Three Phase Hybrid Unidirectional Rectifier Using SVPWM

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Abstract—This paper presents a new topology of rectifier with parallel combination of single switch 3ϕ boost rectifier and space vector PWM 3ϕ unidirectional rectifier. According to the proposed circuit, each rectifier will be processing half of the rated output power. Hybrid rectifier improves output voltage regulation and power factor of the system. The rectifier circuit, principle of operation, control scheme and simulation results using MATLAB are given in this paper.

Keywords—boost rectifier, SVPWM, power factor

I. INTRODUCTION

Power converter systems have a wide variety of topologies with different control mechanisms. Diode rectifiers are the simplest of all rectifier topologies because of its robustness and low cost which allows them to be applied in high power applications. The limitation imposed by these diode circuits in controlling the output voltage has reduced their usage in industry. Also the THD in input currents is very high which again require passive linear filters or power factor correction equipments to compensate the harmonic distortion. To achieve low power factor, very low harmonic distortion active rectifier topologies are used which satisfies the power quality requirements. PWM rectifiers are more expensive and less reliable than diode bridge rectifiers.[5]

To achieve high efficiency, high reliability, high quality input current, a new topology which overcomes limitations of bridge rectifier and PWM rectifiers is introduced which is called as hybrid rectifiers. Hybrid rectifier constitutes of a line commutated rectifier and a self commutated rectifier which are in series and/or parallel.[2]

The important feature of this rectifier is that, they combine robustness and efficiency of line commutated rectifier with the low harmonic current production of self commutated rectifier. The total output power of hybrid converter is processed largely by the uncontrolled rectifier operating at low frequency and Space Vector PWM control rectifier operating at high frequency. By this methodology overall system efficiency will increase.

II. PROPOSED HYBRID RECTIFIER WITH SVPWM

Proposed circuit comprises parallel combination of soft switching boost rectifier with SVPWM 3-Ø unidirectional rectifier. The hybrid converter is depicted in Fig.(1)

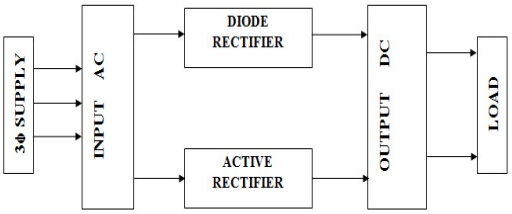


Fig.1: Block diagram of hybrid converter

It is not possible to connect both the rectifiers due to step up characteristics of the boost type SVPWM rectifier and hence a circuitry to connect both the rectifiers in ac side or in dc side is needed.[7]

Ac side connection can be achieved by means of a 3- Ø transformer and dc side connection by dc-dc boost converter. In this hybrid rectifier, inputs are directly connected and dc side connection is done using a boost converter which works at high frequency and allows control of output voltage as shown in Fig.(2)

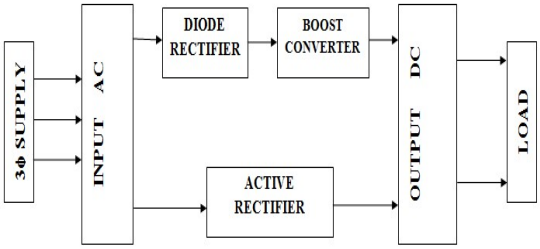


Fig.2: Block diagram of proposed hybrid converter

A. **Line commutated rectifier with boost converter**

A 3- Ø self switching boost rectifiers controls the magnitude of the output voltage and current. It uses boost diode and boost inductor to avoid inappropriate current paths in the system. The boost converter is equipped with all desirable features of both the zero current and zero voltage switching and it overcomes most drawbacks. Main features of these converters are, all switches operate under soft switching conditions. Main switch (T1) is turned n during zero voltage and turned off during zero current. Zero current turn on and zero voltage turn off of the auxiliary switch (T2) is achieved. Since they operate on ZCS and ZVS the stresses on the auxiliary devices are very low.[1]

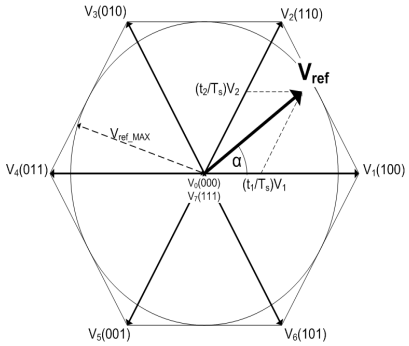
It has new active snubber cell that makes the circuit to turn on at zero voltage and turn off at zero current for the main switch. Snubber cell consist of quasi resonant circuit at high frequency and voltage of two half windings are equal as they are magnetically coupled.

It operates successfully under light load conditions for whole line and load ranges at very high frequencies. It has simple structure, low cost and easy control circuit. As switching losses are low, L and C can be reduced by increasing the operating frequency.

B. **Unidirectional SVPWM 3-ϕ rectifier**

A number of PWM schemes are used to obtain rectified output. The most widely used PWM scheme is space vector PWM. There is an increasing trend of using SVPWM because of their easier digital realization and better utilization.[3]

SVPWM has many advantages over the existing over the natural and regular sampled sinusoidal PWM like high performance in terms of better harmonic spectra and ease of implementation. It has 8 switching states which correspond to turn on or turn ff of all the transistors S1-S6. The 6 active states and 2 zero states are shown in Fig.(3)



Fig,3: Representation of switching states of 3- ϕ SVPWM

Switching time and corresponding switch state for each power switch is selected such that the constant dc voltage is obtained from the topology. The circuit connection of active rectifier is shown in Fig.(4)

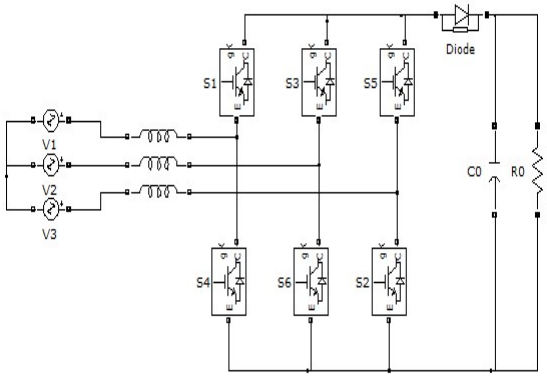


Fig.4: Circuit connection of active rectifier

C. **Proposed hybrid rectifier**

The main objective of this rectifier is to have constant dc output voltage and current employing soft switching boost converter as shown in Fig.(5)

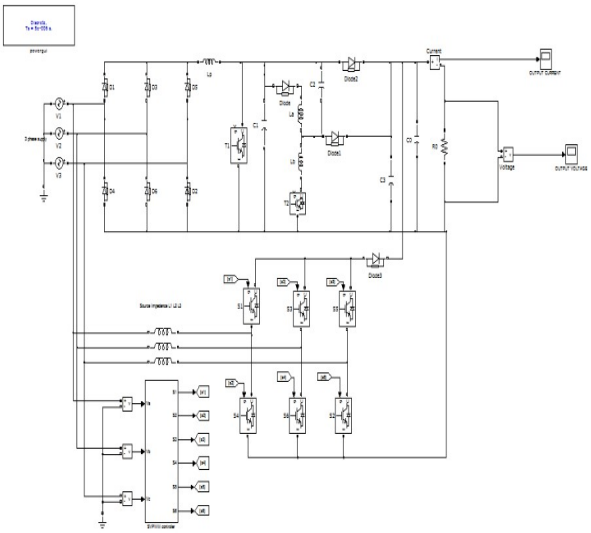


Fig.5: Simulation circuit for proposed hybrid rectifier

The circuit is built up using MATLAB/Simulink Platform to see the performance of proposed Hybrid rectifier.

D. **Functional block diagram**

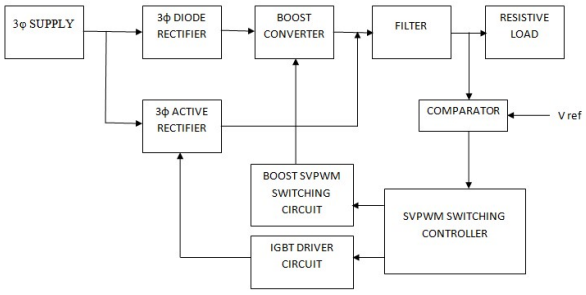


Fig.6: Functional block diagram of hybrid rectifier

III. CONTROL STRATEGY

The currents on mains should be sampled and compared with the reference. The errors produced by the comparison between the sampled signal and reference signal are given to the controller block. SVPWM modulators generate the gate signals to the active rectifiers. Boost inductor current is sampled and compared with a constant reference to generate the gate signal of the boost switch.

IV. SIMULATION RESULTS

Specifications used in simulation are given in Table 1.

Table1: Specification of simulation

Variable	Description	Value
V_p	Peak of line voltage	100V
V_{in}	Rms input voltage	70.7V
V_o	Output voltage	550V
P_o	Output power	1.8kW
L_p	Passive rectifier filter inductor	10mH
L_1, L_2, L_3	Active rectifier filter inductor	50mH
C_o	Output capacitor	4500µF
f_s	Switching frequency	10kHz

According to the specifications, active power processed by diode bridge and DC-DC boost converter is greater than power processed by the SVPWM rectifier. From this method power factor correction can also be achieved. The output voltage and current waveforms are given in fig.(7) and (8).

Average value of output voltage is about 550volts.

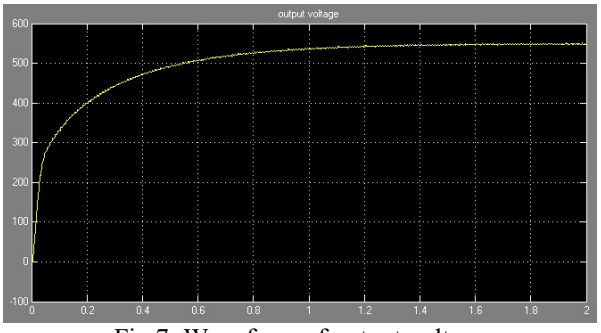


Fig.7: Waveform of output voltage

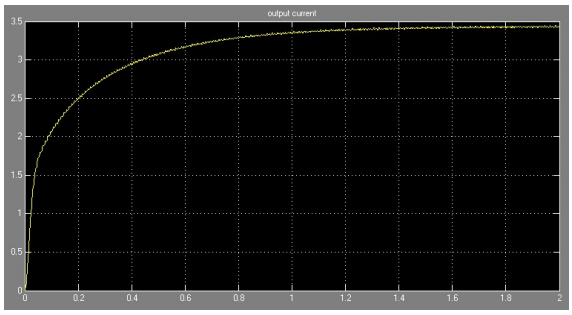


Fig.8: Waveform of output or load current.

V. CONCLUSION

This paper presents two topologies of unidirectional hybrid 3-Ø rectifier suitable for medium and high power applications. The rectifiers employ a 3- Ø diode bridge rectifier and a boost type 3- Ø space vector PWM rectifier. The advantage of this system is its high power delivering capability as connection of these rectifiers is in parallel and efficiency of the system is also improved. Simulation results show a better DC voltage regulation.

The only drawback of this topology is the design of control loop is very complex as it involves current and voltage sensors.

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