

AL16 - Industrial Internet of Things Based Measurement Instrument in Potroom

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Abstract

With the achievement of major milestones in big data analytics, cloud computing, internet of things, artificial intelligence and machine learning, industries are transgressing the traditional manual systems and leaning toward data driven optimal solutions for better and accurate results. In line with the vision of Industry 4.0, Aluminum industry is also transforming itself from taking intuitive decisions to making data centric proactive and predictive decisions.

Vedanta Aluminum Limited has brought Industrial Internet of Things (IIoT) concept into the potroom for digitalization of measurements of critical pot parameters like – side shell temperature (SST), collector bar temperature (CBT), anode current density (ACD) and bath temperature (BT). A digital measurement device has been developed in association with an electric mobility solutions start-up. It is a sensor-based instrument and uses cloud-computing platform to store, read and introspect the data. This device will capture and record the readings in the central server with a single click and thus a reliable data bank will be created consisting of critical values of different pot parameters. It will enable data integrity in process parameters, reduction of manual involvement in measurement, resulting in a significant decrease in human error. Key benefits that can be achieved utilizing this device are – On time data capturing with time stamping for error proof logging, self-identification of abnormality in parameters and generation of automatic alarms and detection of pre-pot leakage condition.

Keywords: Industry 4.0, digitalization, IIoT, pot-leakage.

1. Introduction

Vedanta Aluminium, a subsidiary of Vedanta Limited, is a prominent global producer of aluminium, often referred to as the 'Metal of the Future'. It holds the distinction of being the largest aluminium producer in India, operating in the states of Odisha and Chhattisgarh. The Vedanta Jharsuguda plant has the annual production capacity of 1.8 million tonnes of primary aluminium. Such extensive production necessitates a vast infrastructure, a substantial workforce, and continuous monitoring of operational processes. From the importation of raw materials to the production of finished goods, every aspect of the process is meticulously recorded as data. Some steps involve manual data entry, while others utilize digital data collection. The accurate information and thorough analysis of this data are crucial for maintaining stable operational practices and consistent processes.

The industrial production of aluminium follows the Hall-Héroult process, which involves the electrochemical decomposition of alumina or aluminium oxide (Al_2O_3) dissolved in an electrolyte, composed mostly of cryolite (Na_3AlF_6) with 8-12 % excess AlF_3 , and 4-7 % CaF_2 , also known as the bath. This process occurs at temperatures ranging from 950 °C to 970 °C. Direct

current (DC) is used to reduce alumina to molten aluminium, which is then deposited at the cathode. Oxygen generated during the electrolysis process reacts with the carbon anode to produce carbon dioxide (CO₂).



By implementing the Hall-Héroult process, the industrial production of aluminium becomes feasible on a large scale. The molten aluminium collected at the cathode can then be further processed and used in various industries for manufacturing purposes.

The aluminium smelting process encompasses numerous critical parameters, including alumina feeding, bath temperature, anode current density, cathode type, cathode voltage drop, aluminium fluoride feeding, side shell temperature, and more. All these parameters are not digitally monitored, leading to potential manual errors during data collection. Incorrect entry of vital parameters can result in severe consequences such as red-shell formation, anode clad failure, significant increases in energy consumption, and in extreme cases, pot tap-outs or leaks.

To transition from manual data entry to digital integration, Vedanta has undertaken several initiatives. Embracing the principles of Industry 4.0, Vedanta has placed significant focus on big data analysis and process digitalization. The initiatives involve the development of IIoT-based digital measurement instruments, aligning with the latest advancements in technology.

2. Industry 4.0 and IIoT

The first three industrial revolutions are characterised as being driven by mechanical production relying on water and steam power, use of mass labour and electrical energy and the use of electronic, automated production respectively. Industry 4.0 refers to the ongoing phase of digitalization in the manufacturing sector, driven by data, advanced analytics, automation and advanced manufacturing technologies. It has a broader scope, which includes IIoT, digital transformation, and business sustainability.



Figure 1. Industry 4.0 technologies [1].

Industrial Internet of Things or IIoT is a sub classification of Internet of Things (IoT), more aligned with the application in manufacturing industry. Driven by the convergence of Information Technology (IT) and Operational Technology (OT), the IIoT is a matrix of networks connecting equipment and devices, collecting data via sensor technology, processing it, and integrating data back into platforms as service. IIoT is set to open up a new era of industrial applications with a myriad of opportunities for economic growth.

Primary applications in IIoT includes real-time monitoring and preventive maintenance, so businesses can predict potential risks, such as machine breakdowns, process abnormalities, or stock shortages, before incidents occur. IIoT saves companies money by dealing with urgent failures that might have had an influential impact on business [2].

3. Development of Concept for IIoT Based Measurement

The successful implementation of IIoT-based digital measurement instruments in industrial environments is a complex undertaking that requires the adoption of several key strategies. Firstly, it is imperative to clearly define the objectives and requirements of the digital measurement instruments to ensure their effectiveness. This involves a thorough understanding of the specific parameters to be measured, desired accuracy levels, and intended outcomes of the measurement process. Careful consideration should be given to factors such as measurement range, accuracy, durability, and compatibility with the potroom environment when selecting suitable sensors and devices.

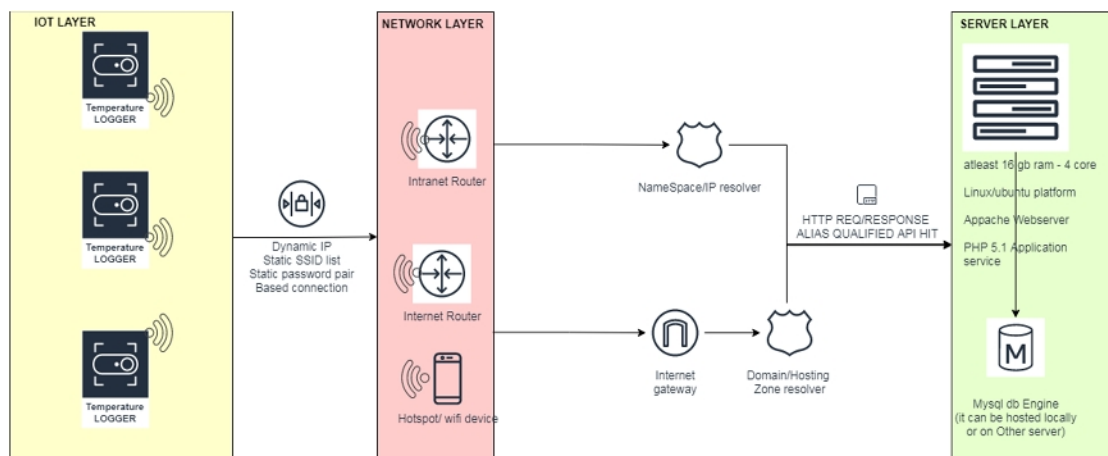


Figure 2. IIoT device and on-premise network architecture.

Traditional process of recording several critical pot parameters involves manual intervention and manual data entry. To eliminate the possibility of bath errors and establish data integrity, IIoT based measuring device is developed to measure side shell temperature, collector bar temperature and bath temperature. Side shell temperature and collector bar temperature are two critical parameters for a pot. Exceeding higher temperature limits of these parameters can be a sign of impending pot tap-out condition. The device performs on three different modes of operation – Side Shell Temperature or SST mode measurement, Collector Bar Temperature or CBT mode measurement and Bath Temperature mode measurement.

3.1 Data Logging Using IIoT Device

The device acts as an infrared thermometer and logger. Once the operator power on the devices, it asks for the unique ID to proceed further. After entering valid unique ID, the device shows options for mode of operation and the pot number is to be entered for the pot to be measured.



Figure 3. Ito- based device: Sensor and data logger.

Then the thermal gun is aimed at the target location to measure the temperature. The device gives the flexibility to reset the mode and recapture the temperature before final logging of the data.

3.2 Side Shell Temperature Measurement

Side shell temperature is an important parameter to monitor health of the pot. A normal operating pot's side shell temperature ranges between 200-500 °C. Escalation of temperature beyond this range may result in pot tap-out through sidewall. Therefore, correct data of side shell temperature is critical to run a pot in stable condition. A pot contains 76 side shells, numbered as S-01 to S-76.

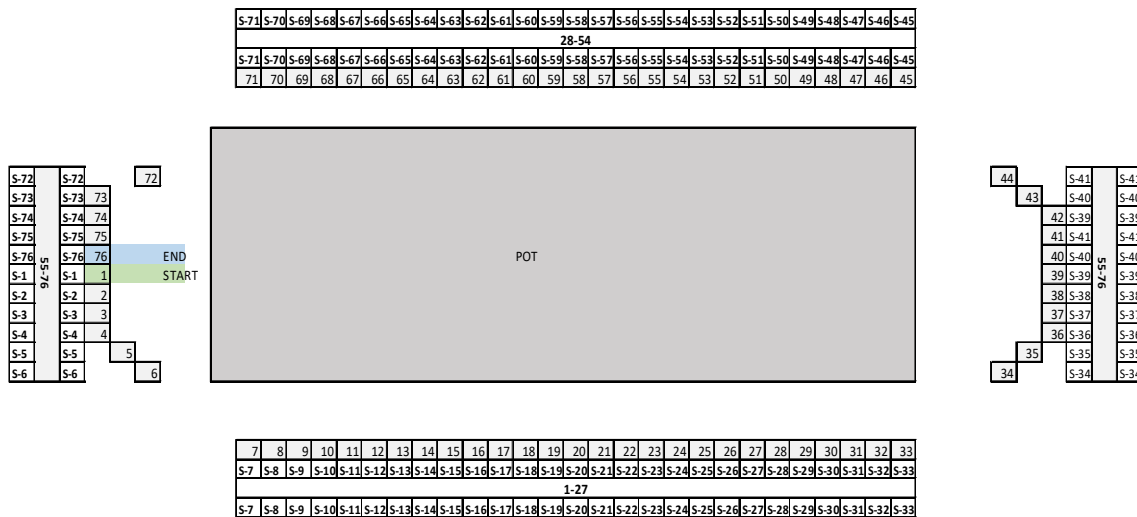


Figure 4. Pot side shell view.

To measure the side shell temperature using the device, the operator has to select the mode of operation as SST mode operation and then by aiming the thermal gun, the temperature can be captured easily. While capturing side shell temperature, the default spot number appears as S-01.



Figure 5. Side shell temperature measurement.

After first spot temperature is measured, it automatically shifts to S-02 and so on. This device also has the provision for measuring particular spot using Spot mode.

3.3 Collector Bar Temperature Measurement

Like side shell, collector bar also plays a crucial role in understanding the sign of ensuing tap-out condition. Normal range of collector bar temperature for an operational pot lies between 150-350 °C. Collector bar temperature beyond this range enhances possibility of pot tap-out through leakage of collector bar. A pot consists of 27 cathode blocks and each cathode block consists of four collector bars. Total 108 collector bars are distributed symmetrically in both sides of the pot, i.e., - 54 on side A and the rest 54 on side B.

WCSPT02	C001	C002	C003	C004	C005	C006	C007	C008	C009	C010	C011	C012	C013	C014	C015	C016	C017	C018	C019	C020	C021	C022	C023	C024	C025	C026	C027	C028	C029	C030	C031	C032	C033	C034	C035	C036	C037	C038	C039	C040	C041	C042	C043	C044	C045	C046	C047	C048	C049	C050	C051	C052	C053	C054			
SEShellA	CONTIN																																																								
SEShellB	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32	B33	B34	B35	B36	B37	B38	B39	B40	B41	B42	B43	B44	B45	B46	B47	B48	B49	B50	B51	B52	B53	B54			
SEShellSpot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27																														
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SEShellA	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	A32	A33	A34	A35	A36	A37	A38	A39	A40	A41	A42	A43	A44	A45	A46	A47	A48	A49	A50	A51	A52	A53	A54			
SEShellB	CONTIN																																																								
WCSPT02	C001	C002	C003	C004	C005	C006	C007	C008	C009	C010	C011	C012	C013	C014	C015	C016	C017	C018	C019	C020	C021	C022	C023	C024	C025	C026	C027	C028	C029	C030	C031	C032	C033	C034	C035	C036	C037	C038	C039	C040	C041	C042	C043	C044	C045	C046	C047	C048	C049	C050	C051	C052	C053	C054			

Figure 6. Pot collector bar view.

The operator has to select mode of operation and the pot number to be measured. Default spot number is CA-01. Here “C” stands for collector bar and “A” stands for side A of the pot. On aiming at the target spot, the temperature will be captured. After first spot temperature is measured and saved, it automatically shifts to CA-02 and so on. After completion of CA-54, it goes to the CB-54 and up to CB-01.



Figure 7. Collector bar temperature measurement.

3.4 Bath Temperature Measurement

In the bath temperature measurement mode, operator has to detach the sensor and fix a thermocouple on the left side of logger. Then the pot number needs be entered of which temperature is to be measured. In this mode, the user can increase or decrease the value to set pot number and has the flexibility to skip the pot if in case there is an offline pot in the section.



Figure 8. Bath temperature measurement.

4. Implementation Strategies for IIoT-Based Digital Measurement Instruments

The critical aspect of implementation is establishing a robust connectivity infrastructure. This entails setting up reliable wired or wireless networks and configuring data transmission protocols to enable seamless communication between the digital measurement instruments and the central monitoring system. Additionally, effective data collection and storage mechanisms should be implemented to handle the vast amount of data generated by these instruments. Depending on factors such as latency requirements, data volume, and real-time analysis needs, edge computing or cloud-based solutions may be employed [3].

Data security and privacy must be prioritized throughout the implementation process to protect the integrity and confidentiality of the collected data. Robust security measures, such as data encryption during transmission and access control mechanisms, should be implemented. Furthermore, integrating the IIoT-based digital measurement instruments with existing systems, such as SCADA, is crucial for centralized monitoring, data analysis, and informed decision-making based on the collected measurements. Real-time monitoring and visualization capabilities should also be implemented to provide operators with actionable insights and facilitate timely responses to anomalies or deviations.

Leveraging data analytics techniques is key to unlocking valuable insights from the collected measurements. Statistical analysis, machine learning, and predictive modeling can be employed to identify patterns, trends, and potential issues, enabling process optimization and predictive maintenance strategies. To ensure the successful adoption of these instruments, proper training programs should be provided to the workforce, enabling them to understand and utilize the IIoT-based digital measurement instruments effectively. Continuous evaluation and improvement of the implementation strategies, including performance monitoring and gathering stakeholder feedback are essential for optimizing the usage and performance of these instruments.

The implementation of IIoT devices for temperature measurement in the potroom of aluminum smelters yields substantial benefits in terms of process control, efficiency and safety. These advanced devices utilize cutting-edge sensing technologies and seamless connectivity to enable real-time temperature monitoring in the potroom environment. Through the integration of IIoT devices, aluminum smelters can achieve improved temperature management, enhanced operational efficiency and a safer working environment in the potroom.

5. Results

The implementation of IIoT-based digital measurement instruments in the potroom environment gives significant results, highlighting the benefits of this technology over traditional measurement methods. The following section summarizes the benefits obtained using the device:

Prevention of Pot Tap out: On time, recording of temperature with accurate readings will help us to take appropriate action to prevent pot tap out. Pot tap-out incurs heavy loss in terms of both financial aspect and operational disturbances. By using this device, we can cut down the annual pot leakage number as low as zero.

Process Optimization: The real-time data monitoring and analysis capabilities of IIoT-based instruments enabled process optimization in the potroom. By continuously monitoring and analysing the measurements, operators could identify areas for improvement, optimize process parameters, and enhance overall efficiency. The timely measurement and the recording of bath temperature in the central server will lead to an effective setting of daily fluoride additions, which will help in thermal stability of the pot. By improvement in energy efficiency, savings in specific power consumption of 100 units can provide the benefit of \$5-6 per ton of aluminium production.

The ability to make data-driven adjustments in real-time resulted in improved productivity, reduced waste, and enhanced resource utilization.

Improved Accuracy and Precision: Compared to traditional measurement methods, the digital measurement instruments offered higher levels of accuracy and precision. This enhanced accuracy ensured more reliable and consistent data, reducing the chances of errors or inaccuracies in process control and analysis. The improved data quality contributed to better decision-making and optimization of potroom operations.

Enhanced Real-Time Monitoring: The industries are adopting Industry 4.0 technologies for smart manufacturing and enhanced production with optimal amount of resources and energy utilization. By integrating advanced technologies like IIoT, Vedanta is thriving for manufacturing excellence and preparing a digitally integrated platform to make its future ready pots. The IIoT-based digital measurement instruments provide real-time monitoring of various parameters in the potroom, enabling operators to access critical data instantly. This combination empowers to gain deeper insights, make proactive decisions.

Once the side shell temperature or the collector bar temperature is recorded by the device, it is promptly transmitted to the server and integrated into the MES (Manufacturing Execution System). During normal operating conditions, the upper limits for side shell temperature and collector bar temperature are considered to be 400°C and 270°C, respectively. When the upper limit is exceeded, an automatic alarm is triggered, and a warning message is shown on the dashboard. After a period of 2 hours, the temperature is retaken. If there is a continuous upward trend in temperature, an automatic email is generated and sent to the corresponding Process In-charge, and thereafter-necessary actions are taken. If Side shell temperature goes above the upper limit, cooling is initiated. For high collector bar temperature, cooling action is taken but if the temperature keeps on rising for 2-3 days, flexible is disconnected for that particular location. This flow is showed in Figure 9.

Utilizing this device for measuring bath temperature has significantly reduced the aluminum fluoride setting time, reducing it from 4-6 hours to just a few minutes. Previously, both the bath temperature measurement and data entry were performed manually. This device is capable of directly sending the data to MES server and subsequently the AIF3 setting is done automatically based on certain criteria. The dashboard includes a feature that displays the number of measurements conducted per shift, thereby enhancing measurement compliance.



Figure 9. Real time monitoring of data collection

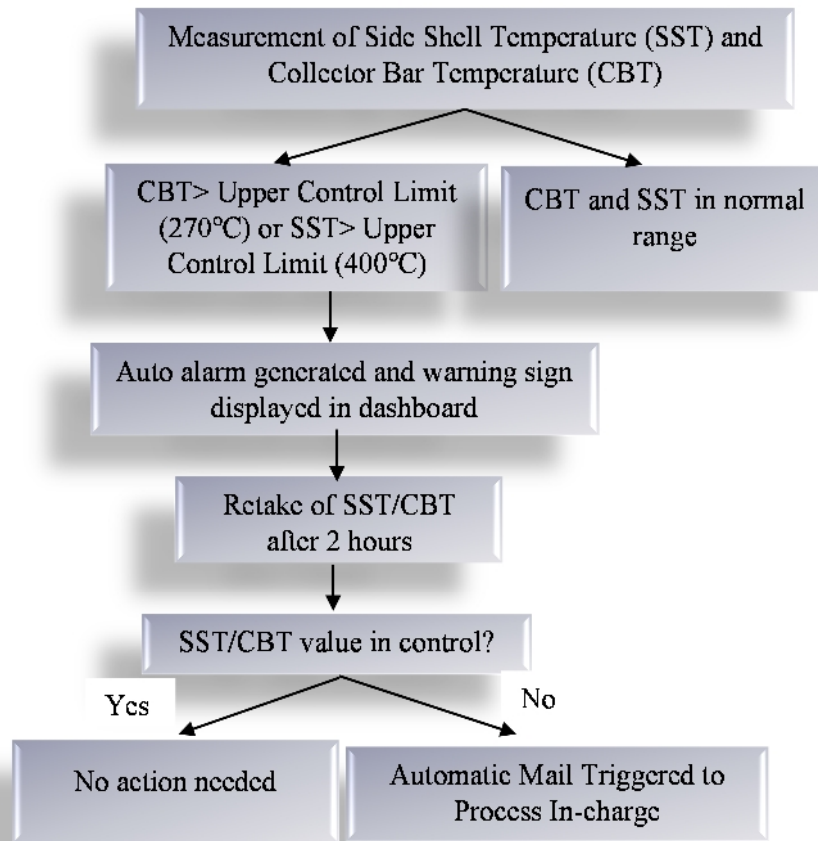


Figure 10. Flowchart of actions after SST and CBT measurements.

Data Visualization and Analysis: The collected data from the digital measurement instruments were visualized and analysed using advanced data analytics techniques. This allows for a deeper understanding of the potroom processes, identification of patterns, trends, and anomalies, and facilitated data-driven decision-making. The visual representation of data enabled operators and management to gain insights quickly and make informed decisions for process optimization.

6. Conclusions

The implementation of IIoT-based digital measurement instruments in the potroom demonstrated several benefits, including enhanced real-time monitoring, improved accuracy and precision.

The data visualization and analysis capabilities using advanced analytics lead to process optimization, and improved safety standards. However, it is essential to acknowledge and address the challenges associated with the implementation, such as sensor selection and placement, data integration and standardization, regulatory compliance considerations, and cost and return on investment.

Future research and development in this field should focus on advancing analytics and machine learning techniques to further optimize the utilization of collected data, exploring edge computing and fog computing solutions to enhance processing capabilities, leveraging block chain technology for improved data security and integrity, and improving human-machine interaction and user experience for seamless integration of IIoT-based measurement instruments.

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Data List										
SHIFT DATE	SHIFT TIME	SHIFT	EMP ID	SUB MODULEM	POT NO	SHELL SPOT	POT SIDE	FIELD NAME	FIELD VALUE	RECEIVED AT
2023-06-17	11:06:27	A	211126	S53P4	3142	0	BATH0	S-00	960.75	2023-06-17 14:27:46
2023-06-17	11:03:19	A	211126	S53P4	3140	0	BATH0	S-00	974.5	2023-06-17 14:27:45
2023-06-17	11:05:36	A	211126	S53P4	3141	0	BATH0	S-00	950.5	2023-06-17 14:27:45
2023-06-17	11:02:15	A	211126	S53P4	3138	0	BATH0	S-00	959	2023-06-17 14:27:43
2023-06-17	11:02:45	A	211126	S53P4	3139	0	BATH0	S-00	960.75	2023-06-17 14:27:43
2023-06-17	11:01:39	A	211126	S53P4	3137	0	BATH0	S-00	962.5	2023-06-17 14:27:42
2023-06-17	11:00:30	A	211126	S53P4	3135	0	BATH0	S-00	958.25	2023-06-17 14:27:41

Figure 11. Real time monitoring of SST and BT with timestamping.

7. References

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