Volume : 1 | Issue : 1 | January 2012 ISSN : 2250 - 1991

Research Paper Electrical Engineering

Comparison Of Conventional Motor Starters And Modern Power Electronic Starters For Induction Motor

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ABSTRACT

In Induction motor, there is no control on starting current. When the voltage is applied, large starting current produces and drive is subjected to jerks during acceleration. With the variation in the load, voltage is not adjustable hence motor consumes more power than it required. The high starting current often causes problem such as voltage dips and flickering lights. Various motor starters were introduced to overcome this problem. The different motors starters available are discussed and analyzed in this paper; these include both conventional electromechanical starters and electronic starters. The advantages, disadvantages and energy saving features of each type of starter mentioned will also be discussed. An analysis of the industrial applications and the demand of these starters in India are also made and to finally conclude, this paper will also provide a suggestion of which starter is most suitable for an application based on the stated constraints.

Keywords : Conventional Starters, Autotransformer, Electronic Soft Starter, Energy Saving

Introduction

There are several starting methods of an induction motor available in the market. Those detailed in this report are the Direct Online, Primary resistance, Primary reactance, Star-Delta, Autotransformer, Soft Starter. All the starters mentioned perform a primary function, which is to supply voltage to the induction motor during start up period. However, each of these starters carries their own advantages and disadvantages. Therefore, in order to determine which starting method is the best and most suitable for a particular application, an investigation is made to assess the various starting characteristics in terms of voltage, starting current and starting torque, the starting cost of installation, the maintenance cost and its payback period.

Induction motor

3-phase induction motors are simple, rugged, low-cost, and easy to maintain. They run at essentially constant speed from zero-to-full load. Therefore, they are the motors most frequently encountered in industry [1].

An Induction motor appears as a short-circuited transformer, if connected to the full voltage supply and it draws large current. To reduce the starting current, reduced voltage is applied at the starting using Starter. The stator is the stationary electrical part of the motor. It consists of a hollow cylindrical core that is made up of a number of stampings with slots to carry three phase windings and a steel frame supports it. The rotor is the rotating part of the electromagnetic circuit. There are 2 types of rotor windings that is the 3-phase windings made of insulated wires and squirrel cage windings. This gives rise to two types of motor that is the famous Squirrel Cage Induction Motor (SCIM) and wound rotor induction motor. However, wound rotor induction motor has higher maintenance cost, larger in size and it's more expensive than a SCIM making the SCIM a preferred choice. Therefore, the starting characteristic of the Induction Motor in this research is based on the SCIM.

Conventional starters

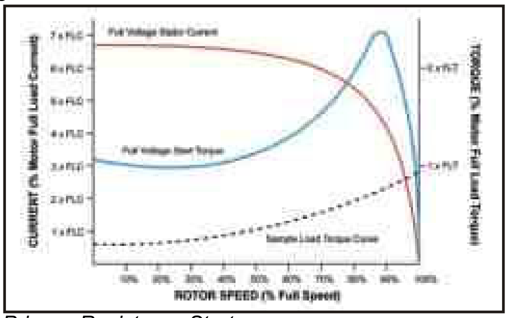
A.C. Induction motors are traditionally started and stopped by applying and removing the A.C. supply. In some cases, a full voltage start is acceptable, but in many situations, the start current must be reduced, and so a reduced voltage starter is employed. The types of starters available are the Direct On-line, Primary resistance, Primary reactance, Star-Delta and Autotransformer starter, each of which is explained below [2].

A. Direct On Line starter

The simplest form of motor starter for the induction motor is the Direct On Line starter. The DOL starter comprises a switch and an overload protection relay. The switch would be an electromagnetic contactor, which can be opened by the thermal overload relay. Typically, separate start and stop buttons will control the contactor, and an auxiliary contact is used as a hold in contact. i.e. the contactor is electrically latched closed while the motor is operating [2][5]. 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, to establish 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. 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 dependant on the acceleration torque and the load inertia. DOL starting results in 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.

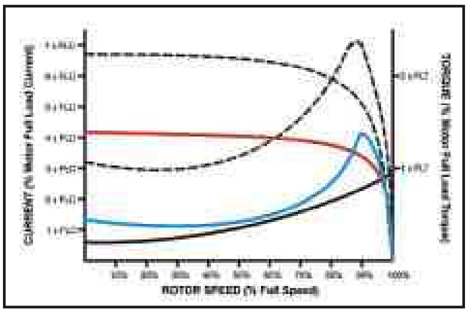
Figure 1 DOL Characteristics



B. Primary Resistance Starter

The Primary Resistance starter will have one or more sets of resistors, which, during start, are connected in series with the supply to the motor. The series resistors limit the starting current drawn by the motor, and thus reduce the starting torque of the motor. Improved starting characteristics with some loads can be achieved by the use of several stages of resistance and bridging out increasing amounts of resistance as the motor accelerates. With the primary resistance starter, it is not easy to alter the resistance and hence the starting characteristics once the starter is built. Therefore, it is important that the correct resistors are selected in the first place. The primary resistance starter reduces the voltage applied to the motor terminals while passing the full starting current to the motor. Consequently, there is very high power dissipation in the resistors, resulting in the requirement for very high power rated resistors. Typically, the resistors will dissipate as much as 150% - 200% the power rating of the motor for the duration of the start. The resistors may be either metallic resistors, or liquid resistors. Metallic resistors have a positive temperature coefficient and as a result, as they heat up, their resistance increases. Liquid resistors, such as saline solution, have a negative temperature coefficient and so consequently, as they heat up, their resistance reduces. The heat build up in the resistors during start, and their temperature dependant resistance characteristics, make it essential the resistors are allowed to fully cool between starts. This restricts the starting frequency and the minimum time between the starts.

Figure 2 Primary Resistance Characteristics



C. Primary Reactance Starter

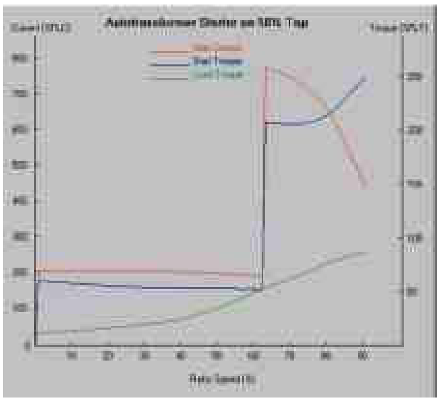
A Primary reactance starter is similar to a primary resistance starter except that the resistors are replaced by a three-phase reactor to limit the starting current. The operation of the primary reactance starter is essentially the same as that of the primary resistance starter, but the use of a three-phase reactor in place of the resistors offers the advantage of reduced heat loss and greater ease of start current setting due to the ability to change taps on the reactor.

D. Auto-Transformer Starter

An Autotransformer starter uses an autotransformer to reduce the voltage applied to a motor during start. The autotransformer may have a number of output taps and be set-up to provide a single stage starter, or a multistage starter. Typically, the autotransformer would have taps at 50%, 65% and 80% voltage, enabling the motor to be started at one or more of these settings.

There are two ways of connecting an autotransformer starter, the most obvious way is to apply full voltage to the transformer via a contactor, and connect the motor to the tap by means of a contactor [2]. When the motor has accelerated to full speed, or has run out of acceleration torque, the tap contactor opens, disconnecting the motor from the transformer and another contactor closes connecting the motor to the supply. The motor acts as a generator until the rotor field decays. The voltage generated by the motor is not synchronized to the supply, and so on reconnection to the supply, the voltage across the contactor at closure can be as much as twice the supply voltage resulting in a very high current and torque transient. This open transition switching is often known as the auto-reclose effect as it yields similar characteristics to opening and closing a breaker on a supply to one or more motors. The consequences of open transition switching can be as bad as broken shafts and stripped gears. When the motor has reached full speed, (or run out of acceleration torque) the star contactor is opened effectively converting the autotransformer starter into a primary reactance starter. Next the primary reactance is bridged by a contactor applying full voltage to the motor.. If the motor is connected to the 50% tap of the transformer, the voltage across the motor terminals will be 50%. Assuming an LRC of 600%, there will be 300% current flowing into the motor. If 300% current flows into the motor, then the current into the transformer will be 150%. This would suggest that the lowest starting current would be achieved by the use of an autotransformer starter. In most instances, the load will require an increasing torque as it accelerates, and so often a higher tap must be selected in order to accelerate the load to full speed before the step to full voltage occurs. If a multistage transformer starter is employed, then the primary current will certainly be lower than other forms of induction motor starter.

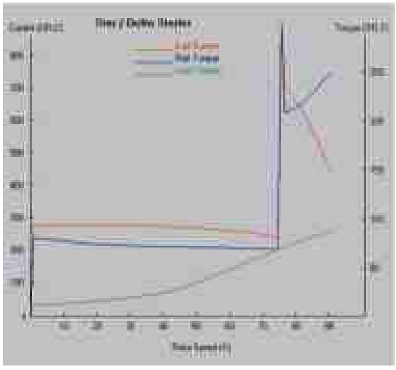
Figure 3 Autotransformer Characteristics on 50% tap



E. Star-Delta Starter

The Star Delta starter can only be used with a motor, which is rated for connection in delta operation at the required line voltage, and has both ends each of the three windings available individually. At Start, the line voltage is applied to one end of each of the three windings, with the other end bridged together, effectively connecting the windings in a star connection. Under this connection, the voltage across each winding is 1/(3) of line voltage and so the current flowing in each winding is also reduced by this amount [2] [5]. The resultant current flowing from the supply is reduced by a factor of 1/3 as is the torque. i.e. A motor which exhibits a LRC of 600% and an LRT of 180% will exhibit characteristics of: LRC_{star} of 200% and LRT_{star} of 60%. In some cases, this may be enough to get the motor up to full speed, but most, as this is a constant voltage starter, the transition to full voltage will occur at part speed resulting in a virtual DOL type start. To step to full opined by a very high torque and current transient. In most situations, there would be less damage to the equipment and less interference tillage, the star connection is opened, effectively open circuiting the motor, and the ends of the windings are then connected to the three phase supply in a fashion to create a delta connection.

Figure 4 Star Delta Starter Characteristics

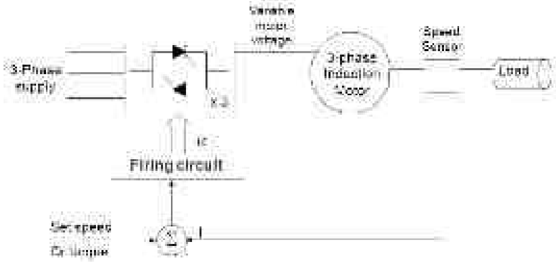


Soft Starter

A soft starter is another form of reduced voltage starter for A.C. induction motors. The soft starter is similar to a primary resistance or primary reactance starter in that it is in series with the supply to the motor [2]. The current into the starter equals the current out. The soft starter employs solid-state devices to control the current flow and therefore the voltage applied to the motor. In theory, soft starters can be connected in series with the line voltage applied to the motor, or can be connected inside the delta loop of a delta connected motor, controlling the voltage applied to each winding. Voltage control is achieved by means of solid-state A.C. switches in series with each phase [4].

By connecting a parallel pair of thyristor between a.c. supply and load, the voltage applied to load can be controlled. This type of power controller is known as an a.c. voltage controller or power controller. Therefore, a.c. voltage controller converts fixed mains voltage directly to variable alternating voltage without a change in frequency. Firing pulses are given with the help of micro controller to the three-phase a.c. voltage controller. Power circuit of soft starter is nothing but an a.c. voltage controller, which can control supply voltage. It consists of six antiparallel thyristors. By controlling the firing angle of the thyristors voltage control is possible. The soft starter employs solid-state devices to control the current flow and therefore the voltage applied to the motor. In theory, soft starters can be connected in series with the line voltage applied to the motor, or can be connected inside the delta loop of a delta connected motor, controlling the voltage applied to each winding. Power circuit of soft starter is nothing but an a.c. voltage controller, which can control supply voltage. It consists of six antiparallel thyristors. By controlling the firing angle of the thyristors voltage control is possible.

Figure 5 Thyristor controlled voltage for induction motor



Energy Conservation

As electrical energy is part of everyday life, energy conservation is very much in evidence subject nowadays. In order to minimize starting current of the induction motor, various methods has been discussed. When soft starter is used to start the induction motor, applied voltage increases in a ramp manner. In order to do this power electronics device is used. This equipment consists of two thyristors per phase in antiparallel connection. The thyristor firing angle can be conveniently varied [4]. Energy saving is possible with the use of soft starter [3].

When a motor is operating at low load, its voltage can be slightly reduced. In this way a reduction in iron losses can be achieved. Voltage should be reduced to the point where current starts increasing or until speed starts varying substantially. Many methods has been developed to improve quality of the currents such that energy can be saved during operations [6].

Conclusion

There are many ways to start an induction motor. The selection of the best method to use will be based on the overall power system constraints, cost of the equipment and the driven equipment. While the full voltage method is the easiest and least expensive from the point of equipment, it may invoke cost penalties from the utility or the power system at the location may not be able to support the required level of energy drawn. These methods may also lead to increase the size of motor in order to generate the torque required for the load. The adjustable frequency drive will remove both of these obstacles. But requires a price premium for the equipment. Therefore the best and most suitable starter to be used in fixed speed applications is the Soft Starter. This is because the Soft Starter provides a low inrush current at start thus minimizing maintenance cost when compared to conventional starters.

Table 1 Technical comparison of various starting methods

	DOL	Star-Delta	Autotransformer	Soft-starter	Energy Saving Soft Starter
Load During Start	Full	Low	Low	Low to Medium	Low to Medium
Step down voltage	No	1/ √3 *Full Voltage	80%-50% of Full Voltage	Ramped up	Ramped up
Starting current	6-8*FLC	1/ √3 *FLC	1.5-3.8*FLC	2-5*FLC	2-5*FLC
Starting torque	Highest	Low	Low	Low	
Energy Saving	No	No	No	No	Yes

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