ELECTRIC DRIVES

K.S.JHA
CI/Electrical

"Nearly 65% of the total electric energy produced in the developed country is consumed by electric motors."

- System efficiency can be increased from 15% to 27% by introducing variable-speed drive operation in place of constant-speed operation.

- **Motion control is required in large number of industrial and domestic applications**
- **Systems employed for motion control are called DRIVES.**
- **Drives employing electric motors**

  are known as ELECTRICAL DRIVES.

- An ELECTRIC DRIVE can be defined as an electromechanical device for converting electrical energy into mechanical energy to impart motion to different machines and mechanisms for various kinds of process control.

Classification of Electric Drives

According to Mode of Operation

- Continuous duty drives
- Short time duty drives
- Intermittent duty drives

According to Means of Control

- Manual
- Semi automatic
- Automatic

According to Number of machines

- Individual drive
- Group drive
- Multi-motor drive

According to Methods of Speed Control

- Reversible and non-reversible uncontrolled constant speed.
- Reversible and non-reversible step speed control.
- Variable position control.
- Reversible and non-reversible smooth speed control.

Advantages of Electrical Drive

1. They have flexible control characteristics. The steady state and dynamic characteristics of electric drives can be shaped to satisfy the load requirements.
2. Drives can be provided with automatic fault detection systems. Programmable logic controller and computers can be employed to automatically control the drive operations in a desired sequence.
3. They are available in wide range of torque, speed and power.
4. They are adaptable to almost any operating conditions such as explosive and radioactive environments
5. It can operate in all the four quadrants of speed-torque plane
6. They can be started instantly and can immediately be fully loaded
7. Control gear requirement for speed control, starting and braking is usually simple and easy to operate.

"An Electric Drive is a system that converts electrical energy to mechanical energy"

Main Parts:

-- Electric Motor

-- Control System

Fixed speeds of electric motors

- Alternating-current electric motors run at speeds closely determined by the number of poles in the motor and the frequency of the alternating current supply. (N=120 f/p)
- AC motors can be made with several sets of poles, which can be chosen to give one of several different speeds (say, 750/1000 RPM for a 50 Hz motor)

Electrical Drives

Drives are systems employed for **motion control**

Require **prime movers**

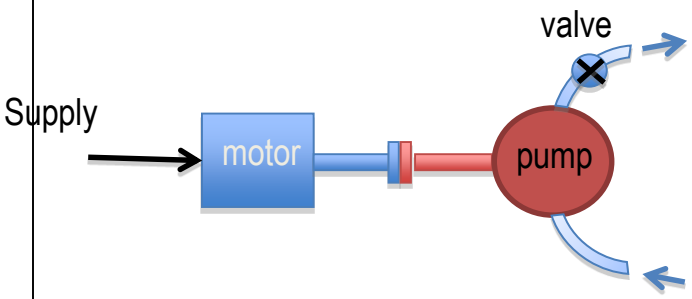
Drives that employ **electric motors** as prime movers are known as Electrical Drives

Electrical Drives

- About 50% of electrical energy used for drives
- Can be either used for fixed speed or variable speed
  - 75% - constant speed, 25% variable speed (expanding)

Example on VSD application

Constant speed



Power In

Power out

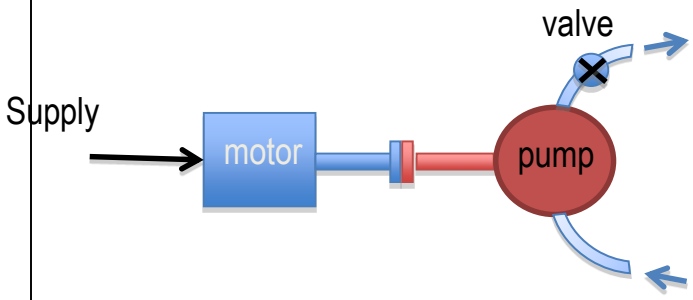
Power loss

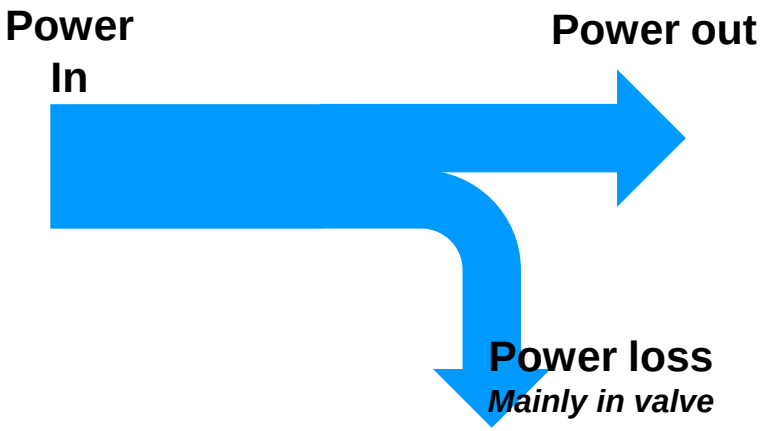
Mainly in valve

Variable Speed Drives

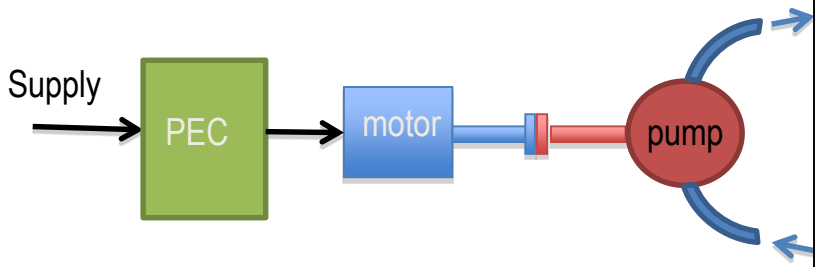
Example on VSD application

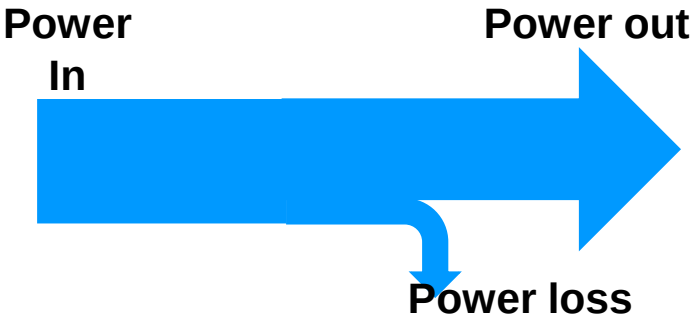
Constant speed





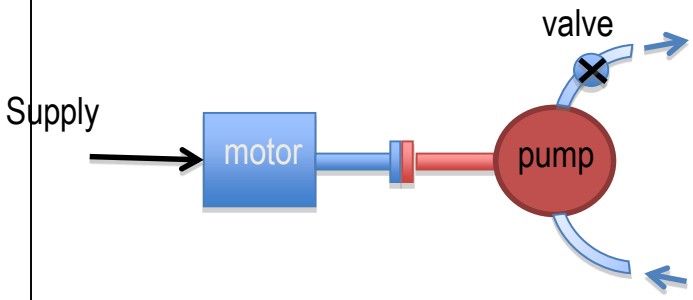
Variable Speed Drives

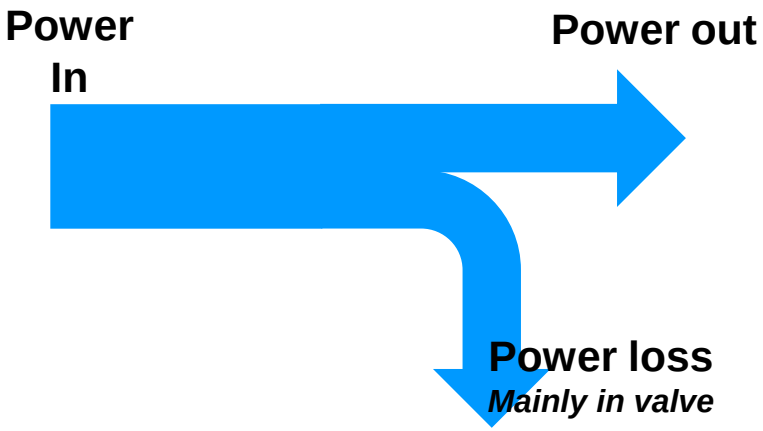




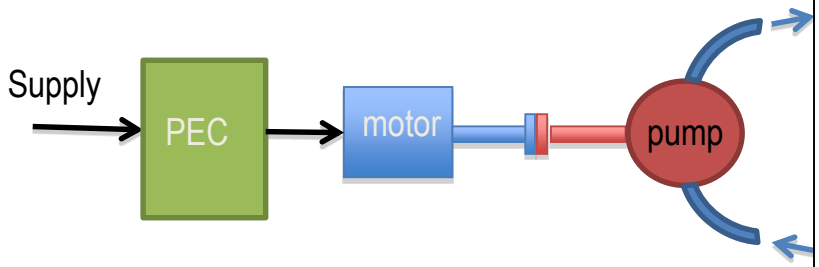
Example on VSD application

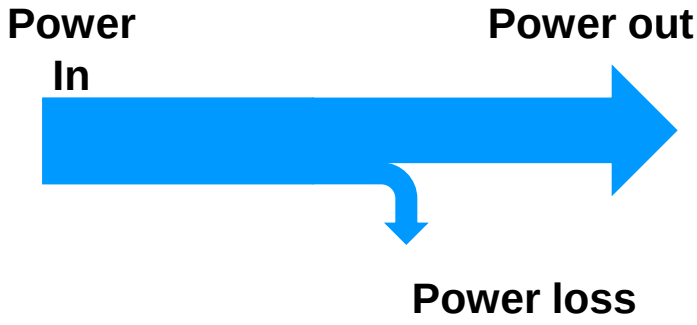
Constant speed





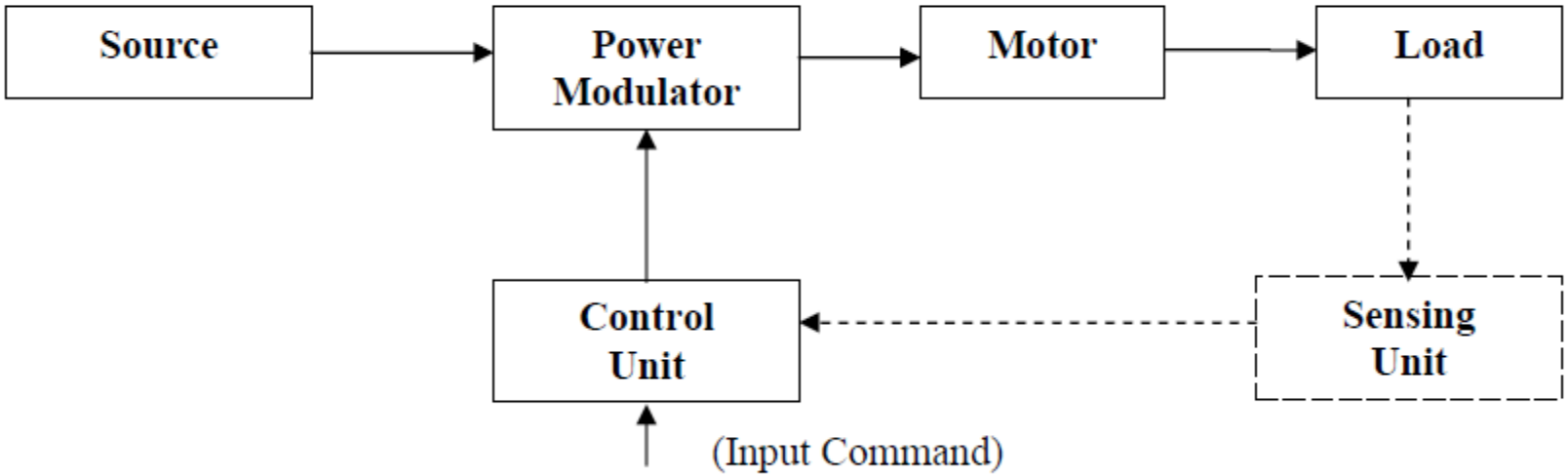
Variable Speed Drives





General Electric Drive System

Block diagram of an electric drive system is shown in the figure below.



A modern variable speed electrical drive system has the following components:

- Electrical machines and loads
- Power Modulator
- Sources
- Control unit
- Sensing unit

Electrical Machines

Most commonly used electrical machines for speed control applications are the following

DC Machines

Shunt, series, compound, separately excited DC motors and switched reluctance machines.

AC Machines

Induction, wound rotor, synchronous, PM synchronous and synchronous reluctance machines.

Special Machines

Brush less DC motors, stepper motors, switched reluctance motors are used.

Power Modulators

Functions:

Modulates flow of power from the source to the motor in such a manner that motor is imparted speed-torque characteristics required by the load

During transient operation, such as starting, braking and speed reversal, it restricts source and motor currents with in permissible limits.

It converts electrical energy of the source in the form of suitable to the motor Selects the mode of operation of the motor (i.e.) Motoring and Braking.

Types of Power Modulators

In the electric drive system, the power modulators can be any one of the following

- Controlled rectifiers (ac to dc converters)
- Inverters (dc to ac converters)
- AC voltage controllers (AC to AC converters)
- DC choppers (DC to DC converters)
- Cyclo converters (Frequency conversion)

Electrical Sources

Very low power drives are generally fed from single phase sources. Rest of the drives is powered from a 3 phase source. Low and medium power motors are fed from a 400v supply.

For higher ratings, motors may be rated at 3.3KV, 6.6KV and 11 KV. Some drives are powered from battery.

Sensing Unit

Speed Sensing (From Motor)

Torque Sensing

Position Sensing

Current sensing and Voltage Sensing from Lines or from motor terminals

From Load

Torque sensing

Temperature Sensing

Control Unit

Control unit for a power modulator are provided in the control unit. It matches the motor and power converter to meet the load requirements.

Classification of Electrical Drives

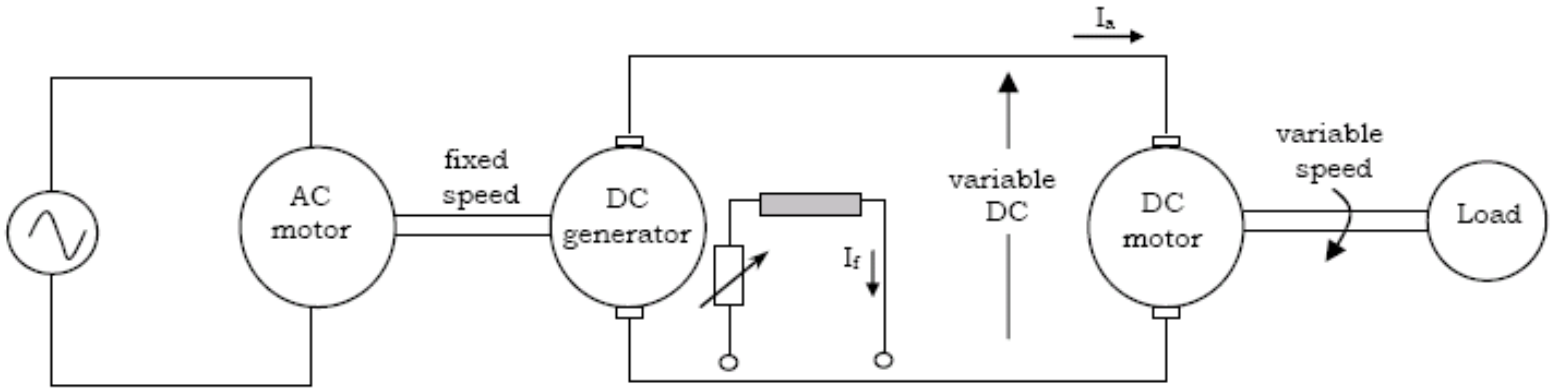
Another main classification of electric drive is

- ✓ DC drive
- ✓ AC drive

Comparison between DC and AC drives

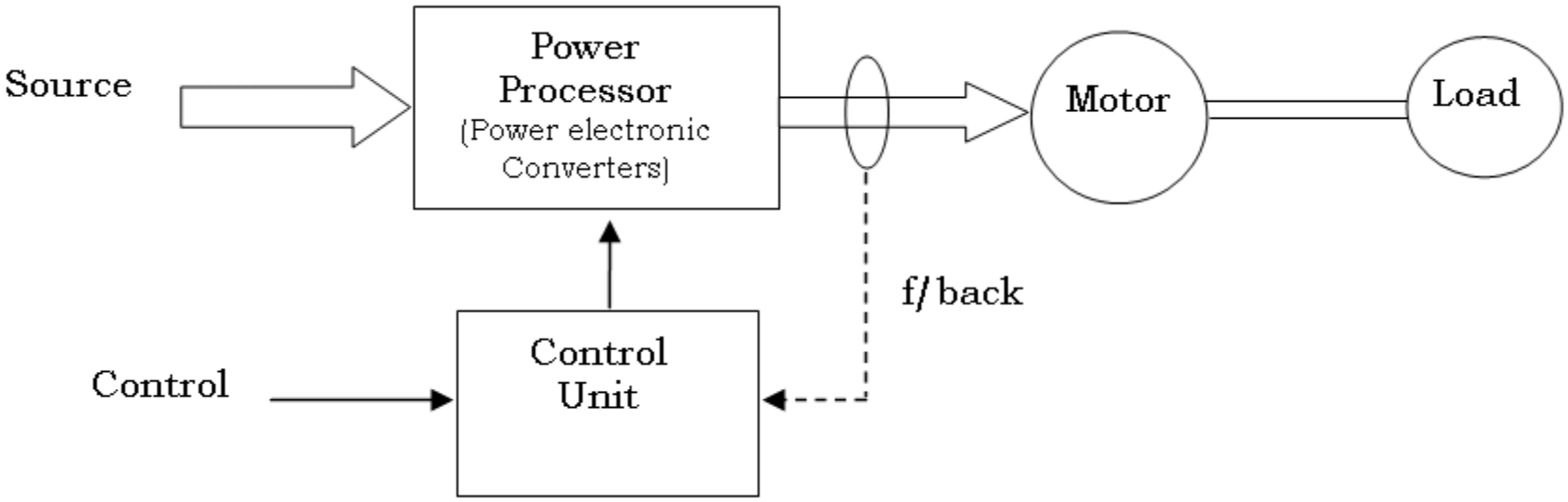
DC DRIVES	AC DRIVES
The power circuit and control circuit is simple and inexpensive	The power circuit and control circuit are complex
It requires frequent maintenance	Less Maintenance
The commutator makes the motor bulky, costly and heavy	These problems are not there in these motors and are inexpensive, particularly squirrel cage induction motors
Fast response and wide speed range of control, can be achieved smoothly by conventional and solid state control	In solid state control the speed range is wide and conventional method is stepped and limited
Speed and design ratings are limited due to commutations	Speed and design ratings have upper limits

Conventional electric drives (variable speed)



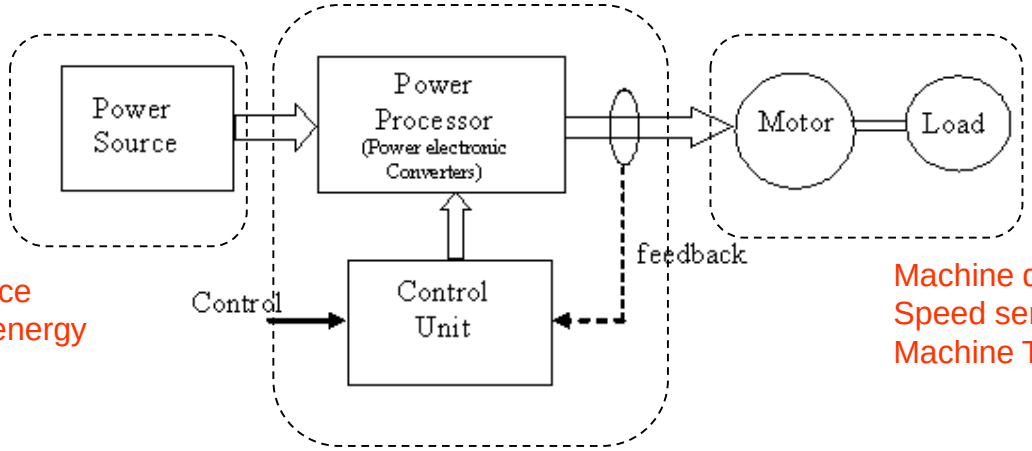
- Bulky
- Inefficient
- inflexible

Modern electric drives (With power electronic converters)



- Small
- Efficient
- Flexible

Modern electric drives



Utility interface
Renewable energy

Machine design
Speed sensorless
Machine Theory

Non-linear control
Real-time control
DSP application
PFC
Speed sensorless
Power electronic converters

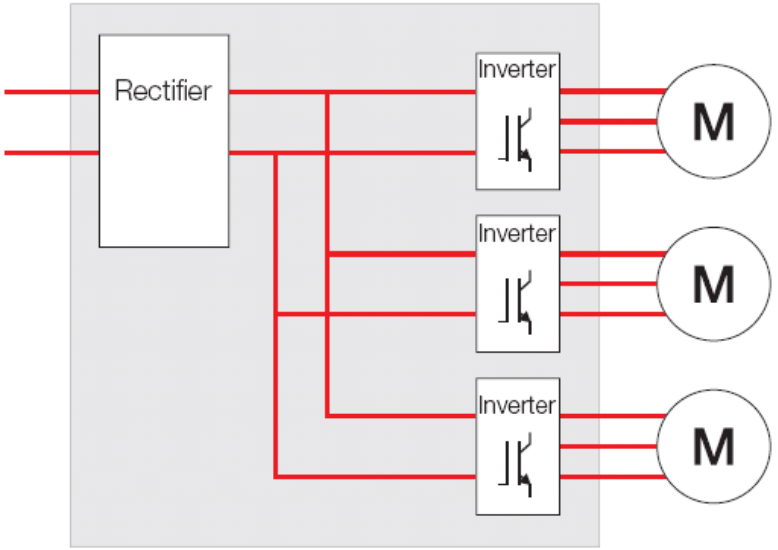
- Inter-disciplinary
- Several research area
- Expanding

Components in electric drives

e.g. Single drive - sensorless vector control from Hitachi

Components in electric drives

e.g. Multidrives system from ABB



Components in electric drives

Motors

- DC motors - permanent magnet – wound field
- AC motors – induction, synchronous (IPMSM, SMPSM), brushless DC
- Applications, cost, environment

Power sources

- DC – batteries, fuel cell, photovoltaic - unregulated
- AC – Single- three- phase utility, wind generator - unregulated

Power processor

- To provide a regulated power supply
- Combination of power electronic converters
    - More efficient
    - Flexible
    - Compact
    - AC-DC DC-DC DC-AC AC-AC

Components in electric drives

Control unit

- Complexity depends on performance requirement
- analog- noisy, inflexible, ideally has infinite bandwidth.
- digital – immune to noise, configurable, bandwidth is smaller than the analog controller’s
- DSP/microprocessor – flexible, lower bandwidth - DSPs perform faster operation than microprocessors (multiplication in single cycle), can perform complex estimations

Overview of AC and DC drives

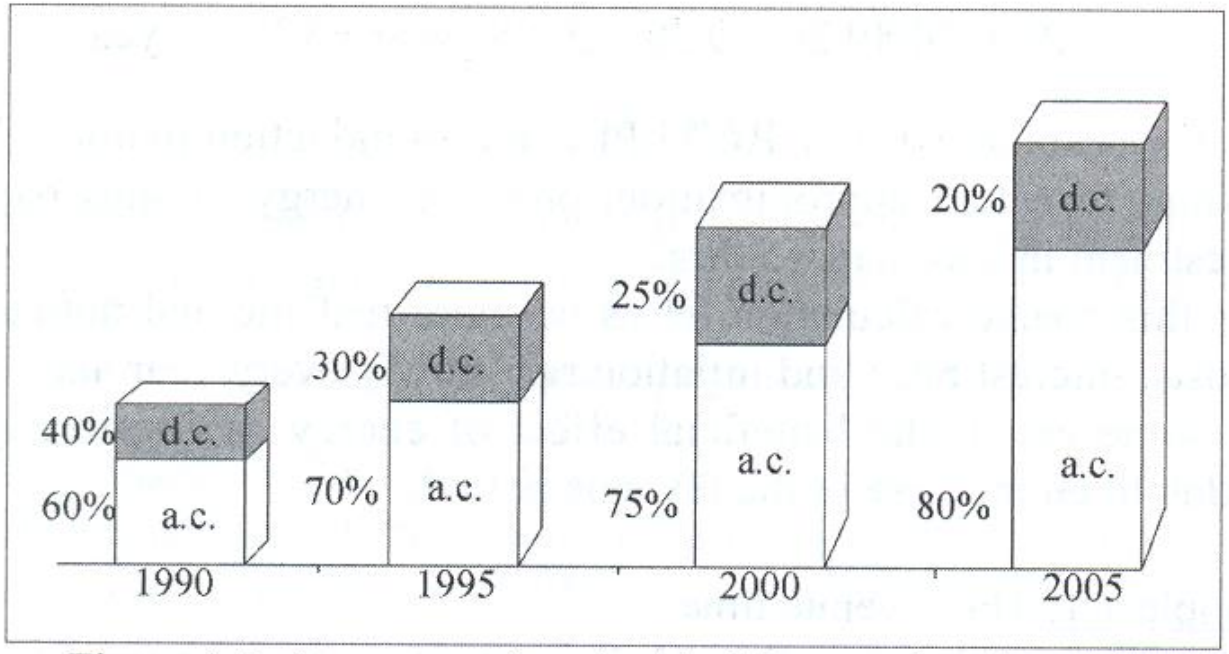


Figure 1.4. A.c. versus d.c. electric drives market dynamics

Extracted from *Boldea & Nasar*

Overview of AC and DC drives

DC motors: Regular maintenance, heavy, expensive, speed limit

Easy control, decouple control of torque and flux

AC motors: Less maintenance, light, less expensive, high speed

Coupling between torque and flux – variable spatial angle between rotor and stator flux

Overview of AC and DC drives

Before semiconductor devices were introduced (<1950)

- AC motors for fixed speed applications
- DC motors for variable speed applications

After semiconductor devices were introduced (1950s)

- Variable frequency sources available – AC motors in variable speed applications
    - Coupling between flux and torque control
    - Application limited to medium performance applications – fans, blowers, compressors – scalar control
- High performance applications dominated by DC motors – tractions, elevators, servos, etc

Overview of AC and DC drives

After vector control drives were introduced (1980s)

- AC motors used in high performance applications – elevators, tractions, servos
- AC motors favorable than DC motors – however control is complex hence expensive

- Cost of microprocessor/semiconductors decreasing –predicted 30 years ago AC motors would take over DC motors