# Leveraging Portable Electric Charging Stations in Rural Areas Using Solar Panel Generation

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*Received: 24 May 2025 | Revised: 30 June 2025 and 11 July 2025 | Accepted: 16 July 2025*

 *DOI: https://doi.org/10.48084/etasr.12352*

## ABSTRACT

**As the global population grows, electric motorbikes are emerging as a promising solution for sustainable, high-mobility transportation. However, in rural areas with limited energy infrastructure, users often struggle with the lack of available charging stations. This work proposes a portable charging station for electric bicycles, powered by renewable energy and battery storage, as a practical solution for communities in remote regions. The system incorporates several user-friendly features. The charging process can be operated and monitored online. Its foldable and portable construction allows transportation via small aircraft, boats, or light off-road vehicles, making it suitable for deployment in rural areas with restricted access and limited logistics. The experimental results indicate that the device provides acceptable accuracy in voltage and current measurements. Real-time notifications were successfully delivered under a stable internet connection. The dimensions of the device are 1315 mm in height, 1564 mm in length, and 404 mm in width. This system aims to strengthen the infrastructure supporting the electric vehicle transportation, contributing to more equitable electrification and the promotion of environmental sustainability.**

***Keywords-charging station; electric bicycle; portable construction; rural areas***

# I. INTRODUCTION

The availability of electricity, transportation, telecommunications, and water is a critical factor for regional development. These sectors provide essential infrastructure and services that support the population mobility. At the same time, Electric Vehicles (EVs) powered by renewable energy can help reduce the emissions in the transportation sector and improve the overall welfare [1, 2]. The global adoption of EVs in rural areas may serve as a potential solution to enhance the productivity of people living in remote regions.

Expanding the electricity access in rural and remote areas is also aligned with the Sustainable Development Goals promoted by the United Nations. Various policies have been implemented to address the low electrification rates, including programs supported by the World Bank and national rural electrification initiatives. According to IEA estimates, while the global population is expected to have increased by around 90% by 2030, the number of people without electricity access has decreased [3]. Nevertheless, policymakers need to intensify the efforts to close the remaining gap.

The electricity networks in remote and isolated areas should be prioritized using locally available energy sources, especially solar power [4]. In developing countries, a large portion of the population lives in rural regions, often with limited income levels [5, 6]. In such regions, solar energy is typically more accessible than other resources, like air or water [7]. Many solar panel initiatives have been introduced in low-electrification areas, often involving a wide range of local stakeholders. The implementation of solar energy solutions can help overcome the distribution limitations and contribute to improving the quality of life in rural communities [8-10].

Mitigating the climate change requires reducing the greenhouse gas emissions from the transportation sector, both in urban and rural areas. In rural regions, vehicles are often essential for mobility. Transportation plays a key role in daily life by supporting the quality of life, meeting social needs, and promoting the economic development [11-13]. Several studies suggest that plug-in EVs are well-suited for rural residents, who typically rely on vehicles for longer trips and often can be charged at home. When powered by renewable energy, these vehicles further contribute to reducing the greenhouse gas emissions [14, 15]. Moreover, charging stations that utilize renewable energy can help reduce the peak electricity demand [16].

A key challenge remains the development of portable charging stations that can be deployed in remote locations. Governments and communities should take advantage of EVs to enhance the mobility, productivity, and well-being in rural areas. Energy monitoring devices can assist in data collection and network control, enabling users to track the performance of the connected systems. Ongoing research continues to explore affordable power measurement solutions [17-20]. Real-time features are also being developed to help users manage the load combinations and improve the energy efficiency. Some studies focus on integrated charging station monitoring within pilot projects [21]. These systems typically involve back-end platforms, IoT infrastructure, and user interfaces that support the scalability and efficient data management. Other efforts include developing e-bike charging systems with alert features and acoustic monitoring [22].

The integration of Internet of Things (IoT) and Artificial Intelligence (AI) technologies offers opportunities to establish sustainable energy communities in rural areas. These technologies can support the electricity consumption monitoring, energy trading, and predictive planning [23]. Despite these advancements, there remains a gap in the development of simple, portable energy monitoring systems tailored specifically for rural charging stations.

Based on the reviewed literature, the use of renewable energy for electricity distribution is recognized as an effective way to improve the productivity and mobility of people living in remote areas. However, a key challenge is the deployment of portable charging stations in locations that are difficult to access. This article proposes the development of a portable charging station tailored for rural environments. The system supports both online and offline monitoring of the charging capacity of electric bicycles. It can automatically activate or deactivate charging by analysing and reporting power consumption. The station's portable and foldable design allows easy transportation, making it suitable for use in rural areas with limited infrastructure and access.

# II. SYSTEM DESIGN AND METHODOLOGY

## A. Estimation for Energy Storage and Solar Generation

The capacity of the solar panel charging station must be determined based on the electric vehicle load [13, 15]. The first step is to perform a load analysis to estimate the required energy consumption and determine the optimal capacity of the solar power station. The energy consumption of electric vehicles can generally be expressed using:

$$KD_{EV} = DP_{EV} \times LP_{EV} \quad (1)$$

where $KD_{EV}$ is the Power consumption of the EV (Wh), $DP_{EV}$ is the Charging power (W), and $LP_{EV}$ is the Duration of the charging hours (H). In other words, the longer the charging duration is and the greater the charging power is, the higher is the power consumption of the EV. The next step is to estimate the battery storage capacity:

$$DPB_{PS} = KB_{PS} \times TB_{PS} \quad (2)$$

where $DPB_{PS}$ is the Power station battery storage capacity (Wh), $KB_{PS}$ is the Battery capacity at the power station (Ah), and $TB_{PS}$ is the Battery voltage at the power station (V). The larger the battery capacity and voltage are, the greater is the power the battery can store. Users can compare the battery storage capacity with the EV power consumption to determine the duration of the vehicle's charging hours without using sunlight. For the device to be used sustainably, the power generation from the solar panel system also needs to be considered. So, the power generation of the solar panel system can be explained by:

$$DP_{PS} = DSP_{PS} \times DS_{PS} \times FR \quad (3)$$

$$DP_{PS\,Max} = DP_{PS} + (DP_{PS} \times FR) \quad (4)$$

where $DS_{PS}$ is the Duration of sunlight hours to the power station (H), $DSP_{PS}$ is the Solar panel power installed at the power station (W), $DP_{PS\,Max}$ is the Peak power generation (kWp), $FR$ is the System loss factor, and $DDP_{PS}$ is the Power Station generation power (Wh). From $DP_{PS}$, $DP_{PS\,Max}$ can be calculated in (4), considering the proper capacity.

*B. Specification and Construction for Charging Stations*

The portable charging station operates with a total capacity of 540 Wh and 150,000 mAh. At its core lies the Flashfish A501 device, which combines a lithium-ion battery pack with a sine wave inverter. This setup allows the station to charge an electric vehicle via a standard AC outlet providing 220 V at 500 W, and it can handle peaks up to 1000 W [24]. It also includes four DC outputs rated at 12 V and 10 A. The integrated battery management system helps protect the device from the overcurrent and overvoltage. Users can control the power outputs individually using simple ON/OFF and AC/DC switches. Charging the station is flexible, as it can draw power from the grid, a car outlet, or a solar panel. The construction of the station was carefully designed with portability as a key priority, enabling flexible use in diverse environments. As illustrated in Figure 1, the total height of the structure reaches 1315 mm, measured from the ground to the top edge of the solar panel. The station is divided into two main sections for easier assembly and transportation. The upper section, measuring 438.3 mm, consists of the inverted solar panel and the instrument box positioned just below it. The lower section, standing at 878.6 mm, includes a central support pole that houses the battery and is connected securely to a tripod base. The tripod is engineered to provide structural stability, with a leg span of 782 mm that ensures balancing even surfaces on uneven ones. The overall footprint of the station is 1564 mm by 404 mm, allowing it to remain compact while still accommodating all necessary components. Thanks to its modular design, the entire unit can be disassembled and packed efficiently, making it easy to be transported by small aircraft, boats, or light off-road vehicles. This makes the system particularly well-suited for deployment in remote or rural areas, where the access to infrastructure is limited and the transport conditions are often challenging.

*C. Workflow Charging Station*

The flow of the power monitoring, notification, and switching sections can be explained in detail in the diagram in Figure 2. The flowchart starts by turning on the power station device and then initiating the switching and monitoring devices. Users only can choose one of the options, which is to charge the power station battery from the solar panel or to charge the vehicle battery. Charging the power station battery from the solar panel can help increase the battery capacity and provide extended energy storage capacity. Charging a battery with solar panels produces about 100 Wh of power. The minimum charging time is estimated to be 5 hours. However, the time can change based on the duration and intensity of sunlight. Energy from the battery is flowed to the power outlet through the PZEM-004T module, which measures the electrical parameters to monitor the charging performance. The ESP32 microcontroller functions as a control center that receives data from the PZEM-004T, sends them to the monitoring application, and controls the relay module that regulates the flow of electricity to the power outlet. The basic idea of device selection refers to the work of other researchers in creating IoT-based smart metering [25-27]. The electric motorbike charging process is monitored in real time via the Blynk application, which can be managed with open access for monitoring and switching.

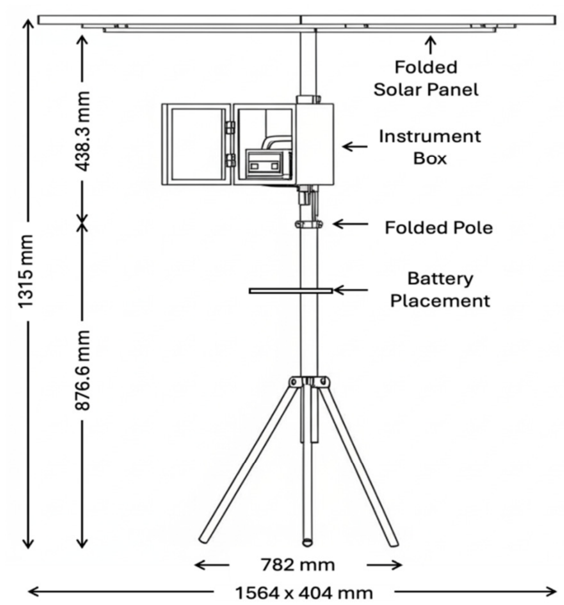



Fig. 1. Portable charging station construction design with monitoring.

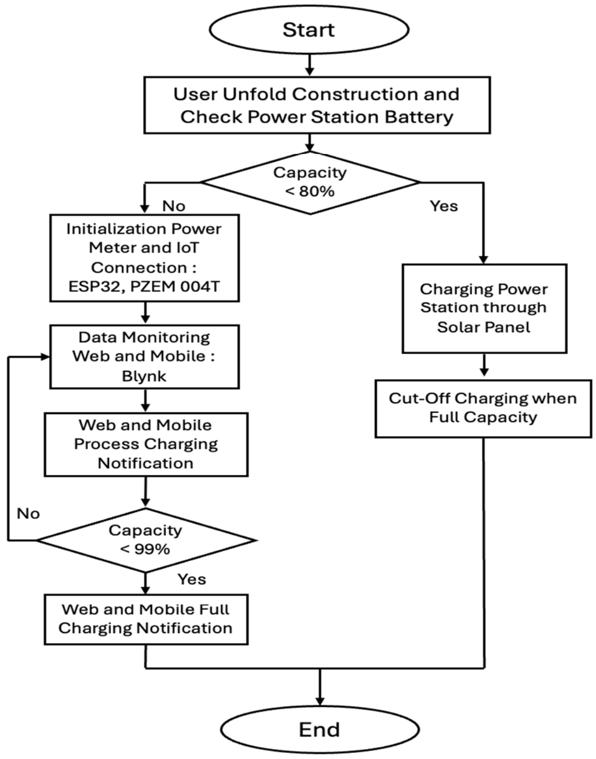
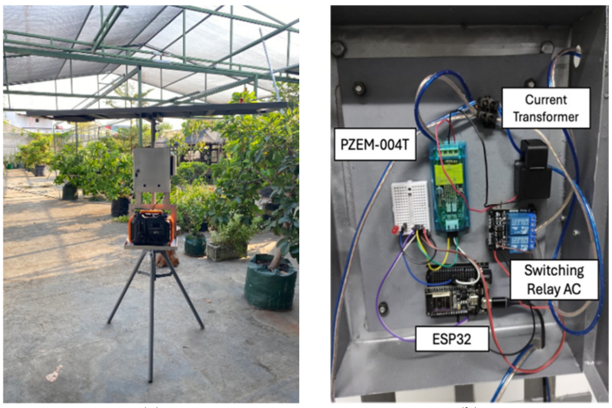



Fig. 2. Flowchart power monitoring for portable electric charging station.

## III. RESULTS AND DISCUSSION

### *A. Installation of Charging Station Monitoring System*

The ESP32 microcontroller test displays the results of voltage, current, and power that have been read by the PZEM-004T sensor and can also control the device by turning off / on the control device connected to the switch. The control device circuit for monitoring and switching can be seen in Figure 3 (a), while the device installation scheme is shown in Figure 3 (b). Furthermore, prototype testing compares the comparative measuring instrument with the results in Table I. The measurement of the PZEM-004T device exhibits a relatively small error compared to standard multimeter measurements. The measurement is divided into several voltage levels, 229.2 V-229.0 V. The error is in the range of 0.10%-0.30%. However, at the current level, several inputs are tested, namely 0.478 A, 0.985 A, and 1.034 A, with an error range of 0.02%-0.07%. The results of the electric bicycle data collection from Migo E-bike contain data on the distance traveled based on the battery capacity of the electric bicycle, i.e. the distance traveled by bicycle when used until the battery is 0%. To drain the power of the Migo E-bike electric bicycle from 100% - 0%, it can cover 23.14 km.




(a) (b)

Fig. 3. Prototype charging station: (a) during device testing and (b) installation of the device in the monitoring box.

TABLE I. MEASUREMENT OF PROTOTYPE COMPARED TO STANDARD MULTIMETER

| Parameter | PZEM-004T | Multimeter | Error (%) |
|---|---|---|---|
| Voltage (V) | 229.2 | 229.3 | 0.10 |
| | 229.0 | 229.3 | 0.30 |
| | 229.1 | 229.2 | 0.20 |
| Current (A) | 0.478 | 0.46 | 0.02 |
| | 0.985 | 0.91 | 0.07 |
| | 1.034 | 1.05 | 0.02 |

### *B. Response Power of Charging Station Using Solar Panel, Utility Grid, and Power Station*

The power station battery used in the charging station has specifications, such as a battery capacity of 540Wh with DC input 5~30V / 6A 120W (max). It has two outputs, namely AC output and DC output. The AC output on the power station battery is 230V 50Hz, and the DC output is 12V / 10A, a total of 120W. The battery charging using solar photovoltaic is DC 18V-12V. Charging the power station battery takes 15 hours during the day. Table II presents data on the charging power station batteries using solar photovoltaic energy. The graph of the charging station battery results can be seen in Figure 4, where the weather conditions also affect the charging process, meaning the environmental conditions during the solar power station battery charging. The solar irradiation increased until it reached its peak of 995.8 W/m² during period 9. This value aligns with the maximum power output capacity of the solar panels, which is 78.28 W. The battery capacity experienced a relatively stable increase from 20% to full capacity. The voltage shows fluctuation, ranging from 15.91V to 19.73V. The environmental temperature ranges from 27°C to 33°C, representing a stable filling process that is not influenced by significant temperature variations.

TABLE II. ENVIRONMENTAL CONDITIONS FOR CHARGING POWER STATION BATTERIES USING SOLAR PANELS

| Period (per 1 hour) | Irradiance (W/m²) | Power solar panel (W) | Voltage (V) | Current (A) | Battery capacity (%) |
|---|---|---|---|---|---|
| 1 | 523.4 | 8.896 | 19.34 | 0.46 | 20 |
| 2 | 729.1 | 29.923 | 19.43 | 1.54 | 24 |
| 3 | 928.7 | 41.604 | 16.38 | 2.54 | 26 |
| 4 | 968.3 | 58.133 | 17.25 | 3.37 | 36 |
| 5 | 964.9 | 65.016 | 17.20 | 3.78 | 44 |
| 6 | 940.1 | 78.277 | 15.91 | 4.92 | 50 |
| 7 | 967.0 | 52.585 | 16.18 | 3.25 | 60 |
| 8 | 881.9 | 55.344 | 16.57 | 3.34 | 65 |
| 9 | 995.8 | 56.884 | 17.29 | 3.29 | 65 |
| 10 | 987.9 | 43.528 | 17.07 | 2.55 | 74 |
| p11 | 915.2 | 59.548 | 17.67 | 3.37 | 80 |
| 12 | 834.9 | 30.060 | 16.70 | 1.8 | 86 |
| 13 | 877.9 | 38.837 | 16.74 | 2.32 | 93 |
| 14 | 965.1 | 54.080 | 16.64 | 3.25 | 93 |
| 15 | 923.6 | 14.008 | 19.73 | 0.71 | 100 |

There is a test of charging an electric bicycle battery using a utility grid source, Perusahaan Listrik Negara (PLN). The electric motor used for testing has a 350W specification supported by a 48V / 12Ah capacity battery. There is a Battery Management System for protection, monitoring, and warnings against the battery. Table III presents data on the electric bicycle battery charging process utilizing the utility network. Notably, the charging of the Migo E-bike electric bicycle took approximately 6 hours. Details of the period compared to the power charging in bicycle batteries using a utility grid are shown in Figure 5. The data collection time interval is 15 minutes, where the power supplied to the battery ranges from 40W to 100W. The battery capacity increases and reaches its highest value at period 13 at 195 minutes, with a capacity of 119.8%. After that, there was a significant decrease in the battery charging at periods 16 and 17, namely 89% and 3.2% capacity, respectively.

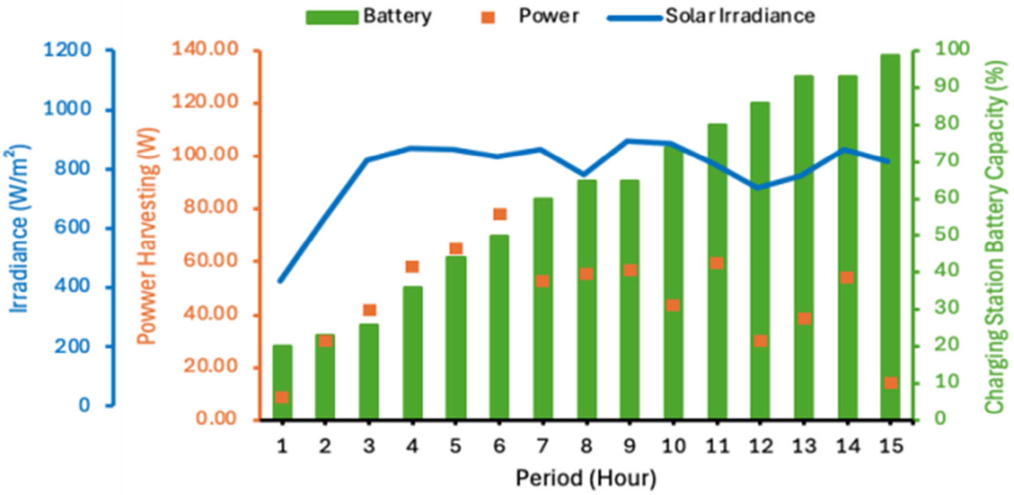



Fig. 4. Charging power station batteries using solar panels for hours.

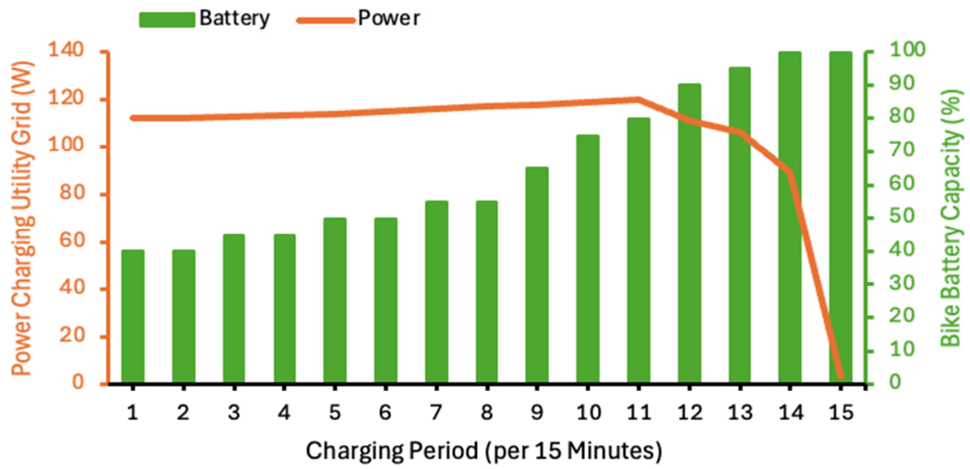



Fig. 5. Charging bicycle battery using utility grid during the charging period.

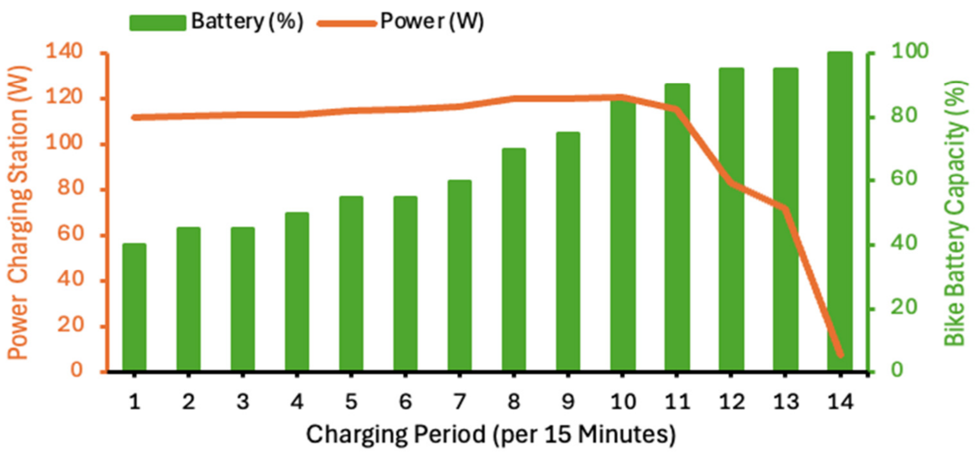



Fig. 6. Charging bicycle battery using a power station during the charging period.

TABLE III. CHARGING PROCESS IN BICYCLE BATTERY USING UTILITY GRID AND POWER STATION

| Chargin g period (per 15 minutes) | Charging using utility grid | | Charging using power station | |
|---|---|---|---|---|
| | Power (W) | Battery percentage (%) | Power (W) | Battery percentage (%) |
| 1 | 112.1 | 40 | 111.5 | 40 |
| 2 | 112.1 | 40 | 112.1 | 45 |
| 3 | 112.7 | 45 | 112.7 | 45 |
| 4 | 113.4 | 45 | 112.9 | 50 |
| 5 | 113.7 | 50 | 114.4 | 55 |
| 6 | 115 | 50 | 115.2 | 55 |
| 7 | 116 | 55 | 116.2 | 60 |
| 8 | 116.9 | 55 | 119.7 | 70 |
| 9 | 117.7 | 65 | 120 | 75 |
| 10 | 118.9 | 75 | 120.5 | 85 |
| 11 | 119.8 | 80 | 115.2 | 90 |
| 12 | 111.1 | 90 | 83.1 | 95 |
| 13 | 106.2 | 95 | 71.8 | 95 |
| 14 | 89.1 | 100 | 7.7 | 100 |
| 15 | 3.2 | 100 | - | - |

The charging of the Electric Bike using a utility grid and power station battery is displayed in Table III. It can be seen that the charging takes 4 hours and the battery charges to 80%. The charging graph using the power station battery is shown in Figure 6, which demonstrates the period compared to the power charging in bicycle battery using the power station on the Migo E-bike electric bicycle.

The data collection time interval is 15 minutes, where the power supplied to the battery ranges from 110.8 W to 120.5 W. The battery capacity increases gradually from 40% to 85% in periods 12 to 83.1% and then to 95%. In periods 14 and 15, the power decreases to a minimum power of 7.70 W, followed by the battery reaching its maximum capacity of 100%. The power station reduces the power before the battery is full.

### *C. Examination of Temporal Analysis*

The control device also provides information to users through notifications to monitor the output from the charging station. This notification displays information while the electric motorcycle is charging. It also provides a notification when the charging is complete, indicating that the electric motorcycle battery is full. It also changes the notification limit according to the user needs. Notifications are obtained through the Blynk software connected to a Gmail account. Figure 7 (a) shows that Blynk sent a notification to a Gmail account that charging was in progress or still in progress. In addition, it will show a notification that charging is in progress or still in progress. The notification-sending process occurred in real-time for 1 minute on a stable internet connection. The control device also sends a notification that charging is complete or the bicycle battery is full, as portrayed in Figure 7 (b).

(a)

(b)

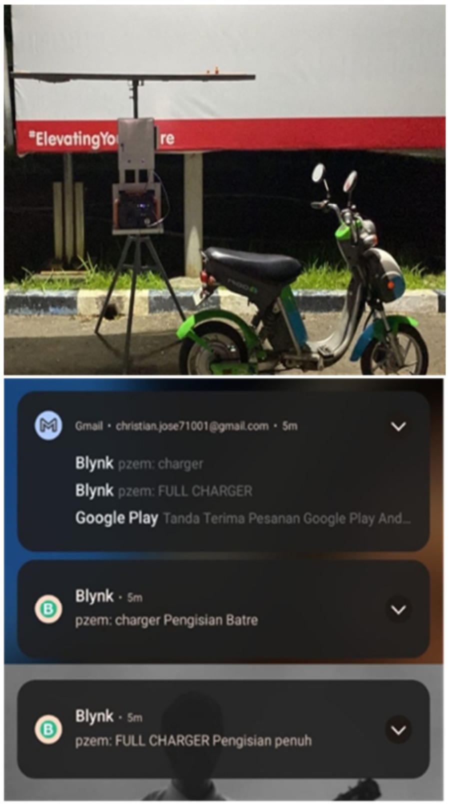



Fig. 7. Use of portable charging stations and their monitoring: (a) for charging electric bicycle batteries and (b) notification to users regarding the charging process.

## IV. CONCLUSION

This study presents the development of a portable electric bicycle charging station powered by solar panels and batteries, aimed at providing a practical transportation solution for individuals living in remote areas. The design, testing, and analysis show that the station can support both online and offline power monitoring with acceptable tolerance levels. A notification system is included to alert users when the battery reaches certain capacity thresholds, with customizable settings based on the user preferences. Additionally, users can remotely activate or deactivate the charging process via smartphone. Under stable internet conditions, the time required for transmitting the power monitoring data to a user device is approximately one minute.

In terms of the physical design, the proposed device stands at 1315 mm in height, with a length of 1564 mm and a width of 404 mm. It features a foldable joint, allowing the entire unit to be compacted for transport. Thanks to its lightweight and modular construction, the station can be easily carried by small aircraft, boats, or light off-road vehicles—making it especially well-suited for deployment in rural or hard-to-reach regions with limited infrastructure.

This portable solution has the potential to improve the energy accessibility for underserved communities. Looking ahead, future developments may include the integration of protection systems compatible with other types of electric vehicles, as well as the incorporation of Internet of Things (IoT) and Artificial Intelligence (AI) technologies to enhance the functionality and address security challenges. The use of such portable charging stations could play a vital role in expanding the EV infrastructure and promoting equitable, sustainable energy use in remote and rural environments.

## ACKNOWLEDGMENT

This work is funded by the Indonesian Government through the Basic Research Scheme from the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia Research Grant and as part of the Internal Fund Research from Telkom University.

## REFERENCES

[1] L. Bokopane, K. Kusakana, H. Vermaak, and A. Hohne, "Optimal power dispatching for a grid-connected electric vehicle charging station microgrid with renewable energy, battery storage and peer-to-peer energy sharing," *Journal of Energy Storage*, vol. 96, Aug. 2024, Art. no. 112435, https://doi.org/10.1016/j.est.2024.112435.

[2] M. F. Roslan *et al.*, "Techno-economic impact analysis for renewable energy-based hydrogen storage integrated grid electric vehicle charging stations in different potential locations of Malaysia," *Energy Strategy Reviews*, vol. 54, Jul. 2024, Art. no. 101478, https://doi.org/10.1016/j.esr.2024.101478.

[3] *Access to electricity*, 1st ed., International Energy Agency, Paris, France, 2024.

[4] C.-W. Shyu, "Lessons from the World Bank's solar home system-based rural electrification projects (2000–2020): Policy implications for meeting Sustainable Development Goal 7 by 2030," *Energy Reports*, vol. 9, pp. 2820–2838, Dec. 2023, https://doi.org/10.1016/j.egyr.2023.01.128.

[5] G. Anríquez and L. Stloukal, "Rural population change in developing countries: lessons for policymaking," *European View*, vol. 7, no. 2, pp. 309–317, Dec. 2008, https://doi.org/10.1007/s12290-008-0045-7.

[6] V. Harahap, L. M. Kamp, and J. Ubacht, "A decision support scheme for solving the mobile coverage gap in rural areas in developing countries – Demonstrated with a case in Indonesia," *Technological Forecasting and Social Change*, vol. 207, Oct. 2024, Art. no. 123600, https://doi.org/10.1016/j.techfore.2024.123600.

[7] *Tracking SDG 7: The Energy Progress Report*, 1st ed., International Energy Agency, Paris, France, 2024.

[8] R. Zaman and S. Borsky, "The impact of supply structure on solar home system installations in rural off-grid areas," *Environmental Innovation and Societal Transitions*, vol. 40, pp. 625–644, Sep. 2021, https://doi.org/10.1016/j.eist.2021.10.015.

[9] N. Narayan *et al.*, "Exploring the boundaries of Solar Home Systems (SHS) for off-grid electrification: Optimal SHS sizing for the multi-tier framework for household electricity access," *Applied Energy*, vol. 240, pp. 907–917, Apr. 2019, https://doi.org/10.1016/j.apenergy.2019.02.053.

[10] Y. Kassem, H. Gokcekus, and F. A. R. Agila, "Techno-Economic Feasibility Assessment for the promotion of Grid-Connected Rooftop PV Systems in Botswana: A Case Study," *Engineering, Technology & Applied Science Research*, vol. 13, no. 2, pp. 10328–10337, Apr. 2023, https://doi.org/10.48084/etasr.5668.

[11] J. Kester, B. K. Sovacool, L. Noel, and G. Zarazua de Rubens, "Rethinking the spatiality of Nordic electric vehicles and their popularity in urban environments: Moving beyond the city?," *Journal of Transport Geography*, vol. 82, Jan. 2020, Art. no. 102557, https://doi.org/10.1016/j.jtrangeo.2019.102557.

[12] D. Newman, P. Wells, C. Donovan, P. Nieuwenhuis, and H. Davies, "Urban, sub-urban or rural: where is the best place for electric vehicles?," *International Journal of Automotive Technology and Management*, vol. 14, no. 3/4, Oct. 2014, Art. no. 306, https://doi.org/10.1504/IJATM.2014.065295.

[13] L. Eriksson and L. Olsson, "The role of middle actors in electrification of transport in Swedish rural areas," *Case Studies on Transport Policy*, vol. 10, no. 3, pp. 1706–1714, Sep. 2022, https://doi.org/10.1016/j.cstp.2022.06.009.

[14] J. MacArthur, M. Harpool, and D. Scheppke, "Survey of Oregon Electric Vehicle & Hybrid Owners," *TREC Final Reports*, Jul. 2018, https://doi.org/10.15760/trec.205.

[15] R. P. Narasipuram and S. Mopidevi, "A technological overview & design considerations for developing electric vehicle charging stations," *Journal of Energy Storage*, vol. 43, Nov. 2021, Art. no. 103225, https://doi.org/10.1016/j.est.2021.103225.

[16] A. Gholami, J. Ansari, M. Jamei, and A. Kazemi, "Environmental/economic dispatch incorporating renewable energy sources and plug-in vehicles," *IET Generation, Transmission & Distribution*, vol. 8, no. 1, pp. 2183-2198, Dec. 2014, doi:10.1049/iet-gtd.2014.0235.

[17] E. Al-Hassan, H. Shareef, Md. M. Islam, A. Wahyudie, and A. A. Abdrabou, "Improved smart power socket for monitoring and controlling electrical home appliances," *IEEE Access*, vol. 6, no. 8454720, pp. 49292–49305, 2018, https://doi.org/10.1109/ACCESS.2018.2868788.

[18] I. Hafidz, A. Priyadi, M. Pujiantara, D. O. Anggriawan, and M. H. Purnomo, "Development of IoT-Based Portable Power Quality Monitoring on Microgrids by Enhancing Protection Features," *IEEE Access*, vol. 11, pp. 49481–49492, 2023, https://doi.org/10.1109/ACCESS.2023.3276241.

[19] I. Hafidz, A. Priyadi, M. Pujiantara, N. K. Adhuna, and M. H. Purnomo, "IoT-Based Power Monitoring and Lifetime Estimation of a Distribution Transformer in Building Scale: 2023 IEEE International Instrumentation and Measurement Technology Conference, I2MTC 2023," *I2MTC 2023 - 2023 IEEE International Instrumentation and Measurement Technology Conference*, 2023, https://doi.org/10.1109/I2MTC53148.2023.10175961.

[20] D. L. S. Mendes, R. A. L. Rabelo, A. F. S. Veloso, J. J. P. C. Rodrigues, and J. V. dos Reis Junior, "An adaptive data compression mechanism for smart meters considering a demand side management scenario," *Journal of Cleaner Production*, vol. 255, May 2020, Art. no. 120190, https://doi.org/10.1016/j.jclepro.2020.120190.

[21] E. Lobato *et al.*, "A Monitoring System for Electric Vehicle Charging Stations: A Prototype in the Amazon," *Energies*, vol. 16, no. 1, Jan. 2023, Art. no. 152, https://doi.org/10.3390/en16010152.

[22] X. Jian, L. Yang, Y. Li, Y.-C. Chen, and G. Xue, "SingMonitor: E-bike Charging Health Monitoring Using Sound from Power Supplies," *Applied Sciences*, vol. 13, no. 5, Jan. 2023, Art. no. 3087, https://doi.org/10.3390/app13053087.

[23] B. Anthony Jnr, "Enabling sustainable energy sharing and tracking for rural energy communities in emerging economies," *Renewable Energy Focus*, vol. 51, Art. no. 100633, Oct. 2024, https://doi.org/10.1016/j.ref.2024.100633.

[24] FlashFish. "Flashfish A501 Portable Power Station | 500W 540Wh. https://www.flashfishtech.com/products/flashfish-a501-portable-power-station-500w-540wh?srsltid=AfmBOor8lyRDa9DuuaNRp1G7TnoR0wMWRXT2ONkEA15XQ1uTE1Rqp5Fv.

[25] H. J. El-Khozondar *et al.*, "A smart energy monitoring system using ESP32 microcontroller," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 9, Sep. 2024, Art. no. 100666, https://doi.org/10.1016/j.prime.2024.100666.

[26] M. Güçyetmez and H. S. Farhan, "Enhancing smart grids with a new IOT and cloud-based smart meter to predict the energy consumption with time series," *Alexandria Engineering Journal*, vol. 79, pp. 44–55, Sep. 2023, https://doi.org/10.1016/j.aej.2023.07.071.

[27] Y. Ledmaoui, A. E. Fahli, A. Chehri, A. Elmaghraoui, M. E. Aroussi, and R. Saadane, "Monitoring Solar Energy Production based on Internet of Things with Artificial Neural Networks Forecasting," *Procedia Computer Science*, vol. 225, pp. 88–97, Jan. 2023, https://doi.org/10.1016/j.procs.2023.09.095.