IJERST

International Journal of Engineering Research and Science & Technology

ISSN : 2319-5991
Vol. 4, No. 4
November 2015

www.ijerst.com

Email: editorijerst@gmail.com or editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 4, No. 4, November 2015

Research Paper

RENEWABLE ENERGY SOURCE BASED 9 LEVEL CONVERTER WITH MINIMUM SWITCHES FOR DISTRIBUTED GENERATION

M Karthika[1]*, Latha L R[1] and Roopa C[1]

*Corresponding Author: M Karthika ✉ Karthikaganesh16@gmail.com

The increase interest in renewable energy production together with higher and higher demand from the energy distribution companies (TSO) regarding grid energy injection and grid support in case of a failure raises new challenges in terms of control for Wind Turbine (WT) systems. Most PV arrays use an inverter to convert the DC power produced by the modules into alternating current that can power lights, motors, and other loads. The modules in a PV array are usually first connected in series to obtain the desired voltage; the individual strings are then connected in parallel to allow the system to produce more current. The PV array is made up of number of PV modules connected in series called string and number of such strings connected in parallel to achieve desired voltage and current. The PV module used for simulation study consists of 36 series connected polycrystalline cells. Due to the above mentioned, grid side inverter control in WT systems is one of the main issues in decentralized power production units. A multilevel power conversion concept based on the combination of Neutral-Point-Clamped (NPC) and floating capacitor converters. In the proposed scheme, the voltage balancing across the floating capacitors is achieved by using a proper selection of redundant switching states, and the neutral-point voltage is controlled by the classical dc offset injection. The proposed 9L ANPC converter is studied in the case of the grid connection of a 6-MW WT without using passive grid filters in DG systems. The connection of a Wind Turbine (WT) to the grid is a delicate issue. In fact, the stochastic power production of large-power wind turbines or wind-parks could create problems to the transmission line designed for constant power and to the power system stability. This important issue justifies the concerns related to increasing penetration of wind energy within the power system. The proper operation and the compliance to the harmonic limit standards of the filter less grid-connected WT system are verified through MATLAB/SIMULINK.

Keywords: Renewable energy, Distributed generation, Wind turbine, MATLAB, SIMULINK

INTRODUCTION

Converting solar energy into electrical energy by PV installations is the most recognized way to use solar energy. Since solar photovoltaic cells are semiconductor devices, they have a lot in common with processing and production

[1] Department of Electrical & Electronics Engineering, New Horizon College of Engineering, Bangalore, Karnataka, India.

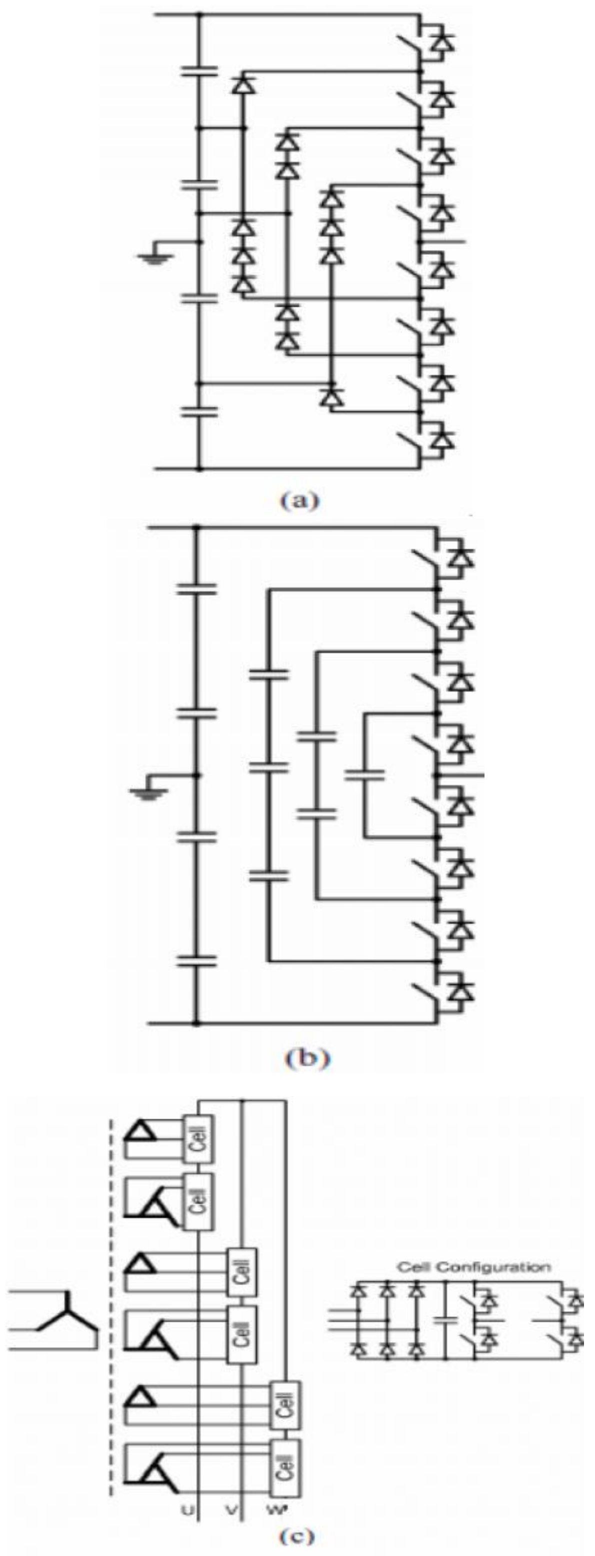
techniques of other semiconductor devices such as computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large. With today's production, which reached a large scale, the whole industry production of solar cells has been developed and, due to low production cost, it is mostly located in the Far East. Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material.

Nowadays, renewable energy systems are undergoing an important development. Among them wind energy stands out for its installed capacity, power generation and steady growth [1]-[3]. Due to the expected rated power growth of the wind turbines [4], the high power converter topologies acquire an increasing interest. Multilevel converters are particularly interesting for power values above 2-3 MW. There are a limited number of topologies that provide multilevel voltages and are suitable for medium voltage applications. The most known topologies are the Neutral-Point-Clamped (NPC), the Flying Capacitor (FC), and the cascaded H-bridge multilevel converters [1] [2] [3] [4]. Other topologies such as the hybrid converters have been proposed as well, but they are not fully accepted for industrial applications Among the different multilevel converters topologies [5] the three-level Neutral-Point Clamped (NPC) converter [6] is the most widely used. 3-level Voltage Source Converters (VSCs), particularly the 3-level Neutral-Point-Clamped Converter (NPCC), are widely used in industrial medium voltage range applications (e.g., rolling mills, fans, pumps, marine appliances, mining, tractions, and renewable energy) [3] [4]. Three-phase three-level NPC converters were proposed in to draw the sinusoidal line currents in phase with mains voltages. The input power factor is close to unity. Recent investigations have shown that the NPCC is also a promising alternative for low-voltage applications power semiconductors in the circuit, a complex control scheme and the neutral-point voltage balance problem. In industrial applications with a unidirectional power flow, conventional multilevel converters are too expensive and complicated to implement. A three-phase three-level AC/DC converter with fewer power switches is presented to achieve almost unity power factor, to regulate the DC link voltage and to achieve fast dynamic response. The circuit topologies of multilevel inverters can be classified into Neutral-Point diode Clamped (NPC) inverters, flying capacitor clamped inverters, and cascade full bridge inverters.

The NPC multilevel converter shown in Figure 1(a) is a natural extension of the three-level converter presented by Nabae (NPC3L). As can be seen, the multilevel NPC converter requires multiple clamping points to synthesize the different voltage levels across the output. The disadvantage of multiple clamping points is a limitation on the maximum modulation index that is allowed with active power to assure voltage sharing across all the dc link capacitors [7]. Another drawback of the multilevel NPC converter is the need for series connection of the clamping diodes.

Power quality is one of the main concerns for the wind Power conversion in DG systems. A successful operation of grid-connected WT systems is required to meet the harmonic limit mandated by utility standards. Therefore, passive grid filters are usually required. But for high power ranges, they are bulky, heavy, and costly, and have potential resonant risk. In this paper, a new

Figure 1: (a) NPC, (b) Floating Capacitor, and (c) Cascaded H-Bridge and Basic Cell



nine-level ANPC (9L ANPC) converter is proposed for the grid-side converter of large WTs in DG systems. The purpose of this new topology is to improve the waveform and power quality, and thus reduce or even completely remove the passive grid filters to achieve a filter less grid connection, which enables to reduce the cost, and increase the efficiency, power density, and reliability of the WT system in DG.

Based upon the previous description, this paper proposes an Active Neutral-Point-Clamped (ANPC) multilevel converter that combines the flexibility of the multilevel floating capacitor converter with the robustness of industrial NPC converters to generate multilevel voltages. The proposed concept is described and supported by simulation results, and experimental validation demonstrates the proposed technology.

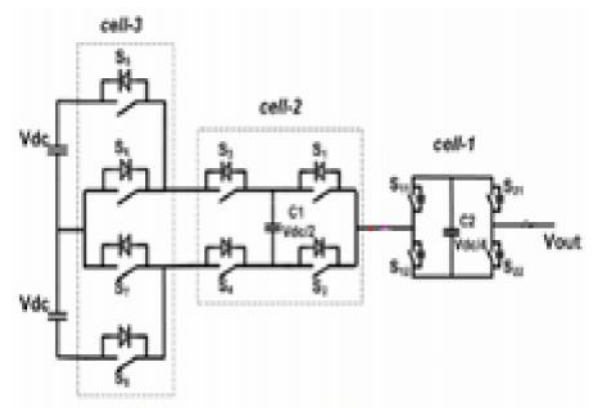
PROPOSED 9LANPC CONVERTER

The main purpose of this paper is to upgrade the ANPC5L Converter to a 9L converter to improve waveform quality, and thus to achieve filter less grid connection for large WT systems. A new 9 LANPC topology, named ANPC5L plus HBBB converter, is proposed and discussed in detail in this section.

Topology of the New 9L ANPC Converter

The circuit of the proposed new 9L ANPC converter is shown in Figure 2. Different from the other aforementioned 9L ANPC converters, in this proposed topology, an HBBB is directly connected to each phase of a standard ANPC5L converter. Each phase of the converter has two floating capacitors, and their voltages are and of half dc-link voltage, respectively. The device blocking voltages are: Vdc for S5-S8, Vdc/2 for S1-S4, and

Figure 2: Proposed 9L ANPC Converter



Vdc/4 for S11-S22. Regarding the floating capacitors, their capacitance needs to limit the voltage ripple seen by the capacitors for a given switching frequency, which can be calculated by the following:

$$C = \frac{Ipk}{\Delta Vc}\frac{1}{fc} \quad ...(1)$$

$$C_2 = 2C_1 \quad ...(2)$$

For one phase leg of the new 9L ANPC converter, the energy stored in the floating capacitor C1 and C2 is expressed by (3) and (4), respectively

$$EC1 = \frac{1}{2}.C_1\left(\frac{V_{dc}}{2}\right)^2 - \frac{1}{8}.C_1.V_{dc}^2 \quad ...(3)$$

$$EC2 = \frac{1}{2}.C_2\left(\frac{V_{dc}}{4}\right)^2 = \frac{1}{32}.C_2.V_{dc}^2 \quad ...(4)$$

Therefore, the total stored energy in each phase of the converter is given by the following:

$$E_{total} = E_{C1} + E_{C2} = \frac{1}{32}(4.\ C_1 + C_2).V_{dc}^2 \quad ...(5)$$

The proposed topology is considered to be an effective and Practical solution to expand an existing ANPC5L converter in the WT system to a 9L converter because it has the following features.

Both ANPC5L and HBBB are standard PEBBs, and have been commercialized in the market [22], [23]. Therefore, the potential technical risk associated with the converter innovations is reduced.

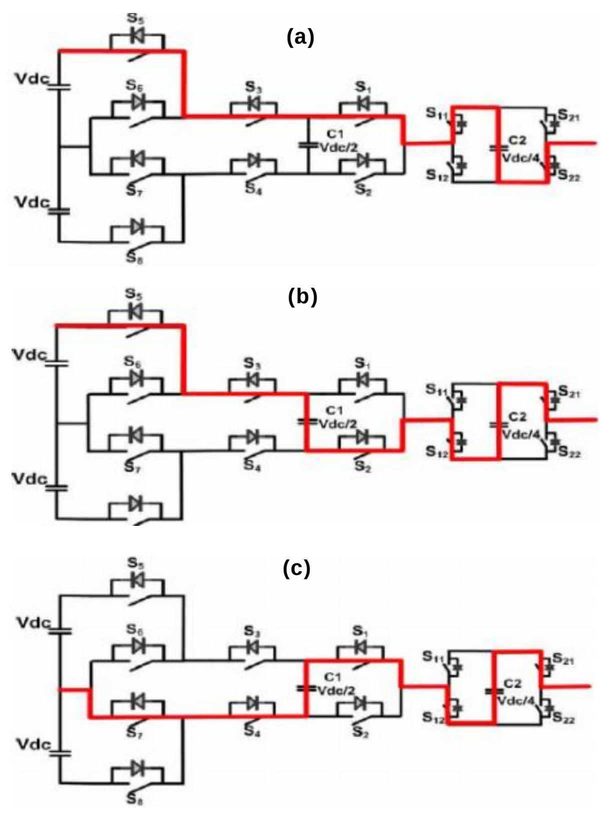
Operating Principle and Control of the New 9L ANPC Converter

In the proposed topology, the ANPC5L and HBBB can generate 5 L and 3 L output voltage waveforms, respectively. Through the proper switching state combinations of the two building blocks, a 9 L output voltage waveform is obtainable. Figure 3 shows the possible switching states and current flow path associated with the output voltage level 3Vdc/4 of the proposed 9L ANPC converter. It can be found that the output voltage is synthesized by adding or subtracting the dc-link capacitor voltages and the floating capacitor voltages. There are three options to generate the output voltage 3Vdc/4. The expressions for the output voltage synthesization are provided in (6), (7), and (8), respectively. These redundant switching states can be used to balance the floating capacitor voltage, which is explained later. The complete switching states, switching sequence. The positive direction of the phase current is defined as flowing out of the ac terminal. For the switching state, “1” and “0” represent the on state and off state of the device, respectively. For the effect on floating capacitor voltage, “+”, “_”, and “0” represent charging, discharging, and no impact, respectively.

$$vdc = vdc - \frac{vdc}{4} = \frac{3vdc}{4} \quad ...(6)$$

$$vout = vdc - vc1 + vc2 = vdc - \frac{vdc}{2} + \frac{vdc}{4} = \frac{3vdc}{4} \quad ...(7)$$

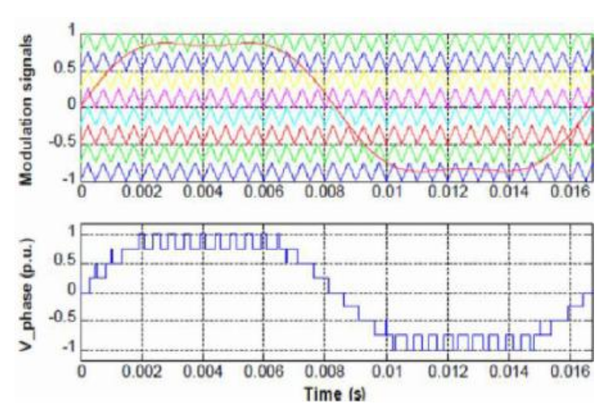
Figure 3: Switching States and Current Flow Path for V_{out} = 3Vdc/4 of the New 9L ANPC Converter: (a) Switching State V2; (b) Switching State V21; (c) Switching State V22



$$vout = 0 + vc1 + vc2 = \frac{vdc}{2} + \frac{vdc}{4} = \frac{3vdc}{4} \quad ...(8)$$

The Pulse-Width-Modulation (PWM) scheme for the new 9L ANPC converter is shown in Figure 4. Carrier-based Sinusoidal PWM (SPWM) with third harmonic injection is used in this PWM method. Eight carriers and one reference signal are used for each phase of the converter. The eight triangle carriers with the same frequency and peak-to-peak amplitude are placed such that the voltage bands they occupy are continuous. The reference signal is centered in the middle of the carrier. By comparing each of the carriers with the reference, the corresponding switching states are switched and the 9L output voltage waveform is generated.

Figure 4: PWM Signals and the Output Voltage of the Proposed 9L ANPC Converter



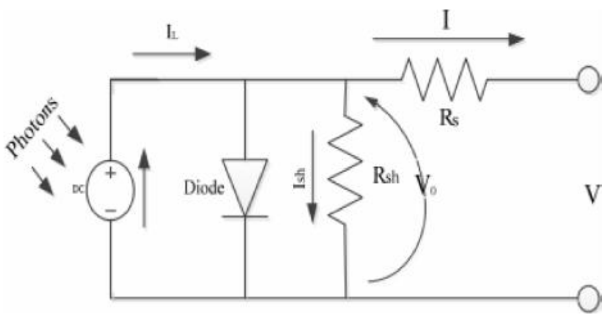
For example, when the phase output voltage is 3Vdc/4, the control scheme for the floating capacitor voltage balance is explained below.

If the voltage deviation of C1 is larger than C2 , then C1 has higher priority: 1) when C1 needs to be charged and if I > 0, Then V21 is selected. Otherwise, if I < 0, then V22 should be selected; 2) when C1 needs to be discharged and if I > 0, then V22 is selected. Otherwise, if I < 0, V21 should be selected. For both cases, while the selected switching state is working on balancing the voltage of C1 , the correct voltage balance action may not occur on the capacitor C2 because the impact on C2 is to discharge when I > 0 and charge when I < 0 without considering the actual voltage state of C2. The voltage deviation on C2 may become larger in the current switching cycle. But in the next switching cycle, if its voltage deviation exceeds that of C1, it will obtain the higher priority, and then the proper control for capacitor C2 will be chosen.

PHOTOVOLTAIC (PV) SYSTEM

In the crystalline silicon PV module, the complex physics of the PV cell can be represented by the equivalent electrical circuit shown in Figure 5. For

Figure 5: Equivalent Electrical Circuit of a PV Module



that equivalent circuit, a set of equations have been derived, based on standard theory, which allows the operation of a single solar cell to be simulated using data from manufacturers or field experiments.

The series resistance RS represents the internal losses due to the current flow. Shunt resistance Rsh, in parallel with diode, this corresponds to the leakage current to the ground. The single exponential equation which models a PV cell is extracted from the physics of the PN junction and is widely agreed as echoing the behaviour of the PV cell.

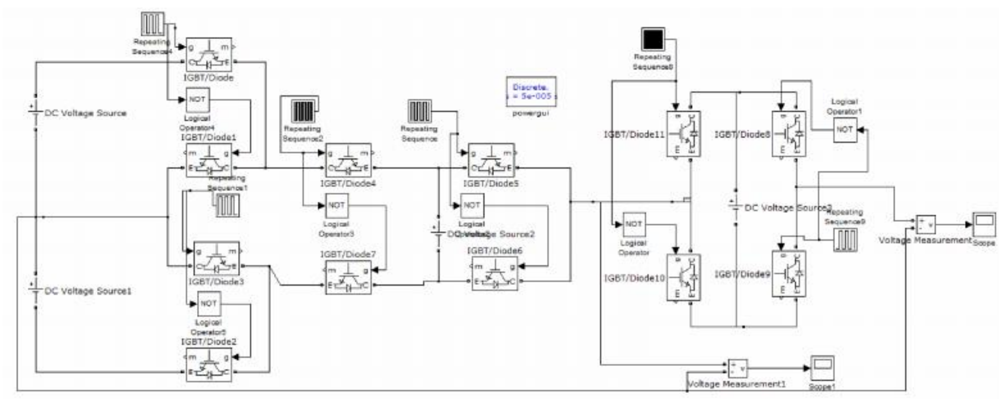
$$I = I_L - I_{sc}\left(\exp\frac{(V + R_s I)}{V_t} - 1\right) - \frac{(V + R_s I)}{R_{sh}} \quad ...(9)$$

The number of PV modules connected in parallel and series in PV array are used in expression. The V_t is also defined in terms of the ideality factor of PN junction (n), Boltzmann's constant (KB), temperature of photovoltaic array (T), and the electron charge (q). applied a dynamical Electrical Array Reconfiguration (EAR) strategy on the photovoltaic (PV) generator of a grid-connected PV system based on a plant-oriented configuration, in order to improve its energy production when the operating conditions of the solar panels are different. The EAR strategy is carried out by inserting a controllable switching matrix between the PV generator and the central inverter, which allows the electrical reconnection of the available PV modules.

MATLAB/SIMULINK MODELLING AND SIMULATION RESULTS

Here the simulation results are carried out in different cases: 1) Proposed Nine Level Converter Topology for Grid Interconnection 2) Proposed Nine Level Converter Topology for Grid Interconnection with PV Cell.

Figure 6: Matlab/Simulink Model of Proposed Nine Level Converter Topology



Case 1: Proposed Nine Level Converter Topology for Grid Interconnection

Figure 6 shows the Matlab/Simulink Model of Proposed Nine Level Converter Topology using Matlab/Simulink Platform.

Figure 7: Nine-Level Output Voltage

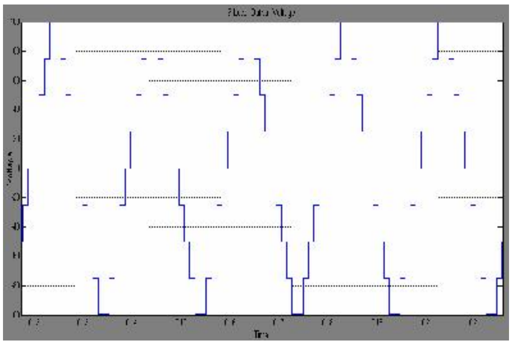


Figure 7 shows the Nine-Level Output Voltage of Proposed Nine Level Converter Topology.

Case 2: Proposed Nine Level Converter Topology for Grid Interconnection with PV Cell

Figure 8 shows the Matlab/Simulink Model of Proposed Nine Level Converter Topology with PV Cells using Matlab/Simulink Platform.

Figure 9 shows the Matlab/Simulink Model of Proposed PV Cell using Matlab/Simulink Platform.

Figure 10 shows the Nine-Level Output Voltage of Proposed Nine Level Converter Topology with PV Cell.

Figure 8: Matlab/Simulink Model of Proposed Nine Level Converter Topology with PV Cell

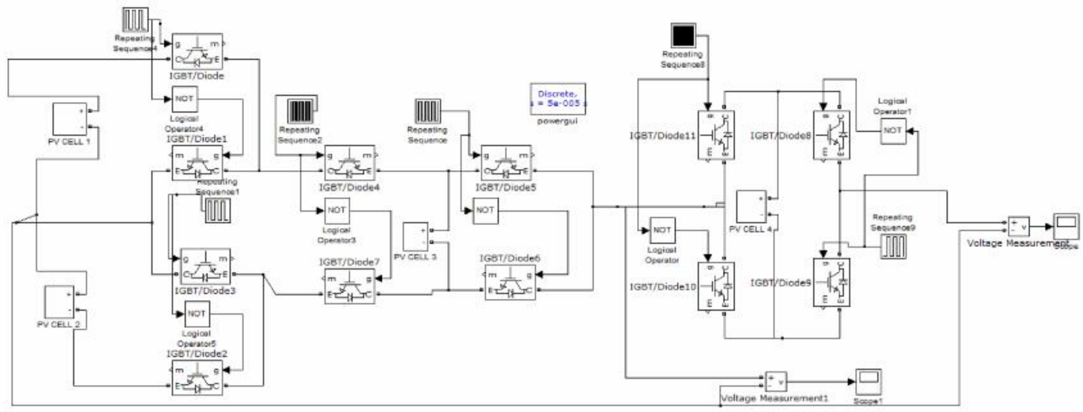


Figure 9: Matlab/Simulink Model of Proposed PV Cell

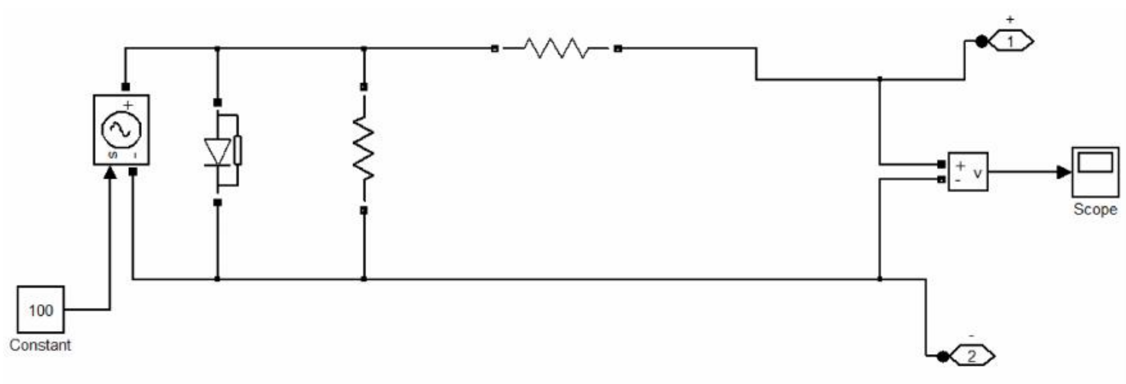
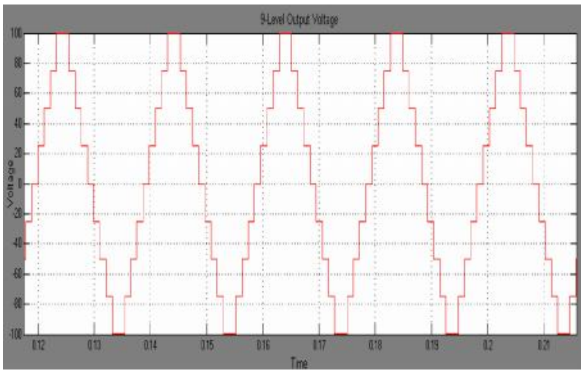


Figure 10: Nine-Level Output Voltage with PV Cell



CONCLUSION

In this paper, a new 9LANPCconverter, named ANPC5L plus HBBB converter and Cascaded H-Bridge Multilevel topology also, has been proposed to improve the waveform quality. A scheme based on redundant switching states and capacitor prioritization is presented for the floating capacitor voltage control. The hybrid converter concept and selection of semiconductor devices are presented to best exploit the individual advantages of different power devices. Simulation results are presented to prove the validity of the proposed converter topology. A comparison between the proposed 9L converter and 9L converters with PV Cell is carried out from several aspects. Simulation results show the proper operation of the PV system and verify the feature indicates that the cost, efficiency, power density, and reliability of the PV Power conversion in the DG systems can be improved.

REFERENCES

1. "20% Wind Energy by 2030: Increasing Wind Energy's Contribution to US Electricity Supply", Wind Manufacturing Workshop, July, US Department of Energy, Washington, DC, Tech. Rep. DOE/GO-102008-2567.
2. Blaabjerg F, Chen Z and Kjaer S B (2004), "Power Electronics as Efficient Interface in Dispersed Power Generation Systems", *IEEE Trans. Power Electron.*, Vol. 19, No. 5.
3. Chen Z, Guerrero J M and Blaabjerg F (2009), "A Review of the State of the Art of Power Electronics for Wind Turbines", *IEEE Trans. Power Electron.*, Vol. 25, No. 8, pp. 1859-1875.
4. Guerrero J M, Blaabjerg F, Zhelev T, Hemmes K, Monmasson E, Jemei S, Comech M P, Granadino R and Frau J I (2010), "Distributed Generation: Toward a New Energy Paradigm", *IEEE Ind. Electron. Mag.*, Vol. 4, No. 1, pp. 52-64.
5. Liserre M, Sauter T and Hung J Y (2010), "Future Energy Systems: Integrating Renewable Energy Sources into the Smart Power Grid Through Industrial Electronics", *IEEE Ind. Electron. Mag.*, Vol. 4, No. 1, pp. 18-37.
6. Li Y W and Kao C-N (2009), "An Accurate Power Control Strategy for Powerelectronics-Interfaced Distributed Generation Units Operating in a Low Voltage Multibus Microgrid", *IEEE Trans. Power Electron.*, Vol. 24, No. 12, pp. 2977-2988.
7. Mohamed Y and El-Saadany E F (2008), "Adaptive Decentralized Droop Controller to Preserve Power Sharing Stability of Paralleled Inverters in Distributed Generation Microgrids", *IEEE Trans. Power Electron.*, Vol. 23, No. 6, pp. 2806-2816.
8. Ng C H, Parker M A, Li R, Tavner P J, Bumby J R and Spooner E (2008), "A Multilevel Modular Converter for a Large, Light Weight Wind Turbine Generator",

IEEE Trans. Power Electron., Vol. 23, No. 3, pp. 1062-1074.

9. Prasad K N V, Ranjith Kumar G, Vamsee Kiran T and Satyanarayana G (2013), "Comparison of Different Topologies of Cascaded H-Bridge Multilevel Inverter", Computer Communication and Informatics (ICCCI), International Conference, January 4-6, pp. 1 & 6.

10. Rodriguez J, Franquelo L G, Kouro S, Leon J I, Portillo R C, Prats M A M and Perez M A (2009), "Multilevel Converters: An Enabling Technology for High-Power Applications", *Proc. IEEE*, Vol. 97, No. 11, pp. 1786-1817.

11. Timbus A, Liserre M, Teodorescu R, Rodriguez P and Blaabjerg F (2009), "Evaluation of Current Controller for Distributed Power Generation Systems", *IEEE Trans. Power Electron.*, Vol. 24, No. 3, pp. 654-664.

International Journal of Engineering Research and Science & Technology
Hyderabad, INDIA. Ph: +91-09441351700, 09059645577
E-mail: editorijlerst@gmail.com or editor@ijerst.com
Website: www.ijerst.com

ISSN 2319-5991