SIMULATION STUDY OF AUXILIARY CONVERTER FOR 6000 HP THREE PHASE ELECTRIC LOCOMOTIVES.

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***Abstract*— This paper is about the simulation study of auxiliary converters used in 6000 HP electric locomotives used in India. Simulation is an mirror of the operation of a realworld method or system. The process of simulating a system first requires that a model be designed.This model represents the key behaviors , characteristics and functions of the selected physical or abstract system. It helps to analyse the behavior of the system without even building it. The results obtained are accurate in general when compared to the analytical model. It also helps to find un-expected errors and behavior of the system.. Simulation is easy to perform "What-If" analysis. For this purpose, MATLAB/Simulink was used.**

***Keywords*— AC-DC converter, DC-AC converter, Closed Loop, Sine Pulse Width modulation**

I. INTRODUCTION

Auxiliary converters convert single phase power from Locomotive step-down Transformer to three phase 50Hz power to supply to all the auxiliary loads of an Electric locomotive. Auxiliary converters forms part of the auxiliary drive system in an ac locomotive which is primarily used to supply power to the auxiliary loads of an electric locomotive. Auxiliary loads include-oil circulating pumps, oil cooling radiator blower, air compressors, motors to operate pantographs, transformer cooling pumps, traction motor cooling pumps, etc. It is typically of IGBT configuration that is fed from the auxiliary windings of the locomotive transformer. The auxiliary converter units (ACU) solve all the vehicle's power conversion needs by switching the input voltage from the overhead lines or 3rd rail power supplies, which is often unstable, into constant regulated voltage. The auxiliary converters are used in electric locomotives.An electric locomotive is powered by electricity from an overhead line, third rail or on-board energy storage such as a battery. As a locomotive which is in motion that is why this paper focuses on to make components of low dimensions and mass, higher efficiency and simplified maintenance as small as possible so that it can attain more speed with lesser power required to pull itself. Electrical engine comes into picture after realising that it is more efficient as compared to diesel engine.The range of load to be carried out is very large and it can attain variable speed with immediate change of.

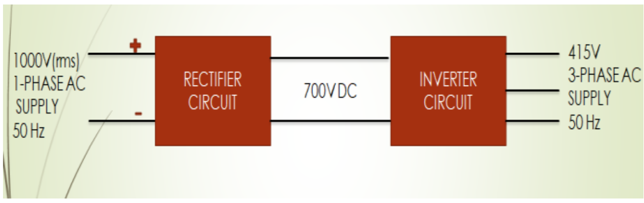


Fig1:- General block diagram

II. RECTIFIER

A. Introduction

A rectifier is an electrical device which converts alternating current (AC), to direct current (DC), that flows in only one direction. The process is known as rectification, since it "straightens" the direction of current. Because of the alternating characteristics of the input AC sine wave, the process of rectification produces a DC wave that, though unidirectional, consists of pulses of current [1].

B. Full wave bridge rectifier

The advantage of Full wave rectifiers over their half wave rectifier counterparts is that the average (DC) output voltage is higher than for half wave. Also the output of the full wave rectifier has much less ripple than that of the half wave rectifier producing a smoother output waveform. The Full Wave Bridge Rectifier uses four individual rectifying diodes connected in a closed loop "bridge" configuration to produce the desired output. This configuration results in two diodes conducting in positive and negative half cycles respectively producing an output during both half-cycles, twice that for the half wave rectifier so it is 100% efficient. As the spaces between each half-wave produced by each diode is now being filled in by the other diode. Hence the average DC output voltage across the load resistor is now double to that of the single half-wave rectifier circuit.

The main advantage of this bridge circuit over normal full wave rectifier is that it does not require a special centre tapped transformer, thereby reducing its size and cost considerably. The single secondary winding is now connected to one side and the load to the other side of the diode bridge network as shown below. As the current flowing through the load is unidirectional, as a result the voltage developed across the load is also unidirectional as same as the previous two diode full-wave rectifier, Hence the average DC voltage across the load is 0.637 Vmax [1].

C. Simulation circuit

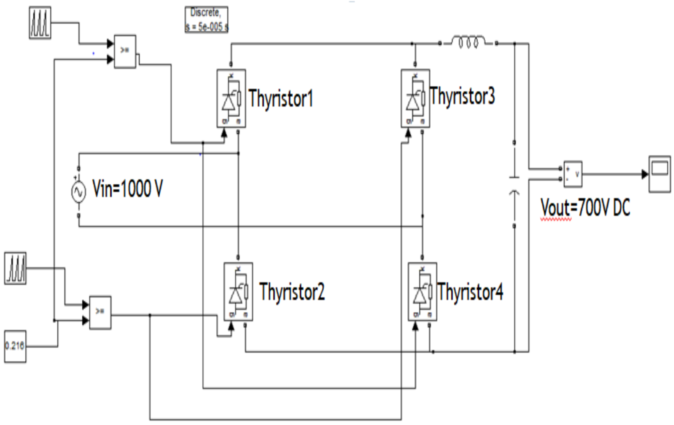


Fig2:- Full Bridge Rectifier Model

D. Equations

$$V_{dc} = (2 * Vm * \cos(a))/\pi$$

Where,

V_m= Peak Voltage

α= Firing angle

π= 3.14

This equation is used by the full wave bridge rectifier to produce single phase 700V DC.

III. INVERTER

A. Introduction

An inverter is an electronic device that converts direct current (DC) into alternating current (AC).The input and output voltages, frequency, and overall power handling depend on the design of the specific device. The inverter does not produce any power. The power is provided to the inverter by the DC source [1].

B. Three phase inverter

A three-phase inverter converts a DC input into a three phase AC output. Its three arms are normally delayed by an angle of 120° so as to generate a three-phase AC supply. At inverter switches switching occurs after every T/6 of the time T (60° angle interval).The switches S1 and S4, the switches S2 and S5 and switches S3 and S6 complement each other.

The circuit for a three phase inverter is shown below. It has three single phase inverters put across the same DC source. The pole voltages generated in a three phase inverter are equal to the pole voltages generated in single phase half bridge inverter [3].

C. 120˚ mode of conduction

In this mode of conduction, each electronic device is in a conduction state for 120°. It is most suitable for a delta connection in a load because it results in a six-step type of waveform across any of its phases. Therefore, at any instant only two devices are conducting because each device conducts at only 120°.

In 120˚ mode of conduction each switch will conduct for 120˚ interval and for each 60˚ interval two switches are on and four switches are off. Whereas in 180˚ mode of conduction each switch will conduct for 180˚ interval and for each 60˚ interval three switches are on and three switches are off.

Hence 120˚ mode of conduction will have less conduction loss than 180˚ mode of conduction due to less number of working switches at a time. One needs to give three pulses for 180˚ mode whereas two pulses in 120˚ mode for the circuitry for each 60˚ interval and hence for the sake of simplicity one would prefer 120 degree mode [3].

D. Simulation Circuit

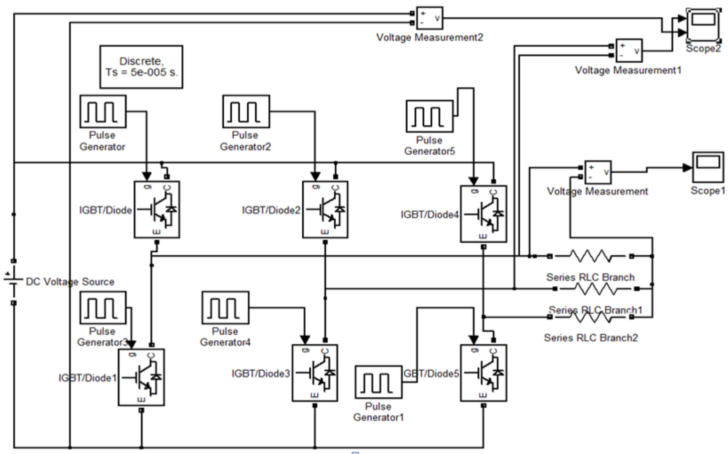


Fig3:- Three Phase Inverter Model

IV. CLOSED LOOP SYSTEM

A. Introduction

The goal of any control system is to measure, monitor, and control a process and one way in doing so is by monitoring its output and "feeding" some of it back to compare the desired output with the actual output obtained so as to reduce the error and if error present, bring the output of the system back to the desired response. The quantity of output being measured is called the "feedback signal", and this type of control system which uses feedback signals to both control and adjust itself is called a Close-loop System [2].

B. Rectifier Circuit

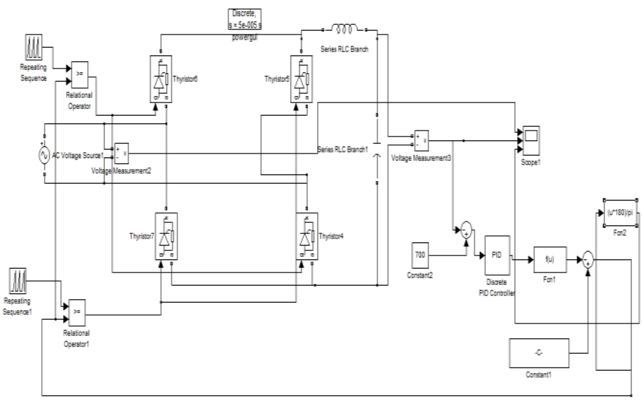


Fig4:- Closed Loop at Rectifier Circuit end

V. Sine Pulse Width Modulation

A. Introduction

Pulse width modulation allows the user to vary range of results by manually changing the time the signal is high (5V) or low (ground) i.e by manipulating the duty cycle in an analog fashion while maintaining the sinusoidal proportionality. It is used in an inverter circuit.

It has many advantages such as signal remains digital all the way from input to output, increased noise immunity making the signal strong, and increases the length of a communications channel increasing the overall efficiency of the signal [2].

B. Abbreviations and Acronyms

SPWM= Sine Pulse Width Modulation.

C. Simulation Circuit

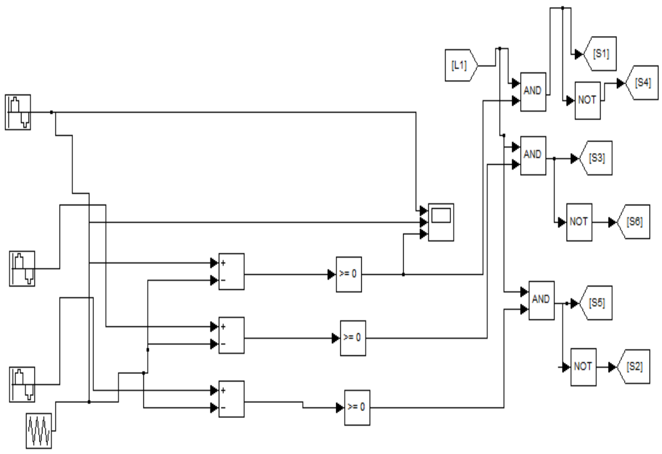


Fig 6:- SPWM Simulation model

VI. Methodology

Single phase 1000V AC supply from overhead lines is converted into single phase 700V DC supply using AC/DC rectifier circuit .One major problem faced during this type of conversion is that since the AC supply is coming through the pantograph placed overhead, is not constant and a variation of around 10-15 % is possible in the input supply. The output of rectifier should be 700 V in all the cases. Hence a closed loop system with an error detector and amplifier is placed in-between, so that it can modify the output DC voltage until the required 700V is obtained. The second stage is DC/AC inverter circuit which further converts single phase 700 DC into three phase 415 AC supply used by the auxiliary circuit. SPWM is used as a common inverter control method . With SPWM control, the switches of the inverter are controlled based on a comparison of a sinusoidal control signal and a triangular switching signal. The sinusoidal control waveform fixes the desired fundamental frequency of the inverter output, while the triangular waveform fixes the switching frequency of the inverter.

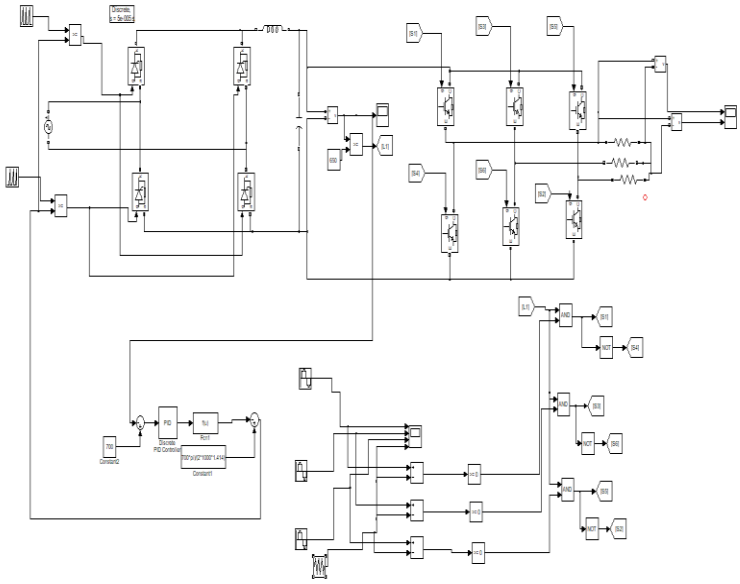
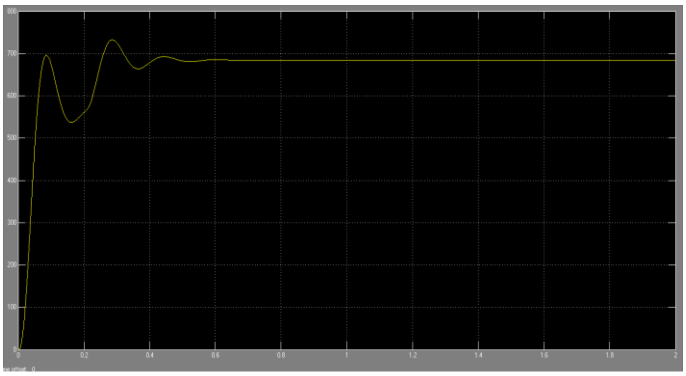


Fig 7:- Resultant Simulation model

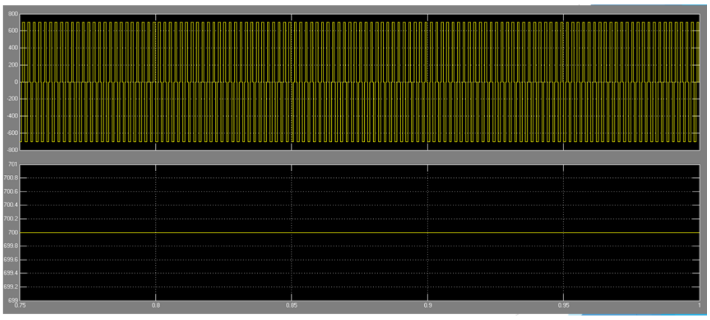
VII. Output

A. Rectifier circuit



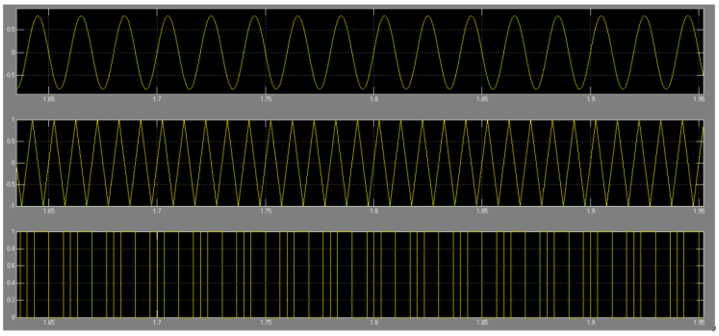
Here the simulation result shows the output of full wave bridge rectifier. i.e 700V DC.

B. Inverter circuit

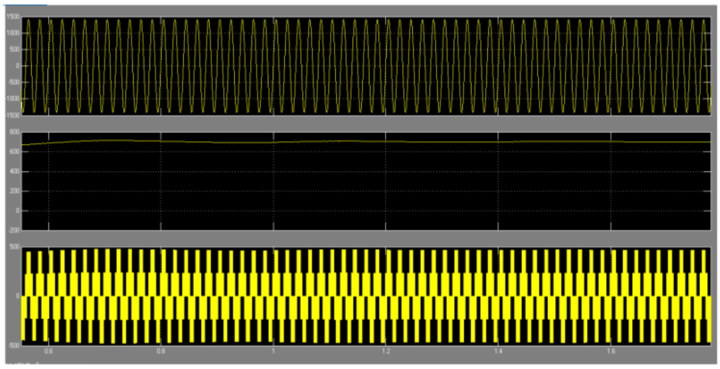


Here the simulation result shows the output of three phase inverter. i.e 415V AC.

C. Sine Pulse Width Modulation



Here the simulation result shows the output of Sine Pulse Width Modulation.



Here the gating signal for the inverter is generated by comparing a sinusoidal reference signal with a triangular carrier wave.

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[3] IEEE PEDS 2011, Singapore- A Single-Phase to Three-Phase AC/AC Converter with Regeneration and Adjustable Power Factor