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PV based Grid Synchronization with Reduced Switches 11 level Inverter

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Abstract:

In this paper a photovoltaic based transformer less eleven level converter topology connected to grid is proposed. The inverters are categorized according to the configuration of the PV system, the configuration of the conversion stages within the inverter and whether they use transformers. After the introduction of the state of the art of inverters for PV systems with and without transformers, the paper focuses on some known problems and challenges for transformer less inverters. Topologies without transformers have big advantages like low weight, volume and cost. In addition they often reach higher efficiencies than topologies with transformers. Eliminating the leakage current is one of the most important issues for transformer less inverters in grid-connected photovoltaic system applications, where the technical challenge is how to keep the system common-mode voltage constant to reduce the leakage current. A novel single phase three-level topology for transformer less photovoltaic systems is presented in this Project.

The CM ground leakage current can be suppressed completely. Virtual DC bus is created to provide the negative voltage level for the negative AC grid current generation. The virtual DC bus is realized with the switched capacitor technology that uses less number of elements. Therefore, the power electronic cost can be reduced. This topology can be modulated with the unipolar SPWM to reduce the output current ripple. A suitable switching strategy is employed to regulate the flying-capacitor voltage, improve the efficiency (most devices switch at the grid frequency), and minimize the common-mode leakage current with the help of a novel dedicated circuit (transient circuit). Simulations and experiments confirm the feasibility and good performance of the proposed converter A smaller filter inductor can be used to reduce the size and magnetic losses. The simulation result of the proposed topology using MATLAB/SIMULINK.

Keywords:

Multilevel inverters, Pulse width modulation, Cascaded Full Bridge (CFB), Transformer less Photovoltaic systems.

I.INTRODUCTION:

A single-phase grid-connected inverter is usually used for residential or low-power applications of power ranges that are less than 10kW [1]. Types of single-phase grid-connected inverters have been investigated [2]. A common topology of this inverter is full-bridge three-level. The three-level inverter can satisfy specifications through its very high switching, but it could also unfortunately increase switching losses, acoustic noise, and level of interference to other equipment. Improving its output waveform reduces its harmonic content and, hence, also the size of the filter used and the level of electromagnetic interference (EMI) generated by the inverter's switching operation [3]. Grid connected photovoltaic (PV) systems have an important role in distributed power generation. Most of the single-phase installations are small scale PV systems, of up to 5-6 kWp [4]. A single-phase system means that there is a pulsating AC power on the output, while the input is a smooth DC. Large DC capacitors are required which decrease the lifetime and reliability of the whole system. On the other hand in a three phase system, there is constant AC power on the output, which means that there is no need for large capacitors, leading to smaller cost and a higher reliability and lifetime of the whole system. Also the power output of these systems can be higher, reaching up to 10-15 kWp in case of rooftop applications. Although the active parts of PV modules might be electrically insulated from the ground-connected mounting frame, a path for ac ground leakage currents generally exists due to a parasitic capacitance between the modules and the frame and to the connection between the neutral wire and

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the ground, usually realized at the low-voltage/medium-voltage (LV/MV) transformer [5]. In addition to deteriorating power quality, the ground leakage current increases the generation of electromagnetic interference and can represent a safety hazard, so that international regulations pose strict limits to its magnitude. This issue must be confronted in all transformer less PV converters, regardless of architecture. In particular, in full-bridge-based topologies, the ground leakage current is mainly due to high frequency variations of the common-mode voltage at the output of the power converter [6]. On the other hand, the transformer less PV systems have been received more attention due to cost and size reduction, as well as efficiency improvement compared with the conventional transformer ones. A number of technical challenges may arise with increased grid-connected transformer less PV systems. One of the most important issues is how to reduce or eliminate the leakage currents through the parasitic capacitor between the PV array and the ground [7-8]. In general, the leakage current can be significantly mitigated from the viewpoint of system topology or modulation schemes.

For example, the single-phase H bridge topology with the bipolar modulation has the inherent feature of the leakage current reduction. However, it leads to the relatively more high frequency ripples due to the two level output voltage. On the other hand, the unipolar modulation with three-level output voltage is beneficial in terms of low voltage ripples and small filter size, but the leakage current is significantly increased due to the time varying high frequency common mode voltage. Several solutions can be found in literature aiming at the reduction of the common-mode voltage harmonic content. Once the grid frequency transformer is removed from a PV converter, the bulkiest wound and reactive components that remain are those that form the output filter used to clean the output voltage and current from high frequency switching components. Further reduction in cost and weight and improvement in efficiency can be achieved by reducing the filter size, and this is the goal of multilevel converters.

Multilevel inverters are promising; they have nearly sinusoidal output voltage waveforms, output current with better harmonic profile, less stressing of electronic components owing to decreased voltages, switching losses that are lower than those of conventional two-level inverters, a smaller filter size, and lower EMI, all of which make them cheaper, lighter, and more compact[3],[9]. Various topologies for multilevel inverters have been proposed over the years.

Common ones are diode-clamped, flying capacitor or multi cell, cascaded H-bridge, and modified H-bridge multilevel. This project recounts the development of a novel modified H-bridge single-phase multilevel inverter that has two diode embedded bidirectional switches and a novel pulse width modulated (PWM) technique[10]-[11]. The topology was applied to a grid-connected photovoltaic system. In NPC topologies, the electrical potential between the PV cells and the ground is fixed by connecting the neutral wire of the grid to a constant potential, resulting from a dc-link capacitive divider. A huge advantage is that single-phase NPC converters are virtually immune from ground leakage currents, although the same is not true for three-phase NPC converters [12]. A recent paper has proposed an interesting NPC design for exploiting next-generation devices such as super junction or SiC MOSFETs.

The main drawback of NPC designs, with respect to full bridge, is that they need twice the dc-link voltage. CFBs make for highly modular designs. Usually, each full bridge inside a CFB converter needs an insulated power supply, matching well with multistring PV fields. In this case, sequential permutation of the full bridges can be used to evenly share power among the parts and to mitigate the effects of partial shading. As an alternative, only one power supply can be used if the output voltage is obtained through a transformer. CFB converters have also been proposed for stand-alone applications. CFBs give developers many degrees of freedom for the control strategy. Together with the aforementioned sequential permutation and with phase shifting, artificial neural networks and predictive control have been proposed to minimize harmonic distortion and achieve maximum power point tracking (MPPT).

A CFB made up of n full bridges (and at least 4n power switches) can synthesize 2n + 1 voltage levels when the supply voltage is the same for each full bridge. Custom architectures can generally provide more output levels with a given number of active devices, and custom converters generally need custom pulse width modulation (PWM) and control schemes, although unified control schemes for different types of multilevel converters have been proposed. In addition to using less switches, custom architectures can be devised so that some of the switches commutate at the grid frequency, thus improving the efficiency. Reduction in the switches-per-output voltage-level ratio can be achieved in CFB structures if different supply voltages are chosen for each full bridge (asymmetrical CFBs). The topology proposed in this paper consists of two asymmetrical CFBs, generating nine output voltage levels. In the proposed converter, the dc voltage source supplies one of the full bridges, whereas a flying capacitor supplies the other one. By suitably controlling the ratio between the two voltages, different sets of output levels can be obtained. Moreover, the flying capacitor used as a secondary energy source allows for limited voltage boosting, as it will result clear in the following section. The number of output levels per switch (eight switches, nine levels) is comparable to what can be achieved using custom architectures. In fairness, it should be noted that two additional very low power switches and a line frequency switching device [transient circuit (TC)] were included in the final topology in order to reduce the ground leakage current. The custom converter proposed generates five levels with six switches but has no intrinsic boosting capability.

In, Rahim et al. used three dc-bus capacitors in series together with two bidirectional switches (diode bridge + unidirectional switch) and an H-bridge to generate seven output levels; however, they give no explanations on how they keep the capacitor voltages balanced. In, five switches, four diodes, and two dc-bus capacitors in series are used to generate five levels with boosting capability. Again, no mention is made about how the capacitors are kept balanced. In PV applications, the PV field dc voltage is constantly changing due to variations of solar radiation and to the MPPT algorithm, but the output voltage has to be controlled regardless of the voltage ratio. A similar approach is followed in this paper. Moreover, the developed PWM strategy, in addition to controlling the flying capacitor voltage, with the help of the specific TC, minimizes the ground leakage current. Finally, it is important to put in evidence that the proposed converter can work at any power factor, while not all the alternative proposals can continuously supply reactive power. Finally in this paper PV based transformer less eleven level converter topology connected to grid is proposed.

II. PROPOSED NINE LEVEL CONVERTER TOPOLOGY:

The proposed converter is composed of two CFBs, one of which is supplied by a flying capacitor (see Fig. 1). In this paper, a different PWM strategy was developed in order to allow grid connected operation with no galvanic isolation (transformer less solution) for this basic topology. Since the PWM strategy alone is not sufficient to maintain a low ground leakage current. As it will be described in the following, the proposed PWM strategy stretches the efficiency by using, for the two legs where PWM frequency switching does not occur, devices with extremely low voltage drop, such as MOSFETs lacking a fast recovery diode. In fact, the low commutation frequency of those two legs allows, even in a reverse conduction state, the conduction in the channel instead of the body diode (i.e., active rectification). Insulated-gate bipolar transistors (IGBTs) with fast anti parallel diodes are required in the legs where high-frequency hard switching commutations occur. In grid-connected operation, one full-bridge leg is directly connected to the grid neutral wire, whereas the phase wire is connected to the converter through an LC filter.

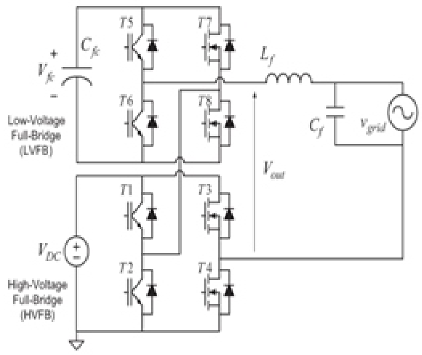

Fig. 1. CFB with a flying capacitor

As it will be described and justified in the following section, flying-capacitor voltage Vfc is kept lower, at steady state, than dc-link voltage VDC. Accordingly, the full bridge supplied by the dc link is called the high voltage full bridge (HVFB), whereas the one with the flying capacitor is the low-voltage full-bridge (LVFB). The CFB topology allows certain degrees of freedom in the control, so that different PWM schemes can be considered; however, the chosen solution needs to satisfy the following requirements.

1) Most commutations must take place in the LVFB to limit the switching losses.
2) The neutral-connected leg of the HVFB needs to switch at grid frequency to reduce the ground leakage current.
3) The redundant states of the converter must be properly used to control the flying-capacitor voltage.
4) The driving signals must be obtained from a single carrier for a low-cost DSP to be used as a controller.

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The switching pattern described in Table I was developed starting from the above requirements. Requirement 2), in particular, is due to the aforementioned parasitic capacitive coupling between the PV panels and their frames, usually connected to the earth. Capacitive coupling renders the common-mode current inversely proportional to the switching frequency of the neutral-connected leg.

TABLE I:DESCRIPTION OF THE CONVERTER OPERATING ZONES:

Zone	Output Voltage	On Devices	Off Devices	Switching Devices
Zone 3B	$-V_{DC}-V_{fc} \leftrightarrow -V_{DC}$	T2, T3, T7	T1, T4, T8	T5, T6
Zone 3A	$-V_{DC} \leftrightarrow -V_{DC}+V_{fc}$	T2, T3, T8	T1, T4, T7	T5, T6
Zone 2A	$-V_{DC}+V_{fc} \leftrightarrow 0$	T3, T7	T4, T8	T1, T2, T5, T6
Zone 2B	$-V_{DC} \leftrightarrow -V_{fc}$	T3, T7	T4, T8	T1, T2, T5, T6
Zone 1B	$-V_{fc} \leftrightarrow 0$	T1, T3, T7	T2, T4, T8	T5, T6
Zone 1A	$0 \leftrightarrow V_{fc}$	T2, T4, T8	T1, T3, T7	T5, T6
Zone 2A	$V_{fc} \leftrightarrow V_{DC}$	T4, T8	T3, T7	T1, T2, T5, T6
Zone 2B	$0 \leftrightarrow V_{DC}-V_{fc}$	T4, T7	T3, T8	T1, T2, T5, T6
Zone 3B	$V_{DC}-V_{fc} \leftrightarrow V_{DC}$	T1, T4, T7	T2, T3, T8	T5, T6
Zone 3A	$V_{DC} \leftrightarrow V_{DC}+V_{fc}$	T1, T4, T8	T2, T3, T7	T5, T6

The converter can operate in different output voltage zones, where the output voltage switches between two specific levels. The operating zone boundaries vary according to the dc-link and flying-capacitor voltages, and adjacent zones can overlap (see Fig. 2). In zones labeled A, the contribution of the flying-capacitor voltage to the converter output voltage is positive, whereas it is negative in B zones. Constructive cascading of the two full bridges can, therefore, result in limited output voltage boosting. Depending on the Vfc/VDC ratio, one of the (a) or (b) situations in Fig. 2 can ensue; nevertheless, the operation of the converter does not differ much in the two cases. If two overlapping operating zones can supply the same output voltage, the operating zone to be used is determined taking into account the regulation of Vfc, as will be described in Section III. As mentioned in the introduction, the duty cycles are calculated on-line by a simple equation, similarly to the approach presented. The switching pattern depends on the instantaneous fundamental component of output voltage Vout and on the measured values of Vfc and VDC.

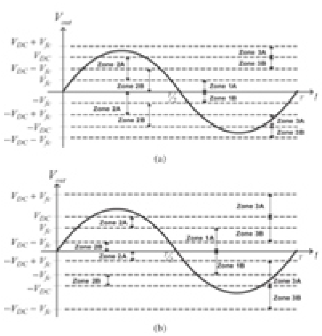

Fig. 2. Operating zones under different Vfc ranges. (a) Vfc < 0.5VDC. (b) Vfc > 0.5VDC.

If Vfc = VDC/3, the converter can synthesize nine equally spaced output voltage levels. Fig. 3 refers to this case and shows the theoretical waveforms, where one leg of the HVFB operates at grid frequency and one leg of the LVFB at five times the grid frequency. Moreover, apart from zone 2, no high-frequency commutations occur in the whole HVFB (see Fig. 2). Since the voltage regulation of the flying capacitor takes place in zone 2, the zone-2 behavior is more articulated and will be described in detail in the following section.Since the main task facing a grid-connected P converter is the transfer of active power to the electrical grid, controlling the voltage of the flying capacitor is critical. Flying-capacitor voltage Vfc is regulated by suitably choosing the operating zone of the converter depending on the instantaneous output voltage request. Depending on the operating zone of the converter (see Fig. 2), Vfc can be added to (A zones) or subtracted from (B zones) the HVFB output voltage, charging or discharging the flying capacitor. In particular, considering a positive value of the current injected into the grid, the flying capacitor is discharged in A zones and charged in B zones. Since a number of redundant switch configurations can be used to synthesize the same output voltage waveform, it is possible to control the voltage of the flying capacitor, forcing the converter to operate more in a zones when the flying-capacitor voltage is higher than a reference value or more in B zones when it is lower than a reference value. Similar considerations hold in case of a negative injected grid current. In each case, some commutations between nonadjacent output levels must inevitably occur (level skipping), with the drawback of a certain increase in the output current ripple. The voltage control of the flying capacitor (which determines the zone-A or zone-B operation) is realized by a simple hysteresis control.

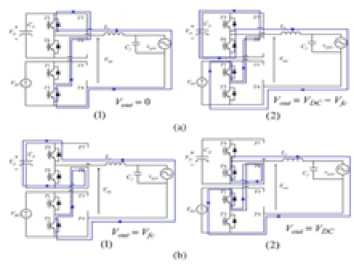

Fig. 3. Converter configurations for the regulation of the flying capacitor. (a) Flying-capacitor charge. (b) Flying-capacitor discharge.

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Fig. 3 illustrates the regulation of Vfc supposing a positive grid current with Vout > 0 and Vfc < 0.5VDC. If Vfc is too low, output level Vfc can be replaced by VDC − Vfc, thus switching between the 0 and VDC − Vfc output levels [zone 2B, Fig. 3(a)]. Similarly, if Vfc is too high, VDC − Vfc can be replaced with Vfc, causing the converter to switch between the Vfc and VDC output levels [zone 2A, Fig. 3(b)]. In Fig. 3, the devices switching at low frequency are short circuited when on and not shown when off.

Similar Vfc regulation strategies can be likewise developed for the case when Vfc > 0.5VDC. If Vfc < 0.5VDC, in order to minimize the current ripple, zone 2 is chosen only when Vfc < Vout < VDC − Vfc (zones 3 are otherwise chosen), limiting level skipping. Level skipping always occurs if Vfc > 0.5VDC; hence, any A or B zone can be chosen according to the voltage regulation algorithm. Since the dc-link voltage can go through sudden variations due to the MPPT strategy, it is important that the converter is able to work in any [VDC, Vfc] condition.

While the distortion of the output voltage is minimized through the on-line duty cycle computation, it is important to assess the capability of the converter to regulate the flying-capacitor voltage under different operating conditions. The ability to control the flying-capacitor voltage through the proposed PWM strategy has been studied in simulation by determining the average flying-capacitor current under a large span of VDC and Vfc values. In the simulations, grid voltage vgrid is sinusoidal with amplitude of 230√2 V; however, the same results hold even for different voltages if the ratio V grid/VDC remains constant.

IV.SIMULATION RESULTS:

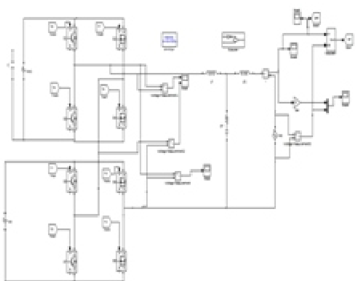

Fig.4.Matlab/Simulink Model of a Nine Level with Grid Connected Systems.

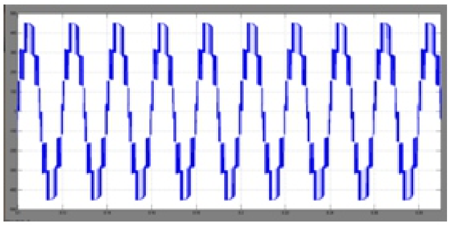

Fig.5.Simulation results for output voltage of inverter with ½ Vdc.

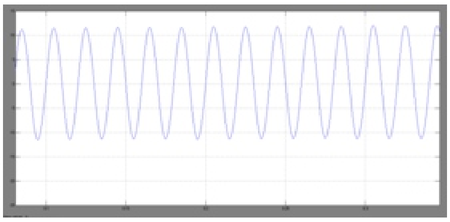

Fig.6. Simulation results for grid voltage.

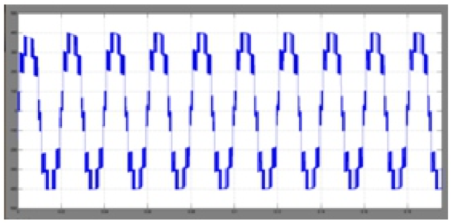

Fig.7.Simulation results for output voltage of inverter with 1/3 Vdc.

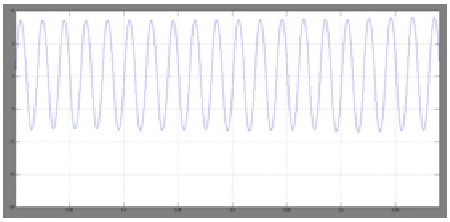

Fig.8. Simulation results for grid voltage.

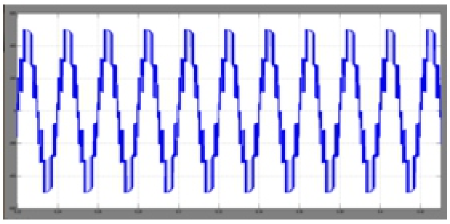

Fig.9.Simulation results for output voltage of inverter with 2/3 Vdc.

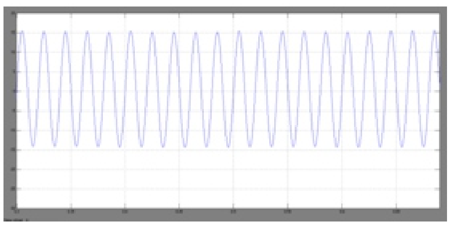

Fig..10. grid voltage.

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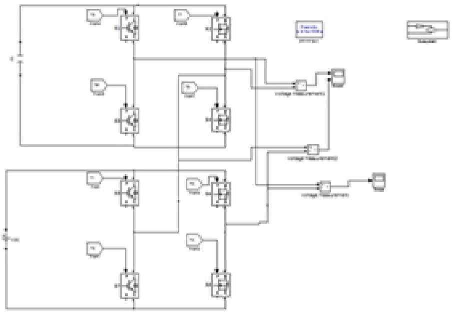

Figure11..Matlab/Simulink Model of a eleven Level inverter.

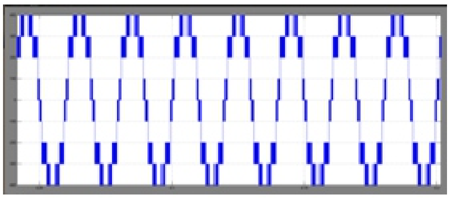

Fig.12.Simulation results for output voltage of eleven level inverter.

V. CONCLUSION:

This paper has proposed a novel eleven-level grid-connected transformer less PV converter based on a CFB topology with two full bridges, one of which is supplied by a floating capacitor. A suitable PWM strategy was developed in order to improve efficiency (most power devices commutate at low frequency) and, with the help of a specific TC, minimize the ground leakage current. The proposed PWM strategy can regulate the voltage across the flying capacitor. Simulations were performed to assess the ability to regulate the flying-capacitor voltage in a wide range of operating conditions.

REFERENCES:

1. M. Calais and V. G. Agelidis, “Multilevel converters for single-phase grid connected photovoltaic systems—An overview,” in Proc. IEEE Int. Symp. Ind. Electron., 1998, vol. 1, pp. 224–229.
2. S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, “A review of single-phase grid connected inverters for photovoltaic modules,” IEEE Trans. Ind.Appl., vol. 41, no. 5, pp. 1292– 1306, Sep./Oct. 2005.
3. P. K. Hinga, T. Ohnishi, and T. Suzuki, “A new PWM inverter for photovoltaic power generation system,” in Conf. Rec. IEEE Power Electron.Spec. Conf., 1994, pp. 391–395.
[4] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. C. P. Guisado, M. A. M. Prats, J. I. Leon, and N. MorenoAlfonso, “Power-electronic systems for the grid integration of renewable energy sources: A survey,” IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002– 1016, Jul. 2008.
[5] H. Xiao and S. Xie, “Leakage current analytical model and application in single-phase transformerless photovoltaic grid-connected inverter,” IEEE Trans. Electromagn. Compat., vol. 52, no. 4, pp. 902–913, Nov. 2010.
[6] O. Lopez, F. Freijedo, A. Yepes, P. Fernandez-Comesaa, J. Malvar, R. Teodorescu, and J. Doval-Gandoy, “Eliminating ground current in a transformerless photovoltaic application,” IEEE Trans. Energy Convers., vol. 25, no. 1, pp. 140–147, Mar. 2010.
[7] E. Gub´ıa, P. Sanchis, A. Ursua, J. Lopez, and L. Marroyo,“Ground Currents in Single-Phase Transformerless Photovoltaic Systems,” Prog. Photovolt., Res. Appl., vol. 15, no. 7, pp. 629–650, Nov. 2007.
[8] W. Yu, J.-S Lai, H Qian and C. Hutchens “High-Efficiency MOSFET Inverter with H6-Type Configuration for Photovoltaic Nonisolated AC Module Applications,” IEEE Trans. Power Electron., vol.26, no.4, pp.1253-1260, April 2011.
[9]. M. Saeedifard, R. Iravani, and J. Pou, “A space vector modulation strategy for a back-to-back five-level HVDC converter system,” IEEE Trans. Ind.Electron., vol. 56, no. 2, pp. 452–466, Feb. 2009.
[10]. R. Stala, S. Pirog, M. Baszynski, A. Mondzik, A. Penczek, J. Czekonski, and S. Gasiorek, “Results of investigation of multicell converters with balancing circuit—Part I,” IEEE Trans. Ind. Electron., vol. 56, no. 7, pp. 2610–2619, Jul. 2009.
[11]. F. Z. Peng, “A generalized multilevel inverter topology with self voltage balancing,” IEEE Trans. Ind. Appl., vol. 37, no. 2, pp. 611–617, Mar./Apr. 2001.
[12] G. Konstantinou, S. Pulikanti, M. Ciobotaru, V. Agelidis, and K. Muttaqi, “The seven-level flying capacitor based ANPC converter for grid integration of utility-scale PV systems,” in Proc. IEEE PEDG, Aalborg, Denmark, Jun. 2012, pp. 592–597.