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DESIGN OF VARIABLE FREQUENCY DRIVE TO CONTROL POWER AND SPEED OF A COMPRESSOR.

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***Abstract*:** Linear Motor Compressor is widely used in cryocooler in order to cool some application to a cryogenic temperature because of its high electrical efficiency than conventional rotary compressor. The present linear motor moving coil compressor has single phase input supply. For variable speed or variable load on electric motor one of the best approach is "Variable Frequency Drive" (VFD). This paper presents Design of single phase Variable Frequency Drive for linear motor compressor.

***Keywords*: cryocooler, variable frequency drive, linear motor compressor.**

I. INTRODUCTION

Cryocooler is a mechanical device which is used to cool the application to cryogenic temperature. Cryo cooler uses linear motor compressor over the conventional rotary compressor due to its enhanced electrical efficiency. At light load condition many mechanical device such as compressors gets overdesigned, in order to save energy variable speed approach is used. Variable speed can also be obtained by using mechanical pulleys, utilizes maximum floor space area and wear and tear of mechanical component is high in order to reduce or eliminate the above disadvantages Variable Frequency Drive (VFD) approach is implemented. Another main advantage of variable frequency drive is maintenance which is low as compared to pulleys. Variable frequency drive or variable speed drive (VSD) is used in many application from small equipment to large plant.

Variable frequency drive adjusts the output of the compressor by controlling the speed of the motor, to ensure it runs at optimum efficiency which results in energy saving at light load condition. Variable frequency drive first converts AC input supply into DC and again it converts into quasi-sinusoidal AC. Present variable frequency drive is designed for 100 Watt load

II. VARIABLE FREQUENCY DRIVE

VFD first converts incoming AC supply into DC and again it converts into quasi-sinusoidal AC, it consists of three unit as shown in Fig. 2.1.

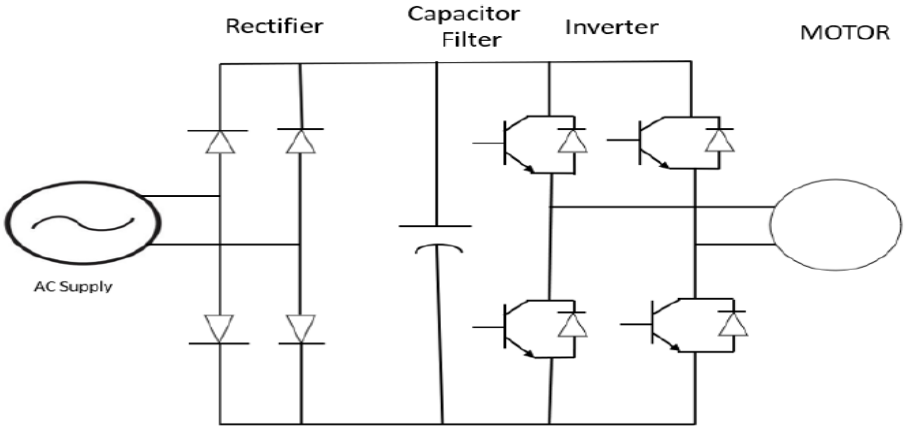

Figure 2.1. Generalized circuit diagram of Single phase VFD

Rectifier Unit: Rectifier unit consists of full wave bridge rectifier which consists of diodes. Diodes are semiconductor devices which allows the flow of current in one direction only. half wave rectifier allows flow of current only in forward biased and it blocks the flow of current when it becomes reverse biased, that is it executes only first positive half cycle at the output to overcome this disadvantage full wave rectifier is used. The input supply first pass through rectifier which converts AC supply into DC.[10]

Filter Unit: A capacitor bank is used to store the voltage coming from the rectifier circuit. Harmonics are produced by the action of nonlinear loads such as rectifiers, saturated magnetic devices harmonics results in increased heating in the equipment and conductor, misfiring in variable speed drive harmonics are removed by using filter

Inverter Unit: DC voltage is applied to the inverter circuit which converts DC into AC. The switches connected in the inverter are basically thyristor or transistor. A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. Transistors are one of the basic building blocks of modern electronics. Transistor is divided into two types Bipolar Junction Transistor (BJT) and Field Effect Transistor (FET). are used as switches in inverter circuit. FET's are faster switching devices than that of the BJT. Thermal stability of FET's are higher than the BJT's, it causes much and more loading effect than that of the FET's. Which is the major disadvantage of using BJT.
So based on above advantages of FET's over BJT's FET is choose as a switch. Metal Oxide Field effect transistor (MOSFET) is chooses as a switch in this circuit. MOSFET is chosen as switch based on the rating of operating voltage and current values and resistance between the drain when it is on. Based on the requirement IRF840 N channel MOSFET is chosen.
Specification of IRF840 N channel MOSFET are [9]
V_{DDS} = 500 V

I_D= 8.5 A

$R_{DS\,(ON)} \leq 0.85$ ohm
Where,
V_{DDS} = Drain-source voltage
I_D = Continuous drain current
$R_{DS\,(ON)}$ = Drain-source on resistance

Simulation of Single phase Variable Frequency Drive

In this work module the simulation of proposed circuit is done through the MATLAB of version R2016a. There are various advantages of using this software to simulate the model. Not only the accuracy but also various helping tools provided in this software make the simulation easy to understand and operate
The circuit consists of a single-phase rectifier circuit and the inverter circuit. In this circuit the pulse generator is denoted by "PG" and the Voltage Measurement is denoted by VM. The supple AC source is denoted by ACVS1. Scope shows the input supply given to the rectifier. Scope 1 gives the output of rectified filter circuit and scope 2 shows the output of inverter circuit. Scope 4 gives the output of the circuit that is quasi sinusoidal wave form. In scope 3 shows the input signal, rectified filtered signal and output that is quasi sinusoidal wave form is shown in fig 2.2.
The switching pulses are the main source to achieve variable frequency in the output. By changing the switching frequency, we can change frequency across the output. The switching frequency (f) is inversely proportional to the time period (T).

$$f = \frac{1}{T} \quad (1)$$

And

$$T = \boldsymbol{T_{on}} + \boldsymbol{T_{off}} \quad (2)$$

The above figure 2.3. Shows the switching characteristic of the switch of the inverter circuit. It can be easily seen that the pair of switches M1 and M2 are operating at same time and the other two switches are to be off state at that moment. Hence, we can say that the pulse timing is accurate according to the requirement of the inverter switches. The same phenomenon occurs for the next pair of switches when switch M3 and M4 are in on state and the M1 and M2 are off state.

The output of the circuit at various stages is shown in figure with 50 Hz switching frequency. The figure shows the input and output characteristic of the rectifier and inverter. First section of the graph shows the input voltage to the rectifier circuit while the second portion shows the rectified output voltage which is being filtered by the capacitor bank. This voltage is then feed to the inverter circuit. The inverter circuit input is the rectified circuit output

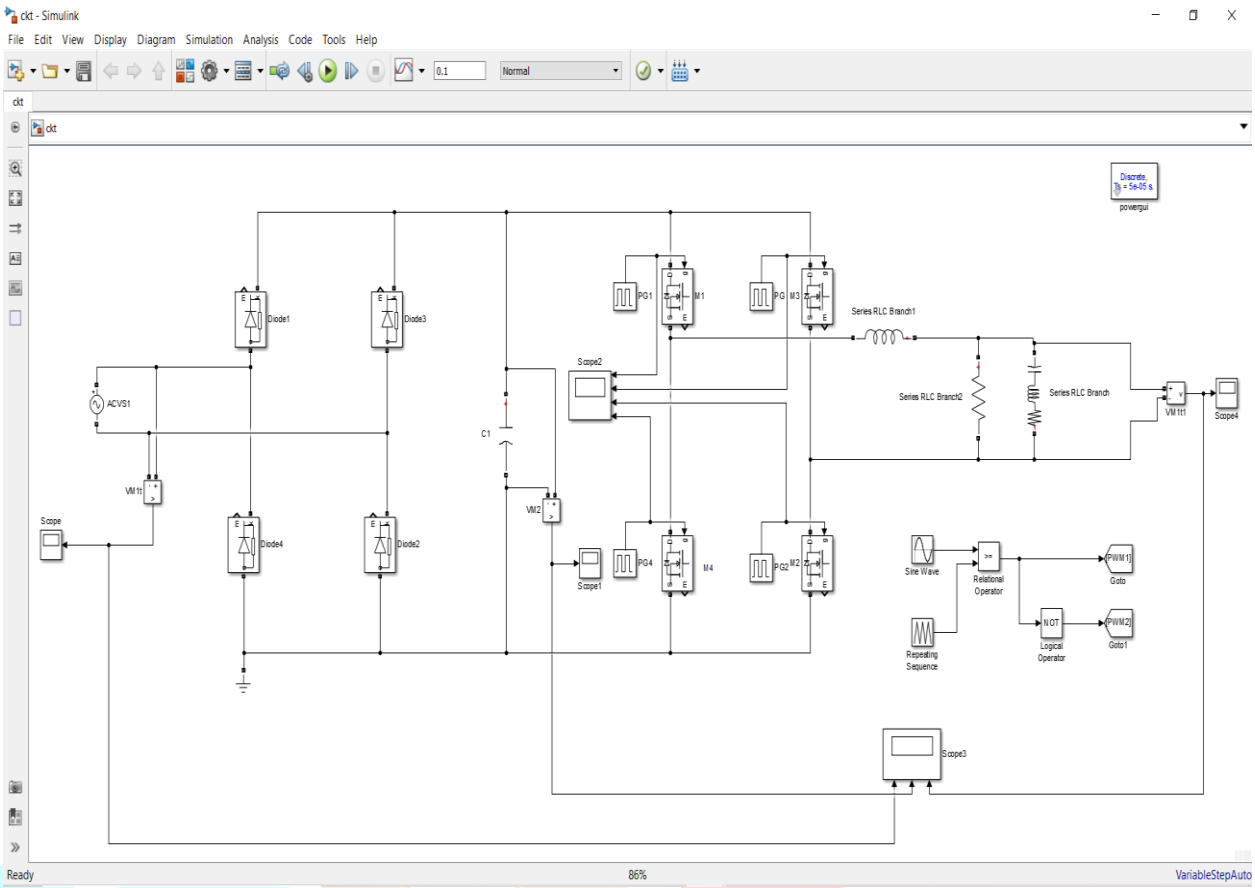

Figure 2.2. Simulation of Single Phase Variable Frequency Drive

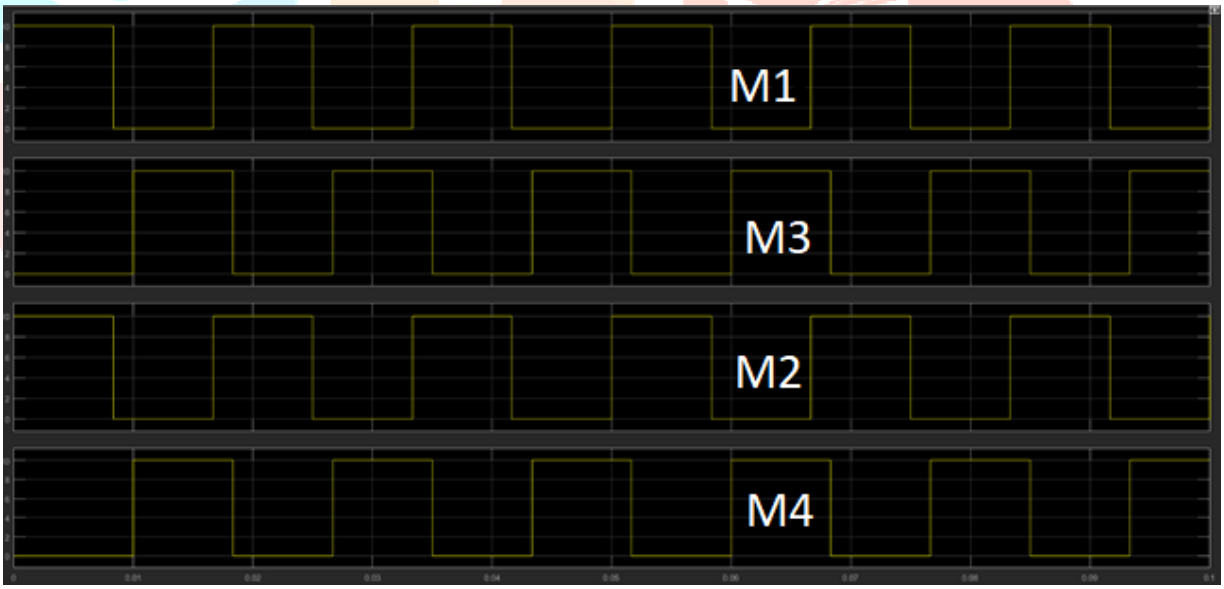

Figure 2.3. Switching pulse of the inverter switches at 50Hz

Signal Controlling part of VFD

VFD first converts incoming AC into DC voltage through rectifier and it again coverts into quasi-sinusoidal waveform through inverter while converting DC to AC it changes the frequency based on the requirement. This can be achieved through signal controlling part of VFD. Signal controlling part consist of microcontroller, for simplicity purpose we use Arduino UNO, it requires 9V DC battery for its operation. to know the frequency of the circuit we are using LCD display, frequency of the circuit is displayed on the LCD screen with the help of the program made in Arduino software and based on the program connection are to be made. The circuit layout for signal controlling part is shown in fig. below.2.4.

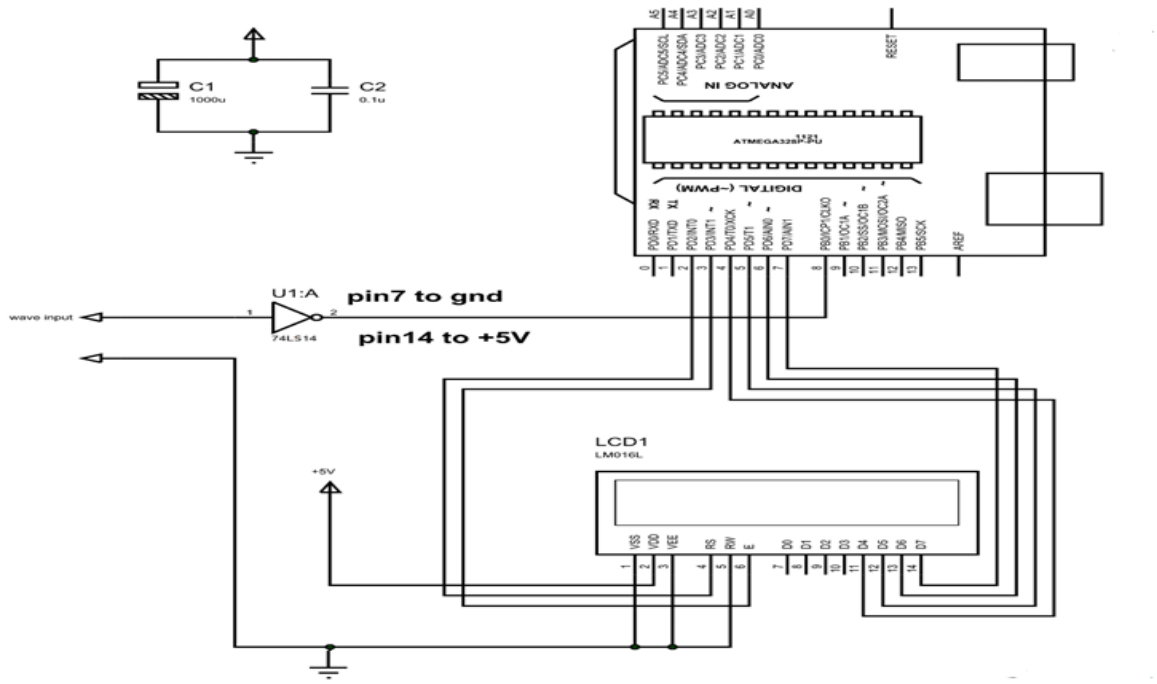

Figure 2.4. Circuit layout of signal controlling part

Based on the above circuit layout connections are made by using connecting wires or jumpers on the breadboard.

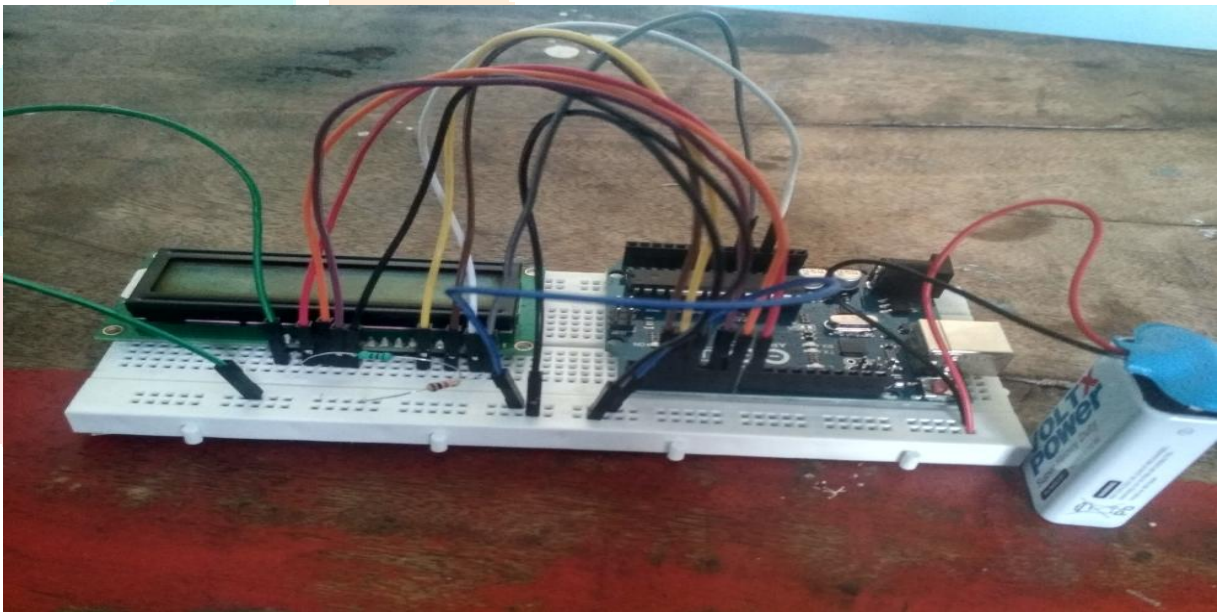

Figure 2.5. Signal Controlling part of Variable Frequency Drive

III Linear Motor Compressor :

When the alternating current carrying coil kept in magnetic field, it experiences force due to change in the magnetic flux. This force is responsible for displacement of coil. The magnitude of force, amplitude depends upon strength of magnetic field, voltage and frequency of current respectively. In the linear motor compressor, the reciprocating member is attached to either a moving coil or moving magnet and the whole system is suspended on springs. An alternating current (AC) carrying coil in presence of a perpendicular magnetic field experiences a force and its direction is given by Fleming's left hand rule. [5]

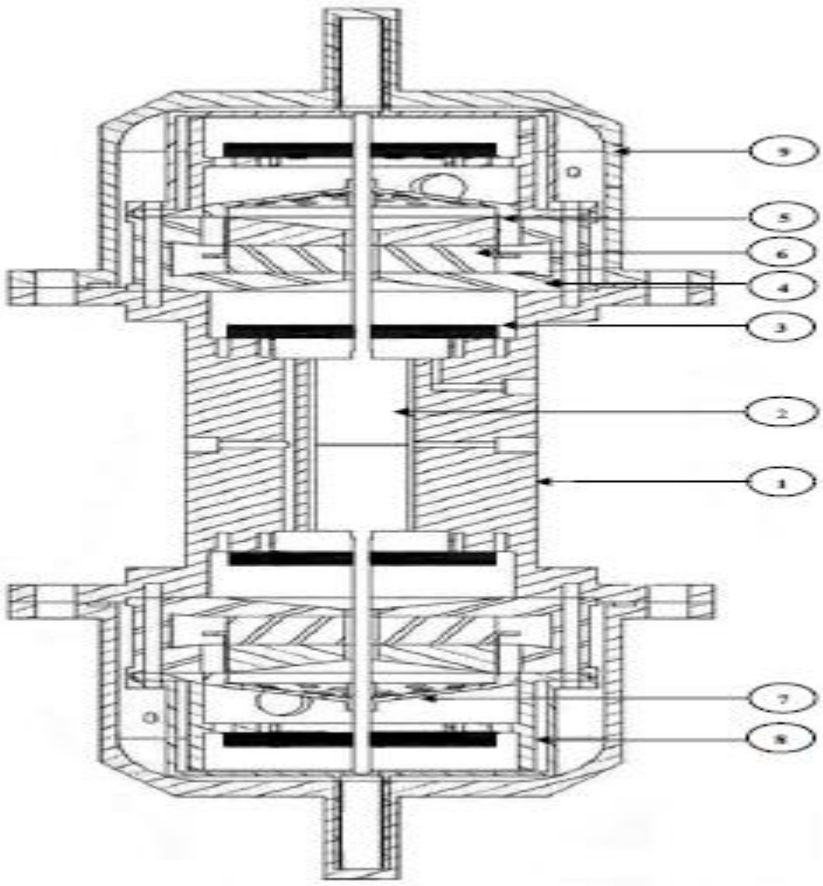

Figure 3.1. Linear motor compressor assembly

Variable Frequency Drive controlled Compressor can be used in cryocooler application in order to maintain desired effect by changing the output pressure of working fluid and speed of compressor. the operating frequency of the linear compressor has significant effect to the input power characteristics, and the compressor with higher charging pressure of working fluid has high pressure ratio [7].

Table No.1. Part list of linear moving coil compressor

Sr. No.	Part Name	Material	Quantity
1	Main body	Aluminum	1
2	Piston	SS 304	2
3	Flexure disc	Be-Cu	20
4	Inner pole piece	Soft Iron	2
5	Outer pole piece	Soft Iron	2
6	Magnet	Nd-Fe-B	2
7	Coil former	Delrin	2
8	Flexure support ring	Aluminium	2
9	End cover	Aluminium	2

3D Modeling of Linear Motor Compressor

In this work 3D modelling of the linear motor compressor is done through the CATIA of version V5R21. There are various advantages of using this software to create the model. Not Only the accuracy but also various helping tools provided in this software make the model easy to understand

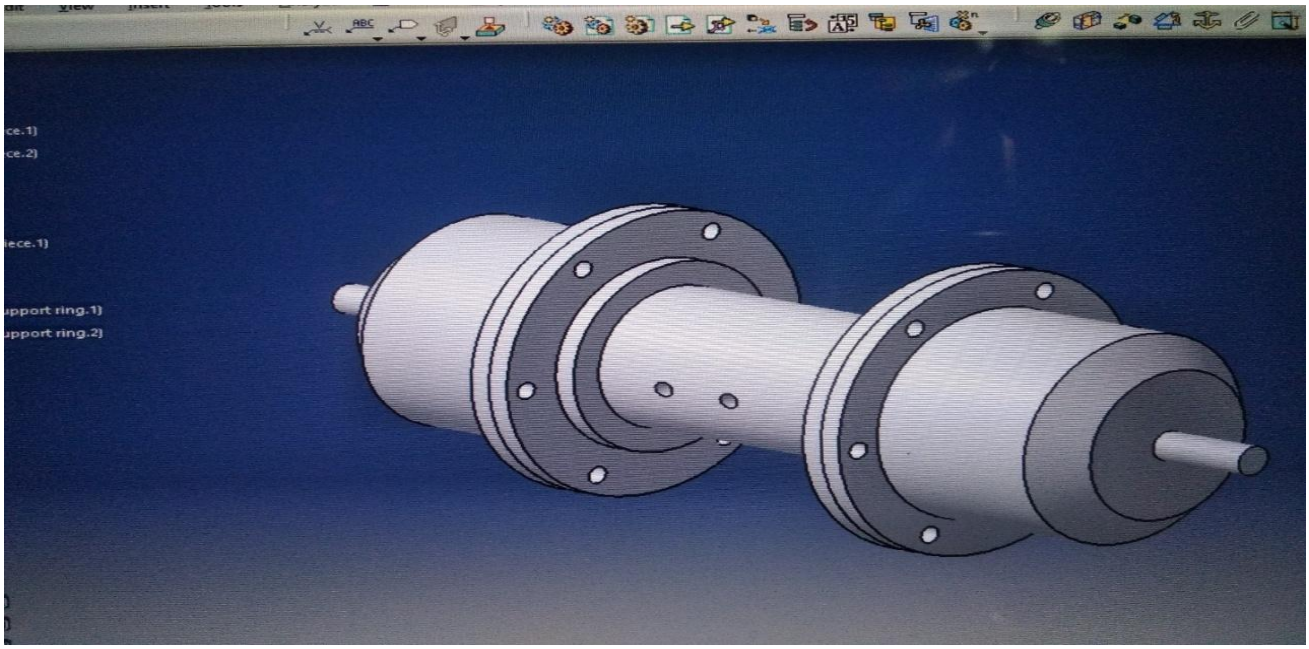

Figure 3.2. 3D model of linear motor compressor

Results and Discussion:

From the figure 4.1 it can be easily illustrated that the inverter output frequency is almost same as that of the supply voltage. This is due to the reason that the both supply voltage and the switching frequency are of same frequency which is 50 Hz.

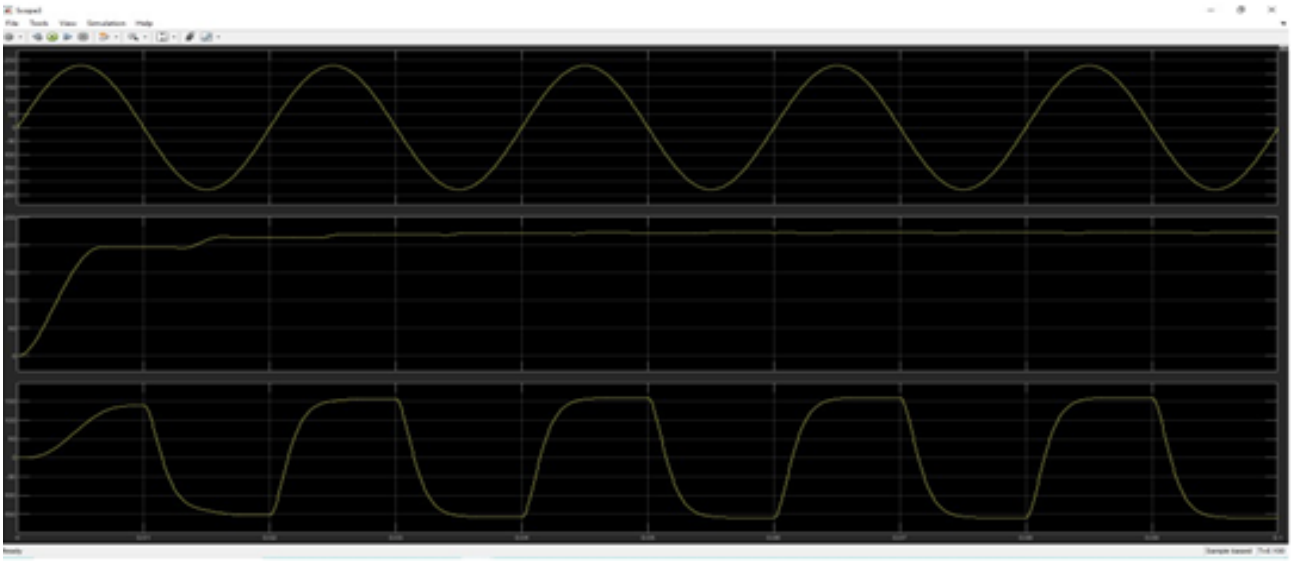

Figure. 4.1. Input and output characteristic of the rectifier and inverter circuit at 50Hz

From the figure 4.2 it can be easily illustrated that the filtered inverter output frequency is less as that of the supply voltage. The time period for completing one cycle of the inverter output is high as compared to the supply voltage. This is due to the reason that the supply voltage frequency is high as compared to the switching frequency of the inverter switches.

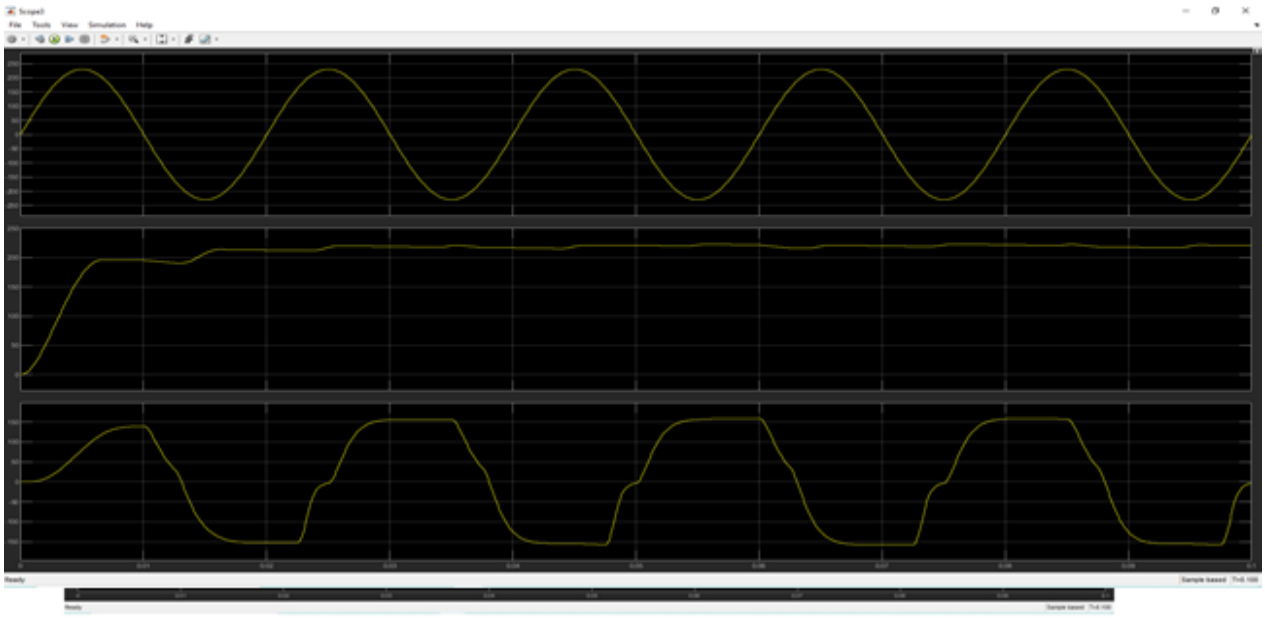

Figure. 4.2.Input 50 Hz and output characteristic of the rectifier and inverter circuit at 40Hz

From the figure.4.3 it can be easily illustrated that the filtered inverter output frequency is higher than that of the supply voltage. The time period for completing one cycle of the inverter output is low as compared to the supply voltage. This is due to the reason that the supply voltage frequency is low as compared to the switching frequency of the inverter switches.

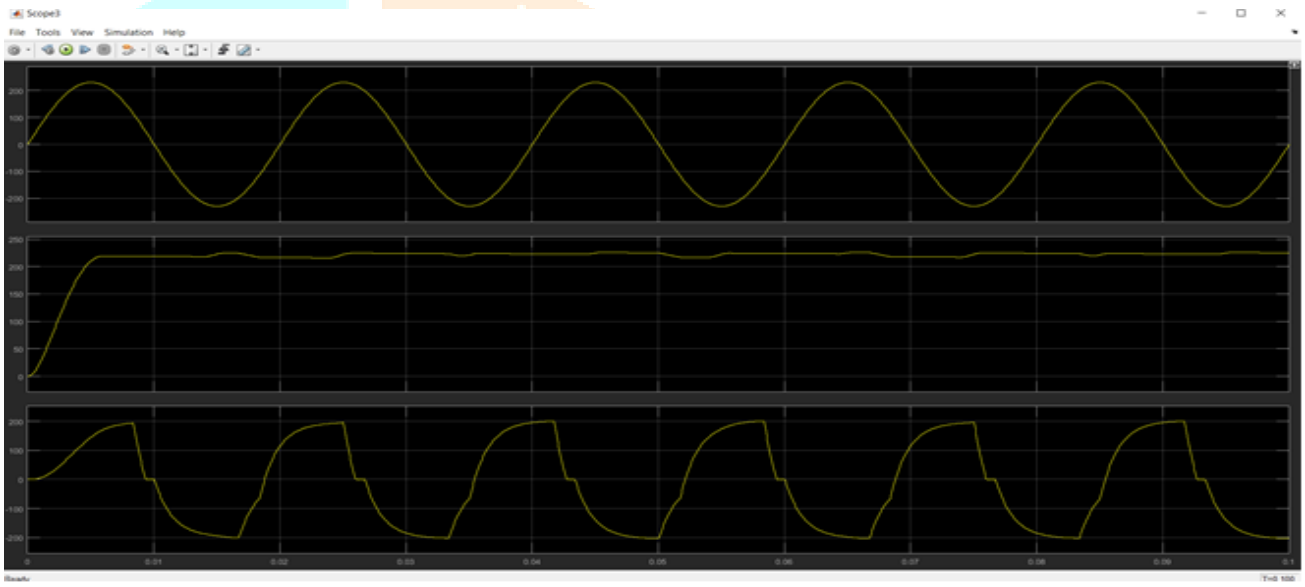

Figure. 4.3. Input 50 Hz and output characteristic of the rectifier and inverter circuit at 60Hz

Conclusion:

Working principle of Variable Frequency Drive and concept of linear motor is studied in this research. Design of single phase Variable Frequency Drive circuit is also made while doing this research, based on requirement proper MOSFET must be chosen while designing VFD, otherwise output of the VFD may not meet the requirement. MATLAB Software is used for simulation of Variable Frequency Drive and based on the results of this Software it is clear that the proposed VFD circuit can be applied to Linear Compressor for further study.

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