



Welcome to PEEEB



Lecture 1: Introduction

Presenter: Dr. Firuz Zare

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Contents:

- 1. What is Power Electronics?**
- 2. Power Converters**
- 3. Power Switches**
- 4. Power Modules**
- 5. Applications of Power Electronics**

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What is Power Electronics?

Power Electronics is Power Processing;

It is an application of electronic circuits to control a power converter in order to change input voltage or current magnitude and/or frequency suitable for different loads.

In a power electronic system, the flow of electric energy is controlled based on a load demand.

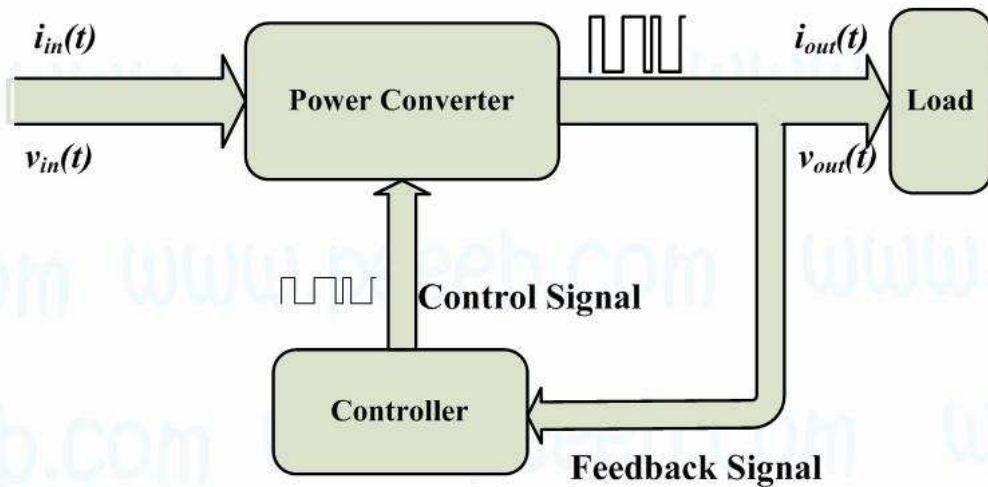
The main aims in modern power electronic systems are to deliver the power with maximum efficiency, minimum cost and weight in an integrated circuit.

Power Electronics has a significant role in different industries when power processing is required such as in computers, telecommunications, motor drives, cars and alternative energy systems.

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What is Power Electronics?



Power Electronics can be split into a Power and an Electronic circuit.

The Power circuit converts the input power and delivers it to the output.

The electronic circuit controls the converter by measuring the input and output voltages and/or currents and generates signals for the Power circuit.

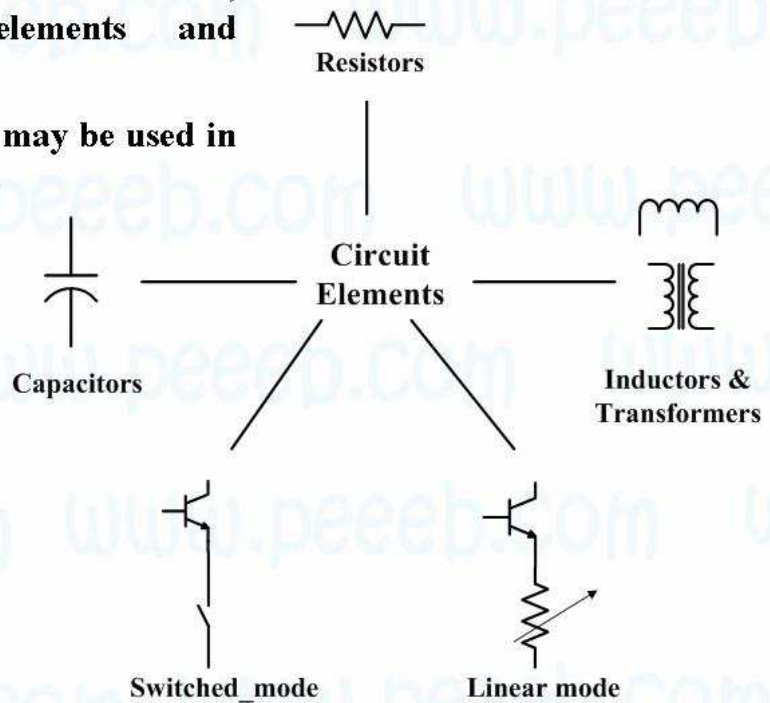
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What is Power Electronics?

In general, circuit elements in most electrical systems are resistors, capacitors, magnetic elements and transistors.

Some of these components may be used in low or high power systems.

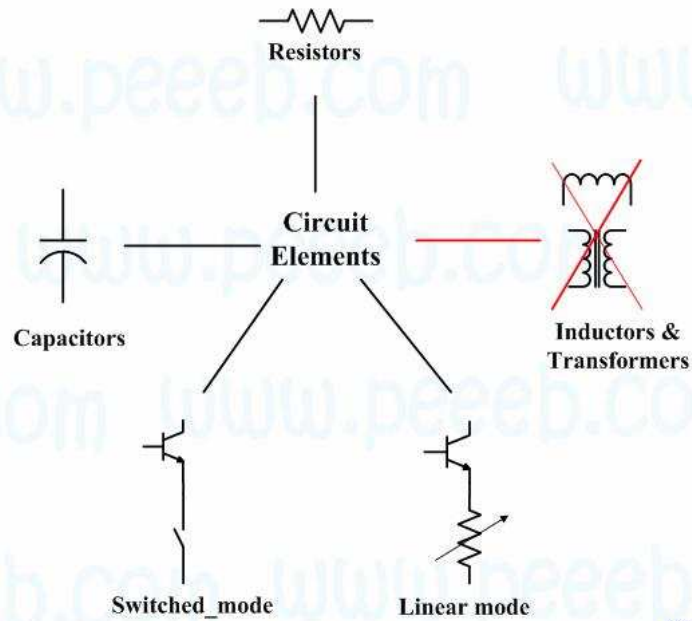


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What is Power Electronics?

In most Electronic Circuits in which efficiency is not the main concern, circuit elements consist of resistors, capacitors and transistors. It is difficult to include magnetic elements into integrated circuits as they are large in size compared to capacitors and resistors. The transistors may operate in linear or switched mode as they transfer low power signals.

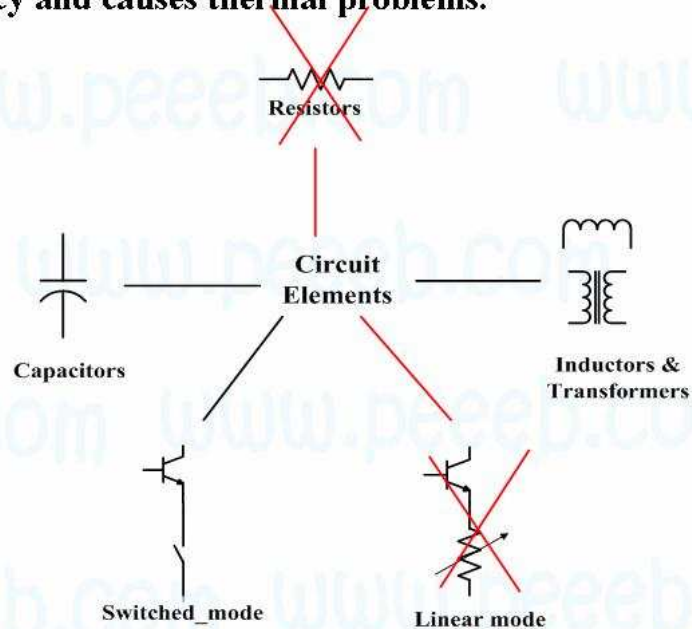


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What is Power Electronics?

In Power Converters, efficiency is the main concern. Power Circuits consist of capacitors, magnetic elements and transistors in switched mode. Resistors and power switches in linear mode are not used in the Power Circuits due to significant losses generated by current through these components which decreases the efficiency and causes thermal problems.



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Power Converters

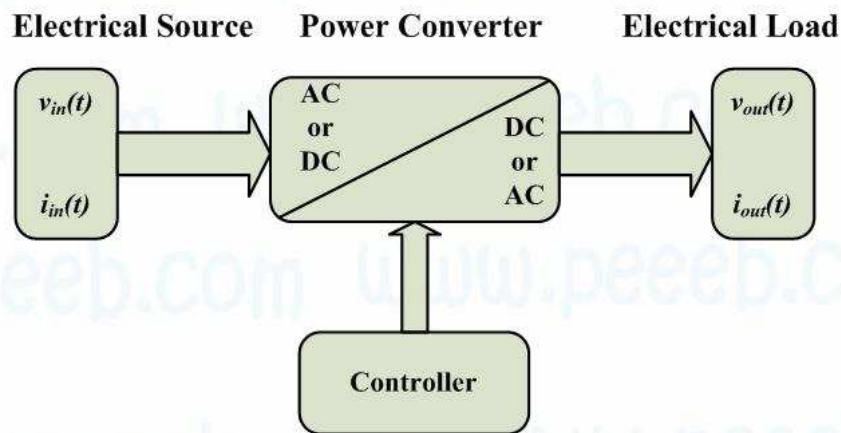
A power electronic system may process input power and deliver it to a load based on these following converters:

DC-DC Converter: Output voltage/current magnitude

AC-DC Converter: Output voltage/current magnitude and/or input current

DC-AC Converter: Output voltage/current magnitude and frequency

AC-AC Converter: Output voltage/current magnitude and frequency



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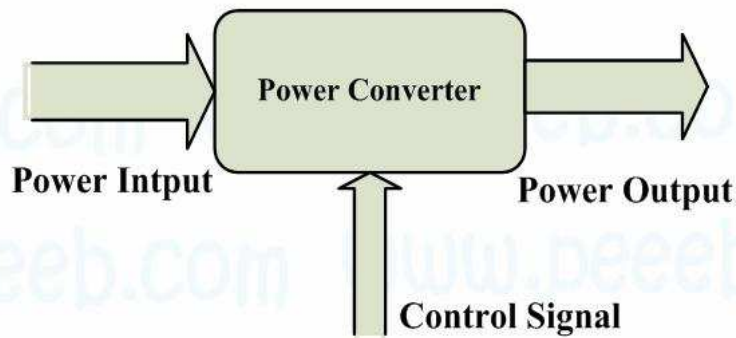
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Power Converters

Different applications have different load requirements which need special considerations in topology and control circuits.

In a **DC power supply**, an output DC voltage may be regulated while in a **DC motor drive** the output DC voltage must be adjustable.

In an **AC power system**, an output frequency may be constant while in an **AC motor drive** both frequency and magnitude must be adjustable.

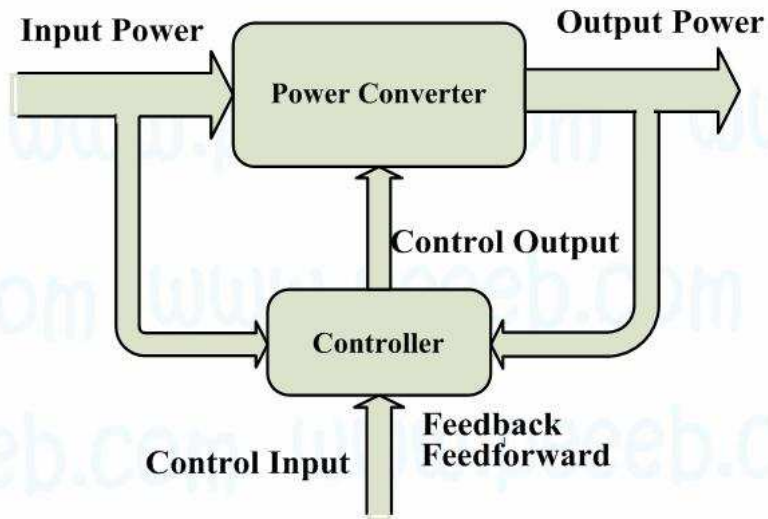


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Power Converters

The controller is an important part of the system to control and regulate output voltage and current and also to protect the system in a harsh situation such as over-current, over-voltage and/or over-temperature.



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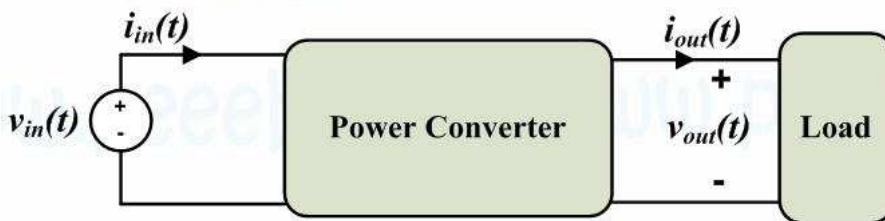
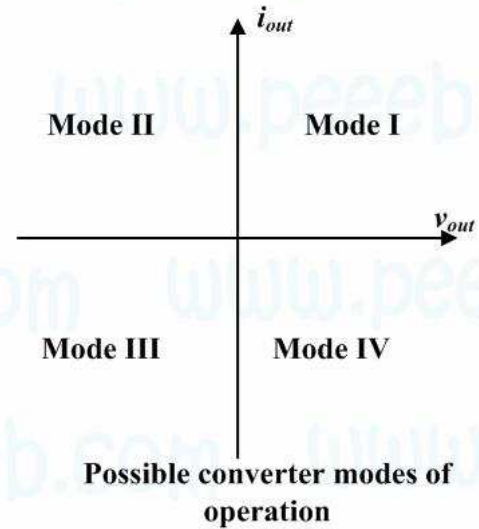
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Power Converters

When we design a Power Converter, the converter modes of operation should be determined according to the system operation.

Load current $i_{out}(t)$, and voltage $v_{out}(t)$, shown in this figure can be either positive or negative which represents four modes of operation.

The converter topology will be different when it operates in one, two or four quadrants.

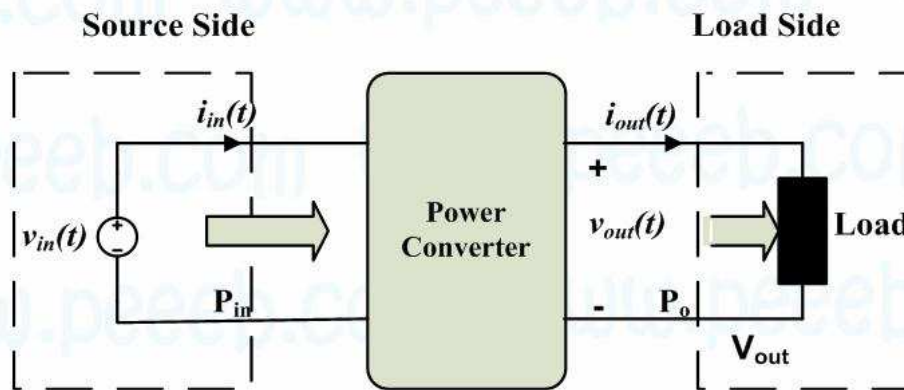


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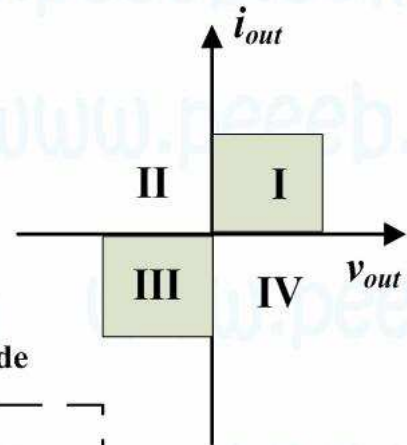
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Power Converters

This is an unidirectional power flow in which the power is controlled and processed from the input side and transferred to the output side. The converter may operate either in quadrant I or III or both.



Power Flow: Unidirectional input to output

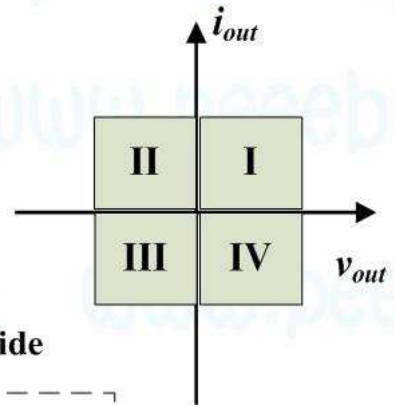
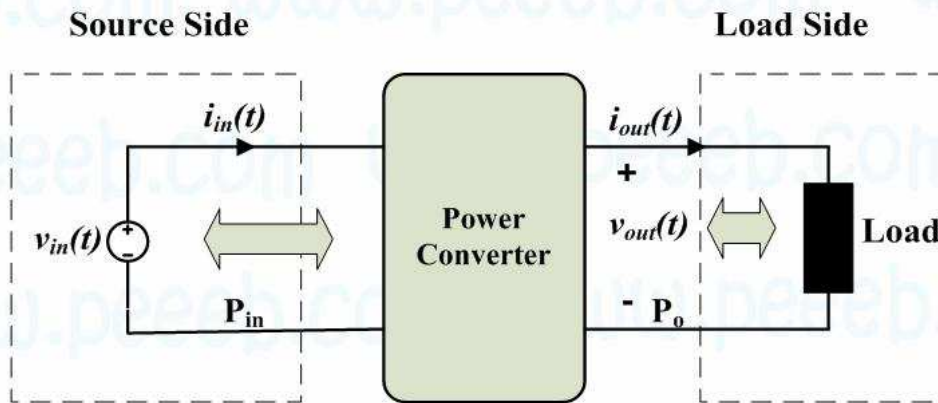


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Power Converters

This is a bidirectional power flow in which the power can be controlled and processed from the input side and transferred to the output side or vice versa. The converter may operate in any quadrant based on the system operating mode.



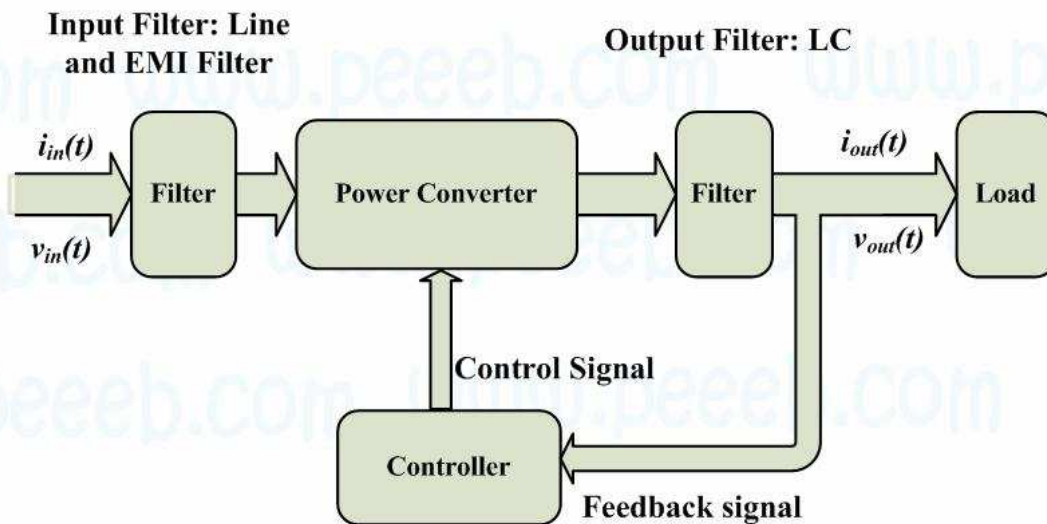
Power Flow: Bidirectional

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Power Converters

In a power electronic system, Line and EMI filters are important sections of the system. There are different load and utility requirements which should be fulfilled to reduce noise and harmonic levels of the system.



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Power Converters

In modern power converters due to advances in semiconductor switches, converters can be classified according to low and high frequency switching devices.

Low (Line) frequency converters (controlled/uncontrolled) which are naturally commutated. The power switches are turned on and off at the line frequency of 50 or 60 Hz.

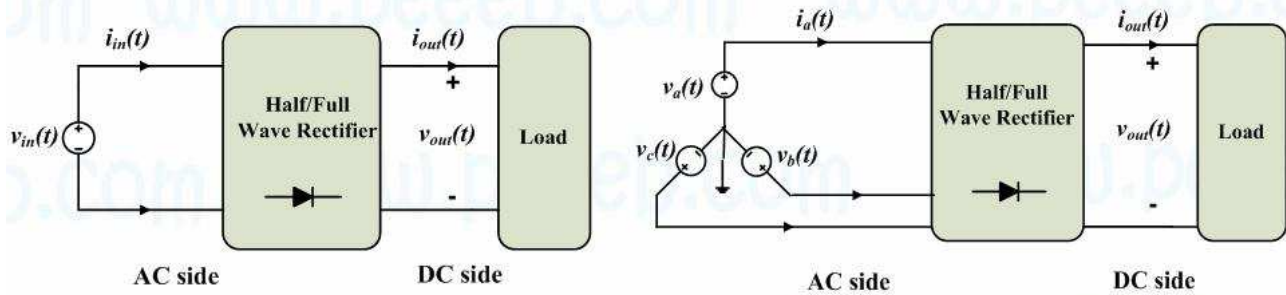
High frequency converters based on hard or soft switching in which controllable switches in the converters are almost turned on and off at frequencies higher than the line frequency.

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Power Converters

Uncontrolled Line Frequency Converter Based on Power Diodes

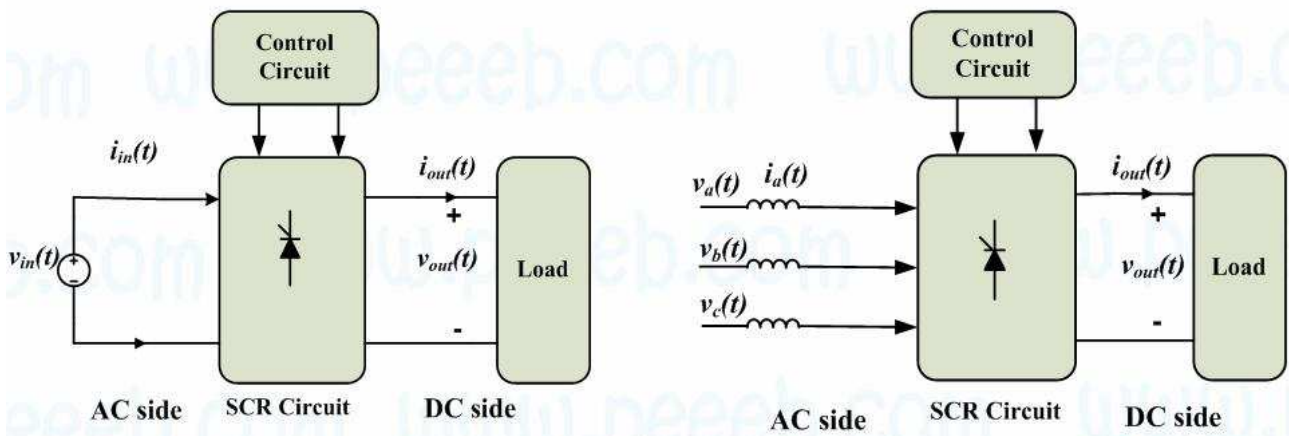


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Power Converters

Controlled Line Frequency Converter Based on Thyristors

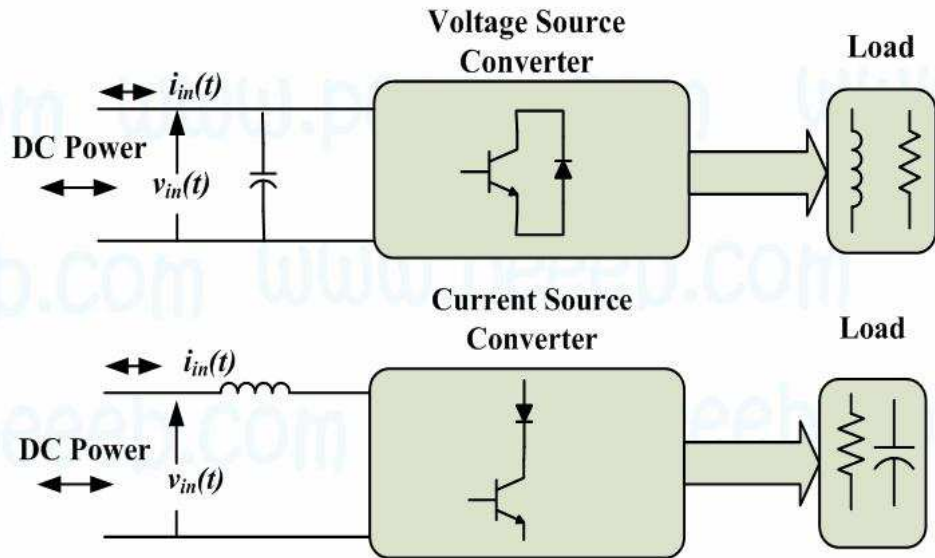


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Power Converters

High Frequency Converters are either Voltage or Current Source Converters
High Frequency Converters are mostly used in DC-DC, DC-AC and AC-AC (Matrix) Converters in which fast switching based on a pulse width modulated signal is required.

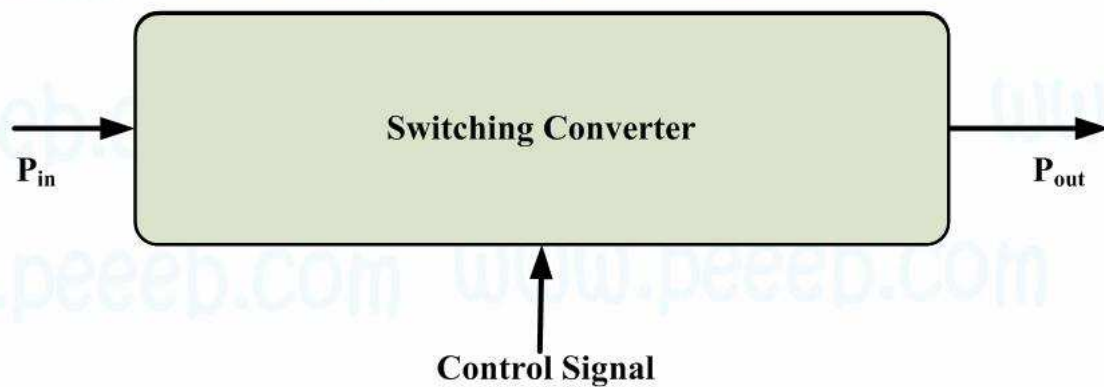


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Power Converters

In some complex power processing systems, the instantaneous input power is not equal to the instantaneous output power. The reason is that we need to have different conversions in order to achieve robustness and to design a reliable power converter.

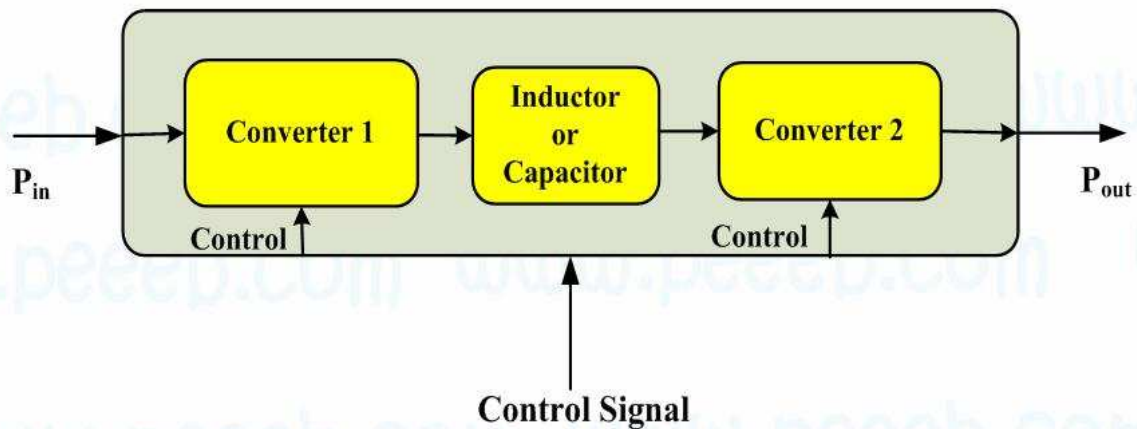


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Power Converters

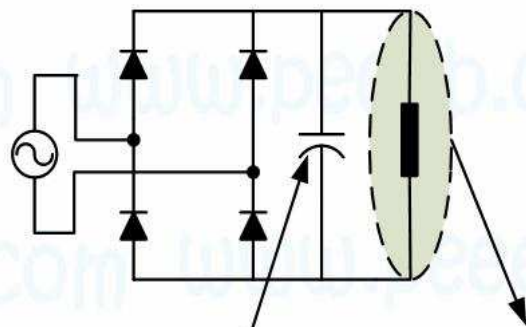
As an example, if an input source is the grid voltage and a demand is to deliver an adjustable DC voltage to a load, thus we need to convert the AC voltage into DC type through a first converter and then change the DC voltage magnitude through the second converter. Between these two converters there is a storage device like an inductor or capacitor which is charged and discharged in a normal operation.



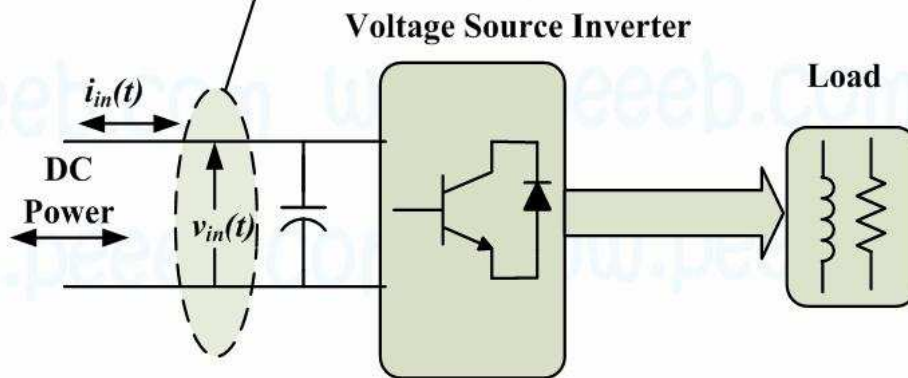
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Power Converters



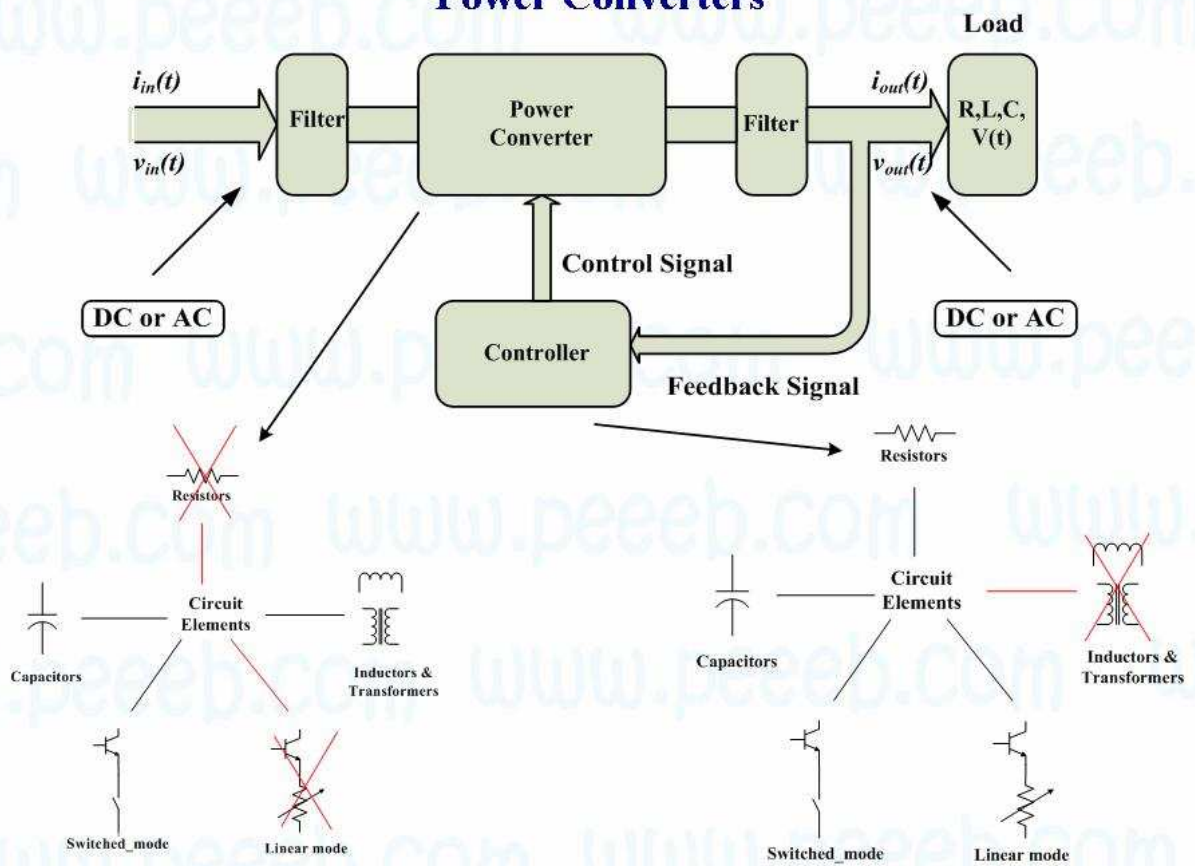
This is a two stage conversion process where the first one is a diode rectifier, with a capacitor as a filter and storage device and the load can be modeled as a DC-AC inverter.



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Power Converters



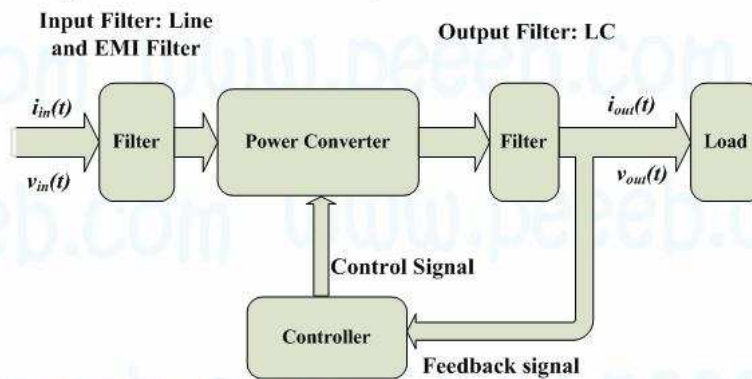
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Power Converters

In general, a power electronic system consists of:

- An input (AC or DC) voltage or current source and a load.
- One or more converters in cascade for power conversion.
- Power semiconductor devices, which are used as switches to chop input voltage or current to control the flow of energy.
- A control system (open or close loop) implemented either in analog and/or digital electronics.
- One or more static-switches acting as a circuit breaker.
- A gating circuit to generate the gate drive signals for the switching devices.
- Current, voltage and thermal sensors.
- Input and output filters for immunity and emission control



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Power Switches

Key elements in a power converter are power switches. The most important power switches in modern power converters are:

- **Power Diode**
- **Power Metal-Oxide Field-Effect Transistor (Power MOSFET)**
- **Insulated-Gate Bipolar Transistor (IGBT)**

There are some other power switches which were very common in the past such as:

- **Silicon-Controlled Rectifier (SCR) or Thyristor**
- **Power Bipolar Junction Transistor (Power BJT)**

Thyristors have an important role in high power high voltage converters due to their advantages in withstanding high voltage and delivering high current. They are also used in low power AC-AC converters in which a simple and cheap converter is required.

The following power switches have special applications in high voltage and high power converters.

- **Gate Turn-off Thyristor (GTO)**
- **MOS-Controlled Thyristor (MCT)**

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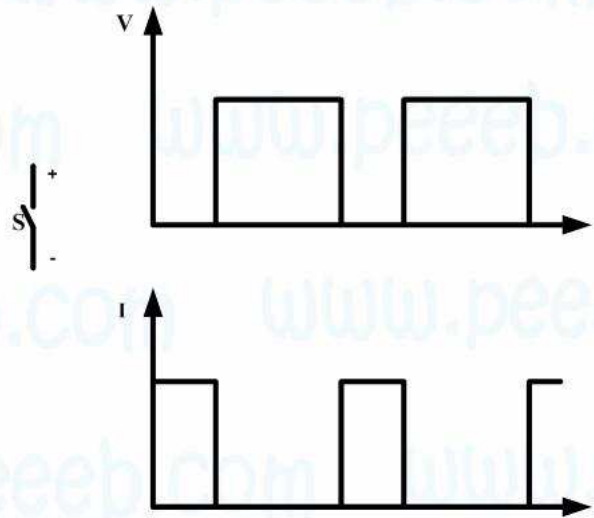
Power Switches

When we consider a power switch as an ideal switch, that means the switch can handle unlimited current and blocks unlimited voltage.

The voltage drop across the switch and leakage current through the switch are zero.

The switch is turned on and off with no rise and fall times.

This assumption helps us to analyze a power circuit but for design and practical considerations we should consider real power switches!

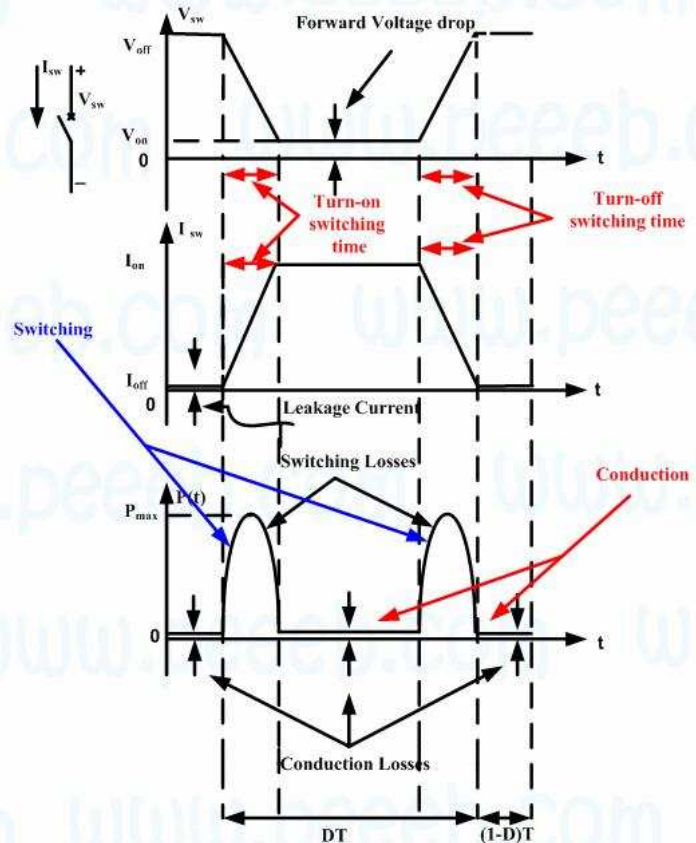


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Power Switches

In a real case, ideal switches do not exist. During switching transients, there are significant switching losses associated with dv/dt and di/dt . These phenomena depend on several issues such characteristics of power switches, control signals, gate drives, stray parameters and operating points of the system.

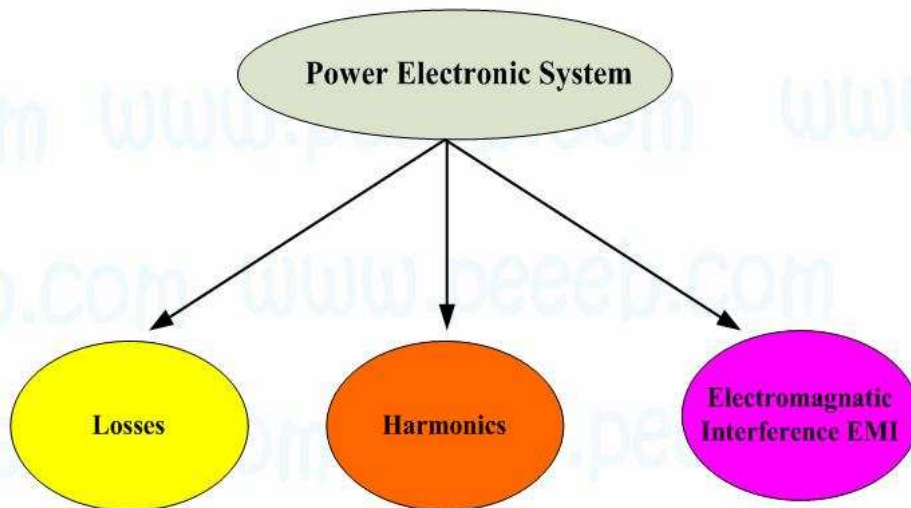


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Power Modules

Three major issues to design a power electronic system are Losses, Harmonics and Electromagnetic Interferences (EMI). These issues affect system cost, size, efficiency and quality. It is a trade-off between these factors.

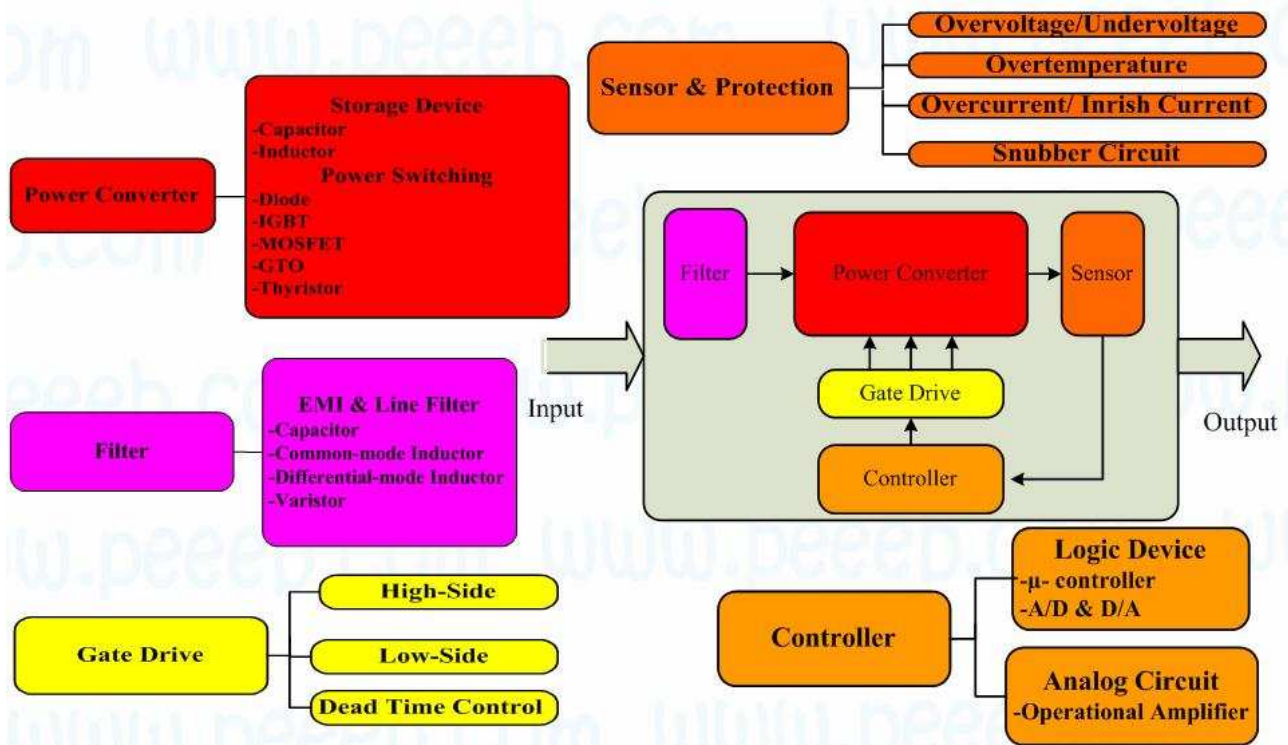


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Power Modules

Integrated (Intelligent) Power Electronic Modules

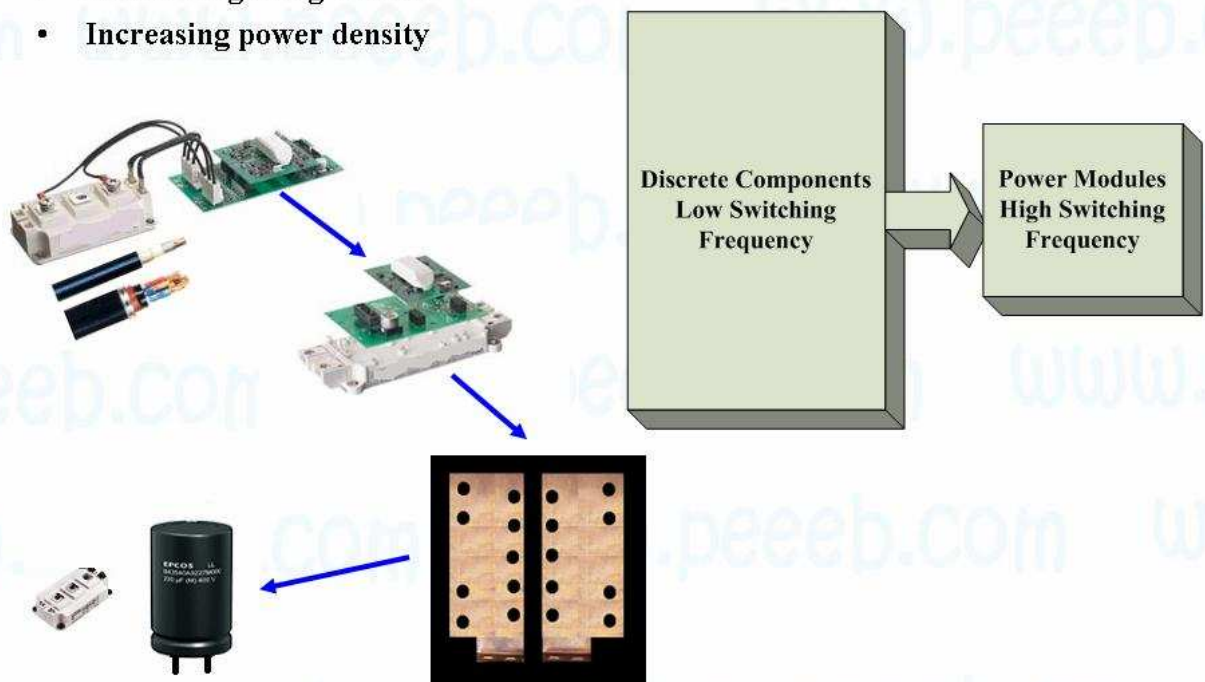


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Power Modules

- Integrated Power Electronic Modules
- Less wiring using busbars
- Increasing power density



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Applications of Power Electronics

Power electronics has an important role in modern technology. Almost in all new electrical systems there is at least one power converter, from mobile phone chargers and computer power supplies to industrial motor drives.

With advances in semiconductor devices (fast switching) and microcontrollers (high frequency), Power Electronics becomes a main solution in renewable energy systems such Photo Voltaic and Wind Turbines to export Green Power into Power Systems with high efficiency.

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Applications of Power Electronics

It is hard to define power levels for Power Electronic systems. Different topologies may be used at different power ratings. In general, we can classify them into:

- Less than 100 W, in Switched-Mode Power Supplies for portable equipment and small motor drives used in home appliances**
- Less than 10 kW, in power supplies for computers or office equipment and variable-speed motor drives used in commercial buildings.**
- 10kW up to 1MW, in high power motor drives in industry, traction control and renewable energy system**
- More than 1MW in utility transmission lines, grid connected systems, reactive power control**

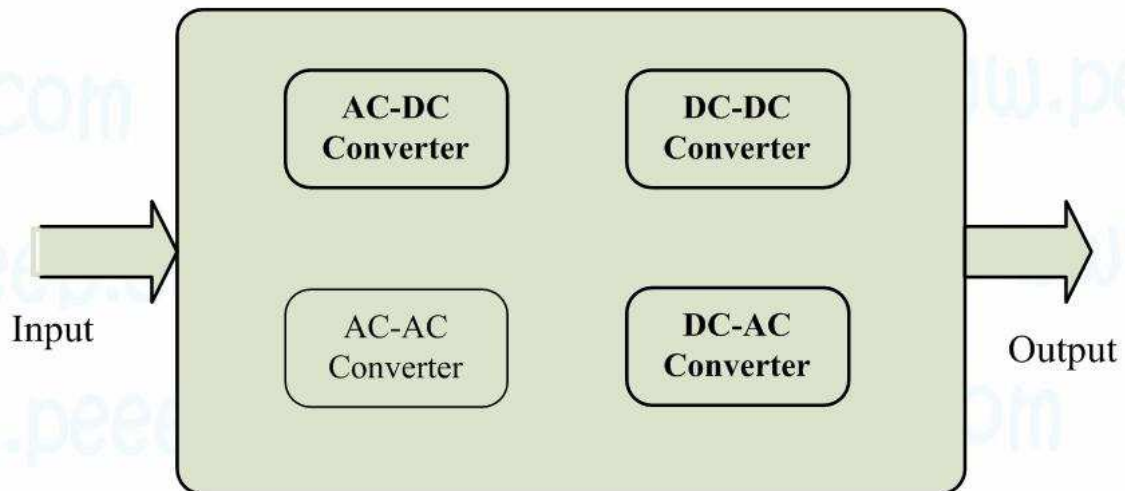
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Applications of Power Electronics

Different combinations of power converters are used in several applications. The converters are classified based on input source and load requirements.

AC-AC converters are not commonly used in Power Electronic Systems.

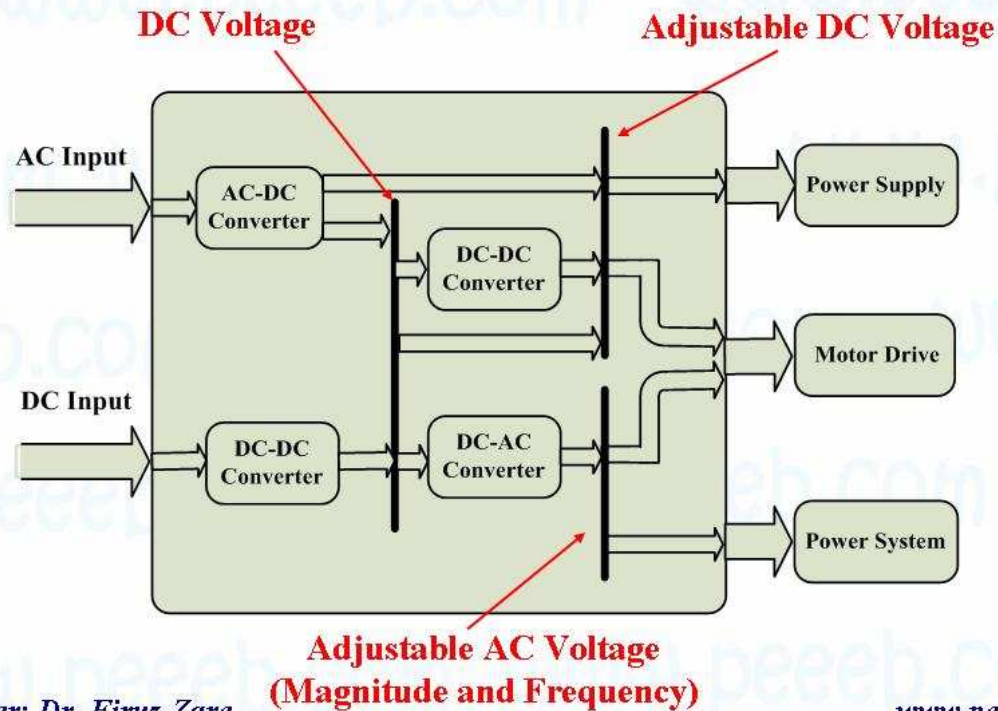


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Applications of Power Electronics

Most Power Converters have multi-power processors in which the input voltage (almost grid voltage) is converted to the DC voltage and then to DC or AC voltage with adjustable voltage and/or frequency based on load requirements.

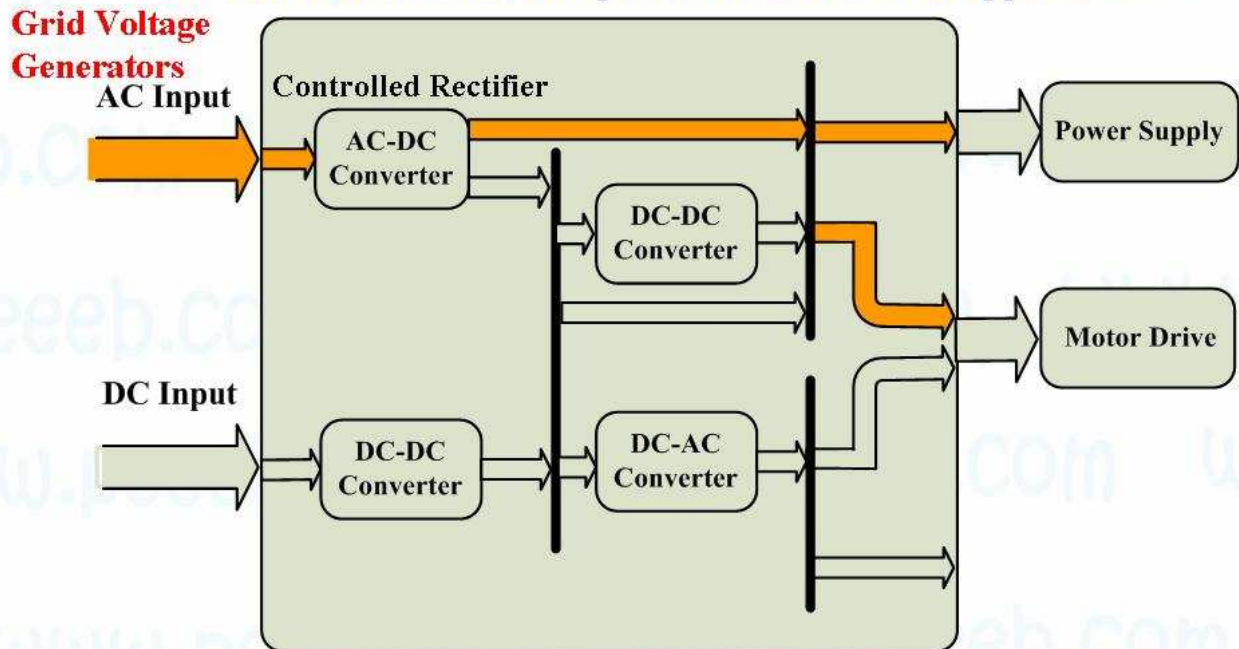


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Applications of Power Electronics

Power Flow Based on Input Source in Different Applications

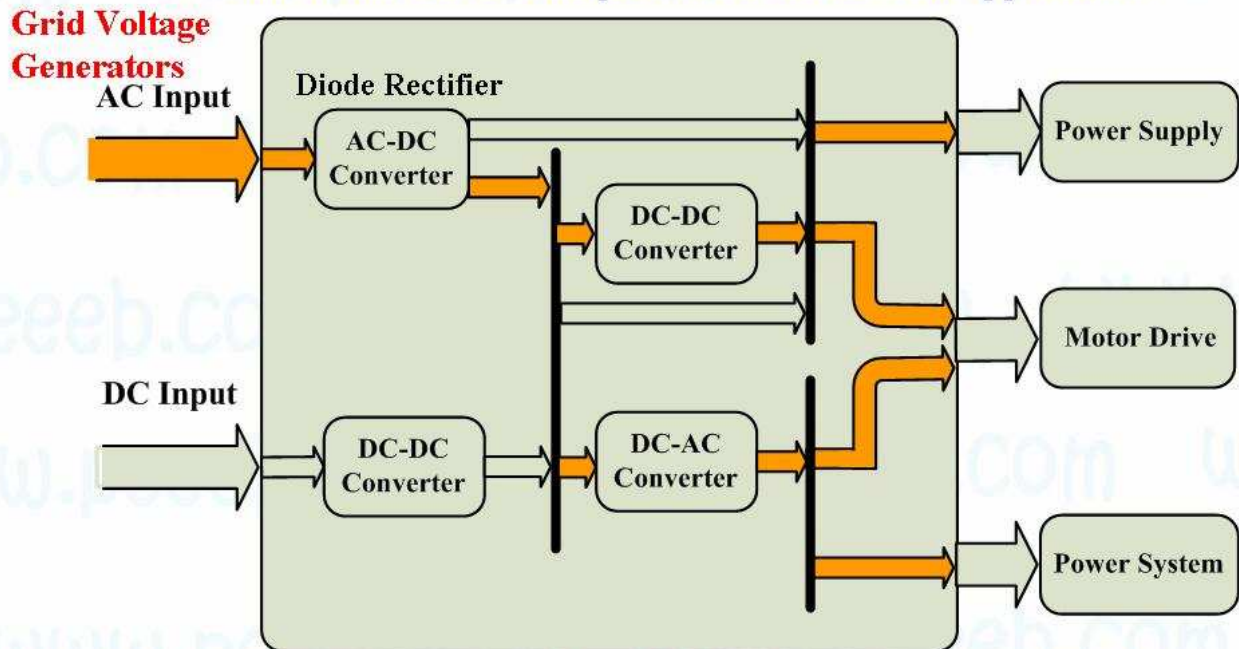


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Applications of Power Electronics

Power Flow Based on Input Source in Different Applications

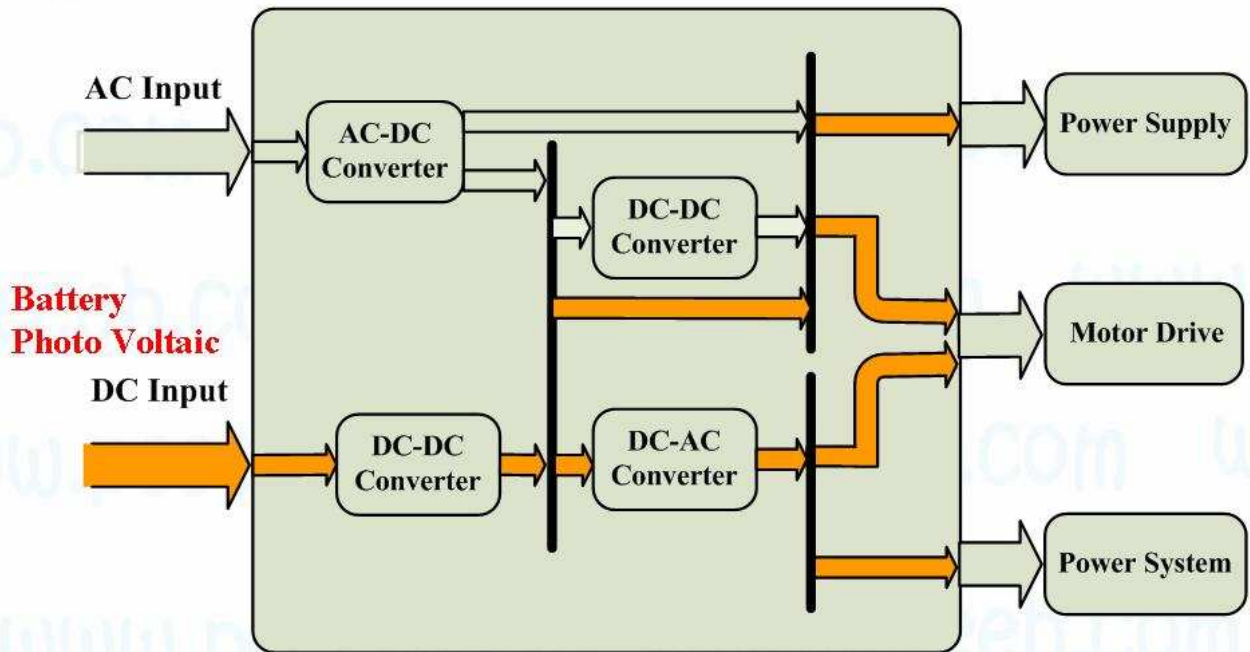


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Applications of Power Electronics

Power Flow Based on Input Source in Different Applications



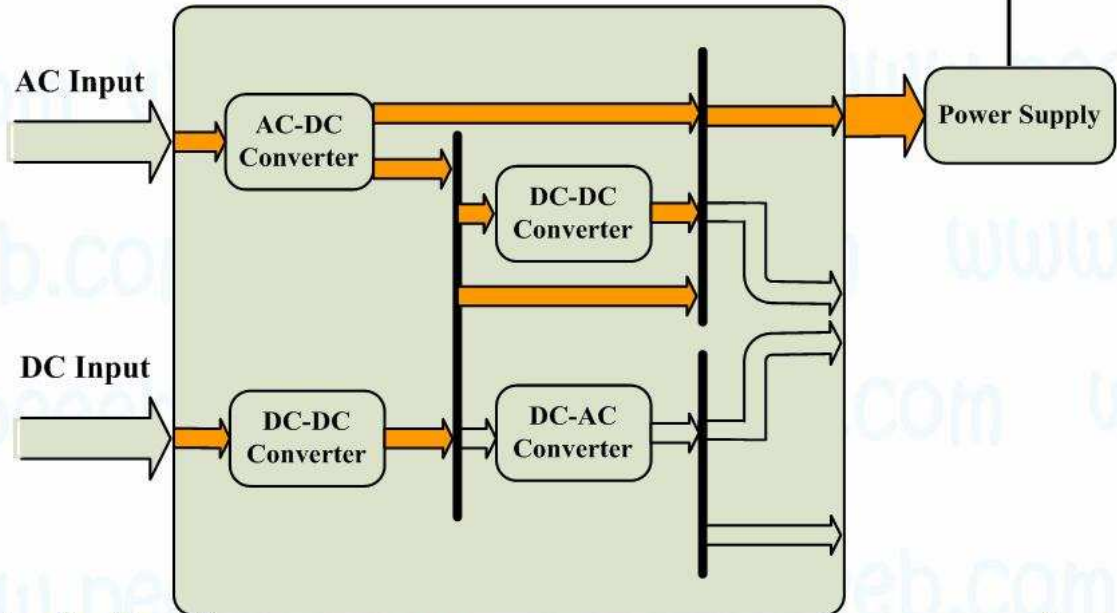
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Applications of Power Electronics

From low power Battery Chargers used in portable devices (Mobile phone, Laptop) to medium and high power chargers like Electric Vehicles, Personal Computer, Copiers, Printers, Telecommunication Devices, Audio and Video Equipments

Power Flow Based on different loads in Different Applications



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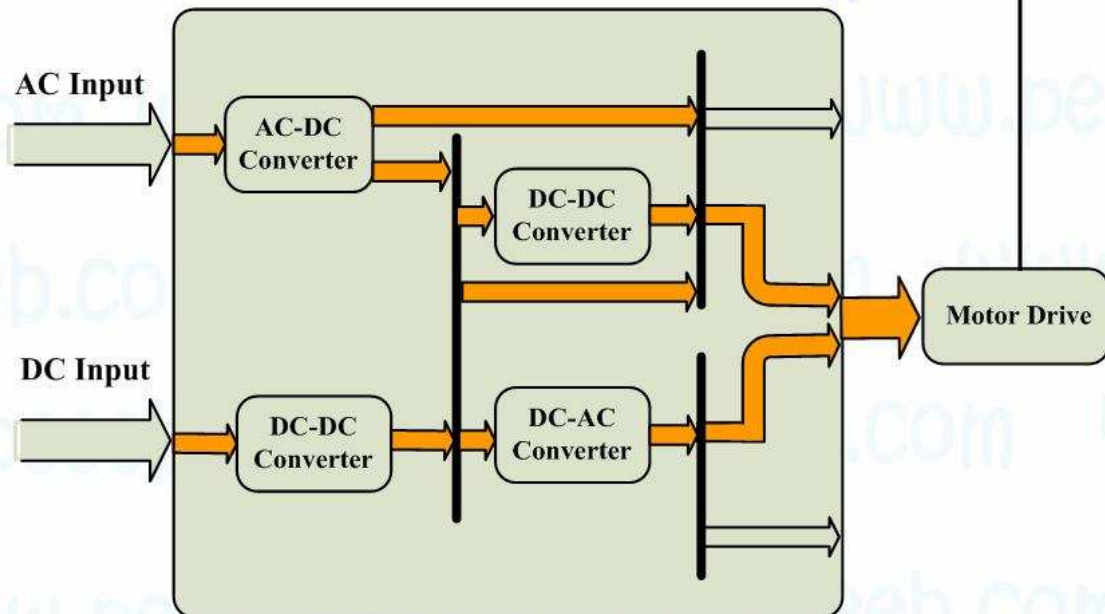
Applications of Power Electronics

DC or AC Variable Speed Drives in Robotics or Industry.

Low/medium power drives in Home Appliances, Air Conditioners, Pumps ...

High power drives in Traction, Electric Vehicles, Conveyers, Lifts, Pumps ...

Power Flow Based on different loads in Different Applications



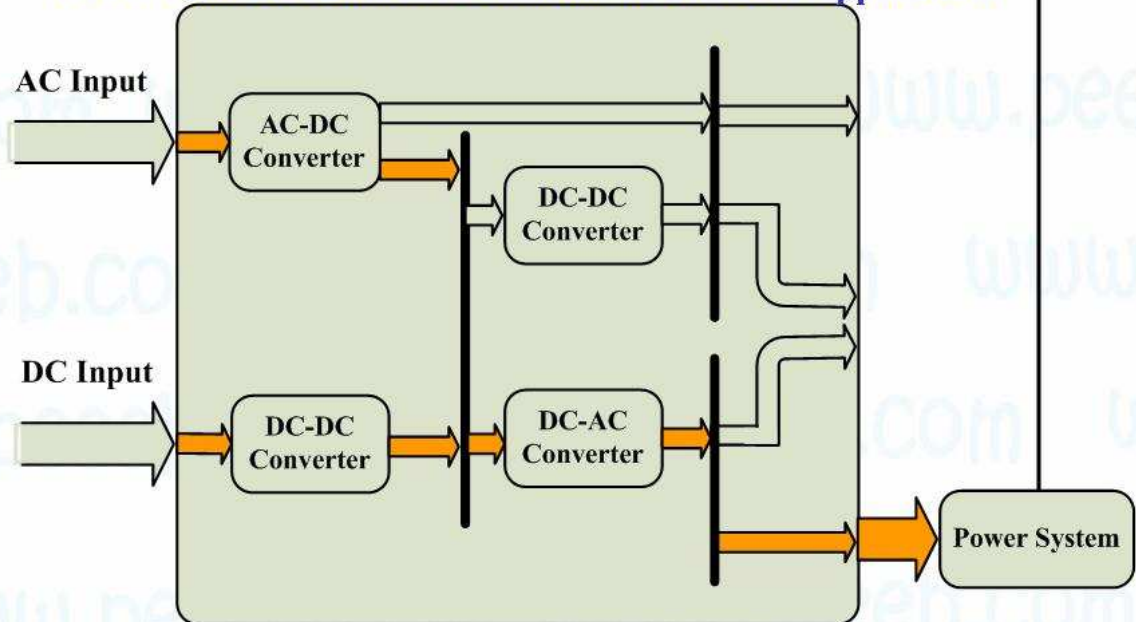
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Applications of Power Electronics

Renewable Energy Systems, Distributed Generations, Flexible AC Transmission, Power Quality, UPS, Active and Reactive Power Control ...

Power Flow Based on different loads in Different Applications

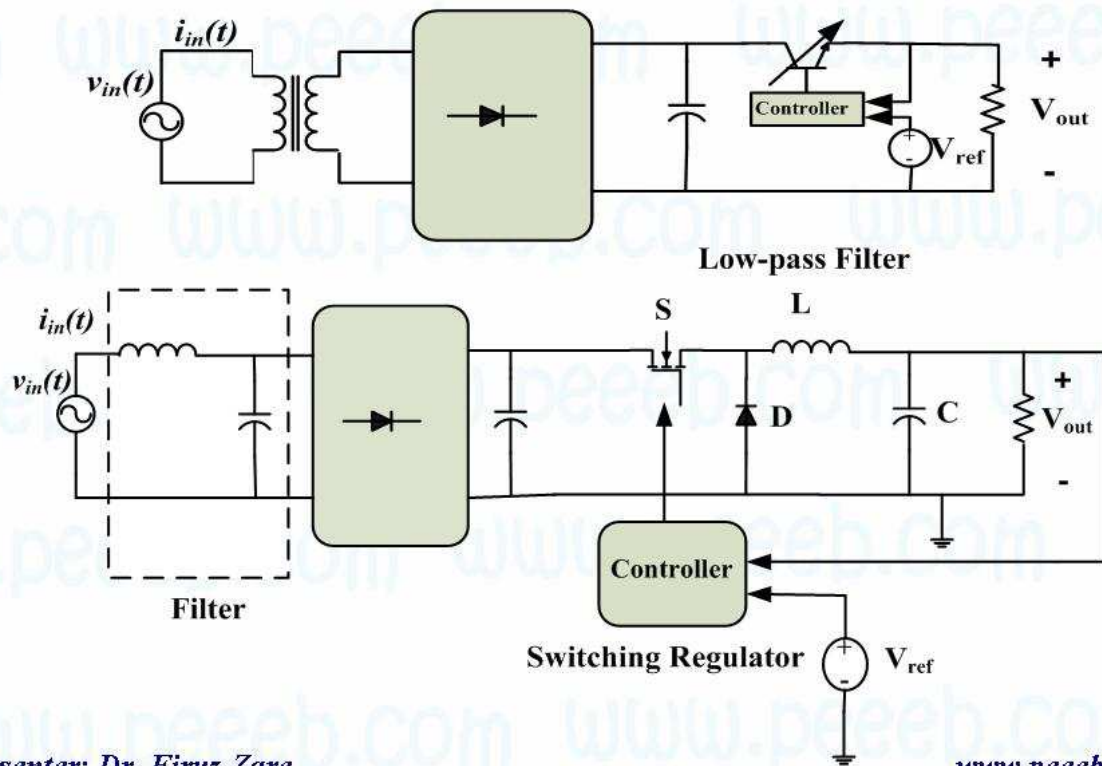


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Applications of Power Electronics

Conventional Linear Circuit v.s. Switched Mode Circuit



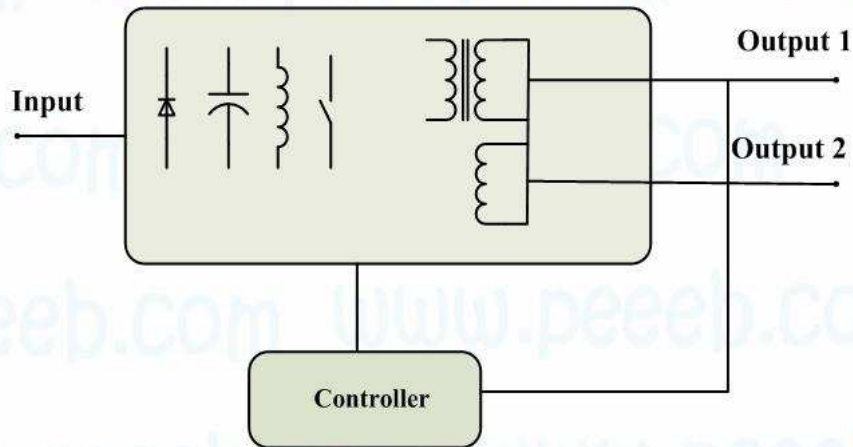
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Applications of Power Electronics

Switched-Mode Power Supply with multi-outputs

DC-DC Power Converter

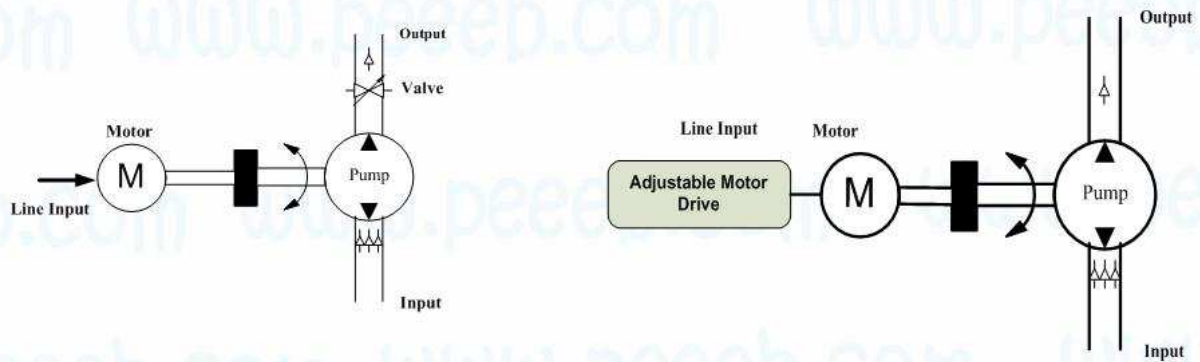


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Applications of Power Electronics

A variable-speed drive system

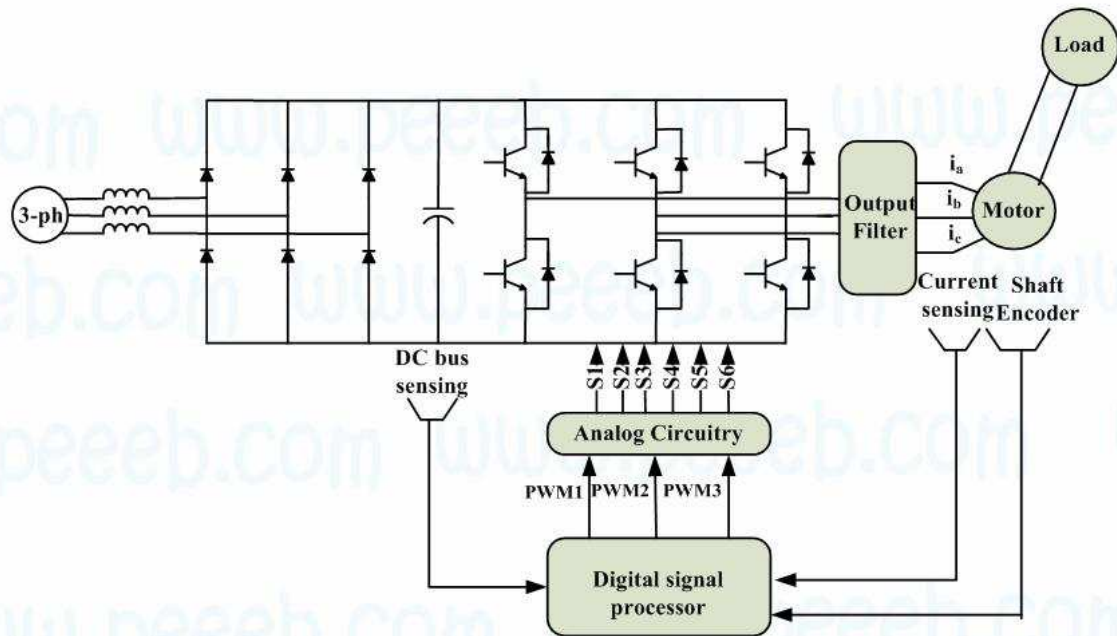


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Applications of Power Electronics

A Motor Drive System: a feedback control loop, A gate drive circuitry, A 3-phase diode rectifier and inverter.

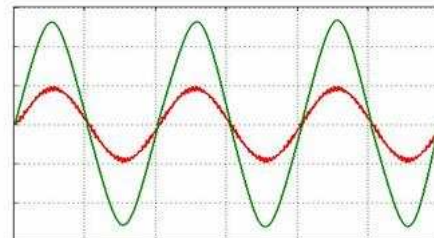
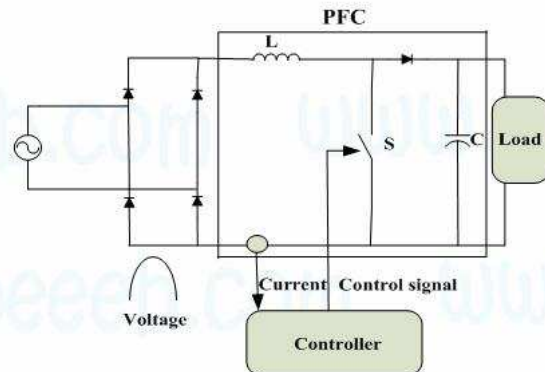
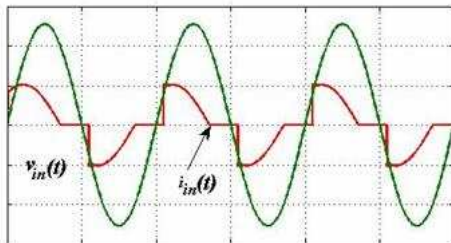
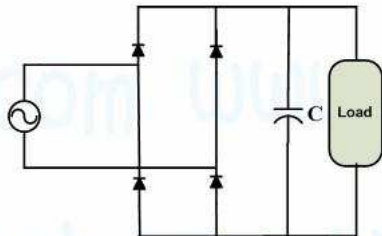


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Applications of Power Electronics

In high power AC-DC converters, the input voltage is supplied from a power grid through a diode rectifier. The line current harmonics must be reduced according to IEC standard. We need to control the input current and shape it to a sine wave using a Power Factor Correction with high switching frequency Converter.

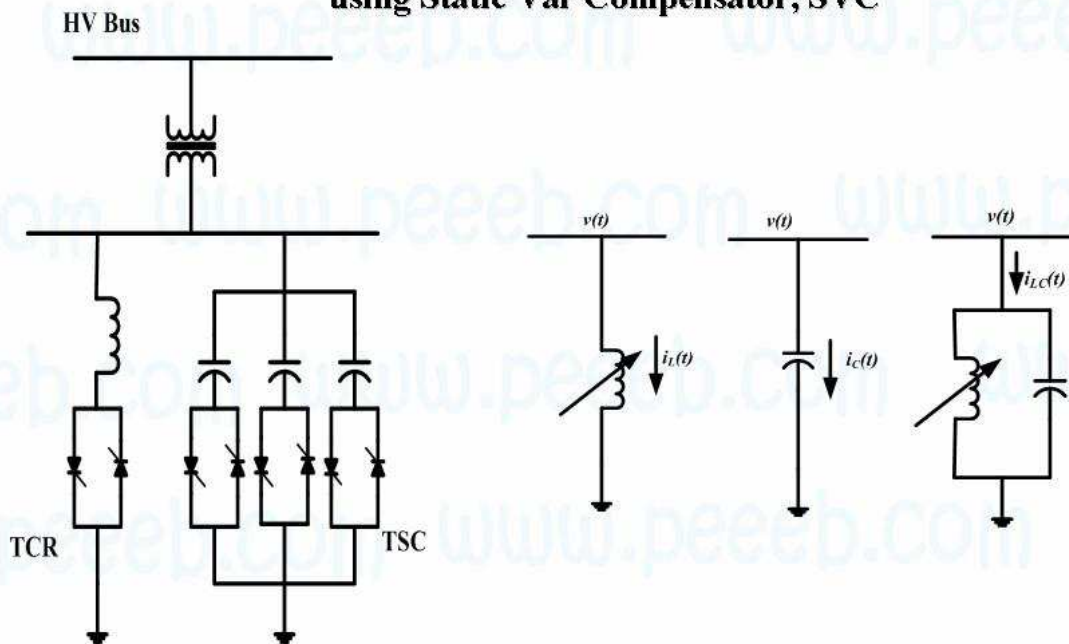


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Applications of Power Electronics

Power System Control: Reactive Power Control using Static Var Compensator, SVC

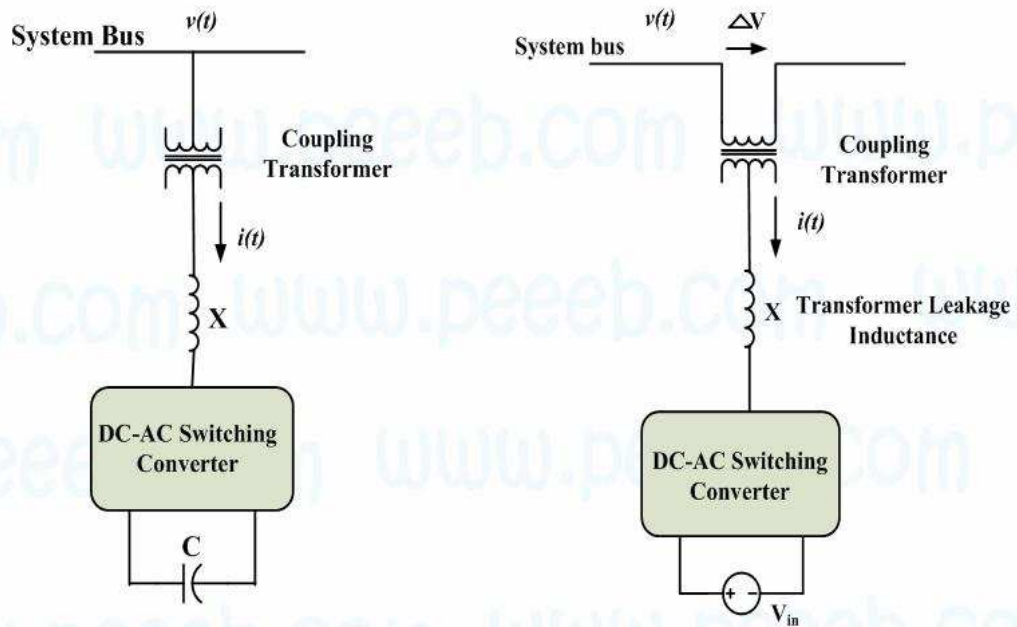


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Applications of Power Electronics

Power System Control, Shunt and Series Compensators



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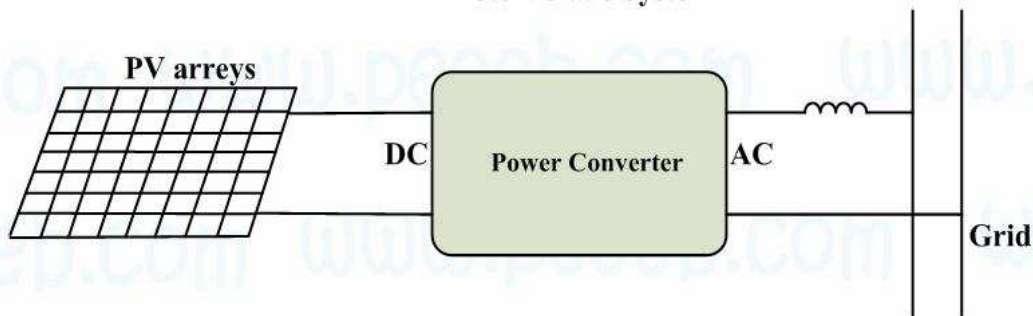
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Applications of Power Electronics

Photo Voltaic Systems

In renewable systems, an unregulated voltage has to be converted to a sine wave at grid frequency and export the power into the power system.

Photo Voltaic System

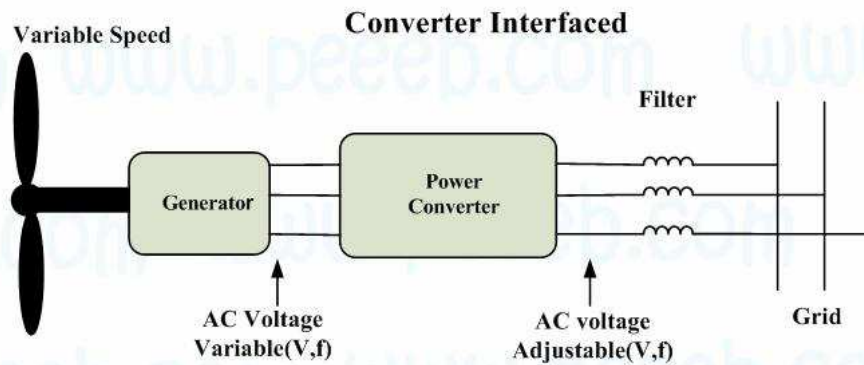


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Applications of Power Electronics

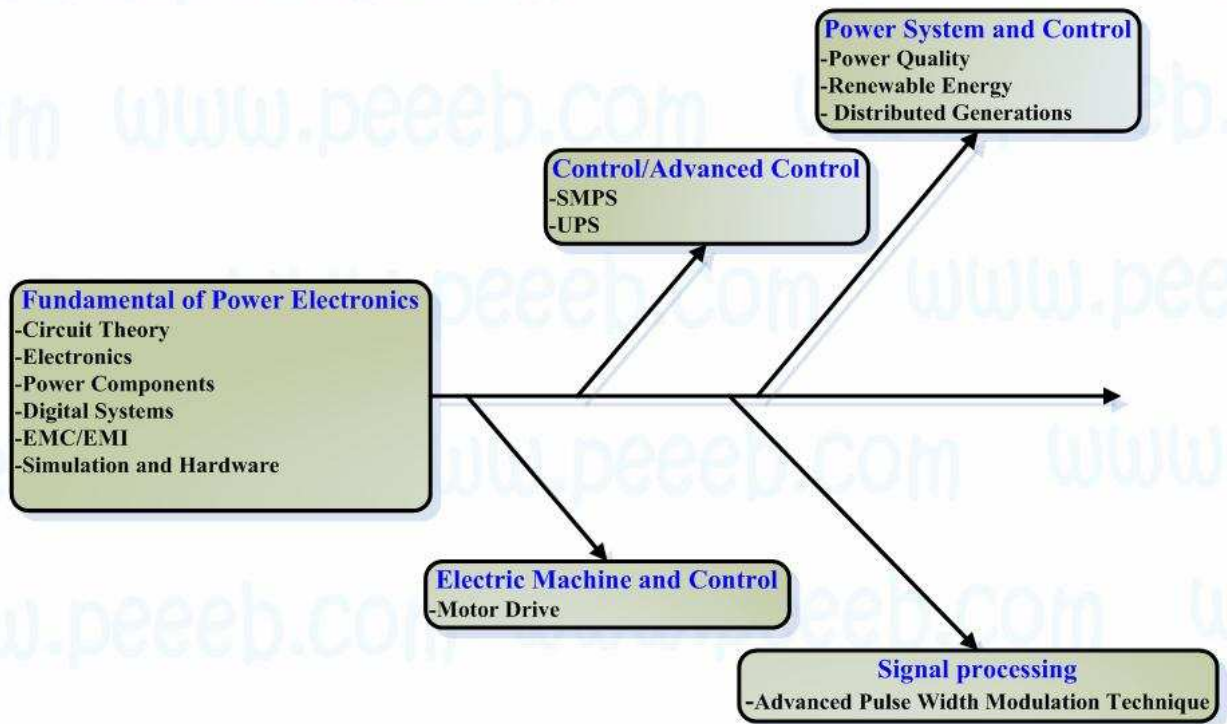
Wind turbines generate variable voltage in magnitude and frequency due to the fact that the wind speed and power is not constant over a day. In order to transfer power from the generator into a grid, a power converter is required to adjust the frequency and magnitude.



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