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A ELEVEN-LEVEL GRID-CONNECTED CONVERTER TOPOLOGY FOR SINGLE-PHASE TRANSFORMERLESS PV SYSTEMS

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Abstract— **This paper is composed of three cascaded full bridges, these full-bridges needs a separate power supply in each full bridge section, the former is supplied by the PV generator and latter is supplied by a flying capacitor. The multilevel output diminishes the harmonic distortion and electromagnetic interference. The effectiveness of the proposed approach also minimizes the common mode leakage current with the help of transient circuit. The addition with the earlier switch another is connects the midpoint of dc-link to the converter output. Simulations show the effectiveness of the proposed solution.**

Keywords— Leakage current, multilevel inverter, grid connected, pulse width modulation (PWM) inverters

I. INTRODUCTION

The growing demand for electric power, along with the reducing stock of traditional energy sources, has affected a growing interest towards micro generation from renewable power sources. In particular, photovoltaic energy (PV) has observed an increasing attention and the scientific community have concentrated its determinations in order to develop innovative solutions for the integration of PV systems into the existing electrical grid [1].

Grid coupled photovoltaic (PV) converters refers the furthest extensive clarification for inhabited for the generation of renewable energy. In the path traditional approaches of PV converters features a giant and premier module having a grid frequency transformer where the interconnection over the converter and the electrical grid, now the canvassers willing to go for transformer less constructions for the reduction of cost, gauge and there for finally for improvement in functionality [2] and given that increase to ground leakage current threat [3], [4]. Behalf of it deteriorating quality of power, the ground leakage increases the electromagnetic interference occurrence and it has be converted as safety hazard, from the international guidelines some magnitude limits strictly . This dispute must be divergent in all transformers less PV converters irrespective of construction. In particular full-bridge-based topologies, the ground leakage current is commonly because of high frequency variations in the common-mode voltage at the power converter results [4]. Limited solutions are found in literature pointing on decline of the common-mode voltage harmonic content [5]-[7].Further deduction in cost and weight and enhancement in effectiveness to be attained by diminishing the filter size and it is the objective of multilevel converters. Multilevel converters are studied for many years [8]. Since they can synthesize the output voltages using extra levels, multilevel converters partition the input voltage among. Several power modules it is for the benefit of further capable modules. Recently, they have created their way to residential-scale single-phase PV converters, where they currently represent a warm research topic [9]. Single phase multilevel converters can be approximately divided into three categories based on design: neutral point clamped (NPC), cascaded full bridge (CFB), and custom [10]. A huge advantage is that single-phase NPC converters are virtually protected from ground leakage currents, although the same is not true for three-phase NPC converters [9]. The main drawback of NPC designs, with respect to full bridge is that they essential twice the dc-link voltage. CFB makes a largely modular design. CFB converters have also been proposed for stand-alone applications [11]. A CFB made up of full bridges can synthesize 2n+1 voltage levels when the supply voltage is the same for both full bridges. custom converters generally need custom pulse width modulation (PWM) and control schemes [12]. The custom converter proposed in generates five levels with six switches but has no intrinsic boosting capability.

The topology proposed now this paper consists of two asymmetrical CFBs, generating eleven 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. Comparison of the number of output levels per switch (eight switches, eleven levels) is what can be achieved using custom architectures. In fairness, it should be noted very low power that two additional switches and a line frequency switching device [transient circuit (TC)] were involved in the final topology in order to decrease the ground leakage current.

Furthermore, the advanced PWM control strategy, in addition to controlling the flying capacitor voltage, with the help of the specific TC clarified in fourth section, the ground leakage current are reduced. Finally the proposed CHB converter can work at any power factor as in the third section in which the other supply reactive power frequently [13], [14]. The proposed based topology was exciting by authors in an earlier paper [15].Now comparing with earlier work; this paper presents a novel set of simulation work and results. This paper is arranged as follows:

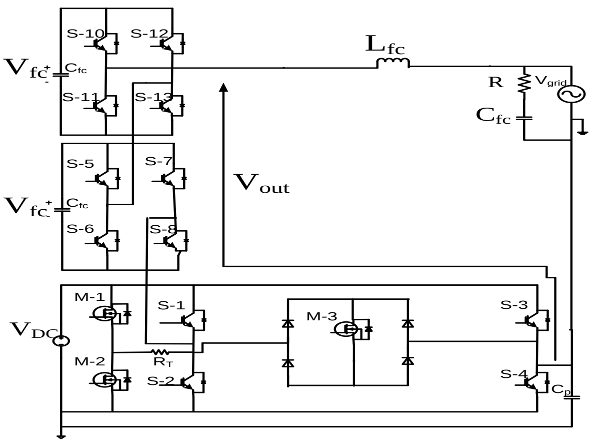
Sinusoidal pulse width modulation (SPWM) maximizes the Performance of the power converter topology selected is discussed in this second section. The regulation of the flying capacitor recycled to supply the second full bridge of the CFB (cascaded full bridge) topology is described in third section. Fourth section describes the principle of operation of transient circuit ground leakage will be reduced. And last Section show the simulation results.

II. ELEVEN-LEVEL CONVERTER AND PWM CONTROL STRATEGY

The proposed converter is combined of two cascaded full-bridges, the former supplied by the PV generator and fling capacitor also latter supplied (see Fig.1). A different pulse width modulation (PWM) method was developed in order to receive grid connected operation with transformer less solution used for this basic desired topology. Since the SPWM technique simply not sufficient to withstand a low earth leakage current, extra elements were added below section 4. Described the following sections, this paper proposed topology of PWM control strategy by using; IGBTs

With fast anti n parallel diodes are needed 4 legs. (High-frequency hard switching commutations occur). In this paper basic operation one full bridge leg is directly connected to neutral wire and above full bridge leg is connected to the phase wire through an LC filter. As it will be referred to and justified next to this description, the flying capacitor is possible by using different switching patterns that lead to the same averaged output voltage.

Figure 1: Proposed topology of a 11 level CHBMLI with a



Flying Capacitor

As it evident, with the choice $v_{fc} = \frac{V_{DC}}{3}$, there are no redundant states that can output the same voltage level with a different switch configuration.

As a consequence, switching between their frames and the PV modules generally connected to the earth. This means that during the commutation high currents will circulate in the neutral conductor due to the panels parasitic capacitance. The converter can perform in different methods of output voltage zones, the voltage controls happening zone 2. Under the hypothesis of positive grid current. In fact, if v_{fc} is added to the output voltage, the result will be a discharge of the flying capacitor, on the contrary, it v_{fc} is subtracted, the output current will charge the capacitor. The basic idea of operating zone divide in different zones, i.e. Zone 1, zone 2, zone 3 and zone 4. In this adjacent zones operating in different boundaries can overlap, vary according to the flying capacitor and dc-link voltage is +ve, it becomes discharged position ($v_{DC} + v_{fc}$), next -ve in zone B case flying capacitor becomes charging position ($v_{DC} - v_{fc}$), similarly every zones are classified. Depending on the $\frac{v_{fc}}{v_{DC}}$ ratio, in Fig 2 can follow; therefore the below operating zones to be every zone is determined the regulation V_{fc}, refer to in third section. Next duty cycles are calculated by a simple equation using on-line equation [13]. The switching pattern in different zones depends on the instantaneous fundamental component of output voltage v^*_{out} on the measured values of V_{fc} and v_{DC}.

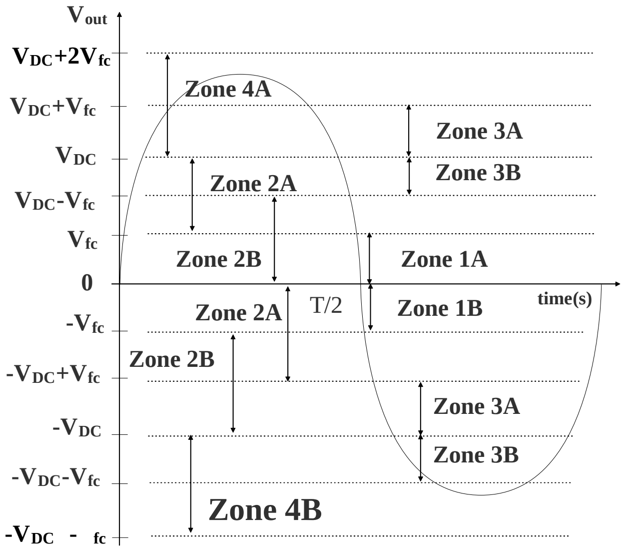
$v_{fc} > 0.5\,v_{DC}$. If $v_{fc} = \frac{V_{DC}}{3}$, the cascaded converter can synthesize up to eleven similarly desired output voltage levels.

III. FLYING-CAPACITOR VOLTAGE REGULATION

The major task is the transfer of active power to the electrical grid while using a grid-connected PV converter, controlling the voltage of the flying capacitor is crucial. By choosing the operating zone of the converter depending on the instantaneous output voltage request flying-capacitor voltage V_{fc} is regulated correctly.

V_{fc} Can be added to (A zones) or subtracted from (B zones) the HVFB output voltage charging or discharging the flying capacitor, Depending on the operating zone of the converter (see Fig.2.),. 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 identical output voltage waveform, it is possible to manage the voltage of the flying-capacitor, forcing the converter to operate further in a zones when the flying-capacitor voltage is higher than a mention value or more in B zones when it is lesser than reference value.

Negative injected grid current. In all the case, some commutations between nonadjacent output levels must certainly occur (level skipping), there is a disadvantage of a certain increase in the output current ripple. The voltage



control of the flying capacitor (which determines the zone-A

Figure 2: shows the choice of the operating zones

or zone-B operation) is realized by a simple hysteresis control.

Fig.3 illustrates the regulation off supposing a positive grid current with $v_{out}>0$ and $v_{fc} < 0.5\,v_{DC}$. If v_{fc} too low, output level v_{fc} can be replaced by $v_{DC} - v_{fc}$, here switching between the 0 and $v_{DC} - v_{fc}$ output levels. Similarly, if v_{fc} is too high; $v_{DC} - v_{fc}$ can be replaced with v_{fc}, cause the converter to switch between v_{fc} and v_{DC} output levels [zone 2A, Fig. 2].

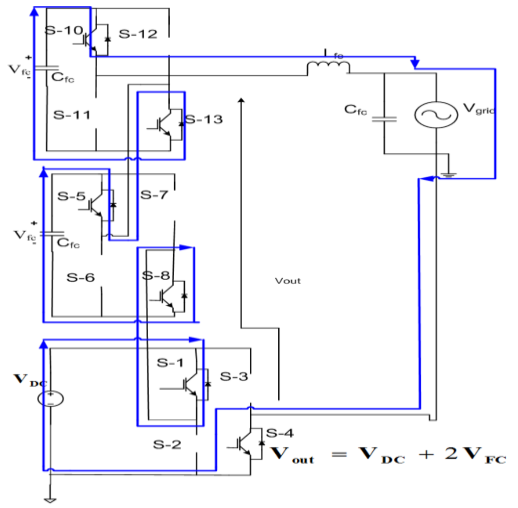


Figure 2: Flying capacitor voltage regulation

The device switching is as follows, at low frequency they are short circuited while on and not shown when off. Similar v_{fc} regulation strategies can be developed for the case when $v_{fc} > 0.5\,v_{DC}$. If $v_{fc} < 0.5\,v_{DC}$, in order to minimize the current ripple, zone 2 is preferred only when $v_{fc}<v^*_{out}<v_{DC}-v_{fc}$ (zone 3 are otherwise chosen) limiting level skipping. Level skip all the time occurs if $v_{fc} > 0.5\,v_{DC}$; since the dc-link voltage can go through abrupt variation due to the MPPT strategy, it is essential to the converter is capable to work in any $[v_{DC}, v_{fc}]$ condition.

IV.APPLICATION TO TRANSFORMERLESS PV CONVERTERS-TC

A specific feature of the commutation analysis of TABLE I is that the switches t3 and t4 are at grid frequency, v_{grid} is commutating at every zero crossing. If negative derivative is considered for the zero crossing in operation then T4 opens and T3 closes, as from zero to v_{DC} the neutral wire voltage (voltage across the parasitic capacitance of the PV field) is changes. By this instance, the commutation can leads to a large tremor of leakage current that can diminishes the power quality and damage the model of PV. To reduce these surge currents, a decent TC was designed. The proposed converter topology shows in Fig.3; it is established of the two cell be selected with current ratings much lower than devices of the CFB. Besides, the power loss because of adding the resistor is insignificant. Assessing the energy lost, charging and discharging a capacitor c_p to v_{DC}.

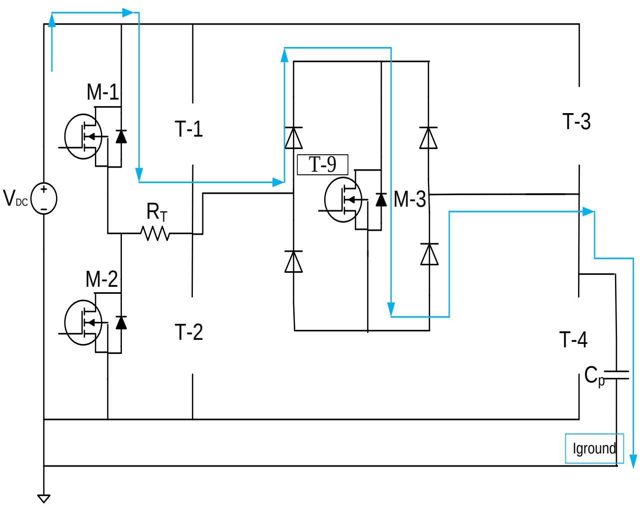


Figure 3: Ground leakage current limitation circuit topology

The TC consists of two low power MOSFETS M1 and M2, bidirectional switch T9, and resistor R_t. When the converter regulated through a proportional-integral regulator plus feed

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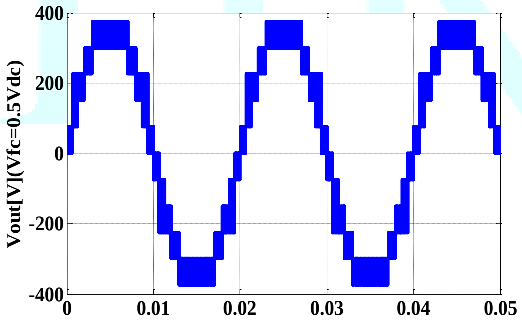
forward reaches operating zone 1, the output zone 1, the output voltage of HVFB must be zero, obtained by making on the switch combination are T1 and T3 or T2 and T4 on. However, to operate the TC, when reaching zone 1, kept the switches T1, T2, T3, and T4 are in off, while T9 is on. This keeps the neutral potential floating, so that the voltage on the parasitic capacitor V_{ground} stays constant [Fig. 5]. At this point, one of M1 and M2 is turned ON (M1 if the slope of the zero crossing is negative and M2 if positive). To limit the current surge doing so C_p is charged through R_T with a first-order transient.

Whereas the TC provides additional components, they can average the validations over a line period T by $P_{tc} = C_p V_{DC}^2 / T$ with C_p =200nF and V_{DC}=300V. Obtained a dissipation of about 1w.The TC operation is not effected by the power factor because in grid connected operation, the output voltage is always very close to the grid voltage. The accurate operation of the TC needs the grid voltage instant angle that can be obtained with a phase-locked loop (PLL) served by the grid voltage.

V. SIMULATION RESULTS

The proposed eleven level solutions are simulated using the MATLAB. The simulations cover a large range of active and reactive power injected into the grid, DC-link voltage, equivalent PV and parasitic capacitance. Extension simulation results concerning grid current distortion and ground leakage



are performed in order to the highlight the characteristic of the proposed converter and modulation strategy.

FIGURE 5:OUTPUT VOLTAGE

The first set of simulation aimed at evaluating the quality of the grid current under different conditions of DC-voltage ratio. For the simulation it is chosen $V_{DC} = 300V$, $L_F = 5mH$, $V_{grid} = 300V$, $F_{grid} = 50HZ$, $C_f = 1\mu F$.

Current with non-ideal grid and simple common mode filter, i_{ground}=300mArms ,Chosen $V_{DC} = 300V$, L_F=5mH , V_{grid}=300V , F_{grid}=50HZ , $C_f = 1\mu F$ .The injected grid current is i_{grid}=8.5Arms . The switching frequency was f_s=20kHz .

The surge current injected into the grid is regulated through a proportional-integral regulator plus feed forward, C_p=200nF. Ground voltage and current with and current with non-ideal grid and simple common mode filter $i_{ground} = 300mA\ rms$ ..

further indications about the regulations of the flying capacitor voltage Fig 8. In this earth leakage current are reduced to an accurate design of common mode filter.

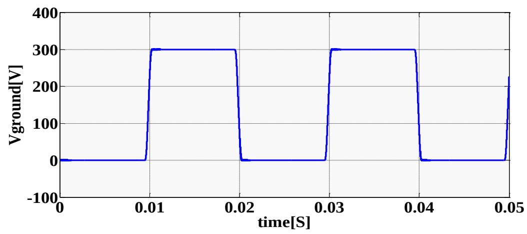


Figure 6:Ground voltage for the transient circuit with 200nF capacitor

Transient circuit operates in two modes of operation. During 1st mode of operation. The voltage across capacitor will be 300V.During 2nd mode of operation. The capacitor will be short circuited and ground current shows transient behaviour between mode changes. In remaining time the ground current is very small.

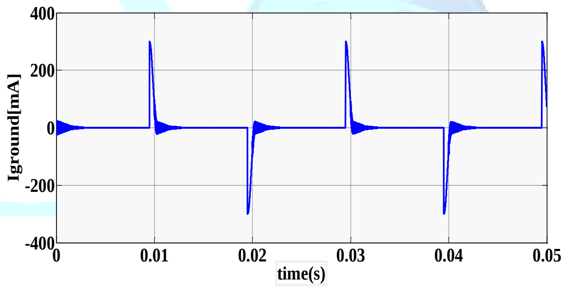


Figure 7:Ground current for the transient circuit with 200nF capacitor

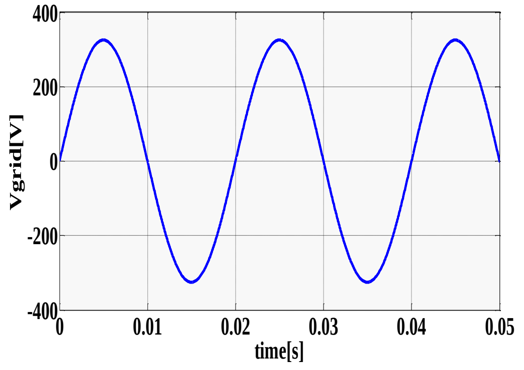


Figure 8:Grid voltage for 0.5V_{fc}

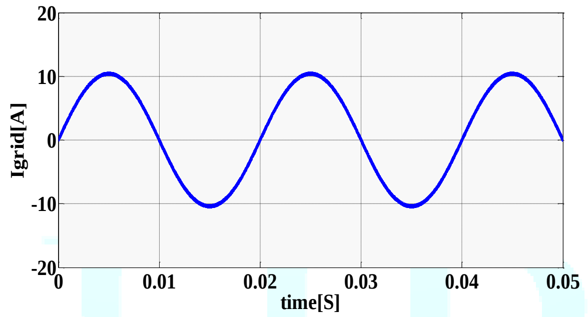


Figure 9:Grid Current for 0.5I_{grid}

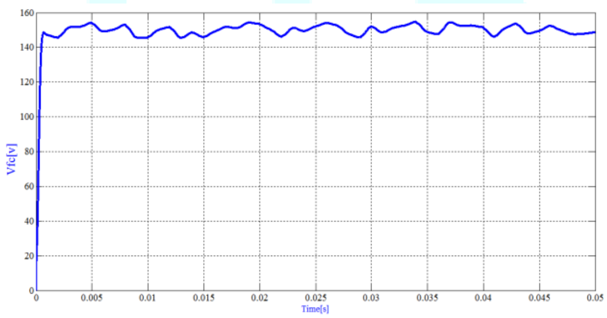


Figure 10: flying capacitor voltage

The characteristics of step variation for V_{fc} from 180 to 200 V occurring at a time of 0.1 s. The V_{fc} average value rises to reference value without overshoot.

VI. CONCLUSION

In this proposed work several topologies of transformer less grid-connected inverters and multilevel inverters are analyzed. A novel eleven-level grid connected transformer less PV converter is proposed and evaluated in terms of grid current and ground leakage current.

The converter used is cascaded full bridge, where one of the full-bridges consists a flying capacitor. An appropriate PWM strategy is developed to reduce the switching losses and the specific TC minimizes the ground leakage current. The ground leakage current represents a problem of paramount importance in PV-fed grid-connected power converters.

The proposed PWM strategy can regulate the voltage across the flying capacitor. Simulations are performed to assess the ability to regulate the flying-capacitor voltage in a wide range of operating conditions. Extensive simulations good performance of the converter as far as ground leakage current and harmonic distortion is concerned.

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Table 1: Description of the operating zones

Zone	Output Voltage	On Devices	Off Devices	Switching Devices	Extra switches
Zone 3B	$-V_{DC}-V_{fc}\leftrightarrow -V_{DC}$	T2,T3,T7	T1,T4,T8	T5,T6	T10,T12
Zone 3A	$-V_{DC}\leftrightarrow -V_{DC}+V_{fc}$	T2,T3,T8	T1,T4,T7	T5,T6	T10,T12
Zone 2A	$-V_{DC}+V_{fc}\leftrightarrow 0$	T3,T7	T4,T8	T1,T2,T5,T6	T10,T12
Zone 2B	$-V_{DC}\leftrightarrow -V_{fc}$	T3,T7	T4,T8	T1,T2,T5,T6	T10,T12
Zone 1B	$-V_{fc}\leftrightarrow 0$	T1,T3,T7	T2,T4,T8	T5,T6	T10,T12
Zone 1A	$0\leftrightarrow V_{fc}$	T2,T4,T8	T1,T3,T7	T5,T6	T11,T13
Zone 2A	$V_{fc}\leftrightarrow V_{DC}$	T4,T8	T3,T7	T1,T2,T5,T6	T11,T13
Zone 2B	$0\leftrightarrow V_{DC}-V_{fc}$	T4,T7	T3,T8	T1,T2,T5,T6	T11,T13
Zone 3B	$V_{DC}-V_{fc}\leftrightarrow V_{DC}$	T1,T4,T7	T2,T3,T8	T5,T6	T11,T13
Zone 3A	$V_{DC}\leftrightarrow V_{DC}+V_{fc}$	T1,T4,T8	T2,T3,T7	T5,T6	T10,T12
Zone 4A	$V_{DC}+2V_{fc}\leftrightarrow V_{DC}$	T1,T8	T7,T2	T5,T6	T11,T12
Zone 4B	$-V_{DC}\leftrightarrow -V_{DC}-2V_{fc}$	T7,T2,	T1,T8	T5,T6	T10,T13