ANALYSIS OF DIFFERENT STARTING METHODS OF INDUCTION MOTOR

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ABSTRACT

Induction Motor is the most widely used motor due to this reliability robust and low cost and it is used in both household. An industrial application is due to their high torque to volume ratio, ruggedness and low maintenance. Induction Motor draws a high starting current during starting period which effects on electromagnetic torque, speed and current. Traditional method include DOL, auto transformer, star delta starter etc. control this parameter up to certain limits. Our project is about the starting method of induction motor DOL starter, star delta, autotransformer starter. Analysis is made for speed, torque and current during start. Simulation is made in MATLAB and comparatively results are estimated.

Keyword: - *D-O-L, Star-delta, Auto-transformer, Speed, Torque and Current.*

1. INTRODUCTION

A 3-phase induction motor is theoretically self-starting. The stator of an induction motor consists of 3-phase windings, which when connected to a 3-phase supply creates a rotating magnetic field. This will link and cut the rotor conductors which in turn will induce a current in the rotor conductors and create a rotor magnetic field. The magnetic field created by the rotor will interact with the rotating magnetic field in the stator and produce rotation. Based on the construction of the rotor, a 3-phase induction motor can be categorized into two types:

i. Squirrel Cage Induction Motor
ii. Wound Rotor or Slip Ring Induction Motor

The stator of both types of motors consists of a three phase balanced distributed winding with each phase mechanically separated in space by 120 degrees from the other two phase windings. This gives rise to a rotating magnetic field when current flows through the stator.

In squirrel cage IM, the rotor consists of longitudinal conductor bars which are shorted at ends by circular conducting rings. Whereas, the wound rotor IM has a 3-phase balanced distributed winding even on the rotor side with as many number of poles as in the stator winding.

Squirrel cage induction motor just before starting is similar to a poly phase transformer with a short-circuited secondary. If normal voltage is applied to the stationary motor then, as in the case of a transformer, a initial current, to the turn of 5 to 6 times the normal current or the normal rated current, will be drawn by the motor from the mains. This initial excessive current is objectionable, because it will produce line voltage (The potential difference or the voltage across two phases) drop, which in turn will affect the operation of the other electrical equipment and the lights connected to the same line.

The initial rush of current is controlled by applying a reduced voltage to the stator (motor) winding during the starting period and then the full normal voltage is applied when the motor has run up to speed. For the small capacity motors say up to 3H.P, full normal voltage can be applied at the start. However to start and stop the motor and to protect the winding from the over load current and low voltages, a starter is required in the motor circuit. In addition to this the starter may also reduce the applied voltage to the motor at the time of starting. A 3-phase induction motors employ a starting method not to provide a starting torque at the rotor, but because of the following reasons:

1) Reduce heavy starting currents and prevent motor from overheating.
2) Provide overload and no-voltage protection Starter

2) OBJECTIVES

One of the most common electrical motor used in most applications which is known as induction motor. We are going to study the starting period of induction motor when its connected with different starter at the time of starting.
We are going to analysis starting current, torque and speed of induction motor when it is started with the help of direct-on-line, star-delta and auto-transformer starter.
Using MATLAB SIMULINK we are going to compare their output form.
This will help to understand there starting period and there effect on induction motor.

3) INTRODUCTION TO STARTER

A 3-phase induction motor is theoretically self-starting. The stator of an induction motor consists of 3-phase windings, which when connected to a 3-phase supply creates a rotating magnetic field. This will link and cut the rotor conductors which in turn will induce a current in the rotor conductors and create a rotor magnetic field. The magnetic field created by the rotor will interact with the rotating magnetic field in the stator and produce rotation. Therefore, 3-phase induction motors employ a starting method not to provide a starting torque at the rotor, but because of the following reasons;

1) Reduce heavy starting currents and prevent motor from overheating.
2) Provide overload and no-voltage protection.

Function of starter is to limit the starting high current to a safe value. The magnitude of E2 depends upon the flux linking with the rotor conductors and its relative speed. The strength of the rotor flux depends upon the applied voltage. At the instant of applying rated voltage to the stator winding, rotor is stationery and as such the ship is unity. So if full rated voltage is given to the stator winding, then the magnitude of the emf induced in the rotor conductors will be high, because the relative speed between the rotor conductors and stator revolving flux is very high i.e. equal to the synchronous speed of the stator flux. Further the rotor conductors are short circuited and thus have low impedance. Hence, the current drawn by the stator winding or motor is very large, approximately 5 to 7 times the full load current.

3.1 Types of starter:

1) Direct-On-Line starter
2) Star-Delta Starter
3) Auto-Transformer Starter

4. DIRECT-ON-LINE STARTERING OF INDUCTION MOTOR

To start, the contactor is closed, applying full line voltage to the motor windings. The motor will draw a very high inrush current for a very short time, the magnetic field in the iron, and then the current will be limited to the Locked Rotor Current of the motor. The motor will develop Locked Rotor Torque and begin to accelerate towards full speed.

As the motor accelerates, the current will begin to drop, but will not drop significantly until the motor is at a high speed, typically about 85% of synchronous speed. The actual starting current curve is a function of the motor design, and the terminal voltage, and is totally independent of the motor load.
The motor load will affect the time taken for the motor to accelerate to full speed and therefore the duration of the high starting current, but not the magnitude of the starting current.

Provided the torque developed by the motor exceeds the load torque at all speeds during the start cycle, the motor will reach full speed. If the torque delivered by the motor is less than the torque of the load at any speed during the start cycle, the motor will stops accelerating. If the starting torque with a DOL starter is insufficient for the load, the motor must be replaced with a motor which can develop a higher starting torque.

The acceleration torque is the torque developed by the motor minus the load torque, and will change as the motor accelerates due to the motor speed torque curve and the load speed torque curve. The start time is dependent on the acceleration torque and the load inertia.

DOL starting have a maximum start current and maximum start torque**.** This may cause an electrical problem with the supply, or it may cause a mechanical problem with the driven load. So this will be inconvenient for the users of the supply line, always experience a voltage drop when starting a motor. But if this motor is not a high power one it does not affect much.

4.1 Simulink model of direct-on-line starting of induction motor

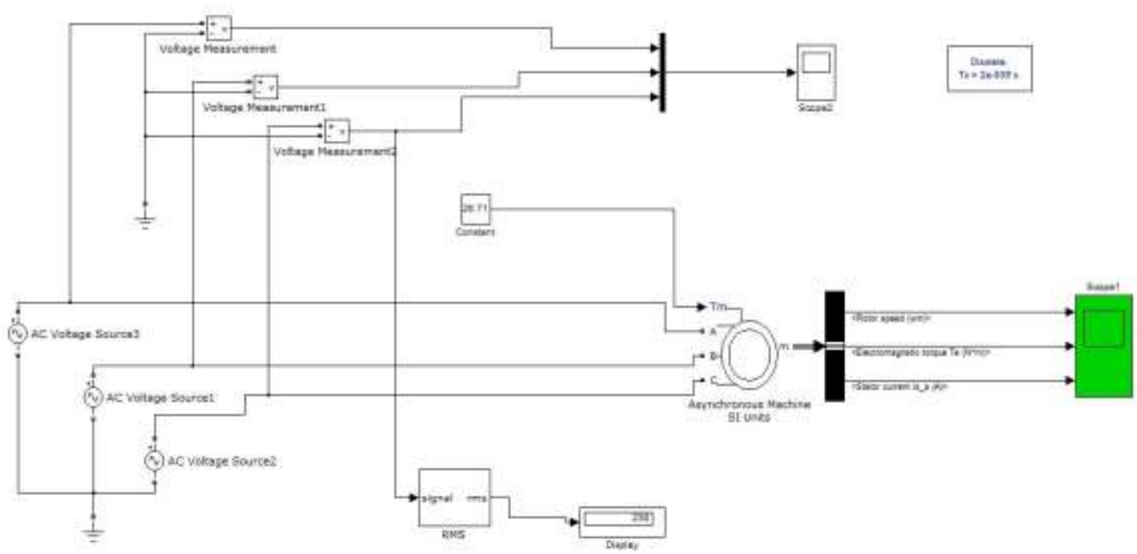

Fig -1 Simulink model of direct-on-line starting of induction motor

Induction motor of 5.4 H.P (4 kw), 400 v at 50 Hz frequency has been used. Phase voltage of 230 volt is given to asynchronous machine.

4.2 Simulink output of direct-o-line starting of induction motor

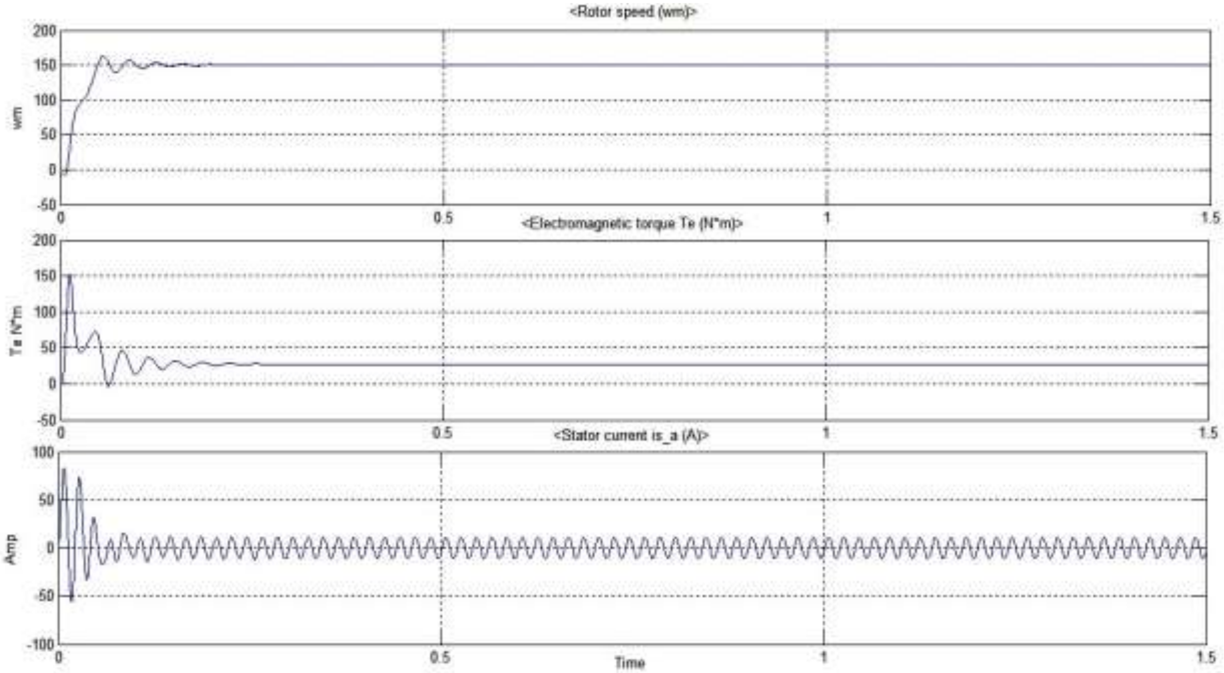

Chart -1 Output waveform of starting speed, torque and current of direct-on-line starter of model

5. STAR-DELTA STARING OF INDUCION MOTOR

This is the reduced voltage starting method. Voltage reduction during star-delta starting is achieved by physically reconfiguring the motor windings as illustrated in the figure below. During starting the motor windings are connected in star configuration and this reduces the voltage across each winding 3. This also reduces the torque by a factor of three. After a period of time the winding are reconfigured as delta and the motor runs normally.

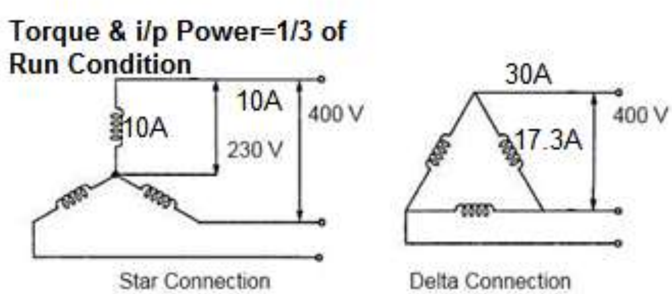

Fig -2 Circuit diagram of star-delta connection

Star/Delta starters are probably the most common reduced voltage starters. They are used in an attempt to reduce the start current applied to the motor during start as a means of reducing the disturbances and interference on the electrical supply.

Traditionally in many supply regions, there has been a requirement to fit a reduced voltage starter on all motors greater than 5HP (4KW). The Star/Delta (or Wye/Delta) starter is one of the lowest cost electromechanical reduced voltage starters that can be applied.

The Star/Delta starter is manufactured from three contactors, a timer and a thermal overload. The contactors are smaller than the single contactor used in a Direct on Line starter as they are controlling winding currents only. The currents through the winding are 1/root 3 (58%) of the current in the line.

There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor. The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is one third of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.

5.1 Simulink model of star-delta starting of induction motor

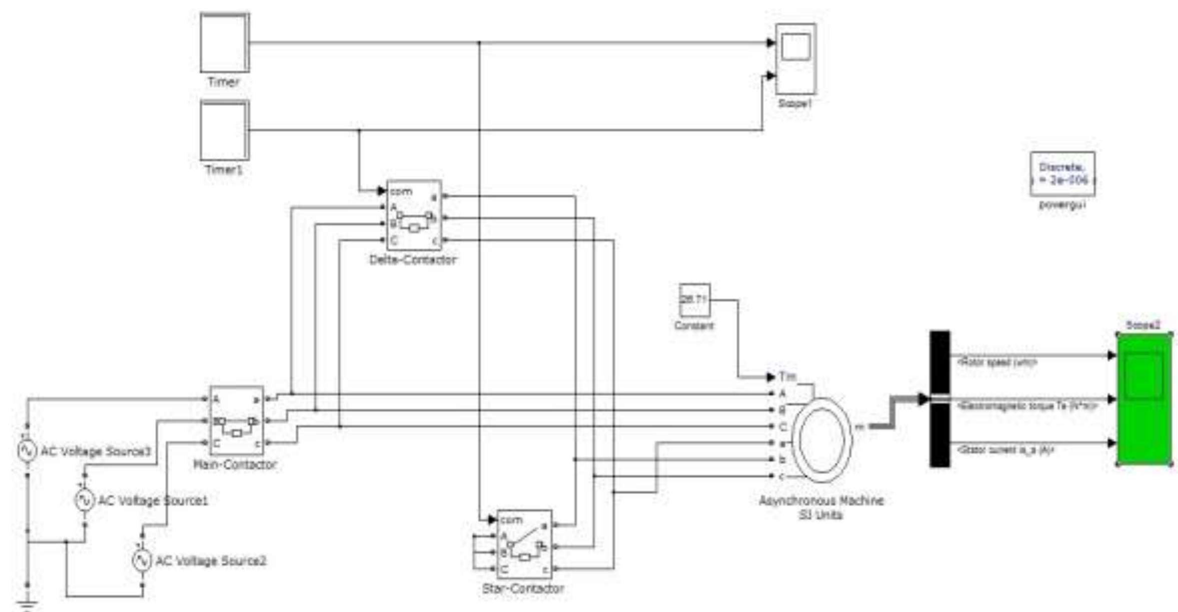

Fig -3 Simulink model of star-delta starting of induction motor

Induction motor of 5.4H.P (4kw), 400v, at 50Hz frequency has been used. In this first star contactor will operate and after 0.16 second delta will operate, making star to close. Timer has been used to operate both the contactor at specified time automatically.

5.2 Simulink output of star-delta starting of induction motor

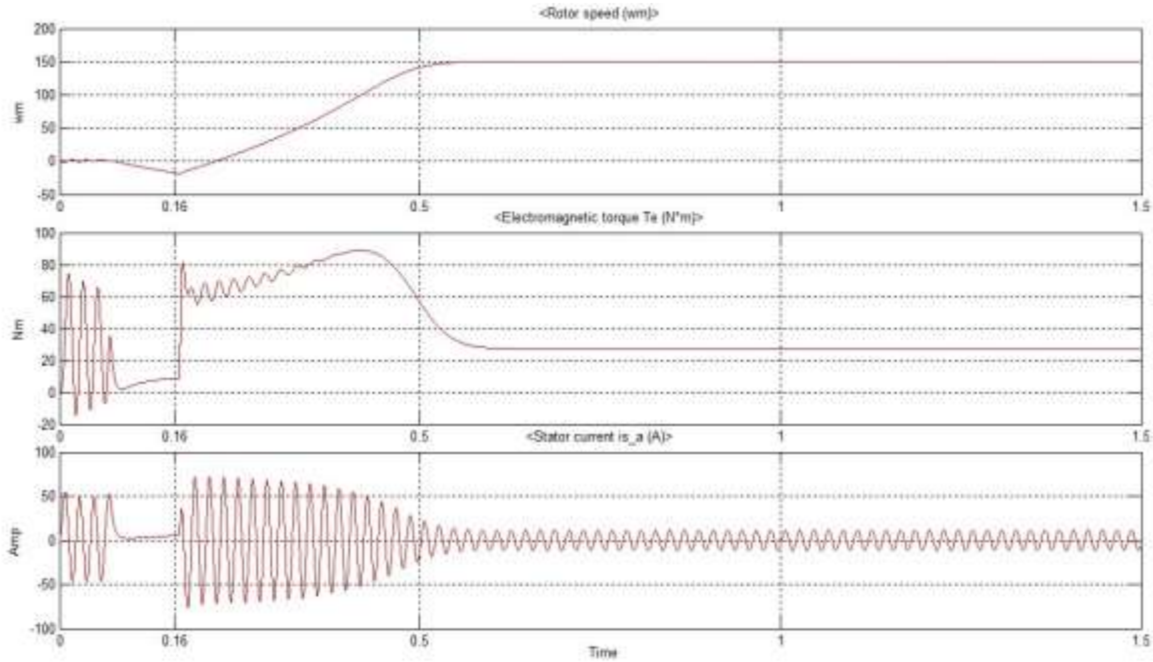

Chart -2 Output waveform of starting speed ,torque and current of star-delta starter model.

6. AUTO-TRANSFORMER STARTING OF INDUCTION MOTOR

An **A**uto Transformer is a transformer with only one winding wound on a laminated core. An auto transformer is similar to a two winding transformer but differ in the way the primary and secondary winding are interrelated. A part of the winding is common to both primary and secondary sides. On load condition, a part of the load current is obtained directly from the supply and the remaining part is obtained by transformer action. An Auto transformer works as a voltage regulator**.**

There are two types of auto transformer based on the construction. In one type of transformer, there is continuous winding with the taps brought out at convenient points determined by desired secondary voltage and in another type of auto transformer, there are two or more distinct coils which are electrically connected to form a continuous winding. The construction of Auto transformer is shown in the figure below.

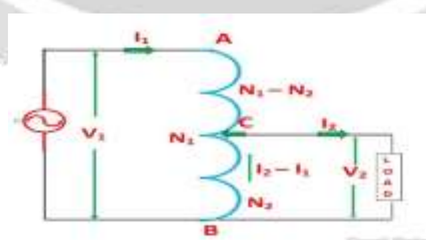

Fig -4 Auto-transformer.

The primary winding AB from which a tapping at C is taken, such that CB acts as a secondary winding. The supply voltage is applied across AB, and the load is connected across CB. The tapping may be fixed or variable.When an AC voltage V_1 is applied across AB, an alternating flux is set up in the core, as a result, an emf E_1 is induced in the winding AB. A part of this induced emf is taken in the secondary circuit.

Let,

V_1 – primary applied voltage
V_2 – secondary voltage across the load
I_1 – primary current
I_2 – load current
N_1 – number of turns between A and B
N_2 – number of turns between C and B

Neglecting no load current, leakage reactance and losses,V1=E1 and V2=E2
Therefore the transformation ratio,

$$\boldsymbol{K = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}}$$

As the secondary amphere-turn are opposite to primary amphere-turns. So the current I_2 in phase opposition to I_1. The secondary voltage is less than primary therefore I_2 is more than I_1. Therefore the resulting current through section BC is I_2-I_1.

6.1 Simulink model of auto-transformer starting of induction motor

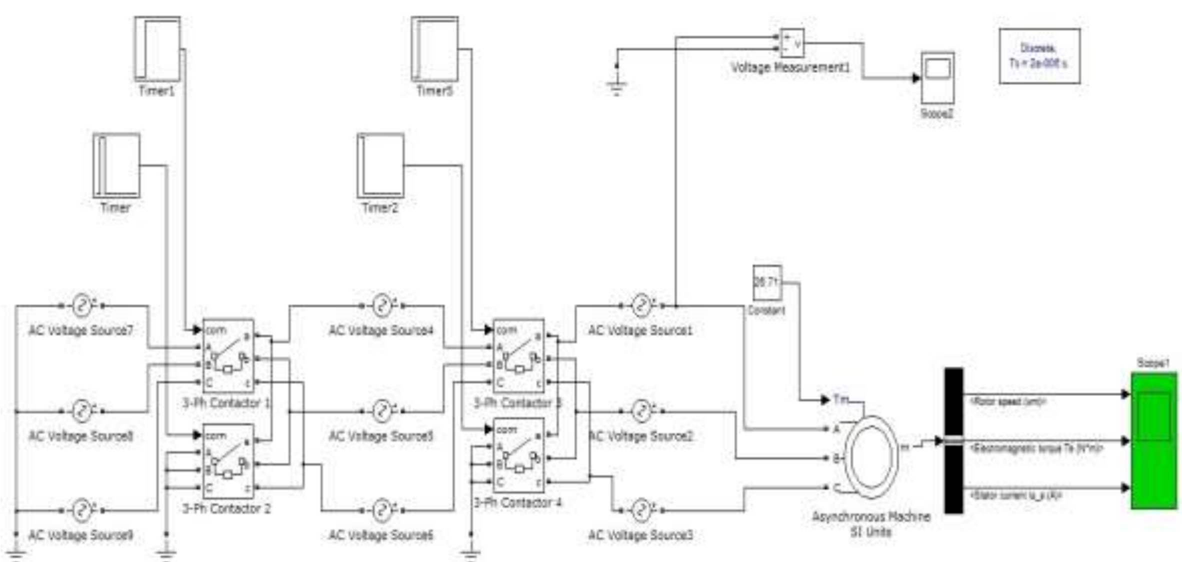

Fig -5 Simulink model of auto-transformer

Induction motor of 5.4H.P (4kw), 400v, at 50Hz frequency has been used .In above model variable voltage is applied at different stages so that they can operate and work as auto-transformer. Ac voltages source 1, 2 and 3 has value of 150 volt. Ac voltage source 4, 5 and 6 is providing 500 volts, ac voltage source 7, 8 and 9 is providing 30 volts. Sum of all the ac voltage sources will be 230 volt.

Breaker is operated through timer to provide different tapping.

Timer values is(0 , 0.1 , 0.2).At time 0sec 150 volt is supplied to the motor and after 0.1sec 50 volt is added ,total 200 volt is given at the time of 0.1 second. At time 0.2 second remaining 30 volt is added and hence full 230 volt supply is given to motor. This is done to provide different tapping, as it is provided in auto-transformer

6.2 Simulink output of auto-transformer starting of induction motor

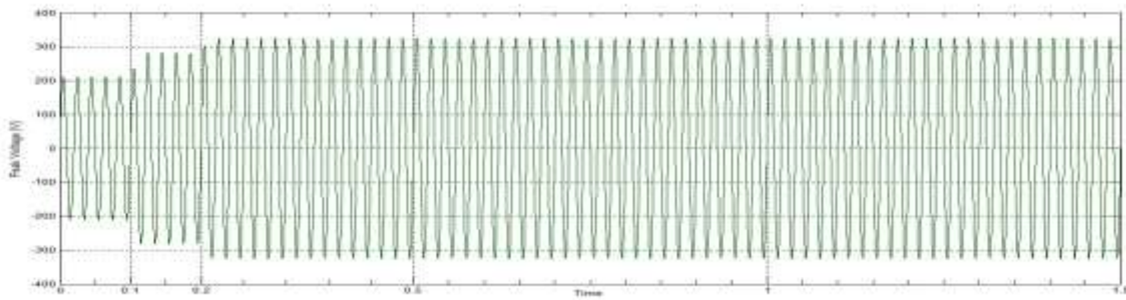

Chart -3 Above waveform shows different voltage level at different time for model.

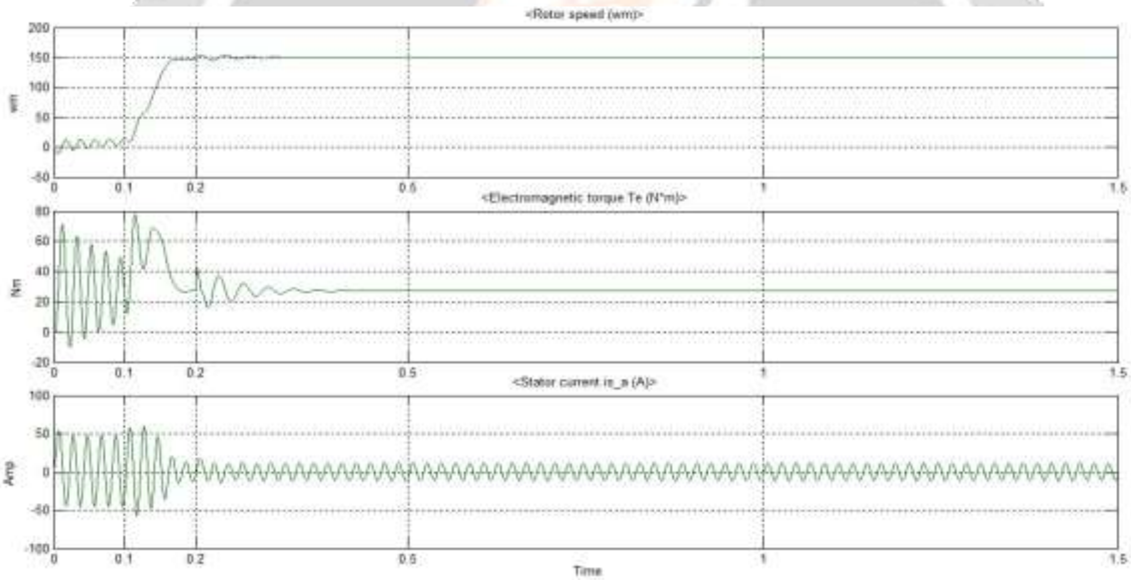

Chart -4 Output waveform of starting speed, torque and current of auto-transformer starter model.

7. COMPARISON OF OUTPUT WAVEFORM OF STARTING PARAMETERS

7.1 Comparison of waveform of starting speed of different starter

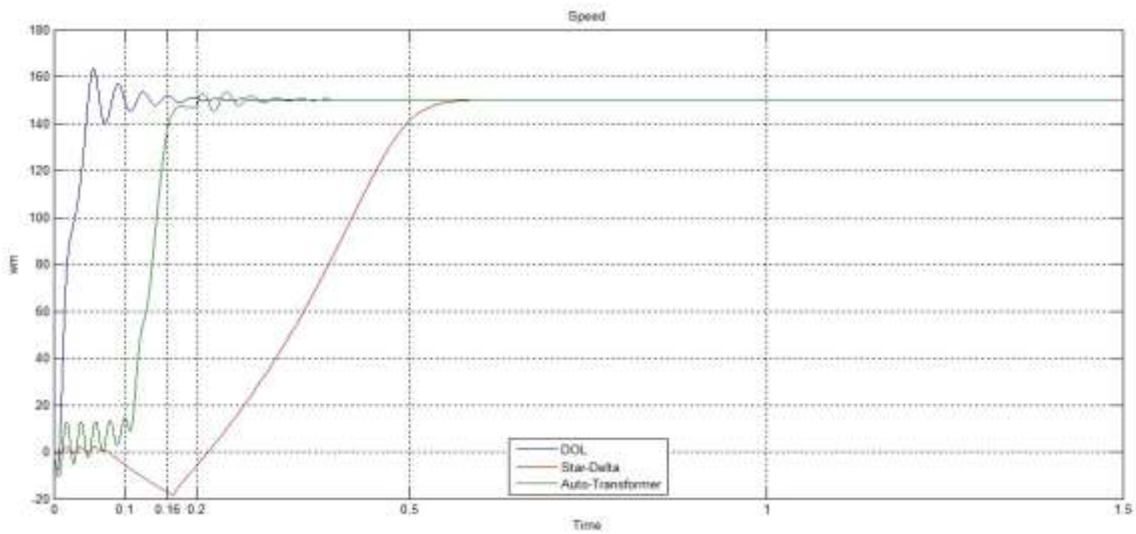

Chart -5 Waveform of comparison starting speed.

7.2 Comparison of waveform of starting torque of different starter

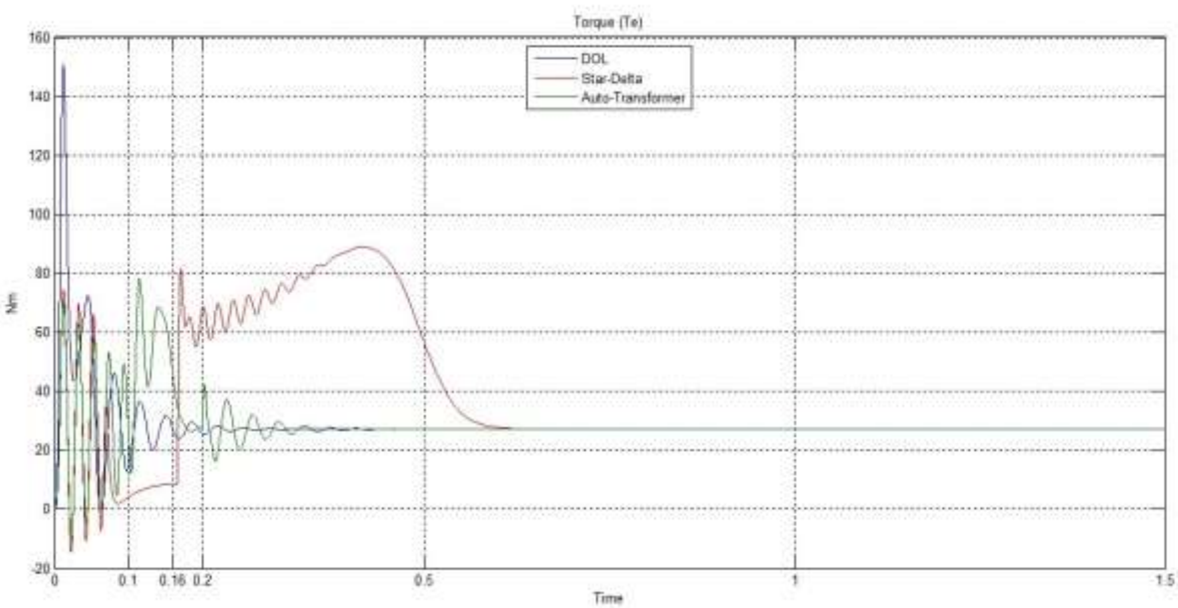

Chart -6 Waveform of comparison of starting torque.

7.3 Comparison of waveform of starting current of different starter

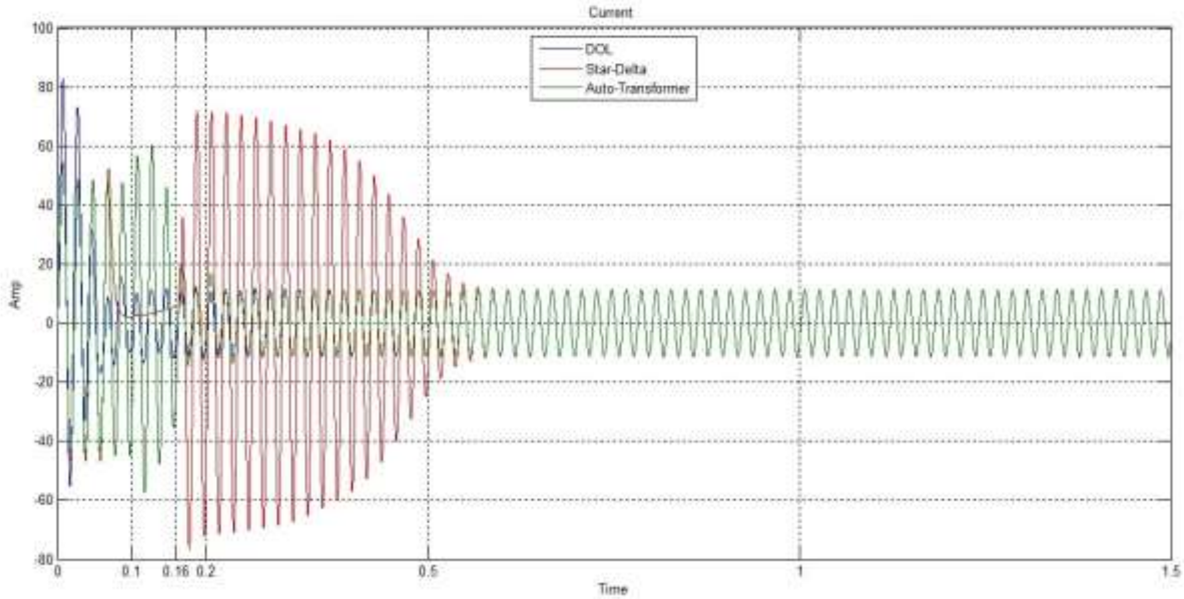

Chart -7 Waveform of comparison of starting current.

8. COMPARISON OF MOTOR PARAMETERS DURING STARTING CONDITION USING DIFFERENT METHOD

Parameters / Starters	Rotor speed		Torque		Stator Current	
	At Transient Time	At Normal Time	At Transient Time	At Normal Time	At Transient Time	At Normal Time
D-O-L Starter	1561 rpm	1434 rpm	151 Nm	27.16 Nm	58.33 A	7.9 A
Star-Delta Starter	(Y) 191 rpm (D) 1445 rpm	1432 rpm	(Y) 73.7 Nm (D) 131 Nm	27.15 Nm	(Y) 39.1 A (D) 49.4 A	7.9 A
Auto-Transformer Starter	(1)136 rpm (2)1407 rpm (3)1467 rpm	1432 rpm	(1)71 Nm (2)78 Nm (3)42 Nm	27.16 Nm	(1)38.18 A (2)42.4 A (3)12 A	7.9 A

9. CONCLUSIONS

After studying all waveform and outputs, we concluded that starting speed during D-O-L starter is very high as compare to the starting speed of the same Induction motor when connected to Auto-Transformer starter.

The value of torque is 151 Nm, when we use D-O-L starter and 131 Nm while using Star-Delta starter and 78 Nm by using Auto-Transformer.

Starting Current of induction motor, using D-O-L starter is 58.33 A, which is more than Star-Delta i.e. 49.4 A .While the starting current in Auto-Transformer is less than both the starters and its value is 42.4 A.

Therefore after studying all three starters and their behavior while transient period, we conclude that Auto-Transformer is better as compared to other two starters and it limits high starting current and voltage, efficiently than the other once.

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