Electrical Drives 1

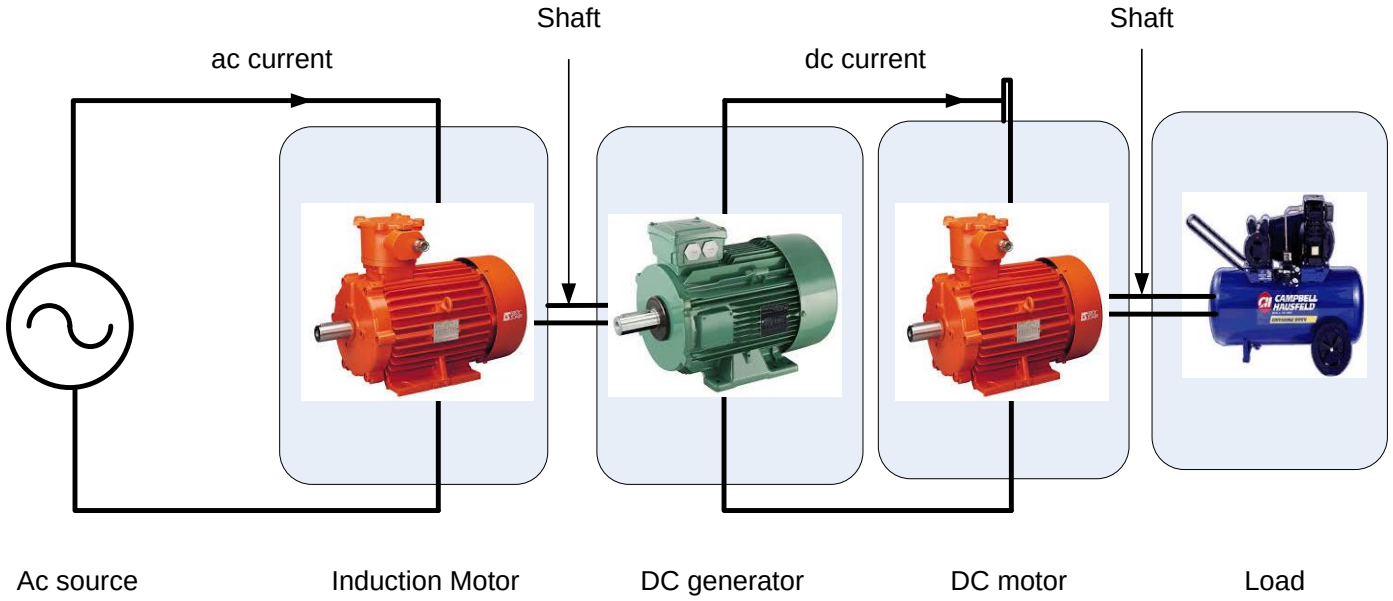
Week 1: Introduction to drive systems

What Do we mean by Electrical Drive System?

It is the study of the electric system involving controlling electric motors in both steady state and dynamic operation. It is achieved through taking into account the characteristics of the mechanical loads and the behavior of the power electronic converters.

The present:

- Use of a single converter for speed control
- Sophisticated design and control
- Built in options such as overcurrent protection (reduces size considerably)
- More precise applications such as position control



Multi machine system for speed control : Ward Leonard Method

In the PAST:

- 3 machines
- Motor-generator-motor set
- Expensive
- Inefficient
- Complex
- Requires frequent maintenance
- Has been a leading option for speed control in the first half of the 20th century
- Still exists in old elevators

Advantages of Electrical Drives

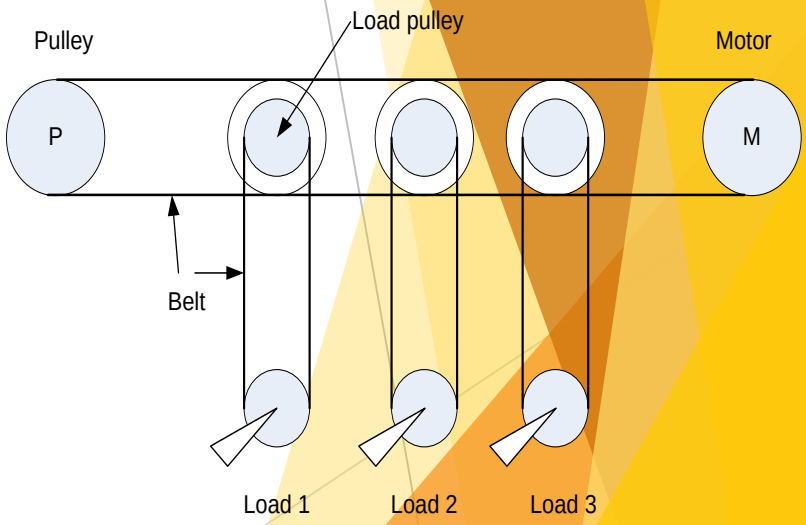
- Flexible control characteristic
  - particularly when power electronic converters are employed
- Wide range of speed, torque and power
- High efficiency – low no load losses
- Low noise
- Low maintenance requirements, cleaner operation
- Electric energy easily transported
- Adaptable to most operating conditions
- Available operation in all four torque-speed quadrants

Historical Background

- Power was provided in a “crude” way without considering the performance
- Advances in industrial manufacturing led to a need for more sophisticated drives which have existed in various forms

1. **Line shaft Drives:** The oldest type of drives. A single motor drives equipment through a common line shaft or belt. It is inflexible and inefficient as you can not change the speed of each load alone.
2. **Single motor single load drive:** most common drive. A single motor is dedicated to each load. Applications include hard disk drives, washers, dryers, fans.

single motor single load drive system



single motor multiple load drive system

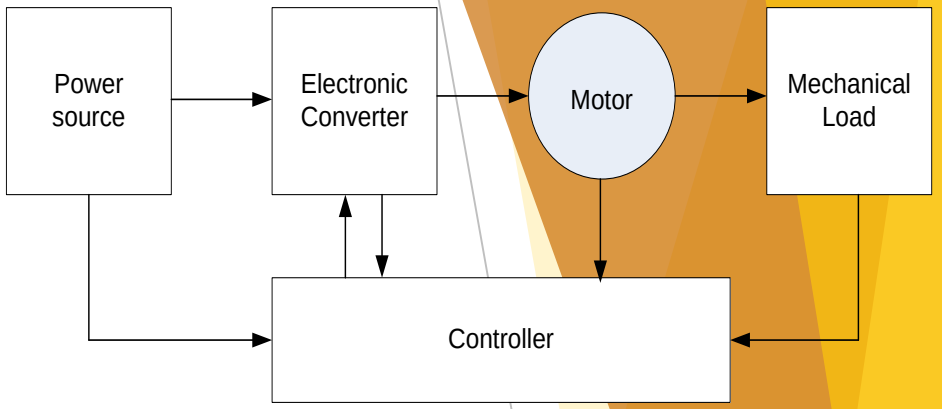
Historical Background (continue):

3. **Multi-motor drives:** several motors are used to drive a single mechanical load. This type is usually complex such as paper making machines, robotics, airplanes.

Multi-motor drive system

Basic Components of an Electrical drive system:

1. Power Source: Provides the energy to the drive system
2. Converter: interfaces the motor with the power source and provides the motor with adjustable voltage, current and/or frequency
3. Controller: supervises the operation of the whole system to ensure stability and enhance the overall performance
4. Mechanical load: Depends on the customer needs and the industrial process
5. Motor: selected according to the power level, environmental factors and performance required by the load. Ex: if load requires high starting torque so dc series motor is better than induction



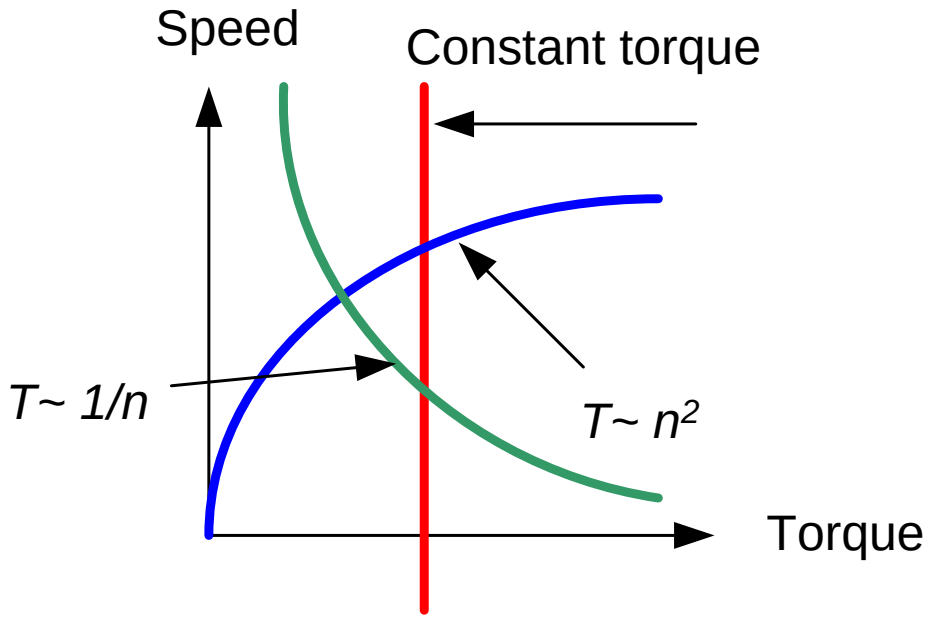
Block diagram of electric drive system

Mechanical Loads:

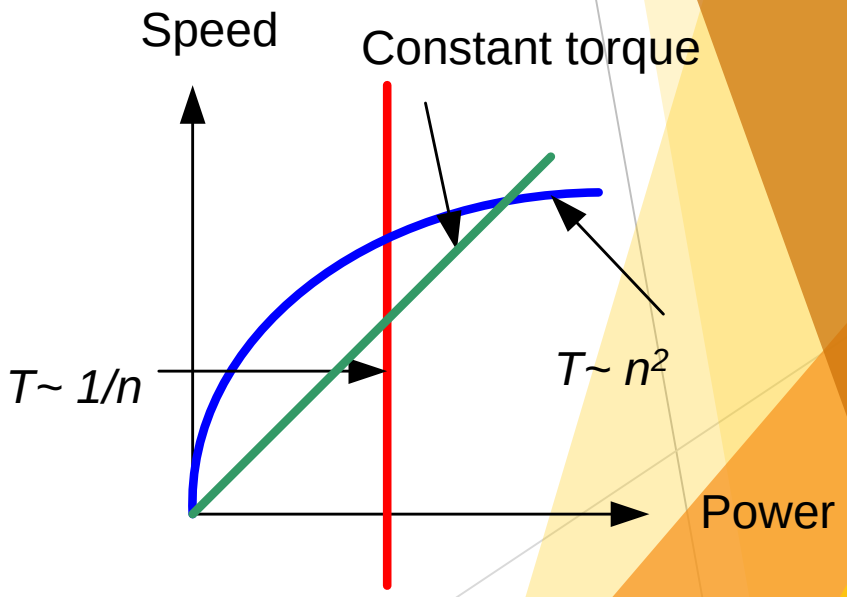
- Have different torque/speed characteristics
- mechanical loads are generally speed dependent

$$T = CT_r \left(\frac{n}{n_r}\right)^k \qquad P = T\,\omega \qquad \omega = 2\pi\frac{n}{60}$$

C= constant
T_r= load torque at rated speed
n_r= rated speed
n= operating speed
k= exponential coefficient representing the torque dependency on speed
P= mechanical power
ω= angular speed



Typical torque speed characteristics of mechanical loads



Typical Power speed characteristics of mechanical loads

Electric Drives – Component Selection

- Several factors affecting drive selection:
  - Steady-state operation requirements
    - nature of torque-speed profile, speed regulation, speed range, efficiency, quadrants of operations, converter ratings
  - Transient operation requirements
    - values of acceleration and deceleration, starting, braking and reversing performance
  - Power source requirements
    - Type, capacity, voltage magnitude, voltage fluctuations, power factor, harmonics and its effect on loads, ability to accept regenerated power
  - Capital & running costs
  - Space and weight restrictions
  - Environment and location
  - Efficiency and reliability

What to choose? How can I decide?

DC or AC Drives?

	DC Drives	AC Drives (particularly Induction Motor)
Motor	• requires maintenance • heavy, expensive • limited speed (due to mechanical construction)	• less maintenance • light, cheaper • high speeds achievable (squirrel-cage IM) • robust
Control Unit	Simple & cheap control even for high performance drives • decoupled torque and flux control • Possible implementation using single analog circuit	Depends on required drive performance • complexity & costs increase with performance • DSPs or fast processors required in high performance drives
Performance	Fast torque and flux control	Scalar control – satisfactory in some applications Vector control – similar to DC drives

Mechanical Loads:

$$T = {}^{P}/_{\omega}$$

$$T = CT_r \left(\frac{n}{n_r}\right)^k$$

Mechanical load characteristics

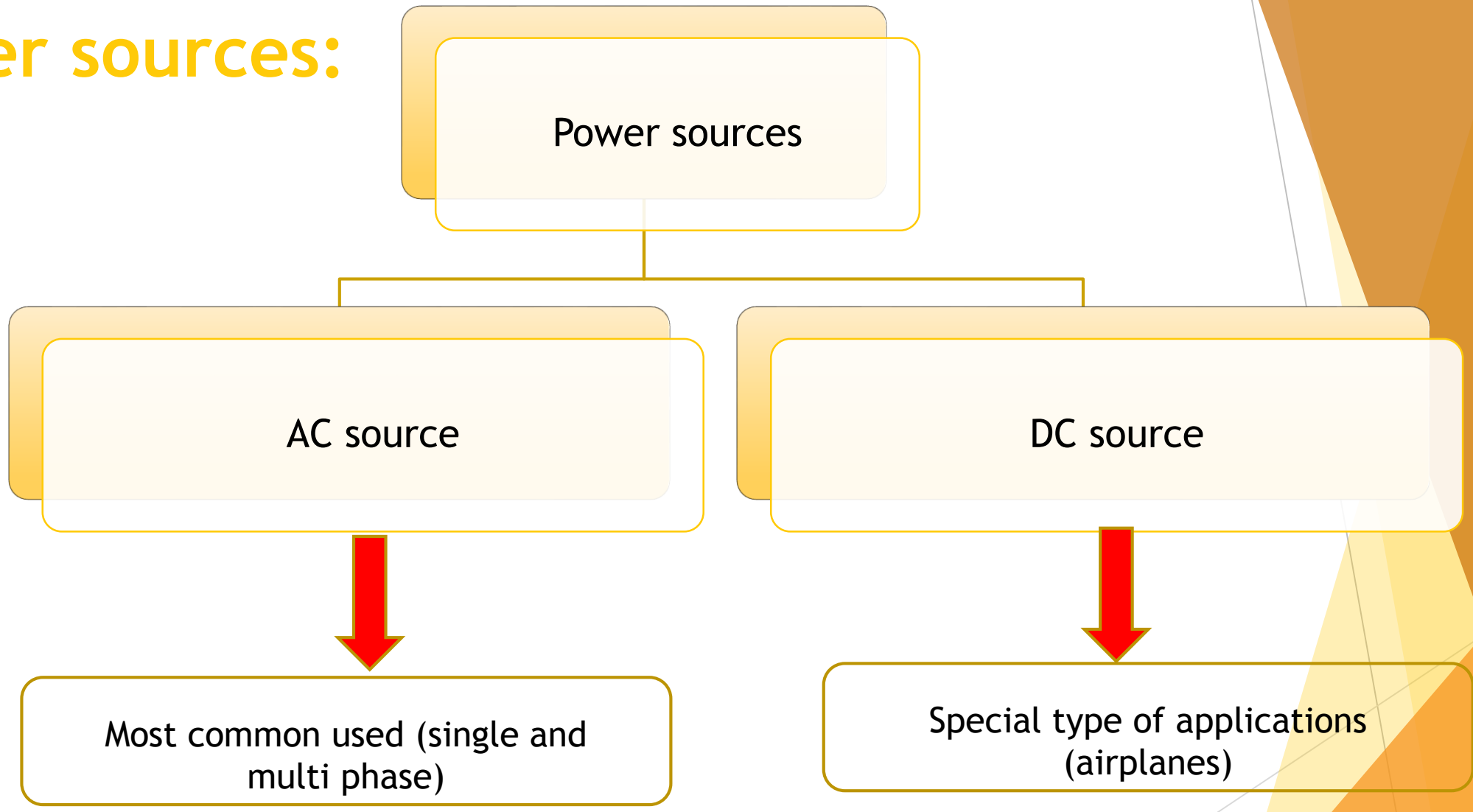
Torque independent of speed	Torque linearly dependent on speed	Torque proportional to the square of speed	Torque inversely prop. To speed
$C = 1$, $k = 0$	$k = 1$	$k = 2$	$k = -1$
Power dependent on speed	Power is prop. to n^2	Parabolic $T\omega$ characteristics, power is prop. to n^3	Requires high starting torque at low speed. Power is speed independent
EX: hoists, pumps	Not so common applications	EX: centrifugal pumps	EX: milling machines

Fan
$k = 1$

Drill
$k = -1$

hoist
$k = 0$

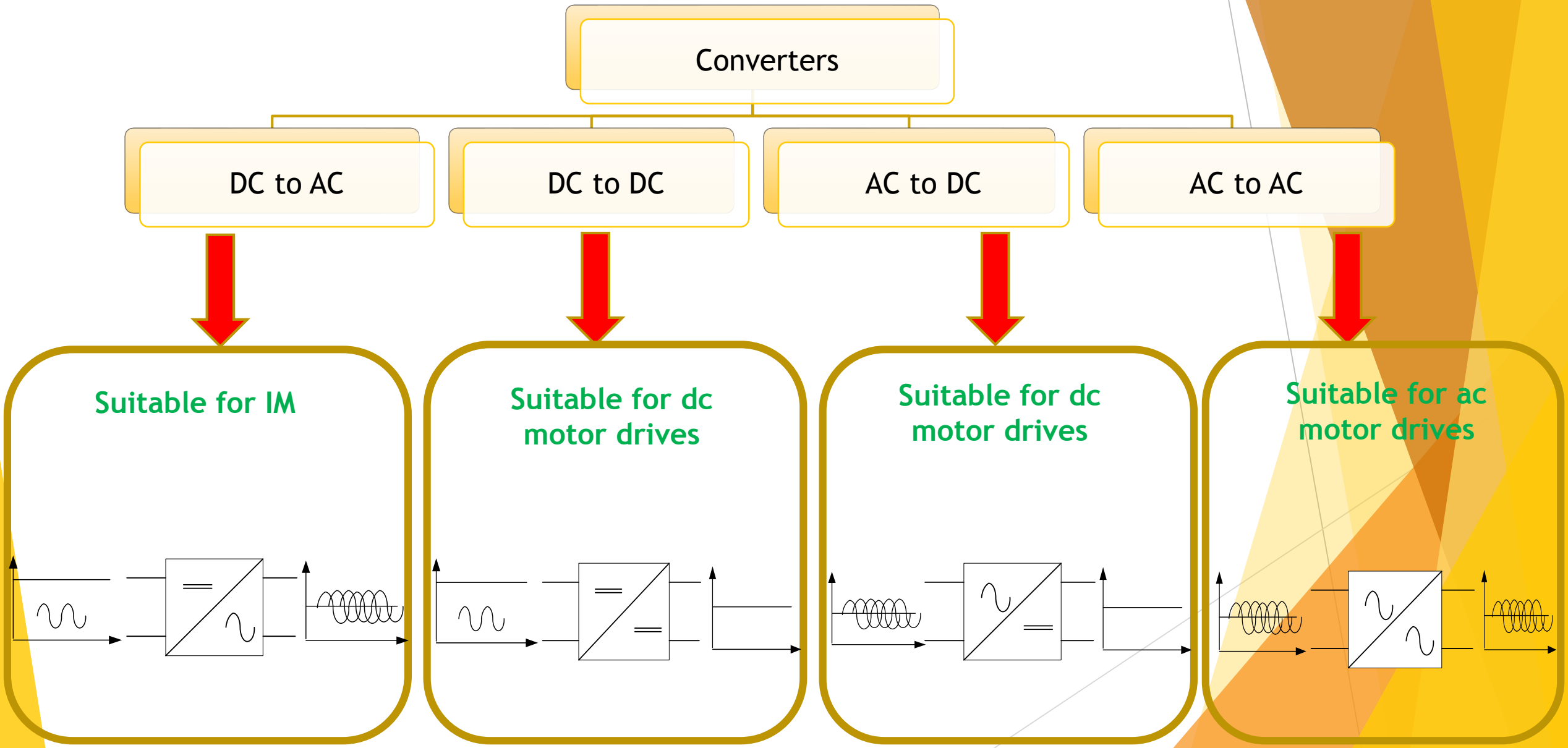
Power sources:



There must be load matching between Motor and mechanical load

depending on the load type.

Converters:


Converters
DC to AC
DC to DC
AC to DC
AC to AC
Suitable for IM
Suitable for dc motor drives
Suitable for dc motor drives
Suitable for ac motor drives