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SIMULATION AND IMPLEMENTATION OF MULTILEVEL ACTIVE BOOST RECTIFIER WITH MULTICARRIER PWM

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ABSTRACT

The application of power converter increase day by day in the industrial application. Due to invention of several power electronics based rectifier the process of converting power from ad to dc become easy. The boost converter is very key feature in the industry to increase dc voltage. But there is a problem in the conventional topology. This paper is based on the new topology for conversion of ac-dc boost converter. The working performance shows the benefit of the proposed system. Here in this paper discuss the multilevel active boost topology. The control circuit is based on multicarrier PWM technique. The whole work is simulated in MATLAB software. The result shows the performance of the proposed work.

Keywords: Active boost rectifier, Multilevel PWM, Multilevel topology,

1. INTRODUCTION

Present day standards and market needs for electronic equipment increasingly require active single-phase rectifiers that can operate over a wide supply voltage range with low input current distortion and ripple, near-unity power factor, and high efficiency and power density. For unity power factor rectifiers that do not require a bidirectional power flow capability, the boost power factor corrector (PFC) rectifier is a common solution. This topology consists of a single semi-bridge phase leg enclosed within a full-bridge diode rectifier, controlled as a conventional step-up dc–dc converter to boost the rectified ac input voltage to a higher voltage dc bus. However, the arrangement has the disadvantage of three series device voltage drops in the incoming conduction path, which limits its maximum possible efficiency [1].

High power factor or PFC boost converters are one of the mostly used equipment in the industries. The main concerns of such converters are the unity power factor operation and low harmonic distortion of the input AC waveforms that can be ensured by generating a DC voltage higher than the grid peak voltage amplitude, which makes use of switching devices inevitable [1, 2]. Conventional two-level rectifiers known as full bridge converters have been working for many decades satisfactorily, however they are being replaced by emerging multilevel converter technologies. The multilevel converters produce more voltage levels decreasing the voltage and current harmonics significantly while operating at lower switching frequency. Multilevel converters are comprehensively investigated as DC-AC energy conversion mode and now they have found many applications in AC-DC power conversion systems called rectifier [3].

With the application of multilevel topology in DC-DC converter, main disadvantage is found due to increasing of level need large number of switches. These switches produce loss in power with the application. Also with the using large number of switches makes circuit more complex and expensive.

Additionally the complex circuits need complex control circuit. Not only the number of gate drive circuits is high, but since it is necessary to ensure that the DC levels in all the capacitors are balanced, their coordination is a complex task that must be performed by a powerful high performance (and therefore expensive) processor.

Overall these characteristics (complex power circuitry, high number of gate drivers and high computational load) combine to drive both system complexity and cost to very high levels, making the multilevel inverter a solution that could be applied only in very high power applications such as marine motor drives, massive chemical industry drives and high power transmission systems where the overall capital invested was so high that the power converter cost was not the main consideration.

In this paper here discuss the different topology used in the ac-dc conversion in industrial application. Also in this paper proposed the new topology of active boost converter for ac to dc conversion. Next section discusses the different topology used for this purpose. Further design of the proposed work and simulate in the MATLAB software, result shows the performance of the system.

2. BACKGROUND OF AC-DC BOOST CONVERTER

In principle, the combination of the diode bridge rectifier and a dc-dc converter with filtering and energy storage elements can be extended to other topologies, such as buck, buck-boost, and Cúk.The boost topology is very simple and allows low-distorted input currents, with almost unity power factor using different dedicated control techniques. Typical strategies are hysteresis control, average current mode control and peak current control [4]. More recently, on-cycle control [5] and self control [6] have also been employed.To overcome the reverse recovery problems, various passive snubber circuits have been proposed [3] and silicon carbide (SiC) Schottky diodes were also developed. SiC Schottky diodes present zero-recovery current and negligible switching losses, and have become a benchmark for virtually lossless operation. They can deliver highly efficient switching at frequencies up to several hundred kilohertz, and have been deployed as the boost diodes in power factor correction units of switched-mode power supplies operating in continuous current mode. However, SiC diodes remain more expensive than their silicon counterparts due to higher material costs.To increase the efficiency of the converter bridgeless boost rectifiers (also referred to as dual boost converters) were introduced in [7] and [8], respectively. An improvement of the topology is proposed in [9], where the diode reverse recovery problems are alleviated by using only a coupled inductor and two additional diodes. The topology called totem-pole boost bridgeless PFC rectifier in [10], suffered some modification as well. An interleaved totem-pole boost bridgeless PFC rectifier with reduced reverse-recovery problems using coupled inductor is proposed in [10], at the cost of two additional main switches.

In high-power applications, interleaving of two boost converters is very often employed to improve performance and reduce size of the PFC front end. Besides, for high current applications and voltage step-up, the currents through the switches become just fractions of the input current [11]. An interleaved boost converter firstly proposed in [13]. This arrangement lowers the net ripple amplitude and raises the effective ripple frequency of the overall converter without increasing switching losses or device stresses. Thus, interleaving can be used to increase conversion efficiency and power conversion density as well as to reduce ripple amplitude [13].However, some drawbacks also exist. Since the current is supposed to be adjusted to avoid overload, the drive and control circuits become more complex. Besides, the reverse recovery problem of the boost diodes Db1 and Db2 still exist. Some efforts to mitigate this problem have been made in [14], although the operation in discontinuous current mode (DCM) causes appreciable EMI levels.The introduction of the passive snubber described in [15] minimizes the reverse recovery phenomenon in the interleaved boost converter.

The half-bridge boost converter has been introduced in [16]. In the half-bridge circuit, the current flows through only one switch during each operating stage, while conduction losses are drastically reduced. This voltage level is well acceptable and is also adopted currently in many commercial boost PFC circuits [16]. Although this circuit is less attractive for the universal input voltage range (85–270 V), a modification using two additional diodes and a single-pole double-throw switch enables the circuit operate from a 220-V system, as shown in [16]. The closed-loop control system with the imbalance control is also studied in [16], where the difference between the voltages across the capacitors is calculated and the resulting dc signal is then added to the reference current

3. SYSTEM MODELLING

Reduces switching is more necessary for decreasing the stress in the system. Here we design the new approach for the PFC boost convert which uses one stage methodology for conversion of the voltage. Figure 1 shows the SIMULINK model of proposed system.

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The proposed five-level boost PFC rectifier in which three active switches and six diodes have been used as a slight modification to a similar topology that includes four switches

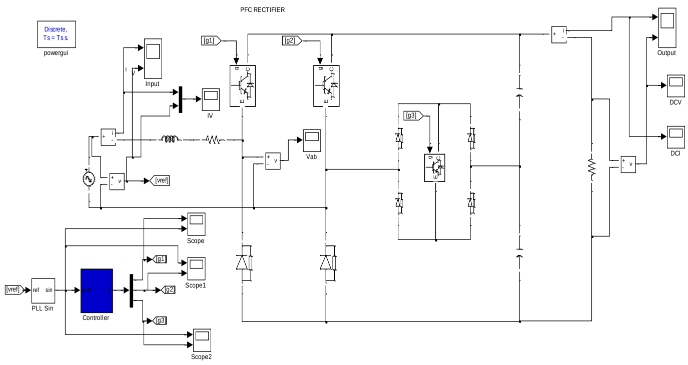

Fig 1: SIMULINK Model of Proposed system

requiring more gate drives and consequently more space on the manufactured board. It is clear from the figure 1 a bidirectional switch (S3) has been connected between leg b and midpoint of DC capacitors to provide different paths for current in order to produce five voltage levels at the output including $\pm V_{dc}$, $\pm V_{dc}/2$ and 0 where V_{dc} is the output DC voltage generated by the rectifier. The bidirectional switch is made by four diodes and one active switch instead of using two active switches to shrink the 0 scheme adopted for producing five level PFC boost configuration.

Table 1: Switching Pattern of Proposed Boost Converter

Switching State	I_s	S_1	S_2	S_3	V_{dc}	**Effect on Capacitor**
1	>0	1	0	0	V_{dc}	C_1 & C_2 Charging
2	>0	1	0	1	$V_{dc}/2$	C_1 Charging
3	≥ 0 & ≤ 0	1	1	0	0	Due to S_1& S_2 conducting
4	< 0	0	0	1	$-V_{dc}/2$	C_2 Charging
5	< 0	0	1	0	$-V_{dc}$	C_1 & C_2 Charging

From the switching table it can be said that based on current direction, different voltage levels would be produced by firing necessary switches. If the current is positive, turning ON the switch S1 leads to conducting the diode D2 so $+V_{dc}$ will be appeared at Vab and both capacitors (C1 & C2) are charged up. In next switching state, by firing switches S1 and S3 simultaneously, a low impedance current path would be provided through C1 and bidirectional switch S3 so the upper capacitor would be charged and Vab will have the voltage level of +Vdc/2. The zero level would be generated by a short circuit between points a and b using switches S1 and S2. For negative current direction, D1 is mostly responsible to prepare required current path. Hence, by turning ON the S3, the current will pass through only the lower capacitor C2 and charges it up while D1 is conducting and the negative voltage level –Vdc/2 would be generated at the rectifier input. Finally, during negative current direction, if switch S2 is fired, then diode D1 conducts and Vab would be equal to –Vdc. Having no redundancy switching states is the most important problem of this topology which makes the dc capacitors voltages balancing difficult.0

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Due to five level output it produce low harmonics in then grid hence it required small size of filter compared to the conventional two-stage rectifier. So reduce size of passive element produce it light weighted and hence manufacturing cost of the converter is low.

4. MULTICARRIER PWM

In order to have low and fixed switching frequency to be suitable for high power and industrial applications, the PWM method should be used to generate required switching pulses. It should be noted that other switching techniques like hysteresis has variable switching frequency which makes annoying audible noises. As illustrated in Figure 2, four carriers (Cr1, Cr2, Cr3 and Cr4) are shifted vertically to modulate the calculated reference signal (Uref). Each carrier is responsible of producing pulses for associate voltage level and switching states as shown by logic blocks. Moreover, corresponding switching pulses for three cycles of the modulated waveform (Uref) have been depicted in Figure 3 to demonstrate the fixed switching frequency in each cycle. The proposed method ensures low and fixed switching frequency functionality of the 5-level converter aims at low switching losses and high efficiency compared to other topologies.

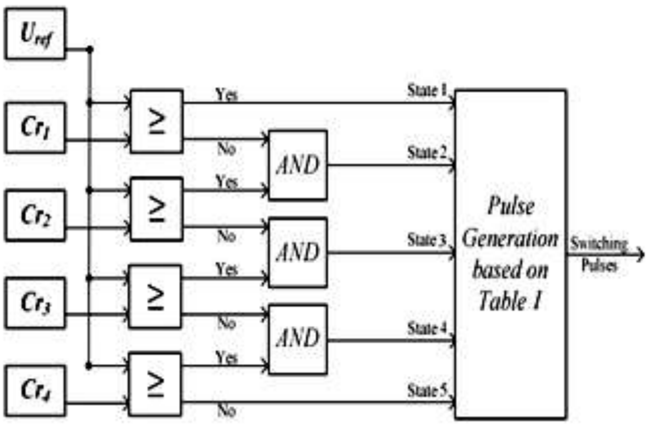

Fig 2: PWM generation with Multicarrier technique

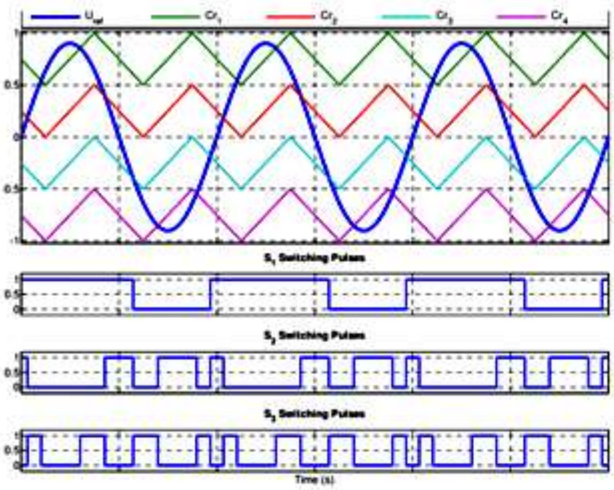

Fig 3: PWM for proposed work

5. RESULTS & DISCUSSION

For showing the dynamic behaviour of the proposed work is implemented in the MATLAB software. Here for simulation use simpower system toolbox. The simulation mode is use variable step discrete with simulation time of 50µs. Table 2 shows the parameter used for the SIMULATION.

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Table 2: Parameter used in SIMULATION

System Parameter	
AC Supply Voltage Peak Value	120 V
AC frequency	50Hz
Inductor size	2.5mH
DC Voltage	220 V
DC Capacitor (C_1& C_2)	47000µF
DC Load (R_L)	100Ω
Switching Frequency	5kHz

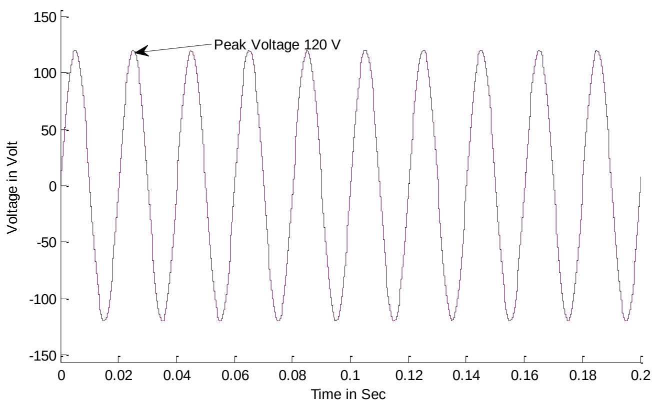

Fig 4: Supply side peak voltage of Grid voltage

Figure 4 shows the input voltage of proposed boost converter. The input voltage is 120V.

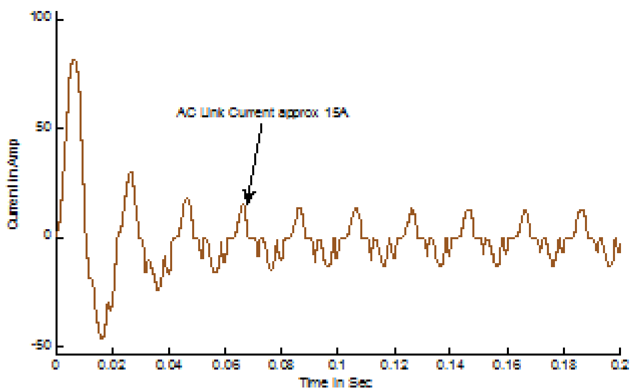

Fig 5: Grid side current supply for proposed converter

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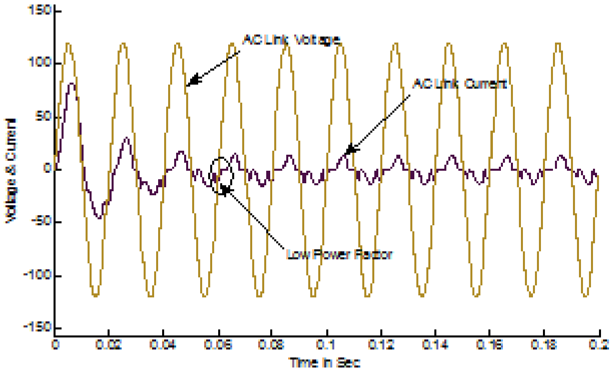

Fig 6: Voltage and current waveform of the input supply

Figure 6 shows the combine figure of both voltage and current. Here from the combine figure it's seen that the voltage and current are in out of phase. Due to application of power switches the power factor becomes low. The power factor is calculated with the help of simulation is approx 0.18.

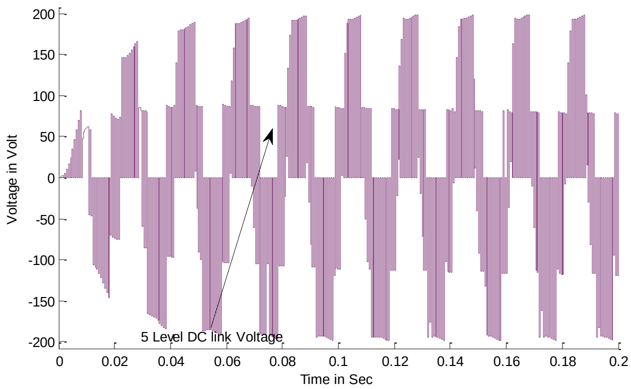

Fig 7: 5 level voltage of proposed boost converter

Figure 7 shows the 5 Level generated due to reduce count of switch for dc link. Figure 8 shows the DC output voltage of the proposed work. The output is approx 200 V.

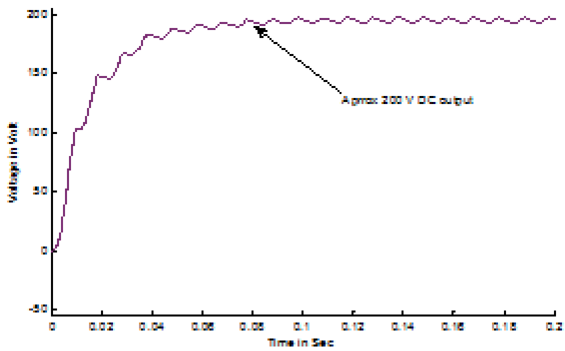

Fig 8: Output DC voltage of proposed System

6. CONCLUSION

AC-DC conversion is now widely used in many applications like SMPS, ASD's battery charging unit etc. Multilevel converter is now use for producing low harmonics. This thesis based on the new topology for AC-DC conversion with reduces number of switch. In this paper new active boost topology is designed and discuss. The whole work is simulated in MATLAB software. The control strategy is also discuss in this paper.

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