Week 2: Importance of Electronics in Automation Industry

Week 2, Day 2, Session 1

Variable Frequency Drive (VFD)

Induction or AC motors rotate at a rate that is set by the number of poles inside the motor itself, and the power supplied.

The frequency (measured in Hertz) is directly related to the Revolutions Per Minute (RPM) of a motor. Higher the frequency, faster is the RPM or the higher the engine rotation speed.

$$Speed\ (RPM) = 120\ X\ \frac{Freq\ (Hz)}{No.of\ Poles}$$

In India, Frequency of AC supply is 50Hz, So

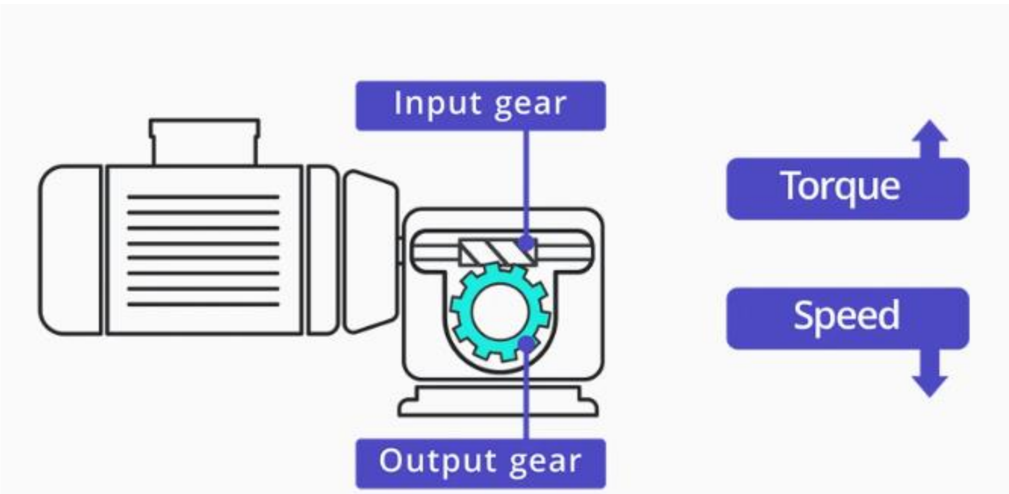
Speed = (120*50)/2=3000 RPM, For 2 poles

Similarly in US where AC supply frequency is 60 Hz, Speed =3600 RPM.

If an application does not require an electric motor running at full speed of 3000 or 3600 RPM, then a few solutions exist:

1. Using a mechanical speed reducer

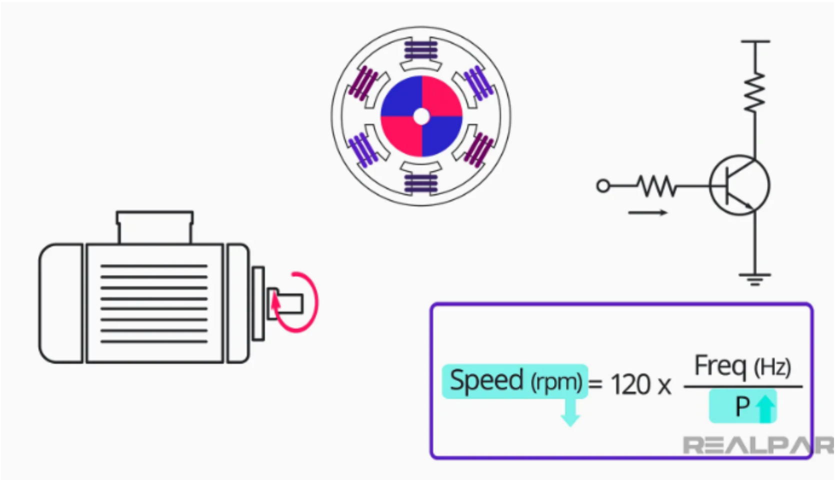
It mechanically decreases the output speed by increasing torque – the output gear has more teeth than the input gear.



The above solution require lubrication, provides no flexibility, and are subtle to vibration and noise, hence not suitable when shafts are distant.

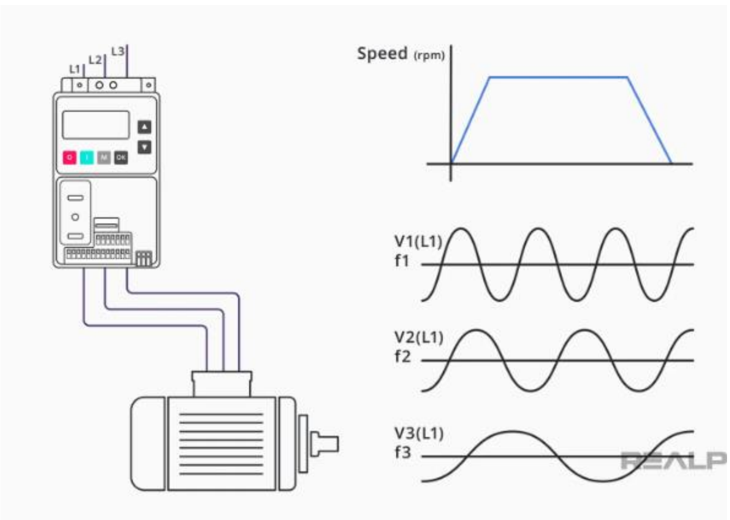
2. Adding more sets of poles

It reduces the speed without altering it electrically. Currently, there are transistor systems that allow for poles inside motors to be turned on and off. However, those systems can be complex and don’t provide fine control.



3. Using a Variable Frequency Drive (VFD)

It can be configured and fine-tuned to generate a ramp, frequency, and voltage so that the motor operates according to the load requirements (desired speed and voltage).



An important feature of the variable frequency drive is that as the motor speed requirements in a given application change, the drive can simply raise or lower the motor’s speed in order to meet new operating requirements, which would not otherwise be possible by using only the mechanical speed reducer, or the transistor system to add more poles.

Variable Frequency Drive (VFD)

A variable-frequency drive (VFD) is a type of motor drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and, depending on the requirement to control associated voltage or current variation. VFDs may also be known as 'AFDs' (adjustable-frequency drives), 'ASDs' (adjustable-speed drives), 'VSDs' (variable-speed drives), 'AC drives', 'micro drives', 'inverter drives' or, simply, 'drives'.

The below figure shows a typical small variable-frequency drive.

- Variable frequency drives allow for precise motor speed control by varying the frequency and voltage of its power supply.
- VFDs are motor controller devices used in numeral applications, from small appliances to large compressors, and much more in between!
- The main function of the VFD is to drive and control motor speed and torque to meet application requirements by varying supply voltage and frequency.

System description and operation

A variable-frequency drive is a device used in a drive system consisting of the following three main sub-systems:

1. AC motor
2. Main drive controller assembly, and
3. Drive/operator interface.

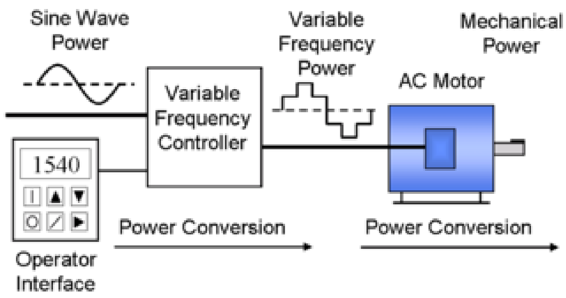


Fig.2.1 VFD system

AC motor

The AC electric motor used in a VFD system is usually a three-phase induction motor. Some types of single-phase motors or synchronous motors can be advantageous in some situations, but generally three-phase induction motors are preferred as the most economical. Motors that are designed for fixed-speed operation are often used.

Controller

The VFD controller is a system consisting of three distinct sub-systems:

- Rectifier bridge converter
- Direct current (DC) link, and
- Inverter.

Most drives are AC-AC drives in that they convert AC line input to AC inverter output. However, in some applications such as common DC bus or solar applications, drives are configured as DC-AC drives.

The most basic rectifier converter for the VSI drive is a full-wave diode bridge. In a VSI drive, the DC link consists of a capacitor which smooths out the converter's DC output ripple and provides a stiff input to the inverter. This filtered DC voltage is converted to sinusoidal AC voltage output using the inverter's active switching elements.

Operator interface

The operator interface provides a means for an operator to start and stop the motor and adjust the operating speed. The VFD may also be controlled by a programmable logic controller through Modbus or another similar interface.

Additional operator control functions might include reversing, and switching between manual speed adjustment and automatic control from an external process control signal.

The operator interface often includes an alphanumeric display or indication lights and meters to provide information about the operation of the drive. An operator interface keypad and display unit is often provided on the front of the VFD controller as shown in the photograph above.

The keypad display can often be cable-connected and mounted a short distance from the VFD controller. Most are also provided with input and output (I/O) terminals for connecting push buttons, switches, and other operator interface devices or control signals.

A serial communications port is also often available to allow the VFD to be configured, adjusted, monitored, and controlled using a computer.

Different types of the VFD

Three main types of VFD are **VSI**, **CSI,** and **PWM.**

The VSI

Among these three, the VSI (voltage-source inverter) is the commonest of the types. The operation of a VSI requires the conversion of AC signal into DC by a simple diode bridge and a capacitor to reserve energy. The inverter then utilizes the reserved power to switch control to give the desired output. Undoubtedly, the use of the VSI comes with advantages and disadvantages.

Advantages

- The production and installation of the VSI are cost-effective.
- In addition, it utilizes multiple motor control facilities which can connect with the single VSI type VFD.
- It possesses a good speed range.
- The design is simple and not complex.

Disadvantages

- The output frequency generates noises of different types.
- As a result of the cogging effect, the load motor face jerks during start and stop situations.

- Due to a controlled or decreased motor speed, resulting in a poor power factor.

Current source inverter (CSI)

The CSI (current source inverter), is dependent on current instead of voltage. A SCR bridge is used instead of the diode bridge rectifier. As an alternative to capacitors, we use inductors to analyze the output energy for smooth current output. Also, the CSI is capable of providing square waves of current.

Advantages

- It supports a higher horsepower induction motor where VSI is not adequate.
- It has higher reliability when compared to VSI.
- Above all, it possesses an excellent regeneration capability.

Disadvantages

- Most times, it generates a poor power factor.
- Also, it experiences a cogging effect that could shake the motor shaft when running.
- Lastly, it is not appropriate for multi-motor operation.

Pulse Width Modulation (PWM)

Pulse Width Modulation (PWM) voltage source variable frequency drives (VFD) presently comprehend the most used equipments to feed low voltage industrial motors in applications that involve speed variation. PWM VFD works as an interface between the energy source (AC power line) and the induction motor.

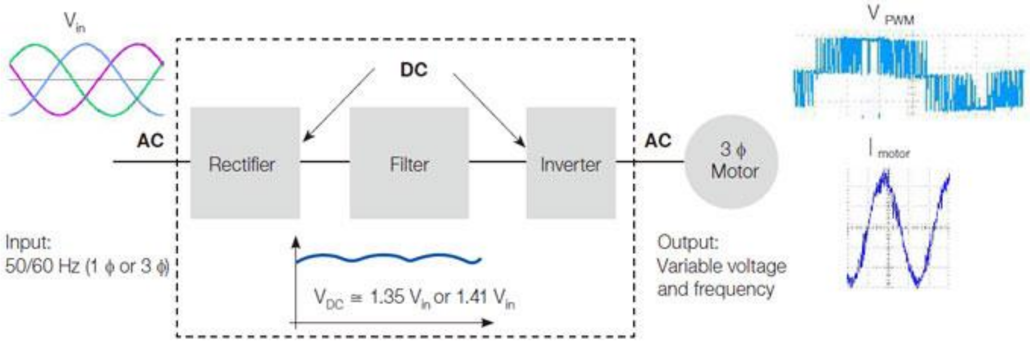
In order to obtain an output signal of desired voltage and frequency, the input signal must accomplish three stages within a PWM VFD:

Diode bridge - Rectification of the AC input voltage - constant amplitude and frequency - coming from the power grid;

DC link or filter - Regulation/smoothing of the rectified signal with energy storage through a capacitor bank;

IGBT power transistors – Inversion of the voltage coming from the link DC into an alternate signal of variable voltage and frequency.

The following diagram depicts the three stages of a Pulse Width Modulation VFD.



Advantages

- No clogging or jerking effect, and offers a wide speed and control knob range.
- Also, there is constant power with very high energy efficiency.
- It comprises different types of circuit protection.

Disadvantages

- There is some complexity concerning design and implementation.
- It generates disturbing noise in the phase driver circuit.
- Finally, it requires additional hardware and is a costly solution.