

Sustainable Water Solutions: Solar- Driven Distillation and Real-Time Monitoring for Rural Community

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Abstract

In an era characterized by rapid population growth and urban sprawl, access to clean water has become a significant concern for societies around the globe. As the world's most precious resource, water scarcity poses a significant challenge to the sustainability of our planet's ecosystems, economies, and human health. However, despite this issue of modernity, the demand for clean water in rural areas is more pressing and must be taken seriously in order to involve the demands of relevant and up to date processes. Therefore, in-depth studies to maintain quality water for this concern area have become increasingly popular and received the attention of many parties. Thus, the seawater distillation method powered by solar panels has been identified as the most effective technological alternative, accessible source of supply and is able to produce more consistent results. The specific methodology implemented involves several components and processes such as 12V solar panels, batteries, inverters, heating coils, water pumps, charging controllers, microcontrollers, sensors, liquid crystal displays and 2-channel relay modules. Next the target for this work is that the evaporation process will take place and the condensing unit will store the distilled water in a specified container. Subsequently, observe the results of the experiment by measuring the water level at different times and finally it is expected that the water level will increase as the hours increase.

1. Introduction

Water is vital to all living organisms in the world, especially the human species. People use water for various purposes, such as hygiene, cleaning, and agriculture. Water usage has improved due to population growth and economic development. Due to its increase, water resources have reached their limits in supplying safe drinking water to consumers. An estimated 20 to 50 liters of clean water per day is required for each person [1]. In fact, not all of the available water is safe for consumption. Many people are unable to have healthy lives and establish secure livelihoods because they lack access to sufficient, safe, and affordable water. According to studies from the past year, water crises have been recognized as major challenges to society and have been identified as the third highest global concern in terms of risk [2],[3]. Therefore, water distillation is a sustainable solution to address the global water crisis. Water distillation is a water treatment method that removes soluble minerals like calcium, magnesium, and phosphorous, along with dangerous heavy metals and bacteria.

This process requires a heating process to create steam and condensing the steam back into liquid water. As a result, it produces freshwater that is safe for drinking and pipeline purposes. Freshwater has the potential to

be supplied to consumers, such as rural communities. Furthermore, the solar photovoltaic (PV) system has the potential to be applied to this study due to its favorable utilization in Malaysia. Solar PV generates electricity from sunlight and converts it directly into electrical energy [4]. Research indicates that rural areas where the person who live near to the sea, in Malaysia face inequality in energy access and lack access to electricity. For instance, urban areas have an access rate of 86% while rural areas have only a 38% electricity access rate [5],[6]. Rural areas are also prone to water crisis problems. The far distance from the water sources makes it difficult and expensive to supply water to these areas. Residents often have to walk long distances to collect water from rivers and are prone to several environmental risks [7]. In addition, it is a waste for them for not using unlimited water source from the sea due to unavailability for producing clean water. It is not only faced with water shortage but also a concern for water quality.

Therefore, the study's aim is to develop the water supply from various water sources. The work is limited to a rural area because it is not suitable for a large population and it affects the system's efficiency in producing fresh water. Rural treatments also vary due to several factors such as water resources, climate, and the skills of people implementing the techniques. Subsequently, with the installation of solar PV, these areas can access electricity that is not connected to the power grid. However, this analysis will be conducted by capturing sunlight, converting it into electricity, and storing it in batteries for later use.

2. Methodology

This study involves a methodology focused on producing clean water through the distillation process by depending on free sources such as solar energy. This section will provide detailed explanations about the hardware components, block diagram and flowchart of the entire process.

2.1 Block Diagram

The block diagram shows the main components of the solar-driven distillation system with real-time monitoring and control, showcasing how connections are established. This system can incorporate a microcontroller to ensure effective and smooth operation.

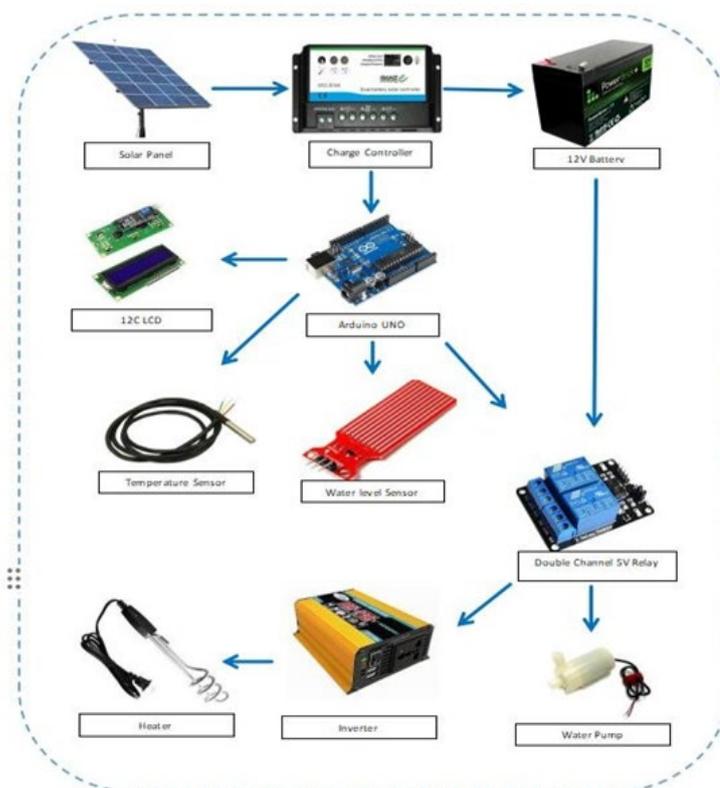


Fig. 1 Block diagram of the system

Fig. 1 shows the connections to establish the water distillation process. The system initiates when the 12V solar panel harnesses the energy from the sun and supplies the 12V battery through a charger controller to

regulate the charging capacity when it reaches the desired amount. The battery serves as the primary power source for the distillation system. A microcontroller such as Arduino Uno is connected to the charger controller along with sensors measuring water level and temperature. The data collected by these sensors is displayed on an LCD. To monitor the water pump and heater coil, a double-channel relay module is employed. The live wire of the battery is connected to the relay module's COM port, with the normally open port connected to the inverter live wire. The neutrals for both the inverter and battery are attached directly. These connections are crucial for ensuring that the supply can be effectively controlled by the relay.

The work's operation has the capability to monitor and control the entire process. For instance, the monitoring process begins as the water pump starts drawing water from the seawater and filling the water tank to a specified level. The ultrasonic sensor sends a signal to the microcontroller when reaching the desired water level and cuts off the supplies from the battery through a contact relay. The process continues to the heating phase, where the heater remains on until the water reaches a fixed temperature point controlled by the water temperature sensor. It will automatically cut off battery supplies using a relay contact. The evaporation will occur and the condensation unit will store the distilled water in a container. Therefore, the process will be repeated when the water tank level drops below the desired value.

Fig. 2 shows the completed prototype that has been implemented for the water distillation process. Conduct all the connections such as the 12V solar panels, battery, inverter, heater coil, water pump, charger controller, microcontroller, sensors, liquid crystal display, and 2-channel relay module. The target for this study is that the evaporation process will occur, and the condensation unit will store the distilled water in a container. Observe the experimental results by measuring the water level at different times. It is expected that the water level will increase when the hours are increasing.



Fig. 2 *The hardware design and experiment set up*

2.2 Flowchart of The Study

The flowchart provides a comprehensive plan, serving as a workflow for the successful execution of the system. This workflow illustrates the progress from inception to completion, attaining predefined goals and objectives. This ensures that the work can be executed as targeted. The upcoming sections of the paper will provide a detailed explanation of the flowchart.

Fig. 3 illustrates the overall flowchart of the system to be implemented. The solar energy collected by the suggested system is stored in a 12V battery and is generated by a 12V solar panel. To heat the saltwater, a buck converter is used to reduce the voltage from 12V to a lower level. The heater is controlled by an Arduino Uno and a relay module. Seawater is pumped into the tank using a water pump managed by an Arduino Uno and a relay module. Using a water temperature sensor, the Arduino Uno measures the water temperature and determines whether it is below or above the intended setpoint before activating or deactivating the heater. Additionally, an ultrasonic sensor is integrated with the Arduino Uno to assess the water level in the tank. Depending on whether the level is above or below the specified setpoint, the Arduino Uno will activate or deactivate the water pump. Thus, distilled water is obtained by condensing the evaporated water after it reaches the point of evaporation, while the remaining brine is released.

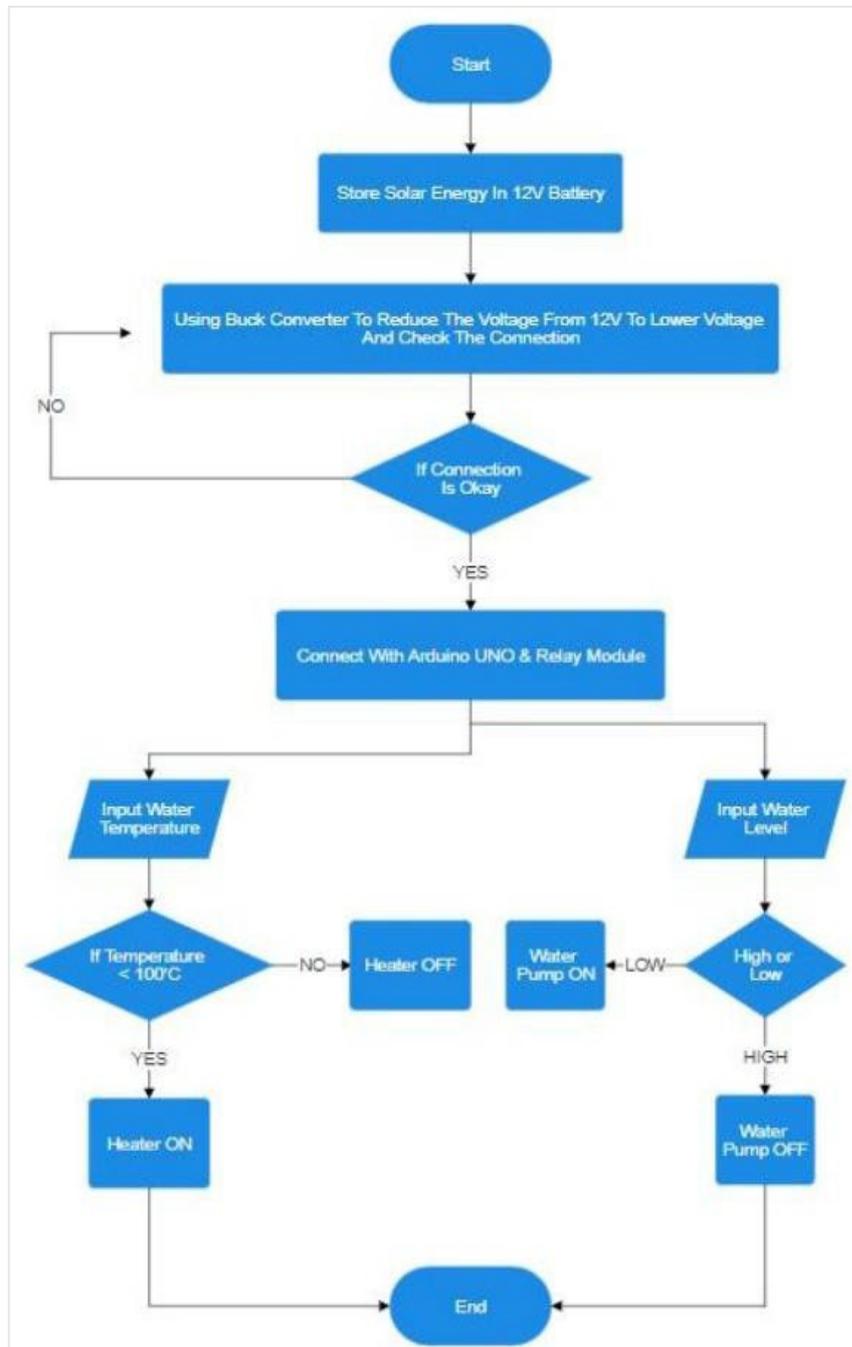


Fig. 3 Flowchart of the system

3. Result and Analysis

The result of the hardware for solar- driven distillation and real-time monitoring for rural community will be discussed in this section. The time taken for the seawater to evaporate will be recorded and the result if the level of heat is increased and reservoir is decreased.

Fig. 4 shows the results collected in the bottle, which serves as the container for different hours. The study’s results were observed by analyzing the highest amount of water produced during the distillation process. After several hours, various water levels were reached throughout the process. The highest level produced by the distillation system occurred within 24 hours, where during the period, the water almost filled the bottle. The second-highest water production was observed at 12 hours. However, the water produced in this timeframe did not reach half of the bottle.



Fig. 4 The distilled water produced with respect to time

The next observations were conducted at 6 hours and 3 hours, portraying the least amount of water produced by the distillation process. The rate of the distillation process is influenced by the water temperature which varies by the temperature of the heating coil. The highest temperature reached by the coil and water temperature is about 98.85 degrees. The heating coil will start heating again when the water temperature drops to 60 degrees. This temperature range is considered ideal for water to evaporate and reach the distillation surface unit.

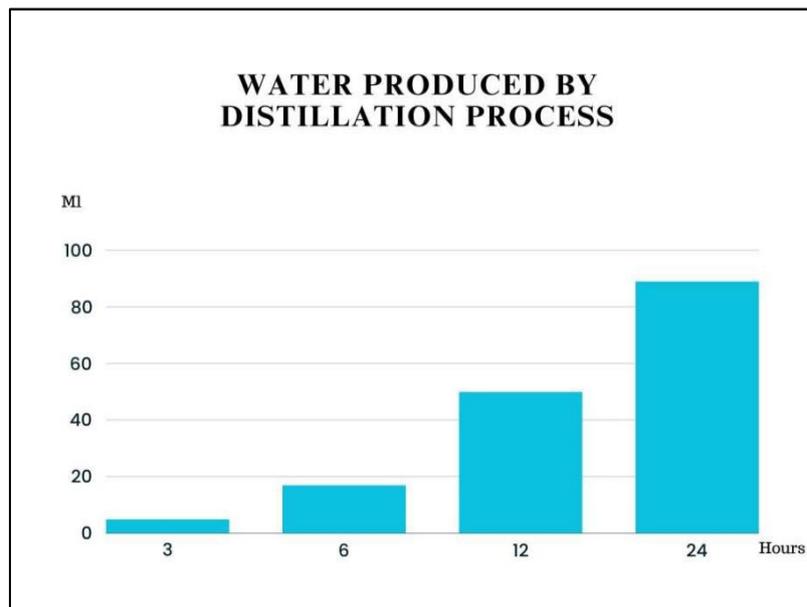


Fig. 5 Graph of distilled water produced

Fig. 5 shows the analysis results using a graph and transfers the actual values to the predicted water level, as the target is set to reach 100 ml. According to the results, the maximum water production occurs at 24 hours, reaching around 90 ml. In contrast, the minimum water production is observed at 3 hours, with a value of around 5 ml. Based on the results obtained, when conducting this water distillation process for 24 hours, which means for one day, it has the potential to produce around 90 ml of fresh water. This production has achieved the target of supplying close to the maximum goal, which is 100 ml. These findings demonstrate the effectiveness of the distillation process. At first, the primary goal of this work is to supply fresh water to rural areas. With a daily

production of only 90 ml of fresh water, it is not sufficient to serve as the primary water supply for these areas. However, this work can function as a secondary water supply, particularly in cases that require immediate water needs during emergencies.

In summary, rural communities now have an alternative water supply to reduce their dependence on a single water service provided by various water companies in Malaysia. The distillation process not only produces high temperatures that effectively destroy various dissolved substances in water but also contributes to an improvement in power quality. Therefore, the water distillation process is highly practical for use as it provides benefits to rural communities.

4. Conclusion

According to the results obtained in section 3, it is proven that all the objectives have been achieved. Water is a basic need for humans besides food and air. Solar distillation stands out as a good and effective technique, especially in areas with limited access to clean water supplies. This is because this method is renewable, cheap, simple, and capable of removing various water pollutants. In this work, a renewable energy source such as solar is used for clean water production. Solar does not require any external fuel because it simply absorbs sunlight and converts it into electricity. This makes solar power a viable option for water purification in locations with limited energy access. Therefore, utilizing solar energy not only saves on electricity bills but also reduces environmental impact.

To enhance the work, it is recommended to incorporate materials with high thermal conductivity to improve heat transfer efficiency within the distillation process. This enhancement will result in faster water heating which will lead to increased water production. Increasing water production assists rural communities in enhancing water availability within these areas. Additionally, implementing a real-time monitoring system that adapts to changing weather conditions to ensure a continuous water supply. For instance, the system can maximize water production during periods of optimal solar exposure and minimize energy consumption during periods of reduced sunlight.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors attest to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

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