MOTORS AND DRIVES

A presentation on

MOTORS

AND

DRIVES

MOTORS AND DRIVES

- INDUCTION MOTOR- INTRODUCTION
- INDUCTION MOTOR- CONSTRUCTION
- INDUCTION MOTOR- WORKING PRINCIPLE
- VARIABLE SPEED DRIVE (VSD) - INTRODUCTION
- VARIABLE SPEED DRIVE (VSD) – PRINCIPLE OF OPERATION
- VARIABLE SPEED DRIVE (VSD) – ADVANTAGES & DISADVANTAGES
- VARIABLE SPEED DRIVE (VSD) – VARIOUS TYPES

MOTORS AND DRIVES

INDUCTION

MOTORS

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- Three-phase induction motors are the most common and frequently encountered machines in industry
  - simple design, rugged, low-price, easy maintenance
  - wide range of power ratings: fractional horsepower to 10 MW
  - run essentially as constant speed from zero to full load
  - speed is power source frequency dependent
- It can be part of a pump or fan, or connected to some other form of mechanical equipment such as a conveyor, or mixer.

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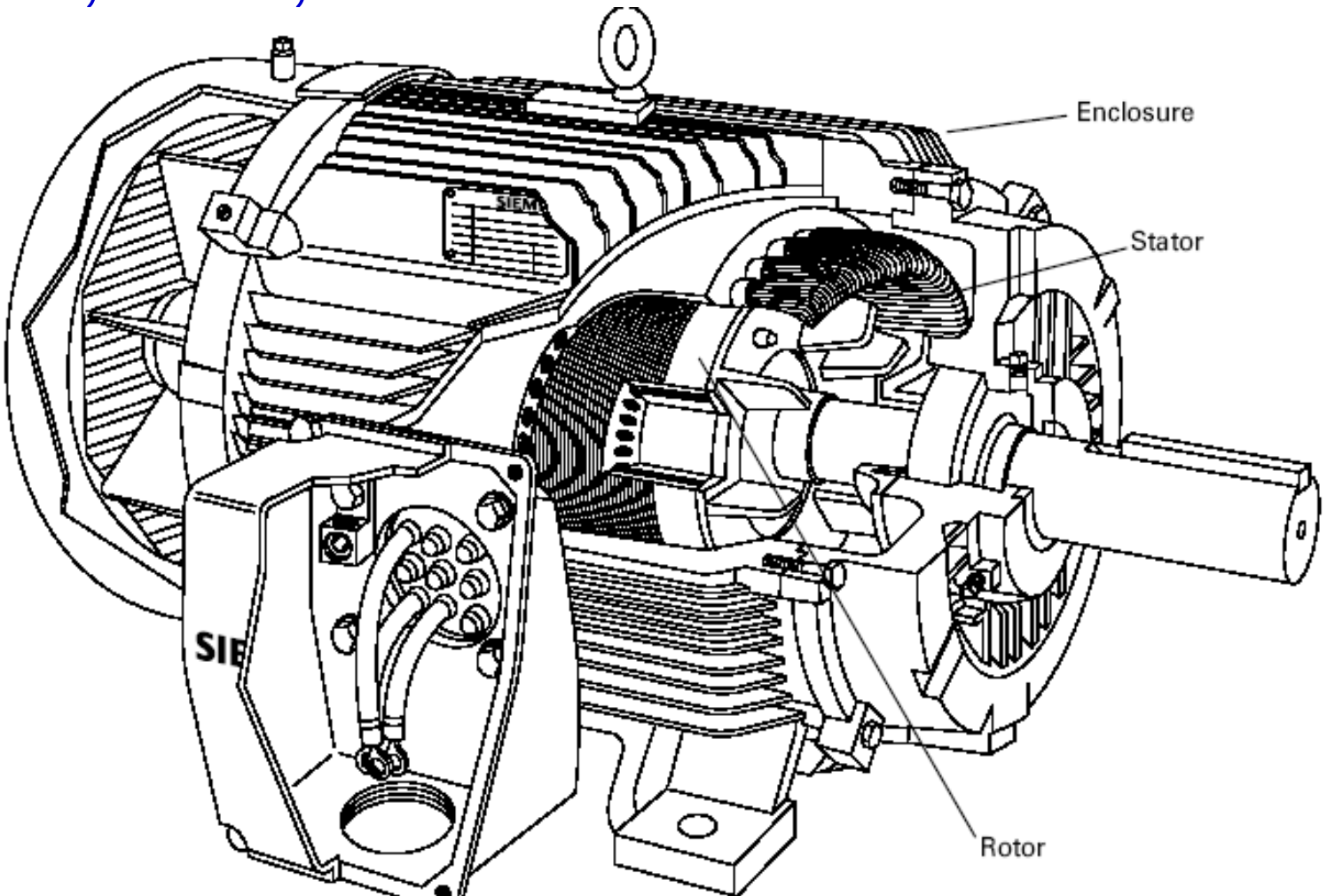
The three basic parts of an AC motor are the rotor, stator, and enclosure.



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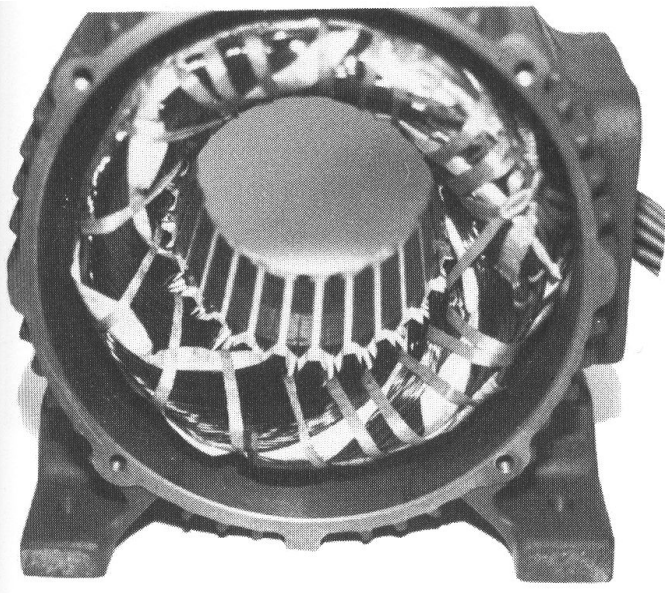
- An induction motor Construction
  - a stationary stator
    - consisting of a steel / Cast Iron frame that supports a hollow, cylindrical core
    - core, constructed from stacked laminations , having a number of evenly spaced slots, providing the space for the stator winding



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- A revolving rotor
  - composed of punched laminations, stacked to create a series of rotor slots, providing space for the rotor winding
  - conventional 3-phase windings made of insulated wire (wound-rotor) » similar to the winding on the stator
  - aluminum bus bars shorted together at the ends by two aluminum rings, forming a squirrel-cage shaped circuit (squirrel-cage)

- Two basic design types depending on the rotor design
  - squirrel-cage
  - Wound or Slip Ring-rotor

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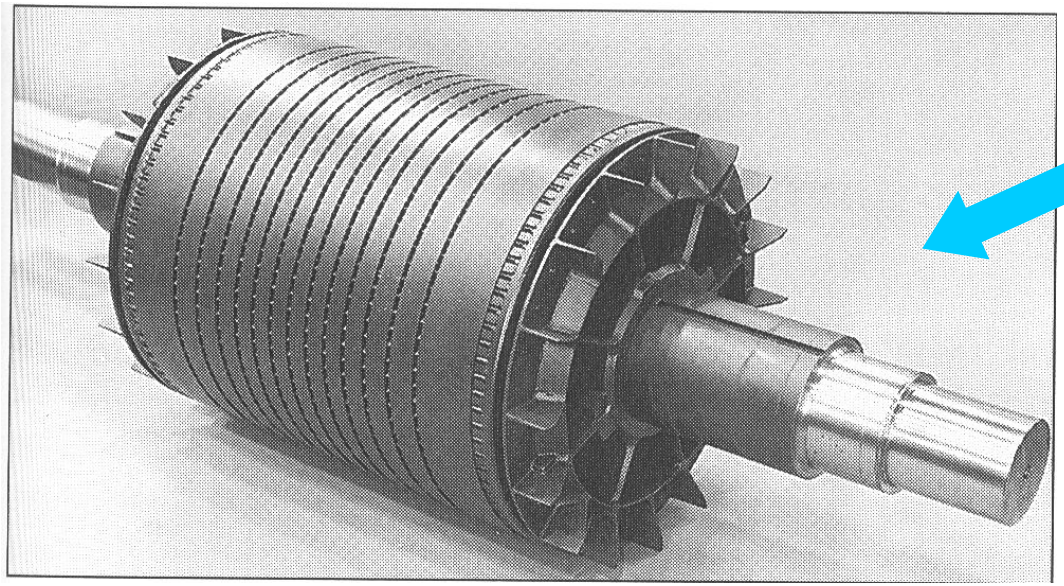
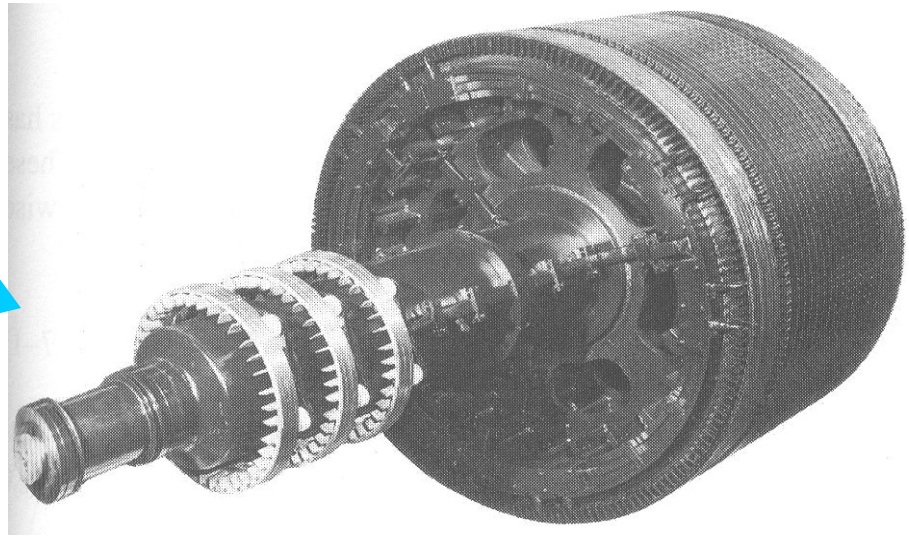


Squirrel cage rotor

Wound rotor

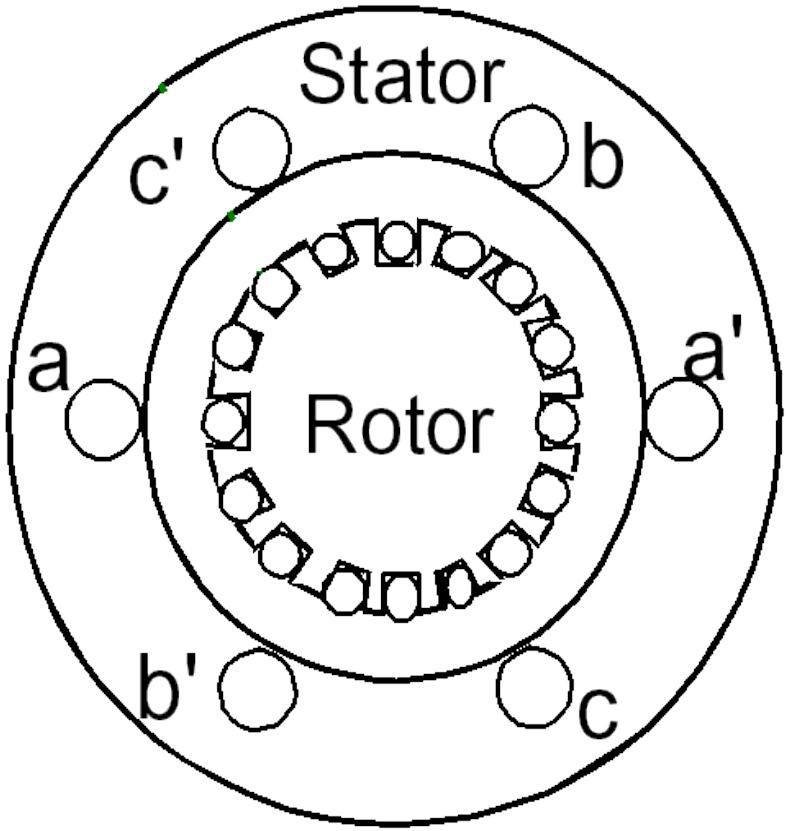


WORKING PRINCIPLE

- Balanced three phase windings, i.e. mechanically displaced 120 degrees form each other, fed by balanced three phase source
- A rotating magnetic field with constant magnitude is produced, rotating with a speed

$$n_{sync} = \frac{120 f_e}{P} \quad rpm$$

- Where f_e is the supply frequency and P is the no. of poles and n_{sync} is called the synchronous speed in *rpm* (revolutions per minute)



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- This rotating magnetic field cuts the rotor windings and produces an induced voltage in the rotor windings
- Due to the fact that the rotor windings are short circuited, for both squirrel cage and wound-rotor, an induced current flows in the rotor windings
- The rotor current produces another magnetic field
- A torque is produced as a result of the interaction of those two magnetic fields

Induction motor speed

- At what speed will the IM run?
  - Can the IM run at the synchronous speed, why?
  - If rotor runs at the synchronous speed, which is the same speed of the rotating magnetic field, then the rotor will appear stationary to the rotating magnetic field and the rotating magnetic field will not cut the rotor. So, no induced current will flow in the rotor and no rotor magnetic flux will be produced so no torque is generated and the rotor speed will fall below the synchronous speed
  - When the speed falls, the rotating magnetic field will cut the rotor windings and a torque is produced

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- So, the IM always run at a speed lower than the synchronous speed
- The difference between the motor speed and the synchronous speed is called the *Slip*

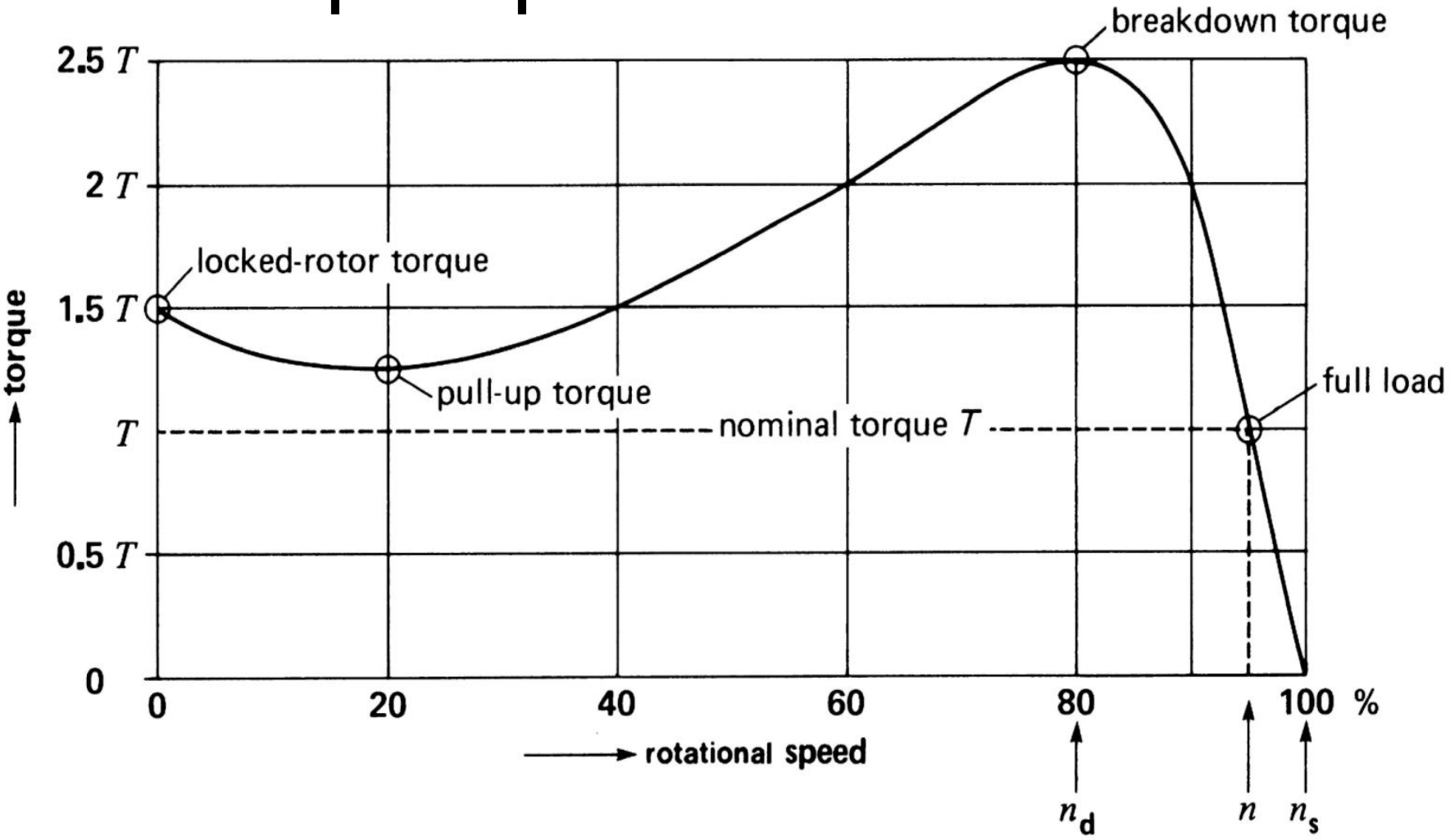
$$n_{slip} = n_{sync} - n_m$$

Where n_{slip}= slip speed

n_{sync}= speed of the magnetic field

n_m = mechanical shaft speed of the motor

Torque-speed characteristics



TEFC (Totally Enclosed Fan Cooled)

CACA (Closed Air Circuit Air)

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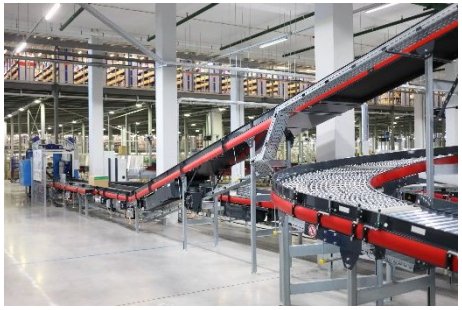
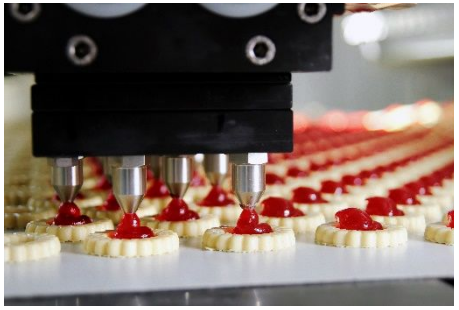
Filling

Compressors



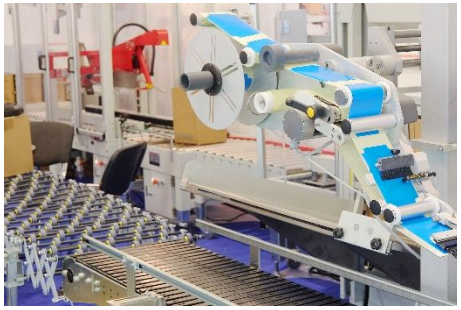
Conveyors



Food

Fans

Pumps



Printing

Packaging

!And more

VARIABLE SPEED DRIVES

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➢Variable Speed Drive

- A variable-frequency drive (VFD) is a system for controlling the rotational speed of an AC motor by controlling both frequency and voltage simultaneously to maintain a constant volts/hertz ratio which keeps current flow similar to full speed conditions.
- This allows the motor to draw full current at any speed and produce full torque as motor speed changes.
- AC drives are used to bring about process and quality improvements in industrial and commercial applications' acceleration, flow, monitoring, pressure, speed, temperature, tension, and torque.

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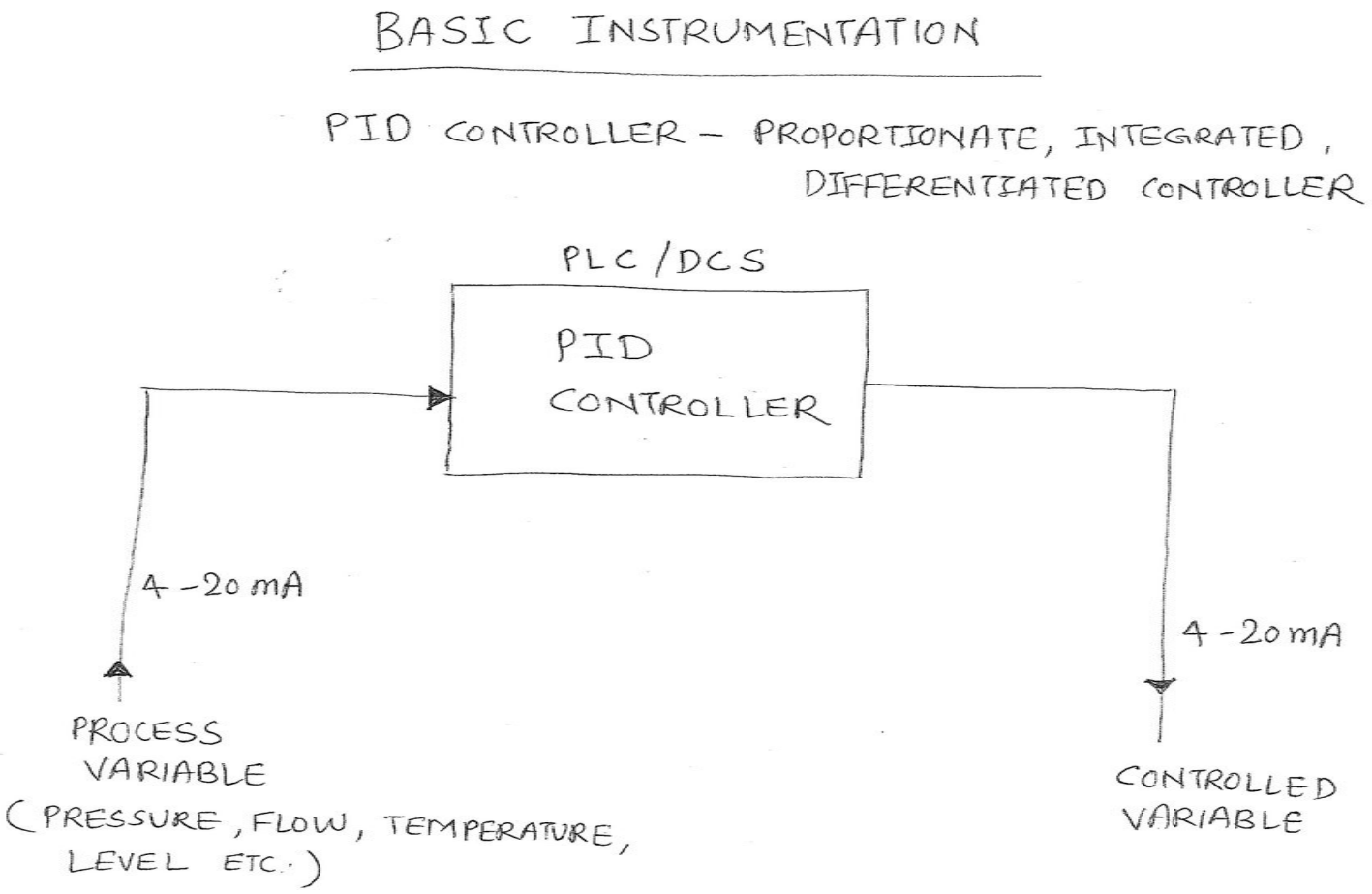
- Variable Speed Drive



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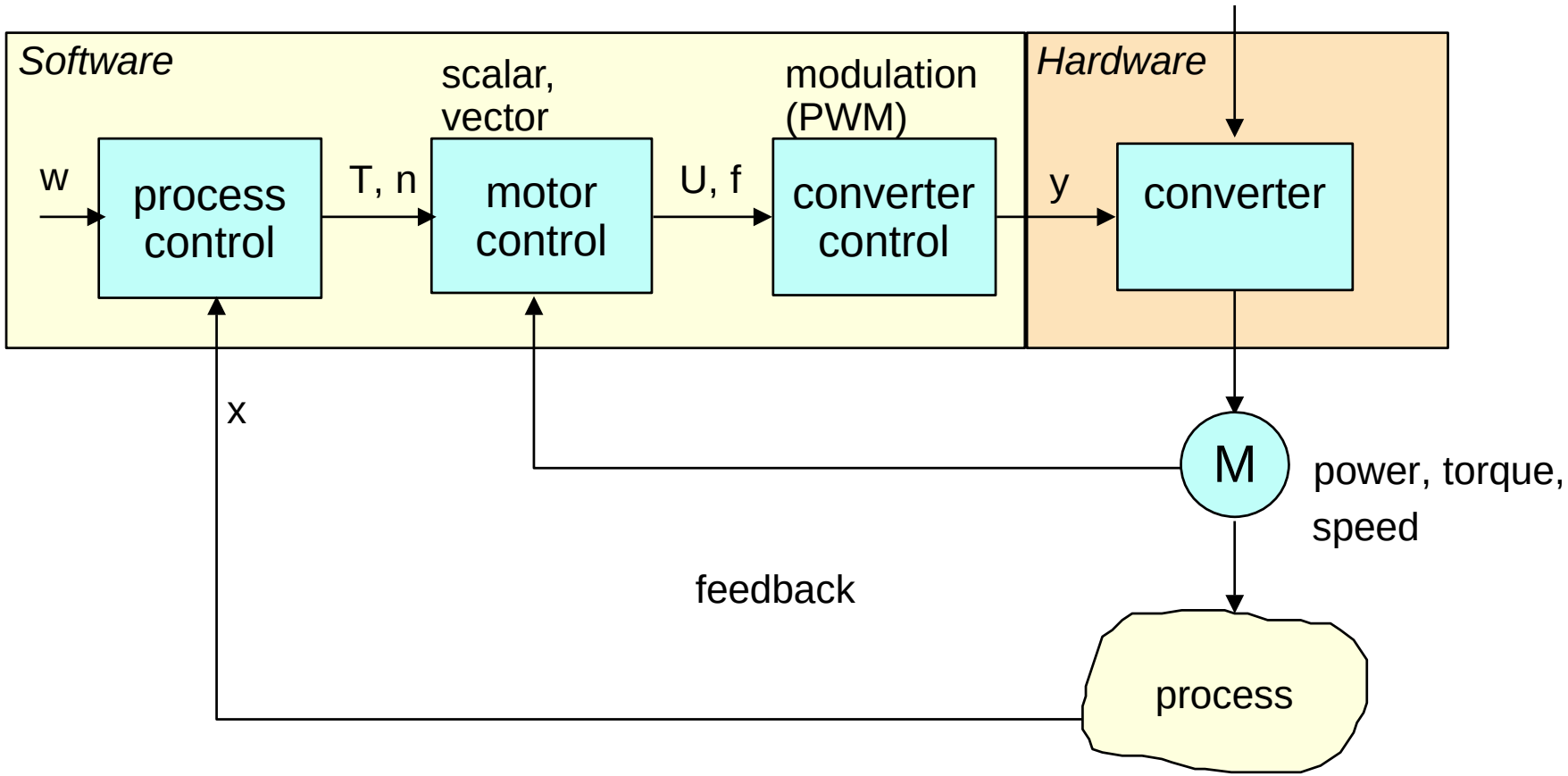

Control system with frequency converter

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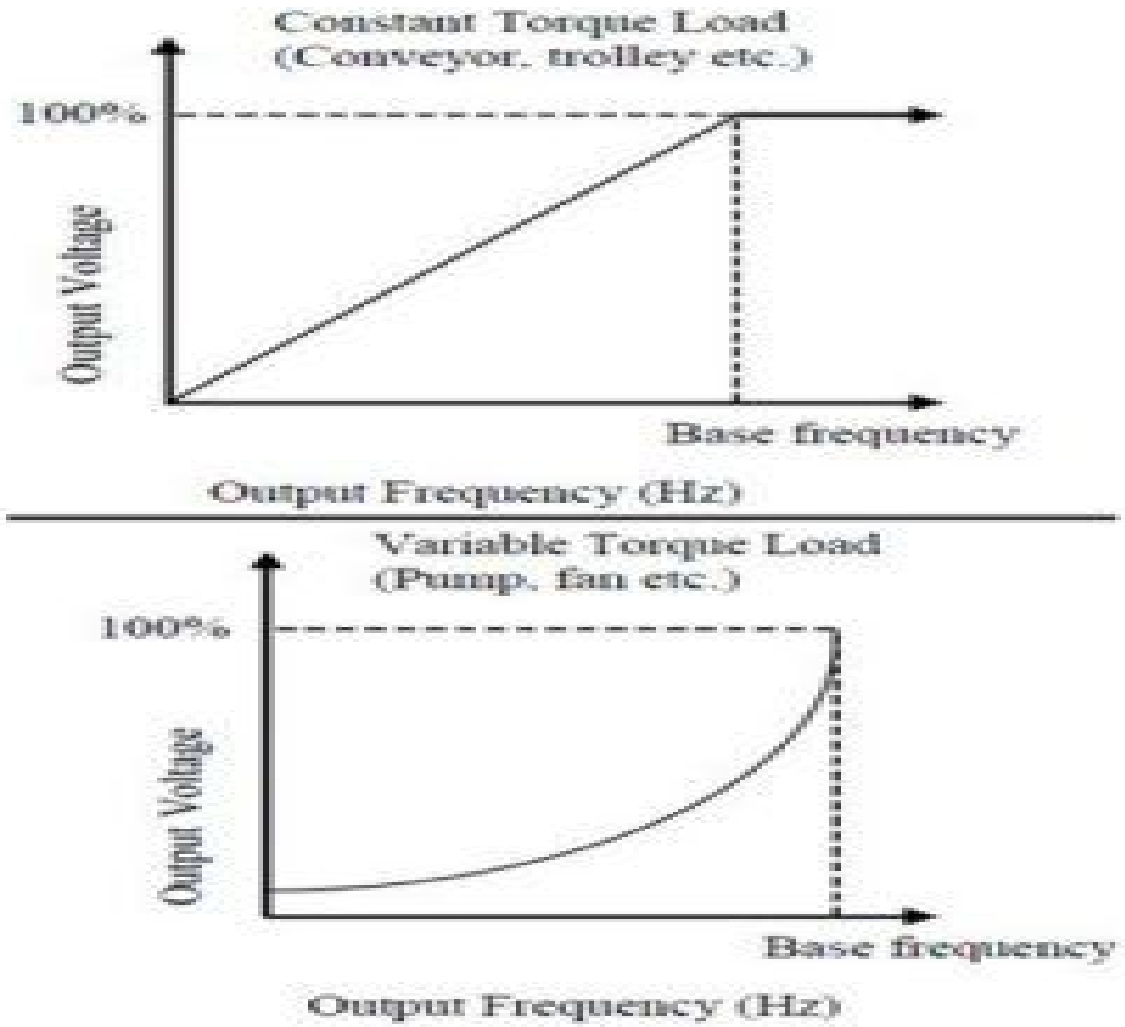
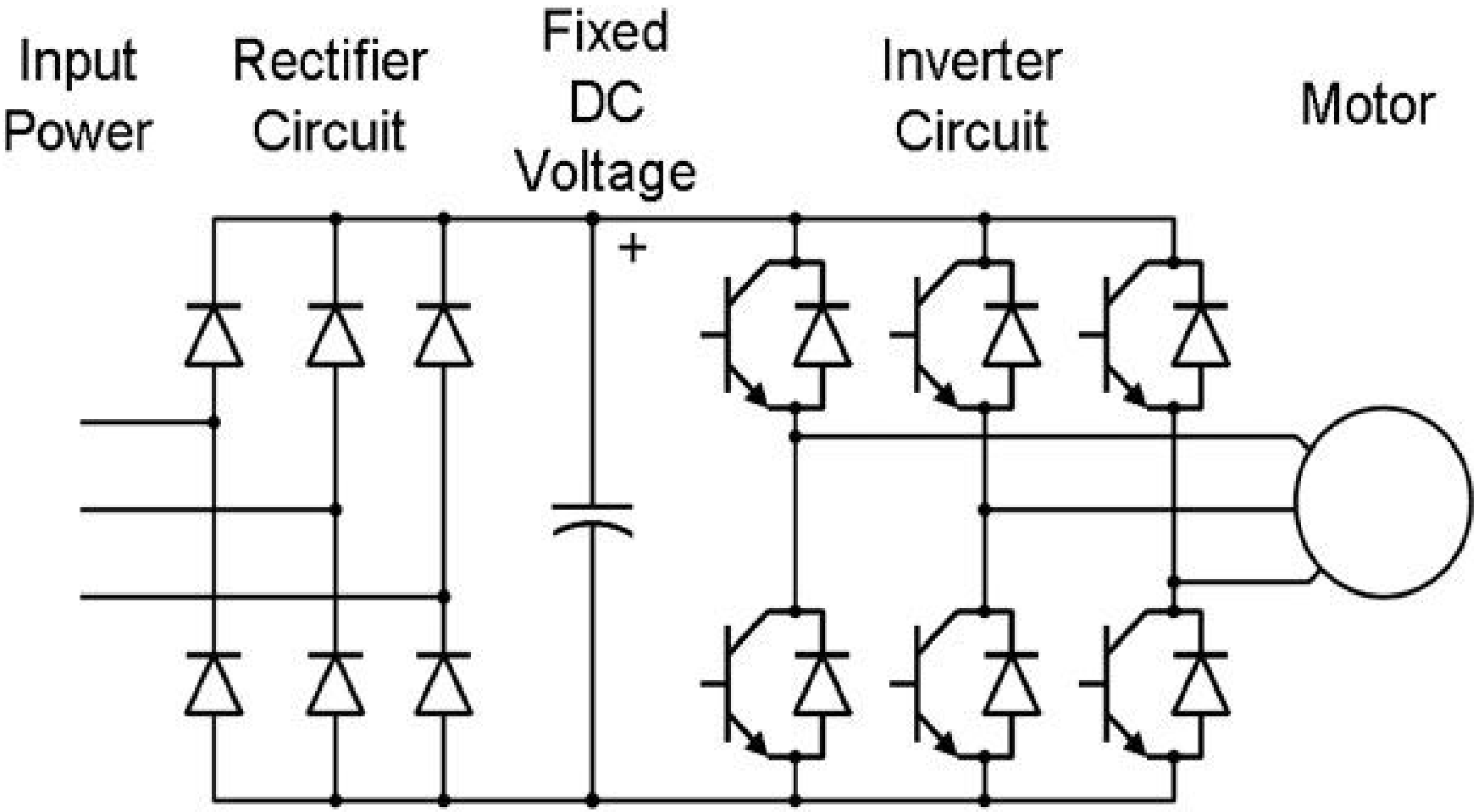
➢Variable Speed Drive

- Variable-frequency drives are also categorized by the following load torque and power characteristics:
- Variable torque, such as in centrifugal fan, pump, and blower applications
- Constant torque, such as in conveyor and positive-displacement pump applications
- Constant power, such as in machine tool and traction applications.

Load Torque- Examples



Variable Speed Drive Block Diagram



Principle of Operation-VFD

- The speed an AC induction motor is given by the following equation:

$$\text{Synchronous Speed} = \frac{120 \text{ X Frequency}}{\text{Number of Poles}}$$

Where:

- Frequency = Electrical frequency of power supply in Hz
- No. of Poles = Number of electrical poles in motor stator

➢ Principle of Operation-VFD..contd

- Motor speed can be changed by altering the frequency of the electrical supply:

  4 pole motor operating on 50 hertz = 1500 rpm.

  4 pole motor operating on 40 hertz = 1200 rpm

- By varying frequency, we can adjust the speed over a wide range or vary the speed precisely using precise changes in the electrical frequency input to the motor.
- Changing the electrical frequency would also require an adjustment to the terminal voltage in order to maintain the same amount of flux level in the machine core. If not the machine will experience

  (a) Core saturation (non linearity effects)

  (b) Excessive magnetization current

➢Principle of Operation..contd

- VSD's actually control both frequency and voltage simultaneously to maintain a constant volts/hertz ratio which keeps current flow similar to full speed conditions
- This allows the motor to draw full current at any speed and produce full torque as motor speed changes.
- What happens to the Horsepower when we lower the speed and torque using frequency?

$$\text{Horse Power} = \frac{\text{Speed (in RPM) x Torque (in pound/ feet)}}{5{,}252}$$

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Advantages

- Energy Savings.
- Improved Process Control.
- Reduced Starting Inrush currents.
- Lower System Maintenance.
- Multi-motor Control.

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Disadvantages

- Initial Cost.
- Motor Heating at Low Speed.
- Maintenance.
- Output Harmonics.
- Induced Power Lines Harmonics.

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Types of Variable Speed Drives

I. Voltage Source Inverter (VSI) Variable Frequency Drive

- The VSI is the oldest AC drive technology and was the first AC drive to gain acceptance in the industrial market.
- The VSI is sometimes called a “six-step drive” due to the shape of the voltage waveform it sends to the motor.
- VSI drives are fairly economical between 25 and 150 horsepower for ranges of speed reduction from 15 to 100% (about 10 to 60 Hertz).
- These drives are also used widely on specialty high speed applications (400 to 3000 Hertz).

Advantages:

- Good Speed Range.
- Multiple motor control from one unit.
- Simple Control Regulator.

Disadvantages:

- Power Factor decreases with decreasing speed.
- Low Speed Motor Cogging (shaft pulsing/jerky motion)

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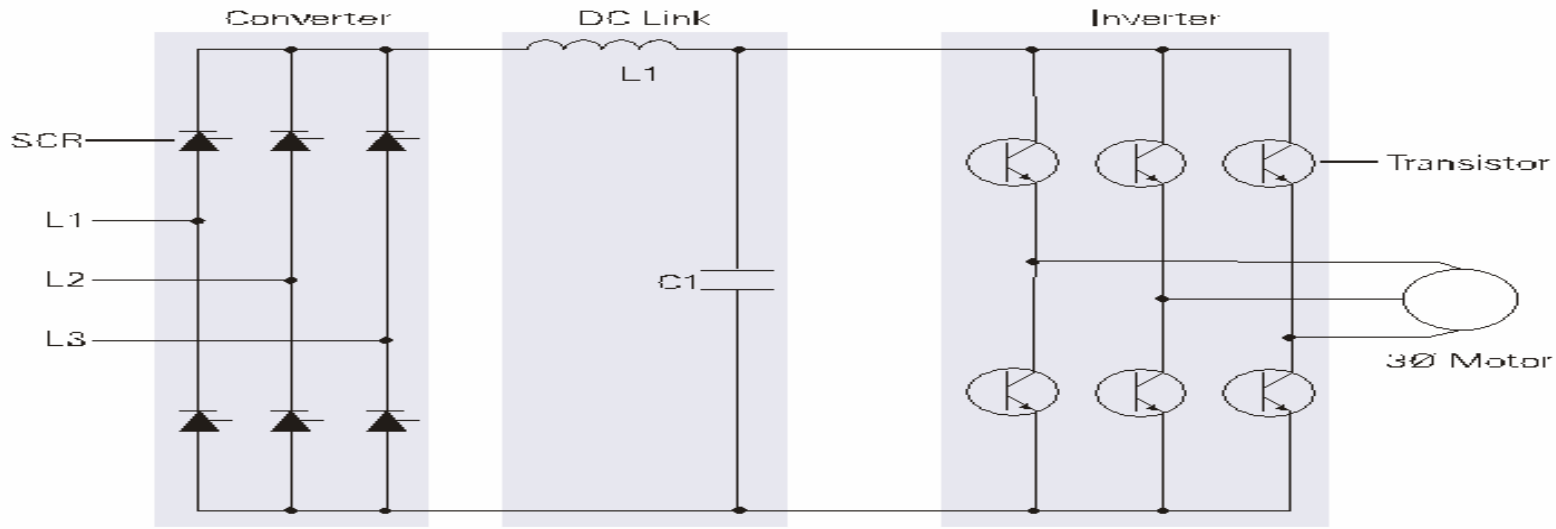

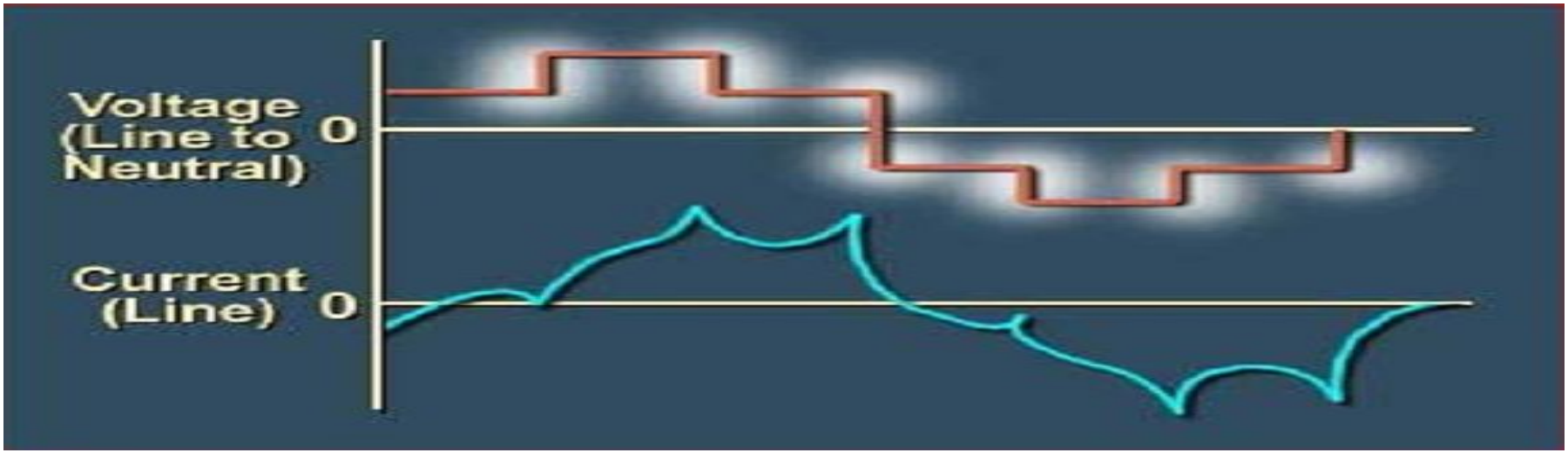

MOTORS AND DRIVES

➢ II. Current Source Inverter (CSI) Variable Frequency Drive

- The CSI is very similar to the VSI except that it is more sensitive to current as opposed to a VVI drive which is more sensitive to voltage.
- CSI drives are usually lower cost above 50 horsepower than VSI drives for pumps and fan applications
- Current Source Inverter also called current-fed inverters, behave like a constant current generator, producing an almost square-wave of current.
- Current-source inverters are used instead of variable source inverters for large VFDs about 200 horsepower because of their simplicity, reliability and lower cost.

MOTORS AND DRIVES

Advantages:-

- High Efficiency
- Inherent Short Circuit Protection

Disadvantage:-

- Power Factor decreases with decreasing speed.
- Low Speed Motor Cogging (shaftpulsing/jerky motion)
- Cannot test drive without motor connected.
- Requires Isolation Transformer on Input Side.
- Large physical size of Drive due to internal power components

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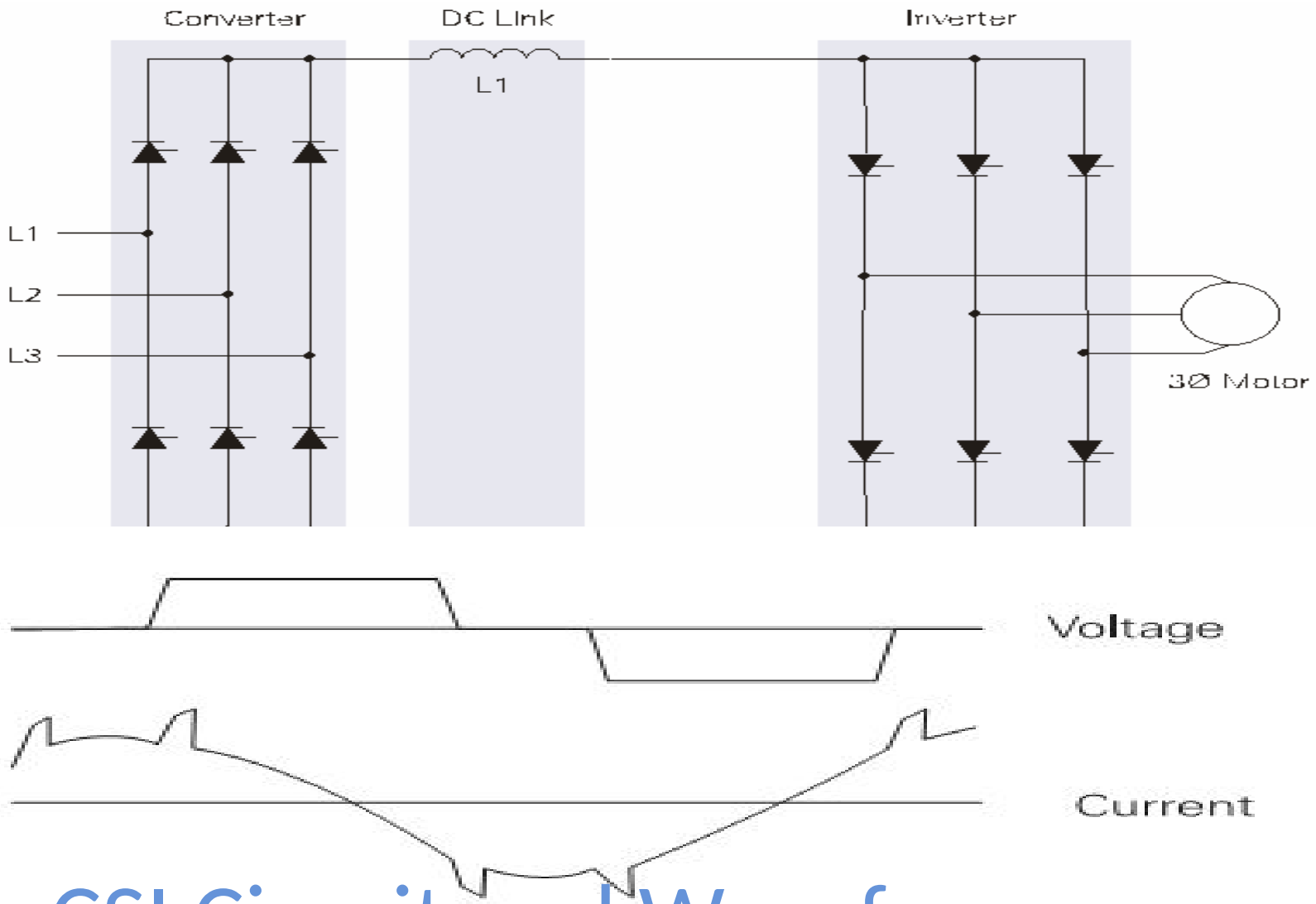


CSI Circuit and Waveforms

III. Pulse Width Modulation (PWM) Variable Frequency Drive

- These drives are the newest technology and use sophisticated power electronics to accomplish the same frequency and voltage control.
- They provide good efficiency with very little motor heating associated with the other types of drives.
- Pulse Width Modulated or PWM drives provide the best output current to operate the motor and are becoming very popular for adjustable speed applications.

MOTORS AND DRIVES

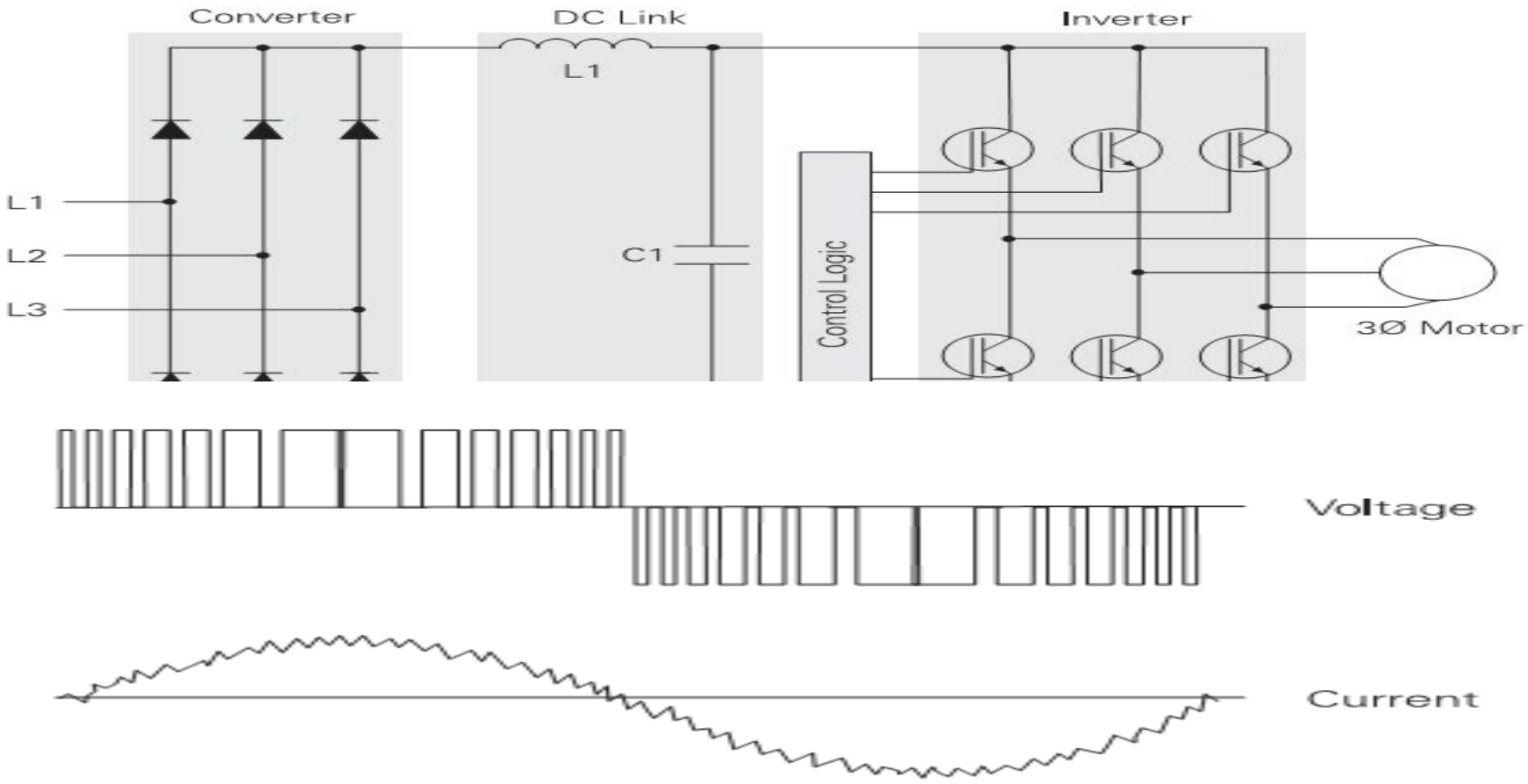
Advantages

- High Efficiency.
- Wide controllable speed range.
- Constant Power Factor regardless of speed.
- Multi motor operation from one drive.
- No cogging problems.
- Competitive Price

Disadvantages

- Extra Hardware required for line regenerative capability.
- Complexity of equipment is high compared to VVI and CSI.
- Some PWM drives produce significant audible noise.

MOTORS AND DRIVES



PWM Circuit & Waveforms

THANK YOU