DESIGN OF CONTROL AND MONITORING SYSTEM MEDIUM VOLTAGE CUBICLE PANEL WITH REDUNDANCY SYSTEM USING POWERLINE CARRIER COMMUNICATIONS (PLCC) BASED ON IOT

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ABSTRACT
This research can monitor the displacement of the load supply of the redundancy system cubicle panels that can be accessed on a web server. The design of this system uses the PLCC KQ330 module to send data. ESP 8266 module as the main microcontroller used to manage the system. The use of powerline carrier as an effective data transmission medium within a predetermined distance. This system is able to monitor load movement with a response time of less than 40 seconds from each available receiver module which can be monitored via LCD and monitoring on a web server. This tool has a good level of accuracy to improve the safety and reliability of the electricity distribution system.

Keywords: *Power Line Carrier (PLCC), Internet of Things (IoT), Cubicle MV, Redundant, Monitoring*

1. INTRODUCTION

The increasing need for air transportation in the current era makes an airport require a development, especially in terms of electricity which is an important factor to support the smooth running of operational activities at the airport requires updating or adding equipment to distribute electricity supply needs, such as the I Gusti Ngurah Rai airport in Bali which is one of the busiest airports in Indonesia which plays an important role in encouraging the regional economy in the tourism sector.

The electricity transmission and distribution system at the airport requires a plan so that in the future it can be developed for smooth operational activities. At the I Gusti Ngurah Rai airport in Bali city, there are 2 sources of subscription from the electricity company with the name metering kiosk 1 and metering kiosk 2, each of which has a power of 10,380 kVA and applies a redundancy system to its electricity distribution which is used as an interrelated backup supply because it can take over the function of one of the supplies when one of the supplies is experiencing interference. To complete this redundancy system, it is usually applied to the distribution of looping loads to connect electrical resources from various load supplies that are divided into each sub panel. Regular and scheduled maintenance makes the main electricity distribution system in the sub panel used for load supply must not die due to busy operating hours.

This research can ensure the reliability of the redundancy system because it can monitor the transfer of load supply by using a web server so that communication between technicians when working in the field is safer when carrying out panel maintenance that is located far apart.

2. METHOD

2.1 Research design

The research was conducted through seven main stages:

1. Problem Identification : At the problem identification stage, research is carried out related to the obstacles that occur during the maintenance and maintenance of medium voltage cubicle panels with redundancy systems. This research focuses on Bali's I Gusti Ngurah Rai Airport, where the electrical distribution system applies a redundancy system to medium voltage panels that are located far apart. This requires on-site inspections to initiate or maneuver load supply. Communication between technicians in the field uses Handy Talky (HT), which has a limited range and sometimes experiences signal interference due to interference from other communications. Therefore, effective communication between technicians is essential when performing starting or load shifting maneuvers.
2. Defining the Problem : After the problem is identified, the next step is to define the problems faced as a basis for understanding to support the title of the final project entitled “Design of a Medium Voltage Cubicle Panel Control and Monitoring System with a Redundancy System Using IoT-Based Powerline Carrier Communications (PLCC)”.
3. Literature Review : After determining the problem, the next step is to conduct a literature review by examining the various components that will be used in designing the tools in this study.
4. Tool Design : After the literature review is carried out, the next step is to design the tool, including designing the components, software, and hardware needed as a solution to the problems that have been identified. This design aims to monitor the load supply switching on the redundancy panel.
5. Tool Testing : After the tool is assembled, testing is carried out to ensure that the tool functions as expected. This test aims to understand how the powerline carrier works in monitoring load switching in the redundancy panel control and monitoring system, as well as to assess the performance of each component used.
6. Testing Results : At this stage, the overall test results of the tool will be evaluated by the researcher.
7. Conclusion : This final stage involves drawing conclusions from the tool that has been made, to assess whether the tool is able to solve the problems that have been identified and whether each stage of the design achieved the desired results.

This research uses powerline carrier communication which is used as a data transmission medium and applied to the design of the tool that has been made. The results of this study are expected to provide results that are used to monitor the displacement of the load supply contained in the redundancy system panel.

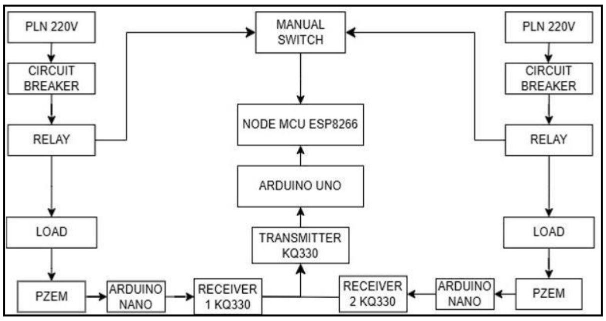

Figure 1 Tool Design Block Diagram

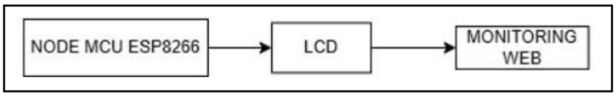

Figure 2 Tool Design Block Diagram Monitoring Tool

Based on the planning block diagram, the control and monitoring system of the cubicle panel with IoT-based redundancy system using powerline carrier communication starts when the 220 Vac voltage supply is received. This voltage passes through the circuit breaker connected to the relay. When the circuit breakers on receiver modules 1 and 2 are activated, the manual control panel will manually adjust the supply to the contactor relays, and the output of these relays is connected to the load. The PZEM-004T voltage and current sensor then reads the voltage and current magnitude, the data of which is processed by the Arduino Nano. The powerline carrier communication on receivers 1 and 2 sends this data to the transmitter module on the Arduino UNO, which then transmits the data to the ESP8266 NodeMCU. The ESP8266, with its WiFi module, displays the result data on an LCD screen as well as web monitoring that can be accessed via a PC or smartphone.

In making this research there are two modules, namely the transmitter (master) and Receiver (Master) Modules :

1. Transmitter/Master

The Transmitter or master module serves as the main module that transmits data to the LCD in the panel box. This module involves several components, including an Arduino Uno, a KQ-330 Power Line Carrier (PLC) Module, and a current sensor to read the voltage received from the receiver/slave module.

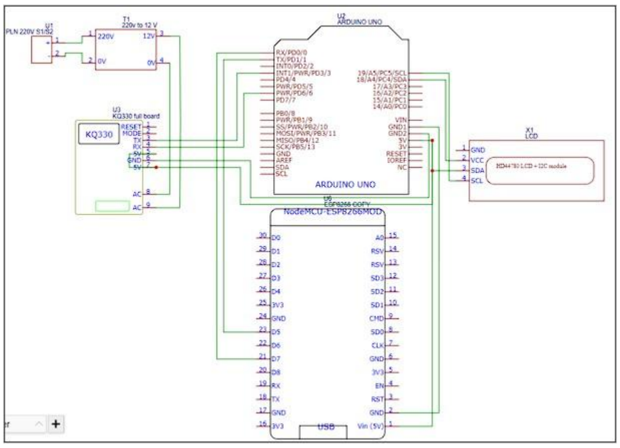

Figure 3 Wiring Diagram Microcontroller Module Transmitter (Master)

2. Receiver/Slave The

Receiver or slave module consists of two parts, slave 1 and slave 2, which are tasked with sending data if there is a disturbance in one of the slaves. The data is then received by the Transmitter module. This module includes various components such as relays, miniature circuit breakers (MCB), sockets, Arduino Nano, and KQ-330 Power Line Carrier Module (PLC).

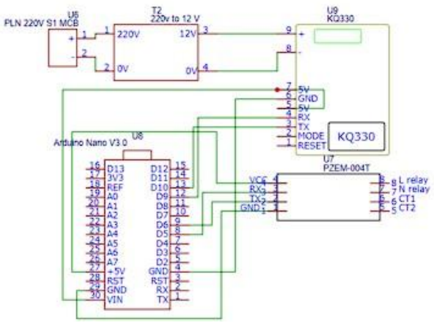

Figure 4 Wiring Diagram of Microcontroller Receiver Module (slave)

2.2 Tool Components

A. Hardware

1. NodeMCU ESP 8266

The ESP8266 chip, which includes a complete TCP/IP protocol stack, provides WiFi capabilities, making it ideal for IoT applications. The microcontroller at the heart of the NodeMCU V3 is the ESP8266, with dimensions of 57 mm x 30 mm. It accepts input voltages from 3.4 to 5 V and is equipped with 13 GPIO pins, 10 PWM channels, and a 10-bit resolution ADC pin. The board offers 4 MB of flash memory and operates at clock speeds of 40/26/24 MHz. Additionally, it supports IEEE 802.11 b/g/n WiFi connectivity in the 2.4 GHz to 22.5 GHz frequency range. The NodeMCU V3 includes a Micro USB port and a CH340G USB to Serial converter, though it does not have a card reader. Given these specifications, the NodeMCU V3 is well-suited for IoT projects that require seamless network integration and wireless control of devices.

2. PLCC module KQ330

The KQ330 module is a Power Line Carrier (PLC) modem that serves to connect two devices over a 220V electrical network without the need for additional components. This module is specifically designed for transmitting broadband data over existing electrical networks, making it suitable for network applications in residential and commercial environments such as offices, apartments, hotels, and warehouses. The KQ330 specifications include a baud rate of 9600 bps, an operating frequency of 120-135 Hz, a working temperature of -25°C to 70°C, and an actual baud rate of 100 bps with a 400 bps buffer of 250 bytes capacity. The KQ330 module pins consist of AC (220 V AC), ±12V (+12 V power source), GND (digital circuit ground), ±5V (+5 V power source), RX (incoming data carrier from microcontroller TX port), TX (outgoing data carrier to microcontroller RX port), Mode (mode selector between high floating or 5V low ground mode), and NC/RST (active low reset pin used for frequency setting).

3. PZEM-004T Sensor

The PZEM-004T sensor module is a multifunctional sensor for measuring current, voltage, and frequency at AC voltage, with results sent via serial communication to a microcontroller. Measuring 3.1 × 7.4 cm and equipped with a 3mm current transformer, this sensor can measure currents up to 100A. Its wiring includes voltage and current input terminals, as well as a serial communication line. Available in 10A and 100A variants, the module measures AC voltage 80-260V, current 0-100A, and power 0-22kW. Although it does not have a display, data is read through a TTL interface with a 5V power supply. This module is popular for its capabilities in a single module and its affordable price.

4. Circuit Breaker (CB)

A Circuit Breaker (CB) is a device that cuts off the flow of electricity at normal load or during a fault. Circuit Breakers must be able to deliver the maximum current continuously, disconnect electricity quickly when a short circuit occurs without damaging the device, and protect the system from damage. Typically, Circuit Breakers can handle voltages up to 240V or 415V and currents from a few amperes to thousands of amperes, depending on the type. Unlike fuses, Circuit Breakers, especially Miniature Circuit Breakers (MCBs), are more effective for protection in commercial and industrial environments because they can disconnect current in one or three phases simultaneously.Stepdown Module LM2596

5. Relay

Relays are electrical devices that control the flow of electric current with smaller electrical signals, operating on electromagnetic principles.The main parts of a relay include contacts that act as a switch, a coil that generates a magnetic field, a frame that protects the internal components, an armature that moves to operate the contacts, and terminals for electrical connections.There are various types of relays, such as electromagnetic, solid state, thermal, and reed, which are used in electrical control systems, industrial automation, electrical protection, and other applications.

6. Rotary Selector Switch

A selector switch is a type of switch that allows selection between various options or positions in a system, similar to a toggle switch but with more positions that can be selected through turning or shifting a switch. Used in applications such as industrial controls to select the operating mode, speed, or direction of a motor, selector switches are often equipped with position indicators and are available in a variety of sizes and configurations, including switches with multiple positions or multiple position sets.

B. Software

1. Arduino IDE

The Arduino IDE, which stands for Integrated Development Environment, is software that provides tools for writing, editing, compiling, and uploading code to the Arduino microcontroller board. Arduino comes with a Bootloader that facilitates uploading code from the IDE to the microcontroller. Text editor features include cut/copy and search/replace functions, as well as a message box for process status. At the bottom of the IDE is information about the board and COM port, and programming is done via a USB cable that connects the IDE to the Arduino board.

2.3 Testing Technique

1. Redundancy system testing

Testing aims to assess the performance of each component of the redundancy panel system after it has been assembled. The system is considered to be functioning properly if the device operates in accordance with the functions planned during design. Testing is done manually to ensure that all working principles of the redundancy system function as they should.

Manual operation system testing is performed by setting the selector switch to the manual position to ensure the panel redundancy system is functioning properly. The test procedure starts with checking the circuit and components. After that, the selector switch is placed in the Manual position. Both switches are switched from OFF to ON, and if the green indicator light is on, it means that the load has been supplied from each power source. If there is a fault in one of the sources, the fault indicator light will come on, while the indicator light of the faulted supply will go off and the supply from the other source will not continue. The selector switch is then moved to the backup position to switch the supply to the faulted source. To disconnect the supply to the off load, the selector switch is returned to manual mode. When the main supply returns to service, the backup supply will be disconnected and the system will return to its normal state, with the main indicator light illuminated and supplying the load as before.

2. Monitoring Testing using Powerline

The test involved monitoring via a web application and a master LCD screen to evaluate the effectiveness of powerline carrier communication in monitoring load supply switching in panels with redundancy systems. The test was conducted with a maximum distance of 10 meters between each load supply and the main module. The focus of the test was to ensure that data from a distance of 10 meters could be sent to the main module, measure the time required to display load switching on the redundancy panel control system, and verify the correspondence of the data displayed on the master LCD screen with that appearing on the web application.

2.4 Data Analysis Technique

This research will design a device to overcome the problems that have been identified previously. The data analysis techniques used include several methods.

1. Literature study method, which is a way of examining, exploring, and studying theories that support the solution of the problem under study.
2. The literature method, namely from various reference books and information from lecturers and relatives as well as from several sites on the internet which are very helpful in obtaining a theoretical basis as a source in this writing and references to the problems raised by the author.
3. Observation method, namely making observations by going to the field in order to find supporting data and information, which if not obtained through literature and laboratories. So that it can be accounted for its existence.
4. The calculation analysis method, namely by analyzing the construction calculations of the designed components.
5. Experimental method, namely by testing the tool to get data on the experimental results of the program made

by simulation so that it helps in solving existing problems.

6. Discuss, namely consulting and guidance with lecturers and other parties who can help the implementation of this design. competent parties in supporting the implementation of this tool design.

2. RESULTS AND DISCUSSION

3.1 Research Result

A. PZEM-004T sensor testing

Testing the PZEM-004T sensor aims to ensure that the voltage and current are read accurately. The test is carried out by checking the output of the PZEM-004T sensor on receiver/slave modules 1 and 2 that get a backup load supply, and comparing the sensor readings displayed on the LCD. In the first test, the measurement values on the multimeter were tested under various conditions on slave 1 and slave 2 to ensure a match between the measuring instrument values and the sensor display on the LCD. In the second test, a similar procedure was applied to slave 2 under several conditions, checking whether the measurement values on the multimeter and the LCD display of the sensor were accurate when slave 1 received supply from slave 2.

Figure 3 LCD display picture of PZEM sensor testing

Berikut merupakan tabel hasil dari pengujian sensor PZEM-004T :

1. Slave 1

Table 1 Sensor PZEM-004T slave 1 testing

Condition	Multimeter		LCD	
	Voltage (V)	Current (A)	Voltage (V)	Current (A)
Supply ON	220,5	0,03	220,8	0,03
Supply OFF	0,00	0,00	0,00	0,00
Slave 1 supplies Slave 2 (V)	220,4	0,03	220,8	0,03

2. Slave 2

Table 2 Sensor PZEM-004T Slave 2 testing

Condition	Multimeter		LCD	
	Voltage (V)	Current (A)	Voltage (V)	Current (A)
Supply ON	220,7	0,03	220,9	0,03
Supply OFF	0,00	0,00	0,00	0,00
Slave 1 supplies Slave 2 (V)	220,7	0,03	220,9	0,03

Analysis Results:

Based on the test results of the PZEM-004T sensor used to read the voltage and current in the redundancy panel control system, the test is carried out by comparing the sensor output reading using a multimeter with the results displayed on the LCD. The conclusion from the data shows that the PZEM-004T sensor functions properly and can work as expected in this study.

B. Testing the Load Switching Monitoring System

The monitoring system test aims to determine the time required to monitor load switching in the redundancy panel control system in this tool. In the test, the tool was tested at a distance of 10 meters by adding a load to each supply, carried out three times a trial by loading two supplies. The test result data is as follows:

Table 3 Monitoring system test results

NO.	Conditions	Trial	Detection Time (s)		Voltage (V)		Current (A)	
			Slave 1	Slave 2	Slave 1	Slave 2	Slave 1	Slave 2
1	Both Supplies ON	1	16	35	226,3	226	0,64	0,8
		2	14	35	226,2	226,5	0,64	0,8
		3	15	35	226,2	226,5	0.64	0,8
2	Slave 1 is OFF and gets supply from Slave 2	1	34	-	226	226,3	0,64	0,8
		2	34	-	225,7	226,1	0,64	0,8
		3	35	-	225,8	226,2	0,64	0,8
3	Slave 2 is OFF and gets supply from Slave 1	1	-	30	226,2	226,2	0,64	0,8
		2	-	30	226,1	226	0,64	0,8
		3	-	30	225,8	226	0,64	0,8

Analysis Results:

Analysis of the results from three experiments on the redundancy panel control monitoring system with a distance of 10 meters between each slave showed the following findings:

1. In the first, second, and third experiments, when both supplies were ON, the average detection time for slave 1 was 15 seconds and for slave 2 was 35 seconds. The resulting voltage and current did not show any

significant changes, showing good performance with a distance of about 10 meters.

2. When slave 1 is OFF and the supply is taken from slave 2, the detection time for slave 1 is 34 seconds. The voltage and current remained stable, indicating good supply conditions.
3. When slave 2 is OFF and the supply is taken from slave 1, the detection time for slave 1 is 30 seconds. The voltage and current remained stable, indicating that both supplies were functioning properly.

Figure 4 Testing the Load Switching Monitoring System

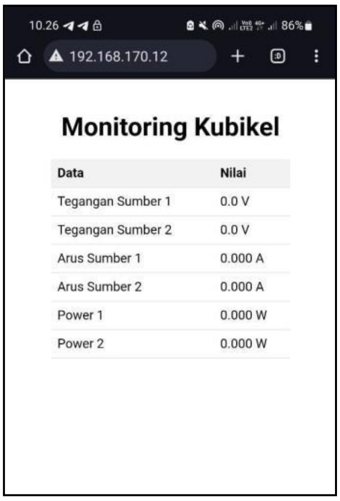

Figure 5 Interface WEB for monitoring

In the web monitoring image above, it will be shown whether the data read from the PZEM-004T sensor and displayed on the LCD layer is the same as the data sent to the web monitoring and can be accessed via smartphone or PC. Web testing is considered successful if it can display information about voltage, current, and power on the load accurately.

3.2 Advantages and disadvantages of tools

The test results and analysis of the final project entitled "Design of Control and Monitoring System for Cubicle TM Panel with Redundancy System Using Powerline Carrier Communications (PLCC) Based on IoT" showed some advantages and disadvantages of the tool:

A. Advantages of the device

1. Facilitates technicians in monitoring the redundancy system panel through web monitoring that displays voltage and current.
2. Able to monitor supply switching in real-time with a response time of less than 40 seconds.
3. Can effectively send data up to 10 meters away from each receiver module without signal interference, as it uses cables for data transmission.

B. Disadvantages of the device

1. The LCD screen often goes blank or takes a long time to display data, and requires a stable signal to access monitoring data on the web.
2. Cable selection is very important because noise in the cable can affect the data transmission process.
3. The number of cable connections on the component can increase resistance.

4. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusion

Based on observations from the final project entitled "Design of a Control and Monitoring System for Medium Voltage Cubicle Panels with Redundancy Systems Using IoT-Based Powerline Carrier Communications (PLCC)," it can be concluded as follows:

1. The use of powerline carrier modules in monitoring load supply switching in the redundancy system cubicle panel facilitates communication between technicians in the field when switching loads. Monitoring data is not affected by physical and weather barriers, making the signal more stable, depending on the distance of application in the field.
2. With the powerline carrier microcontroller module, data can be effectively transmitted at distances of up to 10 meters from each receiver/slave module, enabling monitoring of load supply switching with response times between 15 to 35 seconds.

B. Recommendations

From the existing conclusions, the author realizes that this final project is not entirely perfect. Therefore, the author provides suggestions for the future development of this tool to make it better, among others.

1. The quality of the signal sent by the powerline carrier microcontroller is affected by various factors, so it is necessary to use a higher quality cable to improve performance.
2. The web display should be equipped with a notification that shows the supply source used to supply the load.

REFERENCES

[1] Adam, A., Muharnis, M., Ariadi, A., & Lianda, J. (2020). Penerapan IoT untuk Sistem Pemantauan Lampu Penerangan Jalan Umum. Elinvo (Electronics, Informatics, and Vocational Education), 5(1), 32–41. https://doi.org/10.21831/elinvo.v5i1.31249

[2] Anang Dasa Novfowan, Mochammad Mieftah, Wijaya Kusuma, & Slamet Nurhadi. (2023). Power Line Carrier (PLC) sebagai Media Pendeteksi Phasa Pelanggan Tegangan Rendah. Elposys: Jurnal Sistem Kelistrikan, 10(3), 154–159. https://doi.org/10.33795/elposys.v10i3.4166

[3] Arihutomo, M., Rivai, M., Elektro, J. T., & Industri, F. T. (2012). Sistem Monitoring Arus Listrik Jala-Jala. Jurnal Teknik Its, 1(1), 150–153.

[4] Faisal, F. B., Rakhman, E., & Handayani, P. (2017). Sistem Interlocking Persinyalan Berbasis PLC Dengan Metode HSB (Hot Standby) Vital Safety Critical System. *Polban*, 612–616.

[5] Fajri, M., & Risfendra, R. (2020). Sistem Pengukuran dan Pengiriman Data Arus Listrik menggunakan Power Line Carrier. JTEIN: Jurnal Teknik Elektro Indonesia, 1(2), 37–42. https://doi.org/10.24036/jtein.v1i2.33

[6] Hidayatullah, S., Andang, A., & Maulana, F. (2022). Penerangan jalan umum pintar dengan kendali power line carrier berbasis Internet of Things. *JITEL (Jurnal Ilmiah Telekomunikasi, Elektronika, Dan Listrik Tenaga)*, *2*(1), 47–56. https://doi.org/10.35313/jitel.v2.i1.2022.47-56

[7] Hendarji Anjar Asban, A., Saputra, J., Antarissubhi, & Suryani. (2023). Rancang Bangun Kontrol Ups Redundant Pada Kubikel Mv Bandar Udara Sultan Hasanuddin. *VERTEX ELEKTRO Jurnal Teknik Elektro UNISMUH*, *15*(1), 40–47.

[8] Jiang, H., Lin, J., & Wu, C. (2015). Design of smart home monitoring system based on ARM and power line carrier communication. *International Journal of Multimedia and Ubiquitous Engineering*, *10*(7), 123–130. https://doi.org/10.14257/ijmue.2015.10.7.13

[9] Lestari, N., Suwanto, H., & Gunawan, R. (2020). Sistem Pemantauan Kubikel Tegangan Menengah Berbasis Internet of Things. Infotronik : Jurnal Teknologi Informasi Dan Elektronika, 5(1), 37–42. https://doi.org/10.32897/infotronik.2020.5.1.5

[10] Sistem, I., Dengan, R., & Kristiadi, N. D. W. I. (2023). Implementasi sistem redudansi dengan metode hot standby router protocol (hsrp) pada pt. pratama siaga mandiri.

[11] Tambunan, J. M., & Munajich, A. W. (2018). riki,+45-52+PROSES+PERAKITAN+DAN+PENGUJIAN+KUBIKEL+SM6+VACUUM+CIRCUIT+BREAKER+20+kV+DI+PT.+GALLEON+CAHAYA+INVESTAMA. Energi & Kelistrikan, 10, 1-93.

[12] Wibisono, G., Sukoco, M. H., & Nugroho, K. (2021). Studi Implementasi Komunikasi Data Menggunakan Power Line Communication di Kampus ITTP. Jurnal Teknik Elektro Dan Komputer TRIAC, 8(1), 1–6. https://doi.org/10.21107/triac.v8i1.10038

[13] Wicaksono, B., & Istoni, R. (2020). Monitoring Penerangan Jalan Umum Bertenaga Surya Menggunakan Komunikasi Power Line Carrier Communication. Electrices, 2(1), 30–36. https://doi.org/10.32722/ees.v2i1.3589