International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 1606-1610 www.ijaem.net ISSN: 2395-5252

An overview of several techniques for increasing the speed, power, and efficiency of induction motors.

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Date of Submission: 25-09-2022 Date of Acceptance: 04-10-2022

ABSTRACT:
Most industrial motion control systems employ induction motors. Due to various speed control systems, induction motor industrial applications previously relied on constant speed mechanical drives. However, recent advancements in power electronics components have paved the way for the development of power electronics-based variable speed induction motor drives that will eventually replace DC drives. This dissertation examines the various induction motor driving methodologies. Industrial motor drives use a variety of approaches to manage the induction motor's speed, power, and efficiency. This review investigates various speed control method of Induction motor and how V/f control strategy is used by Proportional-integral (PI) and Fuzzy Logic controller (FLC) with Multilevel Inverter for speed control.

Keywords- Induction motors drives, variable speed drives, multilevel inverter, Power factor, Harmonics.

I. INTRODUCTION

An induction motor (IM) is an AC electric motor in which the magnetic flux in the rotor is produced by the magnetic field of the stator winding, which induces the flux. The rotor and stator are its two most crucial components. The stator, which has winding on it and is the stationary portion of an induction motor, rotates. The shaft is used to attach the rotor to the mechanical load devices. [1][2] Induction motors are classified into two categories, single and three phase, based on the input supply. Three phase induction motors are the only self-starting induction motors of the two varieties. While the operating concept of single-phase and three-phase IM motors is same, the controlling system is slightly different.

Induction motors are referred described as having a constant speed because, in most cases, they do so dependent on the frequency of the power source and the number of windings. Induction motor speeds could not previously be changed to fit the circumstance. Despite having several advantages over DC motors, but were unable to be used because of this limitations in usage. However, the area of drivers has advanced thanks to the creation of variable speed induction motor drives and the availability of thyristors or SCRs, power transistors, IGBTs, and GTOs. Induction motors are becoming more and more common and are replacing DC motors despite the fact that they are more expensive than DC drives.[3]

II. MULTILEVEL INVERTER

Voltage digression and frequency variations, which contribute to harmonic distortions, are two major difficulties that arise in power converters. [4] [5]. An output waveform that looks like a sinusoidal wave may be produced by increasing the number of dc voltage sources on the input side. The outcome is a reduction in total harmonic distortion (THD) and an improvement in output waveform quality, which are the two major benefits of multilevel inverters. Other significant benefits of multilayer inverters are decreased switching losses, less voltage stress on switches, excellent efficiency, and less electromagnetic interference. [6-10]

The architectures of multilayer inverters, which are often employed to create high voltage ac with low voltage rating switches, are developed in [11]. Different modulation strategies, as shown in [12], are used to regulate the multilevel inverter's output voltage. These control methods significantly lower the amount of THD in the inverter output voltage. An enormous number of switching devices are used by a multilayer inverter to provide high staircase output voltage. More dc sources are necessary for the high voltage waveform to be

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generated. The efficiency of the inverter is decreased because a large number of switching devices results in higher switching losses. In order to increase efficiency, it is therefore required to decrease the switching components. When compared to traditional multilevel inverters, the topologies shown in [13], [14] greatly minimize the number of switching devices. Cascaded H Bridge, flying capacitor, and neutral point clamped multilevel inverters are the three fundamental types of conventional multilevel inverters shown in figure 1. Multilevel inverters have a variety of benefits, which are described in [15]. Multilevel inverters' most attractive features include the following:

- They operate through many switches as compared to a traditional switch, which results in a lower common-mode voltage.
- Inverters with many levels produce more power.
- They are capable of running at lower switching frequencies.
- It can be used as environmentally friendly energies like wind and solar energy and convert them to AC.
- It can create output voltages with low distortion and reduced dv/dt and draw input current with extremely low distortion.

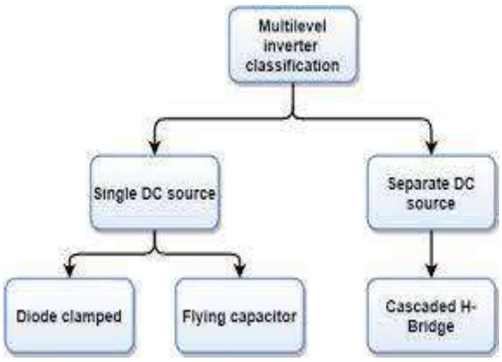

Fig. 1: Multilevel inverter topology

III. METHODS OF SPEED CONTROL

Induction motor speed control, energy loss, and system-wide low efficiency may all be improved using a variety of techniques.

a) Frequency Control Or V/F Control

When an induction motor coil is linked to an AC source, a rotating magnetic field is created, and it rotates at the speed defined by $Ns = 120/p$, N is the rotor speed of the induction motor, Ns is the synchronous speed, and S is the slip. The fluctuating magnetic field of a three-phase induction motor experiences the same kind of induction as a transformer, which is provided by $E = 4.44f\emptyset KTf$ [16]. The best way to maintain flux constant and it is only possible if we change voltage, so by reducing frequency, flux increases but at the same time if we decrease voltage, flux also deceases causing no vary in flux and an increase in no load current. Now, by modifying frequency, synchronous speed changes, but with reduce in frequency, the flux will increase and this vary in flux value causes saturation of rotor and stator cores that further cause increase in no load current of the motor. The name "V/F control technique" is given because the driving method maintains the ratio of V/F as constant.

b) Controlling Supply Voltage

The number of poles, rotor resistance, induced EMF, and other factors all affect how much torque an induction motor can generate [17]. Given that rotor-induced emf $E2 \propto V$. So , $T \propto sV2$. It is obvious from the provided equation that when supply voltage is reduced, torque is likewise reduced. But in order to produce the same load, torque must stay the same, which is only achievable if we increase the slip, which causes the motor to operate at a slower speed. The drawback of this strategy is that it causes induction motors to overheat since minor changes in speed demand severe voltage reductions. For this reason, induction motors are rarely employed. Driving efficiency suffers greatly.

c) Multiple Stator Winding Method

The stator is provided by two independent windings in the multiple stator winding technique of controlling the speed of an induction motor. Electrical isolation separates these two stator windings from one another. They have two separate pole numbers woven into them. Since just one winding is receiving the supply, speed control is available. This technology is more costly and less effective since it can't provide smooth speed control and calls for two distinct stator windings. Only squirrel cage motors may utilize this form of speed control.

d) Adding Rheostat In The Stator Circuit

In this method of induction motor speed control approach, an additional rheostat is added to the stator circuit as a result. In a three-phase induction motor, the voltage drops.The source of the torque is $T \propto sV2$. Torque also reduces as the supply voltage drops. However, given the same load, the torque must stay the same; this is only achievable if the slip is increased and the motor is

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operating at a slower speed during the slip increase [17].

e) Adding External Resistance On Rotor Side

External resistance is connected on the rotor side of the induction motor in this type of speed regulation. Torque reduces when rotor resistance increases. Therefore, if slip increases, rotor speed will also be reduced. Thus, the speed of a three-phase induction motor is decreased by adding more resistance to the rotor circuit. The method's main benefit is that it increases starting torque with the addition of external resistance, but it also has some drawbacks. For example, it is impossible to control induction motor speeds above their normal range, large speed changes necessitate large amounts of resistance, and adding such resistance to the circuit will result in significant copper loss and lower efficiency.

f) Cascade Control Method

The two three-phase induction motors used in this type of induction motor speed control are linked together on a single shaft and are referred to as cascaded motors. The main motor and auxiliary motor are the names of the motors. The main motor's stator receives a three phase supply, and the auxiliary motor derives its power at a slip frequency from the main motor's slip ring.

g) Injecting Slip Frequency Emf Into Rotor Side

When resistance is connected to the rotor circuit for speed control of an induction motor, a portion of the power, known as the slip power is lost as $I^2 R$ losses.[17][18]. As a result, this method of speed regulation reduces the three phase induction motor's efficiency. This slip power loss can be recovered and restored in order to increase the three phase induction motor's overall efficiency. This power recovery strategy is known as the slip power recovery strategy, and it involves connecting an external source of slip frequency emf to the rotor circuit. [19]. the injected emf can either work in opposition to or in support of the rotor-induced emf. The overall rotor resistance rises when it opposes the rotor-induced emf, which results in a drop in speed, and falls when it assists the primary rotor emf, which results in an increase in speed. Therefore, speed may be readily regulated by introducing induced emf into the rotor circuit. The major benefit of this form of three phase induction motor speed control is the wide range of speed control that is available, above or below standard rates.

h) Slip Energy Recovery

Slip Energy Recovery is also one of the methods of controlling the speed of an Induction motor. This method is also known as Static Scherbius Drive. In the rotor resistance control method, the slip power in the rotor circuit is wasted as $I^2 R$ losses during the low-speed operation. The efficiency is also lowered. The slip power can be recovered from the rotor circuit and injected back to the AC source and utilize it outside the motor. Thus, the overall efficiency of the drive system can be increased. In big power applications where the fluctuation in speed over a wide range involves a significant amount of slip power, this form of speed control is employed [20].

IV. V/F CONTROL STRATEGY

In this we will be discussing about two controller i.e. PI and Fuzzy Logic controller using Multilevel Inverter. Both the controller controls speed regulation of induction motor.

Induction motor drives are typically only intended for two-level inverter output voltage. A two-level inverter's voltage output has a substantially higher percentage harmonic content. Thus, this result in additional torque ripples being produced. The induction motor does not operate smoothly. Multilevel inverters are now necessary in order to lessen torque ripples. The torque profile of induction motors fed by multiple inverters is significantly better.

Multiple voltage levels produced by multilevel inverters at the output side greatly reduce torque ripples, harmonic content, and enhance induction motor performance [21].

There is no feedback signal from the induction motor for v/f control in an open loop. The three-phase sine wave's magnitude and frequency are produced using directly reference speed. When producing PWM pulses, the produced three-phase sine wave was compared to a triangle wave. The gates of inverter switches are coupled to these pulses. In an open loop, speed control precision is poor. Closed-loop scalar control improves open-loop scalar induction motor speed control, which has poor precision. Fig.2 shows a block schematic of an induction motor with v/f closed loop control. In this control, a comparator compares the measured reference speed to the motor's actual speed. The comparator's output is linked to the PI controller. The limiter, which is dependent on the motor's rated current, controls the PI controller's output.

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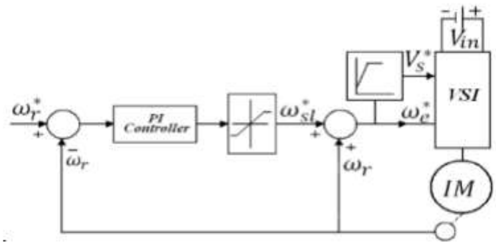

Fig.2 Block Diagram for closed loop speed control of IM

The limiter produces the slip speed indication. The slip speed signal is multiplied by the motor's real speed to produce synchronous speed. Synchronous speed is used to determine frequency. The acquired frequency is then used to create PWM pulses that are applied to the switch gates of inverter circuits.

The research compares the performance of v/f speed controls on an IM in open and closed loop [22].According to simulation tests, the induction motor speed control employing a v/f speed control in closed loop generated the most accurate speeds. Closed loop v/f speed management of IM is hence an accurate control strategy. The ratio of v/f ratio is kept constant in both techniques. [22]

An FLC may be utilized in a number of settings in place of a PI controller allowing the plant to react to changes more quickly. In an FLC, many association functions are used for the input and output variables. Fuzzy logic controller is a most efficient tool which is used to enhance the electrical apparatus through its fastness to evaluate the speed controller incorporating human thinking and rule based protocols.

FL controller mainly follows the four necessary steps, such as: (1) Analog fuzzifier converts input into fuzzy variables (2) Stores fuzzy rules (3) Inference and associated rules (4) Defuzzifier converts the fuzzy variables into actual target

The input to the fuzzy operator has two or more relationship values from fuzzifier input variables. The output is a single truth value. If input 1 is declared to indicate the error means it while the input 2 indicates the changing error. The linguistic variables contain eight fuzzy subsets in which five subsets are used which are described as follows:
(1) Negative error speed Big (NB)
(2) Negative error speed Small (NS)
(3) Positive error speed Small (PS)
(4) Positive error speed Big (PB) and
(5) Zero error speed (ZE)

By using FLC errors are less as compared to PI [23].Time required is also less and speed can be controlled easily.

V. CONCLUSION

A detailed review on Speed Control Methods of Induction Motor is done in this paper and how Multilevel Inverter can be used to improve speed by using PI and Fuzzy Logic Controller.

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