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REAL-TIME DASHBOARD MONITORING AND ALERTING SYSTEM FOR COMPRESSED AIR SUPPLY IN RUBBER COMPOUND MANUFACTURER

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Abstract. *To minimize unexpected disruptions resulting from air supply problems in manufacturing production, a continuous monitoring of air pressures is crucial for predicting and preventing significant issues that may arise. This paper proposes a technique to build a real-time dashboard monitoring and alerting system for improving an availability of existing compressed air supply in a rubber compound manufacturer in Thailand. Flow and pressure transmitters as well as motorized ball valves are installed in the major supply lines of air piping system. In addition, a 3-phase power and energy meter is also installed to measure key electrical parameters of two main air compressors. The proposed technique is based on the use of cost-effective Node-RED web application not only to monitor volumetric flow rate, air pressure values, valve statuses, input/output module statuses, and energy-related parameters on the created dashboard in real time but also to alert plant personnel to pressure readings that fall outside an acceptable range via the LINE Notify application. There are three different notification patterns depending on how long is the pressure reading value out of the acceptable range. Moreover, the on/off status of all ball valves can also be remotely set on the dashboard subpages. Experimental results verify that the improved system can be utilized to assist plant personnel in troubleshooting and solving the problems with compressed air supply.*
Keywords: Alerting, Availability, Compressed air, Dashboard, Monitoring, Pressure measurement, Web application

1. **Introduction.** Compressed air is one of significant sources of power for pneumatic tools and machines in manufacturing processes including rubber compounding. Most industrial plants generate their own compressed air to meet required production schedules. Approaches to align supply side and demand side of a compressed air system are important to ensure its performance [1]. An inefficient compressed air supply can minimize production efficiencies, increase maintenance requirements, increase energy costs, and promote equipment failures [2]. In order to provide an opportunity for improvement, the compressed air facilities should be monitored and controlled in real time [3,4]. An air supply monitoring system based on the use of PIC18FK20 microcontroller and Rasberry Pi board has been presented [3]. The major compressed air parameters can be monitored at local readout and at remote site via web browser. Nevertheless, this monitoring system was designed and implemented for product demonstration. A sequence of three main phases that need to be completed to optimize electrical energy consumption in compressed air system of a pharmaceutical manufacturing plant has been introduced [4]. The first phase of this proposed methodology is measurement plan and data collection. This means that errors in process data reports can impact the effectiveness of the desired optimization.

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Therefore, a real-time electronic reporting system can be used in place of a paper-based system with manual records. Various benefits of digital records such as ease of tracking critical process parameters, ease of accessing data historian, and ease of troubleshooting problems can be obtained [5]. Recently, a remote monitoring and alerting system by using low-cost Internet-of-Things (IoT) platform for odor removal in a beer manufacturer has been suggested [6]. The proposed technique utilizes the Rasberry Pi board to provide remote monitoring via the web application and LINE Notify to deliver alert notification in real time. Alternatively, using dashboards for data visualization has been widely accepted from both designers and users because of their useful concepts [7,8]. To improve an availability of existing compressed air supply system in a rubber compound manufacturer for minimizing unplanned production downtime, this paper aims at presenting a technique to create real-time dashboard monitoring and alerting system for maintaining the optimum pressure values in all piping parts. The layout of existing air supply system is improved by installing new power and energy meter, field instruments, and motorized ball valves. Experimental results showing the proposed system workability are also included.

The rest of this paper is organized as follows. Section 2 explains the existing compressed air supply that requires enhancement of monitoring capability. Section 3 describes the proposed system that offers real-time dashboard and notification. Section 4 shows experimental test results. Finally, Section 5 gives the conclusions and possible future work.

2. **Existing Compressed Air Supply.** Figure 1 depicts a simple diagram of the existing compressed air supply in the studied manufacturer before improvement. It consists of two main air compressors to generate compressed air for responding to pressure demands in production lines and two small air compressors to generate compressed air for responding to pressure demands in quality control testing processes. The interested air supply requires to be delivered at appropriate pressure values to the points of usage within the manufacturing plant. So, the air pressure is defined as the most important parameter to determine system performance. In the past, only pressure gauges (PG01-PG08) were installed to detect the amount of compressed air flowing through the pipes. The plant operators performed spot checks the pressure gauges on their particular production machinery. However, most of plant operators were not always looking at the gauges. In case of low or zero pressure, the manufacturing production was disrupted, and it took a long time to identify and solve the problems. Thus, not only a continuous monitoring for compressed air pressures at both supply side and demand side but also an event alerting

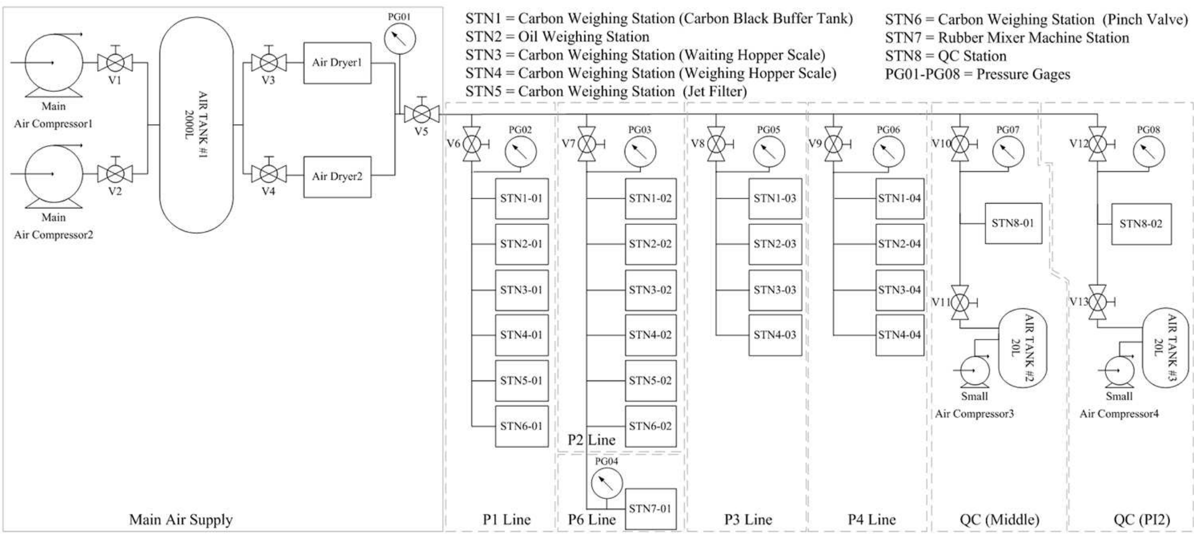


FIGURE 1. Simple diagram of the existing compressed air supply before improvement

strategy to notify plant personnel in real time are essential for overcoming these serious limitations.

3. **Proposed Dashboard Monitoring and Alerting System.** To improve the existing compressed air system, the flow transmitter (FT01), pressure transmitters (PT01-PT25), and motorized ball valves (V05-V26) are installed in the major supply lines of air piping system as shown in the simple diagram of Figure 2. Moreover, the 3-phase power meter using Modbus-RTU protocol (PM01) is also installed for monitoring the electrical energy consumed by the main compressors. To save space, Table 1 summarizes the tags and details of some field devices and equipment, which are connected to the analog input (AI), digital input (DI), digital output (DO) modules for data transfers in the proposed system. Figure 3 depicts the system architecture diagram for providing continuous monitoring and alerting functions in real time. The outputs of the FT01 and PT01-PT25 transmitters are connected to the AI modules, while the position indicators and control signals of the V05-V26 valves are connected to the DI and DO modules, respectively.

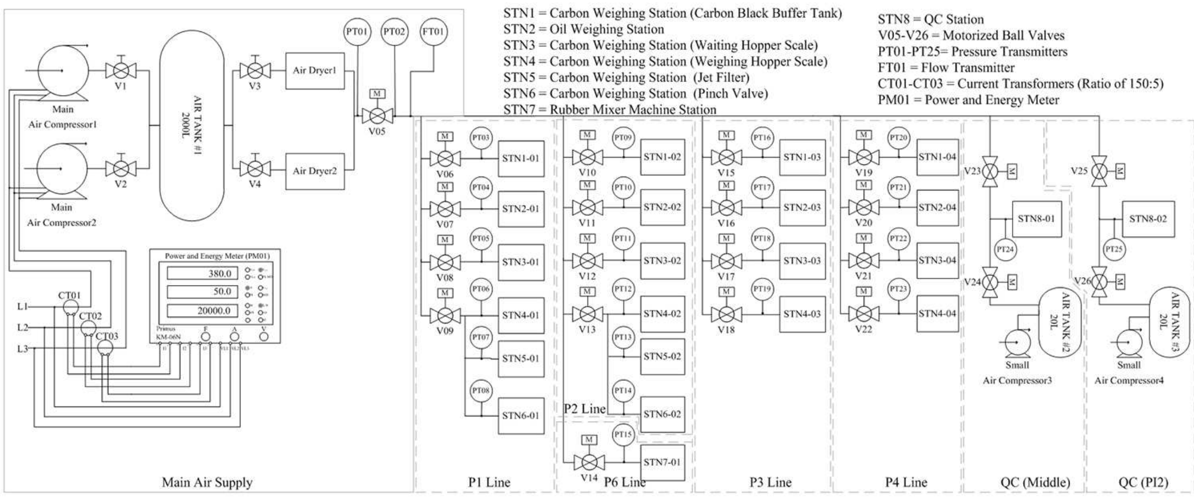


Figure 2. Simple diagram of the improved system for providing continuous monitoring

Table 1. Some device and equipment tags and details for the proposed system

Module	Tag	Description	Function
AI-01	FT01	To measure the volumetric flow rate of air.	Monitoring
	PT01	To measure the air pressure from supply side.	Monitoring & Alarm Notification
	PT02	To measure the air pressure for demand side.	Monitoring & Alarm Notification
DI-01	V05-I	To detect the actual position of the V05 valve installed between supply side and demand side.	Monitoring
DO-01	V05-O	To set the on/off position of the V05 valve, where the '1' and '0' logics are to open and close the valve respectively.	Control Command
CY-01 (PM01)	CT01	To measure the current in L1 transmission line.	Monitoring
	CT02	To measure the current in L2 transmission line.	Monitoring
	CT03	To measure the current in L3 transmission line.	Monitoring
	VL01	To measure the voltage drop across L1 line.	Monitoring
	VL02	To measure the voltage drop across L2 line.	Monitoring
	VL03	To measure the voltage drop across L3 line.	Monitoring

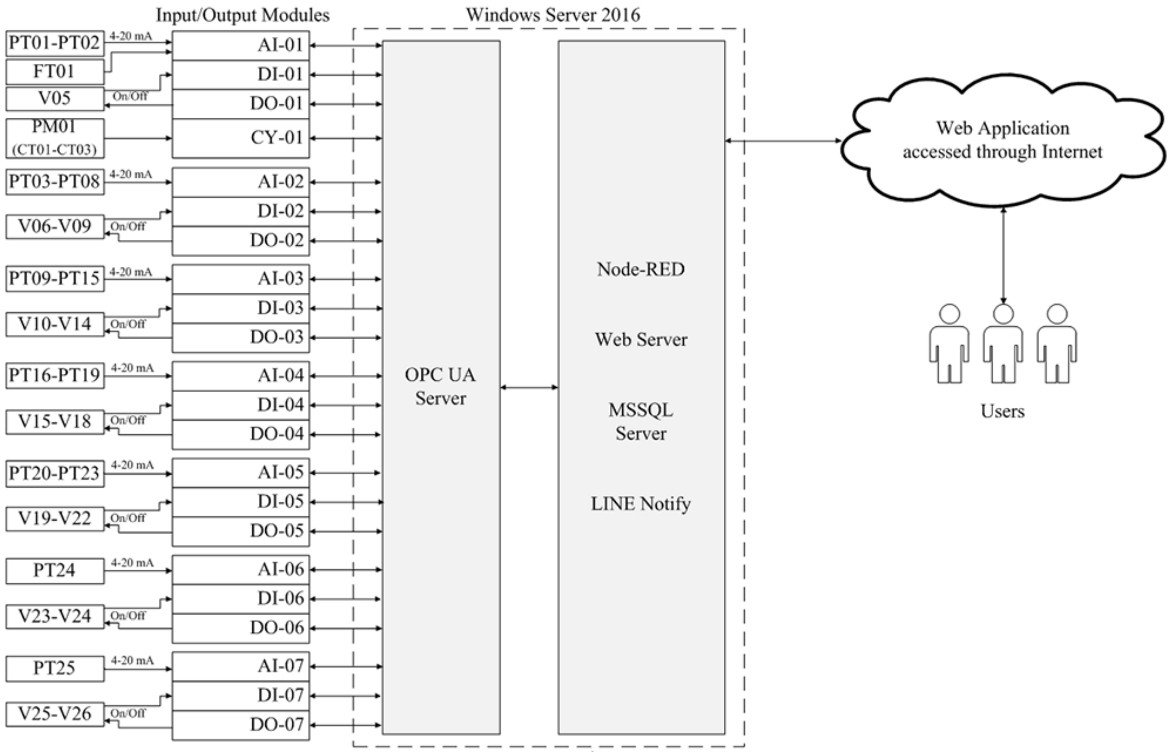


Figure 3. System architecture diagram for providing monitoring and alerting functions

The input/output modules function as the gateways to communicate between the field instruments and the host computer through Modbus TCP/IP protocol. The outputs of the PM01 meter are converted into the Modbus TCP/IP signals by using the CY-01 protocol converter. The host computer is connected with the Node-RED module for web application to operate as the OPC UA server and MSSQL server as well as to support the LINE Notify for alert notification.

Figure 4 shows a flowchart diagram for running the networked applications in the Windows Server 2016 to provide monitoring and alerting functions of the proposed system. The interested air supply parameters and actual valve positions can be displayed on the main and subpages of the created web dashboard by utilizing the AI and DI modules, respectively. The specified electrical parameters to determine the energy consumed by main air compressors can be also displayed on the dashboard main page by using the CY converter module. Based on the use of DO modules, the status of ball valves can be set on the dashboard subpages to be either fully opened (on) or fully closed (off) position. The operating statuses of the input/output modules are also monitored. The LINE Notify application is used for generating alert messages when detecting that the measured pressure readings fall outside an acceptable range (6.5-9 bar). There are three different alarm levels depending on how long is the measured air pressure value out of the acceptable range. The preset values of the timer used for alarm detections are 1 min, 3 min, and 5 min for alarm level 1, level 2, and level 3, respectively. The alarm level is also shown on alert messages to remind plant operators for quick responses. Figure 5 displays the browser-based flow editor of Node-RED programming tool. Figure 6 shows the examples of instruments installed at the plant and devices connected in the power cabinet for the proposed system.

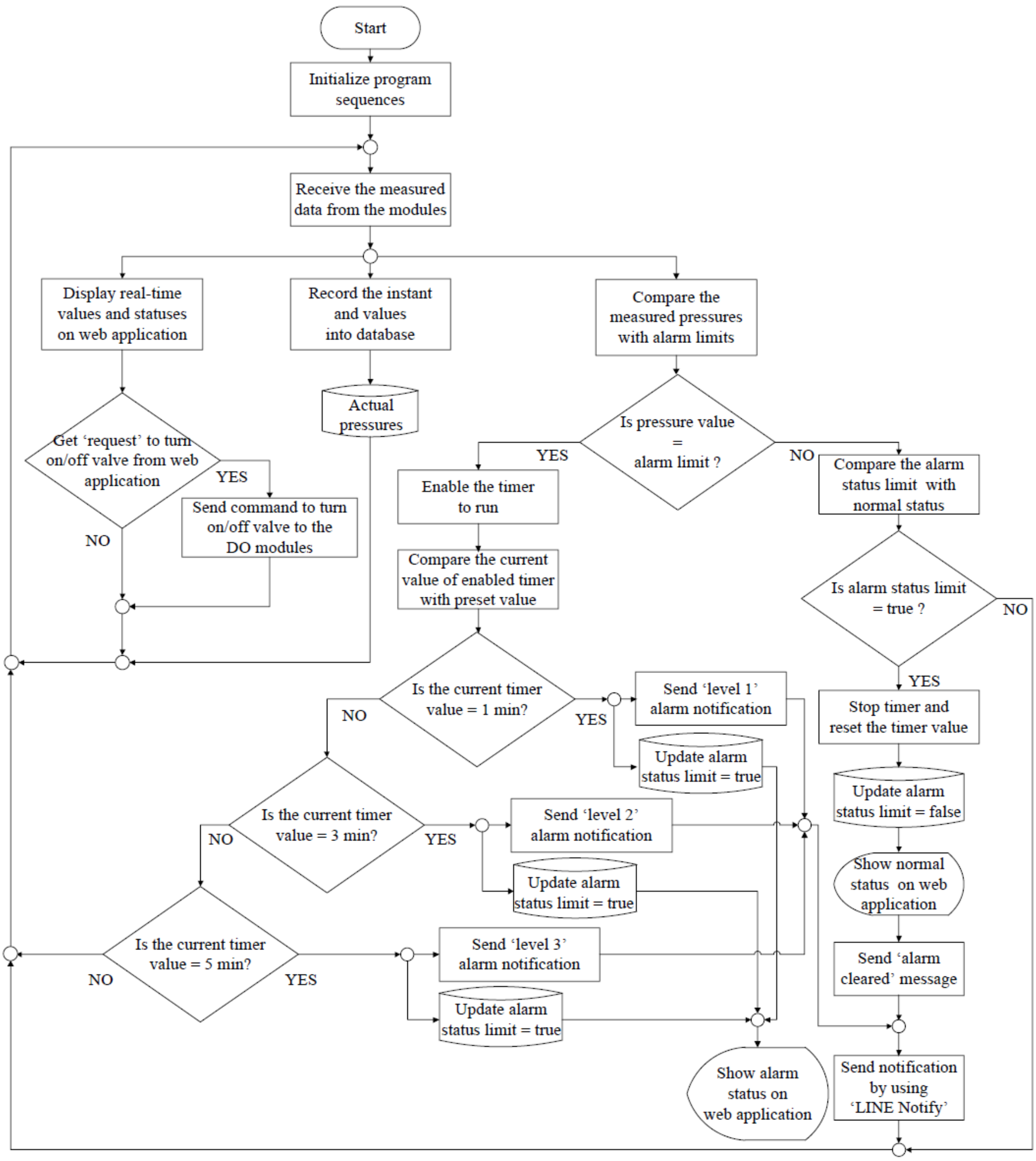


Figure 4. Flowchart diagram for running the proposed monitoring and alerting system

4. **Experimental Test Results.** To save space, only some experimental test results from air pressure measurements are given in Table 2. These pressure values were simultaneously obtained from the local display instrument, the MSSQL database, and the created web dashboard. It can be seen that the dashboard results agree very well with both the local display readings and the MSSQL database values. Figures 7(a) and 7(b) show the examples of experiments performed to verify the functional correctness of dashboard display and alert notification of the proposed system, respectively. Figure 8 illustrates the main page of created dashboard to continuously monitor the interested parameters including air pressures in the major supply lines of the overall system. The measured values from the transmitters and 3-phase power and energy meter are displayed. Figure 9 shows one of created dashboard subpages for showing the interested parameters of the QC (PI2)

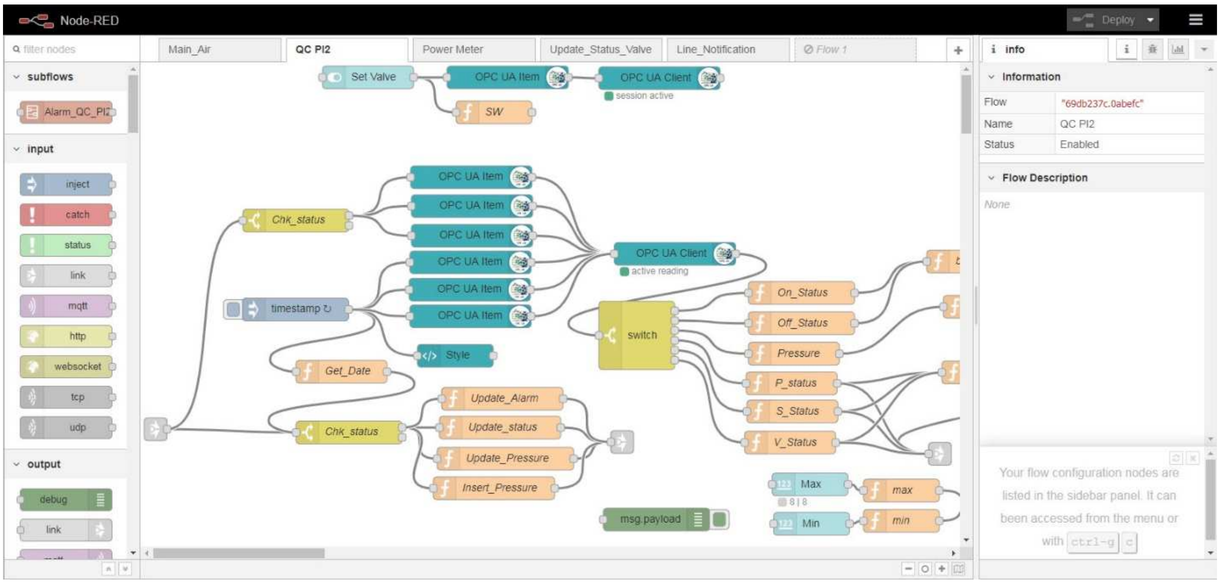
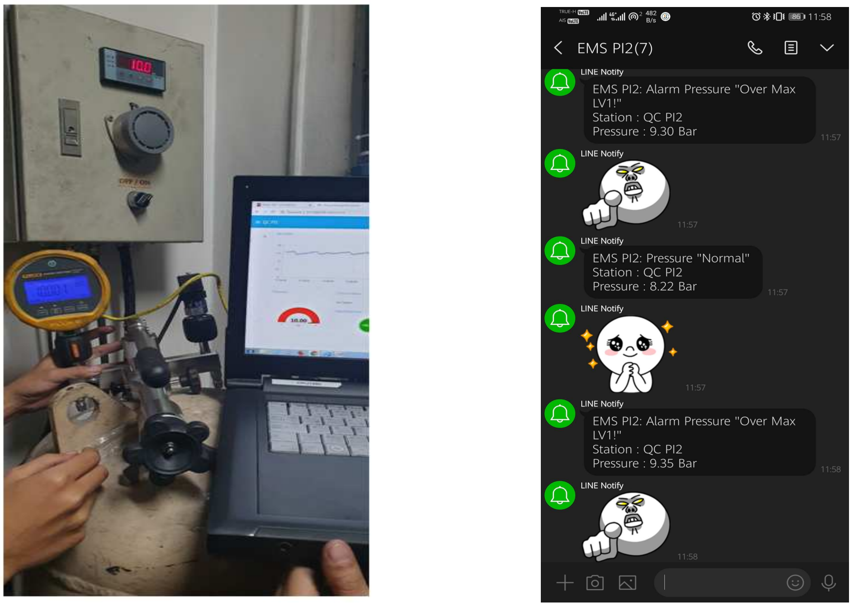


FIGURE 5. Browser-based flow editor of Node-RED programming tool

FIGURE 6. Examples of devices installed at the plant and connected in the cabinet

TABLE 2. Some experimental test results from air pressure measurements

Tag Name	1st Test Results			2nd Test Results		
	Local Display	MSSQL Database	Web Dashboard	Local Display	MSSQL Database	Web Dashboard
PT01	8.6	8.60	8.60	8.6	8.60	8.60
PT02	8.5	8.51	8.51	8.5	8.50	8.50
PT03	7.8	7.83	7.83	7.8	7.82	7.82
PT04	7.8	7.81	7.81	7.8	7.81	7.81
PT05	7.8	7.82	7.82	7.8	7.80	7.80
PT06	8.0	8.03	8.03	8.0	8.02	8.02
PT07	7.9	7.92	7.92	7.9	7.89	7.89
PT08	7.9	7.87	7.87	7.9	7.91	7.91
PT09	7.8	7.82	7.82	7.8	7.79	7.79
PT10	7.7	7.73	7.73	7.7	7.70	7.70



(a) To test display on dashboard

(b) To test alert notification via LINE Notify

FIGURE 7. Experiments performed to verify the proposed system workability

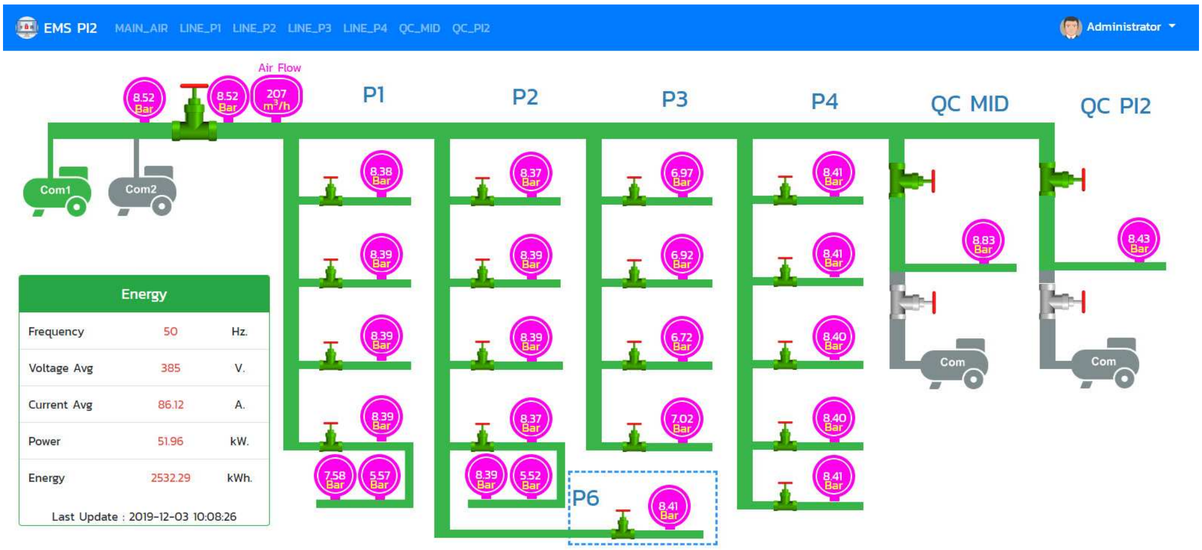


FIGURE 8. Main page to show interested parameters of the overall system

subsystem. The measured pressures from the PT25 transmitter are displayed in trend graph and semi circle donut chart, and the statuses of the AI-07, DI-07, and DO-07 modules are also shown for ease of troubleshooting and solving problems. The on/off status of the main valve (V25) and the second valve (V26) can be set. It is seen that the correct functions of the improved system can be obtained. This means that the proposed system can reduce production downtime by providing real-time alert notifications.

5. **Conclusions.** Improvement of existing compressed air supply of a rubber compound manufacturer by installing new power and energy meter, flow and pressure transmitters and motorized ball valves to offer continuous monitoring and remote on/off control has been described. A technique to create the dashboard monitoring and alerting system by utilizing Node-RED web application to reduce unplanned manufacturing production has

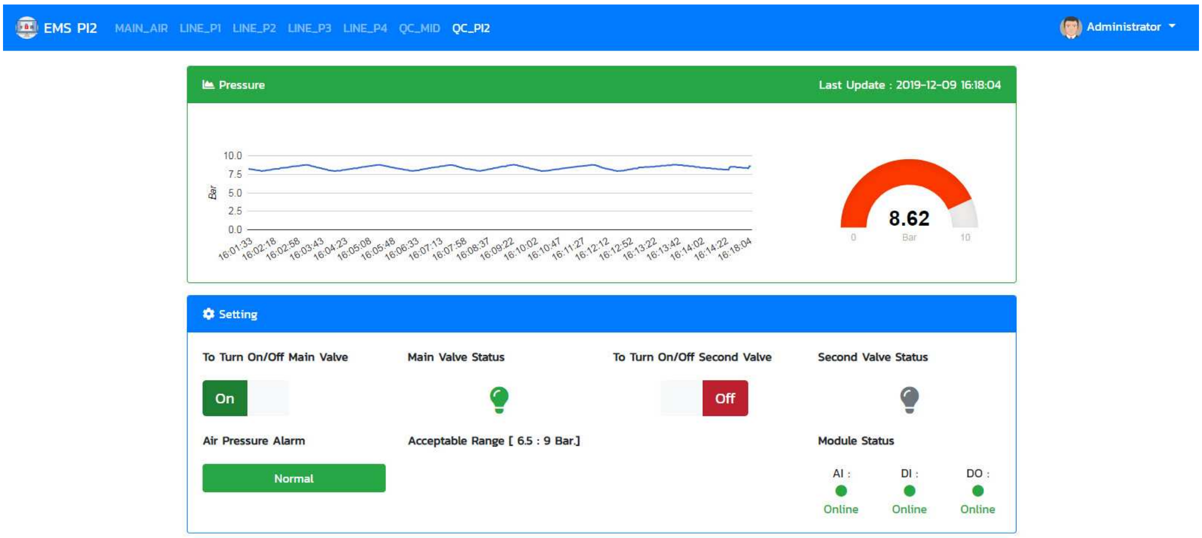


Figure 9. Dashboard subpage to show interested parameters of the QC (PI2) subsystem

been presented. Experimental test results confirm that the workability of the proposed monitoring and alerting system is in accordance with the manufacturer's specification requirements. Moreover, the proposed system with warning function in real time can support the plant personnel to predict and prevent the problems before they happen. A method to minimize energy consumption of the compressed air supply is the future work.

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