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Implementation of MPPT Techniques for a High Step-up Converter with Voltage Multiplier Module based Photovoltaic System

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Abstract

Renewable energy systems such as Photovoltaic system generate low output, thus, dc/dc converters are widely employed in many renewable energy applications to improve the output voltage. But due to leakage inductance, the conventional step-up converters cannot achieve high step-up conversion with high efficiency. Thus A concept of high step-up conventional converter for photovoltaic system has been explained in this paper. The most important improvement of this step-up converter is that as it is operated with the help of voltage multiplier module, it does not depend on the value of extreme duty ratio. This high step-up converter is designed based on dc-dc boost converter and coupled inductors. This work also proposed the application of Maximum Power Point Tracking (MPPT) techniques to PV system for improvement in output power and overall efficiency. The experimental setup for a high step-up based solar system is worked in Matlab and the results are compared for different types of MPPT techniques which shows that the Fuzzy logic based MPPT controller can meet the load easily and have fewer fluctuations around maximum power point; also this method has well regulated PV output power and has high efficiency when compared to Perturb and Observe and Incremental Conductance methods.

Keywords: Coupled Inductors, High Step-up Converter, Maximum Power Point Tracking (MPPT) Techniques, Photovoltaic (PV) Array, Voltage Multipliers

1. Introduction

DUE to the increasing the requirement of electricity, and restricted availability and high levy of non-renewable sources, the Photovoltaic (PV) energy conversion system has becomes an substitute as it is freely available, pollution free, and has less running and low maintenance cost. Consequently, the utilization of PV energy systems has to be increased for standalone and as well as grid-connected modes of PV systems.

The characteristics of Photovoltaic (PV) are non-linear due to various weather conditions, different seasons and its installation cost is comparatively high. A major aspect for obtaining high efficiency of the systems is to drive the PV system near Maximum Power Point (MPP) so to gain in the region of maximum power of PV array. Figure 1 shows a photovoltaic system with high step up converter.

Basically, the previous conventional step-up converters were not efficient to attain high step-up conversion of energy at cost of high efficiency due to the elements used in the converter configuration. And also Maximum Power Point Tracking (MPPT) techniques are used for improving the overall working output of PV systems. Also a power converter, having high efficiency is considered to draw maximum power output from solar panel.

This paper had focused on developing an efficient MPPT controller for PV module systems by merging a new design of high step-up boost converter controlled by a different MPPT methods such as fuzzy and Incremental Conductance algorithm. The major advantage of this converter is that, it is characterized by a low input current ripple and low conduction losses. Therefore this proposed converter makes suitable for high power application. Also, due to capacitor Cb leakage energy is used and sent

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to output terminal. The converter achieves the high step up voltage gain with is required for renewable energy systems.

2. Photovoltaic Module

Solar energy can act as a major source for generation of light energy. This conversion is done by the means of Photovoltaic effect. The devices which are adopted to convert light energy into useful electrical energy by making use of Photovoltaic effect are referred to be called as Solar cell. Solar cell is also commonly known as Photovoltaic cell. The combination of more number of solar cells is generally referred to be called as solar module or solar array. The output power of solar module is high when compared to solar cell. Due to this solar cells are combined to form solar module to meet the required load demand. PV panel, batteries, an inverter, converter and interconnected wires are required for successful installation of Photovoltaic module.

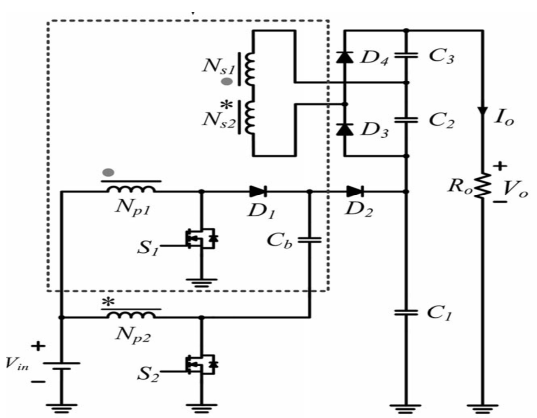


Figure 1. PV array system with high step-up converter.

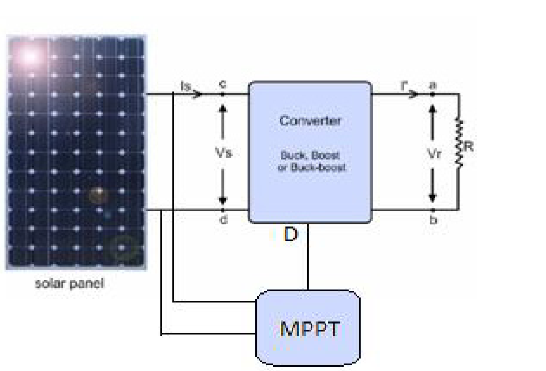


Figure 2. Photovoltaic Module system.

3. Maximum Power Point Tracking Techniques

The following MPPT techniques are most widely used for various types of solar applications such as air craft's, vehicles based on solar, etc.

- Perturbation and Observe MPPT technique.
- Fuzzy Logic (FL)-Based MPPT Technique.
- Incremental Conductance MPPT Technique.

3.1 Perturbation and Observation/Hill Climbing MPPT Technique

Hill climbing implicate in perturbation of duty cycle ratio of the connected power converter, where as P and O technique involves in regulating voltage of PV array. When PV array bridged to power converter it pertubates the duty cycle of connected converter. As a result the values of both voltage and current of the PV array pertubates.

From Figure 3, it can be observed that increasing the voltage will increases the power when operating on left of

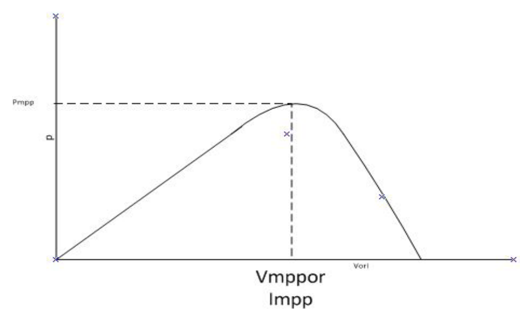


Figure 3. PV characteristics curve.

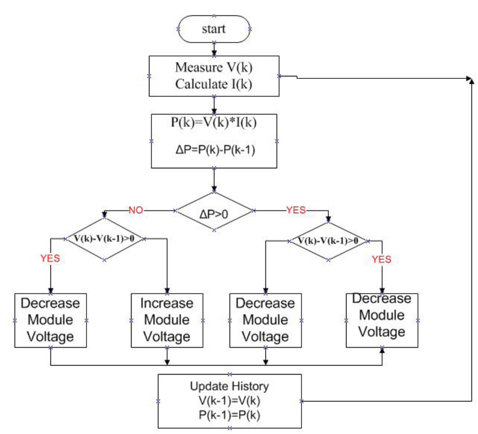


Figure 4. Flow chart representation of P and O technique.

MPP and decreases the power when operating on right of MPP. Therefore if there is an increment in power the subsequent perturbation should be positive. If there is decrease in power the subsequent perturbation should be negative.

a(k) = Perturb value of duty cycle
a(k–1) = Historic value of a(k)
ΔP = P(k)–P(k–1)

Measure the value of V(k) and I(k). As V, I values are known, calculate P(k). Then calculate ΔP, where ΔP = P(k)-P(k-1). Depending on this value there will be two possible cases of operation. If ΔP>0 then difference of V(k) and V(k-1) is calculated. Decrease the module voltage if the value is less than zero else increase the module voltage if V(k)-V(k-1)>0. Second case is if ΔP>0 then difference of V(k) and V(k-1) is calculated. Increase the module voltage if the value is less than zero else decrease the module voltage if V(k)-V(k-1)>0. Then the history is updated and the cycle is repeated.

3.2 Fuzzy Logic (FL)-based MPPT Technique

Fuzzy logic is most familiar control method which was commonly known by its Multi-Rule-Based variable's consideration. Fuzzy logic controller method delivers much accurate results when compared with other MPPT controller methods. Fuzzy logic controller can handle non-linearity conditions and it need not require exact mathematical model of system.

Fuzzy logic controllers are generally categorized into 4 steps:

- Fuzzification
- Membership function
- Inference
- Defuzzification

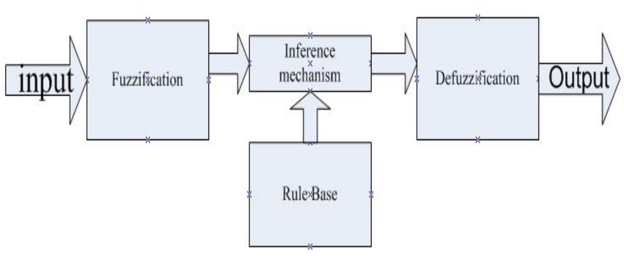


Figure 5. Block diagram of Fuzzy.

3.2.1 *Fuzzification*

The procedure of transforming crisp input value into fuzzy value is called Fuzzificaton. That is converting input variable to linguistic level. The process of fuzzification is completely based on membership function. In this case; five fuzzy levels are used:

- NB(negative big)
- NS(negative small)
- ZE(zero)
- PS(positive small)
- PB(positive big)

For more accuracy more fuzzy levels are used.

3.2.2 *Membership Function*

It is a curvature that describes each point of membership value in input space. Rapid accuracy of the controller can be achieved by using more number of membership functions.

In general error E and change in error $_{\Delta}$E are the inputs of MPPT controller.

3.2.3 *Inference*

This mode of operation is called as Rule-Base mode. A rule base must be applied to obtained membership function. This is done according to MAMDANI.

Mamdani's method is used with Max-Min operation fuzzy combination.

3.2.4 *Defuzzification*

This is the process of converting fuzzy value into crisp value. As the main system requires non-fuzzy value, defuzzification is required. In defuzzification, centroid method is used for obtaining non fuzzy value that is proper value for duty cycle variation.

3.3 Incremental Conductance based MPPT Technique

The controller regularly monitors the incremental value changes of both array voltage and current. Depending on this change in value, the controllers envisage the effect of voltage change. The common point between P and O and Incremental Conductance is that both techniques can produce oscillations in output power. The major drawback in Incremental conductance method is that it requires more number of computations in controller. When compared with P and O method, this method is more accurate in detection or tracking the changing conditions.

This method works by utilizing the incremental conductance, that is (dI/dV) of solar cell to decide the sign of change in power with respect to of voltage (dP/dV). Here INC and Array conductance are compared, if both are equal then output voltage is said to be called as MPP voltage. Till the irradiance changes the controller maintains this voltage. Therefore process is repeated.

4. High Step-up Converter

The proposed step-up converter based photovoltaic cell module is shown in Figure 7. In this model voltage multiplier module is constructed with the help of boost converter along with coupled inductors. Let the Primary windings of the coupled inductors are considered for

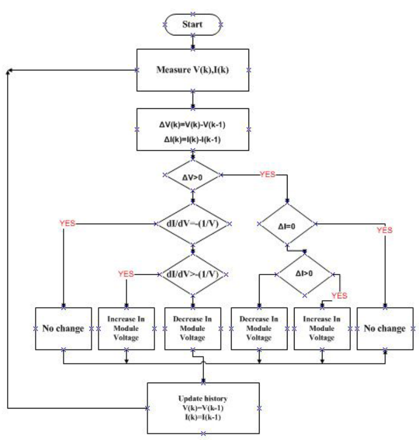


Figure 6. Incremental conductance method algorithm.

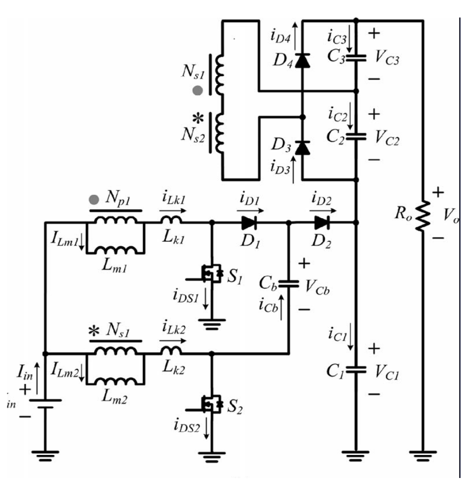


Figure 7. Equivalent circuit for step up converter.

decreasing the ripples in input current, and the number of turns in the secondary windings for coupled inductor be Ns turns and are used to extend voltage.

Hence the operation and implementation of this converter are obtained with the equivalent circuit as shown in Figure 6, in this the inductors Lm1 and Lm2 are acts as magnetizing inductors, and the inductors are Lk1 and Lk2 are leakage inductors, S1 and S2 denote the power switches, Cb is the voltage-lift capacitor, and n is defined as a turn's ratio of the coupled inductors.

The ratio of voltage conversion including conduction losses can be derived from:

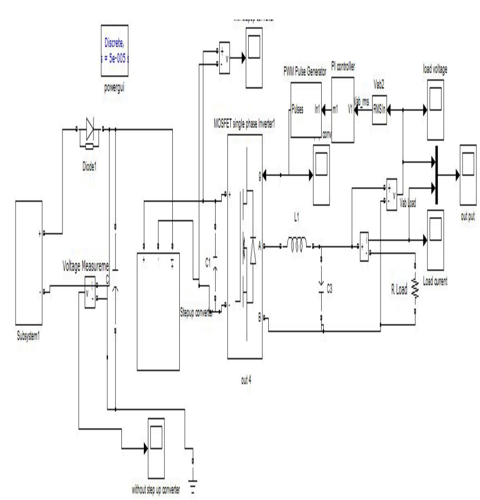
$$\frac{v_0}{v_{in}} = \frac{2n+2}{1-D} - \frac{1}{v_{in}}\left(V_{D1}+V_{D1}+V_{D3}+V_{D4}\right)/1+ \frac{1+n^2(2D-1)r_x}{(1-D)^2 Ro} + \frac{(1+2n)^2 rY}{(1-D)Ro}$$

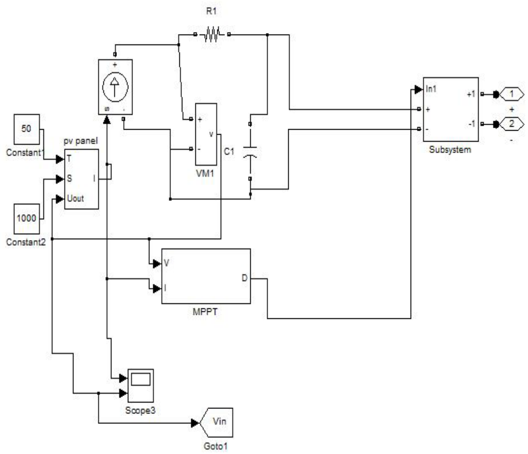
The efficiency is expressed as:

$$\eta = \frac{1-\frac{(1-D)}{(2n+2)v_{in}}\left(V_{D1}+V_{D2}+V_{D3}+V_{D4}\right)}{1+\frac{(1+n)^2(2D-1)r_x}{(1-D)^2 R_0}+\frac{[(1+2n)^2 r_Y}{(1-D)R_0}}$$

In order to evaluate the performance of MPPT controller algorithms, a PV cell under standard testing conditions of irradiance ($G=1000W/m^2$) and Normal Operating Cell Temperature (NOCT) of 25 °C was simulated using MATLAB.

5. Simulation Model Block





6. Simulation Results

The simulation for this type of step-up voltage multiplier based PV system is implemented in Matlab/simulink as per the figure shown in Figure 8.

Here the simulation results are compared for the worked out MPPT techniques. Among all, P and O MPPT

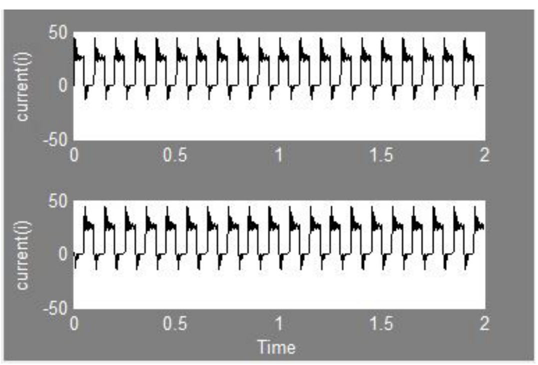


Figure 8. Simulation waveforms for Inductor Currents.

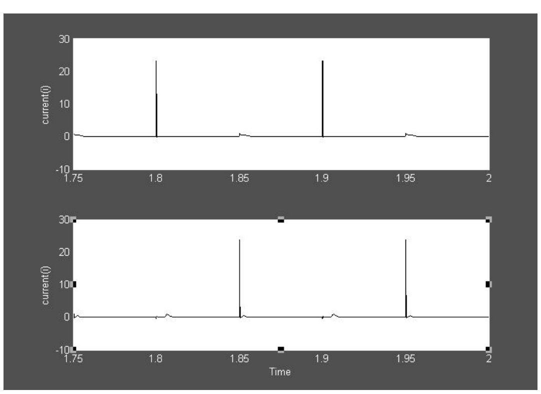


Figure 9. Simulation waveforms for Diode Currents.

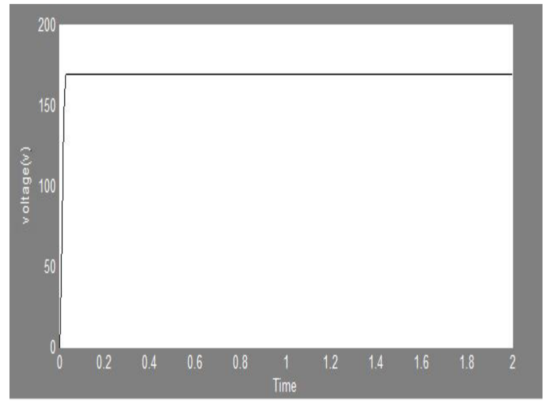


Figure 10. Output Voltage of P and O after step-up.

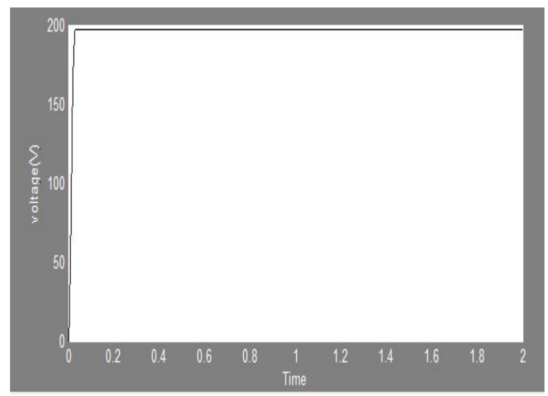


Figure 11. Output Voltage of INC Controller after step up.

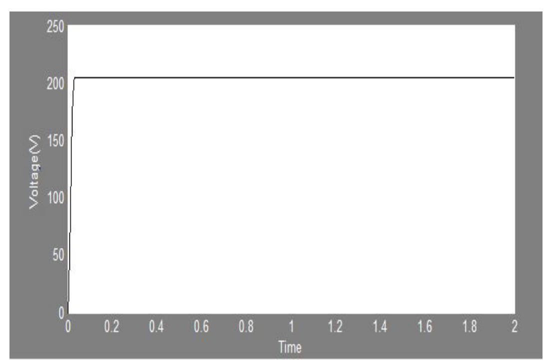


Figure 12. Output Voltage of Fuzzy controller after step-up.

method is easy to implement as it has low computational complexity. The major problem with P and O method is that it has poor tracking of MPPT value under rapidly changing conditions. In case of INC the computation complexity will occur. To extract maximum power from solar PV cell Fuzzy Logic Controller is preferred as it has no problem with tracking of MPPT value under rapidly changing conditions and its overall efficiency is high when compared with other MPPT techniques.

Table 1. Comparision table for MPPT technique

Mppt Technique	Before Step-Up (V)	After Step-Up (V)	Ac Voltage (V)	P(W)	η (%)
P&O	133	170	160	85.2	48.9
FUZZY	154	202	223	173.9	61.1
INC	149	198	220	154.7	57.8

The output voltage of Perturb and observe, Incremental and Conductance and Fuzzy Logic Controller after step up converter are 170V, 198V, 202V respectively.

The overall efficiency of Fuzzy Logic Controller is 61.1% which is high when compared with P and O and INC which are 48.9% and 57.8% respectively.

7. Conclusion

This paper has successfully presented the operation, study and experimental outcome for a high step-up voltage multiplier converter based PV system. The projected converter has been effectively put into practice for high step-up conversion without an excessive duty cycle ratio and a number of turns in multiplier voltage module. This paper also presents that the experimental setup is implemented with different MPPT techniques and results are compared. The above Table 1 shows the comparison of voltage, current and power before and after step-up under different MPPT techniques. The overall efficiency is also compared. Results justifies that, the fuzzy logic based MPPT technique is more efficient when compared to other worked out MPPT techniques.

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