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The Effect of Modifying Stator Winding in 1-Phase 4-Pole Starting Capasitor Induction Motor in Table Drill Machine on Current, Power and Rotation of The Rotor

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Abstract: *1-phase 4-pole starting capacitor induction motor which is used as an activator of the table drilling machine has a more complicated construction because it has a centrifugal switch which is connected in series with the capacitor for its initial start, high current, power and rotational speed of the stator field. Mean while a 3-phase 6-pole induction motor has a simpler construction because it does not require a centrifugal switch and a capacitor for its initial start, besides it has a lower current, power and rotational speed. This paper presents the effect of modifying the stator winding in a 1-phase 4-pole starting capacitor induction motor on the table drilling machine into a stator winding of 3-phase 6-pole induction motor on the current, power and rotation of the rotor. Modifications are carried out on the stator winding of a 1-phase induction motor by changing the number of phases, number of poles, type of winding, wire diameter and number of windings per slot. Modifications are carried out on the windings to obtain a 3-phase 6-pole 24-slots induction motor with 200 windings per slot, a wire diameter of 0.5 mm, and a winding type of spiral double layer. In loading test on the induction motor at table drill machine the current average decreased by 3,56 Ampere or 81,6 %, a power average decreased by 191,4 Watt or 40,06 %, and rotor rotation decreased by 499,7 rpm or 33,75 %.*

Key words: *Start Capacitor 1 phase induction motor, stator winding, 3 phase induction motor*

I. Introduction

Induction motors are alternating current motors that is most widely used as a prime mover in the industries which consume 30–80% of total industrial energy around the world. Their advantages such as sturdy structure, simple construction, and easy maintenance [1-3]. Most of the engines used in the industries are using induction motors. In general, the industries use 1-phase and 3-phase phase induction motors as the driving shaft of their engines when available power source is a 3-phase power source. However, 1-phase induction motors has their own disadvantages since they generally has lower power and efficiency which is between 38% to 70%. Starting capacitor 1-phase induction motors on the table drilling machines have their disadvantages, namely the more complicated construction than the 3-phase induction motors since they require centrifugal switches, capacitors for their initial start, and a high rotational speed of the stator field, which is 1500 rpm. 1-phase induction motor starting capacitor on the drilling machine also requires currents and greater electrical power compared with the 3-phase induction motor which has a similar construction to produce the same power. Drilling machine table is used to make a hole in the object in the form of an iron plate which is in operation requires a low speed with a large torque so that the drilling process can be done properly and safely.

The speed of an induction motor can be changed by changing the number of poles with fixed frequency according to the equation: .

$$N_s = \frac{120f}{p} \qquad (1)$$

where f is frequency (Hz), and p is the number of poles[10]. A solution can be done by simplified the construction and decrease the rotational speed of the stator field of 4-pole starting capacitors 1-phase induction motor is to modify the stator winding in the 1-phase induction motor into a 3-phase 6-pole induction motor so it no longer requires a centrifugal switch and a capacitor for its initial start, while current, power and a low rotational speed of stator field is obtained. Thus saving energy, electricity costs and efficiently [4-6].

This paper is an experimental study conducted on a 1-phase starting capacitor induction motor which is used as an activator on a table drilling machine. This research is an experimental which is done by modifying stator winding in the induction motor in which modification is only done on the stator winding in a starting capacitor 1-phase induction motor. Modifying the stator winding in 4-pole starting capacitor 1-phase induction motor into 3-phase 6-pole induction motor requires data from 4-pole starting capacitor 1-phase induction motor on the table drilling machine, i.e name plate, stator windings, and stator core. The data needed is the number of poles, the number of stator slots, the diameter of the stator core, and the length of the stator core.

The modifications of the stator winding performed at a starting capacitor 1-phase induction motor include : 1) Changes in the number of phases of the stator winding of the induction motor from 1-phase stator winding to 3-phase stator winding. 2) Changes in the number of poles of the stator winding from 4 to 6 poles. 3) Changes in the type of stator winding from concentric semi-double layer to spiral double layer type. 4) Changes in the wire diameter and number of wire windings for each slot. The purpose of this study is to obtain a simpler 3-phase 6-pole induction motor from a starting capacitor 1-phase induction motor on the table drilling machine. Testing conducted on the induction motor are: 1) no-load test, in which the motor is connected directly to the power source and measurement of electrical quantities is then performed. 2) load test, in which the motor is mounted on the table drilling machine and drilling is done to make holes in the metal plate while the measurement of electrical quantities is performed.

II. Modification of Stator Winding Design

Modification to the stator windings in 4-pole starting capacitor 1-phase induction motor into 6-pole 3-phase induction motor is carried out based on the calculation for the design drawings of stator winding in 6-pole 3-phase induction motor and on the calculation to determine the number of email wire windings at stator Slots and on the calculation to determine the email wire diameter which will be used. This is illustrated in the flow chart of Figure 1[12].

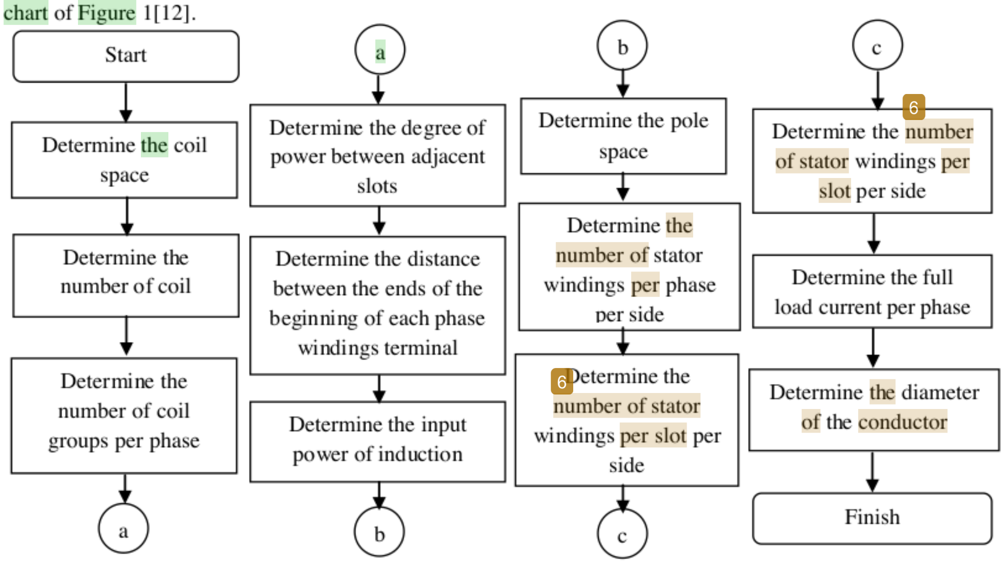


Fig 1. Flow chart of planned modification of stator winding

II.1. Drawing design parameters of stator winding in 6-pole 3-phase induction motor

Calculation parameters in the drawing design of stator winding in 6-pole 3-phase induction motor are as follows:

1. Coil pitch, Y_z, is given by :

$$Y_z = \frac{Ss}{2p} \qquad (2)$$

where Ss is the number of stator grooves, and p is the number of pole pairs.

2. The number of coil groups for double layer winding, K, is given by:

$$K = 3 \times 2 \times p \qquad (3)$$

3. The number of coil groups per phase, Kr, is given by:

$$K_r = \frac{K}{m} \qquad (4)$$

where m is the number of phases.

4. The degree of power between adjacent slots, Θ, is given by :

$$\Theta = \frac{360 \, x \, p}{Ss} \qquad (5)$$

5. The distance between the ends of the beginning of each phase windings terminal, L, is given by:

$$L = \frac{120}{\Theta} \qquad (6)$$

Figure 2 shows the stator windings in 6-pole 3-phase induction motor which is constructed based on the calculated parameters.

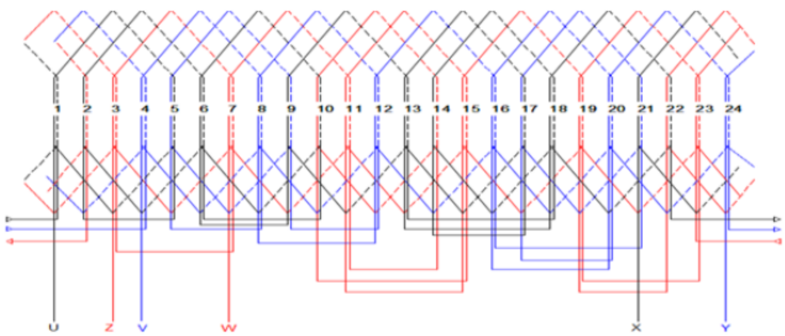


Fig 2. Stator windings in 6-pole 3-phase induction motor

II.2. Determination of windings numbers and wire diameter on stator slot

The parameters to determine the number of email wire windings on stator slots and to determine the email wire diameter that will be used is as follows.

1. Input power, Q, given by:

$$Q = \frac{HP \, x \, 0{,}746}{\eta \, x \cos \Theta} \quad \text{KVA} \qquad (7)$$

where HP is design for output power, η is motor efficiency, and cos Θ is power factor of motor.

2. Pole space, Y, given by:

$$Y = \frac{\pi \, x \, D}{2p} \quad \text{cm} \qquad (8)$$

where D is inner diameter of stator core (cm), π is a constant.

3. Number of stator windings per phase per side, T_S, given by:

$$T_s = \frac{E}{4{,}44 \, x \, Kw \, x \, F \, x \, \varnothing m} \qquad (9)$$

and,

$$\varnothing_m = B_{av} \, x \, L \, x \, Y \quad \text{Wb} \qquad (10)$$

where E is line to netral voltage (volt), Kw is winding constant, F is frequency (Hz), B_{av} is specific magnetic load (Wb/m^2), L is the lengh of stator core (cm).

4. Number of stator windings per slot per side, Tss, given by :

$$Tss = \frac{Ts \, x \, 2}{Gs} = \frac{Ts \, x \, 2}{2p \, x \, 3} \qquad (11)$$

5. Full load current per phase, I_{bs}, given by:

$$I_{bs} = \frac{Q}{3E} \quad \text{Ampere} \qquad (12)$$

6. Cross-section area of conductor, A_s, given by:

$$A_s = \frac{Ibs}{\delta s} \quad mm^2 \qquad (13)$$

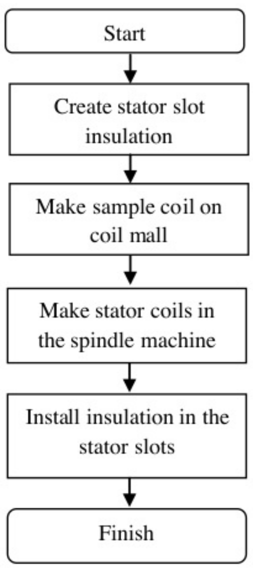
where δs is current density in conductor (in A/mm^2)

7. Diameter of conductor, Ds, given by:

$$D_s = \frac{\sqrt{4 \times as}}{\pi} \quad \text{mm} \qquad (14)$$

III. The Making And Installation Of Stator Winding

The stator winding is made by using auxiliary equipments such as a coil winder, coil mold, cutting plier, plastic hammer, and scissor. Materials used to build stator windings are email wire, conductor cables, slot insulation, and the insulating fluid for email wire. The procedure to build stator windings is described in the flow chart in Figure 3a, while the procedure for installation of stator windings is described in the flow chart in Figure 3b[12].



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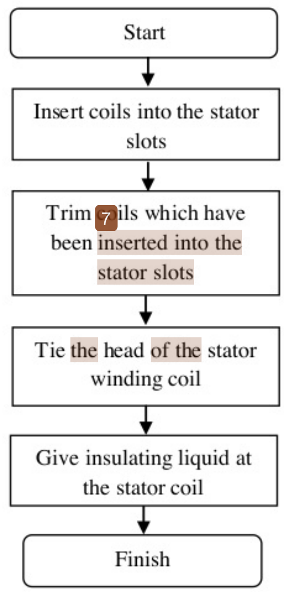

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Figure 3 a. Flow chart of the making of stator windings
b. Flow chart of the installation of stator windings

IV. Tests On Induction Motor

Tests were conducted on a 4-pole starting capacitor 1-phase induction motor prior to the modification of windings and a 6-pole 3-phase induction motor built by modifying the windings. Tests were carried out on the induction motor in no-load condition and loaded condition. The equipment required for the testing process is a digital clamp-On power hitester and digital tachometer. Figure 4 shows a series of tests on induction motor.

a

b

Figure 4 a. No-load induction motor test
b. Locked-rotor induction motor test

V. Test Result

After performing the calculations for the modification of the stator windings of 6-pole 3-phase induction motor, 100 turns per slot per side, 200 turns per slot, and a wire diameter 0.5 mm were obtained. The results of these calculations are used to create images of the stator windings and to build stator windings on winding rolling equipment. Figure 5 shows a stator winding in an induction motor.


a


b

Fig 5. a. 4-pole Starting capacitor 1-phase induction motor windings
b. 6-pole 3-phase induction motor windings

After no-load and locked-rotor test in 1 phase induction motor starting capacitor 4 poles and 3 phase induction motors 6 poles, induction motor parameters obtained as shown in Table 1.

Table 1. Comparison of 1 phase 4 pole starting capacitors induction motor to 6-pole 3-phase induction motor.

NO	Induction Motor Parameter	1-phase Induction Motor	3-phase Induction Motor
1	Stator resistance (Ohm)	4.55	26.3
2	Rotor resistance (Ohm)	1.08	12.24
3	Stator leakage reactance (Ohm)	8.73	34.83
4	Rotor leakage reactance (Ohm)	8.73	34.83
5	Magnetizing reaktance (Ohm)	75.55	341.51

After load testing of 1 phase induction motor starting capacitors 4 pole and 3 phase induction motors 6 pole, results obtained as shown in Table 2 and Table 3.

Table 2. Results of load testing on 1 phase 4 pole starting capacitor induction motor

NO	Diameter drill bits (Inch)	Current (Ampere)	Voltage (Volt)	Power (Watt)	Rotor rotation (rpm)
1	5	4.16	227.4	310	1491
2	7	4.18	226.5	403	1485
3	9	4.25	225.5	456	1481
4	11	4.55	224.8	566	1475
5	13	4.72	224.7	622	1470

Table 3. Results of the testing load on 3 phase induction motor 6 Pole

NO	Diameter drill bits (Inch)	Current (Ampere)	Voltage (Volt)	Power (Watt)	Rotor rotation (rpm)
1	5	0.72	392	210	990.1
2	7	0.76	390	240	985.1
3	9	0.79	389	260	980.9
4	11	0.84	388	280	974.8
5	13	0.93	388	410	972.7

VI. Result analysis

The results of induction motor load testing are shown in Table 2 and Table 3, graphically relationship between drill bit, power, current, rotation can be made which is shown in figure 6, 7, and 8.

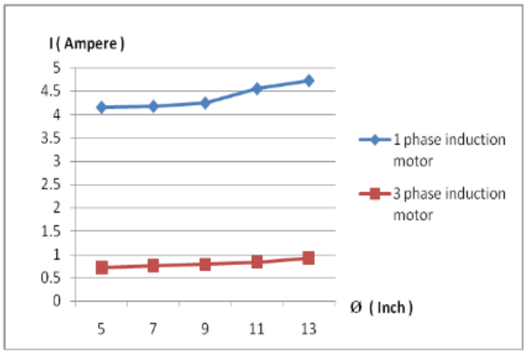

Fig 6. Relationship between the diameter of the drill bit and current in induction motors 1 and 3 phase

From the graph in Figure 6, it appears that after the modification to the stator winding 1 phase 4 pole starting capacitors induction motor into a 3-phase induction motors 6 poles current average decreased to 3.56 amperes, or around 81.6 %.

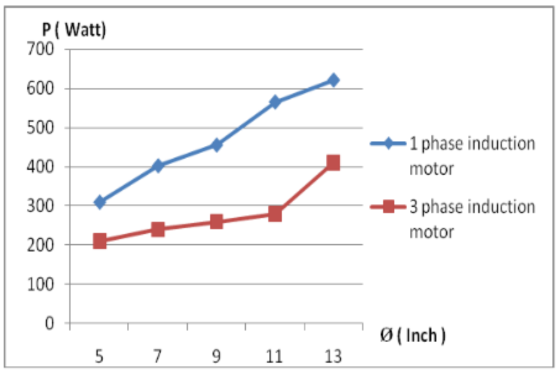

Fig 7. Relationship between the diameter of the drill bit and power in induction motors 1 and 3 phase

From the graph in Figure 7, it appears that after the modification to the stator winding 1 phase 4 pole starting capacitors induction motor into a 3-phase induction motors 6 poles power average decreased to 191.4 watts or around 40.06 %.

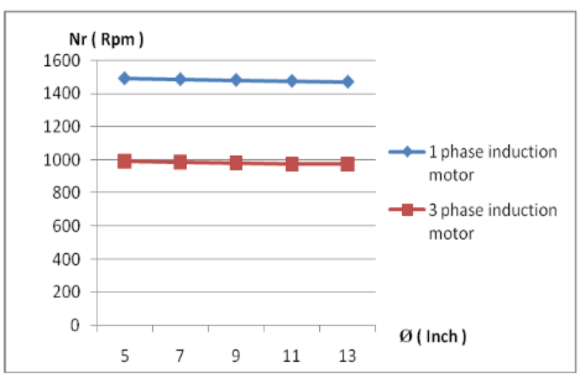

Fig 8. Relationship between the diameter of the drill bit with a rotor rotation of 1 and 3 phase induction motor

From the graph in Figure 8, it appears that after the modification to the stator winding 1 phase induction motor starting capacitors 4 poles into 3-phase induction motor 6 pole rotor rotation average decreased to 499.7 Rpm or around 33.75 %.

VII. Conclution

The performance improving solution of 1 phase 4 pole starting capacitors induction motor on the drilling machine in order simpler construction, lower speed, efficient in current and power by doing modification in stator motor winding from 1 phase 4 pole to 3 phase 6 pole.

The results of load testing after the modification show that the average current decrease to 3.56 Amperes or 81.6 %, a lower average of power 191.4 Watts or 40.06 %, and lower average of rotor rotation to 499.7 Rpm or 33.75 %.

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