NEW STARTING METHOD FOR THREE-PHASE CAGE INDUCTION MOTOR USING PART WINDING ARRANGEMENT

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Abstract :In this paper, a new starting method, part winding starting (PWS) is presented for 4 poles three-phase squirrel cage induction motor. The part winding starters are designed to be used with cage induction motors having two separate and parallel stator windings. The starter energizes half of the motor's windings with full line voltage during starting and the second half of the windings in parallel with the first of the windings for a running condition. A comparative study of various PWS arrangements such as adjacent poles, alternate poles, alternate pairs of groups and alternate groups are presented. Furthermore, the PWS arrangements are experimentally validated on a 3.75 kW motor and compared with direct-on-line, star-delta, auto-transformer and pole-changing starters.

***IndexTerms* - Auto-transformer starter, direct-on-line, star-delta, part winding starting method and pole-changing starters.**

I. INTRODUCTION

Part-winding starting, half-winding type, is the most commonly used method of increment starting of three-phase squirrel cage induction motors. The half-winding method of part-winding starting requires the use of a specific starter with a cage induction motor having two parallel stator windings suitably connected internally for part-winding starting.

The starter must be capable of energizing, with full line voltage, half of the motor winding, then after a slight time delay energizing the complete winding in parallel with the first half of the motor winding.

The advantages of the part-winding starting method are as follows:

- Starting current is reduced to 60 to 65 % of the value encountered if the motor was started across-the line.
- Starting torque is approximately 45 to 50 % of the value encountered if the motor was started across-the-line.
- Continuous connection of the motor to line during the transition period minimizes voltage fluctuation during the transition period.
- It can be applied to most 4, 6 and 8 pole motor designs.

Direct-On-Line starting of induction motors may present difficulties for the motor itself and the load supplied from the common coupling points because of the voltage dips in the supply during starting [1]. This problem can be avoided by starting the motors at a reduced supply voltage. The usual alternate starting method is the star-delta winding. This type of winding can be found in various motors' applications due to its simplicity and economic benefits. However, a problem associated with this method is the need to instantaneously disconnect the motor from supply while the changeover from star to delta is being made. This can cause a significant reduction of rotor speed before the voltage is applied again to the delta connection. The result of this operation is a peak current during the transition, the value of which can approach that of the current peak value of the DOL started motor.

To overcome this problem, so-called part-winding starter was proposed [2], where only a part of the stator winding is connected to the supply initially, and the remaining stator winding is closed in succession as the motor attains speed. This starter has two important advantages as follows:

- Its implementation does not raise costs, which is very important factor in the production of induction motors.
- It does not require disconnection of the winding after the motor is successfully started.

In the literature, Courtin developed various PWS arrangements for 4-pole double cage induction motor [3]. To give a further contribution, various PWS arrangements for 4-pole single cage induction motor are investigated. The comparison of various PWS arrangements reveals that the adjacent poles arrangement provides better starting performance (i.e., higher starting torque and lower starting current) than the other PWS arrangements.

Selection of the most appropriate starting method for induction motors depends on many factors, with the economic aspects of the decision playing an equal, or perhaps, even more important task. The simplest way of starting a three-phase motor is to connect it to the supply voltage, which is termed as Direct-On-Line (DOL) starting. The consequences of starting the motor this way are high initial currents (5 to 8 times the full load currents). When the motor is repeatedly started, the surge current can cause damage to the motor and, furthermore, cause a disturbance of the supply voltage.

To avoid this problem, motors are often started at a lowered supply voltage. The usual alternate starting method is the star-delta starters. A problem associated with this method is the need to instantaneously disconnect the motor from supply while the changeover from star to delta is being made. This can cause a significant reduction of rotor speed before the voltage is applied again to the delta connection. The result of this operation is a peak current during the transition, the value of which can approach that of the current peak value of the DOL started motor.

To overcome this problem, the part-winding starting method was proposed [4]. Part-winding starting method is a reduced voltage starting method in which the power is applied to only part of the stator windings during starting condition and then the power is applied to the remaining windings during normal running condition. The part-winding motor has two sets of identical stator windings which are connected in parallel.

In part-winding starting, the motor draws low starting current and develops low starting torque [5]. The motor draws 60-70% of its locked rotor current and produces 50% of its locked rotor torque. After the motor reaches the steady speed, the second set of stator windings are connected in parallel with the first set of windings, and the motor now produces normal torque. Rawcliffe and Fong have presented the sum and difference winding modulation with special reference to the design of 4/6 P.A.M. windings [6].

Andrej Stermecki et al. have presented a design process of part-winding based on numerical analysis with the movement of the rotor also taken into consideration [7]. Furthermore, the effects of eddy currents in the motor shaft material and their influence on the magnetic field and the motor's performance have been analyzed. Rainer Helmer et al. have used a new calculation method to predict the start-up characteristic of part winding motors [8].

In this paper, to validate the PWS arrangements, a 3.75kW motor is developed and experimentally tested. The results are compared with the DOL, star-delta, auto-transformer and pole-changing starting methods.

II. Pole Changing and Part Winding Starting Methods

Pole changing motor is always being switched to the lower speed when starting. For higher speed, one half of the stator windings is reversed. Pole changing techniques are mostly used for cage motors since the rotor poles are induced in accordance with the number of poles on the stator.

The two techniques are employed in the pole changing. In the first technique, two independent stator windings are made on the stator. The two windings are to be insulated from each another. When any of the winding is used, other winding should be kept open circuited. In other technique, only one winding is wound for a particular number of poles, but the end connections of the coils with the supply is changed such that different numbers of poles are formed.

PWS is the lowest cost method of reducing the starting current for induction motors. In this method, the line voltage is applied to only a part of the winding at first, and connecting the rest of the winding after motor is started. For PWS method, the three-phase winding of the motor is designed with two parallel circuits (parallel path or parallel conductors) in each phase and the voltage is applied initially to only one circuit (half-winding starting). The entire winding being energized few seconds later as the motor started and attained the rated speed.

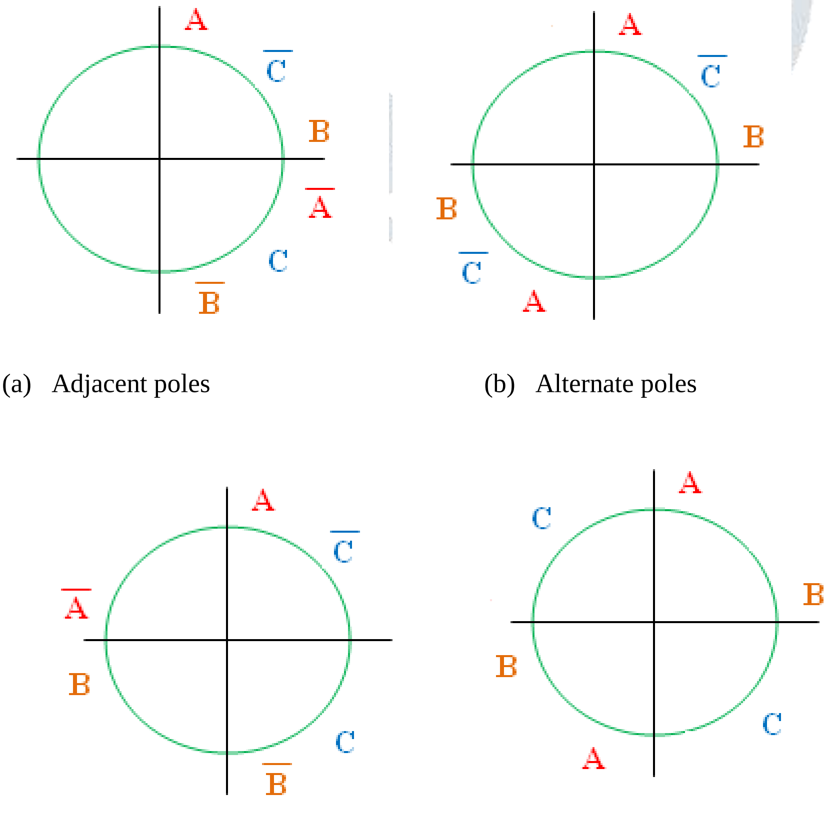
During PWS, the current drawn from line is about 66% of the DOL starting current and the starting torque is about 50% of it. This is the main advantage of the method, and it provides better starting performance in comparison with the star-delta starting method.

III. PWS Arrangements

A standard 4-pole, 36 slots, three phase winding consists of 12 phase groups, each phase group is emerged for four times and each phase group is made up of three coils in series. In part winding starting, one half of the groups of each phase or two of the A, B and C groups of each phase are energized for starting condition. The 4-pole stator winding can be symmetrically divided into four different ways as follows:

- Adjacent poles
- Alternate poles
- Alternate pairs of groups
- Alternate groups

The various PWS arrangements are shown in Fig. 1.



(a) Adjacent poles (b) Alternate poles

(c) Alternate pairs of groups (d) Alternate groups

Fig.1. PWS arrangements

IV. Experimental Realization

To investigate the performances of PWS arrangements, a 3.75 kW cage induction motor are experimentally tested. The starting performances of the various PWS arrangements are compared with the DOL, star-delta, auto-transformer and pole changing starting methods.

A DC shunt generator rated as a 2.2 HP, 110 V, 1400 rpm was coupled with the test machine and also a simple RC differentiating circuit was used to obtain the torque versus speed characteristics. The locked-rotor tests are conducted on the test motor in order to determine the starting current and starting torque obtained by various starting methods. The results obtained by the various starting methods of the motor are given in Table .1 and Fig. 2.

Table 1. Starting characteristics of the motor

Starting methods		**% of full winding current**	**% of full winding torque**
DOL		100	100
Star-delta		33.33	33.33
Auto transformer	50 %	25	25
	65 %	42.25	42.25
	80 %	64	64
Pole changing		45.5	37.53
Adjacent poles PWS		65.8	47.5
Alternate poles PWS		79.11	46.2
Alternate pairs of groups PWS		76.85	35.55
Alternate groups PWS		69.26	21.33

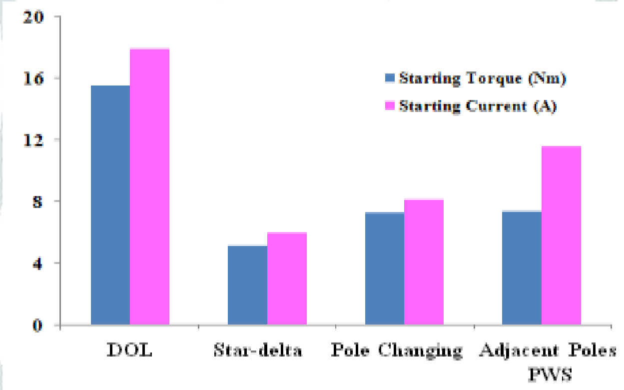


Fig. 2 Comparison of starting current and starting torque obtained from various starting methods

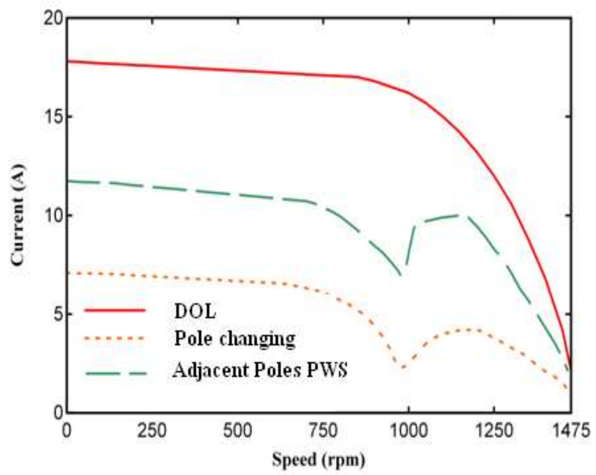


Fig. 3 Current versus speed curves for various starting methods

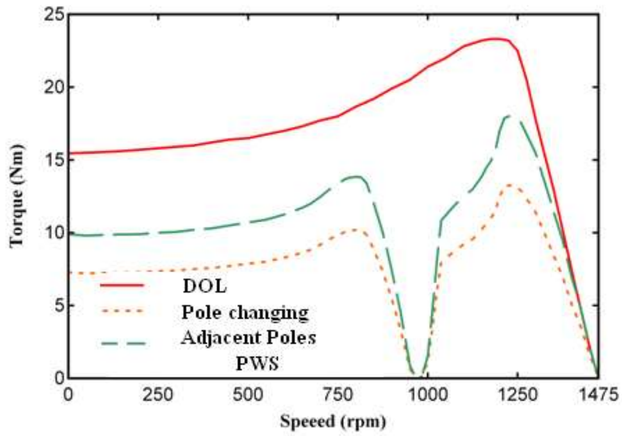


Fig. 4 Torque versus speed curves for various starting methods

The DOL starting current and DOL starting torque are considered as 100%. The following observations can be made from Table 1.

- For alternate poles PWS arrangement, the motor draws the highest starting current than the other PWS arrangements and runs at 4-pole speed.
- In alternate pairs of groups arrangement, the motor runs at 4-pole speed. It is observed that this arrangement produces higher noise than the other symmetrical arrangements.
- For alternate groups arrangement, the motor develops the lowest starting torque than the other PWS arrangements and runs at 4-pole speed.
- For adjacent poles arrangement, the motor draws the lowest starting current, develops the highest starting torque than the other PWS arrangements and runs at 6-pole speed.
- Table 1 and Fig. 2 show the comparative performances of various methods for starting the induction motor. It is observed that the adjacent poles PWS method develops higher starting torque and draws higher starting current than the star-delta and pole changing starting methods.

Figs. 3 and 4 show the current versus speed and torque versus speed curves for DOL, pole changing and adjacent poles PWS of the test motor respectively. It is clear from the Figs. that the motor is in the high torque region of the 4-pole torque versus speed curve and is in the falling current region of the 4-pole current versus speed curve during the transition of PWS to full winding running of the motor.

V. CONCLUSION

In this paper, PWS arrangements for 4-pole cage induction motor have been presented. The performances of adjacent poles, alternate poles, alternate pairs of groups and alternate groups PWS arrangements have been investigated through experimental implementation. The experimental results reveal that the adjacent poles PWS arrangement provides better starting performance than the other compared PWS arrangements. Besides, the performances of the DOL, star-delta, auto-transformer and pole changing starting methods have been compared. The results show that the adjacent poles PWS method provides higher starting torque than the star-delta, auto-transformer and pole changing starting methods.

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