Ilkogretim Online - Elementary Education Online, 2020; Vol 19 (Issue 1): pp. 1212-1219
http://ilkogretim-online.org
doi: 10.17051/ilkonline.2020.661942

Innovative Speed Control Solutions: Harnessing Variable Frequency Drives

Dr. Narendra Kumar Yegireddy Professor, EEE department, Lendi Institute of Engineering and technology, Vizianagaram, Andhra Pradesh, India
narenyegireddy@gmail.com

Dr. M N V S S Kumar Associate Professor, Department of Electronics and Communication Engineering, Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India.

Abstract
In colorful diligence, the demand for machines is a common or garden demand, generally exercised within special disciplines to achieve mechanical tasks at varying pets, ranging from minimum to ultimate haste. Among the different motor manners accessible, roughly 90 of machines assumed are conclusion machines due to their simplicity and cost-forcefulness. Celerity control of conclusion machines can be achieved through several ways, one of which is the constant V/ F(voltage- to- frequence) system. This system maintains a harmonious position of flux while revamping the motor's frequence in reaction to changes in the input force voltage, which is eased by a variable frequence drive (VFD). With the preface of this ingenious path, flawless launch/ stop and jam missions in both forward and rear directions can be exactly executed. These missions are founded through colorful means, similar as VFD buttons, remote control inputs, and computer interfaces linked to a Programmable Logic Controller (PLC).

1. Introduction

Within the vast realm of electrical engineering, we encounter a remarkable innovation—an electrical motor. This ingenious electromechanical device performs a crucial task, adeptly converting electrical energy into valuable mechanical energy. In the context of 3-phase AC operations, a prominent figure among motors is the 3 Phase Induction Motor. What distinguishes this motor in the field of electromechanics is its inherent self-starting capability. It operates autonomously, requiring no external starting mechanisms to set it in motion. This exceptional attribute has firmly established it as the favored choice in a myriad of industrial and commercial applications, cementing its position as an indispensable workhorse in the realm of electrical machinery [1]. The world of electrical engineering is enriched by the presence of an extraordinary invention known as the electrical motor. This ingenious electromechanical device serves as the cornerstone of numerous technological applications, seamlessly facilitating the conversion of electrical energy into valuable mechanical energy. In the domain of 3-phase AC operations, a standout performer emerges—the 3 Phase Induction Motor. Renowned for its self-starting capability, this motor operates with remarkable autonomy, eliminating the need for any external starting mechanisms to initiate its motion. This exceptional feature has solidified its reputation as the preferred choice across a diverse array of industrial and commercial applications, establishing itself as an indispensable workhorse within the expansive realm of electrical machinery.

The 3 Phase Induction Motor operates on a simple yet efficient principle, involving the interaction of rotating magnetic fields generated by the stator windings and the rotor windings positioned within the motor [2]. At full load speed, the rotor trails slightly behind the synchronous speed of the motor, generating the necessary torque for its rotational movement. This process relies on the flow of currents induced within the rotor windings by the magnetic field, a mechanism that is crucial for initiating the motor's rotation. An intriguing consequence of this operation is the concept of "slip," which represents the speed difference between the rotor and the rotating magnetic field. The degree of slip directly influences the torque output, with higher slip values resulting in greater torque generation, making it a vital determinant of the motor's performance characteristics.

The synchronous speed of the motor, determined by the number of poles or coils within the stator and the frequency of the supply current, defines the rate at which the magnetic field revolves. This critical attribute, often referred to as "synchronous speed," provides a foundational framework for understanding the motor's operational dynamics. Notably, the availability of the 3 Phase Induction Motor in various speed configurations, including 3600, 1800, 1200, and 900 RPM, reflects its adaptability to a diverse spectrum of industrial tasks, rendering it a versatile and indispensable component within the realm of electrical engineering.

In summary, the 3 Phase Induction Motor stands as a testament to the remarkable strides achieved within the field of electrical machinery, exemplifying the power of ingenuity and innovation in the pursuit of technological excellence [3-5]. Its unique self-starting capabilities and robust operational dynamics position it as an essential cornerstone of modern industrial and commercial infrastructure, underscoring its pivotal role in powering the engines of progress and development across various sectors of the global economy.

1.1 The AC induction motor

showcases a remarkable engineering achievement, where its rotor is equipped with windings that interact intricately with the magnetic field produced by the stator windings. When the motor operates at full load speed, the rotor experiences a slight delay compared to the synchronous speed of the motor. This phenomenon occurs as the magnetic field induces currents within the rotor windings, resulting in the necessary torque to initiate rotor movement. To clarify, if the rotor were to match the magnetic field's speed precisely, it would lead to no relative motion between them, effectively nullifying torque generation.

The disparity in speed between the rotor and the rotating magnetic field is termed the "slip" of the motor. An interesting aspect of this mechanism is that a higher degree of slip corresponds to increased torque output from the motor. The relationship between torque and speed is graphically illustrated in the diagram below, offering valuable insights into the internal operations of a typical induction motor.

The velocity at which the magnetic field revolves around the stator depends on two key factors: the number of poles or coils strategically arranged within the stator and the frequency of the supplied current. This inherent attribute is referred to as "synchronous speed" and can be calculated using the formula:

Synchronous Speed = (120 x Frequency) / Number of Poles

Induction motors are available in various speed configurations, such as 3600, 1800, 1200, and 900 RPM, highlighting their versatility for a wide range of applications.

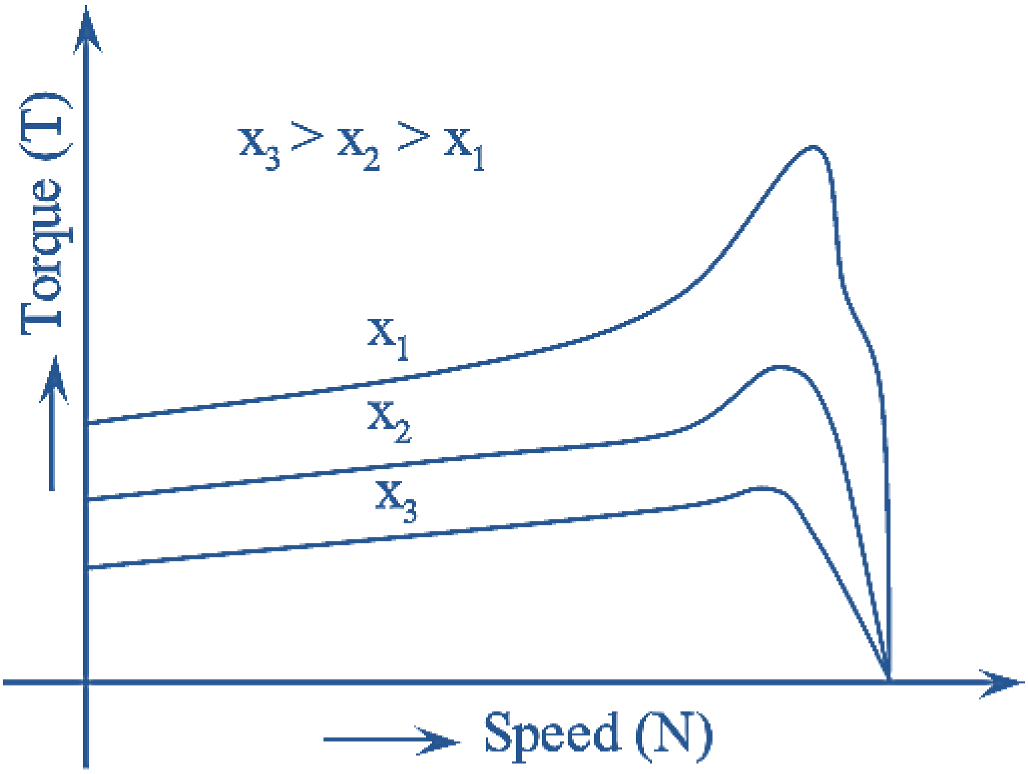

Figure 1. Torque-speed Curve of an Induction Motor

1.2. Squirrel Cage AC Induction Motors

are the most prevalent type of AC induction motors in use. These motors feature a rotor design comprising aluminum or copper alloy bars oriented parallel to the shaft and interconnected by end rings, as depicted in the accompanying diagram.

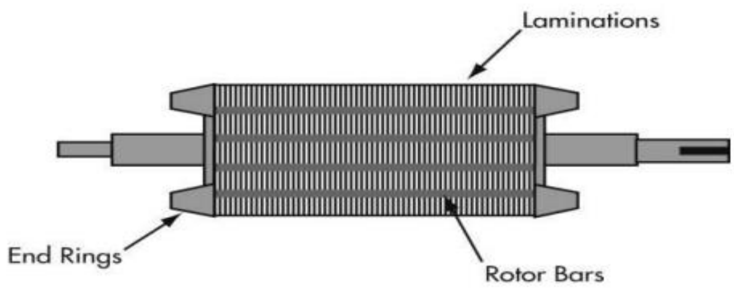

Figure 2. squirrel cage rotor

The configuration and the electrical resistance characteristics of the rotor bars play a crucial role in determining the motor's torque-speed behavior. These variables have a significant impact on how the motor performs, rendering it suitable and effective for a diverse range of applications. The squirrel cage motor's design is renowned for its dependability and adaptability.

1.3. Pulse Width Modulated Variable Frequency

Drives are instrumental in the regulation of AC motor speeds by manipulating the frequency supplied to the motor. Additionally, these drives adjust the output voltage proportionally to the output frequency, ensuring that the voltage-frequency (V/Hz) ratio remains relatively constant to generate the necessary torque.AC drives offer precise torque control, effortlessly manage increased loads, and provide a host of customizable operating modes. They can effectively manipulate the speed, direction, and other critical parameters of a three-phase motor, utilizing the 2-wire method for control. The initial step involves transforming the AC supply voltage into DC through a rectifier, followed by the smoothing of DC power voltage ripples using filter capacitors in the DC link section. Subsequently, this DC voltage is converted back into AC, usually achieved using power electronic devices like IGBT power transistors via Pulse Width Modulation (PWM). PWM involves switching the output voltage on and off at a high frequency, with the pulse width controlled to approximate a sinusoidal waveform.Legacy technologies like Current Source Inverters and Variable Voltage Controllers previously used SCRs or Thyristors as control devices. However, these have been replaced by the more efficient PWM VFDs. The entire process is managed by a microprocessor that continuously monitors incoming voltage supply, speed set-point, and DC link voltage.

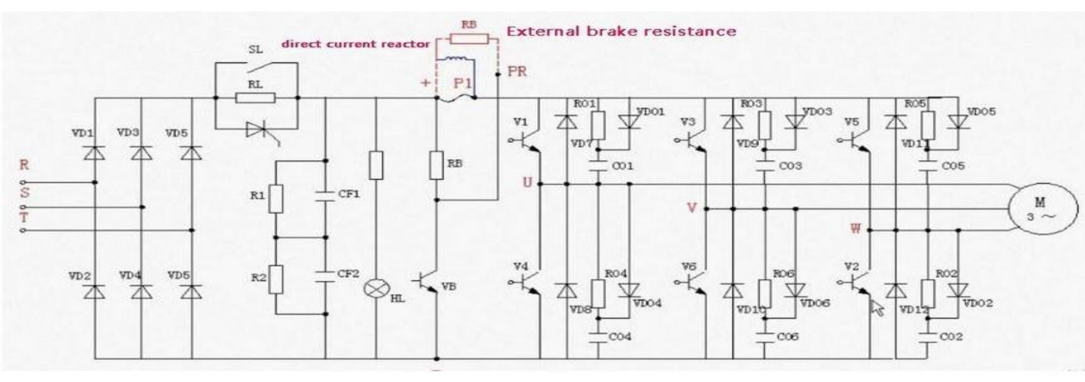

Figure 3. VFD circuit diagram.

It is essential to grasp that the Variable Frequency Drive (VFD) generates an output in the form of a rectangular waveform, in stark contrast to the sinusoidal output commonly found in general-purpose distribution systems. Although this rectangular waveform may not be suited for typical distribution, it offers significant advantages when applied to motor operation. When there arises a need to decrease the motor's frequency, a straightforward approach involves reducing the switching speed of the inverter's output transistors. However, it's imperative to note that any reduction in frequency must be accompanied by a proportional decrease in voltage, maintaining the critical Voltage-to-Frequency (V/Hz) ratio. The method employed to achieve this vital function revolves around Pulse Width Modulation (PWM) techniques.

To illustrate this concept, envision controlling water pressure within a pipe by rapidly toggling a valve on and off. While such an approach may not find practical use in plumbing systems, it serves as a highly effective strategy for VFDs.In this context, consider that during the first half-cycle, the voltage remains active for half of the duration and off for the remaining portion. This results in an average voltage that equates precisely to half of the 480V supply voltage.

In other words, by employing this pulsing method, we can attain a specific average voltage at the VFD's output.

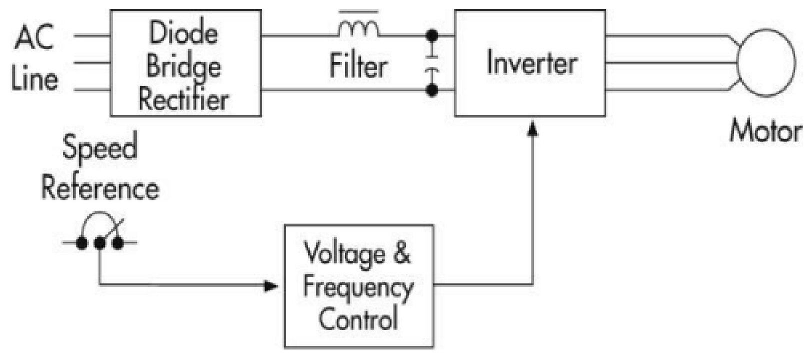

Figure 4. Block diagram of a typical PWM VFD

In simpler drive setups, the speed reference is typically set as a fixed point. However, in more intricate applications, the speed reference is derived from a process controller, such as a Programmable Logic Controller (PLC) tachometer.

Siemen's AC motor drives are engineered to efficiently regulate motor speed, enhance machine automation, and conserve energy, catering to specific application requirements within the industry. These drives find diverse applications across a wide array of systems, including packing machines, dumpling machines, treadmills, temperature/humidity-control fans for agriculture and aquaculture, food processing mixers, grinding machines, drilling machines, small-sized hydraulic lathes, elevators, coating equipment, small-sized milling machines, robot arms in injection machines (clamp), woodworking planers, edge-bending machines, elasticizers, and more.

2. Algorithm

The circuit diagram, as depicted in Figure, offers an insightful depiction of the motor speed control process employing the VFD. This comprehensive schematic comprises several essential components, including the VFD Drive, PLC, a three-phase Induction motor, SMPS (Switched Mode Power Supply), and input/output devices. The primary connection of the induction motor to the input supply is facilitated through the central contacts of the VFD. To exert control over the motor, various remote control signals, such as Run/Stop and direction adjustments (Forward/Reverse), are channelled through the PLC. Furthermore, the integration of a computer into the system is achieved via a USB cable, enabling seamless motor control through the utilization of the PLC's versatile programming languages. This circuit diagram serves as a fundamental representation of a sophisticated motor speed control setup.

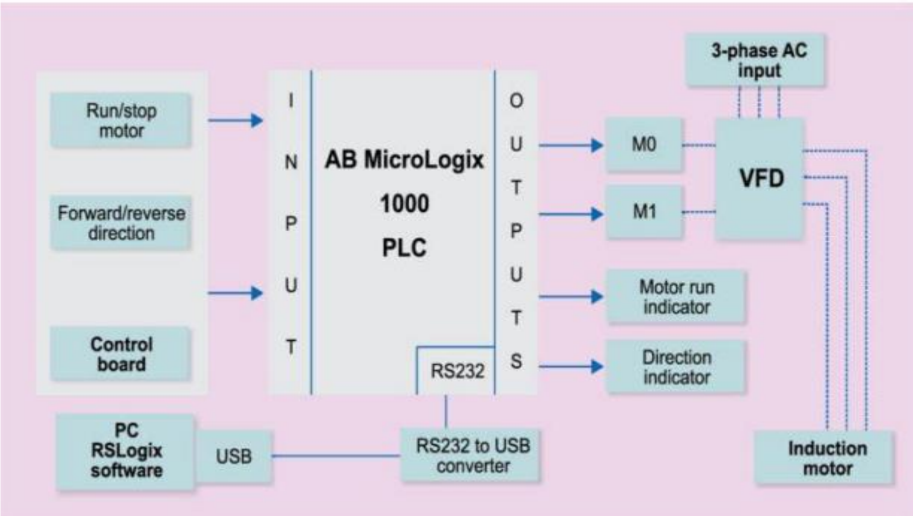

Figure 5. Block Diagram for Proposed Methodology

2.1. Comprehensive Review of Inverter Parameters

An extensive examination of the Inverter's inner workings unveils a multitude of adjustable settings carefully crafted to accommodate an extensive spectrum of applications. These versatile settings, often referenced by specific codes or numerical identifiers (e.g., P0305, denoting Rated Motor Current), house indispensable data pivotal for the seamless operation of the Inverter. To empower the V20 with the capability to adeptly oversee a motor, complete with functions encompassing Run, Stop, and Speed Control effortlessly accessible via the integrated keypad, it becomes imperative to meticulously configure the subsequent parameters. This customization will ensure the Inverter's harmonious integration and effective control over the motor, meeting the precise needs of the intended application.

Figure 6. OMRON –CP1E-N30DR-A PLC

The OMRON CP1E-N30DR-A PLC is utilized with a supply voltage range of 100-230V AC and features CPU units equipped with three built-in ports: USB and RS-232C. It offers straightforward connectivity to computers using commonly available USB cables.

3. Conclusion

This research delves into an extensive approach for regulating the speed of a three-phase induction motor by employing a combination of a Variable Frequency Drive (VFD) and a Programmable Logic Controller (PLC). This system enables meticulous control over the induction motor's speed by adjusting the voltage-to-frequency (V/f) ratios. Within a flexible range, the system can vary the input power supply frequency from 5Hz to 50Hz.

The VFD is equipped with an array of control functionalities, including Run/Stop, Forward/Reverse, Jog operations, and the ability to control the motor's speed in both forward and reverse directions. These controls are easily accessible through dedicated buttons on the inverter. Moreover, the system allows for remote operation through compatible remote-control switches. For more advanced automation and precision, connecting a computer to the system via a USB cable facilitates the use of specific PLC programming languages.

The Variable Frequency Drive (VFD) boasts an impressive repertoire of control features designed to optimize the performance of the connected motor. Among these functionalities are the fundamental Run/Stop commands, the flexibility of enabling Forward and Reverse rotations, as well as the convenience of Jog operations. Most notably, the VFD offers precise control over the motor's speed, permitting adjustments in both forward and reverse directions, thereby catering to a wide spectrum of operational requirements. These controls are thoughtfully integrated into the VFD, easily accessible via dedicated buttons, ensuring user-friendly operation.Furthermore, the system extends its versatility by accommodating remote operation through compatible remote control switches, enabling users to exercise control from a distance. For those seeking a higher degree of automation and customization, the system can be seamlessly connected to a computer using a standard USB cable. This connection paves the way for the utilization of specialized Programmable Logic Controller (PLC) programming languages, empowering users to fine-tune and orchestrate intricate motor control sequences. This combination of accessible onboard controls, remote operation capabilities, and advanced computer integration via USB connectivity collectively positions the VFD as a dynamic and adaptable solution for motor control needs across diverse industrial applications.

The proposed method for speed control in three-phase induction motors exhibits a wide spectrum of potential applications across industries such as automotive, compressors, continuous process control, and crucial sectors like steel production and cement mills. Its adaptability and versatility make it a valuable asset for enhancing industrial processes, resulting in increased efficiency and productivity.

Reference

1. https://ieeexplore.ieee.org/document/6494486 IEEE paper on speed control of induction motor.

2.https://pdfs.semanticscholar.org/5a83/9c9a19cd466f3c3895509dae8c28a4b3aadf.pdf Basic Concept of v/f control of induction motor by M. Alizadeh.

3. https://ieeexplore.ieee.org/document/4124369 IEEE paper on plc and its applications

by A. Alheraish

4. https://ieeexplore.ieee.org/document/8022992/versions IEEE paper on Operation of a VFD by E.B. Agamloh.

5. https://ieeexplore.ieee.org/document/254685 IEEE paper on PWM by J. Holtz.