Chapter One

Introduction

1-1 Background:

During the past 15 years, there has been a substantial amount of research into the development of new condition monitoring techniques for induction motors. Excellent examples of typical failures in random woundlow voltage induction motor are shown in Bonnet and Soukup (1992).Pre-warning of motor failure can only be achieved if shorted turns within a coil can be initiallydiagnosed via on-line diagnostic techniques. This requires continuous on-linemonitoring to diagnose the faults stated in IEEE Survey (1985).[1]

Induction motor starting poses many challenging problems to the machine, in theform of wear and tear, and to maintaining a stable supply of power. Engineers andtechnicians must take these considerations into account when deciding on a startingmethodology.

The dynamic characteristics desired during the starting process are oftenconflicting, and tradeoffs must be made based on system characteristics. Thesecharacteristics include the system robustness, efficiency, equipment cost, and machine lifetime. Many different methods have been developed to address particular inductionmotor starting problems associated with motor size and the stability of the connectednetwork. Induction motors makeup a large part of the load in power systems and inindustrial applications in particular. The three-phase AC squirrel cage induction motorsare the preferred motor type due to theireconomical cost and robustness. They make up approximately 85% of industrial motors.Wound-rotor motors have an advantage during startup; because of their slip ringsresistance can be added to the rotor circuitHowever, wound-rotor motors are moreexpensive and more difficult to maintain.Many reports have been published discussing the parameters that need to be takeninto account during startup that can be used to judge the characteristic features of startingmethods for a particular application. The common factors when considering the choice of starting method are:

-Inrush Current

-Voltage Dip

-Frequency Dip–Acceleration Time

-Torque

-Reactive Power and Starting Power FactorRobustness

-Cost

1-2 Problem Statement:

The main problem in induction motors having high starting current, when started direct-on-line (DOL)about 4-6 times the current at full load, depending on the rating of induction motor, as compared to no load current.

That may:

- Make a short circuit in winding of motor.
- Reduce the performance and default age of motor.
- Absorption the energy from the grid.
- Overmuch the heat degree of motor that will make damage.

1-3 Objectives:

The purpose of this thesis is studying the different method of starting 3-ph induction motor and suggest soft starting method using voltage controller by using solid state switching device because this method is simple and easy for working, that by increase the voltage gradually as well as speed .

This method has some advantages :

- The vast improvement in efficiency relative to the primary resistance starter, due to the low on state voltage of the solid state switches.
- Typically, the power dissipation in the starter, during start, will be less than 1% of the power dissipated in a primary resistance starter during start.
- The average voltage can be easily altered to suit the required starting conditions.
- By variation of the conduction angle, the output voltage can be increased or reduced, and this can be achieved automatically by the control electronics.

1-4 Methodology:

- Theoretically, by using matlab/simulink compare between the direct on line method and solid state method .

1-5Project Layout:

The research in this project in given in s five chapter.Chapter one introduces an introduction and background about the starting of the 3-phase induction motor.Also, it given a note about the project problem, objective, methodology. Chapter two give details about the 3-phase induction motor. It shows the construction, operation and performance characteristic of the 3-phase induction motor. and introduces the conventional methods, and electronic method are also considered. Modeling and simulation of soft-starting using voltage controller based on solid state devices are given in chapter three.Chapter four Simulation results and comparison between direct conduction of the induction motor and the soft starter .Conclusion and recommendations are given in chapter five .References are given at the end of the project.

Chapter Two

The Three-Phase Induction Motor

2-1 Introduction:

The popularity of 3 phase induction motors on board ships is because of their simple, robust construction, and high reliability factor in the sea environment. A 3 phase induction motor can be used for different applications with various speed and load requirements. Electric motors can be found in almost every production process today. Getting the most out of your application is becoming more and more important in order to ensure cost-effective operations. The three-phase induction motors are the most widely used electric motors in industry. They run at essentially constant speed from no-load to full-load. However, the speed is frequency dependent and consequently these motors are not easily adapted to speed control. We usually prefer d.c.motors when large speed variations are required. Nevertheless, the 3-phase induction motors are simple, rugged, low-priced, easy to maintain and can be manufactured with characteristics to suit most industrial requirements. Like any electric motor, a 3-phase induction motor has a stator and a rotor. The stator carries a 3-phase winding (called stator winding) while the rotor carries a short-circuited winding (called rotor winding). Only the stator winding is fed from 3-phase supply. The rotor winding derives its voltage and power from the externally energized stator winding through electromagnetic induction and hence the name. The induction motor may be considered to be a transformer with a rotating secondary and it can, therefore, be described as a “transformer type” a.c.machine in which electrical energy is converted into mechanical energy.

The Advantages of three-phase induction motor

- It has simple and rugged construction.
- It is relatively cheap.
- It requires little maintenance
- It has high efficiency and reasonably good power factor.
- It has self-starting torque.

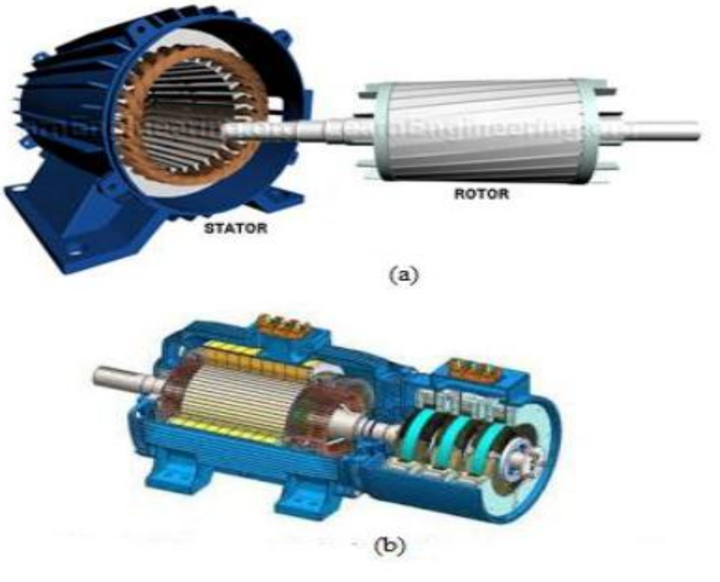
Disadvantages of three-phase induction motor

- It is essentially a constant speed motor and its speed cannot be changed easily.
- Its starting torque is inferior to d.c. shunt motor.

2-2 Construction:

The three phase induction motor is the most widely used electrical motor. Almost 80% of the mechanical power used by industries is provided by three phase induction motors because of its simple and rugged construction, low cost, good operating characteristics, absence of commutator and good speed regulation. In three phase induction motor the power is transferred from stator to rotor winding through induction. The Induction motor is also called asynchronous motor as it runs at a speed other than the synchronous speed. Like any other electrical motor induction motor also have two main parts namely rotor and stator. A 3-phase induction motor has two main parts, stator and rotor. The rotor is separated from the stator by a small air-gap which ranges from 0.4 mm to 4 mm, depending on the power of the motor.The main body of the Induction Motor comprises of two major parts as shows in Fig(2.1):

I. Shaft for transmitting the torque to the load. This shaft is made up of steel.
II. ii. Bearings for supporting the rotating shaft.
III. iii. One of the problems with electrical motor is the production of heat during its rotation. In order to overcome this problem we need fan for cooling.
IV. iv. For receiving external electrical connection Terminal box is needed.
V. v. There is a small distance between rotor and stator which usually varies from 0.4 mm to 4 mm. Such a distance is called air gap.



Fig(2.1) Three phase induction motor (a) Squirrel cage rotor (b) Slip ring rotor.

2-2-1. Stator

Stator: As its name indicates stator is a stationary part of induction motor. A stator winding is placed in the stator of induction motor and the three phase supply is given to it. Stator is made up of number of stampings in which different slots are cut to receive 3 phase winding circuit which is connected to 3 phase AC supply. The three phase windings are arranged in such a manner in the slots that they produce a rotating magnetic field after AC supply is given to them. The windings are wound for a definite number of poles depending upon the speed requirement, as speed is inversely proportional to the number of poles, given by the formula:

$$Ns = \frac{120F}{P}$$

Where

Ns= synchronous speed

f = Frequency

p = no. of poles

Fig(2.2) Stator of three phase induction motor.

It consists of a steel frame which encloses a hollow, cylindrical core made up of thin laminations of silicon steel to reduce hysteresis and eddy current losses. A number of evenly spaced slots are provided on the inner periphery of the laminations [See Fig(2-2)]. The insulated connected to form a balanced 3-phase star or delta connected circuit. The 3-phase stator winding is wound for a definite number of poles as per requirement of speed. Greater the number of poles, lesser is the speed of the motor and vice-versa. When 3-phase supply is given to the stator winding, a rotating magnetic field of constant magnitude is produced. This rotating field induces currents in the rotor by electromagnetic induction.

a) Stator of Three Phase Induction Motor

The stator of the three phase induction motor consists of three main parts:

i. Stator Frame

It is the outer most part of the three phase induction motor. Its main function is to support the stator core and the field winding. It acts as a covering and it provid

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0e protection and mechanical strength to all the inner parts of the induction motor. The frame is either made up of die cast or fabricated steel. The frame of three phase induction motor should be very strong and rigid as the air gap length of motorist very small, otherwise rotor will not remain concentric with stator, which will give rise to unbalanced magnetic pull.

ii. Stator Core

The main function of the stator core is to carry the alternating flux. In order to reduce the eddy current loss, the stator core is laminated. These laminated types of structure are made up of stamping which is about 0.4 to 0.5 mm thick. All the stamping are stamped together to form stator core, which is then housed in stator frame. The stamping is generally made up of silicon steel, which helps to reduce the hysteresis loss occurring in motor.

iii. Stator Winding or Field Winding

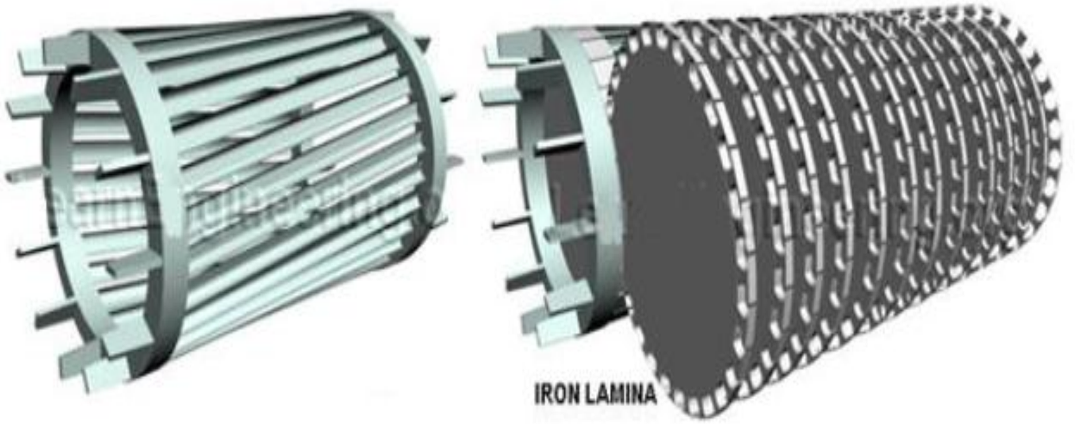
The slots on the periphery of stator core of the motor carries three phase windings. This three phase winding is supplied by three phase ac supply. The three phases of the winding are connected either in star or delta depending upon which type of starting method is used. The squirrel cage motor is mostly started by star – delta stator and hence the stator of squirrel cage motor is delta connected. The slip ring three phase induction motor are started by inserting resistances so, the stator winding of slip ring induction can be connected either in star or delta. The winding wound on the stator of three phase induction motor is also called field winding and when this winding is excited by three phase ac supply it produces a rotating magnetic.

2-2-2 Rotor:

The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft. Rotor consists of cylindrical laminated core with parallel slots that carry conductor bars. Conductors are heavy copper or aluminum bars which fits in each slots. These conductors are brazed to the short circuiting end rings. The slots are not exactly made parallel to the axis of the shaft but are slotted a little skewed for the following reason, They reduces magnetic hum or noise and They avoid stalling of motor. The rotor, mounted on a shaft, is a hollow laminated core having slots on its outer periphery. The winding placed in these slots (called rotor winding) may be one of the following two types: Squirrel cage type and Wound type

2-2-2-1 Squirrel cage rotor:

Squirrel cage three phase induction motor: The rotor of the squirrel cage three phase induction motor is cylindrical in shape and have slots on its periphery. The slots are not made parallel to each other but are bit skewed (skewing is not shown in the figure of squirrel cadge rotor beside) as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of motor more smooth and quieter. The squirrel cage rotor consists of aluminum, brass or copper bars. These aluminum, brass or copper bars are called rotor conductors and are placed in the slots on the periphery of the rotor. The rotor conductors are permanently shorted by the copper or aluminum rings called the end rings. In order to provide mechanical strength these rotor conductor are braced to the end ring and hence form a complete closed circuit resembling like a cage and hence got its name as “squirrel cage induction motor”. The squirrel cage rotor winding is made symmetrical. As the bars are permanently shorted by end rings, the rotor resistance is very small and it is not possible to add external resistance as the bars are permanently shorted. The absence of slip ring and brushes make the construction of Squirrel cage three phase induction motor very simple and robust and hence widely used three phase induction motor. These motors have the advantage of adapting any number of pole pairs. The below diagram shows squirrel cage induction rotor having aluminum bars short circuit by aluminum end rings. It consists of a laminated cylindrical core having parallel slots on its outer periphery. One copper or aluminum bar is placed in each slot. All these bars are joined at each end by metal rings called end rings [See Fig(2-3)]. This forms a permanently short-circuited winding which is indestructible. The entire construction (bars and end rings) resembles a squirrel cage and hence the name. The rotor is not connected electrically to the supply but has current induced in it by transformer action from the stator. Those induction motors which employ squirrel cage rotor are called squirrel cage induction motors. Most of 3-phase induction motors use squirrel cage rotor as it has a remarkably simple and robust construction enabling it to operate in the most adverse circumstances. However, it suffers from the disadvantage of a low starting torque. It is because the rotor bars are permanently short-circuited and it is notpossible to add any external resistance to the rotor circuit to have a large starting torque.



Fig(2-3) Squirrel cage rotor.

Advantages of squirrel cage induction rotor

i. Its construction is very simple and rugged.

ii. As there are no brushes and slip ring, these motors requires less maintenance.

2-2-2-2 Wound rotor:

Slip ring or wound three phase induction motor : In this type of three phase induction motor the rotor is wound for the same number of poles as that of stator but it has less number of slots and has less turns per phase of a heavier conductor. The rotor also carries star or delta winding similar to that of stator winding. The rotor consists of numbers of slots and rotor winding are placed inside these slots. The three end terminals are connected together to form star connection. As its name indicates three phase slip ring induction motor consists of slip rings connected on same shaft as that of rotor. The three ends of three phase windings are permanently connected to these slip rings. The external resistance can be easily connected through the brushes and slip rings and hence used for speed control and improving the starting torque of threephase induction motor. The brushes are used to carry current to and from the rotor winding. These brushes are further connected to three phase star connected resistances. At starting, the resistance are connected in rotor circuit and is gradually cut out as the rotor pick up its speed. When the motor is running the slip ring are shorted by connecting a metal collar, which connect all slip ring together and the brushes are also removed. This reduces wear and tear of the brushes. Due to presence of slip rings and brushes the rotor construction becomes somewhat complicated therefore it is less used as compare to squirrel cage induction motor. It consists of a laminated cylindrical core and carries a 3- phase winding, similar to the one on the stator [See Fig(2-4)]. The rotor winding is uniformly distributed in the slots and is usually star-connected. The open ends of the rotor winding are brought out and joined to three insulated slip rings mounted on the rotor shaft with one brush resting on each slip ring. The three brushes are connected to a 3-phase star-connectedrheostat as shown in Fig(2-5)At starting, the external resistances are included in the rotor circuit to give a large starting torque. These resistances are gradually reduced to zero as the motor runs up to speed. The external resistances are used during starting period only. When the motor attains normal speed, the three brushes are short-circuited so that the wound rotor runs like a squirrel cage rotor.

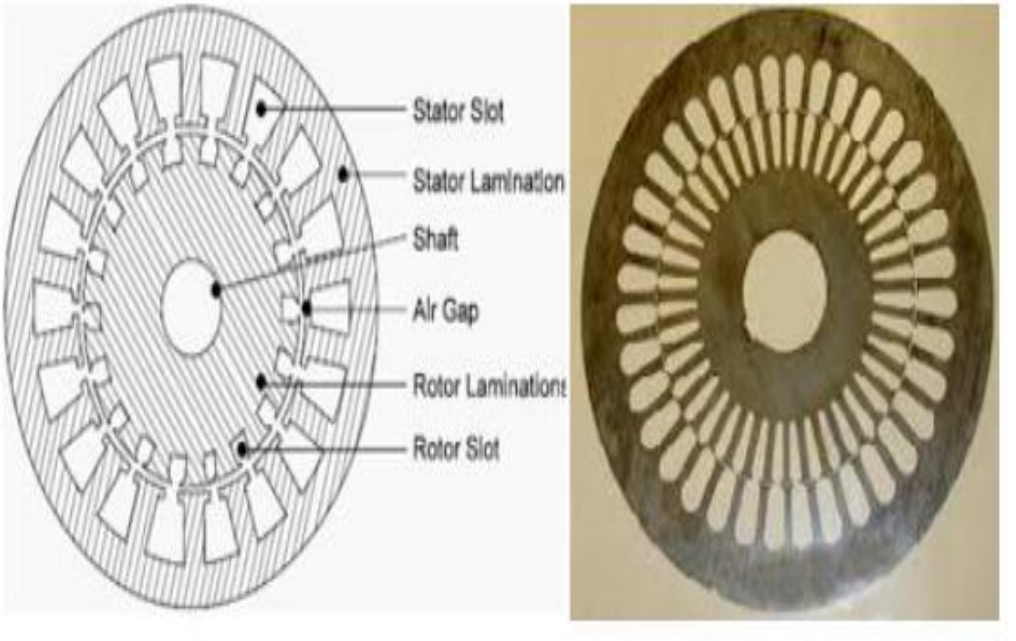


Fig (2-4) Lamination of stator and rotor.

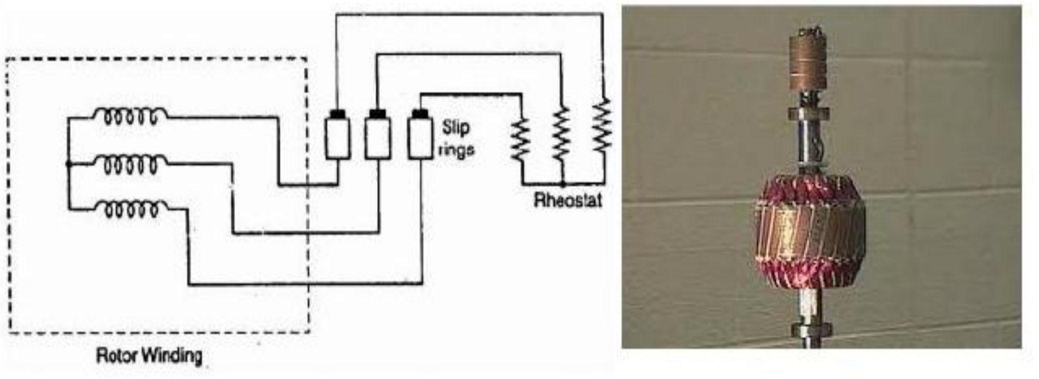


Fig (2-5) Slip ring rotor.

Advantages of slip ring induction motor :

A. It has high starting torque and low starting current.

B. Possibility of adding additional resistance to control speed.

Table 1.1: Difference between Slip Ring and Squirrel Cage Induction Motor

SLIP RING OR PHASE WOUND	SQUIRREL CAGE
Construction is complicated due to presence of slip ring and brushes	Construction is very simple
The rotor winding is similar to the stator winding	The rotor consists of rotor bars which are permanently shorted with the help of end rings
We can easily add rotor resistance by using slip ring and brushes	Staring torque is low and cannot be improved
Slip ring and brushes are present	Slip ring and brushes are absent
Frequent maintenance is required due to presence of brushes	Less maintenance is required

The construction is complicated and the presence of brushes and slip ring makes the motor more costly	The construction is simple and robust and it is cheap as compared to slip ring induction motor
This motor is rarely used only 10 % industry uses slip ring induction motor	Due to its simple construction and low cost. The squirrel cage induction motor is widely used
Rotor copper losses are high and hence less efficiency	Less rotor copper losses and hence high efficiency
Speed control by rotor resistance method is possible	Speed control by rotor resistance method is not possible
Slip ring induction motor are used where high starting torque is required i.e in hoists, cranes, elevator etc	Squirrel cage induction motor is used in lathes, drilling machine, fan, blower printing machines etc

2-2-3 Operation principle:

In an AC motor, there's a ring of electromagnets arranged around the outside (making up the stator), which are designed to produce a rotating magnetic field. Inside the stator, there's a solid metal axle, a loop of wire, a coil, a squirrel cage made of metal bars and interconnections (like the rotating cages people sometimes get to amuse pet mice), or some other freely rotating metal part that can conduct electricity. Unlike in a DC motor, where you send power to the inner rotor, in an AC motor you send power to the outer coils that make up the stator. The coils are energized in pairs, in sequence, producing a magnetic field that rotates around the outside of the motor. The rotor, suspended inside the magnetic field, is an electrical conductor. The magnetic field is constantly changing (because it's rotating) so, according to the laws of electromagnetism (Faraday's law, to be precise), the magnetic field produces (or induces, to use Faraday's own term) an electric current inside the rotor. If the conductor is a ring or a wire, the current flows around it in a loop. If the conductor is simply a solid piece of metal, eddy currents swirl around it instead. Either way, the induced current produces its own magnetic field and, according to another law of electromagnetism (Lenz's law) tries to stop whatever it is that causes it—the rotating magnetic field—by rotating as well. (You can think of the rotor frantically trying to"catch up" with the rotating magnetic field in an effort to eliminate the difference in motion between them.) Electromagnetic induction is the key to why a motor like this spins—and that's why it's called an induction motor. An electrical converts electrical energy into mechanical energy which is then supplied to different types of loads. A.C. motors operates on A.C. supply, and they are classified into synchronous, single phase and three phase induction, and special purpose motors. The operation principle of a three phase induction motors is based on the production of rotating magnetic field.[3]

2-3 Electrical and Mechanical Performance:

The angle between the stator voltage (V) and stator current (Is) is known as the power factor angle represented by the angle (φ), and can be measured at the stator terminals . The stator current is the vector sum of the magnetizing current IM, which is in quadrature to the voltage, and the torque producing current IR, which is in phase with the voltage. These two currents are notreadily available for measurement. Consequently, the total apparent motor power "S" also comprises two components, which are in quadrature to one another.

Apparatus power " S " can be obtained by:

$S = P + jQ$ ……………………………………………….………(2-1)

Active power " P " can be calculated by

$Pin = 3 \times V \times I_S \cos\varphi$……....……………………….........(2-2)

Reactive power " Q " can be calculated by

$Q = 3 \times V \times I_S \times \sin\varphi$…………………………….……...(2-3)

Where:

S ≡ Total apparent power of the motor in (VA)

P_{in} ≡ Total Active power of the motor in (W)

Q ≡ Total Reactive power of the motor in (VAR)

V ≡ phase voltage of the power supply in (V)

I_S ≡ Stator current of the motor in (amps)

φ ≡ Phase angle between V and I_S (power factor = cosφ)

Not all the electrical input power Pin emerges as mechanical output power P. A small portion of this power is lost in the stator resistance ($3.I_S^2R_S$) and the core losses ($3.I_c^2R_C$) and the rest crosses the air gap to do work on the rotor. An additional small portion is lost in the rotor ($3.I'^2_R.R'_R$). The balance (rest) is the mechanical output power P_m

Power flow diagram of 3-phase induction motor as shown in fig(2-6)

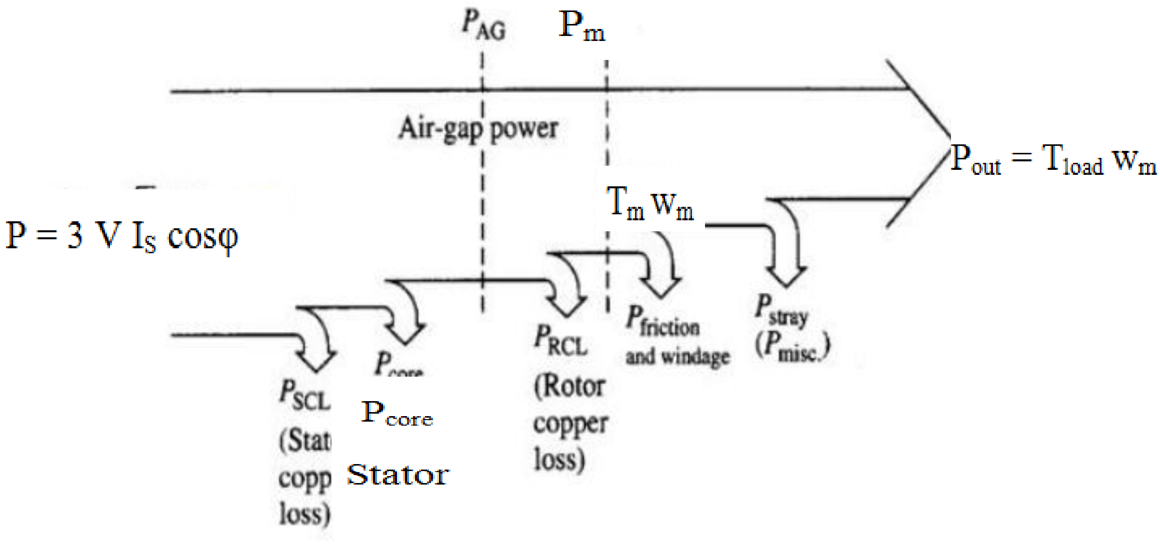


Fig (2-6) :Power flow of induction motor

Another issue to note is that the magnetizing path of the equivalent circuit is mainly inductive. At no-load, when the slip is small (slip s ⇒ 0), the equivalent circuit shows that the effective rotor resistance (R'_R/s ⇒ infinity). Therefore, the motor will draw only no-load magnetizing current. As the shaft becomes loaded and the slip increases, the magnitude of R'_R/s decreases and the current rises sharply as the output torque and power increases. This affects the phase relationship between the stator voltage and current and the power factor cosφ. At no-load, the power factor is low, which reflects the high component of magnetizing current. As mechanical load grows and slip increases, the effective rotor resistance falls, active current increases and power factor improves.

When matching motors to mechanical loads, the two most important considerations are the torque and speed. The torque–speed curve, which is the basis of illustrating how the torque changes over a speed range, can be derivedfrom the equivalent circuit and the equations above. The developed torque of the motor can be expressed in terms of the speed as follows

$$T_e = \frac{3 \quad V^2 \frac{R_R'}{s}}{2\pi \frac{n_S}{60}\left[\left(R_S + \frac{R_R'}{s}\right)^2 + \left(X_S + X_R'\right)^2\right]} \qquad \text{.......................................}(2\text{-}4)$$

Where:

s ≡ slip

n_S≡ Synchronous speed

R'R ≡ Rotor resistance referred to the stator

RS ≡ stator resistance

X'R ≡ Rotor reactance referred to the stator XS ≡ stator reactance

And the curve of this equation in fig(2-7) which shows how the motor developed torque T_e varies when the motor runs from standstill to full speed under a constant supply voltage and frequency:

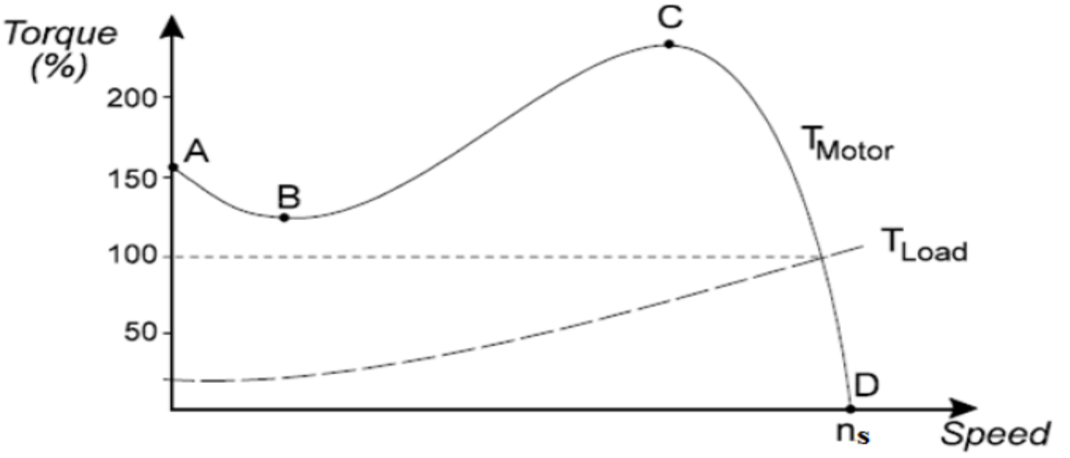


Fig (2-7) : Torque-speed curve of induction motor

Where:

A: is called the breakaway starting torque .

B: is called the pull-up torque.

C: is called the pull-out torque (or breakdown torque or maximum torque).

D: is the synchronous speed (zero torque)

Synchronous speed can be calculated as :

$$N_S = \frac{120\,f}{p} \quad \text{...} (2\text{-}5)$$

Where :

f ≡ Supply frequency P ≡ Number of poles

To control the motor speed, the main methods are summarized as follow:

a) Changing of supply voltage

b) Changing of supply frequency

c) Changing of number of poles

d) Changing of stator or rotor resistance [4]

2.3.1Rotor current and power factor:

Fig (2-8) shows the circuit of a 3-phase induction motor at any slip s. The rotor is assumed to be of wound type and star connected. Note that rotor e.m.f/phase and rotor reactance/phase are sE2 and sX2 respectively. The rotor resistance/phase is R2 and is independent of frequency and, therefore, does not depend upon slip. Likewise, stator winding values R1 and X1 do not depend upon slip. Since the motor represents a balanced 3-phase load, we need consider one phase only; the conditions in the other two phases being similar.

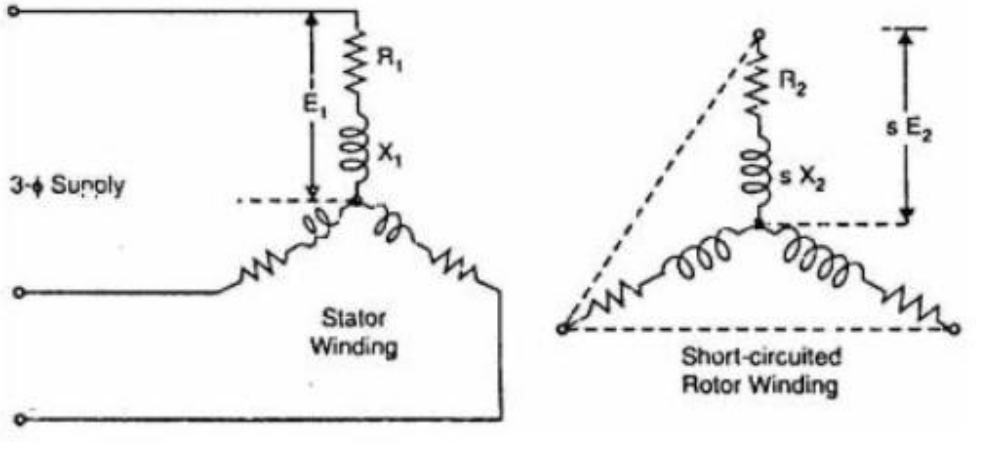


Fig (2-8)The circuit of a 3-phase induction motor at any slip s.

Fig (2-9)one phase of the rotor circuit at standstill.

At standstill.Fig(2-9)shows one phase of the rotor circuit at standstill.

Rotor current $I2 = \frac{E2}{Z2} = \frac{E2}{\sqrt{R2^2 + X2^2}}$

$$power\ factor = \frac{R2}{\sqrt{R2^2 + X2^2}}$$

At running condition

Rotor current $I2 = \frac{sE2}{Z2} = \frac{sE2}{\sqrt{R2^2 + (sX2)^2}}$

2-4 The application of 3-phase induction motor:

2-4-1 Application of squirrel cage induction motor:

Squirrel cage induction motor is used in lathes, drilling machine, fan, blower printing machines etc.

2-4-2 Application of Slip ring induction motor:

The use of induction motors particularly the Squirrel cage rotor has increased tremendously since the day of its invention. The three phase induction motors are the reliable machines of industry because of its robust construction, simplicity in design and cost effectiveness, reliability, high efficiency and good self-starting capability and easy maintenanceThese factors have promoted standardization and development of a manufacturing infrastructure that has led to a vast installed base of motors. It has been estimated that 70% to 80% of all electricity in the world is consumed by these motors. It has become the most widely used machine ever invented by man as it now finds application in virtually all aspects of domestic and industrial operations. Single phase and three phase configurations abound all over the world. In homes, the motor is utilized in appliances such as washer, dryers, air conditioning unit, fans, grinding machines, blenders, video CD players, Video cassette recorders and audio tape players. Motor are found even in wristwatch drives, in computer mother boards to drive fans to cool the processor, while in the industries (oil and gas) they find applications in compressors, fans, pumps, blowers, conveyors. The electric motors utilized in all sorts of drives and also as a major component of industrial process, pumping water into a tank as well as pumping crude oilSlip ring induction motor are used where high starting torque is required i.e in hoists, cranes, elevator etc. [3]

2-5 Starting Method Of 3-Phase Induction Motor:

2-5-1 The conventional method:

a) Direct-On-Line (DOL):

DOL is the traditional and simplest method of motor starting, and most other methods are baselined against it. It is also often called across the line start. This method is thedirect connection of the terminal voltage to he motor stator with no additionalcomponents, and also for this reason is most economical in terms of installation cost andease of use. It is also one of most reliable and robust methods. Of all the starting methodsit produces the highest inrush current, usually six to eight times the rated current, and thehighest starting torque; and due to the high starting torque it has the shortest accelerationtime. The DOL method is most commonlyused for small motors relative to the size of the generation and system, due to the fact that the startup of a small motor will only have a low impact on the system, and in particularthe voltage drop. Other drawbacks include the mechanical stress put on the motor's load and the low startup efficiency due to the high reactive power consumedat startup. This approach is typically not suitable for large motors.The power and control circuits of induction motor with DOL starter are shown in Fig (2.10)

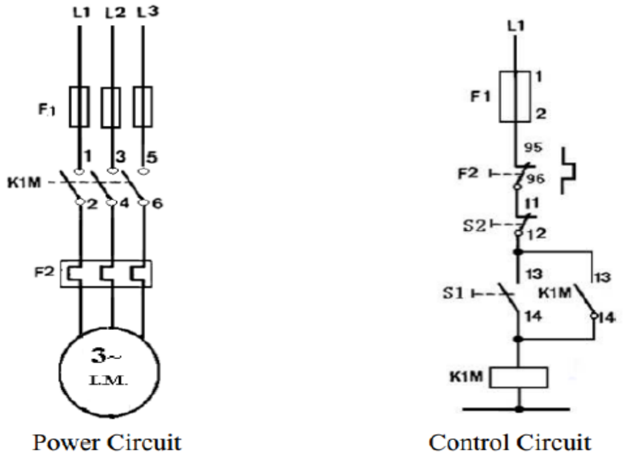


Fig 2.10Power and control circuits of three phase induction motor with DOL starter

b) Primary Resistor or Reactor:

A switchable primary series resistor or reactor bank can be added at the motor terminals to limit the current or limit change in the current, respectively. The resistor bank will cause a drop in voltage across it reducing the current. The heat dissipated from the resistor also needs to be taken into consideration. Series resistor starting is usually only performed for small motors. When using a series reactor bank, it will oppose the inrush current initially and reduce the terminal voltage proportionally. The most advantageous characteristic of the series reactor starting is that the voltage increases over time as a function of the rate of change of the current without additional control. The added reactance will also further increase the starting reactive power and thus lower the starting efficiency. Switching transients will also occur if it is connected in an open-circuit. [2] This simple is one of the primary resistor or reactor into operation. Fig 2.11 shows that there is a resistor for each of the three phases of current. Resistors resist the flow of current. When the motor is started, the resistors resist the current flow resulting in a voltage drop . Approximately 70% of the line voltage is sent to the motor terminals at startup. A timer closes a set of contacts after the motor has accelerated to a pre-determined point. This removes the resistors from the circuit and lets full power through to the motor.[6]

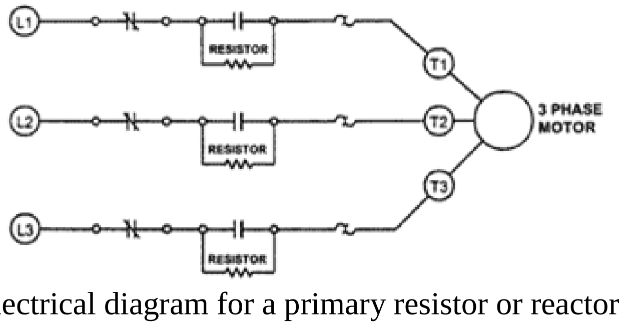


Fig 2.11Typical electrical diagram for a primary resistor or reactor reduced voltage starter

c) Auto Transformer:

An autotransformer uses tap changers to reduce the low voltage as needed on the lowside connected to the motor terminal. Therefore, the current can be reduced duringstartup, however the torque is also reduced as the square of the voltage and needs to betaken into consideration to ensure enough torque is supplied during acceleration. It was claimed that 10% of the full load torque emargin should be supplied at all points on the speed-torque characteristic curve. As themotor speeds up, the line is switched to the full voltage. Common taps range from 50-80% of the rated voltage. IEEE Standard 399-1997 provides a table describing the currents at the typical 50%, 65%, and 80% of fullvoltage as 25%, 42%, and 64% of the current realized at fullvoltage during startup, respectively. A practical advantage of the autotransformer is theability to provide different tap changers so that a wide range of applications, which vary intheir starting torque and inrush current needs, can be performed. The star-delta starter iselectrically equivalent to an autotransformer tapped at 57.7%. However, autotransformershave a higher cost than other conventional electromechanical starting methods. Also Auto transformer starting is one of the most effective methods of soft starting. It is preferred over primary resistor starting when the starting current is drawn from the line must be held to a minimum, yet the maximum starting torque per line amp is required. Instead of using resistors, this starter uses taps on transformer windings to control the power input to the motor. Taps are usually set up to provide 80%, 65% and 50%of the line voltage, respectively. These taps provide built-in flexibility. Activating any one of three taps on the windings allows different amounts of current to the motor.[2]

In Fig 2.12the motor is receiving voltage through the second of the three taps. This type of starter can supply more current to the motor than other soft starters, while keeping voltage low. The transformer steps up the current making it greater than the line current input.Fig 2.12shows the connection of a 3-phase induction motor with auto transformer starter.[6]

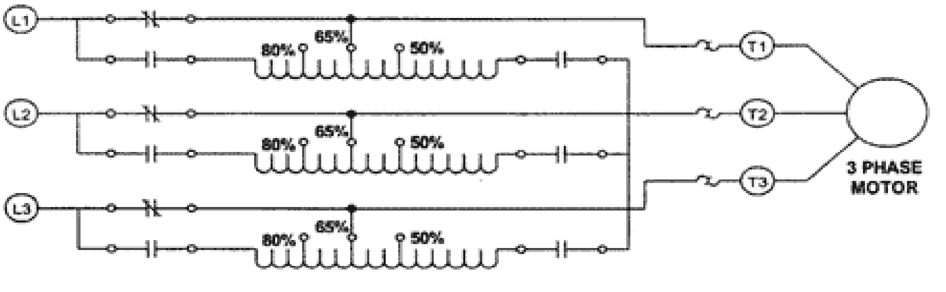


Fig 2.12 Typical electrical diagram for an auto transformer reduced voltage starter.

d) Star-Delta :

The star-delta (wye-delta) starting method controls whether the lead connections fromthe motor are configured in a star or delta electrical connection. The initial connectionshould be in the star pattern that results in a reduction of the line voltage by a factor of$1/\sqrt{3}$ (57.7%) to the motor and the current is reduced to 1/3 of the current at full voltage,but the starting torque is also reduced 1/3 to 1/5 of the DOL starting torque. The motor must be delta connected at rated voltage. The transition fromstar to delta transition usually occurs once nominal speed is reached, but is sometimesperformed as low as 50% of nominal speed. The star-delta method is usually only applied to low to medium voltage motors.The operation of the star-delta method is simple and rugged, and is relatively cheap compared to other reduced voltage methods.Star-Delta starting requires the motor have connection points to each of the three coil windings. These are specially wound with six leads for Delta and Star connections.[2]

Fig(2.14) illustrates thewindingconfigurations as they are connected at startup. It is called the Star Configuration because it is shaped like the letter "Y". This connection results in line voltage applied to an electrically larger winding, reducing the line current. It provides 33% of the normal starting torque and 58% of the normal starting voltage After a pre-determined time (determined by the timer), the starter electrically switches the windings over to a Delta Configuration. The windings are connected in their normal run configuration with every winding receiving full voltage. An important consideration with this starter is at the transition point, where the starter switches from Star to Delta, the motor must disconnect and reconnect. This type of Star Delta starter is known as open transition and can have a momentary hitch in operation, allowing a momentary current inrush .Closed transition is another type of Star-Delta starter. It uses an extra contactor and set of resistors to keep the motor on-line during the transition. It eliminates the inrush concern and the cost is slightly higher than the open transition versionFig 2.13and 2.14show the connection of a 3 phase induction motor with a star – delta starter.[6]

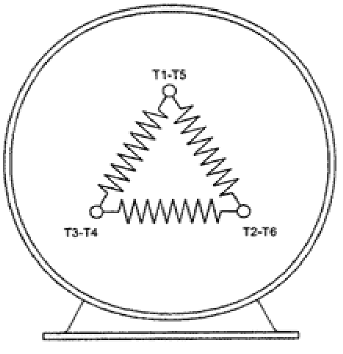


Fig 2.13 Delta configuration as motor nears full speed

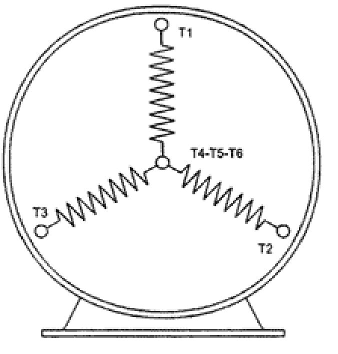


Fig 2.14 Star configuration at start-up

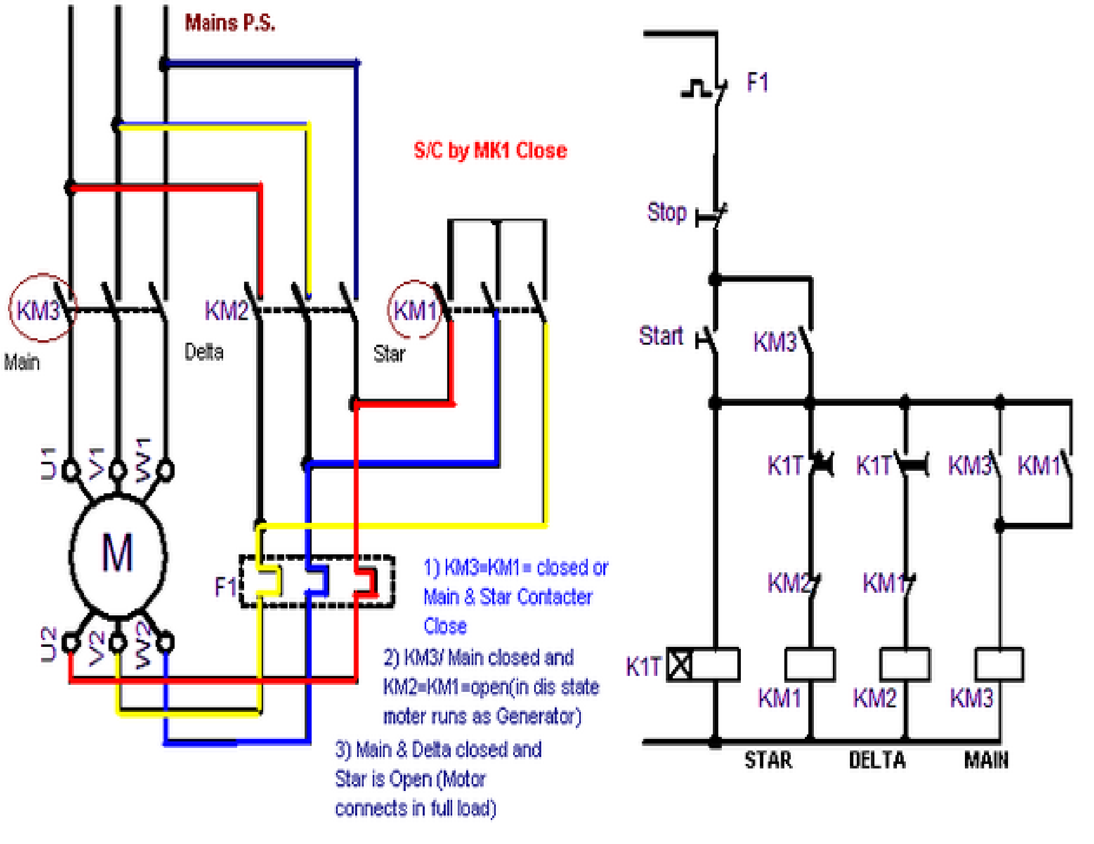


Fig 2.15Power and control circuit of three phase induction motor with star delta starter.

2.5.2 Electronic methods:

The newest startingmethods is the solid state type. It replaces mechanical components with electrical components. The key is the Silicon Control Rectifier SCR, IGPT or traic. During motor acceleration, these devices control motor voltage, current and torque. Fig2.16 shows how the solid state soft starters control the current draw and the starting torque. The SCR has the ability to rapidly switch heavy currents and so can IGPT and triac. This allows the soft starter to provide smooth step less acceleration the smoothest of any of the soft start.

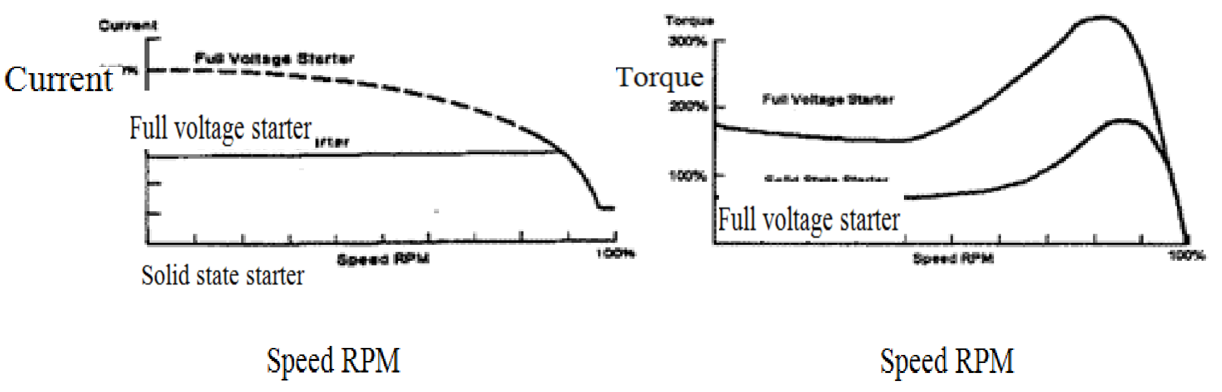


Fig 2.16 Current versus motor speed and torque versus motor speed

2-5-2-1 Usingthyristor:

Fig 2.17 shows typical single-phase and3-phase circuits. The control unit in each case comprises apulse generator which is switched by a stable circuit ofsome kind in such a way as to give only 'off' and 'on'conditions without any phase control, so that the rectifiergroups function simply as open or continuously closedswitches. Feedback into the pulse-generator control circuitfrom a current transformer in series with the motor providesautomatic over-current protection by inhibiting the firingpulses in the event of an overload, conventional electronicprinciples being employed to obtain any inverse-time lawrequired to correspond to the thermal ratings of the motor.

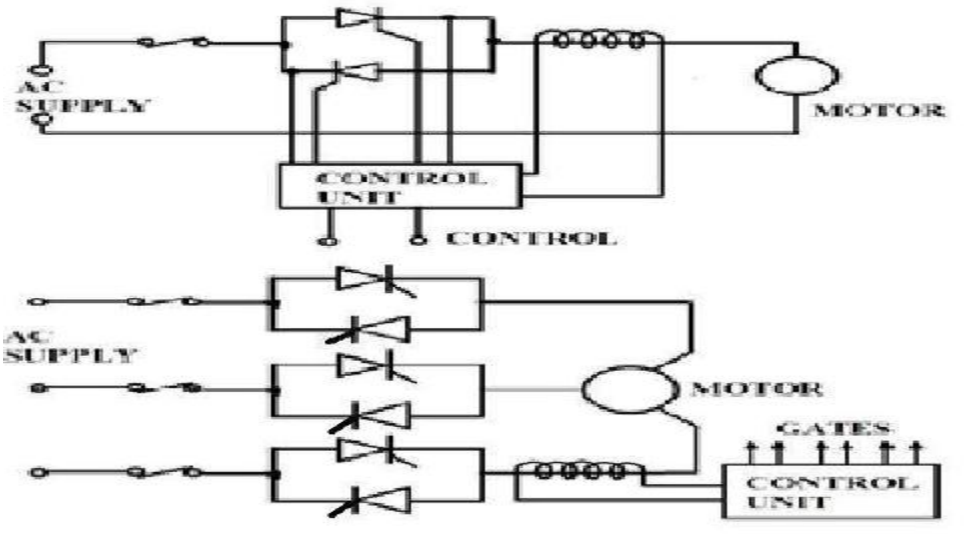


Fig 2.17 Electronic soft start of induction motor.[7]

2-5-2-2using IGBT:

The IGBT"s are used as the switches in this work because of their higher power rating and high efficiency. The Fig2.18 shows the block diagram of the entire system, the motor is connected to the soft starter at the starting and once the motor get its rated speed then the soft starter is disconnected and the motor drive system take the control over the motor. By using soft starter the controlled voltage is applied at the motor input so the motor is protected and life of motor increases.

The Fig 2.19 shows the block diagram of motor drive system. The motor drive system consists of a rectifier, inverter, controller and the filter units. In the inverter the IGBT"s are used as the switches. To operate these switches the gate pulses should be given. The control circuit gives the required gate pulses for the inverter switches, the dsPIC30F2010 is used as the controller. The motor drive system uses V/f control method. The Fig 2.20 shows the block diagram of a soft starter circuit. In the soft starter again the IGBT"s are used as the switches. It consists of zero crossing sensing, control circuit and soft starter (anti-parallel IGBt"s). The zero crossing is used to know where exactly the input voltage is crossing the zero point, depending upon the zero crossing of the input voltage the particular switch of the starter circuit is turned on. By controlling the gate pulses of the switches we are giving the controlled voltage at the motor input terminals.

The advantages of this method are:

oSmooth acceleration of motor .

o Small size of controller.

o Starting current can be adjusted to small value.

o Harmonics reduction is possible.

o Overall maintenance cost of motor reduces.[8]

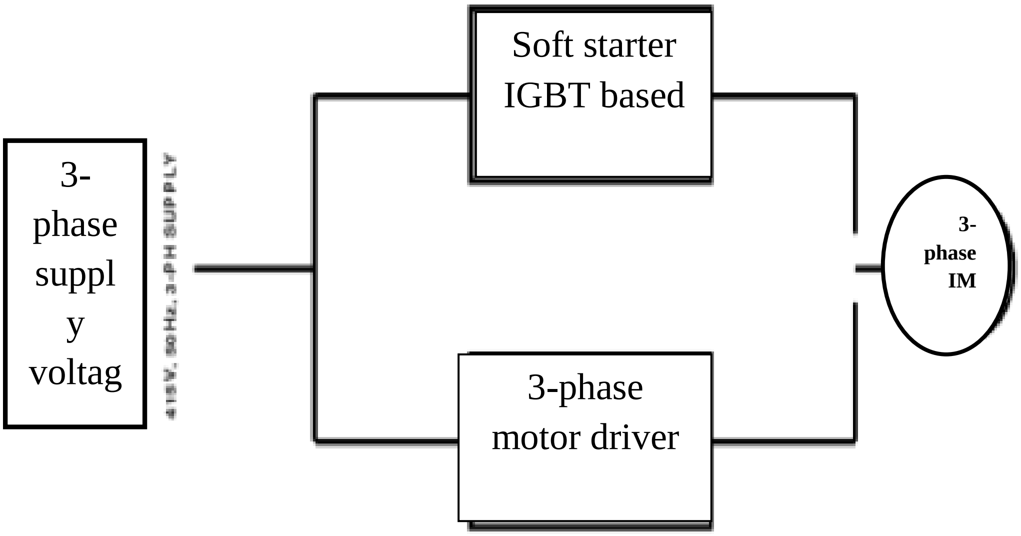


Fig 2.18 Block diagram of complete system

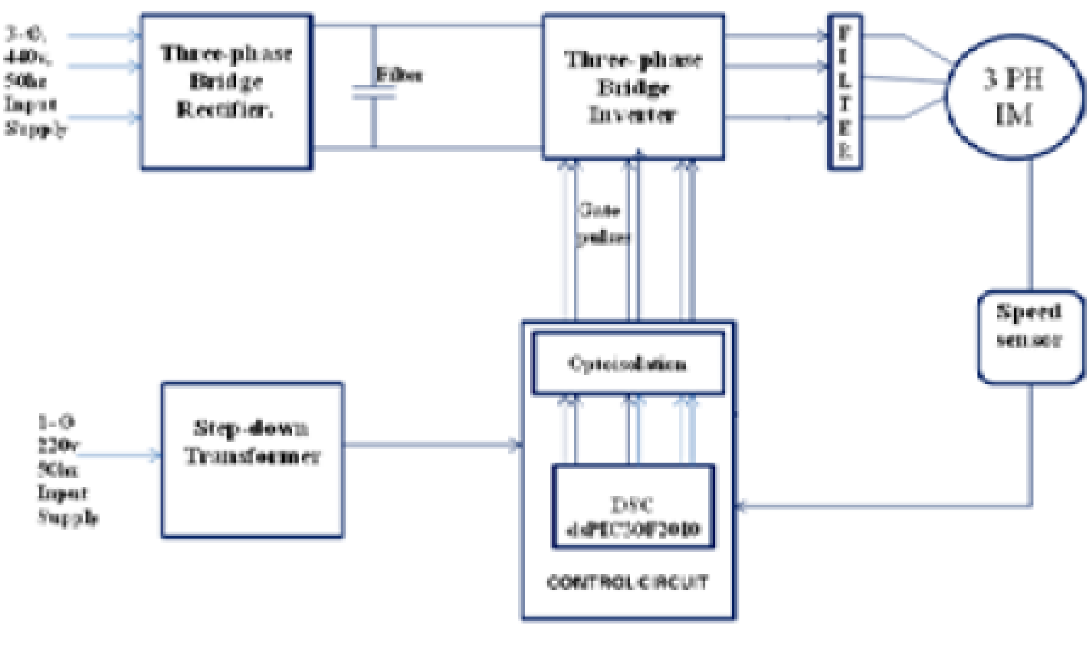


Fig 2.19Block diagram of motor drive system

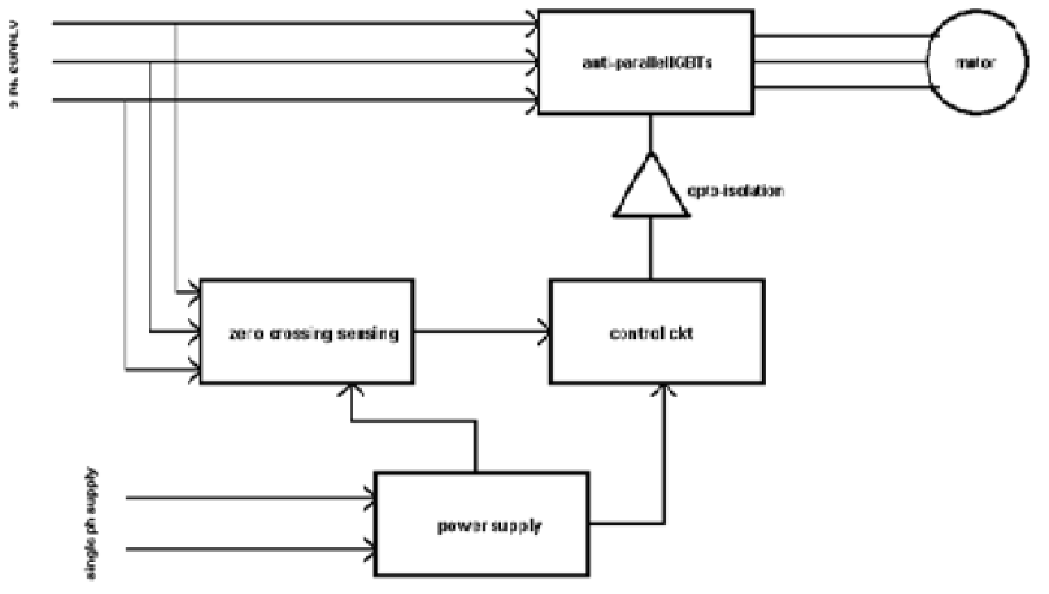


Fig 2.20 Block diagram of a soft starter

2-5-3 Comparison between conventional and electronic methods:

The star-delta (wyes-delta) and autotransformer approaches can be grouped together because of their similar effects through proportional reduction of the terminal voltage. The important tradeoff among these methods is there diced inrush current to the reduced starting torque. Ensuring sufficient starting torque and the starting time are important considerations. The primary resistance and primary reactance starters also have the same tradeoff between the inrush current and torque. But, if the primary impedance size is too large they will make the voltage and frequency dip worse. The size of the induction motor and the motor design characteristics (parameters)as compared to the size of the generator also must be taken into consideration when choosing the starter. The larger the size of the motor the more susceptible the starter is to possibly reducing the starting torque below the requirement.[4]

A soft starter consists of only a few main components. These are the thyristorsthat can regulate the voltage to the motor and the printed circuit board assembly(PCBA) that is used to control the thyristors. In addition to this, there are the heat sink and fans to dissipate the heat, current transformers to measure the current and sometimes display and keypad and then the housing itself. Also by variation of the conduction angle, the output voltage can be increased or reduced, and this can be achieved automatically by the control electronics. It is more and more common to offer integrated by-pass contacts in the main circuit minimizing the power loss in normal operation. Depending on the model of the soft starter, it can be equipped with a built-in electronic overload relay (EOL) eliminating the need for an external relay, PTC input,fieldbus communication possibilities etc.

2-6 Related Work:

1Mr. SatputeAkshaykumar, et al, Malegaon (Bk), Tal-Baramati, Dist-Pune, SavitribaiPhule Pune University, SOFT STARTING OF THREE PHASE INDUCTION MOTOR
This paper, present a soft starting of induction motor. At the time of starting three phase induction motor takes very large current and have low power factor. Due to high current, motor torque content ripples and transients. Due to transients and torque pulsation shaft of motor experiences jerk hence mechanical life of rotor reduces. In order to mitigate this adverse effect if starting current and torque pulsation in induction motor, a popular method is used which is electronically controlled soft starting of induction motor. Normally soft starters are used for avoiding this problems and soft start is achieved by increasing stator frequency. By using soft starter performance of induction motor is improved and also improved load torque characteristics.

Mr. TambeSagar,et al, Hobeii Normal University, Hobeipeoovince China ELECTRONIC SOFT START OF 3 PHASE INDUCTION MOTOR
The project is designed to provide a soft and smooth start to a 3 phase induction motor.The three phase induction motor during the initial starting condition draws up much higher current than its capacity and the motor instantly reaches the full speed. This results in a mechanical jerk and high electrical stress on the windings of the motor. Sometimes the windings may get burnt. The induction motor should start smoothly and gradually catch up the speed for a safer operation. This project is designed to give a soft start to the induction motor based on the SCR firing triggered by heavily delayed firing angle during starting and then gradually reducing the delay till it reaches zero voltage triggering. This results in low voltage during start and then gradually to full voltage. Thus the motor starts slowly and then slowly picks up to full speed. This project consists of a six anti-parallel SCRs, two for each phase, the output of which is connected to a set of lamps representing the coils of a 3 phase induction motor. The charging and discharging of capacitors is interfaced to comparators resulting in delayed firing pulses during start and then gradually reducing the delay till the motor runs at full speed. Output from the comparators is fed through opto-isolators to trigger the SCRs. Further the project can be enhanced by using IGBTs in place of SCRs with PWM control to reduce harmonic distortions often encountered in SCR triggering mechanism.

Lishuefachao   Department of Elcctronics, Hobeii Normal University, Hobeipeoovince China

Design and Simulation of Three-phase AC Motor Soft-start .

Ac motor as a motor soft starter auxiliary circu equipment, can be in ac motor no-load or low load, automatic thus regulation input voltage motor, and may not affect the motor torque. Soft starter for the market, and is engaged in each industry production enterprise welcome, although at present in price, performance and so on have certain difficulty, but with semiconductor devices development of manufacturing technology, and can foresee in the near future, the soft starter certainly become a kind of improving the necessary depth ac motor application equipment. This paper taking three-phase ac induction motor soft starter for research object, soft start analysis principle, design soft starter main circuit and circuit other system module, and application of Matlab simulation, the simulation results indicated that soft start was used in motor start advantages

Chapter three
Simulation

3-1 Introduction:

The use of induction motors particularly the Squirrel cage rotor has increased tremendously since the day of its invention. The three phase induction motors are the workhorse of industry because of its robust construction, simplicity in design and cost effectiveness, reliability, high efficiency and good self-starting capability and easy maintenance [13-14],[16-17],[21]. These factors have promoted standardization and development of a manufacturing infrastructure that has led to a vast installed base of motors. It has been estimated that 70% to 80% of all electricity in the world is consumed by these motors. They are truly elegant machines in that there are no moving parts except the rotor, and there no brushes, commutators, or slip rings to wear out. It has become the most widely used machine ever invented by man as it now finds application in virtually all aspects of domestic and industrial operations. Single phase and three phase configurations abound all over the world. In homes, the motor is utilized in appliances such as washer, dryers, air conditioning unit, fans, grinding machines, blenders, video CD players, Video cassette recorders and audio tape players. Motor are found even in wristwatch drives, in computer mother boards to drive fans to cool the processor, while in the industries (oil and gas) they find applications in compressors, fans, pumps, blowers, conveyors. The electric motors utilized in all sorts of drives and also as a major component of industrial process, pumping water into a tank as well as pumping crude oil. The electric motor exist in ratings ranging from a few watts to hundreds of megawatts. Although recent research aims at using it for generator applications, but it is best used as motors [20].

In recent years the control of high performance induction motor for general industrial applications and area of production has received a lot of research interest, [12],[15],[22]. Induction motor modeling has continuously attracted the attentions of power system engineers and researchers not only because such motors are made and used in larger numbers but also due to their variant modes of operation both under steady state and transient state, [26]. Various models have been developed and the D-Q axis model for the study of transient behavior has been well tested and proven to be reliable and accurate, [11], [21]. Induction motor variable speed drives, soft starters are also essential components in every modern induction motor drives system. The squirrel cage induction motor is widely deployed in many applications. Whenever an induction motor is started, the electrical system experiences a current surge, and the mechanical system experiences a torque surge. With line voltage applied to the motor, the current can be anywhere between three to eight times the motor full-load current depending on the design characteristics [18-19], [23]. These current and torque surges can be reduced substantially by reducing the voltage supplied to the motor during starting. Soft starter controller offer many advantages over conventional starters such as

- Smooth starting.
- Soft starting and stopping.
- Current peaks are reduced.
- Line voltage fluctuations are avoided when starting
- The line supply is relieved.
- The mechanical stress on the drive is reduced.
- Simple to handle.
- Significant amount of space and wiring is saved when compared to conventional starters.

3-2 MATLAB/SIMULINK:

The performance of the proposed system can be evaluated accurately by using proper simulation models. The models should be flexible and accurate to take into account the real time implementation issues as well. With the rapid development in computer software, new simulation packages which are much faster and user friendly are now available. This paper deployed the use of one such software, the MATLAB/SIMULINK. MATLAB (Matrix Laboratory), developed by Math works Inc., is a software package for high performance numerical computation and visualization. The combination of analysis capabilities, flexibility, and powerful graphics makes MATLAB the premier software package for electrical engineers.

MATLAB provides an interactive environment with hundreds of reliable and accurate built in mathematical functions. These functions provide solutions to a broad range of mathematical problems including matrix algebra, complex arithmetic, linear systems, differential equations, signal processing, optimization, non-linear systems, and many other types of scientific computations. In Universities, Polytechnics and colleges of education, it is the standard instructional tool for introducing an advanced course in mathematics, science and engineering. In industry, MATLAB is the tool for high productivity research, development and analysis.

In this modern period, almost all the processes and techniques are first simulated before their actual real time implementation

3-3 block diagram:

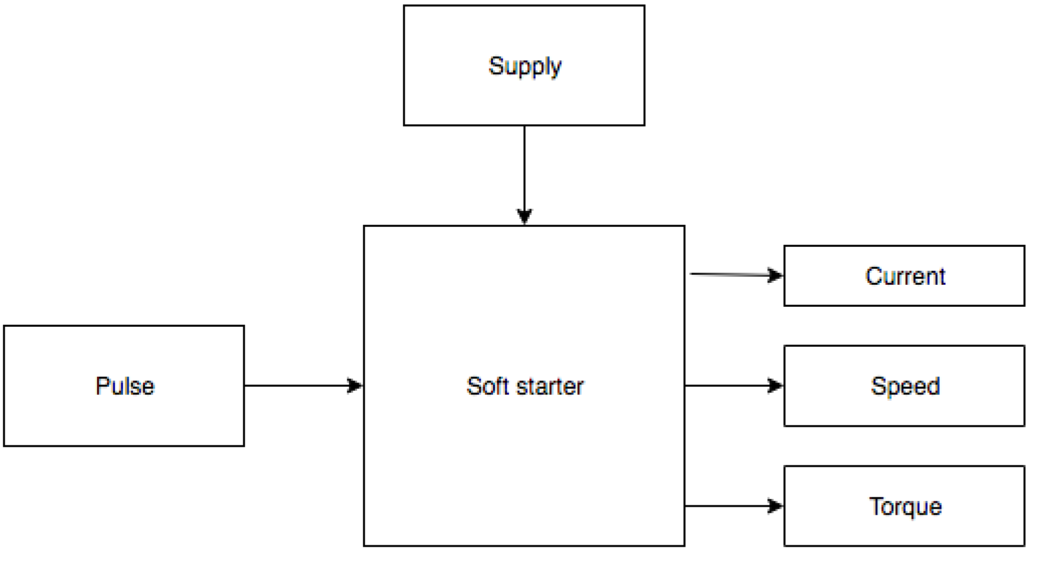
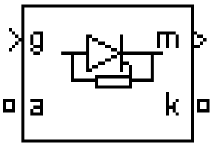


Fig 3-1: System block diagram

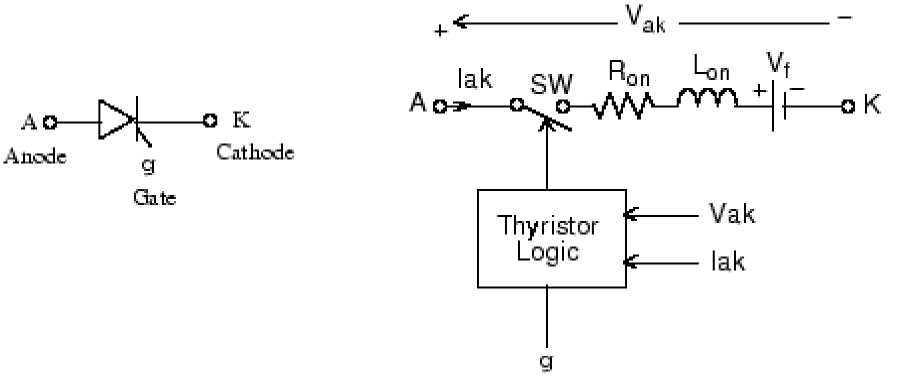
3-4 Modeling Components:

3-4-1 Thyristor:

Description



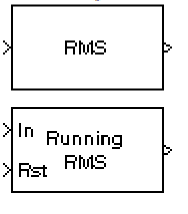
The thyristor is a semiconductor device that can be turned on via a gate signal. The thyristor model is simulated as a resistor Ron, an inductor Lon, and a DC voltage source representing the forward voltage Vf, connected in series with a switch. The switch is controlled by a logical signal depending on the voltage Vak, the current Iak, and the gate signal



3-4-2 RMS:

Compute root-mean-square value of input or sequence of inputsexpand all in page

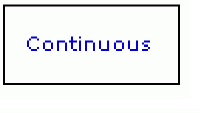
Description



the input, or of the entire input. The RMS block can also track the RMS value in a sequence of inputs over a period of time. The Running RMS parameter selects between basic operation The RMS block computes the RMS value of each row or column of .and running operation the input, along vectors of a specified dimension of

3-4-3 Powergui:

Description



The Powergui block allows you to choose one of the following methods to solve your circuit

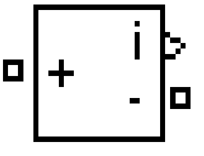
Continuous, which uses a variable step solver from Simulink

Ideal Switching continuous.

Discretization of the electrical system for a solution at fixed time steps Phasorsolution .The Powergui block is necessary for simulation of any Simulink model containing SimPowerSystems™ blocks. It is used to store the equivalent Simulink circuit that represents .the state-space equations of the model

3-4-4 Current Measurement:

Description

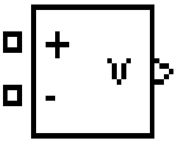


The Current Measurement block is used to measure the instantaneous current flowing in any electrical block or connection line.

The Simulink output provides a Simulink signal that can be used by other Simulink blocks

3-4-5 Voltage Measurement:

Description

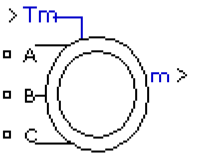


The Voltage Measurement block measures the instantaneous voltage between two electric nodes. The output provides a Simulink® signal that can be used by other Simulink blocks

3-4-6 Asynchronous Machine:

Model the dynamics of three-phase asynchronous machine, also known as induction machine

Description



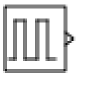
The Asynchronous Machine block implements a three-phase asynchronous machine (wound rotor, single squirrel-cage, or double squirrel-cage). It operates in either generator or motor :mode. The mode of operation is dictated by the sign of the mechanical torque

.If Tm is positive, the machine acts as a motor

.If Tm is negative, the machine acts as a generator

3-4-7 Pulse Generator:

Description



The Pulse Generator block generates square wave pulses at regular intervals. The block's waveform parameters, Amplitude, Pulse Width, Period, and Phase delay, determine the shape of the output waveform. The following diagram shows how each parameter affects the waveform

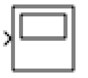
3-4-8 Display:

Show value of input

Description

3-4-9 Scope and Floating Scope:

Description



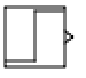
.

.The Scope block displays inputs signals with respect to simulation time

3-4-10 Step:

Generate step function

Description

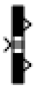


The Step block provides a step between two definable levels at a specified time. If the simulation time is less than the Step time parameter value, the block's output is the Initial value parameter value. For simulation time greater than or equal to the Step time, the output is the Final value parameter value

3-4-11 Bus Selector:

Select signals from incoming bus

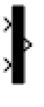
Description



The Bus Selector block outputs a specified subset of the elements of the bus at its input. The block can output the specified elements as separate signals or as a new bus. For information :about buses, see

3-4-12 Mux:

Description



The Mux block combines its inputs into a single vector output. An input can be a scalar or vector signal. All inputs must be of the same data type and numeric type. The elements of the vector output signal take their order from the top to bottom, or left to right, input port signals. See How to Rotate a Block for a description of the port order for various block orientations. To avoid adding clutter to a model, Simulink® hides the name of a Mux block when you copy it from the Simulink library to a model. See Mux Signals for information about creating and decomposing vectors Composite Signals Create and Access a Bus When the block outputs separate elements, it outputs each element from a separate port from top to bottom of the block. See How to Rotate a Block for a description of the port order for various block orientations

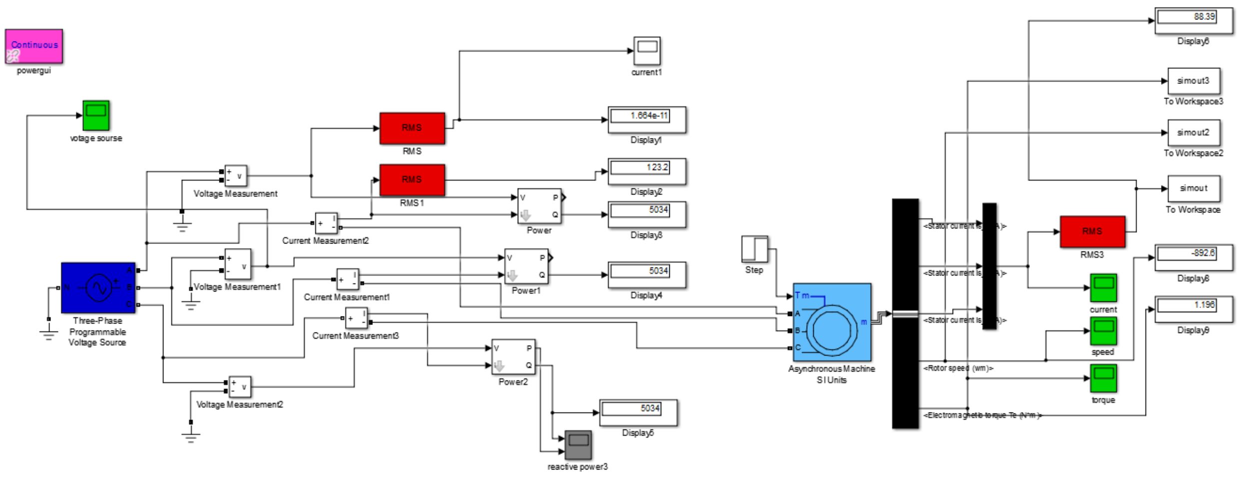
3-4-13 To Workspace:

Description

The To Workspace block inputs a signal and writes the signal data to the MATLAB® workspace. During the simulation, the block writes data to an internal buffer. When the simulation is completed or paused, that data is written to the workspace. The block icon ...shows the name of the array to which the data is written

3-5 Simulation Model of Direct-On-Line Starter (DOL):

DOL is the traditional and simplest method of motor starting, and most other methods are base lined against it. It is also often called across the line start. This method is the direct connection of the terminal voltage to he motor stator with no additional components, and also for this reason is most economical in terms of installation cost and ease of use. It is also one of most reliable and robust methods. Of all the starting methods it produces the highest inrush current, usually six to eight times the rated current, and the highest starting torque; and due to the high starting torque it has the shortest acceleration time



Fig(3.2): SIMULINK Model of Three Phase Induction Motor Direct On Line Starter

3-6 Simulation Model of Soft Starter Controller:

development of a soft starter model to control or reduce the starting current and starting torque for a three phase Induction Motor drive. The soft starter uses two anti-parallel connected switches in each phase. Thyristors are used as the switches because of their higher power rating and high efficiency. Fig.(3.2) shows the block diagram of the entire system.

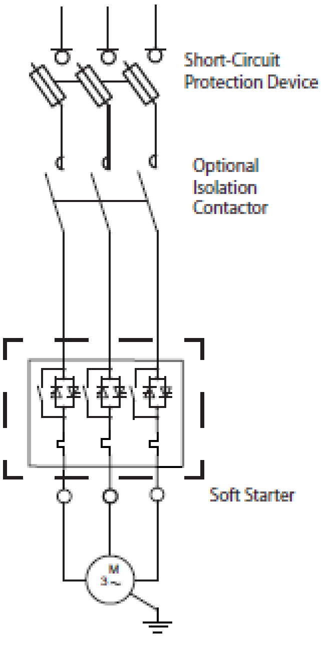


Fig (3.3): Block diagram of Solid-state soft-starter

In technical terms, a soft starter is an electronic device which reduces the starting current and starting torque applied to the electric motor by means of controlling the applied voltage by changing the firing angle every half cycle. The basic three-phase induction motor drive scheme is illustrated in Fig.(3.3), where the power switches are thyristors. In this test system, the supply to the induction motor is not direct but through thyristors. A soft starter consists of a number of anti-parallel thyristors, two in each phase. These thyristors are semi-conductor components which normally are isolating but by sending a firing signal, they can start to conduct, allowing the voltage and current to pass through. By allowing more and more of the voltage to pass through the thyristors, this is seen as a ramping up of the voltage from initial voltage to full voltage. There is no exact rule that can be applied to define what time value should be set and which would be the best pedestal voltage value for the motor to guarantee the acceleration of the load. In a soft starter, voltage control must be done in both directions of the current. An anti-parallel configuration of two thyristors per phase must be used and are connected both in series and parallel to meet the high voltage and high current demands respectively. This method has the ability to regulate or control the supply voltage to the machine. Three-phase sinusoidal voltages are generated using three independent voltage sources having phase difference of 1200 and magnitude of 220V. The 220V sinusoidal voltage is generated using voltage source block from SIMULINK Library. The output of soft starter is connected to the input of a three-phase induction motor. Simulation is carried out and the various operating conditions, the No-load and on load, balanced voltages were analyzed and presented graphically. Also the total harmonic distortion (THD) in the output current and the resulting values were recorded. The controllable range of the firing angle of the Thyristor used was between α = (pi/12) rad. and α = (pi/3) rad. Fig.(3.5) shows the SIMULINK model of three phase soft starter connected to a three phase motor.

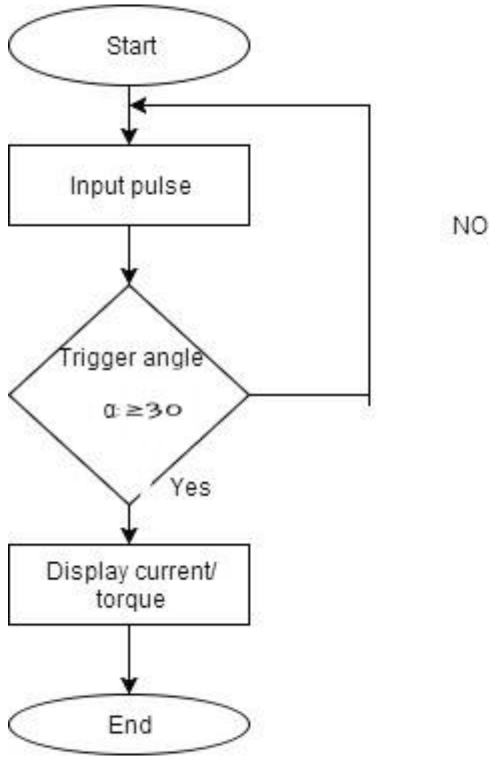


Fig (3.4) :Flow of chart

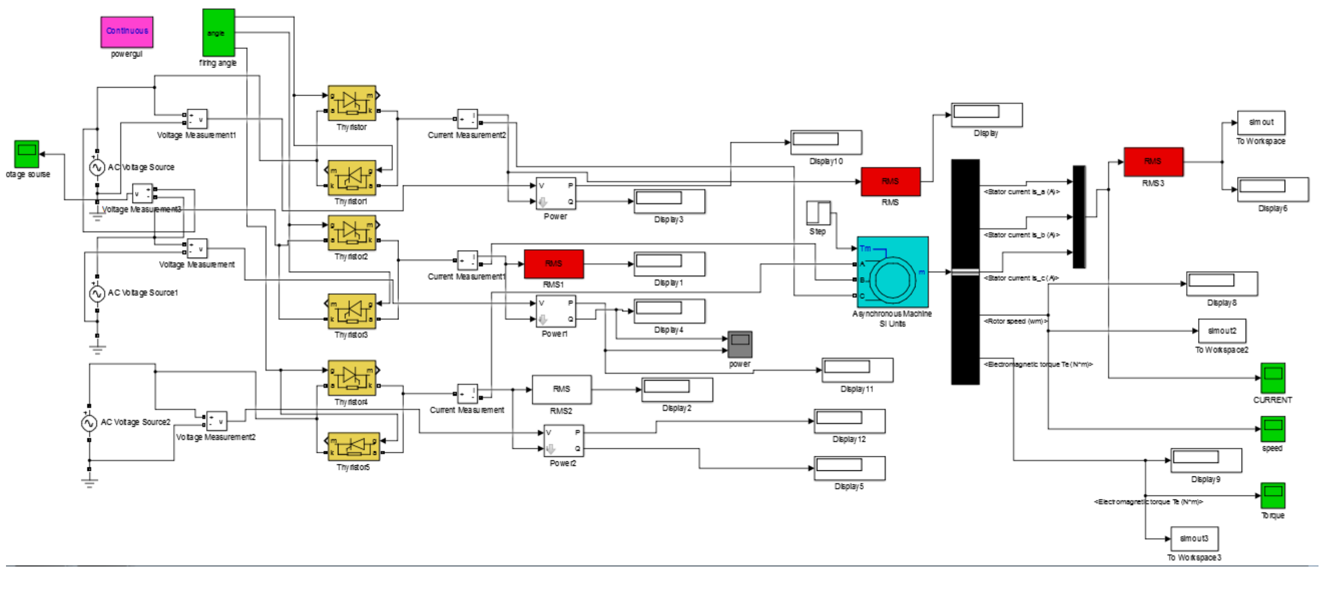


Fig (3.5) : SIMULINK Model of Three Phase Soft Starter Connected to a three Phase Motor.

Chapter four

Simulation Results

4-1 Introduction:

we will examine the starting performance (Torque, Speed and Current) of some of these methods on a 10HP, 4 pole, 220V, three phase, 60Hz, squirrel-cage induction motor with the following parameters

Table 4.1: Three Phase Induction Motor Parameters.

Stator Resistance (R_s)	**0.099 Ω**
Rotor resistance (R_r)	**0.05Ω**
Stator leakage inductance (L_{ls})	**0.000867H**
Rotor leakage inductance (L_{lr})	**0.000867H**
Magnetizing inductance (L_m)	**0.03H**
Moment of inertia (J)	**0.4kgm^2**

The effect of varying parameters such as motor current, torque and speed of the three phase induction motor are investigated and results are analyzed. To illustrate the transient operations of the induction motor, a simulation study of direct on line starting and soft starting is demonstrated, the motor, was de-energized and at standstill, is connected to a 220V, 60Hz, three phase balanced supply through a cable.

4-2Effect of the Soft Starter on the Motor Current:

The best way to observe the effect or the impact of a soft starter controller on the induction motor is to compare the motor inrush current when a soft starter is used to the inrush current when a Direct on Line starter is used.

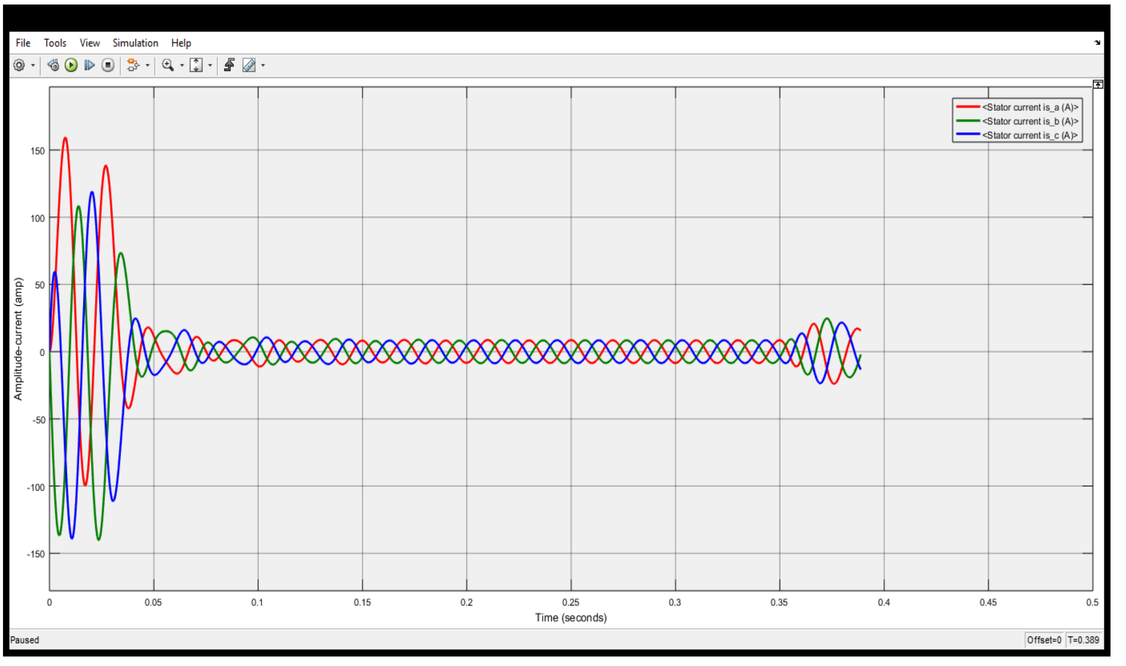


Fig (4.1): StatorCurrent (DOL)

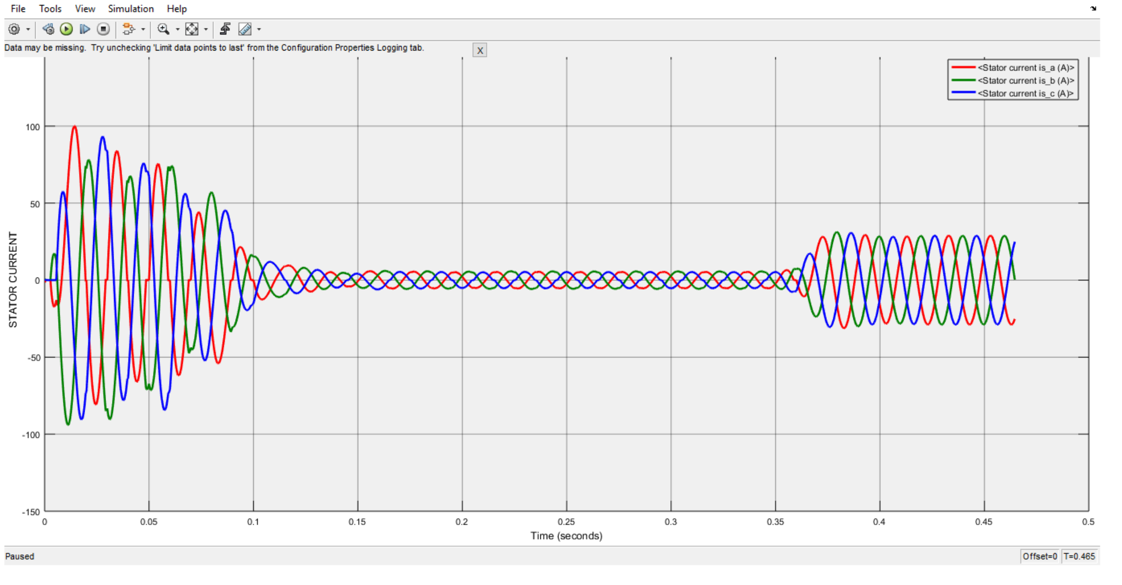


Fig (4.2): StatorCurrent (soft starter)

With a DOL starter, the motor current is maximal at the instant the starter applies power to the motor winding and decreases gradually as the motor gains speed. As the motor approaches full speed, the current decreases more rapidly until it stabilizes at a steady state value when the motor reaches full speed. The value at which the current stabilizes depends on the torque opposing rotation (mainly due to friction). The higher the inertia of the mechanical load coupled to the motor, the longer the current stays high since the motor takes more time to reach full speed. If the current stays high for too long, the motor windings are at risk of overheating and the over load protection trips or the motor burns if it has no functional over load protection.

By contrast, soft starter does not apply the full voltage to the motor windings at start up. Instead, the voltage is gently ramped up to full voltage. This reduces the current that the motor draws and keeps it significantly lower than when a DOL starter is used. As the motor speed increases, the current increases slightly but remains much lower than when a DOL starter is used. The motor current decreases rapidly as the motor approaches full speed in somewhat the same way as when the DOL starter is used. Finally, the current stabilizes at a steady state value as when a DOL starter is used. furthermore, the lower maximum current drawn at start up when using a soft starter helps reduce the undesired effects of voltage sags or dip.

4-3 Effect of the Soft Starter on the Motor Torque:

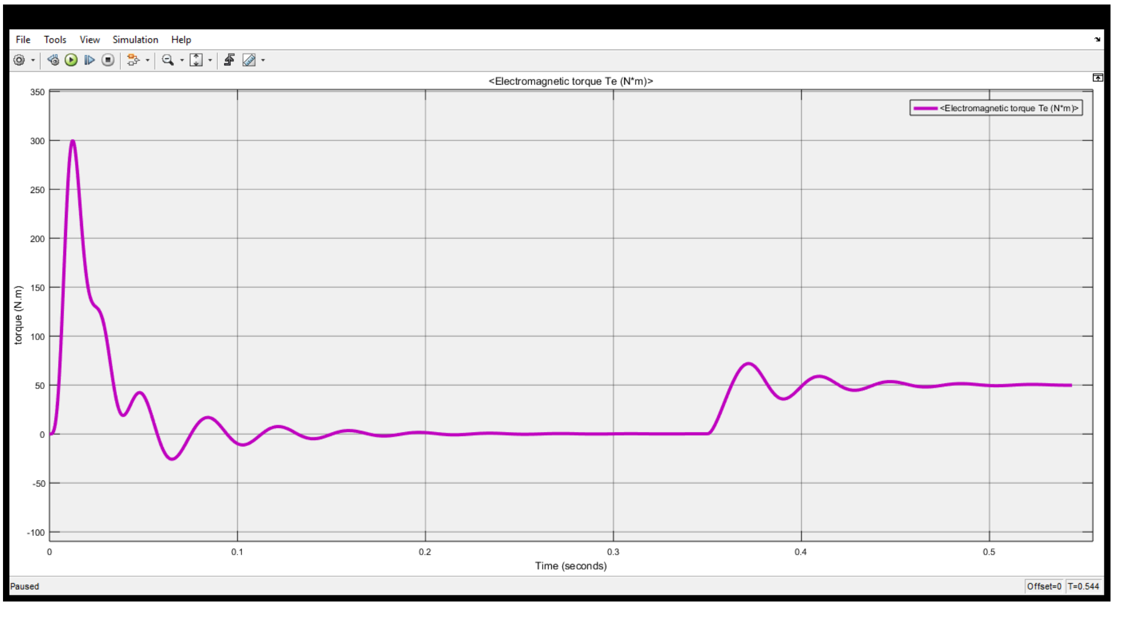


Fig (4.3) : Electromagnetic Torque (DOL)

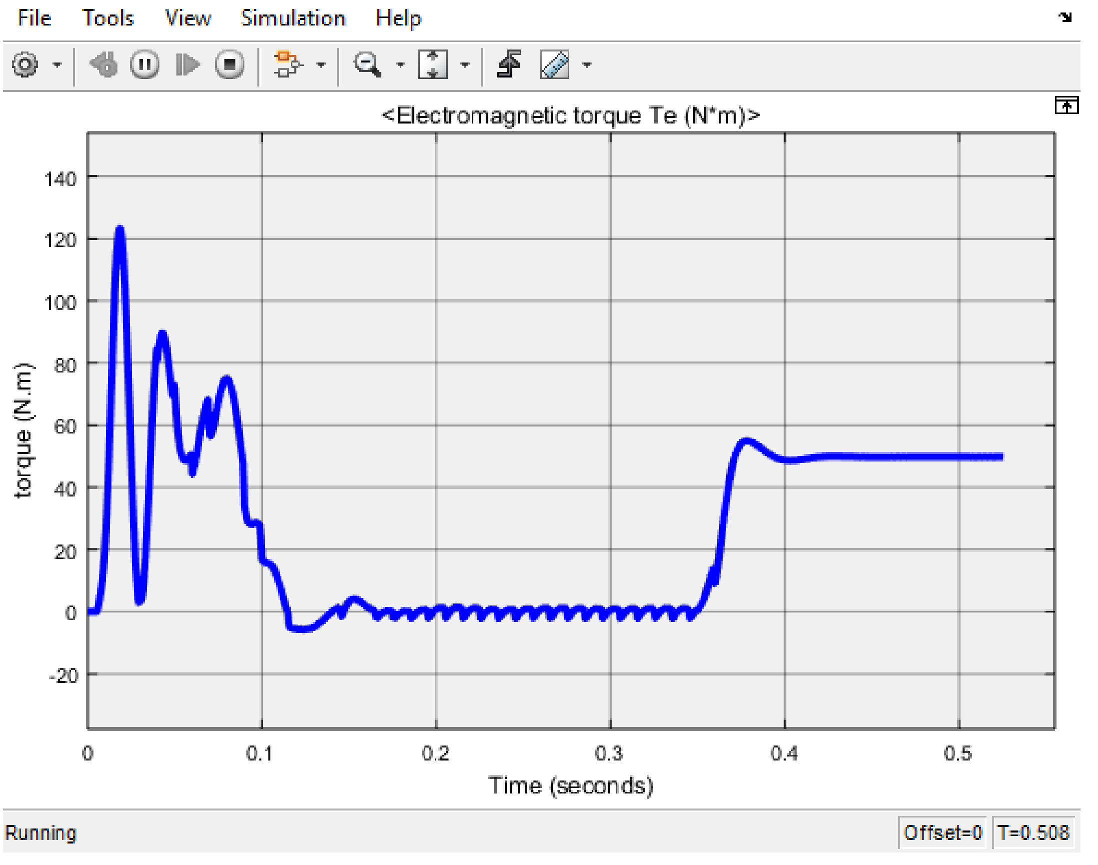


Fig (4.4) : Electromagnetic Torque (soft starter)

With a DOL starter, the full voltage of the power source is applied to the motor at start up and a large torque is exerted on the rotor. This torque is transmitted to the mechanical components connected to the rotor with the aforementioned consequences. Therefore, starting the motor at a reduced voltage using a soft starter also reduces the torque because the torque of induction motor is directly proportional to the square of the voltage applied to the stator windings. Reducing the motor torque at start up is one of the most useful features of soft starters since it reduces the frequency of the mechanical break downs and consequently, the down time and maintenance cost of the equipment.

It is observed that the induction motor exhibits large torque ripple due to transient and settles down to zero in less than 0.2 seconds and the simulation results are shown in Fig. 4.3 With soft starter, the simulation of the electromagnetic torque characteristics are shown in Fig.4.4 under various loading conditions and it is observed that the starting torque is reduced compare to the DOL starter.

4-4 Effect of the Soft Starter on the Motor Speed:

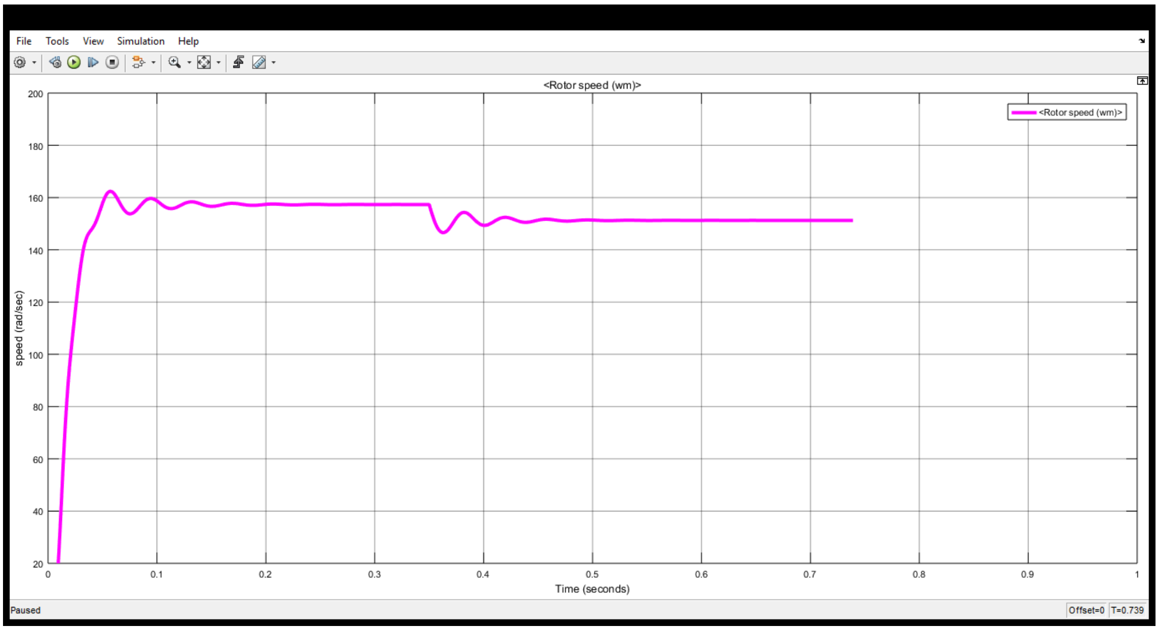


Fig (4.5) : Rotorspeed(DOL)

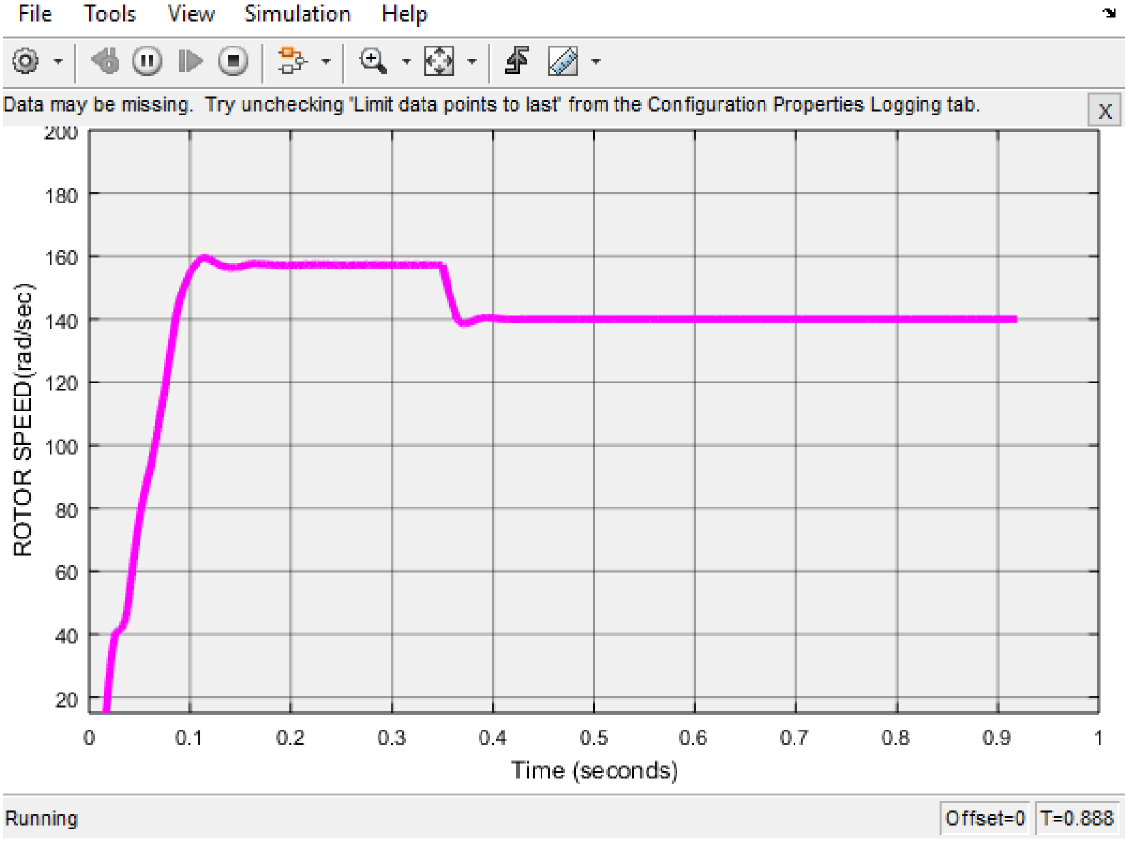


Fig (4.6) : Rotorspeed(soft starter)

Starting a motor at reduced voltage using a soft starter has another interesting effect. The induction motor starts with a small ripple due to transient and settles at the final speed of 160 rad/sec as shown in Fig. 4.5But with soft starter controller, the speed settled at 188.5 rad/sec Less voltage applied to the stator windings means the motor produces less torque to accelerate the rotor. Hence, it takes more time for the motor to reach full speed when a soft starter is used.

5-4 Effect of change of pulse in the Thyristor Firing Angle:

The control of the Thyristor firing Angle is done by controlling the pulse width

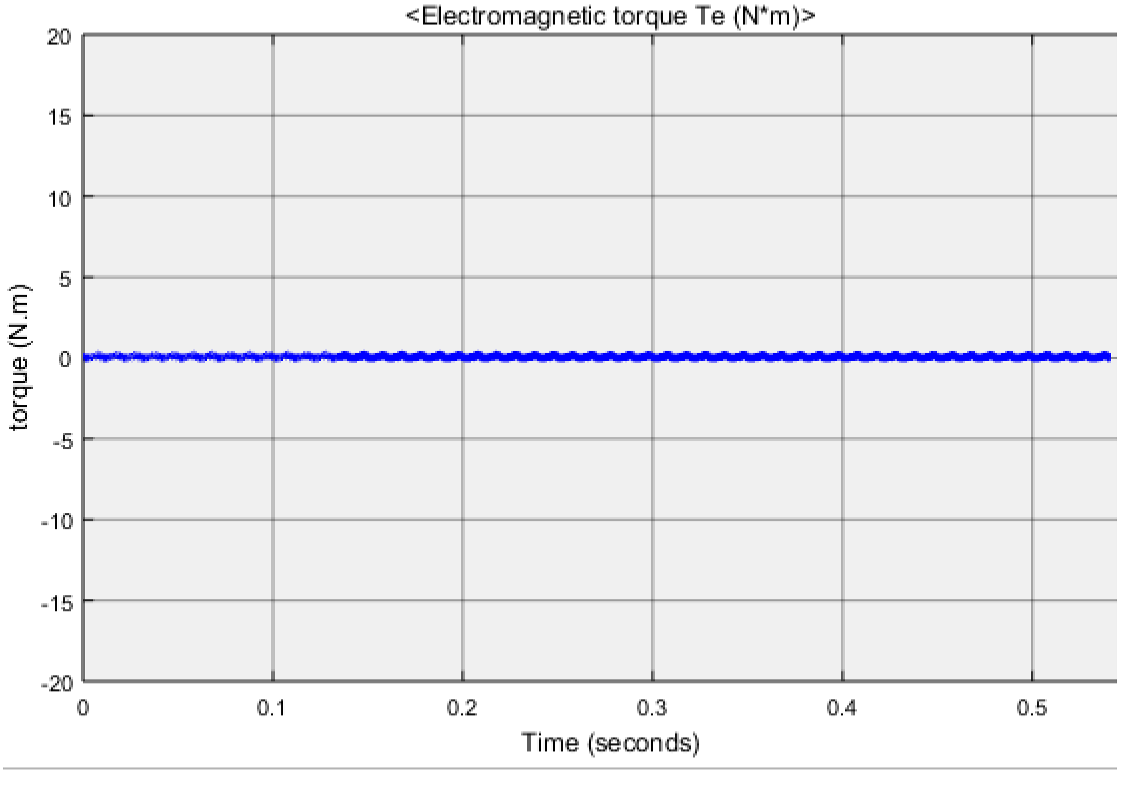


Fig (4.7) Torque at the pulse (30) for Thyristor Firing Angle

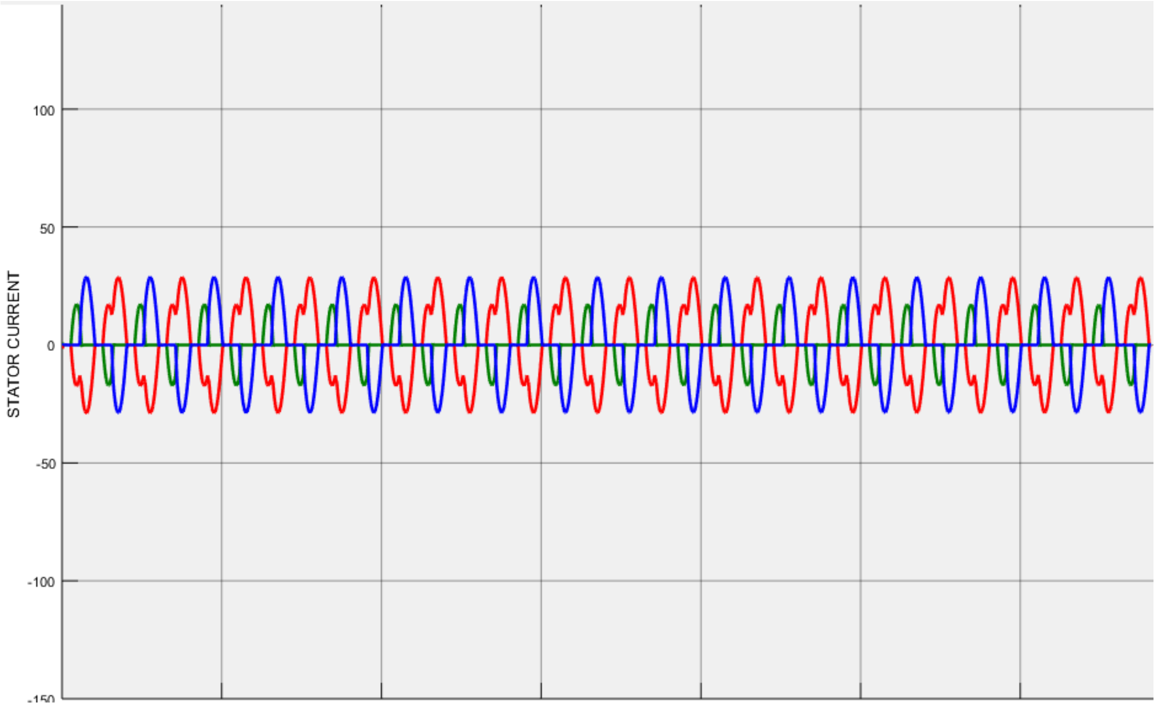


Fig (4.8) Current at the pulse (30) for Thyristor Firing Angle

When using a pulse width (30) we obtain a current of (fig 4.8) and a Torque of (fig 4.7).

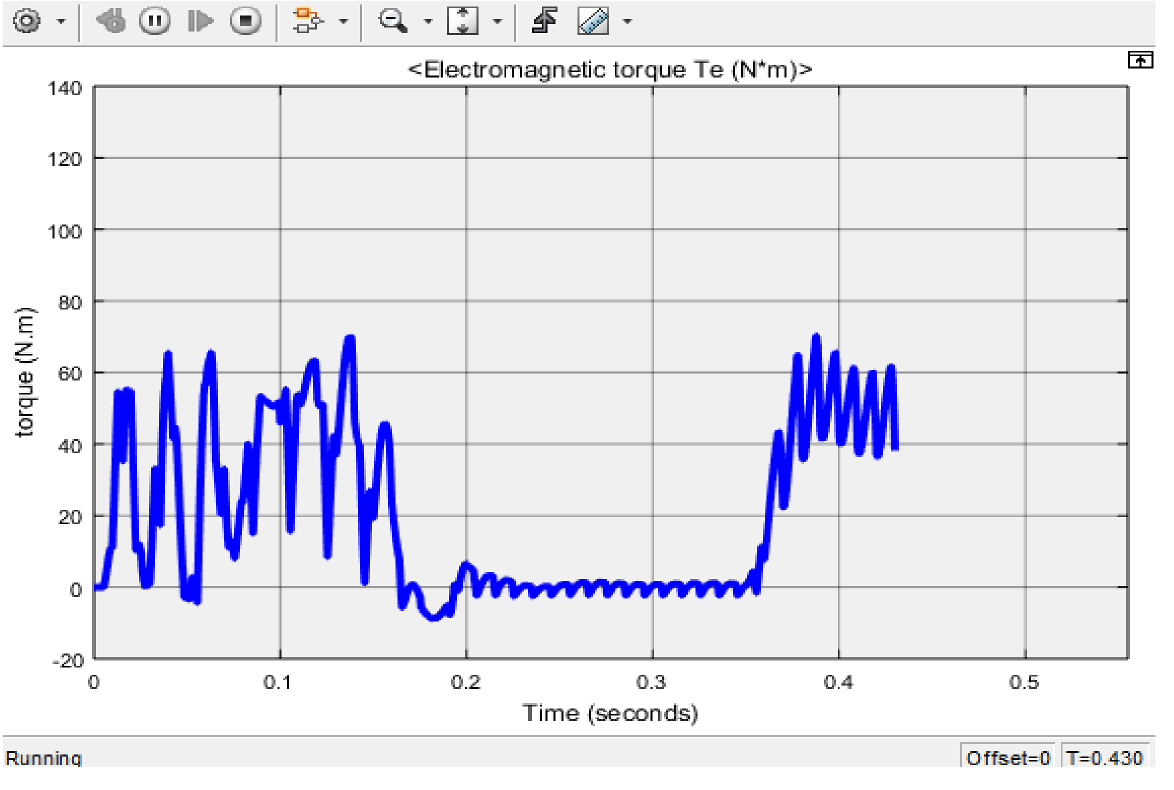


Fig (4.9) Torque at the pulse (66.6) for Thyristor Firing Angle

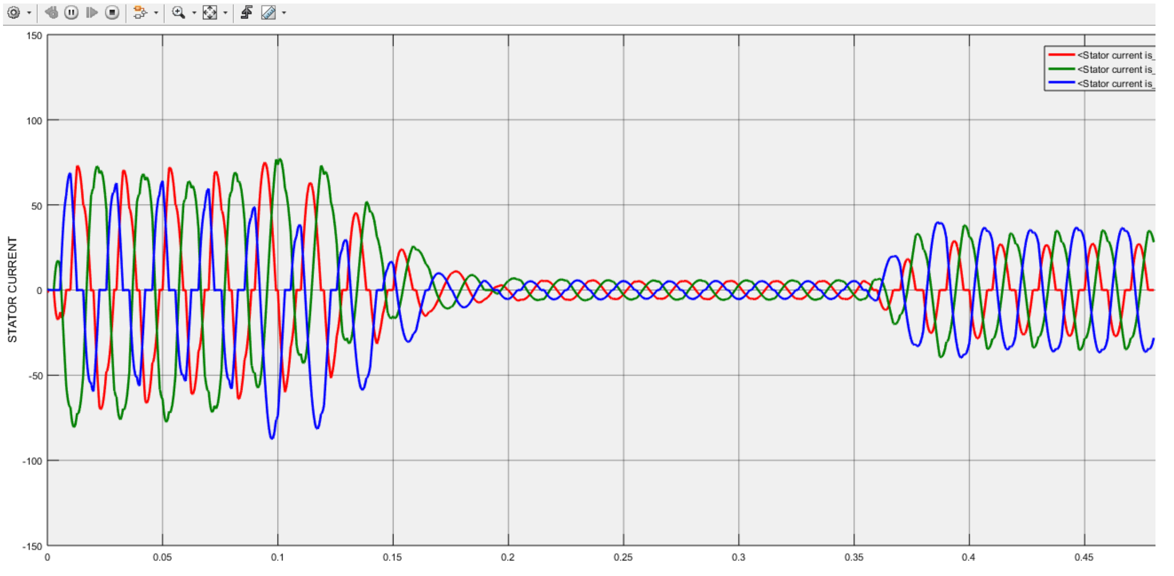


Fig (4.10) Current at the pulse (66.6) for Thyristor Firing Angle

When using a pulse width (66.6) we obtain a current of (fig 4.10) and a Torque of (fig 4.9).

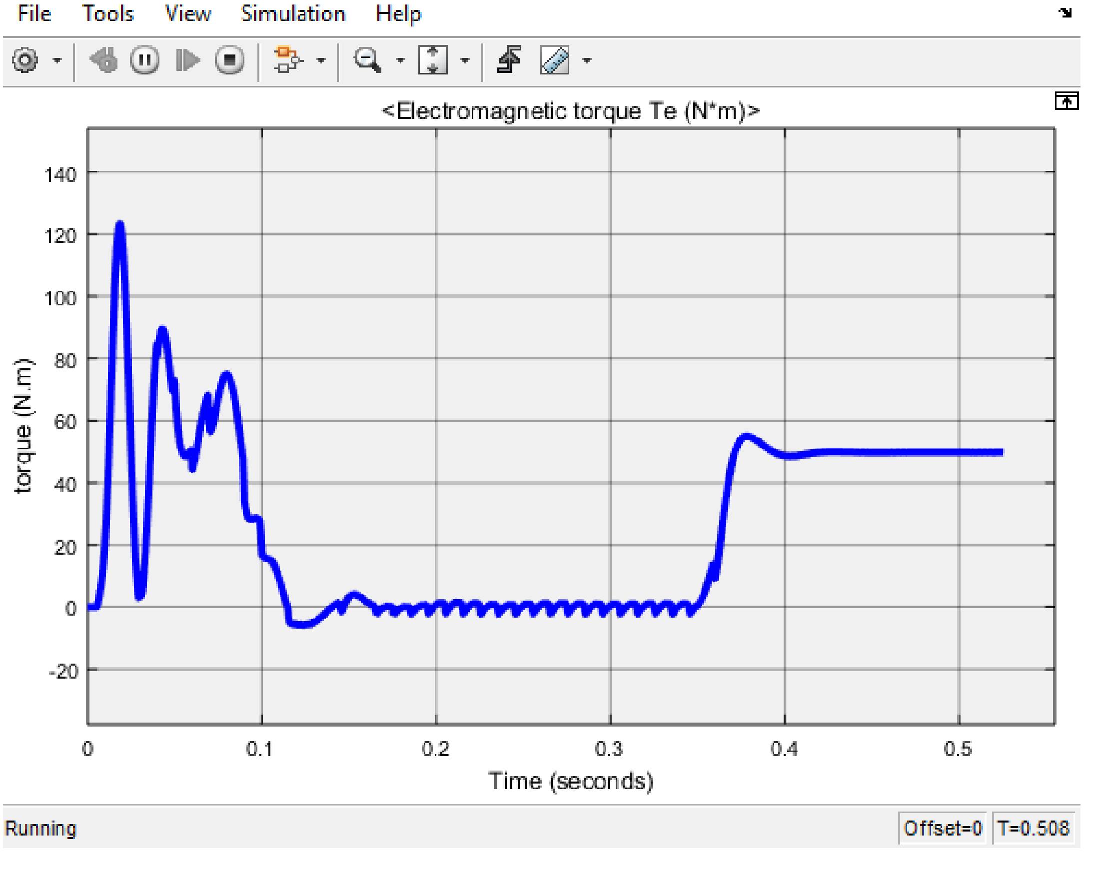


Fig (4.11) Torque at the pulse (83.3) for Thyristor Firing Angle

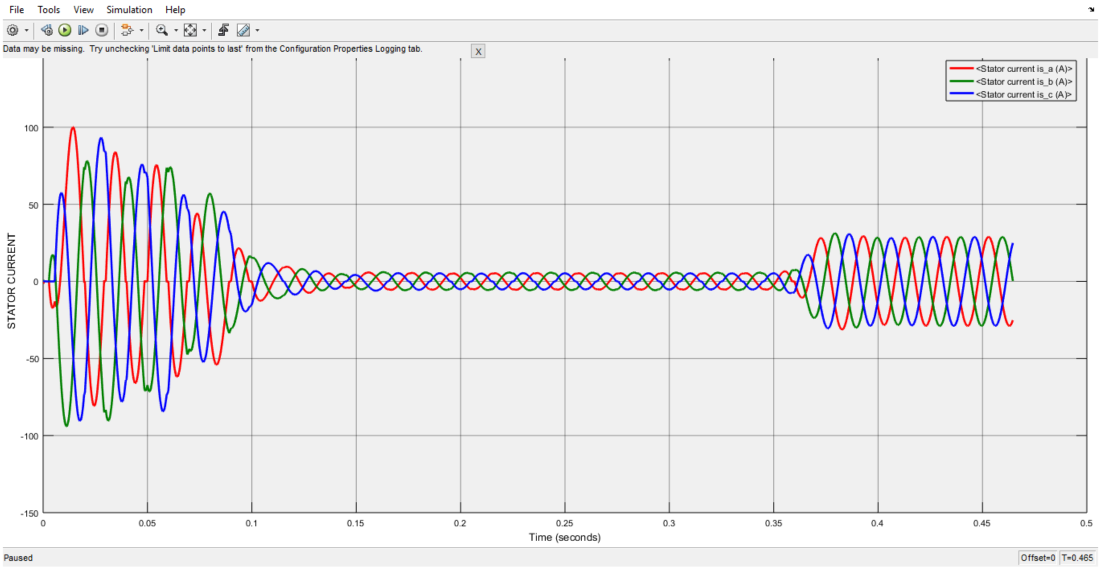


Fig (4.12) Current at the pulse (83.3) for Thyristor Firing Angle

When using a pulse width (83.3) we obtain a current of (fig 4.12) and a Torque of (fig 4.11)

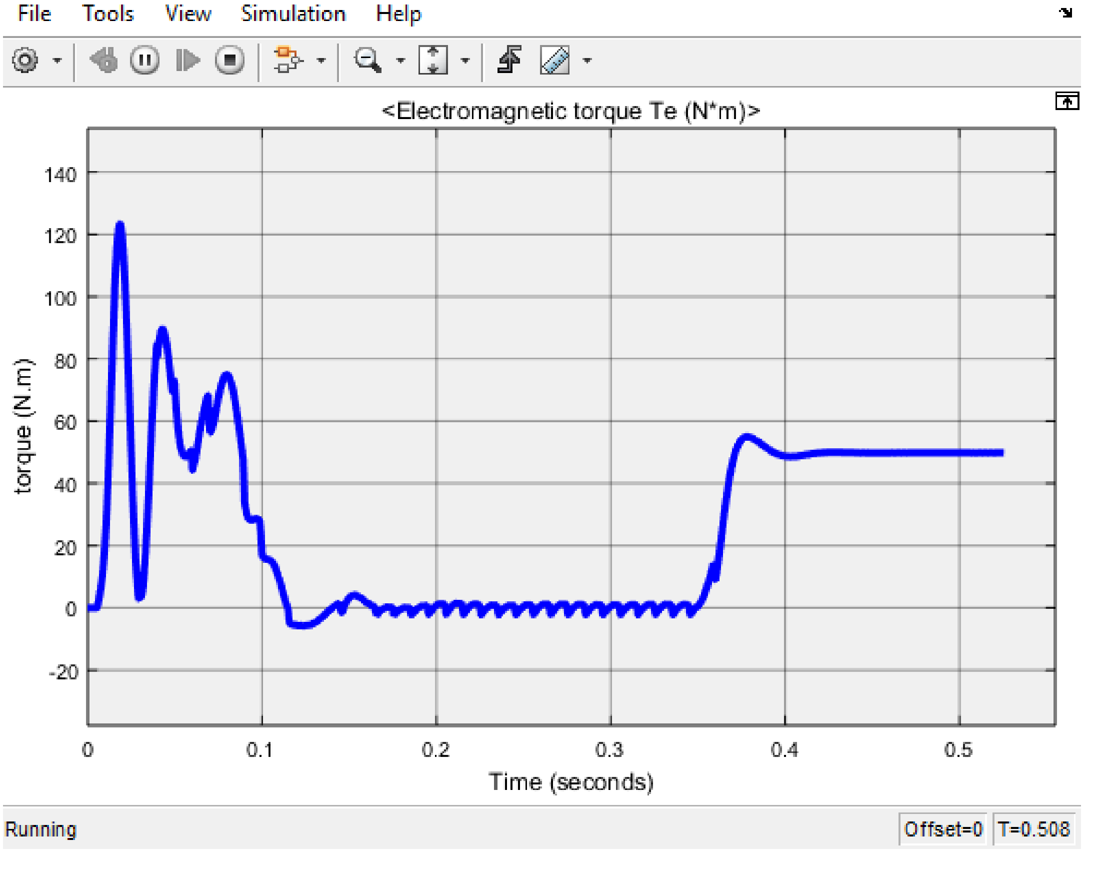


Fig (4.13) Torque at the pulse (90) for Thyristor Firing Angle

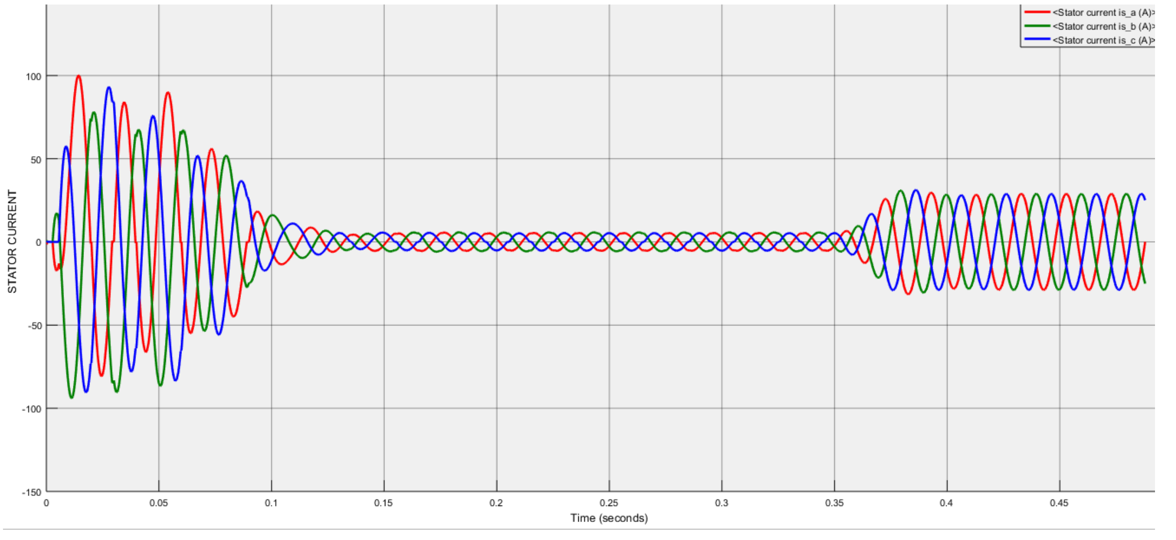


Fig (4.14) Current at the pulse (90) for Thyristor Firing Angle

When using a pulse width (90) we obtain a current of (fig 4.14) and a Torque of (fig 4.13)

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Chapter Five

Conclusions and Recommendations

5-1 Conclusions:

This studying a comprehensive models using MATLAB/SIMULINK in the simulation of the impact of soft starter controller on induction motor

The start current of the inductive motor was controlled by voltage control by controlling the thyristor ignition angle by controlling the pulse width. When Direct-On-Line Starter was used, the current at the start was 7.5 times the rated current of the motor in the case of soft starter 5 times the rated current of the engine and as a result there is a marked decrease in torque

5-2 Recommendations:

Execution of the soft starter circuit in practice.

Working on finding away re duces the starting current of the inductive without making a significant change in the torque

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