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A new approach for grid integration of solar photovoltaic system with maximum power point tracking using multi-output converter

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Abstract

This paper proposes a new approach for grid integration of solar photovoltaic system using modified incremental conductance maximum power point tracking algorithm with multi-output converter and multilevel inverter. The multi-output converter is a combination of boost converter and switched capacitor function to generate different self-balanced output voltages using single switch, single inductor, 2N-1 diodes and 2N-1 capacitors. This topology is proposed to be used as DC link in applications where several controlled voltage levels are required with self-balancing and unidirectional current flow, such as photovoltaic (PV) or fuel cell generation systems with multilevel inverter. The utilization of multilevel inverter in the proposed system provides better quality of output voltage and current waveform thereby reducing the size of passive filters. Also, it eliminates the requirement of bulky transformers for grid integration. Multicarrier unipolar phase disposition pulse width modulation technique is employed for triggering the switches of the multilevel inverter. The proposed system is tested with standard test conditions using MATLAB/SIMULINK.

Keywords: converter, inverter, grid integration, multilevel inverter, photovoltaic, solar

1. Introduction

The increasing penetration of Photovoltaic (PV) power in major developed and developing nations has become higher when compared to the other sustainable power sources. This is owing to the low venture cost, contamination

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free and unlimited nature of solar energy. Stand-alone power era framework has been introduced in several parts of the world which are inaccessible to the grid [1].

Abbreviation and Nomenclature

PV	Photovoltaic
NPCMLI	Neutral Point Clamped Multilevel Inverter
FCMLI	Flying Capacitor Multilevel Inverter
CHBMLI	Cascaded H-Bridge Multilevel Inverter
MLI	Multilevel Inverter
PWM	Pulse Width Modulation
PD	Phase Disposition
MCPWM	Multicarrier Pulse Width Modulation
MPPT	Maximum Power Point Tracking
k	Boltzmann constant (1.3806503 × 10^(−23) J/K)
q	Electron charge (1.60217646 × 10^(−19) C)
a	diode ideality constant
T	absolute temperature
I_{PV}	photovoltaic current

Along these lines, the grid connected photovoltaic system is an ideal solution for peak energy demand and the irregular way of inexhaustible power era. A power converter presents a key part in vitality transformation in an effective manner [2]. Multilevel inverter (MLI) is the most popular research topic in both academic and industry because of many advantages which can be utilized for high voltage application. Neutral point clamped MLI (NPCMLI), Flying capacitor MLI (FCMLI) and Cascaded H-Bridge MLI (CHBMLI) are the prominent conventional topologies [3]. But, these topologies have many disadvantages. Higher number of clamping diodes and clamping capacitors are employed in the NPCMLI and FCMLI respectively whereas CHBMLI employs higher number of switching devices and separate DC sources [4]. To overcome the drawback in conventional topologies, new topologies have emerged for reducing the switching device count with separate DC sources. In literature, many topologies have developed for reducing the switch count [5, 6]. But those topologies utilize higher number of floating DC voltage sources which is the major problem in practical applications [7].

Therefore, the main objective of this work is to eliminate the requirement of separate DC source for each base unit and to reduce the component count along with driver circuit which reduces the cost and installation space of the system. The multi-output converter plays a major role for generating the different self-balanced output voltages from single DC source which may be renewable energy sources like PV.

2. Proposed grid connected system

Fig. 1 shows the proposed grid connected multilevel inverter (MLI) with multi-output boost converter in photovoltaic system. The proposed topology eliminates multiple sources for generating the required output voltage level by utilizing a multi output boost converter. This multi output boost converter topology is proposed to be used as the DC link in applications where several controlled voltage levels are required with self-balancing and unidirectional current flow, such as photovoltaic (PV) or fuel cell generation systems with MLI.

2.1. Single diode photovoltaic model with modified incremental and conductance algorithm

Fig. 2 illustrates the equivalent circuit of single diode model of photovoltaic cell. Fig. 3(a) and 2(b) shows the I-V and P-V characteristics of the PV model. Table 1 show the 80 W photovoltaic panel parameters value.

The following equations are used to design the single diode model for photovoltaic system.

$$I = I_{PV} - I_o\left[exp\left(\frac{V + R_s I}{aV_t}\right) - 1\right] - \frac{V + R_s I}{R_p}\ ;\ V_t = \frac{V_s kT}{q} \quad (1)$$

$$I_{PV} = \left(I_{PV,n} + K_I \Delta_t\right)\frac{G}{G_n} \quad (2)$$

$$I_o = \frac{I_{sc,n} + K_I \Delta_t}{exp\left[\left(V_{oc,n} + K_V \Delta_t\right)/aV_t\right] - 1} \quad (3)$$

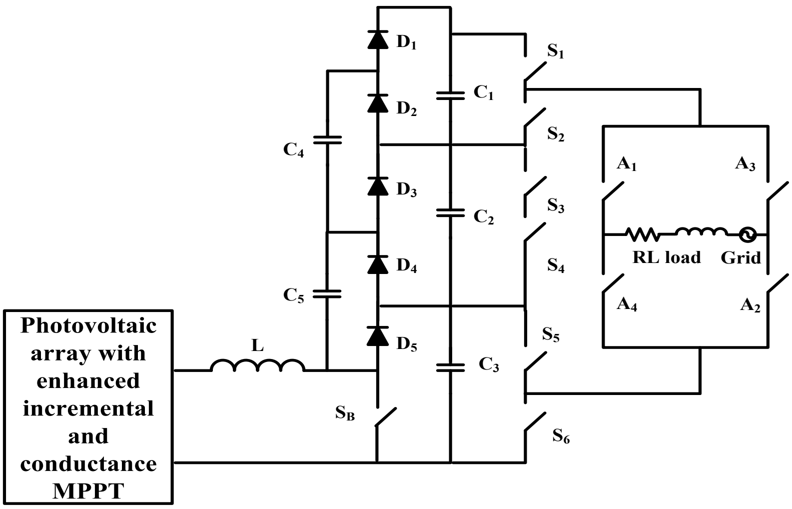


Fig. 1 Proposed grid connected system using multilevel inverter with multi output boost converter

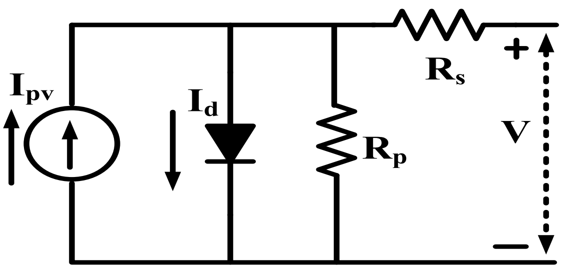


Fig. 2 Single diode model equivalent circuit

Table 1 Parameter details for 80 W PV panel

Parameters	Values
Short circuit current (I_{sc})	4.71 A
Open circuit voltage (V_{oc})	22.24 V
Maximum power point voltage (V_{mp})	18.33 V
Maximum power point current (I_{mp})	4.37 A
Maximum power (P_{mp})	80 W

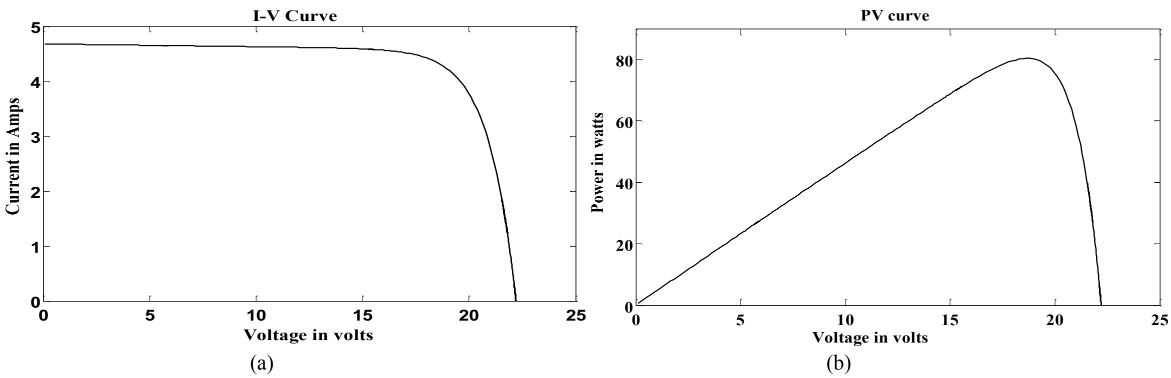


Fig. 3 (a) I-V & (b) P-V characteristics

The conventional incremental and conductance maximum power point tracking (MPPT) algorithm has two major drawbacks, such as when the working point is wavering around the MPP point and it doesn't work legitimately in quick shifting irradiance condition. To conquer this disadvantage, this paper has utilized an enhanced incremental and conductance MPPT [8]. The flowchart of enhanced MPPT technique is shown in Fig. 4. The coloured blocks shown in the flowchart indicate the enhancement part from the conventional incremental and conductance algorithm. The enhanced incremental and conductance MPPT algorithm is worked perfectly under the sudden variance in the irradiance condition.

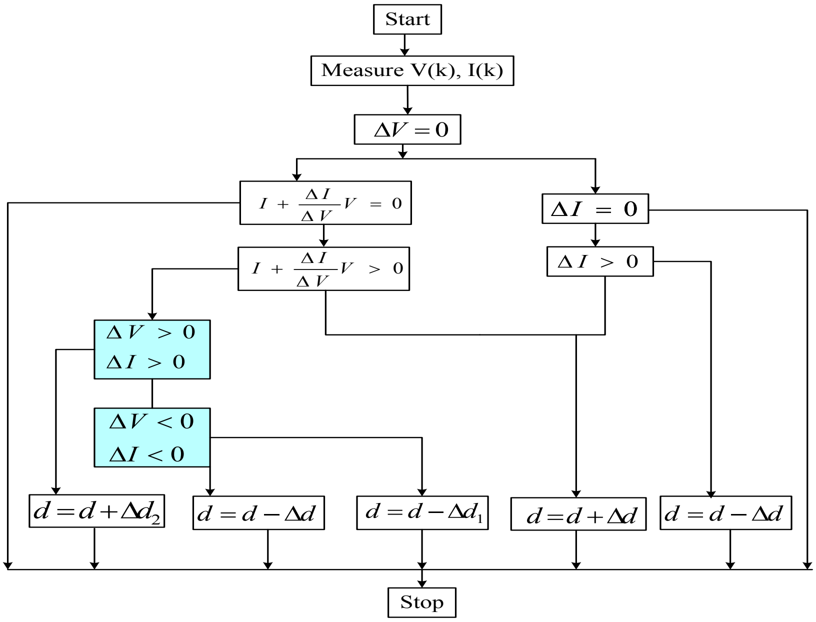


Fig. 4 Improved Incremental and Conductance MPPT algorithm

2.2. Reduced switch multilevel inverter with multi output boost converter

The multioutput boost converter is a combination of boost converter and switched capacitor function. It has only one switch, one inductor, 2N-1 diodes and 2N-1 capacitors. Here, N represents the total number of output in the boost converter. The basic unit has separate DC source with two switches. The reduced switch topology consist of basic units are connected in series with a full bridge inverter. The series connection of basic unit produces the required output voltage based on the input voltage source in one polarity and the full bridge utilized at the end is utilized to duplicate the levels in another polarity.

Number of Switches = 2k+4 (4)

Number of driver circuit = 2k+4 (5)

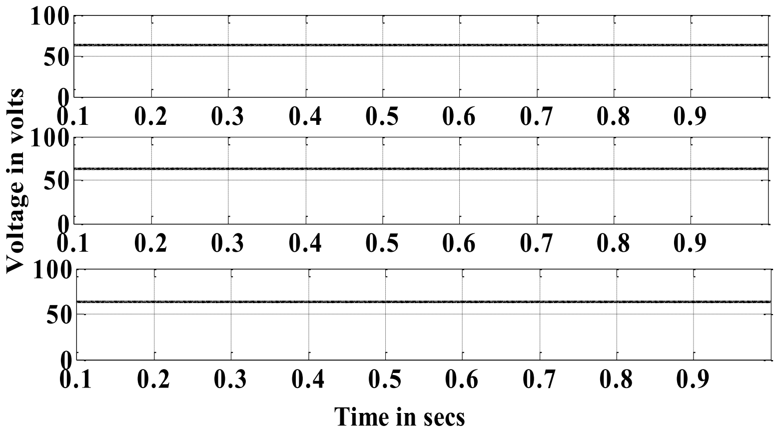
Number of Level = 2k+1 (6)

Ratio of DC-link voltage = 1:1:1 (7)

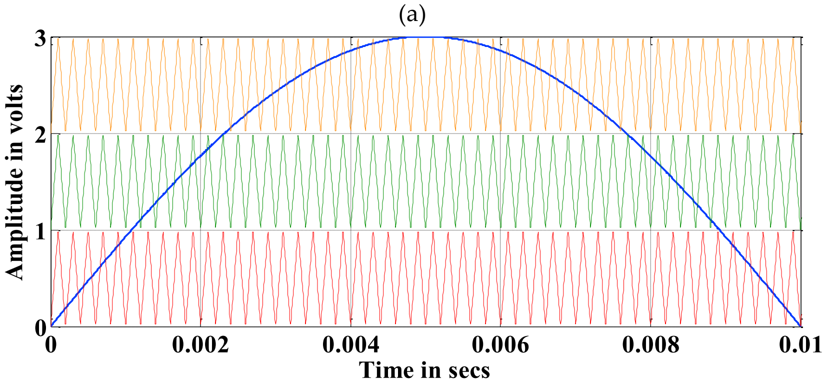
3. Simulation Results

The proposed grid connected system for generating 7-level output voltage is simulated using MATLAB/SIMULINK. The proposed system utilized a multi output boost converter and reduced switch MLI. The multioutput boost converter switch is operated at 24 kHz. The multi output boost converter DC-link voltages are shown in Fig. 5(a). From the figure, it can be observed clearly that the voltage ratio of output voltage is symmetric. Fig. 5(b) represents multicarrier unipolar Phase Disposition pulse width modulation carrier arrangement. The unipolar PWM utilizes '(0.5*m-1)' carriers for generating 'm' level output voltage [9]. Fig. 6(a) shows the output voltage and current waveform of proposed multilevel inverter without filter. Fig. 6(b) shows the FFT plot for 7-level output voltage in proposed multilevel inverter for UPDPWM technique. The switches (S_1 to S_6) in reduced switch MLI are operated at 5 KHz switching frequency and the switches (A1 to A4) are operated at 50 Hz frequency. The RL load is considered and the values are 100 Ω and 20 mH respectively. Fig. 7 shows the grid voltage and current waveform with filter inductance. The formula for filter inductance is given below

$$\text{Filter Inductance } \boldsymbol{L_f} = \frac{V_{f_{sw}}}{I_{f_{sw}}}\left(\frac{1}{2\pi f_{sw}}\right) \quad (8)$$



(a)

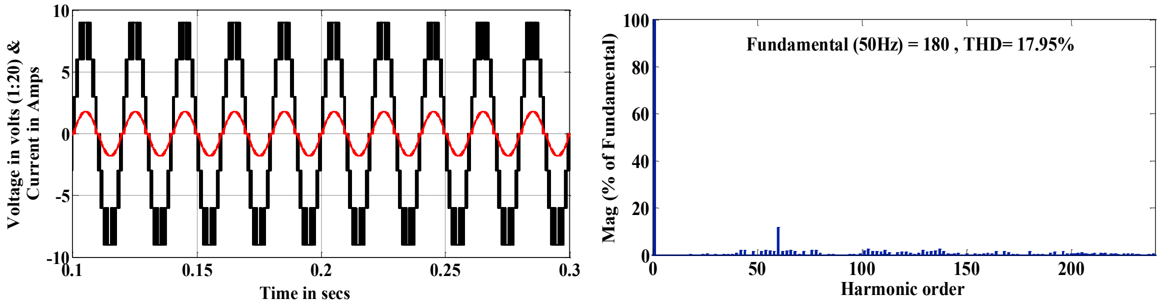


(b)

Fig. 5. (a) Multi Output voltage of boost converter (b) Unipolar Phase Disposition PWM

4. Conclusion

A new approach of grid connected system using multioutput boost converter with multilevel inverter has been proposed in this paper. The enhanced incremental and conductance MPPT algorithm is utilized and the performance improvement is investigated in a grid integrated system. The proposed system requires only one source for generating the required output voltage level which has the major advantage. Multicarrier unipolar PD-PWM method has been utilized for generating the gating pules of the switches to the reduced switch MLI. The proposed grid connected system is examined only in standard test condition. It could be tested with sudden changes at irradiance condition in future work. From the results and discussion, it is concluded that the proposed system is able to provide better quality output waveforms with lesser harmonic distortion and offers the advantage of lesser component count. Therefore the system is more suitable for photovoltaic grid connected operation and provides enhanced operation.



(a) (b)

Fig. 6. (a) Output voltage and current waveform with filter (b) Harmonic spectrum plot for output voltage

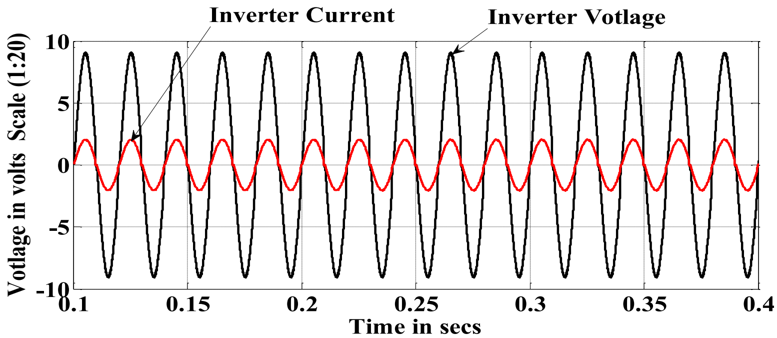


Fig. 7. Grid voltage and current for proposed system

References

[1] Shaahid, S.M. "Review of research on autonomous wind farms and solar parks and their feasibility for commercial loads in hot regions." Renewable and Sustainable Energy Reviews, 15, (2011): 3877-3887.

[2] Ozdemir, S., N. Altin and I. Sefa. "Single stage three level grid interactive MPPT inverter for PV systems." Energy Conversion and Management, 80, (2014): 561–72.

[3] Daher, S., J. Schmid, and F.L. M Antunes. "Multilevel inverter topologies for stand-alone PV systems." IEEE Transactions on Industrial Electronics, 55(7), (2008): 2703-2712.

[4] Iero, D, R. Carbone, R. Carotenuto, C. Felini, M. Merenda, G. Pangallo, and F. G D. Corte. "SPICE modelling of a complete photovoltaic system including modules, energy storage elements and a multilevel inverter." *Solar Energy,* 107, (2014): 338-350.

[5] Bandara, K., T. Sweet, and J. Ekanayake. "Photovoltaic applications for off-grid electrification using novel multi-level inverter technology with energy storage." *Renewable Energy,* 37(1), (2012): 82-88.

[6] Prabaharan N., and K. Palanisamy. "A comprehensive review on reduced switch multilevel inverter topologies, modulation techniques and applications." *Renewable and Sustainable Energy Reviews,* 76, (2017): 1248-1282.

[7] Prabaharan N., and K. Palanisamy. "Analysis and integration of multilevel inverter configuration with boost converters in a photovoltaic system." *Energy Conversion and Management,* 128, (2016): 327-342.

[8] Belkaid A., I. Colak and O. Isik. "Photovoltaic maximum power point tracking under fast varying of solar radiation." *Applied Energy,*179 (2016): 523-530.

[9] Prabaharan N., and K. Palanisamy. "Comparative analysis of symmetric and asymmetric reduced switch MLI topologies using unipolar pulse width modulation strategies." *IET Power Electronics,* 9(15), (2016): 2808-2823.