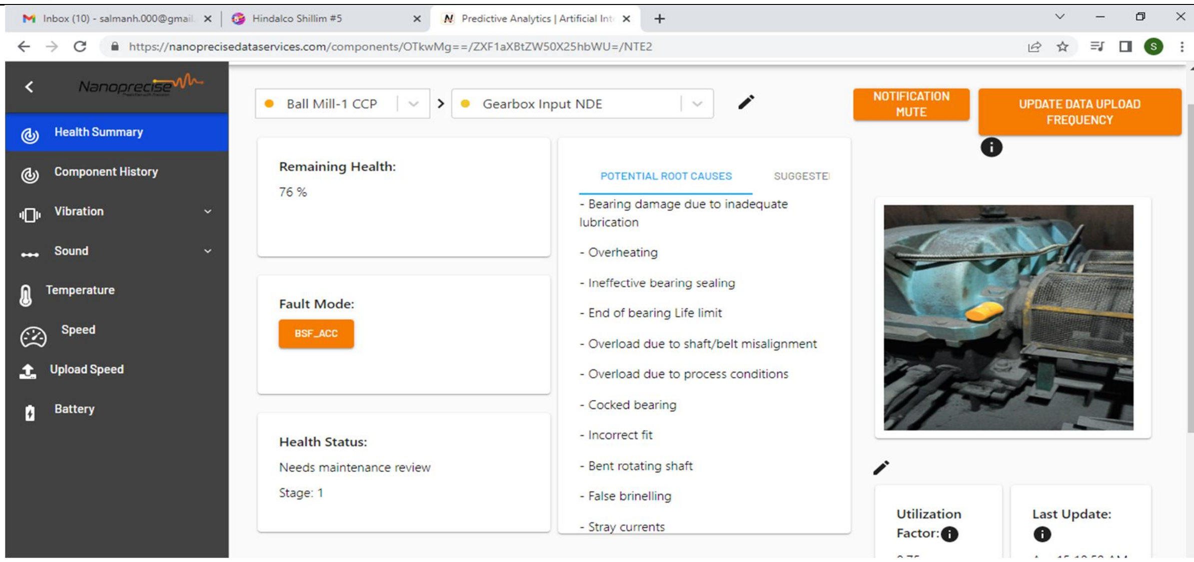

Fig. 21: Dashboard for predictive analysis in Ball Mill in Green Anode Plant.

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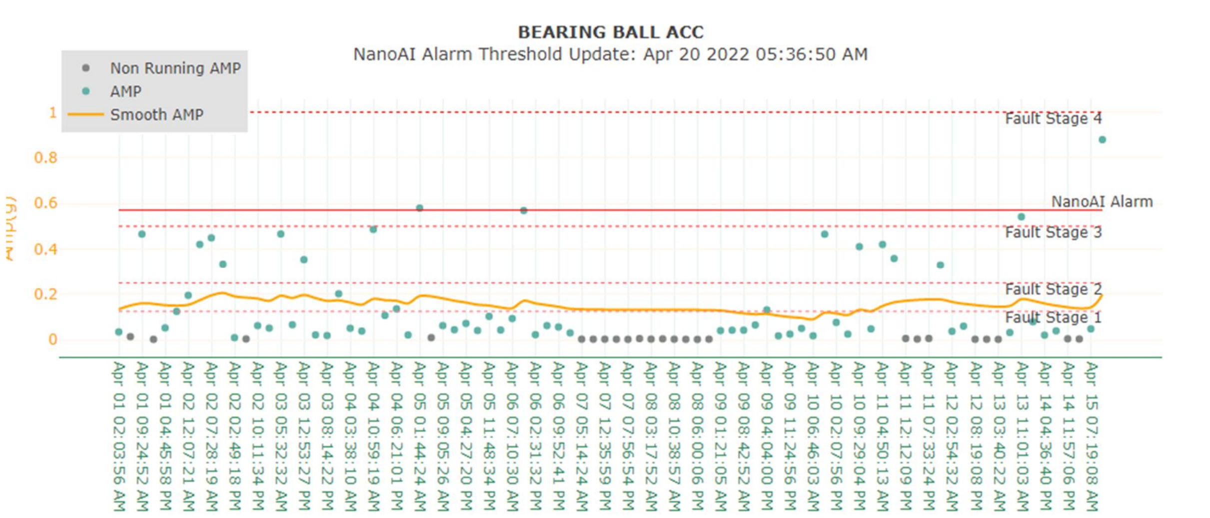

Fig. 22: Real Time DATA for Predictive Analysis.

Intangible Benefits

- Planning & prioritization
- Resource Utilization.
- Team work.

V. CONCLUSIONS

These digital initiatives have greatly improved Reliability, Greater monitoring & control & Safety in CARBON. In the above case study, all the possible and proven technologies were discussed which is being followed to enhance the overall metrics of CARBON Plant.

VI. ACKNOWLEDGEMENT

Special thanks to the whole CARBON Team who shown their dedication and successfully implemented the best practices in all 3 sections of CARBON Plant to sustain the productivity and quality of anodes
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