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Evaluating load Current and MPPT Algorithms for the Solar Energy with an Emphasis on DC systems

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Abstract

The solar energy is a main renewable energy sources which can generates the power. The present study aims to investigate the relation between PV module and the load considering a way to control upmost power point which tracks in PV module. The produced output energies present the load by PV module considering the PV module. The present study relates to MPP (maximum power point) method regarding DC-DC power convertor attempts to use MPPT algorithm with respect to the changes of sun temperature. MPPT algorithm has been used since it has a simple performance mentioned as a quick method to estimate the maximum power point. Based on voltage-based maximum power point tracker (VMPPT), PV open circuit voltage is estimated on line whereby the maximum power point is estimated in PV and the power is continuously synchronized. PV module and DC-DC converter as well as maximum power point tracking are modeled and simulated in this study.

Keywords: MPPT algorithm, DDC systems, solar energy, renewable energy.

Introduction

The importance of the renewable energy has been increased during recent years. The solar energy is the best and cheapest source of energy existing in the environment. The energy has ever been an important issue in the modern industries since lack of energy has ever been a public concern. Many studies have been conducted on the renewable energies in the unlimited sources such as the solar energy, the biomasses, the water energy generating the electricity, and the wind power. Most of these methods are applied to generate the electricity in the spaces far from the general electrical network[1]. After the oil crisis in the world, the photovoltaic (PV) systems are another considerable issue. Furthermore, human has greatly understood the concept of green energy and PV is an appropriate way of conserving the environment since it is the cleanest energy. Also, it has no destructive impact on the environment unlike the fossil fuel energy sources. It seems that emphasizing the renewable energy has a direct relation with change of the oil and gas prices as well as the environmental concerns[2].
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Photovoltaic (PV) module: A single PV module has an output voltage of around 1 and for crystal silicon (si) it is about 0/67. So, many PV networks should be connected to each other as grid to have an appropriate output voltage. If the connected networks are in the installed frames, they will be called the PV modules. To make a PV module, 36 si and 72 si cells are used in the set. A module with 36 cells to provide the battery charge of 12v and a module with 72 cells to provide the battery charge of 24v are appropriate. Although some PV systems do not use the batteries, most of these systems are used as the high voltage batteries. Although there is a need to use PV module with special voltage by high usage of DC-DC converters and increasing the efficiency, the output current will be as the single network in case of the connected PV networks while the output voltage indicates the total voltage of each network in this case. Many modules can be connected in mass or in parallel to provide the needed current and voltage[3].

PV module used in the system: MSX-60module is the selected module in the sample simulated in MATLAB software. The module composing 36 silicon solar cells consists 2 filaments series with 18 cells in each filament. MSX-60module provides 60W maximal nominal power. Table 1 indicates the typical features of MSX-60[4].

Table-1
The typical features of MSX-60

Typical maximum power(Pp)	60W
Voltage at maximum power(Vpp)	17.1V
Current at maximum power(Ipp)	3.5
Short-circuit current(Isc)	3.8
Open-circuit voltage(Voc)	21.1V
Temperature coefficient of Isc	(0.065$\pm$0.015 $/°c$
Temperature coefficient of Voc	-(80$\pm$10 $mV/°c$
Approximate effect of temperature on power	-(0.5$\pm$0.05)%/°c
Guranteed minimum Pmax	58
NOCT	49°c

PV modeling: In this regard, PV module has been used with an average complexity in this study shown in the figure and presents useful results. The module is a composition of resistance (Rs), diode (D), series resistance, and Isc. But in this case, D parameter usually is ignored since it is too small for a single module. Therefore, it does not show a normal parallel resistance. The non-linear and sun and temperature dependent PV circuit is used in the applications. After creating the voltage and current, PV circuit can create DC power or generate the AC current connected to the inverter. PV circuits are obtained as the both cases, the photovoltaic cell and the way of the cells` connectivity. In the semiconductor theory, the base equation is used to determine I-V feature of PV cell with respect to the mathematical method[4].

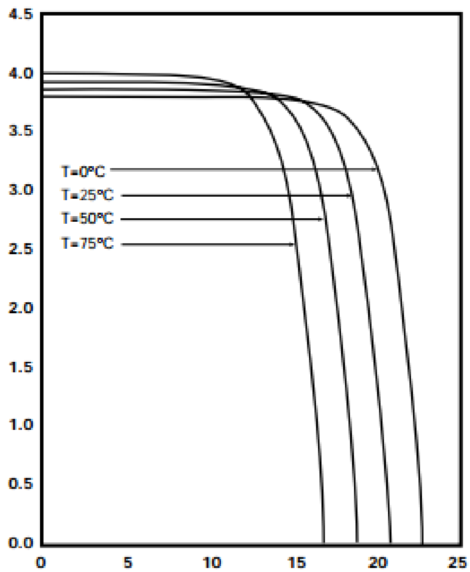

Figure-1
I-V characteristic of MSX-60

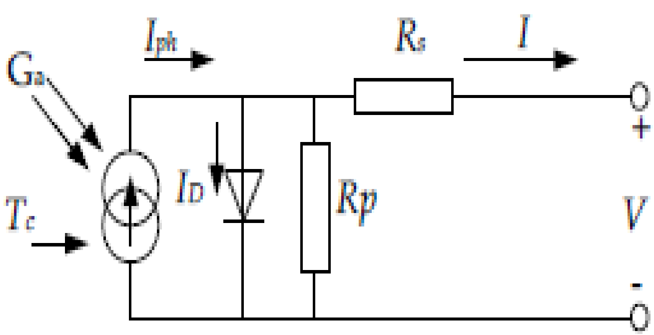

Figure-2
Equivalent circuit for single diode model

Methodology

There are topology types for DC-DC converters including buck convertor, boost convertor and boost-buck convertor. Each convertor is used for a specific application. Generally the output voltage is less than the input voltage where the buck converter is used to charge the battery[5].The boost convertor increases the output voltage more than the input voltage where the boost generally can be used to estimate the voltage level before entering to the inverting stage within a network system[6]. Some topologies can be applied for the boost and buck converters including buck, boost and Ca'K applied for Single-ended primary-inductor converter (SEPIC). A buck converter acts as the maximum power point in all the temperatures and low sun conditions. So, the boost converter is added to the buck converter and can increase the total efficiency of the power slightly[7].

**Boost converter`s performance:** The main reason is that DC-DC converter`s performance is to convert DC input from PV module to the output with a higher DC. The role of DC-DC converter in MPPT is to moderate the voltage of PV module in order to obtain MPP. Figure-3 shows the boost converter. A boost converter consists of DCh input voltage (Vin) and conductor (L) acting as a current source. T switch is parallel with the load source and can be off and on for a period of time. The energy is generated by the inducer and the output and average voltage is increased as well[8].

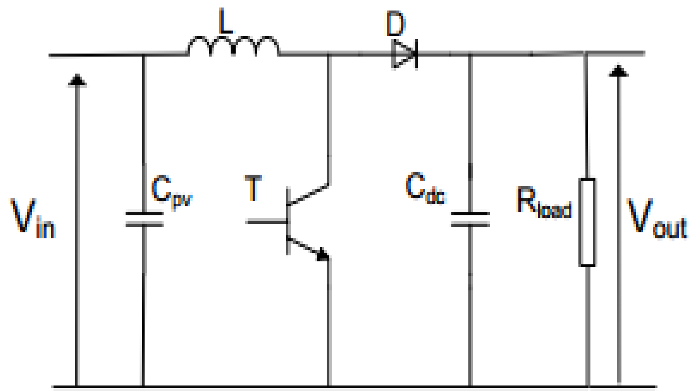

Figure-3
Step-up DC/DC converter

MPPT algorithm: The position by tracking the maximum power point is unidentified on the I-V curve. The voltage and current of the curve depend on the changes in sun and PV temperature. There is only one point in I-V and P-V curves of photovoltaic module for the maximum power point[8]. The voltage as well as the current is optimum in the maximum power point (IMPP). The photovoltaic system is better to act with the highest efficiency in the maximum power point providing the maximum output power as well[9].

The method of MPPT algorithm: There are many algorithmic techniques having their own cons and pros in this regards. Some of these algorithms discuss the maximum power voltage and current briefly[10].

Deviant hill climbing and observation (O and P): Deviant hill climbing (P and O) are two similar strategies. Theses algorithms are applied frequently since they are implemented easily and efficiently. Figure-4 shows the output power and the curve of PV module, depending to the voltage (P-V)[11].

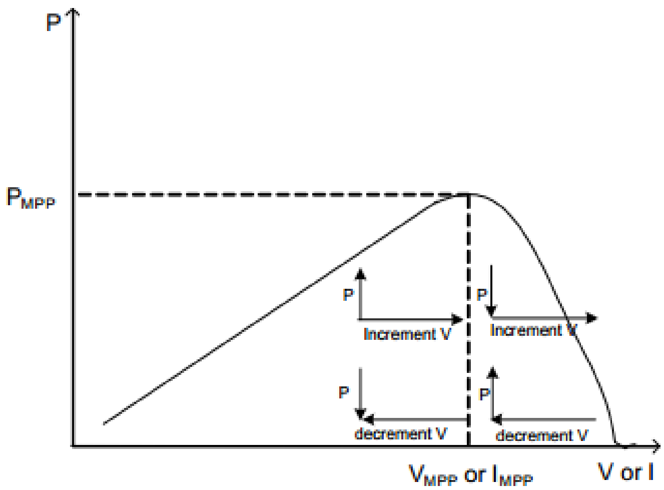

Figure-4
Purpose of perturb and observe

Recording the works will be deviant in the hill climbing method if O and P and the solar PV voltage have deviation as well while the amount of the work cycle changes the current and the output of PV circuit becomes deviant too. Figure-5 indicates the amount of the power voltage and the current. The difference between the reference voltage (Vref) and PV voltage are as an input for PI controller. After moderating the created voltage, PWM causes a signal passes through DC-DC converter[12].

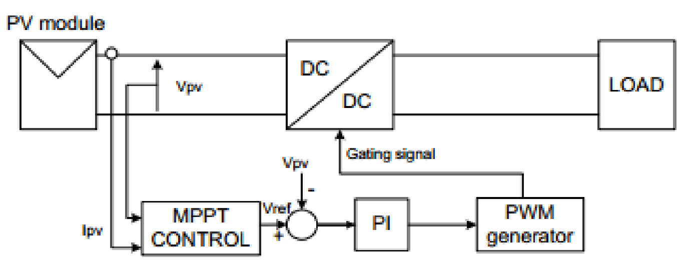

Figure-5
Block diagram of P and O for MPPT

The control process is different in the hill climbing technique and the voltage cause to create a width power module (PWM) for DC-DC converter. Figure-6 shows the hill climbing with the block diagram[12].

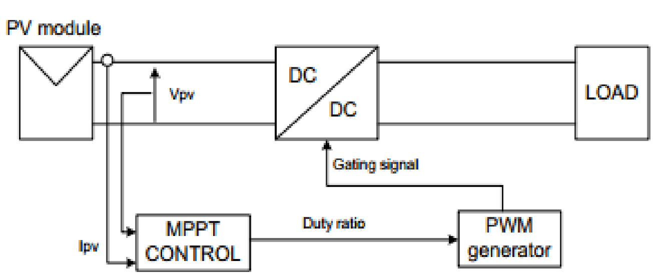

Figure-6
The Hill climbing block diagram for MPPT

According to figure-7, increasing PV voltage leads to PV power stability and the photovoltaic voltage reduction determining PV power considering the left side of MPPT. Also, if the voltage is increased in the right side of MPPT, the voltage power is decreased in this part as well. This technique can be continued up to the time that MPPT controller can obtain an optimal maximum power of PV system[13]. In P and O technique, the system will fluctuate around the maximum power point. As the sun changes are very fast, the increasing and decreasing trend will not be favorable as well. When the sun is increased, the system moves away from the maximum power point. The following figure indicates the flowchart of P and O technique. In the flowchart, PV current and voltage are inputs and then the power can be computed using these two parameters. In the boost converter, the positive worker is a control variable for simulating. In a boost converter with the deviant positive worker, PV circuit current and PV circuit voltage are also computed[14]. The amount of PV cycle and power has been defined as the first value. This load power is computed through measuring PV voltage circuit and current circuit. The amount of the power will be increased in comparison with the previous value and then the cycle in case of the comparison`s positivity. The work cycle is limited to 1 and 5 for the boost converter increasing the input voltage with respect to the existing limitations[15].

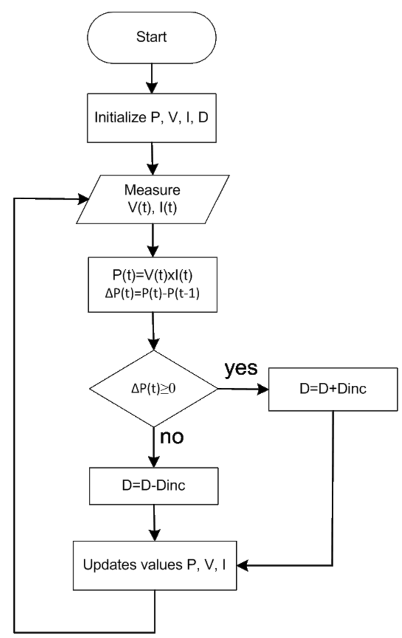

Figure-7
Flow chart for perturb and observe method

Results and Discussion

Simulating PV system using MATLAB software: Simulating PV si ma link module case: PV is used to simulate the model 6 where PV circuit is also simulated using MATLAB software.

Some parameters have been used in MPPT. The model structure is based on some input data including: Ns: the number of the connected cells to the mass, Npp: the number of the connected cells in parallel, A: the identifying factor: K: boltzmann constant value, Isc: PV module current, Kp: the voltage temperature coefficient, Ki: the short current temperature coefficient, Vmp: the voltage maximum power point in the laboratory standard conditions, Imp: the maximum current point in the laboratory standard conditions, Voc: the free alternative voltage.

Based on the data table, MSX-60 module is applied to create a file for Rs, Rp 6 and sometimes to obtain MPP. The maximum power point tracker is determined by connecting PV module and the boost converter to each other. Figure 8 shows PV module simulation[13].

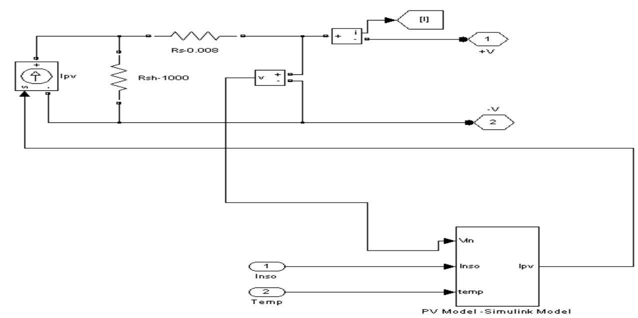

Figure-8
The photovoltaic model simulation in MATLAB

In the module simulation, the mass and the parallel specimens are determined as Nss and Npp respectively. Im value is used to simulate the load current source model to obtain the voltage and the current from the module[14].

Figure-9 indicates PV simulation which can be achieved to various powers of the alternative current. Considering the fact that PV input includes the sun and the temperature, PV module output should be the voltage and the current[15].

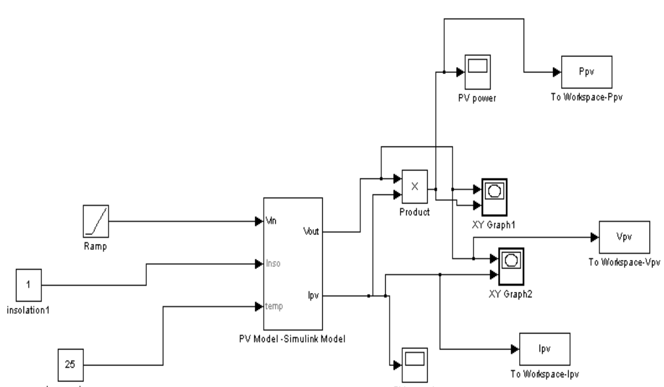

Figure-9
PV Module-Simulink Mode

Based on 6 MSX-60 PV modules, the module has a maximum power output of 60W. Figure-10 shows PV module simulation for the constant sun and the variable temperature.

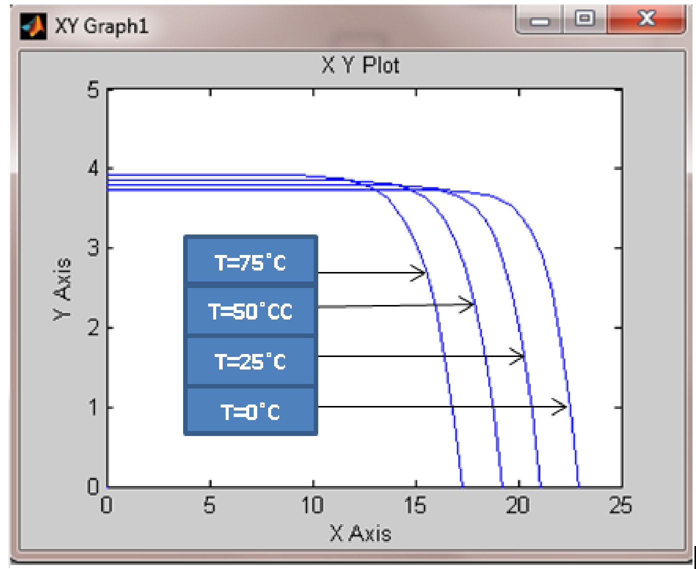

Figure-10
PV MODEL I-V characteristics various temperatures G=1 sun, Temp: 0, 25, 50,75^{0}C

Figure-11 shows the constant temperature and the variable sun of 250, 500, 750, and 1000 W/$\boldsymbol{m^2}$. Therefore, the power-voltage curve leads to determine PV maximum power as well as its reduction while the sun amount is also decreased. Figure-12 indicates the current-voltage curve with respect to the significant current reduction hence the sun is decreased[15].

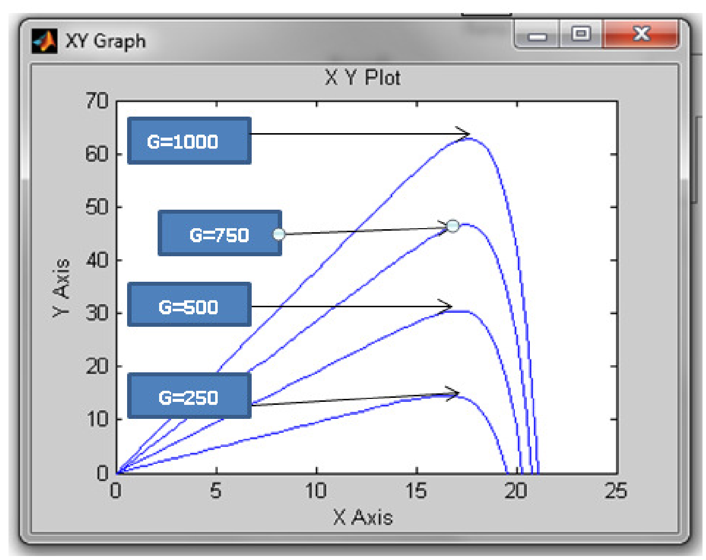

Figure-11
PV MODEL (P-V) characteristics various insulations (G=1000, 750,500,250W/m2 Temp: 25˚C)

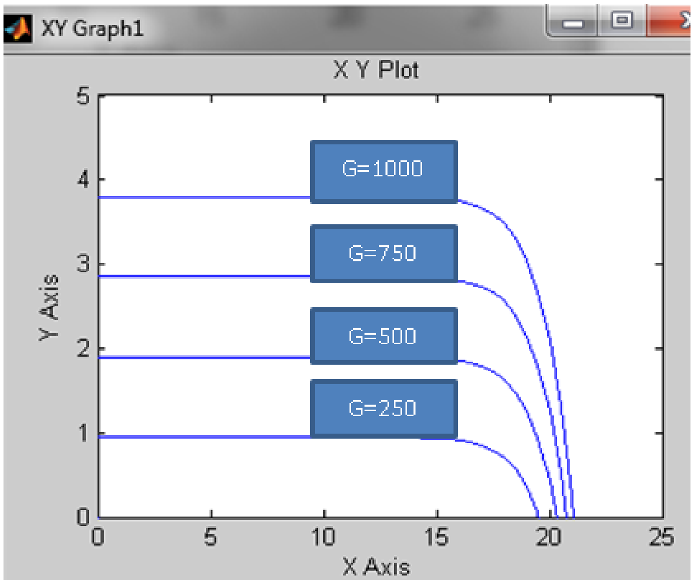

Figure-12
PV MODEL (V-I) characteristics various insulations (G=1000, 750,500,250W/m2 Temp: 25˚C)

Simulating DC-DC boost converter: To design a boost converter, there are some equations for DC voltage including

$$\frac{V0}{Vs} = \frac{1}{1 - D}$$

D is the determined work cycle of the module and control MOSFET in on and off spaces. In the case of increasing inducing mode for the inducer (L), we can have:

$$Lb = \frac{(1-D^2)DR}{2f}$$

To achieve the minimum value of the filter capacitor regarding the voltage fluctuation results, the equation as following is used:

$$C\ min = \frac{DV0}{VrRF}$$

PV module connected to the boost converter: The simulating model for DC-DC boost converter connected to PV module in the certain temperature and sun has been indicated in figure 16 where the results as following have been obtained:

The above results are in the case of 75°c temperature and 1000 W/$\boldsymbol{m^2}$ input sun and the output amount of the model is as follows:

The PV input current value (2 and182 A), The functional voltage value to the increasing converter (167), The functional input power to the increasing converter (34 and 19), The functional output voltage value from the increasing converter (26 and 19), The simulation results with the maximum power point tracing voltage (VMPPT)

Table-2
The values of boost converter

Inductor	$120\mu H$
MOSFET	IRF P460
Capacitor	$330\mu F$
Resistive load	$50\Omega, 50W$
DC voltage	19.7

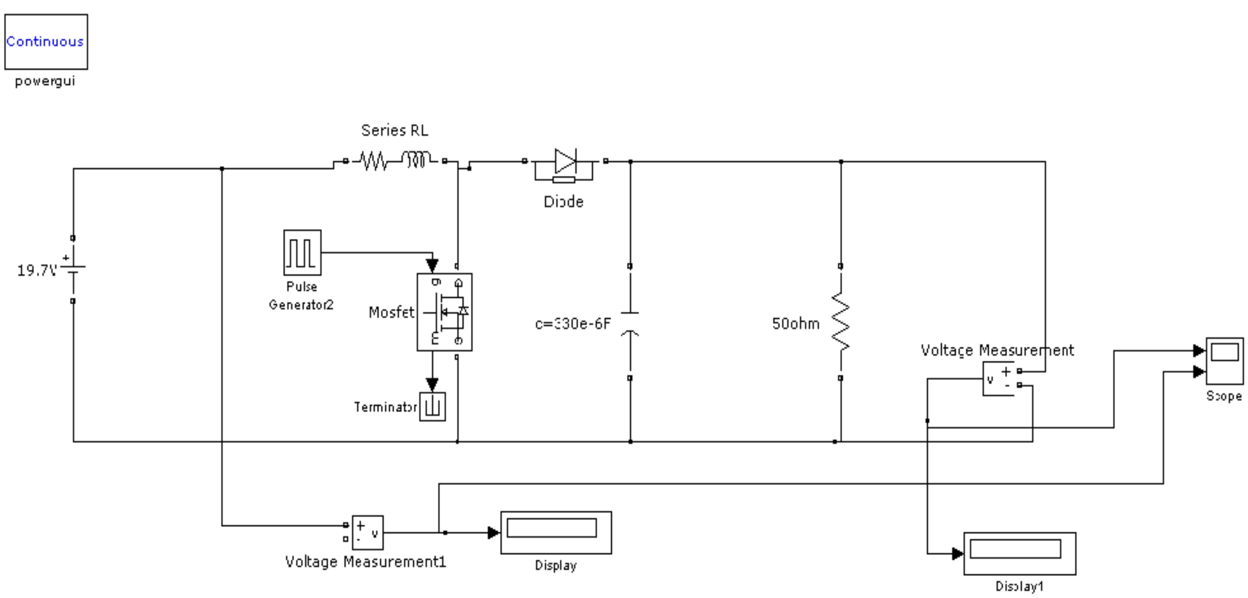

Figure-13
Step-up DC-DC converter

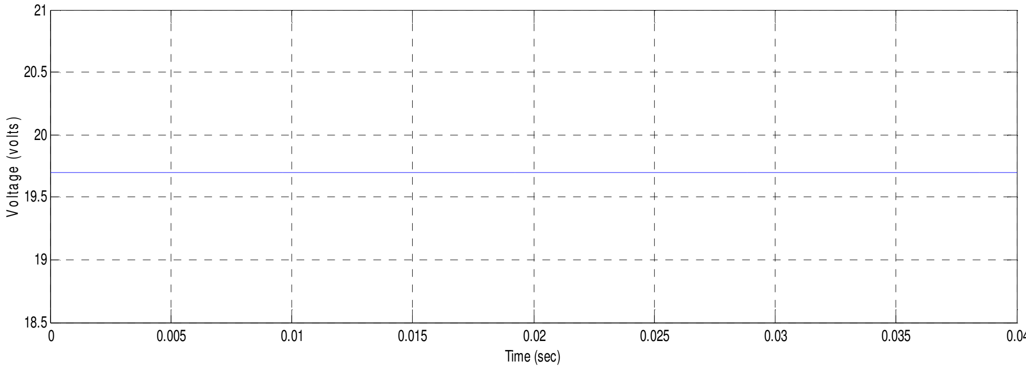

Figure-14
The DC-DC boost converter input voltage

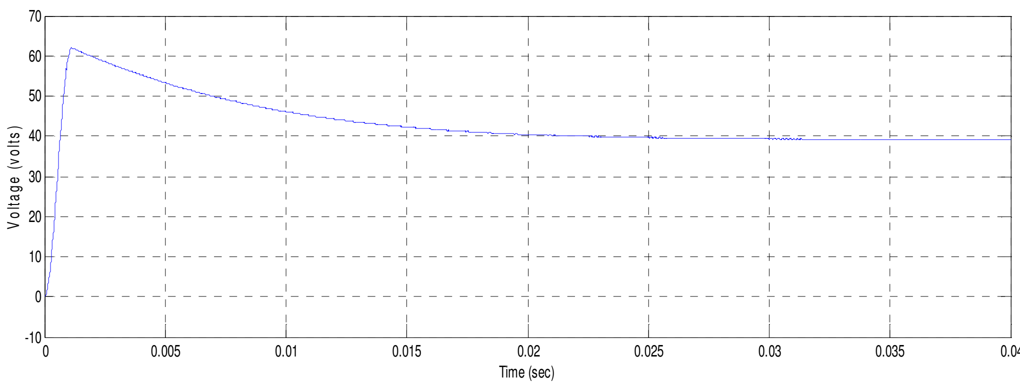

Figure-15
The DC-DC boost converter output voltage

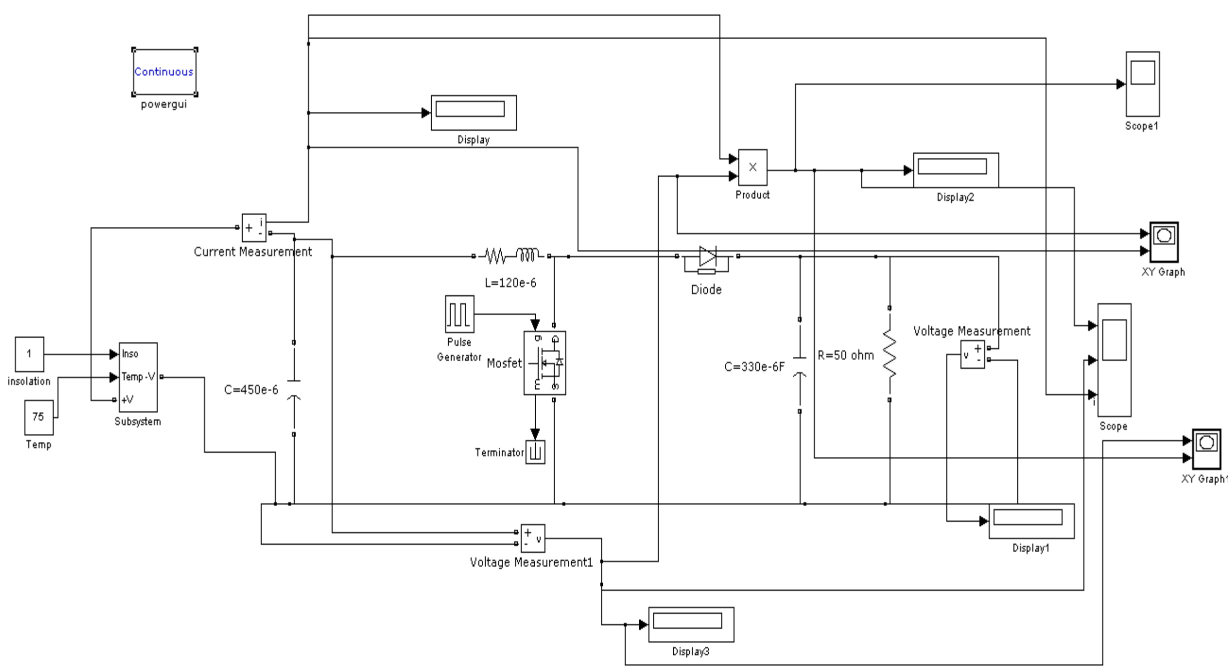

Figure-16
PV model with step-up converter

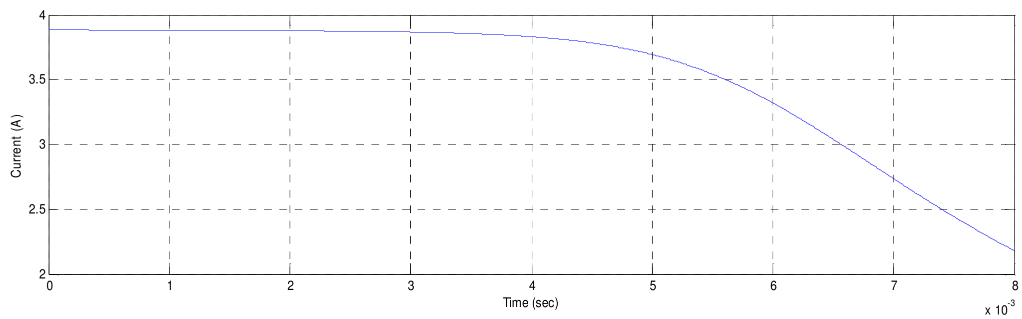

Figure-17
The input power in developed model

Conclusion

A quick and simple independent photovoltaic system was investigated in the study. PV system is derived from the mathematical model. An increasing DC-DC boost converter with PV module in different temperatures and suns were presented. The model was simulated using MATLAB software. The findings indicated that PV module was highly consistent with an actual photovoltaic module. VMPPT algorithm was applied as a quick and simple approach to estimate MPP. Considering the topology of VMPPT-PV maximum power estimation increases the output power of the photovoltaic. Based on the VMPP tracker, PV alternative open circuit voltage was estimated online and then the maximum power point was also computed. The power function point was also synchronized continuously. The power impedance is in the function point of PV module to moderate the load as it is connected to PV. But, it is not a warranty for the fact that the maximum power will be obtained from PV module. DC-DC converter was applied to moderate the loads` impedance optimally in PV module by changing the work cycle. This simulation was applied based on the mathematical equations and the applied model was designed using MATLAB software. Based on the findings, the maximum power point can significantly increase the obtained power from PV module and the system efficiency is greatly higher than the system without MPPT.

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