

# Integrating RTC based scheduling and IoT override for organic fertilizer mixing: design, validation, and improvement roadmap

Rido Putra<sup>1\*</sup>, Aisyah Fadhilah Arif<sup>1</sup>, Zulwisli<sup>1</sup>, Muslim<sup>2</sup>, Iffarial Nanda<sup>2</sup>, Nuzul Hidayat<sup>2</sup>, and Zummi Tridinanti Azry<sup>3</sup>

<sup>1</sup> Department of Electronics Engineering, Universitas Negeri Padang, Padang, Indonesia

<sup>2</sup> Department of Automotive Engineering, Universitas Negeri Padang, Padang, Indonesia

<sup>3</sup> Department of Tourism, Universitas Negeri Padang, Padang, Indonesia

\* Corresponding author's email: [rido\\_putera@unp.ac.id](mailto:rido_putera@unp.ac.id)

## Abstract

This study proposes and validates a hybrid control architecture based on the integration of Real Time Clock and Internet of Things for a laboratory scale automatic compost mixing system using an ESP8266 microcontroller with deterministic scheduling based on absolute time and remote monitoring and override functions. The prototype with integrated wiring that separates the low and high voltage domains demonstrates consistent schedule execution, override response within seconds, and average power consumption of approximately 135 watts or less than 1/10-kilowatt hour per 45-minute cycle. This two-layer architecture improves consistency compared to manual operator-based methods, although long term durability testing and field validation are still required, and contributes to the development of low-cost modular automation systems that are adaptive to connectivity disruptions.

## Keywords

RTC based scheduling, IoT automation, Organic fertilizer mixing, Real time clock (RTC), Smart agriculture technology

**Published:**

May 04, 2026

This work is licensed under a [Creative Commons Attribution-NonCommercial 4.0 International License](https://creativecommons.org/licenses/by-nc/4.0/)

Selection and Peer-review under the responsibility of the 7<sup>th</sup> BIS-STE 2025 Committee

## Introduction

Organic waste is the dominant fraction in municipal solid waste, and its management poses a challenge in sustainable environmental systems [1],[2],[3]. Converting organic waste into compost through controlled biodegradation is an effective process engineering approach to support the circular economy and reduce the burden on landfills [4],[5],[6]. From a technical perspective, composting is viewed as a dynamic bioreaction system that requires control of temperature, humidity, aeration, and the frequency and duration of mixing to maintain microbial stability. Irregular mixing can create anaerobic zones, reduce degradation efficiency, and produce inconsistent

compost [7],[8]. However, in many laboratory scale systems, mixing is still done manually or using simple timers without absolute time references. Manual methods in this context refer to operation based on operator estimates without deterministic scheduling and without structured time documentation [9],[10],[11].

This approach leads to variability in mixing frequency and duration, is prone to schedule shifts due to power disruptions, and lacks synchronisation and control redundancy mechanisms [12],[13],[14]. Although the development of microcontrollers and Internet of Things technology has driven automation in the agricultural and waste processing sectors, most systems still use a single layer architecture, either based on internal timers or relying entirely on cloud connectivity, making them vulnerable to power outages and network instability. To overcome these limitations, this study proposes a hybrid control architecture based on the integration of Real Time Clock and IoT for automatic compost mixing systems [15],[16],[17]. The RTC module is used as an absolute time based schedule controller, while the IoT platform functions as a secondary control layer for remote monitoring and override, allowing the system to continue operating autonomously when the network connection is lost. The contribution of this research lies in the development of a low cost two layer architecture with fail safe mechanisms and time shift mitigation strategies, which are evaluated through testing of schedule consistency, override response, operational failure rates, and energy consumption. This approach offers a more robust and applicable control framework for small to medium scale composting systems [18],[19].

## Method

The system is designed (System Design and Architecture) as a hybrid control architecture that integrates Real Time Clock and Internet of Things modules into a single integrated framework with Wemos D1 R2 based on ESP8266 as the main controller for logic processing, network communication, and actuation. The DS3231 RTC module provides an absolute time reference for scheduling precision, while the Blynk platform enables remote monitoring and override via smartphone. Time and status information is displayed on a 16x2 I2C LCD, while actuation is performed via a single channel relay that controls a 2 HP (horsepower) single phase AC motor as the mixer drive. All subsystems (Wiring Integration) are integrated in a unified wiring configuration that separates the 5 volt DC low voltage domain and the 220 volt AC voltage domain to maintain operational safety. I2C communication between the RTC module and the LCD is carried out via the microcontroller's SDA and SCL pins, while the relay is controlled by digital pins as outputs. The AC phase line is disconnected via a normally open relay terminal and the neutral line is connected directly to the motor, creating isolation between the control system and the high power load.

The firmware (Control Logic and Operating Modes) was developed using Arduino IDE with two operating modes, namely RTC based automatic scheduling and remote override via the Blynk application. The system automatically reads the time from the RTC

to activate and deactivate the relay according to the stored schedule, while override commands are sent via the WiFi network and processed through a virtual pin to update the relay status. The control logic gives priority to overrides during interventions, but the system returns to its normal schedule and continues to operate based on the RTC when network connectivity is lost. Testing (Test Procedure) was conducted on a laboratory scale by simulating daily mixing cycles. The parameters observed included schedule execution consistency, override response latency, relay activation failure rate, and energy consumption during operation. System execution was monitored via an LCD display and direct verification of motor status.

Energy consumption (Motor Energy Consumption Measurement) was measured using a plug in digital power meter placed between the AC power source and the mixing motor. Active power parameters were recorded periodically during a full 45 minute operating cycle. The average power value is calculated from the repeated measurements and used to determine the electrical energy per cycle based on the multiplication of the average power and the duration of operation in hours. Measurements are taken several times to reduce experimental variation and increase data reliability. The total energy per cycle is calculated using the equation:

$$P = P_{avg} \times t$$

Where, E = energy (kWh),  $P_{avg}$  = average power (kW), t = duration of operation (hours)

Measurements were taken three times to reduce experimental error, and the reported values are the average of the three experiments.

## Result and discussion

I2C communication between the microcontroller, RTC, and LCD runs stably without address conflicts, while relay control shows a logical response in accordance with the digital output signal. This can be seen in [Figure 1](#).

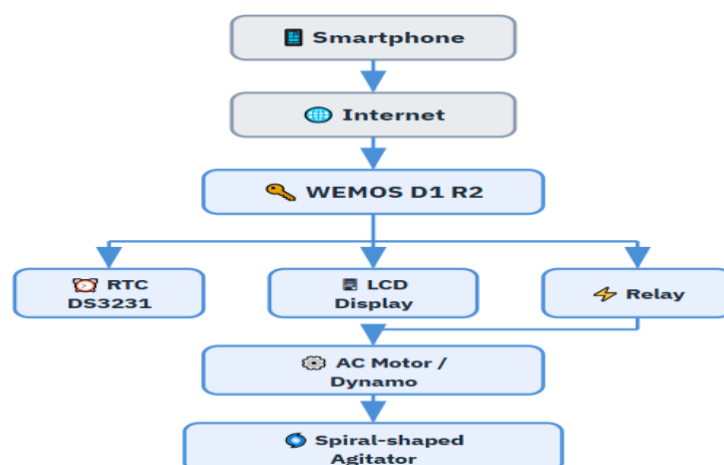


Figure 1. System architecture

The prototype was successfully implemented (System realization) in accordance with the planned architecture. The integrated block diagram and wiring diagram show

consistent integration between the control, communication, and actuation subsystems [20],[21].

The separation of low and high voltage domains provides an adequate level of operational safety in laboratory testing [22],[23]. No electrical interference affecting the stability of the microcontroller was found during motor activation. This can be seen in Figure 2. The wiring design takes into account electrical safety principles by separating low voltage ( $\leq 5V$  DC) and high voltage (220V AC) domains. The relay module functions as an electromechanical isolator that prevents reverse current or high voltage surges from reaching the microcontroller [24],[25]. This is illustrated in Figure 3.

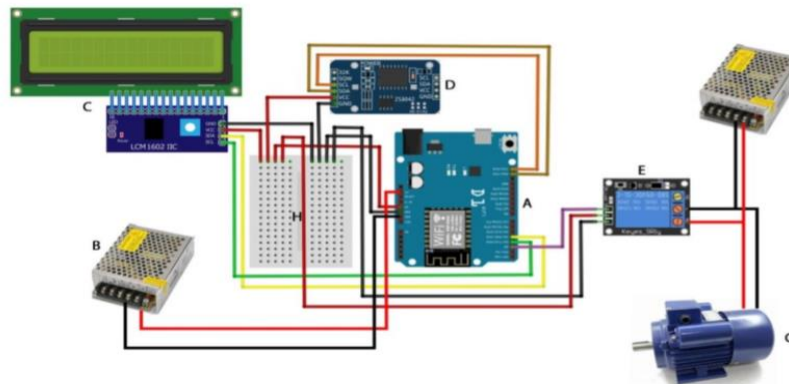


Figure 2. Integrated wiring diagram of the RTC-IoT system showing the I2C (SDA/SCL) connection, relay control line, and isolation between the 5V DC and 220V AC domains

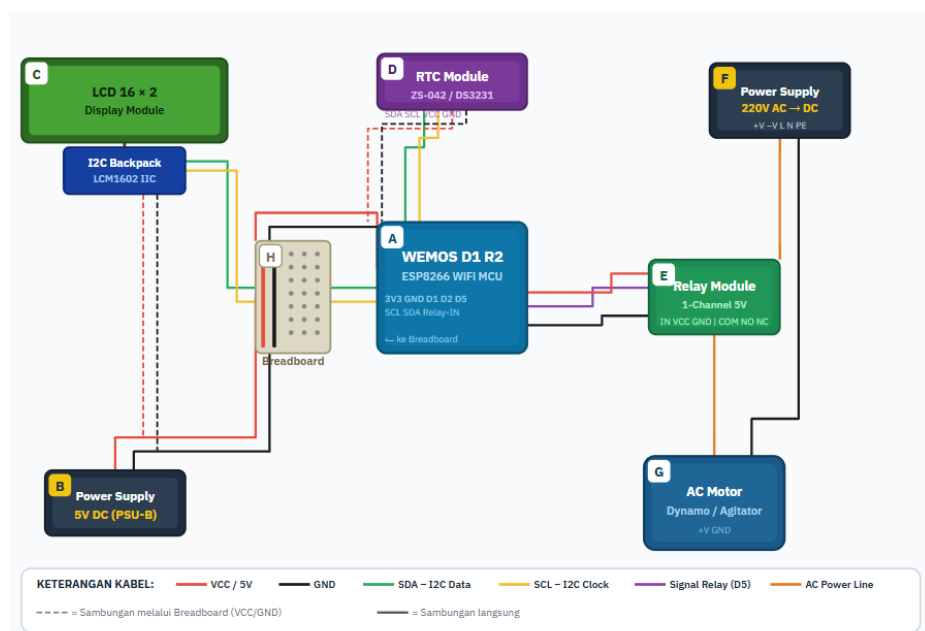


Figure 3. Wiring circuit

This configuration is in line with standard practices for controlling AC motors using relays or magnetic contactors as described in electrical engineering literature [26],[27]. The performance description of the prototype can be seen in Table 1.

Table 1. Prototype performance descriptive table

No	Label	Component	Function	Type
1	A	WEMOS D1 R2 (ESP8266)	Main microcontroller, WiFi/IoT connection	Control
2	B	Power Supply (5V DC)	Power source for microcontroller & module	Power
3	C	LCD 16x2 + I2C Module (LCM1602)	Displays time, status, and system information	Output
4	D	RTC DS3231 / ZS042	Real Time Clock, stores time accurately	Sensor
5	E	Relay Module (1 channel)	Electronic switch to turn AC motor on/off	Actuator
6	F	Power Supply (220V AC to DC)	Power source for AC motor	Power
7	G	AC Motor / Dynamo	Drives spiral shaped agitator	Actuator
8	H	Breadboard	Prototyping board for component connections	Support

The system (scheduled operation) is capable of executing the mixing cycle consistently based on the RTC time reference without experiencing schedule shifts due to restarts or power fluctuations, demonstrating that the use of absolute time effectively overcomes the weaknesses of internal timers. This approach provides better operational stability compared to manual methods based on operator intervention, which rely on time estimates and lack precision synchronisation [28][29]. This can be seen in Figure 5.

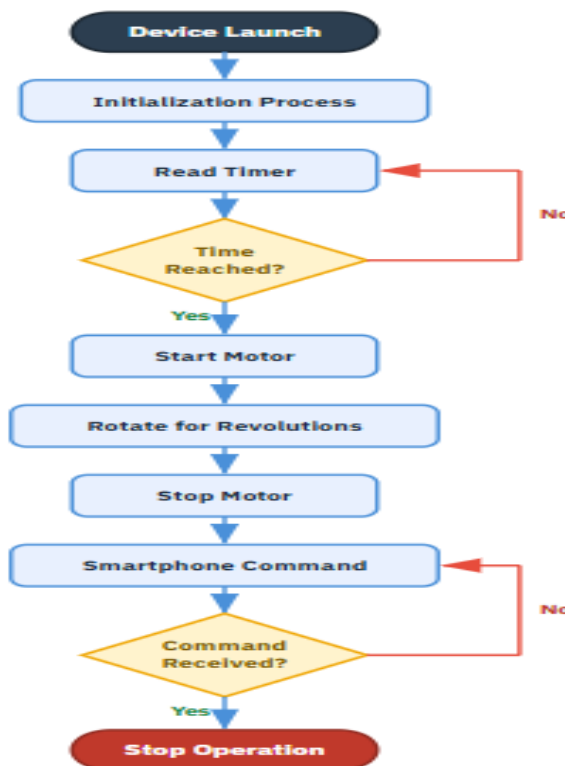


Figure 5. Control flow diagram

The LCD displays the current time and schedule status, enabling local verification of the schedule execution cycle, which supports operator situational awareness during the mixing process. This mode addresses the common problem of irregular manual

scheduling by enforcing repeated mixing without constant human supervision, in line with the goal of reducing labour while promoting compost mixture uniformity [30]. Override testing (Remote Override Evaluation) via the Blynk application shows system response within one to several seconds depending on network conditions, with latency still acceptable for compost mixing applications. The hybrid architecture ensures that core functions continue to operate when connectivity is lost, limiting network dependency to supervisory and intervention functions [31]. This can be seen in Figure 6.

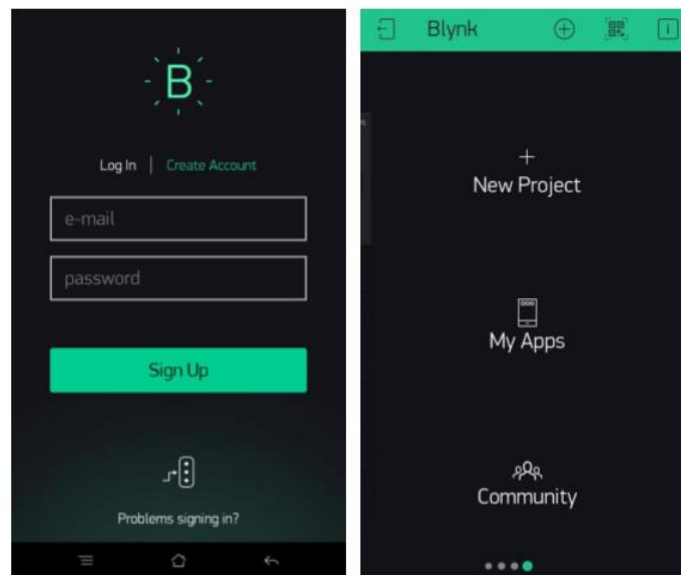


Figure 6. Blynk control interface

This capability enables flexible intervention to accommodate process observations or operational constraints, complementing the automatic scheduler and improving overall control [32]. The prototype (Prototype Performance Description) successfully performed scheduled mixing operations consistently according to RTC settings and responded to application override commands within 1-3 seconds. Experimental measurements show that the average active power during one mixing cycle is  $130 \pm 5$  W based on 3 measurement repetitions, while the execution failure rate, mainly due to network interference, is recorded at less than 5%. The mixing consistency achieved exceeded 90% compliance with the predetermined schedule sequence, indicating higher schedule stability compared to manual operator based mixing methods, which tend to experience variations in execution time and duration due to subjective factors and limitations of continuous supervision. This is shown in Table 2.

Table 2. Comparison of manual and automated systems

No	Aspect	Manual Method	RTC-IoT System
1	Time Reference	Not absolute	RTC based (absolute time reference)
2	Schedule Consistency	Depends on operator	Deterministic
3	Documentation	Not available	Can be developed
4	Operator Dependency	High	Low
5	Control Redundancy	None	Dual layer control

The cycle execution time value indicates the operational duration of a single automatic mixing process adjusted according to user settings. The electrical energy consumed per mixing cycle (45 minutes) is approximately 0.098 kWh. The consistency of the mixing reflects the reliability of the scheduling, which reduces errors and irregularities in the mixture compared to manual methods [34],[35]. This is shown in Figure 7.

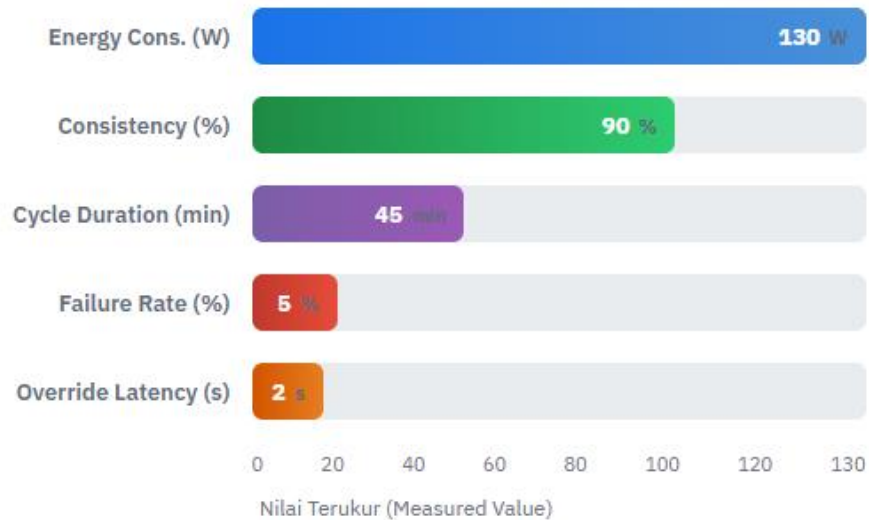


Figure 7. performance measurement results diagram (bar chart)

The execution failure rate indicates the limits of system control stability, especially in fluctuating WiFi network conditions. Energy consumption provides a rough estimate of the system's power requirements for resource planning. Shown in Figure 8.



Figure 8. Performance indicator diagram (line chart)

The prototype demonstrated good performance in laboratory scenarios in terms of mixing consistency, override latency, and energy consumption, although durability and load testing under real field conditions has not yet been conducted. Execution failures were mainly caused by network disruptions and could potentially be minimised through fail safe strategies, while further development is recommended to include local data

logging, NTP based time synchronisation, and real time energy monitoring. Overall, the main contribution of this research is a flexible and adaptive RTC–IoT hybrid model for agricultural community applications. Measurements (Energy Consumption Analysis) show that the average active power during operation is in the range of one hundred and thirty watts. With an operating duration of forty five minutes, the electrical energy per cycle is in the range of less than 1/10 kilowatt/hour. This value indicates that the system is relatively efficient for laboratory scale, although long term evaluation is still needed for a more comprehensive energy optimisation analysis [36],[37].

Although the system (Limitations and Development Implications) demonstrated stable performance in laboratory testing, long term durability testing and evaluation in real world environmental conditions have not yet been conducted. Additionally, the system is not yet equipped with an automatic data logging module or real time energy monitoring based on integrated sensors. Further development could include the integration of local storage, network based time synchronisation, and multi scenario performance analysis to improve readiness for implementation on a community or small industrial scale.

### Conclusion

This research designs and implements an automatic compost mixing system based on a hybrid control architecture that integrates Real Time Clock and Internet of Things into a single integrated control framework, enabling deterministic scheduling based on absolute time while providing flexibility for remote intervention with minimal network dependency. Laboratory testing shows that the system is capable of consistently executing mixing cycles, responding to override commands within an acceptable time frame, and maintaining operational stability through the separation of low and high voltage domains, with relatively low energy requirements for the prototype scale. The main contribution lies in the application of a two layer architecture that combines deterministic control and adaptive supervision with fail safe mechanisms to maintain operational continuity in the event of connectivity disruptions. Although still limited to laboratory testing and not yet including long term durability evaluation or automatic data logging, this approach shows potential for implementation on a community and small industrial scale and can be extended to other bioreactor applications that require time precision and operational redundancy.

### Acknowledgement

The author would like to thank the support of the Institute for Research and Community Service (LPPM), the dean of the faculty of engineering, and the head of the Department of Electronic Engineering, Universitas Negeri Padang, as well as the contributions of lecturers and laboratory technicians.

## References

- [1] M. D. Meena et al., “Municipal solid waste: Opportunities, challenges and management policies in India: A review,” *Waste Management Bulletin*, vol. 1, no. 1, pp. 4–18, Jun. 2023, doi: 10.1016/j.wmb.2023.04.001.
- [2] H. Bian et al., “Transforming Organic Solid Waste Management: Embracing Humification for Sustainable Resource Recovery,” *ACS Sustainable Resour. Manage.*, vol. 1, no. 2, pp. 181–198, Feb. 2024, doi: 10.1021/acssusresmg.3c00080.
- [3] “Impact of municipal solid waste on the environment, soil, and human health,” in *Waste Management for Sustainable and Restored Agricultural Soil*, Academic Press, 2024, pp. 33–58. doi: 10.1016/B978-0-443-18486-4.00011-7.
- [4] A. D. Debele and W. M. Fereja, “Municipal Solid Waste Challenges in Ethiopia and Valorizing the Potential of the Organic Waste Fraction for Composting and Bioenergy,” *International Journal of Chemical Engineering*, vol. 2024, no. 1, p. 7999719, 2024, doi: 10.1155/ijce/7999719.
- [5] M. Gotowska and A. Jakubczak, “Sustainable Biodegradable Waste Management for Circular Economy: Comparative Assessment of Composting Technologies,” *Sustainability*, vol. 17, no. 20, Oct. 2025, doi: 10.3390/su17208978.
- [6] A. A. Afifi, N. Arifin, and I. Taslapratama, “Waste Management in the Circular Economy Framework: A Study on Biomass and Compost Potential Production in Payakumbuh City,” *Journal of Regional Development and Technology Initiatives*, vol. 3, pp. 145–160, Feb. 2025, doi: 10.58764/j.jrdti.2025.3.93.
- [7] R. S. Noor et al., “Recent Trends and Advances in Additive-Mediated Composting Technology for Agricultural Waste Resources: A Comprehensive Review,” *ACS Omega*, vol. 9, no. 8, pp. 8632–8653, Feb. 2024, doi: 10.1021/acsomega.3c06516.
- [8] L. Peng et al., “Effect of aeration rate, aeration pattern, and turning frequency on maturity and gaseous emissions during kitchen waste composting,” *Environmental Technology & Innovation*, vol. 29, p. 102997, Feb. 2023, doi: 10.1016/j.eti.2022.102997.
- [9] H. sapsidi Herli, S. E. Rahim, and Gusmiatun, “Design and Performance Analysis of an Innovative Flow Door in a Brick-Based Dual-Bin Compost Mixing System,” *J. Smart Agri. Env. Tech.*, vol. 3, no. 3, pp. 145–152, Dec. 2025, doi: 10.60105/josaet.2025.3.3.145-152.
- [10] B. Denizhan, E. Yildirim, B. Findikli, M. E. Erbaş, B. Öz, and B. Derya, “Intelligent Workforce Scheduling in Manufacturing: An Integrated Optimization Framework Using Genetic Algorithm, Monte Carlo Simulation, and Taguchi Method,” *Systems*, vol. 14, no. 1, Dec. 2025, doi: 10.3390/systems14010026.
- [11] K. Land, B. Vogel-Heuser, and R. Off, “Test-based behaviour model derivation and adaption to enable automated test case scheduling for automated production systems,” *Prod. Eng. Res. Devel.*, vol. 19, no. 1, pp. 1–13, Feb. 2025, doi: 10.1007/s11740-024-01289-9.
- [12] S. Z. Uddin, “DIGITAL ENGINEERING AND PROJECT MANAGEMENT FRAMEWORKS FOR IMPROVING SAFETY AND EFFICIENCY IN US CIVIL AND RAIL INFRASTRUCTURE,” *International Journal of Business and Economics Insights*, vol. 5, no. 3, pp. 294–323, Sep. 2025, doi: 10.63125/ow76pn26.
- [13] N. Verma, N. Kumar, S. Gupta, H. Malik, and F. P. García Márquez, “Review of sub-synchronous interaction in wind integrated power systems: classification, challenges, and mitigation techniques,” *Protection and Control of Modern Power Systems*, vol. 8, no. 2, pp. 1–26, Apr. 2023, doi: 10.1186/s41601-023-00291-0.
- [14] Y. Liu et al., “Time Synchronization Techniques in the Modern Smart Grid: A Comprehensive Survey,” *Energies*, vol. 18, no. 5, Feb. 2025, doi: 10.3390/en18051163.
- [15] M. Muzammal Islam et al., “Improving Reliability and Stability of the Power Systems: A Comprehensive Review on the Role of Energy Storage Systems to Enhance Flexibility,” *IEEE Access*, vol. 12, pp. 152738–152765, 2024, doi: 10.1109/ACCESS.2024.3476959.
- [16] U. E. Senadheera et al., “Beyond Composting Basics: A Sustainable Development Goals—Oriented Strategic Guidance to IoT Integration for Composting in Modern Urban Ecosystems,” *Sustainability*, vol. 16, no. 23, Nov. 2024, doi: 10.3390/su162310332.
- [17] A. G. Naser, N. M. Nawawi, M. R. Zakaria, M. S. M. Kassim, A. A. Mutalovich, and K. K. Katibi, “A Real-Time Gas Sensor Network with Adaptive Feedback Control for Automated Composting Management,” *Sustainability*, vol. 17, no. 22, Nov. 2025, doi: 10.3390/su172210152.
- [18] L. Wen, “Design automation system synchronization for cyber physical system with dynamic voltage and frequency scaling in industry 5.0,” *Measurement: Sensors*, vol. 31, p. 100981, Feb. 2024, doi: 10.1016/j.measen.2023.100981.
- [19] M. R. Sarker, M. G. M. Abdolrasol, S. Mohamad Hanif Md, R. A. Kadir, M. N. Ahmad, and J. L. Olazagoitia, “Advancing Agriculture Automation Systems: Technological Innovations, Possible

- Applications, Challenges, and Recommendations,” *Advances in Agriculture*, vol. 2025, no. 1, p. 5518653, 2025, doi: 10.1155/aia/5518653.
- [20] B. K. Johnson et al., “A multifunctional soft robotic shape display with high-speed actuation, sensing, and control,” *Nat Commun*, vol. 14, no. 1, p. 4516, Jul. 2023, doi: 10.1038/s41467-023-39842-2.
- [21] J. Feng, Y. Hu, X. Yuan, R. Huang, L. Xiao, and C. Zhang, “Autonomous-rail rapid transit tram: System architecture, design and applications,” *Green Energy and Intelligent Transportation*, vol. 3, no. 6, p. 100161, Dec. 2024, doi: 10.1016/j.geits.2024.100161.
- [22] S. Li, B. Cao, J. Li, Y. Cui, Y. Kang, and G. Wu, “Review of condition monitoring and defect inspection methods for composited cable terminals,” *High Voltage*, vol. 8, no. 3, pp. 431–444, 2023, doi: 10.1049/hve2.12318.
- [23] A. S. Haiba and A. Eliwa Gad, “Artificial neural network analysis for classification of defected high voltage ceramic insulators,” *Sci Rep*, vol. 14, no. 1, p. 1513, Jan. 2024, doi: 10.1038/s41598-024-51860-8.
- [24] A. Ramavath, “Electronic Farmer for Better Yield using GSM Module,” 2025. doi: 10.13140/RG.2.2.35148.12165.
- [25] A. Riza, Suhariningsih, D. O. Anggriawan, and E. Sunaryo, “Multifunctional Digital Protection Relay for Voltage and Current Disturbances in Power Networks,” *Emitor: Jurnal Teknik Elektro*, pp. 309–315, Sep. 2024, doi: 10.23917/emitor.v24i3.5313.
- [26] M. Somantri, M. Fauzan, and I. Surya, “Optimization of IoT-based monitoring system for automatic power factor correction using PZEM-004T sensor,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 39, pp. 860–873, Aug. 2025, doi: 10.11591/ijeecs.v39.i2.pp860-873.
- [27] E. Sunarno, A. T. Nugraha, and R. A. Sobhita, “IoT -Based Air Compressor Monitoring System in Air Distribution Systems,” *Journal of Electrical, Marine and Its Application*, vol. 3, no. 1, Mar. 2025, Accessed: Feb. 25, 2026. [Online]. Available: <https://inergyc.ppns.ac.id/journal/index.php/elrina/article/view/317>
- [28] A. Nebrida and D. R. Millares, “EcoAgriBot: Harnessing Solar Energy and ESP8266 Connectivity for Precision and Sustainability in Rice Cultivation,” Feb. 21, 2024, *Social Science Research Network*, Rochester, NY: 4734212. doi: 10.2139/ssrn.4734212.
- [29] B. K, D. R, B. B. Sinha, and G. R, “Clock synchronization in industrial Internet of Things and potential works in precision time protocol: Review, challenges and future directions,” *International Journal of Cognitive Computing in Engineering*, vol. 4, pp. 205–219, Jun. 2023, doi: 10.1016/j.ijcce.2023.06.001.
- [30] Z. Saqib and Y. Sadeq, “Sustainable waste management through commercial composting: Challenges, opportunities, and future directions for circular economy,” *EUR J SUSTAIN DEV RES*, vol. 9, no. 4, p. em0319, Oct. 2025, doi: 10.29333/ejosdr/16579.
- [31] G. Wu, H. Fu, J. Liu, L. Ma, X. Fan, and R. Liu, “Hybrid-Supervised Dual-Search: Leveraging Automatic Learning for Loss-Free Multi-Exposure Image Fusion,” *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 38, no. 6, pp. 5985–5993, Mar. 2024, doi: 10.1609/aaai.v38i6.28413.
- [32] I. Bamidele, “Data-driven resource optimization approaches enhancing capacity planning, labor utilization, material efficiency and continuous improvement across manufacturing project lifecycles,” *GSC Advanced Research and Reviews*, vol. 17, pp. 220–236, Dec. 2023, doi: 10.30574/gscarr.2023.17.3.0467.
- [33] D. B. Hulwan et al., “AI-Based Fault Detection and Predictive Maintenance in Wind Power Conversion Systems,” *E3S Web Conf.*, vol. 591, p. 02003, 2024, doi: 10.1051/e3sconf/202459102003.
- [34] H. Yang, J. Tang, W. Shao, J. Yin, and B. Liu, “Wind power data cleaning using RANSAC-based polynomial and linear regression with adaptive threshold,” *Sci Rep*, vol. 15, no. 1, p. 5105, Feb. 2025, doi: 10.1038/s41598-025-89177-9.
- [35] A. Khan, M. Bressel, A. Davigny, D. Abbes, and B. O. Bouamama, “Comprehensive Review of Hybrid Energy Systems: Challenges, Applications, and Optimization Strategies,” *Energies*, vol. 18, no. 10, May 2025, doi: 10.3390/en18102612.
- [36] Z. Yao et al., “Machine learning for a sustainable energy future,” *Nat Rev Mater*, vol. 8, no. 3, pp. 202–215, Mar. 2023, doi: 10.1038/s41578-022-00490-5.
- [37] W. Chen, H. Ren, and W. Zhou, “Review of multi-objective optimization in long-term energy system models,” *Global Energy Interconnection*, vol. 6, no. 5, pp. 645–660, Oct. 2023, doi: 10.1016/j.gloe.2023.10.010.