

# Variable Frequency Drives



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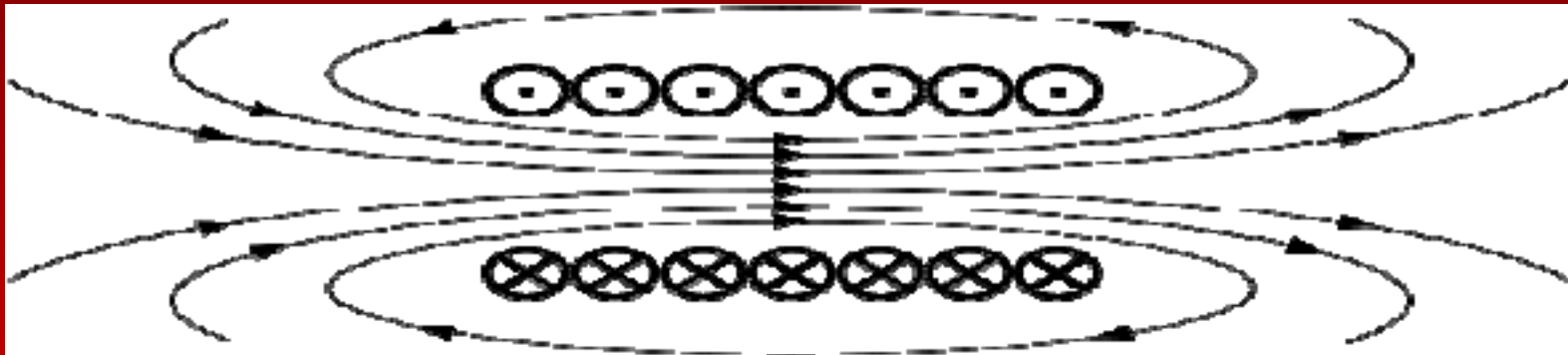
# Introduction

- Variable Frequency Drives are devices which control the speed of alternating current(AC) electric motors by controlling the frequency of the supply voltage of the motor.
- Motor-driven systems are designed to handle peak loads. If the system is running at a reduced load for some period of time, it will lead to energy inefficiency.
- With Variable frequency drives and the ability to adjust the speed of the motor, enables you to match the motor output to load requirement thus resulting in energy savings.

# AC Motor Theory-Background

- AC Motors Convert Electric Energy into Mechanical Energy
  - When a conductor moves across a magnetic field a voltage is induced
  - When the conductor is part of a closed circuit there will be a current induced
  - In a motor, the induction principle is utilized in reverse
    - A live conductor is placed in a magnetic field
    - The conductor is influenced by a force which moves it through the magnetic field

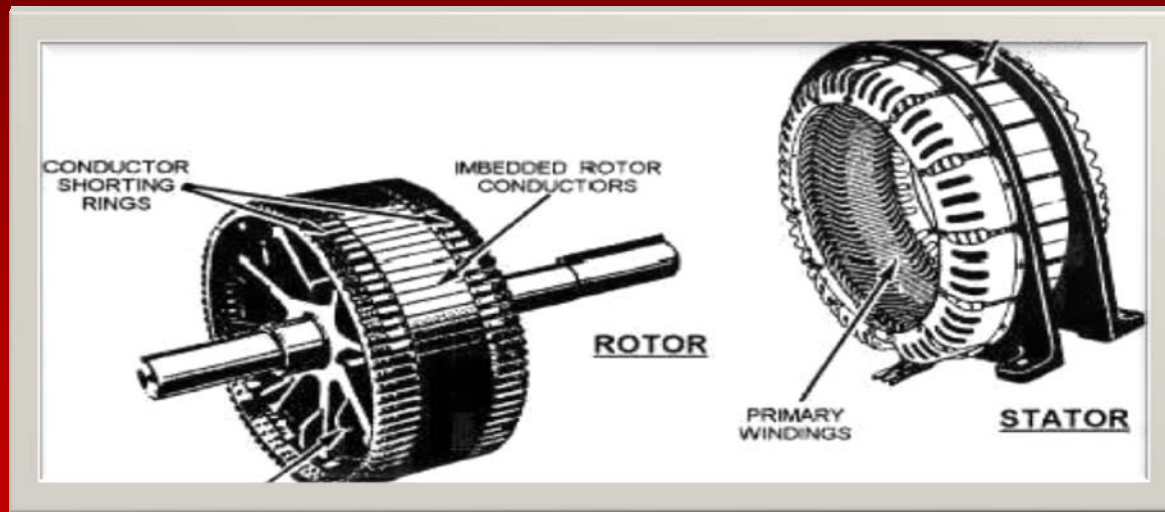
# AC Motor Theory-Background



# AC Motor Theory-Background

- AC Motors Convert Electric Energy into Mechanical Energy
  - The AC motor is made up of two parts
    - The Stator
      - The stationary section that contain the windings
    - The Rotor
      - The rotating section that contains the conductors

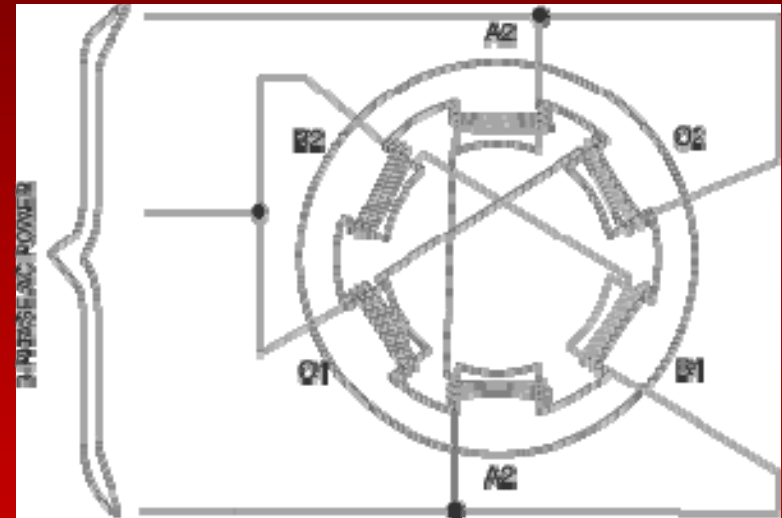
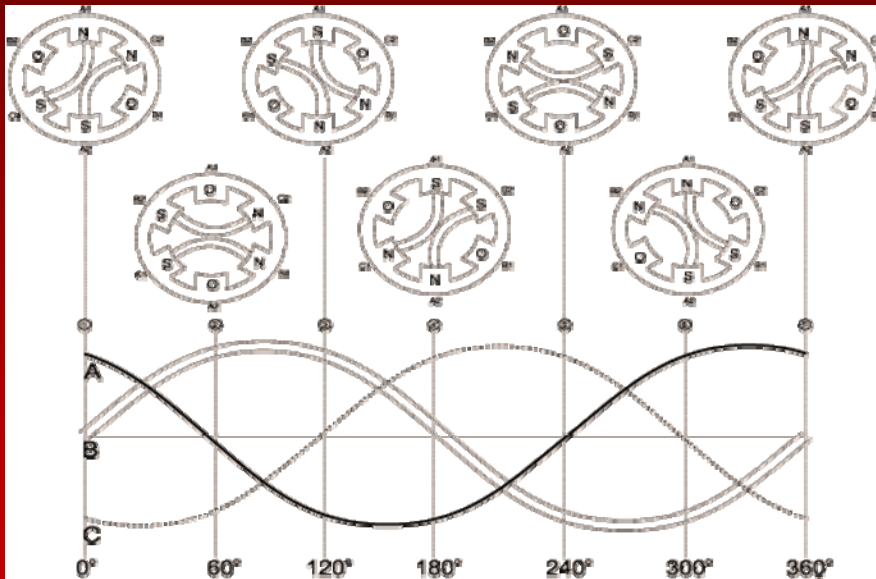
# AC Motor Theory-Background



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- AC Motors Convert Electric Energy into Mechanical Energy
  - The Magnetic Field:
    - Rotates in the air gap between the stator and the rotor
    - Has a fixed location in the stator core which continuously varies in location
    - When three phases are introduced in the motor three magnetic fields are introduced
      - 120 degrees apart
      - Poles of opposite polarity are formed

# AC Motor Theory-Background



# AC Motor Theory-Background

- The speed of an Induction motor rotates at a fixed speed and is determined by the frequency of the supply voltage. Alternating current applied to the stator windings produce a magnetic field which rotates at synchronous speed.
  - Synchronous speed =  $120 \times \text{supply frequency (Hz)} / \text{number of poles}$ 
    - Example: A four-pole motor, for example, has two pole pairs, and therefore the magnetic field will rotate  $120 \times 60 \text{ Hz} / 4 = 1800 \text{ rpm}$ .

# AC Motor Theory-Background

- Usually the rotor speed tries to follow the rotating magnetic field however under load the rotor speed slips slightly behind the rotating field. This generates an induced current, and the resulting magnetic field in the rotor produces excess torque.
  - Note: The size of the slip varies depending on the motor design and varies with load on the motor (slip is the difference between the rotor speed and the rotating magnetic field).
- Taking the slip factor into consideration with the fixed speed of the motor, the actual speed of the motor would be:
  - $\text{speed} = 120 \times \text{supply frequency (Hz)} / \text{number of poles} - \text{slip}$

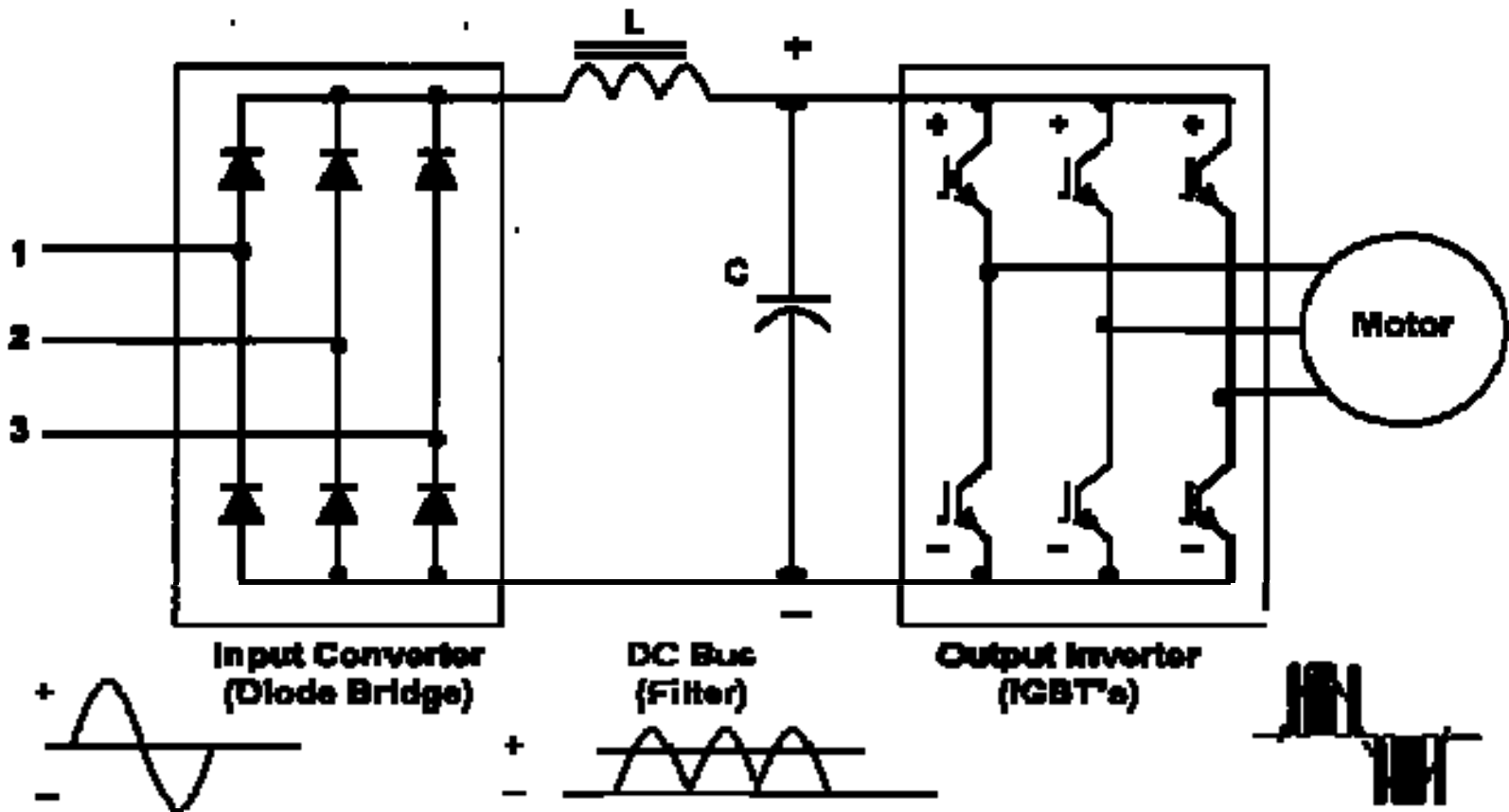
# Solution to excessive Torque?

- By changing the speed of the motor, would solve the problem to excessive torque.
- Therefore 'slip' can be controlled through the motor voltage since the motor torque is affected through its voltage
- Since AC motors are designed for a certain voltage and frequency ratio, changing the voltage alone would cause improper magnetization and increase losses and motor heat
- This means we would have to change the speed of the motor by adjusting the frequency applied to the motor. You could adjust the frequency and hence the speed by changing the number of poles, however this is a physical change to the motor. This requires rewinding, and results in a step change to the speed. This method would be very imprecise, costly and inefficient.
- Therefore other methods of changing the speed via frequency must be considered.

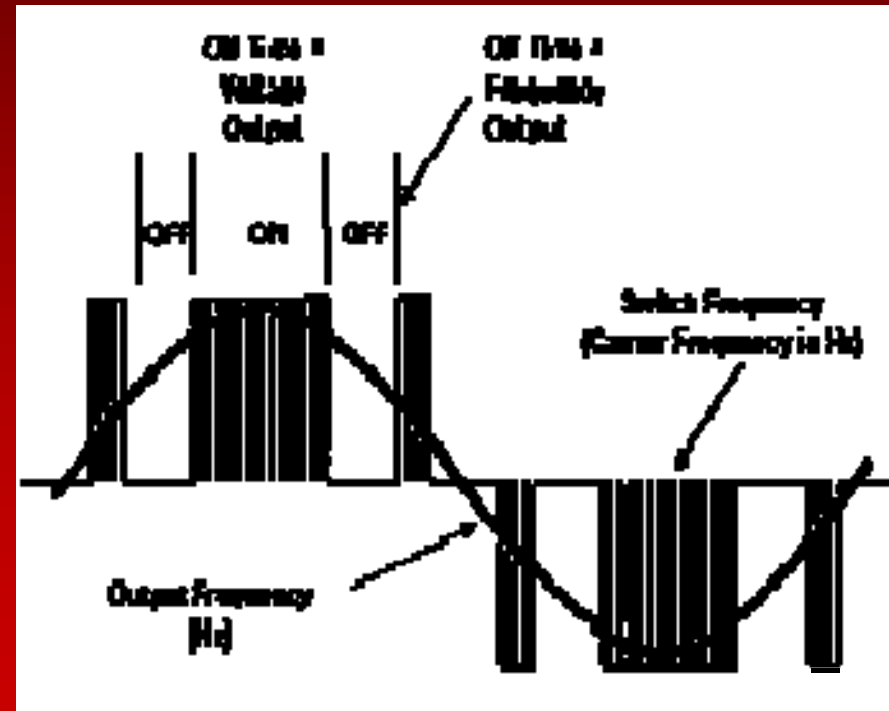
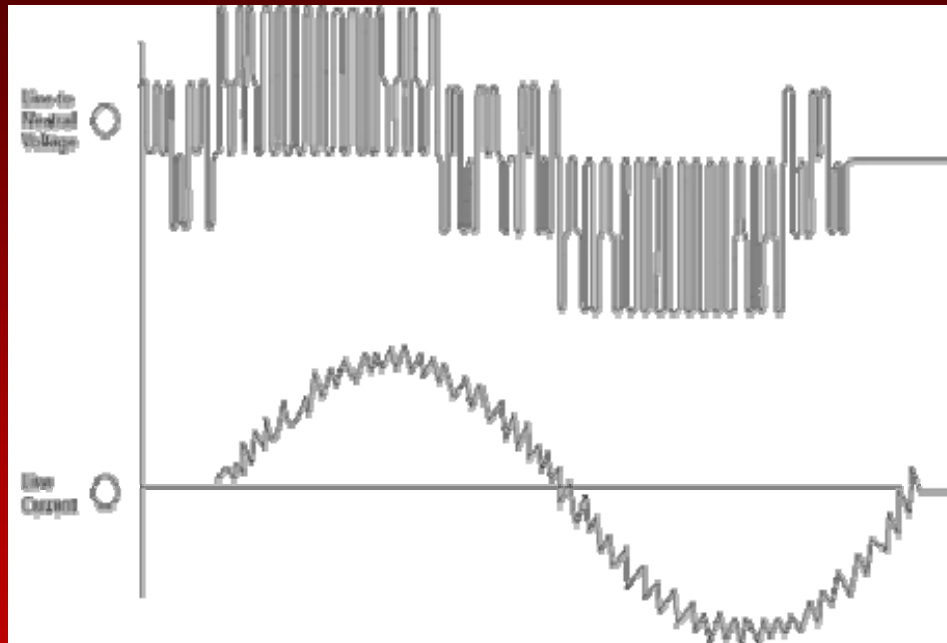
# VFD-Background

- VFDs convert the fixed-frequency supply voltage to a continuously variable frequency, allowing adjustable motor speed and less stress on the motor.
- A VFD can control two main elements of a 3-phase induction motor: speed and torque.

# VFD-Drive Components



# VFD-Output



# VFD-Background

- The speed at which power devices switch on and off is the carrier frequency, also known as the switch frequency. The higher the switch frequency, the more resolution each PWM pulse contains.
- The trend is similar to that of the personal computer. More features, better performance, and lower cost with successive generations. Unlike computers, however, drives have dramatically improved in their reliability and ease of use.
- Drives are increasingly becoming "plug and play."

# Applications

- Variable speed drives are used for two main reasons:
  - Improves the efficiency of motor-driven equipment, matching speed to changing load requirements.
  - To allow accurate and continuous process control over a wide range of speeds.

# Why use a blower with VFD?

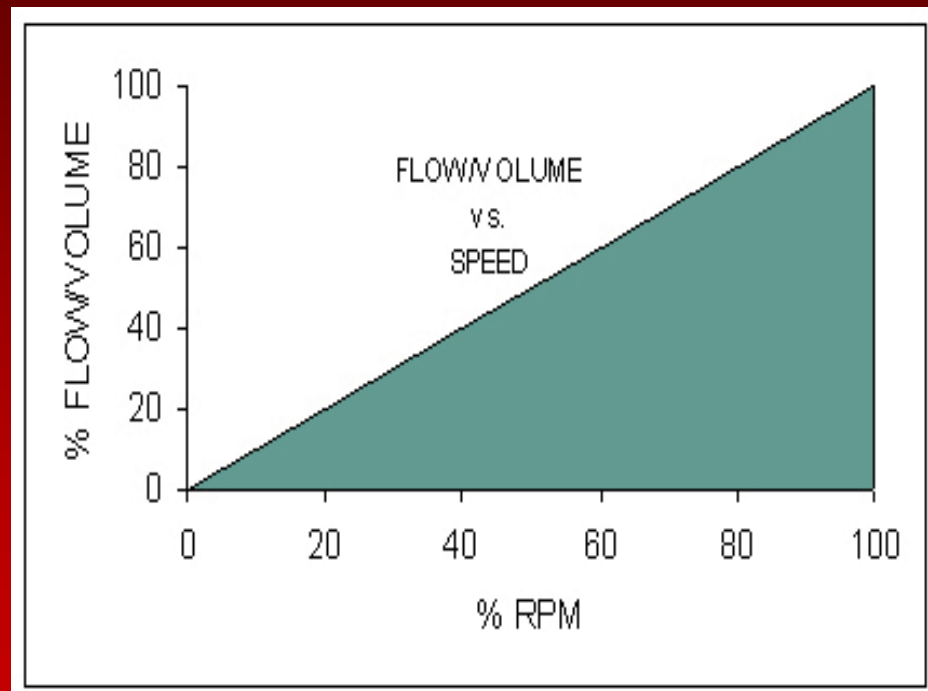
- Motor-driven centrifugal pumps, fans and blowers offer the most dramatic energy-saving opportunities.
- Blowers operate for extended periods at a reduced load.
- Since they are not always operating at their full load the amount of energy you can save by reducing the current to them as well as the amount of stress release on your motor is enormous and results in an energy efficient and longer lasting system.



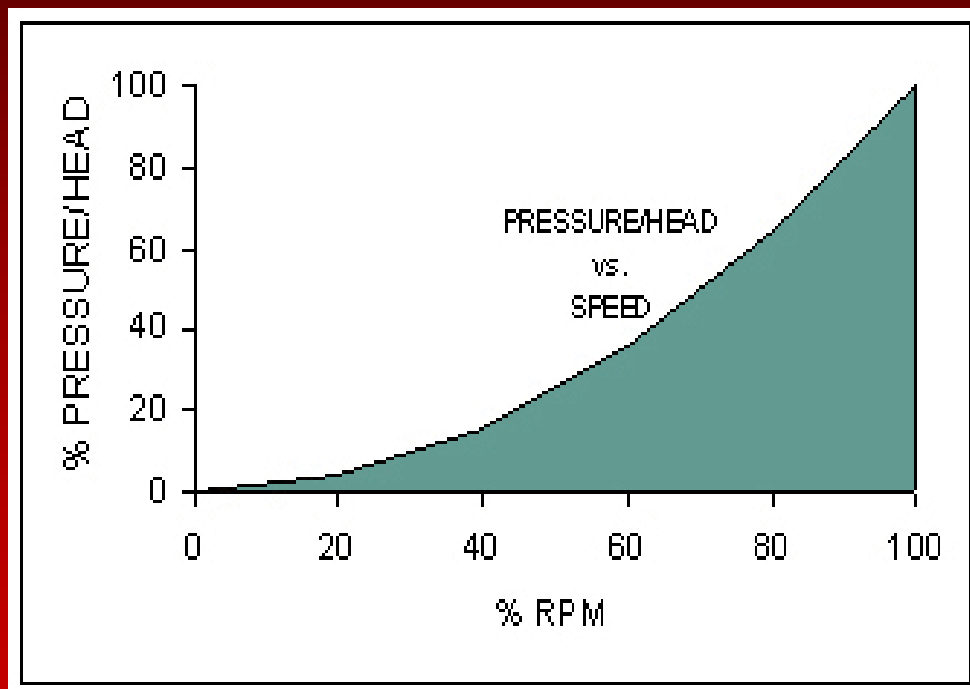
# Blower Background

- Blower affinity laws govern the relationship among speed, flow and input power. The laws state:
  - Flow is proportional to speed
  - Pressure increases with the square of speed
  - Power Increases with the cube of speed
- When speed is reduced to 75 percent of design speed, flow decreases to 75 percent, outlet pressure decreases to 56 percent, and the input power requirement drops to 42 percent of full-speed values.
- Even small reductions in speed and flow can result in significant energy savings.

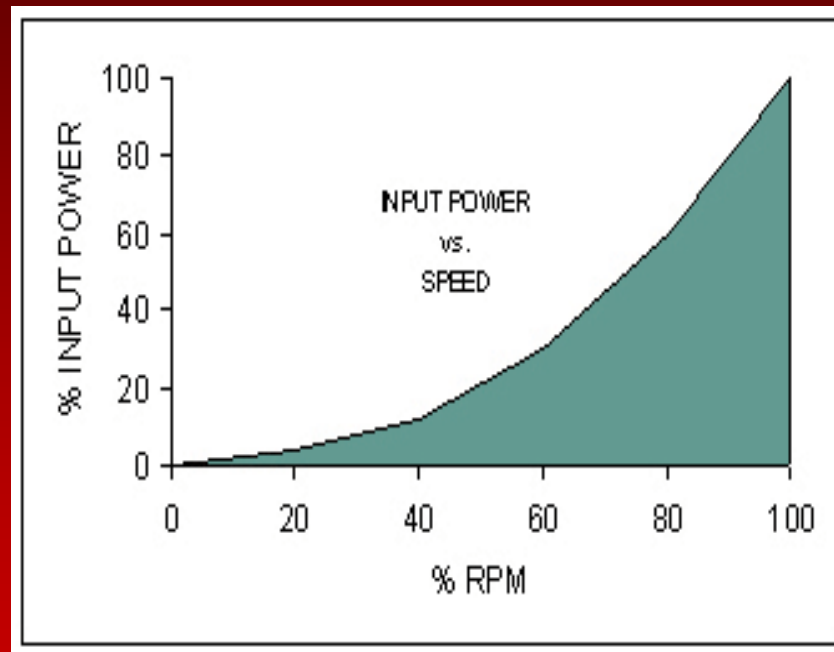
# Blower Background



# Blower Background



# Blower Background



# Other Benefits of VFDs:

- Control:
  - A VFD may be used for control of process temperature, pressure or flow without the use of a separate controller. Suitable sensors and electronics are used to interface the driven equipment with the VFD.
- Maintenance:
  - Maintenance costs can be lower, since lower operating speeds result in longer life for bearings and motors.

# Other Benefits of VFDs:

- Equipment:
  - Eliminating the throttling valves and dampers also does away with maintaining these devices and all associated controls.
  - A soft starter for the motor is no longer required.
- Protection:
  - The ability of a VFD to limit torque to a user-selected level can protect driven equipment that cannot tolerate excessive torque