International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-9, Issue-6, December 2022
https://doi.org/10.55524/ijirem.2022.9.6.11
Article ID IJIRP-1292, Pages 65-69
www.ijirem.org

A New Step-Up Switched-Capacitor Voltage Balancing Converter

K. Venkateswarlu[1], K. Yasaswini[2], SK. Haseena Begum[3], M. Hema[4], V. Ishwarya[5], S. Prasanna Lakshmi[6], K. Sowjan Kumar[7], and G.V.K. Murthy[8]

[1,7]Assistant Professor, Department of Electrical and Electronics Engineering, PACE Institute of Technology and Sciences, Ongole, Andhra Pradesh, India
[2,3,4,5,6] B. Tech scholar, Department of Electrical and Electronics Engineering, PACE Institute of Technology and Sciences, Ongole, Andhra Pradesh, India
[8] Professor, Department of Electrical and Electronics Engineering, PACE Institute of Technology and Sciences, Ongole, Andhra Pradesh, India

ABSTRACT- The new step-up capacitor grid is connected to the solar photovoltaic (PV) having a voltage balancing converters. It's suitable for Neutral-Point-clamped (NPC) Multilevel Inverter (MI). To balance the capacitor DC link voltage effectively we've got to use switched capacitors. By using balancing converter, we will enlarge the higher levels and also by boosting input voltage we are able to see the upper levels of voltage without using magnetic components. This attribute allows operating the input and output voltage by self-balancing. The balancing converter for NPC multilevel inverter-based solar PV system is operated by using vector scheme control. PV system incorporates a Maximum power point Tracking (MPPT) and it's executed in Matlab power system. The output of the simulation result topology can successfully balance the DC voltage and excess power from grid. The injected power within the grid can vary the solar light with active performances.

KEYWORD- voltage balancing converter, switched capacitors, Matlab power system.

I. INTRODUCTION

Multilevel inverters are used for grid connected system, because it has more advantages that are there is no generation of harmonics. We can minimize harmonics by using unit power factor. Multilevel inverters are mainly applicable for medium and high-power voltages. There are some drawbacks for multilevel inverters. So to minimize those drawbacks we are using neutral point clamped. NPC -MLI are used for electric motor drives and grid integration, solar PV system[1].
Solar PV system is a renewable energy source, so mostly we are using those types of systems because it doesn't exhaust and also it is a natural and renewable resource. Wind energy, tidal energy are also a renewable resources but we mostly use solar because its cost is very cheap compared to wind and tidal energies[2].
Grid is a network of connecting parallel lines whether it is real or imaginary. Grid PV System is electricity generating solar power system(see figure 1). When the sun shines on to solar panel, then the energy from the sunlight is absorbed by the PV cells in the panel. Solar energy converts heat energy into electric energy. Residential solar panels generate power 250 to 400 watts energy[3-5].

II. SYSTEM STRUCTURE

The new voltage balancing converter has a PV array, proposed step-up converter for balancing the capacitors voltage, a three phase neutral-point-clamped (NPC) multilevel inverter (MLI), LC filter to improve total harmonic distortion (THD) and converting the stair case voltage by reducing the total harmonics and power grid[6].
Here the PV array input is given to the step-up voltage balancing converter. The output voltage is three times more than the input of PV voltage[7]. These are given to the input to NPC MLI. By using vector scheme we can control the inverter[8-10]. To increment the conductance, the maximum power point tracking is used. The output of the tracker is provides the DC link voltage. The output of DC link voltage is provides the power reference, the reference like reactive power and grid voltage. The flow of active or reactive power in grid is controlled by controlling the d-axis and q-axis currents[11-13].

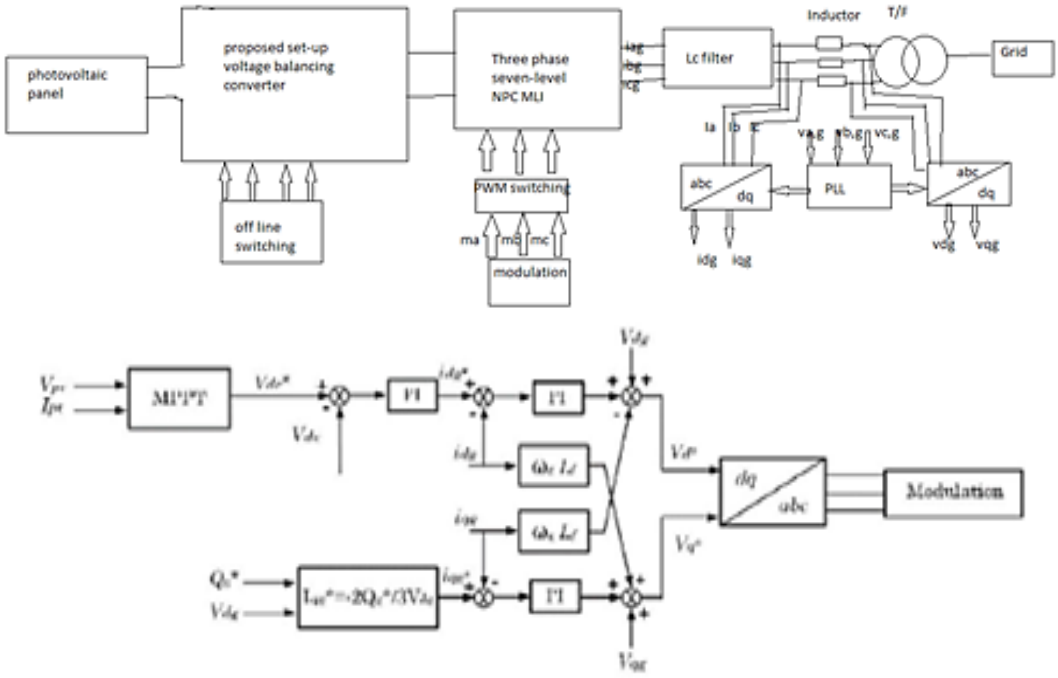

Figure 1: Grid-connected PV system for step-up voltage balancing converter and seven-level NPC-ML

III. PROPOSED STEP-UP BALANCING CONVERTER

Converter is made up of five power switches and two diodes. The input DC source is connected in parallel to the capacitor. By discharging the capacitors high load efficiency is occurs. It is necessary to select the switching states for all capacitor equal to the DC voltage. These converters are connected to a four-level NPC. By connecting three-phase NPC a seven level can be attained.

During the charging state the sum of capacitors are in parallel with input DC source and cause a voltage difference. In this green color demonstrates the charging route, and blue color denotes discharging route, and red color denotes charging and discharging at same time. Here the each capacitor is able to charge one time more than other capacitors. It depends on balancing conditions of capacitors.

Terminal's voltage vab=+2vdc.

The capacitor is placed in between the voltage converter and three-phase NPC Inverter which produces the multilevel output by using simple control strategy (see figure 2).

Here, we use conventional DC-DC converter to convert variable DC-DC converter to fixed DC converter. We use the boost DC-DC converter which comprises a DC source. This converter needs large number of elements. In a converter the power loss is occurred due switching and conduction losses. By calculating these losses we can balance the converter.

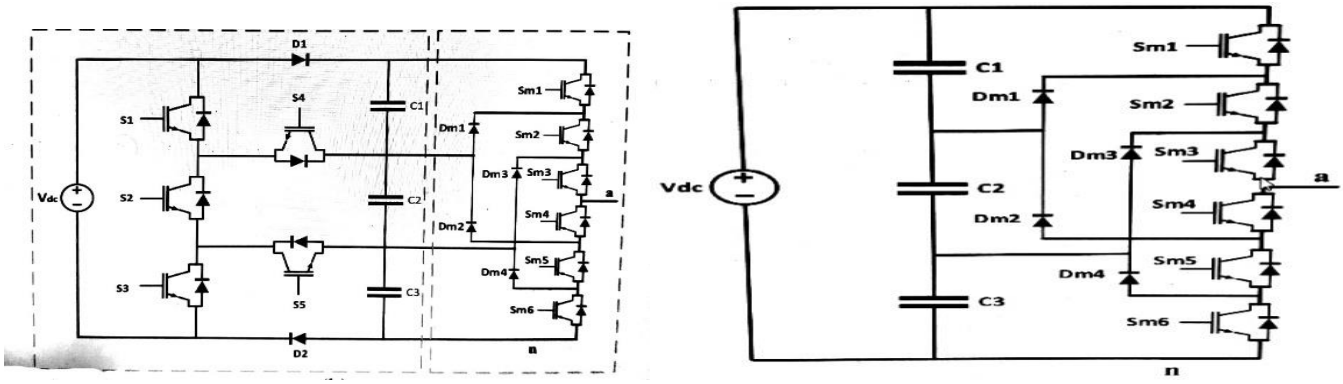

Figure 2: Conventional 4-level NPC converter and proposed voltage balancing converter connected to the four levels NPC

IV. DESIGN AND CONTROL OF GRID SIDE INVERTER

Grid side inverter maintains the DC-Link voltage constant. It is used to balance the voltage of the capacitor. Grid Side Converter (GSC) controls the reactive power at the specific desired value. To control the grid side inverter, we have to maintain unity power factor[14-18]. Thus, it can build the maximum active power output.

In modulation technique Carrier Based (CB) Pulse Width Modulation (PWM) is used attain voltage output with seven levels using frequency switching[19-24]. This method is very easy and simple to enlarge less estimated efforts as compared to Space vector Pulse Width Modulation (SVPWM) (see figure 3) [25-29].

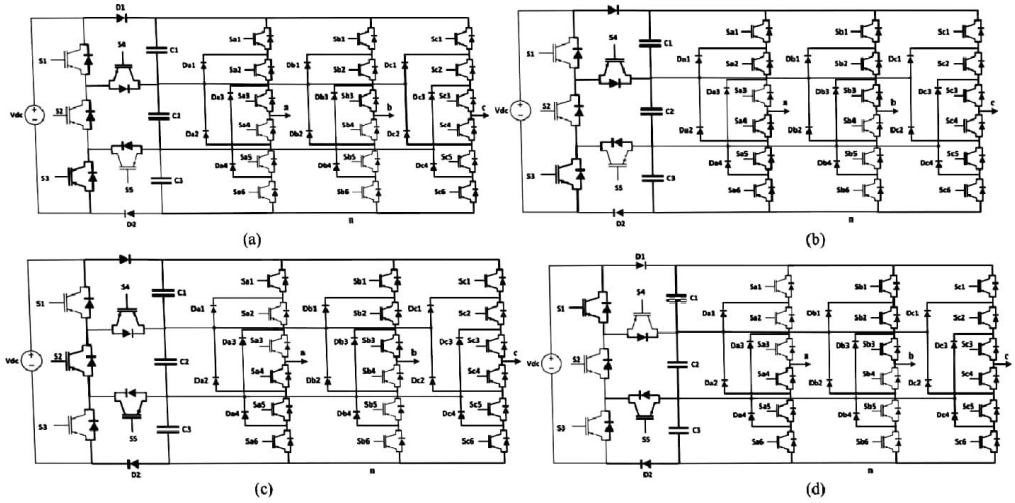

Figure 3: (a) Charging state of C3 and Vab = 0 (b) charging state of C3 and Vab = 1Vdc (c) charging state of C2 and Vab = 2Vdc (d) charging state of C1 and Vab = +3Vdc.

V. SIMULATION RESULTS

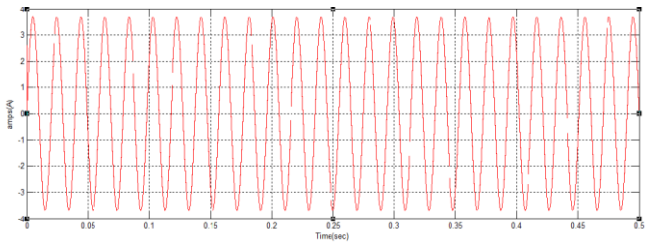

Figure 4: Output current of Neutral Point Clamped (NPC) Multilevel Inverter (MLI).

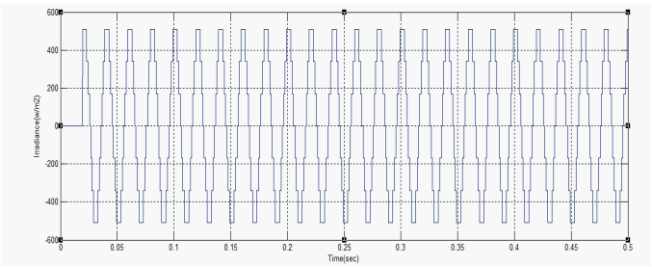

Figure 5: Change in Irradiance

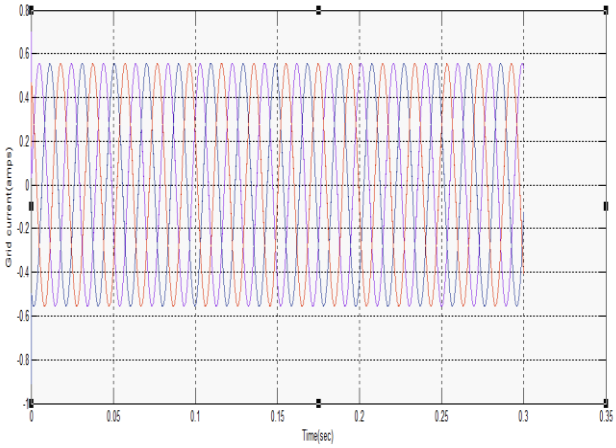

Figure 6: Different irradiance in Grid current

VI. CONCLUSION

Neutral-Point-clamped (NPC) Multilevel Inverter (MLI) is used in the step-up voltage balancing converter for solar Photovoltaic (PV) system. This converter is not only used for increasing the input voltage to desired output voltage, but also it can eliminate the magnetic elements used in system. By eliminating the magnetic elements the cost and weight of the system is reduces. It requires only one PV array or DC source output, to generate multilevel output and to

reduce so many number of input voltage source is required in the system. Normalized energy on the report of output levels, voltage ripple of capacitor and capacitance calculations is also analyzed. A heavy comparison with other DC-DC topologies has been done and it shows the cost effectiveness of the converter. The balancing converter for NPC multilevel inverter-based solar PV system is operated by using vector scheme control. This system is implemented in matlab power system. The simulation results topology can effectively balance the DC link voltage. And it can extract maximum power from the PV modules. This power is injected into a grid by varying the solar irradiances with good and active performances.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] P. R. Bana, K. P. Panda, R. T. Naayagi, P. Siano, and G. Panda, ''Recently developed reduced switch multilevel inverter for renewable energy integration and drives application: Topologies, comprehensive analysis and comparative evaluation,'' IEEE Access, vol. 7, pp. 54888–54909, 2019.

[2] S. Shuvo, E. Hossain, T. Islam, A. Akib, S. Padmanaban, and M. Z. R. Khan, ''Design and hardware implementation considerations of modified multilevel cascaded H-Bridge inverter for photovoltaic system,'' IEEE Access, vol. 7, pp. 16504–16524, 2019.

[3] F. Z. Peng, ''A generalized multilevel inverter topology with self voltage balancing,'' IEEE Trans. Ind. Appl., vol. 37, no. 2, pp. 611–618, Mar./Apr. 2001.

[4] A. Taghvaie, J. Adabi, and M. Rezanejad, ''A self-balanced step-up multilevel inverter based on switched-capacitor structure,'' IEEE Trans. Power Electron., vol. 33, no. 1, pp. 199–209, Jan. 2018.

[5] V. Dargahi, A. K. Sadigh, M. Abarzadeh, S. Eskandari, and K. A. Corzine, ''A new family of modular multilevel converter based on modified flying-capacitor multicell converters,'' IEEE Trans. Power Electron., vol. 30, no. 1, pp. 138–147, Jan. 2015.

[6] J. Shen, S. Schröder, R. Rösner, and S. El-Barbari, ''A comprehensive study of neutral-point self-balancing effect in neutral-point-clamped three-level inverters,'' IEEE Trans. Power Electron., vol. 26, no. 11, pp. 3084–3095, Nov. 2011.

[7] A. Nabae, I. Takahashi, and H. Akagi, ''A new neutral-point-clamped PWM inverter,'' IEEE Trans. Ind. Appl., vol. IA-17, no. 5, pp. 518–523, Sep. 1981.

[8] A. Tripathi and G. Narayanan, ''Torque ripple minimization in neutralpoint-clamped three-level inverter fed induction motor drives operated at low-switching-frequency,'' IEEE Trans. Ind. Appl., vol. 54, no. 3, pp. 2370–2380, May 2018.

[9] W. Zeng, R. Li, and X. Cai, ''A new hybrid modular multilevel converter with integrated energy storage,'' IEEE Access, vol. 7, pp. 172981–172993, 2019.

[10] M. H. Ahmed, M. Wang, M. A. S. Hassan, and I. Ullah, ''Power loss model and efficiency analysis of three-phase inverter based on SiC MOSFETs for PV applications,'' IEEE Access, vol. 7, pp. 75768–75781, 2019.

[11] B. R. Lin and T. C. Wei, ''A novel NPC inverter for harmonics elimination and reactive power compensation,'' IEEE Trans. Power Del., vol. 19, no. 3, pp. 1449–1456, Jul. 2004.

[12] H. Akagi, H. Fujita, S. Yonetani, and Y. Kondo, ''A 6.6-kV transformerless STATCOM based on a five-level diode-clamped PWM converter: System design and experimentation of a 200-V 10-kVA laboratory model,'' IEEE Trans. Ind. Appl., vol. 44, no. 2, pp. 672–680, Mar. 2008.

[13] H. Xiao and S. Xie, ''Transformerless split-inductor neutral point clamped three-level PV grid-connected inverter,'' IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1799–1808, Apr. 2012.

[14] N. Celanovic and D. Boroyevich, ''A comprehensive study of neutral-point voltage balancing problem in three-level neutral-point-clamped voltage source PWM inverters,'' IEEE Trans. Power Electron., vol. 15, no. 2, pp. 242–249, Mar. 2000.

[15] A. Nami, F. Zare, A. Ghosh, and F. Blaabjerg, ''A hybrid cascade converter topology with series-connected symmetrical and asymmetrical diode-clamped H-Bridge cells,'' IEEE Trans. Power Electron., vol. 26, no. 1, pp. 51–65, Jan. 2011.

[16] R. Stala, ''A natural DC-link voltage balancing of diode-clamped inverters in parallel systems,'' IEEE Trans. Ind. Electron., vol. 60, no. 11, pp. 5008–5018, Nov. 2013.

[17] J. Pou, J. Zaragoza, S. Ceballos, M. Saeedifard, and D. Boroyevich, ''A carrier-based PWM strategy with zero-sequence voltage injection for a three-level neutral-point-clamped converter,'' IEEE Trans. Power Electron., vol. 27, no. 2, pp. 642–651, Feb. 2012.

[18] R. Stala, ''Application of balancing circuit for DC-link voltages balance in a single-phase diode-clamped inverter with two three-level legs,'' IEEE Trans. Ind. Electron., vol. 58, no. 9, pp. 4185–4195, Sep. 2011.

[19] A. Nami, F. Zare, A. Ghosh, and F. Blaabjerg, ''Multi-output DC–DC converters based on diode-clamped converters configuration: Topology and control strategy,'' IET Power Electron., vol. 3, no. 2, pp. 197–208, 2010.

[20] V. Yaramasu, B. Wu, M. Rivera, and J. Rodriguez, ''A new power conversion system for megawatt PMSG wind turbines using four-level converters and a simple control scheme based on two-step model predictive strategy— Part I: Modeling and theoretical analysis,'' IEEE J. Emerg. Sel. Topics Power Electron. vol. 2, no. 1, pp. 3–13, Mar. 2014.

[21] V. Yaramasu, B. Wu, M. Rivera, and J. Rodriguez, ''A new power conversion system for megawatt PMSG wind turbines using four-level converters and a simple control scheme based on two-step model predictive strategy— Part II: Simulation and experimental analysis,'' IEEE J. Emerg. Sel. Topics Power Electron. vol. 2, no. 1, pp. 14–25, Mar. 2014.

[22] Y. Chen and K. Smedley, ''Three-phase boost-type grid-connected inverter,'' IEEE Trans. Power Electron., vol. 23, no. 5, pp. 2301–2309, Sep. 2008.

[23] P. Kolahian, H. Tarzamni, A. Nikafrooz, and M. Hamzeh, ''Multi-port DC–DC converter for bipolar medium voltage DC micro-grid applications,'' IET Power Electron., vol. 12, no. 7, pp. 1841–1849, Jun. 2019.

[24] A. Taghvaie, M. E. Haque, S. Saha, and M. A. Mahmud, ''A new step-up voltage balancing circuit for neutral-point-clamped multilevel inverter,'' in Proc. IEEE Int. Conf. Power Electron., Drives Energy Syst. (PEDES), Dec. 2018, pp. 1–6.

[25] S. Saha, M. E. Haque, C. P. Tan, and M. A. Mahmud, ''Sensor fault resilient operation of permanent magnet synchronous generator based wind energy conversion system,'' IEEE Trans. Ind. Appl., vol. 55, no. 4, pp. 4298–4308, Jul. 2019.

[26] J. I. Leon, S. Vazquez, and L. G. Franquelo, ''Multilevel converters: Control and modulation techniques for their operation and industrial applications,'' Proc. IEEE, vol. 105, no. 11, pp. 2066–2081, Nov. 2017.

[27] B. Wu, ‘‘Cascaded HBridge multilevel inverters,’’ in High-Power Converters and AC Drives. Hoboken, NJ, USA: Wiley, 2006, pp. 119–142.
[28] Y. C. Fong, S. R. Raman, Y. Ye, and K. W. E. Cheng, ‘‘Generalized topology of a hybrid switched-capacitor multilevel inverter for high-frequency AC power distribution,’’ IEEE J. Emerg. Sel. Topics Power Electron., early access, Mar. 15, 2019, doi: 10.1109/JESTPE.2019.2905421.
[29] P. Barbosa, P. Steimer, J. Steinke, M. Winkelnkemper, and N. Celanovic, ‘‘Active-neutral-point-clamped (ANPC) multilevel converter technology,’’ in Proc. Eur. Conf. Power Electron. Appl., Sep. 2005, p. 10