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Control and monitoring system of bio-mass weight feeder equipment in Indarung V PT Semen Padang

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ABSTRACT

The Industrial Revolution 4.0 encourages the application of intelligent technologies such as the Internet of Things (IoT) in industrial automation systems to improve efficiency, flexibility, and monitoring accuracy. This study aims to design and implement an IoT-based monitoring system integrated with the Siemens S7-1200 PLC on the biomass weight feeder tool at the Indarung V unit of PT Semen Padang. This system was developed to enable real-time and remote monitoring of equipment conditions, which previously could only be done from a local panel or control room. The design was carried out by combining ladder diagram programming on the TIA Portal and data visualization using Node-RED as an IoT platform. Testing was carried out in the laboratory through three main scenarios, namely variations in induction motor speed, alarm condition simulation, and connectivity testing between PLC, HMI, PC server, and PC client. The test results showed that the system was able to display speed and tool status data accurately with a delay time of less than one second. The indicator alarm successfully detected abnormal conditions and provided visual notifications appropriately. Connectivity between devices was also proven to be stable and synchronous during testing. With these results, this monitoring system is considered effective in supporting digital transformation in the industrial sector, especially in increasing the responsiveness and reliability of monitoring the biomass transportation process, and has the potential to be applied on a wider industrial scale.

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1. INTRODUCTION

The Industrial Revolution 4.0 has brought fundamental changes in various aspects of industry, including in the fields of automation and information technology [1]. This concept emphasizes the integration between the physical and digital worlds through the application of intelligent technologies, such as cyber-physical systems, cloud computing, and the Internet of Things (IoT) [2]. In the manufacturing sector, these changes drive operational efficiency, improve product quality, and reduce human involvement in routine and risky processes [3],[4]. One technology that has long been used to support industrial automation is the Programmable Logic Controller (PLC), which functions to control and monitor equipment and production processes automatically [5],[6]. PT Semen Padang, as one of the oldest cement companies in Indonesia, has adopted a PLC-based automation system, especially in the Indarung V unit. In this unit, the processing of alternative biomass-based fuels such as rice husks, sawdust, and palm oil waste is carried out using a weight feeder controlled by a PLC. This system consists of two main operating modes, namely Auto Mode which is controlled from the control room, and Local Mode which is controlled via an interface in the field. The operation of the tool involves the activation of several devices in sequence, including the air blaster, slide gate, double flap valve, and conveyor drive motor. This system is also equipped with interlocks to prevent damage and alarms as indicators of disturbances.

Despite supporting automation, existing monitoring and control systems still have limitations [7]. Monitoring of equipment conditions is completely dependent on the presence of operators at a particular location, either at the local panel or the control room [8],[9]. This dependency causes delays in detecting disturbances, reduces operational flexibility, and increases the risk of human error, especially in emergency situations that require a quick response [10],[11]. In this context, IoT technology offers solutions that are relevant to the needs of modern industry. IoT allows physical devices to be interconnected via the internet network and provide data in real time [12],[13]. Integration between IoT and PLC systems can create a more adaptive monitoring system, allowing remote monitoring using digital devices such as smartphones or laptops, and accelerating decision-making based on more accurate and up-to-date data [14],[15].

Previous studies have shown that the absence of a real-time monitoring system can cause significant operational disruptions, such as sudden machine breakdowns, which have a direct impact on the company's productivity and efficiency [16],[17]. This was also found at PT Semen Padang, where the biomass transportation system is still not equipped with an IoT-based monitoring system. In fact, a study by Ayu Wulandari [18] showed that the integration of IoT in the salt production system provides positive results in the form of higher operational efficiency and more flexible monitoring capabilities. By considering these problems, the development of an IoT-based monitoring system integrated with PLC is a strategic step to improve the quality of supervision, material transportation efficiency, and overall system reliability [19],[20]. This study aims to design and implement an IoT monitoring system in the biomass processing process using a weight feeder at the Indarung V unit of PT Semen Padang. It is hoped that this system can support the company's digital transformation towards the implementation of a smart industry that is more responsive, efficient, and adaptive to the challenges of the digital era.

2. METHOD

This study applies a systems engineering approach to design and implement an Internet of Things (IoT)-based monitoring system on a biomass weight feeder at the Indarung V unit of PT Semen Padang. The main objective of designing this system is to enable real-time and remote monitoring of equipment conditions, thereby increasing efficiency and responsiveness in the biomass material transportation process. Figure 1 shows the system design starting with the development of a block diagram as a visual representation of the system structure and interactions between components.

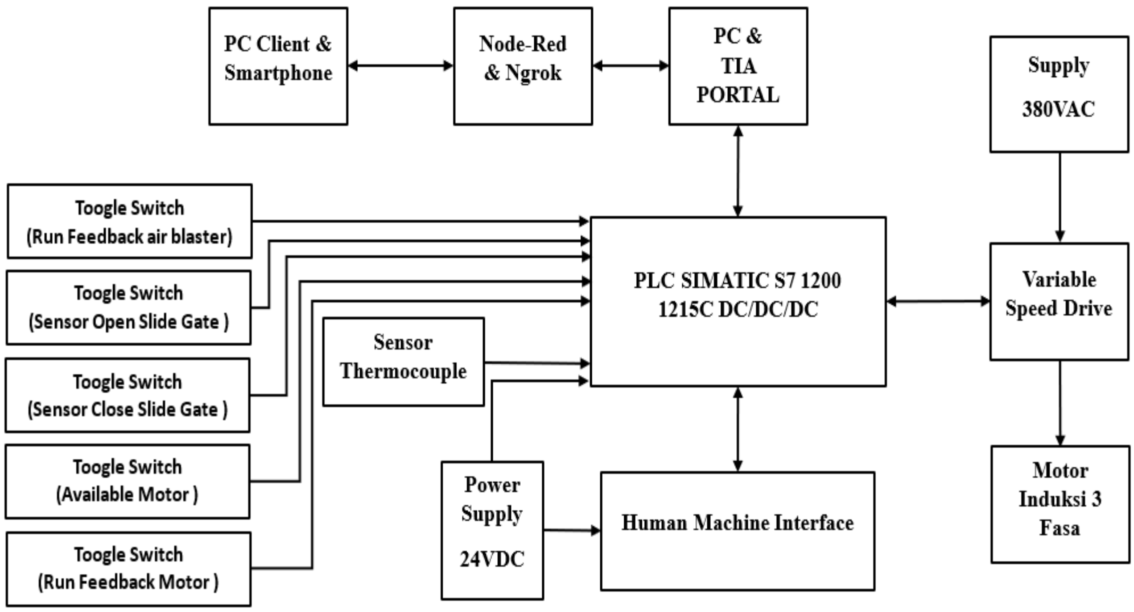


Figure 1. Block diagram of the biomass weight feeder system

Figure 1 shows the system is controlled by a Siemens S7-1200 PLC type 1215C DC/DC/DC as the main controller, which regulates the logic of the tool operation and communication between devices. This PLC is connected to various components via an Ethernet-based network using the SCALANCE module. The main power source consists of a 24VDC supply to support the PLC and HMI, and 380VAC to support the VSD (Variable Speed Drive) and three-phase induction motor. Thermocouple sensors are used to measure biomass temperature, while toggle switches function as a substitute for feedback signals from field devices such as air blasters, slide gates, and conveyor motors. The main hardware components in the system include PLC, HMI, induction motor, Siemens G120 VSD, thermocouple sensors, master PC, client PC, and mobile devices. The PLC controls the tool's operational process automatically and sends data to the monitoring system. The HMI provides a local user interface for direct supervision. The master PC is used for PLC programming with TIA Portal and IoT interface development with Node-RED, while the client PC and smartphone are used by the operator to monitor the condition of the device remotely via the web dashboard. Figure 2 shows the nodes that make up the IoT interface consisting of UI LED, UI push button, Function, S7 in and S7 Out.

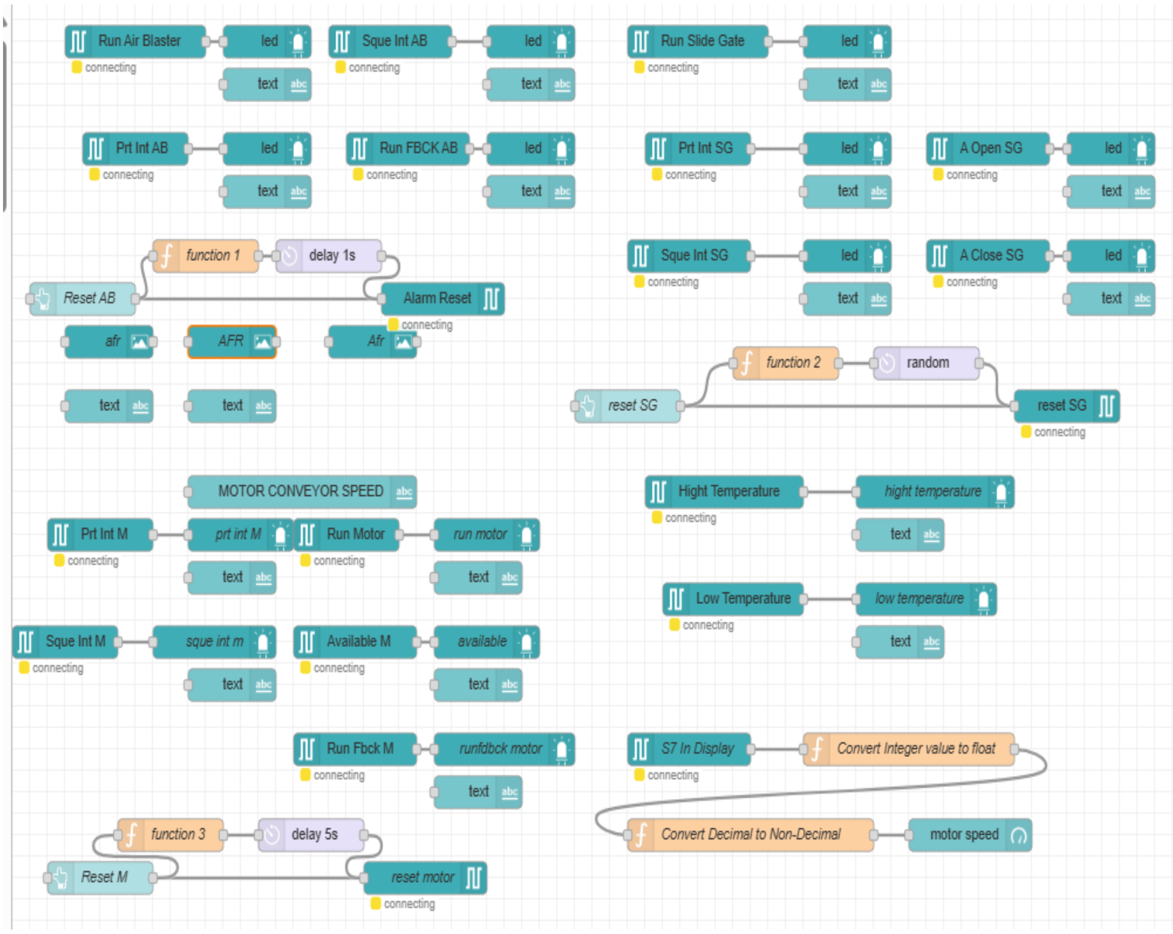
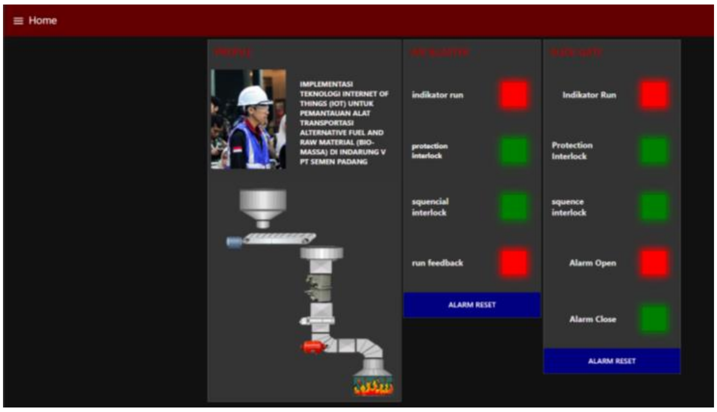
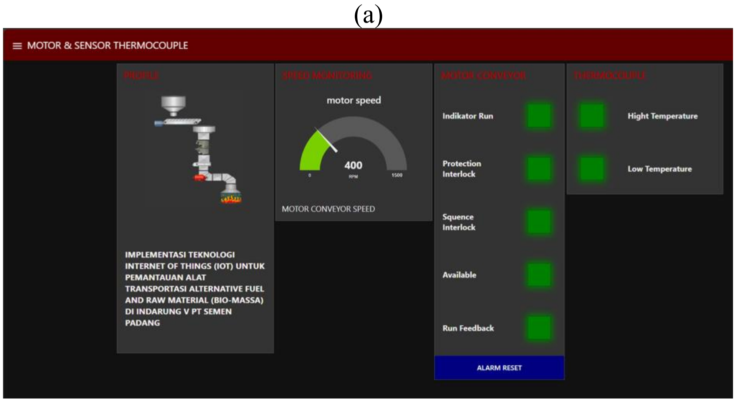


Figure 2. IoT Interface flow structure

The software design consists of two main parts. First, a ladder diagram is developed using TIA Portal to implement the system control logic, including interlocks, alarms, and Auto and Local operating modes. Second, the Node-RED platform is used as middleware to process data from the PLC and present it in the form of real-time visualization on the web interface. Node-RED allows data from sensors and device status to be sent directly to the client using a TCP/IP-based communication protocol. All device statuses and parameters are sent to the PLC, then processed by Node-RED and displayed through a digital interface. With this system, operators can monitor from various locations using PCs or mobile devices, thereby increasing work flexibility and minimizing delays in fault detection. Figure 3 shows the device status on the node-red interface sent from the PLC.



(a)



(b)

Figure 3. Visual display of IoT on node-red (a) home display (b) Motor and thermocouple display

3. RESULTS AND DISCUSSION

The testing of the Internet of Things (IoT)-based biomass weight feeder monitoring system using Node-RED was carried out through a series of experiments in a laboratory environment. The main objective of this test is to evaluate the system's performance in monitoring the operational conditions of the tool in real-time and remotely. The test focused on two main aspects, namely (1) monitoring the speed of a three-phase induction motor controlled by a Variable Speed Drive (VSD), and (2) monitoring and verifying the function of the alarm indicator for various abnormal conditions in the system. In addition, connectivity tests were also carried out between the PLC, HMI, PC server, and PC client to ensure the reliability of data communication in this IoT-based system. Figure 4 shows the hardware installation for the experiment.

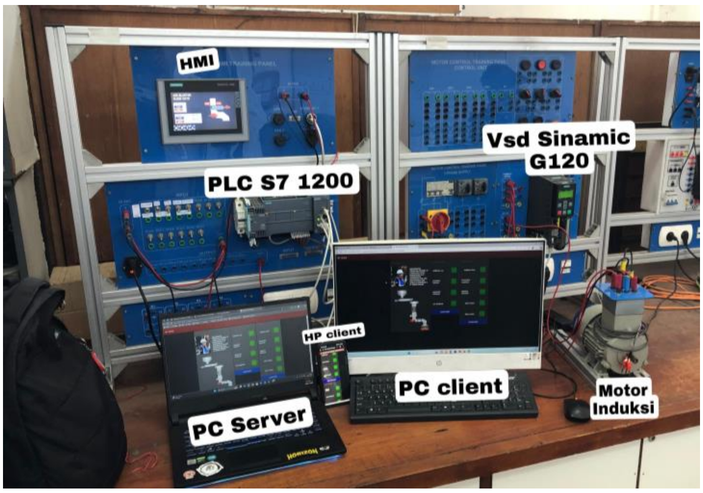
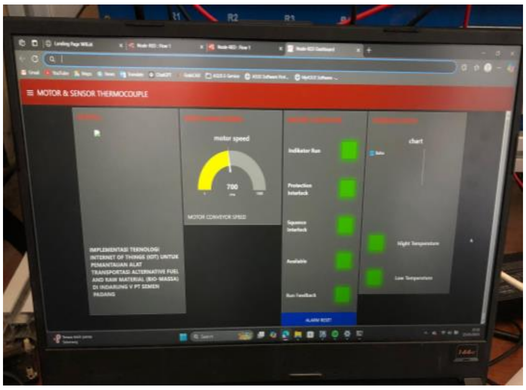


Figure 4. Hardware setup

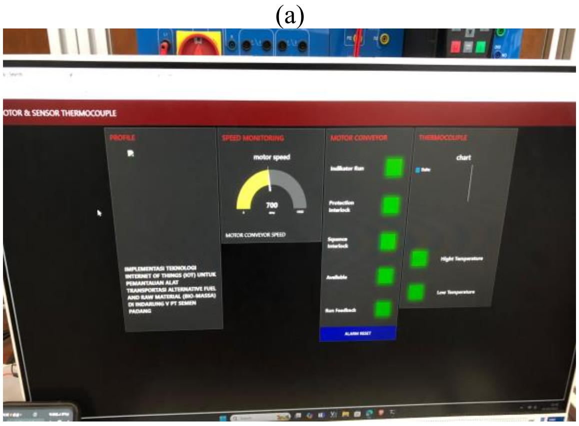
3.1. Motor speed monitoring test

Motor speed monitoring testing is carried out by varying the speed of a three-phase induction motor controlled by a Siemens G120 Variable Speed Drive (VSD). Speed control is carried out via the Human Machine Interface (HMI), while monitoring is carried out via a web-based dashboard built using the Node-RED platform. Figure 5 shows the results of motor speed testing.

(a)



(b)



(c)

(d)

Figure 5. Display of the motor speed monitoring test interface, a) 700 rpm speed operation on the HMI, b) 700 rpm speed operation on the server PC, c) 700 rpm speed operation on the client PC, d) checking the motor speed using a tachometer.

The test results show that the system is able to display motor speed data in real-time with an average latency of less than one second. The speed is set at 700 rpm. This speed value is sent by the Siemens S7-1200 PLC via an Ethernet network using the SCALANCE module to a PC server running Node-RED. The LED UI interface and numeric display successfully represent changes in speed values accurately and responsively. These results prove that the integration between the PLC, VSD, and IoT monitoring system has run according to design. The system's ability to update data quickly increases the effectiveness of monitoring tool conditions and supports fast decision making.

3.2. Alarm indicator testing

Alarm indicator testing is done by simulating abnormal conditions using toggle switches that represent feedback signals from field devices such as air blasters, slide gates, and conveyor motors. Simulated abnormal conditions include excessive temperature (thermocouple simulation), motor failure, and improper gate position. Each abnormal condition successfully triggers the alarm system on both the HMI and the web dashboard. The LED indicators on the Node-RED interface change color according to the programmed logic, such as red for active alarm conditions and green for normal conditions. In addition, alarm notifications also appear on the digital interface when error conditions are detected. The average response time from condition detection to the appearance of the alarm notification is recorded as less than one second. This shows that the alarm system designed through the ladder diagram in the TIA Portal and data processing in Node-RED functions well and reliably.

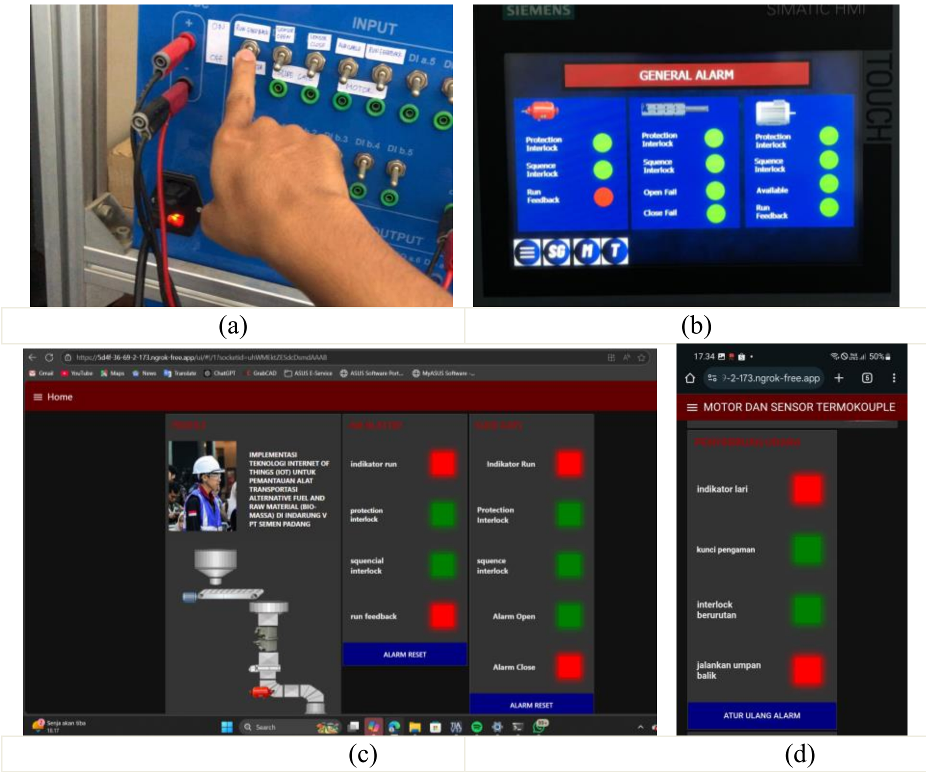


Figure 6. Display of alarm indicator test on air blaster green is safe, red is warning, a) toggle switch as feedback signal is turned off, b) red indicator appears on HMI, c) red indicator appears on server PC, red indicator appears on client HP

4. CONCLUSION

An Internet of Things (IoT)-based biomass weight feeder monitoring system using the Node-RED platform has been successfully designed and tested with satisfactory results. Tests show that the system is capable of monitoring induction motor speed in real time with fast and accurate response, and displays data changes synchronously on the HMI interface and web dashboard. The indicator alarm function also works well in detecting abnormal conditions such as motor failure and improper gate position. In addition, the connectivity between the PLC, HMI, server PC, and client PC is proven to be stable and supports uninterrupted data communication. With its remote monitoring capabilities and good system integration, this system can improve operational efficiency and equipment monitoring reliability, and has the potential for further application on an industrial scale.

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