A Simple Method For Operating The Three-Phase Induction Motor On Single Phase Supply (For Wye Connection Standard)

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***Abstract*— This research is purposed to establish a new method is good and simple to operate the 3-phase induction motor on single-phase power by using the capacitors. The research was conducted at the Laboratory of the Electrical Engineering of the Padang Institute of Technology. The object used in this research was the 3-phase induction motor that has the standard of 2 HP, 380 V, Wye connection, 4 pole, 50 Hz, 1400 RPM, 3.6 A. The results of this research showed that the method could work well to control the motor to operate properly to load 85% of the 3-phase rating. In general, the motor has a better performance when operating on 1-phase power system in all load cases (low and high load). The motor could operate with power factor close to unity, higher speed and better efficiency. The motor operated with higher current harmonic distortion at low loads but lower current harmonic distortion at high loads. Therefore, it is very good to operate the motor at high load up to 85% of the 3-phase rating.**

***Keywords*— Capacitor circuit, capacitance of the start capacitor, capacitance of the run capacitor, Apparent power of the motor, power factor.**

I. INTRODUCTION

The 3-phase induction motor has 3 coils identities are separated from each other across 120^o electricity that powered by a 3-phase power system. They will produce a resultant magnetic flux that rotates like poles actual magnet spinning mechanism. Relationships coil of the 3-phase induction motor with two poles of the stator in the Wye connection system is as shown in Fig. 1.

The 3-phase induction motors of squirrel cage rotor normally operate on a 3-phase power system. To improve the starting torque of the motors, they can operate on a single phase supply as shown in Fig. 2.

Fig. 2 shows some methods of installation the capacitor circuit to the coil of the motor to operate the motor on single phase power. Another methods for operating the 3-phase induction motor on a single phase power also as shown in Fig. 3 and Fig. 4. The Fig. 4 is a form of development from the Fig. 3 that provide the best solution to control the motor. The Fig. 5 shows the control circuit used in the Fig. 4.

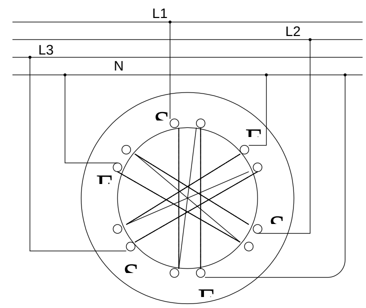

Fig. 1 Relationships coil of the 3-phase induction motor with two poles of the stator in Wye connection system

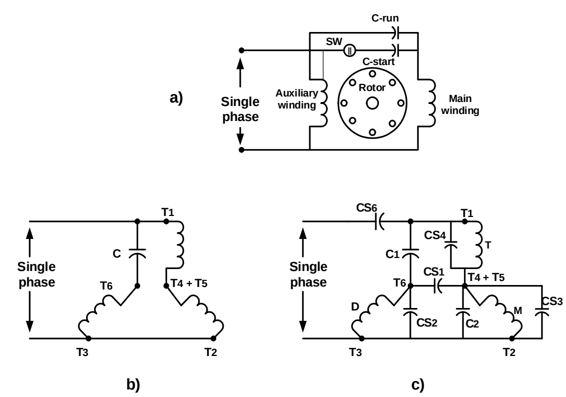

Fig. 2 Induction motors operating on single phase supply: a) single phase capacitor motor: b) 3-phase induction motor according to Scheda[9] : c) 3-phase induction motor according to Smith[10].

From Fig. 4 and Fig. 5 can be explained that Cs is start capacitor, Cr1 is run capacitor when the motor is given a low load up to 70%, and Cr2 is run capacitor when the motor load of 70% to 85%.

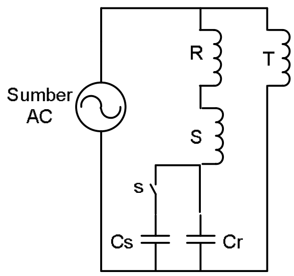

Fig. 3 A method for operating the 3-phase induction motors on single-phase power[5]

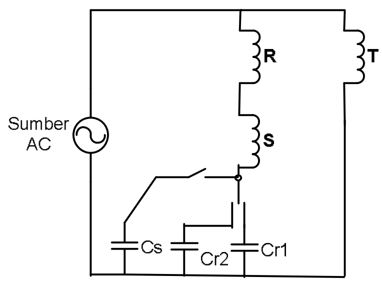

Fig. 4 A new method that is developed from figure 3 to provide the best performance to operate the motor

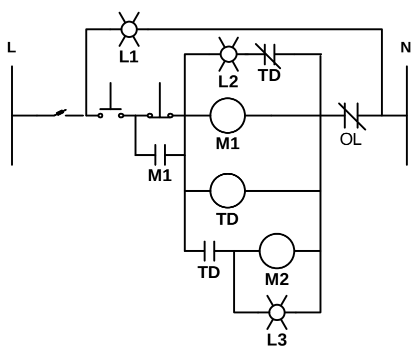

Fig. 5 Control circuit used in Fig. 4

II. START CAPACITOR

Referring to Fig. 4 can be explained that the start capacitor Cs accidentally placed in series with the coil R and S is to get the highest value of the capacitive reactance of the start capacitor. If referring to the theory of the 'Torque start maximum per ampere', the formula then can be obtained as follow[5] :

$$X_{C(PU)} = Xa + \frac{-XmRa + |Zm|\sqrt{Ra(Ra+Rm)}}{Rm} \quad (1)$$

'$X_{C(PU)}$' is the capacitive reactance of the start capacitor to be used (in Pu), 'Xa' is inductive reactance of the coil R and S (in Pu), Ra is the resistance of the coil R and S (in Pu), 'Xm' is the inductive reactance of the coil T (in Pu), 'Rm' is the resistance of the coil T (in Pu) and 'Zm' is impedance of the coil T (in Pu). To obtain the true value of 'Xc', it must be sought from the base impedance values used in induction motor by using the following formula[3].

$$Zb = \frac{V^2}{VA} \quad (2)$$

'V' is a single phase voltage source (V_{LN}), 'VA' is apparent power of the 3-phase induction and 'Zb' is the base impedance of the motor. Furthermore, we will obtain the actual value of the capacitive reactance 'X_C' becomes.

$$X_C = (X_{C(pu)}).(Zb) \quad (3)$$

The value of the capacitance of start capacitor 'Cs' than can be obtained using the following equation.

$$Cs = \frac{1}{2.\pi.f.X_C} \text{ (Farad)} \quad (4)$$

The best solution for starting the 3-phase induction motor on a single phase supply (for Wye connection standard), 'Cs' must be at setting about 92% of the formula (4). This formula then is changed to be the following.

$$Cs_y = \frac{(0,1757).(I_L)}{(f).(V_{LN})}(Farad) \quad (5)$$

Cs_y is the capacitance of start capacitor (Farad), I_L is nominal current of the motor (A), f is frequency (Hz), V_{LN} is the amplitude of the single phase voltage source (Volt).

III. RUN CAPACITORS

Referring to Fig. 4, for best performance of the motor, the run capacitor must be at setting as follow.

$$Cr_y = k\frac{I_L}{(12,5664)(f).(V_{LN})}(Farad) \quad (6)$$

The 'k' is 0.7679 for the motors that operate from low load to 70% of its 3-phase load rating, and 'k' is 1 for the motors that operate from 70% load to 85% of its 3-phase load rating.

Because of capacitors in series with the coil R and S, thus the total impedance of the coil R and S is become 2 times of the coil T, then the voltage on the capacitor 'V_C' is becomes 2 times of the source voltage 'V', or can be made as follows:

$$V_C = 2 . V \qquad (7)$$

The amount of reactive power (VARC) which donated the capacitor is:

$$VAR_C = \omega.C.(V_C)^2 = 4.\omega.C.(V)^2 \qquad (8)$$

C is referred to Cs_y and Cr_y from the Fig. 4. VAR_C will become apparent power of the 3-phase induction motor when it started in 1-phase power. If VAR_{3ph} is a reactive power while the motor operates at 3-phase supply, the amount of reactive power induction motor in a single phase supply (VAR_M) becomes[10]:

$$VAR_M = VAR_{3ph} - VAR_C \qquad (9)$$

The magnitude of the starting current (I_{ST}), power factor (cos ϕ) and input power (P_L) of the motor in a single phase supply become[10]:

$$I_{ST} = \frac{VAR_C}{V} \qquad (10)$$

$$\sin\phi = \frac{VAR_M}{VAR_C} \qquad (11)$$

$$\cos\phi = \cos(\sin^{-1}\phi) \qquad (12)$$

$$P_L = VAR_C.\cos\phi \qquad (13)$$

IV. Test Result

The motor used in this research is the 3-phase induction motor of 2 HP, 380V, Wye-connection, 3.6A,1400 RPM, power factor 0.84 lagging, and class B. Test result of this research about power factor and speed of the motor are given in Fig 6 and Fig. 7. Control box with all components for the motor is given in Fig. 8.

The blue line in the Fig. 6 and Fig. 7 are the characteristics of the motor during operation on 3-phase system, while the red and black lines are during operation on a single phase system using a capacitor 20 μF (red) and 25.55 μF (black). From the figures can be seen that in general the motor can operate with better performance on single phase power compared to operating on three-phase power. The figures show that with the same load conditions the motor can operate on single phase supply with higher power factor and higher speed.

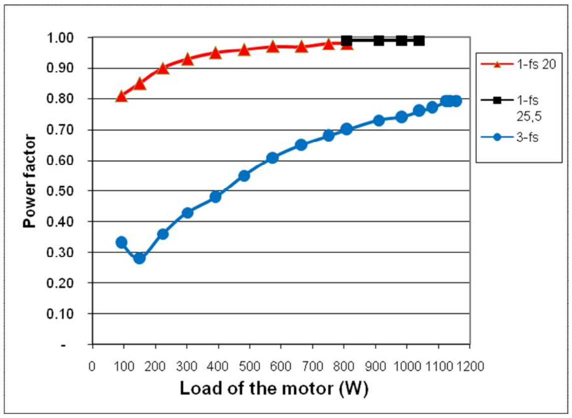

Fig. 6 Power factor characteristic when operating on a 3-phase (3-fs) and a single phase (1-fs)

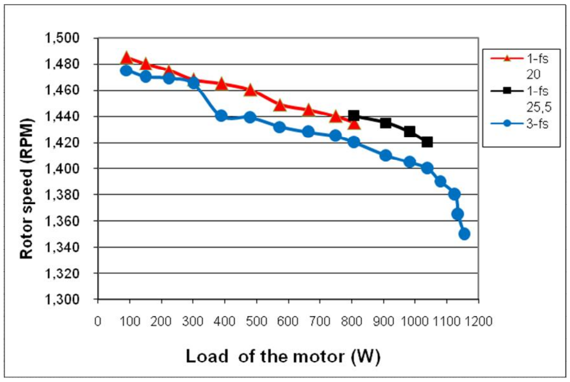

Fig. 7 Speed responds characteristic of the 3-phase induction motor when operating on a 3-phase (3-fs) and a single phase (1-fs)

Fig. 8 Control box with all components for operating the 3-phase induction motor on single-phase power

V. Conclusions

From the research that has been done can be summarized as follows.

1. A simple method for operating the 3-phase induction motor on single phase supply (for Wye-connection Standard) is to operate the motor by using the capacitors that are installed in series with the two coils of the motor (R and S) and the circuit is then installed in parallel with the other one (T).
2. This method can operate the 3-phase induction motor at low to high loads up to 85% of the 3-phase nominal load rating.
3. This method could work well to operate the 2 HP 3-phase induction motor at low to high loads up to 70% by using the run capacitor 20 μF and the load from 70% to 85% by using the run capacitor 25.55 μF

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