Nadar Saraswathi College of Engineering & Technology

NSCET E-LEARNING PRESENTATION

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ELECTRICAL AND ELCTRONICS ENGINEERING

IVth YEAR / VIIIth SEMESTER

EE6009 – POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

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UNIT 03 – Power Converters

Develop a passion for learning. If you do you will never cease to grow.

-Antony J.D’Angelo

UNIT-3

Solar:

- ► Block diagram of solar photo voltaic system
- ► line commutated converters (inversion-mode)
- ► Boost and buck-boost converters
- ► selection of inverter, battery sizing, array sizing

Wind:

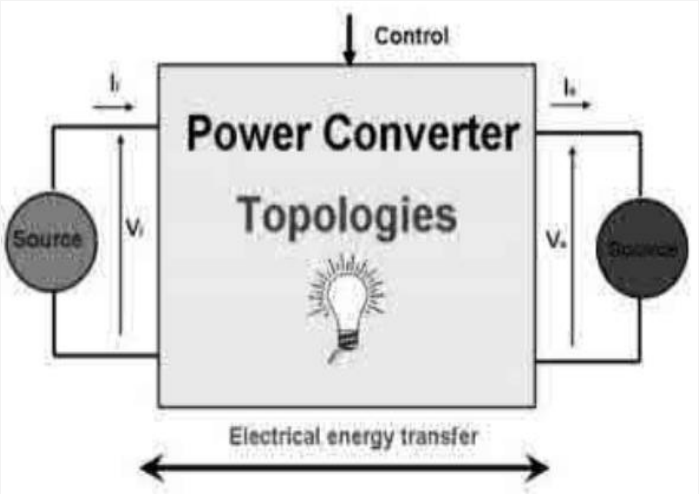
- ► Three phase AC voltage controllers
- ► AC-DC-AC converters
- ► uncontrolled rectifiers
- ► PWM Inverters
- ► Grid Interactive Inverters
- ► matrix converters

Introduction to Power Converters

- The task of a power converter is to process and control the flow of electric energy by supplying voltages and currents in a form that is optimally suited for the user loads.

- They are smaller and lighter and their static and dynamic performances are better.

- Power converter design aims at improving the efficiency.



Solar Photo Voltaic System

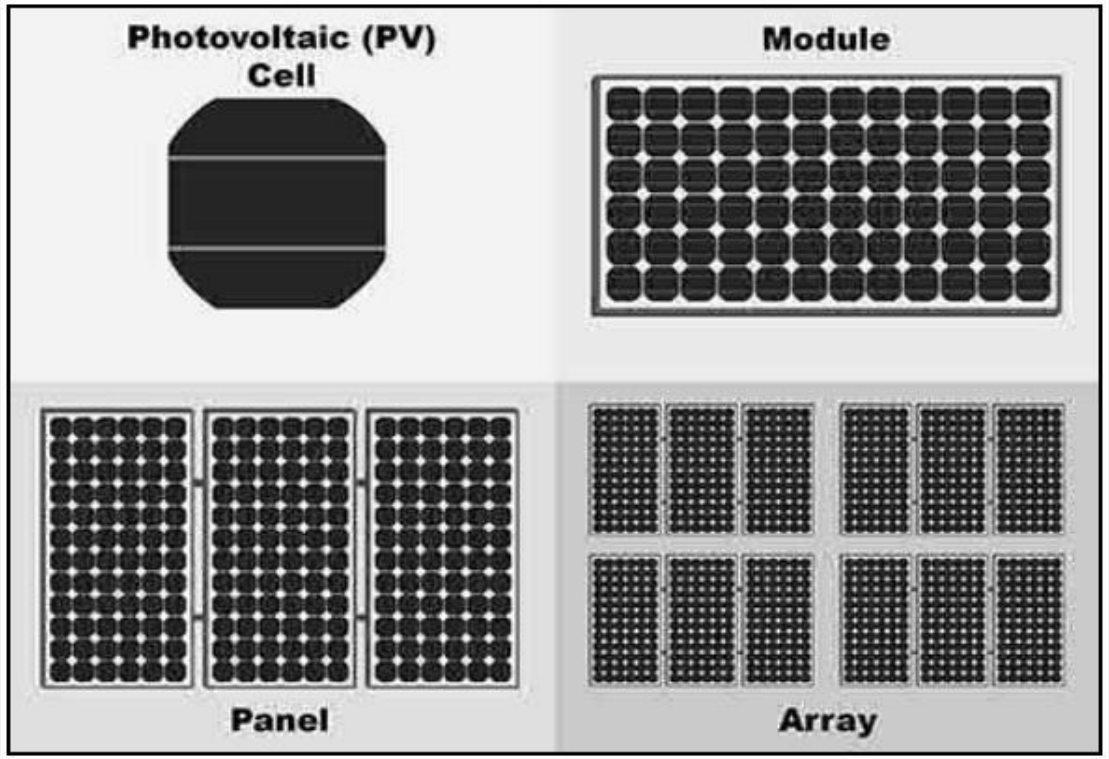
Introduction

- A photovoltaic system, also PV system or solar power system is a power system designed to supply usable solar power by means of photo-voltaic.

- It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity.

- A solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system.

PV module and array



Solar cell

- The solar energy conversion into electricity takes place in a semiconductor device that is called a solar cell. A solar cell is a unit that delivers only a certain amount of electrical power.

PV module

- A number of solar cells have to be connected together to form a solar panel, also called a PV module.

Solar array

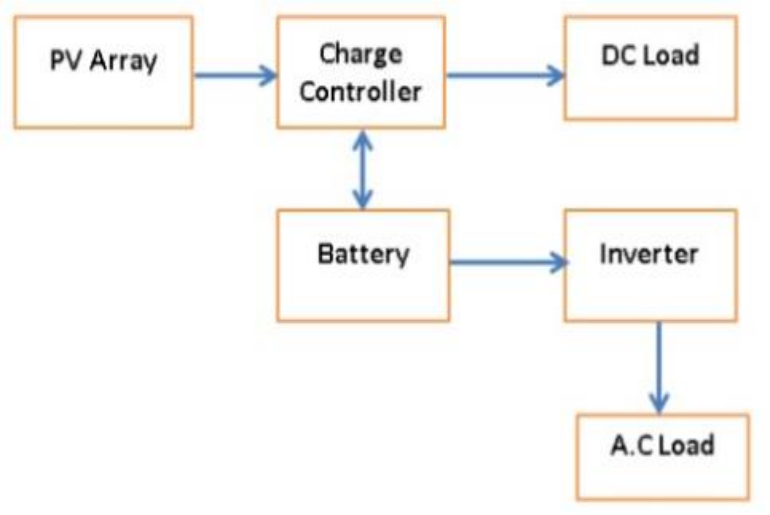
- For large-scale generation of solar electricity the solar panels are connected together into a solar array.

Types of PV systems

Depending on the system configuration,

- Stand-alone PV system
- Grid-connected PV system
- Hybrid PV system

Stand-alone PV system



- Stand-alone systems depend on PV power only.

- These systems can comprise only PV modules and a load or can include batteries for energy storage.

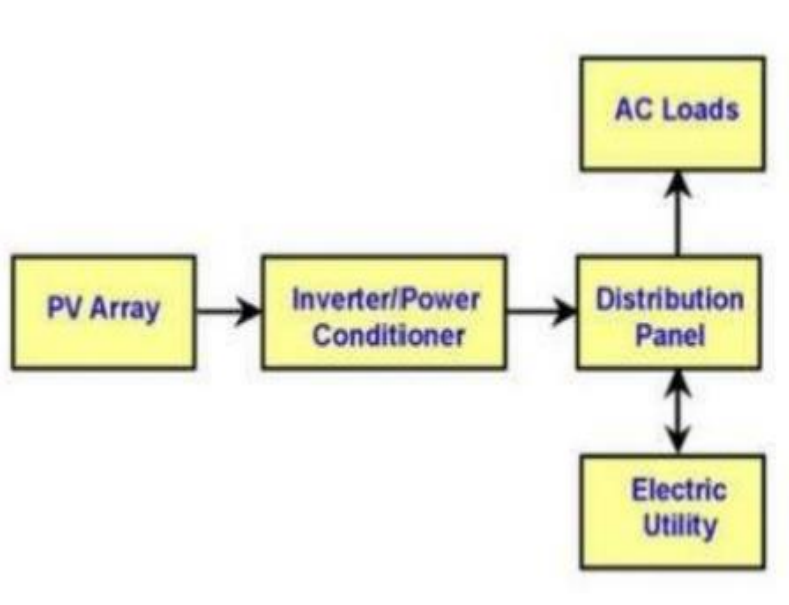
- The batteries must have enough capacity to store the energy produced during the day to be used at night and during periods of poor weather.

Grid connected System

- It is connected to utility grid

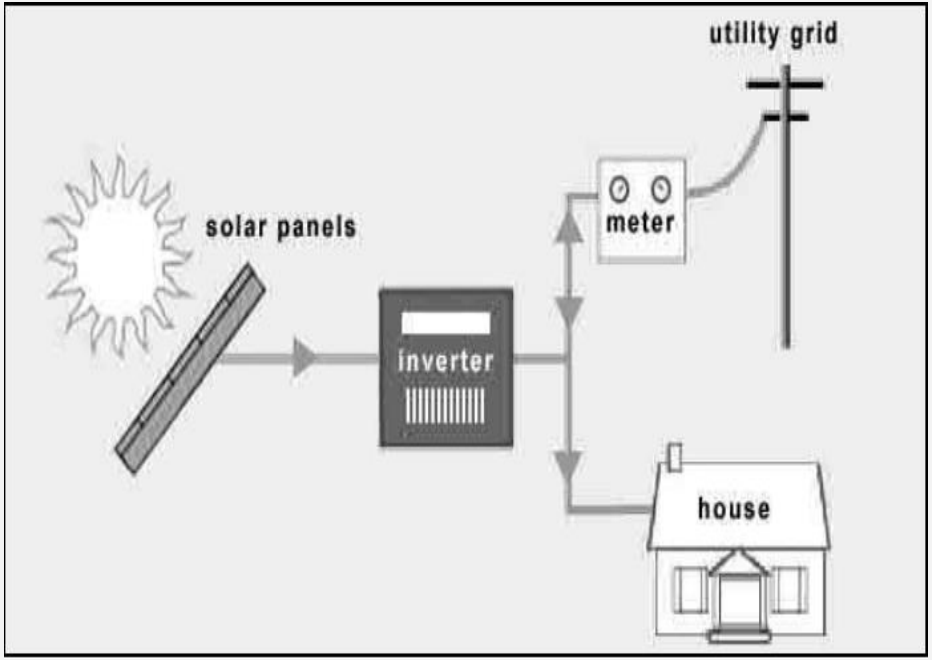
With two way metering system.

- They are connected to the grid through inverters, and do not require batteries because the grid can accept all of the electricity can supply.



Hybrid system

- Hybrid systems consist of combination of PV modules and a complementary means of electricity generation such as a diesel, gas or wind generator.



MPPT

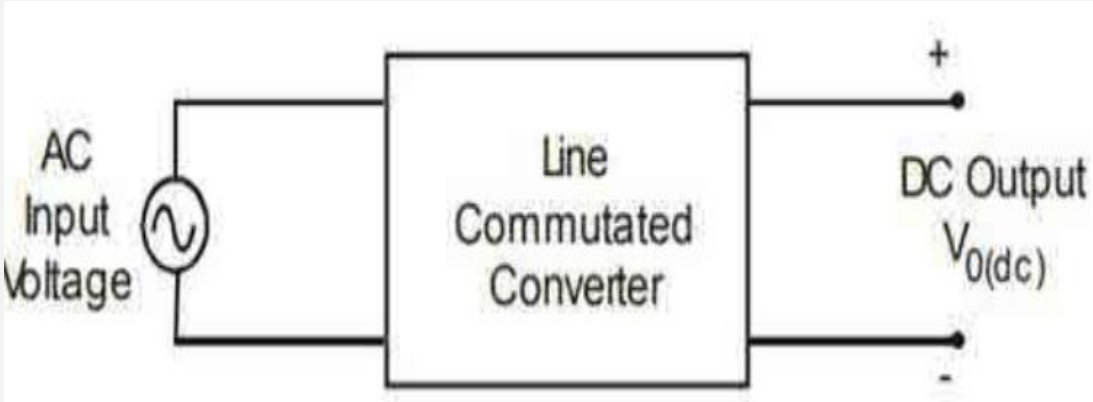
- MPPT(Maximum Power Point Tracking) is an electronic system which commands a solar panel or a set of solar panels to generate the maximum amount of power.

- The MPPT is not a physical system strapped with solar trackers that position the panels so that they remain under the sun at all times.

- This fully electronic system varies the electrical operating point of the panels which enables them to deliver the maximum power.

Line Commutated converters

Introduction to controlled rectifiers



Type of input

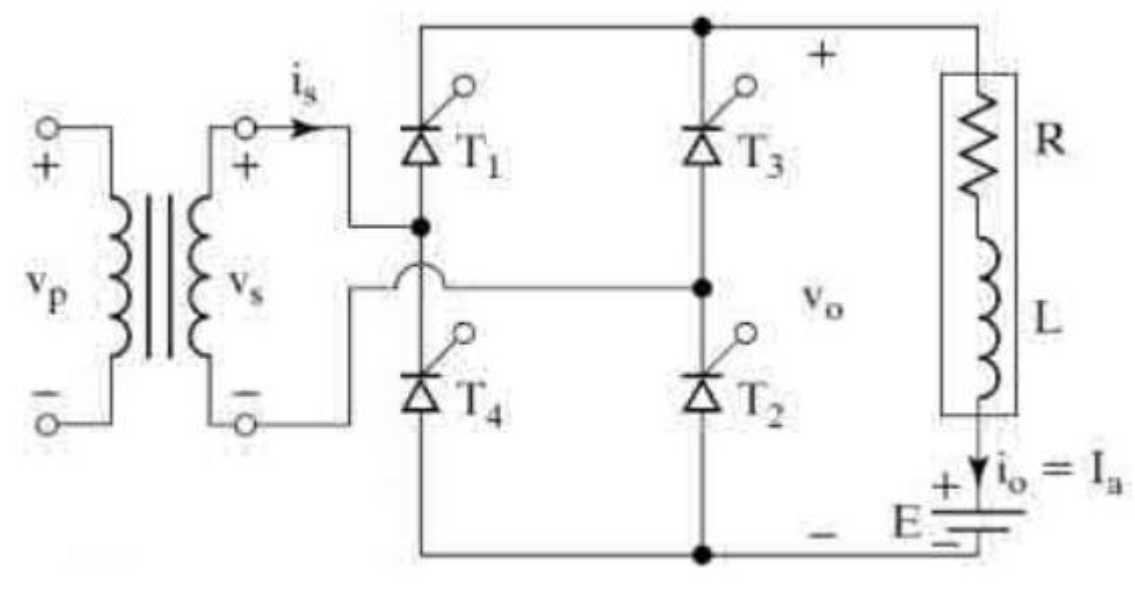
Fixed voltage, fixed frequency ac power supply

Type of output

Variable dc output voltage

Line commutated converters under Inversion mode

Single Phase full converter



- The fully controlled bridge converter consists of four thyristors T1, T2, T3 and T4 connected in the form of full wave bridge configuration.

- During the positive half cycle, thyristors T1 and T2 are forward biased during the time interval ωt = 0 to π.

- As soon as the thyristors T3 and T4 are triggered a reverse voltage appears across the thyristors T1 and T2 and they naturally turn-off and the load current is transferred from T1 and T2 to the thyristors T3 and T4.

Single Phase Dual Converter

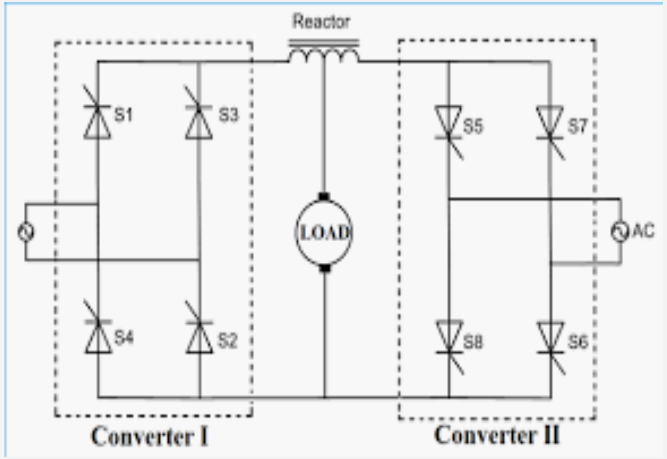
The dual converter system will provide four quadrant operation and is normally used in high power industrial variable speed drives.

<u>Converter 1</u>

provides a positive dc output voltage and a positive dc load current, when operated in the rectification mode.

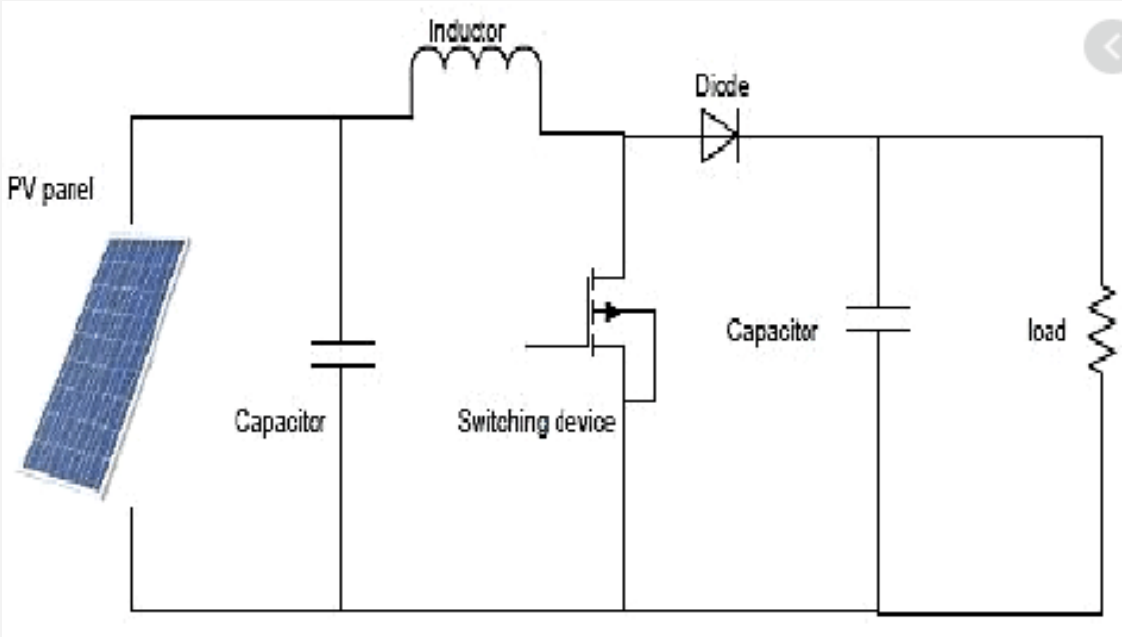
<u>Converter 2</u>

provides a negative dc output voltage and a negative dc load current when operated in the rectification mode.



DC – DC converter

Boost Converter



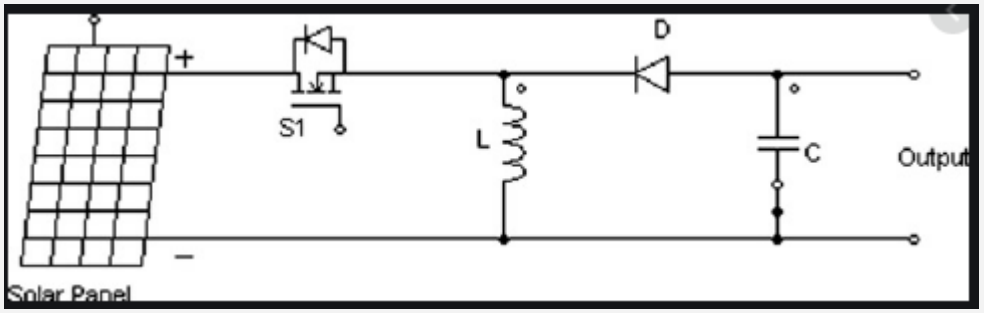
- A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load).

- **When the switch is closed,** current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

- **When the switch is opened,** current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load.

- As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

Buck-Boost Converter



- A Buck-Boost converter is a type of switched mode power supply that combines the principles of the Buck Converter and the Boost converter in a single circuit.

- It provides a regulated DC output voltage from either an AC or a DC input.

Types of modes

- **Continuos conduction mode**

In the continuous conduction mode the current from end to end of inductor never goes to zero. Hence the inductor partially discharges earlier than the switching cycle.

- **Discontinuous conduction mode**

In this mode the current through the inductor goes to zero. Hence the inductor will totally discharge at the end of switching cycles.

Sizing Batteries and Inverters for a solar PV system

Selection of inverters

- Sinusoidal output voltage
- Voltage and frequency within the allowable limits
- Cable to handle large variation in input voltage
- High efficiency at light loads
- Less harmonic generation by the inverter to avoid damage to electronic appliances such as televisions, additional losses, and heating of appliances

- Ability to withstand overloading for a short term to take care of higher starting currents from pumps, refrigerators, etc.
- Surge capacity
- Low no load losses
- Low battery voltage disconnect
- Low audio and RF noise

Battery Sizing

- Battery sizing might mean simply providing enough storage to carry the load through the night and into the next day until the sun picks up the load once again.

- These are typically lead acid batteries that may or may not require maintenance.

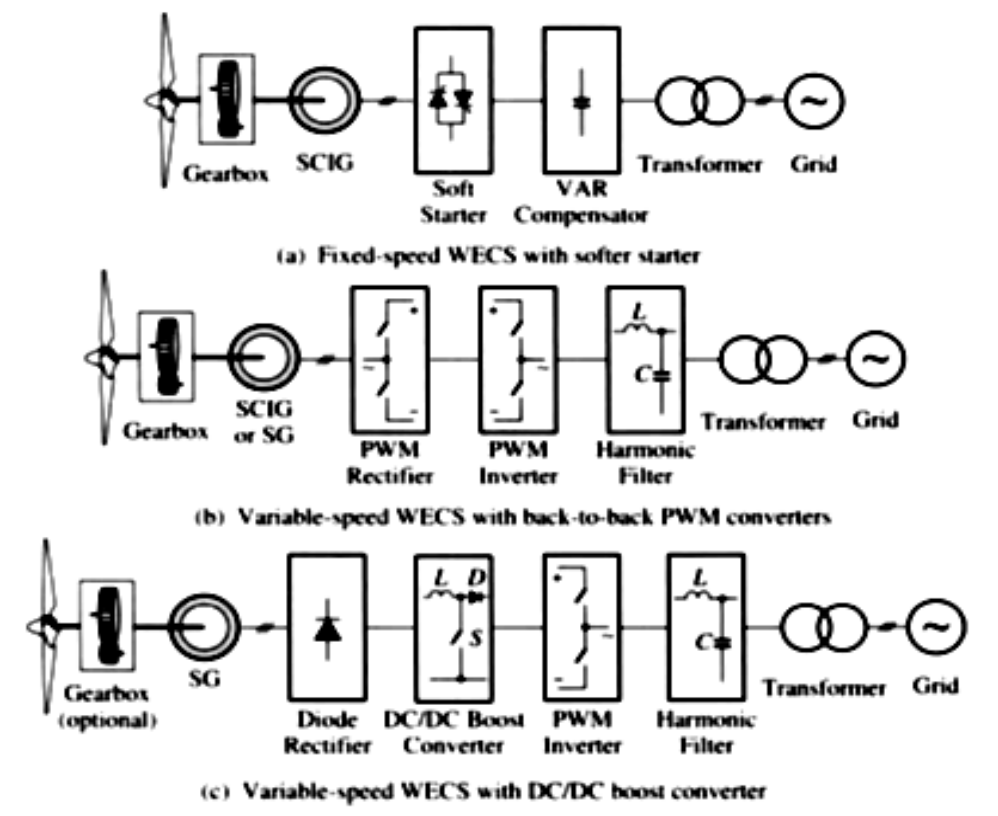
- Batteries have energy storage ratings mentioned in Amp-hour (Ah) or milli-Amp-hour (mAh). They also have a nominal voltage that they generate (typically deep discharge batteries are 12 V batteries, cell phone batteries are 5 V batteries, etc).

- To calculate total energy of battery,
  Units = (Volt x Ah) ÷1000 or (Volt x mAh) ÷1000000.

Array sizing

- To size a PV panel, the most essential thing to know is the Total Units consumed in a day by the appliances in a setup.
- The size of PV system should not be less than the one that can generate total units consume in a day.
- Every PV panels has a peak wattage (Wp) mentioned on them.1 KWP (or peak kilo watt) system would generate 5 to 7 units in a day.
- Thus the right size of PV system (in kWp) should be estimated by dividing maximum daily usage units divided by 5.
- If grid connected system where extra electricity produced will be sold back to the electricity provider.

Typical WECS using different power converter topologies



Three Phase AC Voltage Controller

- Two thyristors connected back to back, or a triac, is used for each phase in most of the circuits as described.
- The three-phase loads (balanced) are connected in star or delta.
- It is composed of three pairs of SCR thyristors connected between the three-phase power supply and the load.
- There are many types of circuits used for the three-phase ac regulators (ac to ac voltage converters), unlike single-phase ones.

Control Strategies

Two control strategies are used to control the power flow in AC voltage regulators

- Phase angle control
- Integral cycle switching control

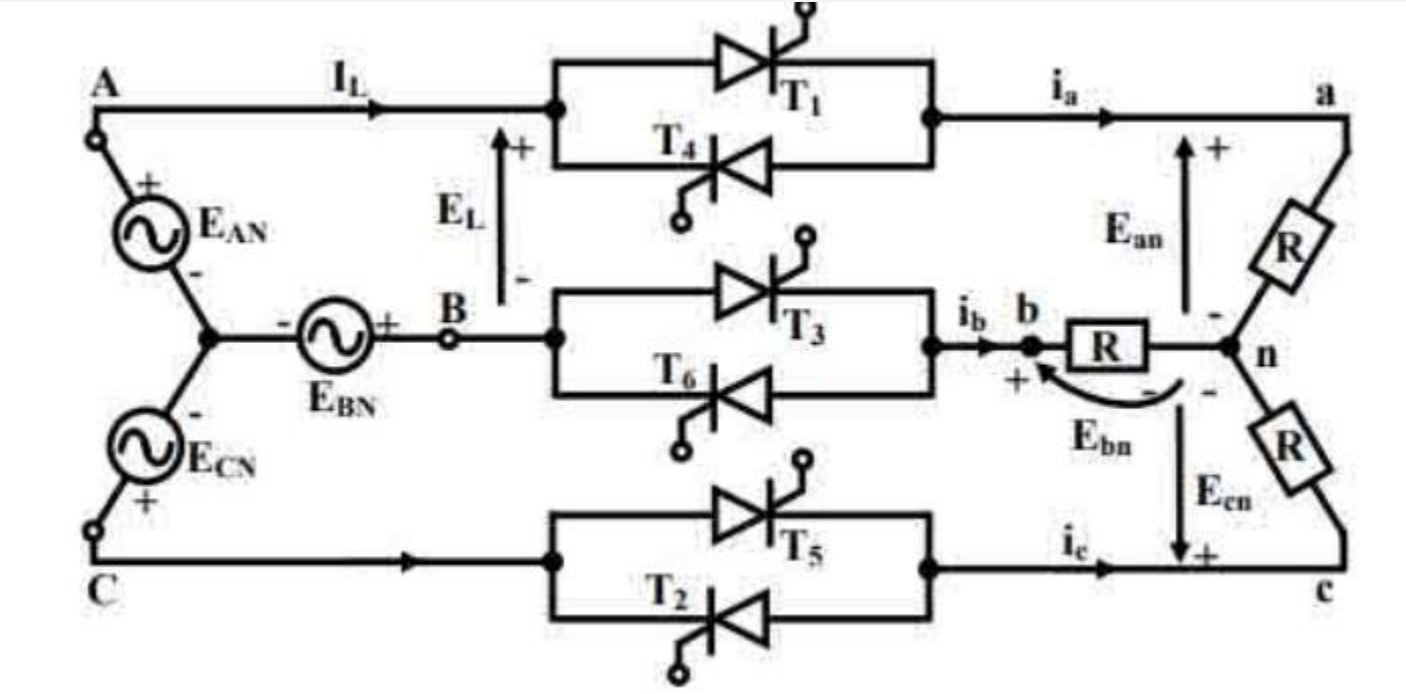
- **Phase angle control**

In this method, the output voltage is controlled by triggering the SCRs. By varying the firing angle the rms value of output voltage is varied.

- **Integral cycle switching control**

Switching on the supply to the load for an integral number of cycles and switching off the supply for a further number of integral cycles.

Three phase star connected AC regulator with Balanced resistive load



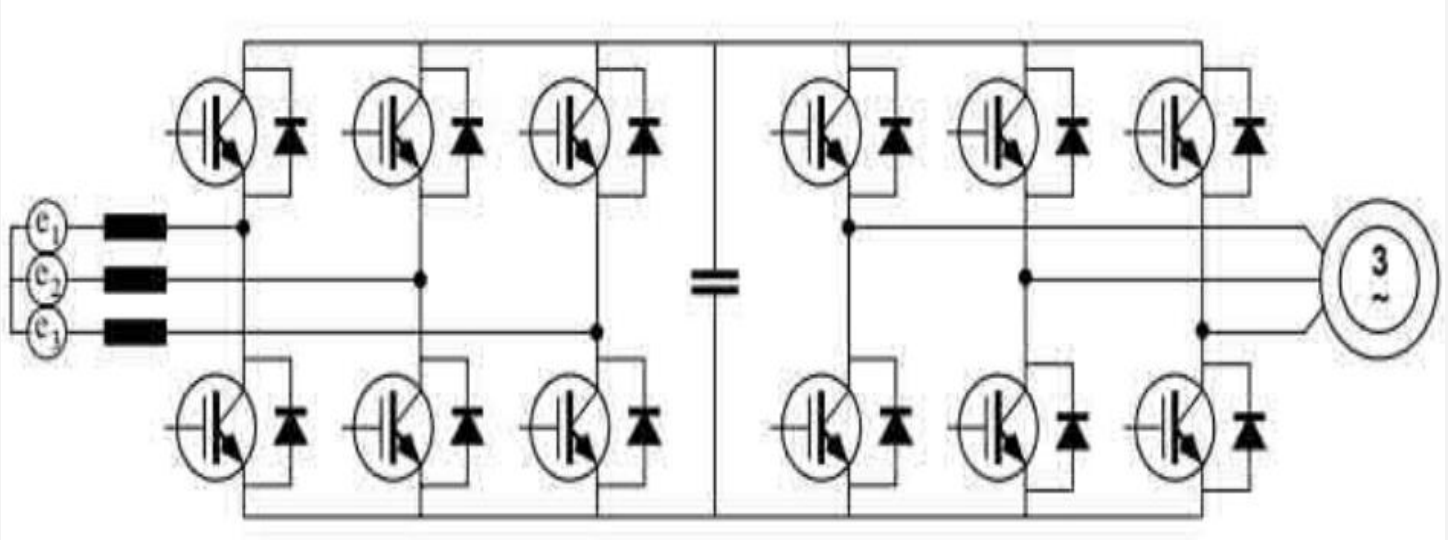
- Two thyristors connected back to back are used per phase, thus needing a total of six thyristors.
- The current flow is bidirectional, with the current in one direction in the positive half, and then, in other (opposite) direction in the negative half.
- Two thyristors connected back to back are needed in each phase. The turning off of a thyristor occurs, if its current falls to zero.
- To turn the thyristor on, the anode voltage must be higher that the cathode voltage, and also, a triggering signal must be applied at its gate.

- The expression of the RMS value of output voltage is obtained by per phase for balanced star-connected resistive load which depends on range of firing angle.

- If is the RMS value of the input voltage per phase, and assuming the voltage, as the reference, the instantaneous input voltages per phase are,

$$e_{AN}=\sqrt[2]{2}E_s\text{Sin}\omega t$$
$$e_{AN}=\sqrt[2]{2}E_s(\text{Sin}\omega t\text{-}120)$$
$$e_{AN}=\sqrt[2]{2}E_s(\text{Sin}\omega t\text{+}120)$$

Three Phase AC-DC-AC converters(Back to Back converter)



- The back-to-back converter is consists simply of a force-commutated rectifier and a force-commutated inverter connected with a common dc-link.

- The properties of this combination are well known; the line-side converter may be operated to give sinusoidal line currents, the dc-link voltage must be higher than the peak main voltage

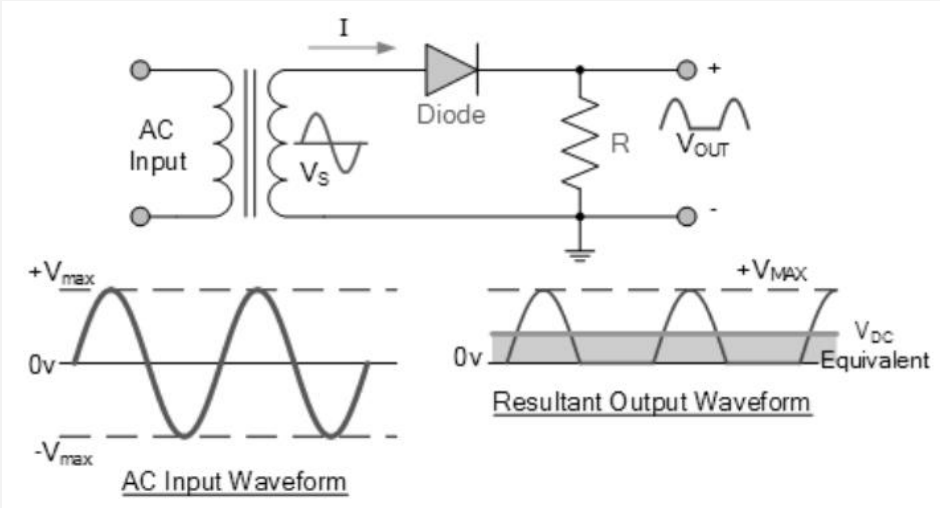
- The dc-link voltage is regulated by controlling the power flow to the ac grid and, finally, the inverter operates on the boosted dc-link, making it possible to increase the output power of a connected machine over its rated power.

- An important property of the back-to-back converter is the possibility of fast control of the power flow.
- By controlling the power flow to the grid, the dc-link voltage can be held constant.
- The presence of a fast control loop for the dc-link voltage makes it possible to reduce the size of the dc-link capacitor, without affecting inverter performance.
- The capacitor can be made small enough to be implemented with plastic film capacitors.

Uncontrolled Rectifiers

- A rectifier is a circuit which converts the Alternating Current (AC) input power into a Direct Current (DC) output power.

Half wave rectifier circuit



- The power diode in a half wave rectifier circuit passes just one half of each complete sine wave of the AC supply in order to convert it into a DC supply. So it is called half wave rectifier.

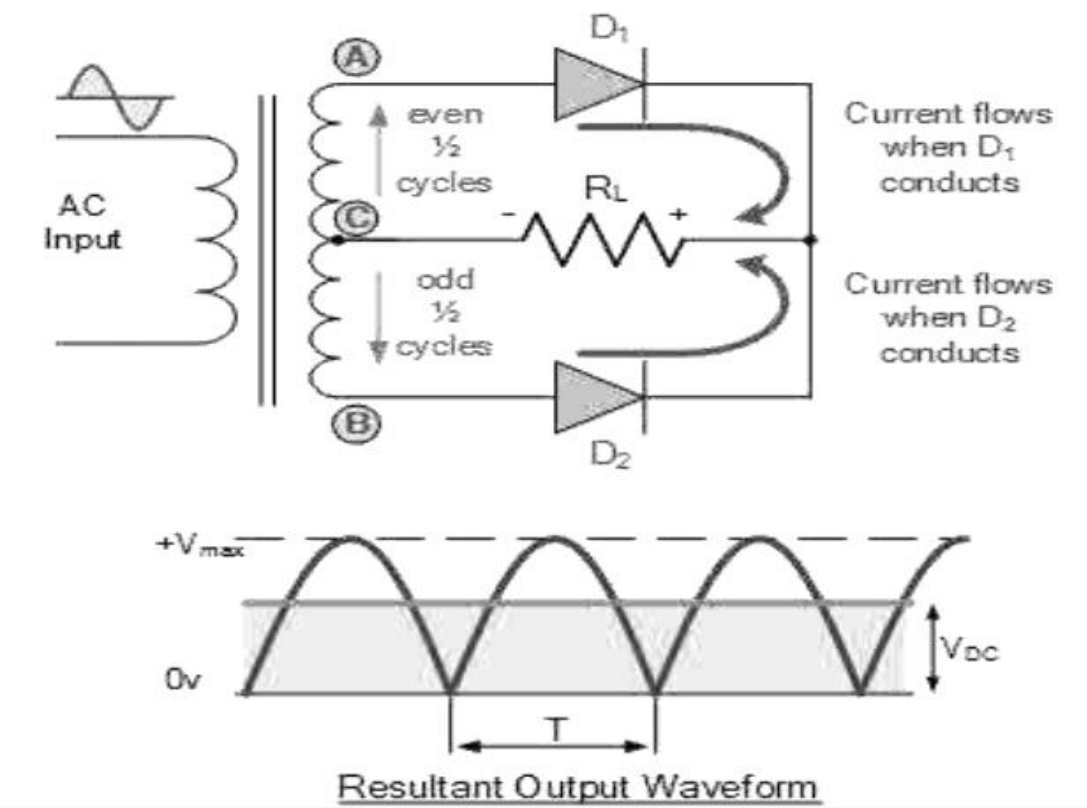
Positive half cycle

- The diode is forward biased as the anode is positive with respect to the cathode resulting in current flowing through the diode.

Negative half cycle

- The diode is reverse biased as the anode is negative with respect to the cathode.

Full Wave Rectifier Circuit



- The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance (RL) with each diode taking it in turn to supply current to the load.

Positive Half cycle

- When point A of the transformer is positive with respect to point C, diode D1 conducts in the forward direction.

Negative half cycle

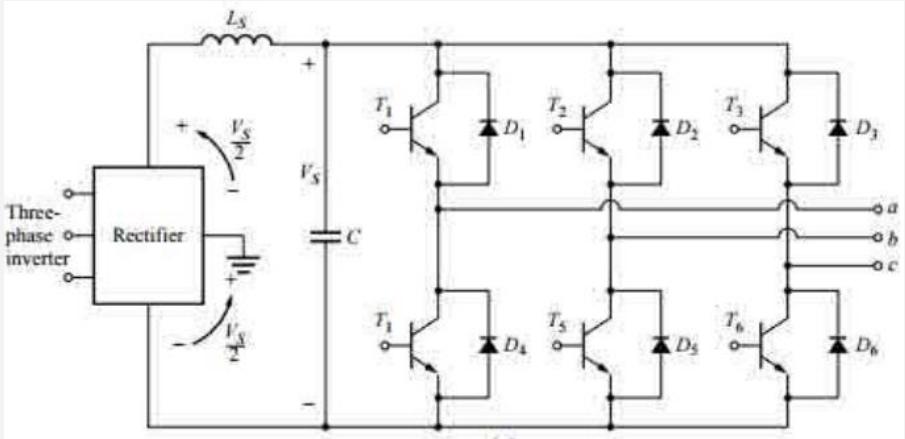
- When point B is positive with respect to point C, diode D2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles.

Pulse Width Modulated(PWM) Inverter

- Pulse width modulated (PWM) inverters are among the most used power-electronic circuits in practical applications.
- These inverters are capable of producing ac voltages of variable magnitude as well as variable frequency.
- The PWM inverters are very commonly used in adjustable speed ac motor drive loads where one needs to feed the motor with variable voltage, variable frequency supply.

- The aim is to generate an output voltage, which after some filtering, would result in a good quality sinusoidal voltage waveform of desired fundamental frequency and magnitude

- Unlike in square wave inverters the switches of PWM inverters are turned on and off at significantly higher frequencies than the fundamental frequency of the output voltage waveform.



Grid Interactive(Grid Tie)Inverter

- A grid-tie inverter converts direct current (DC) into an alternating current (AC) suitable for injecting into an electrical power grid, normally 120V RMS at 60Hz or 240V RMS at 50 Hz.

- Grid-tie inverters are used between local electrical power generators: solar panel, wind turbine, hydro-electric, and the grid.

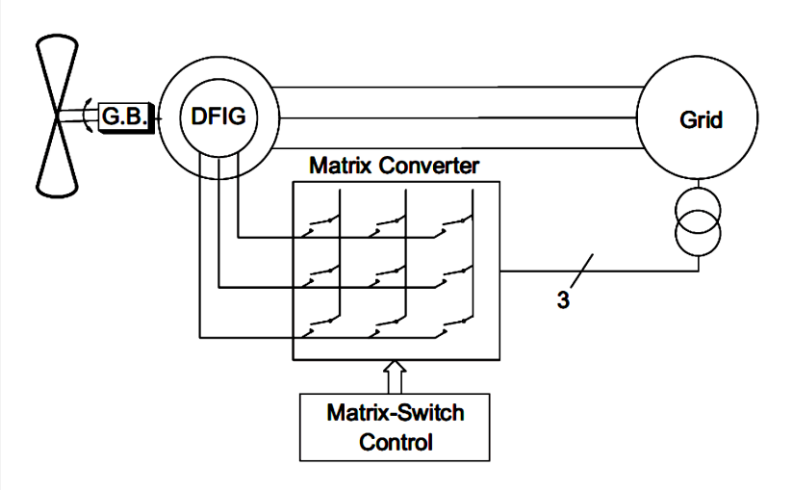
- In order to inject electrical power efficiently and safely into the grid, grid-tie inverters must accurately match the voltage and phase of the grid sine wave AC waveform.

Matrix Converter

- The matrix converter is capable of converting the variable AC from the generator into constant AC to the grid in one stage.
- The main advantage of matrix converter is elimination of dc link filter.
- Matrix converter has a maximum input output voltage transfer ratio limited to 87 % for sinusoidal input and output waveforms, which can be improved.
- Further, matrix converter requires more semiconductor devices than a conventional AC-AC indirect power frequency converter.

- The matrix converter replaces the multiple conversion stages and the intermediate energy storage element by a single power conversion stage, and uses a matrix of semiconductor bidirectional switches connecting input and output terminals.

DFIG with matrix converter



- The matrix converter consists of nine bi-directional switches (18 total), arranged in a manner such that any input phase may be connected to any output phase at any time.

- Each individual switch is capable of rectification and inversion. The matrix converter is controlled using double space vector PWM, employing the use of input current and output voltage SVM.

- One of the major drawbacks of a matrix converter is that 18 total switches are required, causing an increase in converter semiconductor cost.

Thank You