Digital Signal Processing Based Speed Control of Induction Motor Drive System

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Abstract - This paper presents the high processing speed and the control accuracy of the DSPIC which allows sophisticated control technique to be used to build the circuit. The control circuit designed is realized on a digital signal controller DSPIC30F4011 based on voltage/frequency (v/f). Which is specially designed to have an accurate control on the three phase induction motor. The controller in the circuit consists of faster generation of the voltage and frequency inputs of sine wave in PWM. The inner sine generation using the voltage and frequency components, the speed control of a three phase induction motor can be handled accurately and a smoother control can be obtained. The experimental results for the speed (v/f) control of the three phase induction motor drive controlled by a digital signal controller DSPIC30F4011 chip has been observed with the effectiveness of the proposed scheme.

Keywords-Three phase induction motor drive system, voltage / frequency (v/f) control, PWM schemes and DSPIC30F4011.

I. INTRODUCTION

The Induction Motor (IM) has dominated over a number of fixed-speed applications because of its reliability and low maintenance operation compared to DC motors. But speed control has been one of the obvious shortcomings which impeded IM applications in some industrial fields, such as hydraulics. Controlling the speed of a brushed DC motor is simple. This relationship is linear to the motor's maximum speed. In addition, most industrial DC motors will operate reliably over a speed range of about 20:1 down to about 5-7% of base speed. This is much better performance than comparable AC motors. However, in the last two decades, with the evolution of power semiconductor devices and power electronic converters, the Induction Motor (IM) [2] is also well established in the controlled-speed area.

High performance Digital Signal Controllers (DSC)'s introduction makes complicated control algorithms, such as flux vector control available and flexible, which means that Alternating Current (AC) motors can be applied to accurate motor speed control as DC motor. Meanwhile, an AC induction motor, compared with a DC motor, is relatively inexpensive, since the windings consist of metal bars which are cast into steel laminations that make up the remainder of the rotor and the stator windings can easily be inserted in slots in stator laminations. An asynchronous motor, at least the cage variety, has no brushes, no moving parts other than the rotor, and virtually no maintenance. As a result, AC motors are progressively replacing DC machines in variable-speed applications. [1]

II. MOTOR MODEL

Asynchronous motors are based on induction. The least expensive and most widely spread induction motor is the squirrel cage motor. The wires along the rotor axis are connected by a metal ring at the ends resulting in a short circuit. There is no current supply needed from outside the rotor to create a magnetic field in the rotor. This is the reason why this motor is so robust and inexpensive. The stator phases create a magnetic field in the air gap rotating at the speed of the stator frequency (W). The changing field induces a current in the cage wires which then results in the formation of a second magnetic field around the rotor wires. As a consequence of the forces created by these two fields, the rotor starts rotating in the direction of the stator field but at a slower speed (W). If the rotor revolved at the same frequency as the stator then the rotor field would be in phase with the stator field and no induction would be possible. The difference between the stator
and rotor frequency is called slip frequency (Slip = \(W_e - W_r\)). [1]

![An Induction Motor](image)

**Fig 1: An Induction Motor**

### III. CIRCUIT DIAGRAM

In the IGBT (Insulated Gate Bipolar Transistor) Module shown in fig 2, has the three diode bridge rectifier with capacitors which gives the rectified DC voltage to IGBT. The IGBT Module of rating 25A, 1200V is used which consist of three phase inverter or a four quadrant chopper which requires six switching devices, six anti-parallel diodes and a switching device for braking. In addition all six switching devices (IGBT) require gate drive circuitries.

All these require many external interconnections with additional inductance, causing an additional over voltages across the IGBT. IGBT power module consists of six IGBT, six anti-parallel diodes and the breakingswitch, and all are in single unit, on insulated semiconductor substrate. Circuitries for detecting over current rise in temperature are also built-in. Such modules are called intelligent Power Module. [2]

A Digital Signal Processor (DSP) approach implementation of advanced motor drive systems requires the following features from a typical motor controller.

- Capability of generating multiple high frequency, high-resolution PWM waveforms, fast processing to implement advanced algorithms to minimize torque ripple, on line parameter adaptation, precise speed control etc.
- Implementing multiple features using the same controller (motor control, power factor correction, communication, etc.), making the complete implementation as simple as possible (reduced component count, simple board layout and manufacturing etc.).
- Implementing a flexible solution so that future modification can be realized by changing software instead of redesigning a separate hardware platform. A new class of DSC controllers has addressed these issues effectively. These controllers provide the computational capability of a DSC core and integrate useful peripherals on chip to reduce the total chip count.
- The DSC family controller is becoming a viable option for even the most cost sensitive applications like appliances, HVAC (high voltage alternate current) systems etc. In addition to traditional mathematical functions like digital filter, FFT (Fast Fourier Transform) implementations, this new class of DSP’s integrates all the important power electronics peripherals to simplify the overall system implementation. This integration lowers over all part count of the system and reduces the board size. The DSC controller DSPIC30F4011 is for motor control applications [3]

To put DSPIC30F4011 DSC Processor chip into application for motor control, the gate driver must be used to amplify the logic signals to 15V and powerful enough to turn on and turn off the thyristors. Because they have different sources and gates at different voltage levels, the gate drivers (amplifiers) cannot use a common ground. Therefore, the dc power supply for those gate drivers should be isolated. [4]

PWM is widely used in power electronics to “digitalize” the power so that a sequence of voltage pulses can be generated by the on and off of the power transistors. The fundamental component has variable magnitude and variable frequency. [5] Pulse Width Modulation technique is used to generate the required voltage or current to feed the motor or phase signals. This method is increasingly used for AC drives with the condition that the harmonic current is as small as possible and the 16 maximum output voltage is as large as possible. Generally, the PWM schemes generate the switching position patterns by comparing three-phase sinusoidal waveforms with a triangular carrier.

The maximum output voltage based on the space vector theory is double time as large as the conventional sinusoidal modulation. It enables to feed the motor with a higher voltage than the easier sub-oscillation modulation method. This modulator allows having a higher torque at high speeds, and a higher efficiency. For a better understanding of the space
vector process and to represent the switching state of the inverter we define a switching function $S_a$ for phase A as follows: $S_a = 1$ when the upper transistor of phase A is on, and $S_a = 0$ when the lower transistor of phase A is on. Similar definitions can be made for phase B and C [6]. The signals $S_a, S_b, S_c$, controlling the lower transistors, are the opposite of $S_a, S_b, S_c$ with an addition of dead-bands. Dead-band is the name given to the time difference between the commutations of the upper and lower transistor of one phase. The two transistors of each phase are then never conducting at the same time. The aim of the dead-band is to protect the power devices during commutation by avoiding conduction overlap and then high transient current. [1]

The speed sensor has most common ways to sense motor speed on the shaft is the use of an incremental encoder and a tachogenerator. In the case of an encoder, the DSPIC30F4011 includes a module, the quadrature encoder and a tachogenerator. In the case of an encoder, motor speed on the shaft is the use of an incremental encoder which perfectly handles the situation and others generate a number of tachogenerators, some build a dc voltage proportional to the motor speed, and others generate a number of pulses per rotor revolution. In the first case, one of the 16 A/D converters channel of the DSPIC30F4011 is connected to the tachogenerator output. For a Hall Effect sensor, the pulses enter a capture and a software driver allows the frequency measurement. The implemented software is called at fixed time intervals no longer than the minimum period of the measurable frequency. As there is only one signal, it is not possible to measure the motor speed sign. An interface is inserted to add the sign to this speed measurement. The speed sign is memorized in a variable and only when the motor speed goes under a predetermined speed this variable is updated with the current sign. This also allows the user to execute fast speed reversing cycles of the motor.

III. SYSTEM SCHEME AND SOFTWARE DESIGN

The system scheme and the software design with the control circuitry are shown in fig 3.

A. System Scheme

System scheme is shown in fig 3, adopts AC-DC-AC varying voltage varying current, main circuit is composed by rectifier bridge, filtering circuit and intellectual module IGBT inversion circuit. The kernel of control circuit is the DSC chip DSPIC30F4011, and then these form a powerful digital control system.

Fig 3: Complete system scheme

In this system, control kernel DSC accept velocity and which is fed by photoelectric encoder, associating with the space vector algorithm to drive module IGBT, and use keyboard to set parameter and use numeral tube to display electric-mechanic velocity real time. [7]

B. The DSP Programming

The DSP is programmed to generate the pulse width modulated signal of 5 KHz with 20% of duty cycle. The generation of PWM can be verified by using an oscilloscope. The DSP is programmed with the help of some recommended software. The software we require for simulation and programming as follows

1. C program ii. CC Studio iii. Matlab

C. Input/Output Specification

a) Input 3-phase 415V AC supply
b) Output 3-phase variable voltage and variable frequency or dc voltage
c) Bridge Rectifier 25A, 1200V
d) IGBT Intelligent Power module 25A, 1200V
e) Breaking IGBT 10A.

IV. EXPERIMENTAL RESULTS

For the experimental research of control schemes, where experimental motor is induction motor (Table 1), stator winding is star connection. We used oscilloscope to measure voltage and current of motor, and take result into display. The waveform measured is shown in the figure (fig 4-12). The experimental results show this control scheme has goodness in performance, higher control precision, rapid dynamic response and also it has wide range of applications. The results are shown below

<table>
<thead>
<tr>
<th>Motor</th>
<th>Squirrel Cage Induction Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of phases</td>
<td>3 phase</td>
</tr>
<tr>
<td>hp rating</td>
<td>1 hp</td>
</tr>
<tr>
<td>Current rating</td>
<td>1.9 A</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500 RPM</td>
</tr>
<tr>
<td>Power Factor</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 1: Specifications of the Induction Motor
A. Open loop v/f control

The open loop speed control (v/f) of the Induction Motor results are shown below:

<table>
<thead>
<tr>
<th>Voltage (Volt)</th>
<th>Frequency (Hz)</th>
<th>Speed (RPM)</th>
<th>V/f</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>40.43</td>
<td>1241</td>
<td>3.71</td>
</tr>
<tr>
<td>100</td>
<td>27.27</td>
<td>986</td>
<td>3.66</td>
</tr>
<tr>
<td>75</td>
<td>23.23</td>
<td>725</td>
<td>3.22</td>
</tr>
</tbody>
</table>

Motor results are shown below:

Table2: Open Loop v/f Control of Induction Motor (no-load)

B. Closed Loop V/F Control

The closed loop speed control (v/f) of the Induction Motor results are shown below:

<table>
<thead>
<tr>
<th>Voltage (Volt)</th>
<th>f (Hz)</th>
<th>Speed (RPM)</th>
<th>V/f Rati</th>
<th>Set speed (RPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>27.22</td>
<td>951</td>
<td>7.34</td>
<td>953</td>
</tr>
<tr>
<td>270</td>
<td>36.98</td>
<td>1216</td>
<td>7.30</td>
<td>1217</td>
</tr>
<tr>
<td>330</td>
<td>45.50</td>
<td>1481</td>
<td>7.25</td>
<td>1480</td>
</tr>
</tbody>
</table>

Table3: Closed Loop v/f Control of Induction Motor (No-Load)
also generation of fixed PWM has been verified.

REFERENCES


CONCLUSION

The experimental result presented v/f controlled voltage-source inverter fed induction motor. DSPIC30F4011 based control systems have numerous advantages. The high processing speed of the DSPIC30F4011 family allows sophisticated control techniques to be used to build a high-precision control system. The fast processing of DSPIC30F4011 family allows high sampling rates to be used, thus giving analog like performance and minimizing delay time. With the DSC controller an intelligent control approach is possible to reduce the overall system costs and to improve the reliability of the drive system and