Study Of Variable Frequency Drives

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VFD

- **Frequency** is the number of occurrences of a repeating event per unit of time.
- A variable-frequency drive is a device used in a drive system consisting of the following three main sub-systems:

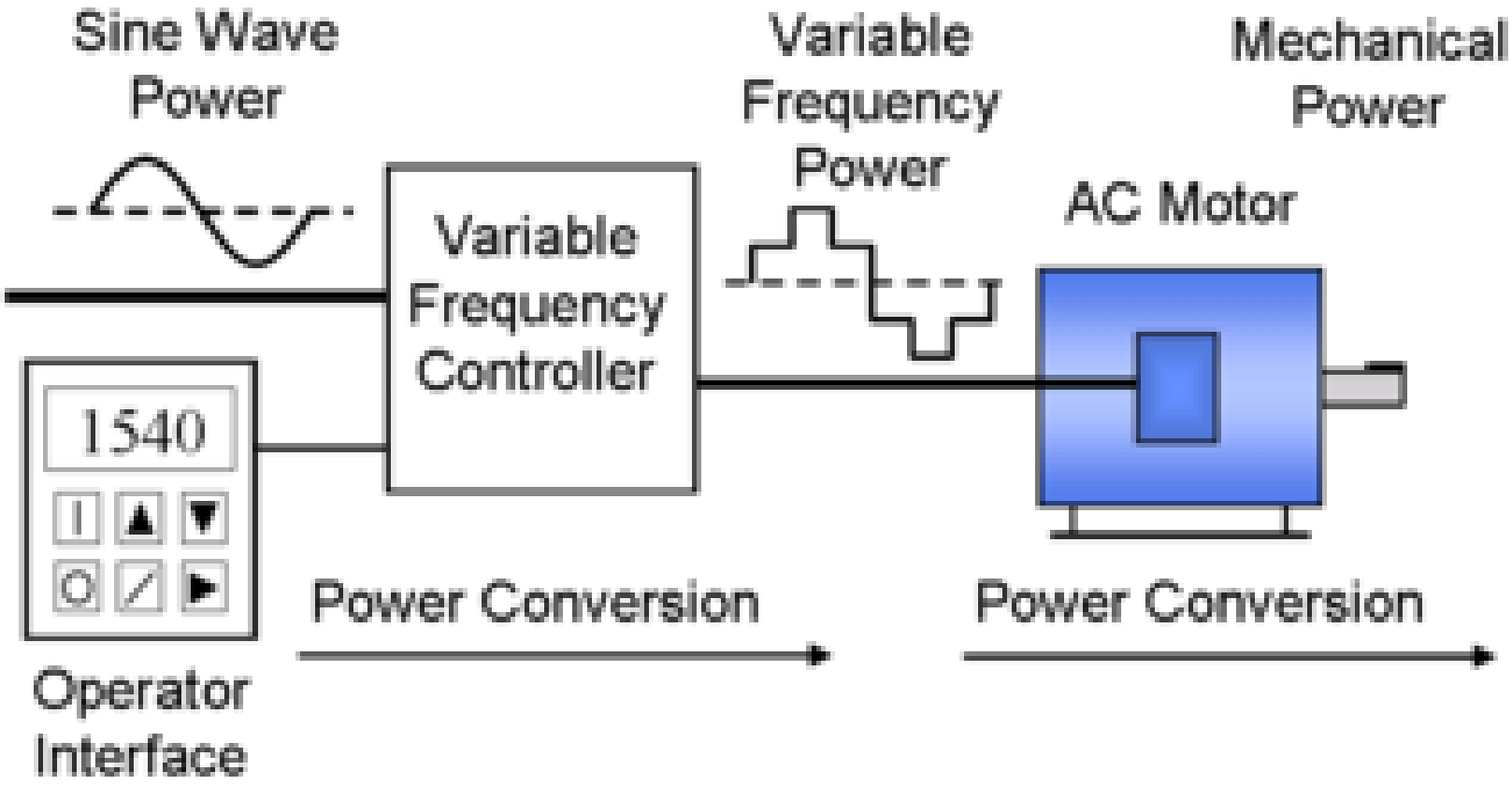
I. AC motor

II. Main drive controller assembly

III. Drive/operator interface.

VFD

VFD


Sine Wave Power
Variable Frequency Controller
Variable Frequency Power
AC Motor
Mechanical Power
1540
Operator Interface
Power Conversion
Power Conversion

Introduction

- An electric drive is defined as a form of machine equipment designed to convert electrical energy into mechanical energy and provide electrical control of this process.
- The basic elements of electric drive are :

I. Electric motor

II. The transmission

III. The electrical control system.

- They often include conversion equipment to attain smoother, versatile control and make the motor to operate on specific speed-torque characteristics.

VFD

- Variable frequency drive (VFD) usage has increased dramatically in HVAC applications.
- The VFDs are now commonly applied to air handlers, pumps, chillers and tower fans
- Variable Frequency Drive (VFD)

  This device uses power electronics to vary the frequency of input power to the motor, thereby controlling motor speed.
- Variable Speed Drive (VSD)

  This more generic term applies to devices that control the speed of either the motor or the equipment driven by the motor (fan, pump, compressor, etc.). This device can be either electronic or mechanical.
- Adjustable Speed Drive (ASD)

  Again, a more generic term applying to both mechanical and electrical means of controlling speed

VFD OPERATION

- Understanding the basic principles behind VFD operation requires understanding the three basic sections of the VFD:

I. Rectifier

II. DC bus

III. Inverter.

Rectifier

- The rectifier in a VFD is used to convert incoming ac power into direct current (dc) power.
- The voltage on an alternating current (ac) power supply rises and falls in the pattern of a sine wave .
- When the voltage is positive, current flows in one direction; when the voltage is negative, the current flows in the opposite direction.
- This type of power system enables large amounts of energy to be efficiently transmitted over great distances.
- Rectifiers may utilize diodes, silicon controlled rectifiers (SCR), or transistors to rectify power.

DC Bus

- After the power flows through the rectifiers it is stored on a dc bus which smoothens it.
- The dc bus contains capacitors to accept power from the rectifier, store it, and later deliver that power through the inverter section.
- The dc bus may also contain inductors, dc links, chokes, or similar items that add inductance, thereby smoothing the incoming power supply to the dc bus

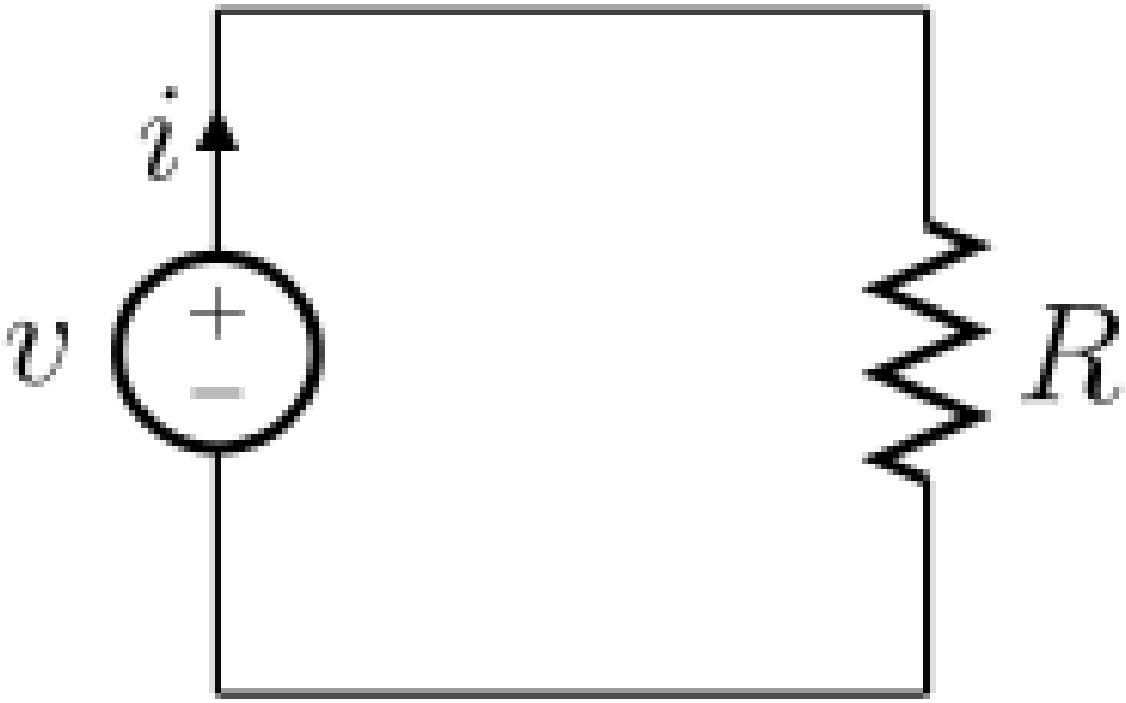
Inverter

- The final section of the VFD is referred to as an “inverter.”
- The inverter contains transistors that deliver power to the motor.
- Composed of transistors acting as switches.
- Utilizing the switches allows VFD to adjust the frequency that VFD supplies to the motor.
- This in turn controls the speed of the motor.
- The “Insulated Gate Bipolar Transistor” (IGBT) is a common choice in modern VFDs. The IGBT can switch on and off several thousand times per second and precisely control the power delivered to the motor.
- The IGBT uses a method named “pulse width modulation” (PWM) to simulate a current sine wave at the desired frequency to the motor.

Electric Motor

- An electric motor is an electrical machine that converts electrical energy into mechanical energy.
- Mechanical energy used to rotate fan or lift material.
- Electrical energy is supplied by the combination of electric current and electric potential that is delivered by an electrical circuit.
- An electrical network is an interconnection of electrical components (e.g., batteries, resistors, inductors, capacitors, switches, transistors) or a model of such an interconnection, consisting of electrical elements (e.g., voltage sources, current sources, resistances, inductances, capacitances). An electrical circuit is a network consisting of a closed loop, giving a return path for the current.

Electric Motor



An Electric Circuit

Electric Motor

- Mechanical energy is the sum of potential energy and kinetic energy. It is the energy associated with the motion and position of an object.
- Potential energy is the energy held by an object because of its position relative to other objects, stresses within itself, its electric charge, or other factors.
- Kinetic energy of an object is the energy that it possesses due to its motion. It is defined as the work needed to accelerate a body of a given mass from rest to its stated velocity.
- E.g. Bow and Arrow

Electric Motor Types

- Electric motors can be powered by
- Direct current (DC) sources

  Batteries, motor vehicles or rectifiers.

  DC Motor : Runs at Fixed Speed

  Or
- Alternating current (AC) sources.

  A power grid, inverters or electrical generators.

  AC Motor : Runs at Variable Speed
- Generator:
- An electric generator is mechanically identical to an electric motor, but operates in the reverse direction, converting mechanical energy into electrical energy.

AC Electric Motor

- Working Principle :

- The AC motor commonly consists of two basic parts:
- Stator
- Rotor

- Stator

  Stationary Component

  Magnetic Part

  Has coils supplied with alternating current to produce a rotating magnetic field

AC Electric Motor

- Rotor

  Rotates the motor shaft to deliver mechanical power

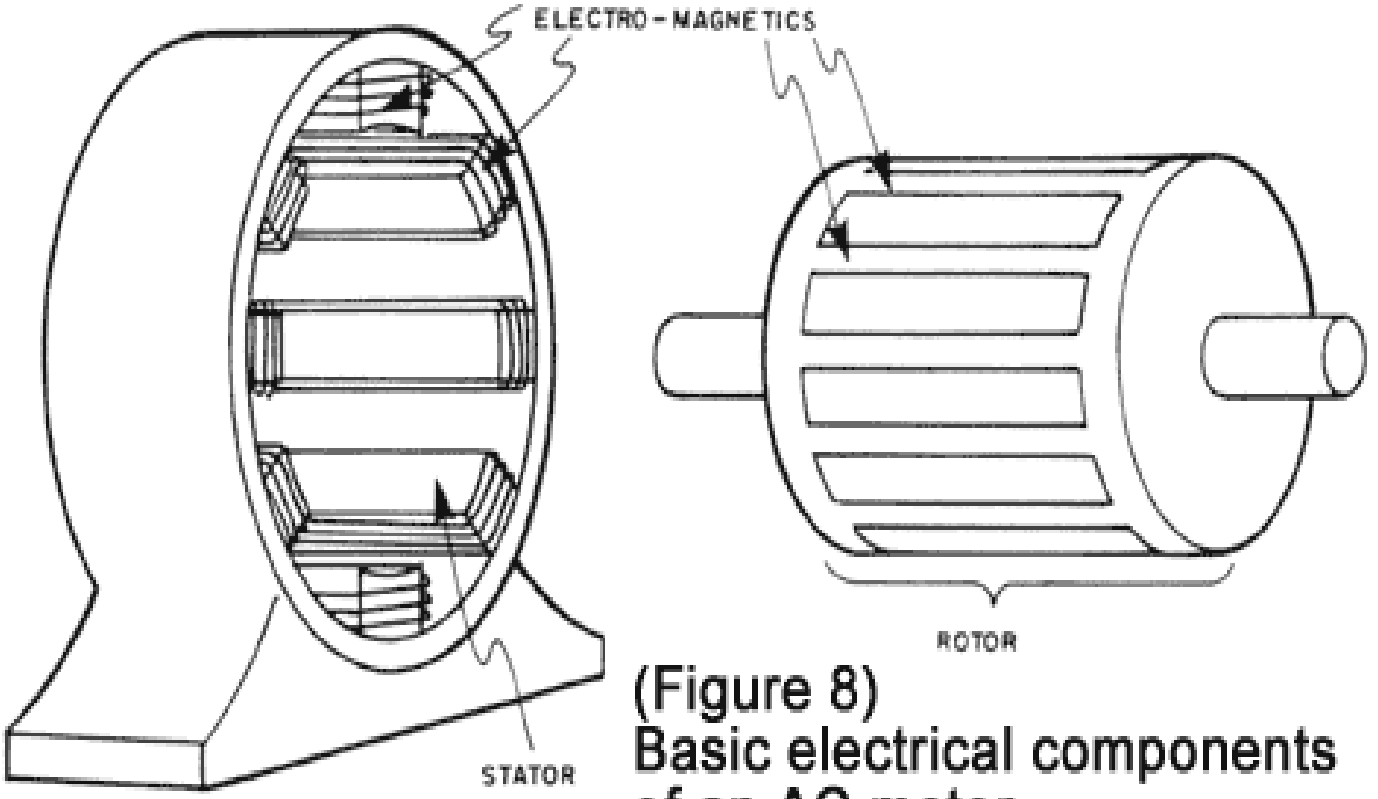
  Attached to the output shaft

  Has conductors which carry currents.

  Interact with the magnetic field of the stator.

  Producing a second rotating magnetic field.

AC Electric Motor

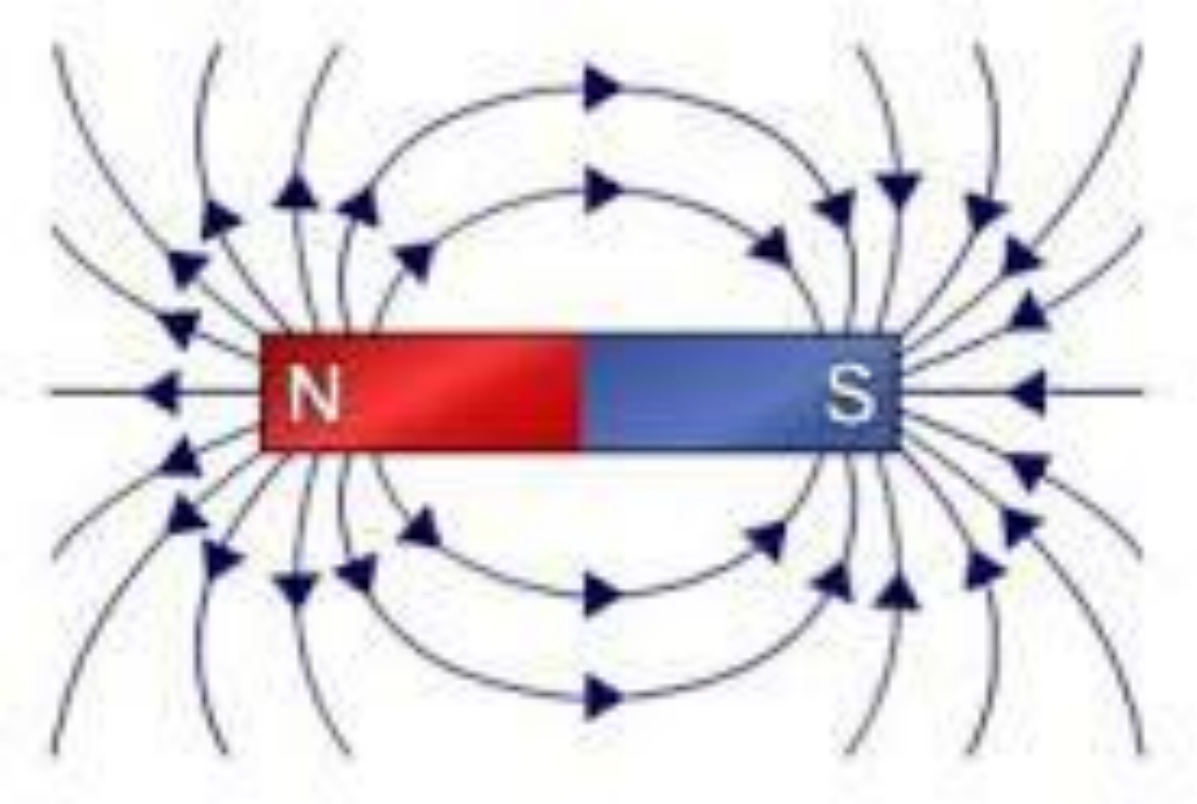


(Figure 8)
Basic electrical components of an AC motor

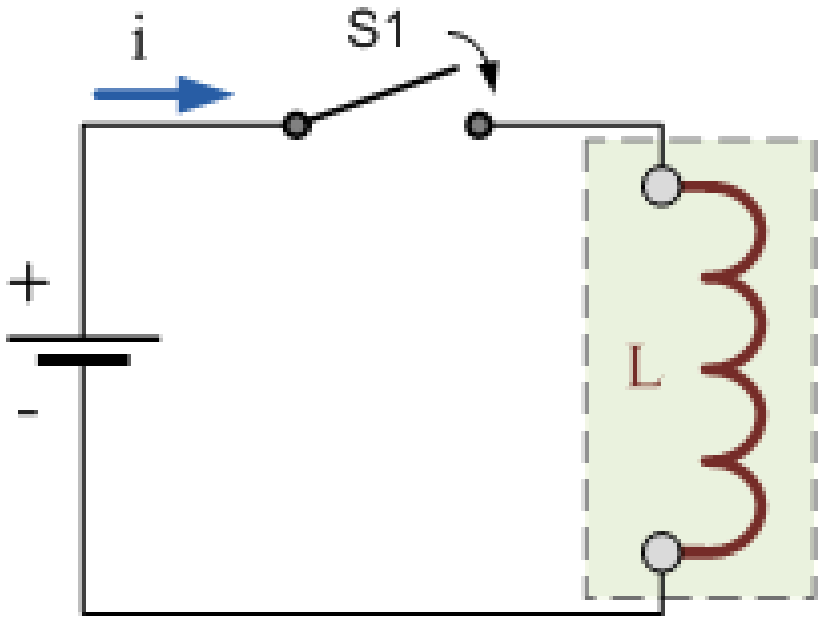
Electric Motor

- Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding
- It results into generation of force in the form of rotation of a shaft.
- The rotor magnetic field may be produced by permanent magnets, reluctance saliency, or DC or AC electrical windings.

Magnetic Flux Lines



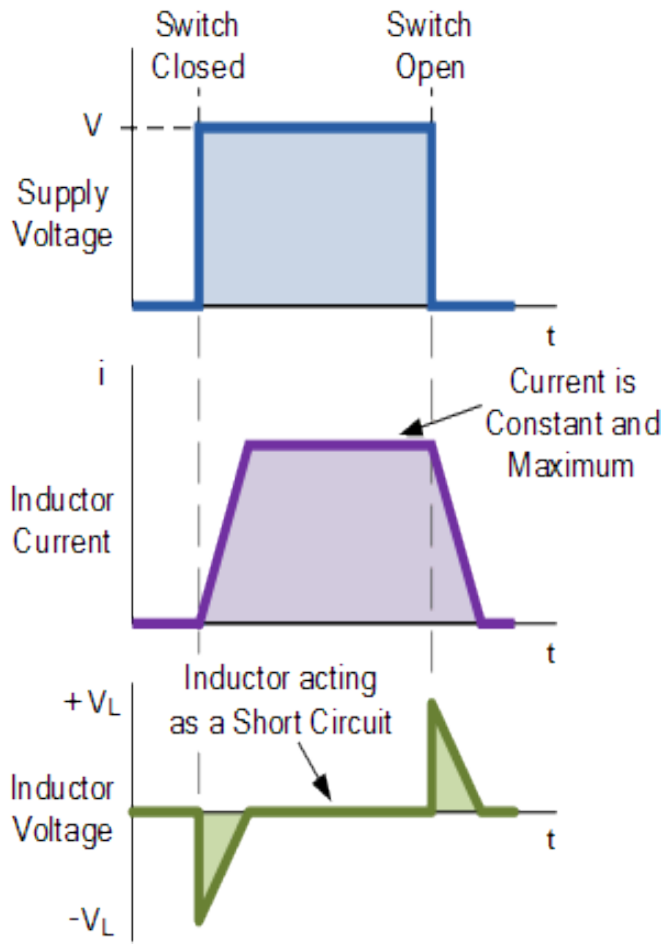
Inductor



An Inductor is a passive electrical component consisting of a coil of wire which is designed to take advantage of the relationship between magnentism and electricity as a result of an electric current passing through the coil

Inductor

$$V_L = -L\frac{di}{dt}$$



❑How much induced voltage will be produced by the inductor depends upon the rate of current change.

❑ **Lenz's Law** stated that: "the direction of an induced emf is such that it will always opposes the change that is causing it".

❑ In other words, an induced emf will always OPPOSE the motion or change which started the induced emf in the first place.

❑So with a decreasing current the voltage polarity will be acting as a source and with an increasing current the voltage polarity will be acting as a load.

❑So for the same rate of current change through the coil, either increasing or decreasing the magnitude of the induced emf will be the same.

Motor Speed(rpm)

- Motor speed (rpm) is dependent upon frequency.
- Varying the frequency output of the VFD controls motor speed:
- Speed (rpm) = frequency (hertz) x 120 / no. of poles
- Example:

  2-pole motor at different frequencies

  3600 rpm = 60 hertz x 120 / 2 = 3600 rpm

  3000 rpm = 50 hertz x 120 / 2 = 3000 rpm

  2400 rpm = 40 hertz x 120 / 2 = 2400 rpm