MODULE: 4

Inverter

It is a device that converts dc power in to ac power at desired output voltage and frequency.

Requirement of a practical inverter

1. The voltage source inverter will produce an output voltage or current to required ranges and frequencies.
2. Power factor of an inverter ranges from 0.6 to 0.8
3. VA rating of inverter= Power Required/Power Factor
4. The inverter must have limited starting current.
5. It must possess efficient energy saving property.
6. An inverter with less noise is preferred.
7. The output voltage of an inverter must be pure sine wave, sometimes it may be square wave.
8. Pure sine wave inverters will have great accuracy and less power loss. But the cost is high.

Classification of Inverters

(I) According to the Output Characteristic

1. Square Wave Inverter
2. Sine Wave Inverter
3. Modified Sine Wave Inverter

(II) According to the Source of Inverter

1. Current Source Inverter (CSI)
2. Voltage Source Inverter (VSI)

(III) According to the Type of Load

1. Single Phase Inverter
   a) Half Bridge Inverter b) Full Bridge Inverter

1. Three Phase Inverter
   a) 180-degree mode Inverter b) 120-degree mode Inverter

IV) According to different PWM Technique

1. Single Pulse Width Modulation (SPWM)

2. Multiple Pulse Width Modulation (MPWM)
3. Sinusoidal Pulse Width Modulation (SPWM)

(V) According to the connection

1. Series Inverter
2. Parallel Inverter

(a) Voltage source inverter (VSI)

- In VSI, output DC voltages are not affected by load.
- Output current waveform is dependent on the nature of load.
- If VSI is made up of SCR, forced commutation circuits is required.

(b) Current source inverter

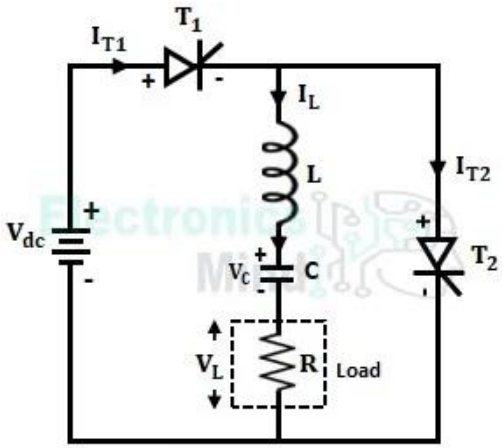
- A current source inverter is fed from a dc current source.
- Output voltage is not affected by load.
- Power semiconductors in CSI have to withstand reverse voltage, so SCR is used.

Comparison of VSI and CSI

VSI	CSI
VSI is fed from a DC voltage source having small or negligible impedance	CSI is fed from a DC source having high impedance
Input voltage is maintained constant	Input current is made constant
The output voltage does not depend on load	The output current does not depend on load
The load current waveform and magnitude depends upon load impedance	The load voltage waveform and magnitude depends upon load impedance
Commutation circuit is complicated	Commutation circuit is simple

Series Inverter

- Inverters in which commutating components are connected in series with load are called series inverters.
- Also called self-commutated inverters or load commutated inverters.
- Used in induction heating, fluorescent lighting etc.
- These inverters are operated at high frequencies and hence small commutating elements.
- Circuit consists of Thyristor T1, T2 and a load R which is connected in series with the commutating elements L and C



Series Inverter

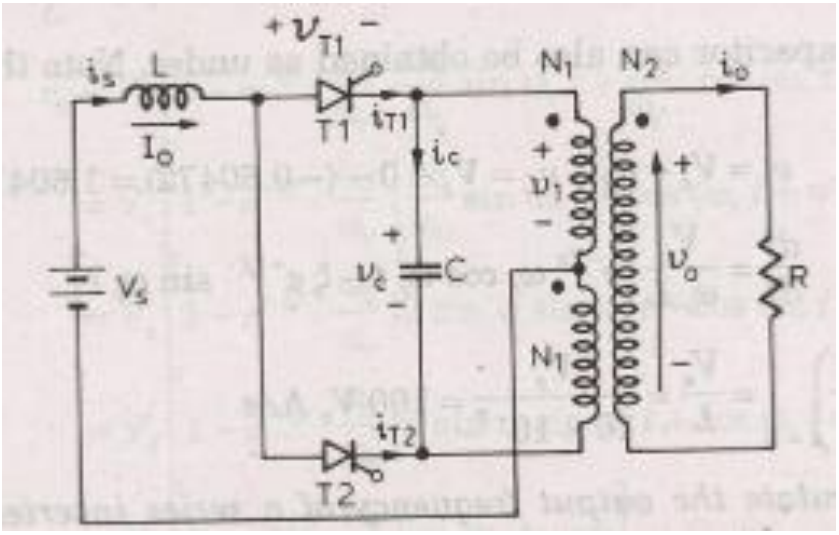
- Mode 1: T1 is ON, T2 is OFF. The circuit current is flowing through T1, L, C, R. the capacitor and inductor charges with this polarity
- Mode 2: Both T1 and T2 are OFF. The charge in the capacitor commutated the thyristor T1. No output current is flowing in this Mode
- Mode 3: T1 OFF, T2 ON. The capacitor and inductor discharged through T2 and the load current is reversed.

Parallel Inverter

It consists of Two Thyristors T1, T2, Inductor, Capacitor C and a Transformer.

❖ Inductor connected in series with the source to improve the load current as constant.

❖ Capacitor is the commutating element connected in parallel with the load.



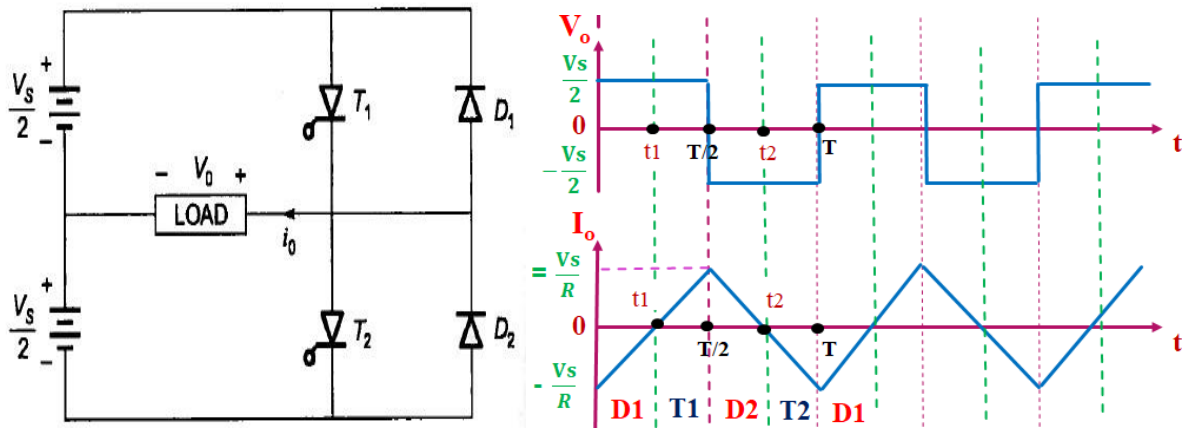
❖ Transformer having turns ratio from each primary half to secondary is one

❖ Mode 1: T1 is ON, T2 is OFF. The current is flowing through the upper half of the transformer. This current produces the same flux in the lower half and hence the voltage across the primary winding is 2Vs. This voltage charges the capacitor to 2 Vs and this voltage commutated T1.

❖ Mode 2: T2 is ON, T1 is OFF. Current flows through the lower part of primary and the total voltage across primary winding charges capacitor in the opposite polarity. It will turn off T2.

❖ Mode 3: time between T1 is turned OFF and T2 is ON. Time b/w T2 is OFF and T1 is ON. In both cases the charged capacitor gets discharged in the same direction as if flows

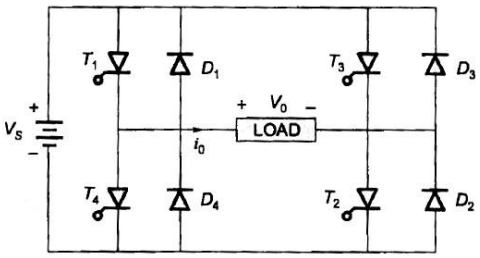
Single phase half bridge Inverter (with RL load)

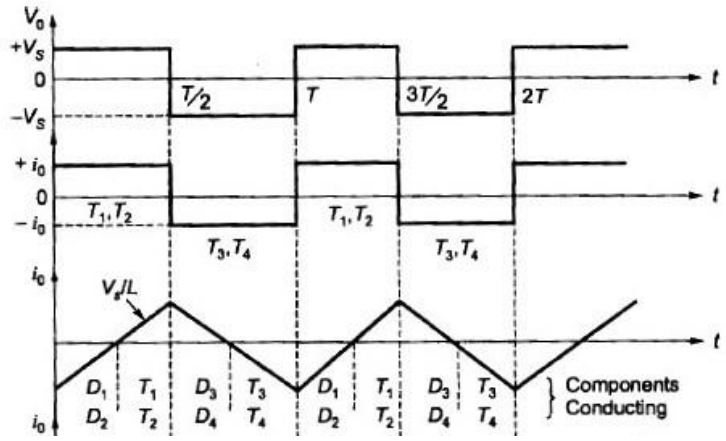


- Consist of two SCR T1 T2 and Two feedback diodes D1 D2.

- When T1 is triggered ON, the circuit is completed through Vs/2, T1, load. (0<t<T/2)
- After T1 turned OFF, due to RL load the load current could not be zero and the charged inductor take a path through D2 to discharge.
- At t=T/2, T1 is turned off by forced commutation and turned on the thyristor T2.
- After T2 is turned OFF, the negative load current flows through the diode D1.

Single phase full bridge Inverter (with RL load)



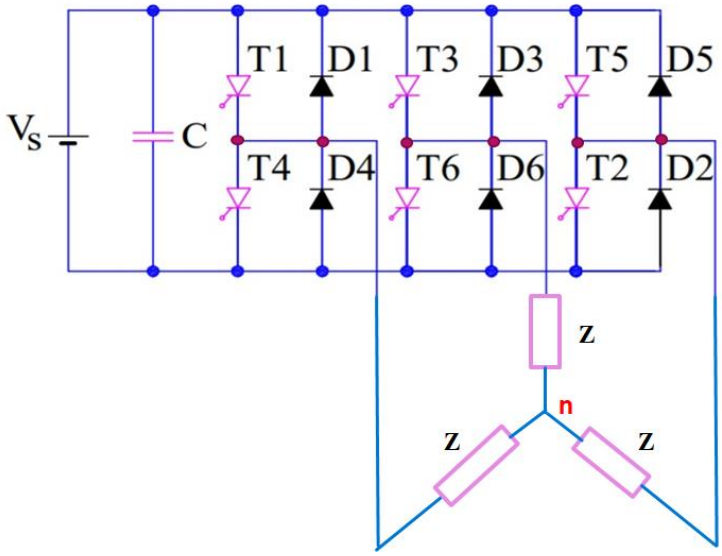


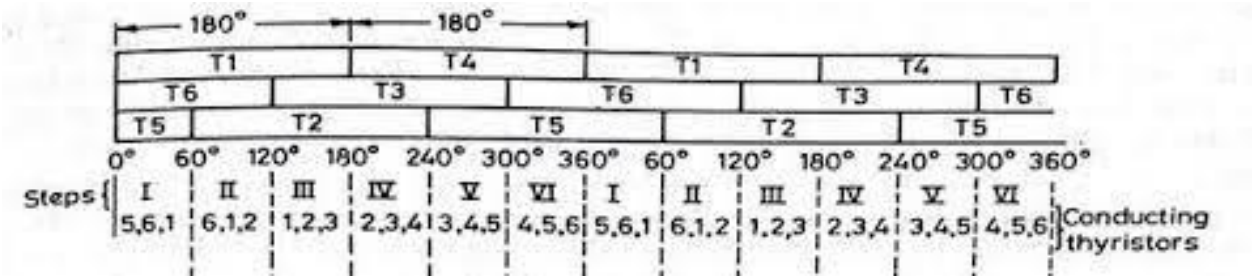
- Before t=0, Thyristor T3 and T4 were conducting, load current from B to A
- At t=0, T3 and T4 are turned off by forced commutation.
- Due to inductive load, current cannot change direction immediately, D1 and D2 gets turned on and load current flows against supply voltage T1 and T2 are gated at t=0, but they won't turn on because they are reverse biased by voltage across D1 and D2

- When current through D1 and D2 falls to zero, T1 and T2 gets forward biased by source voltage and gets turned on as they are given gate pulse for current flows from A to B
- T1 and T2 is turned off by forced commutation at T/2.
- D3 and D4 gets turned on to allow current flow in same direction due to inductive load.
- Even though T3 and T4 are given gate pulses at T/2, they won't turn on because they are reverse biased by voltage across D3 and D4
- When current through D3 and D4 falls to zero, T3 and T4 gets turned on and conduct current from B to A

Three phase bridge inverter

- ✓ A three-phase inverter is a six-step bridge inverter.
- ✓ It consists of 6 SCRs and 6 diodes.
- ✓ There are 2 type conduction mode
  - ❖ 180° Conduction mode: Each SCR conducts for 180°
  - ❖ 120° conduction mode: Each SCR conducts for 120°





- ✓ Positive group SCRS = T1, T3,T5
- ✓ Negative group SCRs = T4, T6, T2
- ✓ A capacitor is connected across input supply to make the input dc voltage constant, also reduces the harmonics.
- ✓ In 180° conduction mode,

  During (0 - 60): T1, T6, T5 conducts

  During (60 - 120): T1, T6, T2 conducts

  During (120 - 180): T1, T3, T2 conducts

  During (180 - 240): T4, T3, T2 conducts

  During (240 - 300): T4, T5, T3 conducts

  During (300 - 360): T4, T6, T5 conducts

Pulse width Modulation (PWM)

Pulse width modulation is a method of reducing the average power delivered by an electrical signal by chopping into discrete parts.

Types of PWM techniques

1.Single pulse width modulation

2.Multiple pulse width modulation

3.Sinusoidal pulse width modulation.

4.Phase displacement control.

Single pulse width modulation

- In this method, only one pulse per half cycle is used.

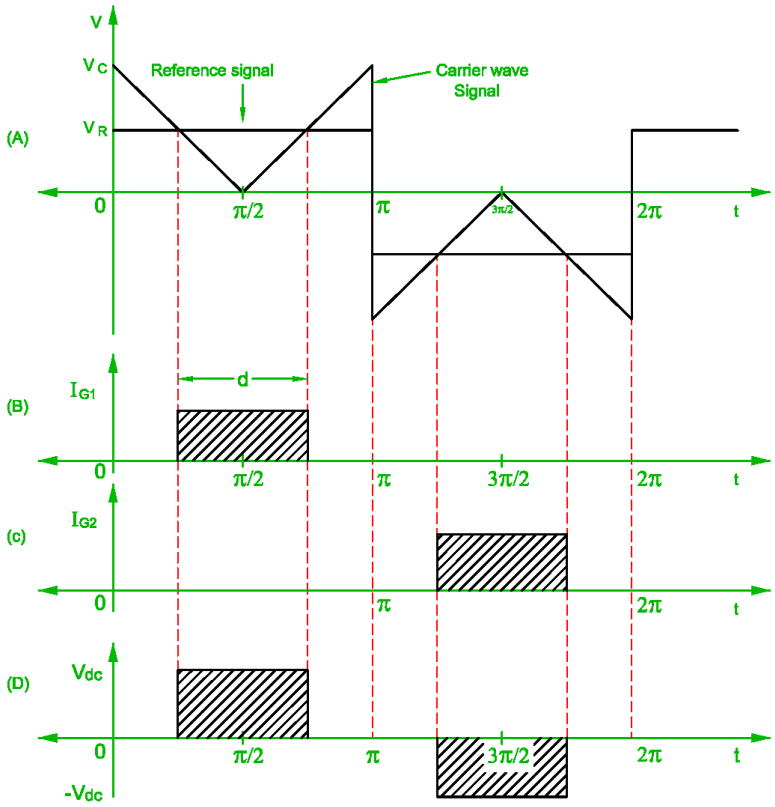
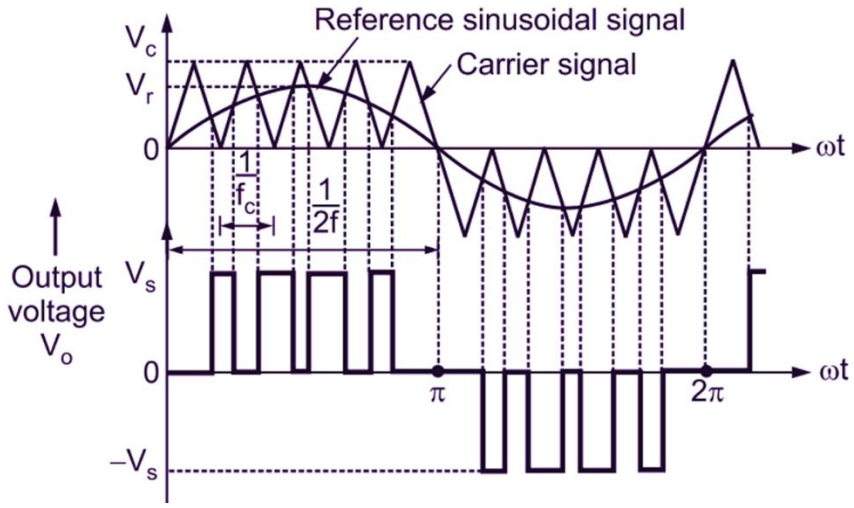


FIG H : SINGLE PULSE WIDTH MODULATION

- The width of pulse is varied to control the output of inverter
- The rectangular reference signal V_R is compared with the triangular wave of amplitude V_c
- When the reference signal amplitude is higher than carrier signal during the positive half cycle, a gate signal IG_1 generated.
- Similarly, during negative half cycle, gate signal IG_2 generated.

Sinusoidal pulse width modulation

- Reference wave is sinusoidal signal.
- Carrier signal is triangular signal.
- A high frequency triangular carrier wave is compared with a sinusoidal reference signal

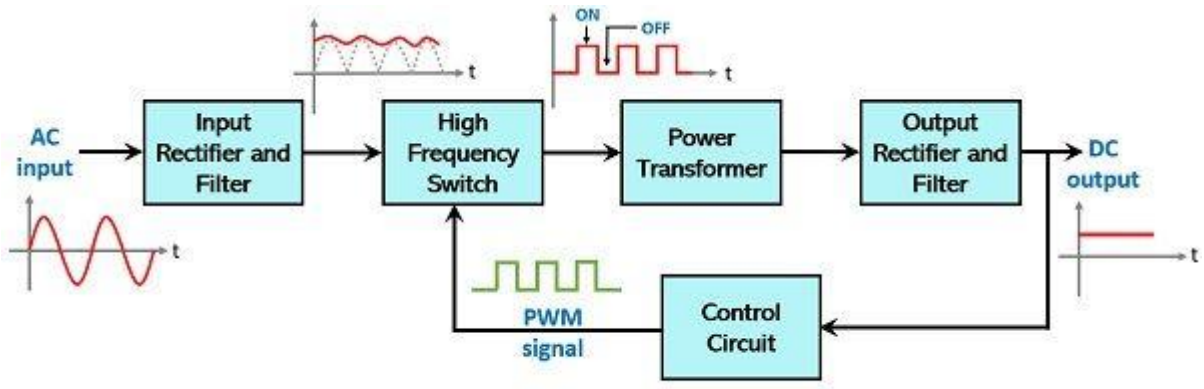


- When a sinusoidal wave has magnitude higher than the triangular wave, the comparator output is high, otherwise it is low.
- The comparator output is processed in trigger pulse generator
- so that the output voltage wave of inverter has a pulse width in agreement with comparator output pulse width

Switched Mode Power Supply (SMPS)

SMPS is an electronic powers supply unit that uses switching regulators to stabilize the output voltage and current.

Block diagram of SMPS



Block diagram of Switch Mode Power Supply

1. **Input rectifier and Filter (Diode rectifier and capacitor filter)**

- unregulated ac input signal is given to the input rectifier and filter circuit.
- The ac input signal is rectified to dc signal
- Then it is smoothened to remove high-frequency noise component from it.

2. **High-frequency switch (Power transistor or MOSFET)**

- power transistor or MOSFET that acts as a high-frequency switch
- This stage converts DC to AC, the frequency is usually chosen to be above 20 kHz, to make it inaudible to humans.

3. **Power transformer**

- The AC is applied to primary of high frequency transformer
- The transformer converts the voltage up or down to required level on its secondary.

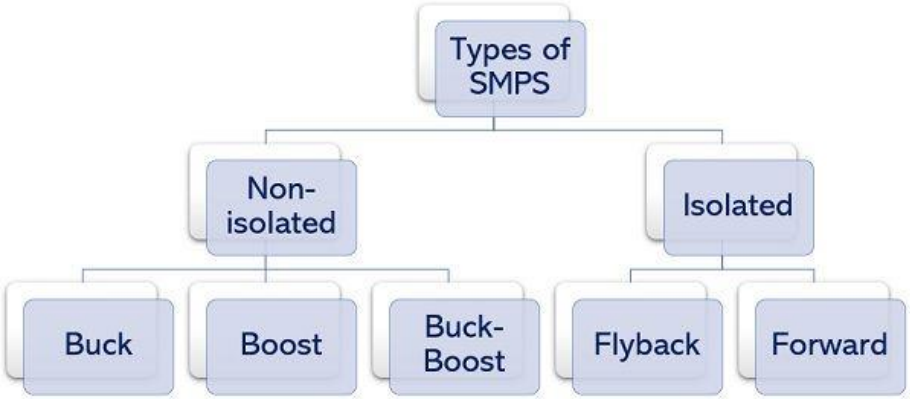
4. **Output rectifier and Filter (Diode rectifier and capacitor filter)**

- This stage comprises of AC output from transformer is rectified to dc
- The rectified output is smoothened by the filter circuit

5. **Control circuit (comparator and pulse width modulator**

- A feed back control is employed to maintain the output voltage constant with the variations of input voltage

Types of SMPS

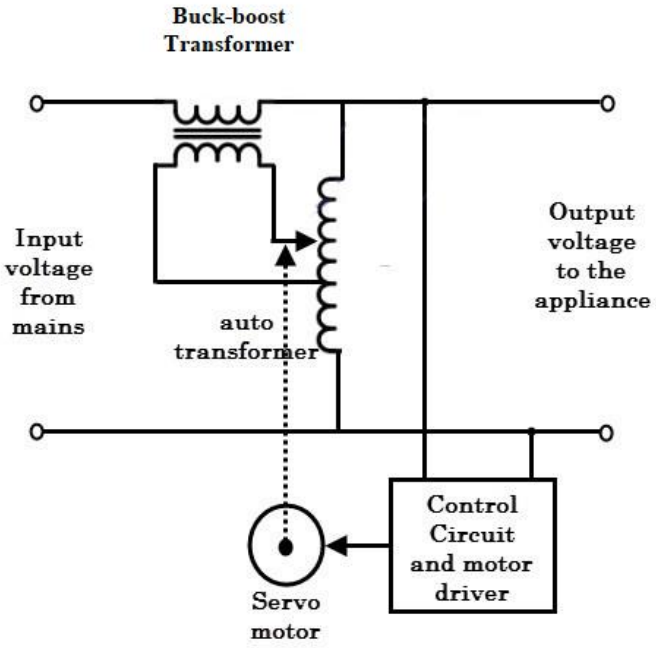


Comparison of linear power supply and SMPS

Sl.No	Particular	Linear power supply	SMPS

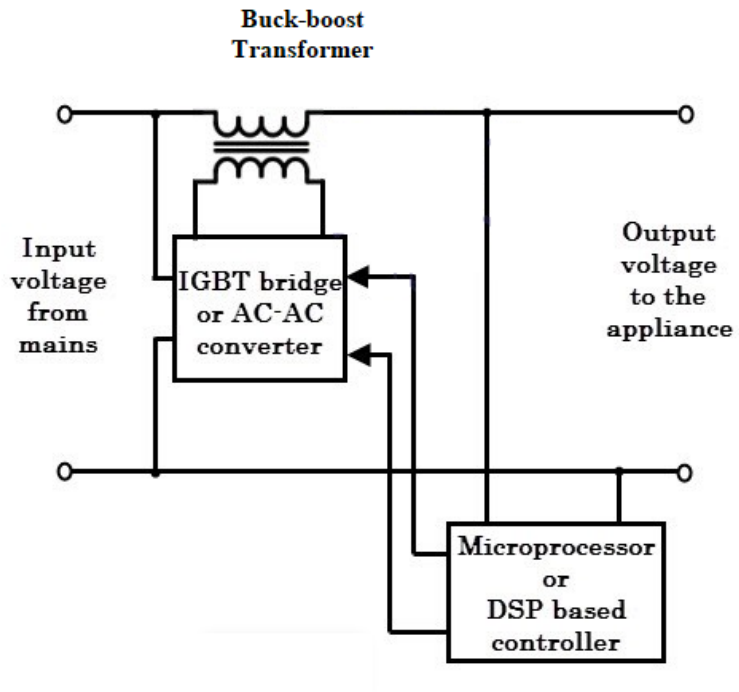
1	Efficiency	Low (25-50%)	High (45-90%)
2	Size	Large	Small
3	Weight	Heavy	Light
4	Circuit	Simple	complicated
5	Ripple	Small	large

Servo voltage stabilizers



- It consists of servo motor, autotransformer, buck boost transformer, motor driver and control circuit
- One end of buck boost transformer primary connected to fixed tap of autotransformer.
- Other end connected to moving arm which is controlled by servo motor.
- Electronic control circuit detects the voltage dip and voltage rise by comparing input and reference voltage.
- When the circuit finds the error, it operates the motor which in turn moves the autotransformer.
- This is given to the primary of buck boost transformer such that obtain a desired output voltage.

Static servo voltage stabilizers



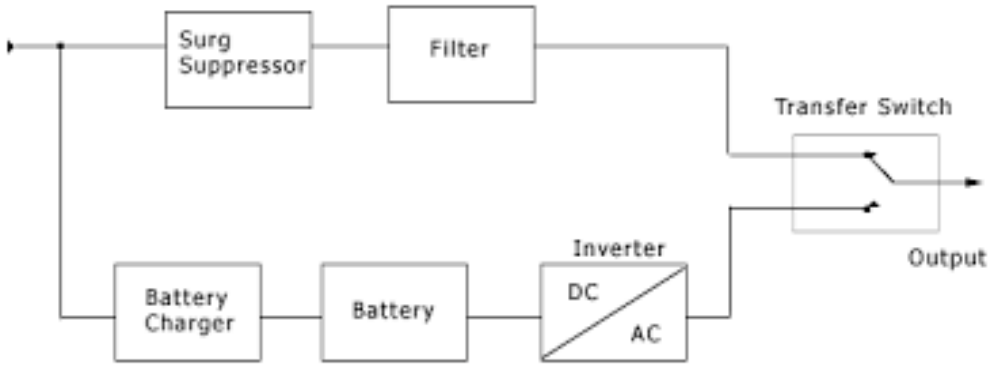
- In static stabilizer, no moving parts as in servo stabilizer.
- It consists of buck boost transformer, IGBT power converter, and microcontroller or DSP based Controller.
- Whenever the microprocessor detects the voltage dip, it sends the PWM pulses to the IGBT converter such that it generates the voltage which is equal to that of the deviated amount from nominal value.

Uninterruptible Power Supply (UPS)

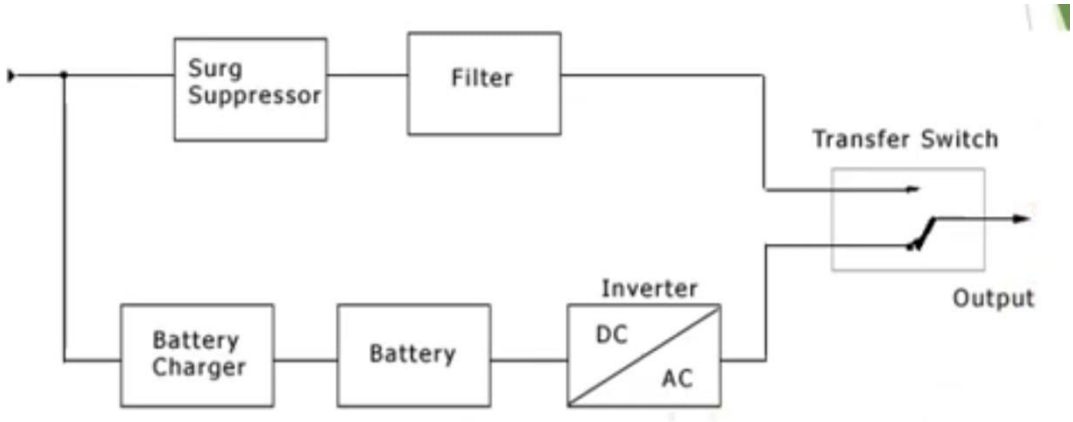
- ✓ A UPS is a device which maintains a continuous supply of electric power to connected equipment by supplying power from a separate source when power is not available.
- ✓ UPS is inserted between power source and load
- ✓ There are generally 3 types of UPS
  - Online UPS or True UPS
  - Offline UPS or stand by UPS
  - Line interactive UPS

Offline UPS

- ✓ It is also called stand by UPS
- ✓ It is the simplest and least expensive UPS design
- ✓ Primary power source is line power from main supply and secondary power source is the battery.
- ✓ During normal condition, battery and inverter are not supplying power to equipment.
- ✓ When the power failure occurs, the transfer switch changes to secondary power source
- ✓ When line power is restored, UPS switches back
- ✓ The filters and surge suppressors are provided for protection against lie noise and other problems.



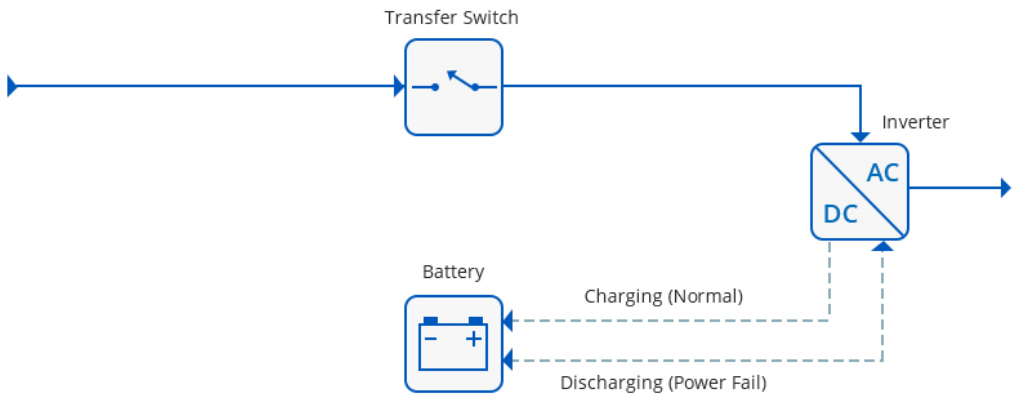
Online UPS



- ✓ It is similar to offline UPS with battery as primary power supply and main power line as secondary supply
- ✓ Under normal, operating conditions, the online UPS is always running from battery using inverter and main power line runs the battery charger
- ✓ So, there is no transfer time in the event of power failure.
- ✓ Secondary supply is kept to provide backup in the event of inverter failure or any other internal problem

Line Interactive UPS

- ✓ In the line interactive UPS, the separate battery charger, inverter and source selection switch are replaced by a combination of inverter/converter circuit
- ✓ This circuit charges the battery and converts its energy to AC for required output
- ✓ When main power supply is available, static switch is closed.it charges the battery
- ✓ When power fails, battery supplies power to load
- ✓ The main advantage of this inverter is that inverter/converter unit is always connected to the output
- ✓ This allows faster response to a power failure than standby UPS
- ✓ Total time taken for sensing and changeover of switch after failure of mains is less than 5 ms



Electric drives

- ✓ An electric drive is a form of machine equipment designed to convert electrical energy into mechanical energy and provide electrical control of this process.
- ✓ It is a combination of a prime mover, transmission equipment and mechanical load.

Block Diagram of Electric drive

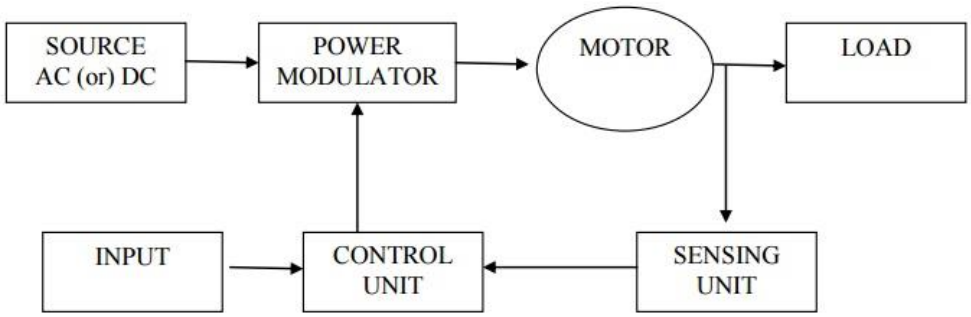


Fig 1.1 Block Diagram for Electrical Drives

Block diagram of electric drive:

1. **Load:** usually a machinery to accomplish a given task. Eg fans, pumps, washing machine etc.

2. **Power modulator:** modulators (adjust or converter) power flow from the source to the motion

3. **Motor:** actual energy converting machine (electrical to mechanical)

4. **Source:** The electrical power supply to the electric drive is either dc or ac supply

5. **Control:** adjust motor and load characteristics for the optimal mode.

6. **Sensing unit:** It is employed for sensing the drive parameters, such as speed motor current etc. These signals provide the feedback to the control unit

Types of electric drive

1. **Individual drive**: One motor is used to drive one load.

2.**Group drive**: Several loads are run on one shaft driven by a single motor.

3.**Multimotor drive**: Separate motors are used for operating different parts of the same mechanism.

Advantages of Electric drives

1. It is quite clean due to the absence of fuel, fumes etc.

2.Electric motors are available over a wide range of power few watts(5W) to mega watt

3.Electrical energy can be transmitted easily

4.No need of fuel storage and fuel consumption

5.No hazardous fuel is required

6. Less pollution

7.Regenerative braking is possible only in electric drives.

8.More life