INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)

www.ijprems.com
editor@ijprems.com

Vol. 04, Issue 07, July 2024, pp: 858-868

e-ISSN : 2583-1062

Impact Factor: 5.725

MATLAB SIMULATION OF GRID –TIED SOLAR PV SYSTEM AND ADVANCED MPPT ALGORITHM

Mr. Rishikesh dongre[1], Asst. Prof. Nivedita Tiwari[2]

[1]Scholar, Truba Collage of science and technology, Bhopal M.P., India.

[2]Assistant Professor, Truba Collage of science and technology, Bhopal M.P., India.

ABSTRACT

There are many power point tracking (MPPT) algorithms that can be used to optimize the power of solar photovoltaic (PV) systems. The main differences between these algorithms are the use of digital or analog, ease of design, sensor requirements, convergence speed, validity interval, and hardware cost. Therefore, choosing the right algorithm is very important for users because it affects the electrical efficiency of the photovoltaic system and reduces costs by reducing the number of solar panels to generate energy. Model parameters are shown light-generated current IL 6.0092 A, Diode saturation current I0 6.3014e-12 A, Diode ideality factor 0.94504, Shunt registration Rsh 269.5934 ohms, Series Resistance Rs0.37152 ohms. In fact, using electricity at the module level can return 10.0% to 30.0% or more of annual operating costs, depending on the configuration and type of equipment. Of the three converter topologies listed in this article, the synchronous boost-buck converter makes the most sense because it can be used with a variety of PV modules and configurations. In addition, it can be seen from calculations, simulations and experiments that the performance of this topology is higher than other topologies.

Keywords- Photovoltaic, Maximum Power Point Tracking System (MPPT), PV System, DC/DC converter, Perturb & Observe (P&O).

1. INTRODUCTION

Solar photovoltaics are one of the fastest growing technologies, growing at an average annual rate of 40% last year. Since solar energy is unlimited and can be found anywhere in space, solar photovoltaic and solar thermal energy have the greatest potential of all renewable energy sources. People discovered the power of the sun's rays as far back as B.C., when the telescope was used to light the lamp. They noticed it from the 3rd century. The photovoltaic effect was discovered by French scientist Edmond Becquerel in 1839 but was not described until its publication by Albert Einstein in 1905, for which he won the Nobel Prize in 1921. Solar cells for space applications have been developed since the 1950s. Terrestrial applications of photovoltaic power generation were popular in the early 1970s. Today, many photovoltaic power plants are operating all over the world, from megawatts for calculators to many electrical home appliances to factories of tens of megawatts. Currently, the majority (almost 90%) of PV modules are made using wafer-based crystalline silicon, but there are other new technologies gaining importance in the PV market. Thin film modules have begun to make their way into the photovoltaics industry in recent years, taking advantage of the shortage of photovoltaic grade silicon and increasing profits in the photovoltaics industry. Concentrated photovoltaic technology attempts to reduce the number of semiconductors needed by using a small area, high-performance cells and inexpensive polymer lenses to view the cells' light. These systems generally require a solar tracking system and are suitable for medium to large photovoltaic systems in areas with high amounts of direct sunlight. Photovoltaic energy has the potential to play an important role in the transition to sustainable energy use in the 21st century, meets most of the world's energy and electricity needs, and is expected to be an important energy technology of this century. This has spurred research into developing not only advanced solar panels but also more efficient energy converters that can extract almost 100% of the energy from photovoltaic arrays.

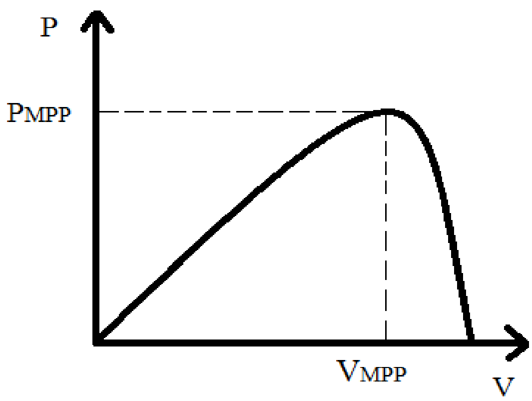

Fig. 1.1: Typical Power-Voltage curve for a photovoltaic cell

Research shows that solar panels convert 30-40% of the energy problem into electricity. Maximum power point tracking algorithms are required to improve the performance of solar panels. Perturbation analysis (ramping method) of MPPT, increasing conductivity, fractional short circuit current, fractional open circuit voltage, fuzzy control, neural network control, etc. There are different methods such as. It is generally used due to its ease of use, short time to follow MPP, and some other compromises. As for sudden changes in weather conditions (irradiance level), since the MPP changes, P&O treats this as a change in MPP due to impact rather than negative, sometimes causing the MPP calculation to be incorrect. However, the incremental method eliminates this problem because the algorithm uses two voltage and current models to calculate the MPP. However, compared to the previous algorithm, this algorithm is more complex rather than more efficient, so its cost increases. So we need to strike a balance between complexity and business. Generally, it is the maximum value for Buck topology, the minimum value for Buck-Boost topology and the minimum value for Boost topology. Another analog system, TEODI is also useful in case of connecting multiple solar modules at the same time and the way it works is that the electronic equipment is connected together by the action of the practical operation of the same operating system. It is very easy to use and works well in both constant and variable weather conditions.

[1].Chihchiang Hua and Chihming Shen. A simple method combining time control and PI compensator is used to monitor the maximum power (MPP) of the solar panel. The storage system works close to MPPT, allowing the maximum amount of electricity to be transferred from the solar panel. Step-down, step-up and step-down converters are tested using a simple Maximum Output Power (MPPT) algorithm. The performance of systems with different converters was compared. This article is used to measure the response of step-up and step-down converters of MPPT systems. The report states that the bucket generator is the best choice for use in MPPT systems due to its higher efficiency.

[2] K.H. Huseyin, I. Muta, I. Hoshino &, M. Osakada. . The study has been conducted through simulations and experiments, and the results show that the improved conductivity (Int Cond) algorithm can effectively monitor MPOP even under rapidly changing weather conditions, and is better, more efficient than the ordinary process of whole photovoltaic power conversion. load. Power release method for maximum power point tracking of solar panels. This method uses only one variable, the load current, to determine maximum power. This method is suitable for battery applications where MPPT is required. The algorithm is implemented with a simple circuit. The article discusses the design of boost converters in detail. for MPPT. Microcomputer control of family photovoltaic power supply control system.

1.2 creation Of DC –DC Converter :-

DC-DC switching converter may be divided into two sorts, the non-remoted one and isolated one. Non-isolated converters are most effective, consisting of dollar converter, improve converter, dollar-boost converter, Cuk converter, Sepic converter, Zeta converter and so on. they have comparable topologies which can be consisted of two switches, inductors, capacitors and the load. by means of connecting these components in distinctive methods, different voltage conversion functions can be obtained. buck converter converts an enter voltage to a lower output voltage. improve converter converters an enter voltage to a better output voltage. greenback converter, improve converter, Cuk converter, Sepic converter and Zeta converter are all capable of offer an output voltage with each higher and decrease value than the enter voltage, which integrate the features of greenback converter and raise converter in a single circuit. isolated converters are cumbersome because of the use of transformers, but in a few instances that the primary strength supply operates at a fairly excessive voltage and/or could be very noise, isolation of the burden from the enter deliver is essential to keep reliable operation of the load. common remoted converters are Fly-again converter, forward converter, Push-pull converter, full-bridge converter, 1/2-bridge converter and so forth. The Fly-lower back converter is based on the dollar-boost converter, and ahead converter is primarily based at the greenback converter. The desk three.1 proven the converter switching losses, efficiency, and alertness.

Table 3.1 Shown the converter switching losses, efficiency, and Application

Converter	R_{in}	θ	**Switching Loses**	η	**Application**
Buck	$\frac{1}{D^2} * R_L$	$0 \le \theta \le \phi$	High	Low	Low load-high module voltage
Boost	$(1-D)^2 * R_L$	$\phi \le \theta \le 90^\circ$	High	Low	High load-low module voltage
Buck-Boost	$\frac{(1-D)^2}{D^2} * R_L$	$0 \le \theta \le 90^\circ$	Low	High	Nearly matched battery and module voltage
Cuk	$\frac{(1-D)^2}{D^2} * R_L$	$0 \le \theta \le 90^\circ$	Low	High	Same rating battery and module voltage
Sepic	$\frac{(1-D)^2}{D^2} * R_L$	$0 \le \theta \le 90^\circ$	Low	High	Higher rating battery and module voltage

1.3 The Dc-DC greenback Converter

The call "greenback Converter" presumably evolves from the fact that the enter voltage is bucked/chopped or attenuated, in amplitude and a lower amplitude voltage appears on the output. A dollar converter, or step-down voltage regulator, presents non-isolated, transfer-mode dc-dc conversion with the blessings of Simplicity and low fee.

The most usually used switching converter is the buck, which is used to down-convert a DC voltage to a lower DC voltage of the identical polarity. The buck converter circuit converts a higher dc input voltage to lower dc output voltage. The basic dollar dc-dc converter topology is shown in parent. 1.2. It consists of a controlled switch Sw, an out of control transfer D (diode), an inductor L, a capacitor C, and a load resistance R.

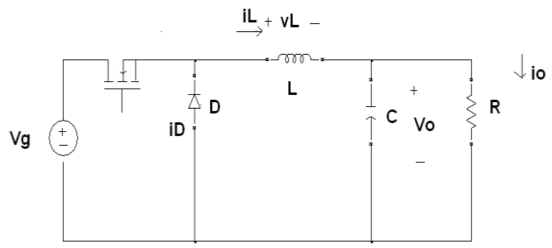

Fig. .1.2: Basic Buck Converter

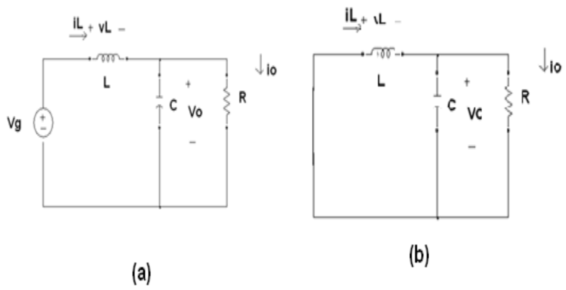

Fig. 1.3 (a) The switch is turned on (b) The switch is turned off

1.4 DC/DC Converters That Aren't Isolated

There is no dc voltage isolation between the input and the output of a non-isolated converter, which often uses an inductor. It is not necessary for dc isolation between input and output voltages in the great majority of applications. There is a dc route connecting the input and output of the non-isolated dc-dc converter. One of the main uses for non-isolated dc-dc converters is in battery-powered systems that do not require the ac power line. Another popular non-isolated use is point-of-load dc-dc converters, which get their input power from an isolated dc-dc converter, such a bus converter. These dc-dc converter integrated circuits (ICs) often employ an external or internal synchronous rectifier. Their output inductor is often the only magnetic component, making it less prone to produce electromagnetic interference.

1.5 BUCK CONVERTER (STEP DOWN)

The average output voltage (Eo) of a step down (BUCK) converter is less than the d.c. input voltage (Edc). The average output voltage of the transistor may be adjusted by adjusting its duty-ratio. The corresponding waveform of voltage and current for the inductor's continuous current flow. At time t=0, transistor T1 is turned on. The route filter's inductor is filtered by the rising supply current. load resistance and filter capacitor. As a result, during that time, the inductor stored energy.

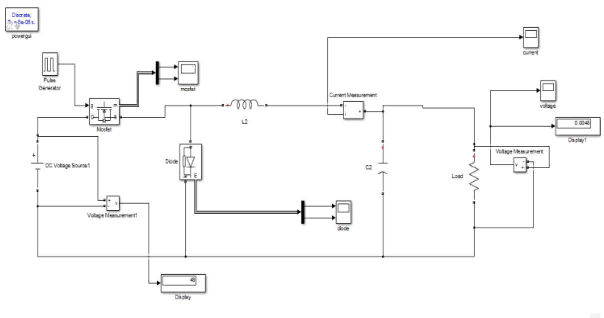

Fig. 1.4 Matlab Model for Buck Converter

When the transistor is on, the diode is reverse biased and the input supplies power to the load and the inductor. Now at time t = T1 transistor is off. During the transistor closure, the inductor current flows through the loads L and C and the freewheeling diode Df, so that the diode Df is open. The output voltage is greatly reduced by using a low-pass filter consisting of an inductor and a capacitor. The corner frequency of the low-pass filter is selected well below the switching frequency, thus increasing the importance of the switching frequency ripple in the output voltage. Depending on the switching frequency, filter inductance and capacitance, the inductor current will not continue.

MPPT solar charge controller deploys MPPT algorithm to increase the current value from PV modules to DC-DC converter. MPPT is a DC-DC converter that works by taking the DC input from the PV module, converting it to AC, and then converting it back to a different DC voltage and current to suit the PV module.

Examples of DC-DC converters are: A boost converter is a power converter where the DC input voltage is lower than the DC output voltage. This means the PV input voltage is lower than the battery voltage in the system. This means that the PV input voltage is greater than the battery voltage in the system. This means the PV input voltage is lower than the battery voltage in the system. In general, the transformer is required when the battery voltage is less than or equal to 48 V. On the other hand, if the battery voltage is greater than 48 V, a power converter should be selected. All applications such as powering the grid, charging batteries or generating power benefit from MPPT. In these applications, the load may require more energy than the photovoltaic system can provide. In this case, the energy conversion is used to power the photovoltaic system. The MPPT solar charger is designed for off-grid solar power generation such as stand-alone solar power generation, solar home and solar water pump.

Main goal:

- Develop a high-performance MPPT strategy suitable for the rapidly changing environment of Northern Europe to be effective in changing conditions

- Develop diagnostic capabilities for photovoltaic devices that can be used as electricity. Panel features Provide information about the system operation so that immediate repairs can be made in the event of a fault. Due to the non-linear I-V characteristics, the power output of the solar photovoltaic system depends mainly on the nature of the connection.

1.6 MPPT Technology: - Many research projects have been carried out to achieve faster, better and more accurate MPPT. MPPT system is divided into indirect control algorithm and direct control algorithm. The operation of the indirect MPPT algorithm is based on calculating the PV cell voltage at maximum power using the measurement model and theory. There are many types of applications for this technology and some of them are listed below. In this case, depending on the battery temperature, the MPP voltage should be higher in winter than in summer. It is calculated by dividing the voltage by a constant (e.g. 0.8 for silicon cells). Measure open circuit voltage continuously. These measurements are made by interrupting the load for short periods of time, such as 1 millisecond every two seconds. 4.1.2 Direct MPPT algorithm. In these MPPT algorithms, the optimal operating point is determined by measuring the current, voltage or power of the photovoltaic panel. Therefore, these methods can prevent performance from changing over time for various reasons and allow for more follow-up. These algorithms use the following formula. Obtain the maximum module power and set the operating voltage corresponding to this power. In practical use, it is easier to measure the output current of the DC/DC converter and increase the maximum value. In this way, the desired goal can be achieved. Here the operating voltage is varied in small steps over time and the increase in module power or current is measured. Therefore, the beginning of the increase or decrease is directly determined and accepted as the operating point. If the power or current increases with each step of the voltage increase, the tracking direction is forward, otherwise it is backward. In this way the maximum power point is determined and the operating point oscillates around the actual MPP. Mathematical equation for tracking maximum power point. Instead of monitoring MPP based on library or pre-recorded data or simply using numerical equations based on known PV properties, direct control methods use instantaneous measurement of PV voltage or current to find MPP independent of the switching process. , temperature and component degradation. Classic P&O (P&O a), Modified P&O (P&O b), Three Point Comparison (P&O c), Constant Voltage (CV), Incremental Conductivity (IC), Open Circuit Voltage (OV)) and short current pulse (SC) as follows compare: Experimental MPPT technology. Traditional and improved landscape MPPT techniques, namely Perturbation and Observation (P&O), Advanced P&O, Incremental Conductivity (INC) algorithms are discussed.

1.7 Perturbation and Observation Perturbation and Observation (P&O) is the simplest method. Here we use voltage meter, which is just a sensor to know the PV array voltage, so it is low in cost and easy to use. The algorithm has very little time, but when it gets too close to the MPP, it does not stop at the MPP and continues to perturb in both directions. When this happens, the algorithm is already very close to MPP and we can create the necessary constraints or use the wait function, which will increase the time complexity of the algorithm. Perturbation and analysis method, also known as perturbation method, is the most widely used MPPT algorithm in the photovoltaic products industry. This is essentially a "trial and error" approach. The photoelectric controller slightly increases the input value of the inverter output power and then detects the actual output power. If the output voltage increases, it will continue to increase until the output voltage begins to decrease; At this time, the controller reduces the input value to prevent the PV output from being distorted due to the quality of the fault characteristics of the PV. Although the P&O algorithm is easy to use, it also has some problems, such as the photovoltaic generator cannot work at maximum power even if there is a certain power due to slow trial and error, the photovoltaic system will always work in oscillation mode. . Sunny conditions cause yield fluctuations. It reacts poorly to rapid environmental changes. Tracking errors may occur because P&O cannot distinguish power changes between two consecutive power cycles due to changes in the environment or interference in the algorithm itself. The revised P&O models easily overcome these shortcomings. However, this method does not take into account rapid changes in irradiance level (and hence changes in MPPT) and treats these as changes in MPP due to interference, ultimately the calculated MPP is incorrect. To avoid this problem, we can use the boost method.

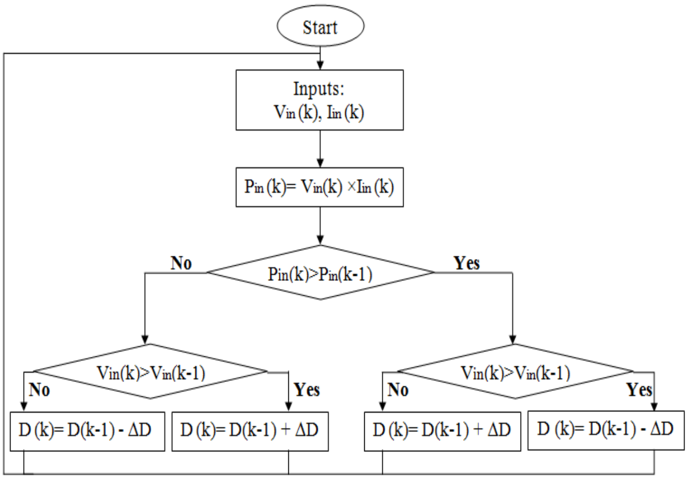

Fig. (1.5): - flowchart for the Perturb & Observe method.

Benefits:

P&O is very popular and most commonly used in practice because of

1. Its simplicity in algorithm.
2. Ease of implementation.
3. Low cost
4. It is a comparatively an accurate method

Drawbacks:

There are some limitations that reduce its MPPT efficiency. They are,

1. It cannot determine when it has actually reached the MPP. Under steady state operation the output power oscillates around the MPP.
2. It cannot always operate at the maximum power point due to the slow trial and error process, and thus the maximum available solar energy from the PV arrays cannot be extracted all the time.
3. The PV system always operates in an oscillating mode which leads to the need of complicated input and output filters to absorb the harmonics generated.

1.8 Results:- In this block diagram the solar pv array has 66 parallel strings and 5 series connected modules per string. The module Array Type selected in MATLAB is sun power SPR-3.5E-WHT-D. The Penal specifications are maximum power 305.226 W per panel, open circuit voltage Voc 64.2V,voltage at maximum power point Vmp 54.7 V, Temperature Coefficient of Voc-0.27269 %/deg.C, Cell per module 96,short circuit current 558A, Temperature Coefficient of Isc0.061745 %/deg.C.

Model parameters are shown light-generated current IL 6.0092 A, Diode saturation current I0 6.3014e-12 A, Diode ideality factor 0.94504, Shunt registration Rsh 269.5934 ohms, Series Resistance Rs0.37152 ohms.

I-V and P-V Characteristics Module Array type sun power SPR-3.5E-WHT-D is shown in fig. ()the sun radiation is selected for standard conditions minimum radiation is 250W/m2 and maximum radiation 1000W/m2. The V-I Characteristics of penal generated voltage is 310 V and the current is 100A at 0.25kW/m2 and voltage is 325 V and

Vol. 04, Issue 07, July 2024, pp: 858-868
e-ISSN : 2583-1062
Impact Factor: 5.725

the current is 400A at 1 kW/m2. The V-I Characteristics of penal generated voltage is 310 V and the current is 20000W at 0.25kW/m2 and voltage is 325 V and the current is 100000W(10to ti power 4) at Max. 1 kW/m2.

For the PV array there are two input is required for input1 is sun irradiance in W/m2 and input 2 cell temperature in deg. C. the input 1 is selected for ramp up/down irradiance 1000-250W/m2. And the temperature Ramp up/down irradiance 25-50 deg. C.

The MPPT Parameter for Pertube and Observe Algorithm is initial value for Buck converter duty cycle output (Dinit) is 0.5, Upper limit for Buck converter duty cycle (Dmax) 0.58, Lower limit for Buck converter duty cycle (Dmax) 0.38, increment value used to increase/decrease (DeltaD)3e-4. Enable MPPT is Step time 0.3 sec.,Initial Vale 0, Final Value 1.

Buck converter implements a buck power converter using the following modelling techniques 1. Switching devices: The converter is modeled with IGBT/diode pairs controlled by firing pulses produced by a PWM generator.

2. Switching function: The converter is modeled by a switching function controlled by firing pulses produced by a PWM generator (0/1 signals) or by firing pulses averaged over a specified period (PWM averaging: signals between 0 and 1).

3. Average model (D-controlled): The converter is modeled using a switching-function model directly controlled by the duty cycle signal. A PWM generator is not required.

Switching devices Technique is the most accurate, while Average model (D-controlled)technique yields to the fastest simulation. The Switching function techniques are well-suited for real-time simulation. We selected the Average model (D- controlled) the parameter are shown Diode on-state resistance 1e-3 ohms, diode snubber resistance 1e6 ohms.

The buck converter results are shown in fig. () to fig. ()

Buck Converter

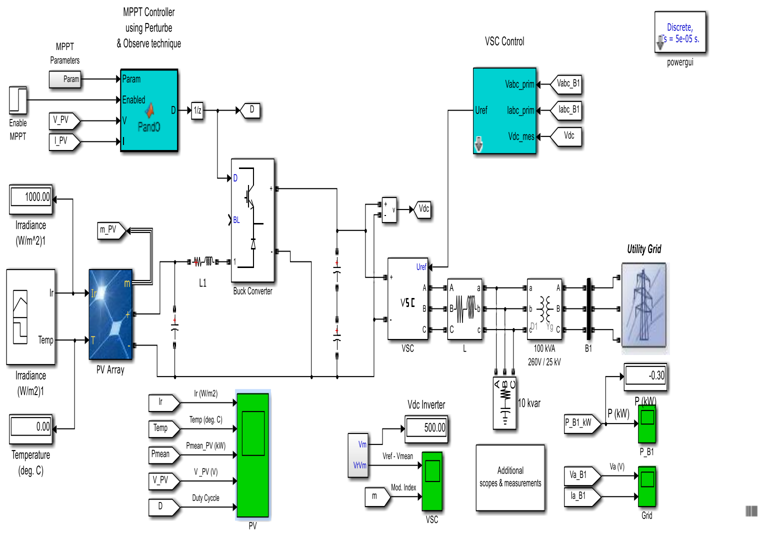

Fig. 1.6 MATLAB Simulation Model for Buck Converter using P&O method

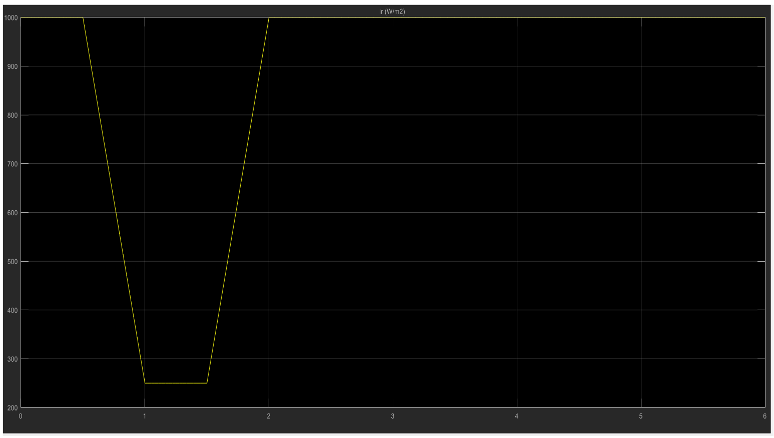

Fig.1.7 MATLAB Simulation Result for Buck converter Solar Panel Radiation in Ir(W/m^3)

INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
www.ijprems.com
editor@ijprems.com
Vol. 04, Issue 07, July 2024, pp: 858-868
e-ISSN : 2583-1062
Impact Factor: 5.725

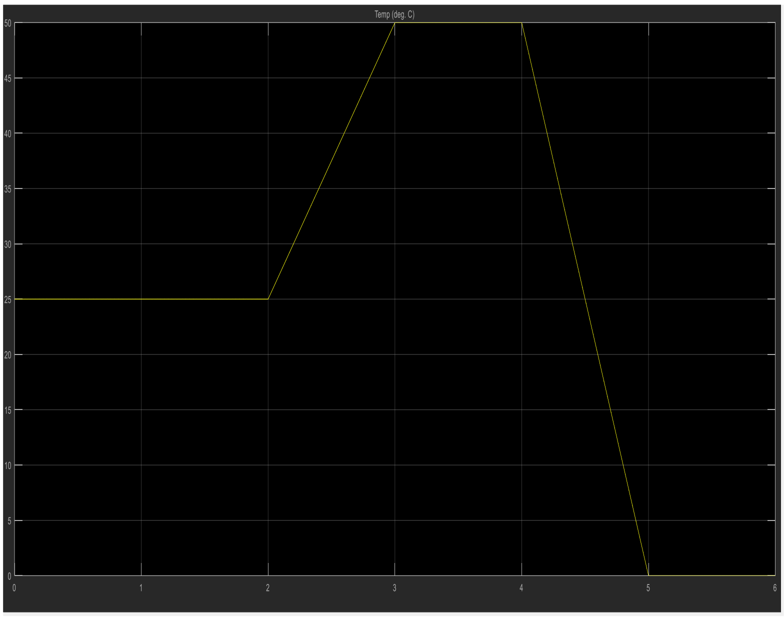

Fig.1.8 MATLAB Simulation Result for Buck converter Solar Penal Temperature (Deg. C)

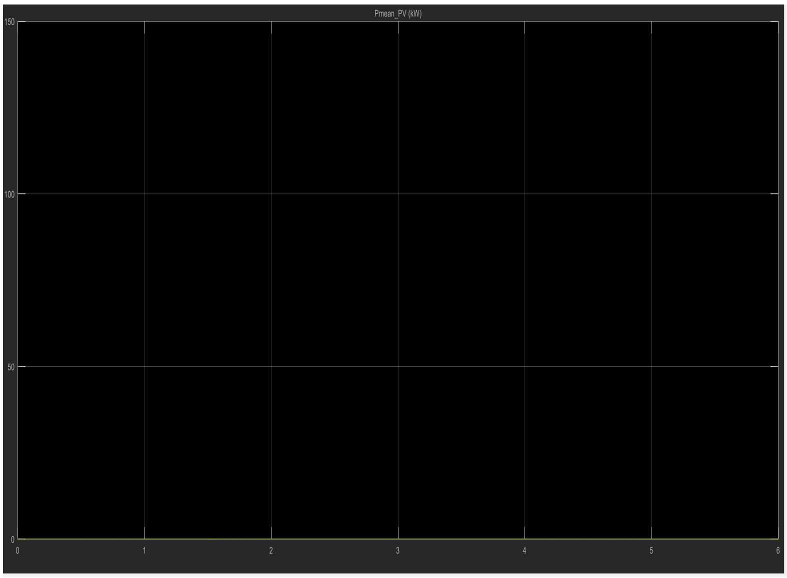

Fig. 1.9 MATLAB Simulation Result for Buck converter Solar panel Mean Power in KW

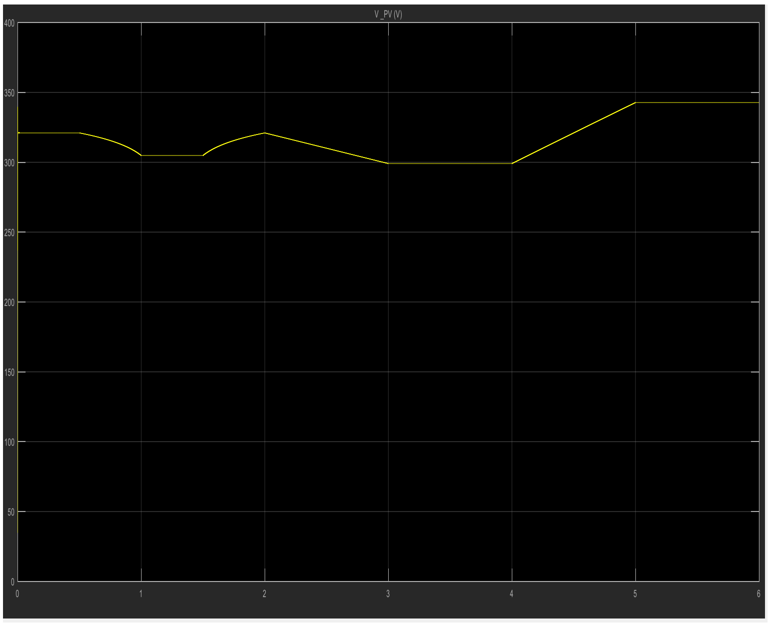

Fig.1.10 MATLAB Simulation Result for Buck converter Solar Panel Voltage (Volt)

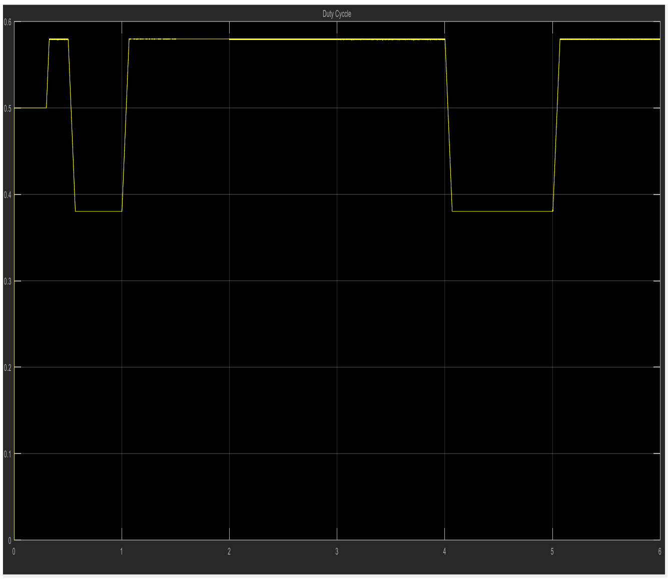

Fig. 1.11 MATLAB Simulation Result for Buck converter Duty Cycle from P&O controller

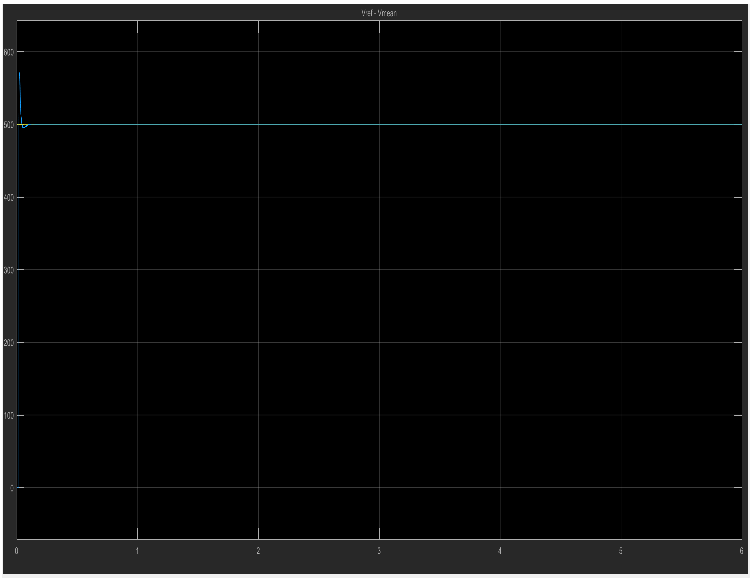

Fig. 1.12 MATLAB Simulation Result for Buck converter Mean output Voltage (VOC inverter)

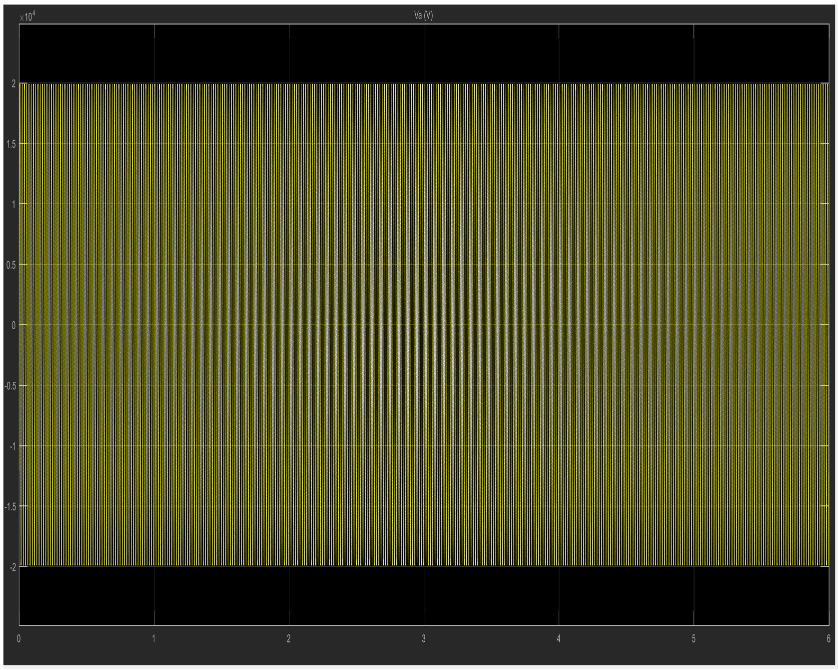

Fig.1.13 MATLAB Simulation Result for Buck converter Va Volt (V)

e-ISSN : 2583-1062

Impact Factor: 5.725

Vol. 04, Issue 07, July 2024, pp: 858-868

Fig. 1.14 MATLAB Simulation Result for Buck converter maximum Power output (KW)

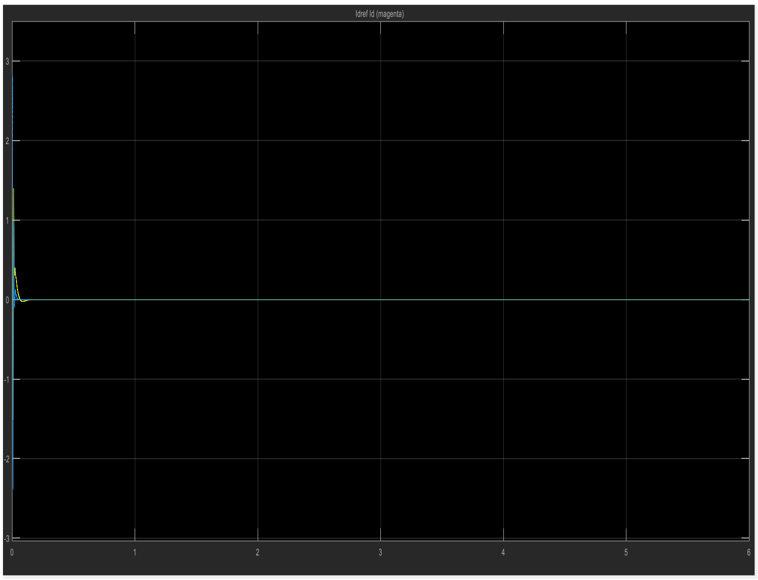

Fig. 1.15 MATLAB Simulation Result for Buck converter current connected to grid

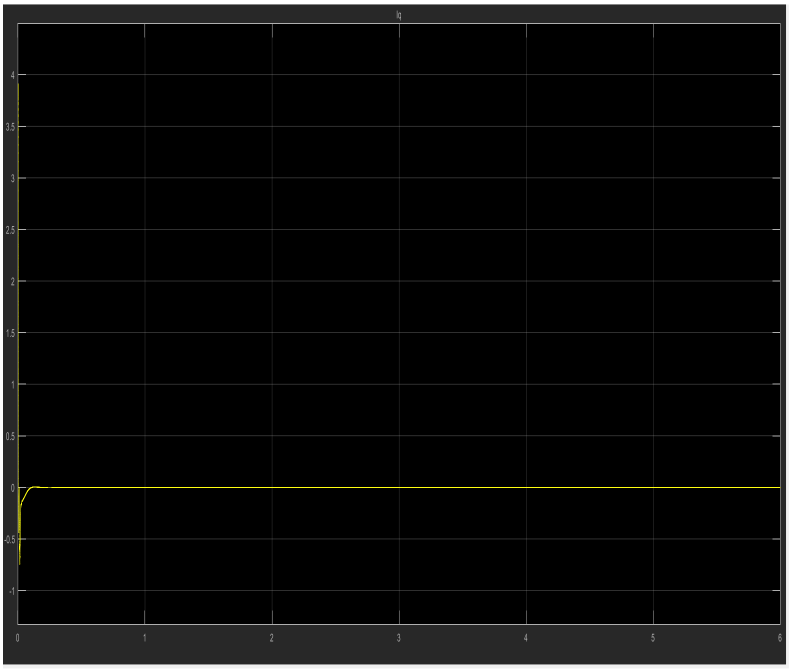

Fig. 1.16 MATLAB Simulation Result for buck converter VSC control idiq (pu)

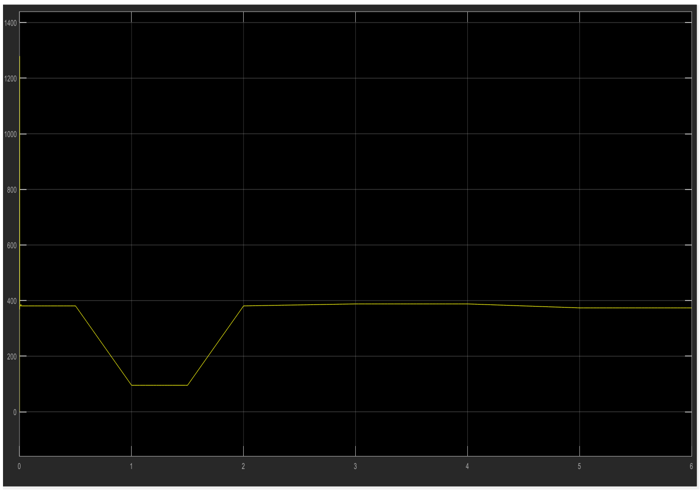

Fig. 1.17 MATLAB Simulation Result for buck converter Diode Current

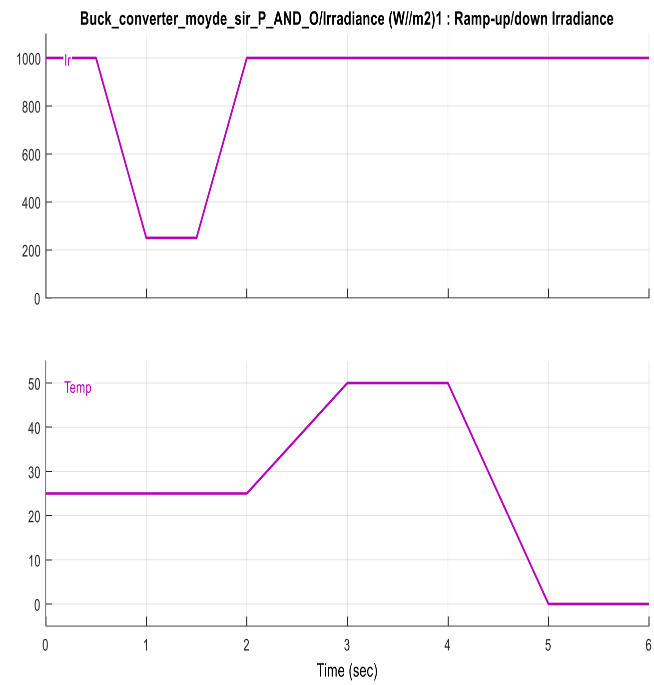

Fig .1.18 Result for Buck converter Ramp up/down irradiance and Temperature Curve

2. CONCLUSION

Current optoelectronic systems have many disadvantages. In some cases, the power output of conventional photovoltaic arrays can be greatly reduced and the lost power cannot be recovered. Integration of DC/DC voltage levels (especially boost-buck converters) into PV arrays will increase performance and eliminate many of the problems that arise today. In fact, using electricity at the module level can return 10.0% to 30.0% or more of annual operating costs, depending on the configuration and type of equipment. Of the three converter topologies listed in this article, the synchronous boost-buck converter makes the most sense because it can be used with a variety of PV modules and configurations. In addition, it can be seen from calculations, simulations and experiments that the performance of this topology is higher than other topologies. Although the designed boost-buck converter can reach a high efficiency of 99.4%, the selected topology makes it difficult to control and add many components, thus increasing the overall cost. As explained in this article, choosing the right product is important, especially when you are trying to get better results. In fact, this equipment is so important that even a percentage decrease in photovoltaic module efficiency can cause the grid to lose megawatts. There are many trade-offs between price, size, and performance when choosing this product. If the cost is too high or the efficiency is too low, there is no point in integrating the design into the optoelectronic module, especially if parallel grid is accordingly not possible. However, as PV module efficiency increases and new technologies become available, DC/DC converters with MPPT algorithms will become important in growing PV modules as alternative energy sources of electricity.

3. REFERENCE

[1] TrishanEsram, Patrick L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques", IEEE Transactions On Energy Conversion, Vol. 22, NO. 2, June 2007, pp 439-449.

[2] Chihchiang Hua and Chihming Shen, "Control of DC/DC Converters for Solar EnergySystem with Maximum Power Tracking".

[3] K. H. Hussein et al, "Maximum Photovolatic Power Tracking: An Algorithm forrapidly changing atmospheric conditions," Proc. Inst. Elect. Eng. vol. 142, pt. G, no. 1,pp. 59–64, Jan. 1995.

[4] C.R. Sullivan and M.J. Powers,"A High-Efficiency Maximum Power Point Trackingfor Photovoltaic Arrays in a Solar-Power Race Vehicle", IEEE PESC'93, 1993, pp.574580.

[5] B.K. Bose, P.M. Szczesny and R.L. Steigerwald,,"Microcomputer Control of a Residential Photovoltaic PowerCondictioning System", IEEE Trans. on Industry Applications, vol. IA-21, no. 5,Sep. 1985, ppll82-1191.

[6] Xuejun Liu and A.C.Lopes,,"An Improved Perturbation and Observe Maximum Power Point Tracking Algorithm for PV Arrays" IEEE PESC '2004, pp.2005-2010.

[7] D. P. Hohm, M. E. Ropp,"Comparative Study of Maximum Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking Test Bed",IEEE,2000.pp.1699-1702.

[8] Mohammad A. S. Masoum, HoomanDehbonei, and Ewald F. Fuchs, "Theoretical and Experimental Analyses of Photovoltaic Systems With Voltage- and Current-Based Maximum Power-Point Tracking", IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 17, NO. 4, DECEMBER 2002.

[9] C. Sungur, "Multi-axes sun-tracking system with PLC control for photovoltaic panels in Turkey," Renewable Energy, vol. 34, no. 4, pp. 1119–1125, 2009.

[10] J. Schmid and H. Schmidt, "Power conditioning for photovoltaic power systems," in Handbook of Photovoltaic Science and Engineering, A. Luque and S. Hegedus, Eds., pp. 871–873, John Wiley & Sons, New York, NY, USA, 2003.

[11] T. Tafticht, K. Agbossou, M. L. Doumbia, and A. Cheriti, "An improved maximum power point tracking method for photovoltaic systems," Renewable Energy, vol. 33, no. 7, pp. 1508–1516, 2008.