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Portable Water Cooler using Solar System

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Abstract

This project aims to construct a portable solar-powered water cooler. This ingenious system uses a 12V solar panel as the primary energy source and a 12V lead-acid battery for energy storage, which also functions as a backup power supply to assure uninterrupted operation during periods of low sunlight. The cooling method uses a Peltier device coupled to a water block to effectively chill the water. This project entails designing and integrating the solar panel with the battery storage and Peltier cooling system, resulting in effective energy transfer and utilisation. The solar panel charges the lead-acid battery, which then powers the Peltier device to provide the appropriate cooling effect. The experiment shows that the system can provide cooled and clean water, proving the concept of a solar-powered portable water cooler. However, the system did not reach the target temperature established early in the project, highlighting possible areas for additional refinement and development. In conclusion, the study successfully created a practical portable water cooler powered by solar energy, demonstrating the viability of such systems in off-grid situations.

1. Introduction

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In today's fast-paced world, staying hydrated is essential for maintaining good health and productivity. Whether at the office, on a construction site, hiking in the great outdoors, or enjoying a day at the beach, access to clean and refreshing drinking water is a fundamental requirement. This need has led to the development of a Portable Water Cooler project, which aims to provide a convenient and efficient solution for quenching thirsts.

The Portable Water Cooler project addresses the challenge of ensuring that clean and chilled water is readily available in various settings. It combines innovative design, technology, and eco-friendly principles to deliver a product that not only meets the hydration needs of individuals but also contributes to environmental sustainability. This project encompasses the creation of a compact, user-friendly water cooler that can be easily transported, making it an ideal solution for people on the go.

The proposed water cooler design incorporates several key features that make it an attractive choice for consumers. These features include energy-efficient cooling mechanisms, easy-to-use interfaces, and robust filtration systems to ensure the water provided is not only chilled but also free from impurities. Additionally, this project prioritizes the use of sustainable materials and eco-friendly refrigerants to reduce the product's environmental footprint.

The Portable Water Cooler project aims to cater to a wide range of applications, from recreational to professional, enhancing the daily lives of individuals and promoting healthy hydration practices. In this project, there will be discussion about design, engineering, and manufacturing processes necessary to bring this product to market, emphasizing the principles of convenience, efficiency and sustainability.

As the demand for portable water solutions continues to grow, this Portable Water Cooler project seeks to make a positive impact by providing an accessible, reliable, and environmentally conscious way to stay refreshed no matter where a person may be.

2. Literature Review

This section discusses the theory of solar panels, the 12V thermoelectric Peltier, the circulation of water and the filtration system, LCD with a functioning display and the explanation of the electrical and hardware components used in this project from previous research.

2.1 Review on Solar Panels

Solar technologies use photovoltaic (PV) panels or mirrors to concentrate solar radiation to convert sunlight into electrical energy. This energy can be converted into electricity or stored in batteries or thermal storage [5].

Solar energy is not only a completely reliable and long-lasting energy source, but it is also incredibly cost-effective and efficient if the solar panels and the environment are well suited. Such optimistic prospects have grown in an industry that has invested much in creating efficient systems for generating, utilizing, and storing the sun's energy through the use of various types of solar panels and transforming the sunshine into valuable power [6]. Table 1 shows the different types of solar panels alongside its efficiency rate and also its advantage(s) and disadvantage(s).

Table 1 *Types of solar panels [6]*

Solar Cell Type	Efficiency Rate	Advantages	Disadvantages
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimized for commercial use; high life-time value	Expensive
Polycrystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	Shorter warranties & lifespan
Concentrated PV Cell (CVP)	~41%	Very high performance & efficiency rate	Solar tracker & cooling system needed (to reach high efficiency rate)

2.2 Review on Thermoelectric Coolers (TEC)

Thermoelectric cooling is a novel technique that has the potential to revolutionize the way food, and drinks are kept cold. In reality, it is an entirely different approach to cooling than traditional compressors.

Thermoelectric cooling systems, as the name implies, rely on electricity passing through two distinct types of conductors, such as copper or zinc. When DC voltage is provided and direct current flows from one conductor to the other, the temperature changes where the two conductors meet. When this minor thermoelectric effect is increased by connecting two ceramic plates, a cooling effect is produced [9]. One plate represents the "cool side," while the other represents the "hot side." The cold side is placed inside an ice-free cooler or wine refrigerator, while the hot side is attached to metal fins that act as a heat sink on the outside of the appliance to help dissipate excess heat. Because there is no liquid refrigerant moving through the system, thermoelectric cooling (TEC) is also known as solid-state cooling.

The Peltier effect describes how heat is absorbed from the exterior or released to the outside when a current travels through the interface of two distinct conductors. Semiconductor coolers are the most obvious application. The Peltier effect is explained physically as charge carriers moving in a conductor to create an electric current. Because charge carriers have varying energy levels in different materials, when they go from a high energy level to a low energy level, they release excess energy; conversely, when they move from a low energy level to a high energy level, they absorb energy from the outside. At the contact of two materials, energy is absorbed or released in the form of heat. If the closed loop of the thermocouple is modified as illustrated in the picture, a completely opposite phenomena known as the Peltier effect can be obtained [10].

2.3 Review on Submersible Pump

The submersible pump, also known as a bell pump, is totally immersed in the water to be extracted. These pumps are utilized in flooding circumstances such as rising groundwater in cellars or basements, swamped vessels, and flooded places. Submersible pumps are available in a variety of styles, with the key distinction being the type of water that needs to be pumped; for example, clean-water submersible pumps are utilized for rainwater. Other models include dirty-water or wastewater submersible pumps, which can process water with sand, soil, and residue, as well as heavy-duty models, which can process even coarser pollutants such huge solid particles. The impeller at the pump's bottom processes solid particles by breaking them up so that they can be emptied easily [11].

A submersible pump is a mechanical device that pushes water towards the surface rather than pulling it. It has a hermetically sealed motor attached to the pump body that aids in pushing the fluid to the surface. It is the most well-known type of centrifugal pump. A submersible pump is mostly used to pump water from wells. This type of pump forces water to the surface by converting rotatory motion (speed) into kinetic energy, which is then converted into pressure energy by diffuser blades [12].

3. Methodology

A cooling system comprising of a TEC that is powered by a solar system, is thoroughly studied and developed through multiple stages. Fig. 1 shows the working principle of the project by only focusing the components used that makes the system operate.

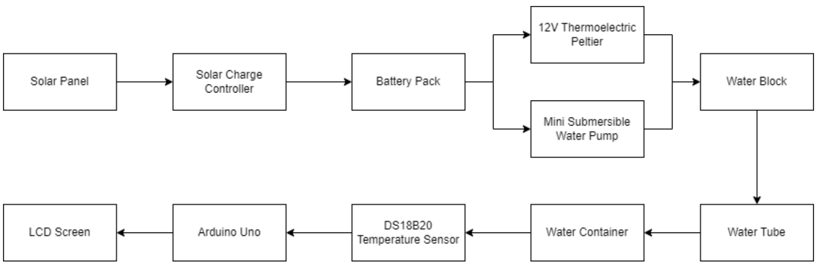


Fig. 1 *Block Diagram of the Project*

Once the solar panel detects sunlight, the energy it received will be stored within the battery pack. From the battery pack, it will powered 2 components simultaneously which are the 12V Thermoelectric Peltier and the mini submersible water pump. The water pump is connected to the water block, which is connected to the water container via a tube. The water circulates through the water block, which is connected to the Peltier module. After some time, the water temperature will drop due to the cooling process of the Peltier. The DS18B20 is submerged within the water container which is connected to an LCD that displays the temperature of the water.

For the function of each components, the solar panel absorbs sunlight to generate power, the battery pack stores the energy that was generated by the solar panel. After that, the battery pack powers up the TEC and the mini submersible water pump. The water pump will pump water through the water block and into the container by using the water tube. The DS18B20 temperature sensor will read the current temperature of the water with the help of Arduino Uno and then displays the reading on the LCD screen.

For the filtration system, a water filter will be installed within the water tube to separate any impurities within the water container. This will make the water safer to drink. The operating principle of the whole system is shown in Fig. 2.

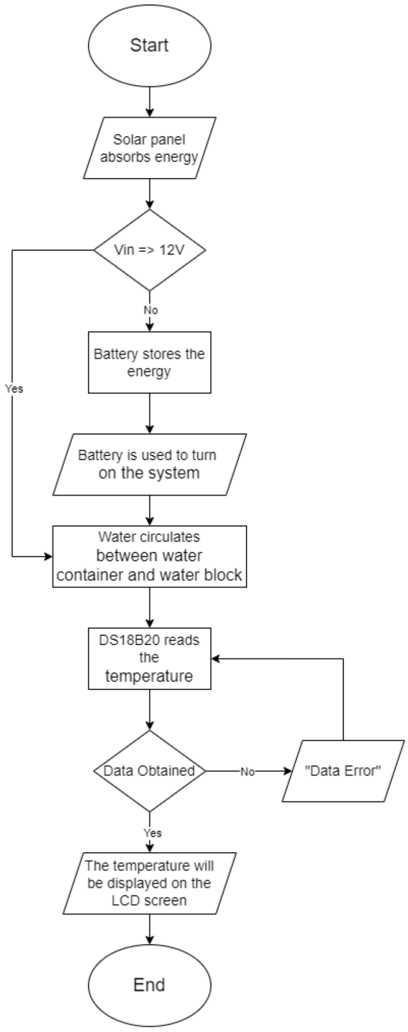


Fig. 2 *System Flowchart*

3.1 Software Development

The Arduino software is used to code the Arduino component that is used to display the temperature of the water with the help of a water temperature sensor DS18B20 and also an LCD to display the reading.

The Arduino IDE's is able to process information almost instantly. It has auto-completion, code navigation, and even a live debugger, in addition to a more modern editor and a more responsive User Interface (UI) [22].

4. Result and Discussion

This chapter discusses the obtained results and provides a comprehensive analysis of the project, highlighting key findings and their implications.

4.1 Simulation Results

After completing the full section of this study, including the software and electronic components, some tests were carried out in order to discover any unknown issues that may occur during the analysis. The results of each part's tests shows that a number of the scopes and objectives have been met. The results of this test are analyzed and used as a reference for future improvements. The elements that have been tested during research are Arduino programming and also the prototype evaluation. Before proceeding to the coding and configuration of the Arduino Uno, refer to Fig. 3, which shows the schematic diagram of the project, including the connections for the Arduino Uno.

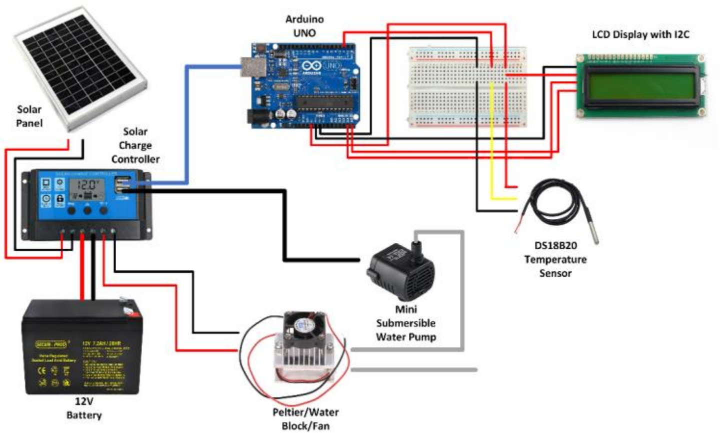


Fig. 3 *Schematic Diagram*

The solar charge controller acts as the distribution point for the whole system. The 12V lead-acid battery acts as an energy storage where the user can activate by turning on the switch, closing the circuit thus enabling the energy stored within the battery to supply power to the system via the solar charge controller.

In this section, the simulation is carried out using the Arduino IDE software which is then connected to the Arduino Uno hardware. Fig. 4 shows the connection for the Arduino Uno.

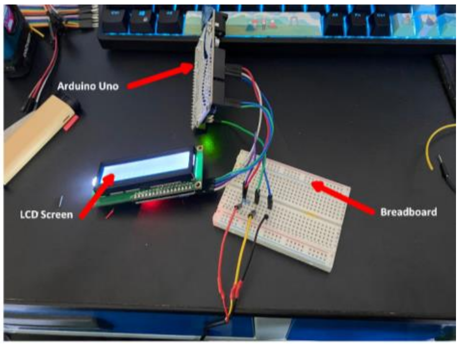


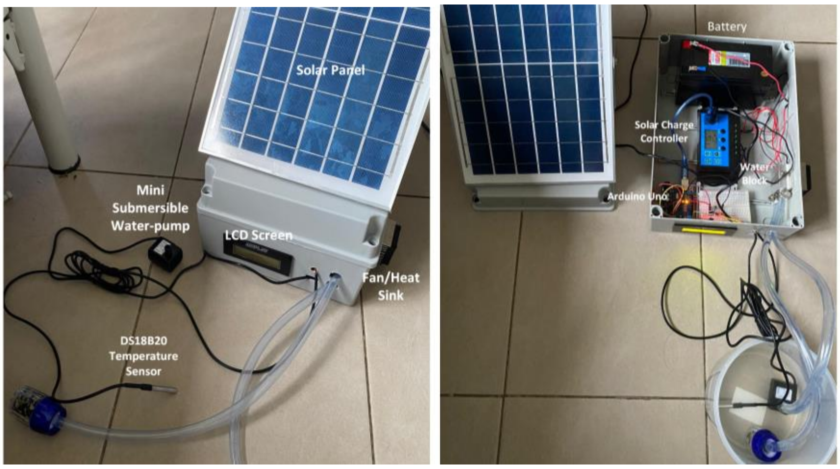
Fig. 4 *Arduino Uno Connection*

The main part of the connection in Fig. 4 is the Arduino Uno itself. It is connected to the LCD and the DS18B20 to ensure that the code that has been written into the Arduino Uno can be run and the reading can be displayed on the LCD.

Before running the hardware, the code written in the Arduino IDE software must first be uploaded to the device. Once the coding has been verified and there are no faults, it can then be compiled and written within the Arduino Uno hardware.

4.2 Project Configuration

This subtopic will discuss about the testing of the project once all the connections and assembly of the project has finished. Fig. 5 shows the structural design of the project.



(a) (b)

Fig. 5 *Structural Design of the Project*

The solar panel is installed on top of the junction box for more exposure of the sun to the solar panel. The cable of the solar panel is connected to the solar charge controller as the main source of power supply. The 12V battery is also connected to the solar charge controller in the middle section which acts as energy storage and also a backup power supply for usage when the sun is not visible. Through the solar charge controller, it powers up the components that are connected to it which are the Arduino Uno, mini submersible water pump, the Peltier, and also the fan.

4.3 Project Testing

Table 2 tabulates the values of maximum/minimum temperature achieved within 5 minutes. Assume the starting temperature of the water is around 32 °C.

Table 2 *Testing Results*

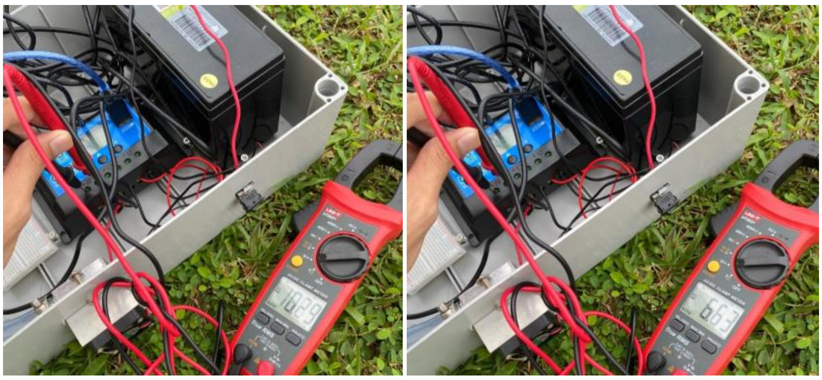
Time (Minutes)	Cold Side (°C)	Hot Side (°C)
2	31	68
3	30	70
4	28.5	70
5	27.5	70.5

The reason why the water cools down at a very slow rate is due to the hot side of the Peltier taking away the efficiency of the cold side. Proper ventilation is needed for the heat sink and fan to disperse the heat thoroughly but because the hot side of the Peltier gets so hot, the heat sink and fan cannot keep up with the amount of heat that the Peltier is producing.

The cold side of the Peltier device only reaches a minimum temperature of 27.5 °C primarily because the hot side of the Peltier is experiencing extremely high temperatures. This elevated temperature on the hot side significantly diminishes the cooling potential of the cold side. In a Peltier device, heat is transferred from the cold side to the hot side through thermoelectric effects. However, if the hot side is not adequately dissipating heat and remains excessively warm, it creates a thermal imbalance. This thermal imbalance leads to a reduced temperature gradient between the two sides, thereby limiting the ability of the cold side to cool further. Consequently, the efficiency of the Peltier device is compromised, preventing the cold side from achieving lower temperatures and effectively capping its minimum temperature at 27.5 °C. Improved heat dissipation on the hot side, such as through enhanced cooling mechanisms, could help in reducing this thermal load and potentially allow the cold side to reach lower temperatures.

4.4 Reading of the Solar Panel

The voltage of the solar panel is measured for 1 hour. Fig. 6 shows the maximum and minimum reading that was achieved throughout the 1 hour period.



(a) **(b)**

Fig. 6 *Maximum/Minimum Voltage Achieved*

The solar panel has a maximum voltage of 12V however during testing, the maximum voltage that was achieved is 10.29V. This amount can power the Arduino Uno and the LCD screen however it cannot power the Peltier, fan, and the submersible water pump due to lack of power. To fully activate all the components involved when there is a lack of power from the solar panel, the switch for the battery is turned on in order to supply enough power to the system.

5. Conclusion

This project focuses on a product called the Portable Water Cooler using Solar that produces cool water for consumption at any given time with the solar panel being its primary source of power. The 12V lead-acid battery acts as a storage for when the battery is not in use and when the solar detects sunlight, making this water cooler able to be used in a lot of scenario.

This project has been successfully produced, achieving all of the objectives that were set early on in the project. The solar panel has been successfully integrated into the project and can be observed turning on the project whenever the solar panel detects sunlight.

Other than that, the project was designed to be portable as to achieve the objective of carrying around the project without it taking too much space. From the design and overall built of the project, it can be seen that it is indeed portable with only the 12V lead-acid battery being the heaviest part of the project. Not to mention that it is not large for being a portable water cooler that is integrated with solar.

Acknowledgement

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