Energy 74 (2014) 340–345

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

A study on current characteristics of induction motor while operating at its base frequency in textile industry

Y. Dhayaneswaran [a,*], L. Ashok Kumar [b]

[a] 205/37A1, P.R.A. Nagar, Jadal Naidu Street, Periyanaickenpalayam, Coimbatore 641020, India
[b] PSG College of Technology, Coimbatore, India

ARTICLE INFO

Article history:
Received 6 June 2013
Received in revised form
21 May 2014
Accepted 25 June 2014
Available online 3 August 2014

Keywords:
Energy
Textile
Motor
Base frequency

ABSTRACT

In the increasing amounts of three-phase squirrel-cage induction motors over the years are fed by variable-speed drives in majority of the industries. This paper deals about the current and power characteristics of induction motor while it operating at its base frequency with variable speed drive. Various studies have been conducted in textile industry to prove the above phenomena. When the motor runs at its base frequency through VFD (variable-frequency drive), considerable energy saving is possible. In this study, around 3.6 units saved for one operating cycle of Ringframe machine in textile industry.

1. Introduction

In recent days, an increasing amount of three-phase squirrel-cage induction motors are fed by variable-speed drives. In industry, induction motors are used more than 90% of the electric motor driven applications. Most of the manufacturers, while selecting the pulleys for mechanical power transmission even with inverter driven motor, they are not concentrating the motor characteristics with respect to base frequency of the motor. Their predominant focus is to achieve the mechanical speed.

Predominantly the manufactures are preferred to go with different combination of pulleys either one is to one or one is to two likewise to vary the speed. Because of the above mentioned pulley combination, when the motor speed is changed with variable speed drive, the frequency changes from minimum to maximum as per the set frequency in the inverter. So, if the motor base frequency is 50 Hz, if the speed changes from 0 to 80 Hz for achieving the required variable speed, motor operate at it's beyond base frequency range.

2. Induction motor speed variation

For an induction motor, rotor speed, frequency of the voltage source, number of poles and slip are interrelated according to the following equation.

$$N = [120\ f_1\ (1 - s)]/P \tag{1}$$

N: mechanical speed (rpm)
f_1: fundamental frequency of the input voltage (Hz)
P: number of poles
s: slips
Source: The text book of Electric Motor Drives – Modelling, analysis and control by R. Krishnan [2]

The torque developed by the induction motor follows the equation below.

$$T = k_1 . \Phi_m \cdot I_2 \tag{2}$$

Despising the voltage drop caused by the stator impedance, the magnetizing flux is found to be:

$$\Phi_m = k_2 . (V_1/f_1) \tag{3}$$

where:

T: torque available on the shaft (N.m)
Φ_m: magnetizing flux (Wb)
f_1: fundamental frequency of the input voltage (Hz)
I_2: rotor current (A) depends on the load
V_1: stator voltage (V)

* Corresponding author. Tel.: +91 9994461526 (mobile).
E-mail addresses: dhayaneswaran_y@yahoo.com (Y. Dhayaneswaran), askipsg@gmail.com (L. Ashok Kumar).

http://dx.doi.org/10.1016/j.energy.2014.06.092
0360-5442/

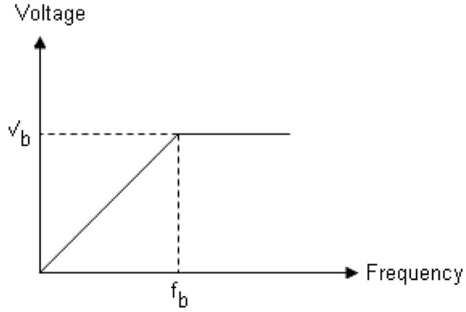

Fig. 1. Base frequency vs. base voltage curve (Ref: SEW drive academy).

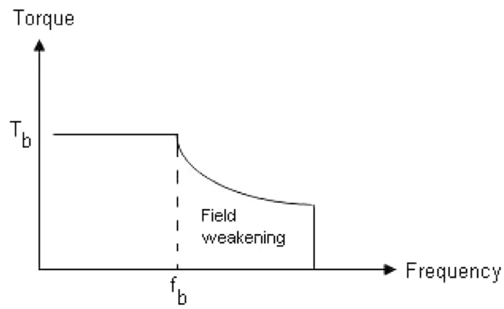

Fig. 2. Base frequency vs. torque and field weakening curve (Ref: SEW drive academy).

k_1 and k_2 : constants depend on the material and on the machine design.
Source: The text book of Electric Motor Drives - Modelling, analysis and control by R. Krishnan [2]

Considering a constant torque load and admitting that the current depends on load (therefore practically constant current), then varying proportionally amplitude and frequency of the voltage supplied to the motor results in constant flux and therefore constant torque while the current remains unchanged. So the motor provides continuous adjustments of speed and torque with regard to the mechanical load. Losses can be thus minimized in accordance with the load conditions by keeping the slip constant at any speed, for a given load.

The curves below are obtained from the equations above. The ratio V_1/f_1 is kept constant up to the motor base (rated) frequency. From this frequency upwards the voltage is kept constant at its base

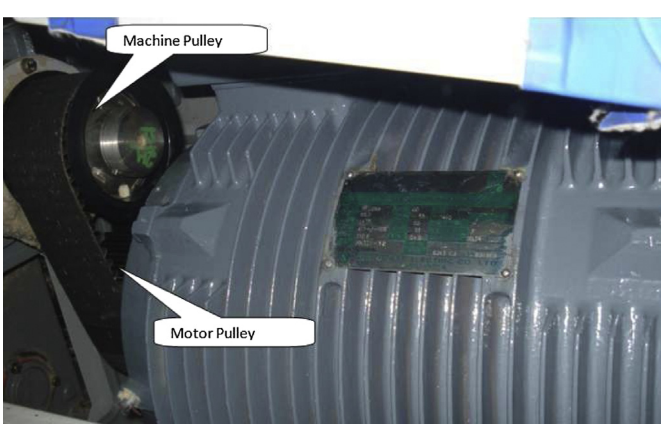

Fig. 3. Induction motor with machine and motor pulley.

Fig. 4. Hioki 3165 make power analyser used for conducting power study.

(rated) value, while the frequency applied on the stator windings keeps growing, as shown in Fig. 1.

Thereby the region above the base frequency is referred to as field weakening, in which the flux decreases as a result of frequency increase, causing the motor torque to decrease gradually. The typical torque versus speed curve of an inverter fed induction motor is illustrated below (see Figs. 2–4).

It comes out that torque is kept constant up to the base frequency and beyond this point it falls down (weakening field). Since the output is proportional to torque times speed, it grows linearly up to the base frequency and from that point upwards it is kept constant.

3. Inverter duty motor

General purpose motors have been around for many years. They are the workhorse of almost every industry. An inverter-duty motor is a much newer concept that became necessary as motors began to be driven by VFDs (Variable frequency drive – inverters or AC drives) [1,3,4]. An inverter duty motor can withstand the higher voltage spikes produced by all VFDs (amplified at longer cable lengths) and can run at very slow speeds without overheating. This performance comes at a cost: inverter-duty motors can be much more expensive than general purpose motors.

AC motors can be driven by across-the-line contactors and starters. The electricity sent to the motor is a very clean (true) sine waves at 50 Hz. Noise and voltage peaks are relatively small. However, there are drawbacks: the motors can only run electrically at one speed (speed reduction is usually handled by gearboxes or some other, usually inefficient, mechanical means) and the inrush

Table 1
VFD details and its settings.

Description	Parameters
Make	Danfoss Industries
Power in kW	55
Input voltage	380 to 500 VAC
VFD output current	106 A
VFD input current	96 A
Power factor	>0.9
Motor control principle	VVC
Acceleration time in seconds	10 s
Deceleration time in seconds	10 s
Switching Frequency	3 KHz
Current Limit	132%
Configuration	Speed Open loop