Solar controller charge design

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Abstract:

Due to the increasing use of renewable energy and economic efficiency of this type of energy, having an efficient charge controller to control the system and increase productivity is important. Charging control in solar panels prevents the battery from overcharging and thus increases battery life. It also prevents the electric current of the batteries towards the solar panels during the night.

The two most common types of charge controllers are PWM charge controllers and MPPT charge controllers, which charge MPPT controllers more efficiently than PWM charge controllers. Charging MPPT controllers tracking the maximum power point using various methods. Conventional methods for tracking the maximum power point are: perturbation and observation, incremental conductivity, constant voltage, short circuit current, fuzzy logic control and artificial neural network.

In this paper, by examining the existing methods, a model for designing a charge controller was proposed. The charge controller design based on MPPT method was selected and fuzzy logic control method was used to track the maximum power point.

The proposed model for designing the charge controller was simulated in MATLAB software and its results are displayed. The results obtained are from four stages with different intensities of radiation and temperatures.

Keywords:- charge controller-solar panel-pwm-mppt-fuzzy logic control

Introduction:

Due to the high cost of fossil fuels and their impact on the environment, the use of alternative energy sources has increased in recent decades.
Solar system or photovoltaic (PV) is an alternative source of clean energy that has received much attention in research and industry. The charge controller (scientific term) is the heart of this solar system. Its function is very important in solar systems because the battery life of the system, which accounts for almost 30% of the total cost, is directly dependent on it. If the battery is overcharged or discharged too much, it will be seriously damaged, so the charger control device is placed in the circuit to protect the battery in case of overcharging or discharging.
Charging controllers are classified based on how many amps of current they can with stand. International charging standards require controllers to withstand 25% of excess current in a limited time. This ensures that the controller is not damaged when the radiation is increased too much [1],[2],[3].
Excessive current can damage the controller. Choosing a charger controller with a larger current than required will allow the system to be developed in the future without incurring much cost.
The controller also prevents backflow at night. Reverse current is the amount of current that flows in the reverse direction at night and discharges the battery.

Also today, the need to optimize energy consumption without creating new problems for consumers is essential, which must also be highly reliable. Therefore, today, the use of hybrid system is inevitable, which leads to the use of more and more powerful electrical consumers, and as a result, the electrical energy required by the consumer increases.
Therefore, the battery industry is looking to supply new batteries, which are in line with the gradual change in the electrical structure of renewable sources. However, the role of the battery has been enhanced as a central tool for maintaining optimal performance and increasing the reliability of renewables and consumers, which can also be monitored and managed [1],[3].
On the other hand, most batteries are sensitive to overcharging and overcharging, which can damage the battery and damage it. In addition, in fast charging processes, it is desirable that the battery be fully charged in the shortest possible time using the usual charging methods, which are mainly done using high currents, while preventing it from entering the supercharging area [4],[5].
Therefore, the optimal performance of the battery depends on the estimation of the charge state (SOC) and its proper control. Therefore, it is necessary to measure and estimate the conditions for proper operation of the battery as well as

electrical devices, through battery management. Battery monitoring makes it possible to use the full capacity of the battery in the best way to power the devices that are highly dependent on electricity. Since the main topic of the dissertation is about battery charging and its control at a certain level, in the following, we will provide a definition of charging mode [1],[5]
The solar charge controller is the heart of the solar system. The two most common types of charge controllers are:

1- Pulse width adjustment (PWM)

2- 2- Maximum power point tracking (MPPT)

Nowadays, the method of tracking the maximum power point has gained a lot of popularity compared to the rest due to the high extraction of electricity from the solar panel [2].
A consumer with a certain amount of resistance must be able to receive the "maximum power" from the panels, or in other words, the load receiving power must be equal to the maximum power point of the panels at that moment, in which case the internal resistance of the panels must be equal to the load resistance. The internal resistance of the panels is a variable parameter and depends on factors such as the amount of sunlight and the temperature of the panels. If this resistance is more or less than the load resistance, the amount of power transmitted to the load will not be maximum, in other words, the gain of the panels will be reduced. Maximum power point trackers use a variety of methods to find the maximum power point and keep solar cell efficiencies at maximum [6],[7].
With the advancement of semiconductor physics, the process of extracting energy has become more efficient these days. Maximum power point detectors may implement different algorithms and move between these algorithms regularly depending on the different operating conditions of the arrays, in particular, perturbation and observation (P&O), incremental conductivity (INC), constant voltage (CV), short current pulse. , Fuzzy Logic Control (FLC), Artificial Neural Network (ANN) and some other techniques have been reported to provide an effective energy extraction process .
Also, due to the current-voltage characteristics (I-V) Solar cells can further improve the efficiency of the energy extraction process [8].
Photovoltaic systems include photovoltaic panels and DC-DC converters such as SEPIC converters or boost-buck converters[9] ,[10]
The MPPT algorithm receives voltage and current from the solar panels and adjusts the PWM diode cycle, which is applied to change the voltage and current applied to MOSFET switches or IGBTs, to regulate voltage and current. In this paper, Buck Boost converter is used in the proposed model.
To charge the battery quickly and reduce losses, a constant current and proper voltage are required during charging.
To have a suitable constant voltage and voltage, we applied PI control after the buck converter. The proposed pattern is as follows.

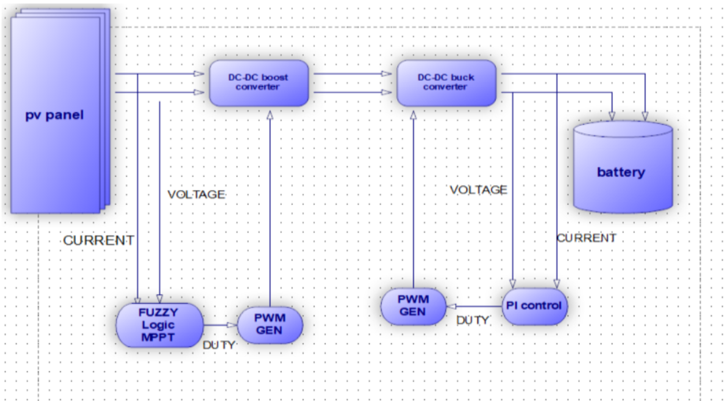

Fig.1.proposed model

2-solar cell model:

To use cells in electrical circuits, we need to have the voltage-current electrical characteristic of a solar cell. This characteristic can be obtained through the following circuit, it is enough to obtain a few points of the characteristic curve and plot it in mathematical software.

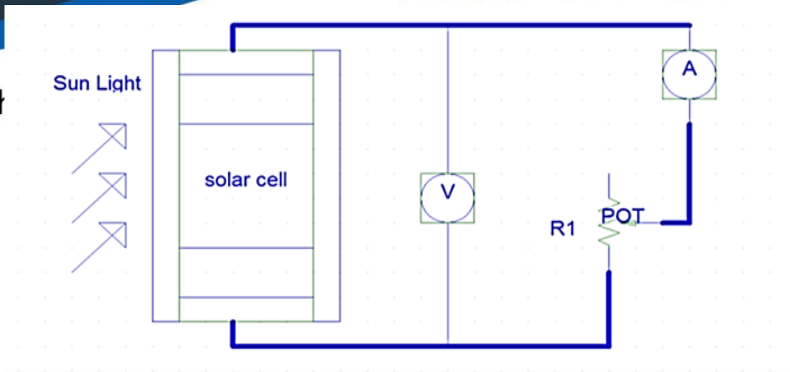

Fig.2. solar cell in electrical circuits

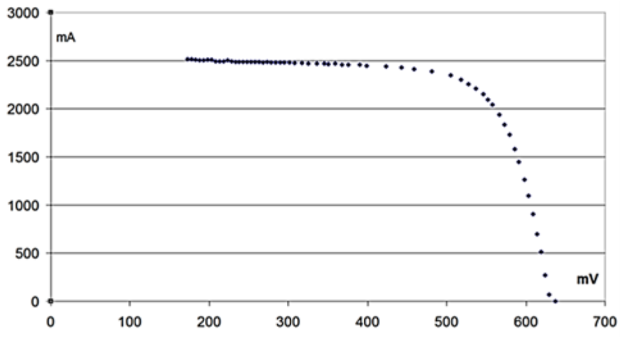

Fig.3.

Fir ... and independent sources
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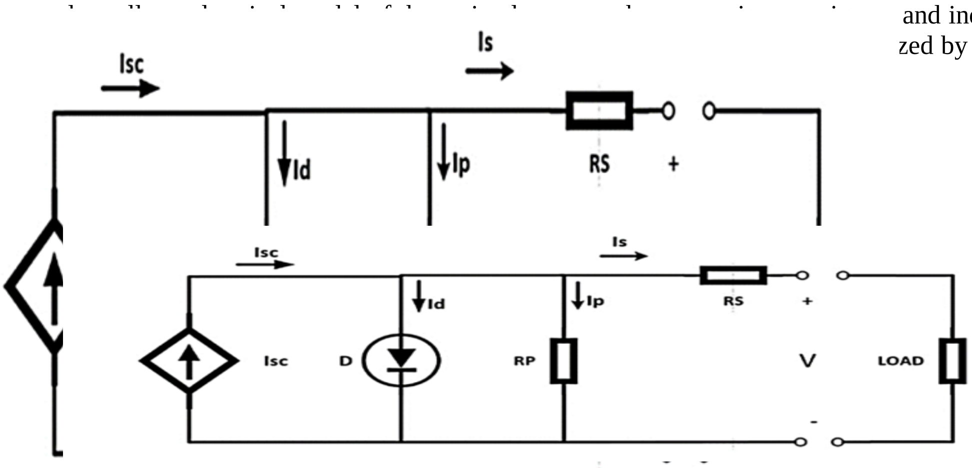


Fig.4. Electronic model of solar cell

$$I_{out} = I_{SC} - I_D \qquad (1)$$

$$I_D = I_0 * \left(e^{q}.\frac{(v + IRs)}{nKT} - 1\right) \qquad (2)$$

$$I_{out} = I_L - I_0 * \left[e^{\frac{q(v+Irs)}{nKT}} - 1\right] - \frac{V+R_s*I}{R_p} \qquad (3)$$

IL is the current of photovoltaic array Io represents the PV array reverse saturated current, q means the electron charge K is the Boltzmann constant (1.38*10−23J/K) T is the temperature of the p-n junction, n is the p-n junction curve constant.
perature of the p-n junction, n is the p-n junction curve constant [12]. The power produced by a solar cell is so low (1–1.5 W) so to get desired power, solar cells must be connected series or parallel to create PV panel.

3- Fuzzy logic controller MPPT method:

In the last decade, the use of microcontrollers with fuzzy logic control to track the maximum power of PV arrays has grown significantly [13].
An important way of intelligent control methods are methods based on fuzzy logic or fuzzy logic control. In fact, this method is optimized with the help of fuzzy controller installed in the systems to find the maximum power point voltage point depending on the design of the controller.
The main advantage of fuzzy logic controllers is the ability to work with inaccurate and nonlinear inputs and fast convergence and low oscillation at the MPP point. On the other hand, this method does not require a precise mathematical model. Fuzzy logic control generally has three stages of operation Does as shown below for the defined input.
Fuzzy input information (fuzzy fication) Set rules based on the designed table and non-fuzzy (DEfuzzy fication) [14].
Fuzzy logic control method even if it has some difficulties. But finding the maximum power point is easy. Fuzzy logic MPPT method doesn't need the knowledge about model of the system, Inputs of the fuzzy logic controller are the error of the system which is E and the change of error is CE the following equations clarify E and CE.

$$E(k) = \frac{\Delta P}{\Delta V} = \frac{P(k) - P(k-1)}{V(k) - V(k-1)} \qquad (4)$$

$$CE(k) = E(k) - E(k-1) \qquad (5)$$

where Pk is power, Vk is voltage of the PV panel and Pk−1, Vk−1 are the previous power and voltage of PV panels.

To understand fuzzy logic MPPT algorithm, you need to look at the figures.
When change in power (PK-PK-1>0) and voltage (VK-VK-1>0) are positive, to reach the MPP, the voltage should be increased. That is illustrated with red arrow in Fig. 5. When change in power is positive and change in voltage is negative, to reach the MPP, the voltage should be decreased. That is illustrated with purple arrow in Fig. 5. When change in power is negative and change in voltage is positive, to reach the MPP, the voltage should be decreased. That is illustrated with green arrow in Fig. 5. When change in power and voltage are is negative, to reach the MPP, the voltage should be increased. That is illustrated with blue arrow in fig .5. [15] ,[16] .

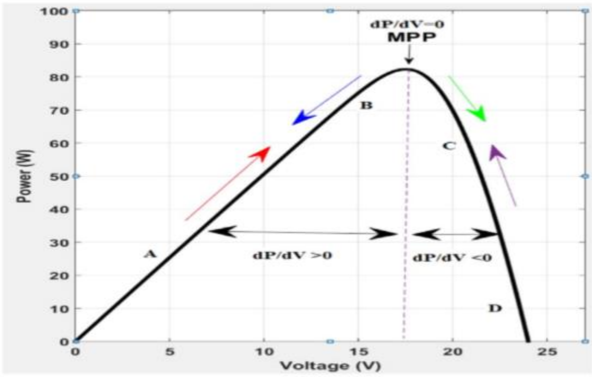


Fig.5. P-V curve for MPP tracking

The Fig. 6 is important for speed of Fuzzy logic MPPT because to compare right side of P-V characteristic curve the change of power according to change of voltage is small at left side of curve the situation must be regulated at equation of 5.

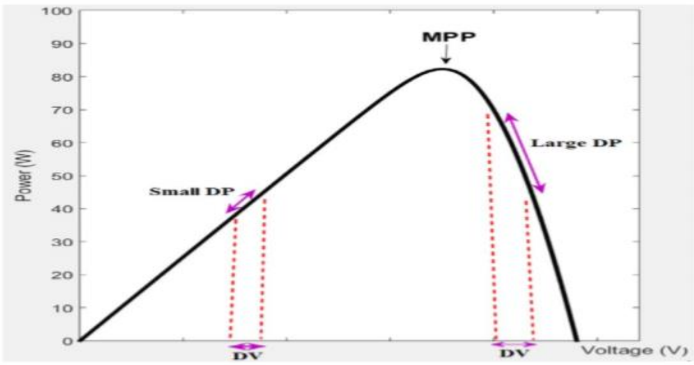
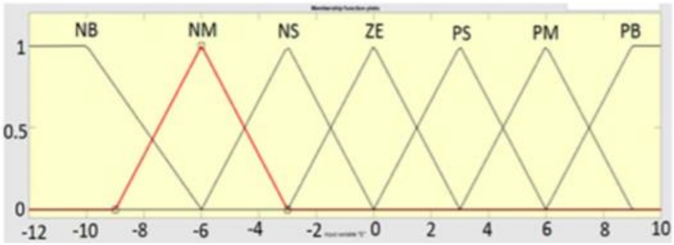


Fig.6. PV curve for MPP tracking speed

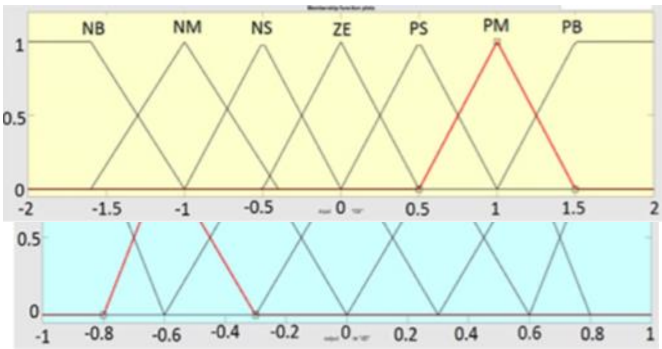
The next step is to create a rule table and membership function for fuzzy logic. The table of maximum power point tracking rules is shown in Table 1, and the membership functions are shown in Figures .7. (a, b, c).

1	E/CE	PB	PM	PS	ZE	NS	NM	NB
2	PB	ZE	ZE	ZE	NB	NB	NB	NB
3	PM	ZE	ZE	ZE	NM	NM	NM	NM
4	PS	ZE	ZE	ZE	NS	NS	NM	NM
5	ZE	NS	NS	ZE	ZE	ZE	PS	PS
6	NS	PM	PM	PS	NS	ZE	PS	ZE
7	NM	PM	PM	PM	PB	ZE	ZE	NS
8	NB	PB	PM	PM	PB	ZE	ZE	ZE

Table.1.



a



C

Fig.7.(a,b,c)

The fuzzy logic control algorithm is simulated to track the maximum power point in Simulink MATLAB.

4-DC-DC converter design:
Boost Converter:

A DC-DC converter is a converter that converts the DC current of a source from one voltage level to another, and the output voltage can be more or less than the input voltage [9].
in this system boost converter is used as MPPT circuit to operate PV panel at maximum power point. Fuzzy logic control method is applied to switch (mosfet) of boost converter to adjust duty cycle of PWM
Mosfet is used as a switch and it is in on or off state. When D is defined as duty ratio, during 0<t<DT, the mosfet is on state and the diode is reverse biased. The voltage across inductoris VL =Vin. During DT <t<T ,the mosfet is in off state and the diode becomes forward bias [17] The voltage across inductor VL =Vin -Vout Operation at the steady state condition the total change of current on inductor must be zero in a period of switching [18].

$$V_{in} = V_{out}.(1 - D) \qquad (6)$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 - D} \qquad (7)$$

We also have the following equations to calculate the inductor and capacitor of the boost converter.

$$\Delta I_L = \frac{V_{in-min}.D}{fs.L} \qquad (8)$$

$$L = \frac{V_{in}.(V_{out} - V_{in})}{\Delta I_L fs.V_{out}} \qquad (9)$$

$$C = \frac{I_{out}.D}{fs.\Delta V_{out}} \qquad (10)$$

Buck converter:

During 0<t<DT, the mosfet is in on state and diode is reverse-biased. The voltage across inductor VL = Vin-Vout when the mosfet is in off state (DT<t<T), the diode is conducting and voltage across inductor VL = -V out. In the steady state operation, the total change of current in the inductor must be zero in a switching period. PI control applied to buck converter to provide constant level current-voltage for charging battery [19] .

$$v_{out} = D.V_{in} \qquad (11)$$

$$\Delta I_L = \frac{v_{out}.(v_{out} - v_{in})}{f_s.L.v_{in}} \qquad (12)$$

$$\Delta V_{rpt} = \frac{DlI\_L}{8.fs.C} \qquad (13)$$

5-Comparison of buck-boost converter with sepic converter:

Based on studies from three sources [20], [21] and [22], Buck Boost converter was proposed for the proposed model.
In a sepic converter, in order to achieve high voltage and fast transient response, this converter must operate at a high frequency, thus increasing the switching frequency. The reverse output current of the output diode affects the switching equipment in the form of additional switching losses.
Other reverse bios problems include the management of excess temperature in the converter. Passive snub circuit can also be used to reduce reverse recovery losses, which in this case increases the voltage and current stress due to the rotational current in the resonant snub circuit, thus reducing the efficiency of the converter.

Also, according to studies, the efficiency of buck-boost converter in tracking the maximum power point is higher than

sepic converter.

6-PI control design for buck converter:

The output of the proportional-integral controller consists of the sum of the proportional and integral control operations.

$$co = \mathrm{kc}(\mathrm{E} + {}^{1}/_{T} \int E\, dt) \qquad (14)$$

The PI control is used to adjust the output voltage and power of the tank converter to charge the battery.
The parts of PI control are integral gain and proportional gain. Ziegler-Nichols method used to determine the proportional gain Kp and integral gain Ki. Proportional gain, Kp is eff ective to reduce the step up time but it is not exact solution to eliminate the steady state error. The integral controller Ki, is eff ective to eliminate steady state error [23] ,[24].

Simulation result:

The general system simulated in Simulink MATLAB consists of five general parts:
1) Solar panel
2) Boost converter
3) Solar panel maximum power point tracker
4) Buck converter
5) Load system - battery To perform the simulation,
the first part to be built is the solar panel, which should be set up based on the information in Table 2

the open circuit voltage	24V
the short circuit current	5.1A
the voltage at MPP	17.5V
the current at MPP	4.8A
the power of MPP	84W
temperature coefficient of open circuit voltage	0.36099
temperature coefficient of Isc	0.102

Table.2.

Then two inputs must be given to the panel:
A) irradiance
B) temperature

In this way the solar panel produces the desired voltage and current at its output

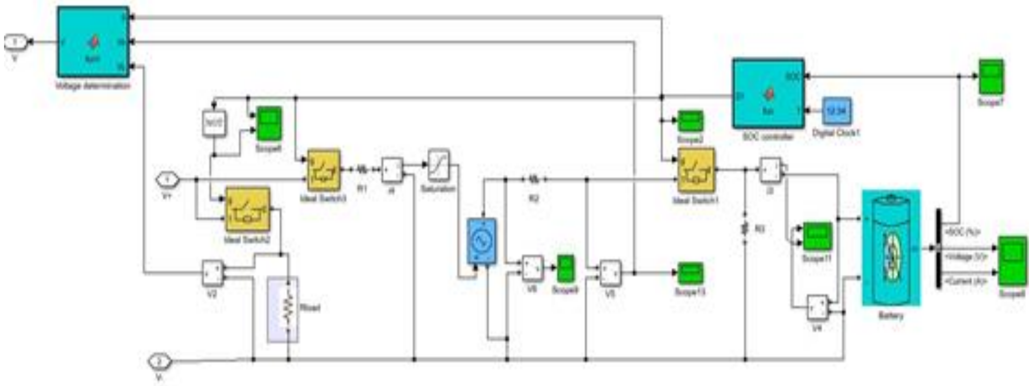


Fig.8.

The tuning frequency can be set between 20,000 and 25,000 Hz. For current changes and voltage changes, the values can be considered as approximately equal to 0.01 amps and 0.05 volts. that before the boost converter, a filter capacitor is placed after the solar panel, the value of which can be adjusted based on experience between 1000 and 2000 microfarads.

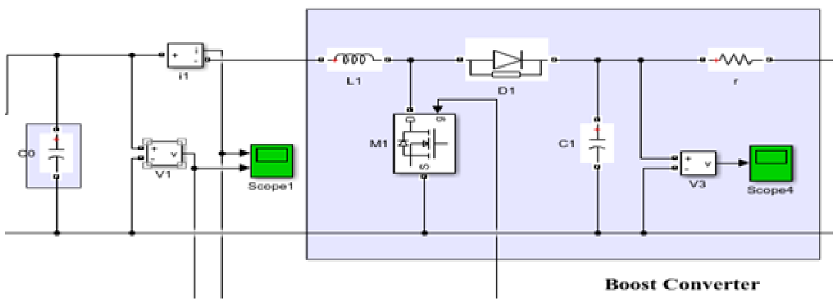


Fig.9. boost converter

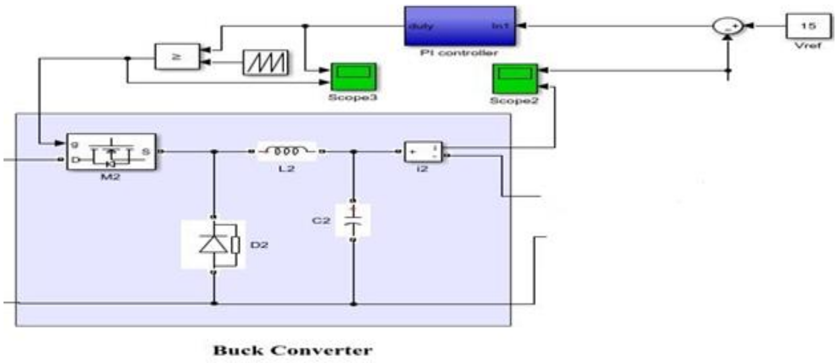


Fig.10. buck converter

How the battery system works - load This is how the battery charge status (SOC) is first checked by the battery charge controller. The control block is a MATLAB function and specifies that if the battery charge status is between 35 and 80%, the battery needs to be charged and the output signal S1 in this case is equal to 1 and activates keys 1 and 3. Slowly On the other hand, using the NOT logic gate, the input signal to key 2 becomes zero. Therefore, the load is disconnected and the output of the tank converter is connected to the battery to charge it. On the other hand, if the battery charge status is more than 80%, the battery does not need to be charged, and in this case, the opposite of the above operation occurs. Therefore, the load is connected to the output of the tank converter and the battery is disconnected.

If the load is connected to the tank converter, the output of the battery-load system is equal to the double voltage of the load using the voltage determination block. If the load is not connected, the output of the tank converter must be connected to the battery. But because the radiation level and the ambient temperature connected to the solar panel change, these changes also affect the output of the tank converter, on the other hand, the battery must be charged with a constant voltage and current. Therefore, a solution must be considered before connecting the output of the tank converter to the battery. To do this, we first hold the output current of the tank converter at a certain level by means of a limiter and then connect the output of the limiter to a current-controlled voltage converter block. This block receives current and converts the converter into a constant voltage source. Because the operating voltage of the battery is 15 volts and the voltage level of the converter is less than this value, we increase its value by adjusting resistor R2. Therefore, the output of the desired resistor is the voltage that can be used to charge the battery.

connecting the load to the buck converter (charge status is set in the battery block 85):

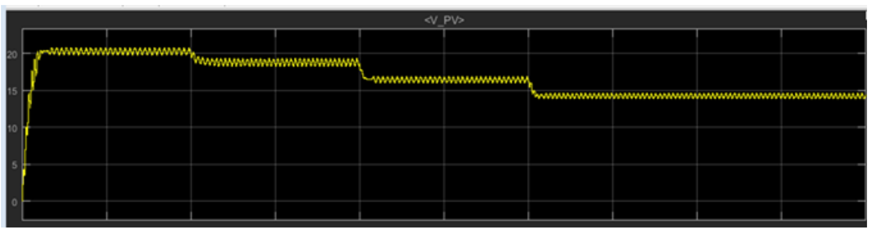


Fig.11 pv-voltage

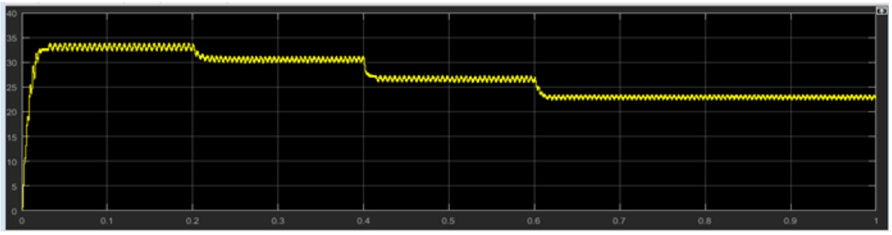


Fig.12. boost voltage

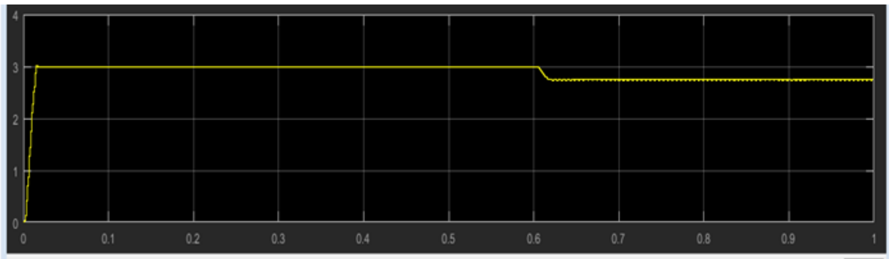


Fig.13.output buck current

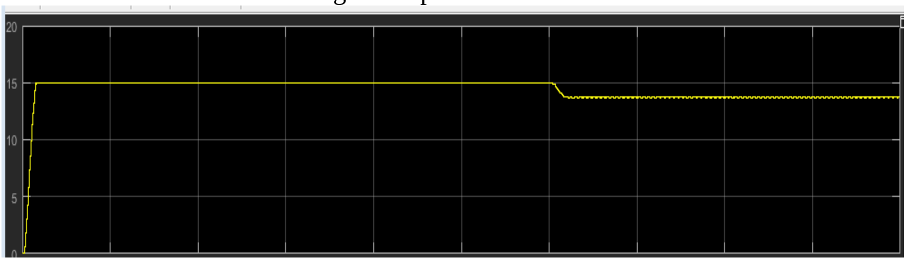


Fig.14. load voltage

the battery is connected to the buck converter (charge status is set in the battery block 50):

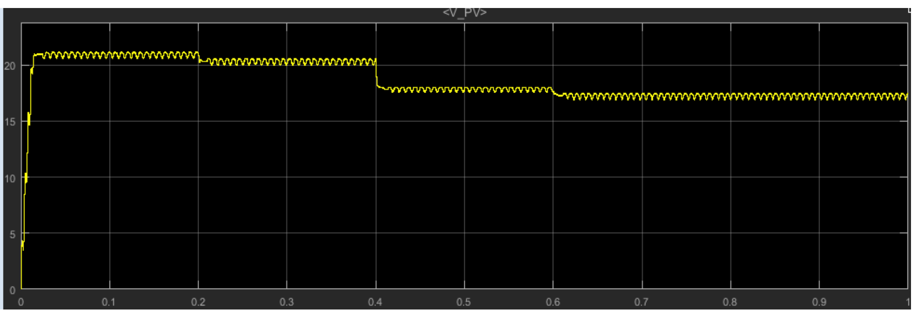


Fig.15.pv-voltage

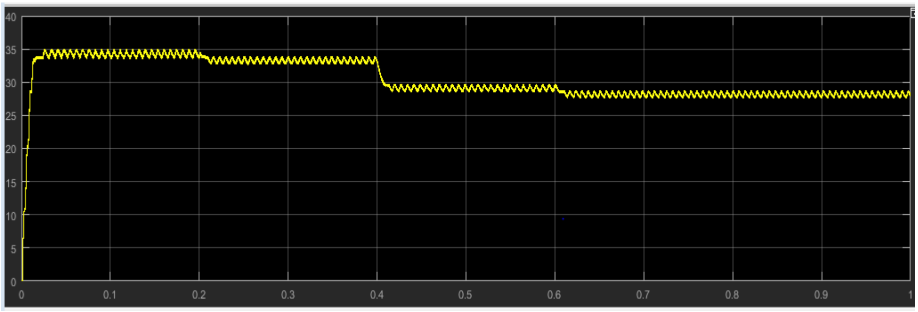


Fig.16.boost voltage

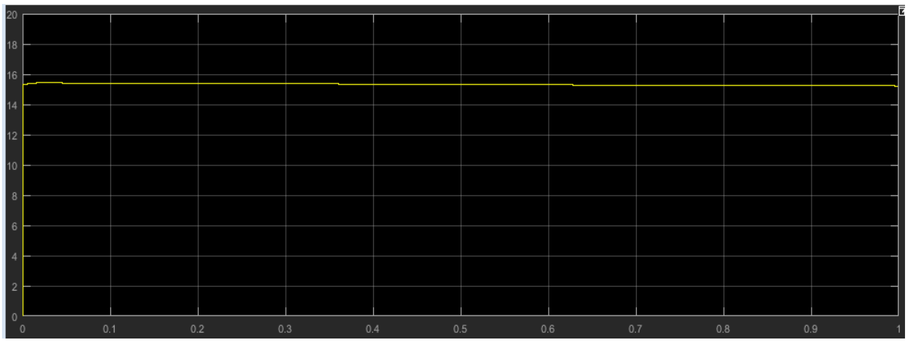


Fig.17.R_3 of voltage

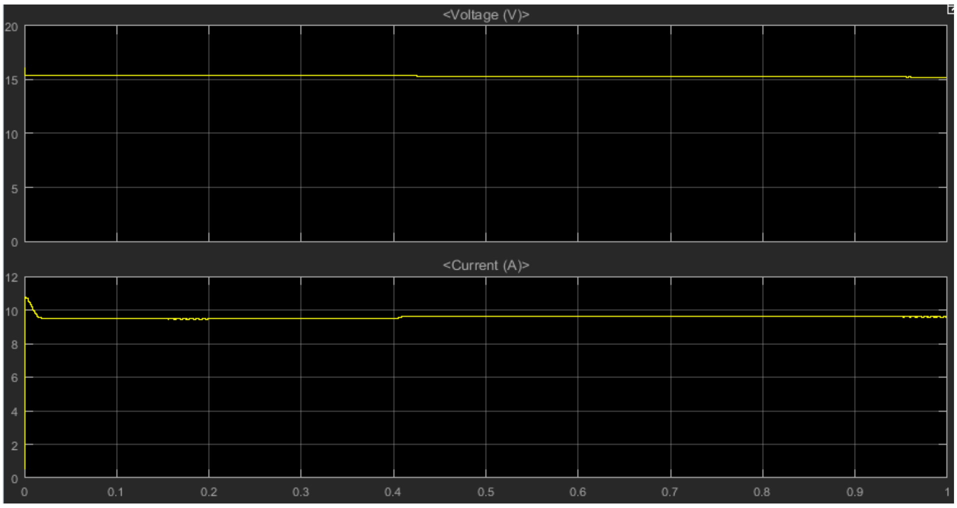


Fig.18. battery voltage

Conclusion:

By reviewing various articles, the fuzzy logic control method was considered with regard to features such as working with inaccurate and non-linear inputs and fast convergence and low oscillation at the maximum power point. This method is in the field of battery charge control compared to other methods. It has a higher efficiency.
To select the converters available in the Boost-Buck converter system, it was preferred because due to the simple implementation and also the lower cost in case of making the proposed model of Boost-Buck converter, less complexity than other converters in terms of It has productivity, which will also have an impact on costs.
The efficiency in finding the maximum power point was between 94% and 99% in the simulation. This efficiency is considerable and this model can be used to build a charge controller.

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