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Practical Study on the Effect of Frequency Changing on the Performance and Operation of Three Phase Induction Motors using an Air Conditioning Equipments

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Abstract: This study presents practical study of the effect of frequency on the performance and operation of three-phase induction motor. The theoretical review of three-phase induction motor is introduced and the effect of frequency changing on motor operation is discussed. The experimental investigation involved frequency changing from 40-60 Hz by using AC drive. The motor performance under frequency changing at different load conditions. It is found that when the frequency increased from 40-60 Hz the motor voltage increased by 44% with no load and 26.5% with load. The current is in creased by 5% with no load and by 31.5% with load. The temperature of motor is increased by 18.6% with no load and 16.6% with load.

Key words: Three-phase induction motor, experimental investigation, temperature, theoretical review, involved, frequency

INTRODUCTION

There are a variety of applications of three phase squired cage induction motor. For example in lift and cranes because of the rugged construction and low maintenance cost of motor. It finds wide use in all industries. Generally where low starting torque is required such as in all pumps, compressors, motor driver in the air conditioning equipment, three phase induction motor is very popular choice. AC motors are frequency sensitive, frequency changes can cause speed changes of rotor. An ac motor stator is an inductance. In an inductance the lower the frequency, the lower its impedance. So, haven constant voltage over it, the current will rise if the frequency gets lower. All motors have a minimum frequency value you must not go below that value, AC motor shall operate successfully under running condition at rated load with a changing in the voltage or frequency, ±10% of rated frequency for induction motors and ±5% of rated frequency with rated voltage.

A combined changing in voltage and frequency of 10% (some of absolute value) of the rated values provided the frequency varste does not exceed ±5% of rated frequency (Jain *et al*., 2012). The speed induction motor can be changed by various methods such as poles changing, voltage changing, connecting the resistance in motor circuit, etc. But the most efficient method is changing the supply frequency and voltage to motor. Speed is directly proportional to the frequency (Kumar, 2018). Electronic devices for speed control of an electric motor. It controls the speed of the electric motor by converting the fixed voltage and frequency of the grid to adjustable values on the motor side (Win *et al*., 2008).

Qazem, Qais, Mahdi, investigated the effect of low frequencies on performance of induction motor, the result obtained also show that sub harmonic can adversely affect the speed stability of induction motor and also it affect on performance of motor slightly (Jaber *et al*., 2007).

Emnemuoh, Okafor, Onuegbu, carried out the modeling simulation and performance analysis of such a variable frequency drive using matlab simulink model, it successfully achieved the control of speed from zero to nominal speed by varying frequency of the applied voltage using width modulation method (Enemuoh *et al*., 2013). The aim of this research is to make a practical study on the effect of frequency changing on the performance and operation of three phase induction motor using in air conditioning equipment.

Literature review: The synchronous speed (N_s) of the induction motor is calculated from Eq. 1:

$$N_s = 120*f_s/P \quad (1)$$

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The slip of the induction motor is calculated from Eq. 2:

$$S = N_s\text{-}N/N_s \tag{2}$$

The rotor frequency of induction motor is calculated from Eq. 3:

$$F_r = S*F_s \tag{3}$$

The rotor speed for induction motor is calculated from Eq. 4:

$$N = (1\text{-}S)*N_s \tag{4}$$

Where:

N_s = Synchronous speed (rpm)
N = Rotor speed (rpm)
S = Slip of motors
P = No. of poles
F_r = Frequency of rotor (Hz)
F_s = Frequency of stator (Hz)

MATERIALS AND METHODS

Experimental work: The proposed system for three phase induction motor is supplied from ac drive shown in Fig. 1. AC drive is a Variable Apeed Drive (VSD) or Variable Frequency Drives (VFD). The correct term is frequency converter. They sit between the electrical supply and the motor. Power from the electrical supply goes into the drive. The drive then regulates the power which in term feed to motor.

Inside the drive, the input power is run through a rectifier that converts the incoming AC power to DC power. The DC power is then feed into capacitors inside the drive to smooth out the electrical wave from which provides a clean power supply for the next step. Power then flows from a capacitors to invertor which changes the DC power to output AC power that goes to the motor (Anonymous, 2019).

AC drive specifications:

- Power 0.5 W
- Temperature -10 to 40°C
- Input power 220/230 V, 50 Hz, single phase
- Output power 0.5-400 Hz (200-230 V) three phase

Three phase induction motor specifications:

- Voltage input (230/400 V), 50 Hz
- Power of motor (0.18 kW/0.025 Hp)
- Current (0.97/0.56 A)
- Power factor (0.77)
- Speed of motor (1350 rpm)

Fig. 1: AC drive

Fig. 2: Testing pench

Specifications of load (compressor):

- Type of compressor is swash type
- Model 55-148 DW5 12V DC

The testing bench of the experimental work is shown in Fig. 2.

RESULTS AND DISCUSSION

Practical results

Effect of frequency changing on supply voltage and current: The frequency is changing from 40-60 Hz, Table 1 shows the variations results of the voltage and current for no load and with load condition. Figure 3 shows the variations of voltage from 151-217 V with frequency changing from 40-60 Hz with no load and from 173-219 V with load (i.e., the increase of voltage by 43.7% at no load and 26.5% with load). Figure 4 shows the variation of current from 0.13-0.18 A with no load and from 0.19-0.25 A with load (i.e., the increase of current by 5% with no load and 31.5% with load).

Effect of frequency changing on the speed and temperature of motor: The frequency change from 40-60 Hz Table 2 shows the variation of frequency with speed (N) and Temperature (T) of motor.

Figure 5 shows the variation of speed of motor (N) with frequency where the speed is increased from

Table 1: The variations results of the voltage and current for no load and with load condition

	No load		With load	
Frequencies (Hz)	V	$I_{1,2,3}$	V	$I_{1,2,3}$
40	151	0.13	173	0.19
45	184	0.14	182	0.20
50	193	0.15	195	0.21
55	205	0.17	205	0.23
60	217	0.18	219	0.25

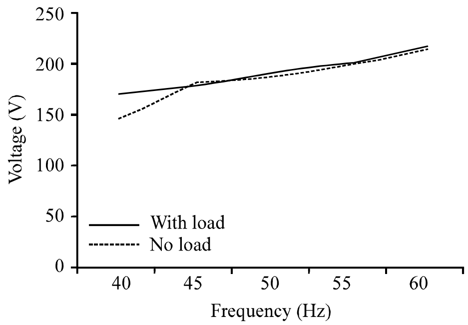

Fig. 3: Variation of voltage with frequency

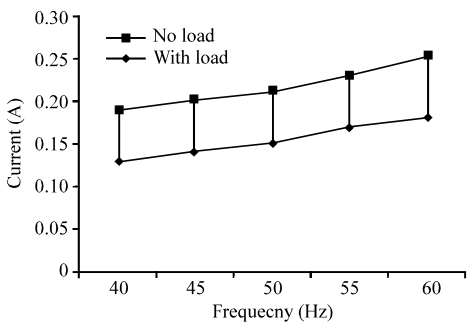

Fig. 4: Variation of current with frequency

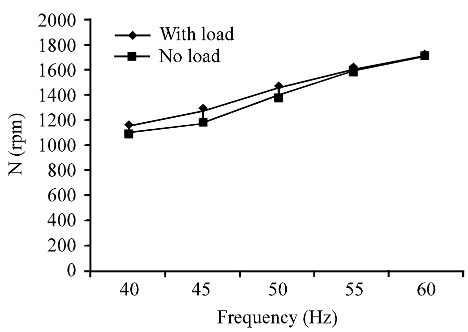

Fig. 5: Effect of frequency changing on the speed of motor

1150-1700 rpm (i.e., the increase of speed by 49.5% at no load and by 54.5% with load). Figure 6 shows the variation of temperature of motor with frequency, the temperature of motor is increased 16.6% with no load and 12.6% with load.

Table 2: The variation of frequency with speed (N) and Temperature (T) of motor

	No load		With load	
Frequencies (Hz)	$N_{rpm.}$	T_c	N_{rpm}	T_c
40	1150	30	1100	35.5
45	1275	31.5	1180	36
50	1440	33	1400	36.5
55	1580	33.5	1600	38
60	1720	35	1700	40

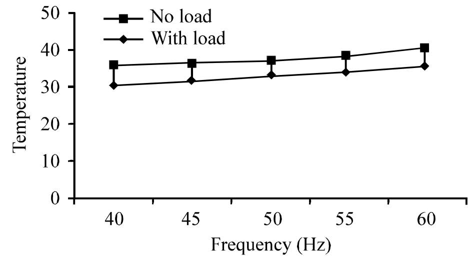

Fig. 6: Effect of frequency changing on the temperature of motor

CONCLUSION

From this practical studying when the frequency of the power supply changing from 40-60 Hz we conclude the following:

- The voltage is increased by 43.7% with no load and 26.5% with load
- The current is increased by 5% with no load and 31.5% with load
- The speed of motor is increased by 49.5% with no load and 54.5% with load
- The temperature of motor is increased by 16.6% with no load and 12.6% with load

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