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# Design of an Advanced Multi-stage Grid-tied PV Inverter configuration for Composed Energy Scheduling

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## ABSTRACT

Due to their appealing qualities in power quality and ease of expansion compared to two-level or three-level inverters, cascaded H-bridge (CHB) inverters have been widely used in distributed photovoltaic (PV) power generating systems. Because they can automatically balance the power difference between phases, modular inverters with an interphase structure made up of four-port isolated DC/DC converters and CHB inverters are mainly preferred by academia and industry. Such modular inverters still have a few problems that need to be fixed, including power imbalance between modules in the same phase. This could endanger the safe and stable operation of the complete modular inverter and cause over-modulation of some H-bridge inverter modules and grid-connected current distortion. This work proposes an AC voltage balancer to establish a power balance between nearby H-bridge inverter units in response to this issue. A better modulation approach is also described to achieve soft switching of VB.

## I. INTRODUCTION

The CHB inverters [1-3] are a preferable option for integrating large-scale distributed PV into the grid in medium-voltage AC (MVAC) applications due to attractive features such as better power quality and generating output voltages much greater than the withstand voltage of the switching devices. Furthermore, CHB inverters can be used to integrate large-scale energy storage systems and wind turbines into the grid. As a result, using CHB inverters has piqued the interest of academia and industry. Interphase power imbalance will result in asymmetrical three-phase grid-connected currents. Existing techniques include zero-sequence current injection [4] and zero-sequence voltage injection [5, but both schemes have low compensability [6]. Researchers proposed a two-stage converter combining quadruple active bridge (QAB) converters with CHB inverters to solve the issue of interphase power imbalance more fully [7-15].

The preceding study work relates to fixing the cause of interphase imbalances in power but does not address interphase power imbalance. The output currents of the rear-stage H-bridge inverter units of different PV modules are equal since they are connected in series. When the power of different PV modules differs, the rear-stage H-bridge inverter unit's output voltage is proportional to the corresponding PV module's output power. Some H-bridge units will be over-modulated if the output power differential between PV modules exceeds a particular threshold. Over-modulation will create grid-connected current distortion and possibly instability, impacting the overall dependability and safety of the converter. It is required to overcome the intra-phase power imbalance issue to improve the practical application value.

The simplest technique to address intra-phase power imbalance is to achieve voltage equalization on the AC side of each H-bridge inverter unit. There are mature techniques for voltage equalization in battery energy storage systems and super capacitor applications. Furthermore, there are some studies on the voltage equalization of cascaded converters in the application of medium-voltage DC-distributed PV systems, and the DC voltage balancer is employed to help realize voltage equalization. The DC voltage balancer's operating concept is to manage the energy exchange between the two capacitors by regulating the duty cycle of the switching device and then to achieve voltage equalization of the two capacitors. However, the approaches described above are ineffective for CHB voltage equalization since they cannot function when the capacitor voltage polarity is negative. As a result, this study proposes an ACVB. The bidirectional switch configuration enables the ACVB to function effectively even when the voltage polarity of capacitors C1 and C2 is negative. On the other hand, the presence of bidirectional switching causes the current of inductor L1 to lose its continuous current circuit during the dead zone. A brief reduction in inductor current to zero results in a very high voltage across the inductor, which may cause the switching device to burn out. This means that the modulation approach used on the DC voltage balancer will not work on the ACVB. To address this issue, this study provides an enhanced modulation technique that not only assures the inductor's continuous current circuit during the dead zone, but also aids in the soft switching of the ACVB's switching devices.

## II. PROPOSED CONTROL STRATEGY

The general Cascaded H-bridges are interconnected with the power Balancing Auxiliary circuit through the inductor L configuration shown in fig. 1. When the distributed PV inverter is not equipped with ACVB, the impact of the differential in output power of the PV panels inside each sub-module on the overall modular inverter is briefly examined here.

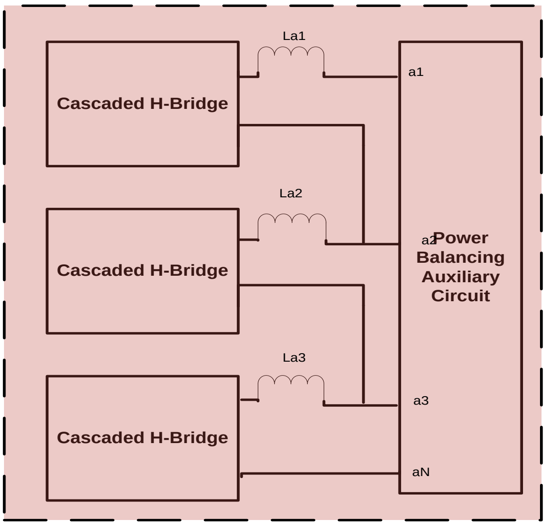

Fig. 1 Block diagram of multilevel CHB inverter with power balancing module

The power output from the PV panels within a single sub-module should ideally be distributed evenly among the three rear-stage H-bridge inverters. The DC voltage balancer's operating concept is to manage the energy exchange between the two capacitors by regulating the duty cycle of the switching device, and then to achieve voltage equalization of the two capacitors. However, the approaches described above are ineffective for CHB voltage equalization since they cannot function when the capacitor voltage polarity is negative. Even if the voltage polarity of capacitors C1 and C2 is negative, the bidirectional switch setting must be regarded for appropriate operation. On the other hand, the presence of bidirectional switching causes the current of inductor L1 to lose its continuous current circuit during the dead zone.

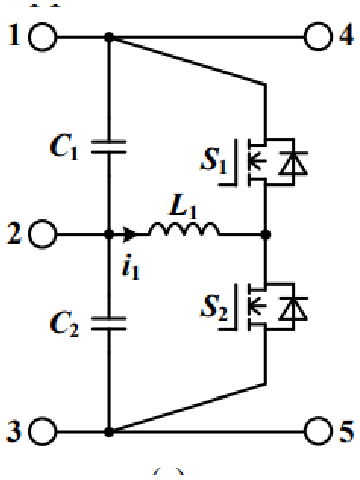

Fig. 2(a) Power balance circuit

A brief reduction in inductor current to zero results in a very high voltage across the inductor, which may cause the switching device to burn out. This means that the modulation approach used on the DC voltage balancer will not work on the Voltage Balance shown in Fig.2.

## III. RESULTS:

In Matlab/simulink, a three-phase 7-level (three cells each phase) cascaded H-bridge inverter is simulated and tested; simulation results are used to validate the proposed ideals. Fig.3 gives the actual signal, modulation index value and the actual modulation voltage signal in the balanced condition. Individual three H-bridges in each phase were powered by three single-phase voltage sources with Umax=100V and 50Hz utilizing single-phase diode rectifiers. Each dc-link contains a capacitor bank with a capacitance of 2400 F. The simulation studies were performed for a 3-phase RL load with R=3 and L =2mH. The length of the reference voltage vector was 420V, and the frequency of the output voltage was 50Hz.

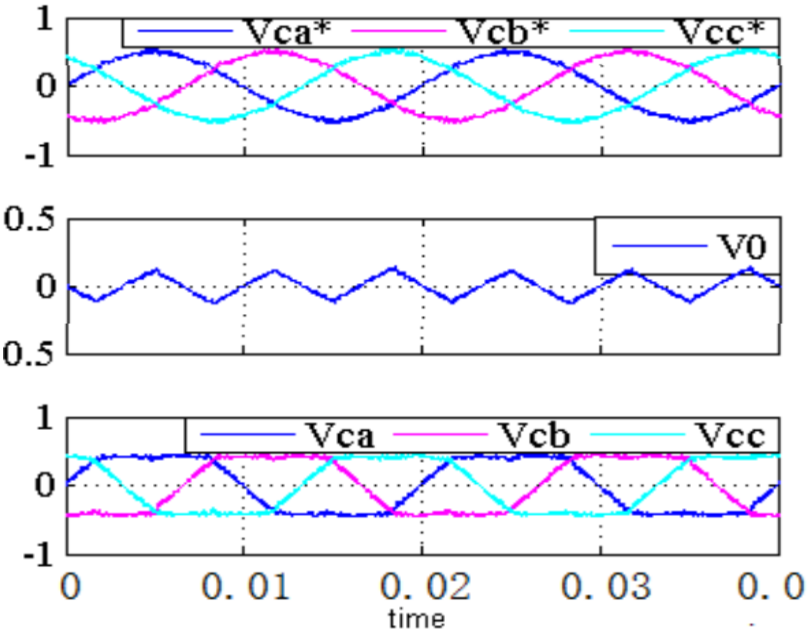

Fig.3. Actual Modulation wave form

Figure 4 shows the balanced three-phase grid voltages. Figure 5 depicts the grid voltage and current waveforms with real and reactive power injection under strong grid conditions (short-circuit ratio: SCR =infinite). The grid current total harmonic distortion (THD) is roughly 3%, which is mostly due to switching current ripples. CBDPWM waveform simulation.MCB-DPWM and Loss with m=0.4 and m=0.7, respectively. To reduce switching losses, the phase with the highest current can be clamped using either approach. Fortunately, the suggested MCBDPWM modulation methods produce no zero-crossing distortion. Furthermore, the proposed MCB-DPWM has a smaller zero-crossing clamping region than DPWM3, lowering the action time of some single redundant tiny vectors. Fig. 6 represents the difference between the DC-link voltages in the individual H-Bridge in phases.

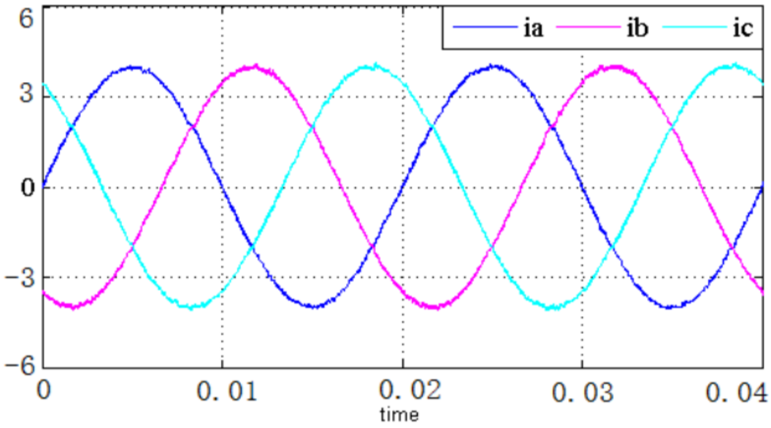

Fig.4. balanced three phase grid currents

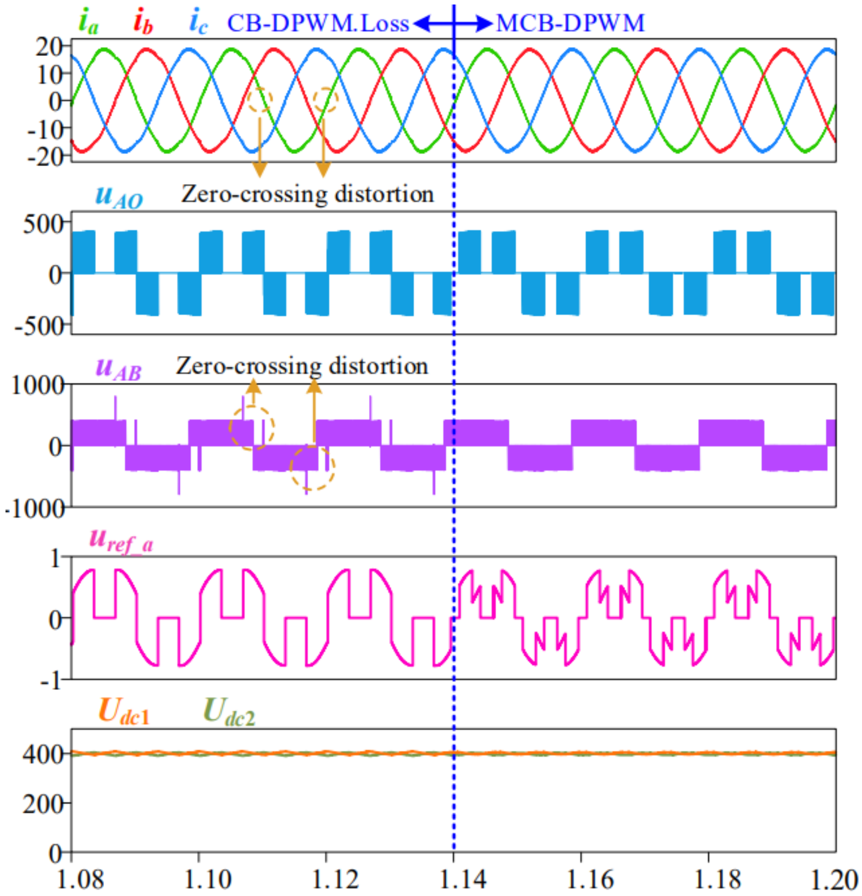

Fig. 5 Voltage, current and load current at balanced conditions

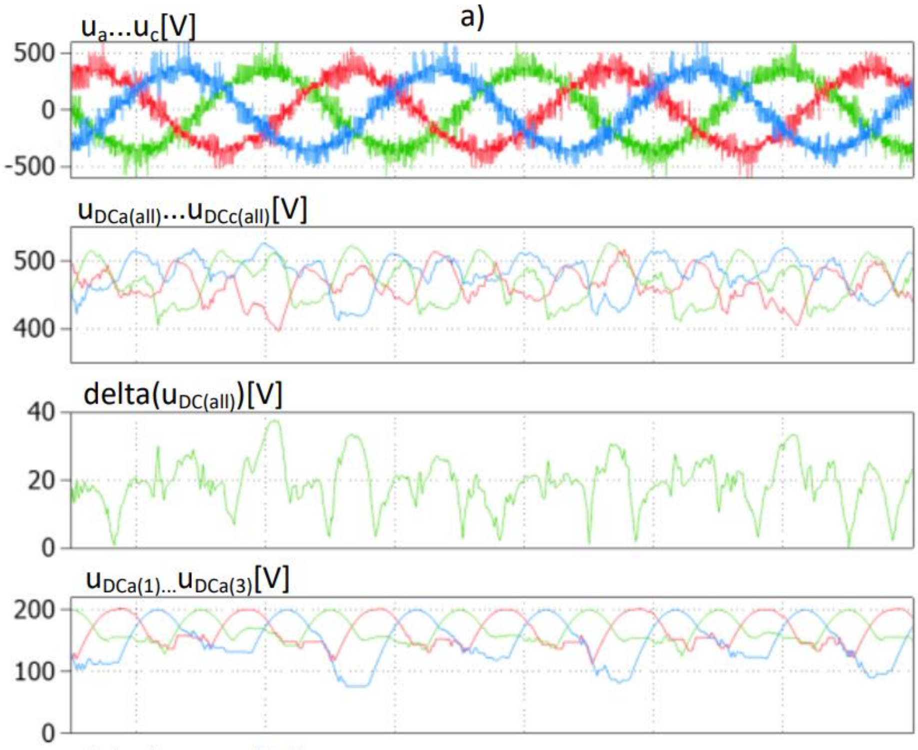

Fig. 6 Difference between the DC-link voltages in the individual H-Bridges in phase

## IV. CONCLUSION:

This work presents a Voltage Balance circuit to balance the output voltage of each sub-module post-stage H-bridge inverter to address the problem of intra-phase power imbalance in distributed PV inverters. In addition, an enhanced modulation approach for Voltage Balance is given, which can aid in implementing soft switching. The suggested Voltage Balance circuit and improved modulation technique are simple in structure and control, making them suitable for practical applications. The downside of this Voltage Balance circuit is that it cannot achieve soft switching of all switches, and further research will be conducted to achieve soft switching of all switches. The experimental results validate the suggested Voltage Balance circuit and the improved modulation approach.

## V. REFERENCES:

1. H. Jafarian, M. Biglarbegian and B. Parkhideh, "Controller robustness analysis of grid-tied AC-stacked PV inverter system considering manufacturing inaccuracies," *2017 IEEE Applied Power Electronics Conference and Exposition (APEC)*, Tampa, FL, USA, 2017, pp. 2349-2354, doi: 10.1109/APEC.2017.7931028.
2. D. Venkatramanan and V. John, "A Modified Common-Mode Filter with Enhanced Attenuation Performance in Single-Phase Grid-Tied Solar PV Inverters," *2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020)*, Cochin, India, 2020, pp. 1-6, doi: 10.1109/PESGRE45664.2020.9070514.
3. X. Yuan and Y. Zhang, "Status and Opportunities of Photovoltaic Inverters in Grid-Tied and Micro-Grid Systems," *2006 CES/IEEE 5th International Power Electronics and Motion Control Conference*, Shanghai, China, 2006, pp. 1-4, doi: 10.1109/IPEMC.2006.4778052.
4. J. V. Parmar, S. K. Reddy, B. Swaminathan, A. Mudlapur and B. Venkatesaperumal, "A Novel Back to Back Inverter Configuration for Solar Water Pumping and Grid-Tie Application," *2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe)*, Palermo, Italy, 2018, pp. 1-6, doi: 10.1109/EEEIC.2018.8494528.
5. M. Coppola *et al.*, "Modulation technique for grid-tied PV multilevel inverter," *2016 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*, Capri, Italy, 2016, pp. 923-928, doi: 10.1109/SPEEDAM.2016.7525980.
6. S. Mondal, S. P. Biswas, M. R. Islam and S. M. Muyeen, "A Five-Level Switched-Capacitor Based Transformerless Inverter With Boosting Capability for Grid-Tied PV Applications," in *IEEE Access*, vol. 11, pp. 12426-12443, 2023, doi: 10.1109/ACCESS.2023.3241927.
7. J. F. Ardashir, M. Sabahi, S. H. Hosseini, F. Blaabjerg, E. Babaei and G. B. Gharehpetian, "A Single-Phase Transformerless Inverter With Charge Pump Circuit Concept for Grid-Tied PV Applications," in *IEEE Transactions on Industrial Electronics*, vol. 64, no. 7, pp. 5403-5415, July 2017, doi: 10.1109/TIE.2016.2645162.

8. C. Anandababu and B. G. Fernandes, "Neutral Point Clamped MOSFET Inverter With Full-Bridge Configuration for Nonisolated Grid-Tied Photovoltaic System," in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 5, no. 1, pp. 445-457, March 2017, doi: 10.1109/JESTPE.2016.2622711.
9. A. Srivastava and J. Seshadrinath, "A Single-Phase Seven-Level Triple Boost Inverter for Grid-Connected Transformerless PV Applications," in *IEEE Transactions on Industrial Electronics*, vol. 70, no. 9, pp. 9004-9015, Sept. 2023, doi: 10.1109/TIE.2022.3215815.
10. K. Saritha, K. D. Kumar, K. Anil and S. Ansari, "Active and reactive power regulation utilising an ANN controller for a PV Fed Trans Quasi-Z Source Network with a Multilevel Grid-Tied System," *2023 International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics (IITCEE)*, Bengaluru, India, 2023, pp. 548-553, doi: 10.1109/IITCEE57236.2023.10090990.
11. J. Ruttanayukol, Y. Du, W. Xiao and M. Elmoursi, "Interleaved flyback micro-inverter with primary side current control for PV application," *3rd Renewable Power Generation Conference (RPG 2014)*, Naples, 2014, pp. 1-6, doi: 10.1049/cp.2014.0924.
12. R. S. Shahakar, K. D. Thakur and N. S. Thakare, "Recent Advancement and Comparative Turnouts of 1Ø Grid Tied Non-Isolated Inverters Topologies," *2022 International Conference on Automation, Computing and Renewable Systems (ICACRS)*, Pudukkottai, India, 2022, pp. 19-25, doi: 10.1109/ICACRS55517.2022.10029237.
13. F. Ishengoma, F. Schimpf and L. Norum, "DSP-controlled photovoltaic inverter for universal application in research and education," *2011 IEEE Trondheim PowerTech*, Trondheim, Norway, 2011, pp. 1-6, doi: 10.1109/PTC.2011.6019266.
14. R. Reedy, K. Davis, D. Click, M. Ropp and A. Shaffer, "Power line carrier permissive as a simple and safe method of enabling inverter ride-through operation of distributed grid-tied photovoltaic systems," *2011 IEEE International Symposium on Power Line Communications and Its Applications*, Udine, Italy, 2011, pp. 209-212, doi: 10.1109/ISPLC.2011.5764394.
15. S. K. Prajapati and R. Lairenlakpam, "Comparative Analysis of Single and Double-Stage Grid-Tied PV Systems," *2023 9th International Conference on Electrical Energy Systems (ICEES)*, Chennai, India, 2023, pp. 46-51, doi: 10.1109/ICEES57979.2023.10110109.