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MONITORING THE CONDITIONS OF INDUCTION MOTORS, HYDRAULIC OIL TANK LEVEL AND CUT-LENGTH OF SHEET METAL USING MQTT

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Abstract— This paper shows an example work of Industrial Internet of things which can be implemented in a factory space for communicating the process status to the supervisor. We have implemented the Message Queuing Telemetry Transport, one of the IoT protocols for monitoring the condition of an Induction motor by analyzing its vibration, To detect the level of oil available in the hydraulic tank and to verify the cut-length of a sheet metal in a Wheel rim manufacturing industry. The idea is to utilize Wi-Fi connectivity by transmitting information for a particular topic from sensor nodes(clients) with ESP8266 to the central raspberry pi broker which pushes these information to the clients whoever subscribes for the topic.

Keywords—condition monitoring, process monitoring, internet of things, ESP8266, raspberry pi and MQTT.
INTRODUCTION

Process control and monitoring is an essential goal for an industry and the evolution of industrial automation has shown many new methods to do so. With recent trends in industrial automation which includes industrial internet of things, a lot of process to process, machine to machine and machine to user communication can be established thus reducing human interference. Industrial IoT, reduces the complexity of having more number of wires for transferring data to the process supervisor or maintenance department and includes the freedom of mobility. In fact the supervision of the process can take place remotely if the supervisor has a connectivity towards the network or through internet. Imagine a situation where the maintenance manager is off duty but still he can monitor the condition of a machine and he can instruct the juniors to shutdown the operation if the condition of the machine moving towards failure. This helps the industry to save lot of cost for maintenance due to failure or even power consumption. Taking this as a simple motivation we further think of establishing the same idea for different purpose within the industry.

Though the process control using internet of things is no match to the control by using SCADA and PLC, we can at least restrict the control features either due to industrial standards or security reasons. There are plethora of areas where human verifications cannot be made all the time and this can be made possible by adopting monitoring through Internet of Things. Considering about the connectivity, we can say IEEE 802.11 Wi-Fi standards have good coverage over a plant or workshop with better industrial Wi-Fi router as discussed in [1],[2]. Security for the network is always the most challenging thing one should consider for designing such an architecture. This could lead to risks of handing over the process to unauthorized persons or hackers[8].

The next issue we need to deal is the system integration which includes the right selection of components to suit industrial atmosphere. The data transmission needs to be light weight, should consume less storage space for programming, low power consumption and finally industrial standards. Various such issues are discussed in our work which can provide necessary details to further research and development.

I. MQTT

The Message Queuing Telemetry Transport proves itself to be lightweight, high scalability and easy to implement[8]. Unlike HTTP, MQTT using Publish-Subscribe architecture where the clients can either send and receive information regarding a topic. The broker is the central server which is responsible for holding the sensor values and directing them towards their subscribers. For example, we can take “Vibration” as a topic and “induction motor 1”, “induction motor 2”… as subtopics whose address in broker is represented as “Vibration\induction\motor1”. The client who needs the data has to subscribe to the topic and even to the sub topic to eliminate other unwanted information of that topic. The subscribers can be a sensor node itself or a PC of the supervisor or his mobile device which is connected to the network where the whole MQTT architecture is built on. [5],[13] discusses heavily about implementation of this by suggesting proper hardware and methodology.

The next advantage of MQTT is, it can be easily implemented over battery powered or energy harvesting powered units. This is a boon where large number of sensor nodes can be deployed with its energy supported by renewable sources such as Sun light, Thermal heat, Pressure and other...
sensor is fixed to the outer case of induction motor by creating bore thread over the body and fixing it to the created thread.

![Fig.1. Vibration sensor for Induction motor](image1)

**A. Level Monitering in Hydraulic Tank**

The level of oil inside a hydraulic tank needs to be maintained in between proper levels for stable process and any changes in it can cause unwanted variations in the process. We choose the level monitoring sensor LR7000 from IFM (Fig.2) for displaying oil level for viewing and gives out current signal for further interface. The sensor has an inbuilt display unit with configurable levels for arising a indication that the level goes out of band. The upper and lower level crossings are indicated by a DC output. On feeding these DC levels to the sensor nodes, we can obtain the information about level crossings in the supervisor end. The sensor is fixed to the oil tank by creating a bore thread over the top surface of the tank. In most cases, the tank itself provides some fixable holes provided with closing caps.

![Fig.2. Illustration of LR7000 from IFM datasheet](image2)

**B. Cut-length monitoring**

The sheet metal for manufacturing wheel rim needs to be cut from a roll before performing any welding or molding process with a set length. To ensure its accuracy apart from CNC’s automation, we have arrangement which can ensure the preset length is maintained while cutting and can alert supervisor in case of deviations. The preset length in CNC input is fed to the sensor node too and it is being compared with practical length acquired after cutting, through a Laser Doppler transmitter sensor fixed aside the conveyor belt with laser pointing the edge of sheet metal rolling over it as shown in Fig.3. The sensor output is in the form of 4 to 20mA, two digital inputs indicating speed of movement obtained from CNC machine which operates on 3 distinct speeds of the conveyor. Another digital output produces a pulse during change in length. The controller is well programmed to detect the length of the sheet metal as the speed and time of short distance between the sensor and sheet metal is known and this can be mathematically said as:

\[
\text{Length} = \text{(time of smaller distance)} \times \text{(speed of movement)}
\]

The time of smaller distance is detected by starting a timer between pulse for shorter distance and its terminating pulse. For the purpose of sensing the distance, LASER SENSOR - ODSL 9/C6-450-S12 from Leuze electronics has been used.

![Fig.3. Arrangement of Cut-length monitoring with laser pointing the sheet metal](image3)

**II. DESIGN OF SENSOR NODES**

From the supply of 24V provided in industry, we need to power the sensor and the sensor node with proper step down and distribution arrangements.
Generally industrial sensors are designed to work on 24V DC supply and there is no need for building supply for sensors. The work of [6] is more satisfying example which has similar goals discussed in this document. The sensor nodes for Vibration and Cut-Length monitoring is the same (only programming part varies) and denoted as type A as shown in Fig.4 and the sensor node for oil level monitoring is type B as shown in Fig.5.

A. Microcontroller and Transceiver

The selection of microcontroller is the crux of the whole process. For our objective we require a better resolution ADC to produce better monitoring and the communication part needs to be reliable. Standard microcontroller which operates on 5V or 3.3V DC is preferred for industrial purpose rather than low power microcontroller unit which can be operated on harvested energy. In our case we choose “NodeMCU” which is a microcontroller + transceiver unit operates on 3.3V supply[5][10]. The transceiver is the ESP8266 module which can be interfaced with a microcontroller with I2C support. For cut-length monitoring we use ATmega328P microcontroller which is capable of scanning three digital inputs simultaneously is interfaced with ESP8266 module.
Current to voltage conversion

The sensor output which is in the form of 4 to 20mA scale for interfacing with PLC and other modules has to be converted into 0 to 5V scale for microcontroller scanning. Variety of modules can be used for this purpose but as we need this to be compact within the sensor node we choose BurrBrown’s RCV420 dual inline IC (refer Fig.6) which offers better isolation and nominal power consumption. To power we create dual rail supply of +12V and -12V with respect to virtual ground from 24V with the help of potential divider(100KΩ 1W resistors and 47µF 25V capable capacitors). In our case nodeMCU can read analog input range between 0 to 3.3V which includes 1:2 potential divider network. But this whole set up is not required for Oil-level monitoring as the sensor gives two digital outputs.

![Figure 5. Block diagram of Sensor node type B](image)

**Power Supply**

As mentioned earlier about 12V dual rail, we use 5V regulator(7805 with TO-220 heatsink) to drop 7V and feed the nodeMCU which has an internal 3.3V regulator(LM117). Proper capacitors are used to maintain DC level without any ripples and a 1nF capacitor for removing high frequency ripples. In the sensor node B for Oil-level monitoring, we use LM317 to regulate for 5V. Additionally LM117 3.3V regulator is provided to power ESP module.

![Figure 7. PCB of sensor node type B](image)

B. Temperature monitoring of the sensor node

In order to provide proper thermal protection and shut down, we include a LM35 temperature sensor and its level crossing circuit for interrupting the nodeMCU when temperature exceeds working conditions. Cooling fan can be attached externally which is relay controlled by the sensor node itself when needed.

![Figure 6. PCB of Sensor Node type A](image)

III. BROKER AND CLIENTS SETUP

MQTT broker is established using Raspberry pi 3 which has Mosquitto package installed in it. Several other Publish-Subscribe packages are available such as hiveMQ, rabbitMQ which are open source to some extent will provide more features such as cryptographic security and easy interface. The broker maintains separate topics for each process where the sensor nodes publish the data and the PC in control room and maintenance room need to subscribe to respective topics to obtain information. As raspberry pi has good storage space for data logging, it holds good for stalling the data when the client does not intend to receive data.

For clients we have specialized software such as Paho but in our work we used PubSubClient library which is available open source[10]. Programming nodeMCU is done using lua which is simple to code and easy to debug especially for wireless applications. The user end can be a mobile phone running MQTT application such as MQTTdash, myMQTT.. etc or an HTML based web page in laptop. The broker starts running on raspberry pi 3, allocated to a static IP address from the router. The nodes will have to connect to the router and broker first before publishing or subscribing to a topic. Once the router and broker...
connections are established, the sensor node will scan the output signal from the sensor to publish to a specific topic. The publish can take place periodically and momentarily i.e. when any warning occurs. In Fig 8, the publish takes place for every 5 minutes and if there is any warning arises between this interval, the publish takes place instantly.

Fig.8. Timing diagram of publish by sensor node.

For cut-length monitoring, the publish takes place for each sheet metal passing over the sensor. The broker will maintain the details about data published and time of publishing in order to record for analysis and report generation.
RESULTS
The proposed system is implemented as stated in previous titles by establishing connectivity among sensor nodes and broker. The Supervisor should have a mobile node or a PC through which one can view the published data from the sensor nodes. For viewing in a smart phone, myMQTT android application is used to connect to the broker IP and subscribe for a topic. Once the sensor node publishes to the specified topic, the client node (mobile phone) can receive data from the broker. Fig 9, shows the data from sensor node being displayed in serial monitor of the microcontroller and myMQTT application. The recent data is displayed at the bottom in serial monitor and top in the application.

Fig.9. Sensor values in serial monitor and in myMQTT android application software.

The hardware components used for realizing the sensor nodes are not completely of Industrial standards except for the regulators, connectors, signal conditioning ICs and biasing components. The microcontroller and transceiver modules used are proprietary and it can be redesigned using industrial standard components for obtaining overall approval for this work. Following table shows the electrical characteristics of the sensor nodes designed for the purpose.

<table>
<thead>
<tr>
<th>Node</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Supply</td>
<td>24 V</td>
</tr>
<tr>
<td>Node A</td>
<td>Current consumption (Considering nodeMCU, RCV20) Ideal case</td>
<td>80mA</td>
</tr>
<tr>
<td></td>
<td>Current consumption (Considering nodeMCU, RCV20) While communicating</td>
<td>100 to 120mA</td>
</tr>
<tr>
<td></td>
<td>Current consumption (including</td>
<td>150 to 180mA</td>
</tr>
</tbody>
</table>

TABLE 1: ELECTRICAL CHARACTERISTICS AND TEMPERATURE TOLERANCE

IV. CONCLUSION
The designing and programming for this objective sets an example for any industrial wireless monitoring project. The sensor node designed was capable of sustaining 60°C without cooling fan switched on and this may extend upto 90°C with stated cooling arrangements. The MQTT protocol used in our work is from open source library and it was found to be ready to use for building up a project. One can develop their own user end interface through computer application or smart phone application with proper interfacing standards but these details are not being discussed in this paper.

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REFERENCES
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[12] https://mosquitto.org/