Journal of Electrical Engineering and Computer (JEECOM)
Vol. 8, No. 1 (2026), DOI: 10.33650/jeecom.v7i2.16852
p-ISSN: 2715-0410; e-ISSN: 2715-6427

Water Level and Solar Panel Power Monitoring System Based on the Internet of Things (IoT)

Affan Bachri [1*], Abdur Rohman Wakhid [2], Muhammad Aflah Kafabi [3]
[1,2,3] Department of Electrical Engineering, Faculty of Science and Technology, Universitas Islam Lamongan, Lamongan, Indonesia

Article Info

Article history:
Received Sept 10, 2025
Revised Okt 10, 2025
Accepted Okt 27, 2025

Keywords:
JSN-SR04T
ESP32
INA219
ThingSpeak
Telegram Bot
renewable energy Accepted Month xx, 20xx

ABSTRACT

Water storage management still requires direct supervision in many household and small-scale applications, while a remote monitoring system also needs a reliable energy supply. This study develops an integrated Internet of Things system that measures water level and photovoltaic electrical parameters in real time. The prototype uses an ESP32, a waterproof JSN-SR04T ultrasonic sensor, two INA219 modules, a 20 Wp solar panel, a PWM solar charge controller, a 12 V battery, ThingSpeak, and a Telegram Bot. Testing covered microcontroller connectivity, distance measurement accuracy, electrical sensing, solar panel output, battery operation, cloud data delivery, and integrated system performance. The JSN-SR04T produced an average reading of 10.16 cm for a 10.00 cm reference, with an average absolute deviation of 0.16 cm. INA219 voltage measurements showed a mean relative error of 2.91% against a multimeter. During integrated testing, the water level remained at 12.0-12.4 cm, solar panel voltage reached 13.44-13.45 V, and panel power reached 4.40-4.41 W. ThingSpeak displayed the measurements continuously, while Telegram delivered synchronized status information. These results show that the proposed system supports remote water-level and energy-source monitoring using an autonomous solar supply.

Corresponding Author:
Affan Bachri,
Department of Electrical Engineering, Faculty of Science and Technology, Universitas Islam Lamongan, Lamongan, Indonesia
Email: [affanbachri@unisla.ac.id]

1. INTRODUCTION

Water is essential for household and productive activities. In water storage systems, tank filling that still relies on manual supervision creates two main risks: water shortages when needed and overflow when filling is not stopped at the appropriate time. Internet of Things systems enable remote monitoring through sensor data acquisition, microcontroller processing, and data transmission over the internet [1]. Implementations in household water tanks show that ultrasonic sensors and NodeMCU devices are suitable for monitoring water levels and sending information to user devices [2]. Other studies report that Blynk-based water availability monitoring displays water level conditions and supports pump control [3].

Sensor accuracy is critical because water level measurements form the basis for calculating volume and storage capacity percentage. The JSN-SR04T was selected because its transducer is resistant to humid conditions and operates without direct contact with water. Apsari et al. reported the use of the JSN-SR04T for water tank monitoring with linear regression correction [4]. Dswilan et al. showed that the JSN-SR04T is suitable for water level monitoring over a wider measurement range in field environments [5]. A recent ESP32-based study also reported an average error of 0.2 cm in an online water level monitoring system [6]. These findings support the selection of the JSN-SR04T for the prototype developed in this study.

System reliability depends on more than water sensing accuracy. An Internet of Things system requires a stable energy source so that sensor readings, WiFi connectivity, cloud storage, and notification delivery operate continuously. Solar panels provide an appropriate alternative energy source for low-power devices and locations that are not always close to the electrical grid. A NodeMCU-based photovoltaic monitoring study showed that voltage, current, and power parameters were transmitted to ThingSpeak for remote evaluation [7]. A water level control system powered by a solar panel and battery also showed that variations in light intensity affect the power available to the system [8]. The integration of ESP32, INA219, a PWM solar charge controller, and a battery has also been applied to real-time solar power supply monitoring [9].

Monitoring the energy source requires an electrical sensor that directly measures voltage and current. The INA219 uses a shunt resistor and an I2C interface, which simplifies integration with the ESP32. An INA219-based electrical monitoring system using NodeMCU showed that voltage and current measurements were transmitted to a web interface in real time [10]. The same sensor has also been used to compare the power consumption of several microcontrollers under different operating modes [11]. On the interface side, ThingSpeak supports sensor data storage and visualization [12], while Telegram Bot provides notification and status-request channels through mobile devices [13]. Solar panel power monitoring through Telegram has also shown that instant messaging is suitable as an electrical monitoring interface [14].

Previous studies generally focused on water level monitoring, photovoltaic power monitoring, or user notification as separate functions [2], [7], [8], [14]. A solar-powered hydroponic study integrated water monitoring and power supply monitoring, but its application focus differed and it did not use the same sensor and interface configuration [15]. A NodeMCU-based solar panel monitoring system also emphasized energy parameter acquisition without measuring water level [16]. A hybrid solar power system for river water level monitoring further supports the relevance of solar energy for field monitoring devices [17]. Based on this research gap, the present study develops an integrated system combining a JSN-SR04T sensor, ESP32, two INA219 sensors, a solar panel, battery, ThingSpeak, and Telegram Bot. The study evaluates the system's ability to measure water level, monitor solar panel and battery power, and transmit information in real time over the internet.

2. METHOD

This study used an experimental prototyping approach. The main stages included a literature review, system design, hardware and software implementation, individual component testing, integrated system testing, performance evaluation, and preparation of the results. The design followed the principles of sensor data acquisition, microcontroller-based processing, WiFi data transmission, and information presentation through a user interface.

The hardware consisted of an ESP32, a JSN-SR04T ultrasonic sensor, two INA219 modules, a 20 Wp solar panel, a PWM solar charge controller, a 12 V battery, and supporting circuitry. The JSN-SR04T was positioned above the water surface to measure the distance between the sensor and the surface. Water level was calculated from the difference between the known container reference height and the measured distance. Two INA219 modules measured the electrical parameters of the solar panel and battery. Power was calculated from the measured voltage and current. Sensor and actuator selection followed the measurement functions required by the Internet of Things system.

The software was developed using the Arduino IDE. The ESP32 periodically read the JSN-SR04T and INA219 sensors, processed water level and electrical parameters, and transmitted the data through WiFi. ThingSpeak served as the real-time data visualization and storage platform, while Telegram Bot displayed system status to the user. Similar cloud integration models have been applied to photovoltaic monitoring and NodeMCU-based energy systems [16].

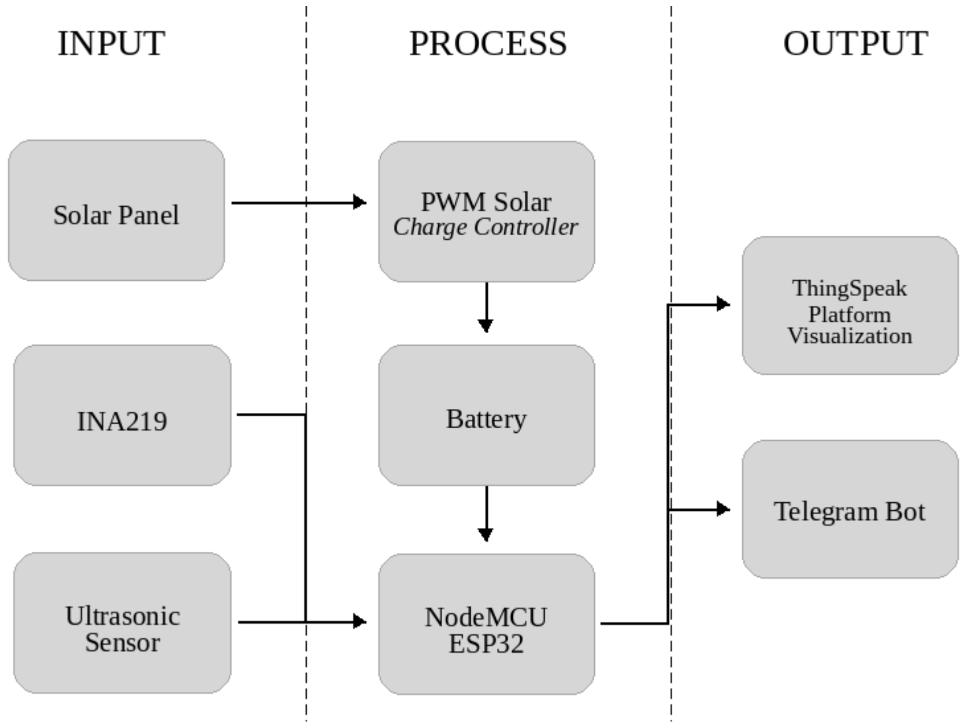

Figure 1. Block diagram of the water level and solar panel power monitoring system

Figure 1 illustrates the relationship among input, processing, and output stages. Energy from the solar panel is routed through the solar charge controller to charge the battery. The ESP32 receives water level data from the JSN-SR04T and electrical data from the INA219 sensors. The processed results are transmitted to ThingSpeak and Telegram. This architecture integrates water and energy monitoring functions under a single controller.

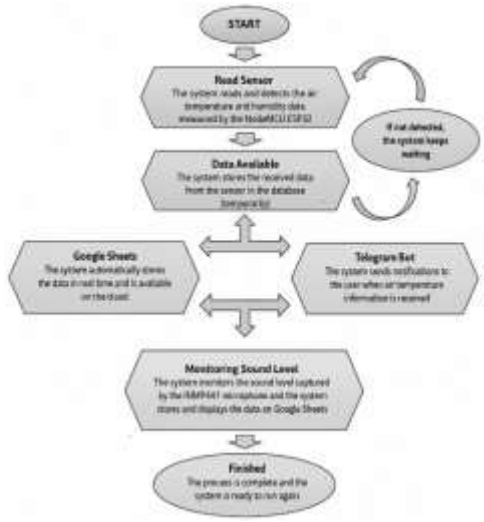

Figure 2. Flowchart framework of the water level and solar panel power monitoring system

The flowchart illustrates the workflow of an Internet of Things-based water level and solar panel power monitoring system. The process begins with the sensor measuring the water level and transmitting the data to the NodeMCU ESP32. The system then verifies the validity of the received data. If the data are not detected, the reading process is repeated. If valid, the information is sent to Google Sheets for real-time storage and analysis and to the Telegram Bot for user notifications. The INA219 sensor then monitors the power generated by the solar panel. The power data are also stored in Google Sheets for continuous monitoring.

2.1. Testing Procedure

The ESP32 was tested at distances of 5 m, 10 m, 15 m, 20 m, and 25 m from the WiFi access point. The observed parameters were connection success and response time. The JSN-SR04T was tested against a ruler at an actual reference distance of 10 cm. Nine sensor readings were compared with the reference value to determine the measurement difference.

The INA219 was tested three times. Sensor voltage readings were compared with a multimeter, while current and power values were recorded from the system. Relative voltage error was calculated as the difference between the INA219 reading and the multimeter reading divided by the multimeter value. Solar panel testing was conducted from morning to late afternoon by recording light intensity, panel voltage, and weather conditions. Battery testing was performed while the system operated without solar charging to evaluate voltage stability.

Integrated system testing was performed after all modules had been connected. Water level, volume, voltage, current, and power data were monitored through ThingSpeak and Telegram. Agreement between the values displayed on both platforms served as an indicator of successful data transmission. Component-level and integrated testing approaches have also been used in ESP32-based water monitoring systems and Internet of Things solar energy systems [17].

3. RESULTS AND DISCUSSION

3.1. Performance of ESP32 and JSN-SR04T Sensor

The ESP32 remained connected to the WiFi network up to a distance of 20 m. Connection response time increased from 4.03 s at 5 m to 7.40 s at 20 m. At 25 m, the device no longer established a connection. These results indicate that increasing distance reduced communication quality under the test conditions. For field applications, the access point should be positioned within a range that maintains a stable connection.

Table 1. JSN-SR04T sensor test results

No.	Reference distance (cm)	Sensor reading (cm)	Difference (cm)
1	10.00	10.15	0.15
2	10.00	10.16	0.16
3	10.00	10.15	0.15
4	10.00	10.15	0.15
5	10.00	10.16	0.16
6	10.00	10.15	0.15
7	10.00	10.16	0.16
8	10.00	10.17	0.17
9	10.00	10.17	0.17

The mean JSN-SR04T reading was 10.16 cm at a reference distance of 10.00 cm. The mean absolute difference was 0.16 cm, equivalent to approximately 1.6% of the reference value. Variation among readings was only 0.02 cm. These results are consistent with the low error commonly reported for ultrasonic sensors in short-range measurements. The error in this study is close to the average error of 0.2 cm reported by a recent ESP32-based system [6] and lower than the 2.5% error reported for an ultrasonic aquaculture prototype [20]. Maintaining the sensor perpendicular to the water surface remains important to reduce reflections from the container walls.

3.2. Performance of INA219 and Solar Energy Source

Table 2. INA219 test results compared with a multimeter

No.	INA219 voltage (V)	Multimeter voltage (V)	Current (A)	Power (W)	Voltage error (%)
1	10.20	10.34	0.19	1.98	1.35
2	10.05	10.42	0.24	2.03	3.55
3	10.08	10.48	0.28	2.10	3.82

INA219 voltage readings tended to be lower than the multimeter readings. The relative errors were 1.35%, 3.55%, and 3.82%, with a mean of 2.91%. This accuracy is adequate for monitoring power trends, although further calibration is required if the system is used for energy measurements requiring higher precision. Studies on INA219-based electrical monitoring confirm its suitability for Internet of Things voltage and current acquisition [10], [11]. For comparison, a Telegram-based solar panel monitoring system using a different sensor reported a voltage error of approximately 0.5% [14]. The difference is associated with sensor characteristics, signal conditioning, calibration, and power source conditions.

Table 3. Solar panel test results by time and light intensity

No.	Time	Light intensity (lux)	Voltage (V)	Weather
1	06:00	1,200	5.20	Sunny
2	08:00	12,000	16.85	Sunny

No.	Time	Light intensity (lux)	Voltage (V)	Weather
3	10:00	21,000	21.02	Sunny
4	12:00	20,000	20.51	Cloudy
5	14:00	15,000	20.60	Cloudy
6	17:00	350	14.35	Cloudy

Table 3 shows the change in solar panel voltage throughout the day. The voltage increased from 5.20 V at 06:00 to 21.02 V at 10:00 and remained close to 20 V from midday to early afternoon. At 17:00, the voltage decreased to 14.35 V when the measured light intensity was 350 lux. This pattern indicates that panel output followed the available solar irradiation. The result is consistent with a solar-powered water level control study reporting power variations with changes in light intensity [8]. An ESP32-based power supply monitoring system also used voltage measurement as an important indicator of energy source condition [9].

3.3. Integrated System Performance and Remote Monitoring

Figure 3. Internet of Things based water level monitoring prototype

The integrated prototype consisted of a solar panel at the top, a control box, a supporting frame, an ultrasonic sensor, and a water container. The control box housed the ESP32, INA219 modules, solar charge controller, battery, and supporting components. This arrangement allowed the measurement and communication processes to operate using energy stored in the battery. Battery testing without solar input showed a stable voltage of 12.66 to 12.67 V during the observation period, indicating that the device remained active for sensor acquisition and data transmission.

Table 4. Integrated system test results

No.	Parameter	Result	Description
1	Water level	12.0-12.4 cm	Stable in real time
2	Water volume	24.3-25.1%	Followed changes in water level
3	Panel voltage	13.44-13.45 V	Stable
4	Panel current	0.33 A	Relatively constant
5	Panel power	4.40-4.41 W	Sufficient for system demand
6	Battery voltage	13.42 V	Stable during charging
7	Battery current	0.28 A	Battery received charging current
8	Battery power	3.76 W	Energy available for system operation
9	ThingSpeak	Successful	Graphs displayed in real time
10	Telegram Bot	Successful	Status received on smartphone

During integrated testing, the water level ranged from 12.0 to 12.4 cm with a volume of 24.3 to 25.1%. The solar panel produced 13.44 to 13.45 V and 4.40 to 4.41 W. The battery voltage was 13.42 V with a power value of 3.76 W. These values indicate that the energy source maintained operation of the ESP32, sensors, and network communication. The findings are consistent with a solar-powered water level monitoring study showing that solar energy supplies monitoring devices continuously [17]. A NodeMCU-based solar monitoring system also emphasized the value of observing panel and battery parameters to determine energy source conditions directly [16].

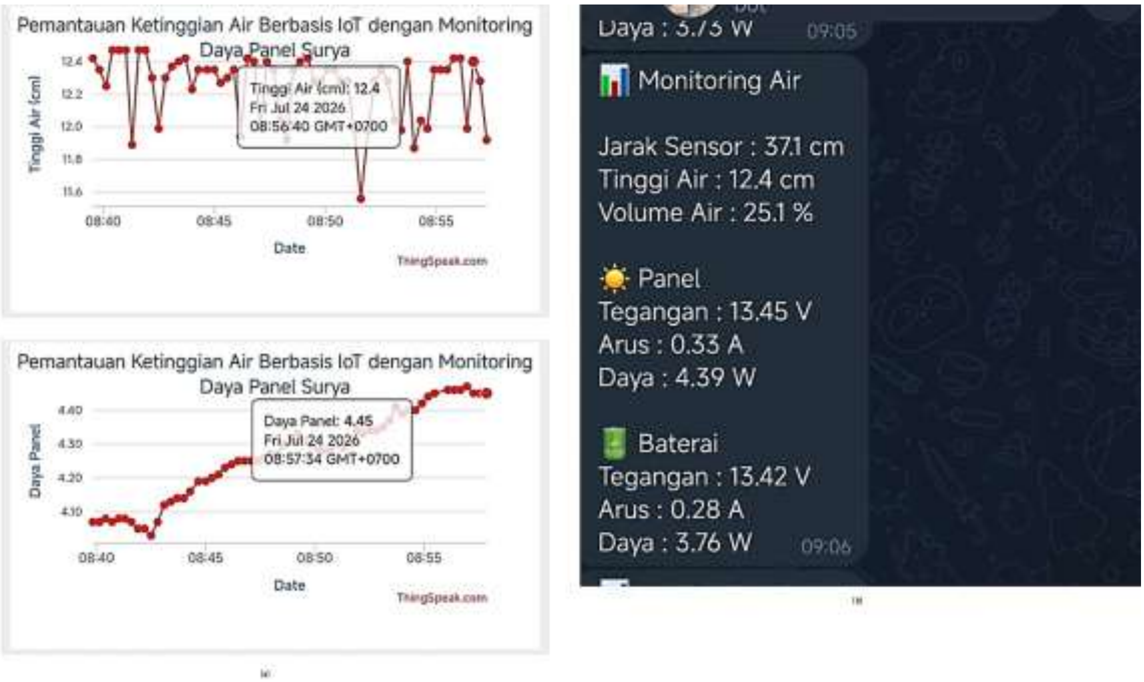

Figure 4. System monitoring: (a) ThingSpeak graphs for water level and panel power, (b) status information through Telegram Bot

ThingSpeak received data from the ESP32 and displayed the measurements as time-series graphs. During testing, the water level graph ranged from approximately 11.6 to 12.5 cm, while the panel power graph increased from approximately 4.07 W to 4.45 W. Telegram displayed the same measurements as text messages, including a water level of 12.4 cm, volume of 25.1%, panel voltage of 13.45 V, panel current of 0.33 A, battery voltage of 13.42 V, and battery current of 0.28 A. Agreement between the two interfaces indicates synchronized data acquisition, processing, and transmission. ThingSpeak supports historical trend observation [7], [12], while Telegram provides faster status access without opening the dashboard [13], [14].

The contribution of the system lies in integrating water monitoring and energy monitoring within one prototype. Rindra et al. focused on tank water level and control through Blynk [2]. Muhammadhy et al. emphasized battery power monitoring in a water level control system [8]. Al Amin and Yuhendri developed a power supply monitoring system using INA219 and ESP32 for solar panels and grid power [9]. The present study combines these functions with a JSN-SR04T sensor, simultaneous solar panel and battery monitoring, ThingSpeak visualization, and Telegram Bot. This configuration reduces the need for direct inspection and provides simultaneous information on water conditions and energy availability.

4. CONCLUSION

The Internet of Things based water level and solar panel power monitoring system was successfully implemented using an ESP32, JSN-SR04T, INA219 modules, a solar panel, battery, ThingSpeak, and Telegram Bot. The JSN-SR04T produced a mean absolute difference of 0.16 cm at a 10 cm reference distance. INA219 voltage measurements showed a mean relative error of 2.91% compared with a multimeter. During integrated testing, the water level ranged from 12.0 to 12.4 cm, panel voltage ranged from 13.44 to 13.45 V, and panel power ranged from 4.40 to 4.41 W. ThingSpeak presented the measurements as real-time graphs, while Telegram displayed status information consistent with the dashboard data. The results demonstrate that the solar panel and battery supported remote monitoring operation. Future work should add automatic pump control, water flow or quality sensors, stricter electrical calibration, and long-term data storage for system performance analysis.

ACKNOWLEDGEMENTS

The authors thank the Department of Electrical Engineering, Faculty of Science and Technology, Universitas Islam Lamongan, and the academic supervisors for their guidance during the design, testing, and preparation of this research.

REFERENCES

[1] F. Nahdi and H. Dhika, “Analisis dampak Internet of Things (IoT) pada perkembangan teknologi di masa yang akan datang,” INTEGER: Journal of Information Technology, vol. 6, no. 1, pp. 33-40, 2021, doi: 10.31284/j.integer.2021.v6i1.1423.

[2] A. K. Rindra, A. Widodo, F. Baskoro, and N. Kholis, “Sistem monitoring level ketinggian air pada tandon rumah tangga berbasis IoT (Internet of Things),” Jurnal Teknik Elektro, vol. 11, no. 1, pp. 17-22, 2021, doi: 10.26740/jte.v11n1.p17-22.

[3] I. N. T. A. Putra, I. G. M. N. Desnanjaya, P. K. G. Saputra, and K. S. A. Astuti, “Perancangan sistem monitoring ketersediaan air otomatis menggunakan aplikasi Blynk berbasis Internet of Things (IoT),” Jurnal Ilmu Komputer dan Sistem Informasi, vol. 6, no. 3, pp. 154-164, 2023.

[4] G. H. I. Apsari, S. Pramono, and N. A. Zen, “Implementation of linear regression using the JSN-SR04T sensor for monitoring water level in water tanks through Antares platform,” Journal of Electronic and Electrical Power Applications, vol. 2, no. 2, pp. 123-129, 2022, doi: 10.58436/jeepa.v2i2.1277.

[5] S. Dswilan, Harmadi, and Marzuki, “Flood monitoring system using ultrasonic sensor SN-SR04T and SIM 900A,” Journal of Physics: Conference Series, vol. 1876, no. 1, Art. no. 012003, 2021, doi: 10.1088/1742-6596/1876/1/012003.

[6] Diono, M. S. Gozali, and H. T. Guntoro, “IoT implementation in water level monitoring system using ESP32 and Antares platform,” Jurnal Integrasi, vol. 18, no. 1, 2026, doi: 10.30871/ji.v18i1.12814.

[7] T. Sutikno, H. S. Purnama, A. Pamungkas, A. Fadlil, I. M. Alsofyani, and M. H. Jopri, “Internet of things-based photovoltaics parameter monitoring system using NodeMCU ESP8266,” International Journal of Electrical and Computer Engineering, vol. 11, no. 6, pp. 5578-5587, 2021, doi: 10.11591/ijece.v11i6.pp5578-5587.

[8] T. Muhammadhy, U. T. Kartini, Endryansyah, and N. Kholis, “Monitoring penggunaan daya baterai pada sistem alat water level control berbasis IoT,” Indonesian Journal of Engineering and Technology, vol. 5, no. 1, pp. 11-19, 2022, doi: 10.26740/inajet.v5n1.p11-19.

[9] A. Al Amin and M. Yuhendri, “IoT based monitoring system of power supplies using solar panel and PLN,” Journal of Industrial Automation and Electrical Engineering, vol. 2, no. 1, pp. 194-200, 2025, doi: 10.24036/8wn0hq45.

[10] M. I. Fahlevi, “Sistem kontrol dan monitoring listrik ruangan menggunakan INA219 berbasis NodeMCU dan web,” Prosiding Seminar Nasional Mahasiswa Fakultas Teknologi Informasi, vol. 2, no. 2, pp. 1994-2002, 2023.

[11] S. Refly and H. A. Kusuma, “Analisis konsumsi dan fluktuasi arus dan daya pada mikrokontroler menggunakan sensor INA219,” Jurnal Sustainable: Jurnal Hasil Penelitian dan Industri Terapan, vol. 11, no. 1, pp. 44-48, 2022.

[12] D. Nettikadan and S. R. M. S., “Smart community monitoring system using ThingSpeak IoT platform,” 2018.

[13] M. I. Maulana, “Implementasi Bot Telegram pada proses retrieval data dalam database,” Indonesian Journal of Data and Science, vol. 2, no. 1, pp. 13-20, 2021, doi: 10.33096/ijodas.v2i1.24.

[14] D. A. Ratnasari, B. Suprianto, and F. Baskoro, “Monitoring daya listrik pada panel surya berbasis Internet of Things (IoT) menggunakan aplikasi Telegram,” Indonesian Journal of Engineering and Technology, vol. 5, no. 1, pp. 1-10, 2022, doi: 10.26740/inajet.v5n1.p1-10.

[15] J. P. R. Sitindaon, D. P. Sari, and R. Kusumanto, “Implementasi sistem monitoring air dengan sensor ultrasonik HC-SR04 dan water flow di Asone hidroponik berbasis Internet of Things menggunakan energi panel surya,” Journal of Applied Smart Electrical Network and Systems, vol. 5, no. 1, pp. 22-28, 2024.

[16] K. Thopate, S. Shilaskar, and S. Bhatlawande, “An Internet of Things based solar power monitoring system using Node MCU,” International Journal on Recent and Innovation Trends in Computing and Communication, vol. 11, no. 10s, pp. 708-714, 2023, doi: 10.17762/ijritcc.v11i10s.7709.

[17] M. I. A. Saputra, S. A. D. Prasetyowati, S. F. Firdaus, and I. R. Widodo, “Water level monitoring device with hybrid solar power based on IoT for river safety monitoring,” Green Engineering: International Journal of Engineering and Applied Science, vol. 2, no. 3, pp. 1-11, 2025, doi: 10.70062/greenengineering.v2i3.217.

[18] A. R. Azhar, D. A. Setiawan, N. A. A. Yasmin, T. A. Putri, and G. F. Nama, “Sistem monitoring kapasitas air dan pengisian otomatis berbasis IoT menggunakan modul ESP8266,” Jurnal Informatika dan Teknik Elektro Terapan, vol. 12, no. 1, 2024, doi: 10.23960/jitet.v12i1.3966.

[19] A. Mukhtar, R. Hermana, A. Burhanudin, and Y. Setyoadi, Sensor dan Aktuator. 2023.

[20] A. Yazid, W. I. Kusumawati, and R. Febriliana, “Prototipe sistem monitoring suhu, ketinggian air, dan kontrol otomatis pada budikdamber berbasis IoT,” Journal of Advances in Information and Industrial Technology, vol. 5, no. 2, pp. 93-104, 2023, doi: 10.52435/jaiit.v5i2.371.

[21] R. W. Pradana, G. F. Pratiwi, and T. N. Arifin, “Rancang bangun sistem pemantau ketinggian air otomatis menggunakan sensor ultrasonik HC-SR04 berbasis Arduino Uno dengan antarmuka komputer berbasis Microsoft Visual Basic 6.0,” Jurnal Teknik dan Science, vol. 3, no. 1, pp. 13-24, 2024.