Chapter – IV

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CHAPTER 4

CONTROL OF INDUCTION MOTORS

4.1 INTRODUCTION:

Poly-phase induction machines are today a standard for industrial electrical drives. Cost, reliability, robustness and maintenance free operation are among the reasons these machines are replacing dc drive systems. The development of power electronics and signal processing systems has eliminated one of the greatest disadvantages of such ac systems, which is the issue of control. With modern techniques of field oriented vector control, the task of variable speed control of induction machines is no longer a disadvantage [55-59]. This chapter focuses on various control methods for speed control of induction motor. Vector control is discussed in detail and sensor less vector control is explained. Space vector Pulse width modulated inverter (SVPWM) is discussed in detail. Matlab simulation of vector control of Multi motor is discussed with output waveform and finally compared with three phase motor.

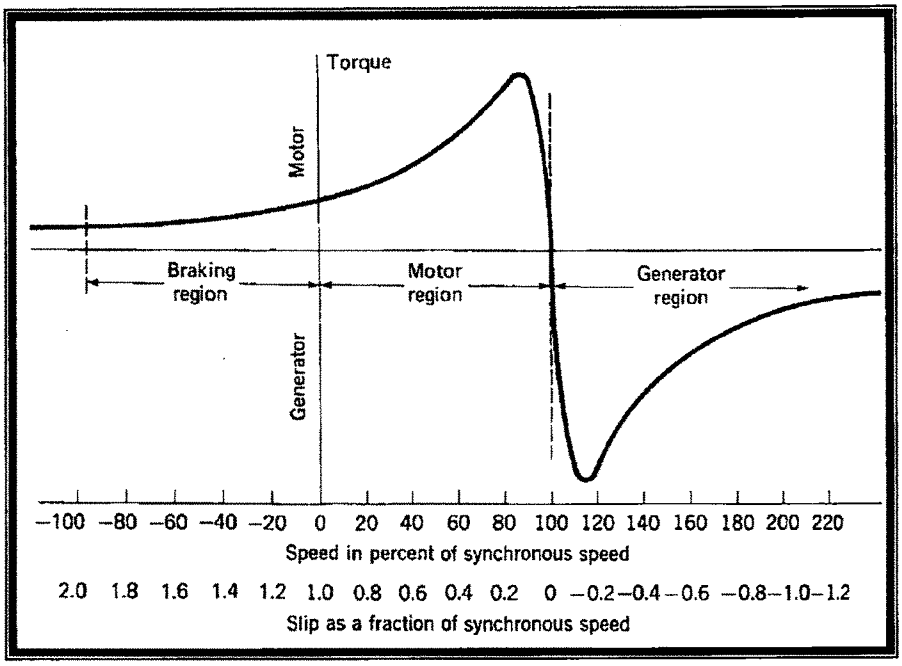


Figure 4.1 A typical speed-torque curve of induction motor

4.1.1 Speed control of three phase induction motor

Controlling a DC machine is much easier because of the fact that the main flux and the armature current distribution are fixed in space and can be controlled independently while with an AC machine these quantities are strongly interacting and move with respect to the stator as well as the rotor. They are, in a complex way determined by the amplitudes, frequency and phases of the stator currents. The three stator currents can be reduced to two independent control variables and Field oriented control can be achieved.

4.2 VECTOR CONTROL

The control and estimation of ac drives is complex than those of dc drives. The main reason for this complexity is the need for variable frequency. Now-a-days the vector control overcomes the drawbacks of scalar control improving the transient performance of motor and hence ac induction motor is the winner in industry. Application of induction motors in continuous duty variable speed drives calls for static inverters of adequate power, generating three phase voltages of variable amplitude and frequency. In that case, indirect frequency conversion methods are appropriate. The indirect frequency changer consists of rectification and inversion. There is a large variety of solution for the inverter and control problem.[55-56]

In vector or field oriented control both the magnitude and phase alignment of vector variables are controlled. The invention of vector control in the beginning of 1970s and the demonstration that an induction motor can be controlled like a separately excited dc motor brought renaissance in the high performance of control of ac drives. Because of dc like performance vector control is also known as "decoupling" orthogonal or trans-vector control.

Field orientation is a technique that provides a method of decoupling the two components of stator current: one producing the air-gap flux and the other producing the torque. The principle of field orientation originated in the former West Germany through the work of Blaschke and Hasse (Blaschke 1972; Hasse 1969). A variety of implementation methods have now been developed but these techniques can be broadly classified into two groups: direct control and indirect control [55].

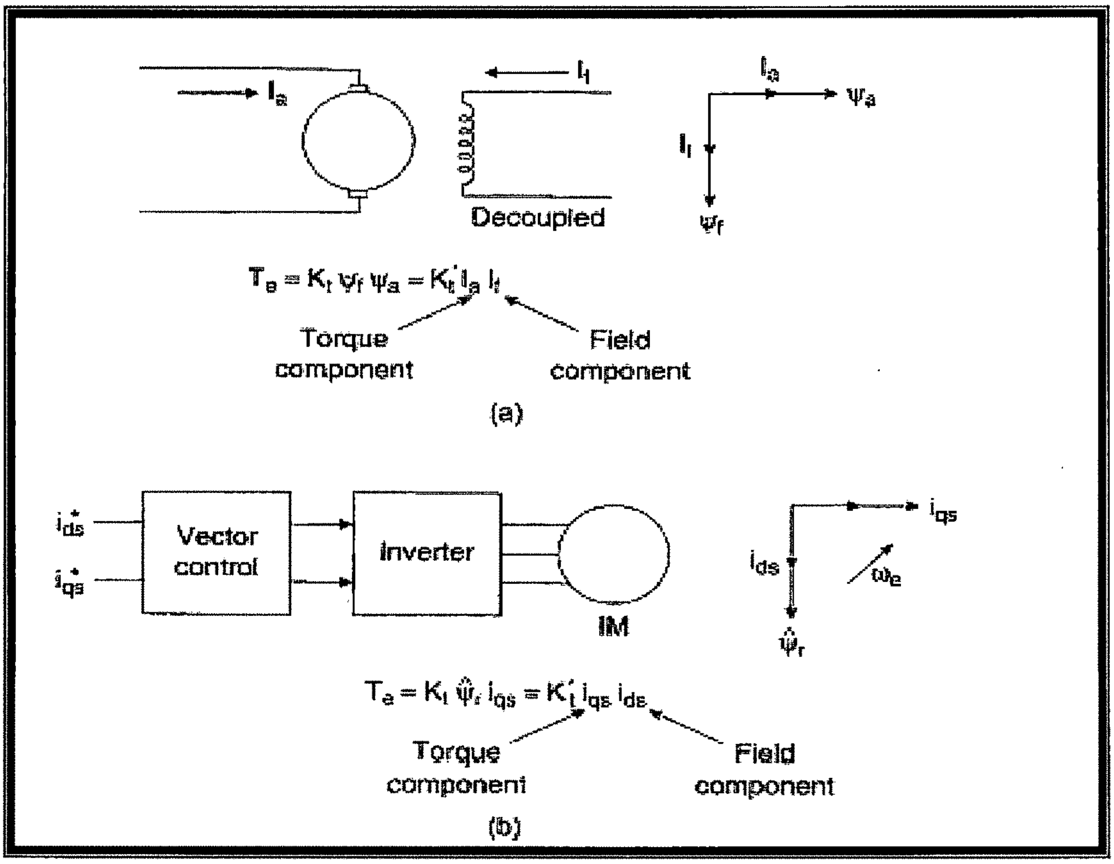


Figure 4.2 Principle of field oriented control

Figure 4.2 explains the principle of vector control. Here analogy of three phase induction motor with separately excited dc motor is shown. For field oriented control, three phase induction motor is run like a separately excited dc motor. For this a d-q axis model of induction motor is must.

In vector or field oriented control both the magnitude and phase alignment of vector variables are controlled. Induction motor can be controlled like a separately excited dc motor. Because of dc like performance vector control is also known as "decoupling" or Vector control is the most popular control technique of AC induction motors. In special reference frames, the expression for the electromagnetic torque of the smooth-air-gap machine is similar to the expression for the torque of the separately excited DC machine.

In the case of induction motor, the control is usually performed in the reference frame d-q (d- direct axis, q- quadrature axis) attached to the rotor flux space vector. That's why the implementation of vector control requires information on the modulus and the space angle (position) of the rotor flux space vector. The stator currents of the induction machine are separated into flux- and torque-producing components by utilizing transformation to the d-q coordinate system, whose direct axis (*d*) is aligned with the rotor flux space vector. Orthogonal or Trans - vector control.

4.2.1 Sensor less vector control

AC drives often need mechanical sensors (tachometers, position encoders) for field orientation. In many applications these sensors reduce robustness and increase costs of a drive considerably. Sensor-less control schemes using motor terminal voltages and currents, works very well at high speeds of operation.

Consequently, this has opened a new interesting area for research and during the last few years a variety of different solutions has reached the market. Neural networks, artificial intelligence and sensor less control are names that might sound familiar. The last one is a method that consists, as indicated by the name, of different ways of controlling the induction motor without using a speed sensor. Even though the induction motor is cheap and simple in its construction, this is not the case when it comes to its mathematics. The machine is represented by a nonlinear model with unknown variables and external inputs, which with its complexity makes sensor less control a challenging theoretical problem.

Sensorless vector control of an induction motor drive essentially means vector control without any speed sensor. An incremental shaft-mounted speed encoder (usually an optical type) is required for close loop speed or position control in both vector- and scalar-controlled drives. A speed signal is also required in indirect vector control in the whole speed range and in direct vector control for low speed range, including the zero speed start up operation.

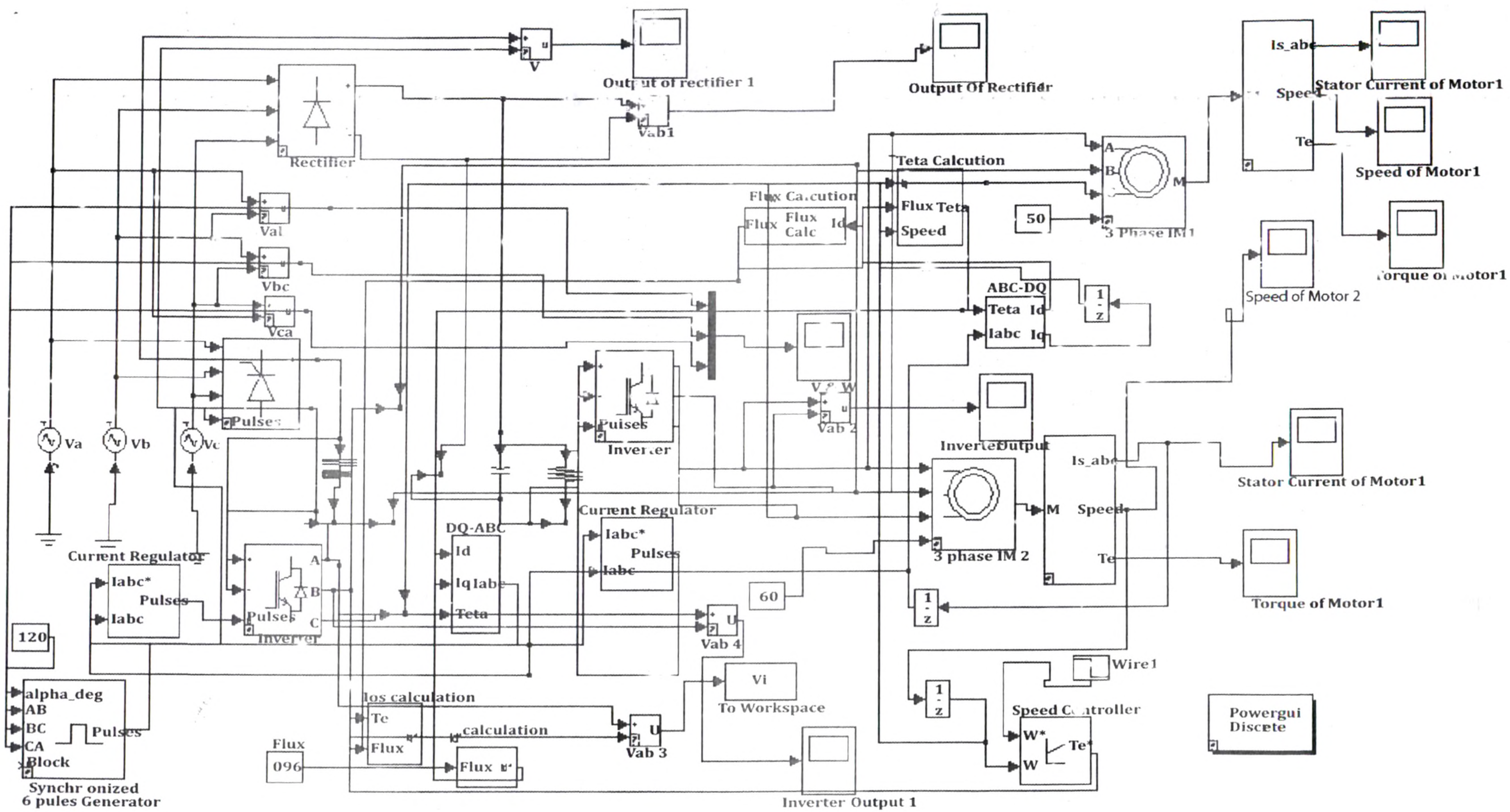
A speed encoder is undesirable in a drive because it adds cost and reliability problems, besides the need for shaft extension and mounting arrangement. It is possible to estimate the speed signal from machine terminal voltages and currents with the help of DSP (Digital Signal Processor) [55].

4.3 SIMULATION OF VECTOR CONTROL OF MULTI-MOTOR DRIVES IN MATLAB SOFTWARE:

The classic vector-control scheme consists of the torque and flux control loops, and motor 1 is supplied from a voltage source inverter (VSI) and motor 2 is supplied from current source inverter (CSI). Although most of the power absorbed by the motor is supplied by the CSI, from the control point of view it is the VSI that constitutes the actuator, and, consequently, the motor can be considered as voltage-controlled. The voltage source characteristic of the tandem converter is decisive with respect to the structure of a vector-control scheme. For the vector control of induction motors, the rotor-field orientation has the advantage of easy decoupling of the torque and flux controls. The two motors are controlled using Tandem converter i.e. One motor fed by Voltage source inverter, VSI and the other fed by current source inverter, CSI.

Three phase sinusoidal voltage is converted to dc voltage with the help of universal diode bridge rectifier. Rectified voltage is fed to Voltage source inverter & Current source inverter. Inverter pulses are regulated through Bang- Bang current controller. Two three phase Induction motors are modeled in a synchronously rotating reference frame. Stator currents, Speed & Torque of the induction motor 1 are seen in figure 4.4 to figure 4.6 Stator currents; Speed & Torque of the induction motor 2 are seen in figure 4.7 to figure 4.9 Speed controller used is PI controller. Flux is calculated in flux calculator & there from theta is calculated. A Bang-Bang current controller is used. Stator current, Speed & Torque characteristics of motor 1 for change in reference speed can be seen in figure 4.10 to 4.12. Stator current, Speed & Torque characteristics of motor 2 for change in reference speed can be seen in figure 4.13 to 4.15.

Computer simulations using Matlab/Simulink have been performed for assessment of operating features of the proposed scheme. The simulation involved a start-up of an unloaded, 5.5-kW, 380-V, 50-Hz motor and 4.5 Kw, 380-V, 50 Hz motor, followed by a step torque command at the rated-torque level and reversal of the drive with the same rated torque. All pertinent mathematical models have been developed individually, using Simulink's S-function blocks for the power electronic converters and the motor (the "Power System" block set could be used as well).


Output of rectifier 1
V
Output Of Rectifier
Vab1
Rectifier
Val
Vbc
Vca
Pulses
Va
Vb
Vc
Current Regulator
Iabc*
Pulses
Iabc
120
alpha_deg
AB
BC
CA
Block
Pulses
Synchr onized
6 pules Generator
Flux
096
Te
Flux
calculation
Flux
A
B
C
Pulses
DQ-ABC
Id
Iq Iabc
Teta
Inverter
Vab 2
Vab 4
Vab 3
60
Vi
To Workspace
Inverter Output 1
Flux Calc
Id
Teta Calcution
Flux Teta
Speed
ABC-DQ
Teta Id
Iabc Iq
1
z
50
A
B
M
Is_abc
Speed
Te
Stator Current of Motor1
Speed of Motor1
Speed of Motor 2
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W
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Powergui
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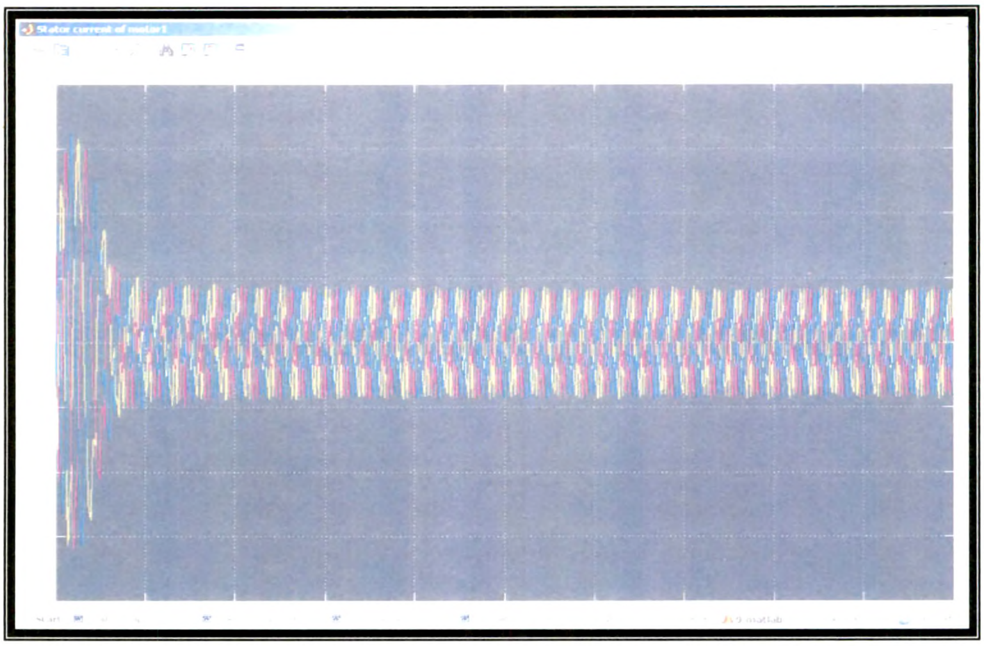

Figure 4.4 Stator current waveform of motor 1

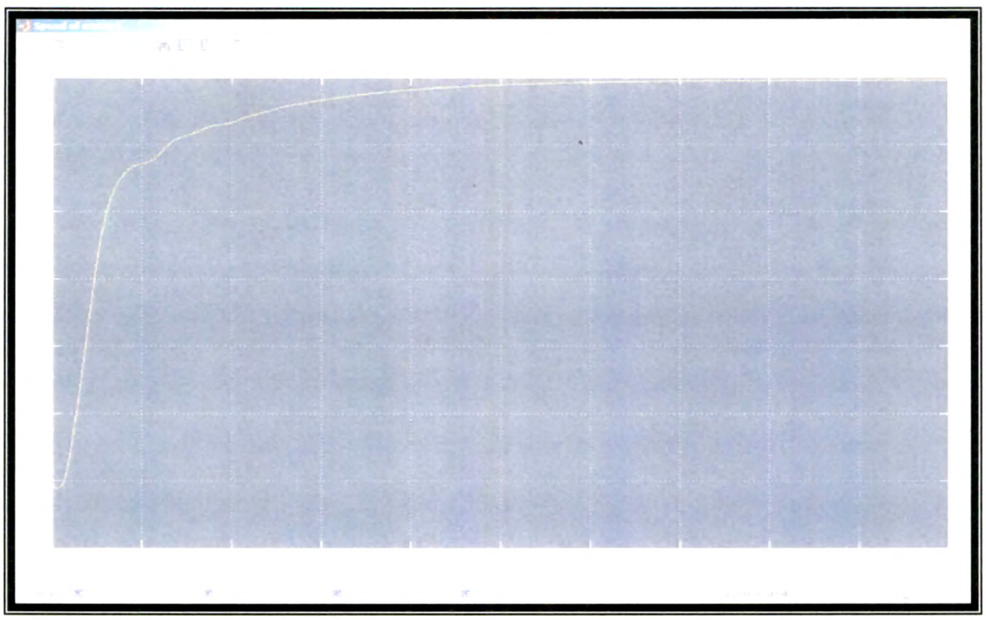

Figure 4.5 Speed of motor 1

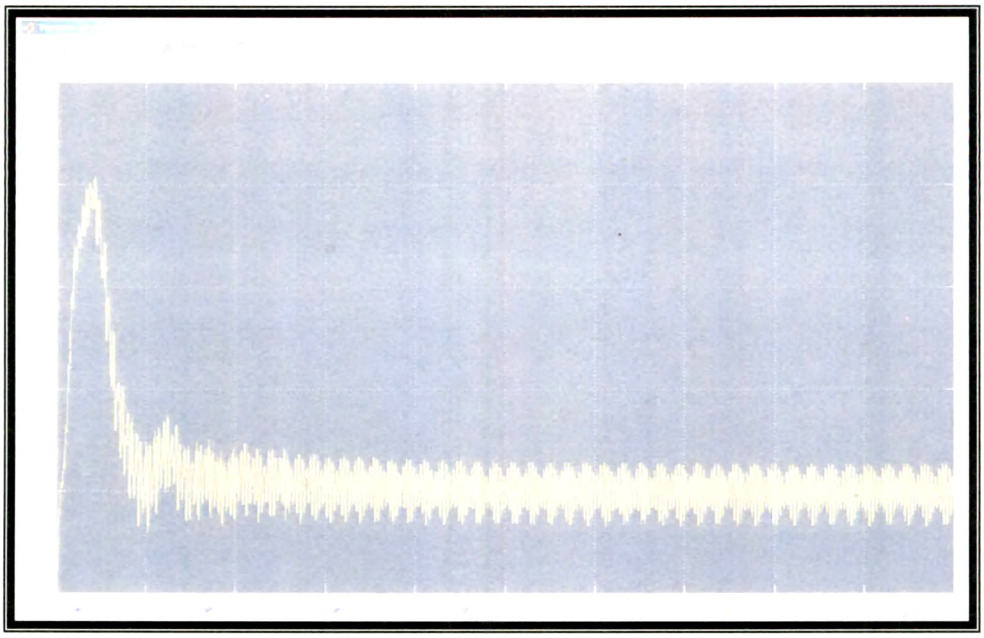

Figure 4.6 Torque of motor 1

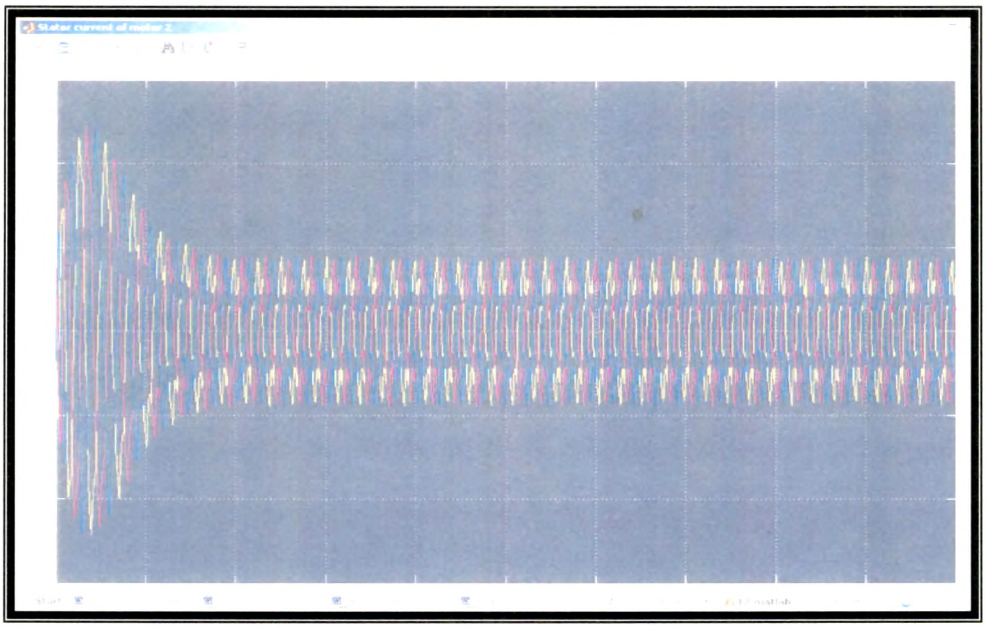

Figure 4.7 Stator current of motor 2

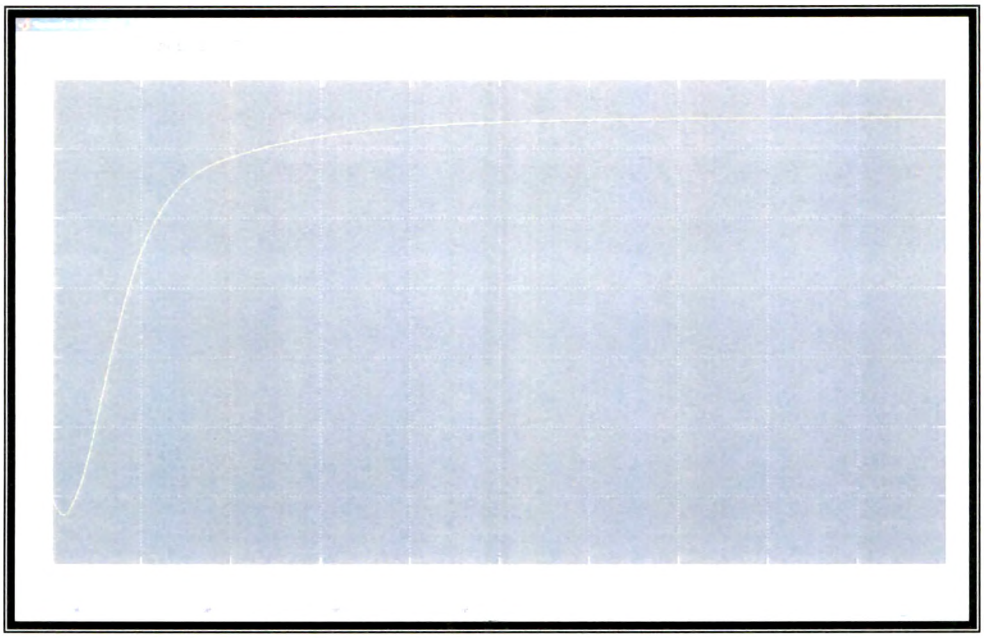

Figure 4.8 Speed of motor 2

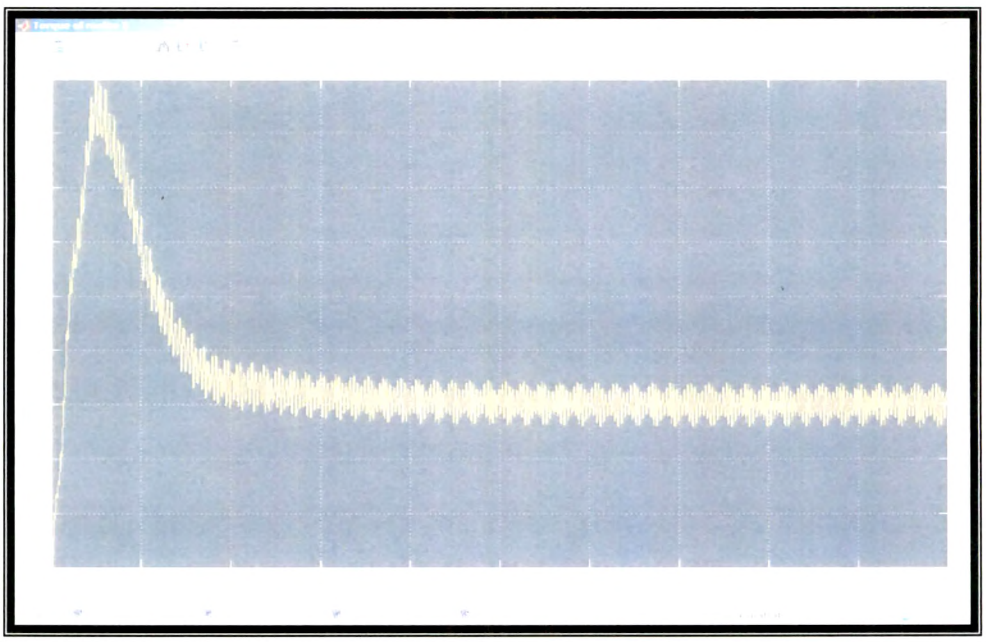

Figure 4.9 Torque of motor 2

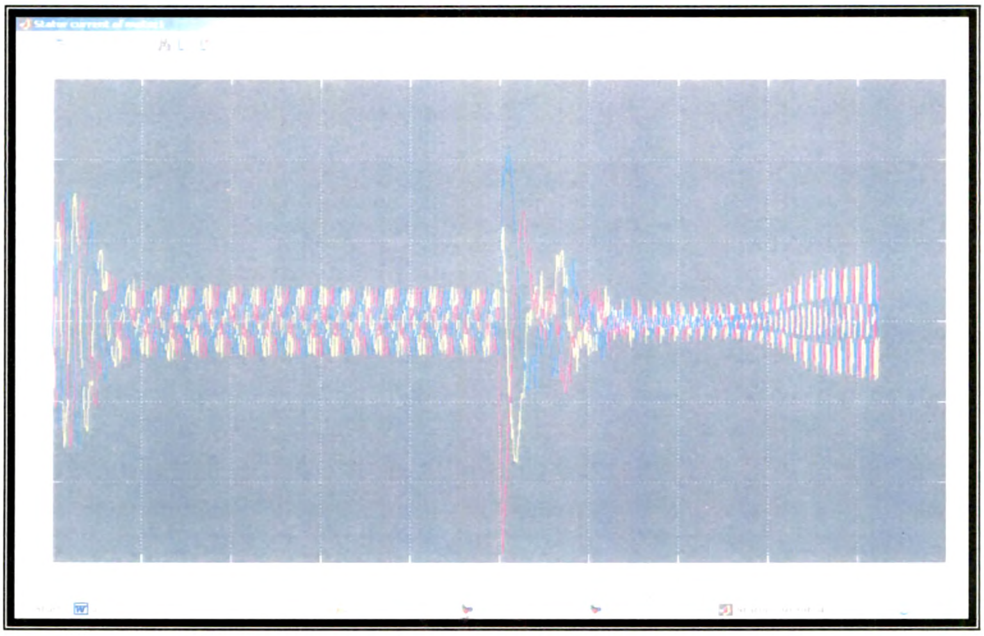

Figure 4.10 Waveform for Stator current of motor 1 for change in reference speed

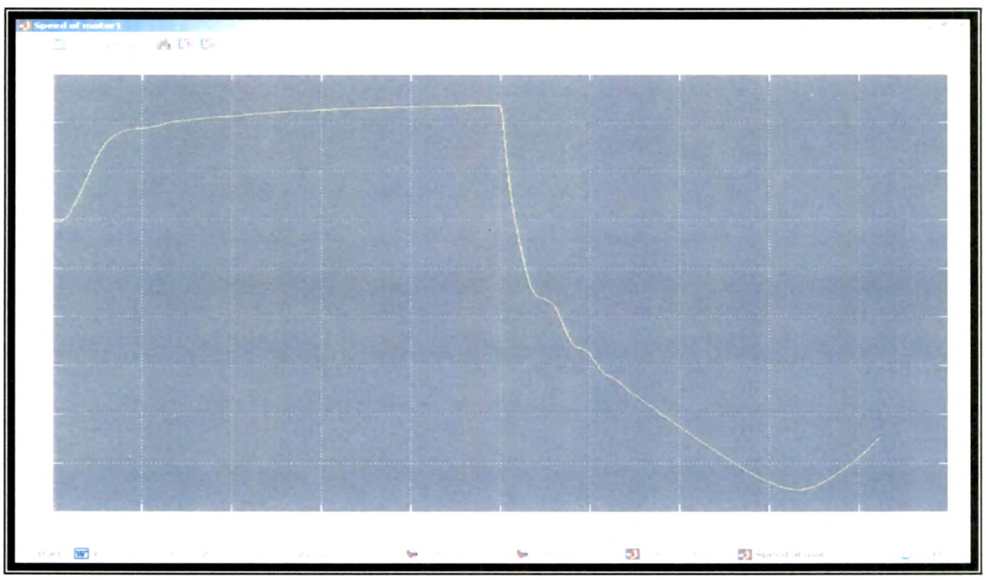

Figure 4.11 Waveform of speed of motor 1 for change in reference speed

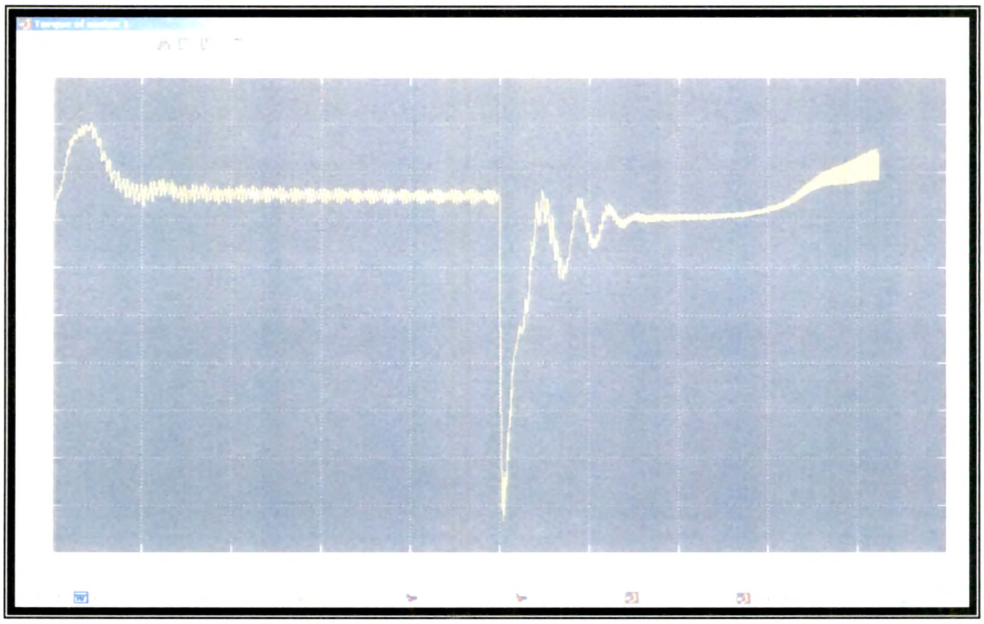

Figure 4.12 Waveform for torque of motor 1 for change in reference speed.

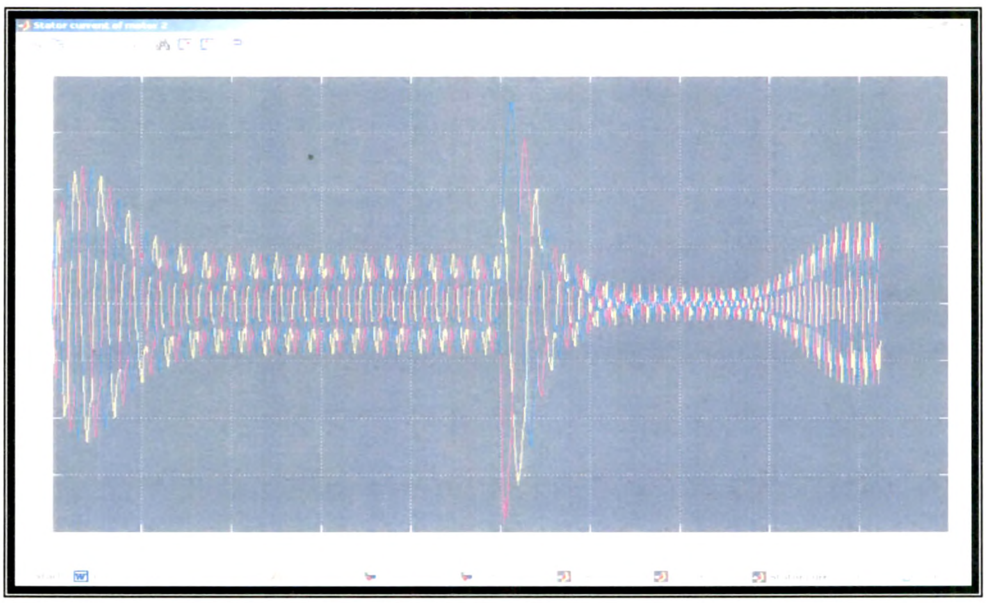

Figure 4.13 Waveform for Stator current of motor 2 for change in reference speed

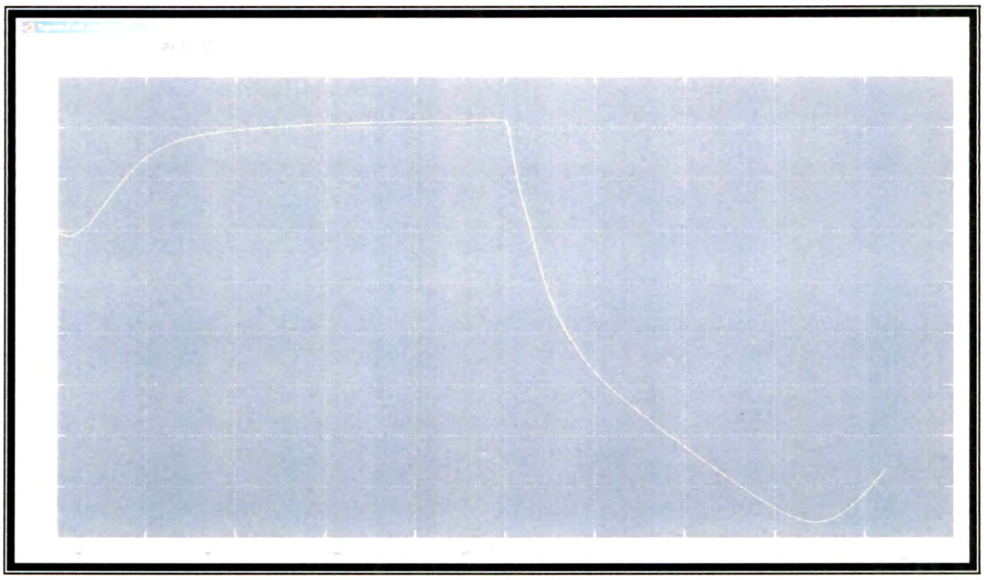

Figure 4.14 Waveform of speed of motor 2 for change in reference speed

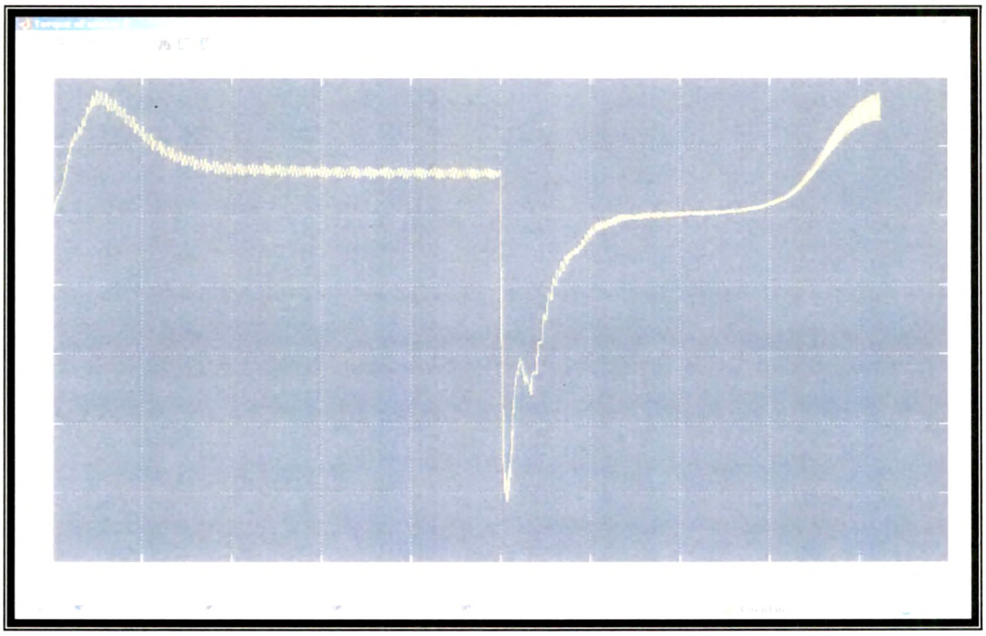

Figure 4.15 Waveform for torque of motor 2 for a change in reference speed.

Motor Specifications:-

Motor 1:- 5.5 kw, 380-V, 50-Hz

Motor 2:- 4.5 Kw, 380-V, 50 Hz

4.3.1 Comparison with single, three phase induction motor:

Reliability is the main advantage of multi motor operation over single three phase motor. If one of the motor fails by any reason the continuity of operation is maintained.

4.4 CONCLUSION

Though there is an advantage of reliability there are no other advantages like torque and efficiency improvement. Thus instead of using two, three phase motors if a single, six phase motor is used, torque and efficiency can be improved. The Matlab simulation for vector control of six phase induction motor is discussed in next chapter.