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Cloud Based Monitoring and Control System for Industrial Process Variables

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Abstract- Cloud Based Monitoring and Control System for Industrial Process Variables is presented in this paper. It is a software developed system that measures on real time basis some selected industrial variables like temperature, pressure voltages supplied to a heavy industrial machines as well as load balancing on such machines. The system involves both hardware and software implementation. The technical specifications of the hardware were presented here while the software was developed using PHP programming language and MySQL database management system. The system monitors and measures the physical variable values and issues a control command to automatically short down the equipment when an abnormal condition occurs. Cloud computing was employed because of its many advantages over web or internet applications. Cloud Based Monitoring and Control System for Industrial Process variables is said to be the transformation of industrial operations that are enabled through the wide use of software. Operators of such equipment can remotely monitor and control the activities of an industry irrespective of his her locations without been exposed to hazards and risks post by such big industrial equipment. The system was fully designed, simulated and applied to a real process monitoring and control system, it was found working and meeting the designed objectives.

Keywords-*Cloud, Equipment, Temperature, Pressure, Voltage, Hardware, Software, PHP, MySQL, Interface, GUI, Database, Control, Monitoring. Industry*

I. Introduction

The present increase in industries has made it compulsory to automate almost all industrial processes. Most industrial devices like pump controller, power meter, and operating temperature of equipment and so on can be automated and remotely monitored [2]. This paper focuses on the use of wireless interface to remotely monitor and control temperature, pressure, voltage supply to three phase and single phase machines as well as load balancing in a three phase induction motor in an industrial setting. The paper analyzes a significant amount of programming language based on PHP software platforms as well as the standard protocol for enabling interconnections. It also involves the use of MySQL relational database management system to adequately store and make available all required data stored in the system. The Cloud Based monitoring and control system for industrial process variables also has the ability to keep the history of the equipment's conditions. Data collected are stored in cloud which could easily be accessed and relevant decisions could easily be taken.

Approach drawn on data collection from devices via sensors at the node of operation of industrial equipment are finely tuned and mobilized quickly for analysis via cloud [1]. The adoption of these new technologies is helping industries to build on existing technologies, thereby reducing costs and achieving better monitoring and control processes over their equipment [2]. At present, the major limitation of industrial wireless applications lies within the imaginations of the software developers. The major factor is the way to minimize risk and mitigate the complexities of networking and computing hardware that are involved in the processes.

II. Methodology

Modified form of waterfall methodology and prototyping methodology was used in the work. The system is decomposed into units and designed separately, tested and certified working. The designed individual units are then integrated to realize the overall system design. The design involves both hardware and software. The system block diagram is shown in figure 1.

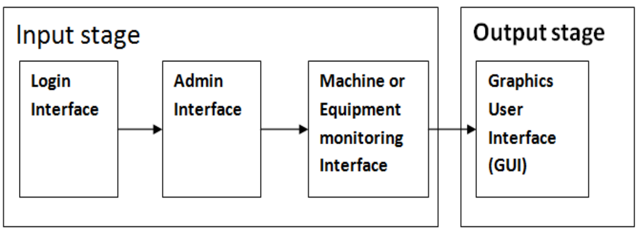

Figure 1. Block Diagram of the Cloud Based Monitoring and control System Processes

The block diagram shows that the system is divided into two major stages. Namely; The input stage and the output stage. The input stage accepts inputs from users. The system processes such inputs before giving out an output. The output stage is otherwise called the graphic user interface (GUI). Figure 2 shows the block diagram of algorithm of design of the system monitoring interface.

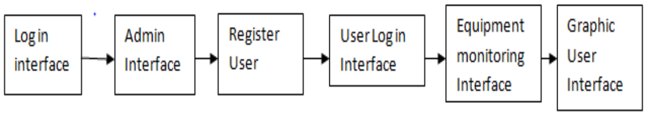

Figure 2. Block Diagram of the design steps of the various interfaces

A. Login Interfaces

The log in interface is the first stage in the monitoring platform. It is designed such that it accepts inputs from user or an admin. The basic feature here is the provision for accepting Username/Admin name and password. If a user is not registered he/she must be first registered by an Admin.

B. Equipment monitoring Interface

This is the interface that enables user to choose the machine variables to be measured. It was designed such that the list of various parameters was presented for user to choose by a single click. Any parameter the user selected is quickly displayed on the Graphic user interface (GUI) which is basically the output.

C. Graphic User Interface (GUI)

This stage is designed such that it displays to the user the conditions of the equipment in real time. The GUI was designed differently for different parameters to be monitored and controlled.

The entire interfaces were implemented using PHP and MySQL. PHP is a server-side scripting language used as general purpose programming language. It is a highly productive graphical programming language for building data into systems. It also supports network communication protocol such as TCP and UDP. PHP code was particularly important in carrying out this task because it was easily embedded into HTML and MySQL and it can be used in combination with various web template systems. MySQL is a freely Relational Database Management System (RDBMS) that uses Structured Query Language (SQL). The system was designed to automatically generate random data to mimic a real life situation.

The system uses browser like internet explorer. The user should be able to see what is happening in plants via the platform. The main objective is to enable the operators to access monitor and control systems from a far distance. The various user interfaces displays the various processes and makes it possible for users to see the conditions of his or her equipment and at same time keeping records of the details of the machines' operating conditions for reference purposes. By so doing the user can make informed decisions from wherever locations if danger is signaled. Another interesting area is that the monitoring panel provides a dynamic view of all essential information regarding the current status of the system. Unlike normal web page, the dynamic image is regularly generated by the server according to system status, sent to the clients and is automatically refreshed after a certain period of time to provide client real time information about the system.

D. System Design Flow Chart

Figures 3 to 7 are the flow charts for the operation of the Cloud Based Monitoring and control System for industrial processes. The flow charts were designed in line with standard engineering ethics. From the start the system processes and loads the user interface and displays the login page. It then accepts data from the user and processes the data. If the system confirms the user it lunches the user interface otherwise it returns to the login page. At the user interface the user have options of which parameters to monitor. It allows the user to choose, after which the system will display the conditions of the chosen parameter.

Figure 3 shows that first the user will have to login. After which the system processes the input from the user and load the system interface to decide whether the user is a valid user or not. If the user is valid the system displays the monitoring interface otherwise it returns the user back to the login page with a message describing the user as invalid. At the monitoring interface the system accepts input from user by choosing any of the four available parameters to be monitored. Among the list of 1 to 4 any of them selected by the user the system will display the conditions of the equipment by lunching the GUI. This is described in figure 4 to figure 7, but if none is selected the system remains at the monitoring interface. This is depicted by the return1 as shown in the flowcharts.

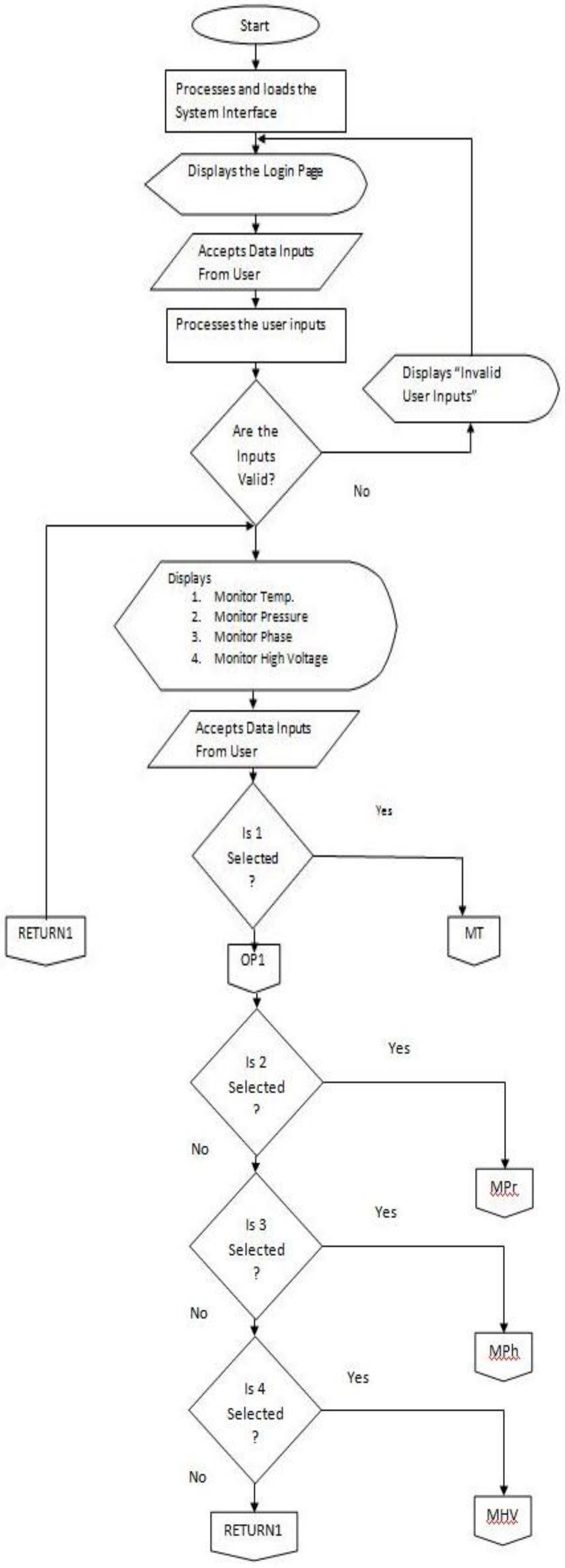

Figure 3. User interface flow chart

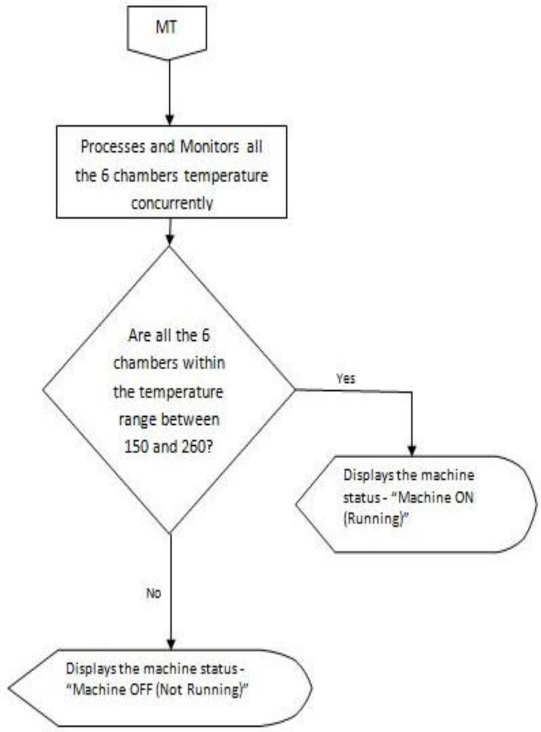

Figure 4. Temperature Monitor flow chart

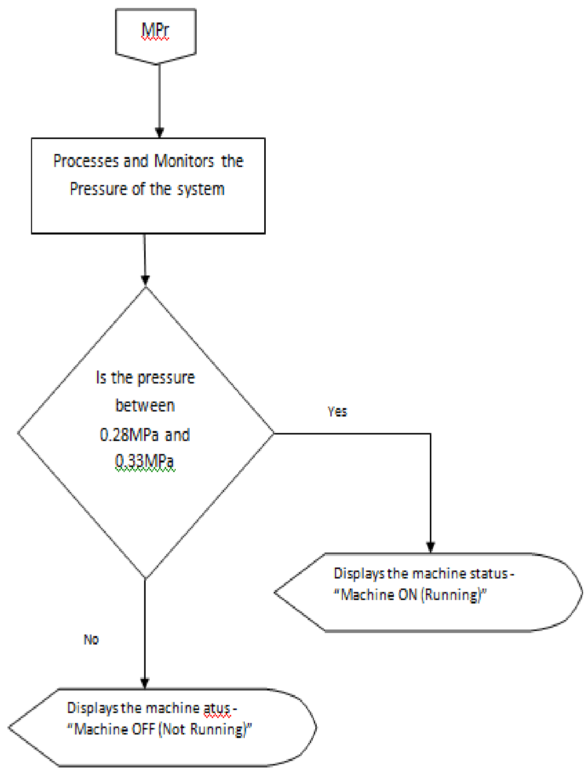

Figure 5. Pressure monitor flow chart

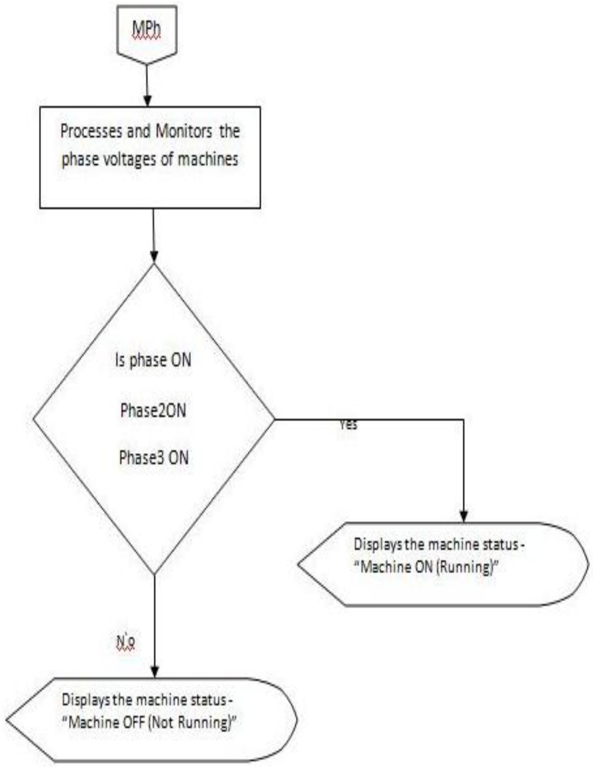

Figure 6. Phase monitor flow chart

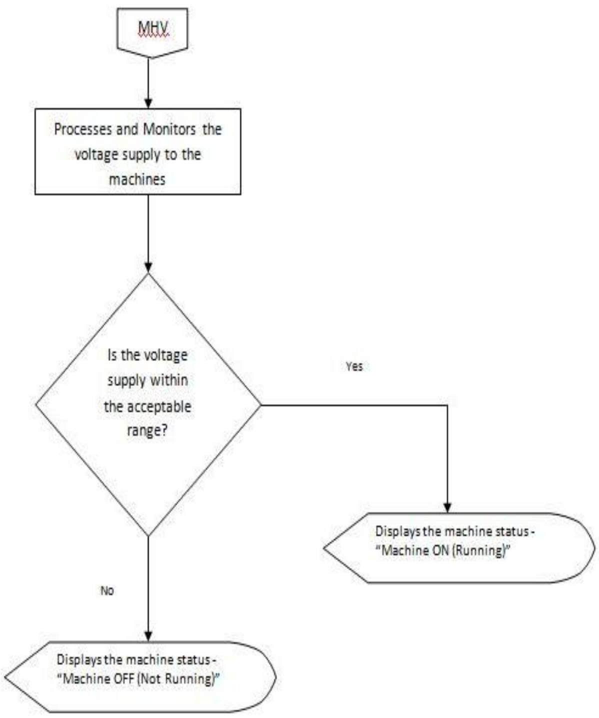

Figure 7. High voltage Monitor Flowcharts

E. Software Requirements

The requirements to run the proposed system for optimal performance are listed below.

- Microsoft windows vista or windows7 or higher version of windows as well as other operating systems like Linux is compatible.
- Apache server version 1.3.14 & above
- PHP version 4.1.0 & above
- MySQL version 4.1.0 & above
- All browser compatible
- Operating system requirements
  - Adequate temporary space for paginations to virtual memory
  - 32-bit and 64-bit compatible
  - Windows 7/Server 2007 or higher and Linux Redhart
  - OS patch level 1
  - System and kernel parameters must be enabled
  - Sufficient swapping
  - Nonempty XAMP htdocs_HOME
  - MySQL database

F. Hardware Requirements

The minimum hardware requirements for the system include:

- Monitor
- 4GHZ processor
- 4GB of RAM
- 1TGB of available hard-disk space
- 1280 X 800 display with 64-bit video card
- Memory requirements:
  - 1 GB for the logic instance (grid control)
- Disk space requirements:
  - 1.5 GB of swap space
  - 400 MB of disk space in the /tmp directory
  - Between 1.5 GB and 3.5 GB for the CBMS
  - 1.2 GB for the preconfigured database (optional)
  - 2.4 GB for the flash recovery area (optional)

The hosted software can be accessed using any browser from lower capacity system.

G. Architecture of the Cloud Based Monitoring and control System for industrial processes

Figure 8 shows the basic structure of the cloud based monitoring system for industrial processes.

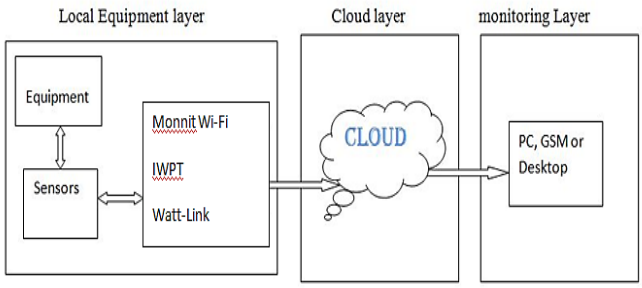

Figure 8. Architecture of the Cloud Based Monitoring System

The proposed architecture for the Cloud Based Monitoring and control System for Industrial processes is divided into three layers, namely; the Local Equipment layer, the cloud layer and the monitoring layer. At the local equipment layer all equipment to be monitored are directly connected with appropriate sensors which directly generates real time data for the system. The data generated can be transmitted to the cloud by the use of devices such as Monnit WiFi high temperature sensors, IWPT wireless pressure sensors and watt-Link wireless energy meter among others. The cloud layer lies between the equipment layer and the monitoring layer. Data acquired by the sensors are transmitted directly to the cloud by the use of these devices. Once data arrives at the cloud it is recorded according to data logging settings of the system. This data can be viewed at the same time by the Graphic User Interface (GUI) by the user at the monitoring end. Users only need a standard web browser to access the cloud from any location of their choice.

H. Sensors design Specifications

1) Monnit Wi-Fi Temperature Sensor

Monnit wireless high temperature sensor also known as Resistance Temperature Detectors (RTDs) uses a resistance thermometer to accuracy measure temperatures from -50ºC to +370ºC [11]. It is good for high temperature industrial applicators like ovens, heaters, furnaces and boilers. The instrument allows users to customize and set the frequency of sensors and create notifications from the system when certain criteria have been met or exceeded. The instrument perfectly fit into my design because the range of temperature under monitoring is between150ºC to 260ºC.

Product Features: Frequency = 900MHz, Accuracy = +/- 0.3ºC at 0ºC, Prob Length = 3feet.

2) IWPT Wireless Pressure Transducer

[9] This is a cost effective pressure transducer. It offers advantage of a low- cost installation in a difficult environment. It also offers a “plug and play” solution to our pressure measuring applications.

Product features;

– Covers up to 750 m line of sight range depending on receiver.

– Up to five years battery life at 10 seconds transmission update rate.

– Simple DIL switch pairing with the single or five channel receiver.

– Pressure range from -1 to +400 bar gauge

– Piezo–resistive thick film ceramic sensor with stainless steel body.

3) Voltage sensors

[10] Watt-link wireless energy meter is suitable to remotely aggregate real - time energy data. It is a plug and play wireless power and energy monitoring on a scalable, cloud-enabled platform. It is an easy to install solution for distributed load control, process allocation and equipment monitoring system.

The LORD MicroStrain Watt-Link wireless energy meter allows facility owners and operators to remotely collect real-time data for evaluation. This is applicable to high load equipment, or discrete production departments. It also enables operators to proactively monitor power in other to reduce operating costs and enhance predictive maintenance. Watt - Link operates within large synchronized, wireless network sensors (temperature, humidity, vibration etc.) users can quickly implement single phase or three phase power meter and sub – metering capabilities. With the use of this device operators can easily track power usage, assesses machine health, identify deviation in power quality and so on. This in turn has made maintenance easier, reduce cost-effectiveness on industrial processes.

I. Integrated Management

There are connections to be made between the plant side and the user side and these connections are only possible via internet and it must involve several services simultaneously and such services must be integrated properly for optimal performance. To achieve this, a procedure must be followed. To this end a cloud computing is preferred. There are several reasons for choosing cloud computing, one among them is the joint management which is provided by this platform [4]. All elements are located behind the joint management. Once malicious hackers are trying to attack the system they are actually trying to attack the joint management rather than individual system and therefore any protection offered by the joint management equally covers every individual subscriber. Second, the integrated architecture reduces the actual numbers of links with the internet and also provides control over all the links. Third, most monitoring systems lacks the ability to network and the structure like this management system can offer a great potential for networking in monitoring system.

J. Database Design

MySQL is a freely Relational Database Management System (RDBMS) that uses Structured Query Language (SQL). The design employed MySQL to store the necessary data for reference purposes as well as keeping the system running as efficient as possible. The database schema is shown in figure 9. It shows the organisation of data and consists of the tables that made up the relational database used by the system platform. It served as a plan showing how the database was constructed. It shows the relationships between the different tables that make up the database. It represents the logical view of the database. It also defines how the data is organised and how the relations among them are associated.

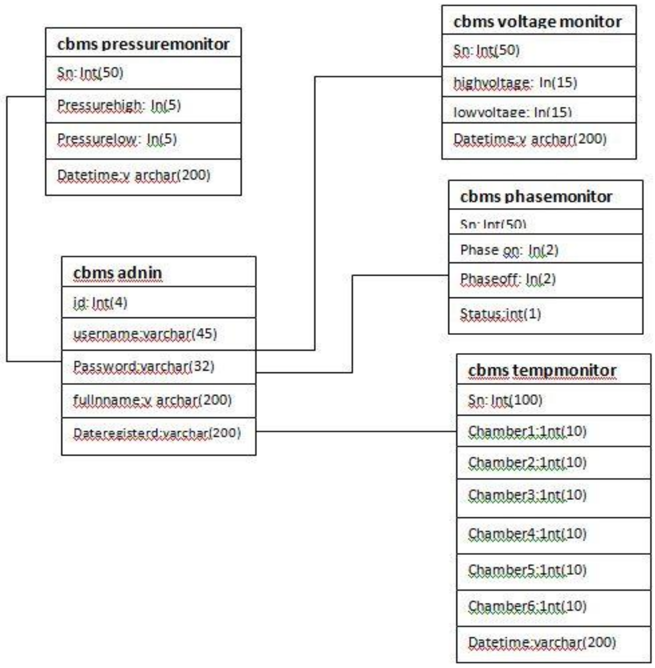

Figure 9. Schema diagram for the database

K. *Design of Database Tables and data Dictionaries*

These tables are used to store all the data in the system such as user's full names, usernames, password, etc. Any data collected are stored here. The table contains several fields as shown in table 1, to 5. The tables show the different fields of the database table; the field type, data type, and the field length. In table 1 the primary key is the User ID which is unique for every user. Likewise each table has its own primary keys. The various tables associated with the platform include; Admin Table, Phase monitor Table, Temperature monitor Table, Voltage monitor Table and Pressure monitor Table.

TABLE I. DATA DICTIONARY FOR ADMIN DATABASE

Field Name	Field data type	Field length	Field description
User_id (PK)	Int	20	Unique number identifying the each user
Full Name	Varchar	50	Full name of the user
User_name	Varchar	50	Username assigned to each user
User_password	Varchar	50	User password
Date_Registered	Varchar	200	Handles the Time and date each temperature an Administrator was registered

TABLE II. DATA DICTIONARY FOR PHASE MONITOR

Field Name	Field data type	Field length	Field description
Serial_Number (PK)	Int	20	Unique number identifying the each phase record
PhaseOn	Int	2	Used to check when any phase is ON.
PhaseOff	Int	2	Used to check when any phase is OFF.

TABLE III. DATA DICTIONARY FOR TEMPERATURE MONITOR

Field Name	Field data type	Field length	Field description
Serial_Number (PK)	Int	20	Unique number identifying the each Temperature record
Chamber1	Int	15	Handles the temperature values for the first chamber
Chamber2	Int	15	Handles the temperature values for the Second chamber
Chamber3	Int	15	Handles the temperature values for the Third chamber
Chamber4	Int	15	Handles the temperature values for the Fourth chamber
Chamber5	Int	15	Handles the temperature values for the Fifth chamber
Chamber6	Int	15	Handles the temperature values for the Sixth chamber
Datedtime	Varchar	200	Handles the Time and date each temperature was captured/Monitored

TABLE IV. DATA DICTIONARY FOR VOLTAGE MONITOR

Field Name	Field data type	Field length	Field description
Serial_Number (PK)	Int	20	Unique number identifying the each record
High Voltage	Int	15	Used to handle when voltage is high
Low Voltage	Int	15	Used to handle when voltage is high
Datedtime	Varchar	200	Handles the Time and date Voltage was captured/Monitored

TABLE V. DATA DICTIONARY FOR PRESSURE MONITOR

Field Name	Field data type	Field length	Field description
Serial_Number (PK)	Int	20	Unique number identifying the each Pressure record
Pressure_high	Int	5	Used to handle when Pressure is high
Pressure_Low	Int	5	Used to handle when Pressure is high
Datedtime	Varchar	200	Handles the Time and date Voltage was captured/Monitored

To retrieve information from the database, the SQL select statement is used. Data is retrieved from the MySQL RDBMS using the SQL select query which helps to retrieve record from a database table.

L. *Data Security*

The system has to be properly secured especially from the user end. Measures taken to prevent malicious attacks include establishing sufficient access restrictions to all data. The use of encryption was a good option. User authentication was alphanumeric as only alphabets could easily be broken by wiretapping because the system passes alphabets as plain text [8]. Therefore cryptosystem algorithm was implemented to secure the system from malicious attacks.

M. *Coding*

Hypertext pre-processor (PHP) was chosen for the implementation of the system because of its light weighted nature which is acceptable in cloud computing context. Also it is widely used for general purpose scripting and can be embedded into HTML and the presence of the Apache server makes the system runs on any web browser freely. The design implementation showing the different graphical user interfaces for the system been generated from the codes is shown in section 3.

III. RESULTS AND DISCUSSION

Before the system was made fully operational, it was thoroughly tested for vulnerability checks, syntax errors, compatibility checks etc. Here the entire program for the system was tested using different approaches. The system was tested with application on a local host server machine. The various aspects of the work were tested before the final integration. This various subsystems were then integrated to form the platform. Also the system was tested on a datacenter network, and it was observed that the application scaled very well in terms of web server utilization.

A. *Temperature Monitor Interface*

Figure 10 shows the web monitoring interface of the temperature of the six chambered production plant. When the temperature of all the chambers are within the working range the system will be on and running. There is high tendency for the temperatures to fall outside the working range because of the nature of work the machine is doing, hence the need for regular and constant monitoring. They system was designed t issue a control command and automatically short down the equipment if the temperature rises to a level that is beyond acceptable limits.

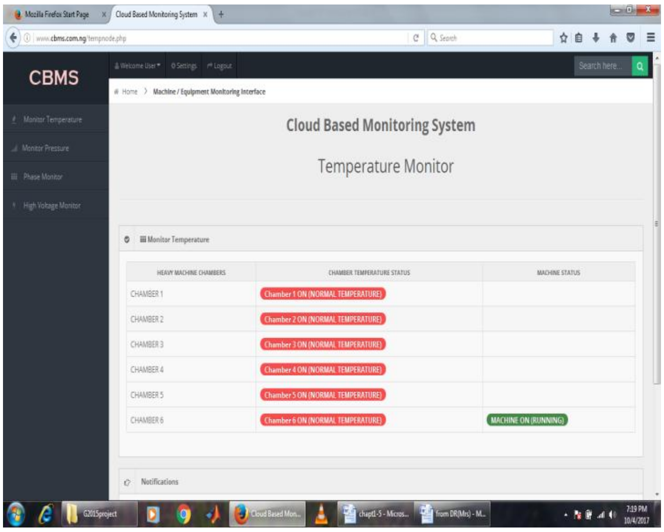

Figure 10. Temperature monitoring; machine ON and Running

Figure 11 shows another scenario where the temperature of one or more of the chambers was outside the acceptable limits and that leads to the machine stop running.

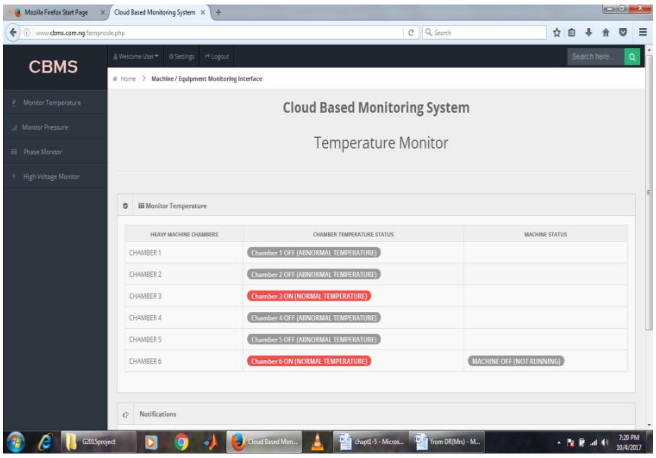

Figure 11. Temperature monitoring; machine OFF and not running

Another interesting aspect is that the systems keep the records of all data in case of unforeseen circumstances one can easily refer to the history and trace the fault and fix it without having to troubleshoot the entire system. Figure 12 shows the history of the temperature monitoring interface. It shows the date, hour and seconds of every single events of the machine. In case of accumulation of data there is a provision to wipe out history if need be.

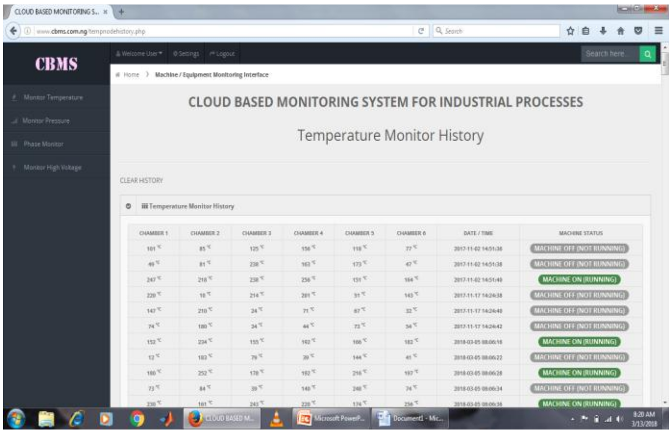

Figure 12. Temperature monitoring; machine history

B. *Pressure Monitoring Interface*

The pressure of the system was to be maintained between 0.28MPa to 0.33MPa. Anything outside this range is an abnormal condition and the system will not function properly. Figure 13 and 14 demonstrated the two conditions when the machine is ON and when the machine is OFF respectively.

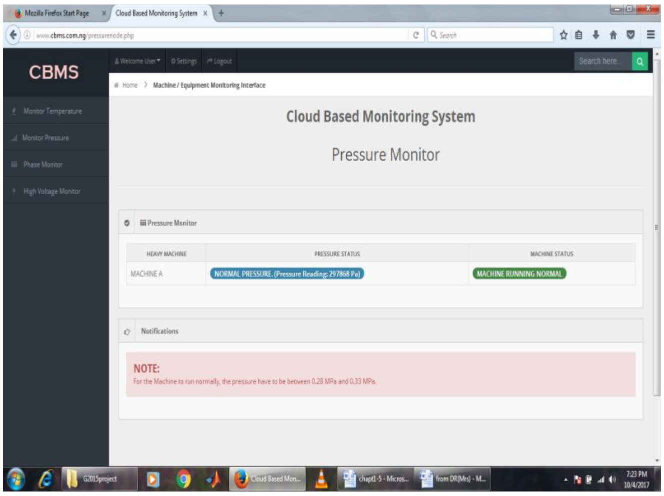

Figure 13. Pressure monitoring; machine is ON and running

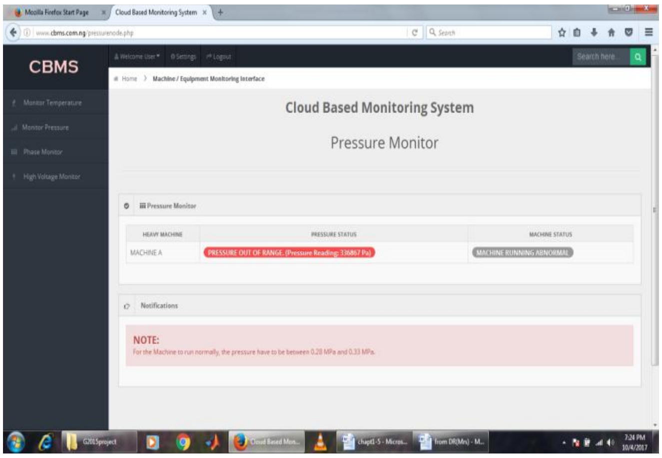

Figure 14. Pressure monitoring; machine is OFF not running

C. *Phase Monitor*

The load on the three phase machine has to be balanced for the machine to work effectively. So there is need to monitor the voltage supply on each phase. For the machine to be ON and RUNNING all the three phases has to be ON otherwise the machine is OFF. Figure 15 and 16 show the two conditions of ON and OFF respectively.

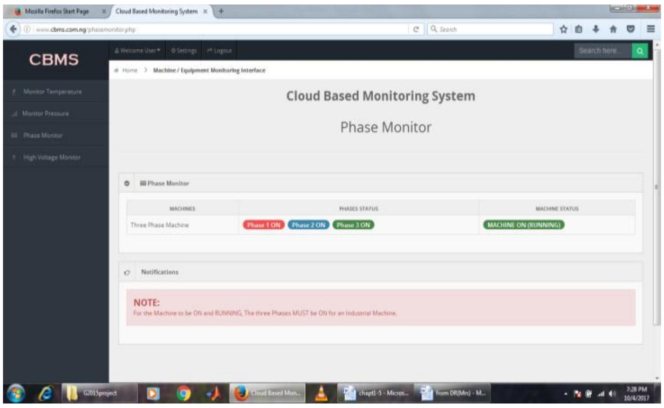

Figure 15. Phase monitoring; machine is ON and running

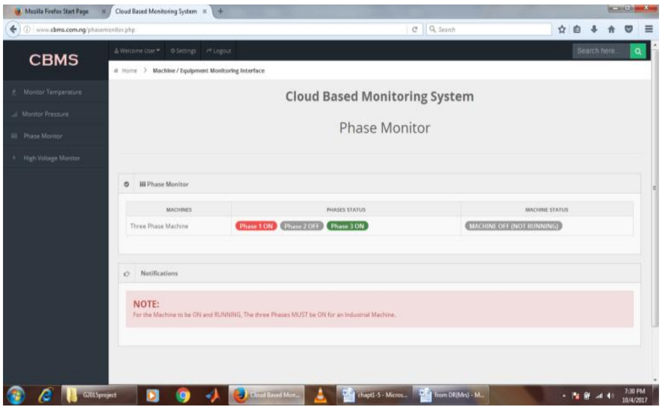

Figure 16. Phase monitoring; machine is OFF not running

D. High Voltage Monitoring

The heavy equipment machine is designed to run on certain voltage range of 373Volts to 439Volts AC and 200V to 240V DC. Any voltage outside this range will post abnormal condition to the system. Figure 17 shows the normal working conditions of the systems and figure 18 and 19 show the state of the equipment when the voltages are outside its range.

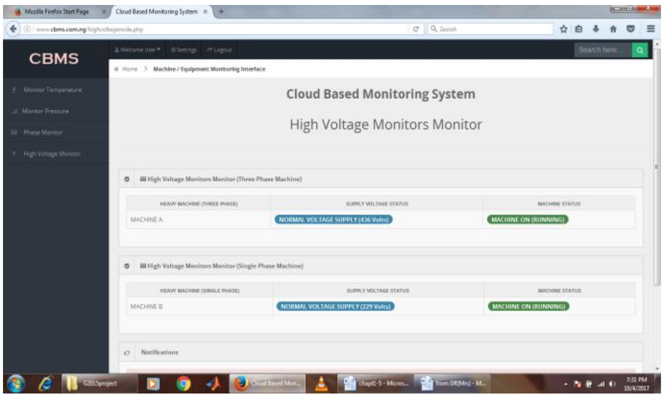

Figure 17. High Voltage Monitoring; machine is ON and running

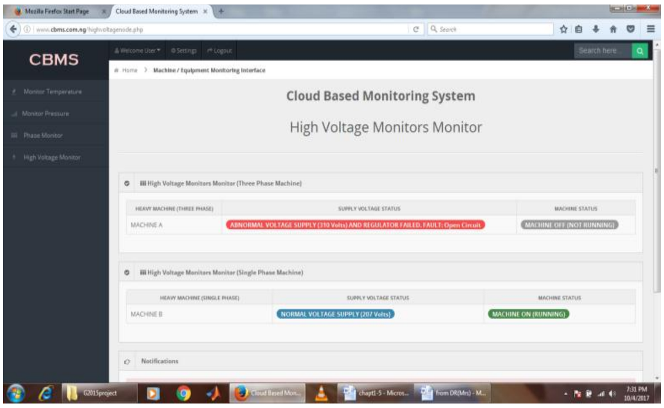

Figure 18. High Voltage Monitoring; 3-phase machine is OFF not running

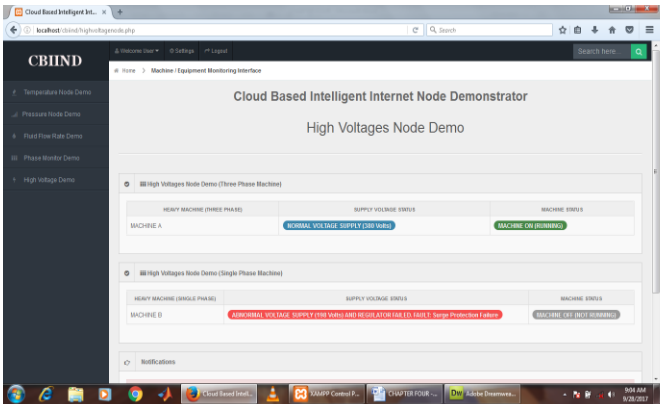

Figure 19. High Voltage monitoring; single-phase machine is OFF not running

IV. CONCLUSIONS

The research was aimed at designing a cloud based monitoring and control system for industrial processes and to show how effective it is to remotely monitor and control heavy equipment from any location via cloud computing. It was clearly shown that any operator can perfectly monitor the activities of an industry irrespective of his her locations via a web interface. The system offers some levels of control by shorting down the equipment when an abnormal condition that cannot be automatically regulated occurs. To accomplish the stated objectives, the system employed the use of PHP programming language and MySQL database management system. Cloud computing gave this work an edge over the normal web or internet based monitoring systems because of its outstanding benefits in the areas of large storage of data and back-up facilities, reduced cost and time savings, increased speed and performance of the system and it also ensures better security for the system. The system also has the ability to keep the history of all equipment been monitored. This data been stored in the cloud could easily be accessed for analysis and key decisions concerning the equipment could easily be taken based on the available information.

V. RECOMMENDATIONS

Since the software design of the system is based on PHP which is an open source widely-used general purpose scripting language the system can easily be upgraded to accommodate more equipment when the need arrives. Furthermore, system upgrade that could add intelligence to the processes by automatically administering more control measures to correct any abnormal situations that may arise in other to keep the equipment safe and running is highly recommended.

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