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Development of 'Cloud and IoT based' Online Condition Monitoring System for Analytical Instruments

K.V.N.S. Sriveena[1] and K.V.N.S.V.P.L. Narasimham[2]
[1]BITS-Pilani, Pilani Campus, Vidya Vihar, Pilani-333031, Rajasthan, India
Email: ksriveena7@gmail.com
[2] Scientific Officer (G), NCCCM/BARC, ECIL Post, Hyderabad-500062, Telangana, India
Email: kvnarasimham@gmail.com

Abstract: **Analytical Instrumentation Systems are very much essential for compositional characterization of materials and form part of instrumental methods of analysis. Most of the analytical instrumentation systems are highly expensive and sophisticated in nature. Performance of these systems can be optimized by operating them in a controlled laboratory environment and precise monitoring of process parameters of the system. Hence continuous monitoring of ambient parameters of the laboratory, in which these systems are located, and process parameters related to each instrument is very important for obtaining the best out of these instruments. This paper describes an innovative application that has been designed using Cloud and IoT based Online Condition Monitoring of sophisticated laboratory instrumentation systems. Implementation of the thought process, involved in the realization of the objectives, has been described at length.**

Index Terms: Cloud Computing, IoT, Analytical Instruments, Mass Spectrometers, Embedded Systems, Sensors.

I. Introduction

The Internet of Things (IoT) has been a new revolution and a fundamental facilitator for modern industrial technological advancements. The Pandemic (Covid-19) impact has transformed the conventional method of monitoring into a digitalized way, which led to the unprecedented growth of the Industrial IoT sector globally. Thus, technologies like IoT, Cloud computing, Embedded System Design, Networking, Wireless Communications, and Smart devices paved the way and made our lives faster, efficient, and quicker to communicate between people-people, people-machine & machine-machine. Analytical instruments such as Mass spectrometers, Spectrophotometers, and Gas Chromatography systems etc., are well known for their usefulness in material characterization. Mass spectrometry systems are widely used in laboratories for identification and quantification of compounds/elements in different types of materials. A typical Inductively Coupled Plasma Quadrupole Mass Spectrometer (ICPQMS) system has various sub- systems such as Sample introduction, Ionisation source, RF generator, Lens supplies, Mass analyser, Control electronics, and Data acquisition system etc. A number of process parameters need to be continuously monitored and controlled for achieving optimum utilization of these instruments. The details of the process parameters, considered in this work, are described in the subsequent sections.

II. Need For the Development of Proposed System

Care must be taken to protect mass spectrometry systems, indigenous or imported instruments, as they are highly sensitive and expensive products. Any deviation from ambient parameters will lead to malfunctioning of instruments. These instruments operate in certain conditions and if the conditions are deteriorating, it is very important to switch off and protect expensive detectors and critical subsystems at the right time. Hence, it is vital to monitor RH, ambient temperatures, vacuum etc., and read the necessary parameters of laboratories and analytical instruments through sensors. For example, in an Inductively Coupled Plasma Quadrupole Mass Spectrometer (ICPQMS) system, vacuum (of the order of 2E-8 mbar) is crucial and is required for accurate and precise results. Similarly gas flow rates such as COOL GAS, NEBULISER, and AUX GAS need to be monitored. The inventory monitoring of various consumables is also an important activity for maximizing the utilization of the instrument. Hence there is a need for continuous monitoring of these process parameters for the optimum performance of the instruments. In this regard, an attempt has been made to develop a smart remote process monitoring system for laboratories in general and Mass Spectrometer Systems in particular.

III. Literature Survey

Yohanes et al., proposed an IoT server platform called Smart Environmental Monitoring and Analytical Real-time (SEMAR) [1] for integrating many IoT application systems. This paper provided in-depth technical end-to-end implementation of IoT application systems. Raghuvaran K. and J. Thiyagarajan [2] described how Raspberry Pi and wireless communications can be used for industrial remote process monitoring systems. They proposed RPi based global process monitoring of parameters such as light intensity, current, water level, and voltage are tracked and

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controlled. Seema et al., described the role of IIoT in manufacturing units [3]. Rajeswari et al., achieved a reduction in power consumption [4] through the

Lakkundi [9] proposed an industrial gas monitoring system using Arduino and Linux based OS. Review paper by Perigisetty Vedavalli et al., [10] was published on Automated Monitoring Systems based on R-Pi. Banagar et al., [11] proposed smart IoT systems but limited to offline and not online based.From the above literature survey, it is understood that there are some smart IoT systems that monitor the parameters such as temperature, humidity, smoke etc., in an industry or laboratory ambient conditions only. All the systems proposed were limited to demo only. But, the condition of the highly- expensive and high end scientific instruments was not being monitored such as capturing of vacuum real time signals from the instruments etc., Also, continuous live streaming of the Instruments facility was not proposed earlier. Hence there is a need for continuous online monitoring of highly sophisticated and imported Analytical instruments which need to be monitored round the clock and the monitoring system should be smart enough to generate alerts in case any parameter crosses its threshold. Hence the present work proposes "Development of 'Cloud and IoT based' Online Condition Monitoring System for Analytical Instruments". The Methodology has been described in the following section.

IV. Methodology Description

An online condition monitoring system for Mass Spectrometer Systems using IoT and cloud-based tech stacks, has been developed and presented in this paper at length. The hardware is designed using a Raspberry Pi microcontroller and various sensors such as vacuum gauges, temperature and humidity sensors for monitoring instruments and ambient conditions. The readings of all deployed sensors are stored, analyzed, processed, and aggregated in the IoT cloud platform. When any unintended situation arises, alarms and email notifications are triggered to the user and they monitor the statistics using Web interfaces like mobile or login onto a website. This system will help in minimizing or eliminating the need for manual readings and

frequent on-site visits to Laboratories. This development work also enables timely and early detection of events round

implementation of ESP8266 based smart system. Referenced papers from [5-8] described monitoring of process parameters using Arduino microcontroller. Naveen the clock by tracking various parameters like temperature, humidity, and vacuum etc., remotely through virtual tools & applications.

V. Experimental Work

The architecture of the IoT based system is depicted as shown in Figure 1. The system consists of the following modules: (i) Sensor modules – Sensors or components like Vacuum gauge (combo) for Vacuum levels, DHT22 sensor for temp & RH, are deployed in the premises. Sensors have high self-configuring reading capabilities based on the surrounding conditions and they are the sources of capturing physical entities of the environment at fixed periods. (ii) Hardware and Sensor interfacing – Raspberry Pi 4 acts as an Hardware IoT device (microcontroller) that has CPU, RAM, ROM, 40 GPIO pins and several external interfaces like USB, language software that runs on OS of RPi. All the sensors are interfaced using GPIO pins and then powered on in order to read the sensor values locally. The RPi uses Wi-Fi and lightweight MQTT protocol to connect to 'ThingsBoard' Cloud using python programming and then sends the processed meaningful data. (iii) IoT Cloud – The readings of all deployed sensors are stored, analyzed, and processed. Here, the virtual entity having attributes of temperature, humidity, and vacuum are created in the Things Board where data is collected and stored in the dashboard. The ThingsBoard has a Transport layer that carries the data through the other nodes for successful propagation. It has a rule engine that is the heart of ThingsBoard where the functions can be configured. It supports many kinds of Widgets on which Realtime information can be displayed. (iv) End users/Web – when any unintended situation arises, alarms and email notifications are triggered for the user and the concerned users monitor the statistics using web interfaces like mobile or they login into the ThingsBoard website/portal.

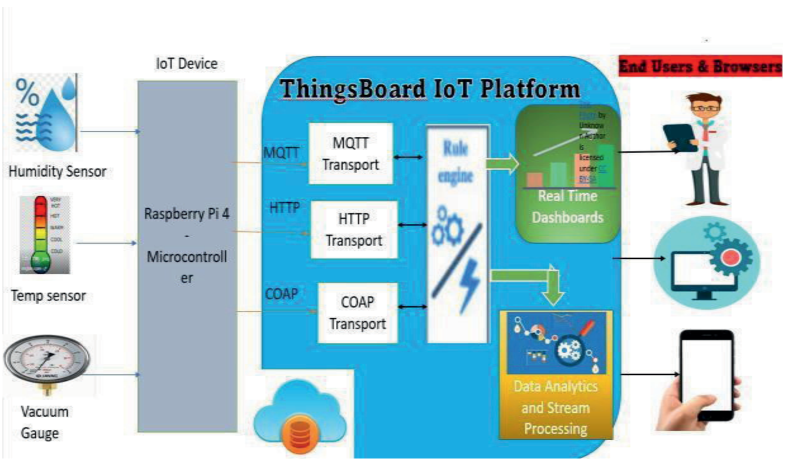

Figure 1. Functional block Diagram /Description of IoT based Instrument Condition Monitoring System

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VI. RESULTS AND DISCUSSION

The entire experiment has been carried out in the laboratory by deploying the hardware circuit and software program. The instrument's ambient Temperatures, Humidity, and Vacuum levels are captured by the Web Dashboard that has been designed and developed in the IoT Cloud Platform for user interaction. If any of the values exceed the set threshold values, alert notifications are triggered continuously to take appropriate action as shown in the Figure 2 and Figure 3 below. Table-1 shows the theoretical vacuum level calculated using the Eq (1), instrument gauge display and the values sent to the IoT cloud. Theoretical Formula to convert o/p voltage from gauge to pressure (mbar) is given by

Figure 2. Humidity Readings on UI and Alert

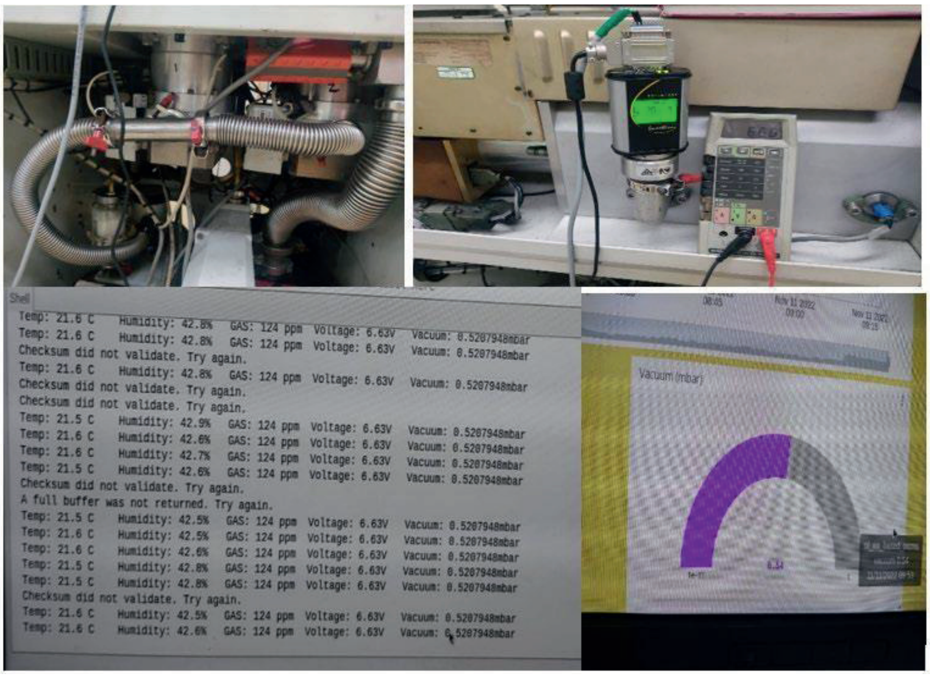

Figure 3. Vacuum Readings (mbar) on UI and Alert

Vacuum Pressure =10 pow[(Vout–6.8/0.6] Eq (1)

Dashboard output format can be defined as per the user requirement. In this project, an attempt has been made to display the real time parameter readings on the dashboard. Customization of the trends can be done based upon the users' requirements and interests.SMS alerts can be generated to take appropriate actions if the process parameter value exceeds safe value defined by the user.

TABLE 1.
Vacuum Gauge and IoT Cloud Readings

Gauge O/P Voltage (Volts)	Vacuum Level (mbar) shown in IoT cloud	Vacuum Level (mbar) shown on gauge	Error
6.06	5.84 E-2	5.84 E-2	0
5.897	3.06 E-2	3.14 E-2	0.08
4.043	2.1E-5	2.54E-5	0.44
3.785	9.5 E-6	9.44 E-6	0.5
2.89	3 E-7	3.04 E-7	0.04
2.87	3 E-7	2.8 E-7	0.2

VII. Conclusions

This proposed work demonstrated the design and implementation of an IoT Level-4 end-to-end system called "Development of 'cloud and IoT based' online condition monitoring system for analytical instruments" from 'Data collection' to 'Data Dissemination'.

The implemented system transformed a traditional lab into a Smart laboratory where the data management process improved by leaps and bounds. This development work also enabled timely and early detection of events by tracking various parameters like temperature, humidity and instrument vacuum remotely through virtual tools & applications. If any instrument parameter value exceeded the 'SET' limit, this system generated an alert and a real-time/live image of the lab would be sent to the email of authorized users. This system minimized the need for manual readings and frequent on-site visits to Laboratories. The result of the transformation helped in the advancement of Quality Control (QC) labs and production plants using IoT and Cloud-based tech stacks and made a way for Digital India.

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