International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 6, Issue 4, pp 147-149, April-2022

https://doi.org/10.47001/IRJIET/2022.604035

Review on Step-Up Switched-Capacitor Voltage Balancing Converter for NPC Multilevel Inverter

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***Abstract* - A new voltage balancing converter suitable for Neutral-Point-Clamped (NPC) Multilevel Inverter (MLI). The switched capacitor used in the proposed converter is able to balance the DC link capacitor voltage effectively by using proper switching states. The proposed balancing converter can be extended to any higher levels and it can boost the DC input voltage to a higher voltage levels without using any magnetic components. This feature allows the converter to operate with the boosting capability of the input voltage to the desired output voltage while ensuring the self-balancing. In this system the proposed converter is used for a grid system with NPC multilevel inverter, which is controlled using vector control scheme. The proposed grid connected system with associated controllers and maximum power point tracking (MPPT) is implemented in Matlab / Sim Power System and experimentally validated using SPACE system and designed converters. The simulation and experimental results show that the proposed topology can effectively balance the DC link voltage extract maximum power from PV module and inject power to the grid under varying solar irradiances with very good steady state and dynamic performances.**

Keywords: Neutral-Point-Clamped (NPC), Multilevel Inverter (MLI)., maximum power point tracking, MPPT, Matlab/ Sim Power System.

I. INTRODUCTION

Multilevel inverters (MLIs) are broadly used for the grid integration of solar photovoltaic (PV) systems due to several advantages such as lower harmonic distortions, less electromagnetic interference (EMI), less standing voltage on semi- conductors, high output waveform quality and smaller filter size. Three principal types for MLIs are Cascaded H-Bridge (CHB), Neutral-Point-Clamped (NPC), and Flying Capacitors (FC). These MLIs have several drawbacks and limitations such as: 1) CHB converters require large number of separate input DC-link sources, 2) FC MLIs have both balancing and large number of capacitors problems in high output voltage levels, and 3) NPC MLIs also require separate DC source and have balancing problems due to the use of capacitors which necessitate an additional balancing circuit. The adjacent switching technique is used in to balance the capacitors' voltage where redundant states are used for voltage balancing and maintaining the output voltage at the acceptable range. However, the external circuit used to balance the capacitors' voltage increases the inductor size at higher voltage levels which introduces challenges in implementation. A voltage balancing technique for DC-link capacitors in parallel three-phase and single-phase NPC MLIs is presented in. In this method, the voltage balancing capability is achieved where NPC-MLIs are connected in parallel. In this system, at least one of the inverters generates opposite voltage which limits the output voltage levels and increases the number of power semiconductors in higher voltage levels. A carrier-based pulsed-width modulation (CB-PWM) using zero-sequence voltage injection proposed in. The switching frequency under this method is low and can balance the capacitors' voltage without using any extra control. However, this method above mentioned methods are computationally intensive. Another DC-link voltage balancing method is proposed in.

This method uses a passive RLC circuit which requires magnetic elements. This method uses a passive RLC circuit which requires magnetic elements. Some topologies are suggested in for the balancing capacitors' voltage at higher voltage levels, which are derived from 3L NPC. Although these topologies can be used for more than two level; however, they have difficulties for balancing capacitors in more than five voltage levels. It is worth mentioning that in NPC-MLIs, the series connection of the DC-link capacitors is used to charge the capacitors through the PV unit in order to produce high voltage levels at the output. However, these converters with series capacitors are more vulnerable to capacitors unbalancing and voltage dynamics instability as compared to the converters using capacitors in parallel. Another concern in NPC-MLIs is voltage boosting incapability which causes the use of massive magnetic components. This condition is dealt using DC-DC boost converter. A multi- output boost (MOB) DC-DC converter is suggested in [19] as an additional circuit to balance the DC-link capacitors while boosting the voltage. A new power conversion sys- tem for wind turbine application is proposed

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and validated in. In this system a four-level boost converter has been proposed as an alternative to the traditional DC-DC boost converters. Another boost-type grid-connected inverters are proposed in, where magnetic elements are used to boost the input voltage to its chosen value at the output. However, in these topologies, the drawback is using magnetic elements at the input, which increase size, volume and complexity, and reduces the efficiency of the system.

II. METHODOLOGY

The proposed converter comprises of five power switches and two diodes which are designed in such a way that input DC source can be connected in parallel with each capacitor during charging states. Simultaneously, the higher efficiency is achieved by discharging the capacitors at the load. It is essential to select appropriate switching states for charging all capacitors equal to the input DC voltage while the boosted output voltage can be achieved by series connections of all capacitors. Table 1 shows the switching states for the proposed converter. Moreover, during the charging states, the sum of the capacitors (series connection) are connected in parallel with input DC source which affects the dynamic performance of the capacitors and causes voltage difference across each capacitor. Therefore, an appropriate converter needs to be proposed to not only boost the input DC voltage to a desired output voltage but also to charge each capacitor in parallel with input DC voltage. The voltage balancing www.jespublication.com and boosting can be achieved by connecting the proposed balancing network with the NPC converter as shown in Fig. 3 (b). Figures 4 (a-d) shows the potential switching states for the proposed converter which is connected to a seven-level NPC-MLI. It is clear that a three-phase NPC-MLI has been considered to investigate the potential switching states (three levels for the positive states and one level for zero state).

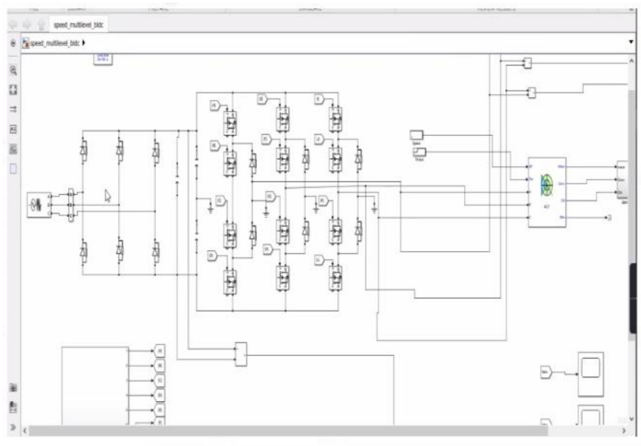

Figure 1: Simulation Circuit Diagram

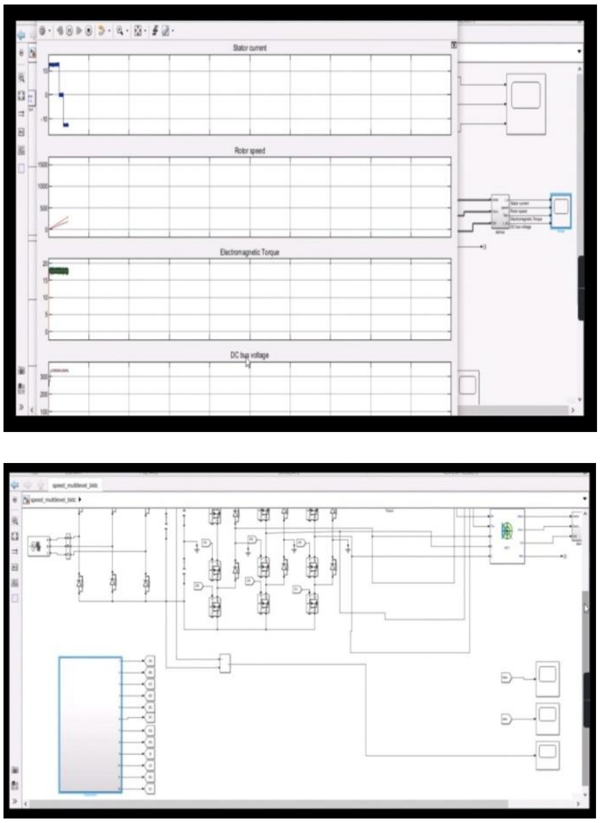

Figure 2: Simulation Analysis

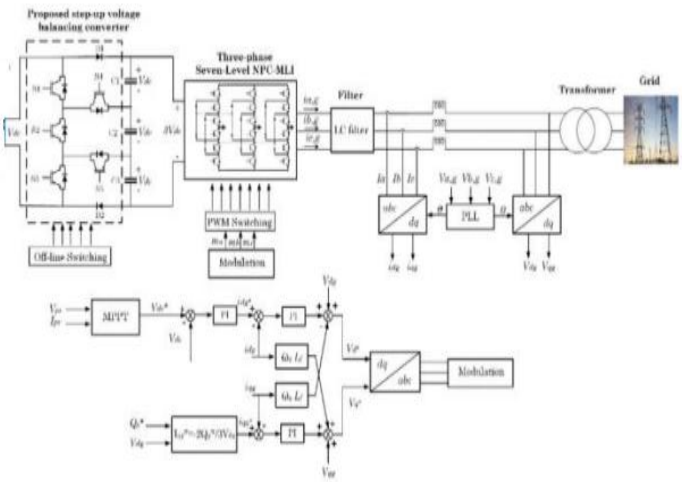

Figure 3: Block Diagram

III. RESULTS AND CONCLUSION

A new step-up voltage balancing converter which is suitable for NPC-MLI has been proposed in this paper. The proposed converter not only can boost the input voltage at the desired output level, but also can remove the magnetic elements which reduce the weight and cost of the system. It also requires only one DC source or array output to produce multilevel output, which reduces the number of input voltage sources required in such systems. Capacitance calculation, voltage ripple of the capacitors, out-put power and normalized

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energy according to the number of output levels are also analyzed. A deep comparison with other DC-DC topologies has been done and showed the cost effectiveness of the proposed converter. The proposed converter is implemented for a grid connected solar PV system with a NPC multilevel inverter, which is controlled using vector control scheme. The proposed system with associated controllers is implemented in Matlab/ Sim Power System and experimentally validated using dSPACE DSP (digital signal processor) system and designed converters. The simulation and experimental results confirms that the proposed topology can effectively balance the DC link voltage, extract maximum power from module and inject power to the grid under varying solar irradiances with very good steady state and dynamic performances.

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Citation of this Article:

Harshadeep N. Patil, Prof. S.G. Kanade, "Review on Step-Up Switched-Capacitor Voltage Balancing Converter for NPC Multilevel Inverter" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 6, Issue 4, pp 147-149, April 2022. Article DOI https://doi.org/10.47001/IRJIET/2022.604035

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