International Journal of Applied Engineering Research ISSN 0973-4562 Volume 15, Number 5 (2020) pp. 481-486

MATLAB for the Study of a Two Phase System

Dr. .A.Y. Fadnis
Associate Professor
Department of Electrical Engineering
Y.C.College of Engineering, Wanadongri
Nagpur, Maharashtra, India.

Dr.D.R.Tutakane
Head of the department
Department of Electrical Engineering
Wainganga college of Engineering and management,
Nagpur, Maharashtra, India.

Abstract

Today's research scenario has got two parts 1) Hardware part 2) software part Usually a hardware is complemented by a software. The results of the system can be known beforehand with the help of software .Even though all the problems related with the system are not known , a general behaviour of circuit can be studied with the help of simulation.

Many softwares are available for the study of various systems , The popular softwares are 1) MATLAB 2)E-Tap 3)SCADA etc. The choice of software depends on parameters required for the study of a system. Out of several softwares MATLAB is a software which is used worldwide for the study of a power system .It is a popular software amongst students and teachers throughout the world.

MATLAB (Matrix laboratory) consists of several blocks which can be interconnected according to system under study .The system can be simulated and the corresponding waveforms can be observed on the oscilloscope. The software also provides a facility of writing programmes. Thus it can be used for conceptual verification.

I. INTRODUCTION

The history of a two phase supply goes long back in the year 1895. There are still two phase distribution systems in USA supplying two phase power. In –fact a two phase motor fabricated by Tesla is an example of a two phase load .Fig. 1 shows the motor developed by Tesla.

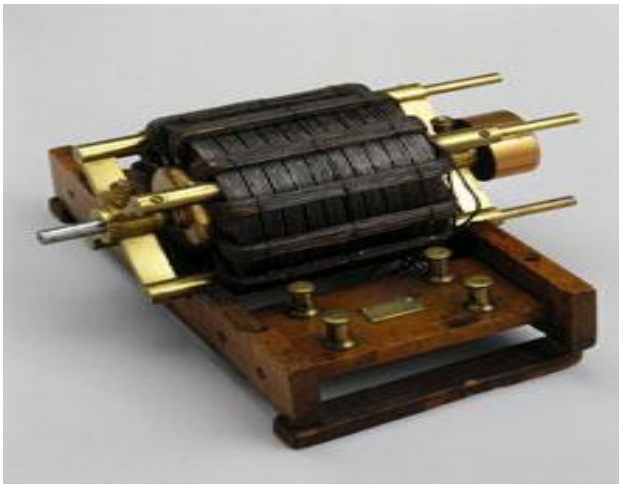

Fig. 1: Tesla's two phase induction motor

A three phase system is a common prevelant system .A three phase system is basically used in industry whereas the single phase supply is basically used in houses. Apart from a three phase load industry needs a two phase load like an induction furnace . An induction furnace acquires a two phase supply from a Scott connection. With the advent of power electronics a new way of control and utilities are available. Hence now a two phase supply is derived from a two phase inverter.

II. INVERTERS AND CONTROL STRATEGIES OF INVERTERS

Two Phase Invertes:

There are many configurations of two phase inverters. They are as follows[1].

1. Two leg inverter
2. Three leg inverter
3. Four leg inverter

All the aforesaid inverters give output as two phase voltages which are 90 degree apart. The output is obtained by switching of the switches in proper sequence. The switches used are MOSFETs or IGBTts . The selection of an inverter depends on the type of application and economy. The switching sequence is decided by control strategies such as 1) Sinusoidal pulse width modulation (SPWM) 2) Space vector pulse width modulation (SVPWM).Fig..2 shows the block diagram of two phase inverter with two phase load.

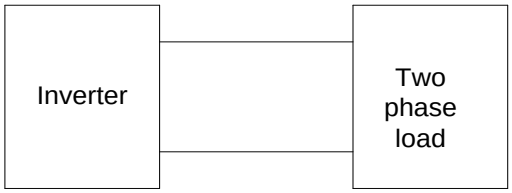

Fig.2: Two phase inverter with two phase load

Control strategies :

Usually a pulse width modulation is the strategy adopted for changing the width of the output pulse and thereby changing the average voltage across the load .SPWM and SVPWM basically achieve this.

SPWM : SPWM is adopted for deciding switching sequence of the switches of an inverter. .The outcome of this is shifting the harmonics on the higher order side. Hence if Fourier Analysis is done it reveals the presence of harmonics along with the fundamental. Fig 3 shows a block diagram in MATLAB used for SPWM.

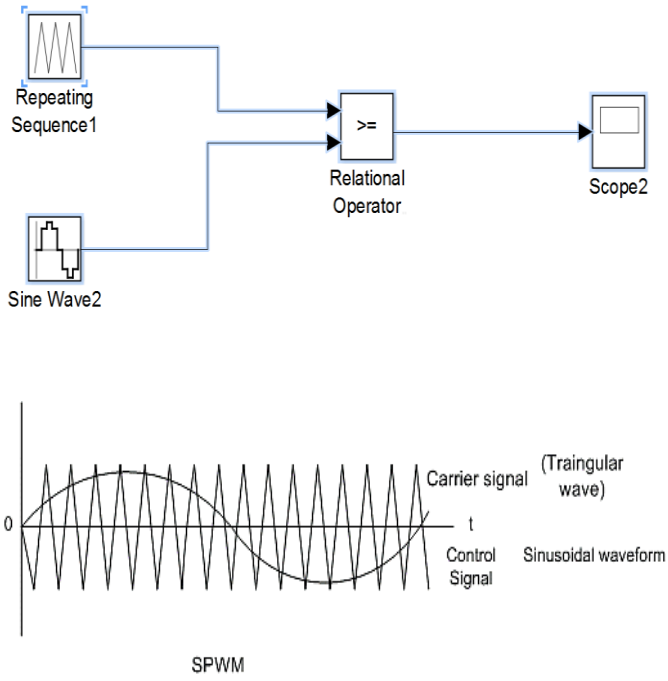

Fig.3: Comparison of carrier and control signal with the help of MATLAB

SPWM consists of comparison of a triangular waveform (carrier waveform) and a sinusoidal waveform (modulating waveform). Adopting a logic we create pulses for firing the switches of the inverter. Fig 4 shows the pulses obtained from the simulation

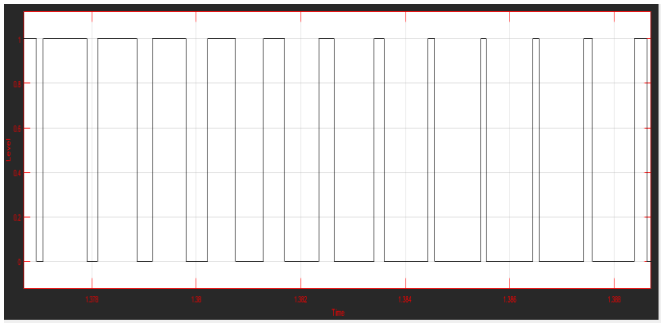

Fig.4: Firing pulses obtained from simulation

SVPWM: Another method of pulse width modulation is space vector pulse width modulation . An inverter creates space vectors with the help of switching states of an inverter. The switching states are decided by the permutationsa and combinations of the upper three switches of an inverter. Fig 5 shows a three leg inverter.

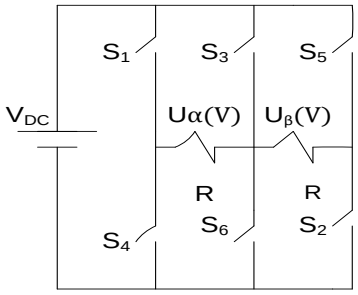

Fig. 5: Three leg inverter

The table below shows the switching states of three leg inverter for a two phase load

Table 1: Switching states of three leg inverter for a two phase load.

S_1	S_3	S_5	U_α (V)	U_β (V)
0	0	0	0	0
1	0	0	V_d	0
1	1	0	0	- V_d
0	1	0	- V_d	- V_d
0	1	1	- V_d	0
0	0	1	0	Vd
1	0	1	V_d	V_d
1	1	1	0	0

It is quite clear that SPWM or SVPWM both create space vectors for some specific loads. But a deliberate attempt to create space vectors is called as space vector modulation [2]. Fig. 6 shows the output obtained from three leg inverter with the help of space vector modulation

Fig. 6: Two phase output from three leg inverter

Two –leg Inverter :

Fig.7 shows a two –leg inverter. The circuit consists of two legs Each leg consists of complimentary switches.S1,S2 and S3,S4 along with diodes D1,D2,D3 and D4. Diodes are used for freewheeling the load energy back to source(depends on type of load)

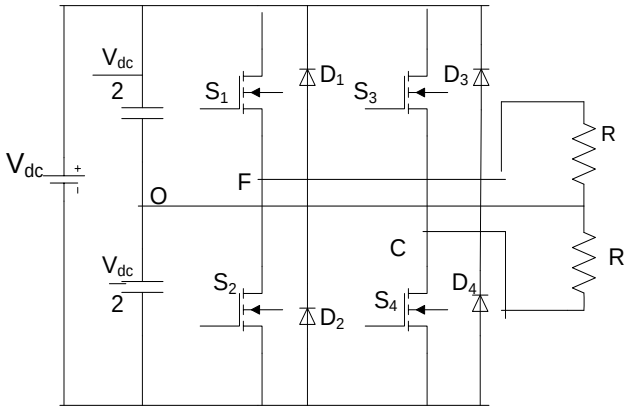

Fig. 7: Two leg inverter

The switches are operated in such a way that a two phase output is obtained from the circuit. Fig. 8shows the MATLAB block connections for obtaining the output from two leg inverter. Such type of output waveform is called bipolar waveform since it has two levels.

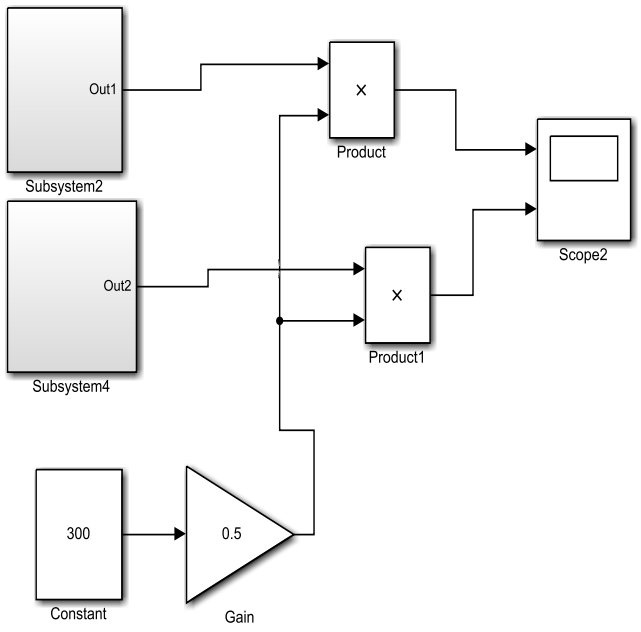

Fig.8: MATLAB block connections for obtaining the output from two leg inverter

The simulation for waveform is done with the help of switching functiononcept [3]. The frequency of the triangular waveform (carrier waveform) is 1000 Hz. and the frequency of the sinusoidal waveform is 50 Hz. The output waveform is nonsinusoidal containing harmonics . Fig. 9 shows the two phase output acquired from the two leg inverter

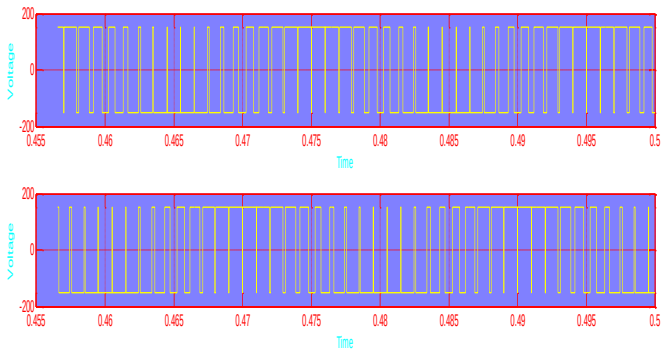

Fig.9: Two phase output from the two leg inverter

Because of the non-availability of zero vectors SVPWM is rarely used in case of two leg inverter.

Three –leg Inverter:

A three leg inverter consists of three legs made up of six switches. The switches are operated in such sequence that the output is two phase output. This can be done with the help of space vector modulation. Fig, 10 shows three leg inverter. The two phase output obtained from the circuit with the help of SVPWM is shown in fig,6. SPWM also will give a two phase supply in this case.

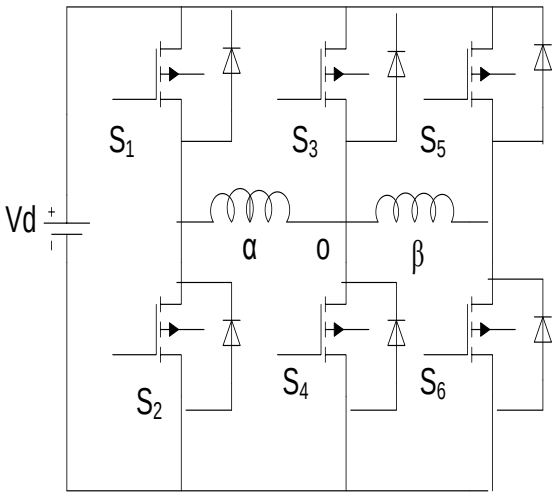

Fig.10: Three leg inverter

Four -leg Inverter:

A four leg inverter has four legs (fig.11), Two switches are present in each leg The switches are operated in a proper sequence to generate two phase waveforms. The output waveform of the circuit is obtained with the help of SPWM.

Fig. 12 shows a two phase output obtained from four leg inverter.

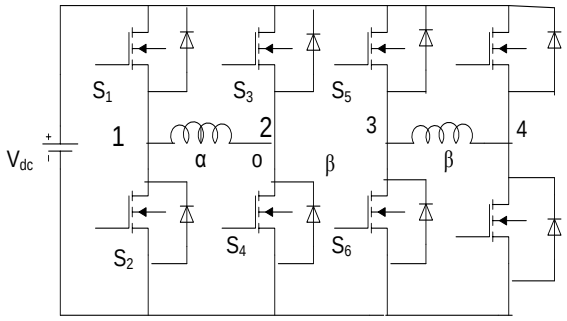

Fig. 11: Four – leg inverter

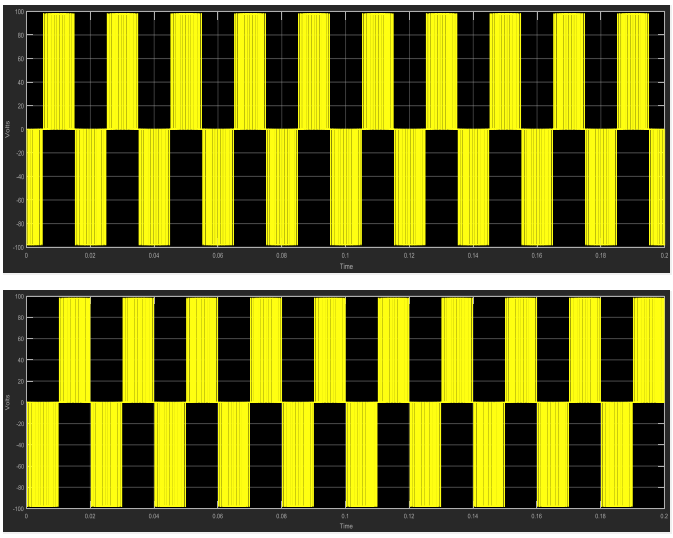

Fig.12: Two phase output obtained from four –leg inverter

For a four –leg inverter we can use unipolar modulation and bipolar modulation .SVPWM for four-leg inverter is a tidious procedure because of the higher no, of space vectors.

III. TWO –PHASE MOTOR AS A TWO PHASE LOAD

In olden days the low power applications involved a single phase motor .Since the efficiency of the motor is low and the control of the aforesaid motor is unsatisfactory hence the scenario has been shifted to two phase motor. The single phase motor is asymmetrical two phase motor. This motor can be replaced by two phase symmetrical motor [4] . The two phase symmetrical motor can be controlled with the help of two phase inverter. Thus a two phase motor can be treated as a practical example of aa two phase load. Since MATLAB does not have a block for a two phase motor hence modelling of the motor is done with the help of equations. Equations are written with the help of equivalent circuit of two phase symmetrical sirrel cage induction motor(fig.13).The two windings named as auxillary and main winding are similar windings having same no. of turns . α and β are two axes which are 90 degree apart .Auxillary winding is on α axis and main winding is on β axis.

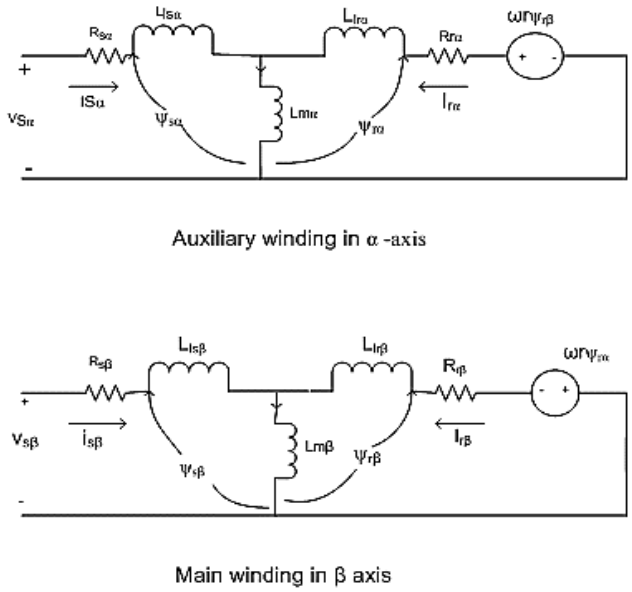

Fig.13: Equivalent circuits of two phase motor

The two phase symmetrical motor is described with the help of following equations.[5]

$$V_{s\alpha} = R_{s\alpha} i_{s\alpha} + \frac{d}{dt}\Psi_{s\alpha} \quad (1)$$

$$V_{s\beta} = R_{s\beta} i_{s\beta} + \frac{d}{dt}\Psi_{s\beta} \quad (2)$$

$$V_{r\alpha} = 0 = R_{r\alpha} i_{r\alpha} + \frac{d}{dt}\Psi_{r\alpha} + \omega_r \Psi_{r\beta} \quad (3)$$

$$V_{r\beta} = 0 = R_{r\alpha} i_{r\beta} + \frac{d}{dt}\Psi_{r\beta} + \omega_r \Psi_{r\alpha} \quad (4)$$

$$\Psi_{s\alpha} = L_{s\alpha} i_{s\alpha} + L_m i_{r\alpha} \quad (5)$$

$$\Psi_{s\beta} = L_m i_{r\beta} + L_{s\beta} i_{s\beta} \quad (6)$$

$$\Psi_{r\alpha} = L_{r\alpha} i_{r\alpha} + L_m i_{s\alpha} \quad (7)$$

$$\Psi_{r\beta} = L_{r\beta} i_{r\beta} + L_m i_{s\beta} \quad (8)$$

$$i_{s\alpha} = \frac{L_{r\alpha}\Psi_{s\alpha} - L_m \Psi_{r\alpha}}{L_{r\alpha} L_{s\alpha} - L_m^2} \quad (9)$$

$$i_{s\beta} = \frac{L_{r\beta}\Psi_{s\beta} - L_m \Psi_{r\beta}}{L_{r\alpha} L_{s\alpha} - L_m^2} \quad (10)$$

$$i_{r\alpha} = \frac{L_{s\alpha}\Psi_{r\alpha} - L_m \Psi_{s\alpha}}{L_{r\alpha} L_{s\alpha} - L_{m^2}} \quad (11)$$

$$i_{r\beta} = \frac{L_{s\beta}\Psi_{r\beta} - L_m \Psi_{s\beta}}{L_{r\alpha} L_{s\alpha} - L_{m^2}} \quad (12)$$

$$T_e = T_L + J\frac{d_{\omega m}}{dt} \quad (13)$$

Where $R_{s\alpha}$ and $R_{s\beta}$,are resistances of stator windings on α and β axes respectively. $R_{r\alpha}$ and $R_{r\beta}$ are the resistances of rotor windings on α and β axes. $\Psi_{s\alpha,}$. $\Psi_{s\beta}$ are flux linkages of stator

windings on α and β axes. Similarly $\Psi_{r\alpha}$, and $\Psi_{r\beta}$, . are flux linkages of rotor windings on α and β axes. $I_{s\alpha}$ and $i_{s\beta}$ are the currents in the stator windings on α and β axes. $I_{r\alpha}$ and $i_{r\beta}$ are currents in rotor windings on α and β axes..$T_L$is a load torque J is moment of inertia T_e is an electromagnetic torque produced by motor. □m is the speed of rotor.

Fig.14 shows the MATLAB blocks connected for simulation of two phase symmetrical induction motor .

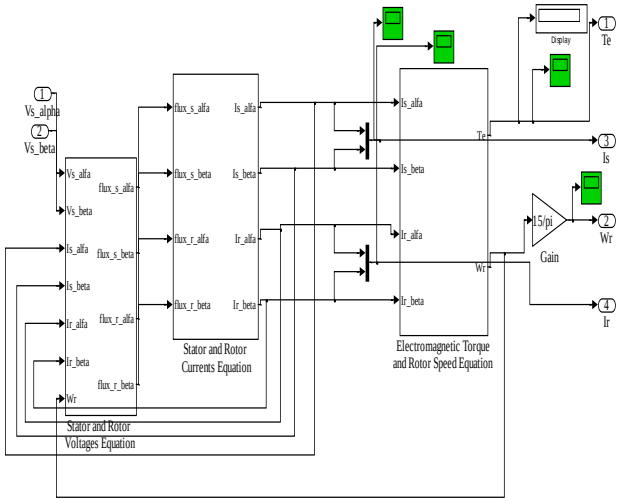

Fig.14 : Modelling of two phase symmetrical induction moto

The motor parameters used for simulation are as follows:

$R_{s\alpha} = R_{s\beta} = r_s = 2.2\Omega$

$R_{r\alpha} = R_{r\beta} = r_r = 1.5\Omega$

$L_{s\alpha} = L_{s\beta} = L_s = 51mH$

$L_{r\alpha} = L_{r\beta} = L_r = 49mH$

$L_{\alpha m} = L_{\beta m} = L_m = 43mH$

$J = 40^{X}10^{-3}$ kg- m^2

P = 4

Rating of motor =1.4 Kw

The motor torque and speed are as shown in in fig. 15 and fig. 16

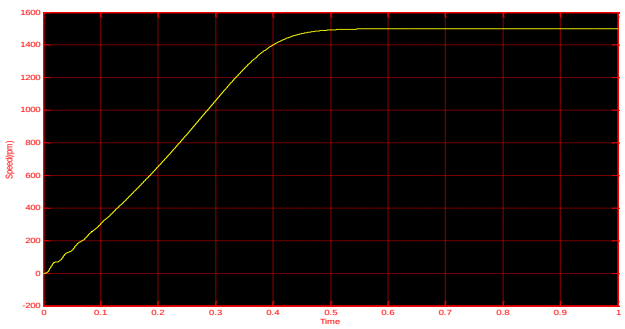

Fig 15: Speed of the motor

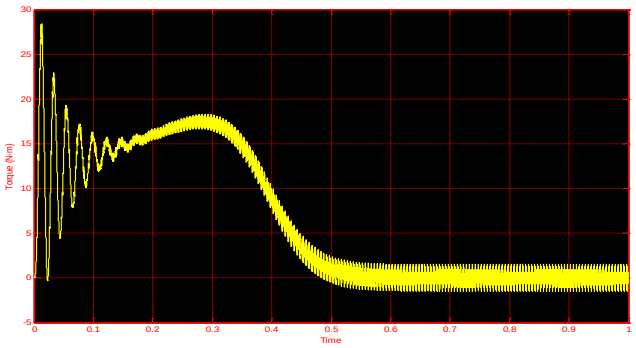

Fig. 16: Torque of the motor

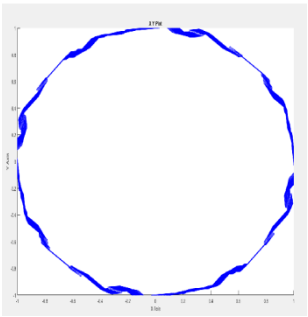

Fig.17: Rotating magnetic 0f the simulated motor

The motor is given supply with the help of four-leg inverter. The four leg inverter helps in producing two phase currents which are 90 degree apart and hence produce a rotating magnetic field (fig.17)

A two phase supply obtained from two leg inverter ,three leg inverter and four-eg inverter with the help of pulse width modulation contains a fundamental component along with the rest of the harmonics. The windings act as a filter hence a supply given from the aforesaid inverters produce a two phase current which consists of two waveforms which are able to give rotating magnetic field in the air gap of the machine. The speed waveform shows that the motor runs at 1500 r.p.m . The torque waveform indicates torque pulsations because the motor is driven with the help of inverter. The rotating magnetic field indicates the locus of the rotating field. which is almost circular. Fig. 18 shows one such fabricated two phase symmetrical motor similar to Tesla's motor.

Fig.18: Fabricated two phase symmetrical motor (Rating 1.3H.P.1000 rpm)

IV CONCLUSION

Two phase system can be studied with the help of MATLAB. A two phase motor is commercial possibility because of power electronics. A practical two phase load is a two phase symmetrical or asymmetrical induction motor. Two main parameters i.e. torque and speed can be simulated with the help of MATLAB by modelling a two phase induction motor with the help of mathematics. A rotating magnetic field indicates that four leg inverter used as utility supply and the two phase induction motor modelled are compatible to each other. Response of the motor with other circuits like two leg inverter and three leg inverter can be studied in similar way .

REFERENCES

[1] D.H. Jang "PWM Methods for two-phase inverters" IEEE Ind. APPL. Mag.vol.13, no.2, pp 50-61. Mar/Apr.2007 pp 50-61

[2] Mrs. A.Y.Fadnis, Dr. D.R.Tutakane "A Space Vector and Space Vector Modulation In lectric Machine" International Journal of Applied Engineering Research ISSN 0373-4562 Volume 10, Number 3(2015) pp 8877-8885

[3] Byoung-KukLee and Mehardad Ehasani A simplified Functional Simulation Model for Three Phase Voltage Source Inverter Using Switching Function Concept IEEE Transaction on Industrial Electronics,vol.48, No.2,April 2001,pp309-321

[4] Do Hyan Jang " Problems Incurred in a Vector – controlled Single –Phase Induction Motor,and a Proposal for a Vector Controlled Two Phase Induction Motor as a Replacement" IEEE transaction of Power Electronics Vol. 28, No.1, January 2013 pp 526-536

[5] Yuttana Kumsuwan, Watcharin Srirattannawichaikul, and Suttichai Primru decprececharin "Analysis of a two-phase induction motor using dynamic model based on MATlAB/Simulink "As.J. Energy Env. 2010,11(01) pp 43-59