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Development of 3 Phase Pump Panel Monitoring System based on Internet of Things (Case Study PERUMDAM)

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ABSTRACT

To maintain the distribution of water, PERUMDAM uses a water pump panel to run and monitor the water pump to keep running. Even so, the water pump can be damaged at any time, so PERUMDAM officers do routine activities to check the health of the water pump. Therefore, this article tries to solve the problem by making the design and implementing the IoT-based pump panel system.

An IoT-based pump panel is a device that is connected to an Android application to control and monitor the pump panel in real-time. Android applications can send notifications if there are anomalies in the sensor data. Controlling that can be done is by changing the mode on the analog pump panel from manual to automatic, and vice versa. The monitoring data obtained by the IoT-based pump panel is divided into two types. The optocoupler generates data related to the sensors on the analog pump panel in the form of boolean values. The power meter generates data in the form of values for voltage, current, frequency, and others as needed.

The result of this article is the IoT pump panel monitoring system is successfully implemented. This conclusion is based on several test results ranging from Modbus test, SSR test, application interface test, and notification test.

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1. INTRODUCTION

The quality of the society is strongly influenced by the availability of water. Water is the most basic human need. With water, people can clean themselves, make food, and most importantly, replace body fluids. In Indonesia, the government provides water to the community through PERUMDAM (Perusahaan Daerah Air Minum).

There have been several studies on monitoring the distribution and availability of water more efficiently that have been carried out previously. This paper [1] discusses the manufacture of a water monitoring system using a flow meter sensor. There are studies on the amount of water used through customer billing or using IoT systems [2], [3]. Research in this paper [4] makes an IoT-based water distribution system.

Water monitoring using several parameters was carried out in studies [5] and [6]. This paper [7] discusses a water quality monitoring system using IoT and Deep Learning.

In addition to the availability of clean water, several studies on early warning systems have been carried out previously. IoT-based early warning systems are used in natural disasters, such as floods [8], earthquakes [9], [10], volcanic activity [11], and forest fires [12].

PERUMDAM uses a pump panel that is useful for monitoring the pump so that it is running properly. This tool can monitor several statuses on pumps, such as WLC, PLN, Pump Motors, etc. In addition, the pump panel can also control the water pump mode that is manual/automatic and turn on/turn off the water pump. However, the current pump panel is analog, so monitoring the pump panel is still carried out routinely. If there is a problem with the water pump malfunctions while the officer is not on duty in the area, it can take a long time for the officer to know that there is a pump malfunction in the area.

The objective of this paper is to develop an IoT system to monitor and control the pump panel in real-time. IoT pump panels are monitored through the Android application in the form of a dashboard that can monitor the IoT panel pump. The monitoring instruments are voltage (R, S, T), electric current (R, S, T), frequency, power, power factor, and pump status. In addition to monitoring, this application can control pump mode (manual or automatic). Notification/early warning system is also included so that the officers can get notified if there is a change in the status of the pump state, or if the voltage or electric current pump panel is outside the normal range.

2. THEORETICAL BASIS

2.1. Internet of Things

Internet of Things (IoT) is a technology that can connect electronic devices to the Internet [13], [14]. This technology allows devices previously not connected to the network into devices that can communicate with other devices and connected to the network. “Things” in IoT can be interpreted as electronic devices that can be adjusted, such as lights, cameras, and motors.

IoT has a system consisting of devices that have microprocessors and sensors. This device takes information obtained from the sensor and sends the data to a local server or the cloud. IoT works by providing programming instructions that can result in an interaction between connected devices. These devices can work without human intervention and humans only serve as supervisors of the device system.

2.2. NodeMCU ESP8266

NodeMCU is an open-source hardware platform. This platform has the key components of the Tensilica Xtensa LX106 RISC microprocessor and the ESP-12e module containing ESP8266. ESP8266 is a Wi-Fi module so that the IoT device can be connected to the Wi-Fi network. With a small shape, low power, and low prices, NodeMCU is often used in IoT products.

NodeMCU ESP8266 has 4 MB of flash memory and 80 MHz clock speed. This microcontroller is used in this paper to send data to Firebase, receive data from Firebase, receive data from the optocoupler, receive data from the power meter using RS-485, and give commands to the SSR.

2.3. Optocoupler

Optocoupler is hardware that functions to convert a 220-volt voltage (high voltage) into a 5-volt voltage (low voltage) so that the microcontroller can read the voltage and manage the data provided by Optocoupler. The optocoupler consists of 2 main parts, namely the Transmitter which functions as an optical light sender, and the Receiver which functions as a light source detector.

An optocoupler is a combination of a Light Emitting Diode (LED) and a Phototransistor consisting of an LED component that emits infrared light (IR LED) and a light-sensitive semiconductor component (phototransistor) as a part used to detect infrared light emitted by IR LEDs.

2.4. Solid State Relay (SSR)

Solid-State Relay (SSR) is an electromechanical switch that has semiconductor properties. SSR is the latest type of non-contact electronic switch that has sophisticated foreign performance and technology and equipment. Slightly different from the general relay, the operation of the solid-state relay is quite simple. The end of the input requires a smaller current with less control and better compatibility with IC TTL, HTL, and CMOS.

SSR also uses a series of outputs that adopt a thyristor and high-power transistor that functions to connect and break the load current [15]. SSR has several advantages. These advantages are minimal noise and no sparks produced when the state is changed, long lifespan, no corrosion, and can withstand some vibration.

2.5. Power Meter 3 Phase

Power Meter 3 Phase is a device that can measure various electrical parameters, from currents and voltages to resistance, continuity, and so forth. Electrical contractors use 3 phase power meters to evaluate live cables and circuit breakers to electrical panels and power transformers.

3 phase power meter functions as a voltage gauge, current gauge, digital multimeter, electricity examiner, oscilloscope, circuit testers, voltage detectors, miliohmmeters, phase rotation meters, and network analysis [16]. 3 phase power meter uses several equations in calculating 3-phase electrical parameters [17]. To calculate power, this power meter uses (1).

$$Power(kWh) = \frac{\sqrt[2]{Volt} \times \sqrt[2]{Current} \times 1{,}732 \times 0{,}75}{1000} \quad (1)$$

In this equation, there are several constants. 1.732 is a constant of 3, 0.75 is a constant of the power factor, and 1000 is a constant for converting Wh to kWh.

2.6. Modbus Communication

Modbus communication is the communication method used by the power meter using the RS-485 communication module either as master or slave [18]. Modbus communication is located at the 6th layer of OSI layers, which is the application layer. Modbus communication can support various common electrical interfaces or industrial interfaces such as Ethernet, RS485, RS232, etc. [19].

Modbus communication used an unsigned integer in the register. To read the register it is necessary to convert the unsigned integer data to a float or integer value. The address used on the IoT pump panel is based on the power meter manual.

The following is an example of a Modbus address power meter table:

Table 1. Modbus Power Meter Addresses

Address	Project	Describe	Byte Address
9,10	Ua (three phase four wire)	A Phase voltage	18,19,20,21
11,12	Ub (three phase four wire)	B Phase voltage	22,23,24,25
13,14	Uc (three phase four wire)	C Phase voltage	26,27,28,29
15,16	Ia	A Phase current	30,31,32,33
17,18	Ib	B Phase current	34,35,36,37
19,20	Ic	C Phase current	38,39,40,41
27,28	PFS	Total power factor	54,55,56,57
29,30	HZ	Frequency	58,59,60,61

3. METHOD

This research was conducted in the PERUMDAM of Madiun Regency. There are three stages in this study. The first stage is designing the IoT pump panel circuit, programming the IoT, and developing the Android app. The second stage is the installation of the IoT panel pump and connecting the IoT device with the Android app. The last stage is to collect data by taking two data. The first data is to retrieve the IoT pump panel sensor data every hour for about 14 days. The second data is to measure the Android application delay with the database on Firebase.

The design system is described in the following diagram.

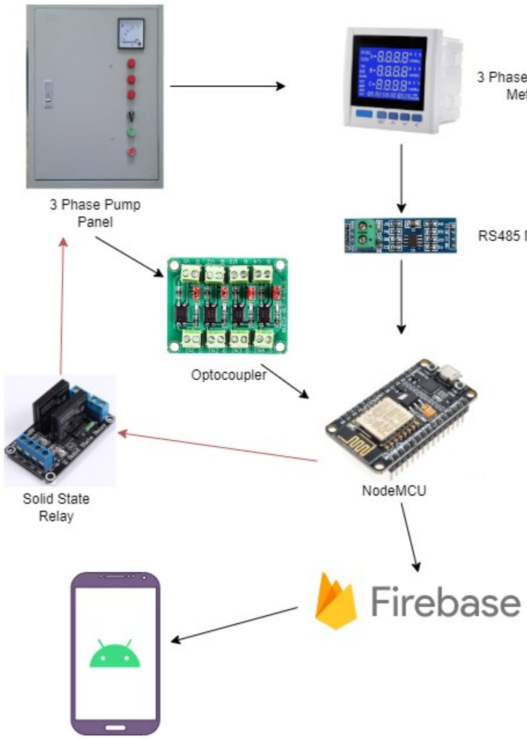

Figure 1. System Diagram

Based on Figure 1, there are 3-phase pump panels, IoT pump panels, Firebase Realtime databases, and Android applications. The 3-phase pump panel is the pump panel used in PERUMDAM today. To be used in IoT, the IoT pump panel is made to convert analog data on analog pump panels into digital data. The IoT pump panel uses the NodeMCU ESP8266 which has WiFi capability. The data already obtained by the IoT pump panel is sent to the Firebase Realtime Database.

The IoT pump panel is designed to be able to read analog data from electronic components on the analog pump panel, so this IoT pump panel consists of several electronic components that can convert analog values to digital and are connected directly to the NodeMCU ESP8266 and the Firebase Realtime Database. The optocoupler will be connected to the NodeMCU which functions to monitor the sensors on the 3-phase pump panel. Power Meter functions as a 3-phase electrical data reader. NodeMCU will send the data obtained continuously to Firebase, then a mobile application will retrieve the data from Firebase so that when there is a change in the value of the sensor, the mobile application will notify the user. When the user gets a notification from the mobile application, the user will analyze whether this is an anomaly value that needs to be investigated or not.

In addition to monitoring, the application can control the pump panel, such as the pump mode can be controlled to be manual or automatic. The application will send the control status to the database, then NodeMCU will read the control status from the database and set the Solid State Relay according to the control status in the database.

Here is the system design on the IoT pump panel.

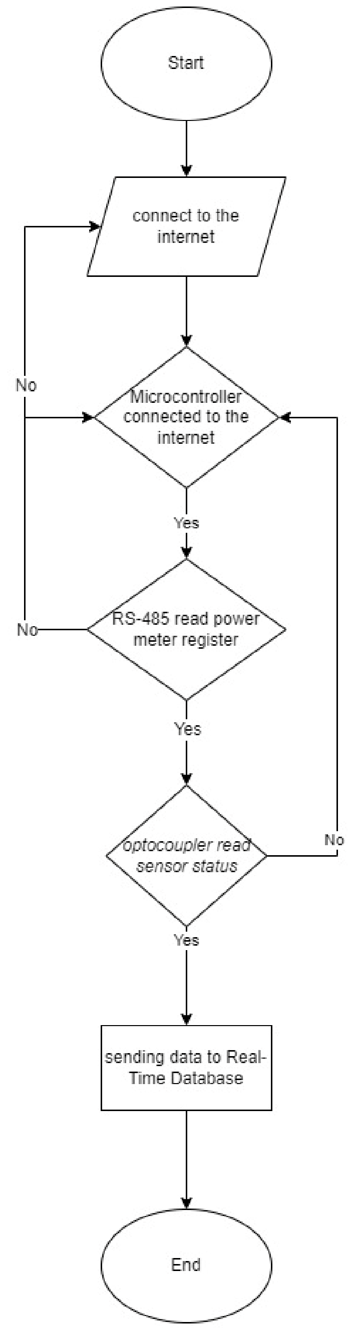

Figure 2. IoT Pump Panel Architecture

In the IoT pump panel, there is also an SSR with two channels that will be connected to the NodeMCU ESP8266. SSR on the first channel is used to activate the manual mode and the second channel is used to activate the automatic mode in the pump panel. When automatic mode is activated, the water pump will turn on or off automatically. When manual mode is activated, the water pump mode must be turned on or off manually. All these things are controlled by the Android app. The diagram for IoT pump panel controlling is shown on figure 3.

NodeMCU is also connected to the power meter that functions as a receiver of data related to current, voltage, power factor, frequency, and power that is on the 3-phase pump panel and sent to NodeMCU using the RS-485 communication protocol. Data obtained by NodeMCU will be sent to Firebase to be managed.

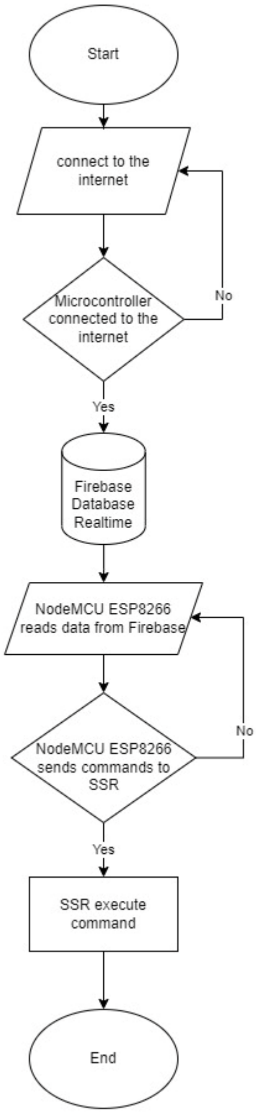

Figure 3. IoT Pump Panel Controlling Flow

Figure 4 shows the architecture of the Android app. The application has a user interface that focuses on presenting real-time data on IoT devices. This user interface consists of a list of monitors and a pump dashboard panel.

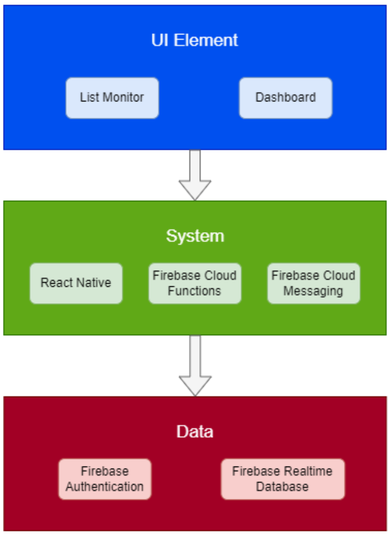

Figure 4. Android App Architecture

Android applications are developed using the React Native framework and the JavaScript programming language. Firebase is used as a database and early warning system. The database uses the Firebase Realtime Database service, and the early warning system uses a combination of Firebase Cloud Functions and Firebase Cloud Messaging.

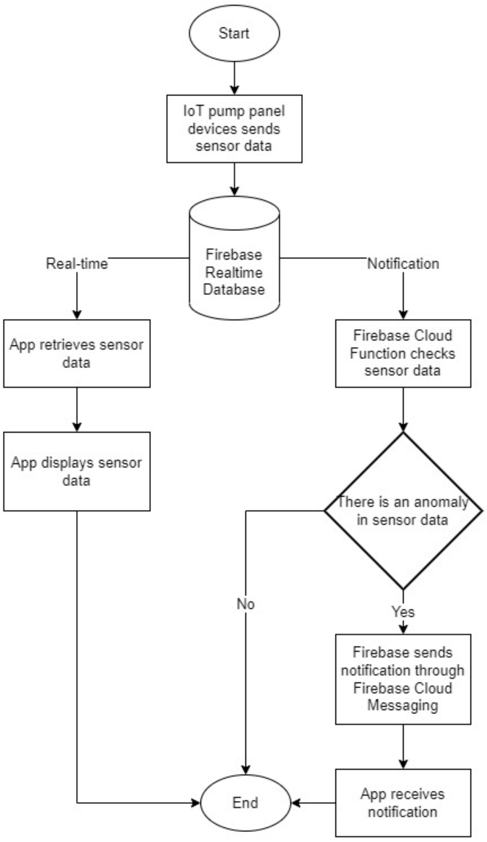

Figure 5. Android App System Flow Chart

Figure 5 shows the system flow on the Android app. For monitoring IoT pump panel, IoT pump panel devices will send data that has been obtained from sensors to Firebase. The app then fetches data from Firebase using the Firebase API. After the data is obtained, the application displays the data on the dashboard page.

The notification system works with Firebase Cloud Functions for comparing sensor data with the normal limit in the database of each IoT device sending the data to Firebase. If the sensor data is outside the limit, the Firebase will send the appropriate notification using Firebase Cloud Messaging.

4. RESULTS AND DISCUSSION

4.1. Test and Calculation of IoT Pump Panel

The test on the IoT pump panel was carried out for 14 days, to monitor electricity on the pump panel. This test is carried out by taking the data received from the power meter per hour. The hourly data is sent to Firebase and stored. The hourly data is then calculated to get the average parameter data by 24 hours per day. Table 2 shows the average parameter data per day calculated by the hourly data obtained.

Table 2. Average Parameter Data per Day

Day	Current R	Current S	Current T	Volt R	Volt S	Volt T
1	19.65975	18.47395833	16.893	228.4729192	226.7524988	227.11125
2	19.60241667	18.42716667	16.8555	228.2004163	225.9512492	226.4899983
3	20.72366667	19.244	17.72025	227.6350004	226.1008304	226.2233346
4	19.70566667	18.484625	16.90433333	228.1554175	226.1541671	226.3504175
5	20.53695	19.09885	17.4952	227.7135	225.8649985	226.4589995
6	19.6555	18.47029167	16.88754167	227.7866663	226.1987508	226.3687521
7	19.94545833	18.65275	17.17670833	228.8624988	227.3904171	227.1779154
8	19.670125	18.49316667	16.89429167	227.997085	226.50875	226.4233329
9	19.75591304	18.48404348	17.01573913	227.7139117	225.7621726	225.9452187
10	19.65095833	18.44691667	16.88533333	227.6624979	225.3291688	226.1666667
11	20.05495833	18.68825	17.29883333	227.8058338	226.145835	226.4412492
12	19.66526087	18.45765217	16.88830435	228.0856535	225.842173	226.6421722
13	19.65541667	18.43566667	16.88133333	228.1024983	225.6745825	226.5533325
14	20.062625	18.710125	17.30941667	228.5775	227.2283333	227.2483338

From the formula of equation 1 on the 3-phase power meter, the power calculation is carried out from the data obtained in table 2. The calculation results can be seen in table 3.

Table 3. Power Calculation Results (kWh)

Day	Power (kWh)
1	16.28849625
2	16.20591167
3	17.02377125
4	16.26898625
5	16.861236
6	16.23739583
7	16.5351925
8	16.26460667
9	16.28547522
10	16.19964708
11	16.54002167
12	16.24168609
13	16.22453542
14	16.61652833

The calculations are carried out on NodeMCU ESP8266, so the mobile application can show the power data (kWh) in the dashboard. All the data obtained can later be used for other data processing, as needed.

To get the data above, the Modbus serial communication protocol is used, this communication test is done by entering the address and the register values in the manual. The following is a table of data taken on the IoT-based pump panel.

Table 4. Modbus Test Result

Address	Register	Data	Test Result
9,10	1	A phase voltage	Pass
11,12	1	B phase voltage	Pass
13,14	1	C phase voltage	Pass
15,16	1	A phase current	Pass
17,18	1	B phase current	Pass
19,20	1	C phase current	Pass
27,28	1	Total power factor	Pass

Address	Register	Data	Test Result
29,30	1	Frequency	Pass
71,72	1	Positive active energy	Pass

In the analog pump controlling panel, the component used is the Solid State Relay (SSR). Testing on the SSR is carried out using the black box method, namely by connecting the pump panel mode to the SSR, then the user will send a command using a mobile application and the command will be received by the ESP8266 nodeMCU. So that when the manual mode is turned on, the automatic mode will turn off, and when the automatic mode is on, the manual mode will turn off. The following table is the result of the black box SSR test.

Table 5. SSR Control Test Result

Test	Function	Output	Test Result
Relay channel 1/ manual mode	To turn on or off manual mode	If the relay channel 1 is given a value of 0 then the relay will flow electricity so that the manual mode will turn on, and the automatic mode will turn off.	Pass
Relay channel 2/automatic mode	To turn on or off automatic mode	If relay channel 2 is given a value of 0 then the relay will flow electricity so that the automatic mode will turn on, and the manual mode will turn off.	Pass

4.2. Application Test

Application is developed using a React Native and is targeted to be used on Android devices. Firebase is used as a back-end using the Realtime Database feature for databases and a combination of Cloud Function and Cloud Messaging as a notification system. Figure 6 shows the interface of the monitor list of pump panels and panel pump dashboard in the application. The application is tested with two test methods, which are the black box test and the latency test.

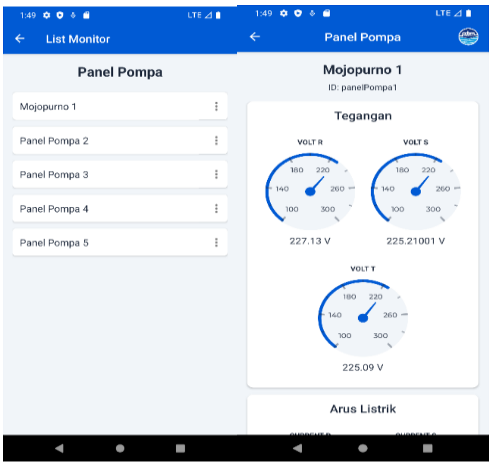

Figure 6. Application Interface

The black Box test is used to know that all functionality in the application is working correctly. The test is done in two parts. The first part is the application interface test to test the UI and the navigation. The second part is the notification test to test the notification system. Test results on the application interface are presented in Table 6 and the test results on notifications can be seen in Table 7.

Table 6. Application Interface Test

Component	Expected Result	Test Result
Pump Panels List	If the user selects the pump panel from the monitor list on the home screen, the application will display the text "Panel Pompa" and items of various pump panels along with the menu option.	Pass
Pump Panel Dashboard	If the user selects one of the devices on the pump panel list screen, the application will display the pump panel page that contains sensor indicators.	Pass
SSR Controls	If the state on the Relay Manual is OFF, then the state on the automatic relay is supposed to be ON. Whereas if the state on the Relay Manual is ON, then the State on the automatic relay should be OFF.	Pass

Table 7. Notification Test

Component	Expected Result	Test Result
Volt and Current notification	Send “under” notifications if below normal limits, and/or send “over” notifications if above the normal limit.	Pass
Pump state notification	Send notifications if one of the pump status changes.	Pass

The test results in Table 6 and Table 7 show that functionality in the application runs well. The dashboard displays the latest sensor data, SSR can be controlled from the application, and notifications work well. To measure the length of the application showing the data from the database, latency testing is carried out.

Latency test measures how long the application takes data from Firebase until the application displays the data on the dashboard interface. This test is carried out 10 times in 5 days through the performance monitoring feature on Firebase. This is because Firebase only displays median data from a certain time, so data cannot be obtained singly. The data taken is median data within 24 hours. Following are the results of latency testing in Table 3.

Table 8. Application Latency Test

Day	Latency (median)
1	151 ms
2	158 ms
3	164 ms
4	147 ms
5	188 ms

Based on the results in table 8, the smallest latency was achieved on the first day with a latency of 151 ms and the largest latency was achieved on the fifth day, with a latency of 188 ms. The latency is stable across 5 days, within a range of 150 ms to 190 ms.

5. CONCLUSION

In conclusion, the IoT pump panel monitoring system is successfully implemented. This conclusion is based on several successful test results ranging from Modbus test, SSR test, application interface test, and notification test. Additional conclusions can be drawn, namely: (1) The IoT-based pump panel is running well, and is in line with expectations, both on sensor monitoring or analog pump panel electrical monitoring, as well as on the controlling function is by which is expected, and (2) the application can run properly with all functionalities functioning, with sensor data retrieval latency time is quite stable with an average of 161.6 ms.

Suggestions for further research are connecting IoT Pump panels with water pumps directly without using analog pump panel intermediaries because this article still uses analog pump panels to connect to water pumps. In addition, mobile applications can use native platforms such as Kotlin or using other mobile cross-platform application platforms such as Flutter.

REFERENCES

[1] D. P. A. R. Hakim, A. Budijanto, and B. Widjanarko, “Sistem Monitoring Penggunaan Air PDAM pada Rumah Tangga Menggunakan Mikrokontroler NODEMCU Berbasis Smartphone ANDROID,” *Jurnal IPTEK*, vol. 22, no. 2, Art. no. 2, Dec. 2018, doi: 10.31284/j.iptek.2018.v22i2.259.

[2] I. Saraswati, F. Erwiza, A. S. Pramudyo, Suhendar, and Y. Muharni, "Development of water tap control systems and PDAM cost monitoring based on IOT," *Proceedings of the Conference on Broad Exposure to Science and Technology 2021 (BEST 2021)*, Feb. 2022.

[3] W. I. Pasaribu, D. P. S. Nainggolan, R. F. Hasani, and S. Danaryani, "Design of PDAM Water Payment Bill Monitoring System Prototype Based Long Range (LoRa) Communication," *Seminar Nasional Teknik Elektro*, vol. 6, no. 2, Art. no. 2, Feb. 2021.

[4] J. G. Natividad and T. D. Palaoag, "IoT based model for monitoring and controlling water distribution," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 482, p. 012045, Mar. 2019, doi: 10.1088/1757-899X/482/1/012045.

[5] Efrizon, M. Irmansyah, E. Madona, N. Anggara, and Yultrisna, "Design and Development of Water Distribution Monitoring System in Regional Drinking Water Companies (PDAM) Based On Internet Of Things," *J. Phys.: Conf. Ser.*, vol. 2111, no. 1, p. 012024, Nov. 2021, doi: 10.1088/1742-6596/2111/1/012024.

[6] K. S., S. T.V., M. S. Kumaraswamy, and V. Nair, "IoT based Water Parameter Monitoring System," in *2020 5th International Conference on Communication and Electronics Systems (ICCES)*, Jun. 2020, pp. 1299–1303. doi: 10.1109/ICCES48766.2020.9138001.

[7] A. Jerom B., R. Manimegalai, and R. Manimegalai, "An IoT Based Smart Water Quality Monitoring System using Cloud," in *2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)*, Feb. 2020, pp. 1–7. doi: 10.1109/ic-ETITE47903.2020.450.

[8] B. M. Shankar, T. J. John, S. Karthick, B. Pattanaik, M. Pattnaik, and S. Karthikeyan, "Internet of Things based Smart Flood forecasting and Early Warning System," in *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)*, Apr. 2021, pp. 443–447. doi: 10.1109/ICCMC51019.2021.9418331.

[9] A. A and R. G, "Earthquake early warning system by IOT using Wireless sensor networks," in *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, Mar. 2016, pp. 1201–1205. doi: 10.1109/WiSPNET.2016.7566327.

[10] A. M. Zambrano, I. Perez, C. Palau, and M. Esteve, "Technologies of Internet of Things applied to an Earthquake Early Warning System," *Future Generation Computer Systems*, vol. 75, pp. 206–215, Oct. 2017, doi: 10.1016/j.future.2016.10.009.

[11] V. F. Amaliya *et al.*, "Development of IoT-Based Volcano Early Warning System," *J. Phys.: Conf. Ser.*, vol. 1772, no. 1, p. 012009, Feb. 2021, doi: 10.1088/1742-6596/1772/1/012009.

[12] A. Divya, T. Kavithanjali, and P. Dharshini, "IoT Enabled Forest Fire Detection and Early Warning System," in *2019 IEEE International Conference on System, Computation, Automation and Networking (ICSCAN)*, Mar. 2019, pp. 1–5. doi: 10.1109/ICSCAN.2019.8878808.

[13] S. Wasista, Setiawardhana, D. A. Saraswati, and E. Susanto, *Aplikasi Internet Of Things (IOT) Dengan Arduino Dan Android "Membangun Smart Home Dan Smart Robot Berbasis Arduino Dan Android."* Deepublish, 2019.

[14] J. H. Nord, A. Koohang, and J. Paliszkiewicz, "The Internet of Things: Review and theoretical framework," *Expert Systems with Applications*, vol. 133, pp. 97–108, Nov. 2019, doi: 10.1016/j.eswa.2019.05.014.

[15] "Pengertian SSR (Solid State Relay) Dan Cara Kerjanya," Aug. 15, 2019. https://serviceacjogja.pro/pengertian-ssr-solid-state-relay/ (accessed May 05, 2022).

[16] "Three-Phase Power Meter PCE-ND20 | PCE Instruments." https://www.pce-instruments.com/english/measuring-instruments/test-meters/3-phase-power-meter-3-phase-power-analyzer-pce-instruments-three-phase-power-meter-pce-nd20-det_5930064.htm?_list=qr.art&_listpos=20 (accessed May 05, 2022).

[17] "Digital display three phase multifunctional LCD instrument (LCD) An instruction manual Products Instructions."

[18] "B&B Electronics - RS-422 and RS-485 Applications." https://www.bbelec.com/Learning-Center/All-White-Papers/Serial/RS-422-and-RS-485- Applications-eBook.aspx (accessed Apr. 29, 2022).

[19] L. Hui, Z. Hao, and P. Daogang, "Design and Application of Communication Gateway of EPA and MODBUS on Electric Power System," *Energy Procedia*, vol. 17, pp. 286–292, 2012, doi: 10.1016/j.egypro.2012.02.096.