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Overvoltage Reduction System for 220V Electrical Requirements Against Overloads

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Abstract
Overvoltage disturbances in the 220V electrical system can cause damage to electrical equipment and reduce operational efficiency, especially in industrial environments that depend on a stable power supply. This study aims to design and realize an overvoltage disturbance repair system for overloads based on the Internet of Things (IoT) with real-time voltage monitoring and control capabilities. This system uses an ESP-32 microcontroller integrated with ZMPT-101B, ACS712, DHT-22 sensors, and an AC Dimmer module, and utilizes the Firebase platform and website as monitoring media. The method used is Research and Development (RnD), starting from needs analysis, hardware and software design to the testing stage. The system was tested under three load conditions: minimum, medium, and maximum, in two scenarios: without and with an overvoltage system. The test results show that the system is able to maintain the voltage within safe limits according to the SPLN No.1:1995 standard (198 V - 231 V) and cut off the electricity supply when the voltage exceeds the tolerance limit. Furthermore, monitored temperature and humidity data also maintain overall system stability. In conclusion, the developed system has been proven to correct overvoltage, protect electrical components, and facilitate remote monitoring. This research contributes to the development of IoT-based voltage protection technology that can be applied in both industrial and residential environments.

Keywords: Control Systems, Over Voltage, IoT, Real-Time Monitoring

1. INTRODUCTION

The stability of an electrical system is a critical factor in ensuring the effective operation of industrial machinery. This is particularly evident in the context of electricity supply with a nominal voltage of 220 V, which is widely utilized across diverse industrial sectors [1]. Electrical disturbances, including overvoltage, have been demonstrated to result in equipment damage, diminished operational efficiency, and an elevated risk of systemic production malfunction [2]. Conversely, voltage irregularities have been shown to lead to diminished operational efficiency, as well as an augmented need for maintenance and machine downtime [3]. This condition has been observed in various industrial contexts, including PT Univenus Surabaya, a tissue manufacturing facility that operates on a 24-hour basis with numerous automation systems that are vulnerable to voltage fluctuations.

The phenomenon of overvoltage arises due to the system's weakness in regulating the incoming mains voltage, particularly in instances of overloading or sudden load shedding. Voltage levels that exceed the standard tolerance limit specified in SPLN No.1:1995 (-10% to +5% of 220 V) have the potential to induce malfunctions and even damage to electronic components such as programmable logic controllers (PLCs), contactors, and drive motors that facilitate the production process [4]. At PT Univenus Surabaya, for instance, overvoltage disturbances have been the cause of tissue production machines ceasing to operate and resulting in losses due to significant downtime. The advent of the Internet of Things (IoT) has precipitated the evolution of innovative solutions, exemplified by the integration of real-time voltage monitoring and control systems with cloud platforms [5]. The employment of microcontrollers such as the ESP-32, in conjunction with precise voltage and current sensors, facilitates the early detection and automation of voltage regulation in electrical loads This, in turn, contributes to the extension of equipment lifespan and the enhancement of process reliability within industrial contexts [6].

The urgency of this research is of paramount importance, as the stability of the 220V electrical system is a crucial factor in ensuring the continuous operation of industrial machinery [7]. Frequent overvoltage disturbances have the potential to cause damage to electrical components and reduce production efficiency, particularly in companies like PT. Univenus Surabaya, a company that relies on a stable supply for the operation of automated machinery in the tissue manufacturing process, is an exemplary of this phenomenon. The failure to detect and address undetected and unaddressed overvoltage conditions can result in system control malfunctions and even total machine failure, which can lead to significant time and cost losses.

Moreover, the conventional approach of manual voltage and system condition monitoring has been demonstrated to be deficient in terms of responsiveness and efficacy in addressing disruptions. Consequently, the implementation of the Internet of Things (IoT) technology for real-time overvoltage repair and monitoring systems offers an innovative and pertinent solution [8]. This system has been demonstrated to provide automatic protection against voltage surges. In addition, it has been shown to enable remote monitoring, optimize machine management, and facilitate maintenance. Consequently, the present study emphasizes the necessity of enhancing the reliability of electrical systems and industrial productivity through the development of IoT-based protection technology [9].

The objective of this research is to design and implement an Internet of Things (IoT)-based overvoltage fault repair system for 220-volt electrical needs. This system is capable of monitoring and controlling voltage conditions in real time through a website. It is anticipated that this system will maintain voltage within acceptable limits as per standard guidelines, deactivate electricity in the event of hazardous overvoltage, and present environmental data, including temperature and humidity, which contribute to the system's operational stability [10].

The research methodology employed a research and development (RnD) approach, encompassing a needs analysis, hardware and software design, and an evaluation of system performance through trials under various load conditions. The findings are anticipated to contribute to the development of IoT-based voltage protection technology that is applicable to industrial environments and household use.

2. METHOD

3.1 Contruction Method

The research design method was executed in stages, as delineated in the subsequent steps.

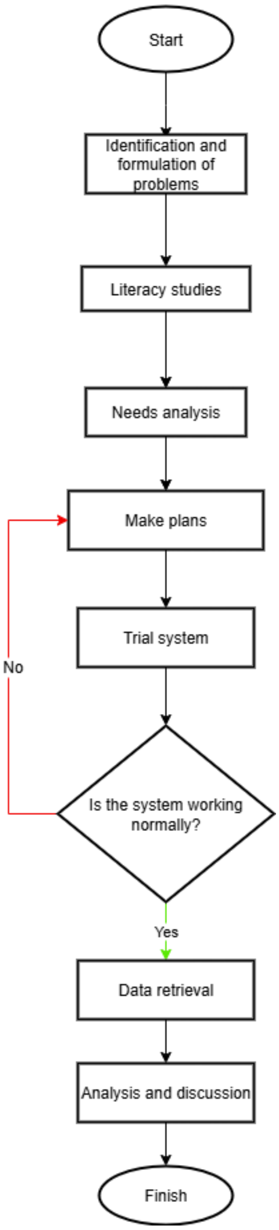

Figure 1. Flowchart Research Method

Figure 1 presents a flowchart delineating the stages involved in the creation and testing of a system through the utilization of the Research and Development (R&D) method [11]. The process commences with the initial step, designated as "start," which is followed by the identification and formulation of problems to ascertain the issues occurring in the production machines at PT. Univenus Surabaya. Following the identification of the issues, a "literature review" is conducted to gather and understand information related to the concept of an IoT-based overvoltage improvement system. Subsequently, a "needs analysis" is conducted to ascertain the necessary components. Subsequently, the "Design Development" stage is initiated to conceptualize the system in accordance with the stipulated requirements. The components, which have been meticulously designed, will undergo rigorous testing in the "Equipment Testing" stage. This stage is instrumental in ascertaining the system's functionality and identifying any potential anomalies. If the system does not operate in accordance with the established parameters, the process reverts to the "Design Development" stage for the purpose of revising the system. If the system functions in accordance with its intended design, the process advances to the subsequent stage, designated as the "Data Collection" stage. The final stage is the "Analysis and Discussion" of the obtained data, concluding with the "Completion" stage, indicating a cycle that may be repeated for further refinement.

3.2 Hardware System Design

This section delineates the hardware design process, emphasizing the selection and specifications of components necessary for the overvoltage repair system. The hardware system in the IoT-based overvoltage repair system will elucidate the circuitry and the functionality of each device in the designed system [12].

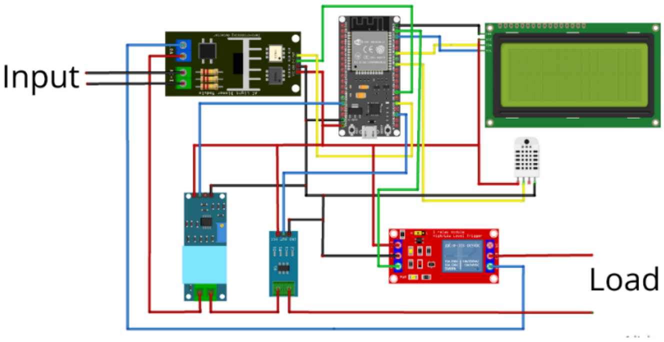

Figure 2. Hardware System Design

The hardware design is depicted in Figure 2, which illustrates the hardware design scheme of the overvoltage correction system. This system can be monitored remotely via an LCD screen through a website connected to the internet. The primary sensors employed in this system are the ZMPT-101B, the ACS712, and the AC dimmer module. These components serve as the function of overvoltage output voltage correction. The ZMPT-101B and ACS712 are utilized to assess the AC output voltage and current of the dimmer [13]. The tolerance is in accordance with the standard of the SPLN, which ranges from -10% to +5%. Furthermore, the module incorporates a DHT-22 sensor, which serves to monitor temperature and humidity levels within the module. The device's operational parameters are delineated by specified limits, and the occurrence of overvoltage is detected by the device [4]. If the device's operational limits are exceeded or overvoltage is detected, the electrical current is automatically interrupted by the relay, thereby ceasing the system's functionality. Each device is processed by an ESP-32, which is equipped with integrated cloud monitoring capabilities. The resulting data is then displayed on an internet-connected website [14].

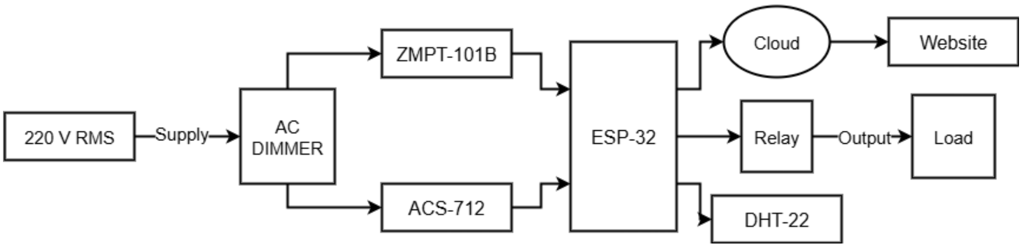

Figure 3. Hardware Block Diagram

Based on Figure 3 above, the block diagram depicts the operational mechanism of the IoT-based Overvoltage Repair System module. The principle of operation is as follows: when the system is active and receives an input voltage, the ESP-32 microcontroller responds by using a relay and sending logic to the AC dimmer module to calibrate the system [15]. After the calibration process, the voltage is set to 220VAC, which is then measured by the sensors and directed to the load. The programming for each sensor can be viewed in Appendix 1. The ESP-32 is responsible for processing data from the sensors to display on the LCD and transmit to the cloud (Firebase). The relay is designed to function in the event of a system malfunction by disconnecting the current and activating the indicator light [12]. In the event of undervoltage, the red indicator light is illuminated; in the event of overvoltage, the yellow indicator light is illuminated; and if the voltage is within the normal range, the green indicator light is illuminated. The LCD display presents the results of current, voltage, temperature, and humidity measurements, which are recorded in real-time and transmitted to a website connected to the internet [16].

3.3 Software Design

The software design for the IoT-based overvoltage repair system facilitates the collection of data from sensors and the subsequent transmission of that data to a predetermined website. The programming process utilizes the Arduino IDE (Integrated Development Environment) and Visual Studio Code with JavaScript and libraries from React Native [17]. This website provides comprehensive coverage of software development and programming processes, with a particular focus on sensors. The program incorporates a series of steps, including the implementation of logic to regulate the sensors, the selection of data types, the initialization process, and the designation of names within the software. The monitoring system will be connected to an LCD and a website accessible via the internet, with data retrieval through the cloud (Firebase) integrated with the ESP-32 as the system's central processing unit [18].

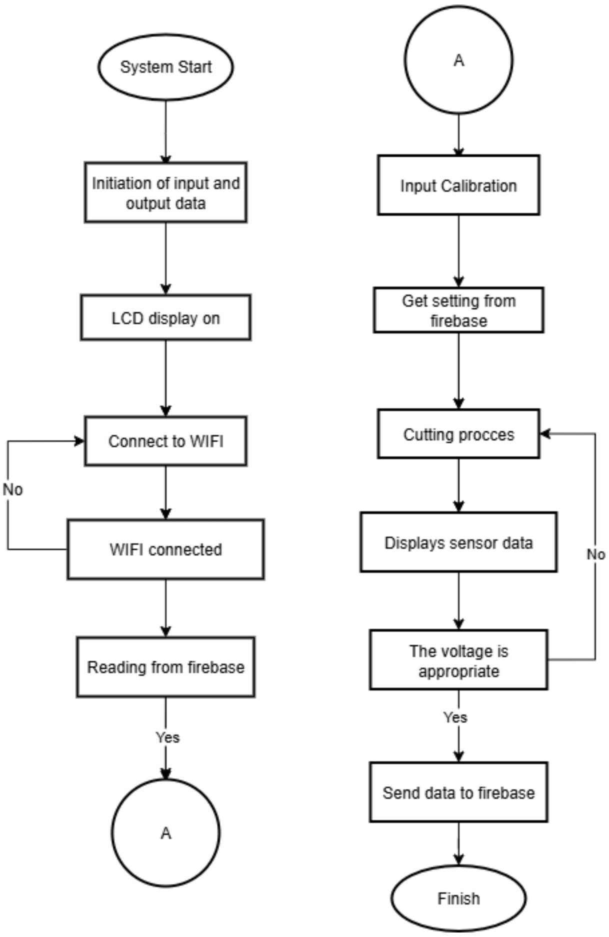

Figure 4. Software Flowchart

Figure 4 presents a flowchart illustrating the software process. The process is divided into two stages. In the initial stage, upon commencement of the ESP-32 microcontroller system, it responds by initializing input and output data. After this, the LCD is activated during the Wi-Fi connection process. Upon establishing a connection, the ESP-32 begins to retrieve data from Firebase, which is integrated with the module in real time. In the subsequent stage, the module initiates the calibration of the input readings and subsequently retrieves the pre-programmed settings from Firebase, subsequently displaying the sensor data. Subsequent to the attainment of an optimal voltage, the system transmits the data to Firebase, a component that is integrated with the website [19].

3. RESULT AND DISCUSSION

3.1 Hardware Manufacturing Results

The test is carried out to determine the performance of the device and the sensors connected by the *website*. The hardware can be seen in Figure 5.

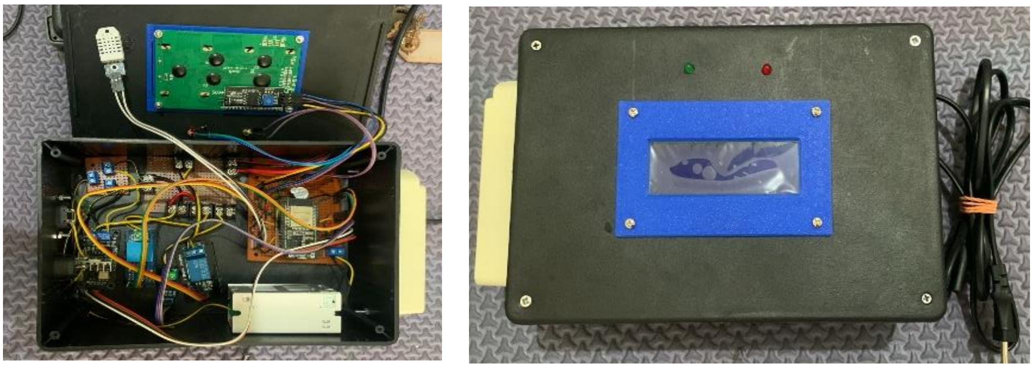

Figure 5. Overvoltage Repair System Design

Figure 5 shows the Overvoltage repair system module in the form of sensor layout to wiring between components arranged in the X7 project box, this tool is equipped with an AC dimmer module at number (1) which functions as an over voltage repair, ZMPT-101B voltage sensor at number (2), ACS-712 current sensor at number (3), relay at number (4) as a cut-off when the tool is outside the standard limit, also equipped with a DHT-22 temperature and humidity sensor at number (5) and a 20x4 LCD screen at number (6) as a monitoring display. The entire system is controlled by an IoT system in the form of ESP-32 at number (7) as a microcontroller that is integrated with the cloud (firebase) and connected to the internet (wifi). In addition, there is a power supply at number (8) as an input for the microcontroller and sensor, plus a jumper cable at number (9), and box X7 at number (10) as a box cover and an outlet at number (11) as an output for the load.

IoT systems require 5V input to activate microcontrollers, sensors and LCDs. When it is in supply, the red indicator light will turn on along with the LCD which shows that the system is active. Then the device requires configuration via the internet (wifi) to be able to activate the system with the relay on and a green indicator light with voltage calibration according to the SPLN standard that has been programmed in the microcontroller and if it is less or more, the automatic tool does not work.

3.1.1. Software Creation Results

The results of the software development in this study can be monitored from the website in real-time which is connected to the internet using the C++ language through audio visual code software and can be monitored directly through the 20 x 4 LCD display installed on the X7 box. The following are the results of the design:

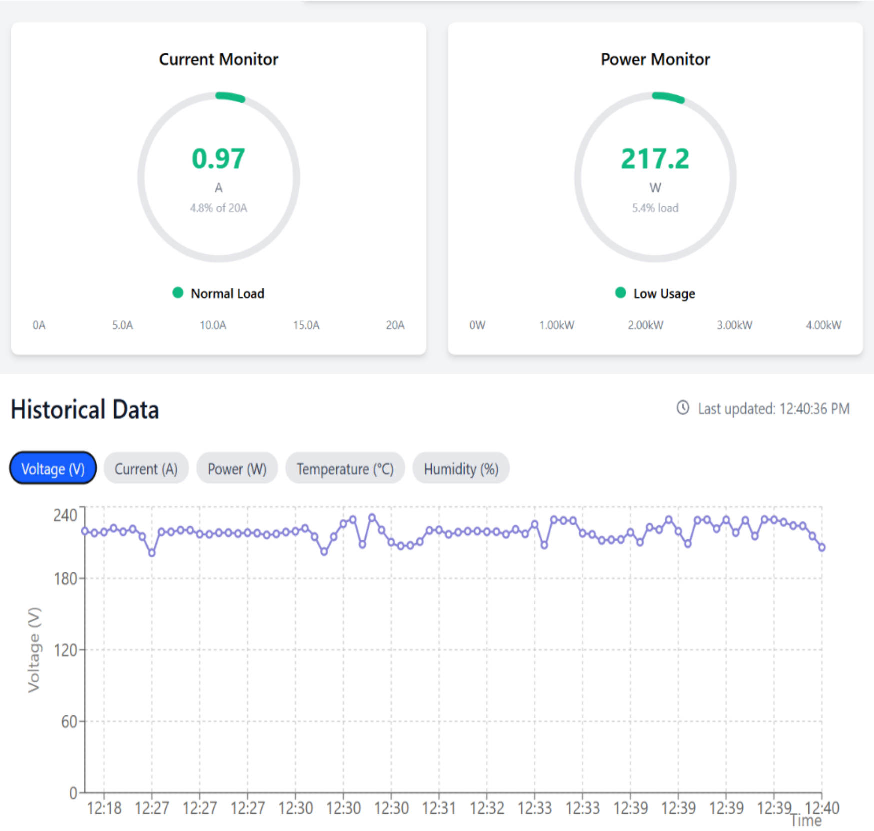

Figure 5. Website Monitoring Results

Figure 5 shows the display of the 20 x 4 LCD by displaying the voltage indicator shown on the letter (V) meaning voltage, then there is (I) which is the unit of current, then there is (H) and (T) which represent the unit of humidity and temperature temperature and there is a range of tool tolerance limits according to SPLN standards from the voltage range of 198V RMS to 231V RMS which is monitored and connected to website. Then in figure 4.3 is the real-time display of the website and graph menu with the indicators displayed first there is device information as a display of connected device status information, then on the right there is a monitoring of the voltage, also below there is a monitor of the current and power consumed as well as a real-time graph from voltage, current, power, temperature, and humidity with the values on the left and the monitoring time at the bottom.

3.2 Experimental Results

System tests were conducted on three primary input voltage scenarios: 198 V RMS (undervoltage near the lower limit), 220 V RMS (nominal voltage), and 240 V RMS (overvoltage exceeding the upper limit). The evaluation process entails a comparison between the conditions when the system is deactivated (not operating) and when it is activated (operating).

3.2.1.Input Voltage Testing 198 V RMS

The system was tested with the output voltage reduced to 195 volts of RMS at motor load. The current increase to 2.7 amperes due to the voltage drop. The recorded power at load was lower due to the unstable supply, resulting in decreased motor performance, especially during starting. Concurrently, the test with System ON did not activate the output because the voltage was below the threshold (198 V), which caused the current to be cut off automatically to prevent damage. This configuration is intended to ensure the protection of equipment during conditions of undervoltage.

Table 1. Results of OFF and ON System Testing at 198 V RMS Input Voltage

Load (Ω)	Command	Motor Output Voltage (V RMS)	Generator Output Voltage (V DC)	Current (A)	Power (VA)	Description
No burden	OFF	195	-	2.7	523.8	Voltage drops, current rises, risk of motor weakening
100	OFF	195	54.45	0.54	29.40	
55	OFF	195	-	-	53.91	
22	OFF	195	-	-	134.49	
No burden	ON	Not working (current cut off)	-	-	-	Voltage < 198V, system cuts off current

3.1.2 Input Voltage Testing 220 V RMS

The system was tested with the apparatus deactivated. The voltage was stabilized at approximately 217 volts RMS, with a current of 2.2 amperes and a power of approximately 477 watts. This condition is indicative of normal operation, devoid of overvoltage interference. Concurrently, the system ON performs voltage calibration by reducing the output voltage to 215 V RMS, thereby ensuring that the voltage remains within the acceptable limits. The output current exhibited a slight increase (2.5 A), resulting in a power output of 464 VA, suggesting that the system demonstrated effective power output management. Additionally, temperature and humidity data are monitored in real-time to ensure system stability [20]. Waveform graphs demonstrate minor distortions resulting from the operation of the AC dimmer module; however, these remain within the safe range, thereby eliminating the risk of damage.

Table 2. Results of OFF and ON System Testing at 220 V RMS Input Voltage

Load (Ω)	Command	Motor Output Voltage (V RMS)	Generator Output Voltage (V DC)	Current (A)	Power (VA)	Temperature (°C)	Humidity (%)	Description
Unburdened	OFF	217	-	2.2	477.4	-	-	Stable output voltage
100	OFF	217	60.50	0.60	36.30	-	-	
55	OFF	217	-	1.10	66.55	-	-	
22	OFF	217	-	2.75	166.38	-	-	
Unburdened	ON	215		2.5	464.2	25	79	Voltage corrected, current slightly increased
100	ON	214	59.67	0.60	35.61	25	79	
55	ON	214	-	1.08	64.75	25	79	
22	ON	214	-	2.71	161.87	25	79	

3.1.3 Input Voltage Testing 240 V RMS

According to the findings of the test, when the system was deactivated, the voltage attained 237 V RMS, with a current of 1 A. This result indicates the system's proximity to overvoltage conditions, a factor that has been demonstrated to lead to the overheating of motors and generators. Consequently, this could potentially reduce the lifespan of components. Concurrently, system testing demonstrated a reduction in output voltage to 223 V RMS, thereby ensuring compliance with the SPLN standard's prescribed tolerance limits. The output current increased to 1.9 A, and the power generated was approximately 439 VA, indicating enhanced power consumption efficiency. Temperature and humidity monitoring revealed ambient conditions indicative of a normal working environment, with an ambient temperature of 25.8°C and humidity of 50%. The waveform exhibited by the system demonstrates acceptable distortion, attributable to the dimmer module, while maintaining consistent cycle and voltage amplitude.

Table 3. OFF and ON System Test Results at 240 V RMS Input Voltage

Load (Ω)	Command	Motor Output Voltage (V RMS)	Generator Output Voltage (V DC)	Current (A)	Power (VA)	Temperature (°C)	Humidity (%)	Description
Unburdened	OFF	237	-	1.0	273	-	-	Overvoltage conditions, risk of overheating
100	OFF	237	66	0.66	43.56	-	-	
55	OFF	237	-	1.20	79.20	-	-	
22	OFF	237	-	3.00	198	-	-	
Unburdened	ON	233	-	1.9	439	25.8	79.5	The voltage was successfully corrected, and the current increased.
100	ON	220	61.33	0.61	37.61	25.8	79.5	
55	ON	220	-	1.11	68.38	25.8	79.5	
22	ON	220	-	2.79	170.94	25.8	79.5	

3.2 Discussion

Based on the discussion stage, a comparative analysis will be conducted on the data obtained above. Discussion when the system is on and when the system is off in the above test.

3.2.1 Input Voltage Test 198 V RMS

In Figure 5, the test results graph for the input voltage indicator at 198 V RMS reveals that the system produces an output only when the system is deactivated. Conversely, when the system is activated at that input value, the system malfunctions and cuts off the incoming current due to undervoltage. In the deactivated state of the system, the blue chart displays an output value of 195 volts of RMS, with the maximum current value from the test indicator recorded at 2.7 amperes and a constant frequency of 50 hertz. The observed phenomenon can be attributed to a decline in output voltage to 194 volts of RMS, leading to an increase in current. This, in turn, can result in suboptimal startup and reduced rotation speed, consequently decreasing the motor's lifespan.

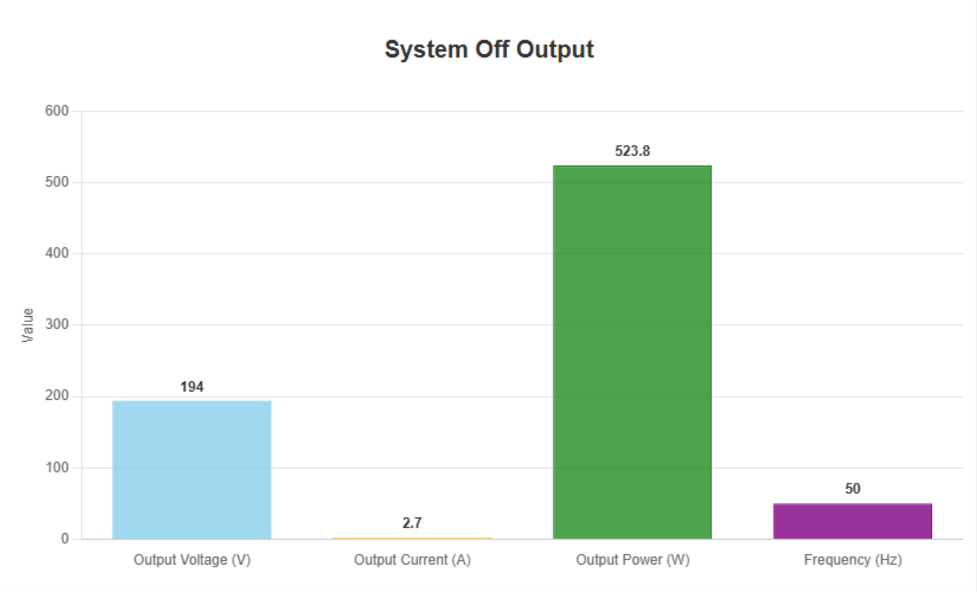

Figure 5. Comparison Chart At 198 V RMS Input Value

3.2.2 Input Voltage Test 220 V RMS

Figure 6 shows the performance and effectiveness of the system when activated (on) compared to when the system is not operating (off). When the system is off, the recorded voltage is 220 volts, while when the system is on, it is recorded at 215 volts. Although the voltage when the system is on is slightly lower, this difference is still within the acceptable and safe tolerance range for electronic equipment. This indicates that the system could regulate and reduce the output voltage according to the load requirements, which is important to prevent damage caused by voltage surges. There is an increase in current from 2.2 amperes when the system is off to 2.5 amperes when the system is on. This increase indicates that when the system is active, there is a greater flow of energy to the load, showing that the system is functioning to actively supply power to the connected equipment. The power generation of the system is measured at 477.4 watts in the off state and 464.2 watts in the on state. Despite the slight reduction in power value when the system is operational, this is indicative of enhanced energy efficiency. This is since, with higher current, the system can generate a similar amount of power without the expenditure of excess energy. This suggests that the system can adapt to changing demands and managing power more efficiently. The most salient discrepancy is evident in environmental parameters. During periods of system shutdown, environmental parameters such as temperature and humidity are not subject to monitoring, suggesting that the environmental sensors are in a state of inactivity. Conversely, when the system is operational, the temperature is recorded at 25 degrees Celsius and the humidity level at 79 percent. This suggests that the environmental monitoring feature is operational during system operation, which is beneficial for maintaining optimal conditions.

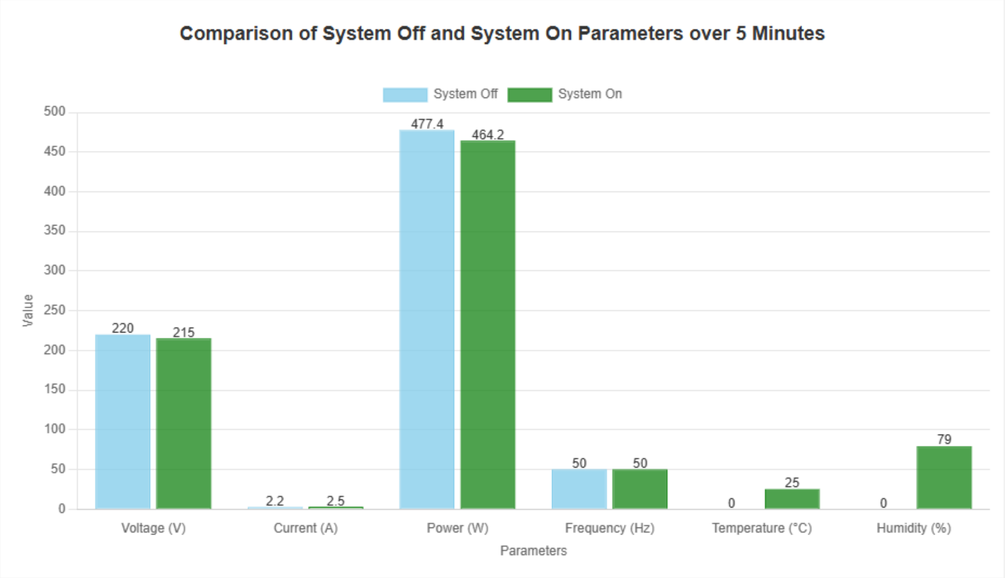

Figure 6. Comparison Graph at 220 V RMS Input Value

3.2.3 Input Voltage Test 220 V RMS

Based on figure 7, a comparative analysis was conducted between the system's off and on conditions, utilizing the measurement data collected at the 5-minute mark. The parameters evaluated encompassed output voltage, output current, output power, frequency, temperature, and humidity. In the deactivated state of the system, the output voltage is 237 volts, and the current flowing is 1 ampere. This results in an output power of 273 watts. The measured frequency is 50%, with temperature and humidity at zero. This indicates that the system is not active or generates heat and environmental humidity changes.

Upon activation of the system, a slight decrease in output voltage to 223 V is observed. This decline remains within the acceptable range and signifies the initiation of active power absorption by the system load. The present increase is substantial, reaching 1.9 A, thereby contributing to a significant rise in power output, which reaches 439 W. This rise signifies that the system is functioning more efficiently and possesses the capacity to generate more energy during operation. The frequency remains constant at 50%, indicating the system's stability in terms of electrical signals and operational rhythm even during periods of activity. Furthermore, the temperature rises to 25.8°C, and the humidity level increases to 50%, indicating thermal activity from electronic components and the possibility that the system is in an enclosed space or interacting with a humid environment.

A comprehensive evaluation of the system's functionality reveals a pronounced benefit associated with the ON system condition, in comparison to the off system. The enhancement in both current and output power is indicative of elevated system efficiency and performance during active operation. Despite a minor decline in voltage, this is counterbalanced by a substantially augmented power output. The rise in temperature and humidity levels serves to substantiate the overall functionality of the system. Consequently, the system exhibits significantly enhanced performance and responsiveness when activated.

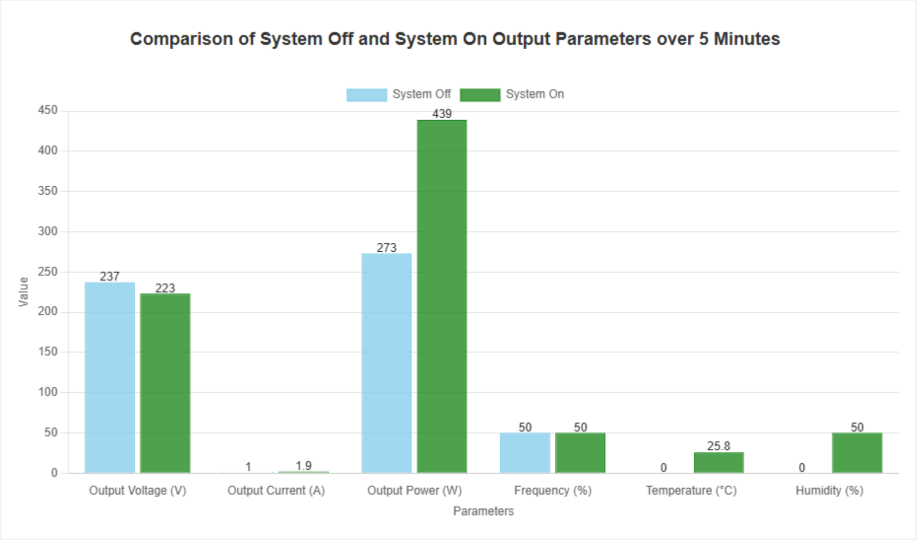

Figure 7. Comparison Graph at 240 V RMS Input Value

4. CONCLUSION

A comparison of the test results under both on and off system conditions reveals that the IoT-based overvoltage fault repair system can maintain voltage stability within the prescribed tolerance limits of SPLN No. 1: 1995 (198 V - 231 V). This system has been demonstrated to function in two primary ways. Firstly, it is capable of mitigating voltage fluctuations by discontinuing the flow of electricity during instances of extreme conditions. Secondly, it offers the advantage of real-time monitoring of electrical conditions through an online platform. The implementation of temperature and humidity sensors serves to augment the safety and maintainability of the system, thereby ensuring optimal long-term operational efficiency. About energy efficiency, one system demonstrates a substantial enhancement in comparison to the off condition. This finding suggests that the system is efficacious in mitigating energy losses and averting potential damage to components. Consequently, this innovation provides an advanced voltage protection solution that can be applied to both industrial and domestic environments.

The proposed system development involves scaling up from a single-phase to a three-phase configuration to meet the high-power demands of large-scale industrial applications, enhancing undervoltage mitigation through the integration of a Battery Energy Storage System (BESS) for preventive power injection, and incorporating advanced filtering mechanisms to refine the output waveform into a purer sinusoidal form for improved power quality.

REFRENCES

[1] M. S. Paran, F. A. Quadery, M. A. A. S. Arju, and S. T. Abdullah, “Over Voltage And Under Voltage Protection System With Phase Sequence Checking Using Auto Transfer Switch (Ats),” no. May, 2025, doi: 10.5281/zenodo.1345040.

[2] S. D. Yusuf, V. Omojorla, I. Umar, and A. . Loko, “Implementation of a 220v Ac Overload and High Voltage Monitor Alert System with Auto Shut Down,” *Int. J. Eng. Mod. Technol.*, vol. 8, no. 5, pp. 32–40, 2023, doi: 10.56201/ijssmr.v8.no1.2022.pg32.40.

[3] Rimbawati, Cholish, E. Saputro, and P. Harahap, “Design of a Voltage Stabilization Control System Using PLC M221 at the Bintang Asih Micro Hydro Power Plant,” *J. Tek. Elektro*, vol. 3, no. 2, pp. 62–70, 2021, [Online]. Available: https://jurnal.umsu.ac.id/index.php/RELE/article/view/v3i2.6482.

[4] O. Isaiah, B. Bolaji, S. Oluwasina, and A. Oluwaseun Sodiq, “Development of an Undervoltage and Overvoltage Device Using Programmable Interface Controller (PIC),” *J. Multidiscip. Eng. Sci. Technol.*, vol. 9, no. 2, pp. 2458–9403, 2022, [Online]. Available: www.jmest.org.

[5] M. Mustafa, U. Rahmah, M. Mustapa, N. Azizah, and E. Budiarti, “Internet of Things (IoT) in Defense and S ecurity.pdf AUTHOR 8% Overall Similarity Excluded from Similarity Report Internet of Things (IoT) in Defense and Security Systems: A Literature Review,” *Int. J. Sci. Eng. Sci.*, vol. 7, no. 5, pp. 2456–7361, 2023, [Online]. Available: http://ijses.com/.

[6] R. R. Lachanna and L. Arokiasamy, “Electrical Circuits Protection Against Under Voltage or Over Voltage,” *Int. J. Eng. Appl. Sci. Technol.*, vol. 04, no. 11, pp. 59–62, 2020, doi: 10.33564/ijeast.2020.v04i11.012.

[7] R. F. Firdaus, S. I. Haryudo, A. I. Agung, and A. C. Hermawan, “Programming a Voltage Stabilizer Prototype to Overcome Over-Under Voltage Disturbances Using ArduinoProgramming a Voltage Stabilizer Prototype to Overcome Over-Under Voltage Disturbances Using Arduino,” *J. Tek. Elektro*, vol. 10, pp. 153–161, 2021, [Online]. Available: https://ejournal.unesa.ac.id/index.php/JTE/article/view/36874%0Ahttps://ejournal.unesa.ac.id/index.php/JTE/article/download/36874/32818.

[8] B. Narote and R. Mhanta, “IoT in Industrial Automation: Application and Benefits,” *Int. J. Innov. Eng. Res. Technol.*, pp.

1–5, 2020, [Online]. Available: https://www.neliti.com/publications/428936/iot-in-industrial-automation-application-and-benefits.

[9] V. Pravalika and C. Rajendra Prasad, "Internet of things based home monitoring and device control using Esp32," *Int. J. Recent Technol. Eng.*, vol. 8, no. 1 Special Issue 4, pp. 58–62, 2019.

[10] A. Wagyana, "Prototipe Modul Praktik untuk Pengembangan Aplikasi Internet of Things (IoT)," *Setrum Sist. Kendali-Tenaga-elektronika-telekomunikasi-komputer*, vol. 8, no. 2, p. 238, 2019, doi: 10.36055/setrum.v8i2.6561.

[11] S. Gustiani, "Research and Development (R&D) Method as a Model Design in Educational Research and Its Alternatives," *Holistics J.*, vol. 11, no. 2, pp. 12–22, 2019, [Online]. Available: https://jurnal.polsri.ac.id/index.php/holistic/article/view/1849.

[12] A. S. Hakiki, M. A. Hamid, and E. Nurcahyo, "Design of a 220Vac Voltage Protection Relay Based on Arduino," p. 4, 2022, [Online]. Available: http://eprints.itn.ac.id/id/eprint/9495.

[13] A. Syhari and A. Bintoro, "Monitoring dan Controling Daya Berbasis Arduino Uno Menggunakan Sensor PZEM-004T," *J. Energi Elektr.*, vol. 12, no. 1, p. 43, 2023, doi: 10.29103/jee.v12i1.9836.

[14] R. Singh, R. Kumar, and H. Shabbir, "Over/Under Voltage Tripping Circuit for Distributed System Load with GSM alert using Microcontroller," *Int. J. Innov. Technol. Explor. Eng.*, vol. 8, no. 9, pp. 1335–1339, 2019, doi: 10.35940/ijitee.i8185.078919.

[15] J. Kuswanto, R. Dimas Pratama, and M. Syafrizal, "IoT Technology Design Using ESP32 to Optimize Smart Irrigation Systems in Salak Pondoh Plantations," *Jurnalnya Orang Pint. Komput.*, vol. 14, no. 1, 2025.

[16] E. Barakat, N. Sinno, and C. Keyrouz, "A remote monitoring system for voltage, current, power and temperature measurements," *Phys. Procedia*, vol. 55, no. December, pp. 421–428, 2014, doi: 10.1016/j.phpro.2014.07.061.

[17] P. R. Meattini and F. Paganelli, "Prototype System For Enhancing Hand Neuromuscular Rehabilitation Exercises Exploting Semg Signals And Visual Feedback," 2023.

[18] D. Despa, G. F. Nama, M. A. Muhammad, and K. Anwar, "The Implementation Internet of Things(IoT) Technology in Real Time Monitoring of Electrical Quantities," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 335, no. 1, 2018, doi: 10.1088/1757-899X/335/1/012063.

[19] A. Kiswantono, H. Afianti, Saidah, and B. Purwahyudi, "IoT-Based Voltage Protection: Smart and Responsive Monitoring System," *SinarFe7*, vol. 6, no. 1 SE-Articles, pp. 43–47, 2024, [Online]. Available: https://journal.fortei7.org/index.php/sinarFe7/article/view/637.

[20] Y. A. Kurnia Utama, "Comparison of Quality Between Temperature Sensors Using Arduino Pro Mini," *e-NARODROID*, vol. 2, no. 2, 2016, doi: 10.31090/narodroid.v2i2.210.