Power Electronics: an Overview

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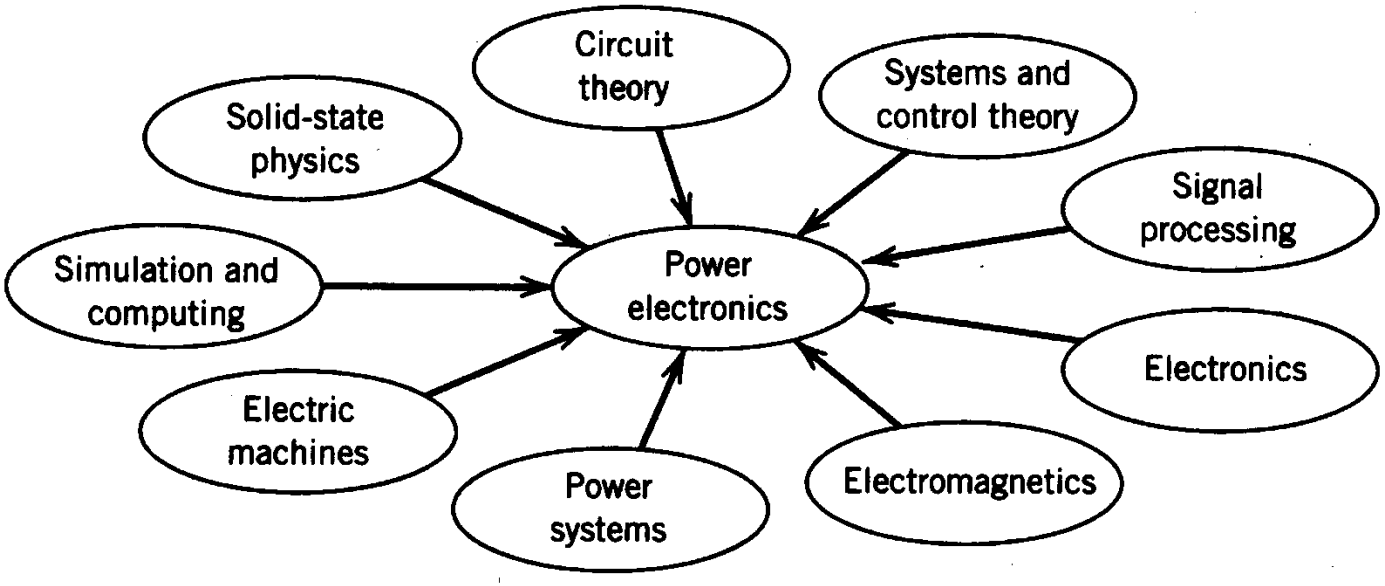
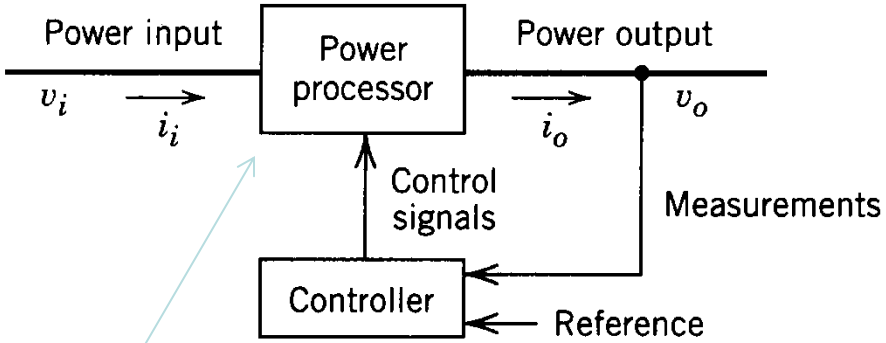
EE 442-642

Power Electronics: an Overview



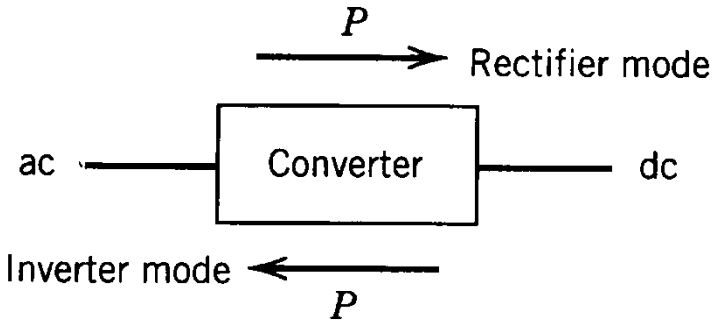
Power electronics is an interdisciplinary subject within electrical engineering.

Power Electronic System



A power electronic system consists of power electronic switching devices, linear circuit elements, digital circuits, microprocessors, electromagnetic devices, DSPs, filters, controllers, sensors, etc….

Power Converter



- "Converter" is a general term - an AC/DC converter is shown above.
- Rectifier Mode of operation when power from AC to DC
- Inverter Mode of operation when power from DC to AC

Power Electronic Applications

TABLE 1-1 Power Electronic Applications

(a) *Residential*
- Refrigeration and freezers
- Space heating
- Air conditioning
- Cooking
- Lighting
- Electronics (personal computers, other entertainment equipment)

(b) *Commercial*
- Heating, ventilating, and air conditioning
- Central refrigeration
- Lighting
- Computers and office equipment
- Uninterruptible power supplies (UPSs)
- Elevators

(c) *Industrial*
- Pumps
- Compressors
- Blowers and fans
- Machine tools (robots)
- Arc furnaces, induction furnaces
- Lighting
- Industrial lasers
- Induction heating
- Welding

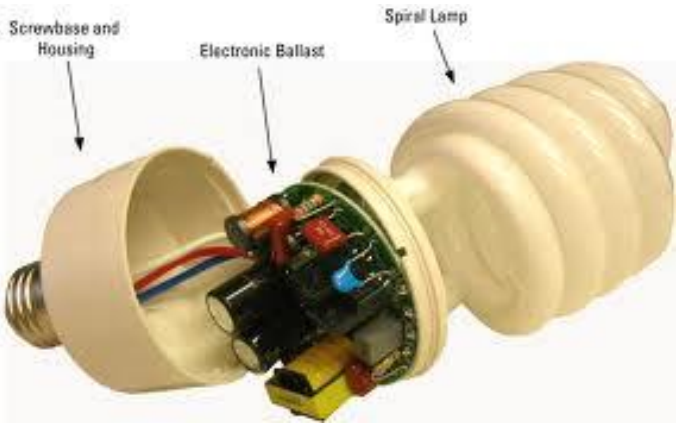
(d) *Transportation*
- Traction control of electric vehicles
- Battery chargers for electric vehicles
- Electric locomotives
- Street cars, trolley buses
- Subways
- Automotive electronics including engine controls

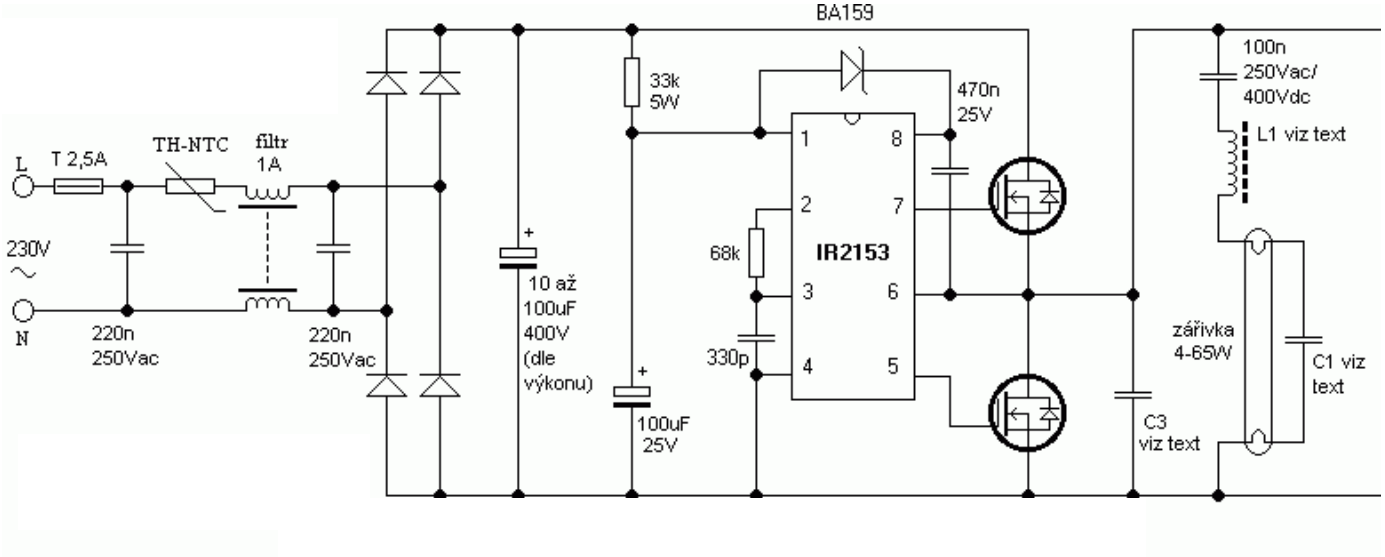
(e) *Utility systems*
- High-voltage dc transmission (HVDC)
- Static var compensation (SVC)
- Supplemental energy sources (wind, photovoltaic), fuel cells
- Energy storage systems
- Induced-draft fans and boiler feedwater pumps

(f) *Aerospace*
- Space shuttle power supply systems
- Satellite power systems
- Aircraft power systems

(g) *Telecommunications*
- Battery chargers
- Power supplies (dc and UPS)

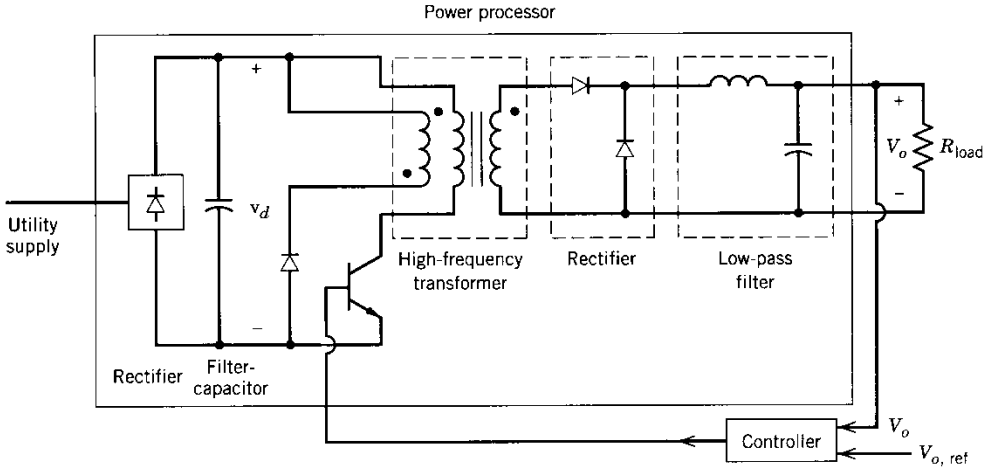
Example: Fluorescent Electronic Ballast





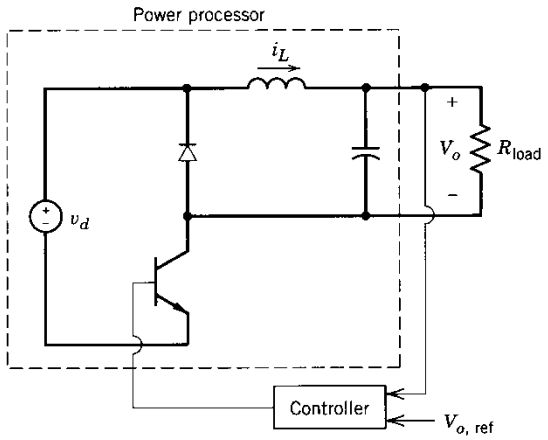
The line-frequency AC is converted to DC, then to high-frequency AC.

Example: Switch-Mode Power Supply

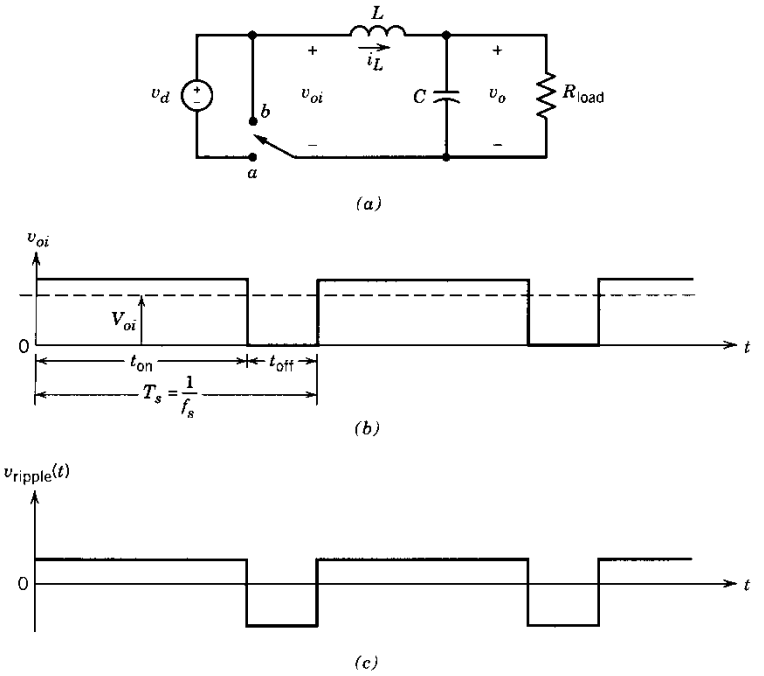


- Transistor is operated in switch mode (either fully ON or fully OFF) at high switching frequency.
- Electrical isolation achieved by high-frequency transformer (smaller, lighter and more efficient)
- Result: compact and efficient power supply

Basic Principle of Switch-Mode Synthesis



Simplified equivalent circuit



- Constant switching frequency f_s
- pulse width controls the average value of v_{oi}
- L-C circuit filters the ripple, and allows the average (dc value) to appear across the load

Example: Adjustable Speed Drives

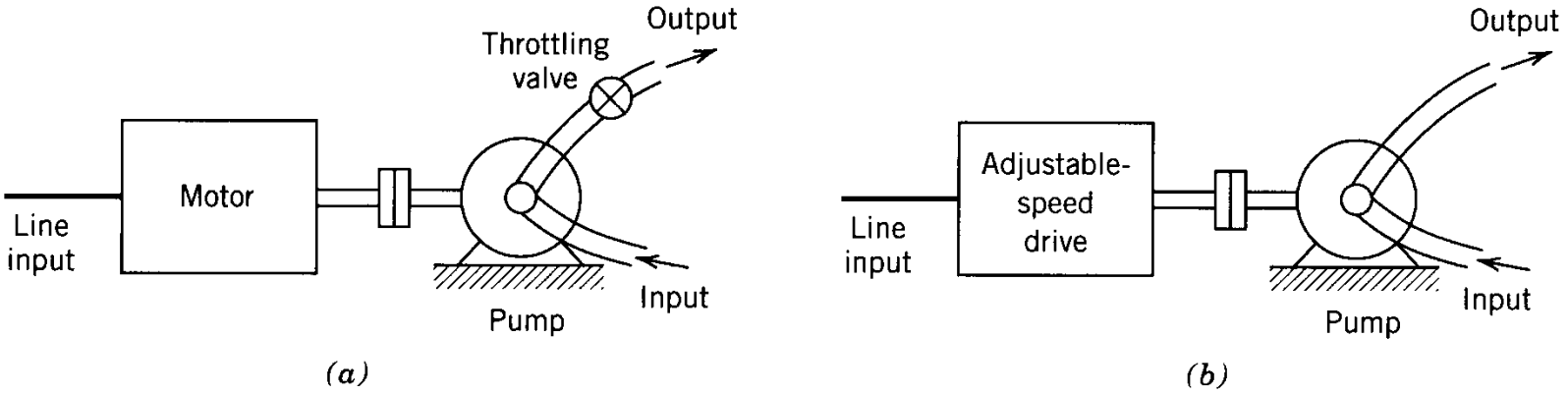


Figure 1-5 Energy conservation: (*a*) conventional drive, (*b*) adjustable-speed drive.

- Conventional drive wastes energy across the throttling valve to adjust flow rate.
- Using power electronics, motor-pump speed is adjusted efficiently to deliver the required flow rate.

AC Motor Drive

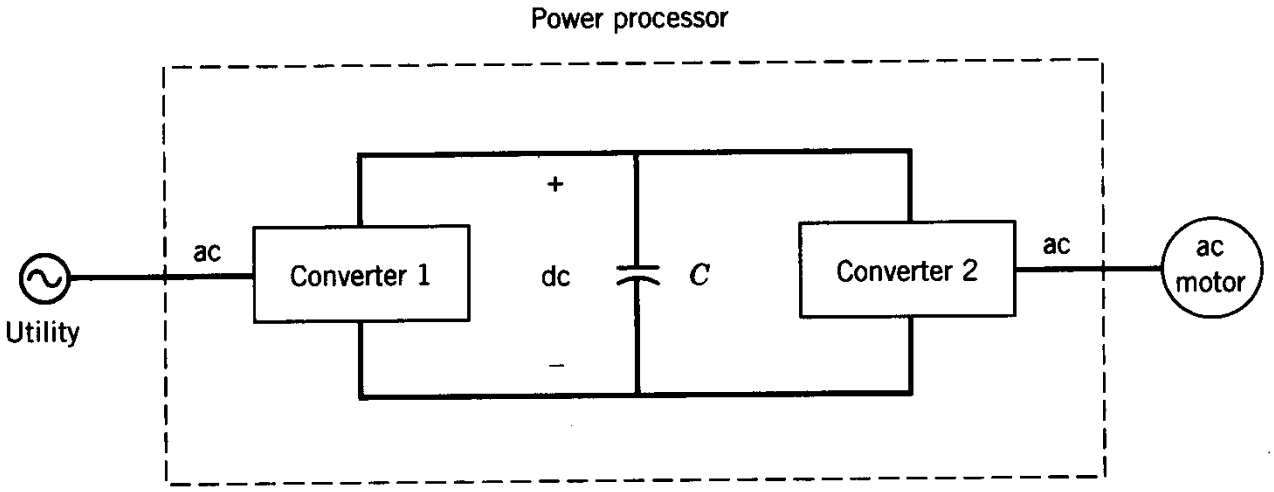
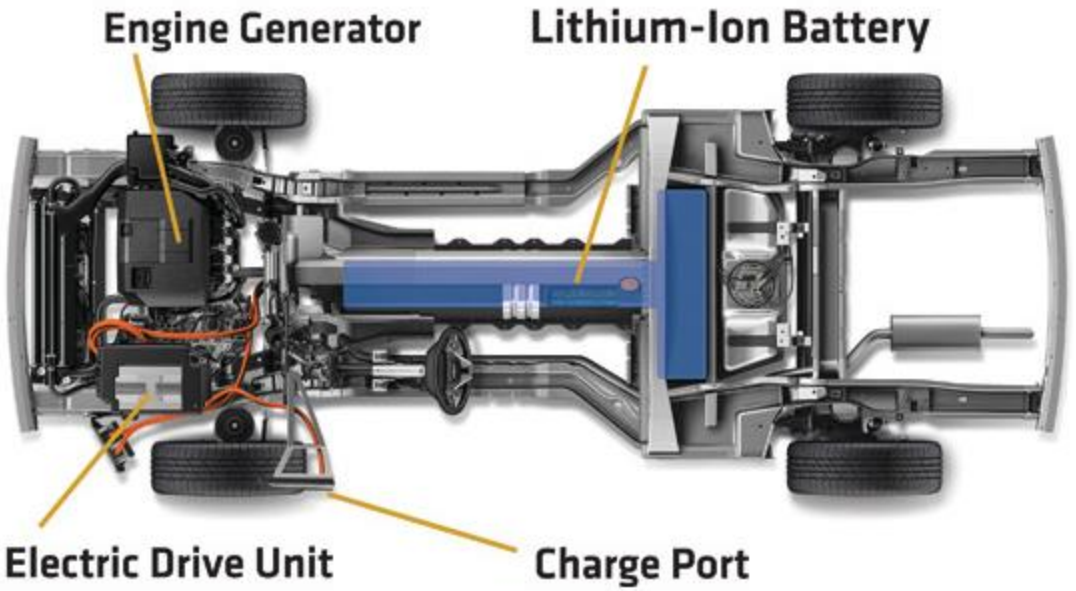


Figure 1-8 Block diagram of an ac motor drive.

- Converter 1 rectifies line-frequency AC into DC
- Capacitor acts as a filter; stores energy and decouples the two converters.
- Converter 2 inverts dc to variable frequency AC – as needed by the motor.

Pure Electric or Electric Hybrid Vehicles



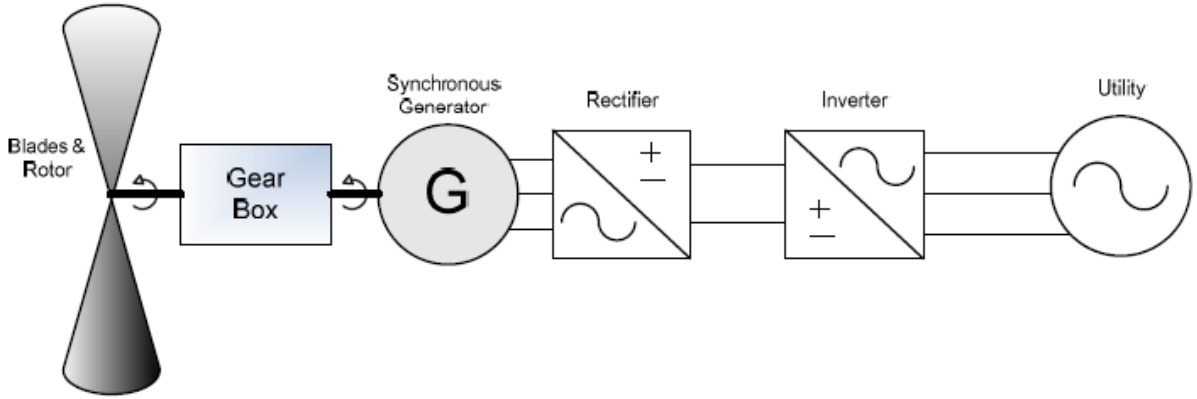
Battery Charger: AC-DC converter

Electric Drive System: DC-AC Converter

Example: Renewable Power Generation (PV)

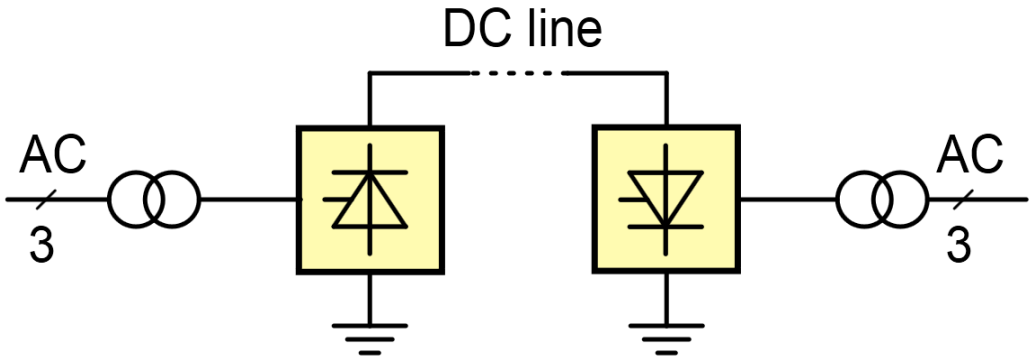
PV Inverters: DC-AC Converters

Example: Renewable Power Generation (Wind)



The rectifier-inverter converts variable-frequency AC to fixed line-frequency AC.

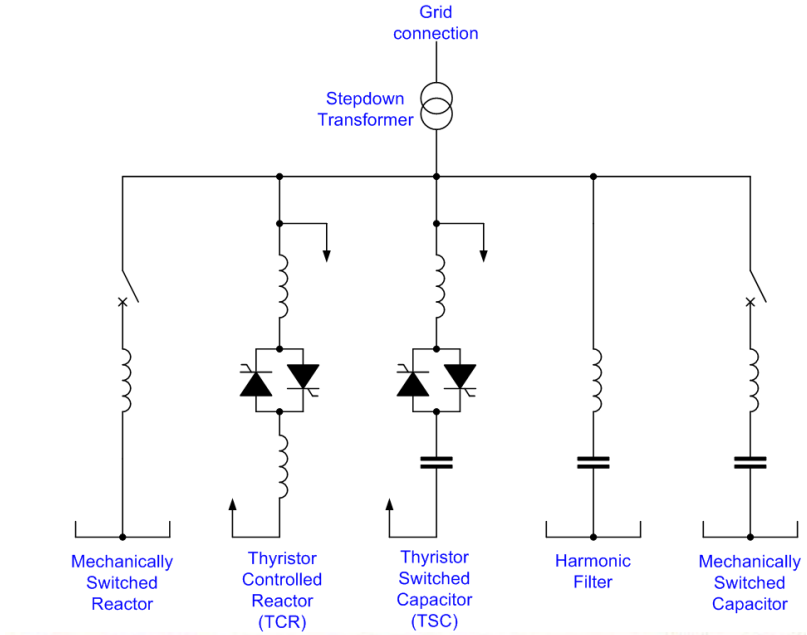
Example: HVDC Transmission



- Because of the large fixed cost necessary to convert ac to dc and then back to ac, dc transmission is only practical in specialized applications
  - long distance overhead power transfer (> 400 miles)
  - long underwater cable power transfer (> 25 miles)
  - providing an asynchronous means of joining different power systems.

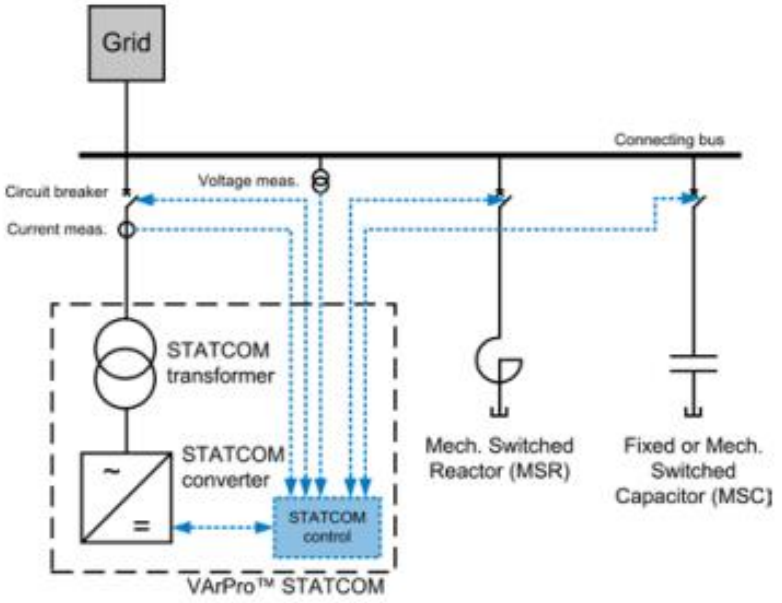
Example: SVC

Static Var Compensators (SVCs) are devices that can quickly and reliably control line voltages. An SVC will typically regulate and control the voltage to the required set point under normal steady state and contingency conditions and thereby provide dynamic, fast response reactive power following system contingencies (e.g. network short circuits, line and generator disconnections). In addition, an SVC can also increase transfer capability, reduce losses, mitigate active power oscillations and prevent over voltages at loss of load



Example: STATCOM

A STATCOM (static synchronous compensator) is a voltage regulating device. It is based on a power electronics voltage source converter and can act as either a source or sink of reactive power. It is a member of the flexible AC transmission systems (FACTS) family. As a fully controllable power electronic device, the STATCOM is capable of providing both capacitive and inductive VARs.



Example: DVR

The basic principle of dynamic voltage restoration is to inject a voltage necessary to restore the load side voltage to the desired amplitude and waveform, even when the source voltage is unbalanced or distorted. The DVR can generate or absorb independently controllable real and reactive power at the load side.