International Journal of Advance Research in Science and Engineering
Vol. No.9, Issue No. 01, January 2020
www.ijarse.com
IJARSE
ISSN 2319 - 8354

A Innovative Control System Using Multi Level Converter Topology for Single-Phase Transformer less PV System

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Abstract: This article contains another control strategy for a seven-level converter topology for single stage transformerless PV system. The proposed control system has been executed for a cascaded full bridge working on one bridge being taken care of from dc source and the other from a flying capacitor. This plan uses the redundant switching states of the cascaded full bridge. The proposed plan works after keeping up the capacitor voltage consistent, which helps in keeping up the inverter output. Simulation results have been introduced to validate the legitimacy of the proposed component.

Index Terms: Leakage current, multilevel systems, photovoltaic (PV) systems, cascaded full bridge, sinusoidal pulse width modulation.

1. INTRODUCTION

Grid connected Photo Voltaic convertors have been utilized quite abundantly in residential renewable energy solutions. These convertors traditionally involve a hefty and costly grid frequency transformer which functions as an interface between the grid and the convertor. Transformerless frameworks have been investigated upon and have demonstrated to be appropriately successful as far as proficiency, cost and weight yet burden as far as the nature of the yield power, overrunning the lattice with dc current [1], [2] and causing an expansion in the ground spillage current [3], [4].The module and the edge alongside the association between unbiased wire and ground prompts parasitic capacitance permitting AC spillage current [3]. Aside from ground spillage current upsetting the force quality it likewise prompts electromagnetic obstructions trading off the security of the framework. Global guidelines present exacting cutoff to this. Hence frameworks need to take care about this issue independent of the design onwhich they are based upon. The basic mode voltage existing in full-connect based geographies prompts improvement of the ground spillage current, essentially because of the recurrence variety of the basic mode voltage saw across the yield [4]. Loads of arrangements have been proposed throughout the years with respect to the moderation of the consonant substance present in the basic mode voltage [5]–[7]. With the framework recurrence transformer out of the framework, the solitary cumbersome part that remains is the channel which channels the yield from high recurrence exchanging segments. Any decrease in the size of the channel prompts significant decrease in cost and weight and prompts improvement in proficiency as well. Staggered invertors center around this angle and have discovered path into the new plug PV convertors. Staggered convertors equipped for blending the yield voltage utilizing a greater number of levels score over the traditional two-and three-level convertors as far as decrease in symphonious contortion and they likewise present a benefit of effective. gadget utility by virtue of its capacity to sub split the input voltage between a few power gadgets. Better nature of the yield voltage waveform of the staggered converter helps in the decrease of the filter size, with an ensuing decrease in the expense and weight of the inverter and relating improvement in the productivity of the system. Multilevel converters were at first utilised in high-voltage mechanical applications, just as power train applications. Continuously they were utilized in environmentally friendly power convertors are still generally utilized for these applications [9]–[13]. Of late they have had the option to discover their way in private scale single-stage PV converters, giving bunches of freedom to specialists to work after improving the frameworks utilizing staggered convertors [14]–[29].

Fell Full Bridge (CFB) converters have been

famously utilized for independent applications [17], [22]. CFBs permits host of control techniques like successive stage enhanced with stage moving [19], prescient control [23] and fake neural organizations [24] to be utilized to alleviate consonant contortion and accomplish greatest force point following (MPPT). A n full extension based CFB which has at any rate 4n force switches is fit for blending 2n + 1 voltage levels for same degree of supply voltage for each scaffold. Models can be tweaked to work with various control procedures and permits decrease in the quantity of switches [25]–[29]. It is feasible to diminish the switches-per- outputvoltage-level proportion utilizing distinctive stock voltages for each scaffold (awry CFBs) [32], [33]. This work examines a geography wherein two lopsided CFBs are utilized, creating seven yield voltage levels. For this convertor, one scaffold is fueled by a dc voltage source while the other extension is controlled by a flying capacitor. Adjusting the proportion between two voltages permits diverse arrangement of yield voltages. With flying capacitor filling in as an auxiliary source, it permits restricted voltage boosting and the yield is tantamount to different other custom models. PV applications deal with the issue of variety in sun powered radiation bringing about factor DC voltage being taken care of into the framework and need to utilize methodologies which can handle the yield voltage. This issue was concentrated in [34]–[36], and it zeroed in on estimation of the different full-connect voltages and online calculation of obligation cycles expected to adjust the voltages and to examine the force balance between various cells. This paper manages the capacitor voltage adjusting of examined converter when used a seven-level CFB converter. The technique is simple and much easier to use, and it achieves the desired results. Simulation results are presented to validate the proposed technique.

2 CASCADED FULL BRIDGE CONVERTORWITH AFLYING CAPACITOR

Fig. 1 shows a cascaded full bridge converter with a flying capacitor for single-phase transformerless PV applications [38]. The converter uses two full bridges in cascade. One full bridge is fed from a dc source, while the other bridge is fed from a flying capacitor. The number of voltage levels available at the output of the converter depends on the voltage ratio maintained between the dc voltage V_{DC} and the flying capacitor voltage V_{fc}. If the ratio is kept at 2:1, the inverter works as a seven-level CFB converter. If the ratio is maintained at 3:1, the number of output voltage levels obtained is nine. For the present study, the inverter is operated as a seven-level CFB converter. Hence the capacitor voltage magnitude should be kept at half of the dc supply voltage. The advantage of supplying one bridge with a flying capacitor is that only one dc supply is required for the inverter. This is an advantage over the conventional CFB converter which would require two isolated dc power sources for each phase. However, the topology discussed here presents a challenge, in that, it is not easy to maintain the capacitor voltage constant. Even if the capacitor is initially charged, it has a propensity to discharge as the circuit operates. As the capacitor discharges, the output voltage waveform deteriorates and the purpose of the circuit fails. The successful functioning of the

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ISSN 2319 - 8354

circuit as a seven-level CFB converter, absolutely essentially requires that the capacitor voltage be held constant at a level that is half of the dc supply voltage. [38] presents a method to maintain the capacitor voltage constant; however, the method is quite complex. Here a simpler control technique is presented to control the capacitor voltage and maintain it at its desired value, so that the desired output voltage waveform is obtained.

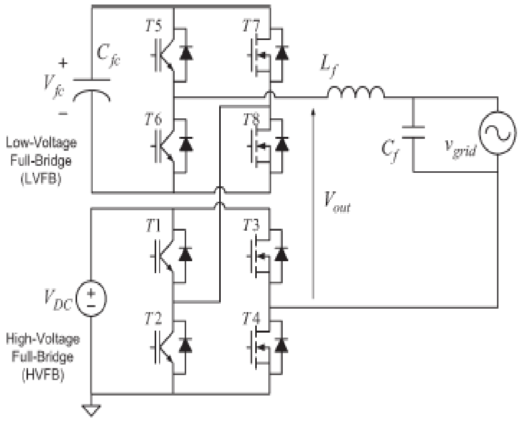

Fig.1 *CFB with a flying capacitor*

2.1 Proposed Control Scheme

A number of control techniques are available for multilevel CFB converters. These include the Sinusoidal Pulse width modulation (PWM) technique, the Space Vector PWM technique, the Selective Harmonic Elimination PWM technique, and so on. Out of these, the two most prominently used techniques are the sinusoidal PWM and the space vector PWM technique. However, the space vector PWM technique cannot be used for single phase converters. As such, the sinusoidal PWM technique will be considered in this work.

Among the sinusoidal PWM techniques available for multilevel converters, the level-shifted PWM (LSPWM) technique is the simplest. Hence this work uses the LSPWM technique to modulate the CFB converter. This technique uses a single modulating wave for the single phase converter and six level-shifted carrier waves to obtain a seven-level output, as shown in Fig 2.

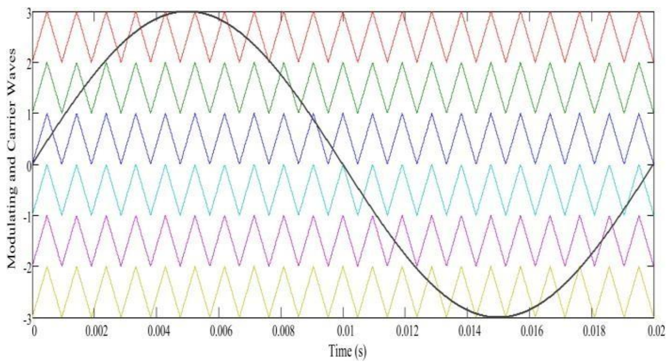

Fig.2 *Modulating and Carrier Waves for the Seven-Level CFB converter*

The carrier waves can be labeled from top to bottom as v_{cr3+}, v_{cr2+}, v_{cr1+}, v_{cr1-}, v_{cr2-} and v_{cr3-}; whereas the modulating

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ISSN 2319 - 8354

wave can be labeled as v_m. When v_m is greater than v_{cr3+}, those switches of the converter are turned on which give an output voltage equal to 3E. Here 2E is the dc supply voltage whereas E is the voltage across the flying capacitor. When v_m is greater than v_{cr2+}, the switches of the converter which give an output voltage of 2E are turned on, and so on. The switching states for the seven-level asymmetrical CFB converter modulated using LSPWM technique are listed in Table 1.

TABLE 1

SWITCHING STATES OF THE SEVEN-LEVEL CFB CONVERTER MODULATED USING THE LSPWM TECHNIQUE

Switches in ON state	Capacitor status	Output voltage	
1, 2, 5, 6	Discharging	2E + E = 3E	3E
1, 2, 5, 7	Floating	2E + 0 = 2E	2E
1, 2, 7, 8	Charging	2E - E = E	E
1, 3, 5, 6	Discharging	0 + E = E	
1, 3, 5, 7	Floating	0 + 0 = 0	0
1, 3, 7, 8	Charging	0 – E = -E	-E
3, 4, 5, 6	Discharging	-2E + E = -E	
3, 4, 5, 7	Floating	-2E + 0 = -2E	-2E
3, 4, 7, 8	Charging	-2E – E = -3E	-3E

For the output voltage levels of 3E, 2E, 0, -2E and -3E, there is only one possible combination of switches. However, for the voltage level E and –E, the CFB converter offers redundant switching states. The redundancy of switching states is an important advantage in case of multilevel converters, and can be put to good and effective use. The capacitor status during each switching state of the inverter is also shown in Table 1. When a switching state causes the capacitor current to leave from its upper plate, it causes the capacitor to discharge. On the other hand, if a switching state causes the capacitor current to enter through its upper plate, it results in the charging of the capacitor. If no current flows through the capacitor during a switching state, it neither charges nor discharges, and is said to be floating. It is observed from Table 1 that there is a natural balance in the charging and discharging times of the capacitor during each cycle of the inverter output waveform. During the positive half cycle, the capacitor discharges for the output voltage level 3E and floats for 2E. For the output voltage level E, switches 1,2,7,8 can be turned on so that the capacitor charges. During the negative half cycle, the capacitor charges for the output voltage level – 3E. If the switches 3,4,5,6 are turned on for the voltage level – E, the capacitor would discharge. Thus for the equivalent voltage levels in the positive and negative half cycle (equivalent voltage levels will have equal on- times in a cycle), if the capacitor charges for a level in the positive half cycle, it discharges for the corresponding level in the negative half cycle, and vice versa. This implies that if the capacitor were lossless and was initially charge to a voltage E, the capacitor voltage would remain constant over a cycle on account of alternate charging and discharging for equal times in the cycle. However, in practice, the capacitor will have some losses. As a result, the capacitor voltage will continue to decrease as the inverter operates and the output voltage waveform will be affected. To overcome this problem, the redundant states of the seven-level invertercan be utilized. Those states which cause the capacitor to discharge can be discarded in favor of those states which result in the charging of the capacitor. As such, during the positive half cycle, the switching state +E with switches 1,2,7,8 on is chosen as it causes the capacitor to charge. Also, in the negative half cycle, the switching state – E with switches 1,3,7,8 on, which again causes charging of the capacitor is chosen. With this choice, the capacitor discharges only when the switches 1,2,5,6 are on for the switching state 3E; whereas it is either floating or charging during all the other switching states. This choice of switching states helps in maintaining the capacitor voltage at its desired value (to the one that it has been charged initially). If the capacitor still continues to lose charge, a slight negative offset can be provided in the modulating wave. This will cause the discharging time of the capacitor on account of the switching state 3E to decrease, with a corresponding increase in the charging time. This will further help in maintaining the capacitor voltage constant. It must be mentioned here that these techniques will keep the capacitor voltage constant only in case of light loads, i.e. loads that do not draw a significant amount of current. If the load current has a large value, then these techniques will not be sufficient in maintaining the capacitor voltage constant.

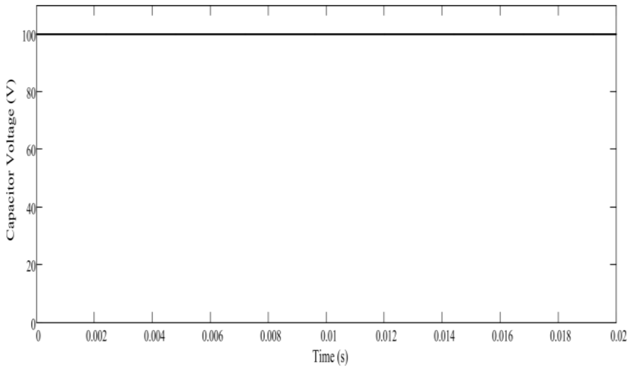

Figure 3. *Voltage across the flying capacitor*

3 SIMULATION RESULTS

The CFB converter shown in Figure 1 is simulated using MATLAB Simulink with the proposed control technique. Fig.3 shows the flying capacitor voltage for one cycle of the inverter operation. As seen, the capacitor voltage remains almost constant at the value to which it was initially charged citations

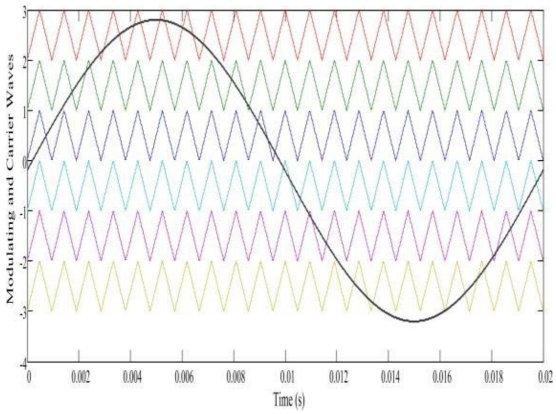

Fig.4 *Modulating and Carrier Waves for the proposedscheme*

Fig.3 shows the modulating and carrier waves for the seven-level CFB converter with a 20% negative offset in the modulating wave. This will cause the on-time of the switching state 3E to decrease, resulting in the decrease of the discharging of the capacitor. At the same time, it will increase the on-time of the switching state − 3E so as to increase the charging time of the capacitor. The dc supply voltage is selected as 200 V, while the capacitor voltage is taken as 100 V to ensure a ratio of 2:1 between the two. The frequency of the modulating wave is taken as 50 Hz to obtain a 50 Hz inverter output voltage. The frequency modulation index m_f is taken as 21 so that the harmonics appear across the sidebands of m_f, $2m_f$ and so on. This ensures that the lower order harmonics are eliminated, as a result of which the size of the filter decreases. The simulation here is done without considering a filter as the focus of this research is only on the capacitor voltage balancing. A 10 kΩ resistive load is considered for the inverter so that the load current has a small value. A 20% negative offset is provided in the modulating wave to assist in keeping the capacitor voltage constant.

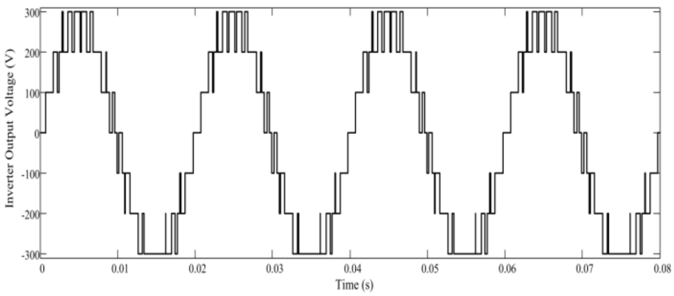

Fig. 5. *Inverter Output Voltage*

modulating wave to decrease the capacitor discharging time while simultaneously increasing the capacitor charging time. This results in keeping the capacitor voltage constant during inverter operation in spite of losses in the capacitor, which would otherwise have decreased the capacitor voltage and deteriorated the inverter output voltage waveform. The dc offset, however, introduces a dc component in the inverter output voltage, the magnitude of which is directly dependent on the amount of negative offset provided. Also, the technique is useful only for light loads, and not where the load draws a large current. Simulation results are presented to validate the proposed Fig. 5 shows the inverter output voltage waveform with the proposed control scheme. As seen from the output voltage waveform, there is a consistency in the output over a number of cycles. This is on account of the capacitor voltage being held constant. Also, the capacitor discharging time, corresponding to a voltage of 300 V, is less as compared to the capacitor charging time corresponding to the voltage − 300 V. This is on account of the negative offset provided in the modulating wave. The unbalance in the times, as well as in the negative and positive half cycles, will depend on the percentage of offset provided.

Fig. 6 shows the frequency spectrum of the inverter output voltage waveform. As can be seen from the frequency spectrum, the lower order harmonics are negligible (less than 2%) with the significant harmonics spread around the frequency modulation index (21) and its multiples. However, there is almost a 6% dc component introduced into the inverter output voltage. This dc component is on account of the negative offset introduced in the modulating wave. The magnitude of the dc component will be proportional to the offset introduced.

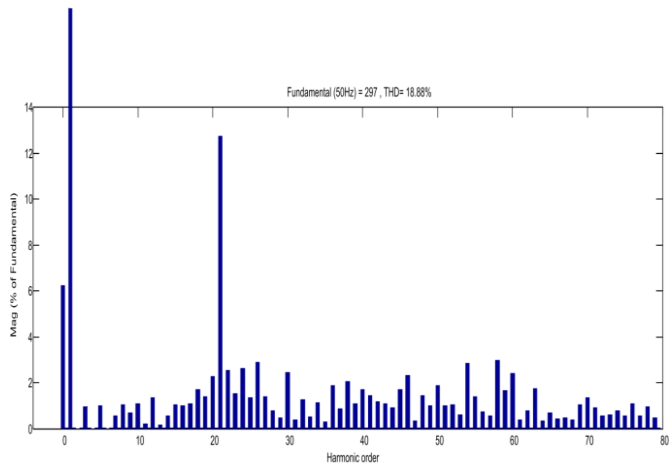

Fig. 6. Frequency spectrum of the inverter output voltage

4 CONCLUSION

A simple control scheme has been proposed in this paper for a CFB converter having one bridge fed from a dc source and the other bridge fed from a flying capacitor. The control scheme is based on the level-shifted sinusoidal pulse width modulation technique for CFB multilevel converters. The proposed scheme utilized the redundant switching states offered by the CFB multilevel converter. It selects those states which charge the capacitor, discarding the switching states which result in the capacitor discharging, whenever possible. It also introduces a negative offset in the technique and prove its effectiveness in keeping thecapacitor voltage constant.

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