



Design of Safety Monitoring System for Switching Substation using the Industrial Internet of Things

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Abstract. The vulnerability of switching substations to temperature and humidity levels inspired an IIoT-based security monitoring system to prevent fire hazards due to short-circuit electricity. An industry-standard security monitoring system is designed using PLC, HMI, and SHT20 - XYMD20 sensor module, which can measure temperature and humidity values simultaneously. In addition, the SHT20 - XYMD20 sensor module is equipped with Modbus protocol. PLC and HMI use Haiwell fabrication, equipped with RS485, RS232, and Modbus protocol. Modbus protocol is used to transmit sensor reading data to HMI and PLC. This sensor reading data is used as a trigger for warning alarms. The interface display is designed on the HMI screen and is connected to a mobile phone using IIoT. The interface design consists of the current sensor reading data, the threshold temperature value, the humidity level set, and an alarm if the current temperature of the switching substation exceeds the predetermined limit. The temperature value at the switching substation with the humidity level has a close correlation with a correlation value of -0.98, indicating that the temperature value is inversely proportional to the humidity level, which means the higher the switching substation temperature value, the lower the humidity level value, and vice versa.

Keywords: IIoT, Modbus Communication, Safety Monitoring System, Switching Substation

1 Introduction

Industrial Revolution 4.0 has significantly affected industry development, especially the automation sector. The application of Internet of Things (IoT) technology as part of the Industrial Revolution, 4.0 in the automation industry sector, allows remote real-time monitoring and control of a system [1]. IoT represents sensors, actuators, control instruments, and other devices interconnected in a network [2]. IoT and IIoT have the same principles, but the main differences are scalability, the volume of data generated, and data handling. In general, IIoT has a large amount of data needed for manufacturing

[3]. The development of sensor and actuator technology based on wired-based communication technologies such as serial communication, Fieldbus (Modbus, Profibus, and Highway Addressable Remote Transducer (HART)) and Ethernet-based communication and wireless-based such as wireless fidelity (Wi-Fi), Bluetooth and long-range (LoRa) allow the use of centralized communication protocols for monitoring and controlling data flow [4-6].

Over the last few years, research related to developing industrial standard IIoT using programmable logic control (PLC) and human-machine interface (HMI) has become the focus of researchers in implementing intelligent monitoring and control systems in industrial factories. Energy consumption monitoring systems and compressor performance efficiency research have been applied to refrigerators using IIoT technology [7]. This research still focuses on the monitoring system to collect observation parameter data. IIoT is used as a monitoring and control system for production processes in the manufacturing industry sector. Apart from that, IIoT technology was also developed to support the development of research related to monitoring systems for research devices, such as improving power quality in induction motors, smart grid performance with electric vehicles, and developing predictive maintenance schemes for diesel generators [8-10]. The application of IIoT covers manufacturing and high-tech industries and has developed in other industrial sectors such as livestock and agriculture. IIoT in the livestock industry sector is used to maintain the health condition of honey bee hives based on the hive's temperature, humidity, and sound conditions [11]. The application of IIoT in the agricultural industrial sector has been realized as a multimodal communication model to integrate systematic multi-vendor agricultural production systems [12]. This agricultural sector IIoT experiment was applied to small-scale hydroponics to ignite system performance regarding throughput, latency ratio, and packet delivery. Other agricultural sector applications of IIoT lead to predictive maintenance of high-tech agricultural equipment [13, 14].

The annual increase in electrical energy demand continues with economic growth and population. Based on the 2023 performance report of the Ministry of Energy and Mineral Resources, the need for electrical energy in Indonesia from 2019 to 2024 will experience an average annual increase of 6.58%. In an effort to guarantee the availability of electrical energy supply, technological improvements are being made in many aspects, including generation, transmission, substations, and development of smart grid infrastructure. The application of IIoT in the field of electrical energy supply is developed in the form of an integrated monitoring and control system between generators, transmission networks, and distribution networks in the form of a smart grid system [15-17]. One of the central infrastructures in a smart grid is a security system on the generator side and transmission and distribution networks. This paper discusses the security and monitoring system at switching substations based on temperature and humidity data, which is equipped with an early warning system to prevent fires. Experimental testing was carried out using industry-standard equipment with Modbus communication. IIoT is used to monitor the temperature and humidity conditions of switching substations in real time via a smartphone or website. The Early Warning System notifications will be sent when conditions can lead to a switching substation fire.

2 Materials and Methods

A security system based on switching substations' temperature and humidity conditions consists of hardware and communication system design. The hardware design of the security system uses industry-standard devices with the parameters shown in Table 1. The main components in the experimental testing, as shown in Fig. 1, consist of Haiwell C7S HMI, Haiwell PLC, and SHT20 - XYMD20 sensors, which have been integrated with communications. Modbus. Using sensors that meet industry standards means that security systems based on temperature and humidity conditions can be easily integrated with PLCs and HMIs. The sensors used are SHT20 – XYMD20, with sensor parameters shown in Table 2. This sensor has Modbus and RS485 communication protocols, which can be connected to PLC or HMI devices. In this security system, the HMI is a master, collecting temperature and humidity data from the SHT20 – XYMD20 sensors, which function as slaves. The PLC will process this sensor reading data to control the alarm in the switchgear security system. The Modbus communication protocol obtains temperature and humidity data from the SHT20 – XYMD20 sensors based on the register addresses in Table 3.

Table 1. HMI parameter

Parameter	Value
TFT Screen	7" (800 x 480 pixel)
Storage	4G + 512 M + SD
LAN	1
USB	2
COM	3
WiFi	No
COM Port	RS485 / RS232
Dimension (mm)	200 x 146 x 37

Table 2. Industrial sensor parameter

Parameter	Value
Product Name	Modbus RTU RS485 SHT Temperature Humidity Transmitter
Working Voltage	5 Volt ~ 30 Volt
Output Signal	RS485 Signal
Communication Protocol	Modbus RTU and ordinary protocol
Communication Address	1 ~ 247 (default 1)
Temperature Range	-40°C ~ 60°C
Temperature Precision	+ / - 0.5°C
Temperature Resolution	0.1°C
Humidity Range	0%RH ~ 80%RH
Humidity Precision	+ / - 3%RH
Humidity Resolution	0.1%RH
Work Temperature	-40°C ~ 85°C
Work Humidity	0% ~ 95%RH

Table 3. Modbus Protocol Address

Command Register	Function
0x03	Read keep register
0x04	Read input register
0x0101	Keep register (Device Address)
0x0102	Keep register (Baud Rate)

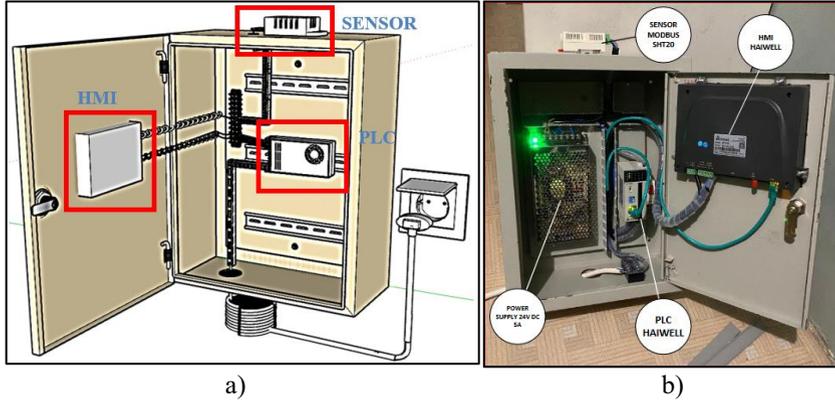


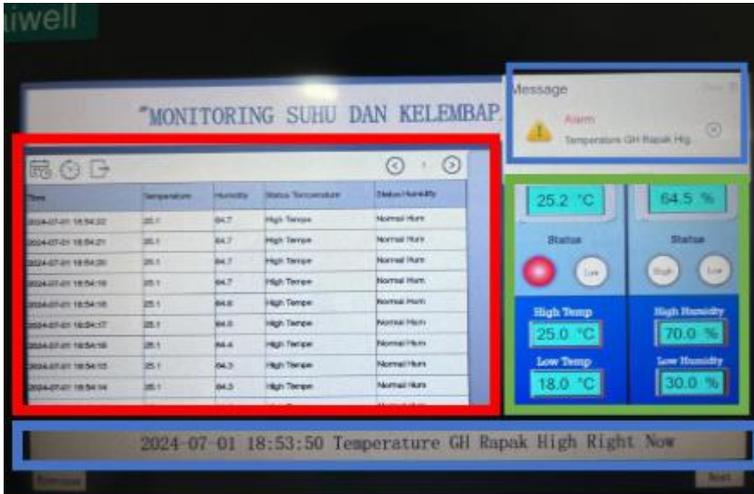
Fig. 1. Experimental setup of IIoT based safety monitoring system (a). panel design; (b). hardware implementation

The communication system protocol applied to experimental testing of switching substation security systems based on temperature and humidity conditions is designed using the Modbus communication protocol. The open protocol includes the communication protocol that can be used freely. In the design of experimental testing, Modbus is used to obtain temperature and humidity data read by sensors and then displayed on the HMI. The Modbus communication protocol has a simple construction that makes it easy to install relatively quickly. In addition, the Modbus communication protocol has extensive connection flexibility, such as RS-232, RS-485, and TCP/IP. The connection design in this substation security system uses an RS-485 connection to connect the SHT20 - XYMD20 sensor with the HMI. At the same time, communication between the HMI and PLC uses an RS-485 and TCP/IP connection. The switching substation security system is equipped with IIoT-based remote monitoring features. This monitoring system is designed using Haiwell cloud computing services that can be accessed through the Haiwell C7S HMI [18]. Haiwell Cloud is a data storage, computing, database, and mobile application. The Haiwell cloud has advantages such as cost efficiency, high scalability, and guaranteed data security.

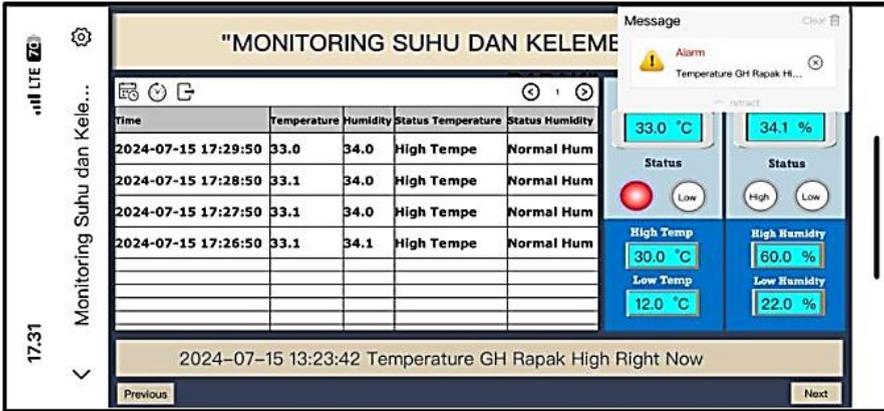
3 Results



Fig. 2. IIoT of safety monitoring system for switching substation



(a)



(b)

Fig. 3. Alarm of safety monitoring system for switching substation (a). HMI; (b). mobile phone

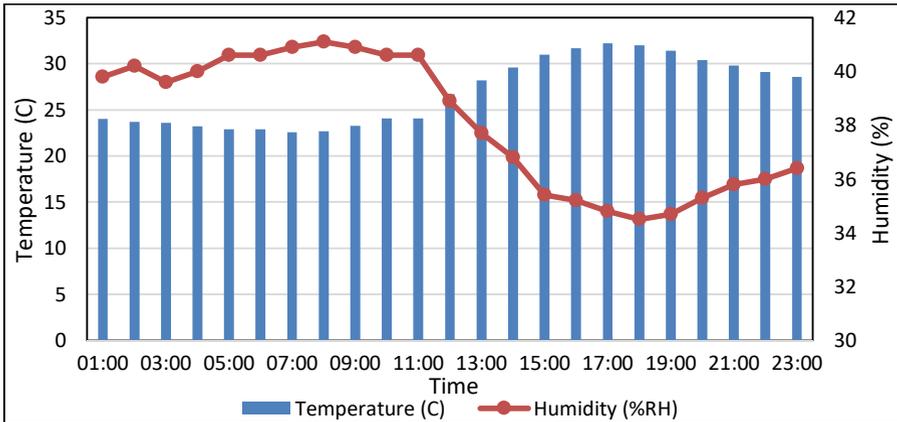


Fig. 4. Temperature and humidity monitoring results

4 Discussion

Research on temperature and humidity condition monitoring systems has been performed in various studies, as shown in Table 4. The studies have used sensor data acquisition devices not equipped with wireless modules that support IoT systems such as Arduino [19-20]. More modern devices, combining data acquisition devices with wireless modules such as ESP 8266 and ESP32, have been introduced since the era of the Industrial Revolution 4.0 in the domestic to medium industrial sectors with limited range and capacity. The IoT platform used has also evolved significantly in recent years. The IoT platforms, such as MIT App Inventor, Blynk, telegram, and Thinkspeak,

have experienced ease of application [21, 22]. In addition, these IoT platforms also provide easy access to databases such as MySQL and Firebase.

The IoT system is better known as IIoT in the complex manufacturing industry. The significant difference between IoT and IIoT systems lies in the use of hardware, the communication system, and the ease of design. The IIoT system uses devices commonly used in industry, such as PLC, HMI, sensor and actuator modules. In addition, the communication system used in IIoT uses Modbus, Profibus, and serial communication in the data transfer process. IIoT devices have a cloud-based storage system with easy access and data security.

Table 4. A review of humidity and temperature-based monitoring system in related study

Authors	Results of Research	Finding
Firdaus Hashim, Ruslina M., Murizah Kassim, Saiful Irwan., Nuzli Mohamed., and Anas Zaki A.B [23]	This research focuses on determining the right amount of water based on soil moisture and temperature data for tomatoes. This research uses Arduino uno as the data acquisition device of the DHT22 sensor, combined with LoraWan and Node-RED technology to realize IoT. The communication system in this research uses serial communication to transmit sensor reading data.	This study uses industrial-standard devices such as Haiwell HMI and PLC and SHT20 - XYMD20 temperature and humidity sensors. The Modbus communication protocol is used to transmit sensor reading data. Security features are added as an early warning system for temperature and humidity conditions of the substation. This study uses an IIoT platform connected to the Haiwell Cloud database. Current condition data and early warning system alarms are displayed on the HMI screen and mobile phone.
Farrukh Hafeez, Usman Ullah S., Attaulah K., M. Akram Bhayo, Saleh Masoud A. A., and Touqeer Ahmed J [24]	The hardware design in this research uses ESP8266 as a DHT22 sensor data acquisition device. This research is implemented in a robotic vehicle with recurrent neural network-based temperature and humidity value prediction.	
Rafizah Ar Rahman, Ummi Raba'ah H, and Sabrina Ahmad [20]	This research uses Arduino Mega2560 R3 equipped with an Ethernet shield to collect temperature and humidity data from the DHT 11 sensor. This research uses the AT&T M2X platform to design the IoT system.	
Dwi Ely K., Mohd Iqbal, John F., Rohmat Indra B., and Rio Rinaldi [25]	Temperature and humidity measurements were conducted in the server room. The temperature threshold in this study was 30 degrees Celsius, and the humidity was 60%. The hardware used in this study was Wemos D1 mini ESP8266 equipped with a DHT 11 shield and Raspberry Pi. Temperature and humidity reading data were stored in a MySQL database and sent to a mobile phone via WhatsApp.	

Experimental testing of the security monitoring system was conducted at the switching substation – distribution control implementing unit Kaltimra of State Electricity Company. The experimental test was performed 24 hours, with humidity and temperature data collected every 1 hour. The temperature and humidity data are displayed in tables and numbers on the HMI screen and the mobile phone, as shown in Fig. 2. The substation has a tolerance threshold for different humidity and temperature levels based on the technical specifications of the equipment used. The substation safety monitoring system was tested at temperatures of 25°C and 30°C with humidity levels of 60% and 70%, based on the operator's considerations, as shown in Fig. 3. The alarm function of the early warning system is activated when the substation temperature reaches the pre-determined thresholds of 25 °C and 30 °C. In addition, the alarm function is activated when the humidity in the substation exceeds the pre-set thresholds of 60% and 70%. This alarm function is displayed on the panel's HMI screen and the interface device on the mobile phone.

Fig. 4 shows the relationship graph between the switching substation temperature and humidity level. Temperature uses units of degrees centigrade, while the humidity level is expressed in percentage relative humidity (RH) units. Substation temperature during the night to morning tends to be low in the range of 22 °C to 24 °C, while in the afternoon to evening, the temperature will increase linearly and decrease at night. In contrast, the humidity level from night to morning is 39% to 41% and will decrease as the switching substation temperature increases. Based on correlation analysis, temperature and humidity levels have an inverse relationship with a correlation value of -0.98. It means that the temperature is inversely proportional to the humidity level; the higher the temperature value, the lower the humidity value.

5 Conclusions

The security monitoring system of the switching substation is designed using industry-standard equipment based on PLC, HMI, and sensor modules. PLC and HMI are designed using Haiwell, while the sensor module uses the SHT20 - XYMD20 module. The communication system and sensor data transmission use the Modbus communication protocol. The design of the interface display of the safety monitoring system for switching substations consists of the maximum temperature and humidity level values, the current sensor reading data in numeric form, and tables. The alarm is active while the current temperature and humidity exceed predetermined limits. The use of mobile phone-based IIoT makes it easy to monitor the current condition of the switching substation by the operator. Based on the results of temperature measurements and humidity levels, the switching substation has a close correlation with a value of -0.98, which can be interpreted as the temperature value at the switching substation is inversely proportional to the value of the humidity level that occurs.

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