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New approach to Charging Laptop Using Solar Energy

[1]Dana Al-Jamea, [1]Omar Badran, [1]Ismail Al-Masalha, [2]Anwar Al-Mofleh, [1]Ghazi Almarahleh, [1]Hisham Almujafet, [1]Abdallah N Aljbour.

1 Department of Mechanical Engineering, Faculty of Engineering Technology, Al-Balqa Applied University, Amman, Jordan.

2 Department of Electrical Engineering, Faculty of Engineering Technology, Al-Balqa Applied University, Amman, Jordan.

Abstract

Study investigates multiple energy generation methods, considering time, cost, and regional usability, to ascertain their viability for providing energy in resource-constrained settings. The primary objective is to identify and evaluate viable energy resources, specifically focusing on charging laptop batteries, to support access to technology in Third World countries. A predesigned solar-powered generation system was implemented as a proof of concept. Additionally, other energy resources were analysed, though not physically demonstrated. The system was modelled and simulated using MATLAB/Simulink with the Simscape system block set. The computer simulation demonstrated the crucial role of simulation in the design, analysis, and evaluation of the solar energy system and its components.

Keywords: Solar energy, laptop, charging, Computer simulation, batteries.

1. Introduction

Janet Roloff, in “The Third World Needs Energy Too, ” highlights the looming energy crisis in developing nations, predicting a severity surpassing that experienced by the United States decades prior [1-6]. Energy generation is intrinsically linked to economic growth, a critical need for these countries. Increased energy availability fuels productivity, driving sales and ultimately fostering economic development [7-10]. Furthermore, these nations grapple with technological deficits, particularly in electronics essential for global communication.

1. 1 Population growth and rising energy demand

Global population growth, a key factor in current and future energy consumption, has followed an exponential trend in recent decades, indicating limited controllability. We are currently experiencing a 'demographic transition, ' characterized by a rapid decline in death rates outpacing the reduction in birth rates, resulting in overall population growth. Historically, high and relatively equal birth and death rates (over 3% annually) have shifted towards a stabilization phase with lower rates (approximately 2%). This current scenario approximates the inflection point of the S-curve that models world population growth over time.

The global population is growing rapidly, with an estimated net increase of 200, 000 people each day due to the difference between birth and death rates. As of mid-2005, the world population stood at approximately 6. 5 billion and is projected to reach between 8 and 10 billion in the coming decades [11, 12]. This significant growth places increasing pressure on natural resources, especially in critical sectors such as food, water, and energy.

At the same time, global annual energy consumption is estimated at around 15 terawatts (TW) [5]. Currently, nearly 80% of the world's energy needs are met by fossil fuels: oil accounts for 34%, coal for 25%, and natural gas for 21%. Other sources include biomass (8%), nuclear energy (6. 5%), and hydropower (2%), while renewable technologies such as wind and solar contribute only a small fraction [13, 14].

These trends underscore the urgent need to adopt more sustainable energy strategies and accelerate the transition toward cleaner, renewable sources to ensure long-term environmental and economic stability in the face of growing global demand. In parallel with the global shift toward renewable energy sources, research has increasingly focused on enhancing the thermal performance of photovoltaic (PV) systems, which directly affects their efficiency and energy output—especially under high solar irradiance conditions common in developing countries. Recent studies have explored innovative cooling techniques to mitigate overheating in PV panels, which can significantly impact their ability to charge sensitive devices like laptops. Masalha et al. [15–21] have conducted extensive investigations into the use of porous media such as sandstone, gravel, and flint for passive and hybrid cooling solutions. These approaches have shown substantial improvements in panel performance, both in experimental setups and CFD-based numerical simulations. Integrating such thermal management strategies could enhance the practicality and reliability of solar-powered laptop charging systems in remote or off-grid environments.

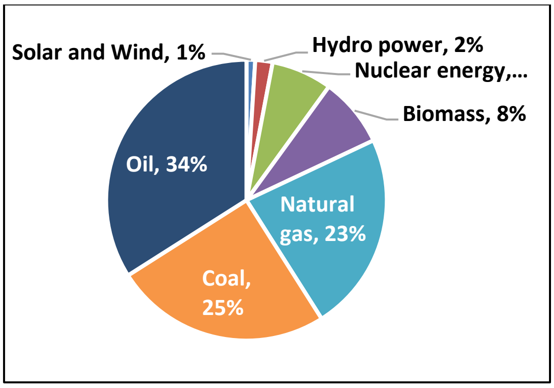

Fig. 1: World energy consumption.

Complementary observations about the future of fossil fuels are as follows:

Considering the future of fossil fuels, coal stands out with the most substantial estimated reserves, approximately 600 Gtoe (including lignite). This volume could sustain current production for centuries. In contrast, gas reserves are estimated at 160 Gtoe. However, gas consumption has seen a consistent rise in recent years, attributed to its operational flexibility (Figure 2).

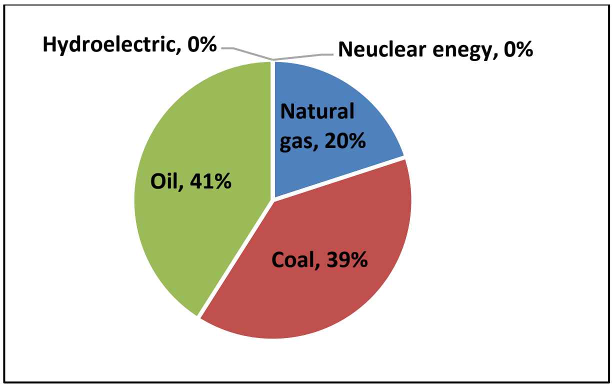

Fig. 2: Total conventional energy emissions in 2011.

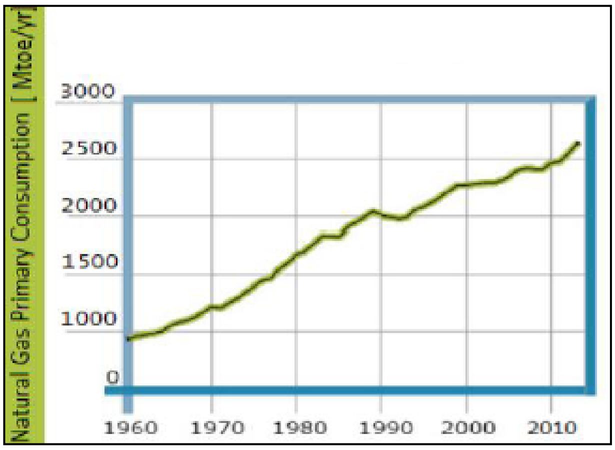

Fig. 3: Evolution of world gas consumption.

With the rapid developments in global energy demand, oil usage is increasingly being restricted to the transportation sector, such as cars, airplanes, and ships, due to its high efficiency in these fields and ease of transport and storage. Recent studies indicate that oil consumption rates are being re-evaluated and estimates are being raised annually, reflecting the ongoing increase in global demand for this vital resource [22-25].

On the other hand, fossil fuels, particularly coal, oil, and natural gas, are the primary contributors to anthropogenic carbon dioxide emissions, which are one of the major greenhouse gases impacting the global climate balance and contributing to the phenomenon of global warming.

Although the combustion of contemporary biomass products, such as wood and other plant residues, also releases carbon dioxide, these emissions are not considered as net contributions to carbon pollution. This is because they represent part of the carbon cycle in the "Earth Surface, Oceans, and

Atmosphere" (ESOA) system. When plants are replanted after harvesting, they absorb carbon dioxide from the atmosphere through photosynthesis, thereby restoring the balance in this vital cycle, making the emissions from biomass closer to being carbon-neutral.

Therefore, bioenergy sources are seen as more sustainable compared to fossil fuels, making them a promising option in the global efforts to transition towards a cleaner and more sustainable energy system.

2. Energy Conversion

We take advantage of solar energy by using solar cells which in turn give us the amount of DC power for charging the laptop. Laptop gets the electric power fed DC and hold the shipment must be secured DC voltage suitable for work ranging from 18 to 19. 5 volts. Power output of solar cells is not constant with time, as it varies with the angle of the fall of the sun. So, we do not connect the solar cells directly with the laptop, to avoid any electrical problems affecting it, such as sudden changes in voltage. And we have designed a circuit as shown in Figure. 4 works to secure the fixed voltage on the output of the system. This circuit contains a DC battery, these batteries provide constant voltage output, and using the voltage regulation, we can get a fixed voltage and suitable for laptop of these batteries.

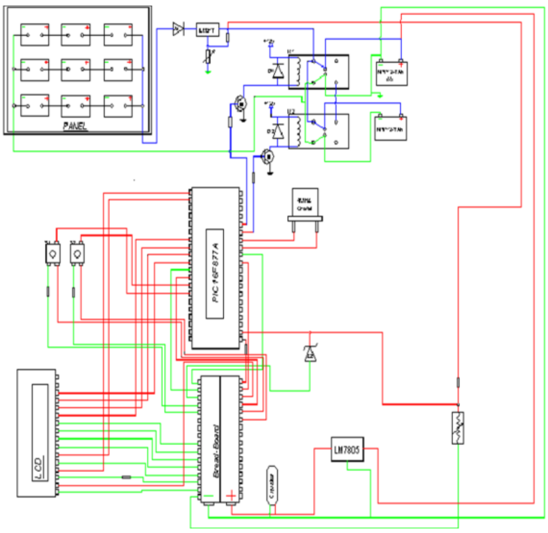

Fig. 4: Battery charging stage.

3. The P-V Cells with The Load Variation Circuit Model (1)

Represents the hardware cells which are (16. 5 V, 220 mA) by the data sheet of the cells and describes its response due to the load variation with all characteristics curves according to a several values of irradiation at seven days with changing I the surrounding temperature of three different atmospheric degree, all of that is simulated as shown in Figure. 5, this modeling method at MATLAB using a certain values of parameters giving us the current, voltage, power, irradiation and temperature curves according to time variation.

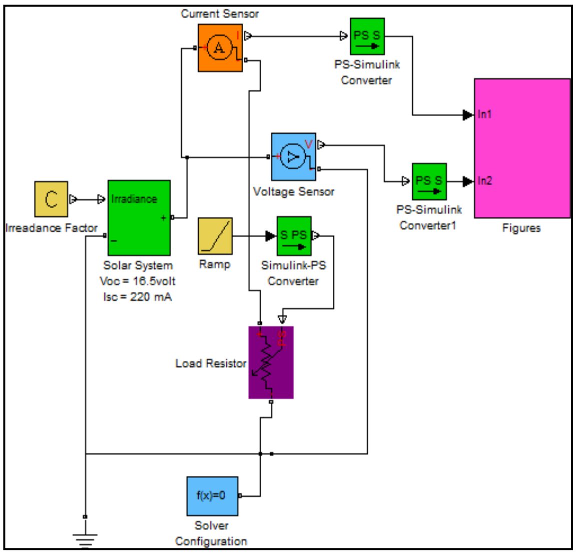

Fig. 5: P-V cells with load variation circuit model (1).

That is making the test and study of our project easier than the hardware testing process because we can use the MATLAB simulation to simulate different working situations by verifying the parameters values of the hardware components in the simulated blocks.

Model (1) consists of two parts: the solar cell module and the test load. the solar cell module is made up of (9-solar cells) connected in a parallel series connection to give us the desired output voltage (16. 5 V) and the current (220 mA), the irradiance is given as an input to the cells, this parallel series connection of the solar cells is shown in Figure 6, which represent what consisted at green block at Figure 5.

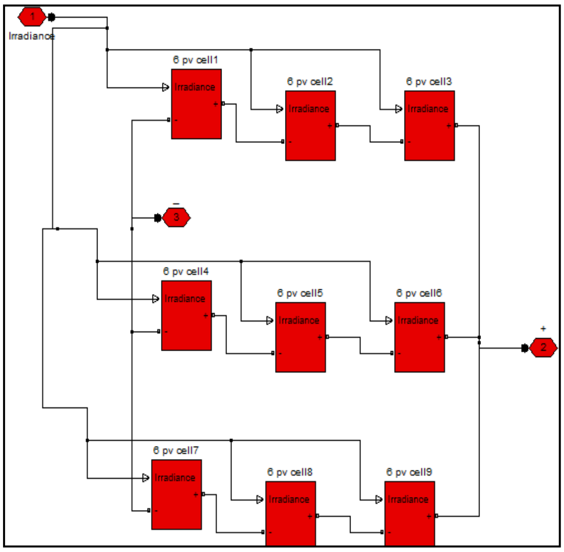

Fig. 6: parallel series connection of the P-V cells.

3. 1 Simulation Results of Model (1)

A variable resistor is used to represent the variation of the load, by that we can obtain the characteristic curves of V-I and P-V for the solar cell module, and from the voltage and current curves the values of $V_{O.C.}$ and $I_{S.C.}$ are deducted. Two versions of the system are built; one with variable temperatures and the other with seven variable values of Irradiance, this is to analyze the performance of the solar cell module under different climate conditions.

3. 1. 1 Current, voltage and power waveforms

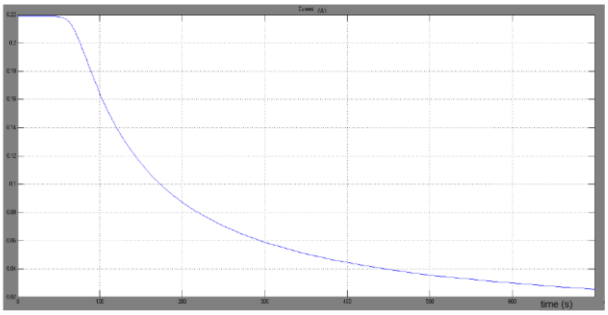

Fig. 7: I-waveform

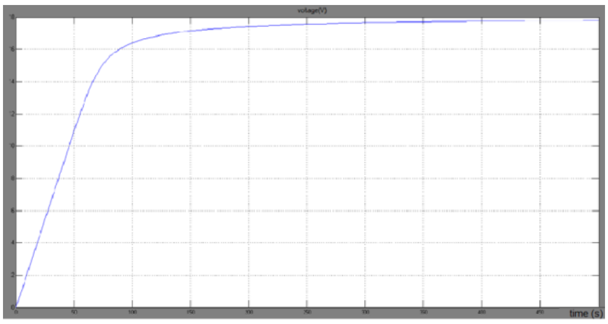

Fig. 8: V-waveform

The test load is increased from zero using a ramp function, it can be seen in Figure 7, that the current at the beginning is equal to the short circuit current (8. 19 A), as the load is increased the voltage will increase until it reaches a steady state value equal to the open circuit voltage (36. 7 V) as shown in Figure 8, and from Figure 9, we can see the maximum power of the P-V cells.

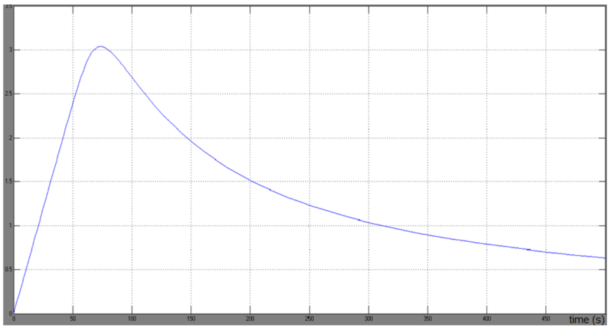

Fig. 9: P-waveform.

3. 1. 2 I-V and P-V Characteristics

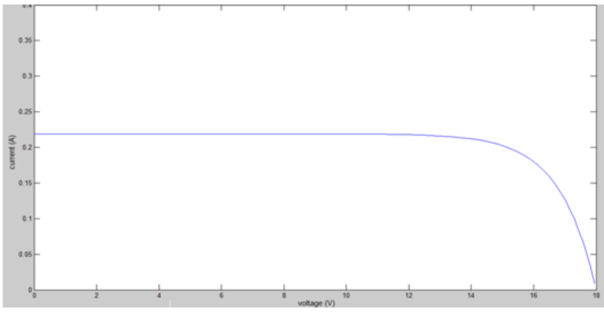

Fig. 10: I-V characteristics.

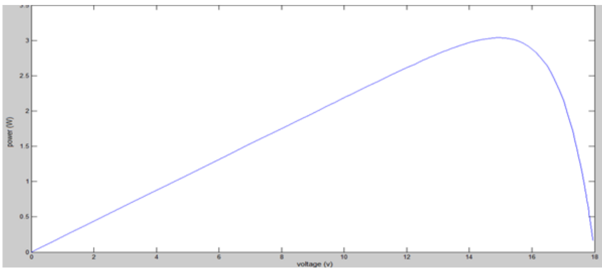

Fig. 11: P-V characteristics.

In Figure 10, we can see the values of $V_{O.C.}$ and $I_{S.C.}$, and how the voltage changes with current for the variable test load. The second Figure 11 shows the power output versus the voltage of the cells, the maximum power can be explained by the fact that the impedance of the variable load is equal to the internal impedance of the cells.

3. 1. 3 Variable Temperature Results

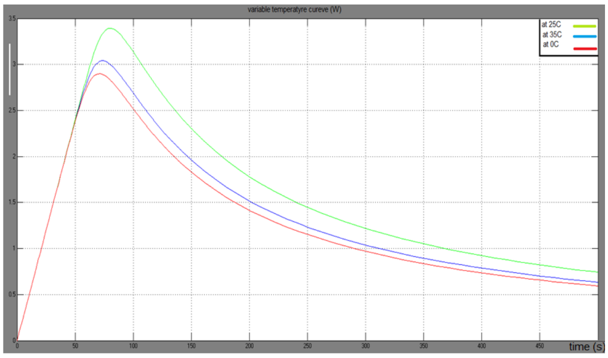

Fig. 12: variation of power with temperature.

Here the effect of varying the temperature can be seen at Figure 12, at the nominal temperature (25 Co) the power output in maximum as the temperature decreases the power decreases, and with excessive temperatures the output power will greatly decrease as can be seen.

3. 2 Simulation of the Hardware Working Method Model (2)

Representing two stages of work, charging and discharging steps for two (12V, 7A) batteries on parallel and series, we have tried to simulate the hardware operation to get results making our test a study easier for several work states which give us a very important feature that is the flexibility in applying system several parameters to get the best characteristics of working. The parallel series connection method as what we has been discussed in the previous chapter when the relays coil has no signal, the normal contact of each relay is connecting the terminals (C and S1) with each other's in the 1st and 2nd relay which make the batteries working in parallel and giving a signal to the relays coil make the contactors moves by the magnetic field generated from these coils, this change in position for the contactors makes (C and S2) terminals connected with each other's which make the circuit work in the series for the batteries, for the control of this method of operation we used a simple Manual Switch turning on of the relay circuits, all of that is according to Figure 13.

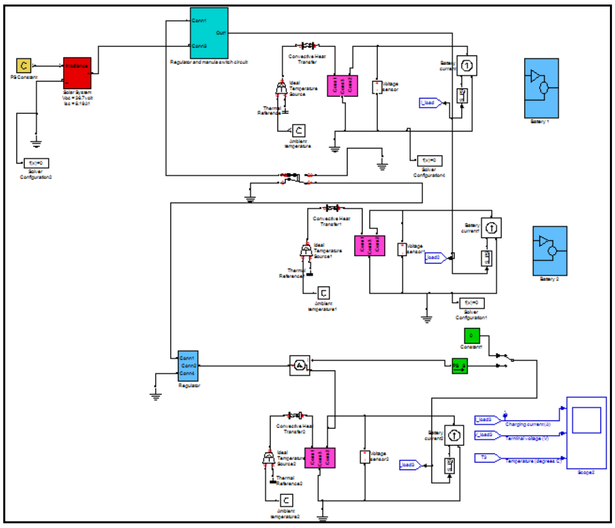

Fig. 13: The charging state (mode 1) for the 2nd model.

3. 3 The Charging State Mode (1)

At this stage the contactors are connecting the terminals of relay (C and S1) as shown in the Figure 14, and the first switch allow the signal to reach the (ps) terminal of the relay from the positive port (connection 2) of the P-V cells and the other switch prevent the signal from reaching to the laptop as shown in Figure 13, which represent the connection of the two batteries. The method of connecting the first relay is clear in Figure 14, which contains the voltage regulator circuit.

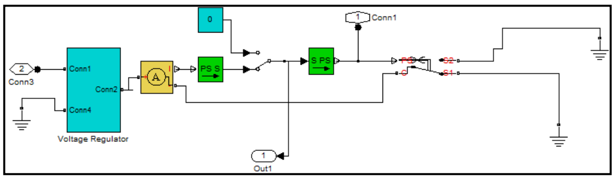

Fig. 14: voltage regulators before batteries.

The voltage going to the batteries a crossing the relays should be a steady state value because the changing of the P-V cells voltage (up and down with the time interval change) make those batteries to get loose in Avery short time comparing with its factorization so we add a voltage regulator consist of several restive loads to control the amount of current going on the system and zener diode for controlling the voltage a crossing the batteries all of that is very clear according to the outputs of the Figure 15.

Each lead acid battery on MATLAB has about (2. 15 V) so to simulate our battery at the hardware project we connect (6 batteries) on series to get an amount of voltage near to the reality, this connection is shown in Figure 16.

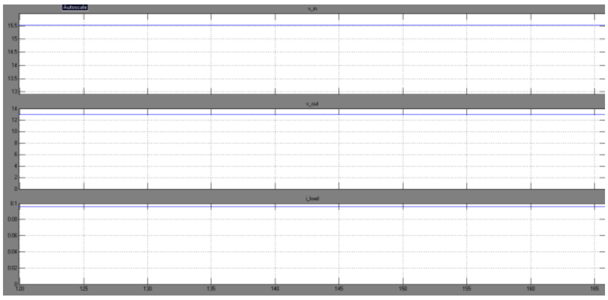

Fig. 15: (V-in, V-out, I-load) of the 1st regulator.

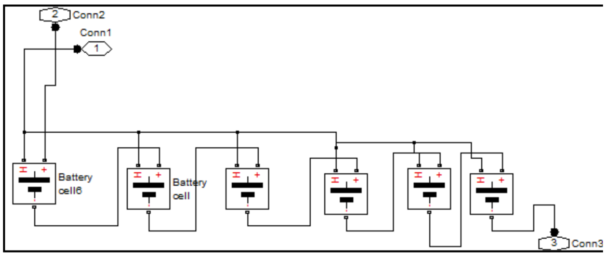

Fig. 16: Internal configuration of l. a. b.

At this step the batteries are connected in parallel and charging from the P-V cells, terminal voltage of each battery is going to increase with time according to this stage and the parameters are shown clearly at Figure 17.

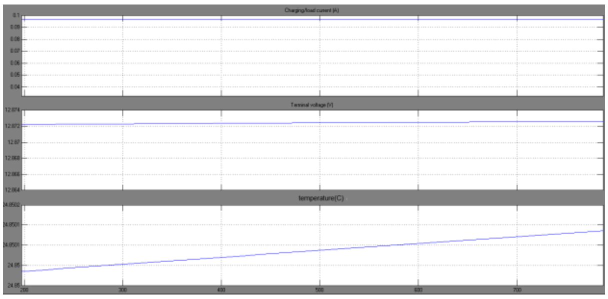

Fig. 17: Batteries (Voltage, current, temperature).

3. 4 The Discharging State Mode (2)

At this stage the contactors are connecting the terminals of relay (C and S2), the first switch prevents the signal to reach the (ps) terminal of the relays (the two batteries) from the positive port (connection 2) of the P-V cells, the other switch now is deliver the signal to the (ps) terminal of the 2nd switch, that makes the current goes on the magnetic core of the 2nd relay which produce magnetic flux causing a change in the contactors position. After that, this whole process caused the laptop to be supplied from the series batteries, this configuration is simulated at Figure 18.

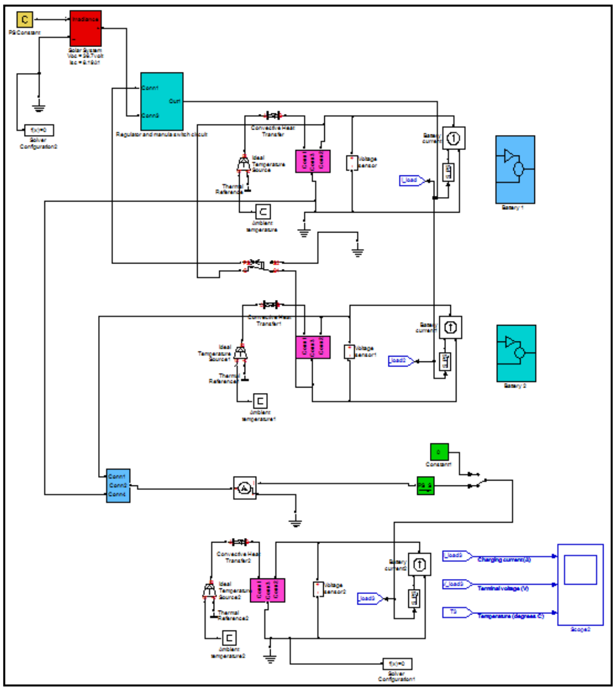

Fig. 18: The discharging state (mode 2) for the 2nd model.

The other regulator on this system, Figure 19, is supplying the laptop with a constant voltage but not exactly, this voltage rises in every small value according to the time interval and this regulator gives the needed current to the laptop as in Figure 20.

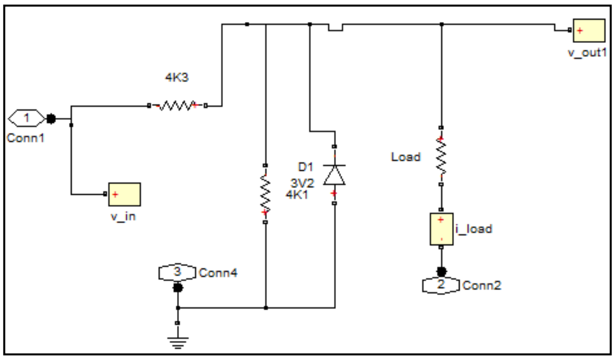

Fig. 19: Voltage regulator before the laptop.

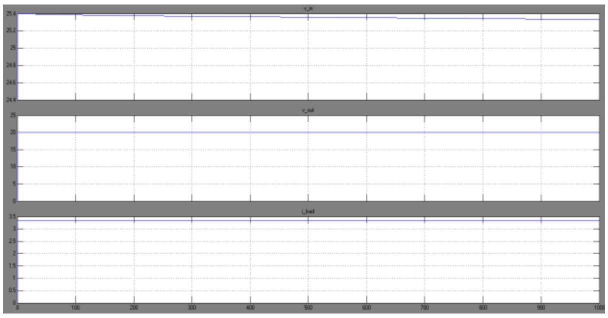

Fig. 20: (V-in, V-out, I-load) of the 2nd voltage regulator.

The characteristics of the 2nd voltage regulator are shown by describing the V-in, V-out (to the laptop) and I-load according to figure 20.

The rated voltage of the laptop is increasing in a small deviation according to the time interval, the laptop characteristics are shown at Figure 21.

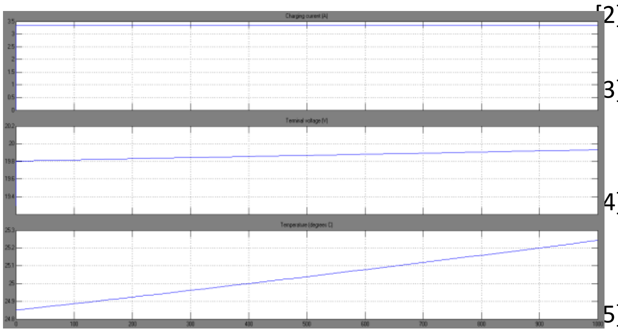

Fig. 21: The laptop characteristics.

4. Conclusion

1) Dealing with DC circuits gives us easier handling and design than the AC-systems for the model we aim to create that is by supplying the load (which is the laptop in our project) with a rated voltage and giving the ability to the load for consuming the needed current with all working cases.

2) We have achieved a very important feature which is making our system that we designed easy to carry so that it is not boundary to a certain place which gives us the opportunity to take advantage for longest period.

3) The renewable energy (the solar one) is stabilized, effective and practical energy system and can be applied for a long time in the working state.

4) We simulate our project by using the MATLAB program, which is easier for us to design and modification the components of our circuit depending on several working circumstances.

5) When applying the idea of our project in the charging and discharging states we found that this system and its component has a law economic value compared with the created solar system, keeping in mind that our system can be developed to be designed with a minimum cost value and high efficiency.

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Authors' contributions

Authors provided the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revised it critically for important intellectual content, and final approval of the version to be submitted

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.