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Optimized Car Cooling System Using Solar Energy

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Abstract. Most of the time, people suffer from the high and low temperatures inside cars, throughout the various seasons. The cooling system used in cars does not allow proper air filtration and thus submits either cold or hot air depending on the external temperature. To avoid this problem, the air should be modulated to deliver the needed temperature. This raises the need to create a new system that can change the temperature in the car without damaging or affecting any other parts. This paper consists of integrating semiconductors that can affect the ability to light and heat. The connection of the semiconductors to a solar panel allows the conversion of the sunlight into electricity. Adding a fan to the system is crucial because colder air can be drawn into the car from the outside and expels air from the inside. This addition can also cool the intimate car atmosphere by moving air across a heat sink. After the structure had been created, many experiments are tested. These tests reflect good performance under temperature changes causing different incoming currents related to time.

1 Introduction

The "Cooling and Heating" structure is the proposed solution to filter the air inside the car to control the temperature either for cooling or heating. This structure can change the inner climate of the vehicle in a way that meets the user's desire. It includes many semiconductors that generate the cold and the heated air when energized. Thus, this system acts as the central air of the car that connects to solar cells that convert the radiation of the sunshine into electricity to stimulate the semiconductors. Also, the fan linked to the front of the device containing relays, thermostats, and the electrical circuit.

The use of semiconductors and solar panels grant the system its efficiency. For instance, this device can decrease the temperature to 5° and increase it to 65°. The solar panels that are present capture the sunlight and change it to electricity that energizes the semiconductors. Usually, the structure is inactive, but relying on temperature captured by the thermostat, the system will be activated. The fabric then linked to the controlling circuit where it relays are related to the semiconductors, and the fan is attached to it. The thermostat is bound to give the order to the system to be either on "on or off" mode.

Besides, this project is considered as an economic system, and it could be expanded in the future for use inside the house also by using semiconductors and solar panels.

2 Convert the energy into electricity

To convert energy into electricity, we should use solar cells. Where, each solar cell can produce voltage through the release of electrons from a material that is shelled by electromagnetic radiation, which is in our project the radiation for the sun, or photons. The quantity of electron volts decreases when the wavelength increases. In this case, the visible spectrum of light and gamma radiation have more electron voltage than the infrared radiation, and the visible spectrum of light and infrared radiation have fewer electron volts than the ultraviolet which is entirely applicable and different.

3 Significance of Solar Panels

Linking many solar cells (Fig. 1), will help in building a system with a higher voltage that increases each time we add more batteries. The installed and connected solar cells are placed on the roof of the car. The panel is connected to a thermoelectric cooling device (N-P semiconductor) device that creates both cold and heat [1] [2].

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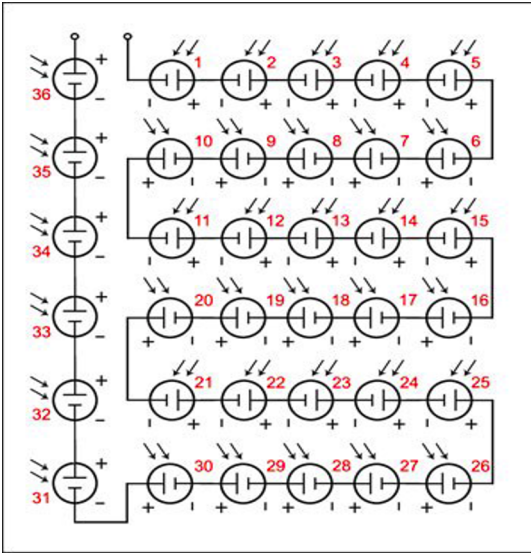


Fig. 1. Connected solar cells.

The Peltier module is represented in Fig. 2. The semiconductors are moving continuously forming n-p- and p-n-junctions. When the current is switched on, both junctions will be working simultaneously. The first one will be in the cooling mode while the other will be heating.

Two ceramics are used to separate inside the N and P-type semiconductor [3] [4].

4 Control System Design

4.1 Peltier Effect

The thermoelectric cooling device will produce a considerable warmth difference of 70 °C between both sides.

The heating power formula related to time and current is represented as follows:

$$Q = \alpha It \quad (1)$$

α represents the See-beck coefficient.

The cooling side absorbs heating when a direct current is applied. The procedure will work by moving the electrons of N and P types in opposite directions producing an electric current [5] [6]. This procedure is named "the holes."

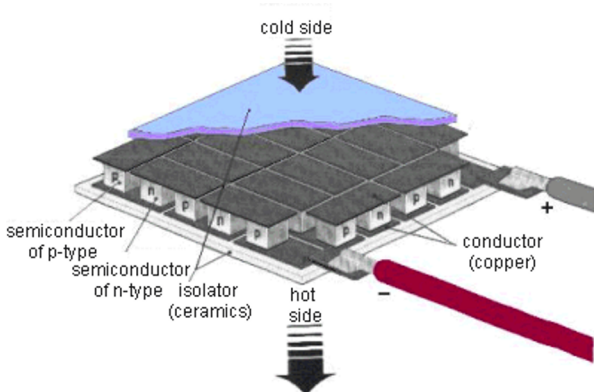


Fig. 2. Peltier structure.

4.2 See-Beck Voltage

An electrical current will produce variable temperature output if applied to a semi-conductive pair. This is defined by the See-beck voltage. The thermal conductivity should be low, or it will cause a reverse flow of heat which makes the temperature at all junctions equal.

5 System Boundaries

The work studied in this paper consists of multiple levels, as shown in Fig. 3. The board contains two parts: the solar cells (orange) and the Peltier elements (green). Many factors affect the output of the solar, like solar irradiance and inclination of the panel. However, the input voltage is fundamental for the Peltier elements to succeed. The systems will be analyzed separately, both theoretically and practically, and the outcome is added to give an image of energy outcome for the entire panel. An economic perspective of the system will be performed so that to define the temperature panel of the heat of the car [7] [8].

5.1 Heat System

The total energy used is related to the temperature inside the car, the focus lies on efficient heating in relation to outdoor temperature. The panel is designed to raise the temperature of incoming air during winter and lower it in summer. Consequently, the operation of the heating system falls outside the scope of this paper.

5.2 Solar Panel

By cooling the solar cells, we have improved the temperature of the air flow.

5.3 Cost

When we use Peltier elements and solar panels, we will reduce the cost per year. The panel producing price and the fuel price will change according to the different systems. The pay-back time affects the value of the investment.

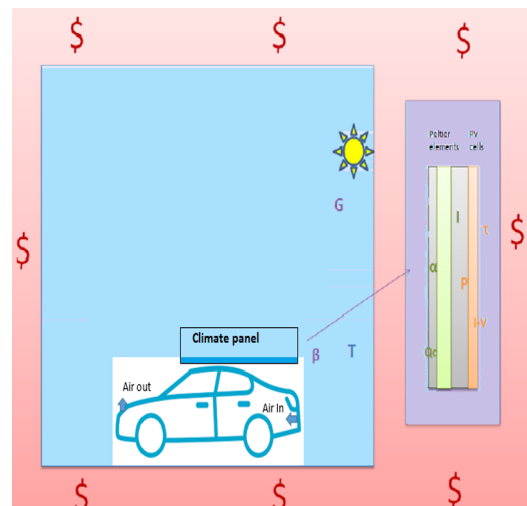


Fig. 3. The different levels of the proposed system.

6 Prototype Chosen

The prototype tested is described in Fig. 4. We connect a fan directly to the semiconductors where both are linked to the relays of the circuit. We combine a thermostat with the fan, just to control the runtime of the system or the cutoff. When we run the system, the center point of the car will get cold. The heat will be thrown outside. The heating mode can be activated by creating a series connection between the semiconductors connected to the solar panel. However, during cooling, the temperature rises significantly reaching around 40 °C making effective cooling unfeasible at this level of solar irradiance. For cooling purposes, parallel connections are more effective, while series connections are better suited for heating. The final prototype shown in Fig. 5 consists of the existing PV panel with two aluminum sheets creating a channel for the air to flow. One of the fins will be cooled and the second heated. The sheets will be eliminated by insulation in order to stop heating between the two sides.

7 Simulations

The output current and voltage of a photovoltaic (PV) system are influenced by the level of solar irradiance, denoted as G . To examine the thermal behavior of the air stream used to cool the PV cells, a simulation was conducted. The resulting data, shown in Figure 6, reveals a direct, nearly proportional relationship between the solar irradiance and the air stream's temperature rise. Further analysis involved adjusting the airflow rate to observe its impact on temperature. It became evident that as the flow rate increases, the temperature of the air stream drops, though not in a linear fashion indicating diminishing returns at higher flow rates. Figure 7 illustrates these findings at an ambient temperature of 25 °C. Interestingly, when the same simulation was repeated under colder conditions, specifically at -5 °C, the output characteristics current and voltage shifted accordingly with temperature. However, the change in air stream temperature followed the same trend. This suggests that the thermal gain from the PV system depends primarily on the mass flow rate of the cooling air, rather than the ambient outdoor temperature.

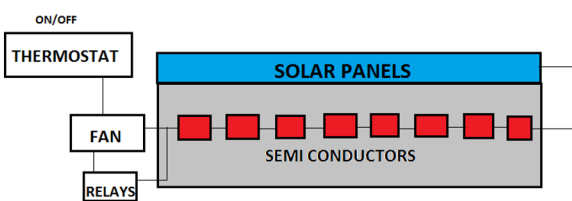


Fig. 4. Design Prototype.

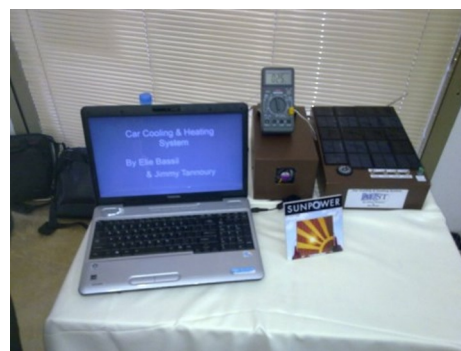


Fig. 5. Final Prototype.

The temperature variation in the air stream, as influenced by the thermoelectric (TE) modules, was analyzed through simulation. Two primary operating scenarios were considered: a summer setting with an ambient temperature of 25 °C, and a winter setting at -5 °C. In line with seasonal requirements, the modules operated in cooling mode during summer and switched to heating in winter. A key point in interpreting the simulation results is distinguishing between the optimum current associated with the highest coefficient of performance (COP) and the actual input current. One of the main challenges in this analysis stems from the fact that nearly all system parameters are temperature-dependent. For the sake of clarity and feasibility, some variables had to be held constant while others were varied, though in reality, these parameters are interrelated and cannot be adjusted independently without impact. Figure 8 presents how a single TE module's power output changes as the optimum current is adjusted. In heating applications, the relationship is straightforward: as the current increases, so does the heating power. This makes optimization yields more heat, with no need to search for an ideal operating point. Cooling performance, on the other hand, behaves differently. The data reveal that cooling power peaks at a specific optimum current. Beyond this point, performance declines, requiring more careful tuning. Thus, finding the most effective current for cooling is less direct and requires identifying the peak point under given conditions, making it a more complex task compared to maximizing heating output.

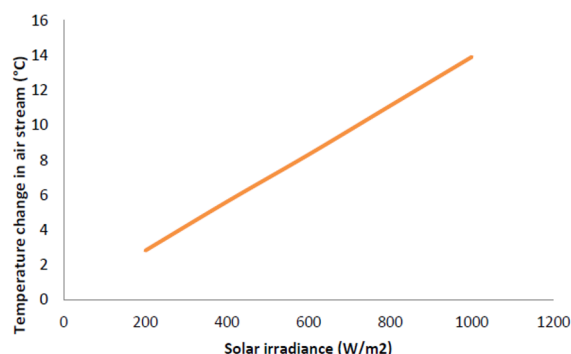


Fig. 6. Solar irradiance measuring function of the temperature change in the air stream.

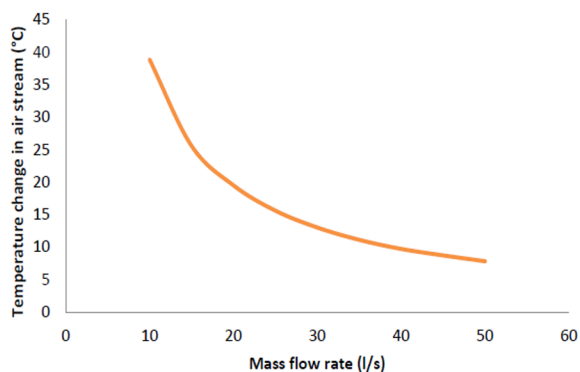


Fig. 7. Varying the mass flow rate depending on the temperature change of the air passing the PV cells.

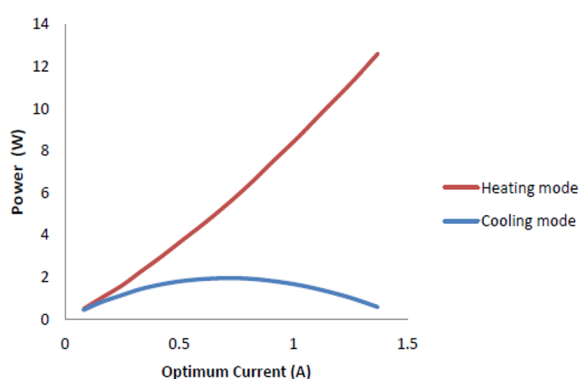


Fig. 8. Changing the power to heat and cool with maximum current.

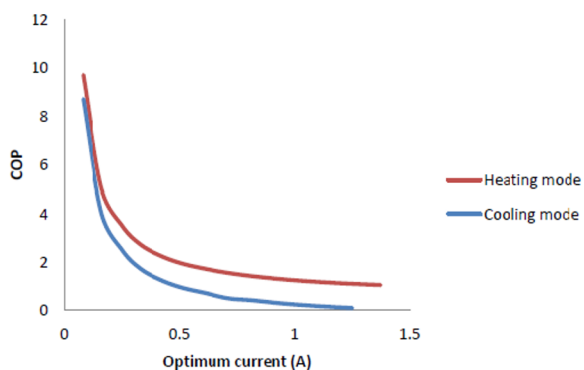


Fig. 9. COP changes with the maximum current to heat and cool.

Figure 9 illustrates how the coefficient of performance (COP) changes in both heating and cooling modes. It's clear from the data that, for any given current, the system operates more efficiently in heating mode than in cooling. Notably, the COP reaches higher values when the operating current remains relatively low. However, once the current approaches or exceeds roughly 1 ampere, the TE module's efficiency declines, and the COP no longer surpasses the 100% mark.

7.1 Variable airflow temperature

This study explores the use of thermoelectric (TE) modules for heating and cooling air. The process involves transferring heat from the TE module to an aluminum fin, which then passes the heat to the moving air. Conduction carries the heat from the module to the fin, while convection transfers it from the fin to the airflow. However, in the simulations conducted, the conductive heat transfer was not included due to insufficient data, making the temperature predictions somewhat conservative. As a result, the changes shown in Figure 10 likely represent a lower bound on the actual temperature shift. Figure 10 presents the simulated effect of a single TE module—without any fin—on an air stream moving at 35 liters per second. In heating mode, the air temperature rises with increased optimum current, which aligns with the power output trends shown earlier in Figure 8. In cooling mode, however, there is a distinct point where the cooling effect peaks, beyond which performance drops off. It's important to note that the impact on air temperature is relatively modest at this airflow rate. Since the amount of heat transferred is tied to how fast the air is moving, reducing the flow rate can enhance performance. Simulations indicate that lowering the flow to 10 liters per second would roughly double the temperature change in both heating and cooling scenarios.

7.2 Prototype output

The previous results outline the theoretical performance of the thermoelectric (TE) modules under ideal conditions, where parameters like the optimum operating current can be precisely set. However, this controlled scenario doesn't necessarily reflect how the system will behave in practical use, especially during prototype testing. The simulations assumed that the TE modules would always operate at the current level that yields the highest coefficient of performance (COP). In reality, this project integrates the modules with photovoltaic (PV) panels, where the current cannot be manually regulated. The system is designed so that under peak solar irradiance around 1000 W/m² the PV panels deliver the maximum current and voltage that the TE modules are rated to handle. In testing, the known values are the electrical input—current and voltage while the quantities of interest are the temperature shift and output power. Unfortunately, the thermal model is too complex to run a simulation based solely on input voltage and current because many of the relevant parameters fluctuate with temperature.

To address this, an estimate was made of how the temperature differential across the TE modules varies as a function of input current. This involved referencing the I-V characteristics of the PV panels to relate irradiance to electrical output, then incorporating these values into a broader model to estimate the resulting air temperature change. This approach was applied in both heating and cooling configurations, using eight TE modules powered directly by the PV array.

Figure 11 presents the anticipated air temperature change across the full panel setup, including any additional cooling effect on the PV cells themselves. The data suggests that in heating mode, the system could

theoretically raise the air temperature by up to 15 °C when solar irradiance reaches 1000 W/m². On the other hand, cooling performance peaks under much lower irradiance levels, achieving only about a 0.5 °C reduction. This indicates the panel is likely to perform well in colder seasons, while offering limited effectiveness during hot summer conditions.

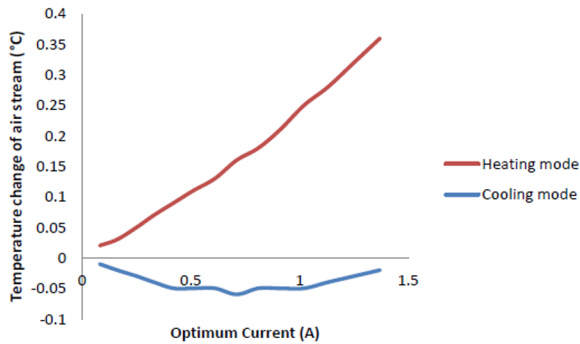


Fig. 10. The temperature change of an air stream with a flow rate of 35 l/s is caused by one thermoelectric to cool and heat.

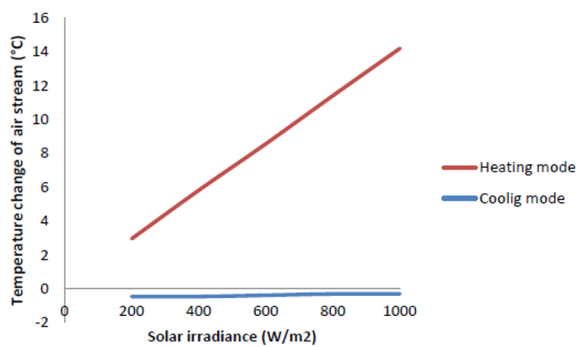


Fig. 11. Overall estimation of the maximum achieved temperature change of on airflow with ratio 35 l/s with solar irradiance to cool and heat.

7.3 Test in parallel connection

The experimental setup used the prototype previously described. It was supplied with a maximum of 13 V and up to 10 A. Temperature sensors were secured inside the module, positioned where the aluminum fin makes direct contact with the thermoelectric (TE) element. Measurements were recorded on both the hot and cold sides over a 60-minute period.

Tests were conducted at four different current levels, ranging from 2 A to 8 A. In the case of parallel wiring, the current measured roughly double the voltage. For example, at 8 A, the input voltage to the system was approximately 4 V. The resulting temperature data for both cooling and heating modes is shown in Figures 12 and 13. In cooling mode, the lowest temperature was observed at 6 A, suggesting this may be close to the optimum current for that configuration. The variation across measurements in cooling mode was minimal around 2 °C which might be attributed to slight differences in ambient temperature during testing.

In heating mode, the results showed more variation. The highest recorded temperature was 25 °C at an input current of 8 A. For reference, the ambient temperature in the test room was about 17 °C. The use of parallel connections seems to have limited the voltage available to each module, which may explain the relatively small temperature rise and the modest power output observed.

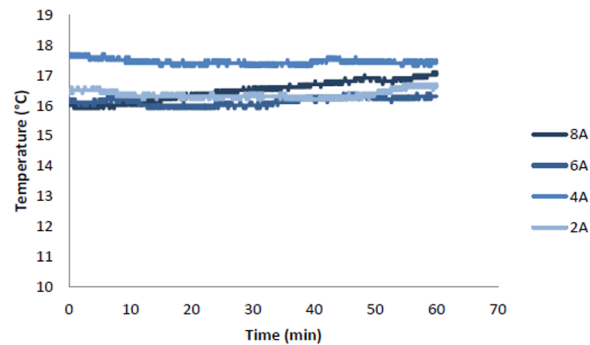


Fig. 12. The temperature is in contact with the thermoelectric on the cold side for different incoming currents to the prototype.

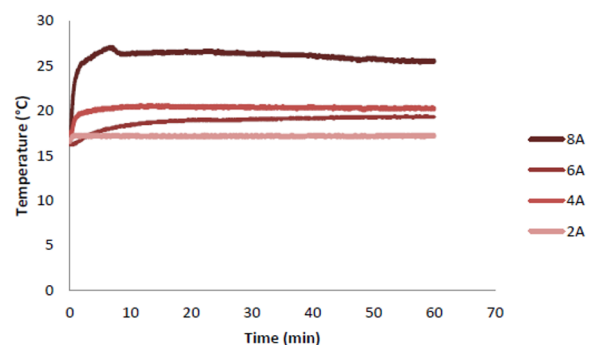


Fig. 13. The temperature is in contact with the thermoelectric on the hot side for different incoming currents to the prototype.

7.4 Test in series connection

For this experiment, the same prototype was used as in the earlier test, but with the modules connected in series rather than in parallel. To accommodate the higher voltage requirements of the series configuration, the system was powered by a different supply, capable of delivering up to 30 V and 10 A. The temperature sensors remained in the same positions as before, and measurements were recorded over a 60-minute period. Four different current levels were tested, ranging from 1 A to 4 A. Unlike the parallel setup where current was higher than voltage this configuration required a higher voltage relative to current. The applied voltage ranged from 4 V to 20 V depending on the current input. Temperature data for both heating and cooling modes is presented in Figures 14 and 15. In cooling mode, the system maintained temperatures below ambient across all test currents. The temperature initially dropped and then stabilized for most inputs, except at 4 A, where the behavior was less consistent. The series connection

appeared effective for cooling at lower current levels. In heating mode, the highest temperature reached was 45 °C at 4 A. Lower current levels failed to raise the temperature significantly above ambient. Compared to the previous results with parallel wiring, the series setup produced a noticeably higher temperature increase, suggesting it's the more effective configuration when heating is the primary goal.

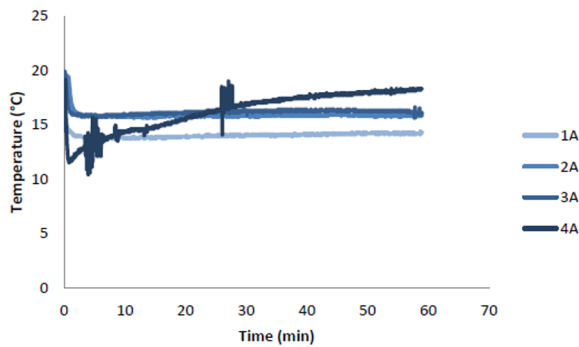


Fig. 14. The temperature at fin in contact with thermoelectric in time to cool at different incoming currents.

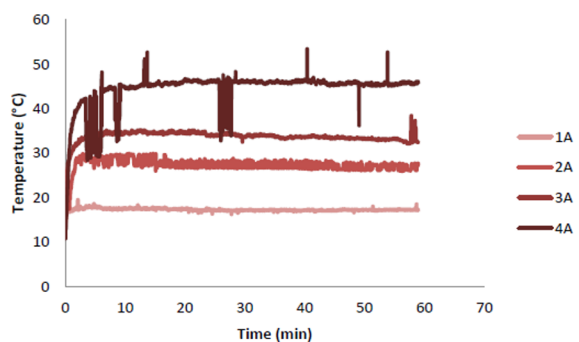


Fig. 15. The temperature at fin in contact with thermoelectric in time to heat at different incoming currents.

7.5 Connection to solar panel

The prototype was positioned in the same workshop as in previous tests. Temperature readings were taken at three points on both the hot and cold sides, with data collected over a 1.5-hour period during the afternoon. Figures 16 and 17 display the recorded temperatures for both parallel and series configurations. Before connecting to the prototype, the photovoltaic (PV) panel output measured 35 V and 8 A. The figures clearly illustrate that the series connection leads to significantly higher temperature levels compared to the parallel setup. With the modules wired in parallel, the fin temperature remains only slightly above ambient, indicating minimal heating or cooling effect from the TE modules. In this configuration, temperature distribution along the fin stays fairly uniform.

In contrast, the series connection generates a much more noticeable temperature gradient across the fin. It also takes longer for the temperatures to stabilize. Under these conditions, the fin temperature can rise as high as 90 °C, which is highly favorable for heating applications. However, the cold side also reaches elevated temperatures around 40 °C meaning effective

cooling is not achievable under this level of solar irradiance.

Overall, these results reinforce that parallel wiring is more suitable for cooling scenarios, while a series configuration is clearly more effective for heating purposes.

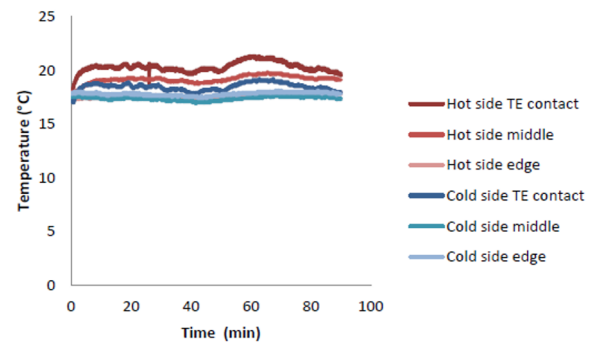


Fig. 16. Parallel connection. Prototype connected to solar cells with output 35 V and 8 A.

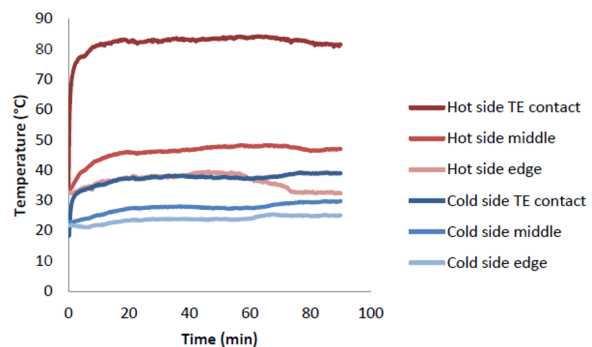


Fig. 17. Series connection. Prototype connected to solar cells with output 35 V and 8 A.

8 Summary of experiments

When the prototype is connected to the power, the heating mode will be on directly, and the cooling way will refuse to start. Where the temperature will be continuously stable until the opposite side is switched. During insulation, the cold side is kept less than the ambient temperature because there is always for a high current heat rolling between sides of the thermoelectric. Since the prototype is handmade, the measurements are not exact, and it has been hard to keep the same contact and pressure at TE.

9 Conclusion

The main idea for this prototype is to use solar cells with air to the air pump, after that testing and analyzing every test and every possibility to check if the potential of solar panels has given best results for the prototype. After performing a study, the conclusion can be drawn that: it is possible to do it, and there is enough potential to produce more trials. Besides, we can develop a prototype to be used in the car to heat and cool at the same time, and more we can design it to use in the

houses, by this we decrease the cost of electricity in both cars and homes.

This prototype can save almost 1300 kWh per year by adding panels to our car or house system to gain more safe energy with lower cost and efficiency. As a result, we can say that if we need to use this project for a house, then it will correspond to about 9 % of the heating and 5 % of the total energy. There are two considerations which can be used for this project. The first one is using the panel as a complement to a presenting system to heat, this means the board should be optimized to maximize the heating output, so we can save more energy per year by producing more heat. The second consideration is to include in this project a regulator to provide the highest cool and heat power improves the inside of the car. We can add a battery to power the panel when it is at night.

This project is a friendly solution since it contains no transfer fluids and is powered by renewable electricity from the sun. In houses, this project will help to reduce the cost a lot per year. However, this system as it is can be used only in the morning or little afternoon, but not in the evening. That is why we suggest using batteries at night so it will work correctly.

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