Monitoring and Control Design of Automatic Transfer Switch-Automatic Main Failure with Human Machine Interface (HMI)

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ABSTRACT

Automatic transfer switch-Automatic main failure is a commonly used technology for shifting supply from PLN to a generator in the case of a PLN blackout. The ATS-AMF module system frequently employs a PLC, which comes at a high cost, and the system alarm information only is seen by the user close to the system. The purpose of this research is to design an automatic transfer switch-automatic main failure system that used SCADA to improve the reliability of electricity supply by providing notification alarm information and buzzers. This research contribution is a development of an automatic transfer switch-automatic main failure, which can be used as a simulator for studies on measuring voltage, current, power, and frequency of main power supply in real cases. Furthermore, this instrument is used fuel level and temperature measures for its backup power (Genset), the result of measures will be monitored SCADA system with the available failure data, alarm logs, and status logs recorded in historical data, which is designed at a low cost and is easy to use. This information result of the measured sensor will be transferred in real-time to the SCADA system, so can be directly obtained for analysis. The main components for this system are microcontroller STM32 Nucleo, PZEM 004T sensor, ultrasonic sensor, DS18B20 sensor, ethernet, and VTSCADA. The result of this system is the temperature detects 89°C, and alarm information has been sounded with the statement “Genset Temperature Warning HIGH” thus instructing the generator to turn off the system. Meanwhile, based on the results of the fuel adjustment test, SCADA gives the information “Genset Fuel Level Warning LOW” when setting the fuel at 36%. The data historical viewer that stores up to 6 months and alarm information for the warning system on the SCADA has been successfully designed.

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1. INTRODUCTION

Access to electricity is a basic need for people, so it requires a reliable electricity network. According to the International Energy Agency (IEA), Indonesia's population of more than 270 million citizens spread across 17000 islands, Indonesia is expected to become the world’s fourth-largest economy by mid-century and Indonesia emerges from the Covid-19 crisis and takes major steps towards growing its economy and modernizing its energy sector (IEA 2021 [1]). The developing countries, the most challenge faced by many micro and small enterprises (MSEs) is the reliability of electricity supply [2]. When the power supply is poor, the generator as a way to cope with power outages grows up productivity.

Automatic Transfer Switch (ATS) is a switchgear control system that provides automatic switching of power supply between public utility and generator. ATS also known as “Generator Transfer Switches, has an additional circuit component which is normally in form of a computer that monitors the incoming power supply [3]. The main supply and the generator occur in milliseconds, if the main supply is switched off, the generator automatically comes on and load is transferred back to the house. Also, if the main supply comes back on, the load switches from a generator to the main supplies, and this initiates generator shutdown [4][5]. Supervisory Control and Data Acquisition are used in automated management and manufacturing processes around the world to remotely and optimally control the entire production process in a plant, so it is improve production efficiency [6][7][8]. Furthermore, its can improve reliability, safety, and economic benefits of grid operations [9]. Supervisory Control and Data Acquisition comprise of I/O signal hardware, controllers, software, Networks, and Communications. SCADA system was being used in industries to control easily and simply, this performs four-function is data acquisition, networked data communication, data presentation, and control, and is a computer-based production procedure control and dispatching automation system [10][11][12].

Supervisory Control and Data Acquisition have been designed and applied in many fields. Table 1 presents a summary of the related work as well as the specifications and drawbacks of each research. The study in reference [13] introduced the design of automatic transfer switch (ATS) and automatic main failure with a capacity of 66 kVA using the DKG 207 datacom module. Reference [14] presented automatic transfer switch ACOS for backup supplying power in the ship with human-machine interface monitoring. Reference [15] presented the design SCADA system programmed by Java and the lower central controller and upper WEB monitoring system were connected by the SCADA system. Reference [16] presented developing SCADA system used Arduino microcontroller with graphical drawing Interface (GDI). In contrast, this research purposed a design Automatic transfer switch-Automatic main failure system that used SCADA to improve the reliability of electricity supply by providing notification alarm information and buzzers. This research contribution is a development of an automatic transfer switch-automatic main failure, which can be used as a simulator for studies on measuring voltage, current, power, and frequency of main power supply in real cases. Furthermore, this instrument is used fuel level and temperature measures for its backup power (Genset), the result of measures will be monitored SCADA system with the available failure data, alarm logs, and status logs recorded in historical data, which is designed at a low cost and is easy to use.

Table 1. Summary of the relevant work

Ref.	Method	Specification	Drawback
[13]	Modul deep sea DSE6020 MKII for controlling switch and display on LCD	Voltage, current, and power measurement display on LCD Module deep sea DSE6020 MKII	The cost of building is still not cheap, No information of failed system, No fuel level and temperature measurement.
[14]	Concern about design ACOS with PLC system	The design system distributes electricity with a centralized control system on PLC receiving instructions and has phase detection sensor failure	Only detection in a phase, the cost of building is still not cheap
[15]	Designed a SCADA system programmed by Java integrate WEB monitoring system	The SCADA system communicates with the upper WEB monitoring system with deliver them to the bottom central controllers over the UART Ethernet interface.	No historical data
[16]	Build a monitoring system based on an existing SCADA system and develop HMI software with a graphical user interface (GUI)	Sensors and actuators measurement show in HMI software in real-time data, used graphical user interface (GUI) design and stored in databases	No provide alarm information in case of system failure

2. METHOD

This study aims to design an Automatic transfer switch-Automatic main failure system that used SCADA to improve the reliability of electricity supply by providing notification alarm information and buzzers. The system design has three method stages: first, designing the hardware to establish a control system for voltage, current, frequency, temperature, and fuel level system, second, designing network architecture to deliver data monitoring, and third, analyzing the result of recorded data in supervisory control and data acquisition system. This research will validate our predictive ability based on the SCADA monitoring system using the available failure data, alarm logs, and status logs recorded in historical data. We will examine the effectiveness of predicting failure when there is entering multiple input variables in real-time data. Designing this system refers to the theories and datasheets of components collected from numerous credible sources in order to get optimal results and in accordance with what is desired. We have built a model representative of the ATS-AMF system with the SCADA system that will always provide information about the healthy state of the main power supply (PLN or Genset). Next, we have predicted the main power supply's health status in the testing, this healthy or failed system state of the ATS-AMF system will serve as a reference for getting analyze results. Therefore, when new SCADA data has been obtained, the deviations between the standard operation of the ATS-AMF system are compared with the latest data. These deviations will be tracked through the historical data menu; data points that go outside of the allowed fault threshold have been termed an anomaly.

2.1. The Architecture of Automatic Transfer Switch-Automatic Main Failure System

Fig. 1 shows the block diagram of the prototype. The main components for this system are microcontroller STM32 Nucleo, PZEM 004T sensor, ultrasonic sensor, DS18B20 sensor, ethernet, and VTSCADA.

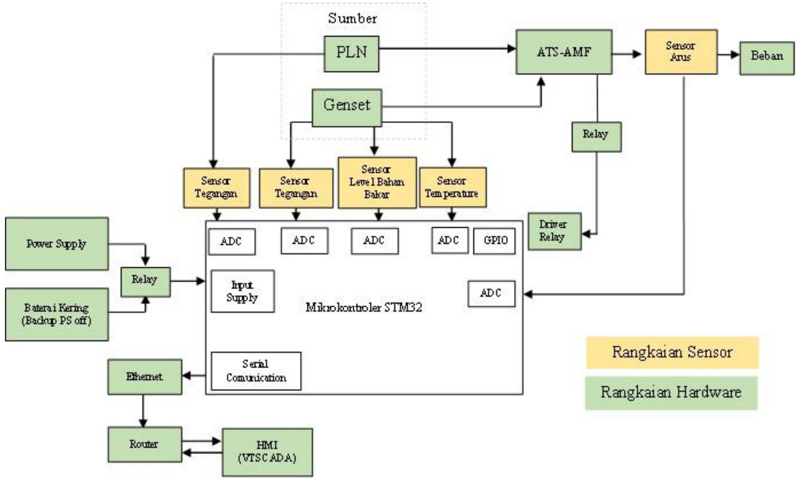

Fig. 1. Block diagram

The PZEM 04T is a multifunction AC power monitor used in electrical consumption measurement projects. It is great for measuring voltage, current, power, and energy, it comes with a serial TTL interface and the main part of the PZEM 004T module is of SD3004 chip [17]. The DS18B20 is a waterproof temperature sensor used to measure liquids, soils, or solutions, range temperature from -55°C to 125°C, and uses a 3.0–5.0 V supply for its operation [18][19]. This sensor worked at the voltage of 5V, so it is integrated with the microcontroller. Sensor ultrasonic is a sensor that works based on the tension of the working sound measuring the distance and speed of moving objects or persons, has two units, it is transmitter and receiver unit [20][21]. The ultrasonic sensor consists of a circuit ultrasonic transmitter called transmitter an and ultrasonic receiver circuit called the receiver. The ultrasonic signal generated will be emitted from the ultrasonic transmitter, when a trigger signal the sensor produces an up-transition TTL output, indicating that the sensor is calculating the measurement time [22][23]. The trigger pin transmits signals at a frequency of 40 kHz towards a space or a target, the waves are reflected and caught by the sensor through an echo pin, the distance is computed using the sound speed and the time from send to receive [24].

The ST has introduced the STM32Cube ecosystem which is a combination of software tools and embedded software libraries, and the inside the stm32Cube ecosystem have access to the following software packages are STMCubeMX, STMCubeIDE, STM32CubeProgrammer, and STMCubeMonitor [25]. The STM32 Nucleo series of low-cost microcontroller development boards are comprised of compact yet capable boards based on the cutting-edge 32-bit ARM Cortex-M architecture [26]. Microcontroller STM32 device processing input logic status from 32 input buttons that makes 32-bit word and there is master/slave architecture, where slaves scan the pins and send the status to the master device [27]. Compared with STM32F401 and other series of single-chip microcomputers as the core embedded system, sensors equipment testing has a higher, more accurate, reliable measurement, more stable system, and energy efficiency has been greatly improved [28][29].

Ethernet is a standard way to connect computers on a network over a wired connection, the interest in industrial applications of Ethernet-based solutions has greatly contributed to the worldwide standardization process that aims to develop an independent standard dedicated to industrial networks [30]. Ethernet provides a high transmission rate and excellent universality due to international standardization and supports various protocols such as the transmission control protocol/internet protocol (TCP/IP) and scalable service-oriented middleware over IP (SOME/IP) [31]. However, a recently created Ethernet that uses switching technology can circumvent these restrictions, and some work has been carried out to explore its application to vehicle communication and factory automation [32][33]. The Transmission Control Protocol/Internet Protocol (TCP/IP) suite is the most popular network protocol in use today, thanks mostly to the rise of the Internet, TCP/IP actually contains dozens of protocols working together to help computers communicate with one another which takes large blocks of information from an application and breaks them into segments [34]. The operation vessel as a Transmission Control Protocol (TCP) client communicates with the TCP server of the unmanned measurement platform through TCP mode [35].

The SCADA operations, such as data collection, control operations, and visualization, have undergone substantial changes because of technological advancements [36]. Modern power grids use supervisory control and data acquisition (SCADA) protocols for automation and “smart” operation. Smart grid which uses advanced approaches to control the critical infrastructures, the systems must be connected to the enterprise network [37][38]. Through the SCADA system, the nature of a fault can be seen efficiently, and conventional SCADA communication has been point-to-multifunctional in-line or private radio communications technology has been used more and more in SCADA communications with the advent of the Internet Protocol (IP) [39]. The delivery time of transmitted messages, which should not exceed the prescribed limitations, is the most important indicator of the quality of operation of the information and computer network. All of these operations in electrical systems are monitored, data logging, and controlled through an HMI, which is usually linked to the SCADA system's databases to save time and effort of critical infrastructures [40][41][42]. The control ATS-AMF used two contactors as a lock, the principle of this project if the mains supply is switched off, the generator automatically comes on. Also, if the mains supply (utility public) comes back on, the load switches from a generator to the mains supply.

2.2. The Design of SCADA System

The VTScada programming used Modbus address in the design of this project, it is used for STM32F401 Nucleo data communication with Personal Computer in the form of discrete coil data and analog data in the form of registers. Modbus address used Keil and VTScada software for writing program listings that contain Modbus address configurations sent to the STM32Nucleo microcontroller so that the microcontroller can store discrete and analog data in Modbus addresses. Fig. 2 shows tagging VTSCADA, and Fig. 3 shows the design interface VTSCADA, while the use of VTScada software on Modbus address is used to display the data sent by the microcontroller and give commands to the STM32F401 Nucleo microcontroller. Table 2 shows the type Modbus program at STM32F401 Nucleo.

Table 2. Address VTSCADA

No	Name	Tag VTScada	Modbus	Type
1	Tombol_Genset	00001	Mb.C[0]	Digital Control
2	Tombol_Switching	00002	Mb.C[1]	Digital Control
3	Lampu_Beban	00003	Mb.C[2]	Digital Status
4	Lampu_Genset	00004	Mb.C[3]	Digital Status
5	Lampu_PLN	00005	Mb.C[4]	Digital Status
6	Sensor_Tegangan_PLN	40001	Mb.C[5]	Analog Status
7	Sensor_Tegangan_PLN	40002	Mb.C[6]	Analog Status
8	Sensor_Arus	40003	Mb.C[7]	Analog Status
9	Sensor_Temperature	40004	Mb.C[8]	Analog Status
10	Sensor_Level	40005	Mb.C[9]	Analog Status

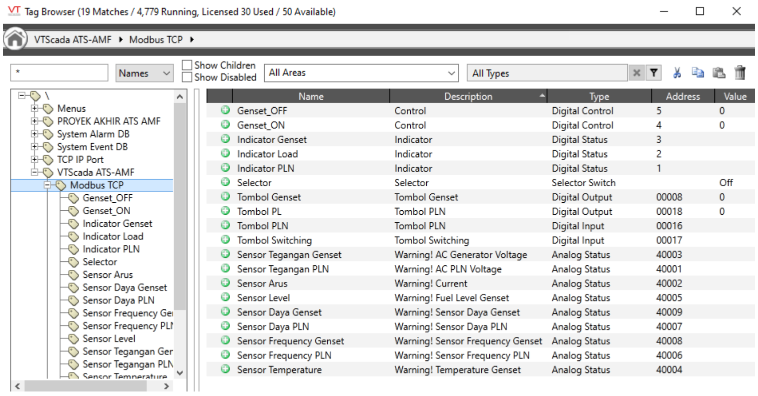

Fig. 2. Tagging List VTSCADA

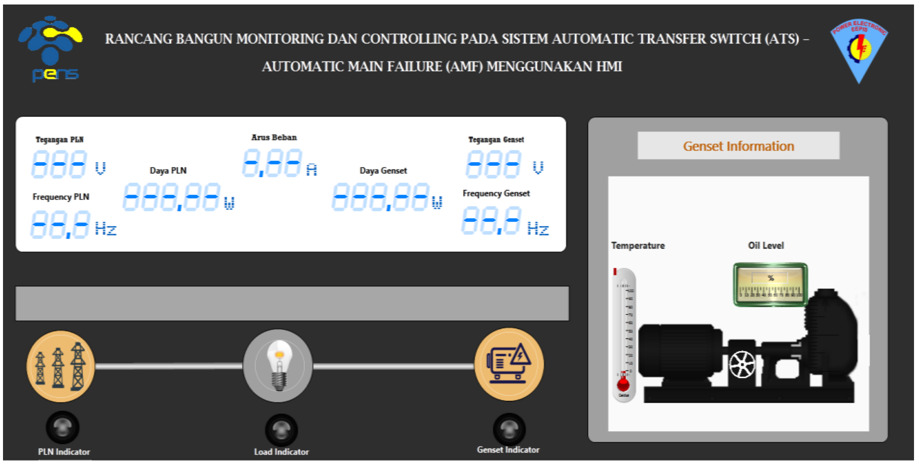

Fig. 3. Design Interface VTSCADA

2.3. Flowchart Monitor and Control System

The SCADA system invokes the “start” method, after that will invoke asynchronously the “run” method in the control system, and the alarm monitor processing is in the “run” method. The system receives the TCP/IP protocol data, after the received data, have been parsed and verified, they are classified as information notification setting systems on each alarm. The data are processed in four different notifications according to the results of the classification: Warning pada Fuel level Genset LOW, Warning! Temperature Genset High, Warning! Volage PLN High, and Warning! Volage Genset High. Fig. 4. Flowchart controlling system condition 1. For information required by alarm information regarding temperature, fuel level, and voltage, system condition 1 starts the address 00003 (digital status) worth 1, address 00002 (digital status) worth 1, and address 00001 (digital status) worth 0. Which is switch 1 microcontroller has been read “off”, after that Genset warming up.

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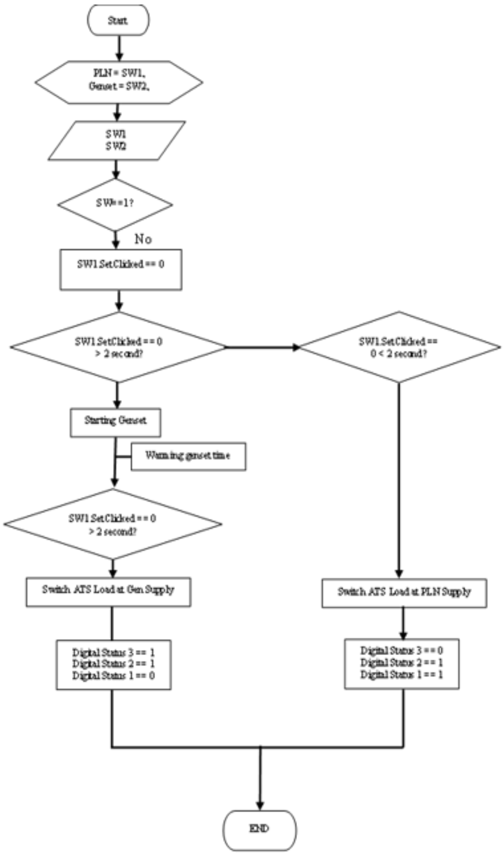

Fig. 4. Flowchart Condition 1

Flowchart controlling system condition 2 show as Fig. 5. The condition 2 starts the address 00003 (digital status) worth 0, address 00002 (digital status) worth 1, and address 00001 (digital status) worth 1. Which is switch 1 microcontroller has been read “on”, and load has been supplied main power.

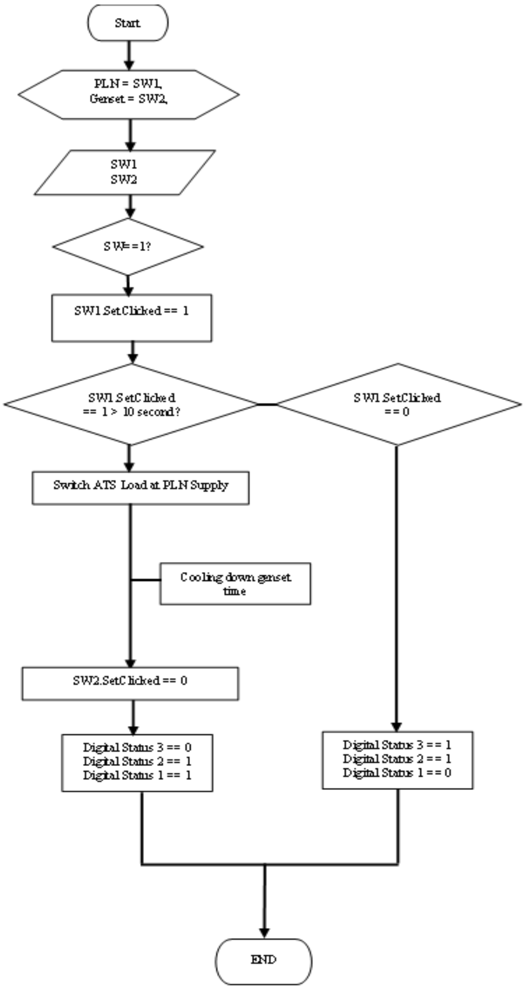

Fig. 5. Flowchart Condition 2

3. RESULTS AND DISCUSSION

Data collection using prototype shows as Table 3 for fuel level and Table 4 for temperature measurement. The prototype microcontroller connected ethernet, and software VTSCADA integrated TCP/IP for identifying IP port SCADA system, as shown in Fig. 6.

Fig. 7 shows as VTSCADA monitoring interface when testing the fuel level sensor. From Table 3, it can be analyzed that based on the alarms and indicator lights designed and tested on the PUIL 2000 basic system in point 8.21.5.3.4, in the running test the engine must be equipped with an indicator that sounds (alarm) and appears (light) when the engine fails to start or stops. And the existence of an alarm at the fuel level is designed based on the PUIL 2000 in point 8.21.3.3.1 which contains the fuel supply subsection so that the subsection discusses that every fuel tank must have an easily visible fuel gauge available. The content of 2/3 must be marked reminding the need to charge again. The gauge is made in such a way that if it is damaged, or in the presence of oil, it will leak. It also refers to NFPA 110 regarding the emergency and standby power systems subsection in chapter 4 which covers the design and use of emergency power supply systems that are divided into level 1 and level 2, where level 1 is equipment failure that can result in serious injury to people. equipment users while at level 2 regarding system failures that can ensure user safety, with this point, indicators and alarm system information are needed to ensure user safety. With PUIL and standard NFPA, when the fuel sensor detects below 2/3, there is an alarm detecting a low fuel level.

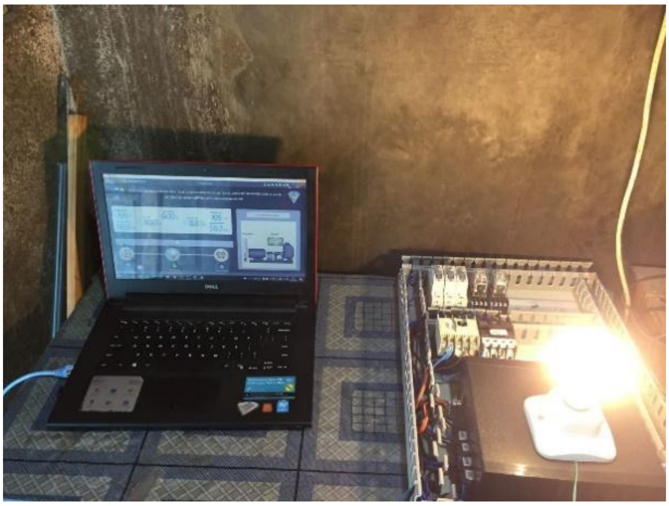

Fig. 6. Prototype of Automatic Transfer Switch-Automatic Main Failure

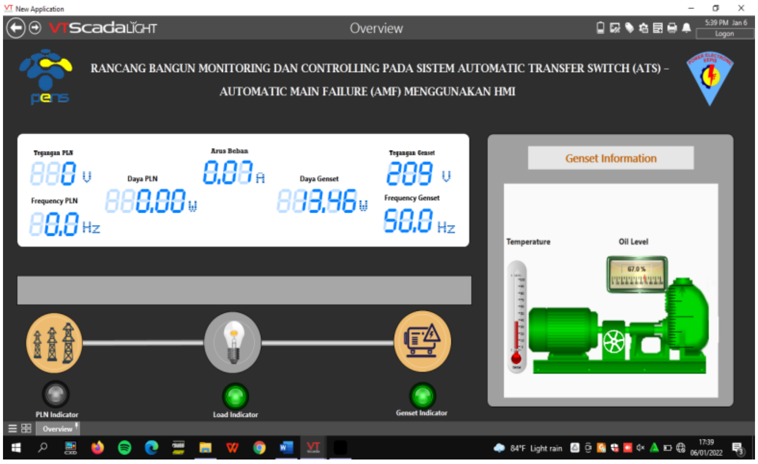

Fig. 7. VTSCADA Display when sensor tested

Table 3. Result of measurement fuel level

Time	V (V)		I (A)	P (W)	F (Hz)		Temperature (ºC)	Fuel Level	Alarm Information
	PLN	Gen			Gen	PLN			
20:43	0V	213	1.59	348.15	50	0V	37	96%	-
20:37	0V	213	1.59	348.15	50	0V	37	88%	-
20:24	0V	212	1.59	348.15	50	0V	37	76%	-
20:19	0V	213	1.59	348.15	50	0V	37	32%	Alarm on "Warning pada Fuel level genset LOW"
19:40	0V	212	1.59	348.15	50	0V	37	26%	Alarm on "Warning pada Fuel level genset LOW"
19:11	0V	213	1.59	348.15	50	0V	38	21%	Alarm on "Warning pada Fuel level genset LOW"
14:26	0V	195	0.07	13.02	50	0V	38	16%	Alarm on "Warning pada Fuel level genset LOW"

From Table 4, the temperature setting on the generator which is used as an alarm system is designed based on the characteristics of the generator engine, the efficiency of the engine operation, namely if the temperature is 60ºC-90ºC, the test is carried out by providing the operating limit of the engine. With this, there is a temperature sensor that is designed to be made if the generator has a temperature increase of more than 90ºC, the ATS-AMF system will give an off command and the alarm will turn on based on the real-time reading. This is related to the existence of Law No. 1 of 1970 on occupational safety regarding the prevention and protection of work accidents and is in accordance with UL 1008 regarding Standard for Transfer Switch

Equipment which reads transfer switch equipment where this standard pays attention to the condition of temperature rise which is clarified in point 9.8.2-9.8.12 which may cause system damage or create a fire risk.

Table 4. Result of measurement temperature sensor

Time	**V (V) (PLN)**	**V (V) (Genset)**	**I (A)**	**P (W)**	**F (Hz)**	**Temperature (ºC)**	**Fuel Level**	**Alarm Information**
18:32	0V	194	0.07	13.32	50	89	80%	Alarm on "Warning pada Temperature genset HIGH" & genset off
17:58	0V	195	0.07	13.32	50	59	80%	-
17:46	0V	195	0.07	13.32	50	51	80%	-
17:32	0V	195	0.07	13.32	50	49	80%	-
17:22	0V	195	0.07	13.32	50	43	80%	-
17:13	0V	195	0.07	13.32	50	31	80%	-
17:05	0V	195	0.07	13.32	50	28	80%	-

Fig. 8(a) display the history data viewer voltage and frequency sensor, which displays a real-time and a graphic of voltage and frequency that stores data up to 6 months. Fig. 8(b) shows the history data viewer temperature and fuel level generator for real-time, and a graphic show time movement and that stories data up to 6 months. Fig. 9 shows a warning system that will notify if the sensor upper setting, notification in the form buzzers and text message.

(a) (b)

Fig. 8. History Data Viewer, (a) frequency and voltage sensor, (b) Temperature and Fuel Level Sensor

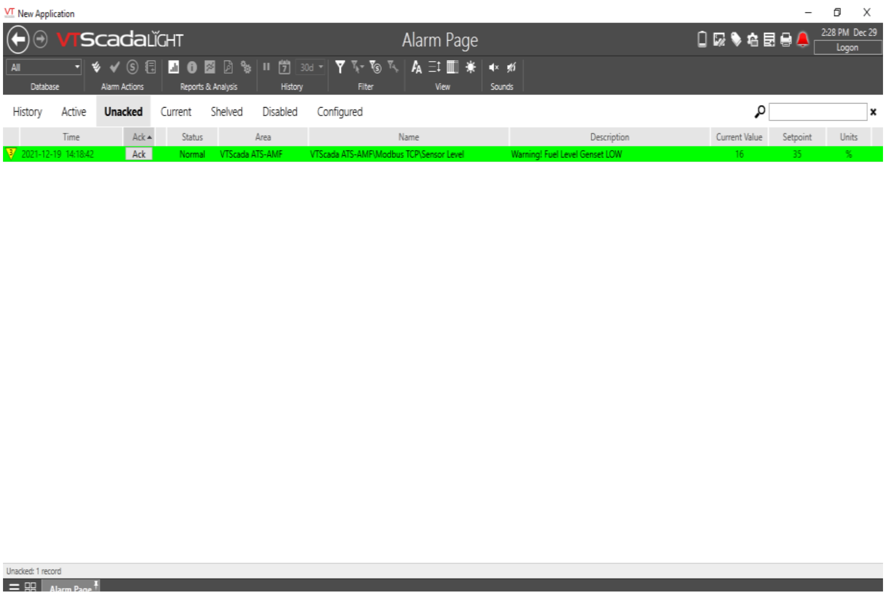

Fig. 9. Alarm page SCADA

4. CONCLUSION

Based on the research data described above, conclusions can be drawn from monitoring system used real-time, history viewer that stores up to 6 months, and alarm information for the warning system on the SCADA has been successfully designed. Setting generator set of temperature sensor by providing input 28ºC-89ºC then the alarm information sounds with the statement "Genset Temperature Warning HIGH" when the temperature detects 89ºC thus instructing the generator to turn off the system, which is in accordance with UL1008 regulations concerning Switch Equipment Standards Transfer. Meanwhile, based on the results of the fuel adjustment test, SCADA gives the information "Genset Fuel Level Warning LOW" when setting the fuel at 36%, this is by PUIL 2000 and NFPA 110.

Acknowledgments

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