P-ISSN 2586-9000
E-ISSN 2586-9027
Homepage : *https://tci-thaijo.org/index.php/SciTechAsia*
Science & Technology Asia
Vol.29 No.2 April - June 2024
Page: [45-52]

Original research article

Real Time Production Status Monitoring System

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Received 15 January 2024; Received in revised form 29 February 2024
Accepted 1 April 2024; Available online 25 June 2024

ABSTRACT

This research aims to develop a monitoring system to show production data and analyze machine status in real-time. It uses the Internet of Things (IoT) and the LoRa communication system. The researcher uses a tension sensor to receive tension variables in the beaming process. A tension sensor connects to the LoRa sender. The first LoRa device is the one that takes data from a tension sensor and sends it to the second LoRa receiver. Then the ESP32 board sends the tension data to the database server. It uses an API to take the data into the Google Sheet database. Then, the tension data will be extracted and analyzed. The researcher assumes a hypothesis about the machine's operation from the data obtained to make a decision whether the machine is working or stops working. If the tension value is 0 for more than a specified time, the machine has stopped running. It can use data to calculate the length of time the machine has stopped running. It can also calculate the length of time the machine has been running. If the tension value is not the standard, the machine will be damaged. The Line application also sends notifications. Maintenance departments and related agencies can then hurry and fix the issues in time. Moreover, the researcher used the length of time the machine is running and the length of time the machine is stopped to calculate the MTBF, MTTR, and availability. These variable values are displayed in a report on a Looker Studio dashboard. This allows production status to be tracked and analyzed to solve problems in time.

Keywords: Availability; Dashboard; Internet of Things; LoRa; Monitoring

1. Introduction

Nowadays, technology is advancing, particularly with the development of Industry 4.0 technology, which is the Internet of Things (IoT) concept that uses intelligent technologies to improve manufacturing operations. The Internet of Things (IoT) is a network concept that supports the interconnection of various devices. It is also able to communicate and connect

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automatically. It is a way to connect the various needs of users to produce various forms according to the needs of users efficiently.

Therefore, it has been important in the industrial era. This will help improve production efficiency. It will enable monitoring of data in the production line. This will allow analysis and collection of data from the production process, using technology.

Currently, there are many production problems in the manufacturing. Production problems include 1) Errors cannot be checked and corrected quickly when the machine stops working. 2) The machines used in production do not have the technology to collect the operational data of each machine. It is not possible to check and evaluate the performance of the machine. Furthermore, it is impossible to determine the quality of the produced products meets the standard required by the factory. 3) In the process of recording data. The operator will often record the parameters of the data collected from the machines used in the production process. The operator will then analyze the recorded data to prepare a report on the machine's operating status. This causes errors in data collection and recording. It is a random recording method at certain times of the day without continuous recording. This is a problem because the factory can't follow up on the status of the real-time machine and may receive incorrect data.

Considering all of these problems, the researcher has the idea of applying technology to the production process to solve problems. It helps the factory monitor the status of the machinery in the production process on time, be able to check the machine in time if it has a problem and helps reduce damage that occurs in the production process. This research will bring technology to develop in the beaming process in manufacturing plant. They are pulled and extended according to the factory's product standards. The researcher installs sensor technology to receive data on important parameters, such as tension values. The system will then collect the data obtained from the sensors into a database via the LoRa system and will display those data on the dashboard to display the operating status of the machine in real-time.

2. Materials and Methods

2.1 Literature reviews

Industrial systems in smart factories can control production rates to meet demand. The practical use of IoT technology necessitates a comparison of LPWA technologies which have research that compares LoRaWAN and NB-IoT technologies. The research shows that LoRaWAN has advantages in terms of battery life, capacity, and cost. LoRaWAN is suitable for use in large areas. In addition, another research tests the performance of ZigBee and LoRa networks for application in community energy management systems. The research conducted a test to measure the Received Signal Strength Indicator (RSSI) of ZigBee devices inside buildings. The results showed that the RSSI value decreased as the distance increased. RSSI measurement of LoRa devices within the area of Rajamangala University of Technology Srivijaya found that LoRa communication can transmit and receive data with sufficient coverage. The maximum distance is 573 meters. [1, 2]

Therefore, the researcher has chosen to use the LoRa communication system in this research so that the data can be used to create reports on the Dashboard. The other research surveyed people in various positions in five Finland machinery manufacturing companies. The research team for that research created a questionnaire about the KPIs that companies wanted to see on their company dashboards. The majority of the respondents included production line operators and production managers. They want to use the dashboard on mobile and tablet. The dashboard must display production information and machine status. They want there to be colors that show the status of the machines at all times and the production time for each job [3].

According to a theoretical study and a review of the literature, the usage of IoT technology can help in the development of machine status monitoring systems. Using sensors for gauging values and the LoRaWAN network, results can be shown quickly on the dashboard, allowing users to go in and solve problems in real-time [4].

2.2 Equipments

2.2.1 Tension sensors

In the process of warp beaming, the researcher has chosen a tension sensor. Use 1 sensor and 1 machine to measure the tension in an experiment.

2.2.2 LoRa system

Factories are large areas. Communication between buildings is required. This research has used two LoRa devices. They receive and send tension data from sensors. The first LoRa is the LoRa sender. A tension sensor will connect to it. Then, it will receive data from the sensor. Measure tension and send it to the second LoRa. Set the second LoRa as the receiver. It will have an ESP32 board for sending the tension force value to the database server. Use the Visual Studio Code program written in C language. Write commands of the LoRa system.

2.2.3 Server

This research uses Google Sheets as a database. It will retrieve data using the API language. The researcher will then analyze the data. They'll configure a dashboard to retrieve the data. They'll display it both in real-time and in an automatic summary report. Looker Studio is a tool from the Google website for doing Data Visualization.

2.3 System flow

For LoRa communication system, the working direction starts from the left of Fig. 1. The LoRa device extracts the tension from the sensor installed on the machine. The database server will use API language to retrieve data from the server. It will display production status in a dashboard.

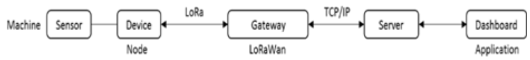


Fig. 1. Data flow architecture.

LoRaWAN, which is the main communication system, has three main parts: Devices, Gateway, and Network Server.

2.3.1 Device or node

Node is a low-power device that communicates to the gateway. This research will be the sensor installation on the machine. It also has a LoRa device that converts and transmits the signal from the device to the gateway-LoRaWAN.

2.3.2 Gateway

Gateway receives packets from LoRa devices. It forwards them to the Network Server.

2.3.3 Network server

The Network Server eliminates duplicate packets. Then, it sends packets back to the destination device to support different applications [5].

2.4 System

The researcher took pieces of equipment to install and write as shown in Fig. 2.

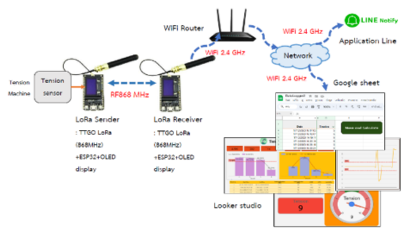
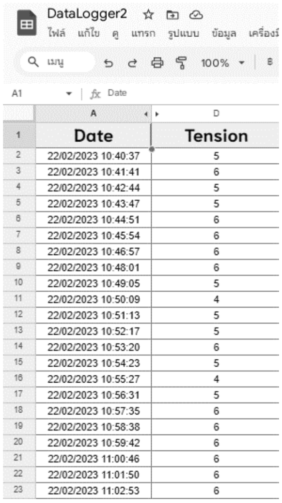


Fig. 2. System diagram of real time production status monitoring system.

Fig. 2 shows how to connect various devices. The research designed the devices in the following steps.
Step 1. Connect a tension sensor and LoRa sender and install it on the machine. Write a program for the sensor to receive tension value. Then the LoRa sender receives tension value. It processes it and sends data to the LoRa receiver, which has an ESP32 board on the LoRa device. The OLED screen shows the displayed data from a tension sensor.
Step 2. The LoRa Receiver processes the received data. Then, it connects to Wi-Fi with ESP32 and sends the data to the server. The OLED screen will display the data as tension.
Step 3. Write a program with API language to get data from the LoRa receiver. Then store it on a Google sheet. Write an Apps script to display tension, day/month/year, and time the data was received, as shown in Fig. 3.



	Date	Tension
2	22/02/2023 10:40:37	5
3	22/02/2023 10:41:41	6
4	22/02/2023 10:42:44	5
5	22/02/2023 10:43:47	5
6	22/02/2023 10:44:51	6
7	22/02/2023 10:45:54	6
8	22/02/2023 10:46:57	6
9	22/02/2023 10:48:01	6
10	22/02/2023 10:49:05	5
11	22/02/2023 10:50:09	4
12	22/02/2023 10:51:13	5
13	22/02/2023 10:52:17	5
14	22/02/2023 10:53:20	6
15	22/02/2023 10:54:23	5
16	22/02/2023 10:55:27	4
17	22/02/2023 10:56:31	5
18	22/02/2023 10:57:35	6
19	22/02/2023 10:58:38	6
20	22/02/2023 10:59:42	6
21	22/02/2023 11:00:46	6
22	22/02/2023 11:01:50	6
23	22/02/2023 11:02:53	6

Fig. 3. Database server system.

The researcher will test the installation for 24 hours. The researcher will collect data by sending it to a Google Sheet every 1 minute. Set the normal standard tension value to be 4-6 from proportion 0-10 and when the machine is stopped, the tension value will be value 0.
Step 4. After collecting all the data, the researcher will analyze the data. Then, they will calculate the desired values. Then, they will display them on the dashboard and they will send notifications to the Line app.

2.5 Decision analysis

From the tension data received, the status of the machine must be analyzed. The tension data is a value from proportion 0 to 10 for each case. As a result, the decision for each machine status are as follows.
Case 1. In the case where the value is 0 for more than 2 minutes. It means the machine stops working. The machinery has damage and someone is fixing it. This causes downtime. If the value is 0 in less than 2 minutes, that case to the warp beaming process setting up the machine to produce the next part (Set up time).
Case 2. In the case where the value is 4-6, it means the tension is on the standard value. The machinery works normally.
Case 3. In the case where the values are 1-3 and 7-10, the values are not on to standard due to a malfunction of the machine and may damage machinery if not resolved in time.

2.6 Notification via Line application

From the assumptions mentioned above the researcher has written a Visual Studio Code program. The Line application can notify. 1) When the machine is first started up, there will be a notification via the Line application. 2) When the tension is equal to 0, there will be a notification via the Line application. 3) When the tension is between 1-3 and 7-10, It will send a notification every 1 minute. A program will keep notifying until the sensor value returns to normal. The notification will notify groups in the Line application. It will only notify a group that has members in the group. Members of the group have machine maintenance technicians, machine operators, and leaders. Then create a notification system using the Line Notify tool to send notifications to group chats.

2.7 Availability

The researcher used the assumptions in Section 2.5 to calculate the values of the following variables: how long the machine works, how long the machine stops working, and the number of times to repair the machine. This created an automatic calculation according to the following steps.
Step 1. Write apps script on Google sheet. Create a button for clicking once to move the data to a new sheet to store the data. Then use the data to automatically calculate the duration value. Calculated as the starting period until the end period will be the total running time in minutes.
Step 2. Add-in calculation formula function on Google sheet. The assumptions mentioned in Section 3.4 include 1) If the value is 0, and the sent value is more than 2 minutes, calculate the time to get the total repair time or downtime. The total repair time or downtime is measured in minutes. It counts the number of times it takes to stop the machine. By calculating how many times the data has been 0 for more than 2 minutes (Repair) 2) Use the calculated values to calculate the MTBF MTTR and %Availability values. Using the formula from Eqs. (2.1)-(2.3) as follows:

$$MTBF = \frac{\sum_{i=1}^{n} BFi}{n}, \tag{2.1}$$

$$MTTR = \frac{\sum_{i=1}^{n} Ri}{n}, \tag{2.2}$$

$$Availability = \frac{MTBF}{MTBF + MTTR}, \tag{2.3}$$

where $\sum_{i=1}^{n} BFi$ is the difference of total running time and total repair time, unit is minutes, n is number of repairs, $\sum_{i=1}^{n} Ri$ is total repair time. From Eqs. (2.1)-(2.3), It gets the Eqs. (2.4)-(2.6)

$$MTBF = \frac{Total\ running\ time\ -\ Total\ repair\ time}{Repair}, \tag{2.4}$$

$$MTTR = \frac{Total\ repair\ time}{Repair}, \tag{2.5}$$

$$\%Availability = \frac{MTBF}{MTBF + MTTR} \times 100. \tag{2.6}$$

Enter the equation into the calculation formula in the Google Sheets table as shown in Tables 1-2.

Table 1. The calculation formula in the Google Sheets each header.

Total running time (min)	Repair	Total repair time (min)
Calculated as the starting period until the end period	Number of repairs, when value 0 is more than 2 minutes	Total downtime, when value 0 is more than 2 minutes

Table 2. Use Eqs. (2.4)-(2.6) and the result from Table 1 add-in the calculation formula.

MTBF	MTTR	Availability
Eq. (2.4)	Eq. (2.5)	Eq. (2.6)

The researcher will collect data 4 times, 24 hours each time. Then, the researcher will command Google Sheets to automatically calculate it when pressing the button. To use the data to design reports on the dashboard.

2.8 Dashboard

Create a dashboard page on Looker Studio by retrieving data from the Calculated Results Sheet page and the real-time Sheet page. The researcher has created a summary page in the form of a bar chart, and a summary table, and used the Gauge tool to measure. The page displays real-time tension results and reports real-time results. The researcher specified that the data be updated every 1 minute and used data visualization principles to make it easier to understand. The data used to report results includes tension, MTBF graph, Availability graph, total running time, total repair time, and Repair. It is divided into 2 pages: a real-time page every 1 minute and a summary page.

The real-time page will be set to be red when the tension obtained does not meet the standard value.

3. Results and Discussion

3.1 Results from installing the system and collecting data

After the system was installed data was collected four times, for twenty-four hours each time. It was discovered that the dashboard could retrieve and show data once every minute. As illustrated in Fig. 6, the display was designed to indicate in red when the tension was not on the standard value and in green when it was.

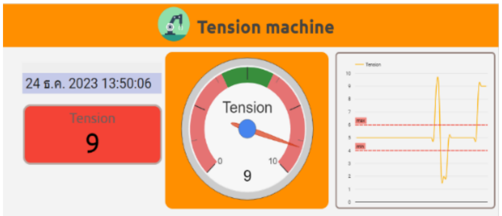


Fig. 4. Tension machine dashboard.

From Fig. 6, Max = 6 and Min = 4 have been defined to be able to monitor production status data according to factory standards in real time. If the tension value is lower than the min value and higher than the max value, the measuring needle will point to the red area, the graph will be lower or higher than the Min or Max value. The Tension message box will be red color immediately. Following a 24-hour data collection period, the operator will click the Move & Calculate button once. As seen in Fig. 7, the data will be recorded and used to automatically calculate the results.

When the operator presses the Move and Calculate button, the result will be as shown in Table 3. The data will be pulled to another page.

Table 3. Machine start time and end time of each round.

Round	Start time	End time
1	22/2/2023, 10:40:37	23/2/2023, 10:41:30
2	1/5/2023, 12:37:08	2/5/2023, 12:38:40
3	8/5/2023, 11:41:31	9/5/2023, 11:54:43
4	9/5/2023, 11:55:47	10/5/2023, 11:57:05

From Table 3, the time to end the machine takes the user to press the Move and Calculate command button. The first set of data is when production starts and the last set is when production ends. It will automatically calculate the duration as shown in Tables 4-5.

Table 4. Results from all calculations of time.

Round	Total running time (min)	Repair	Total repair time (min)
1	1441	2	29
2	1442	1	39
3	1454	3	73
4	1442	8	251

Table 5. Results from the calculation of MTBF, MTTR, and Availability each round.

Round	MTBF	MTTR	Availability
1	706.00	14.50	97.99%
2	1403.00	39.00	97.30%
3	460.33	24.33	94.98%
4	148.88	31.38	82.59%

From Tables 4-5, the results that were calculated in the Google Sheet will be reported on the dashboard page that has already been connected, as shown in Fig. 5.

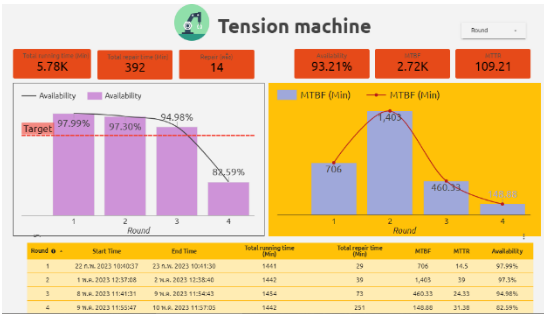


Fig. 5. Tension machine report dashboard.

From Fig. 5, the researcher has set the target value of availability to be 93, which is the KPI value that most factories set. It was found that if the MTBF is high, the availability value will be high due to the less time the machine will be stopped for repairs. It can be seen that the greater the MTBF, the less MTTR it will have a positive effect on the machine and % availability.

The dashboard developed by the researcher can enable access to data for executives and industrial operators to monitor results from any device, including computers, tablets, laptops, and smartphones.

3.2 Results from notifications via Line application

From the data collection, it was found that when the tension is equal to 0, there will be a notification via the Line application, and when the tension is lower than 4 and greater than 6, it does not meet the standard. The system will then send a notification via the Line application. If the tension value is not on the standard value, a notification will be delivered to the group chat. Members of the group were told, and relevant departments hastened to fix it as soon as possible to avoid damage to machines. The notification will continue to alert every 1 minute until it is rectified to return to normal. As a result, corrective action and repair can be carried out on time.

3.3 Results from using the LoRa system in the factory

From the installation of the system, it was found that the LoRa device can transmit data over a distance. The data can be sent from the machine to the receiver at the office to follow up on the data. In addition, the data received is accurate. From the inspection, it was also found that data was sent quickly and allows recipients to follow up in real time.

4. Conclusion

After the implementation, it was found that the sensors that received the data with LoRa devices read the values and sent the data to the server, displaying the results on a dashboard. Real-time notification via Line application if the machine stops working and the machine almost stops working. This allows relevant operators to go in and repair immediately. The data received is accurate and can be transmitted over long distances. It also generates automatic summary reports to help users understand the status of machines' productivity using data visualization. Monitoring machine production status on the dashboard also allows users who are both operators and maintenance technicians, leaders, engineers, and executives to obtain data from anywhere. They can monitor the production KPI value, such as the availability calculated from MTBF and MTTR. When MTBF is higher, MTTR is lower, and availability improves. Even if the numbers do not achieve the intended goals, they are still important in allowing users at various levels to analyze them to solve problems further.

Therefore, the development of a real-time production status monitoring system in industry with the Internet of Things system helps solve problems and develop the production process so that factories can monitor the operating status of machines in the production process in time. It can detect problems at the machine or production process and help reduce damages that occur in the production process.

Recommendation

A real-time production status monitoring system that has been installed on 1 machine. As a result, the status can be tracked and problems can be solved in time. Therefore, we would like to expand the results to other machines and other processes all the factory. The factory to become a Smart Factory or an intelligent factory. It is also a guideline for the organization's executives to use production status data to follow up and then use it can analyze the data to solve production problems.

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