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A REVIEW ON ENERGY EFFICIENT DRIVE OF AN INDUCTION MOTOR

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Abstract: This paper reviews the different methodologies of induction motor drive. IM drive is a process of controlling the speed, power and efficiency of the induction motor using various techniques. Such driving techniques includes V/F control or frequency control, changing the number of stator poles, controlling supply voltage, adding rheostat in the stator circuit, adding external resistance on rotor side, cascade control method, injecting slip frequency EMF into rotor side. Among these methods of IM drive techniques, this paper explains the advantages of building V/F IM drive to attain better system efficiency.
Keywords: Induction motor drive, pulse width modulated inverter, driver circuit, variable speed drive.

I. INTRODUCTION

Induction motor: An induction motor[1] is an AC electric motor in which the magnetic field of the stator winding induces the magnetic flux in the rotor, intern produces the rotating torque on it. Basically it has two main parts namely rotor and stator [1]. Stator is a stationary part of induction motor and it has winding on it. And rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft [2] [3]. There are basically two types of induction motor that depend upon the input supply – single phase induction motor and three phase induction motor. Single phase induction motor is not a self starting and three phase induction motor is a self-starting motor. Working principle of single phase and three phase IM motor is same but controlling mechanism slightly differs from each other. This paper reviews the energy efficient variable frequency drive over various IM drive techniques [3]. When it comes to the efficiency of driving the system, there are so many approaches have been introduced in the market to achieve the best. Efficiency of the IM can be improved by different methods like stator control, rotor control, real time monitoring etc. among those IM drive using embedded system [4] is current method to achieve better performance. In embedded system control, devices like real time computing system, microcontrollers, micro processers and embedded IC's are used as master devices to have control over it. On the basis of IM driving requirements like torque, drive load capacity, frequency of operating, driving speed, driving environment embedded system devices are chosen to get better efficiency [4].

II. INDUCTION MOTOR DRIVE

A. ISSUES RELATED TO IM DRIVE TECHNIQUES

A induction motor speed control is a method of controlling the speed of an IM by monitoring and varying various parameters of an induction motor. IM is basically a constant speed motor so it is somewhat difficult to control its speed (drive) [5] [6]. The speed control of induction motor is done at the cost of decrease in efficiency and low electrical power factor(PFC). This paper reviews various methods of IM drives like stator side method, rotor side method, PWM inverter method [6], microcontroller based driving method along with its driving efficiency.

B. DRIVING TECHNIQUES

1. V/F Control Or Frequency Control:

Whenever AC supply is given to induction motor coil, an rotating magnetic field is produced and it which rotates at synchronous speed [7] given by

$$\boldsymbol{Ns = 120f/P}$$

Where,

N is the speed of rotor of induction motor Ns is the synchronous speed, S is the slip. In three phase induction motor emf is induced by induction like to that of transformer which is given by

$$\boldsymbol{E\ or\ V = 4.44\emptyset KTf}$$

Now by modify frequency, synchronous speed changes but with reduce in frequency & flux will increase and this vary in value of flux causes saturation of rotor and stator cores which further cause increase in no load current of the motor, its key to maintain flux Φ constant and it is only achievable if we change voltage i.e. by reducing frequency, flux increases but at the same time if we decrease voltage, flux will also decease causing no vary in flux and hence it remains stable. Since by keeping the ratio of V/F as constant in drive method, the name is given as V/F control method [7].

2. Controlling Supply Voltage:

The torque produced by running induction motor is depends on number of poles [8] [9], rotor resistance, induced EMF, etc. Since rotor induced emf $E2 \propto V$. So, $T \propto sV2$. From the equation given it is clear that by decreasing supply voltage torque also decreases. But for supplying the same load, the torque must remains the same and it is only possible if we increase the slip and if the slip increases the motor will run at reduced speed . This method of speed control is rarely used because small change in speed requires large reduction in voltage, and hence the current drawn by motor increases, which cause over heating of induction motor. Hence driving efficiency is reduced

3. Multiple Stator Winding Method:

In multiple stator winding [9] method of speed control of induction motor , the stator is provided by two separate winding. These two stator windings are electrically isolated from each other and are wound for two different pole numbers. The supply is given to one winding only and hence speed control is possible. Disadvantages of this method is that the smooth speed control is not possible . This method is more costly and less efficient as two different stator winding are required. This method of speed control can only be applied for squirrel cage motor.

4. Adding Rheostat In The Stator Circuit:

In this method of speed control of induction motor technique, rheostat is added in the stator circuit due to this voltage gets dropped .In case of three phase induction motor torque produced is given by T ∝ sV22 [9]. If there is decrease in supply voltage torque also decreases. But for supplying the same load ,the torque must remains the same and it is only possible if there is increase the slip and if the slip increase motor will run reduced speed.

5. Adding External Resistance On Rotor Side:

In this method of speed control of IM, external resistance are added on rotor side. If there is increase in rotor resistance, torque decreases. So if increase in slip, there will further results in decrease in rotor speed. Thus by adding additional resistance in rotor circuit the speed of three phase induction motor is deduced. The main advantage of this method is that with addition of external resistance starting torque increases but this method of speed control of IM also suffers from some disadvantages like, the speed above the normal value is not possible, large speed change requires large value of resistance and if such large value of resistance is added in the circuit it will cause large copper loss and hence reduction in efficiency, presence of resistance causes more losses, this method cannot be used for squirrel cage induction motor.

6. Cascade Control Method:

In cascade control method of speed control of induction motor, the two three phase induction motor are connected on common shaft and hence called cascaded motor. One motor is the called the main motor and another motor is called the auxiliary motor. The three phase supply is given to the stator of the main motor while the auxiliary motor is derived at a slip frequency from the slip ring of main motor.

7. Injecting Slip Frequency Emf Into Rotor Side:

When the speed control of induction motor is done by adding resistance in rotor circuit, some part of power called, the slip power is lost as I2R losses. Therefore the efficiency of three phase induction motor is reduced by this method of speed control. This slip power loss can be recovered and supplied back in order to improve the overall efficiency of three phase induction motor and this scheme of recovering the power is called slip power recovery scheme and this is done by connecting an external source of emf of slip frequency to the rotor circuit. The injected emf can either oppose the rotor induced emf or aids the rotor induced emf. If it oppose the rotor induced emf, the total rotor resistance increases and hence speed decreases and if the injected emf aids the main rotor emf the total resistance decreases and hence speed increases. Therefore by injecting induced emf in rotor circuit the speed can be easily controlled. The main advantage of this type of speed control of three phase induction motor is that wide range of speed control is possible whether its above normal or below normal speed.

III. METHODOLOGY IN INDUCTION MOTOR DRIVE USING VARIOUS PWM CONCEPT

Micro controller plays an role in induction motor driving mechanism [9]. The controlling singles for the IGBT switching will be taken care by micro controller. In pulse width modulation (PWM), the amplitude is maintained constant but the width of each pulse is varied. The width of each pulse is made directly proportional to the amplitude instantaneous value of modulating signal. The information being carried on the pulse train by encoded the width of pulses [5] [6] [7]. The initiation of high power, fast switching devices and fast microcontroller has facilitated the expansion of variable speed induction motor drive systems. An induction motor drive system is comprised of a changeable frequency converter, a controller and an induction machine. Classic variable frequency converter consists of a rectifier, DC link, and inverter. There are two fundamental classifications of inverters used in variable speed induction motor drives

- Current-source-inverter: Suitable for high power levels.
- Voltage-source-inverter: Suitable for lower levels hence PWM inverter is popular.

The present job makes use of Microcontroller, in order to activate induction motor using V/F method. The various factors which make the microcontroller based system smart are

- Simplicity of execution in variable speed drives
- Better reliability and bigger flexibility.
- Little cost and high precision
- Possible to adjust torque speed characteristics of drive by software adjustment.

IV. MICROCONTROLLER BASED PWM INVERTERS:

Speed control of open loop V/F control of induction motor consists of rectifier with a capacitor bank, buck/boost converter, IGBT driving module, microcontroller, three - phase PWM inverter and three phase/single phase induction motor [7] [8]. Different probes for speed control, direction of rotation is given at the microcontroller side. In this the reference speed is set. This frequency and amplitude are used to update the PWM duty cycle. IGBT based inverter gives the supply to the induction motor. Below are the different methods of designing inverter drive along with their features.

A. Single-phase full-bridge PWM inverter drive:

In this topology a full bridge diode rectifier plus a full bridge IGBT based inverter is used [10]. A dc link capacitor is required to supply the reactive power needed by the motor. In this topology, the motor voltage can be controlled without much difficulty.

B. Half-bridge rectifier with full-bridge PWM inverter:
In this topology a half bridge rectifier is used, this configuration operates in 2 mode, the first one as full bridge inverter with the maximum motor voltage equal to that of the rectified input ac voltage. In second topology it works as a half bridge inverter where the two switches in one of the legs work at 50% duty ratio to form a mid-point of the dc bus. In this case, the maximum motor voltage will be half that of the rectified input supply [11] [12]. It is possible to achieve reduced torque and speed pulsations, lower vibrations and lower noise with second topology.

C. Controlled rectifier with full bridge PWM inverter:
This topology while maintaining the Advantages of the old circuit has an extra advantage. Two extra IGBTs (used as an active rectifier) are used to Control the utility supply current. In this case, the front-end Controlled rectifier can be used to limit the total harmonic Distortion (THD) and also increase the utility side power Factor. This drive system has a wide speed range in the Forward and reverse directions and operates with near unity Power factor and also regenerative capability.

D. Half-bridge rectifier with half-bridge PWM inverter:
In the topology a half-bridge rectifier is used. However, care should be taken in maintaining the dc bus mid-point balanced. In this case, only two IGBTs and two diodes are used.

E. Controlled Half-Bridge rectifier with half-bridge inverter:
This topology is an extension of the previous case with a controlled half-bridge rectifier. The half-bridge controlled rectifier in conjunction with the right hand side switches is needed to regulate the voltage across the motor terminals. The problem associated with this topology is same as that of the previous half bridge topologies, which is in maintaining the dc bus mid-point balanced.

F. Two-phase full-bridge PWM inverter:
In this configuration a two phase PWM inverter motor drive is presented. An H-bridge is used to supply each winding. The two winding voltages and currents can be controlled independent of each other. Therefore, accurate control of torque and speed is possible. It is possible to implement the field-oriented control with this topology. Notice that 8 switches are used. However, there is no need for an ac capacitor in the single-phase induction motor. The main and auxiliary windings are supplied separately.

G. Two-phase half-bridge PWM inverter:
This is a half bridge version of two phase full-bridge PWM inverter. In this case only four switches are used. However, the voltage across the motor windings would be half of the dc bus voltage, which means the motor will operate under half of the rated voltage. Also, it is crucial to keep the voltage across the dc bus capacitors balanced.

H. Two-phase PWM inverter with controlled rectifier:
The source current and therefore the supply power factor and THD can be controlled by using IGBTs instead of diodes [13, 14, 15, 16]. It is possible to implement a space vector PWM (SVPWM) in this case. There are four voltage space vectors and no zero voltage vectors in this two-phase inverter. In this case, the full rated voltage would be applied to the motor windings. However, it is crucial to keep the voltage across the dc bus capacitors balanced. As discussed various driving techniques, PWM control method is most widely used control technique. The mechanism includes the generation of PWM signal. These signal are generated using analog circuit as well as digital circuit. PWM generation using analog circuit requires large number of discrete circuits such as triangular carrier wave generator circuit, sine wave generator circuit; comparator, adder circuits and phase shifters etc. Thus analog method is critical and increases complexity and cost of the circuit. Digital method of PWM generation requires only microcontroller and its minimum configuration. With the advent in the technology now many microcontrollers has in built feature of PWM generation. Microcontroller ICs are designed and fabricated for three phase PWM generation and control purpose. PWM generation digitally require only knowledge of internal architecture of controller and good programming skill.

Advantage Of Using Microcontroller Based PWM Inverter For IM Drive:

- Change of PWM frequency at any time
- The speed of the motor can be controlled smoothly.
- 50 Hz and 60 Hz base frequency both are equally applicable for constructed inverter.
- Motor acceleration or deceleration can be controlled and can change the direction of motor at any time.
- In online and off line it is possible to change the modulation index and voltage boost therefore it is achievable to control the output voltage.
- It is possible to monitor the dc bus voltage of the inverter.

V. CONCLUSION

This paper explains review of induction motor drive techniques and advantages of v/f control using micro controller. In the first part of the review, among various methods of induction motor control, v/f control method is preferable for large efficient drive which is having better driving efficiency and performance. To achieve the Frequency control drive there are different methods available in the market as explained above. Current technology to achieve v/f drive is by using embedded system devices like computers, micro controllers, micro processers, etc. The second part of discussion reviews the application of embedded system control in IM drive, i.e. constant v/f control by use of PWM inverters. Among various inverter methods, suitable method is adopted according to the requirement. In embedded drive it is possible to vary the supply voltage as well as the supply frequency such that the V/F ratio remains constant. So that the flux remains constant too, and can be obtained in different operating regions for various speeds, torques and also can get different synchronous speed with approximately same maximum torque.

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