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Verification of Three Phase Full Wave Controlled Rectifier using MATLAB Simulation Model

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Abstract

In this paper, the modeling and implements of a three phase full wave controlled rectifier has been modeled on MATLAB SIMULINK software version 7.10.0.449[R2010a]. It is also deals with the simulation analysis of three phase full wave controlled rectifier by obtaining various waveforms. For large power dc loads, three phase ac to dc converters are commonly used. Three phase half wave converter is rarely used because it introduces dc component in the supply current. Some years back ac to dc power conversion was achieved using motor generator sets, mercury arc rectifiers, and thyratorn tubes. The modern ac to dc power converters are designed using high power, high current thyristors and presently most of the ac-dc power converters are thyristorised power converters. This paper also presents that how a full wave controller works for different firing angles at a given time and waveforms were obtain for verification.

Keywords: *Thyristor, firing angle, MATLAB software, R, RL, RLE load*

INTRODUCTION

Ac to dc converters convert constant ac input voltage to dc output voltage. Ac to dc converter is also known as phase controller rectifiers. These rectifiers use line voltage for their commutation as such these are also called line-commutated or naturally commutated ac to dc converters [1, 2]. Phase controller convert may be fed from single phase or three phases. These are used in dc drives, excitation systems for synchronous machines, magnet power supply, high voltage transmission line, etc. a scheme of power conversion in any industry is shown in Figure 1.

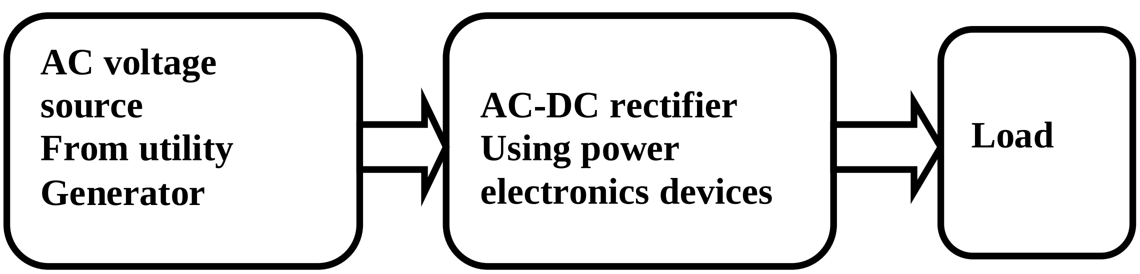

Fig. 1: *Power Scheme in an Industrial Application.*

Presently, phase controlled ac to dc converters employing the used of thyristors for changing the constant ac to controlled dc voltage. These are less expansive, simple and, therefore, large used in industries where controlled dc power is required. The way of classifying the rectifier is done by according to the number of input power supply [3, 4].

As per this classification the ac to dc converter are two types;

- Single Phase Controlled Rectifiers which operate from single phase ac input power supply.
- Three Phase Controlled Rectifiers which operate from three phase ac input power supply.

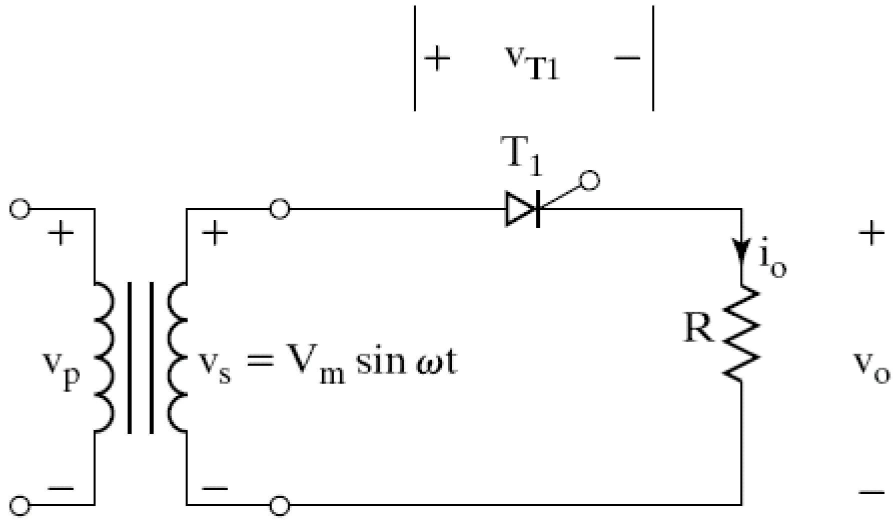

Fig. 2: *Single Phase Controlled Rectifier.*

Single phase controlled rectifier are used extensively in industrial applications up to about 15 KW of output power and provide two output pulses during each input cycle. Ripple frequency is equal to the twice of the input ac frequency. Due to this drawback of single phase controller, three phase are commonly use because it is operate on three phase supply and provide higher output voltage, power and ripple frequency than single phase controlled rectifiers. The load current is mostly continuous in three phase converters.

THREE PHASE RECTIFIER

In three phase full wave controlled rectifier six Thyristors are used in bridge configuration as shown in Figure 3.

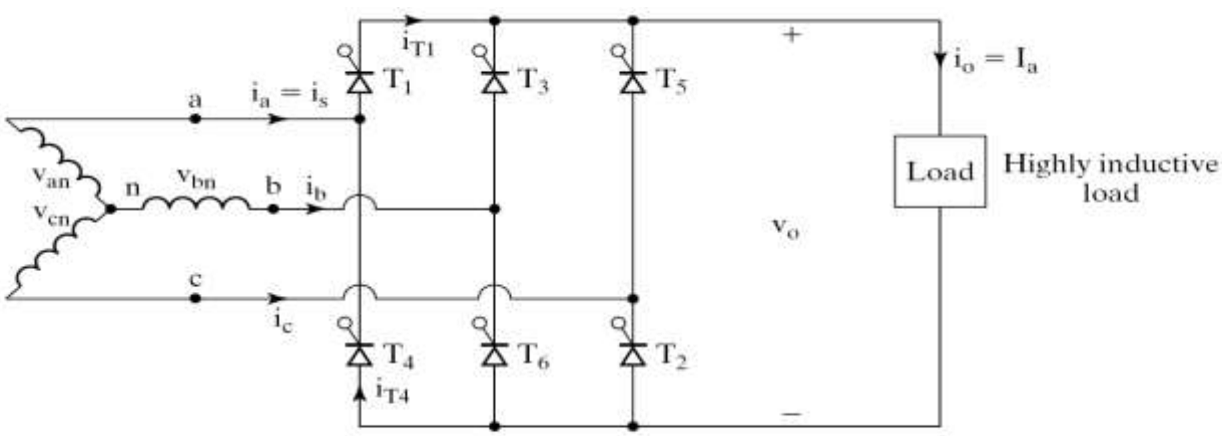

Fig. 3: *Three Phase Controlled Rectifier.*

All the six thyristors are fully controlled switch which are triggered at an appropriate time by applying suitable gate pulse. Three phase full wave controlled rectifier are extensively used in industrial power about 120kw where two quadrant operations required. For any flow of current in the load at least one device from the top (or positive) group (T1, T3, T5) and one from the bottom (or negative) group (T2, T4, T6) must conduct. Thyristors T1,T3,T5 which are positive group SCR fired at an interval of 120°. Similarly T2,T4,T6which are negative group SCR fired with an interval of 120° amongst them. Now, the thyristors are fired in the sequence T1 → T2 → T3 → T4 → T5 → T6 → T1 with 60°intervals between each firing. Therefore, thyristors on the same phase leg are fired at an interval of 180° and hence cannot conduct simultaneously. This leaves only six possible conduction mode for the converter in the continuous conduction mode of operation. These are T1T2, T2T3, T3T4, T4T5, T5T6, and T6T1. Each conduction mode is of 60° durations and appears in the sequence mentioned. Table 1 shows the firing sequence of SCRs [5, 6].

Table 1: *Sequences of Firing to the SCR.*

S. No.	Firing Angle	Conducting Pair	Incoming SCR	Outgoing SCR	Line Voltage (LOAD)
1.	30+ α	T6,T1	T1	T5	Vab
2.	90+ α	T1,T2	T2	T6	Vac
3.	150+ α	T2,T3	T3	T1	Vbc
4.	210+ α	T3,T4	T4	T2	Vba
5.	270+ α	T4,T5	T5	T3	Vca
6.	330+ α	T5,T6	T6	T4	Vcb

For α =0 degree; T1, T2,……T6 behave like diodes. For α =0 degree, T1 is triggered at ωt=30deg, T2 at90 degree, T3 at 150 degree and so on.

For α =60 degree, T1 is triggered at ωt=30 +60=90 degree, T2 at 90 + 60=150 degree and so on.

Figure 4 shows the waveforms of different variables and Figure 5 shows gate signals of three phase rectifier. To arrive at the waveforms it is necessary to draw the firing sequence which shows the interval of conduction for each thyristor. If the converter firing angle is "α" each thyristor is fired "α" angle after the positive going zero crossing of the line voltage with which it is firing is associated. Once the conduction diagram is drawn all other voltage waveforms can be drawn from the line voltage waveforms. It is clear from the waveforms that output voltage and current waveforms are periodic over one sixth of the input cycle. Therefore, this converter is also called the "six pulse" converter.

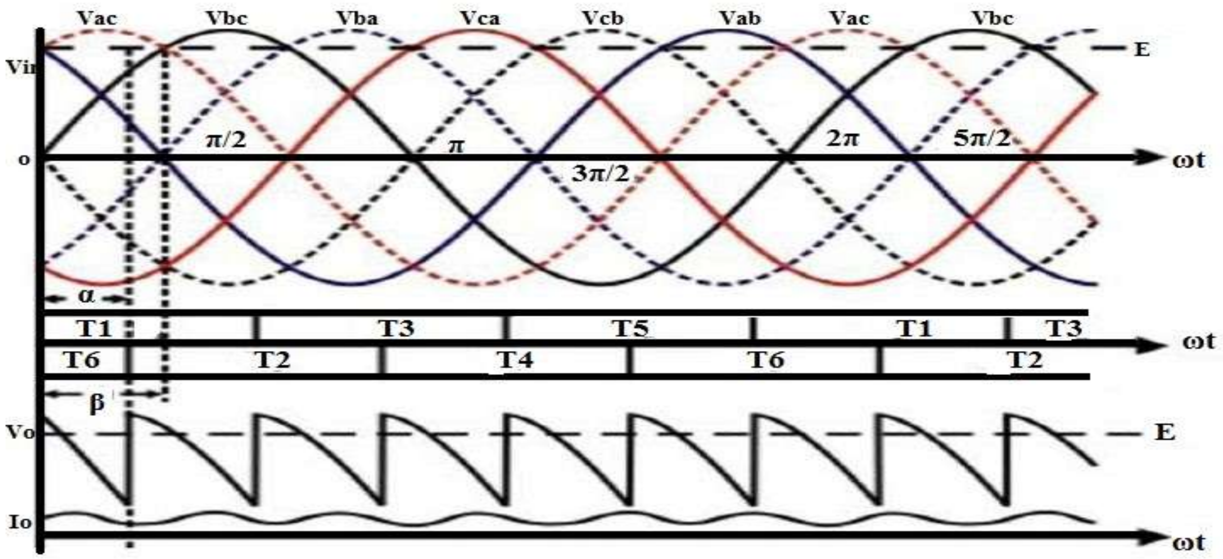

Fig. 4: *Input and Output Waveform.*

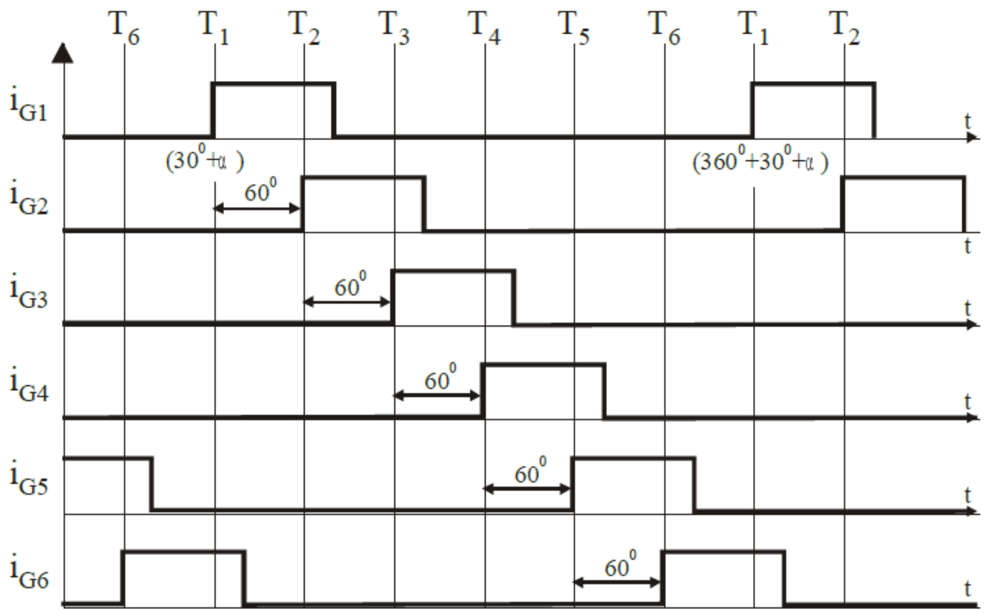

Fig. 5: *Gating Signals of Three Phase Converter.*

SIMULATION MODEL

The Simulation model of three phase full wave controlled rectifier is shown in Figure 6.

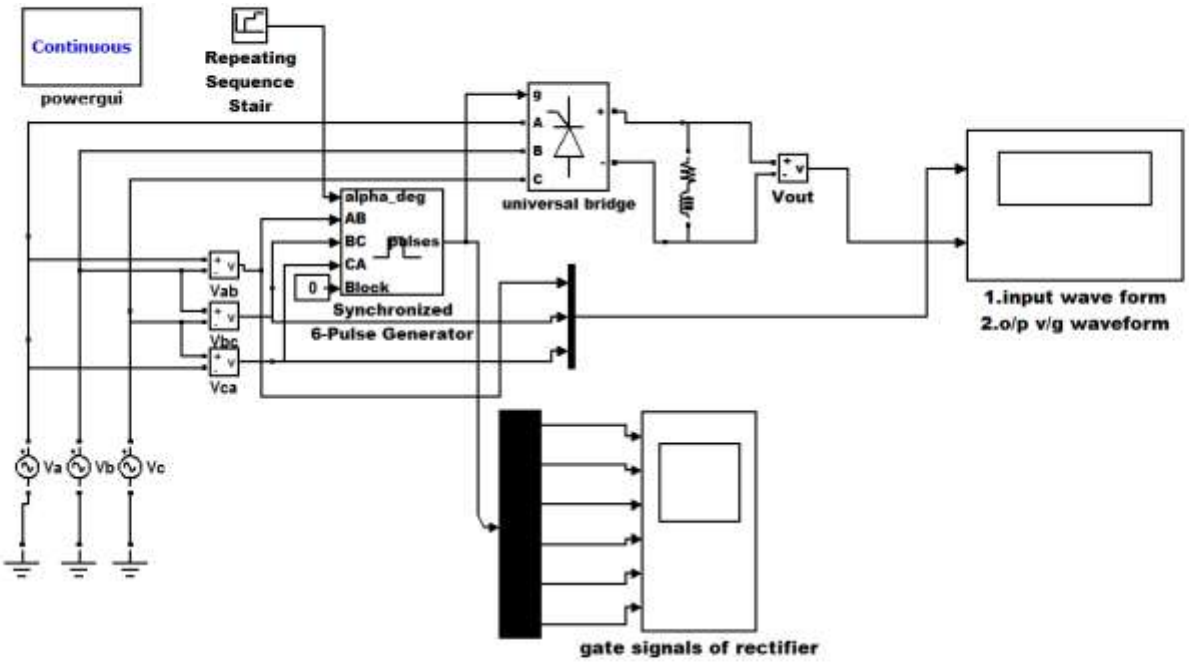

Fig. 6: *Modeling of Three Phase Full Wave Controlled Rectifier*.

Model descriptions- The universal bridge which consists the six thyristors in bridge configurations as shown in Figure 7 is connected to three phase supply given by the three voltage source (100 volts,50Hz) and phase displaced by 120 ^{0} to each other.

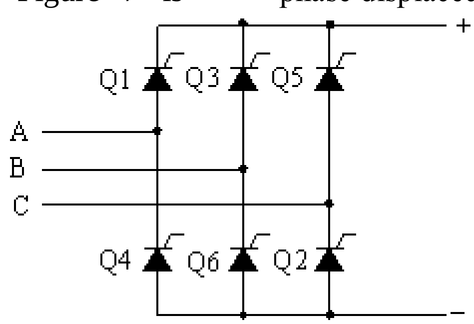

Fig. 7: *Six Thyristors Configuration.*

A 6-pulse synchronized generator is used to generate the six synchronized pulses for triggering the thyristors. The pulse generator is synchronized with the load current and the firing angle of the thyristors.

Firing angle is applied to generator by using the Repeating sequence stair which generates the signal in repeating sequences. The load which may be R, RL, and RLE is applied to the universal bridge (rectifier), input and output waveforms are obtain on scope shown in the below Figures.

SIMULATION RESULT

In this paper various waveforms are obtaining to verify the working of three phase full wave controlled rectifier for different firing angle at a specified time duration.

Figure 8 shows the input waveform for three phase controlled rectifier and from Figures 9 to 11 shows the waveforms for firing angles at 0, 30 and 45 degree.

Figure 12 shows the output waveform of a three phase full wave rectifier for different firing angles at a given time period.

It is clear from Figure 12 that form

ωt= 0-0.0167 (converter)rectifier works for 0 deg firing angle

ωt = 0.0167-0.033 for 30deg firing angle

And for ωt=0.033-0.05 for 45deg firing angle.

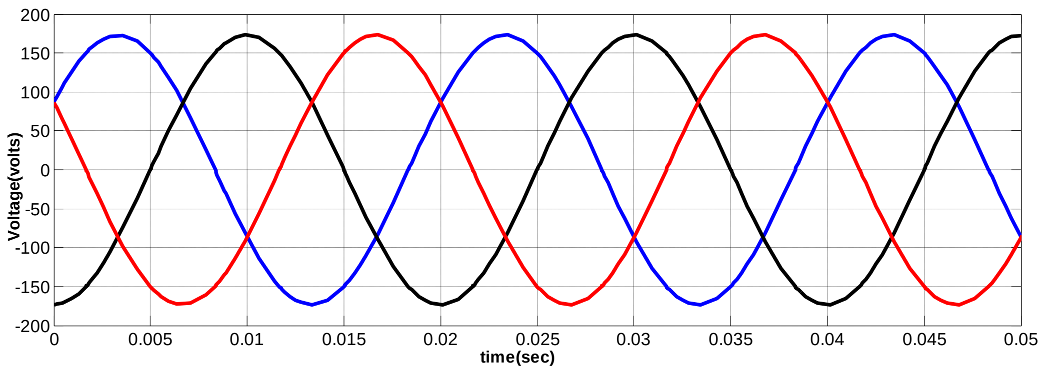

***Fig. 8:** Input Waveform for 3-ϕ Full Wave Controlled Rectifier.*

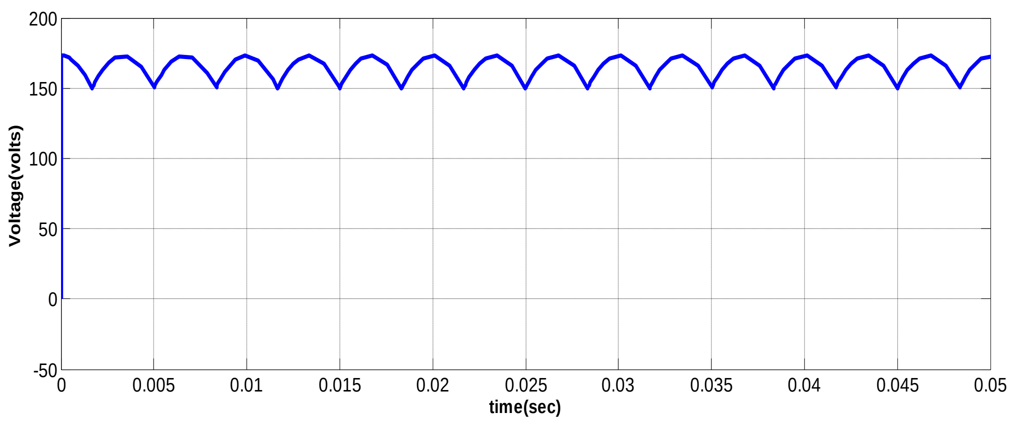

***Fig. 9:** Output Waveform (α=0deg).*

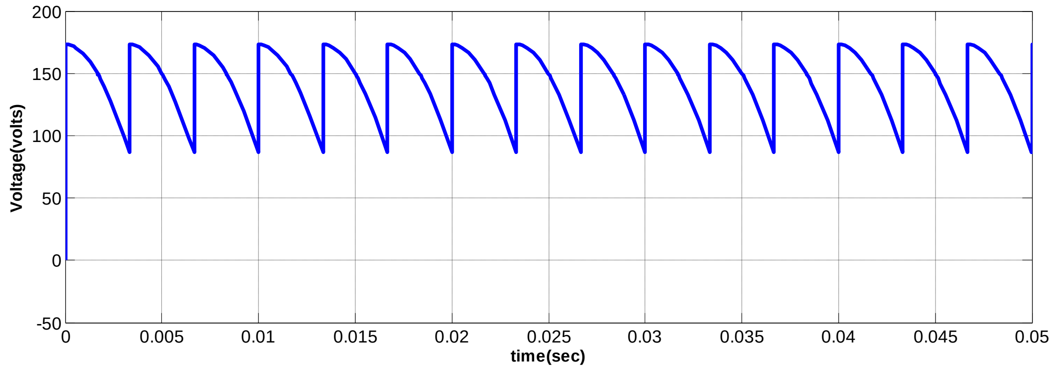

Fig. 10: *Output Waveform (α=30deg).*

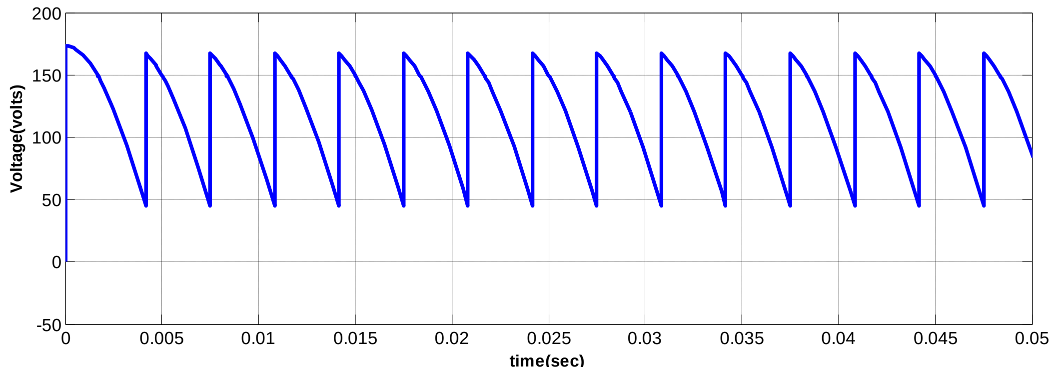

Fig. 11: *Output Waveform (α=45deg).*

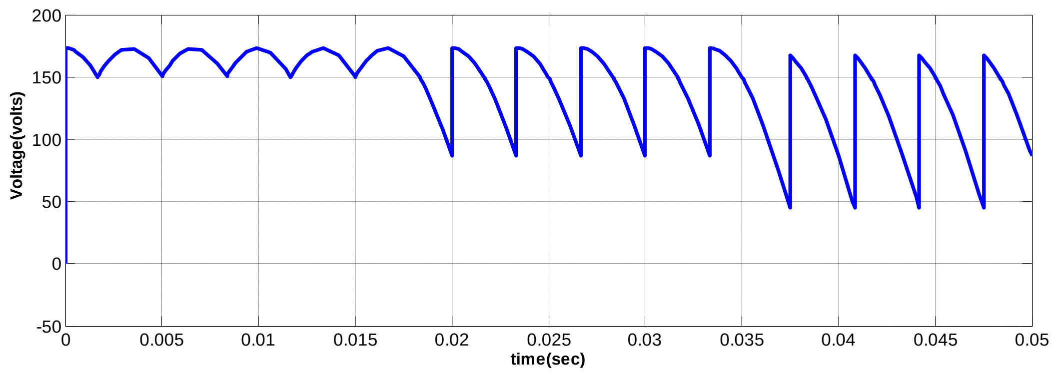

Fig. 12: *Output Waveform (α=0:30:45deg).*

CONCLUSION

In this paper, implementation in Simulation model for three phase full wave rectifier (convertor) has been introduced. This paper also shows the working methodology of three phase full wave (convertor) rectifier at different firing angle at a given time. Various waveforms were obtaining to compare with the actual waveform of three phase rectifier which gives useful result whereas three phase's rectifier is required.

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