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Volume 08, Issue 08, Pages: 1–8.

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PHOTO-VOLTAIC ARRAY FED TRANSFORMER-LESS INVERTER WITH ENERGY STORAGE SYSTEM FOR GRID CONNECTED APPLICATIONS

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Abstract—With the increase in the level of solar energy integration into the power grid, there arises a need for highly efficient multilevel transformer less grid connected inverter which is able to inject more power into the grid. In this paper,a novel 5-level Hybrid Neutral Point Clamped transformer-less inverter topology is proposed which has no inherent ground leakage current. The proposed inverter is analyzed in detail and its switching pattern to generate multilevel output is discussed. The proposed inverter is compared with some popular transformer-less inverter topologies. Simulations and experiments results confirm the feasibility and good performance of the proposed inverter.

1. INTRODUCTION:

Photovoltaic is the field of technology and research related to the devices which directly convert sunlight into electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic effect involves the creation of voltage in a material upon exposure to electromagnetic radiation.The photovoltaic effect was first noted by a French physicist, Edmund Becquerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel prize in physics. The first photovoltaic module was built by Bell Laboratories in 1954. It was billed as a solar battery and was mostly just a curiosity as it was too expensive to gain widespread use. In the 1960s, the space industry began to make the first serious use of the technology to provide power aboard spacecraft. Through the space programs, the technology advanced, its reliability was established, and the cost began to decline. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications.The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon. One of the properties of semiconductors that makes them most useful is that their conductivity may easily be modified by introducing impurities into their crystal lattice. For instance, in the fabrication of a photovoltaic solar cell, silicon, which has four valence electrons, is treated to increase its conductivity. On one side of the cell, the impurities, which are phosphorus atoms with five valence electrons (n-donor), donate weakly bound valence electrons to the silicon material, creating excess negative charge carriers.

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On the other side, atoms of boron with three valence electrons (p-donor) create a greater affinity than silicon to attract electrons. Because the p-type silicon is in intimate contact with the n-type silicon a p-n junction is established and a diffusion of electrons occurs from the region of high electron concentration (the n-type side) into the region of low electron concentration (p-type side). When the electrons diffuse across the p-n junction, they recombine with holes on the p-type side. However, the diffusion of carriers does not occur indefinitely, because the imbalance of charge immediately on either sides of the junction originates an electric field. This electric field forms a diode that promotes current to flow in only one direction. Ohmic metal-semiconductor contacts are made to both the n-type and p-type sides of the solar cell, and the electrodes are ready to be connected to an external load. When photons of light fall on the cell, they transfer their energy to the charge carriers. The electric field across the junction separates photo-generated positive charge carriers (holes) from their negative counterpart(electrons). In this way an electrical current is extractedonce the circuit is closed on an external load.

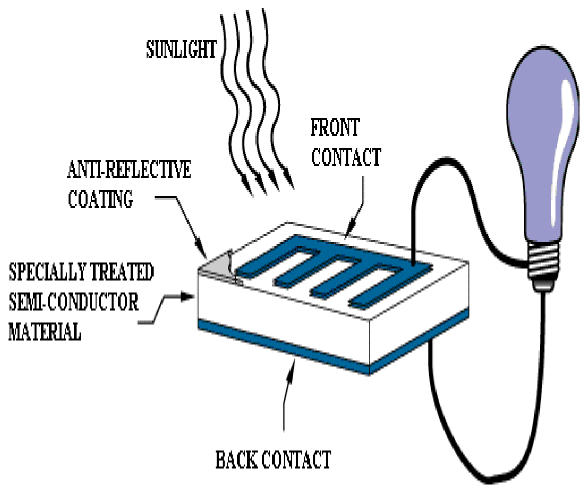

Figure 1:Photovoltaic cell

2. OVERVIEW OF GRID CONNECTED SOLARPHOTOVOLTAIC SYSTEMS

The PV Power Conversion System (PCS) plays an important role in renewable energy source based power generation. The PCS converts the available DC supply from the source into required AC voltage (415 V, 50 Hz)as specified by the utility grid by means of power electronic converter and is feed into the grid. This chapter focuses on the components of a PV grid connected system and its characteristics. The various power conversion systems are studied in literature and compared based on efficiency, cost and volume from which a suitable power converter for PV power conversion system is suggested to obtain high reliability and high efficiency with low cost. Then a brief literature review of transformer less grid connected system is carried out to identify the setbacks of conventional transformer less inverter. Finally synchronization methods of grid connected system are discussed.

2.2 SYSTEM DESCRIPTION

Figure 2.1 shows the block diagram of a grid connected PV system. It consists of PV plants, MPPT controller, PWM controller, power conditioner(inverter), and filter. PV plant converts the sunlight into DC power, and a power conditioning unit that converts the DC power to AC power. The generated AC power is injected into the grid and/or utilized by the local loads through the filter. In some cases, the PV system is combined with storage devices which improve the availability of the power. The subsequent section provides more details about various components of the PV system.

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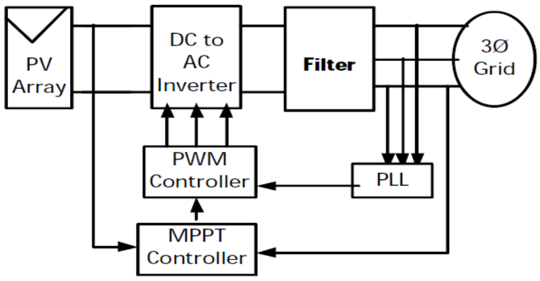

Figure 2 Block diagram of PV grid connected inverter

3. PV ARRAY MODEL

The PV plant consists of PV cells and it is arranged in series and parallel combination to supply the desired DC voltage and current. Normally PV cell is made up of silicon semiconductor and each silicon cell generates0.6V. The commercially available PV module consists of 36 or 72 cells connected in series to form a PV plant. The typical PV module used for simulation parameters are listed in Table 1.

Table 1 Electrical parameters of BP 3235T PV panel at standard testcondition G=1000W/m2 C

PV Parameters	Ratings
Maximum output Power (P_{Max})	235 W
Power Tolerance (P_T)	[0 to 5] W
Percentage Efficiency of Module (η)	15.0%
Voltage at maximum power point (V_{MPP})	30.0 V
Current at maximum power point (I_{MPP})	7.84A
Open circuit voltage (V_{oc})	37.44 V
Short circuit current (I_{sc})	8.83 A

The simple equivalent circuit of the PV cell model is shown in Figure 3. It consists of ideal current source in parallel with the diode. The practical model of PV cells consists of series resistance (Rs) and parallel resistance (Rp) and is shown Figure.2.3.

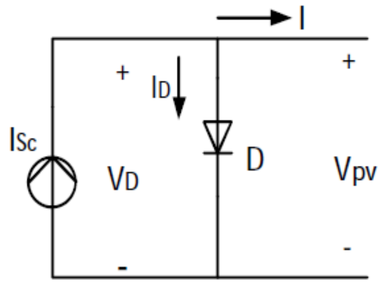

Figure 3 Basic equivalent circuit of PV cell

From the basic model, output current (I) is represented in Equation (2.1) and diode current is given in Equation (2.2).

$$I = I_{sc} - I_D$$

$$I_d = I_o\left(e^{\frac{qvd}{kT}} - 1\right)$$

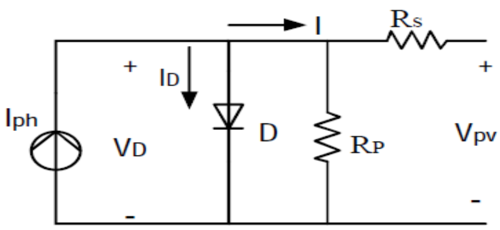

Figure 4 Practical equivalent circuit model of PV cell

The voltage current (Vg Ig) relation of the PV plant is given in the literature Rauschenbach (1980).

$$I = I_{ph} - I_0\left\{\exp\left(\frac{V+IR_s}{n_s V_t}\right) - 1\right\} - \left(\frac{V+IR_s}{R_{sh}}\right)$$

where

V - Module voltage

I - Module current

Iph - Photon generated current

I0 - Dark saturation current respectively

Vt - Junction thermal voltage, Rs is the series cell resistance,

and Rsh cell shunt resistance

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ns - number of cells connected in series
Is - saturation current,
K - Boltzmann constant 1.38×10-23 J / K
A - solar cell ideal factor of the diode,
q - electron charge 1.6×10-19 C

$$V_t = \frac{KTA}{q}$$

The photo current mainly depends on the solar irradiance and celltemperature (Tsai et al 2012).

$$I_{ph} = (I_{sc} + k_i (T_c - T_{ref}))G$$

where
Isc - Shortcircuit current of PV cell at 25°C
G - Solar insolation (kW/m2). = (1 kW/m2),
ki - Temperature coefficients
T-ref- Reference temperature of the cell.

4. PROPOSED SYSTEM

Over the years, solar photovoltaic (PV) energy has stoodout to be an attractive solution for global energy crisis.Advances in highly efficient PV module fabrication technologieshave made the dream of rooftop solar energy areality today. Due to their low cost and high efficiency,transformerless inverters are usually preferred to integratethe solar energy into the power grid. However, the in herentdemerit of the transformer less inverters is the presence of
galvanic connection between the grid and the PV array.This can lead to high ground leakage current, there by compromising the safety of the overall system [1, 2]. Themagnitude of these leakage currents between the PV panelterminals and ground depends mostly on the value of thisstray capacitance and the amplitude and frequency content ofthe common-mode voltage variations that are present at thePV panel terminals [4]. This has led to the development ofseveral new transformerless inverters, which employ variousmethods to suppress this leakage current [2, 6]. The inverterslike the H5 and HERIC inverter employ decoupling methodsduring the freewheeling period [2]. Another method is toclamp the inverter to the midpoint of the DC link during thefreewheeling period [2]. Recently, a new inverter topology
is proposed wherein; the leakage current is eliminated byconnecting the grid neutral point directly to the PV negativeterminal, thereby bypassing the PV stray capacitance[13].These available transformerless inverters output maximumpower in the range of few kWs. Therefore, in order tooutput even higher power, there arises a need for a multileveltransformerless inverter which is devoid of ground leakage.currents. Full bridge based transformerless inverters cannever truly eliminate the leakage current due to the virtue
of its topological properties[4]. Moreover, a multilevel fullbridge based transformerless inverter can lead to very highleakage currents. Hence, half bridge based transformerlessinverters, like the diode clamped multilevel inverter, arepreferred for high power systems as they clamp the gridneutral point directly to the midpoint of the dc link, this
can be seen in Fig. 1. A multilevel diode clamped inverterwas proposed in [5], wherein across the individual dclink capacitors, multiple PV arrays are connected and arecontrolled independently. However, as the output

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voltagelevel increases, the total inverter cost increases, whereasthe efficiency of the inverter reduces. Therefore, there is aneed for a high efficiency low cost multi-level transformerlessinverter. In this paper, a novel 5-level hybrid neutralpoint clamped transformerless inverter is proposed, whichattempts to provide a solution for the need of high efficiency,high power multilevel inverter.

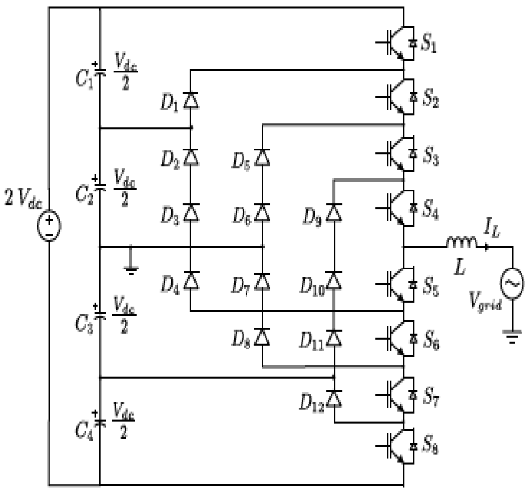

Fig. 5. 5-level diode clamped multilevel inverter

The proposed 5-level hybrid neutral point clamped (5LHNPC)inverter consists of 8 switches S1-S8, four diodesD1-D4 and four DC link capacitors C1-C4 as shown in Fig.2 [8].

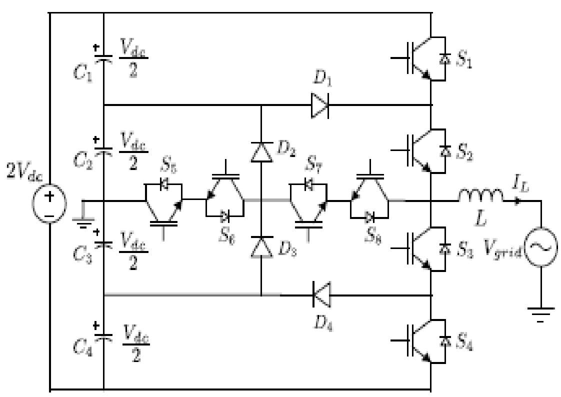

Fig. 6. Proposed hybrid neutral point clamped inverter

There are two structures, which can be employed forgrid-connected PV inverters with the proposed 5L-HNPC:multistring structure and multi PV array structure as in [5],where across the individual DC link capacitors, multiple PVarrays are connected and are controlled independently. Incase of multistring structure, addition chopper circuitry [9]is required to balance the DC link capacitors. In case ofmulti-array structure [5], the DC link voltages are balancedwith appropriate control technique as each of the capacitoris connected directly to PV arrays. In the proposed topology,for a DC link voltage of 2Vdc, the output voltages obtainedare Vdc, Vdc/2, 0, -Vdc/2 and -Vdc. The switching patternsto generate appropriate voltages is shown in Table I. Thecurrent direction is as shown in Fig. 2. The + and - symbols in Table I represent the positive and negative currentdirections respectively. The proposed 5L-HNPC inverter issimulated in MATLAB Simulink and the results for outputvoltage and current are shown in Fig. 3.

The comparison between the proposed inverter and theconventional 5-level diode clamped inverter (5L-DCMLI) isshown in Table II. Here the devices S2 and S3 are ratedfor 3Vdc/2, S1, S4, S5, S6, S7, S8, D1 and D4 are rated

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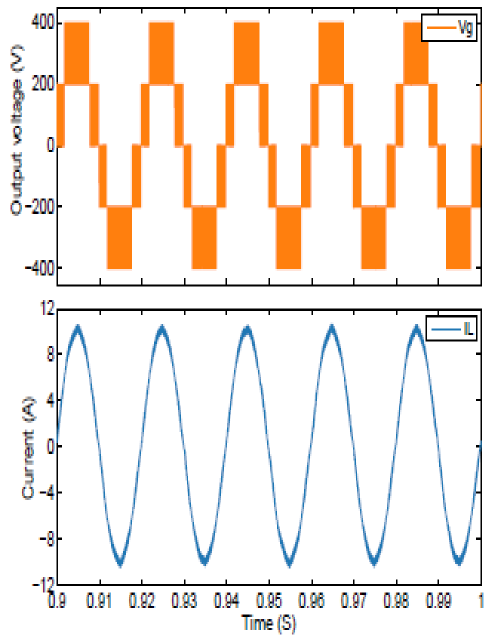
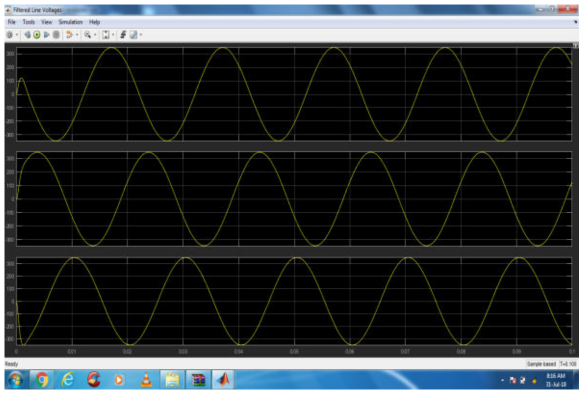
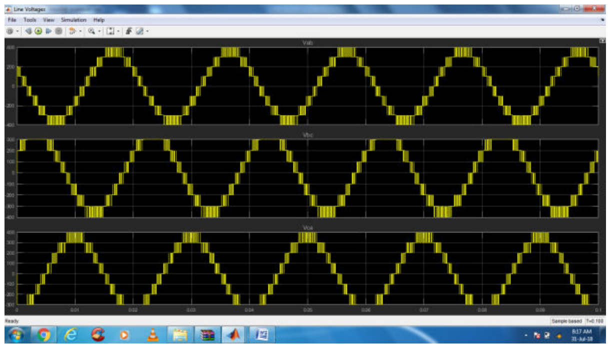


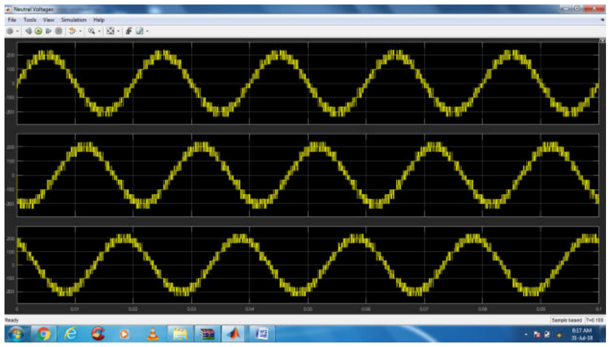
Fig. 7. Simulation results for 5L-HNPC

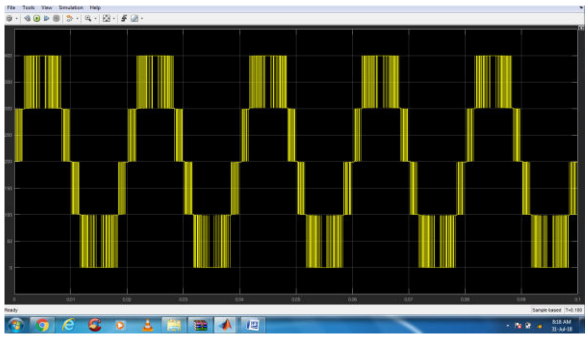
for Vdc/2 and D2 and D3 are rated for Vdc, which makestotal of 18 semiconductor devices each rated for Vdc/2. Theconventional 5L-DCMLI shown in Fig. 1 has 8 switchesand 12 diodes each rated for Vdc/2, which makes total of20 semiconductor devices. Therefore, the proposed inverterneeds two fewer devices as compared to 5L-DCMLI. Theproposed inverter needs only 6 identical diodes as comparedto 12 diodes needed for 5L-DCMLI. Therefore, the proposedtopology is subjected to lower reverse recovery loss ascompared to the 5L-DCMLI. The output voltage of a singlephase transformerless inverter is generally in the range of110-250 V [2]. Therefore, instead of 12 identical switcheseach rated for Vdc/2 (200 V), only 8 IGBT switches, asshown in Fig. 2, can be used. This further reduces the switchcount, thereby reducing the overall inverter cost.

5. SIMULATION RESULTS









6. CONCLUSION

A 5-level Hybrid neutral point clamped transformerlessPV grid connected inverter is presented in this paper. Themain characteristics of proposed transformerless inverter are:

1) Lower stress on the grid interfacing inductor, therebyreducing the filtering cost and size as compared to.conventional 3-level inverters like H5 and HERICinverter.
2) Lower cost as compared to 5L-DCMLI as the proposedinverter requires less no of clamping diodes.
3) Higher power handling capability as compared toconventional 3-level inverters.
4) Higher efficiency as compared to 5L-DCMLI and H5inverter.
5) No common mode leakage current as the proposedinverter belongs to the family of half bridge inverters.
6) The proposed inverter is capable of exchanging reactivepower with the grid.

Therefore, with excellent performance in eliminating theCM current, multilevel output voltage and high efficiency,the proposed inverter provides an exciting alternative to theconventional transformerless grid-connected PV inverters.

Moreover, due to its superiority over the 5L-DCMLI interms of efficiency and cost parameters, the pertinence ofthe proposed inverter is not limited to grid connected PVinverters and it can find its way for all the applications wherecurrently 5L-DCMLI are employed.

REFERENCES

[1] M. Calais and V. G. Agelidis,"Multilevel converters for single-phasegrid connected photovoltaic systems-an overview," Industrial Electronics,1998. Proceedings. ISIE '98. IEEE International Symposium on,Pretoria, 1998, pp. 224-229 vol.1. doi: 10.1109/ISIE.1998.707781

[2] R. Teodorescu, M. Liserre et al., "Grid converters for photovoltaicand wind power systems". John Wiley & Sons, 2011, vol. 29.

[3] E. Gubia, P. Sanchis, A. Ursua, J. Lopez, and L. Marroyo, "Ground currentsin single phase transformerless photovoltaic systems", Progressin Photovoltaics: Research and Applications, vol. 15, no. 7, pp.629650, 2007.

[4] H. Xiao and S. Xie, "Leakage current analytical model and applicationin single-phase transformerless photovoltaic grid-connected inverter",IEEE Transactions on Electromagnetic Compatibility, vol. 52, DOI10.1109/TEMC.2010.2064169, no. 4, pp. 902913, Nov. 2010.

[5] S. Busquets-Monge, J. Rocabert, P. Rodriguez, S. Alepuz and J. Bordonau,"Multilevel Diode-Clamped Converter for Photovoltaic GeneratorsWith Independent Voltage Control of Each Solar Array", in IEEETransactions on Industrial Electronics, vol. 55, no. 7, pp. 2713-2723,July 2008. Doi: 10.1109/TIE.2008.924011

[6] W. Li, Y. Gu, H. Luo, W. Cui, X. He, and C. Xia, "Topology review andderivation methodology of single-phase transformerless photovoltaicinverters for leakage current suppression", IEEE Transactions onIndustrial Electronics, vol. 62, DOI 10.1109/TIE.2015.2399278, no.7, pp. 45374551, Jul. 2015.

[7] P. Knaup, "Wo2007048420 a1", Patent, May 3, 2007, wO Patent App.PCT/EP2005/011,402.

[8] "Hybrid multilevel inverter" Indian Patent 4840/MUM/2015 &4841/MUM/2015, US patent US 2017/0194877A1, 17 Nov 2016.

[9] A. Shukla, A. Ghosh and A. Joshi, "Control of dc capacitor voltagesin diode-clamped multilevel inverter using bidirectional buck-boostchoppers", in IET

Power Electronics, vol. 5, no. 9, pp. 1723-1732,November 2012. doi: 10.1049/iet-pel.2012.0237

[10] R. Gonzalez, E. Gubia, J. Lopez, and L. Marroyo,"Transformerless single-phase multilevel-based photovoltaicinverter", IEEE Transactions on Industrial Electronics, vol. 55,DOI 10.1109/TIE.2008.924015, no. 7, pp. 26942702, Jul. 2008.

[11] B. Gu, J. Dominic, J. S. Lai, C. L. Chen, T. LaBella and B. Chen,"High Reliability and Efficiency Single-Phase Transformerless Inverterfor Grid-Connected Photovoltaic Systems", in IEEE Transactions on.Power Electronics, vol. 28, no. 5, pp. 2235-2245, May 2013. doi: 10.1109/TPEL.2012.2214237.

[12] https://www.semikron.com/products/product-classes/igbtmodules/detail/skm50gb12t4-22892000.html

[13] A. Kadam and A. Shukla, "A Multilevel Transformerless Inverter EmployingGround Connection Between PV Negative Terminal and GridNeutral Point," in IEEE Transactions on Industrial Electronics, vol.64, no. 11, pp. 8897-8907, Nov. 2017. doi: 10.1109/TIE.2017.2696460