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Telegram Application for Monitoring, Controlling and Protecting the Consumption of Household Electrical Appliances

Dicky Andrian Nugraha[1)], and Amirullah[2*)].

[1,2)] Electrical Engineering Study Program, Universitas Bhayangkara Surabaya, Indonesia
Corresponding Email: [*)] amirullah@ubhara.ac.id

***Abstract* – Nominal electricity rates always increase, so it is necessary to take steps to save electricity consumption. One of the steps to save electricity consumption is taken by implementing a remote electrical equipment control system based on the Smart Home Internet of Things (IoT) system. Besides being able to save money, IoT systems are also able to help simplify work and human activities. This research aims to implement Internet of Things (IoT) equipment to monitor, control, protect, and On/Off timers for household electrical appliances monitored by the Telegram application and 16×2 LCD. Monitored system parameters i.e., voltage, current, frequency, power, energy, and electricity rates for each device. Device hardware i.e., Arduino Uno, 1 Channel Relay, PZEM-004t Voltage Sensor, NodeMCU ESP8266, and Current Sensor (Current Transformer). The equipment has been successfully tested on 10 different household appliances i.e., cellphones charger, fans, laptops charger, solder, iron, fluorescent lamp 36 W, television (TV), set-top box (STB)-TV, printer, and 5-W bulb lamp. The results showed that the prototype is capable of monitoring, controlling, protecting, and On/Off timer settings as well as being able to be monitored from home electric appliances both near and far using the 16×2 LCD and the Telegram application, respectively. The sensor tool using the Telegram application is able to measure/monitor the parameters of voltage, current and frequency at 10 loads with an average error value of 0.32%, 12.83% and 0.1%, respectively compared to measurements using a Multimeter. The IoT prototype is also able to provide more complete, faster (4-5 sec) monitoring, control, protection, timer On/Off parameters and superior performance compared to devices designed by a number of previous researchers.**

Keywords: Arduino Uno, Controlling, Internet of Things, Monitoring, NodeMCU, Protection, Telegram, Timer

I. INTRODUCTION

Electrical energy is a primary need for humans in carrying out their daily activities. On the other hand, the nominal electricity tariff is always increasing, so it is necessary to take steps to save electricity consumption. One way to make these savings is to implement a remote electrical equipment control system that uses the Smart Home internet of things (IoT) system. In addition to saving the use of IoT systems in household applications, it also aims to facilitate work and human activities. Implementing a prototype IoT for monitoring temperature and controlling household electrical equipment using the NodeMCU ESP8266 microcontroller monitored by the Telegram application has been carried out in [1]. The proposed system as a whole was able to work well on parameters i.e., connection to Wi-Fi, communication with the Telegram server, receiving orders, transmitting notifications, and reading status from sensors and relays. The weakness of this system is not equipped with home security sensors. Implementing a kWh-meter for monitoring current, voltage, cos θ, and 900 VA household electrical energy using IoT with the Ethernet Shield W5100 module and Arduino has been carried out [2]. The tool that has been designed was able to save consumption and monitor the use of electrical energy with a measurement error difference of below 10%. The IoT system for monitoring house doors and controlling lights using NodeMCU and the Telegram application has been conducted in [3]. The proposed model was able to monitor house doors and control telegram-based lights from smartphones in real time. The design of tools and monitoring of automatic sprinklers using telegram notifications and cameras on chilli plants has been implemented in [4]. The soil moisture sensor on the device was able to detect soil conditions so that it can turn on and turn off the pump, based on the sensor data displayed on the LCD.

Remote home control using Arduino and Wemos D1 mini monitored via the Telegram application has been implemented in [5]. Data received and sent by users via Telegram can control and monitor homes remotely more easily without incurring significant costs. Implementation of NodeMCU and Arduino as household light controls monitored by Telegram and Thingspeak has been carried out in [6]. The Telegram application was able to display current, voltage and lamp power consumption with minimal sensor reading errors and maximum lamp control accuracy. The monitoring system for tracking the position of electric motorbikes in real time uses the Neo 6 sensor and the Telegram and Organic Light-Emitting Diode (OLED) applications have been applied [7]. The sensor used was capable of transmitting process coordinates of location points with a speed accuracy of 53.3% compared to the Timer and transmitting notifications to the admin with an accuracy of 86.6%. Remote control of household electricity consumption using the ZMPT101B voltage sensor, ACS712 current sensor, relay, power supply, Arduino Uno, and monitoring nodeMCU through the Blink application on Smartphones has been implemented in [8]. The tool was able to show good performance based

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on the monitoring function and the manual or automatic mode relay control function. Power, current and voltage monitoring systems in buildings that can be accessed via telegram messenger using telegram bots have been observed by [9]. The sensors in the monitoring system were able to read and measure three parameters with an average error of 5%.

Current and voltage monitoring devices for solar generators connected to State Electricity Company or PLN (on-grid) based on IoT under no-load and load conditions using the Telegram application have been implemented [10]. The average percentage of tool measurement error between the current and voltage sensors compared to the multimeter produces values of 0.14% and 0.094%, respectively. The prototype for monitoring temperature and controlling residential electrical equipment using the Telegram application has been designed [11]. The component consists of NodeMCU ESP8266, relay module, indicator LED, and Active Buzzer. The system was able to work properly i.e., connection to Wi-Fi, communicating with the Telegram server, receiving orders, transmitting notifications, and reading status from sensors and relays. Remote control of household electrical switches using Arduino Uno and Telegram controllers with Eagle software has been designed in [12]. The tool was able to control electrical equipment from a long distance using Wireless Fidelity (WiFi) based communication. The downside was that when WiFi is interrupted, the device cannot send and receive messages via the Telegram application.

The electric power monitoring system for solar generators connected to PLN (on-grid) using the Telegram application has been validated by the fuzzy logic method that has been designed in [13]. The proposed tool is capable of monitoring the output power of on-grid PLTS through smartphones via the Telegram application in real-time. Arduino Uno-based household electrical load monitoring and control system using smartphones and computers with internet access has been made in [14]. The tool that has been designed is able to monitor current, voltage, and power as well as control home electricity consumption both from smartphones and computers/laptops. Current and voltage monitoring tools based on microcontrollers and SMS gateways for micro-hydro power plants and PLTS have been designed [15]. The design of the tool was capable of monitoring the current and voltage of the hybrid generator periodically via SMS to the user every 5 minutes.

The majority of previous studies have only monitored, controlled, or monitored and controlled household electricity consumption using sensors and the Telegram application. Unlike before, this study aims to monitor current, voltage, frequency, power, electricity prices, consumption control, and protection of household electrical equipment simultaneously using the PZEM-004T v3 sensor, the Telegram application, and a one-channel relay. The Telegram application was chosen because it is free, lightweight, cross-platform, and has a fairly complete and well-developed bot API that makes it possible to create smart bots that are able to respond to messages from the users where the bot features were not found in previous Instant Messenger. Bots are autoresponder accounts that can respond to certain texts according to commands given by the user.

The paper is organized as follows. Chapter II presents the methodology i.e., proposed method and tool for testing. Chapter III presents the results and discussion i.e., system implementation, monitoring test results for voltage, current, frequency, power, energy, and electricity rates, control systems, protection, and on/off timers, as well as a comparison of the advantages of the prototype designed by the author compared to the prototype by previous researchers. Finally, the paper is concluded in Chapter IV.

II. METHODOLOGY

A. Proposed Method

Figure 1 shows the flow chart of the proposed model design. The first stage is to design the control, protection and monitoring mechanism of the system. The second stage is to design a series of control, protection and monitoring systems based on predetermined design results. The third stage is the integration of the series with the Telegram application. The fourth stage is manual testing of the relay protection system i.e., on-off relay. The fifth stage is testing the automatic control of the relay i.e., voltage protection. The sixth stage is load measurement i.e., voltage, current, energy, and frequency. The last stage is the recording and analysis of test data. The test is carried out on 10 electrical loads i.e., cellphones charger, fans, laptop charger, solder, iron, fluorescent lamp 36 W, television (TV), set-top box (STB)-TV, printer, and a 5-W bulb lamp.

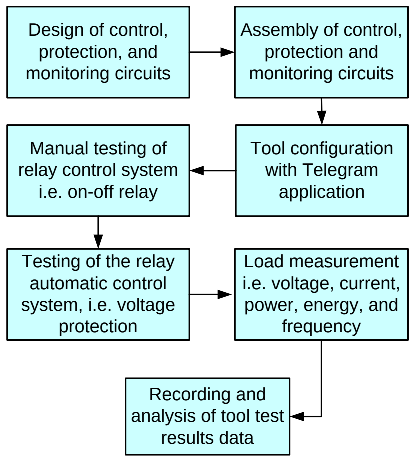


Figure 1. Model design flowchart

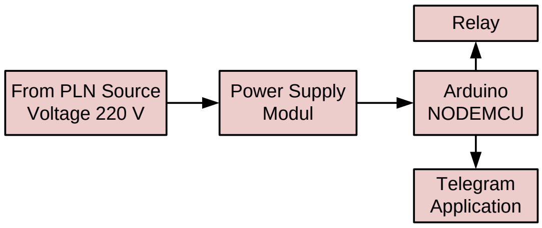


Figure 2. Block diagram of the control system and on/off timer

Figure 2 shows a block diagram of the control system and on/off timer. The block diagram starts from a 220 V-AC PLN power source and must be converted to a 5V-DC voltage via the power supply module because the Arduino NodeMCU ESP8266 is only capable of working with a DC input voltage. After receiving the DC voltage, the NodeMCU ESP8266 and the relay will activate and automatically connect to WiFi or the internet. Then the relay is ready to wait for the command to turn on or off from the Telegram application through the NodeMCU ESP8266 intermediary.

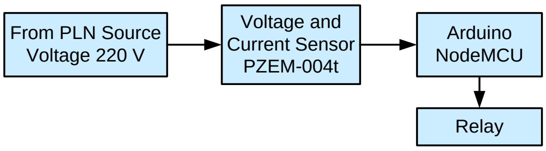


Figure 3. Block diagram of the protection system

Figure 3 shows the block diagram of the protection system. The PZEM-004t voltage and current sensor collect data for both parameters from the PLN 220 V-AC power source. Conversion of current and voltage values through hardware and software is carried out on the NodeMCU ESP8266 microcontroller to produce VAC voltage and AC current readings that are compatible with measuring instrument standards. If the read voltage exceeds the specified voltage, which is 240 V, the relay will automatically order the switch to turn off.

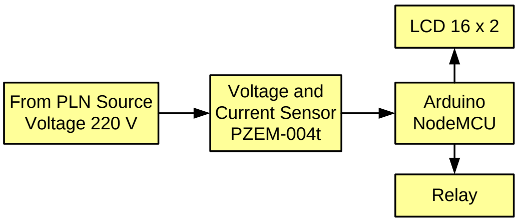


Figure 4. Block diagram of the monitoring system

Figure 4 shows the block diagram of the monitoring system for current, voltage, power, energy, and frequency. The PZEM-004t voltage and current sensor collect data for both parameters from the PLN 220 V-AC power source. Conversion of current and voltage values through hardware and software occurs on the Arduino NodeMCU ESP8266 microcontroller so that it is able to produce AC voltage and AC current readings that are compatible with standard measuring instruments. The measured AC voltage and current values are then displayed on both the LCD screen and the Telegram application.

Figure 5 shows the system flow diagram. The PZEM-004t voltage and current sensor collect data for both parameters from a PLN 220 V-AC power source according to the load connected to that source. The voltage and current data that has been recorded and read by the sensor is then converted and sent by Arduino NodeMCU ESP8266 to display data on a 16×2 LCD. Arduino NodeMCU ESP8266 will then instruct the relay to be active/deactivated. If the relay has not worked, the system automatically connects to WiFi or the internet to instruct the Telegram application to display the current, voltage, power, energy, and frequency data. If the voltage value on the display of the Telegram application is > 240 V, then the relay orders the switch to be off (deactivated).

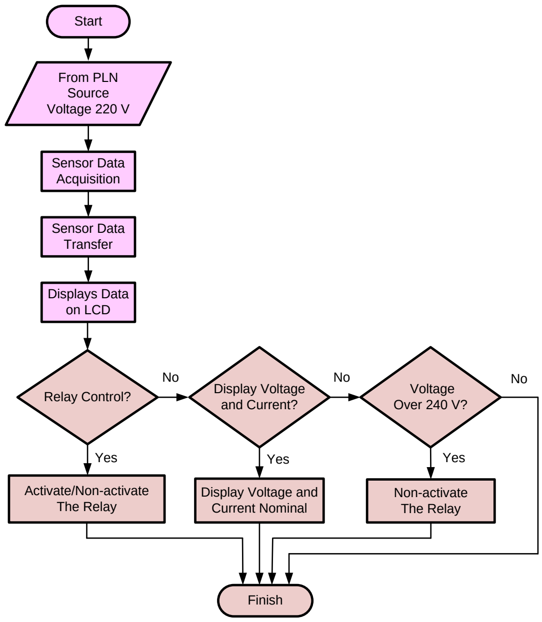


Figure 5. System flowchart

B. *Tool Experiment*

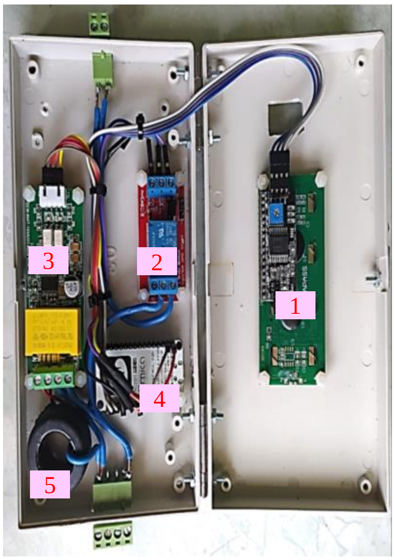
To find out the performance of the tool, researchers carried out a number of tests i.e., voltage, current, power, frequency, energy and price. In the control system, on/off timing, protection, and monitoring are all done through the use of an IoT-based Telegram bot. Testing is carried out on system functionality and then the output results on the Telegram display are compared with the Multimeter measurement results. If the projected results match the test results, the software conforms to the previous design. Conversely, if not, then settings must be made again on the hardware and software components of the tool to be able to provide performance as desired. The difference between the measurement value of the Telegram sensor and the measurement value using a Multimeter is presented in Equation 1.

$$Error = \frac{Sensor\ Value - Multimeter\ Value}{Sensor\ Value} \times 100\% \quad (1)$$

III. RESULTS AND DISCUSSION

A. *System Implementation*

The discussion in sub-chapter III covers control systems, on/off timers, protection, and monitoring for household electricity consumption through the Telegram application bot system. Figure 6 shows the hardware components of each tool i.e., (a) rearview and (b) front view. Figure 6.a shows the respective parts i.e., (1) 16×2 LCD, (2) 1 Channel Relay, (3) PZEM-004t Sensor, (4) NodeMCU ESP8266, and (5) Current Sensor (Current Transformer).



(a)

(b)

Figure 6. Equipment hardware components
(a) rear view and (b) front view

The design of the control system includes four main components, namely the PLN 220 V-AC source connected to the load and relay, sensor, microprocessor and LCD. The relay functions as a circuit breaker. LCD functions to display data obtained from the sensor via the NodeMCU ESP8266. The microprocessor contains a microcontroller and additional components. The microcontroller is NodeMCU ESP8266 as a microprocessor which functions for sensor coordination, data processing, data storage, and data transmission. The sensor detects current, voltage, power, kWh and frequency in electrical loads. The sensor is placed at the end of the line on the electrical network, where this section will detect five measured parameters which then become a reference signal for the microcontroller.

In the early stages, the user instructs the system to activate the Telegram bot including commands namely relay timer On to activate the relay, relay timer Off to turn off the relay, and the status of measuring the electric load. These statuses include voltage, current, power, energy, frequency, and prices. Figure 7 shows the display of transmitting data on the Telegram application.

Figure 7. Display of transmitting data on Telegram

B. Monitoring Test Results for Voltage, Current, Frequency, Power, Energy, and Electricity Tariff

Testing of the voltage sensor is carried out to validate the voltage measurement on the 16×2 LCD and display the Telegram application. The voltage sensor is directly connected to the NodeMCU ESP8266 as a medium to read the value specified in the software. The PZEM-004t voltage sensor has eight pins, four of which connect to a power source and the other four to Vin, D5, D6, and ground on the Arduino. Figure 8 shows the voltage sensor test compared to the multimeter test for charged handphone loads.

(a)

(b)

Figure 8. Testing the voltage value at a charge HP load using
(a) a voltage sensor and (b) a multimeter

In the same procedure, the voltage test was carried out on nine other household electrical loads and the results are shown in Table 1 and Figure 9.

Table 1. Voltage monitoring test results

No.	Loads	Sensor (*Volt*)	Multimeter (*Volt*)	Error (%)
1	Charge HP	215.9	217.0	0.51
2	Fan	216.6	217.0	0.18
3	Charge LP	214.5	215.7	0.56
4	Solder	214.9	215.6	0.33
5	Iron	213.5	213.8	0.14
6	FL Lamp	216.6	217.6	0.46
7	TV	220.5	221.2	0.32
8	STB TV	218.1	218.4	0.14
9	Printer	217.0	218.0	0.46
10	Bulb Lamp	211.8	212.1	0.14
			Average Error	0.32

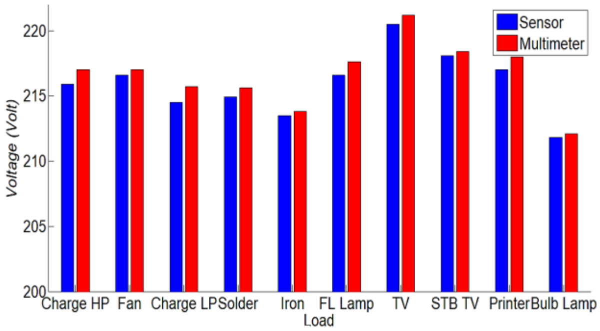
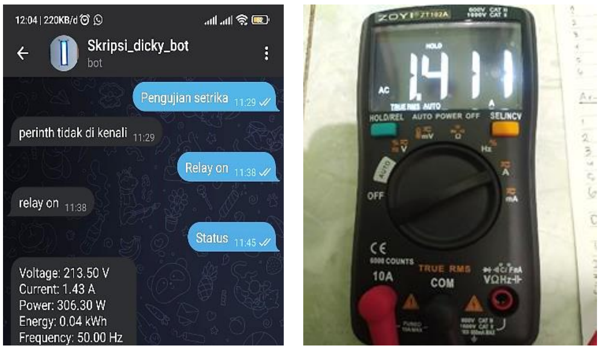


Figure 9. Result of voltage monitoring test

Table 1 and Figure 9 shows that the voltage measurement on the TV load using a sensor and a multimeter produces the highest voltage values of 220.5 V and 221.1 V, respectively. The smallest voltage measurements are produced by iron loads of 213.5 V and 213.8 V, respectively. Voltage measurements on ten loads produce an average error of 0.32% and meet the requirements below 5%. Figure 10 shows the current sensor test compared to the multimeter test for the iron load.



(a) (b)

Figure 10. Testing the current value on the iron load using (a) a current sensor and (b) a multimeter

With the same procedure, current tests were carried out on nine other household electrical loads and the results are shown in Table 2 and Figure 11.

Table 2. Current monitoring test results

No.	Loads	Sensor (*Ampere*)	Multimeter (*Ampere*)	Error (%)
1	Charge HP	0.10	0.12	20.00
2	Fan	0.19	0.17	10.53
3	Charge LP	0.20	0.21	5.00
4	Solder	0.14	0.13	7.14
5	Iron	1.43	1.41	1.40
6	FL Lamp	0.34	0.36	5.88
7	TV	0.27	0.25	7.41
8	STB TV	0.07	0.06	14.29
9	Printer	0.05	0.03	40.00
10	Bulb Lamp	0.06	0.05	16.67
			Average Error	12.83

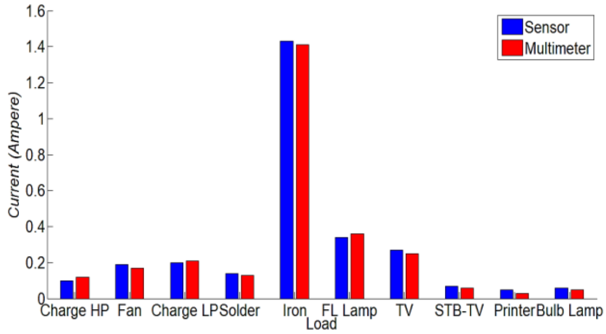
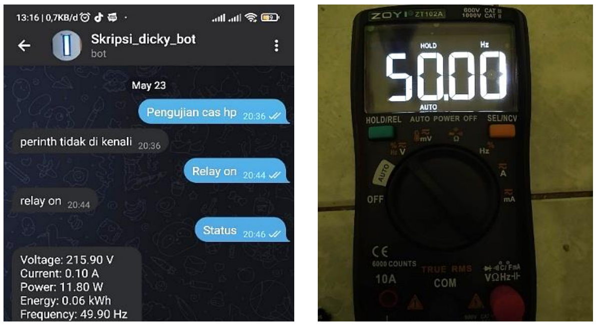


Figure 11. Result of current monitoring test

Table 2 and Figure 11 show that current measurements on iron loads using sensors and multimeters produce the highest current values of 1.43 A and 1.41 A, respectively. The smallest current measurements are generated by printer loads of 0.06 A and 0.06 A, respectively. Current measurements on ten loads produce an average error of 12.83% which exceeds 5%. Figure 12 shows the frequency sensor test compared to the multimeter test for phone charging loads.



(a) (b)

Figure 12. Testing the frequency value on a charge HP load using (a) a frequency sensor and (b) a multimeter

With the same procedure, the frequency test was carried out on nine other household electrical loads and the results are shown in Table 3 and Figure 13.

Table 3. Frequency monitoring test results

No.	Loads	Sensor (Hertz)	Multimeter (Hertz)	Error (%)
1	Charge HP	49.9	50.0	0.2
2	Fan	50.0	49.9	0.2
3	Charge LP	50.0	49.9	0.2
4	Solder	50.0	50.0	0.0
5	Iron	50.0	50.0	0.0
6	FL Lamp	50.0	50.0	0.0
7	TV	50.0	50.0	0.0
8	STB TV	50.0	50.0	0.0
9	Printer	50.0	50.0	0.0
10	Bulb Lamp	50.0	50.0	0.0
			Average Error	0.1

Table 3 and Figure 13 show that frequency measurements on solder loads, irons, FL lamps, TVs, TV STBs, printers, and bulb lamps using sensors and multimeters produce the same frequency value of 50 Hz. Frequency measurements on charge HP, fans, and charge LP yield slightly different frequency values of 49.9 Hz and 50 Hz, respectively. Thus the frequency measurement at ten loads is able to produce a relatively small average error of only 0.1% and meets the requirements below 5%. Figure 14 shows the power monitoring test on the iron.

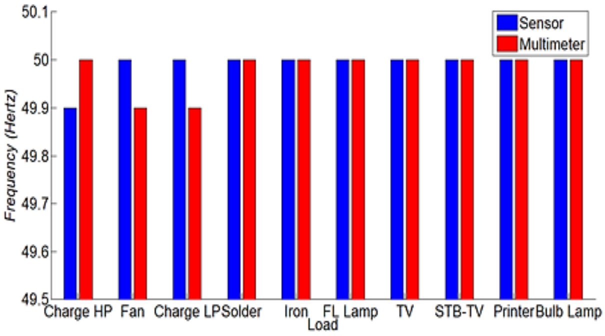


Figure 13. Result of frequency monitoring test

Figure 14. Power monitoring test at iron load

With the same procedure, the power test was carried out on nine other household electrical loads and the results are shown in Table 4 and Figure 15.

Table 4. Power monitoring test results

No.	Loads	Sensor Power (W)
1	Charge HP	11.8
2	Fan	36.2
3	Charge LP	24.9
4	Solder	29.3
5	Iron	306.3
6	FL Lamp	41.0
7	TV	37.2
8	STB TV	8.0
9	Printer	2.2
10	Bulb Lamp	11.2

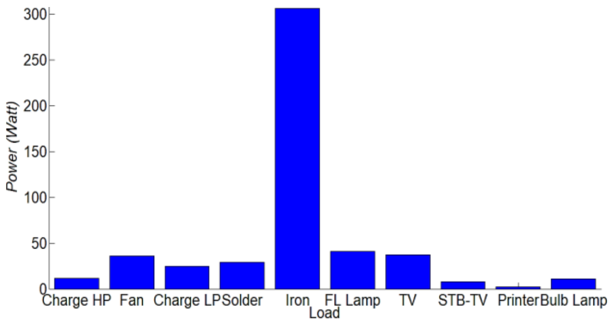


Figure 15. Result of power monitoring test

Table 4 and Figure 15 show that the power measurement on the iron load using the sensor produces the highest power value of 306.4 A. The smallest power measurement is produced by the printer load of 2.2 A.

Figure 16 shows the energy monitoring test (kWh) via the Telegram application at $t_1 = 15\ min$ to $t_4 = 60\ min$ using a sensor for iron.

Figure 16. Energy (kWh) monitoring test at iron load

With the same procedure, energy monitoring tests were carried out on nine other household electrical loads and the results are shown in Table 5 and Figure 17.

Table 5. Energy monitoring test results

No.	Loads	Times (Minutes)			
		15	30	45	60
		Energy (kWh)			
1	Charge HP	0.01	0.02	0.03	0.04
2	Fan	0.01	0.02	0.03	0.04
3	Charge LP	0.01	0.01	0.02	0.02
4	Solder	0.01	0.01	0.02	0.03
5	Iron	0.03	0.05	0.08	0.11
6	FL Lamp	0.01	0.02	0.03	0.04
7	TV	0.01	0.02	0.03	0.04
8	STB TV	0.00	0.00	0.00	0.01
9	Printer	0.00	0.00	0.00	0.00
10	Bulb Lamp	0.00	0.00	0.01	0.01

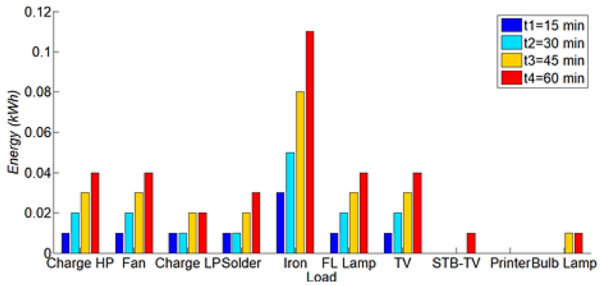


Figure 17. Result of energy monitoring test

Table 5 and Figure 17 show energy measurements of the iron $t_1 = 15\ min$, $t_2 = 30\ min$, $t_2 = 45\ min$, and $t_4 = 60\ min$ by using the sensor, produce the highest power values: 0.03 kWh, 0.05 kWh, 0.08 kWh, and 0.11 kWh, respectively. The lowest energy measurement is produced by the printer load $t_1 = 15\ min$, $t_2 = 30\ min$, $t_2 = 45\ min$, and $t_4 = 60\ min$ with the same value at 0 kWh.

Figure 18 shows the testing of electricity tariff monitoring in rupiah (Rp) via the Telegram application on an iron at $t_1 = 15\ min$, $t_2 = 30\ min$, $t_2 = 45\ min$, and $t_4 = 60\ min$ using a sensor for the iron load. The price per kWh is applied at Rp. 1,444.70/kWh for power class and tariff class (R1/TR) 2200 VA with a fuse limiter on the kWh-meter of 10 A.

Figure 18. Tariff monitoring test on iron load

In the same procedure, testing of tariff monitoring via the Telegram application at $t_1 = 15\ min$, $t_2 = 30\ min$, $t_2 = 45\ min$, and $t_4 = 60\ min$ using sensors was carried out on nine other household electricity loads, and the results are shown in Table 6 and Figure 18.

Table 6. Tariff monitoring test results

No.	Loads	Times (Minutes)			
		15	30	45	60
		Tariff (Rp)			
1	Charge HP	3.98	7.95	11.92	14.57
2	Fan	11.92	23.85	34.45	47.70
3	Charge LP	7.95	15.90	22.53	30.48
4	Solder	9.28	18.55	27.82	38.42
5	Iron	35.78	70.22	103.35	141.77
6	FL Lamp	13.25	27.82	42.40	55.65
7	TV	11.92	23.85	35.78	47.70
8	STB TV	1.33	3.98	6.63	9.28
9	Printer	0.00	0.00	0.00	0.00
10	Bulb Lamp	2.65	6.63	10.60	14.57

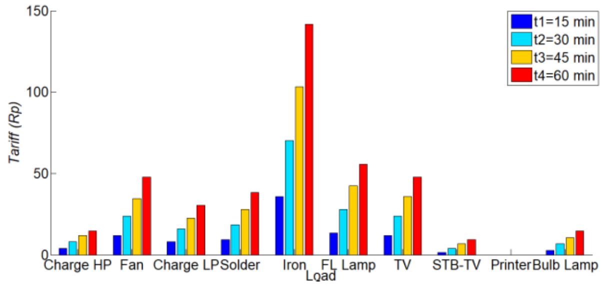
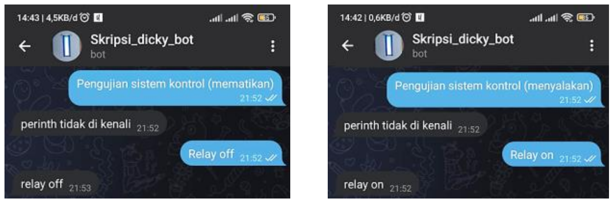


Figure 19. Result of Tariff monitoring test

Table 5 and Figure 17 show that measuring the electricity bill at iron load $t_1 = 15\ min$, $t_2 = 30\ min$, $t_2 = 45\ min$, and $t_4 = 60\ min$ using a sensor, produces the highest tariff value of Rp. 35.78, Rp. 70.22, Rp. 103.35, and Rp. 141.77, respectively. Price measurements on printer load at $t_1 = 15\ min$, $t_2 = 30\ min$, $t_2 = 45\ min$, and $t_4 = 60\ min$ produce the lowest and the same value as 0 kWh.

C. Test Results for Control, Protection, and On/Off Timer Systems

The tool control system is tested by connecting the PLN source with the load and the relay module. Figure 20.a and Figure 20.b respectively show the relay control system for the command to turn on and turn off the load. Table 7 shows the function test of the control components.



(a) (b)

Figure 20. Relay control system for commands to (a) turn on and (b) turn off the load

Table 7 Component function testing for control

No	Command	Description	Delay	Result
1	Relay On	Turn on the load	5 *sec*	Succeed
2	Relay Off	Turn off the load	4 *sec*	Succeed

Figure 20.a and Table 7 show when the relay is On, then in the next 5 sec, the load will turn on. Figure 20.b and Table 7 show when the relay is Off, then within the next 4 seconds the electrical load will turn off.

Testing of the protection system aims to ensure that the relay is able to cut off electric current when it receives commands from NodeMCU ESP8266. Testing is carried out by connecting and disconnecting the relay power supply. Testing the function of the protection system components is shown in Table 8.

Table 8. Testing the function of the components of the protection system

No	Voltage	Description	Condition
1	80–239 V	Turn on the relay	Connected
2	240 V	Turn off the relay	Disconnected

Table 8 shows that at a voltage of 80-239 V, NodeMCU ESP8266 is able to turn on the relay so that the source to the load is connected. However, at 240 V, NodeMCU ESP8266 is able to turn off the relay so that the source up to the load is disconnected. Final testing is to test the on/off relay time at a specific time. Testing is done by comparing the on/off Timer with the time recorded using a Stopwatch. Table 9 and Table 10 respectively show the timer testing when turning off and turning on the relay at specific times.

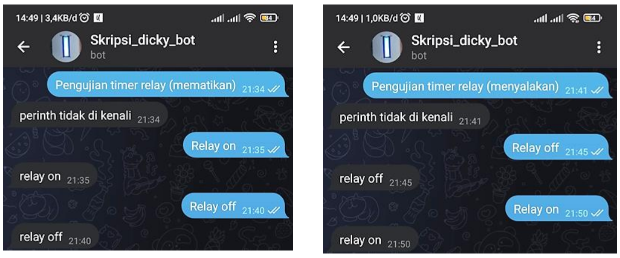
Table 9. Testing of turning off the relay at a specific time

System Time	Specific Time Timer Off	Delay Time	Stopwatch
21:35:00	21:40:00	5 min	5 min 4 sec

Table 10. Testing of turning on the relay at specific time

System Time	Spesific Time Timer On	Delay Time	Stopwatch
21:45:00	21:50:00	5 min	5 min 5 sec

Figure 21.a and Figure 21.b respectively show the command display in the Telegram application in the timer test of turning off and on the relay.



(a) (b)

Figure 21. Timer testing (a) turns off and (b) turns on the relay

Table 9 and Figure 21.a show that the system was off at 21:35:00, while the on/off timer was able to turn off the relay at 21:40:00 or there is a 5-minute delay. When compared to testing using a stopwatch, a time delay of 5 minutes and 4 seconds was recorded. Table 10 and Figure 21.b show that in testing, the system was turned on at 21:45:00, and the on/off timer was able to turn on the relay at 21:50:00 or there is a 5-minute delay While the stopwatch recorded a delay of 5 minutes and 5 seconds.

Table 11. Comparison of the author's proposed prototype design compared to previous studies

Auth	Methods/Devices	Monitor								Con.	Pro.	Timer On/Off	Monitor Devices
		V	*A*	*W*	*kWh*	*Rp*	*Hz*	*Cos θ*	℃				
[1]	NodeMCU ESP8266	N	N	N	N	N	N	N	Y	Y	N	N	Telegram
[2]	Arduino Uno-Ethernet Shield W5100	Y	Y	Y	Y	N	N	Y	N	N	N	N	LCD 16x2
[3]	NodeMCU ESP8266	N	N	N	N	N	N	N	N	Y	N	N	Telegram
[6]	NodeMC, Arduino Uno, Think-speak	Y	Y	Y	N	N	N	N	N	Y	N	Y	Telegram
[8]	NodeMCU Arduino Uno	Y	Y	Y	Y	N	N	N	N	Y	N	N	Blynk
[11]	NodeMCU ESP8266	N	N	N	N	N	N	N	Y	Y	N	N	Telegram
[12]	NodeMCUAArduino Uno	N	N	N	N	N	N	N	N	Y	N	N	Telegram
[14]	Web based Arduino Uno-R3	Y	Y	Y	N	N	N	N	N	Y	N	N	Website
[15]	Arduino Uno, SMS Gateway	Y	Y	N	N	N	N	N	N	N	N	N	LCD 16x2
Prop.S tudy	**Arduino, Sensor PZEM-004t, Current Sensor NodeMCU, ESP8266**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**N**	**N**	**Y**	**Y**	**Y**	LCD 16x2, **Telegram**

Y : Yes ; N : No ; LCD : Liquid Crystal Display

Table 11 shows a comparison of the author's proposed prototype compared to previous studies. Parameters observed are voltage, current, power, energy, price, frequency, power factor, temperature, control, protection, timer On/Off, and monitor devices. In this table, Y means Yes (available) and N means No (not available). In [1], Pangestu et al have implemented a prototype IoT system for monitoring temperature and controlling household electrical appliances using the NodeMCU ESP8266 monitored by the Telegram application. In [2], Santoso et al have designed a kWh-meter for monitoring current, voltage, power factor, and household electrical energy using IoT with the Ethernet Shield W5100 module, Arduino Uno, and 16×2 LCD. An IoT system for home door monitoring and light control with NodeMCU ESP8266 and the Telegram application has been proposed by Ramady et al [3].

In [6], Kamil et al have designed NodeMC, Arduino, Thinkspeak, and Telegram to monitor current, voltage, and power as well as control household lights. Controlling household electricity consumption and monitoring voltage, current, power and energy using Arduino Uno, NodeMCU, and the Blink application on Smartphones have been implemented by Jatmiko et al [8]. In [11], Iftikhor et al designed a prototype of a temperature monitor and control of residential electrical equipment using the NodeMCU ESP8266 and Telegram. Control of household electrical switches using NodeMCU ESP8266, Arduino Uno which is monitored by Telegram with Eagle software has been designed by Fitriyanto et al [12]. In [14], Riantiarto et al have implemented a tracking system for voltage, current, power and household electrical load control based on Arduino Uno and monitored by the website from both smartphones and computers. Furthermore, Arduino Uno-based current and voltage monitoring tools, SMS gateways, and 16×2 LCDs for micro hydropower plants and PLTS have been designed by Fitriandi et al [9].

In this research, the authors proposed four studies, i.e., monitor, control, protect, and on/off timers, for household electrical appliances that are monitored either with a 16×2 LCD or Telegram. Monitored system parameters are voltage, current, frequency, power, energy, and electricity rates for each device. Device hardware, i.e., Arduino Uno, 1 Channel Relay, PZEM-004t Voltage Sensor, NodeMCU ESP8266, and Current Sensor (Current Transformer), have been successfully tested on 10 different household appliances. With more complete performance, this equipment is able: to monitor, control, protect, and set On/Off timers; be monitored from both the 16×2 LCD and Telegram; and to provide superior performance compared to the prototype designed by-previous researchers.

IV. CONCLUSION

Implementation of an IoT prototype for monitoring, controlling, protecting, and setting On/Off timers for household electrical equipment, which is monitored by the Telegram application and 16×2 LCD, has been carried out. Monitored system parameters are voltage, current, frequency, power, energy, and electricity rates for each device. Device hardware, i.e., Arduino Uno, 1 Channel Relay, PZEM-004t Voltage Sensor, NodeMCU ESP8266, and Current Sensor (Current Transformer) have been successfully tested on 10 different household appliances. The results of the study show that the prototype is capable of monitoring, controlling, protecting, and setting the On/Off timer as well as being able to monitor each one from close and far distance from the 16x2 LCD and the Telegram application. The sensor tool using the Telegram application is able to measure/monitor the voltage, current and frequency at 10 loads with an average error value of 0.32%, 12.83% and 0.1%, respectively, compared to measurements using a Multimeter. In the protection scheme, at a voltage level of 80-239 V, NodeMCU ESP8266 is able to turn on the relay so that the source to the load is connected. However, at a voltage of 240 V, NodeMCU ESP8266 is able to turn off the relay so that the source up to the load is disconnected. The tool prototype is also capable of providing more complete, faster (4-5 sec), and superior performance of parameter monitoring capabilities compared to tools designed by a number of previous researchers. However, this prototype has not been able to store the past data monitoring results. In the future work, it is necessary to add options to save, download, and print the history of measured data, so that users can print power consumption and home electricity rates per day, week or month. So that the goal applying the tool as an IoT prototype to save power and reduce monthly electricity bill can be achieved.

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REFERENCES

[1] A. Pangestu, A.Z. Iftikhor, Damayanti, M. Bakri, and M. Alfarizi, "Sistem Rumah Cerdas Berbasis IoT dengan Mikrokontroler Nodemcu dan Aplikasi Telegram", Jurnal Teknik Informatika dan Komputer (JTIKOM), Universitas Teknokrat, Bandar Lampung, Vol. 1, No. 1, pp. 8-14, June 2020.

[2] K.A. Santoso and D.A. Prasetya, "Rancang Bangun KWh Digital Berbasis IoT", Simposium Nasional RAPI XIX FT Universitas Muhammadiyah Surakarta, pp. 39-46, 2020.

[3] G.D. Ramady, C.R. Apriandi, G.K. Sukandi, R.Budi, Resmana, and S. Santoso, "Rancang Bangun Sistem Sistem Monotoring Pintu Rumah dan Kontrol Lampu Berbasis Telegram", Jurnal Isu Teknologi, Sekolah Tinggi Teknologi Mandala, Bandung, Vol. 16, No. 2, pp. 52-58, December 2021.

[4] Ratna, S.W. Sidehabi, and Muslimin, "Rancang Bangun Penyiraman Otomatis dan Monitoring Menggunakan Notifikasi Telegram dan Kamera pada Tanaman Cabai", Final Project, Politeknik ATI Makassar, Kementrian Perindutrian, pp. 1-39, 2021.

[5] A. Baharuddin, H. Nirwana, and Rahmania, "Perancangan Lampu Pintar Menggunakan Kontroller Jarak Jauh Berbasis Telegram", Final Project, Program Studi Teknik Elektro, Fakultas Teknik, Universitas Muhammadiyah Makassa, pp. 1-42, 2019,

[6] M.I. Kamil, R. Ardianto P, and Ig P.D. Wibawa, "Prototype of IoT Based Home Light Monitoring and Control Systems", e-Proceeding of Engineering : Vol.6, No.2, pp. 2974-2981, August 2019.

[7] A.T. Cahyadi, P. Susanto, and W.I. Kusumadewi, Rancang Bangun Sistem Monitoring Kendaraan pada Persewaan Motor Listrik, Final Project, Program Studi Teknik Komputer, Fakultas Teknologi dan Informatika, Universitas Dinamika Surabaya, pp. 1-26, 2022.

[8] Jatmiko, F.N. Alwi, and R.N. Rohmah, "Alat Monitoring dan Pengendalian Konsumsi Listrik Rumah Tangga untuk Rumah Pintar Berbasis IoT", EMITOR: Jurnal Teknik Elektro, Universitas Muhammadiyah Surakarta, Vol 22, No 1, pp. 34-38, February 2022.

[9] S. Abdurrahman, Z. Tharo, and S. Anisah, "Rancang Bangun Sistem Penggunaan Daya Listrik Berbasis Aplikasi Telegram", Program Studi Teknik Elektro, Fakultas Sains dan Teknologi, Universitas Pembangunan Panca Budi, Medan, pp. 1-67, 2019.

[10] D. Wijayanto, S.I. Haryudo, T. Wrahatnolo, and Nurhayati, "Rancang Bangun Monitoring Arus dan Tegangan Pada PLTS Sistem On Grid Berbasis Internet of Things (IoT) Menggunakan Aplikasi Telegram", Jurnal Teknik Elektro (JTE), Universitas Negeri Surabaya, Vol. 11, No. 3, pp. 447-453, September 2022.

[11] A.Z. Iftikhor and C. Bella, "Rancang bangun Rumah Cerdas Menggunakan Internet of Things (IoT0 dengan Aplikasi Telegram dan Mikrokontlroler Nodemcu", Portaldata.org, Vol. 2, No. 1, pp. 1-20, 2022.

[12] I. Fitriyanto and F. Amri, "Rancang Bangun Alat Kontrol Saklar Listrik Jarak Jauh Berbasis Nodemcu dan Telegram, Jurnal Rekayasa Energi, Politeknik Negeri Indramayu, Vol. 1, No. 1, pp. 36-42, 2022.

[13] M.F. Pratama, M. Haddin, and A. Marwanto, "Sistem Monitoring dan Kontrol Daya PLTS Menggunakan IoT Berbasis Fuzzy Logic", Thesis, Program Magister Teknik

Elektro, Universitas Islam Sultan Agung Semarang, pp. 1-62, 2021.

[14] A. Riantiarto, D. Suryadi, and Saifurrahman, “Rancang Bangun, Alat Monitoring Arus pada Beban Listrik Rumah Tangga Menggunakan Web Berbasis Arduino Uno R3”, ELKHA : Jurnal Teknik Elektro Universitas Tanjungpura Pontianak, Vol. 2, No. 1, pp. 1-9, 2019.

[15] A. Fitriandi, E. Komalasari, and H. Gusmedi, Rancang Bangun Alat Monitoring Arus dan Tegangan Berbasis Mikrokontroler dengan SMS Gateway, ELECTRICIAN – Jurnal Rekayasa dan Teknologi Elektro, Vol. 10, No. 2, pp. 87-98, May 2016.