DESIGN OF TWELVE PULSE RECTIFIER USED IN HVDC SYSTEM

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ABSTRACT

The prototype model of a twelve pulse bridge rectifier circuit with a power rating of 2KW, transmission voltage level of 200V and current rating of 5A is developed for a bipolar HVDC transmission system. A twelve pulse bridge rectifier circuit is the cascade connection of two six pulse bridges connected in series on the DC side. The phase displacement of 30 degrees is given to the lower six pulse rectifier bridge with reference to the upper six pulse rectifier bridge. This phase displacement is obtained by proper designing of three phase converter transformer with the 500VA, 415V/50V, 3A Star/Star, Star/ Delta rating. The transformer secondary winding is connected in star and in delta to obtain a phase shift of 30 degrees. The simulation models of both six pulse and twelve pulse bridge rectifiers are simulated using MATLAB platform. The FFT analysis is performed on both the models and the comparison results proves that with the increase in the pulse number the total harmonic distortion (THD) content is reduced from 35.66% for six pulse rectifier to 12.46% for twelve pulse rectifier. Due to this reason twelve pulse bridge rectifiers are preferred in HVDC transmission systems. The experimental results of twelve pulse rectifier were tabulated and observed that with increase in the firing angle (α) the DC output voltage decreases for both R and RL loads. The waveforms were recorded using digital oscilloscope for different firing angles and by adding LC filter the ripples are further reduced and smooth waveform is observed.

Keyword: *- HVDC, Three Phase Converter Transformer, Twelve pulse Bridge Rectifier, Passive filter.*

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1. INTRODUCTION

To deliver a good quality of power to various loads is an issue in power transmission system. In an AC system for transmission of power over a long distance, three conductors are required, and the losses and cost increases. In contrast HVDC requires only two conductors. Hence the losses decrease and also the cost decreases for long distance beyond the breakeven distance [1] .So with the advancement in HVDC transmission technology over HVAC transmission it is possible to keep power sector free from pollution [2]. During conversion process HVDC converters produces characteristic and non characteristic harmonics in both AC and DC sides [3]. These harmonics may cause severe damages to the transmission systems such as distortion of voltages and currents, overheating of equipments and its control [4]. Hence by reducing the harmonic content in HVDC converters the quality of power transmission system can be improved [5]. The ripple content in HVDC converters is reduced by increasing the number of switches in converters.

In this paper a prototype miniature model of twelve pulse bridge rectifier with a power rating of 2KW is implemented. The twelve pulse rectifier is designed by cascade series connection of two six pulse bridges. The simulation results of both six pulse and twelve pulse rectifiers are compared. By using FFT tool in MATLAB the total harmonic distortion (THD) is measured for both the pulse rectifiers. The results shows that the THD content in twelve pulse rectifier model is 12.46% and that in six pulse rectifier model is 35.66%. The experimental results were tabulated and observed that with the increase in the firing angle the output DC voltage is reduced for both R and RL loads.

2. METHODOLOGY

The experimental model of twelve pulse bridge rectifier involves the cascade series connection of two six pulse bridge rectifiers. The twelve 25TTS12 series of silicon controlled rectifiers are used as switches for implementing twelve pulse bridge rectifiers. Snubber circuit is connected across each switch to suppress the rapid rise of voltage in rectifiers. The ratings of the snubber circuit are R =100Ω / 5W and C = 0.1 µF / 1000V. The following are the ratings of SCR switches.

2.1 SCR ratings and characteristics

Table -1: SCR ratings and characteristics

Characteristics	25TTS12	units
Iav Sinusoidal waveform	12	A
Irms	25	A
Vrrm/Vdrm	800/1200	V
Itsm	300	A
Vt, Tj = 25	1.25	V
dV/dt	500	V/µs
dI/dt	150	A/µs
Tj range	-40 TO 125	^{0}C

2.2 Twelve pulse bridge Rectifier Specifications

The system specifications of the physical twelve pulse bridge rectifier miniature model are as follows.

Table -2: Bridge rectifier specifications

Power rating of miniature Rectifier model	2KW
Rectifier - Three phase bridge	200V, 5A
Transmission level	200V
Three phase converter transformer	500VA, 415V/50V, 3A Star/Star, Star/ Delta
Load	Resistive

The twelve pulse rectifier involves micro controller circuit to generate PWM signals for triggering the twelve switches and driver circuits with pulse transformer to isolate the power and control circuits.

2.3 Twelve Pulse Rectifier Bridge

A twelve pulse bridge is effectively two six pulse bridges connected in series on the DC side and arranged with a phase displacement of 30 degrees between their respective AC supplies so that some of the harmonics voltages and currents get cancelled. The circuit diagram of twelve Pulse bridge is shown in Fig 1.

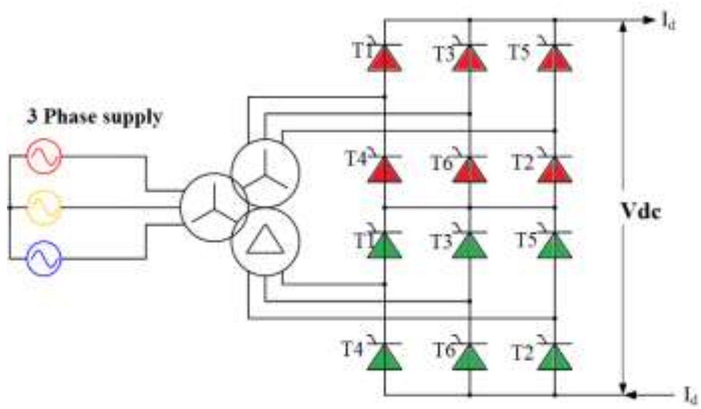

Fig -1: Twelve pulse bridge rectifier

The sequence of triggering of the SCRs and their conduction period are given in the tabular column shown below:

Table -3: SCR conducting sequence

CONDUCTION PERIOD	**SCR PAIR**
α + 30° to α + 90°	S1 and S6
α + 90^0 to α + 150^0	S1 and S2
α + 150^0 to α + 210^0	S2 and S3
α + 210^0 to α + 270^0	S3 and S4
α + 270^0 to α + 330^0	S4 and S5
α + 330^0 to α + 360^0 and α + 0^0 to α + 30^0	S5 and S6

The output voltage and the sequence of triggering of the thyristors along with their conduction period are shown in the waveforms in Fig 2 below.

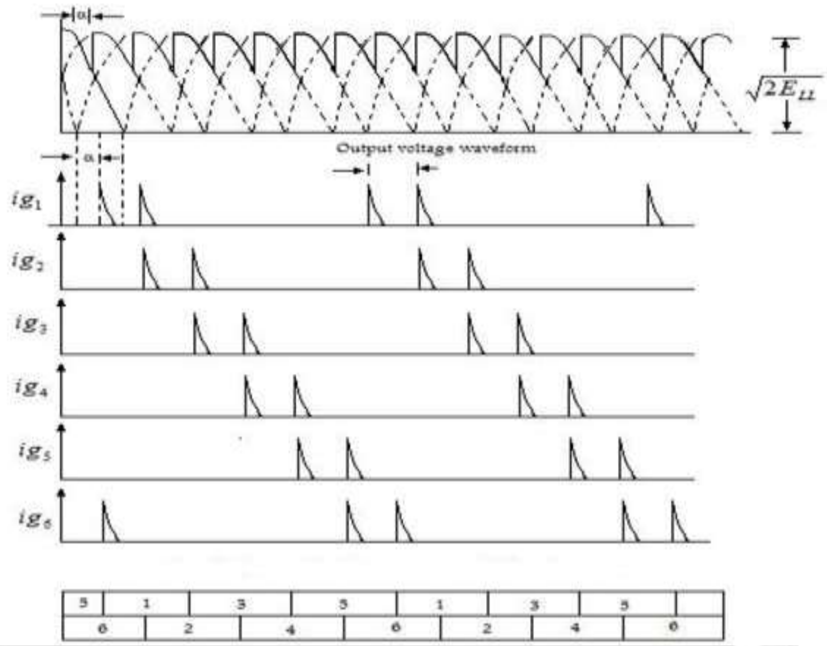

Fig -2: Triggering gate pulses to thyristors and Conduction sequence of thyristors

2.4 Three phase Converter Transformer

The transformer used in the twelve pulse converter will be normally connected with primary Y-Y and secondary is Y-Δ windings. The main purpose of this is to provide a 30° phase shift, which is can be able to provide 12 pulse output as well as to provide isolation between the two systems.C1 and C2 are two 6 pulse bridge rectifier circuits as shown in Fig 3.

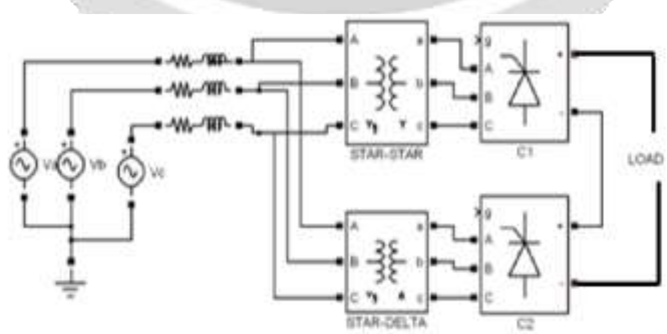

Fig -3: Transformer connections to give 12 pulse dc converter output

Fig -4: Three phase 500VA converter Transformer

3. SIMULATION RESULTS

The simulation model of a twelve pulse rectifier with thyristors is shown in Fig 4 using MATLAB simulink platform. Fast Fourier transform (FFT) analysis was carried out on both six and twelve pulse rectifier circuits as shown in Fig 5. With increasing the pulses in the converter, the input side Total Harmonic Distortion (THD) has reduced and efficiency of the system has increased for R and RL type loads. The FFT analysis shows that for twelve pulse rectifier THD content is 12.44% and that of six pulse rectifier is around 36%.

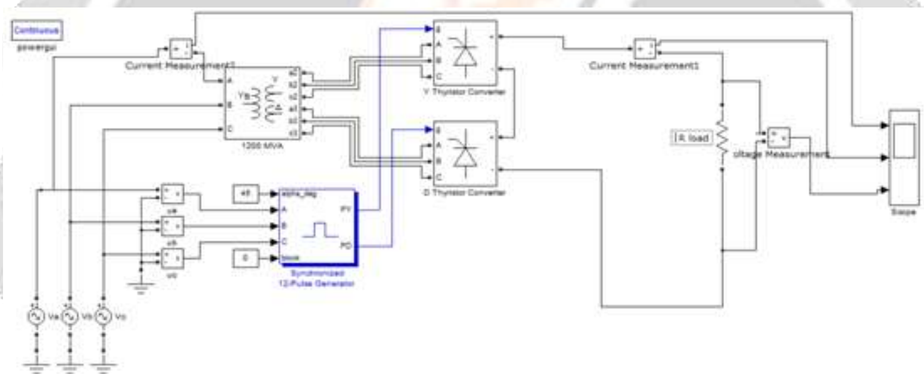

Fig -5: Simulink model of a twelve pulse rectifier

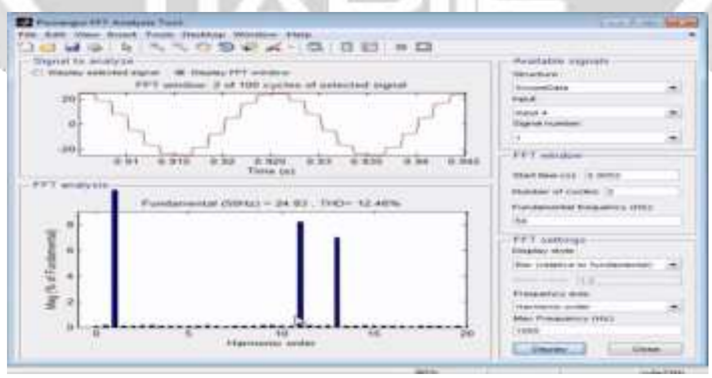

Fig -6: FFT analysis of a twelve pulse rectifier

4. HARDWARE RESULTS

The waveforms are captured using digital oscilloscope and DC output voltage are recorded and tabulated for both R and RL loads with and without LC filter by varying firing angle (α). The DC output voltage of twelve pulse rectifier waveform for $\alpha = 60^{\circ}$ for R load is shown in Fig 6.a without filter and with LC filter the ripples are reduced and smooth waveform is observed as shown in Fig 6.b.

Fig -7: Output voltage Vd for 12-pulse converter when α= 60º for R Load without filter

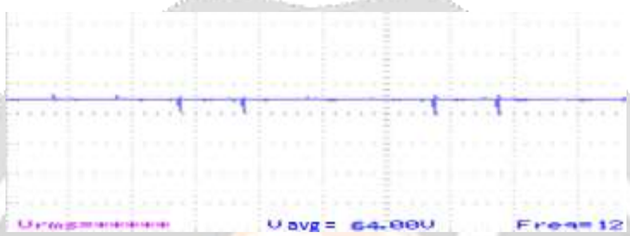

Fig -8: Output voltage Vd for 12-pulse converter when α= 60º for R Load with filter

The DC output voltage of twelve pulse rectifier waveform for α = 60º for RL load is shown in Fig 7.a without filter and with LC filter the ripples are reduced and smooth waveform is observed as shown in Fig 7.b.

Fig -9: Output voltage Vd for 12-pulse converter when α= 60º for RL Load without filter

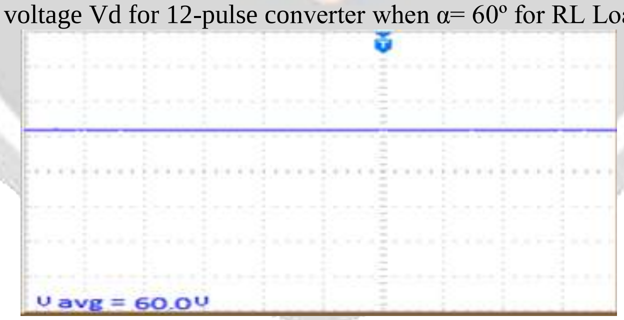

Fig -10: Output voltage Vd for 12-pulse converter when α= 60º for RL Load with filter

The experimental results of twelve pulse rectifier are tabulated as shown in table 2 for R load and in table 3 for RL load. It is observed that DC output voltage decreases with increase in firing angle α and obtained DC voltage matches with the theoretical values. The DC output voltage of twelve pulse rectifier for R load is given by equation (1) and for RL load in equation (2).

$$Vd=6\times\sqrt{3}\times Vm/\pi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$Vd=(6\times\sqrt{3}\times Vm/\pi)\cos\alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Table 2: DC output voltage of twelve pulse rectifier for R load

Firing Angle(α)	Output voltage (V_d)Theoretical	Output voltage (V_d) measured
0o	135.04v	127.01v
30º	116.94v	111.05v

60º	67.00v	64.9v
90º	18.09v	10.8v
120º	0v	0v

Table 3: DC output voltage of twelve pulse rectifier for RL load

Firing angle (α)	Output voltage (V_d)Theoretical	Output voltage (V_d) measured
0	+135.04V	+124.18V
30	+116.94V	+108.10V
60	+67V	+60.00V
90	0V	0V
120	-67V	-60.00V
150	-116.94V	-108.10V
180	-135.04V	-124.18V

Fig 8 shows the miniature model of twelve pulse bridge converter with cascade connection of two series bridge rectifiers.

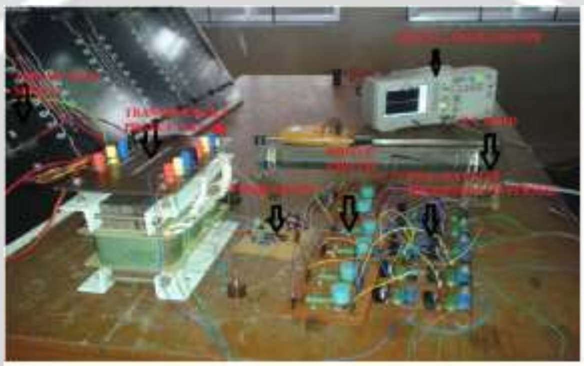

Fig -11: Hardware model of twelve pulse rectifier circuit

5. CONCLUSION

The prototype model of twelve pulse bridge rectifier circuit consisting of two six pulse bridge rectifier circuit is designed. The phase displacement of 30 degrees between the two six pulse bridge rectifiers is maintained by proper designing of converter transformer. The simulation results on FFT analysis proves that with the increase in pulse number the magnitude of ripple is reduced. The THD content in twelve pulse is 12.46% and that of six pulse rectifier is 35.66%. The experimental results shows that with the increase in firing angle (α) the DC side output voltage is reduced and matches with the theoretical formula for both R and RL loads.

6. REFERENCES

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