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THREE PHASE INDUCTION MOTOR INVERTER APPLICATION FOR MOTION CONTROL USING CRUSHER MACHINE

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ABSTRACT

The aim of this research is to familiar with the operation and use of the Toshiba VFFS1 inverter. It is used to reduce motor starting current and also to improve on the quality of the motion executed motor-driven equipment. Various methods exist to reduce the high starting currents of three phase induction motors. A low starting current not only reduces stresses on the power utility, but also decreases stresses on the motor and the driven equipment. As designed, inverters can reduce the starting current especially by programming the motion to follow a trapezoidal or s-curve profile. A trapezoidal motion profile reduces jerky motion, while the s-curve profile totally eliminates it. The challenge in motion control is on how to achieve precise motion with minimum jerk and overshoot in position as well as velocity. There are four methods that can be used to connect the inverter to a motor namely control panel by using a controller computer, remote terminal box or a Programmable Logic Controller (PLC). A number of induction motors were tried with the inverter to observe their response to the different motion profiles which programmed into the inverter. The results are reported and discussed later.

Keywords: three phase induction motor, inverter, motion control.

INTRODUCTION

In a three phase induction motor, the induced electromagnetic field (EMF) of the rotor circuit depends on the slip of the induction motor and the magnitude of the rotor current [1, 2]. When the motor is started, the slip is equal to one as the rotor speed is zero, so the induced EMF in the rotor is large. As a result, a very high current flows through the rotor. When an induction motor starts, a very high current is drawn by the stator by 5 to 9 times of the full load current. This high current can damage the motor windings which causea heavy line voltage drop, and other appliances connected to the same line may be affected by the voltage fluctuation. To avoid such effects, the starting current should be limited. A starter is a device which limits the starting current by providing reduced voltage to the motor [3]. Once the rotor speed increases, the full rated voltage is applied to it.

Inverter

A variable-frequency drive (VFD**)** is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor [3, 4]. The use of inverters which produce motion profiles trapezoid that still produces small jerk, and s-curve performs in a fluid motion. Otherwise, inverters also can show profiles of start current and starting torque. Variable-frequency drives are also known as adjustable-frequency drives (AFD), variable-speed drives (VSD), AC drives, micro drives or inverter drives. Since the voltage is varied along with frequency, these are sometimes also called VF (variable frequency) drives.

Objectives of study

i. To familiarize with the Toshiba VFFS1 inverter operation.
ii. To study the PCM001Z program software that controls the inverter.
iii. To learn how to connect the inverter to the induction motor.
iv. To observe the effects on motor behavior under different motion profile settings.

LITERATURE REVIEW

The use of three phase induction motor inverter is to control the parameters of the motion profile. This enables the reduction of starting current and starting torque apart from reducing jerk. By using inverters, there is the option of selecting either to use trapezoid or s-curve which depends on the applications.

Motion profiles work best for motor applications and provide maximum performance. The two profiles commonly used for point-to-point profiling are the s-curve profile, and its simpler cousin the trapezoidal profile. In [8] states that s-curve profile is smoother than a trapezoidal profile. This means that the more rapid the change in acceleration, the more powerful the vibrations will be and the larger number of vibration modes will be excited.

Various forms of motion profile may be used for the actual load motion in industry with acceptable performances. In [9] is focused on achieving smooth motion, stability of low acceleration, jerk-free motion and low vibration.

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The challenge of achieving fast motions without residual vibration pervades many modern manufacturing applications. In [6], it is well known that simple trapezoidal velocity profiles in which the machine is accelerated to a constant velocity at constant acceleration and decelerated to rest at a constant deceleration, it can achieve fast motions.

In motion control systems, controllers are used together with closed loops to control the velocity and position of machines in order to generate desired motions. The challenge in motion control is to achieve precise motion with minimized vibration, and overshoot in position as well as velocity. In [5] explains that although various researches on s-curve motion profiles have been carried out, there is no systematic investigation on the general model of polynomial s-curve motion profiles have been considered.

The reduced current conditions are desired not only to lessen the burden on the electrical system and avoid power company penalties, but also to decrease the strain on both motor and the connected mechanical system. Electronic soft-starters offer the most versatility for their price and a very good selection of starting high inertia loads. The low currents drawn by the motor coupled with the extended acceleration time lead to the relatively low temperature rises even with very high inertia loads. In [7] supports that the low rise is beneficial for both motor reliability and longevity.

METHODOLOGY

This section describes the whole procedures involve in the research. The flowchart of the research work procedures is illustrated in Figure-1.

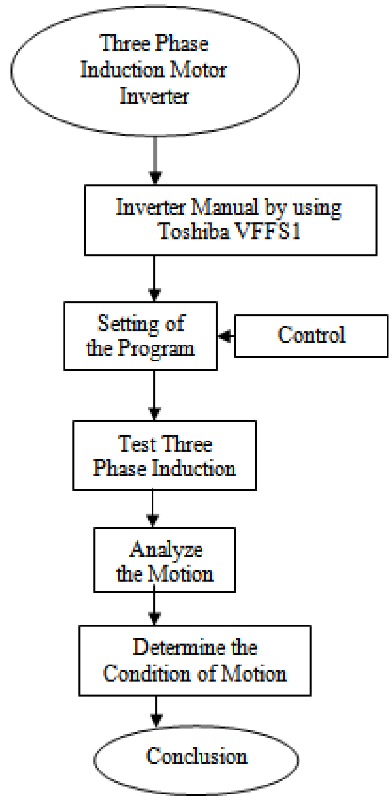

Figure-1. Flowchart of research work procedures.

RESULTS AND DISCUSSIONS

From Figure-2, it shows the waveform when the setting AU1=1. The starting torque is 25% small higher compared with the starting current of 18%. Acceleration time only needs 2 seconds for motor reach to the full speed and has a small jerk. Currently, it is fast enough where the inverter can detect time suitably which are playing by ear load. The jerk still exists when speed approaching maxima. This is where jerk still required for something particular function. After 2 seconds, torque and current back to the normal rated. When load changes, value torque and current will also be changed. The output voltage is 90% from inverter rated and the input voltage is 100% of rated. The period was approximately the same when the output voltage decline abruptly from the steady state. There is a sudden rise of output current in 2 seconds, where it influences the torque of the motor. At the same time, it generates the output frequency and rises until it reaches the frequency reference. At the steady state time, both output current and torque decline simultaneously to 10% and 5% respectively. The situation also occurred to the output frequency. The controlling by the load where the input and output voltage is constant, but the current obtain small increase and follow the torque increase. If the output frequency is 50Hz, the speed has a 3000rpm maximum.

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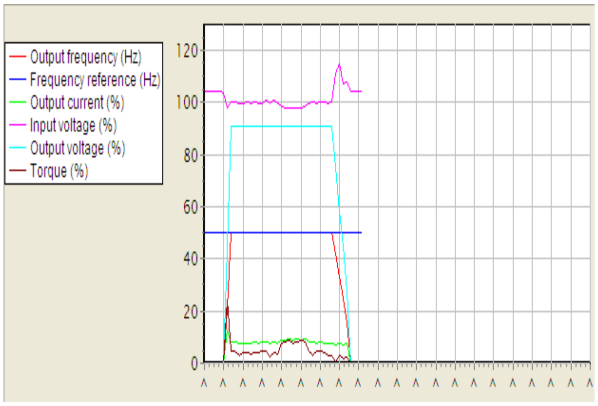

Figure-2. The waveform when setting AU1=1, ACC/DEC = 10, ACC1/DEC1=10, F502/F503=0, F504=1.

Figure-2 shows the waveform when setting AU1=0, ACC/DEC = 10, ACC1/DEC1=10, F502/F503=1, F504=2. The starting torque is 2% lower compared to the starting current which is 10%. The input voltage was in the range of 100% to 105% from the beginning to the end of the process. The output voltage was rising sharply from 0% to 90% in 10 seconds acceleration time. Acceleration time is 10 seconds to obtain a maximum speed. It has no jerk where setting F504 is 2(s-curve). The period was approximately the same when the output voltage decline abruptly from the steady state. There is a sudden rise of output current in 10 seconds. It influences the torque of the motor and generate the output frequency, where it rises until it reaches the frequency reference. At the steady state time, both output current and torque decline simultaneously to 10% and 5% respectively. The situation also occurred to the output frequency. In controlling by the load, input and output voltage is constant. But, the current receives small increase and follow the torque increase. When the output frequency at 50Hz, then the speed has a 3000rpm maximum.

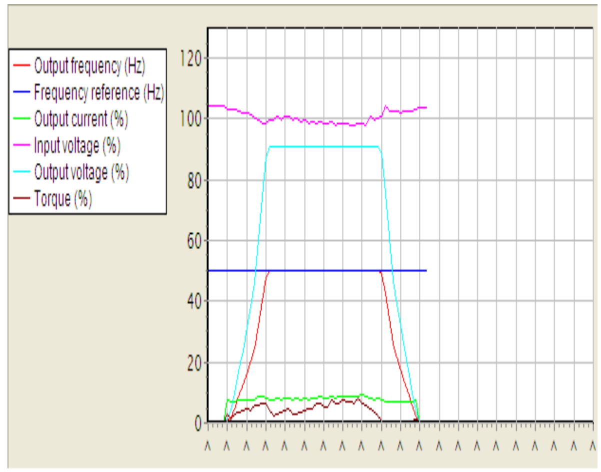

Figure-3. The waveform when setting AU1=0, ACC/DEC = 10, ACC1/DEC1=10, F502/F503=1, F504=2.

Based on the Table-1 and Figure-4, it indicates that AU1=0 (manual setting) is better that AU1= 1 (automatic settings). There is no current spiking as it is important to maintain a certain current, and torque limit on the motor to ensure safe operation.

Table-1. Comparison testing with inverter and without inverter.

Item test	**Testing with inverter**				**Testing without inverter**
	AU1 = 1		**AU1 = 0**		
Starting current	18%	5.49A	10%	3.05A	6.15A
Starting torque	35%		2%		
Jerk	yes		no		yes
Acceleration time	2 s		10 s		
Constant current	10%	3.05A	10%	3.05A	3.85A
Constant torque	5%		5%		
Output voltage	90%	342V	90%	342V	402V
Speed	300rpm		3000rpm		3000rpm

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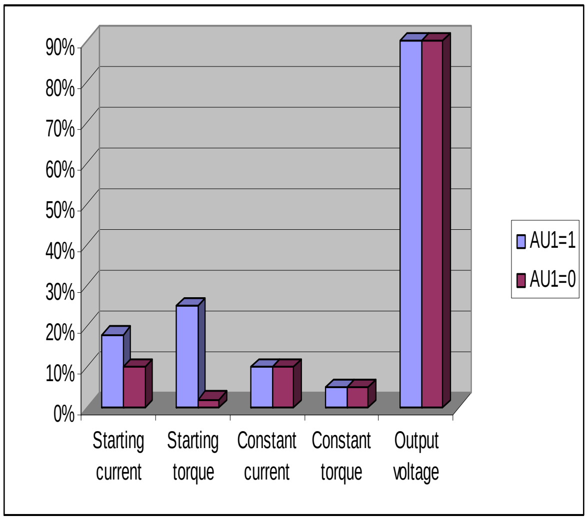

Figure-4. The comparison between AU1=1 and AU1=0.

CONCLUSIONS

In this work, it has investigated the operation and performance of the Toshiba VFFS1 inverter when be used to the motor load. It founds that the inverter has a lot of programming features that makes it a very versatile electronic drive. The interesting and useful feature is that it can be programmed to produce a trapezium profile or a s-curve. The type of motion profile used will determine the presence or absence of jerk in the motion of the driven equipment. With the trapezium profile, a small jerk is still present in the motion. By employing the s-curve profile, the jerk is totally eliminated. Whether the s-profile or the trapezoidal profile is used, it will depend on the type of load the motor is driving. Jerk is needed for starting stiff loads, but it has to be totally eliminated to obtain a smooth motion.

The Toshiba VFFS1 inverter also comes with an assortment of programming features that allow the motor starting current and the temperature rise to be set. Motor starting current can be limited by the inverter without comprising on the high starting torque which required to start a stiff load and at the same time holds the temperature rise to the set limit. The inverter also allows the speed of the motor to be adjusted above or below base speed as the frequency is varied as to ensure safe operation.

In conclusion, it founds that the Toshiba VFFS1 inverter is very easy to use and understand. The hardware and display can be used together for programming the desired operating parameters during setup. The display also provides information about the motor operating conditions while the inverter is driving the motor.

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