

(An ISO 3297: 2007 Certified Organization) Vol. 5, Issue 7, July 2016

# A High Gain Soft Switched Interleaved Boost Converter with an Improved MPPT Control for PV Applications

Sidharth T<sup>1</sup>, P Sundaramoorthi<sup>2</sup>

PG Scholar, Department of Electrical and Electronics Engineering, Nehru College of Engineering and Research Centre

Thrissur, India<sup>1</sup>

Asst. Professor, Department of Electrical and Electronics Engineering, Nehru College of Engineering and Research

Centre, Thrissur, India<sup>2</sup>

**ABSTRACT**: PhotoVoltaic (PV) module is an important source of energy, it utilizes sunlight to generate electricity. PV system always has unique Maximum Power Point (MPP), depending on the environmental conditions this maximum power point keeps changing with the irradiance levels and ambient temperature. The output power produced from PV modules is directly proportional to the solar irradiation and inversely proportional to the ambient temperature. For better PV energy utilization it must be operated at equilibrium point, due to the low output voltage generated from PV module, DC-DC converters are required. In this system a high gain Soft-Switched Interleaved Boost (SSIB) DC–DC converter is used. The interleaved characteristic increases the flexibility and power rating of the converter. The high gain capability of the SSIB converter allows it to be connected directly to a Medium-Voltage (MV) DC bus. A Maximum Power Point Tracking (MPPT) technique is used for extracting the maximum power from the PV panel and transferring this power to the load. By the implementation of Model Predictive Control (MPC) technique for controlling the PV module can be used to modify the system in order to achieve more efficiency. This MPC based algorithm has the ability to track the maximum power under rapidly changing weather conditions and reaches to steady state at a very short time. Then the system attains a very high gain and it also enables reducing number of PV modules connected in series.

KEYWORDS: PhotoVoltaic (PV), SSIB converter, Interleaved technique, MPPT, MPC

#### I. INTRODUCTION

Global energy demand is growing continuously. In the past decades the capacity of PhotoVoltaic (PV) electricity generation system has been and is now gradually increasing. Moreover, many researchers and scientists state that photovoltaic system will play a key role in future energy needs. In order to meet the demand for energy in the near future itself we have to depend up on any other energy resources. To meet these requirements among the renewable energy sources solar energy is certainly favourable in terms of the environment. When compared with conventional energy sources such as coal, gasoline and oil etc, the solar energy is considered a satisfactory energy resource because it is very clean, inexhaustible, reliable, abundant and free of cost. A photovoltaic energy generation system would be one of the most beneficial alternative energy sources for the future. Interest in renewable energy sources continues to gain popularity with 60% annual growth in the installed capacity of PV systems from 2004 to 2009 and 80% in 2011[1]. However the conversion efficiency of the PV cell is less due to the rapidly changing atmospheric conditions such as insolation, shading, spectral characteristics of sunlight and dust which results in poor performance of the PV system. This problem is a significant obstacle against it's wide spread use. Therefore a Maximum Power Point Tracking (MPPT) is required to ensure the maximum available power from the solar panel. This generated power from PV panel is feed through a DC-DC converter. The converter boosts the output voltage which is tracked from the PV array. Here a high gain Soft Switched Interleaved Boost converter (SSIB) is used for this purpose. This interleaved technique gives out the



(An ISO 3297: 2007 Certified Organization)

#### Vol. 5, Issue 7, July 2016

input current according to the each phase of the converter and the current rating of the switching device can be reduced. It also reduces the dimensions of the passive components present in the circuit. For high power applications boost converters are often paralleled in an interleaved manner to increase the output current and reduce the output current ripple.

There are numerous MPPT technique has been developed in the past few decades. They differ in many aspects such as complexity, cost, convergence speed etc. The names of some of these techniques are Purturb and Observe (P&O), incremental conductance (INC), Fuzzy logic and neural network based control. P&O method is a best known technique with relatively good performance, but this method cannot always converge to the true maximum power point under certain environmental conditions. Also P&O method can't always give better results because it is relatively slow which limits its ability to track under varying atmospheric factors. This paper presents a MPPT algorithm based on Model Predictive Control technique and control of the converter when connected to a grid connected PV system.

#### II. SSIB CONVERTER

The interleaved technique is a strategic interconnection of two or more switching cells. This arrangement can reduce the current ripple and improve the overall efficiency of the converter without increasing switching losses or voltage stress [6]. interleaved operation has many desirable features such as a lower value of ripple amplitude, high ripple frequency in the resulting input and output waveforms and it also reduces maintenance, increases reliability and fault tolerance. This technique is mostly preferable for high current application. The conversion efficiency of solar cell is relatively low and the increasing the overall efficiency of PV panel is a important factor. This can be achieved with help of a high efficiency converter and Maximum Power Point Tracking (MPPT) technique. The characteristics of this type of converters are:

- Current ripple is less in input side
- Efficiency of the converter should be high

However, converter can extract the maximum power generated from the PV module by matching the output characteristics of PV system to the input characteristics of the load. Different kinds of simple conventional Dc-Dc converters like buck and boost converters are used in past decade to boost the output voltage level of the PV system, but it has more ripple and conduction losses. Interleaving technique is the one of the solution for all this problems. This paper Considered a Soft Switched Interleaved Boost (SSIB) converter and also this converter can be used for medium voltage PV applications it as shown in Fig.1[1].



Fig.1. Architecture of Large Scale PV system



(An ISO 3297: 2007 Certified Organization)

#### Vol. 5, Issue 7, July 2016

A PV system architecture based on high gain Soft Switched Boost (SSB) converter was already introduced in [7]. The circuit diagram of the SSB converter is as shown in Fig 2. It consists of diode rectifier of a conventional boost converter with a switch  $S_2$  and an auxilary circuit. This auxilary circuit contains an inductor ( $L_2$ ) a capacitor ( $C_1$ ) and a voltage doubler circuit. Voltage doubler circuit is made up of two diodes (D1 & D2 ) and a capacitor C2. The advantages of using auxilary circuit in SSB converter is to allows the converter to attain a higher voltage gain than the conventional boost converter and with the help of this Zero Voltage Switching (ZVS) can obtained in both the lower switch S1 and upper switch S2.



During the Discontinuous Mode Operation of inductor L2, it can achieve Zero Current Switching (ZCS) of the voltage doubler diodes (D1 and D2).



Fig.3. SSIB converter

Implementing interleaving technique in SSB converter can transform SSB to an interleaved SSB or SSIB converter is shown in Fig.3. It can be connected in either parallel or series. Here N is the number of series connected voltage doubler and P is the number of parallel connected diode legs in voltage doubler circuit. Increasing the value of N results in to higher voltage gain and while increasing P the elevated rating of the converter can be attained. The values of N and P are 2, 1 respectively.



(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

#### **III. MAXIMUM POWER POINT TRACKING TECHNIQUE**

The output power generated from the PV panel is varying under certain environmental conditions such as temperature, irradiation, shading etc, hence PV system has low conversion efficiency [9,10]. Therefore a good MPPT is required to ensure the maximum available power from the solar panel. The output power of the PV module is directly proportion to the solar irradiation and inversely proportional to the ambient temperature. For better PV utilization it must be operated at equilibrium point. This point is commonly known as Maximum Power Point (MPP) or peak power voltage. MPPT technique can be used in both standalone and grid connected PV system. The general block diagram of MPPT technique is as shown in Fig.4. normally it consists of a PV array, DC-DC converter for boosts the output voltage generated from PV array and a MPPT controller .



Fig.4. General block diagram of MPPT technique

There are many MPPT methods have been introduced [8] and implemented over the past few decades. Such as Purturb and Observe (P&O), Incremental Conductance (INC), Current sweep method, Fractional Open Circuit voltage, Fuzzy logic etc. Each MPPT methods has its own advantages and disadvantages for the present applications. P&O is the well known tracking technique with relatively better performance, however P&O method can't always get satisfactory results. This limits its ability to track under certain environmental conditions such as partial shading, irradiance etc. The solution for this problem is to improve the performance of P&O method by predicting the error one step ahead in horizon through model predictive control technique. The proposed method has faster response than conventional P&O under rapidly varying environmental conditions.

#### IV. PRINCIPLE BEHIND THE MODEL PREDICTIVE CONTROL

Application related to model predictive control (MPC) in power electronics with low switching frequency has been found 1980's for high power applications. The use of high switching frequency for the model predictive control is not feasible at that time, because of the large calculation time required for the MPC algorithm. In the past decade, with the rapid growth of high speed and powerful microprocessors, interest in the application of MPC in power electronics has increased significantly.

The main peculiarity of this control technique is predicting the future behaviour and optimize the process performance of the desired control variables until a particular step ahead in horizon of time. The predicted variables are used to get the optimal switching state by diminishing a cost function. The model used for prediction is a discrete-time model which can be presented as state space model. The MPC technique for power electronics converters can be designed using the following procedure [3].



(An ISO 3297: 2007 Certified Organization)

#### Vol. 5, Issue 7, July 2016

- Modelling of the power converter identifying all possible switching states and its relation to the input or output voltages or currents.
- Defining a cost function that represents the desired behaviour of the system.
- Obtaining discrete-time models that make it possible to predict the future behaviour of the variables to be controlled.

The designed controller should consider the following tasks:

- Predict the behaviour of the controlled variables for all possible switching states.
- Evaluate the cost function for each prediction.
- Select the switching state that minimizes the cost function.

The general block diagram of MPC for power electronics converter is given in Fig.5. [4]. In this schematic diagram the measured variables X (k) are used to estimate predictions in the model and X (k+1) of the controlled variables for all of the 'n' possible switching states. After that all these predictions are evaluated with the help of a cost function .Then it will compares them to the reference values  $X^*(k+1)$  by considering the design constraints. The next stage is selecting the optimal actuation and it is applied to the converter. The general structure of the cost function 'g' can be formulated as shown below [2].

$$g = [X_1(k+1) - X_1^*(k+1)] + \lambda_1 [X_2(k+1) - X_2^*(k+1 + \dots + \lambda_n [X_n(k+1) - X_n^*(k+1)]$$
(1)

Where  $\lambda$  is the weighting factor. Cost function 'g' is minimized by selecting the appropriate switching state. After that all possible states are evaluated and the optimal value is gathered to be applied next stage.



Fig.5. General block of MPC for power electronics converter

In this paper a SSIB converter is chosen as a DC-DC converter. The reference current for the MPC is determined by P&O as depicted in Fig.6 and later MPC determines the next switching state. This method can predict the error of the next sampling time and based on optimization of the cost function 'g' as shown in Fig.7 [3] and switching state of the system will be determined. The inputs given to the predictive controller are the PV system current, voltage and the reference current



(An ISO 3297: 2007 Certified Organization) Vol. 5, Issue 7, July 2016



Fig.6. Flowchart of MPC procedure to determine reference current using P&O



Fig.7. Flowchart of MPC MPPT procedure

Now after determination of the reference current using P&O method, the cost function 'g' can be obtained as following



(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

 $g_{s=0,1} = |i_{pvs=0,1}(k+1) - i_{ref}|$ 

(2)

The objective of this procedure is to minimize the cot function 'g'. The final switching state for MPPT can be determined using the Procedure depicted in Fig.7.

#### **V. SIMULATION RESULTS**

Solar PV energy conversion system with a high gain soft switched interleaved boost DC-DC converter was simulated in MATLAB/Simulink software with MPC technique for extracting maximum power generated from PV array. A PWM generated VSC is used to control the inverter side. The generated output voltage from PV is obtained by simulation model of SSIB sub system as shown in Fig 8-9. The overall closed loop simulation of grid connected PV array with MPC is shown in Fig.10. Grid side voltage and current waveforms are as shown in Fig.11.



Fig.8. SSIB sub system simulink model

SSIB sub system simulink model consists of a solar panel SSIB converter and MPC technique to track maximum power from the solar panel.



(An ISO 3297: 2007 Certified Organization) Vol. 5, Issue 7, July 2016



Fig.9. Output voltage of PV system with SSIB converter



Fig.10. Overall closed loop simulation model with MPPT controller



(An ISO 3297: 2007 Certified Organization) Vol. 5, Issue 7, July 2016



Fig.11. Grid side voltage and current waveforms

#### VI. CONCLUSION

This paper presents a SSIB converter with MPPT technique that uses MPC to predict the error at the next sampling time, before applying the switching signal. The simulation of overall system has been carried out using MATLAB. The detailed information about MPC technology and its principle of operations were discussed. The high gain capability of SSIB converter allows it to be connected directly to a medium voltage DC bus. By the implementation of MPC for controlling the PV module improves the efficiency of the system by gaining the extra power during changing the environmental conditions and it reaches to steady state at a very short time. From the simulation results, it can be observed that the proposed model of PV system is working well with SSIB converter.

#### REFERENCES

- [1] Z. Peng, W. Yang, X. Weidong, and L. Wenyuan, "Reliability Evaluation of Grid-Connected Photovoltaic Power Systems," *IEEE Trans on Sustainable Energy*, vol. 3, pp. 379-389, 2012.
- [2] M.B.Shadmand, M.Mosa, R.S.Balog, and H.A.Rub, "An Improved MPPT Technique Applications," in IEEE Applied Power Electronics Conference and Exposition (APEC), 2014, PP.2993-2999
- [3] M. Shadmand, R. S. Balog, and H. Abu Rub, "Maximum Power Point Tracking using Model Predictive Control of a flyback converter for photovoltaic applications," in *IEEE Power and Energy Conference at Illinois (PECI)*, 2014, pp. 1-5.
- [4] J. Rodriguez, M. P. Kazmierkowski, J. R. Espinoza, P. Zanchetta, H. Abu-Rub, H. A. Young, et al., "State of the Art of Finite Control Set Model Predictive Control in Power Electronics," *IEEE Transactions on Industrial Informatics*, vol. 9, pp. 1003-1016, 2013.
- [5] H. Choi, M. Ciobotaru, and V. G. Agelidis, "High gain dc/dc converter for the grid integration of large-scale PV systems," in Proc. IEEE Int. Symp. Ind. Electron., 2012, pp. 1011–1016.
- [6] L. Wuhua, Z. Yi, D. Yan, and H. Xiangning, "Interleaved converter with voltage multiplier cell for high step-up and high-efficiency conversion," *IEEE Trans. Power Electron.*, vol. 25, no. 9, pp. 2397–2408, Sep. 2010.
- [7] S. Park and S. Choi, "Soft-switched CCM boost converters with high voltage gain for high-power applications," *IEEE Trans. Power Electron.*, vol. 25, no. 5, pp. 1211–1217, May 2010.
- [8] T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Transactions on Energy Conversion, vol. 22, pp. 439-449, June 2007.
- D. Sera, T. Kerekes, R. Teodorescu, and F. Blaabjerg, "Improved MPPT Algorithms for Rapidly Changing Environmental Conditions," in *IEEE Pow. Elec. and Motion Cont. Conf. (EPE-PEMC)*, 2006, pp. 1614-1619.
- [10] A. Bidram, A. Davoudi, and R. S. Balog, "Control and Circuit Techniques to Mitigate Partial Shading Effects in Photovoltaic Arrays," IEEE Journal of Photovoltaics, vol. 2, pp. 532-546, 2012.