HIGH VOLTAGE GAIN INTERLEAVED BOOST CONVERTER FOR PV SYSTEM APPLICATIONS WITH A NEURAL COMPENSATOR

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Abstract

In the present scenario the utilization of renewable energy sources are happening to be more popular due to more vigorous regulations in fuel economy and carbon. This paper deals with the high voltage gain interleaved boost converter for a Photo Voltaic (PV) system with a neural network based Maximum Power Point Tracking (MPPT) controller. So as to nourish the high power electrical appliances it is necessary to design high voltage gain converters. In order to meet this requirement, a three phase interleaved boost converter (IBC) which can provide high voltage gain is proposed and designed for a PV system is proposed in this paper. The interleaving technique is adapted for the proposed converter as it is able to maintain less ripple content at the converter input current thereby improves the life time of PV array. It also results less voltage stresses on the power semiconductor devices which are employed for high rated PV system. Unlike conventional modelling of PV array procedure, modelling of PV array using neural network does not require involvement of any scientific definitions. Consequently they can possibly give an unrivalled strategy for inferring non-linear models than the officially settled regular procedures. In this paper a radial basis neural network trained model is employed to simulate and anticipate the MPP of a Photo Voltaic array utilizing an arbitrary arrangement of information gathered from a genuine photovoltaic array. In this paper Simulink platform of MATLAB software is employed to break down the performance of the proposed system by carrying simulation. Furthermore, it is additionally demonstrated that the MPPT from the solar PV array with the reduced harmonics is achieved through the proposed model.

Keywords: Photovoltaic array modelling, Maximum power point tracker, Neural network, MPPT, Interleaved connection.

I. Introduction

Presently a days the electrical vitality request is expanding consistently because of the modern transformation over the globe. The expanding costs and exhaustion in the wealth of non-renewable energy sources inspires towards the utilization of sustainable power sources. PV based generation is one of the promising innovations in the current circumstance. And furthermore, solar energy sources are receiving wide
attention for various applications like household, agriculture and industrial use, as a result of their wealth in mass, nonappearance of cost of fuel and vitality creation without ecological contamination. This gives a radical decline in cost of power electronic devices as far as possible. Regardless, the substantial establishment cost and less viability of the PV systems confining the execution PV systems. In order to beat these hindrances, it is imperative to plan MPP trackers while realizing PV systems. Since the barometrical conditions illumination and temperature choose the power age from the PV system, these variables additionally manages the design of MPP tracker.

The fundamental point of any MPPT tracker is that to operate the PV system to the point where it conveys greatest power \(V\). Such significant number of methodologies are tended to in the writing to design the MPP. When all is said in done a perfect MPP tracker prerequisites are simple and minimal effort, little yield variance and quick most extreme power following under robust conditions \([II]\). Unlike conventional modelling of PV array procedure, modelling of PV array using neural network does not require involvement of any scientific definitions. Consequently they can possibly give an unrivalled strategy for inferring non-linear models than the officially settled regular procedures. So in this paper a neural system based MPPT controller is actualized. In the design of effective PV systems, job of converter is additionally extremely significant. Also, among all the dc-dc converters support boost converters are intended to build the lower input voltage level to higher. Yet, the conventional boost converters neglect to supply the high power applications because of its poor dynamic response, thermal management issues and low current handling capabilities. The main reason behind the poor dynamic response is that both output voltage and input currents suffer from higher ripple content. To eliminate some of these issues, distinctive DC-DC converters are demonstrated \([III, I, IV, VIII, IX]\).

Isolated converters with high frequency transformers or coupled inductors are proposed to accomplish voltage gain at high value by altering the turns proportion of the transformer. Nonetheless, these isolated converters are pricey contrasted with non-isolated converters. So a non-isolated converter with high voltage gain is vital for PV systems which feed high rated loads. In literature \([I]\), a high voltage gain converter is demonstrated for the fuel cell based applications, which also may have the capability of improving the performance of any kind of nonlinear system including PV system.
Fig. 1 depicts a three phase high voltage gain interleaved boost converter (IBC) which feeds high rated resistive load. Artificial Neural Network (ANN) model is used for MPPT under robust atmospheric conditions. The sections in this paper are organized as pursue, in section II, the modelling of PV is described; in section III, modelling of the proposed converter is discussed; in section IV, neural based MPPT technique is covered; section V deals with the analysis of simulation results and ends with summarization of conclusions in section VI.

II. PV array modelling

Modelling of any PV based system is to be begun with the modelling of PV cell since it is the fundamental structure of PV module. Fig. 2 demonstrates the least complex electrical identical circuit of PV cell. It comprises internal series and shunt resistances which account the losses in PV cell due to small intrinsic leakage currents and metal contacts in current path. The scientific condition of the PV output current (I) is derived in the form of equation from standard hypothesis as,
\[ I = I_L - I_D - I_{SH} \]  
(1)

\[ I = I_L - I_0 \left( e^{\frac{q(V+IR_s)}{nkT}} - 1 \right) - I_{SH} \]  
(2)

Where \( I_L \), \( I_D \) and \( I_{SH} \) are the photo, diode and shunt currents whereas \( R_s \) and \( R_{sh} \) are the internal series and shunt resistances of the PV cell respectively.

A solar PV array is designed to feed the high rated resistive load in the proposed model. Above scientific demonstrating alongside the recorded parameters displayed in Table 1 is utilized to simulate the solar PV array. What's more, the reproduced attributes of the PV exhibit are appeared in fig.3 at standard test conditions (STC).

| PV Module specifications | Design of PV Array 12 X 1 |
|--------------------------|---------------------------|
| Voltage when module is open circuited, \( \text{Voc} = 21.5 \text{ V} \) | Voltage when array is open circuited voltage, \( \text{VOC} = 258 \text{ V} \) |
| Current when module is short circuited, \( \text{Isc} = 4.9 \text{ A} \) | Current when module is short circuited, \( \text{ISC} = 4.9 \text{ A} \) |
| Voltage at MPPT, \( \text{Vm} = 17.1 \text{ V} \) | Voltage at MPPT, \( \text{Vmax} = 205 \text{ V} \) |
| Current at MPPT, \( \text{Im} = 4.39 \text{ A} \) | Current at MPPT, \( \text{Imax} = 4.39 \text{ A} \) |
| Maximum Power, \( \text{Pm} = 75 \text{ W} \) | Maximum Power, \( \text{Pmax} = 900 \text{ W} \) |
Figure 3: Voltage - Current and Power-Voltage of PV module characteristics at constant temperature (25°C) and different irradiation levels

III. Three phase High voltage gain IBC

The proposed converter comprises of three phase filtering inductors (L1, L2 and L3) along with the phase controlled switches (S1, S2 and S3) and three phase uncontrolled diodes (D1, D2 and D3) for the phases of 1, 2 and 3 respectively.

The assumptions are taken to analyse the proposed converter are all controlled and uncontrolled switches are ideal with the mode of continuous conduction. And the values of all energy storage elements capacitors and inductors are also assumed to be ideal i.e. L1=L2=L3=L, C1=C2=C. The switching sequence of proposed converter is as follows, a phase shift of 180° is provided between two gate pulses. One of the two pulses is fed to the switch S2 and the second pulse is given to both S1, S3 simultaneously. The design specifications of the converter is listed in Table 2.

| Parameter description     | Rating  |
|---------------------------|---------|
| Inductors L1=L2=L3=L      | 35mH    |
| Capacitors C01=C02=C      | 16 µF   |
| Input capacitor Cin       | 25 µF   |
| Input voltage Vin         | 205V    |
| Output voltage Vout       | 600V    |
| Load Resistance R_L       | 400Ω    |
Design procedure for the proposed converter:

Step 1: The DC bus voltage which feeds the selected high rated resistive load decides converter output voltage. i.e. \( V_o = 600\text{V}\) (approx.)

Step 2: The total number of series connected modules are decided by the wattage of resistive load (say 900W) to be supplied and the wattage of each PV module selected (i.e. \( P_m = 75\text{W} \)). Hence number of modules connected in series = \( \frac{P_{max}}{P_m} = 12 \).

Step 3: step 2 decides the converter input voltage of Boost Converter as \( V_{in} = 205\text{V} \).

Step 3: Output current \( I = \frac{P}{V_{out}} = \frac{900}{600} = 1.5\text{ A} \)

Step 4: Duty ratio \( D = 0.658 \)

Step 5: Inductor \( L = \frac{V_{in} \times D}{f \times f_s} = 35\text{ mH} \)

Step 6: Capacitor \( C = \frac{V_{in} \times D}{f_s \times f} = 16\text{ µF} \), at switching frequency, \( f_s = 10\text{kHz} \)

IV. ANN model based controller

To obtain more power from solar PV system in this paper is back propagation neural network based MPPT method is proposed. The backward computations are performed in this neural based algorithm through the network. And the algorithm also features the weights which move in the direction of negative gradient. While the network is under training process there should be proper set of samples in terms of network inputs and target outputs to decide network behaviour. Figure 4 shows the architecture for the proposed neural network for MPPT tracking of PV array at different atmospheric conditions with 3 outputs and 2 hidden layers (10 neurons).

The architecture of the proposed Neural Network for MPPT tracking is shown in fig.4 in MATLAB Simulink platform.
The trained neural system is validated through the simulation results, when the training line and the goal line gets converged as shown in fig.5 for the current model. This training ceased when the approval error expanded for six emphases, which happened at emphasis 32. Fig.6 demonstrates the regression examination of the present system. The yields of this trained system can generate the error signal to the well-tuned controller. Eventually the controller can give the changing switching pulses to the proposed three phase IBC to draw the most extreme power from the photo voltaic array.
V. Simulation Model and Result Analysis

Figure 7: Simulink model of the proposed PV system

The above figure 7 shows the developed model of proposed scheme in MATLAB R2014/Simulink GUI environment.

Figure 8: PV current

Figure 9: PV current ripple
The proposed PV generation system is simulated in MATLAB software and the simulation results are obtained at STC (at 25°C and 1000 W/sq.m). Figure 7-12 illustrate that the maximum power is tracked by the proposed model at a constant load resistance of 400Ω. Fig.7 and Fig.8 shows the PV current reaches steady value of 4.39A (I_{max}) with the ripple current of 0.093A. Fig.9 and Fig.10 illustrate that the PV voltage and PV power reaches the steady values of 205V (V_{max}) and 900W (P_{max}). It is also observed that the MPP is tracked for the proposed system at the reduced ripple content of value 1.4 V in the output load voltage V_o. Which results high voltage gain with the proposed converter at 511V shown in Fig.11 and Fig.12.

VI. Conclusion

The proposed ANN based High Voltage Gain Interleaved Boost Converter for PV System is designed and developed in MATLAB/Simulink platform. In this paper a radial basis neural network trained model is employed to simulate and anticipate the MPP of a Photovoltaic array utilizing an arbitrary arrangement of
information gathered from a genuine photovoltaic array. Results of simulation illustrates the accuracy of the developed Simulink model and they show excellent correspondence to manufacturer’s data. Furthermore, it is additionally demonstrated that the proposed model is able to track the MPPT from the solar PV array with the reduced harmonics.

References

I. A. R. VijayBabu, V. Rajyalakshmi, K. Suresh, Renewable Energy Integrated High Gain DC-DC Converter with Multilevel Inverter for Water Pumping Applications, Journal of Advanced Research in Dynamical and Control Systems, Volume 9, Issue 1, PP. 172-190, 2017.

II. Avvaru Sriharibabu, Gorantlasrinivasara Rao “MPPT Design for Photo Voltaic Energy System Using Back-stepping Control with a Neural Compensator”, Int. Jour. of Eng. Tech., vol.7, PP. 129-132, Iss. 4.24, 2018.

III. D Y Jung, Y-Hyok Ji, S-Hoon Park, Y-Chae Jung, and Ch-Yuen Won, “Interleaved Soft-Switching Boost Converter for Photovoltaic Power-Generation System” in IEEE trans. on power electron. vol. 26, no. 4, April 2011.

IV. Maheswararao, Ch Uma, YS Kishore Babu, and K. Amaresh. "Sliding mode speed control of a DC motor." 2011 International Conference on Communication Systems and Network Technologies. IEEE, 2011.

V. Martin A.D., Vazquez J. R. "MPPT algorithms comparison in PV systems: P&O, PI, neuro-fuzzy and backstepping controls", IEEE International Conference on Indust. Tech. (ICIT), 2015.

VI. Niraj Rana, Mukesh Kumar, Arnab Ghosh and S. Banerjee, "A Novel Interleaved Tri-State Boost Converter with Lower Ripple and Improved Dynamic Response," in IEEE Tran. on Indust. Electronics, vol. 65, no. 7, pp. 5456-5465, July 2018.

VII. SHAH, ASHISH P., et al. "INSILICO DRUG DESIGN AND MOLECULAR DOCKING STUDIES OF SOME NATURAL PRODUCTS AS TYROSINE KINASE INHIBITORS." International Journal 5.1 (2017): 5.

VIII. Sukumar, Durga, JayachandranathJithendranath, and Suman Saranu. "Three-level inverter-fed induction motor drive performance improvement with neuro-fuzzy space vector modulation." Electric Power Components and Systems 42.15 (2014): 1633-1646.

IX. Yadlapalli, Ravindranath Tagore, and Anuradha Kotapati. "A fast-response sliding-mode controller for quadratic buck converter." International Journal of Power Electronics 6.2 (2014): 103-130.