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A Novel Approach Development to Control Solar Air Cooler Using Intelligent Technique

Mashhood Hasan
Department of Electrical Engineering Technology,
College of Applied Industrial Technology (CAIT),
Jazan University, 45142, Jazan, Kingdom of Saudi Arabia.
Corresponding author: mhasen@jazanu.edu.sa

Abdullateef H. Bashiri
Department of Mechanical Engineering,
College of Engineering and Computer Sciences,
Jazan University, Jazan P.O. Box 114, Kingdom of Saudi Arabia.
E-mail: absheiri@jazanu.edu.sa

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Abstract
An intelligent technique is used to control a novel design solar air cooler, where, a solar air cooler has two sections, one is the solar photovoltaic system and the second is an air cooler. A photovoltaic system has non-linear characteristics of active power versus voltage graph that depends on solar irradiation (Watt/Area). Thus, here, an intelligent technique is developed using Arduino IED to extract maximum power from the solar panel. At maximum power buck converter is pulsed to charge the 12V battery. Whereas a second section has a novel approach to circulate unpleasant humid air to pleasant cool air and it completes its duty in three stages. In the first stage, hot or humid air comes from the atmosphere and enters into the tank where 20 W DC pump circulates water inside the evaporator which is made of circular copper coils. The circular coil maintains the cool temperature, whenever, hot air comes into contact with the cool copper coils. In the second stage, a DC fan 60W is installed in between the coils which takes cool less humid air and exhaust through the narrow gap and in the third stage, air takes another path to circulate pleasant air. These approaches reduce 10% of relative humidity and maintain 26^0C temperature inside the 12ft-by-12ft room. Moreover, relative humidity and temperature are fully controlled under the hybrid condition of the proposed air cooler. Hybrid condition is the condition when the proposed air cooler runs with a split-phase air conditioner.

Keywords- Algorithm, Arduino IDE, Intelligent techniques, Nano microcontroller, Solar air cooler.

1. Introduction

In the modern power system, clean energy is needed to sustain a CO_2 free climate. The global threats are a big challenge for researchers in sustainable energy to control disasters. Every innovation has the challenge of creating clean energy. As nature behaves unnaturally to return to a stable mode while its consequences cause disasters, devastating rainfalls and landslides struck Pakistan in 2022, affecting millions of people (Hasan, 2023). On the other hand, glaciers are disappearing as the earth's temperature rises due to the greenhouse effect. On the other hand, glaciers are disappearing as the earth's temperature rises due to the greenhouse effect. Consequently, green energy is needed to balance the global threats, however, a solar panel cost significantly less. A novel approach development to control solar air cooler using intelligent techniques is manufacturing and design to support green energy. Where, a solar panel of 80 watts is taken to supply the required power to the air cooler in the day via DC to DC buck converter. The duty cycle (D) of a buck converter is controlled using an intelligent control algorithm and pulse at the maximum power of the solar panel. The solar panel has a non-linear power versus voltage graph. Thus, a soft approach is required to design a control algorithm to explore the highest DC power constantly (Ganguly et al., 2023). Many more algorithms are available to explore maximum power point tracking (maximum PPT) and to explore solar insolation. In Hasan et al. (2022a) and Hasan et al. (2022b), conventional techniques, artificial intelligence and hybrid techniques are studied. An adaptive solar insolation forecasting using neuro-fuzzy approach is given (Mohanty et al., 2022). Whereas, an incremental condition technique is complex to design a MPPT with minimum error (Ahmadi et al., 2022; Ez-Zghari et al., 2022). A modified technique of perturbation and observations method is used to extract MPPT (Manjunath et al., 2021). In literature (Ahmed et al., 2012; Zhu et al., 2018) P& O and Hill Climbing (HC) analog to digital conversion method is used to explore the maximum power point. While under partial condition a maximum power is extracted to modified the grey wolf optimization algorithm (Millah et al., 2022) and a fuzzy rule-based algorithm and bio inspired technique are given (Hasan et al., 2022c; Zafar et al., 2021) to extract maximum power under partial condition. On the other hand, some researchers find the maximum power extraction under dynamic partial conditions (Chalh et al., 2021; Eltamaly et al., 2020a, 2020b) to get maximum power. A fast adaptive particle swarm optimization control algorithm is used to find the peak value of the power under dynamic partial shading condition. Both, simulation and experimental models are validated in this case. The millions of research articles are available to get maximum power from solar panels which is a non-linear characteristic of power versus voltage. A maximum power point tracker (MPPT) system is used to pulse a buck converter. Where the buck converter controls the 12.5V output voltage to charge the battery. In the lab, an 80W solar panel is used to charge 12V, 17A battery via a buck solar charger.

A buck converter has a simple design to charge the battery and reduces its weight, cost and volume due to its design. Thus, in a satellite system a two-switch forward converter with an integrated buck converter is proposed in (Park et al., 2023). In the literature, various DC to DC converters is available while solar panel is examined at CAIT electrical workshop lab 401 under various insolation and found that under minimum 200 W/m2 insolation the open circuit voltage is 13.6 Volt and at maximum power 13.2Volt whereas solar power delivered least energy under this case. Thus, the buck converter is good to choose to step down the voltage level at 12.5V to charge the battery and to run the 60W DC fan. A buck-based solar charger is opted for in the given article (Venkatramanan and John, 2019) to control the maximum power output.

In the literature survey, very few good publications are available in solar air cooler. Zheng et al. (2019) Researchers tried to oppress the humidity level upto 30% under full condensation conditions and indirect evaporation cooling system is so designed that condensation takes place near the outlet. While, Lotfizadeh and Layeghi (2014) have designed a small solar evaporative cooler where 10W DC fan is used to circulate the cool air and evaporate the moisture using cooling pads. In Jaber and Ajib (2011), this article, design an evaporative cooling system to minimize the total consumption of energy in kWh by air conditioners. Whereas, researchers explore the annual energy consumption using advanced methods of cooling (Khandelwal et al., 2011) In this case, a regenerative evaporating cooling system using cool water to reduce the energy consumption while cool water generation is another issue. In this work, indirect evaporative air conditioning is proposed to reduce electricity bill consumption it includes the economic impact on the proposed model (Jaber and Ajib, 2011). Again, it has insufficient work related to humidity level control using solar power. While Belarbi et al. (2006) used the evaporating cooling method in buildings and towers for sizing evaporative cooling systems. In Kittas et al. (2001), a greenhouse evaporative cooling analyzed its data and reduced the electrical energy while it again failed to control the humidity level in coastal areas (Zellweger, 1906). In Bowman et al. (1997), the mechanism of evaporative cooling in hot dry weather. This technique is used to reduce energy consumption. Al-Turki and Zaki (1991) did intermittent spraying techniques on the roof of the building to maintain the cooling which is now old-fashioned. Moreover, a few designs of solar are available which is unable to be commercialized. It has some drawbacks as compared to air conditions. While authors have introduced a novel approach development to control a solar air cooler using intelligent techniques. Broadly, solar air cooler has two sections one is solar photovoltaic system whereas the second section has air cooler. The photovoltaic system has a nonlinear characteristic of active power versus voltage graph which depends on solar irradiation (Watt/Area). Thus, here, an intelligent technique is developed using Arduino IED to extract maximum power from the solar panel. At maximum power buck converter is pulsed to charge the 12V battery. Whereas the second section has a novel approach to circulate unpleasant humid air to pleasant cool air. Solar air cooler has three sections to complete its novelty, In the first stage, hot or humid air comes from the atmosphere and enters into the tank where 20 W DC pump circulates water inside the evaporator which is made of a circular copper coil. The circular coil maintains the temperature cool when hot air comes into contact of the cool coils, the hot air becomes cool, while cool air having more humidity which makes the room unpleasant, Thus, the authors keep a first-stage water absorber to absorb the moisture of the cool air which are mounted with the evaporator.

In the second stage a DC fan 60W, 12V, is installed in between the coils which take cool less humid air and exhausts through the narrow gap. It maintains high pressure due to its novel design and the high speed of DC fan (2000rpm). A high pressure is required to extract the water from the air. Moreover, water absorbs blocks the air to pass in the same direction. Thereby, a huge air pressure is developed which evaporates the maximum water of cool air. In the third and last stage, air takes another path to circulate cool air. Further, a water absorber is available in the cool air-circulated path to reduce the moisture level of humid cool air. Thus, a proposed high-pressure technology is a novel approach development to control solar air cooler using an intelligent technique. Moreover, the author's contributions are given as,

- An open-source Arduino Integrated Development Environment (IED) is used to develop an intelligent program to explore the maximum power and burn it into the microcontroller to control the charging current.
- The proposed air cooler takes natural air and doesn't evaporate the heat in the atmosphere while air conditions evaporate heat into the atmosphere again nature treats which causes the ozone (O_3) layer in dangerously reduced.
- It can easily develop and be naturally friendly.

This paper is organized in sections to understand things clearly. In the next section model is presented while in the third section algorithm is given and in the fourth section results and discussion are presented and at last paper is concluded.

2. Model Description

In this section, the proposed model is explained in detail about its working principle. In **Figure 1**, the PV panel is connected with the DC to DC buck converter and the converter switch is pulsed at the maximum power of the solar PV panel. A buck converter is connected to the DC fan and DC pump and maintains its constant output voltage of 12.5 V. Moreover, the buck converter charges the battery which supplies backup current to the DC fan and pump of the solar air cooler. The further explanation is given in subsections.

2.1 Photovoltaic System

The light energy or sun energy can generate electrical energy using solar panels. This method to generate current is known as the photovoltaic effect. It can use the sun insolation to harvest DC current. The sun insolation breaks the barrier voltage of the semiconductor and harvests electrical current (Iph). All parameters are evaluated under standard test condition (STC) which is represented as,

$$Tc = 25\ ºC\ and\ Geff = 1000\frac{W}{m2} \tag{1}$$

A semiconductor based multiple solar cells can be arranged in series and parallel to get open circuit voltage and short circuit current. Many factors of solar cell are thinkable to design panels while temperature and insolation factors are significant. The open circuit voltage (Voc) can be estimated as,

$$Voc \approx ast \ln\left({I_{ph,st}}/{I_{rs,st}} + 1\right) \tag{2}$$

and constant, ast= nkT/q (I_(ph,st)= light current, I_(rs,st) = reverse current, n=identity factor, k=Boltzmann constant, T=Temperature and q= Charge). Moreover, an important short circuit current parameters are given as,

$$I_{sc} = I_{ph,st} - I_{rs,st}\left[e^{\frac{I_{sc,st}.R_{s,st}}{a_{st}}} - 1\right] - \frac{I_{sc,st}.R_{s,st}}{R_{sh,st}} \tag{3}$$

And constant, (Rs= series resistance and Rsh= shunt resistant).

The Equations (1), (2) and (3) are helpful to design the solar panel. While six to eight parameters are required to design actual solar panel which are given in (Hasan et al., 2022b).

2.2 Solar Charger

In the literature, more than 100 DC to DC converter configurations are exist. Solar charge is somehow different from the DC to DC converter. As, solar photovoltaic power characteristics are nonlinear. Thus, it needs an algorithm to explore maximum power continuously at input port of the buck converter. The proposed work is to use a buck converter-based solar charger. A buck converter shows satisfactory performance under all conditions of solar insolation. **Table 1** shows the required parameters to design a buck solar charger. It requires one inductor while two capacitor input Cpvin and output Cpvo respectively with control switch MOSFET Q and uncontrol switch Freewheeling Diode D. The theoretical and practical data are given in **Table 1**. The solar charge is in a continuous current mode of operation and its duty cycle can be varied as solar insolation is varied. Mathematically, the duty cycle (D_T) can be evaluated as,

$$D_T = \frac{V_o}{V_{in}} \tag{4}$$

and (V_o=*ouput voltage*, V_{in}=*voltage at maximum power*)

$$V_o = D_T(V_{in}) \tag{5}$$

However, solar chargers can work under step-down voltage

Table 1. Buck converter constraints.

Constraints	Theoretical value	Practical value
Duty Cycle (D_T)	Using Equation (4) = 07	0.7-0.9 (Range depends on insolation)
Input Capacitor (Cpvin)	118.75μF	100 μF
Inductor (L)	1.9mH	2mH
Output Capacitor (Cpvo)	118 μF	100μF
Diode (D)	Uncontrol Switch	Freewheeling Diode
MOSFET (Q)	Control Switch	IRFP250N

2.3 Battery

Battery is the storage cell of DC current which is the effect of electrochemistry. Numerous classes of batteries are available in the market. In the proposed hardware model, a Lead Acid battery is used to work at night or in cloudy weather. In the presence of full or partial insolation solar panels charge the battery via a buck converter which has a wide range of duty cycles to maintain the DC output. A 12V, 35Ah lead acid battery can discharge at 11.5V in 2-3 hours while it can take 20-30 minutes to get recharged up to 12V under full solar insolation. Besides, charging time can increase or decrease due to the current penetration level in the circuit.

2.4 Air Cooler

A novel approach development to control solar air cooler using intelligent technique is shown in **Figure 1** where a solar panel supplies DC current to the DC fan and DC pump via DC to DC buck converter. A hot air or humid air is taken from outside and circulated it to room 12*12 ft^2 via a cool water surface area. A hot or humid air passes from the water tank which is covered by the Water absorber. The water absorber makes the system cool air and doesn't exchange the heat ΔQ. Whereas, solar air cooler has three sections to complete its novelty, In the first stage hot or humid air comes from the atmosphere and enters into the tank where 20 W DC pump circulates water inside the evaporator. It is made up of a circular copper coil. The circular copper coil maintains the temperature cool when hot air comes into contact with the cool copper coils. And so, on inside cooler air becomes cool. While cool air has more humidity which makes the room unpleasant, thus, authors keep a first-stage water absorber to absorb moisture of the cool air which is mounted with the evaporator. In the second stage, a DC fan 60W is installed in between the coils which takes cool less humid air and exhaust through the narrow gap. It maintains high pressure due to its novel design and the high speed of DC fan (2000rpm). A high pressure is required to extract the water from the air. Moreover, water absorption blocks the air to pass in the same direction. Thereby, a huge air pressure is developed which separates the water content from cool air. In the third and last stage, air takes another path to circulate cool air. Further, a water absorber is available in the cool air circulated path to reduce the moisture level of humid cool air. Thus, a proposed high-pressure technology is the novel in a novel approach development to control solar air cooler using an intelligent technique.

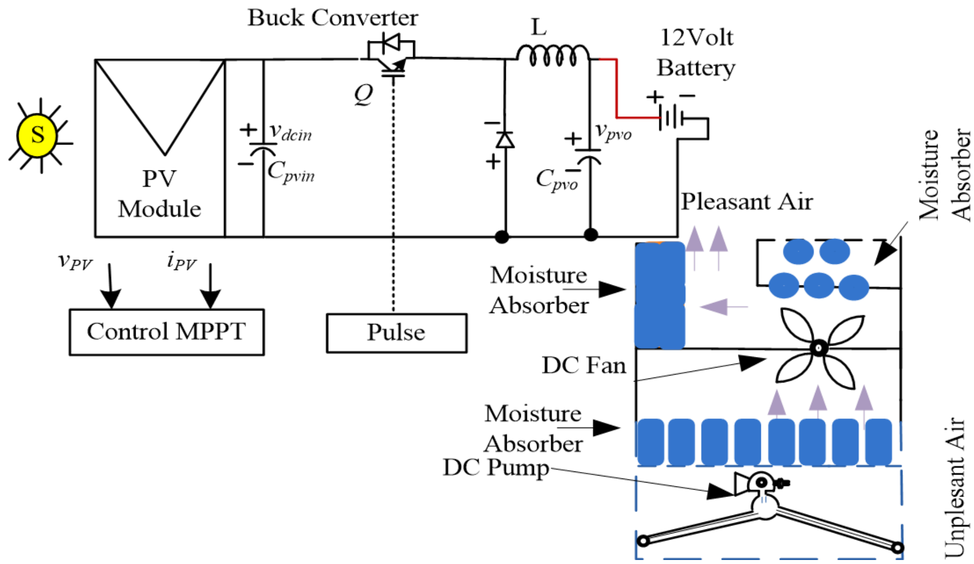

Figure 1. A schematic diagram of a novel approach development to control solar air cooler using an intelligent technique.

3. Control Algorithm

An Arduino, Integrated Development Environment (IDE), aids programmers in combining the dissimilar aspects of developing a computer program. IDEs enhance programmer efficiency by combining collective actions of developing software into one application: editing source code, building executables, and debugging. There are two steps in the microcontroller Arduino program algorithm to explore maximum power.

- ***Measurements-*** It senses two analog signals input voltage and current at T sampling time and T-1 sampling times, and compares solar charger output analog voltage signals to evaluate the duty cycle.
- ***Feedback-*** In this case, with the output analog voltage signals of the battery are measured and compared with the output of the battery voltage and sent a signal to the microcontroller to control the duty cycle of the buck converter accordingly.

In **Figure 2**, an intelligent algorithm is an incremental algorithm that is coded into a microcontroller, as opposed to an intelligent algorithm that uses C++ programming to create a duty cycle. The microcontroller detected the battery's output voltage, and if it was 13V, it stopped pulsing the buck converter.

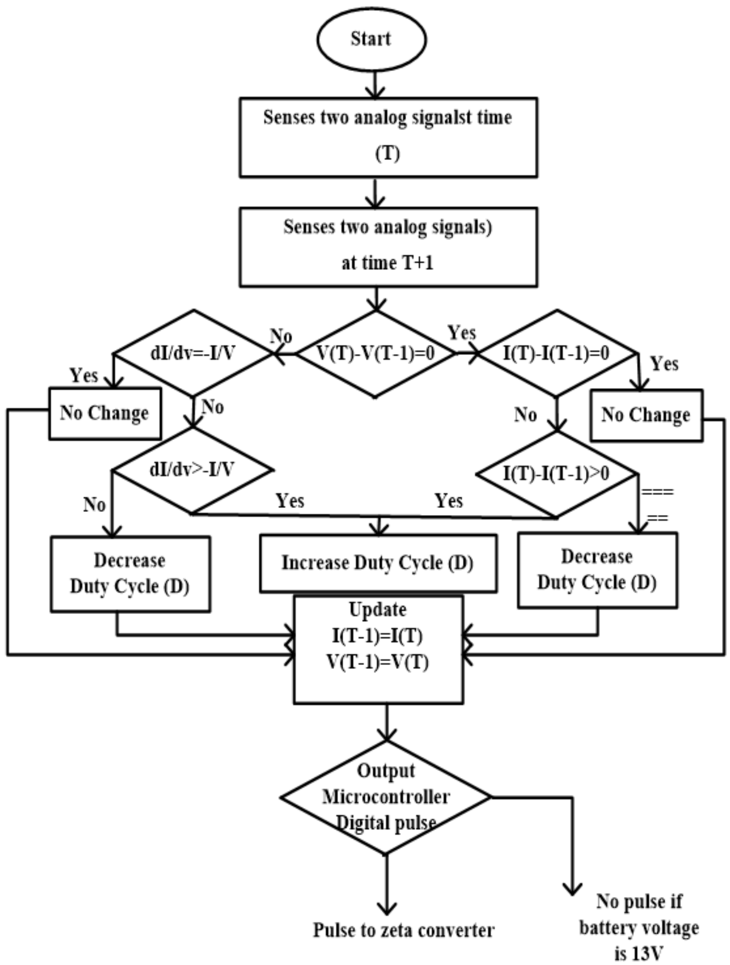

Figure 2. An intelligent algorithm for generation pulse at MPPT using a microcontroller.

4. Results and Discussion

To comprehend the quality and level of pleasure of the proposed air cooler, the performance of a hardware model is presented here. In **Table 2**, hardware required items are given which are used to design an air cooler. At the lab, there is a maximum solar insolation of 800W/m2. The results are performed under 800W/m2, 400W/m2 and 200W/m2 insolation respectively. Using a digital hygrometer, the relative humidity and temperature are monitored and recorded for comparison purposes. Below are the outcomes for each component of the solar air cooler.

Table 2. Hardware parameters.

Required Items	Specification
Solar Panel	80 Watt
Light	800 W/m2 solar insolation in lab
Lead acid battery	12 V, 17 Ah
DC to DC converter	Buck converter
Microcontroller	16 pins
DC fan	12 V, 60W
Water pump	12 V, 10W
Copper Coil	3-7m long, 16mm dia
Water absorber	1m long, 0.3m wide
Water absorber	3-6 Pieces
RH and Temperature meter	Digital LCD hygrometer including thermometer

4.1 Performance of Solar Panel

In **Figure 3**, open circuit voltage under various solar insolation conditions is shown. At 800 W/m2 insolation, the open circuit voltage is recorded at 18.2 V, while at partially insolated conditions, it is recorded at 16.6 V, and at 200 W/m2 it is recorded at 14 V. The solar panel gives satisfactory results. Moreover, in **Figure 4**, at maximum power point voltage and current is recorded to generate a duty cycle and give constant output voltage to charge the lead acid battery under variable solar insolation. As the duty cycle DT is varied as solar insolation is varied to maintain the constant output of buck converter and under all conditions control intelligent algorithm is working satisfactorily. Whereas, the buck converter is also satisfied with its performance under all conditions.

4.2 Buck Converter Performance

The highest output voltage of the solar panel at MPPT is shown in **Figure 5** under varied solar insolation, whereas the maximum output voltage of the buck converter is 12.8V constant with DT 0.41 during 0s to 18 seconds. And from 18s to 42 seconds, when the solar insolation drops to 400 W/m2, the DT changes to 0.46 in order to keep the output buck voltage constant at 12.8 V. During 42s to 60s the output voltage of solar panel is 14.2V because of solar insolation reduces to 200W/m2 while buck output voltage remains unchanged. During this performance charging current is affected as solar insolation is reduced. Moreover, lead acid battery supplies continuous current to the DC pump and DC solar air cooler which is shown in **Figure 6**. As the DC fan starts the buck output voltage gets down further its down as the DC pump also starts. During all switching conditions of DC loads, the output voltage of the buck converter is nearly constant up to 12.2V. Hence, the performance of the buck converter is unaffected and satisfactory.

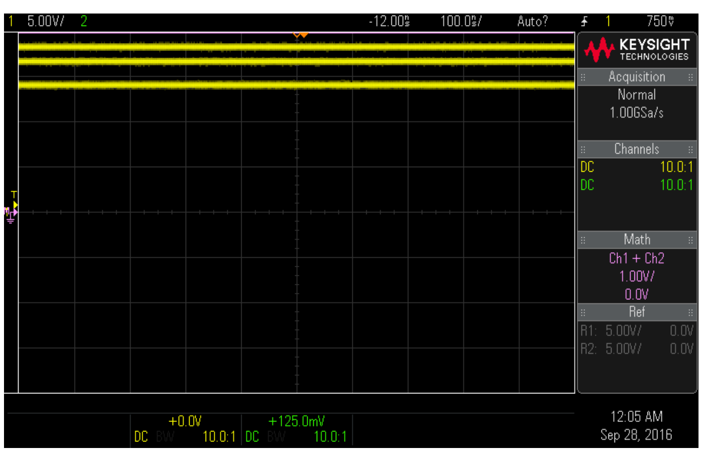

Figure 3. Open circuit voltage under various condition of solar insolation.

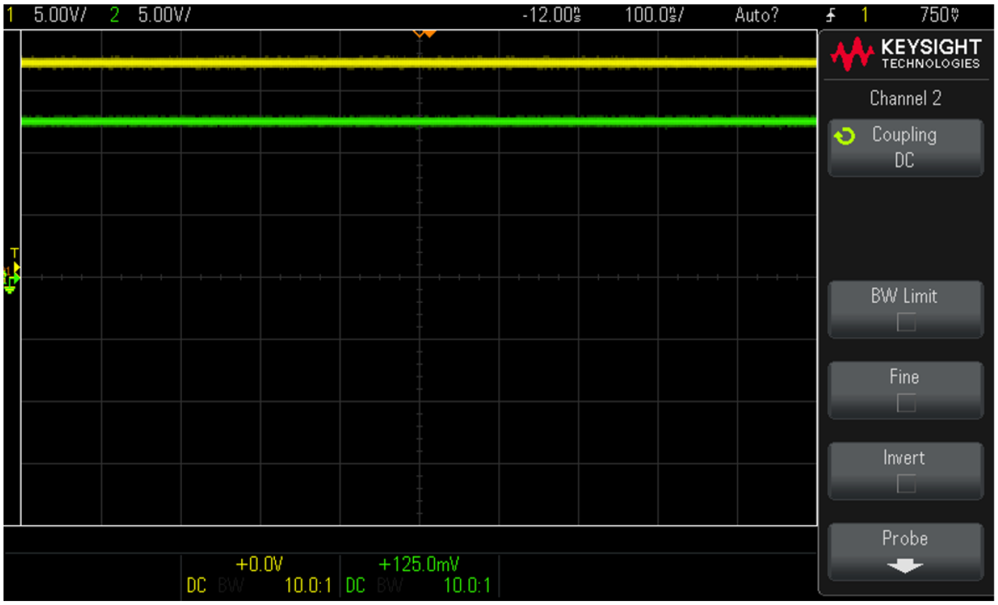

Figure 4. Input voltage of solar panel and output voltage of buck converter under load DC fan and DC pump.

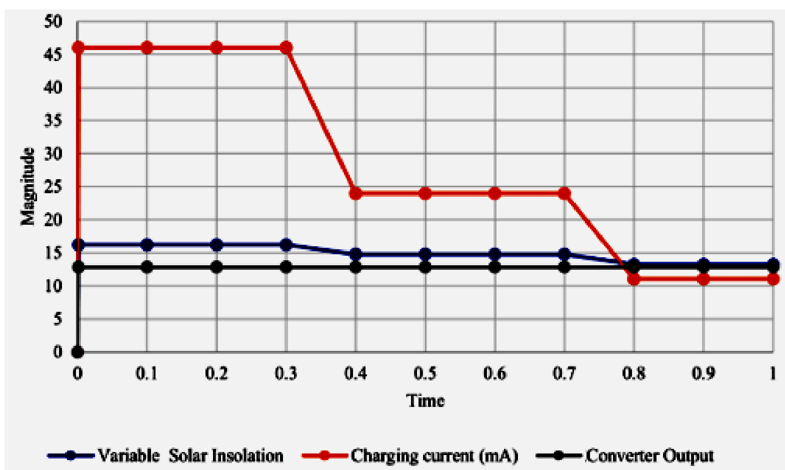

Figure 5. Performance of buck converter under various conditions of solar insolation.

4.3 Solar Air Cooler

In **Figure 7-10**, the performance of the proposed solar air cooler is given to know its market values. The relative humidity (RH) is recorded in percent whereas, the temperature is recorded in degree Celsius. A relative humidity is the ratio of actual humidity inside the atmosphere and the maximum value. While humidity is the water content level inside the air. These parameters are recorded in 12ft by 12ft a small research room for 50 minutes only in the noon. The atmosphere of the southern part of Saudi Arabia is recorded for practical knowledge of the proposed cooler using solar power. In February the relative humidity was recorded 74% while inside the water tank of the proposed solar air cooler is increased upto 90%. It is because of water spring inside the cooler tank and circulating to maintain the temperature down. In **Figure 7**, the relative humidity (RH) level reduces upto 66% for three turns of copper coil. The RH is reduced as the authors proposed novel approach to enhance the effectiveness of cooler in remote areas. The temperature of the atmosphere is recorded 39 ℃ hot air and when hot air enters into the tank, the temperature is reduced upto 26-24 ℃. The air inside the tank is cool with high relative humidity level. A novel technique is introduced to reduce the temperature level upto 27 ℃ of the room with control RH and it can be seen in **Figure 8**.

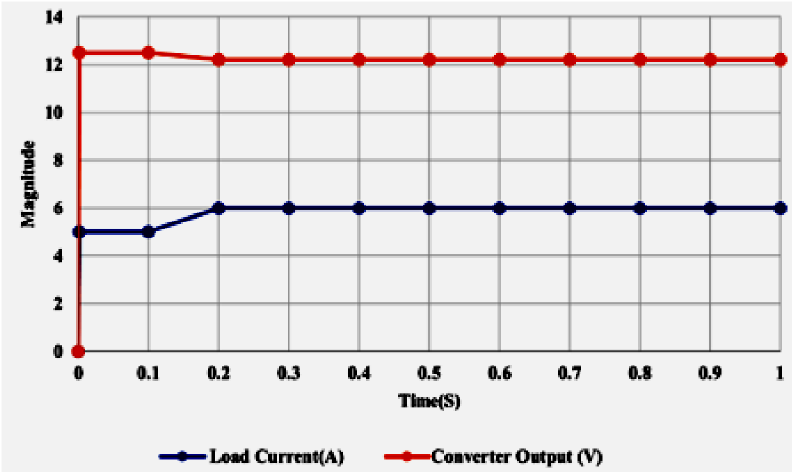

Figure 6. Performance of buck converter under working condition of solar air cooler.

Numbers of copper coil turns inside the tank can change the temperature and humidity level of the room air. As turns increases the humidity level going down it can be observed in **Figure 9**. It is because of water circulating through the copper coil for long time. The inside the room RH is controlled by a novel structure of DC fan circulates air which is already discussed in model description section D.

In **Figure 10**, inside the water tank 26-22 ℃ as a result inside the room the same temperature is recorded. These results show that the novel structure of solar air cooler is a good option for trade.

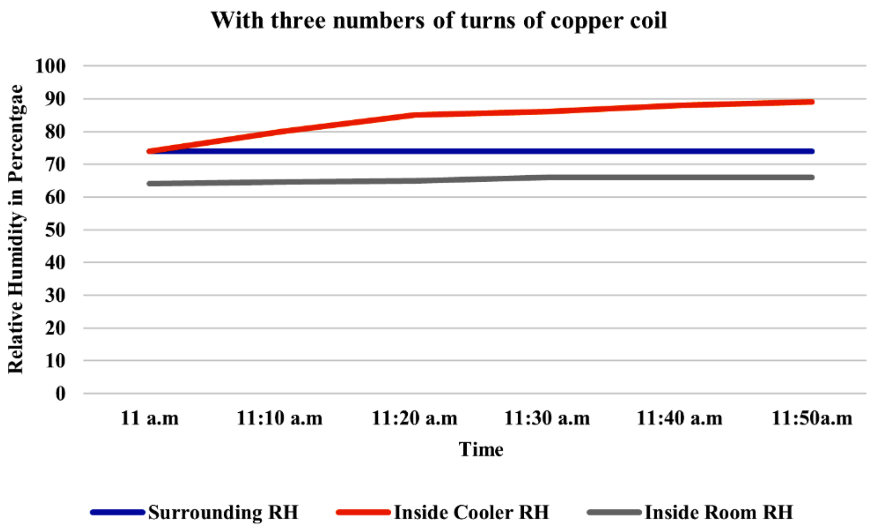

Figure 7. Performance of relative humidity in the percentage of solar air cooler under three turns of copper coil.

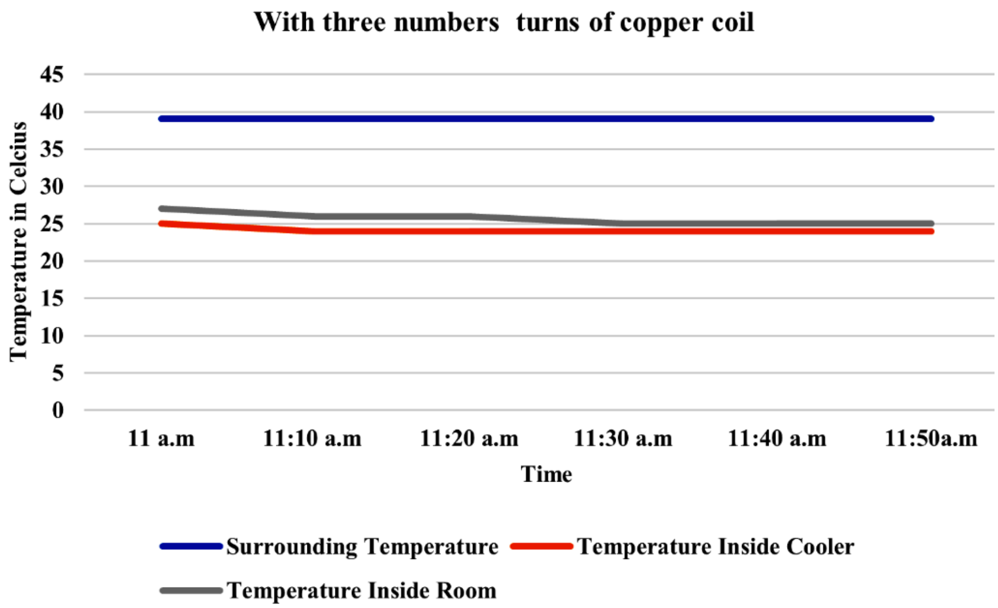

Figure 8. Performance of temperature of solar air cooler under three turns of copper coil.

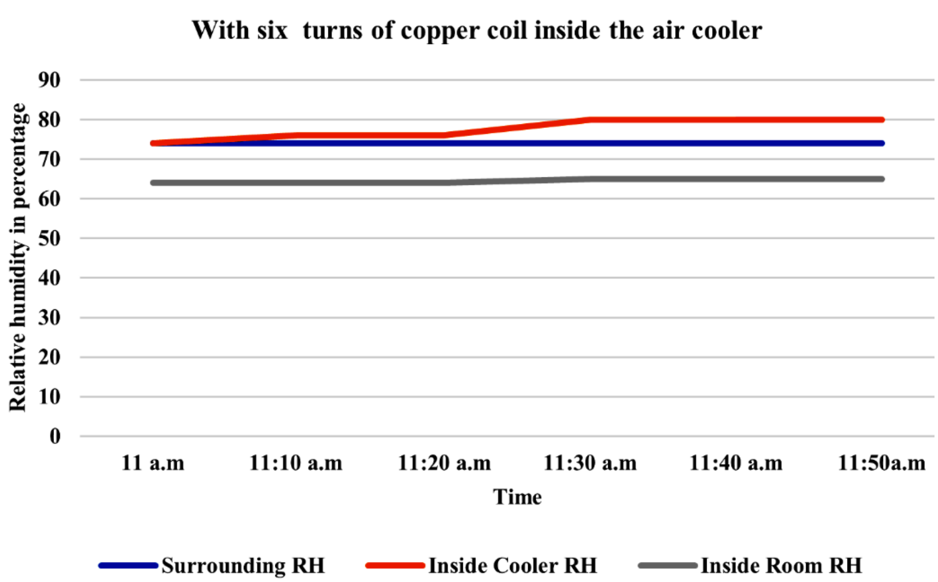

Figure 9. Performance of relative humidity in percentage of solar air cooler under six turns of copper coil.

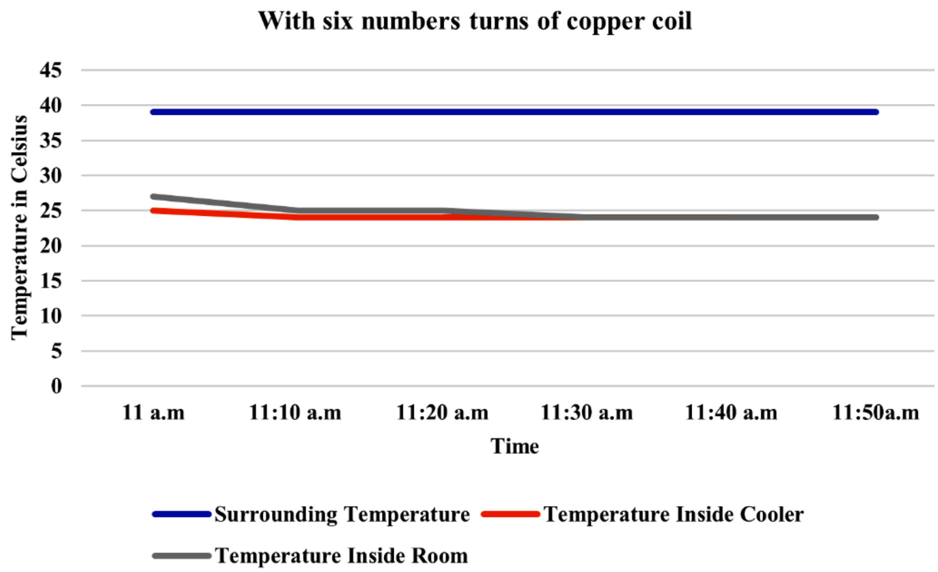

Figure 10. Performance of temperature of solar air cooler under six turns of copper coil.

4.4 Performance of Solar Air Cooler under Hybrid Conditions

It is proposed that inside workshops, hospitals, offices, and big areas the novel construction air cooler can work in hybrid conditions. Hybrid condition, when both split air conditioner or windows air conditioner and solar air cooler work together. The performance of the proposed cooler under hybrid conditions is seen in **Figure 11**. Where, RH reduces slightly as split AC is switched on under 28 ℃. While temperature reduces substantially and room temperature is recorded upto 20 ℃ which is shown in **Figure 12**.

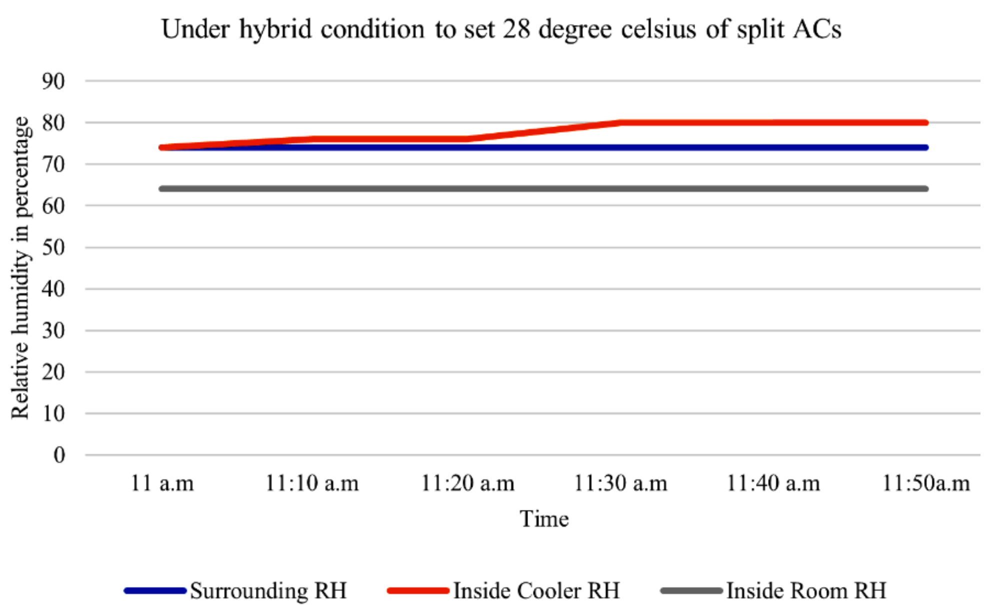

Figure 11. Performance of relative humidity under hybrid condition of solar air cooler.

Thus, authors have suggested running the proposed solar air cooler as a hybrid condition to save electricity bill. The proposed air cooler consumes an electricity bill of zero dollars while split AC consumes an electricity bill of $60-$70 per month.

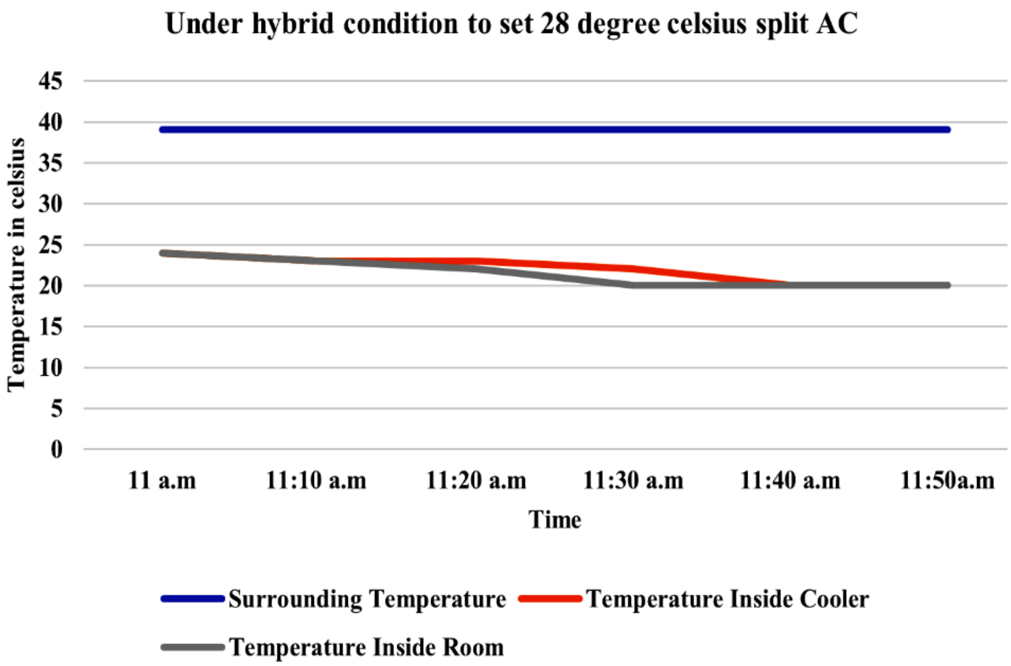

Figure 12. Performance of temperature under hybrid condition of solar air cooler.

5. Conclusion

It is observed that the proposed solar air cooler has a novel structure to minimize the relative humidity. A buck solar charger is used to extract power from the maximum peak and charge to the battery. The performance of the buck solar charger is good enough to charge the battery under all conditions of solar irradiation. It maintains 12.5V and charge the battery to 12V. Battery supplies to the air cooler pump and the DC fan. A lab results shows that an intelligent algorithm is pulsed to the buck converter at maximum power. Thus, the proposed algorithm is performed well. Furthermore, the results of the solar air cooler are improved as the copper coil layer is increased. Relative humidity and temperature are going down in the room as the number of copper coils is increased. In this work, the difference of atmosphere air humidity and room humidity is 10% while the temperature difference is 12 ℃. This work also proposes a hybrid mode of operation which is suitable for big areas where, temperature and humidity are fully controlled. Thus, the proposed technique to control the humidity level is a good option. And work of solar air cooler is economically good for developing and developed countries. The performance of all sections of solar air cooler is satisfactory and reliable.

Conflict of Interest

There is no conflict of interest in this paper.

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