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Energy Procedia 138 (2017) 1177–1183

Energy Procedia

www.elsevier.com/locate/procedia

2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies 2017 AEDCEE, 25-26 May 2017, Bangkok, Thailand

Integration of Single Phase Reduced Switch Multilevel Inverter Topology for Grid Connected Photovoltaic System

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Abstract

Renewable power generation becomes more popular nowadays due to the low availability of fuels. This paper proposes an integration of single DC source reduced switch multilevel inverter topology for grid connected photovoltaic system to achieve a good quality output waveform. The proposed configuration requires less number of power semiconductor devices when compared to conventional multilevel inverter configurations for generating higher output voltage level with lower total harmonic distortion. A sine reference with phase disposition triangular carrier arrangement is utilized for generating the switching pulses to the proposed multilevel inverter. A single diode model in photovoltaic system and dual output boost converter is utilized in the proposed system to reduce the complexity. Also, the improved incremental and conductance maximum power point tracking is selected in this work. The proposed system is tested only in standard test condition using MATLAB/Simulink. Hence, the proposed system is well suitable for grid connected in photovoltaic system.

Peer-review under responsibility of the scientific committee of the 2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies.

Keywords: Multilevel inverter; converter; photovoltaic; grid integration; renewable energy; solar

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Peer-review under responsibility of the scientific committee of the 2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies.
10.1016/j.egypro.2017.10.231

1. Introduction

The amount of fossil fuels which result in carbon emissions to the atmosphere is finite. Hence the necessity for renewable energy resources has been increasing nowadays [1]. Solar and wind are the most commonly used renewable sources for grid integration. These are reliable, greener and more eco-friendly. They have an environmental boon like low emission comparatively [2]. In recent decades the solar power through photovoltaic systems is affordable and free from dirt or pollution [3]. Photovoltaic power generation is emerging topic of interest in more developing countries when compared to other renewable energy power generation due to low investment cost, pollution free and inexhaustible nature.

Nomenclature

k	Boltzmann constant ($1.3806503 \times 10^{-23}$ J/K)
q	Electron charge ($1.60217646 \times 10^{-19}$ C)
a	diode ideality constant
T	absolute temperature
I_{PV}	photovoltaic current

The keystone to exploit the solar based photovoltaic sources is the inverter. It plays a vital role in energy conversion process from DC to AC in grid connected system. In past decade, multilevel inverter concept is more popular in renewable energy application. Generally three types of universal multilevel inverter topologies like diode clamped MLI, flying capacitor MLI and the cascaded H-Bridge MLI is utilized for high voltage and high power application [4]. In diode clamped MLI, the count of diode raises followed by the increases in output voltage level, whereas in flying capacitor MLI, the capacitor count has its dominance. The cascaded H-Bridge MLI has less number of switches and separate DC sources [5]. Reduced switch multilevel inverter topologies have developed to overcome the drawback of conventional multilevel inverter topologies regarding the component count. Different topologies of multilevel inverters are explained in a detailed manner in [6]. Every type has its advantages and disadvantages. A potential drawback of all these topologies is high number of independent floating DC voltage sources that makes their practical use quite questionable. Therefore, in this paper mainly concentrate to eliminate the utilization of multiple DC sources in multilevel inverter topology.

The main novelty of this paper is to integrate reduced multilevel inverter with dual output boost converter for solar photovoltaic system along with improved incremental and conductance maximum power point technique. Stand-alone power generation system have installed in many places around the world where there is no access to the grid. So, the grid connected system is the perfect solution for peak demand and the intermittent nature of renewable power generation. Therefore, the proposed topology is integrated with grid connected system through the passive filter. The operation of proposed system is tested in standard test condition and the selective test results are portrayed in this paper.

2. Proposed grid connected system

Fig. 1 shows the equivalent circuit of single diode model of photovoltaic cell. Fig. 2(a) and 2(b) show the I-V and P-V characteristics of the PV model. The generalized formula for photovoltaic panel is discussed in [7] and given below. Table 1 shows the different parameters value of 80 W photovoltaic panel.

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

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

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

The PV panel output voltage is connected to dual output boost converter. The rating of PV panel is 80 W. Here, the improved incremental and conductance maximum power point tracking is utilized for achieving good response form the PV panel. The conventional INC MPPT algorithm has the two different drawbacks such as the operating point is oscillating around the MPP point and it does not operate properly in fast varying irradiance condition. To overcome this drawback the improved INC MPPT is discussed in this paper. The detailed algorithm is discussed in [8]. Fig. 3 shows the flow chart of improved incremental and conductance MPPT algorithm. The improved INC MPPT algorithm work perfectly under fast varying irradiance condition. The proposed system is shown in Fig. 4. The proposed system is the combination of dual output boost converter and reduced switch multilevel inverter. The main advantage of the proposed system is to eliminate the requirement of separate DC sources for multilevel inverter. Also, it requires less semiconductor devices when compared to conventional MLI topologies for generating the required output voltage level. The photovoltaic panel is the source of dual output boost converter. The concept of dual output boost converter is discussed in [9].The dual output boost converter voltage is directly fed to the reduced switch multilevel inverter. The important note is the switch S_2 is a bidirectional switch which helps in blocking voltage and conducts current in both directions. The proposed topology can extend to any number of output voltage levels. The dual output boost converter is operated at asymmetric condition. The proposed topology can generate seven-level output voltage. Here, the switch S_1, S_2 and the dc-link voltage V_{c1} and V_{c2} are the level generation part. The Switches S_3 to S_6 are the polarity generation part.

The number of output voltage level (L_V) is calculated as follows

$$L_v = 2^{n+1} - 1 \tag{4}$$

The number of switches (N_S) for multilevel inverter is calculated as follows

$$N_S = 2S + 3 \tag{5}$$

Here, n denotes the number of capacitor in boost converter. S denotes number of switches in multilevel inverter topology. The output voltage of dual output boost converter is maintained by adjusting the duty cycles of the switches. The voltage across capacitor is different. Here, the ratio of voltage across capacitor is binary fashion. The proposed topology switches are triggered by multicarrier phase disposition pulse width modulation technique. Six carriers are needed for generating the seven level output voltage. The six carriers are in phase with same frequency and amplitude which is called Phase Disposition. Fig. 5 shows the multicarrier arrangement for seven level output voltage.

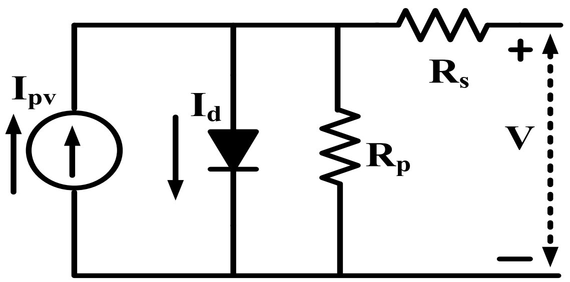
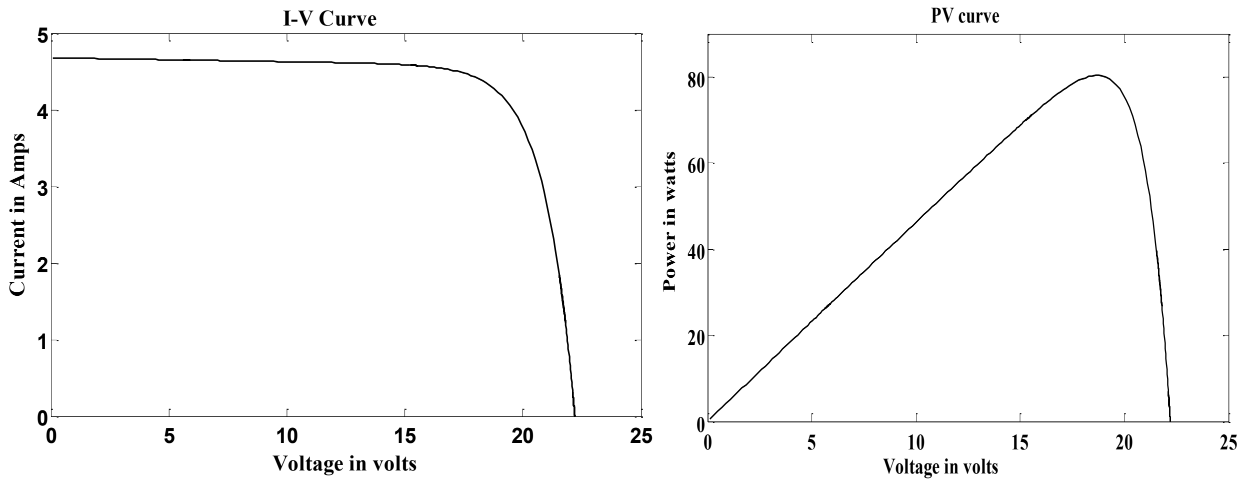


Fig. 1 Single diode model equivalent circuit

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



(a) (b)

Fig. 2 (a) I-V & (b) P-V characteristics

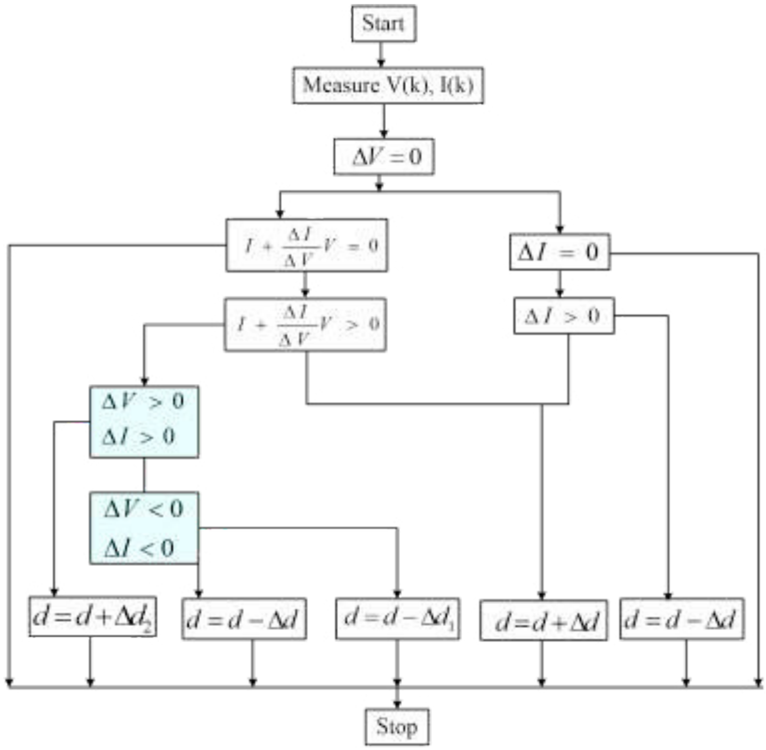


Fig. 3 Improved Incremental and Conductance MPPT algorithm

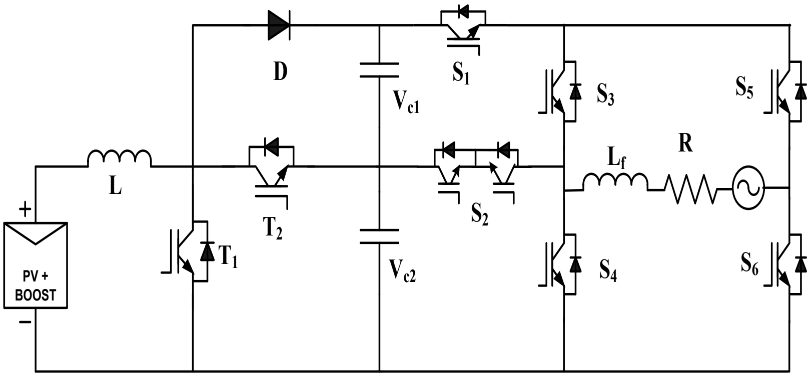


Fig. 4 Proposed multilevel inverter with dual boost converter

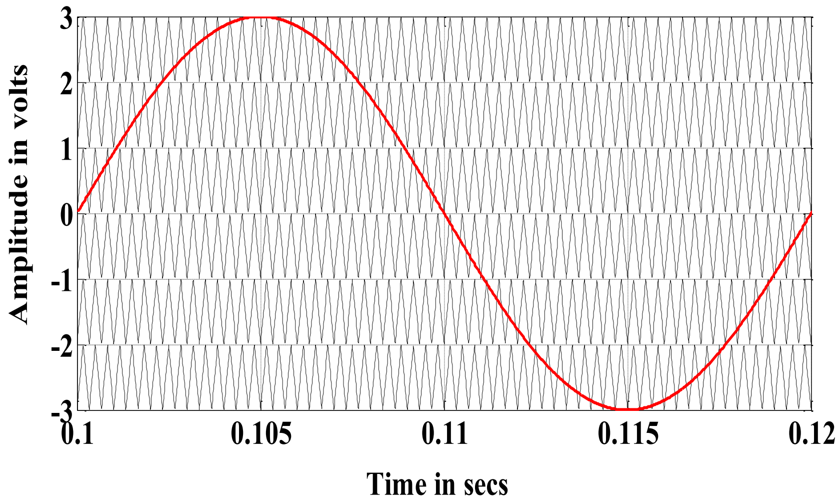


Fig. 5 Phase Disposition carrier arrangement for 7-level output voltage

3. Simulation results for standard test condition

The proposed grid connected reduced switch multilevel inverter with dual output boost converter for generating 7-level output voltage is simulated using MATLAB/SIMULINK. The proposed structure has only one DC source for generating the 7-level output voltage. The single diode model for PV and improved incremental and conductance method is implemented in this paper for giving the better performance when compared to conventional INC method. The dual output boost converter produces two different rating of output voltage which is shown in Fig. 6. Fig. 7 (a) shows the output voltage and output current waveform of proposed multilevel inverter without filter. Fig. 7(b) shows the harmonic spectrum plot for 7-level output voltage in proposed multilevel inverter for PD technique. Fig. 8 depicts the grid voltage and current waveform with filter inductance. The calculation of filter inductance formula is given below.

Filter Inductance $$L_f = \frac{V_{f_{sw}}}{I_{f_{sw}}}\left(\frac{1}{2\pi f_{sw}}\right) \tag{6}$$

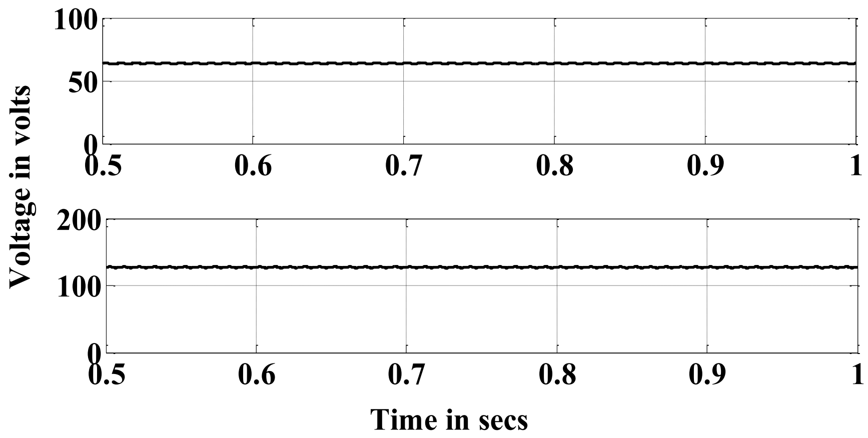
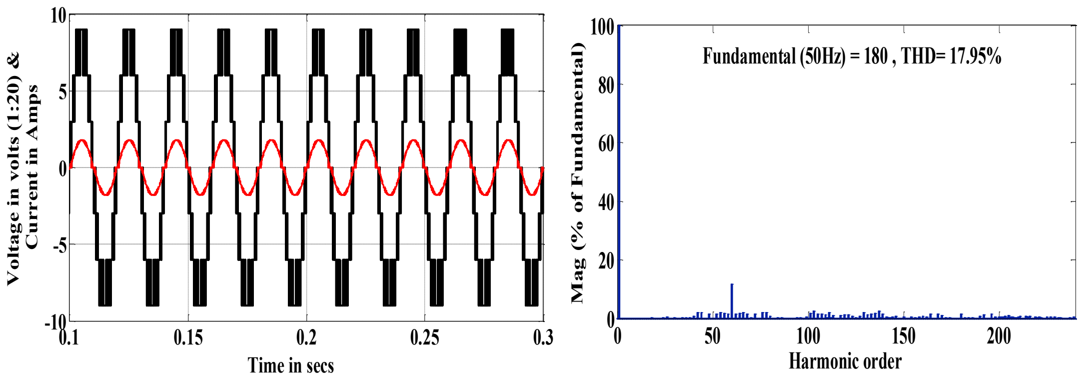


Fig. 6. Dual output boost converter output voltage waveform (upper and bottom: V_{c1} & V_{c2})



(a) (b)

Fig. 7. (a) Output voltage and current waveform with filter (b) Harmonic spectrum plot for output voltage

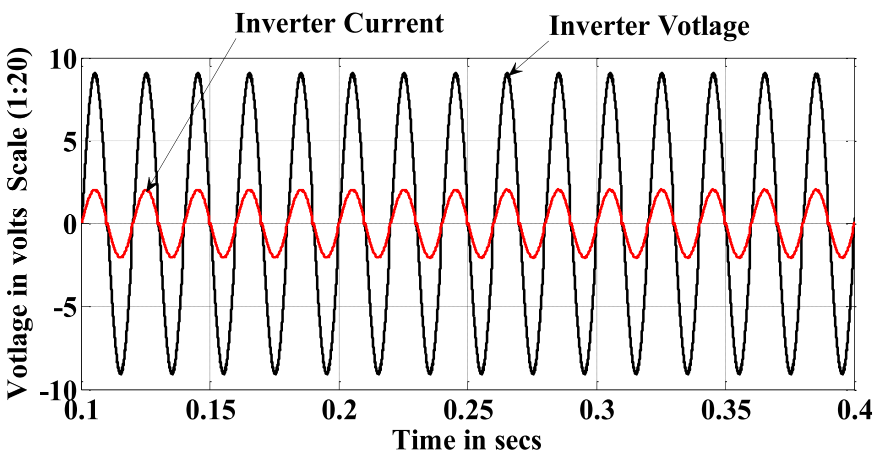


Fig. 8. Grid voltage and current for proposed system

4. Conclusion

The combination of dual output boost converter with reduced switch multilevel inverter has been introduced for photovoltaic grid connected operation. Also, the improved incremental and conductance MPPT algorithm is tested in this paper. In this paper, the proposed system requires only one source for generating the required output voltage level which has the distinct feature. Multicarrier Phase Disposition carrier arrangement is utilized for triggering the proposed multilevel inverter switches. The proposed system is tested only in standard test condition in this paper. From the results and discussion, it is concluded that the proposed system provides better quality output waveforms with lesser component count and also suitable for photovoltaic grid connected operation.

References

[1] Ogbomo OO, Amalu EH, Ekere NN, Olagbegi, PO. A review of photovoltaic module technologies for increased performance in tropical climate. Renewable and Sustainable Energy Reviews 2017;75:1225-1238.
[2] Hasan R, Mekhilef S, Seyedmahmoudian M, Horan B. Grid-connected isolated PV micro inverters: A review. Renewable and Sustainable Energy Reviews 2017;67:1065-1080.
[3] Ishaque K, Salam Z, Shamsudin A, Amjad M. A direct control based maximum power point tracking method for photovoltaic system under partial shading conditions using particle swarm optimization algorithm. Applied Energy, 2012;99: 414-422.
[4] Alishah RS, Nazarpour D, Hosseini SH, Sabahi M. New hybrid structure for multilevel inverter with fewer numbers of components for high-voltage levels. IET Power Electronics 2014; 7(1): 96-104.
[5] Prabaharan N, Palanisamy, K. Comparative analysis of symmetric and asymmetric reduced switch MLI topologies using unipolar pulse width modulation strategies. IET Power Electronics. 2016; 9(15): 2808-2823.
[6] Prabaharan N, Palanisamy, K. A comprehensive review on reduced switch multilevel inverter topologies, modulation techniques and applications. Renewable and Sustainable Energy Reviews 2017; 76(C): 1248-1282.
[7] Prabaharan N, Palanisamy, K. Analysis and integration of multilevel inverter configuration with boost converters in a photovoltaic system. Energy Conversion and Management 2016; 128(C): 327-342.
[8] Belkaid A, Colak I, Isik O. Photovoltaic maximum power point tracking under fast varying of solar radiation. Applied Energy, 2016; 179:523-530.
[9] Nami A, Zare F, Ghosh A., Blaabjerg F. Multi-output DC–DC converters based on diode-clamped converters configuration: topology and control strategy.. IET power electronics 2010; 3(2):197-208.