# Enhancing Thermal Comfort for Motor Biker via PV and Peltier Module Mounted Helmet

Anamul Haque Arif
Department of Electrical and Electronic Engineering, Chittagong University of Engineering & Technology (CUET)

Md. Imtiaz Hyder
Department of Electrical and Electronic Engineering, Chittagong University of Engineering & Technology (CUET)

Adwayatananda Das
Department of Electrical and Electronic Engineering, Chittagong University of Engineering & Technology (CUET)

Bidyut Baran Saha
International Institute for Carbon-Neutral Energy Research, Kyushu University

他

https://doi.org/10.5109/7323400

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.1135-1140, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

# Enhancing Thermal Comfort for Motor Biker via PV and Peltier Module Mounted Helmet

Anamul Haque Arif[1], Md. Imtiaz Hyder[1], Adwayatananda Das[1], Bidyut Baran Saha[2], Sampad Ghosh[1]
[1]Department of Electrical and Electronic Engineering, Chittagong University of Engineering & Technology (CUET), Chattogram, Bangladesh
[2]International Institute for Carbon-Neutral Energy Research, Kyushu University, Fukuoka, Japan
Corresponding author email: sampad@cuet.ac.bd

**Abstract:** *This study addresses the development and application of a smart helmet cooling system that utilizes a Peltier module, aimed at enhancing two-wheeler riders' safety and comfort in high-temperature environments. The system combines a TEC1-12706 thermoelectric cooler, a flexible solar panel, and rechargeable lithium batteries to create a dependable and environmentally friendly source of electricity. The Arduino Uno microcontroller is essential for overseeing and controlling the power supply, temperature, and overall system operation, using real-time data from embedded temperature sensors to maintain optimal cooling conditions. The system is designed to automatically switch between solar and battery power as needed, ensuring uninterrupted functioning. The obtained results illustrate the system's capacity to consistently maintain a stable and pleasant temperature within the helmet, emphasizing its potential for practical use in various conditions.*

**Keywords:** Arduino Uno microcontroller, Peltier Module, PV module, Smart helmet, Thermal comfort

## 1. INTRODUCTION

Helmets are essential protective equipment for riders, ensuring their safety from accidents and other injuries. The temperature of the world is increasing rapidly. Research suggests that the mean temperature in the latter part of the 21st century might escalate within the range of 1.4°C to 5.8°C [1]. A human body at rest produces approximately 100W of metabolic heat, which needs to be carried away [2]. Human skin must be cooler than other parts of the body because metabolic heat is conducted through the skin. Under normal circumstances, the temperature of human skin is strongly regulated to be 35°C or lower [3]. Riders' thermal comfort will suffer in situations with high temperatures and humidity levels. The absence of thermal comfort could potentially have an adverse effect on the driver's ability to concentrate and maintain focus [4]. A report by Mohan et al. showed that helmets can reduce head injuries by 70-88% [5]. So, comfort in wearing a helmet is very much necessary.

Airaksinen et al. found that about 34°C is a comfortable temperature for the head [6]. In hot weather circumstances, the temperature inside the helmet can approach 50°C when there is no wind [7]. So, it is very important to maintain the thermal comfort of riders in high-temperature countries. Therefore, a modified helmet is designed using a thermoelectric cooling module, which is eco-friendly and has a high cooling capacity. The thermoelectric cooling module is a two-sided device that acts as a hot and cold reservoir and controls the heat pump by means of electrical energy, or vice versa [8]. It is seen from tests that TEC1-12706 gives better performance than other thermoelectric modules above ambient temperature (>25°C) [9]. So, in the proposed design, TEC1-12706 is used because of its high performance and efficiency.

The smart helmet designs that are available are either based on solar cells or DC batteries. TEC1-12706 is used in a DC battery-based design [10]. One of the major drawbacks of DC battery design is the discharging of the battery. The design of a DC battery also does not include any control mechanisms for voltage or temperature control. Solar cell-type design can solve the discharging problem and integrate phase-change material as a coolant [11]. However, this design doesn't involve any mechanism to control voltage or temperature.

In this work, we have proposed a flexible solar cell-based temperature-controlled smart helmet design where a thermoelectric cooler module (TEC1-12706) can be used as cooling material. A DC battery is used as a backup source of energy. In adverse weather conditions, this DC battery can be used as an energy source as it can store energy from solar cells. Furthermore, Arduino Uno is used to control various parameters like the voltage of the solar cell and battery, the temperature inside the helmet, and the cooling fan.

## 2. PROPOSED DESIGN

The proposed cooling mechanism for the helmet employs thermoelectric cooling (TEC) modules, particularly the TEC1-12706, which are combined with a flexible solar panel attached to the outer shell of the helmet. This solar panel delivers the necessary power to the entire system, ensuring the management of the cooling mechanism. The cooling system functions within a specific voltage range that is appropriate for both the cooling circuit and the microcontroller. Inside the helmet, the cold side of the TEC is situated to provide comfort cushioning, while the hot side is connected to an exhaust fan and heatsink, seamlessly integrated into the exterior of the helmet. The control circuit is strategically positioned at a discreet location on the lower edge towards the back of the helmet pad, enhancing user accessibility, behavior, and safety considerations. The strategic placement of these crucial components within the proposed design is depicted in Fig. 1(a).

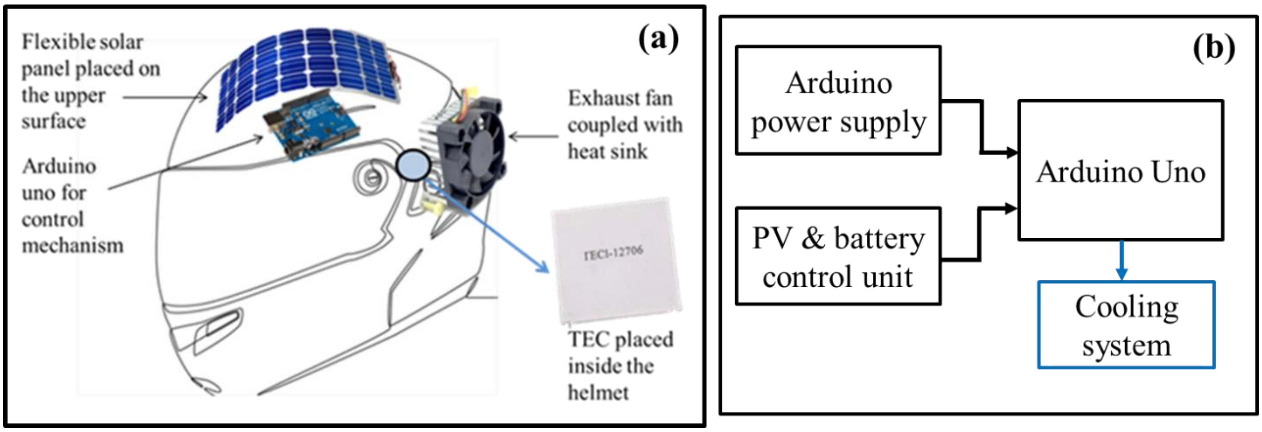


Fig. 1 (a) Proposed design with PV and Peltier module, and (b) Block diagram representations of smart helmet cooling system.

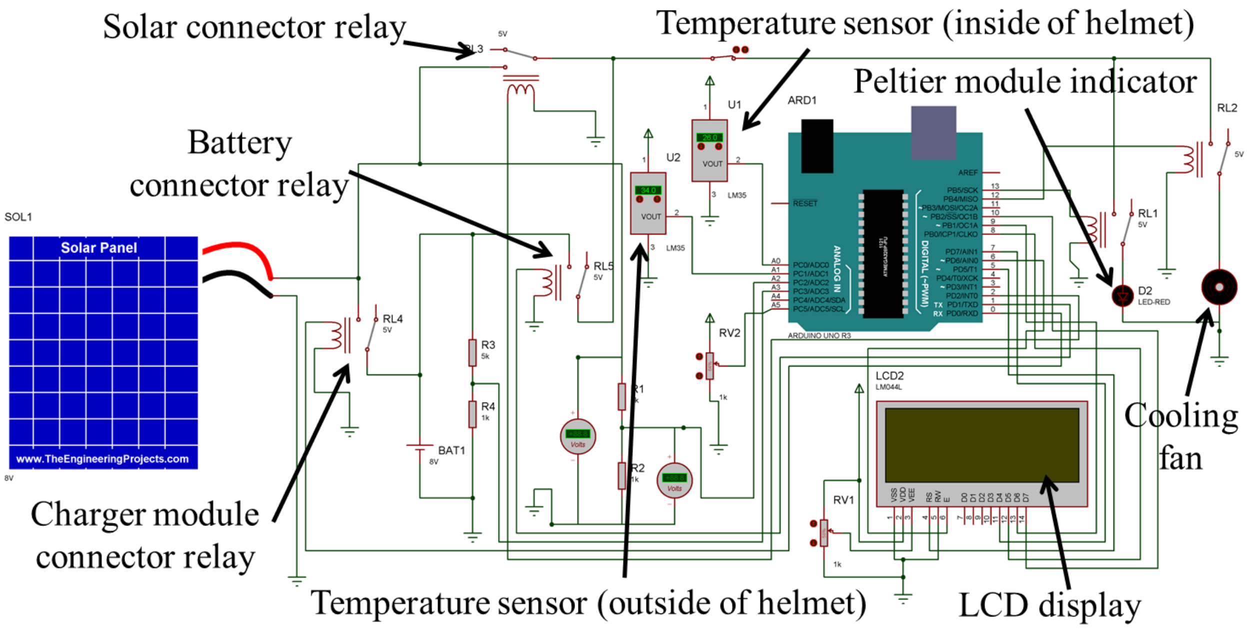


Fig. 2 Schematic representation of the proposed design for simulation analysis.

### 2.1 Complete Design Framework of Cooling System

Fig. 1(b) illustrates a comprehensive design framework for a smart helmet cooling system, which aims to overcome the limitations of traditional cooling technologies by incorporating renewable energy sources. Fundamentally, the system is centered around an Arduino Uno, driven by an ATmega328 microprocessor, that coordinates the functioning of three essential elements: Arduino power supply system, solar and battery control unit, and cooling system. The Arduino power supply assurances a steady and reliable energy supply to the microcontroller, thereby enhancing the system's dependability. Simultaneously, the solar and battery control unit manages the energy captured from sustainable sources and stored in backup batteries, ensuring a consistent power source for the cooling system. The cooling system is activated by built-in sensors that continuously monitor internal helmet conditions, including temperature and humidity, and adjust these variables to maintain an optimal internal environment.

## 3. SIMULATION DATA

The proposed design, as shown in Fig. 2, with Arduino 1.8.13 is simulated by Proteus ISIS 7. During simulation, six different cases are considered depending on the voltage conditions of solar panels and backup batteries. The cases are: Case-I: both solar panel and backup batteries in acceptable range, Case-II: backup batteries voltage level in between 5V to 12V with lack of solar energy, Case-III: backup batteries in between 5V to 12V with PV voltage above 12V, Case-IV: PV voltage in between 5V to 12V with lack of battery voltage, Case-V: PV voltage less than 5V and no backup battery voltage, Case-VI: PV voltage exceeds 12V with no voltage from backup batteries.

Fig. 3(a) shows Case-I which is displayed by the solar voltage "SV" and backup battery voltage "BV" on the LCD. For this work, the working voltage is 5-12V. Based on the predetermined logical specifications, the solar panel voltage will provide electricity to the cooling system. In Fig. 3(b) for Case-II, the backup batteries are within the acceptable voltage range, while the solar panel provides voltage less than 5V. Consequently, the backup batteries supply power to the cooling system.

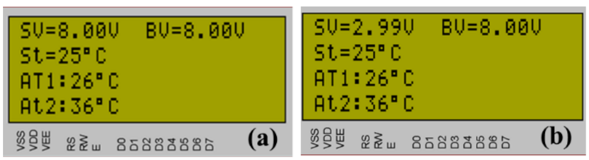


Fig. 3. Display values for (a) Case-I and (b) Case-II.

The display values for Case-III and Case-IV are shown in Fig. 4 (a) and (b), respectively. In Case-III, the backup batteries are within the allowed voltage range; however, the voltage of the solar panel exceeds the permitted range. As a result, the solar panel will not provide electricity to the cooling system. Rather, electricity will come from the backup batteries. On the other hand, for Case-IV, the solar panel is able to supply power to both the cooling system and the charging of the backup batteries.

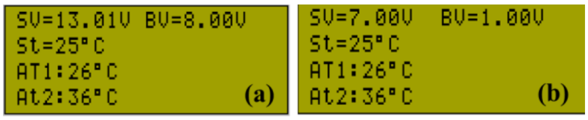


Fig. 4. Display values for (a) Case-III and (b) Case-IV.

In Case-V, the solar panel voltage is below the allowed range, and there is no voltage from the backup batteries, as shown in Fig. 5(a). Consequently, the solar panel can only provide power for charging the backup batteries. During Case-VI, it was noted that the backup batteries did not have any supply voltage; however, the voltage from the solar panel was higher than the allowed range for the cooling system, as shown in Fig. 5(b). As a result, both the solar panel and the backup batteries failed to provide electricity to the cooling system.

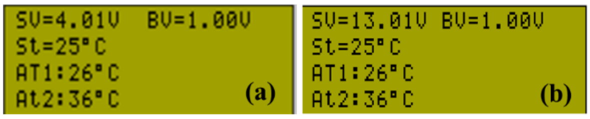


Fig. 5. Display values for (a) Case-V and (b) Case-VI.

### 3.1 Peltier Module Operation

When the input temperature, indicated as "St" on the LCD, is raised above the present low surface temperature, the TEC1-12706 thermoelectric cooler does not operate, as can be seen in Fig. 6(a). This indicates that the Peltier module does not turn on when the desired temperature is higher than the current temperature of the cooling surface. However, when the input temperature is lower than the cold surface temperature of the TEC, the thermoelectric cooler starts functioning, as shown in Fig. 6(b). This activation verifies the predetermined logical condition, indicating that the TEC functions when the desired temperature is below the existing surface temperature.

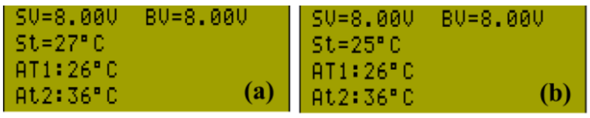


Fig. 6. The Peltier module is (a) inactive and (b) active.

### 3.2 Cooling Fan Operation

The cooling fan is activated when the temperature hot surface of the TEC reaches or exceeds 35°C, as determined by a specified logic condition. Fig. 7(a) shows that the heated surface temperature indicated as "AT2" on the LCD display, reached 36°C. This caused the cooling fan to start functioning. Fig. 7(b) shows that the temperature on the hot side of the thermoelectric cooler decreased to a value lower than 35°C. Consequently, the cooling fan was kept inactive. This action is consistent with the defined logical condition that disables the cooling fan when the temperature on the hot side is lower than the specified threshold.

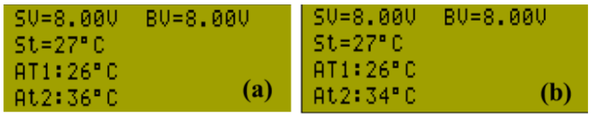


Fig. 7. The cooling fan is (a) active and (b) inactive.

## 4. HARDWARE IMPLEMENTATION

The proposed cooling system consists of two key circuits: The Arduino power supply circuit, and the solar and backup battery control circuit as depicted in Fig. 8(a), (b). Fig. 8(c) demonstrates the placement of two TEC1-12706 thermoelectric cooling modules. In addition, a DS18B20 temperature sensor was attached to the cold surface of a TEC1-12706 module, and the heat dissipation setup circuit shown in Fig. 8(d). Fig. 9 illustrates the complete construction of the proposed work.

## 5. RESULTS AND DISCUSSION

### 5.1 Voltage Level Conditions for Arduino System

Fig. 10(a) shows that when the DC battery voltage used to power the Arduino Uno is between 5V and 12V, as indicated by "AV" on the LCD, the charger module does not operate. In contrast, Fig. 10(b) illustrates that if the DC battery voltage falls below 5V while the solar voltage remains between 5V and 12V, the charger module is triggered, enabling the solar panel to recharge the DC battery.

### 5.2 Arduino Operation Under Different Voltage Conditions of PV and Backup Batteries

Previously explained six different cases were examined in physical structure. Fig. 11(a) demonstrates that both the solar panel and backup batteries operate within the voltage range of 5V to 12V, as displayed by the solar voltage "SV" and backup battery voltage "BV" on the LCD. Based on the predetermined logical specifications, the solar panel voltage will provide electricity to the cooling system. In Fig. 11(b), the backup batteries are within the acceptable voltage range, while the solar panel provides a voltage of less than 5V. Consequently, the backup batteries supply power to the cooling system.
According to Fig. 12(a), the backup batteries are within the allowed voltage range; however, the voltage of the solar panel exceeds the permitted range. As a result, the solar panel will not provide electricity to the cooling system. Rather, electricity will come from the backup batteries. In Fig. 12(b), the solar panel voltage is within the permitted voltage range, while backup batteries are insufficient. Consequently, the solar panel is able to supply power to both the cooling system and the charging of the backup batteries.
In Case-V, the solar panel voltage is below the allowed range, and there is no voltage from the backup batteries, as shown in Fig. 13(a). Consequently, the solar panel can only provide power for charging the backup batteries. In Case-VI, it was noted that the backup batteries did not have any supply voltage, but the voltage from the solar panel was higher than the allowed range for the cooling system, as shown in Fig. 13(b). As a result, both the solar panel and the backup batteries failed to provide electricity to the cooling system.

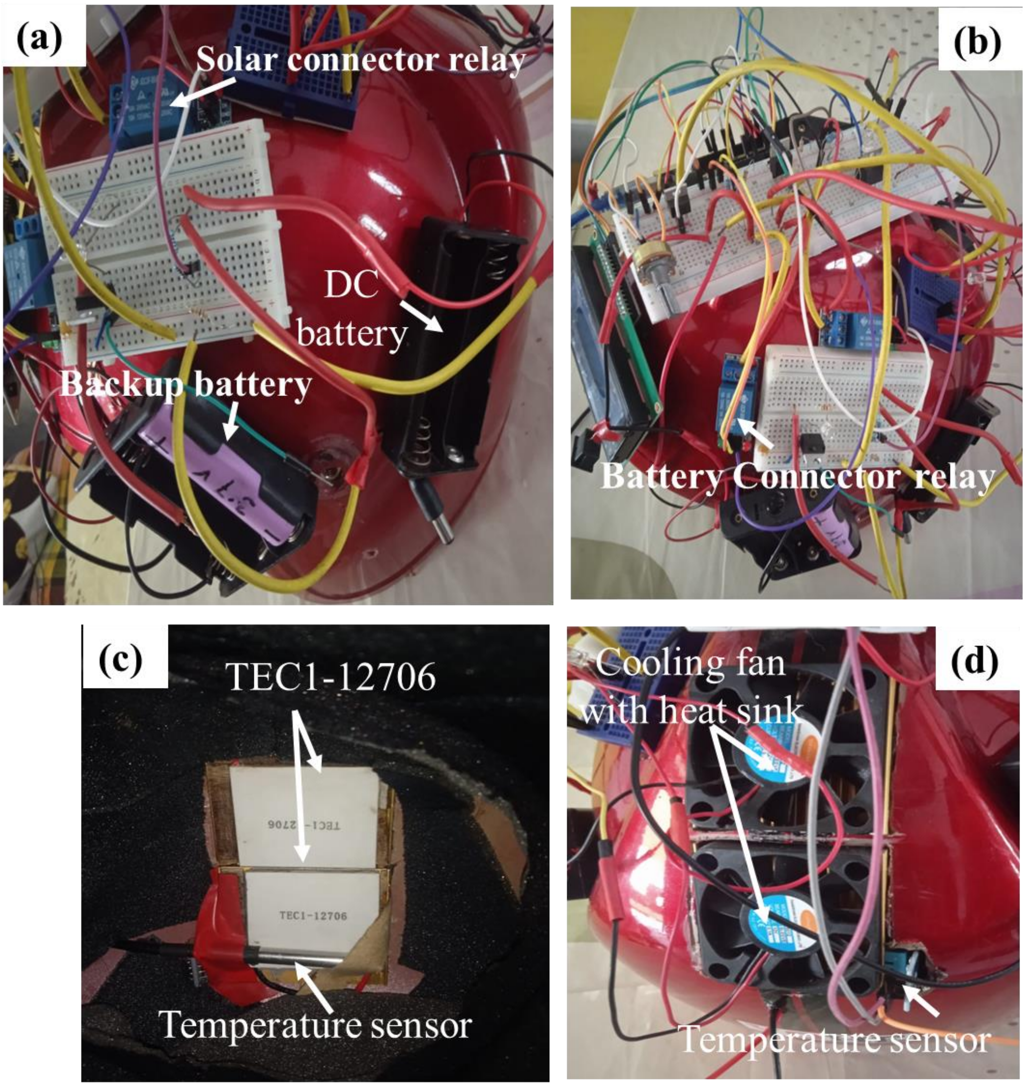


Fig. 8 (a) Arduino supply circuit, (b) solar & battery control circuit, (c) TEC1-12706 placed helmet and (d) heat dissipation setup.

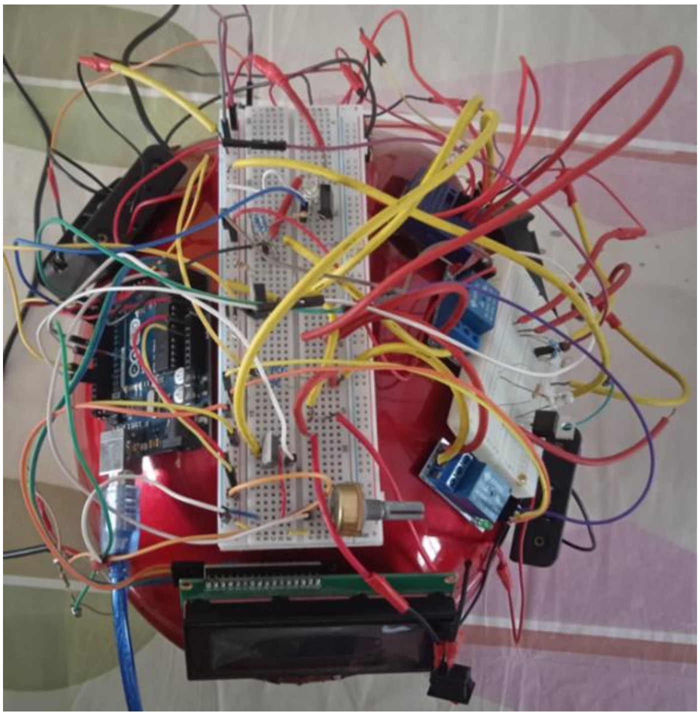

Fig. 9. Completed hardware implemented helmet.


Fig. 10. Arduino supply voltage is (a) between 5V to 12V and (b) less than 5V.


Fig. 11. The cooling system is supplied by (a) solar panels and (b) backup batteries.

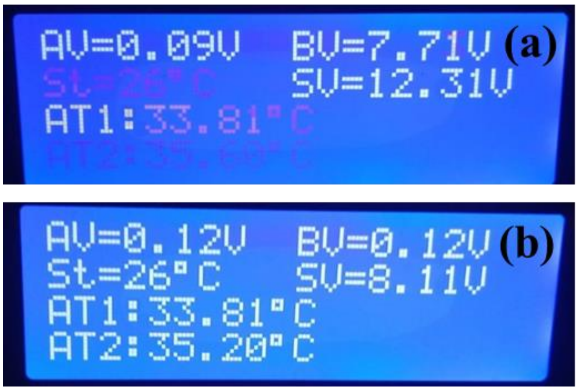


Fig. 12. Measured values for Case- (a) III, (b) IV.


Fig. 13. Measured values for Case- (a) V, (b) VI.

### 5.3 TEC Operation Analysis

In this work, we have found that setting the DC supply voltage to 6.04V resulted in the thermoelectric cooler reaching its lowest cooling value of 22.12°C on the cold surface. This value was displayed as "AT1" on the LCD display, as shown in Fig. 14.


Fig. 14. Cold surface temperature of TEC at 6.09V.

When the input temperature, indicated as "St" on the LCD, is raised above the present low surface temperature, as shown in Fig. 15(a), the thermoelectric cooler does not operate. This indicates that the TEC1-12706 does not turn ON when the desired temperature is higher than the current temperature of the cooling surface. When the input temperature is lower than the cold surface temperature of the TEC1-12706, as illustrated in Fig. 15(b), the thermoelectric cooler starts functioning. This activation verifies the predetermined logical condition, indicating that the TEC1-12706 functions when the desired temperature is below the existing surface temperature.


Fig. 15. TEC (a) inactive and (b) active status.

### 5.4 Cooling Fan Operation

The cooling fan is activated when the temperature hot surface of the TEC reaches or exceeds 35°C, as determined by a specified logic condition. Fig. 16(a) shows that the heated surface temperature indicated as "AT2" on the LCD display, reached 45.30°C. This caused the cooling fan to start functioning. Fig. 16(b) shows that the temperature on the hot side of the thermoelectric cooler decreased to a value lower than 35°C. Consequently, the cooling fan was kept inactive.

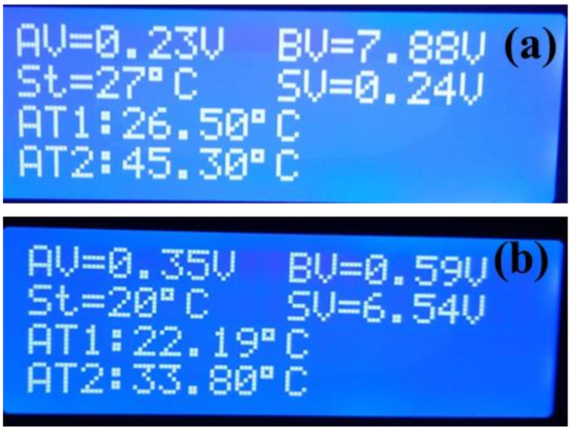

Fig. 16. Cooling (a) ON and (b) OFF status.

## 6. FUTURE RESEARCH WORK

In this research work, we weren't able to use the flexible solar panel which can be bent perfectly due to their unavailability in the local market. This may cause the current design little bit inferior in terms of aerodynamic point of view when the biker wearing the helmet in the running conditions. Moreover, we are looking to integrate a solar paint-based PV system which can further enhance the system's reliability and esthetic property. In the implementation of this work, we have incorporated electro-mechanical relays to manage the involvement of solar and backup battery power in the cooling system. These relays may be replaced by suitable solid-state relays due to their faster switching speed which in turn can improve the system performance. Future research studies will also cover a details thermal analysis of the helmet to ensure adequate comfort for the biker.

## 7. CONCLUSIONS

This proposed design demonstrates a smart helmet cooling system that efficiently overcomes thermal comfort issues using the combination of thermoelectric cooling technology, renewable energy sources, and an Arduino-based control mechanism. In this design, the combination of the Peltier module, solar panels, and rechargeable lithium-ion batteries offers a sustainable and dependable power solution, ensuring uninterrupted operation and user convenience in hot environments. The Arduino Uno microcontroller plays a crucial role in improving the efficiency and responsiveness of the system by monitoring and regulating power and temperature in real time. The simulation and experimental results confirm that the proposed design effectively regulates the internal temperature of the helmet, highlighting its practical usefulness and potential for wider acceptance. This novel method not only enhances the comfort of the rider but also supports the objectives of environmental sustainability, providing an efficient solution for current wearable technology.

## 8. REFERENCES

[1] Hafiz S. Ullah et al., Evaporative Cooling Systems for Thermal Comfort of Foreign Cattle Breeds: THI Evaluation and System Feasibility, In Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), 6 (2020) 98-103.

[2] Steven C. Sherwood and Matthew Huber, An adaptability limit to climate change, In Proceedings of the National Academy of Sciences, 107 (2010) 9552–9555.

[3] McNab BK, The Physiological Ecology of Vertebrates: A View from Energetics. Ithaca, New York: Cornell University Press, 2002.

[4] Mahmood Riaz and Muhammad H. Mahmood, An Overview of Thermal Comfort for Operators in Tractor Cabin, In Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), 7 (2021) 302-308.

[5] Dinesh Mohan, K. P. Kothiyal, B. K. Misra, and A. K. Banerji, Helmet and head injury study of crash involved motorcyclists in Delhi, In Proceedings of International Conference on the Biomechanics of Impacts (IRCOBI), (1984) 65-77.

[6] Miimu Airaksinen, Pekka Tuomaala, and Riikka Holopainen, Modelling Human Thermal Comfort, In Proceedings of Clima 2007 Wellbeing Indoors: REHVA world congress, (2007) 177-182.

[7] Yeh-Liang Hsu, Chi-Yu Tai, and Ting-Chin Chen, Improving thermal properties of industrial safety helmets, International Journal of Industrial Ergonomics, 26 (2000) 109-117.

[8] Dongliang Zhao and Gang Tan, A review of thermoelectric cooling: Materials, modeling and applications, Applied Thermal Engineering, 66 (1) (2014) 15-24.

[9] E Salsabila, TA Ajiwiguna, and A Suhendi, Performance Evaluation of TEC1-12706 Thermoelectric Cooler Module at Low Temperature Experimentally, In Proceedings of International Conference on Information and Communications Technology (ICOIACT), (2019) 835-838.

[10] Sk. Mohammad Shareef, P. Lavakumar, M. Udaya Kiran, and B. Bhanu Rohit, Helmet Cooling using Peltier Module, International Research Journal of Engineering and Technology, 7(1) (2020) 14-18.

[11] Wentao Hu et al., Composite Design and Thermal Comfort Evaluation of Safety Helmet with Phase Change Materials Cooling, Thermal Science, 25(2) (2021) 891-900.