*Journal of Advanced Research in Applied Mechanics* 115, Issue 1 (2024) 77-87

SEMARAK ILMU
PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in
Applied Mechanics

Journal homepage:
https://semarakilmu.com.my/journals/index.php/appl_mech/index
ISSN: 2289-7895


# Smart IoT Approach for Renewable Energy Monitoring System

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**ARTICLE INFO**

***Article history:***
Received 26 November 2023
Received in revised form 22 January 2024
Accepted 5 February 2024
Available online 22 March 2024

***Keywords:***
Renewable energy; IoT; green supply; global warming

**ABSTRACT**

Numerous factories, commercial establishments, and private residences require an uninterrupted power supply. The primary source of this supply is often the grid. Industries, businesses, and residential areas needing 24-hour power inevitably require backup systems to ensure continuous operation of essential electronic devices. Typically, diesel generators are employed as backup power sources, utilizing diesel oil to generate electrical energy. While this approach has been successfully employed for many years, it carries a significant drawback. Diesel oil falls under the category of non-renewable energy sources, unable to be regenerated and requiring an extensive period for renewal. Furthermore, diesel generators emit substantial amounts of carbon dioxide into the atmosphere, contributing to air pollution in the vicinity. To address these challenges, a prototype implementing a smart Internet of Things (IoT) approach has been developed. This study introduces the utilization of an Arduino Nano microcontroller, allowing users to control their power supply source, choosing between the grid, solar panels, or water generation. This control process is facilitated through a smartphone application, granting users the ability to manage it remotely, enhancing monitoring capabilities. The system incorporates two environmentally friendly power sources: solar panels and a mini water turbine, both considered safe for ecological balance. The outcomes of this research demonstrate that users can effectively utilize the generated electricity supply for approximately 12 hours, thereby reducing reliance on the grid and harnessing the potential of renewable energy sources.

## 1. Introduction

In the modern context, the unceasing need for continuous electricity in homes and businesses is paramount. Essential devices like refrigerators, security systems, and communication tools rely on uninterrupted power, while the challenge of reducing electricity costs persists. Green generation methods like solar panels, water turbines, and wind turbines offer promising solutions, harnessing environmentally friendly sources for backup power [1]. The dilemma, however, lies in the persisting

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https://doi.org/10.37934/aram.115.1.7787

issue of high costs associated with constant power usage, including inconspicuous yet energy-intensive equipment like fire alarms. This challenge extends to fledgling businesses grappling with unexpected power expenses, as well as remote regions relying on limited power options, often resorting to diesel generators with their capacity constraints and environmental impact. These issues underscore the need for alternative, efficient, and ecologically conscious power supply solutions.

This research pursues multifaceted objectives centred on the creation of a backup power supply system using the Arduino Nano microcontroller, complemented by solar panels and mini water generation. With the integration of the Internet of Things (IoT), the study strives to develop an intelligent electrical supply framework that optimally utilizes green energy sources. The key objectives encompass establishing a dependable backup power mechanism, augmenting control through IoT integration, and assessing the efficiency and ecological implications of the green generation supply. Through these aims, the research envisions a pathway to practical and sustainable energy solutions catering to diverse needs and applications. Moreover, the implementation of dual green generation holds immense societal benefits. By considering the critical role of electrical supply backup in billing and efficiency management, society can manage electricity costs more effectively, ultimately leading to improved efficiency in electrical management systems. Notably, this approach extends beyond individual consumers, offering advantages to government efforts as well. Through the adoption of green generation as a backup supply, the government can optimize distribution and generation maintenance budgets for residential and small-scale factory electrical supply, channelling more focus toward heavy industries. This strategic shift empowers the government to manage electrical supply and generation systems independently from non-renewable sources, thus fostering a more sustainable and self-sufficient energy landscape.

## 2. Related Study

In the contemporary era, numerous countries are experiencing rapid economic growth, especially within the industrial and manufacturing sectors. For instance, China has earned the reputation of being the "world's factory," highlighting its significant manufacturing and export capabilities [2]. Within this context, the provision of electrical power relies on two main methods of generation: renewable energy and non-renewable energy. Renewable electricity generation harnesses naturally occurring energy sources such as wind, solar radiation, heat, and tidal movements, transforming these sources into usable electricity [3]. What's remarkable is that this approach eliminates the need for traditional fuel sources, instead relying on nature's abundance, which bodes well for the environment. The concept of renewable electricity generation gained traction in the 1970s when environmental advocates championed it as an eco-friendly alternative to fossil fuels and a means to reduce dependence on oil [4]. A notable example of this type of generation is the Three Gorges hydropower plant in China, boasting a capacity of 22.5 gigawatts and ranking among the largest hydroelectric facilities globally. Impressively, China contributed to around 40% of the global increase in hydroelectric capacity in 2018 [5].

However, several important factors require consideration. Establishing renewable electricity generation often demands substantial land use. Take, for instance, China's Tengger Desert Solar Park, spanning an area of approximately 1,547 megawatts and covering about 43 square kilometres [6]. Such expansion may potentially encroach upon forests, impacting natural habitats for various species. While renewable electricity generation is lauded for its environmental benefits, it's crucial to strike a balance with preserving wildlife habitats. On the flip side, non-renewable electrical generation relies on sources that are finite and cannot be replenished within a human lifespan [7]. Fossil fuels like coal, petroleum, and natural gas are the primary sources of non-renewable energy, predominantly composed of Carbon, a compound that took around 360 to 300 million years to form during the Carboniferous Period [8].

The primary objective behind this proposed endeavor is to establish an energy backup supply monitoring system that ensures minimal impact on environmental health while addressing previously identified limitations. Through the innovative concept termed the "Dual Backup Green Generation," this system can generate power under various conditions, encompassing both rainy days and daylight. Moreover, it boasts the advantage of being free from carbon dioxide emissions, thus upholding environmental well-being. The resulting power supply is stored within a battery, harnessed through the collaborative efforts of two distinct generation sources: the mini solar and mini water turbine. Notably, the charging process is intelligently orchestrated via smartphones, leveraging rain or daylight scenarios, and facilitating simultaneous supply while charging. Moreover, evaluating the mini solar power supply approach reveals its limitation—it solely charges during daylight and falters during rainy days, potentially leading to insufficient battery charging. Particularly, prolonged rain spells can exacerbate this issue. To mitigate this challenge, the proposed framework introduces the mini water turbine, an innovative solution that sustains battery charging through continuous rainfall, even during nighttime hours.

Conversely, the rain gutter power approach offers power exclusively during rainy days, catering well to locales characterized by frequent rainfall. However, this method bears the limitation of sole operability during rain, contrasting with the versatile nature of the mini solar power panel. Given this context, the hybrid nature of this project allows the electric generation process to function in the absence of rainy conditions, thereby broadening its practical applicability. In essence, this proposed project serves as a solution applicable to both household and industrial settings, potentially alleviating the reliance on non-renewable electrical generation sources. By doing so, it aids consumers in curtailing their monthly electricity expenses, while simultaneously contributing to sustainable energy practices.

## 3. Methodology

This section offers insight into the systematic development of the dual green backup supply, an innovative system featuring two distinctive backup sources: solar panels and mini water turbines. These sources play a critical role in generating electricity through solar energy absorption and water pressure activation, respectively. Solar panels are strategically positioned on rooftops to harness solar energy and transform it into electric power. Conversely, mini water turbines are strategically located within downspouts, leveraging water pressure to initiate turbine rotation. The resultant electrical output from these dual green sources is efficiently stored in a designated battery. Facilitating this setup, the Arduino Nano microcontroller empowers users to seamlessly switch between the primary power supply and the dual green supply, conveniently managed through a smartphone interface facilitated by a Bluetooth Module. This adaptive configuration grants users the autonomy to select their preferred energy source according to their specific requirements. Furthermore, the implementation includes a cooling fan mechanism to regulate the Arduino Nano's temperature, preventing any potential overheating issues. Figure 1 shows the prototype of the energy monitoring system.

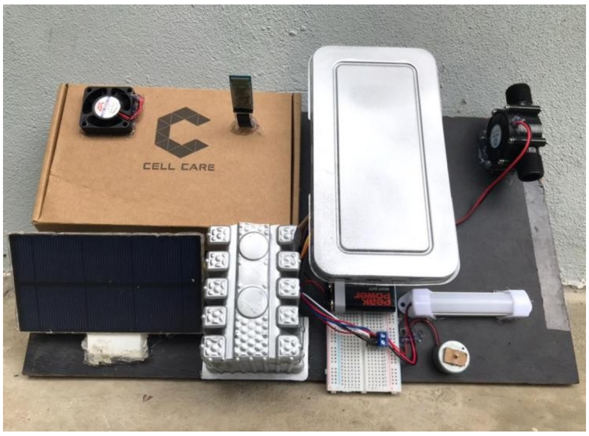


**Fig. 1.** The prototype of the energy monitoring system

### *3.1 Block Diagram and System Flowchart*

The block diagram depicted in Figure 2 illustrates the conceptual framework of the dual green backup supply proposed in this study. This configuration comprises essential components such as a 3.7V DC battery supply, Arduino Nano, three relays, a 5V DC battery, Bluetooth transceiver, battery charger TP4056, solar panel, and mini water turbine. To energize the Arduino Nano, a stabilized 5V DC supply is drawn from the battery supply unit.

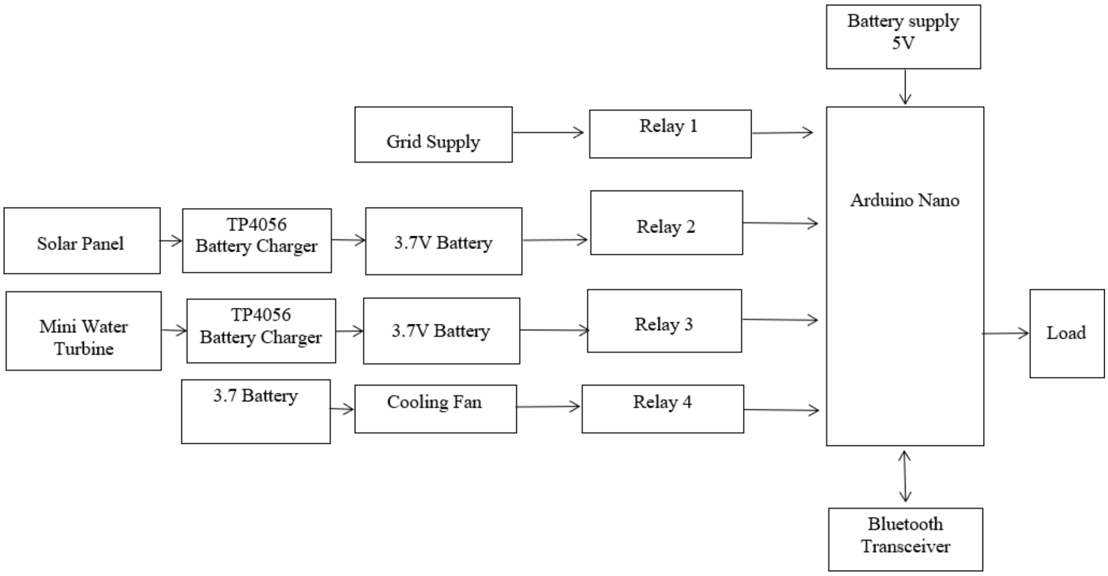


**Fig. 2.** Block diagram for the proposed system

Illustrated in Figure 3 is the operational framework of the proposed concept. The initial step requires the user to ensure the Arduino Nano is adequately powered using a 5V DC Battery. This empowers the Arduino Nano to issue system commands based on pre-configured code programming. Upon receiving a command from the smartphone, the Bluetooth Transmitter communicates it to the Arduino Nano. Subsequently, the Arduino Nano signals the user to select the preferred relay. Specifically, Relay 1 activates the grid supply. In the event of an outage, the user can switch to either of the other two relays to sustain electricity provision. Moving forward, activating Relay 2 triggers the engagement of the solar panel. When sunlight reaches the solar panel, the 3.7V Battery undergoes charging through the TP4056 Battery Charger. Each relay activation maintains the battery in standby mode, serving as a reliable backup supply. However, if the solar panel lacks sunlight exposure, the battery remains uncharged, rendering it unprepared for backup deployment. Finally, the activation of Relay 3 initiates power supply from the mini water turbine. If water flows through the downspout, the mini water turbine converts mechanical energy into electrical energy, charging the battery via the Battery Charger TP4056. Conversely, the mini water turbine remains unable to generate electricity in the absence of water flow and the associated mechanical energy.

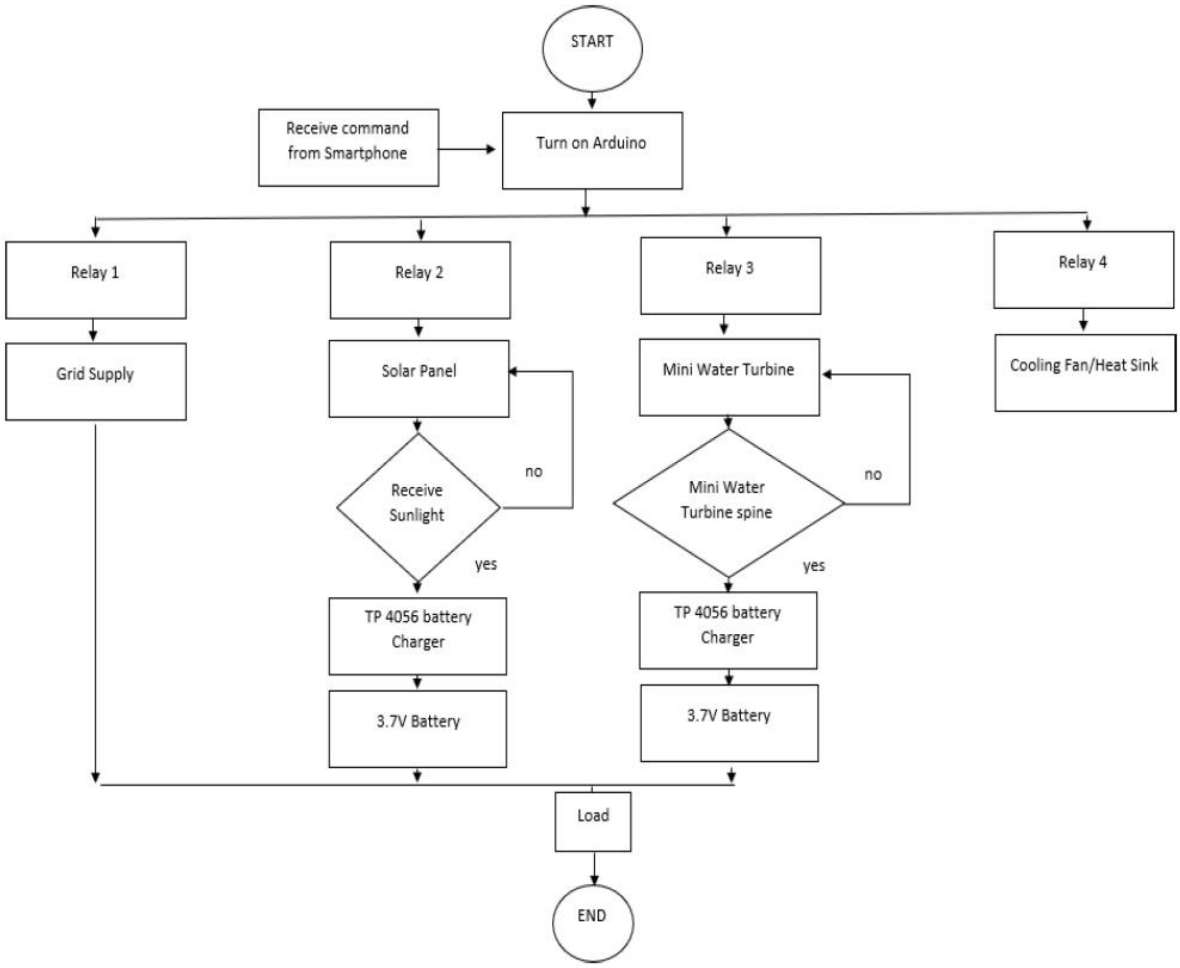


**Fig. 3.** Flowchart of the proposed system

### *3.2 The Application of MITAPP Inventory*

The smartphone application is developed using the MITAPP Inventory, illustrated in Figure 4. Within this application, eleven distinctive buttons are thoughtfully integrated, each serving a specific purpose. The initial button is dedicated to Bluetooth functionality, facilitating the identification of available Bluetooth devices. Following this, the relay power supply section incorporates a pair of buttons, one for activating power (ON) and the other for deactivating it (OFF). This feature proves invaluable in halting all power supplies during unforeseen circumstances, such as maintenance or safety contingencies, thus ensuring load protection. Among the remaining buttons, six enable the toggling of diverse power sources, including grid supply, solar supply, and water-generated electricity. Furthermore, two buttons are allocated for controlling the cooling fan, designed to regulate the temperature of the Arduino Nano. Once the application's development is concluded, the software is transferred to the smartphone via a QR code.


**Fig. 4.** MITAPP Inventory application

Once executed, the application interface becomes accessible through the MITAPP Inventory, as depicted in Figure 5.

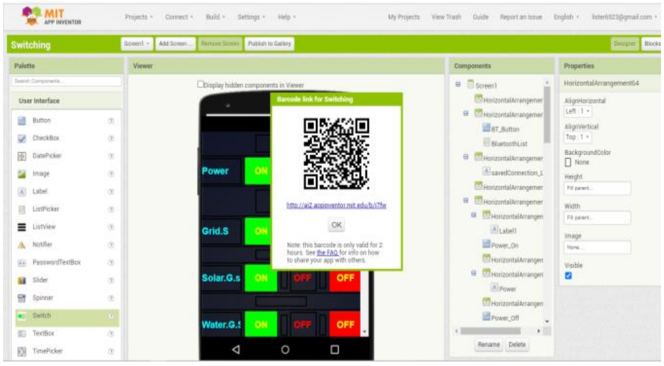


**Fig. 5.** QR code of the MITAPP Inventory

Throughout the solar panel charging process, illustrated in Figure 6, the battery charger module signals its status through indicator lights. Initially, a red light signifies the ongoing charging process. This indication persists until approximately two hours have elapsed, at which point the battery charger module transitions to a blue light. This blue light serves as confirmation that the battery is fully charged and prepared for utilization.

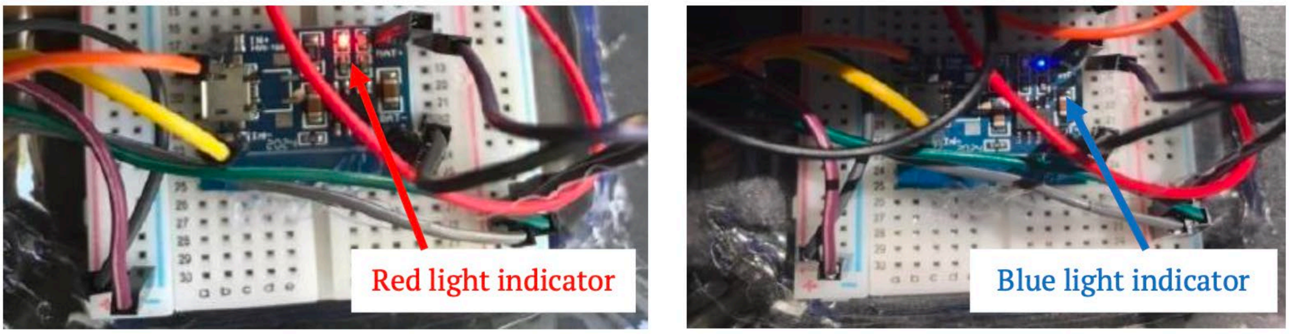


**Fig. 6.** The mini solar panel charging process

The testing of water generation yields three distinct outcomes. Firstly, upon opening the water pipe, the charger module's indicator light transitions to red, signifying the successful commencement of the charging process. Following this, both the red and blue LEDs are activated, indicating that the battery is nearing full charge. Lastly, as depicted in Figure 7, the red indicator light switches off while the blue indicator light remains illuminated, affirming that the battery has attained full charge status and is primed to provide power to the load.

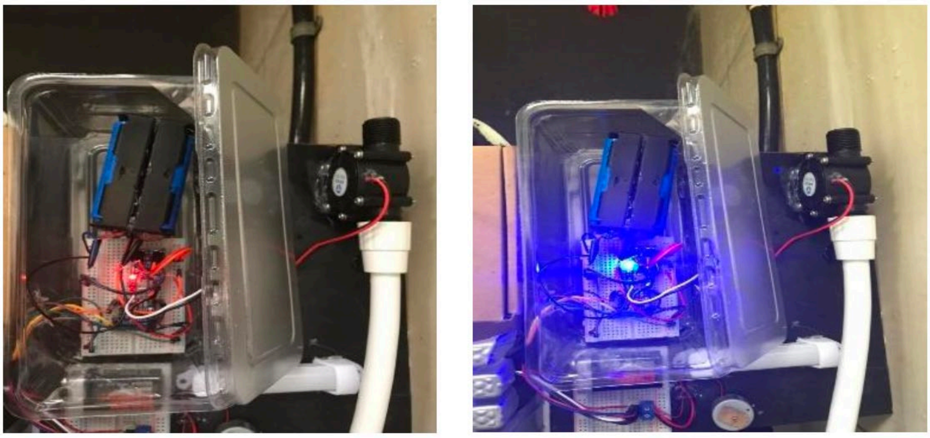

**Fig. 7.** Water generation charging process

In the switching phase, the connectivity between the smartphone and the Bluetooth module is established to ensure a successful system connection, as depicted in Figure 8. Subsequently, the grid supply is activated via the smartphone interface. As the grid supply is engaged, the DC motor initiates rotation, accompanied by the illumination of the lamp.


**Fig. 8.** Before the switching supply is on

These actions collectively verify that the load has effectively received power from the grid supply, showcased in Figure 9.


**Fig. 9.** Lamp and motor are turned on when switching to the grid supply

Similarly, the activation of the solar panel supply switch results in the illumination of the lamp and engagement of the DC motor, illustrated in Figure 10.


**Fig. 10.** Lamp and the motor are turned on when switching to the solar generation supply

Similarly, the activation of the water generation supply switch leads to the concurrent activation of the lamp and the DC motor, depicted in Figure 11. Throughout these switching processes, the operational sequences remain consistent; the distinguishing factor lies in the specific type of electrical supply employed.


**Fig. 11.** Lamp and the motor are turned on when switching to the water generation supply

## 4. Results

Figure 12 illustrates the outcome presented through a line graph, depicting the stored electric supply resulting from solar power generation and mini water turbine generation over time during daylight hours. This graph vividly showcases the electric supply that finds its place within the battery during daylight hours, excluding instances of rainfall. During these non-rain periods, there is no electrical generation attributed to the mini water turbine, nor is there any electric storage in the battery associated with it. Examining the graph pattern, it becomes evident that between 2:00 am and 8:00 am, the energy stored within the battery remains consistent at 20%. This can be attributed to the solar panel's inability to generate electric supply due to the absence of sunlight. Conversely, a remarkable surge in electrical energy storage to 100% is observed between 8:00 am and 10:00 am. This significant increase is attributable to the solar panel effectively harnessing ample sunlight energy during this timeframe. The panel is designed to yield 6V in a broad range of light conditions, predominantly serving the purpose of current selection for charging. The provided current demonstrates a proportional relationship with light intensity, assuaging concerns regarding the optimization of sunlight exposure. It is noteworthy that the solar panel theoretically possesses the capability to fully charge a 3.7V, 1000mAh battery within a mere 2-hour span during daylight hours [9].

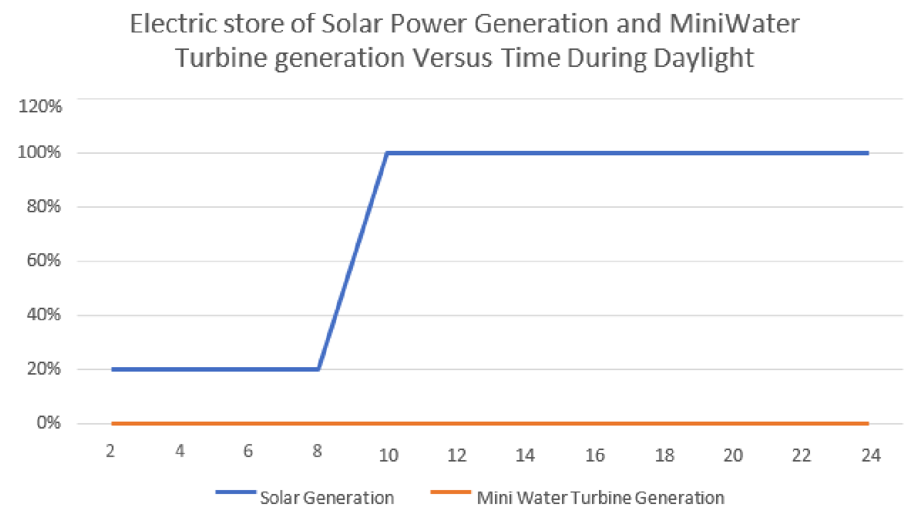


**Fig. 12.** Electric store of solar power generation and mini water turbine generation versus time during daylight

While Figure 13 shows a line graph demonstrating the electric storage resulting from solar power generation and mini water turbine generation over the course of a rainy day. In instances where rainfall persists throughout a substantial portion of the day, the battery attains full charge status between 2:00 pm and 2:00 am. This prolonged charging duration of approximately 12 hours ensures the complete charging of the 3.7V battery for operational readiness. Notably, the progress of electrical generation via solar panels during rainy days remains sluggish due to inadequate sunlight energy exposure. A comparative analysis of Figures 12 and 13 underscores the swifter electrical storage capacity of solar panels in contrast to the mini water turbine. This disparity can be attributed to the consistent sunlight source that empowers solar panels to continually generate electrical energy, while the mini water turbine solely generates such energy during rainy days. Nonetheless, the mini water turbine still demonstrates proficiency in generating and storing electrical energy for smaller equipment, furnishing a reliable supply over a continuous 12-hour duration.

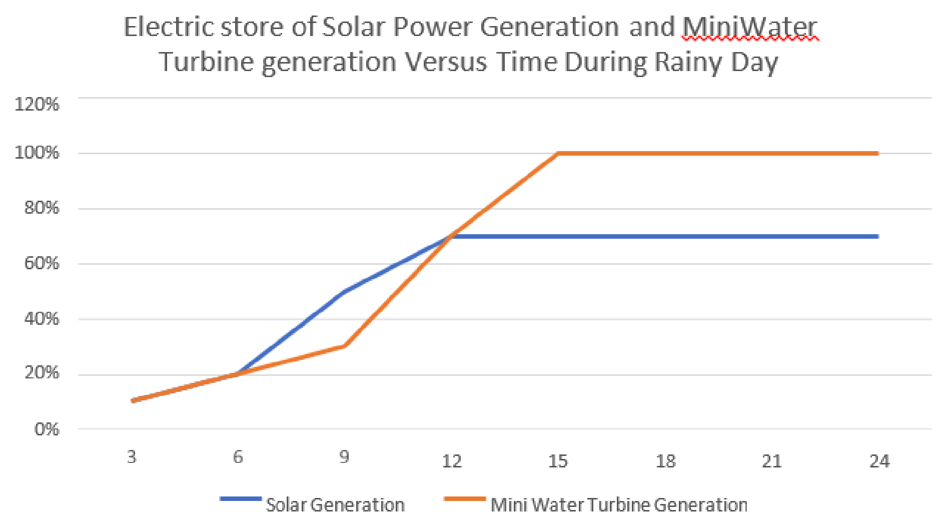


**Fig. 13.** Electric store of solar power generation and mini water turbine generation versus time during a rainy day

## 5. Conclusions

In conclusion, the primary objective of this proposed project is to mitigate reliance on conventional grid supply and shift focus towards sustainable green alternatives like solar and water generation. This endeavour holds significant promise in safeguarding environmental well-being and mitigating the impacts of global warming. The applicability of this solution extends to both residential and industrial domains, offering a means to curtail dependence on traditional power grids, as evidenced in previous research [10]. Furthermore, widespread adoption of this method could foster collaborative efforts to preserve environmental health collectively. In summary, the project has effectively attained its intended objectives. Nonetheless, several recommendations for future enhancements stand out to optimize the performance of the electrical energy monitoring system. Firstly, expanding the solar panel's surface area could amplify electrical generation efficacy during daylight hours. Additionally, augmenting the capacity of the battery power bank has the potential to accommodate a larger pool of generated electrical energy for storage.

## Acknowledgement

The authors would like to thank the Ministry of Higher Education and Universiti Teknologi MARA Shah Alam for the grant support in publishing this paper. The grant ID is 600-RMC/GPK 5/3 (248/2020).

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