International Journal of Power Electronics and Drive System (IJPEDS)
Vol.1, No.1, September 2011, pp. 41~46
ISSN: 2088-8694

A Novel method of Starting Induction Motor: A Comparative Study

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Abstract

Polyphase induction motor, when started from rest with full voltage impressed, the starting current is 5 to 8 or more times the rated current. The large line current drawn by such a motor is objectionable because of the possible sharp drop in voltage of the supply circuit and undesired effects upon other connected loads/devices. Accordingly it is customary to start such motors at reduced voltage by using auto transformers, star delta starters etc. This paper deals with a new approach to start poly phase induction motors without using any primary voltage compensators thereby limiting the inrush of starting current. The rotor of the motor is driven at suitable speed in the specified direction of rotation by using crank driving mechanism. Then te rated voltage is applied to the motor. This is enunciated using a case study on a 3- phase, 5hp, NGEF make motor with oscillographic records obtained from the experimentation and is compared with the various starting techniques.

Keywords: *Induction motor, starter, inrush current, voltage dip, new approach*

1. Introduction

Three phase induction motors are more robust, require less maintenance and cheaper compared to other types of motors of equal power and speed ratings. As such these motors are widely used for most of the industrial applications ranging from small workshop to large industry. When the 3-phase winding on the stator is supplied with 3 phase balanced ac supply, a uniformly rotating magnetic field of constant magnitude is produced. The rotating field sweeps across the rotor conductors, as a result, an emf is induced in these conductors. The rotor conductors are equivalent to a short circuited winding, carries current. The rotor current interacts with the field produced by the stator winding, so as to produce torque, responsible for the rotation of the motor. For starting such motors, invariably starters are employed to limit the inrush of current which is of the order of 5 to 8 or more times the rated current of the motor. This will cause the effect on the system voltage to reduce and adverse effect on the connected loads/ devices.

The interpretation for large starting current drawn by the motor is, due to the large relative speed between the field rotating at synchronous speed and rotor conductors at standstill condition. According to Faraday's law, the magnitude of the induced emf is proportional to the rate of change of flux linkages. Since the relative speed is maximum, magnitude of the rotor induced emf is quite large and will circulate large current in the rotor winding having finite resistance, which is the only opposition to the flow of current. On the other hand the slip being unity, the frequency of the rotor emf equals the supply frequency and the rotor emf induced per phase is

- Rotor induced emf $E2 = 4.44 f_r \Phi T_2 k_{wr}$
- where f_r - frequency of the rotor induced emf.
- T_2-number of turns per phase in the rotor winding
- k_{wr} - winding factor of the rotor winding.
- At stand still $f = f_r$ then
- Rotor induced emf at standstill
- $E_2 = 4.44\ f\ T_2 \Phi\ k_{wr}$

Hence, the magnitude of rotor induced emf at the instant of starting is quite large, that will circulate large current in the rotor winding. Thus the stator is forced to draw high current at the instant of starting, causing considerable heating effect due to high copper losses in the motor and might damage the insulation of winding apart from the system voltage reduction and adverse effect on the loads connected to the same line. Another interpretation for large starting current is, since the rotor is at standstill condition; require more energy during starting to overcome the inertia to set into motion. This is accomplished by drawing large current during starting at a given system voltage in accordance with the fundamental torque relation,

$$T_m - T_L = \alpha J \quad (1)$$

Received Jul 12th, 2011; Revised Aug 28th, 2011; Accepted Sep17th, 2011

where Tm and T_L are the torque due to motor and to the load, respectively,
α is the angular acceleration and
J is the polar moment of inertia of the entire rotating system.

Hence, it is customary to start such motors at reduced voltage by means of auto transformer, star-delta starters etc.. Such starting equipments will add purchase cost and running cost to those of the motor. An approach to start induction motor to limit the starting current without using starters and without affecting the performance of the motor could be by the proposed method mentioned below.

2. Starting of Induction Motors without Starter

In this method the starting equipments are not used. When the voltage is applied to the motor at stand still condition, the relative speed between the rotating field and rotor conductors is maximum and thus induces large emf in the rotor circuit. If the relative speed is reduced before the voltage is applied, then the emf induced in the rotor circuit is less. In this method, before applying the rated voltage, the rotor is rotated by mechanical means to suitable speed. This is done by using crank to rotate the shaft of the rotor, then the rated voltage is impressed. Since the rotor is in motion, the relative speed is considerably reduced and this reduces the emf induced in the rotor circuit proportionally. Thus the current circulated in the rotor circuit is relatively less at the instant of starting. The rotor induced emf

$$E_2 = 4.44\, f_r \Phi\, T_2\, k_{wr} \qquad (2)$$

Since the rotor is rotated in the beginning, frequency of the rotor emf is less and hence the magnitude of the induced emf. It is clear that an external energy is supplied to the motor at the time of starting. It is obvious that, to overcome the inertia and to set into motion, the energy drawn from the supply is less. Therefore, for a given system voltage, less energy is supplied, of course at reduced current. The fundamental torque relation

$$T_m - T_L = \alpha J$$

Now the motor torque T_m is

$$T_m = T_{internal} + T_{external} = T_i + T_e \qquad (3)$$

$$\text{i.e. } (T_i + T_e) - T_L = \alpha J \qquad (4)$$

T_e is the torque provided only at the instant of starting by driving the rotor with crank driving arrangement as shown in Fig.1.

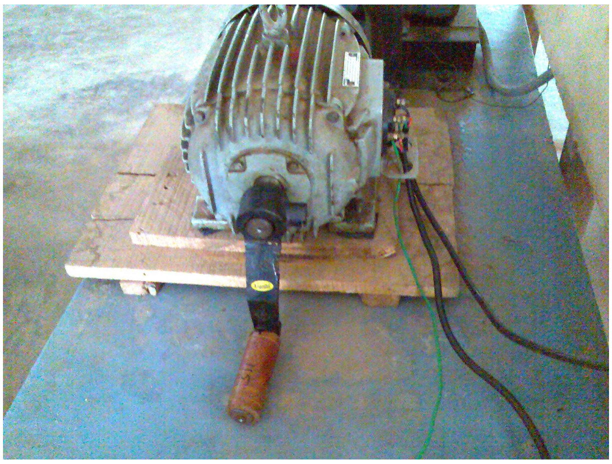

Fig.1.Experimental set up.

Once the supply is switched on motor picks up to the rated speed, then

$$T_m = T_i \qquad (4)$$

Thus, the motor draws low current from the supply during starting. However, while rotating the rotor, it is to be doubly ensured that, it is driven in the specified direction of rotation. The result would be catastrophic if driven opposite to the specified direction. This problem can be solved by using a crank that will clutch the shaft of the motor only when it is rotated in the specified direction and becomes free wheeling when tried to rotate in the reverse direction. The magnitude of the starting current now depends upon the speed at which the rotor is driven. It is clear that higher the speeds of the rotor lower the relative speed and hence reduced current. Since 90% of the industrial drives are induction motors and 75% to 80% of them are squirrel cage induction motors and 50% of the drives are generally starting without load. Hence this scheme of starting is more suitable for motors starting without/with light load. It can be used for both squirrel cage and wound rotor motors that are starting against light load. The proposed method of starting will offer few advantages like:

- reduction in system disturbances
- reduction in time to reach steady state
- reduction in heating effect
- reduced premature failure of insulation
- increased life span of the motor
- reduced energy at the time of starting
- no complexity in employing the scheme
- improved transient behavior
- economical, since no starting equipments are needed

To justify the suitability and above listed merits of the scheme, a case study has been carried out on a low capacity motor.

3. Case Study

A case study has been carried out on a 3-phase 5 hp(3.7 KW), 415 V, 50Hz, 1440 rpm, 7.3A, NGEF make induction motor. A comparative study is done by starting the motor with star–delta starter and the proposed scheme. The experimental procedure and observations made are as explained below.

* The motor is started with star delta starter and the starting current waveform is captured using a digital scope. When repeated for different random switching instants, the obtained waveforms are as shown is Fig.2 and Fig.3. The switching transient is also obtained and is as shown in Fig.4

* The rotor is driven using crank driving mechanism at a speed of 1320 rpm, then the rated voltage is applied to the stator windings. The corresponding current waveforms obtained at different random switching instants are as shown in Fig.5, Fig.6 and Fig.7 shows the switching transients obtained with the proposed method of starting.

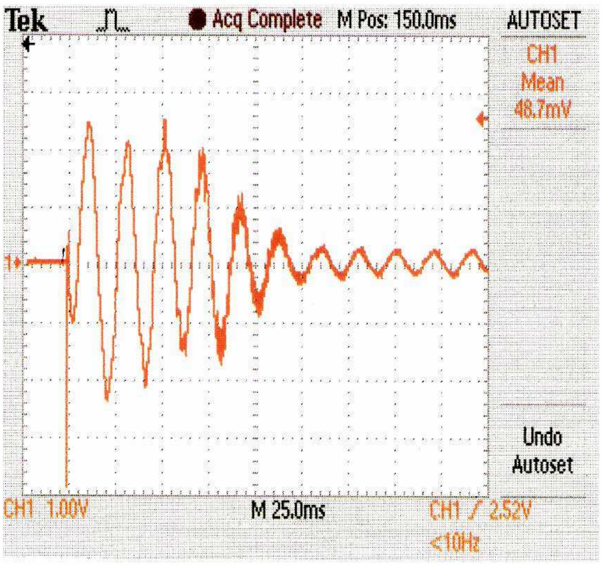

Fig.2. Starting current waveform with star delta starter

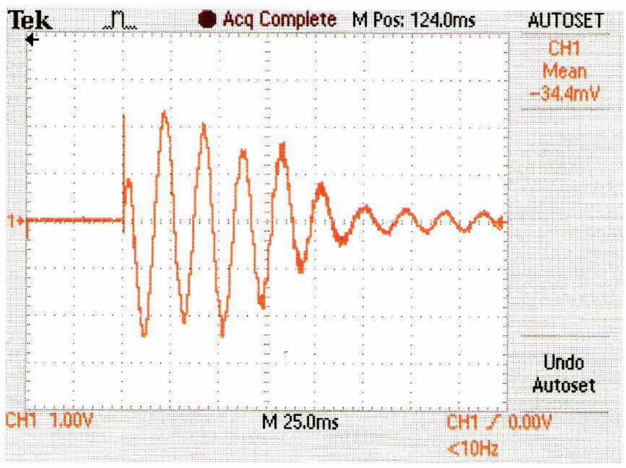

Fig.3. Starting current waveform with star delta starter(at some other switching instant)

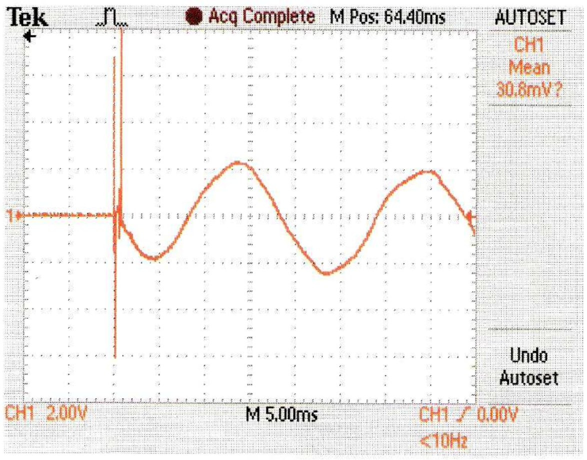

Fig.4.. Switching transients with star delta starter.

4. Inferences

Based on the experimental observations and in accordance with theory and principle of operation of induction motor the following inferences are drawn

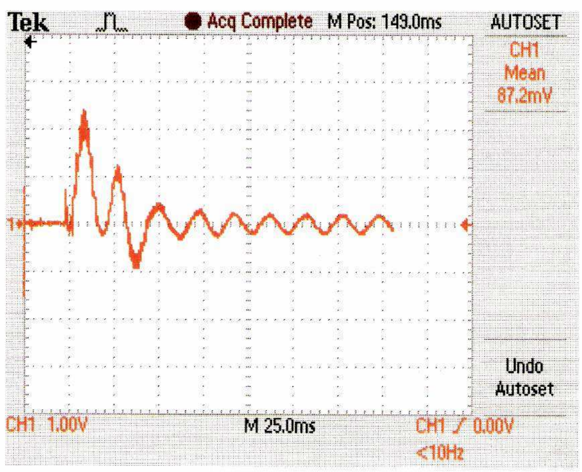

Fig.5. Starting current waveform with proposed method of starting.(Initial rotor speed is 1320 rpm before applying the voltage)

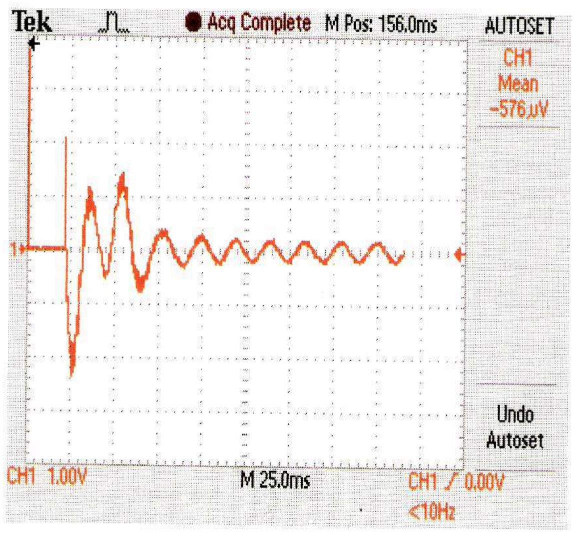

Fig.6 Starting current waveform with proposed method of starting.(Initial rotor speed is 1320 rpm at some other switching instant before applying the voltage)

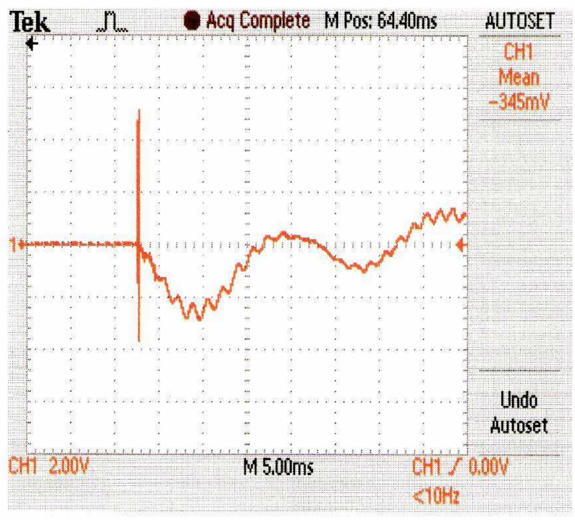

Fig.7. Switching transients with the proposed method of starting

- The starting current is reduced by 50% to75% and that of course depends on the speed at which rotor is driven before applying the voltage.
- The starting current will take only 2 to 2.5 cycles to attain steady state whereas it require 5 cycles with star delta starting to reach steady state.
- There is considerable reduction in the magnitude of the transient current.
- Minimized system voltage disturbance and reduced adverse effect on the connected loads, thus maintaining the quality of the supply. Owing to the above observations the proposed method of starting can be effectively used.

5. Comparision of different starting techniques

5.1 Direct-on-line starting

In this the motor is switched on directly to full supply voltage and the initial starting current is normally about 5 to 7 times the rated current. The starting torque is likely to be 0.75 to 2 times the full load torque and DOL starter is typically only used for motors with a rating of less than 5kW.

5.2 Star Delta starter

The phase voltages and the phase currents of the motor in star connection are reduced to 1/(square root of 3) of the direct -on -line values in delta. The line current is 1/3 of the value in delta. Most of the moderate capacity machines are started by star-delta starters and the starting torque is reasonably good.

5.3 Rotor resistance starting

The addition of resistance in rotor circuit reduces the starting current, so that a starting torque in the range of 2 to 2.5 times the full load torque can be obtained at a starting current of 1 to1.5 times the full load current.

5.4 Primary resistors/reactors

In this method, reduced voltage is applied at starting by connecting resistors/reactors in series. This reduces the current, but there will be continuous power loss.

5.5 Auto-transformer starting

This method also reduces the initial voltage applied to the motor and therefore the starting current and torque The advantage of the method is that the current and torque can be adjusted to the required value, by taking the correct tapping on the autotransformer. This method is more expensive.

5. Conclusion

This method can be used to start induction motors which are preferably starting against light loads. It is smooth starting that result in limiting the inrush of starting current to a safe value. It will have the reduced heating effect and there is no threat to the insulation thereby ensuring the life of the motor. The system disturbance is minimized to greater extent and will avoid undesirable effects on connected loads/devices. The method is more economical as it eliminates the purchase and running cost associated with starting equipments. There is no deviation in the performance of the motor. Hence, the method is more suitable for starting the induction motor. The starting current drawn is relatively low when started with the other starting techniques.

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