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Performance Analysis of Three Phase Two Quadrant Controlled Converter for DC Load Applications

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ABSTRACT

This paper provides the operation and analysis of three phase two quadrant controlled converter. In this paper, the converter is being checked with varying the duty cycle for two different loads R and RL. The Power factor, Total Harmonic Distortion (THD) and efficiency are better for very low duty cycle which is the same for RL load. This analysis estimates THD and power factor at various conditions. The FFT analysis is done to find the harmonic content present in the input current waveform. This analysis is done using MATLAB software.

Keywords : Total Harmonic Distortion, Power Factor and efficiency.

I. INTRODUCTION

This paper addresses the Buck-Boost AC-DC Cuk Converter using power factor correction techniques for reducing THD and improving power factor. The proposed converter is designed for low power rating and low output voltage 20W with 13.5V. The voltage follower approach an average current control technique. The proposed converter is simulated using MATLAB and it shows low THD in the supply current and improves the power factor of AC mains. [1] The PWM rectifier gate pulse is generated using FPGA based controller to drive the devices of the rectifier. In this paper PWM rectifier and Phase controller rectifier is compared on the basis of input current harmonics. The power factor can be regulated to unity by demanding a phase shift between the first harmonic of the input current and first harmonic of the supply voltage. [2]

This paper presents the single-phase AC-DC three-level converter for improving power quality at AC mains. The proposed converter is simulated with three different voltage and a current controller such as PI-Hysteresis, Fuzzy-Hysteresis and Fuzzy tuned PI Hysteresis. By comparing all the three controllers fuzzy-tuned PI voltage controller with the hysteresis current controller showed better performance, with 0.93% in simulation and 1.351% in the experiment without any filter in the source side. [3-8-20] In this paper, a single-phase positive output super-lift Luo converter is proposed converter operates in continuous conduction mode. The proposed converter is tuned using Neuro-fuzzy inference system (ANFIS) controller. For voltage control Proportional and Integral (PI) is used and for current loop Hysteresis controller. [5-19]. The simulation results show the very low THD of 0.44% and by obtaining unity power factor at the source side and load side. The ANFIS tuned PI voltage controller and the hysteresis current controller is implemented in an FPGA based hardware of the proposed LED drive with reduced input current THD of 1.24% and input power factor close to unity without any source side filter. [4-7-8-9]

The main objective of this paper is to achieve unity power factor, reduce source current total harmonic distortion (THD) and regulate output voltage using an AC-DC three-level boost converter. The Xilinx Spartan-6 XC6SLX25 FPGA board is used for implementation of the controllers. As a result, Fuzzy logic voltage controller with Hysteresis current controller has better performance and ability to achieve input current THD less than 5%. [5-6-8] The paper discusses the different control methods implemented in AC-DC boost converter namely (Hysteresis control, Fuzzy Logic Control). The fuzzy logic is used to derive a control scheme of boost rectifier for the improvement of power quality. [6-9] This paper analysis single phase Three level AC-DC converters in MATLAB SIMULINK. The fuzzy logic controller with PI voltage controller reduces the source current THD of about 3.23% for wide load variation and attains unity power factor. The main advantage of the three-level converters are high voltage can be obtained by reduced stress on the switches. The fuzzy logic current controller produces better power quality and enhanced THD. [7-10-16]This paper dealt with a fuzzy-tuned PI voltage controller and a hysteresis current controller operating a single-phase AC-DC three-level converter is proposed for improving power quality at AC mains for LED drive applications. [8]

The main objective of this paper is to achieve unity power factor with less harmonic distortion. Battery charger and the input stage of Three-level inverter is the main application of this proposed single phase three-level rectifier. [9] A bridgeless modified Single Ended Primary Inductance Converter (SEPIC) is discussed in this paper. Using MATLAB SIMULINK open loop and closed loop simulation are done in both steady state and dynamic conditions. PI and fuzzy tuned PI controllers are used to tune the proposed converter. [10] The paper presents the theoretical analysis of the parallel-bridge rectifier which is supplying a resistive load does not introduce line-to-line short circuits during commutation. This states that the parallel-bridge rectifier is better than other conventional rectifiers by providing reduced losses and increased power output. [11] This paper proposes a large current rectifier using a fork-connected auto transformer and dc-side current injection. A single-phase full bridge inverter is used to inject the compensation currents into the dc side of two three-phase half-wave rectifiers which reduces harmonics in input current side. This proposed converter is used in the front-end rectifier application. [12]

A 24-pulse diode rectifier for low voltage and high-current applications is proposed in this paper. By the addition of ASFR, the proposed application is low cost and simple. [13]. The paper discusses the comparison of class E rectifier and conventional full-bridge rectifier in terms of power quality analysis. The Class E full-wave rectifiers are mainly used in harmonic reduction and efficiency when used in MHz WPT systems. [14]

A novel EM radiation-to-dc power conversion system is proposed realizing full-wave rectification. The power rectified and transferred to dc load between two antennas. The antenna is optimized according to the rectifier. [15] The single-phase PWM AC-DC boost converter is proposed and examined in steady-state conditions, dynamic conditions and during load variation. [16] A three-phase Boost rectifier is designed for applications like wind turbines, windmills, fuel cells, etc. the controllers like PI Controller and PR Controller are used to control the DC output voltage of three-phase Boost rectifier using Space Vector Pulse Width Modulation technique (SVPWM). The controllers are examined in various conditions and the PR controller shows very good performance when compared to other controllers. [17] This paper displays the investigation and outline of a negative output Luo converter for the enhancement of power quality as far as enriched power factor and less source current Total Harmonic Distortion (THD). The PI controller has lessened peak overshoot and THD with enhanced power factor. [18]

To overcome the problems like low order harmonics in the ac power supply, low power factor, high peak current, line voltage distortion, increased electromagnetic interference and various additional losses in conventional technique of single-phase AC-DC conversion this paper propose single phase AC-DC Zeta converter.[19] This paper proposes the appropriate design of a closed loop controller for AC-DC super lift Luo converter to achieve unity power factor and reduced source current THD. [20]

II. OPERATING PRINCIPLE

A three-phase fully controlled converter is as shown in Fig. 1. The current flow in the converter will be seen when the top group (T_1, T_3, T_5) or the bottom group (T_2, T_4, T_6) conduct. The input cycle of the thyristors conducts 120° and they are fired between the sequences of 60°. The thyristors present in the same phase angle are fired at 180° and hence they cannot conduct simultaneously. There are only six possible conduction modes present in the continuous conduction mode they are T_1T_2, T_2T_3, T_3T_4, T_4T_5, T_5T_6, and T_6T_1.

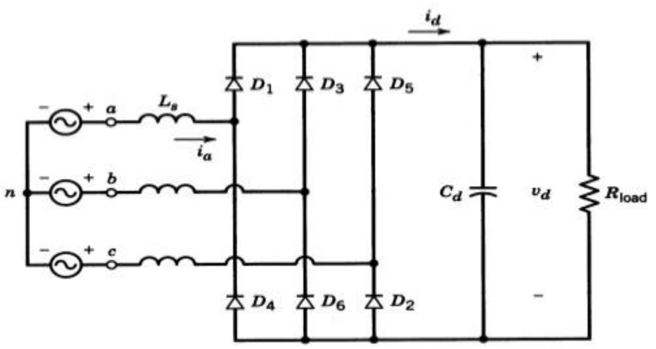

Fig.1 Circuit Diagram of Three Phase Fully Controlled Converter

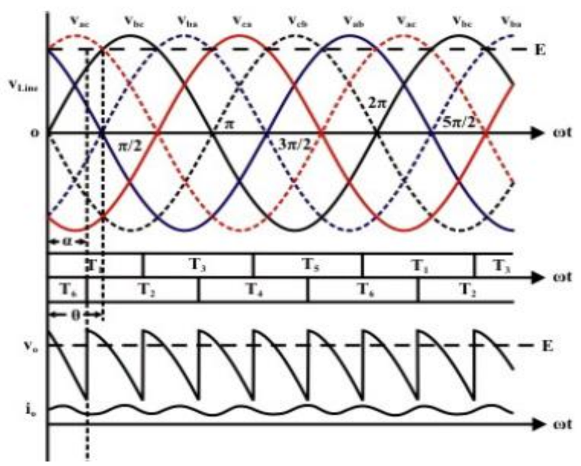

Fig.2 Waveform for Rectification Mode

III. MODES OF OPERATION

There are two modes of operation:

A. Rectification Mode

When the firing angle α < 90¬0, the converter is operating is rectification mode. In this mode, the dc output voltage obtained is positive. This implies the power is flowing from the three-phase ac supply to the dc load side. For example, when the converter is fired at an angle α(say 30¬0), then each thyristor conducting for 1200 of the input cycles and are fired in the sequence as mentioned in the operating principle. As we can see from the waveform, at α the line voltage Vac appears across the load from the R phase. Then after 600 duration, the line voltage Vbc appears across the load. This trend continues as Vba, Vca, Vcb, and Vab again. Thus, six pulse per cycle appears across the load, hence the other name six-pulse converter. The waveforms for rectification mode are shown in figure 2.

B. Inversion Mode

No, When the firing angle α > 90¬0, the converter is operating in inversion mode. In this mode, the dc output voltage obtained is negative, hence the name inversion (of voltage) mode. This implies the power is flowing from the dc load side to the three-phase ac supply side, that is power flow gets reversed. If the RLE load is connected, then the EMF is also reversed to suitable dc polarity. For example, when the converter is operating in inversion say at an angle 1200, as we can see from the waveform (fig.), Vbc appears across the load. This trend continues as V_{ba}, V_{ca}, V_{cb}, and V_{ab} again which is the same as rectification mode. But the value of α has the inherent restriction of range because for successful commutation of the thyristor it is essential that, β is larger than the turn off time of the thyristor. In practice, this upper value of α is further reduced due to commutation overlap. The waveform of the Inversion mode is shown in figure 3.

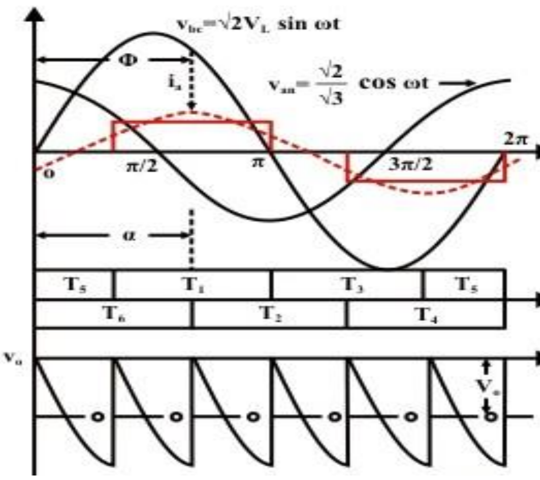

Fig.3 Waveform for Inversion Mode

Figure 2 & 3 shows the Rectification and Inversion mode waveforms of Three Phase Fully Controlled Converter

IV. CIRCUIT ANALYSIS

The output voltage waveform can be written as

$$V_o = \frac{3\sqrt{2}}{\pi} V_L \cos\alpha$$

The RMS output voltage is

$$V_{ORMS} = V_L\left[1+\frac{3\sqrt{3}}{4\pi}\cos 2\alpha\right]^{1/2}$$

The input power factor is

$$\text{Input Power Factor} = \frac{\text{Actual Power}}{\text{Apparent Power}} = \frac{2\sqrt{2}}{\pi}\cos\alpha$$

Percentage THD

$$\%THD = \frac{\sqrt{V_2^2+V_3^2+V_4^2+\cdots}}{V_1}$$

V. SIMULATION ANALYSIS

The simulation analysis of three-phase fully controlled rectifier with R and RL loads.

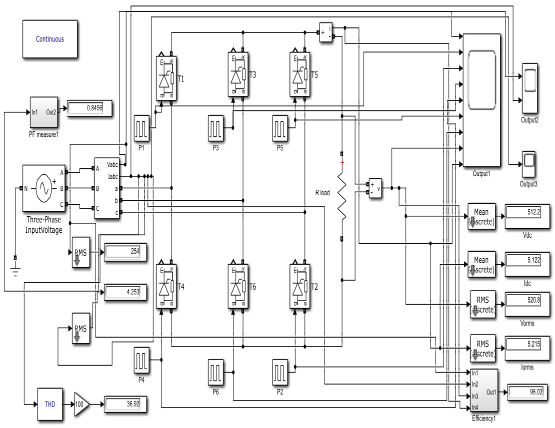

Fig.4 Simulation of Three Phase Full Controlled Rectifier with R Load

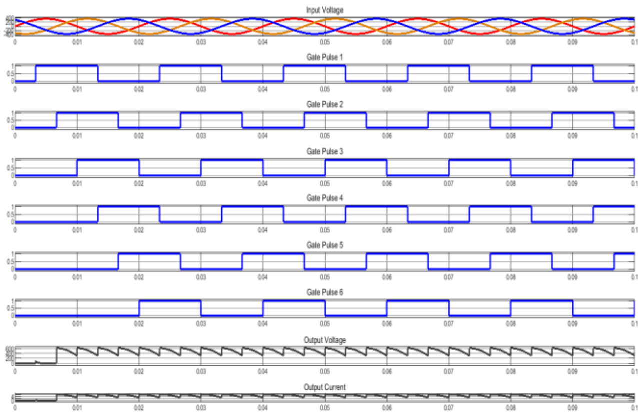

Fig.5 Switching Waveforms

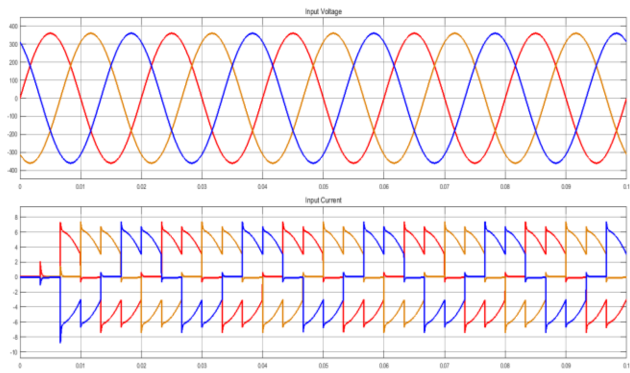

Fig.6 Input Voltage and Input Current Waveform for R load

Figure.5 shows the Input voltage, Gate pulse, and Output voltage and Output current waveforms. Figure.6 represents the Input voltage and Input current waveforms of Three Phase Fully Controlled Converter.

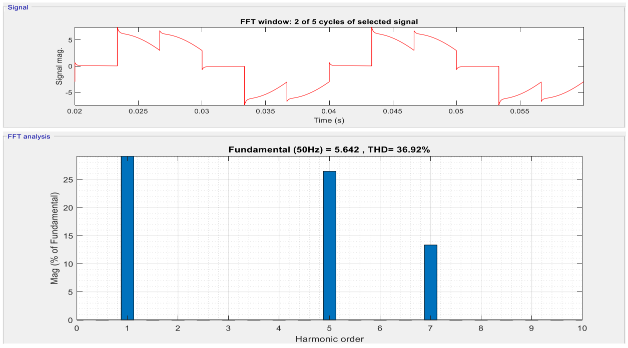

Fig.7 FFT Analysis of Source current @ α = 30^0

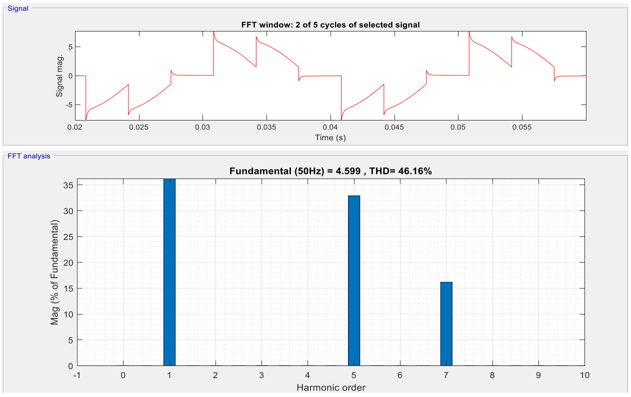

Fig.8 FFT Analysis of Source current @ α = 45^0

The source current FFT analysis of Three Phase Fully Controlled Converter for two different firing angles 30^0 and 45^0.The THD for firing angle 30^0 is 36.92 and for 45^0 is 46.16.

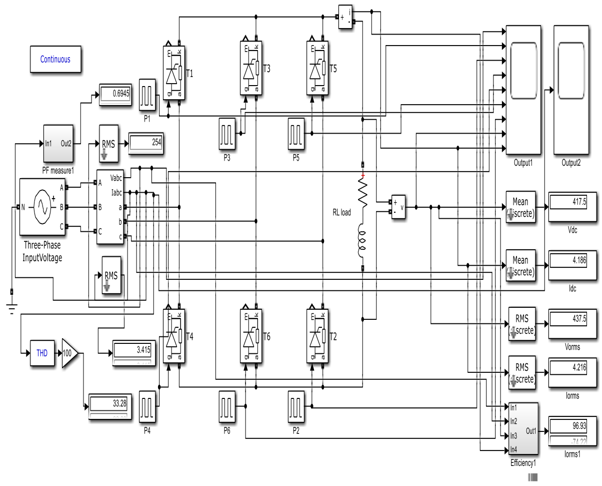

Fig.9 Simulation of Three Phase Full Controlled Rectifier with RL Load

TABLE I Shows the Firing Angle Variation of Three Phase Full Controlled Rectifier with R Load

S.No	α	I_{in}(A)	V_o(V)	I_o(A)	V_{orms}(V)	I_{orms}(A)	PF	Source Current THD(%)	η
1	30	4.253	512.2	5.122	520.8	5.215	0.8456	36.92	96.02
2	45	3.582	417.5	4.175	437.5	4.384	0.7152	46.16	89.74
3	60	2.76	294.2	2.942	334.5	3.355	0.5535	66.01	75.02
4	75	1.89	172.1	1.721	227.4	2.285	0.3879	97.86	53.65
5	90	1.075	78.35	0.7835	127.5	1.284	0.2424	147.7	31.54
6	120	0.197	5.499	0.05499	18	0.1886	0.1377	687.4	1.617

TABLE II Shows the Firing Angle Variation of Three Phase Full Controlled Rectifier with RL Load

S.No	α	I_{in}(A)	V_o(V)	I_o(A)	V_{orms}(V)	I_{orms}(A)	PF	Source Current THD(%)	η
1	30	4.181	512.2	5.13	520.8	5.143	0.8366	31.8	98.72
2	45	3.415	417.5	4.186	437.5	4.216	0.6945	33.28	96.93
3	60	2.428	294.2	2.955	334.5	3.018	0.5132	37.29	91.97
4	75	1.316	150.7	1.522	232.4	1.668	0.3213	54.37	71.89
5	90	0.665	64.77	0.6598	147.9	0.8644	0.2113	94.41	40.65
6	120	0.1668	6.46	0.07306	78.71	0.1945	0.1887	422	2.227

Table I and II show the firing angle variation of the Three Phase Full Controlled Rectifier with R Load and RL Load.

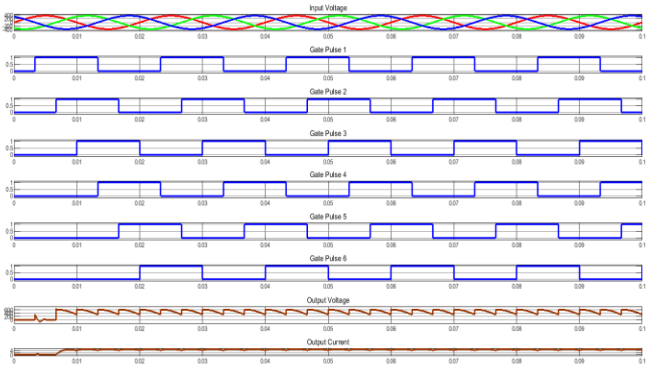

Fig.10 Switching Waveforms

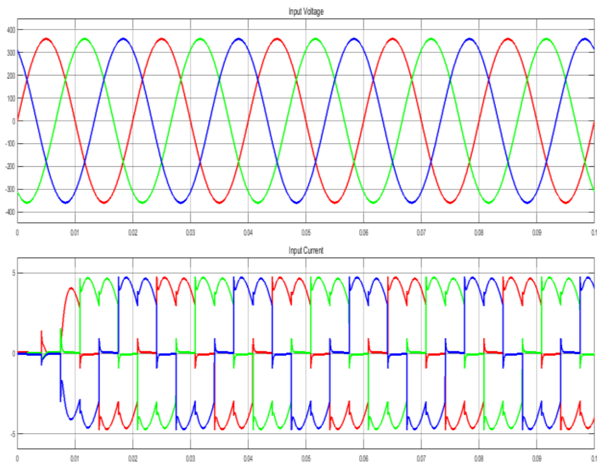

Fig.11 Input Voltage and Input Current Waveform for RL Load

Figure.10 shows the Input voltage, Gate pulse, and Output voltage and Output current waveforms. Figure.11 represents the Input voltage and Input current waveforms of Three Phase Fully Controlled Converter.

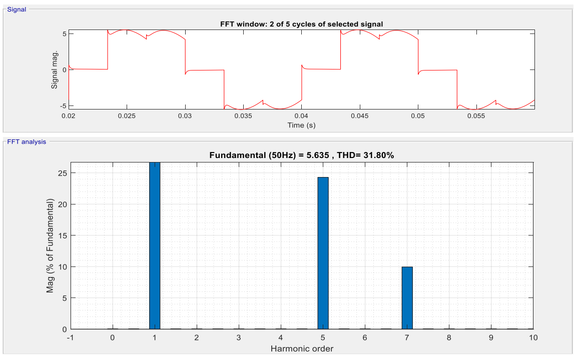

Fig.12 FFT Analysis of Source current @ α = 30^0

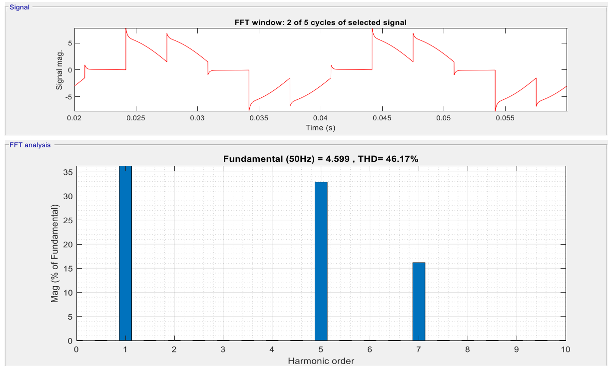

Fig.13 FFT Analysis of Source current @ α = 45^0

The source current FFT analysis of Three Phase Fully Controlled Converter for two different firing angles 30^0 and 45^0.The THD for firing angle 30^0 is 31.8 and for 45^0 is 33.28.

VI. CONCLUSION

The analysis of three-phase Fully Controlled Converter for various firing angles has been performed. From the simulation analysis, as the firing angle is increased for both rectification and inversion modes the THD and power factor for the input current also varies. From the tables, it can be inferred that harmonic content of the input current increases because as the firing angle increases, the waveform distortions further increase the harmonic content. Since the THD rises, power factor and efficiency decrease considerably. In order to decrease THD filters can be used. This converter can be used for higher power DC applications.

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