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Development of a Solar-Powered Car Ventilation System with Wireless Monitoring

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Abstract
The heat effect induced by hot weather causes car cabins to absorb heat from the surrounding area, making the temperature inside the compartment higher than the temperature outside. The excessive heat that gets trapped in closed cabins makes drivers and passengers uncomfortable when they enter their cars. This situation can be resolved by increasing air conditioning power while the engine is running, and this condition would increase the heat load of the air conditioner system. To this end, the present study describes the development of a solar- powered car ventilation system that relies on the Internet of things (IoT). The proposed solar- powered car ventilation system consists of a temperature sensor (DHT22) that detects the temperature inside the car cabin. Further, NodeMCU ESP32 has been used as a microcontroller to control the system. Temperature, fans, windows, and rainfall conditions were monitored via wireless connections using the Blynk application. The results show that the proposed ventilation system can reduce car cabin temperature and that its temperature readings can be monitored through the user's mobile device. Furthermore, because the system operates on solar energy, it is environmentally friendly.
Keywords: Solar-Powered Car, Solar Energy, Car Ventilation System, Wireless Monitoring

Introduction

Cars are a vital means of transportation for many individuals. However, the current high demand for private transportation has caused many problems, such as global warming, traffic jams, and a lack of parking spaces. Therefore, drivers who prefer low-cost parking will choose open-air car parks (Basar et al., 2013; Latief et al., 2015). However, parking in the sun for several hours significantly increases the temperature inside a car. In order to re- establish a comfortable car cabin, drivers need to run the air conditioner at high speeds when they resume driving. Doing this increases the heat load of the air conditioning system and, thus, increases the car's use of energy and release of carbon dioxide pollution (Kumar and Sravanthi, 2017; Yusoff et al., 2014).
Air conditioning has many disadvantages associated with energy efficiency and the use of chlorofluorocarbon (CFC) refrigerators. Both are indirectly associated with global warming. Therefore, the use of standard air conditioning should be reduced by designing environmentally friendly methods that can cool individuals. Using alternative cooling

systems can save energy and regulate the release of greenhouse gases into the environment (Kumar et al., 2017; Yusoff et al., 2014). Various methods for reducing cabin temperature have been developed. These include the installation of car cooling systems, the use of sunshades, and the installation of window tints (Shah et al., 2018). Car cooling systems help cool off parked cars on sunny days. Such systems can cool the car cabin without running a car engine.

Thus, when the user starts their car, the air conditioner does not require much power to lower the temperature inside the car.

The primary purpose for using innovative heating, ventilation and air conditioner (HVAC) systems that use a thermoelectric couple (TEC) is to solve the drawbacks of current HVAC systems (Basar et al., 2013) (Jasni and Nasir, 2012; Zafar et al., 2018). Innovative methods can reduce the air temperature of a car's windscreen and dashboard by an average of up to 8.3°C (Yusoff et al., 2014; Rios et al., 2014; Accardo et al., 2018; Vanos et al., 2018). The proposed HVAC system is expected to result in an upsurge in the manufacturing industry. Also, the TEC system is expected to help protect the environment against the present alarming increases in population and pollution, as it is environmentally safe, small, and inexpensive (Alabdullah et al., 2020; Yingmeng et al., 2015).

This research describes the design of a cooling system that can reduce car cabin temperature via solar energy source and integrate a system that can the control car cabin air ventilation. The rest of this paper is organized as follows. Section II explains the implementation of hardware and indicates the components used in this research; this section also deals with the operation of the system, how it operates, and how it controls the car cooling system. Section III presents the results regarding car cabin temperature differences and explains how the system can be monitored wirelessly with a mobile device. Section IV offers the study's conclusion and recommendations for future research.

Method

This section describes the process by which the proposed cooling system operates. This process encompasses the implementation of hardware, system operation, and control processes of car cooling systems.

A. Hardware Implementation

Fig. 1 shows the hardware implementation. The components used in this project are a solar panel, charge controller, 12V battery, voltage regulator, NodeMCU 32 (Fig. 2(a)), DHT22 temperature sensor (Fig. 2(b)), rain sensor (Fig. 2(c)), limit switch, fan motor, and power window motor.

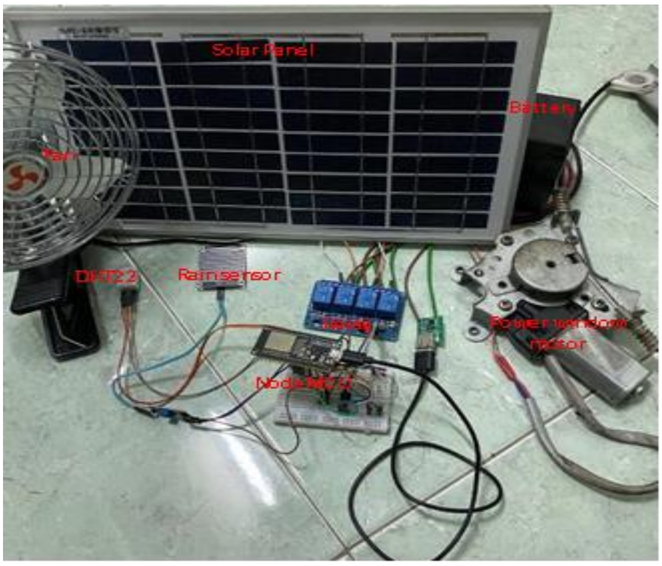
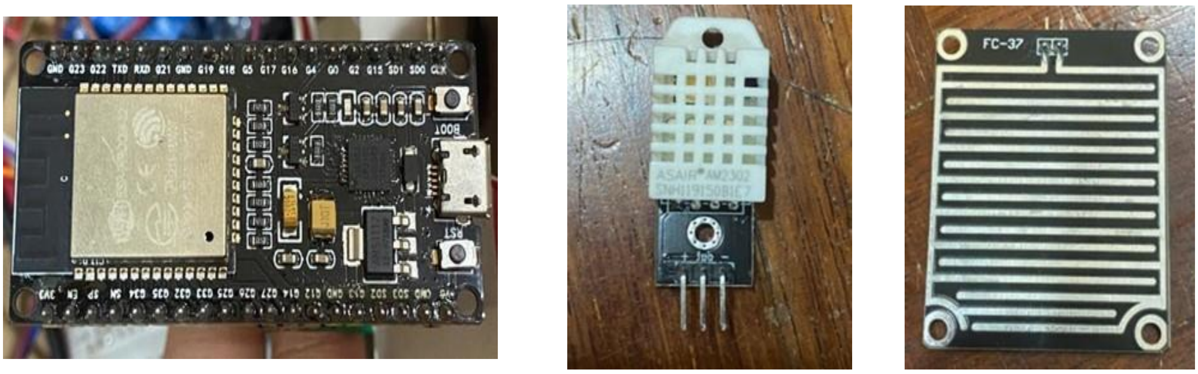


Fig.1: Hardware implementation for the proposed solar-powered car ventilation system

Fig. 3 is a block diagram of the system. The process starts when the solar panel transfers harvested energy to the battery through the charger circuit. Then, the temperature sensor circuit detects the temperature inside the car and sends this information to the controller. The switching circuit then switches the circuit to output '1', which turns the fan on and opens the car's windows. The heat in the car is subsequently discharged. If it is raining, the rain sensor circuit is trigged after sensing a water drop. In this case, the output is switched to '0'. The fan then switches off, and the power window motor is rotated clockwise, which closes the window to prevent rainwater from entering the car.



(a) (b) (c)

Fig.2: (a) NodeMCU ESP32, (b) Digital temperature and humidity sensor (DHT22), and (c) Rain sensor

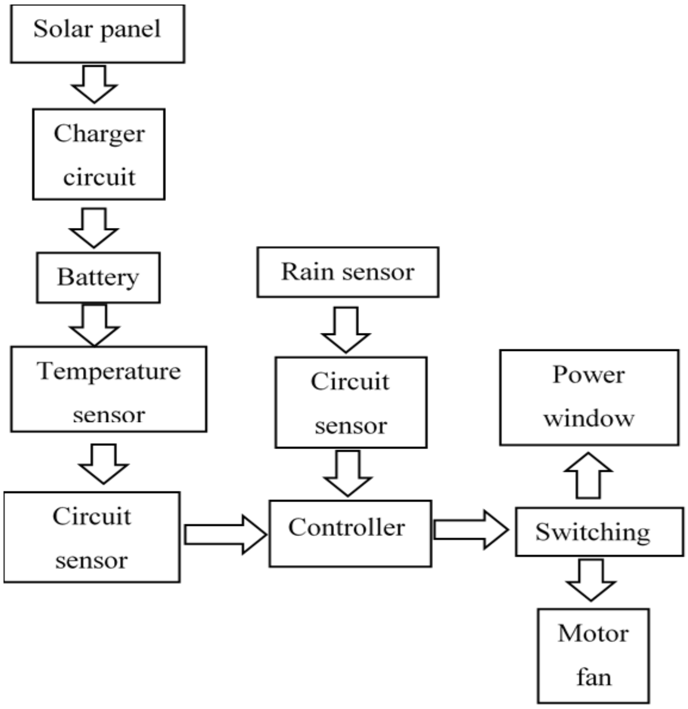


Fig.3: Block diagram for the proposed solar-powered car ventilation system

Fig. 4 is a flow chart that illustrates the operation of the solar-powered car ventilation system. The system starts when the battery supplies it with energy. Once the system is supplied with energy, the temperature sensor detects the temperature inside the car. A temperature is 31°C or higher triggers the fan motor to switch on and the power windows to open. If the temperature drops below 31°C, the power windows will close and the fan motor will switch off. Also, a rain sensor was used; if the sensor detects rainwater, the fan will turn off and the power windows will close.

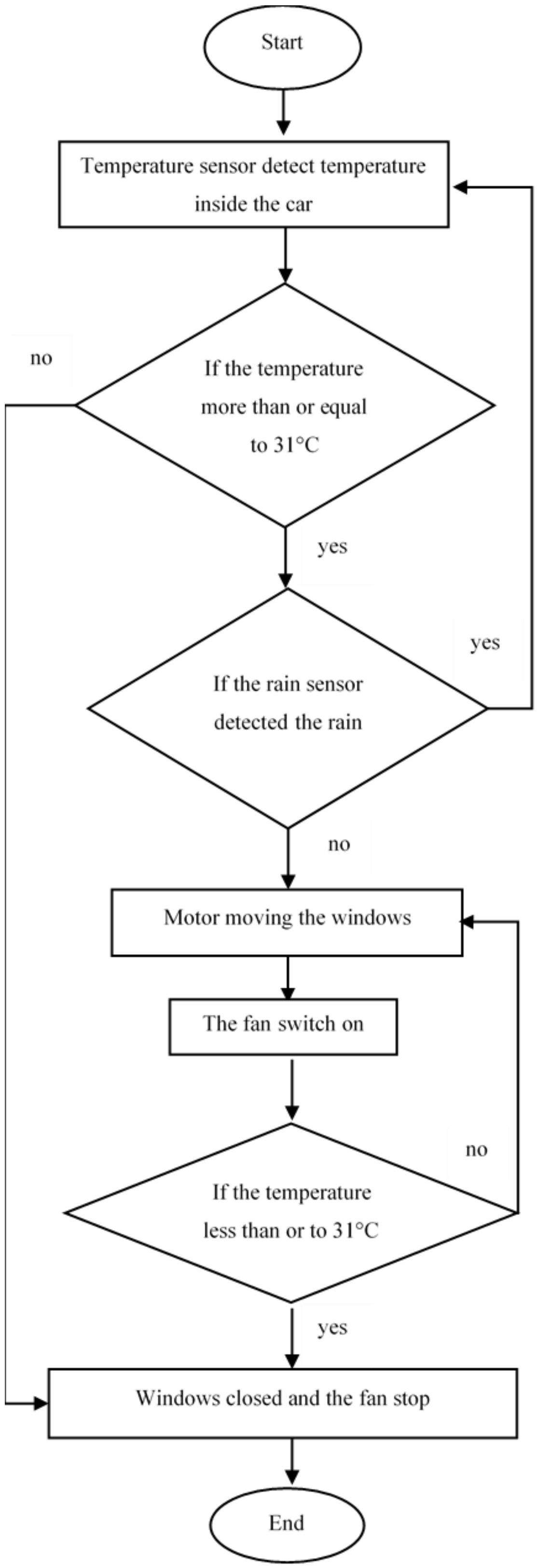


Fig.4: Flow chart for solar powered car ventilation system operation

Results and Discussion

The results presented in this section are based on the graphical user interface (GUI) of the wireless monitoring via a mobile device and differences between temperature readings in the car cabin. There are three cases of temperature differences. In Case 1, only one front window was opened two inches. In Case 2, only one rear window was opened two inches. In Case 3, the comparative temperature between the temperature taken when using the car ventilation system and the temperature was taken using non-contact digital laser inflammatory thermometer.

A. Wireless Monitoring

Fig. 5(a) shows the car cooling system's user interface. The application system allows the user to monitor the temperature, window position, rain, and fan operation inside the car cabin. Also, users can set the system to run wither automatically or manually. Fig. 5(b) illustrates a case when the user has set the automatic setting to 'ON' and the temperature has exceeded 31°C. As can be seen, the fan has been turned on and the car window has been opened automatically.

(a) (b)

Fig.5: (a) Car cooling system user interface and (b) the application's interface with the automatic setting turned on while the temperature is above 31°C

Fig. 6 (a) shows the same condition after the rain sensor has detected a raindrop. The window has been closed, and the fan has been turned off. When the user sets the automatic setting to 'OFF', (as shown in Fig. 6(b)), the user can control the fan and window manually.

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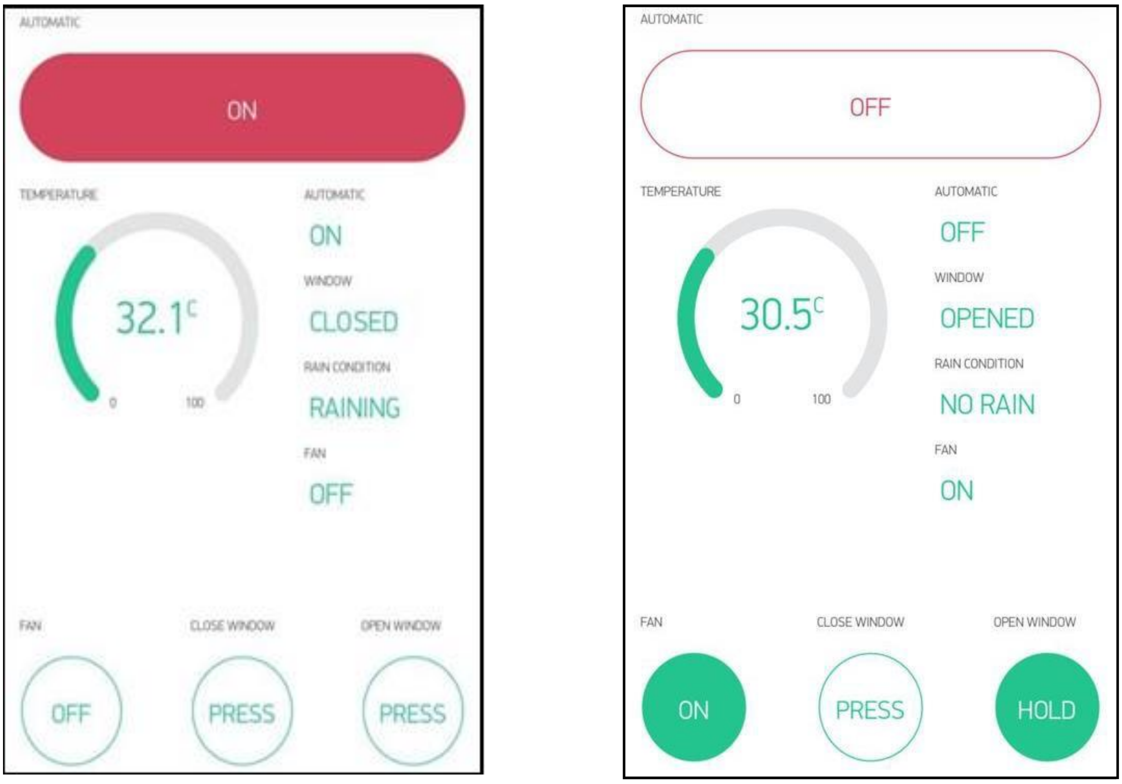

Fig.6: (a) The application interface with the automatic condition turned on while the temperature is above 31°C after the detection of a raindrop and (b) the application's interface with the automatic condition turned off

B. Temperature Difference

Fig. 7 illustrates the graph for Case 1. The temperature was taken in the car from 9.00 a.m. to
6.00 p.m. before and after the ventilation system was introduced. The reading increased slightly from 9.00 a.m. increased until noon. The temperature in the car cabin was the highest at 1.00 p.m. due to the high exterior temperature. The temperature readings decreased slowly starting at 2.00 p.m. Fig. 7 also shows that the ventilation system can reduce the temperature by up to 10°C.

Fig. 8 shows the temperature in the car from 9.00 a.m to 6.00 p.m before and after the car cooling system was introduced for Case 2. Again, the temperature readings increased slightly from 9.00 a.m. until noon before peaking at 1.00 p.m. Meanwhile, starting at 3.00 p.m., the temperature decreased significantly as the weather became cloudy. Fig. 8 indicates that the ventilation system can reduce the temperature by up to 7°C for Case 2.

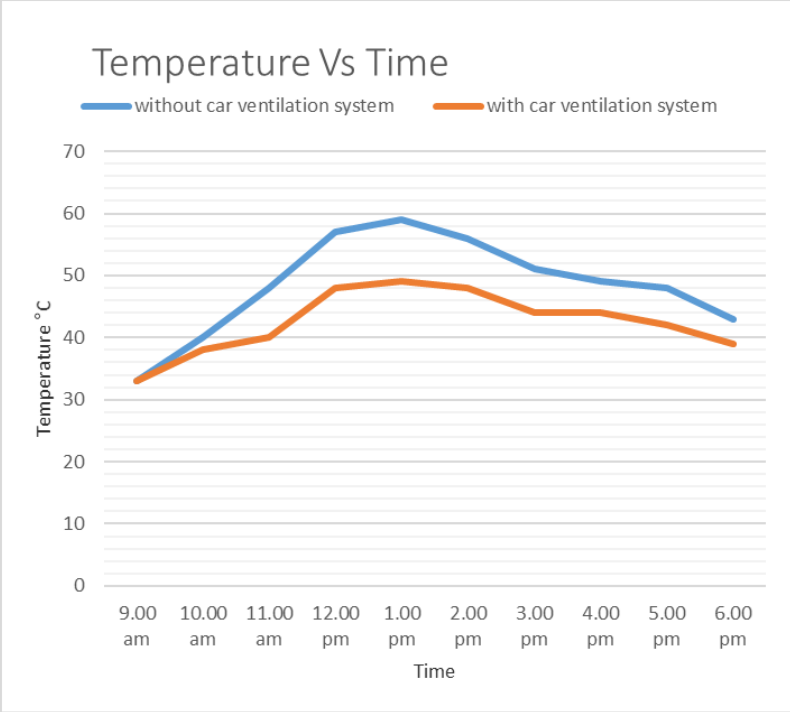

Fig.7: Temperature differences before and after using the car cooling system for Case 1 (one front window opened two inches wide)

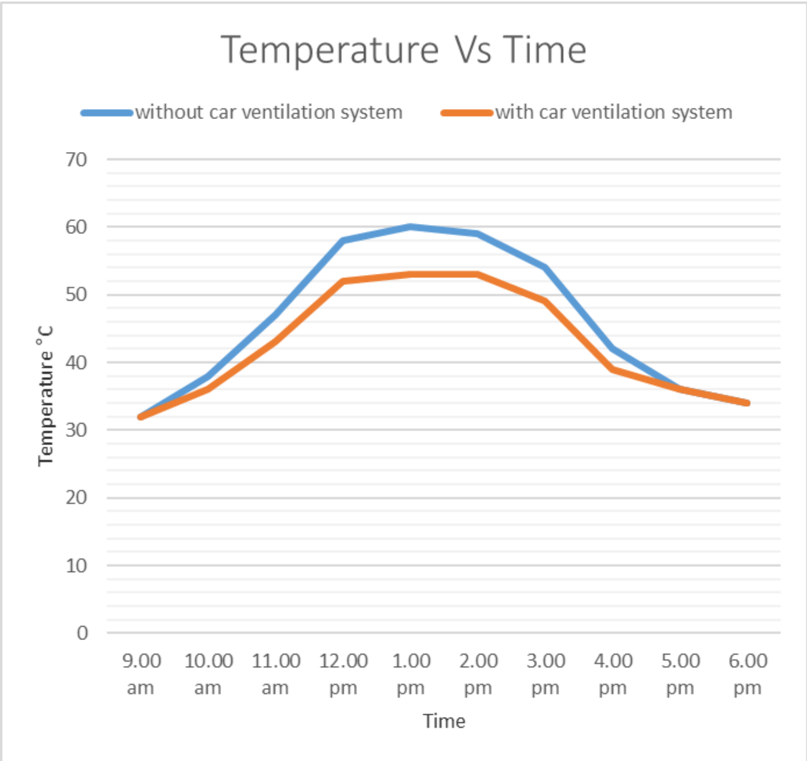

Fig.8: Temperature differences before and after using the car cooling system for Case 2 (one rear window opened two inches wide) Case 3 was carried out at the same place as Cases 1 and 2 but on different days. The temperature was measured by the car ventilation system as well as by a non-contact digital laser infrared thermometer. The two sets of readings were then compared. The laser of the thermometer was located in the car cabin at the same place

as the temperature sensor (DHT22). Based on Table 1, the differences in the readings were ±1°C. This indicates the accuracy of the car ventilation system's temperature readings.

Table 1
Temperature of car cabin using car ventilation system and non-contact digital laser infrared thermometer

Time	Car ventilation system	Non-contact digital laser infrared thermometer
9.00 a.m.	33°	32°C
10.00 a.m.	38°C	39°C
11.00 a.m.	49°C	48°C
12.00 p.m.	57°C	57°C
1.00 p.m.	59°C	59°C
2.00 p.m.	58°C	59°C
3.00 p.m.	55°C	55°C
4.00 p.m.	51°C	50°C
5.00 p.m.	47°C	48°C
6.00 p.m.	43°C	43°C

Conclusion
This research discusses the successful development of a solar-powered car ventilation system with a wireless monitoring system. The results indicate that the system can reduce car cabin temperature by up to 10°C during the hottest part of the day. Moreover, the car cooling system successfully integrated with IoT, allowing users to monitor the temperature and rain while controlling the car window and fan operation from a mobile device. Also, the system is powered by solar energy, making it environmentally friendly.

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