Regulated power supply

Every electric device needs a power supply. Of course an electric device can’t work without electricity and the power supply gives this constant electric output to our electric devices. Most of our devices use DC current as their input power. On the other hand, due to the advantages of AC current in transmitting over long distances, the electric output we get in our houses are in AC form. Hence, we must use a device which converts this AC input to a DC output suitable for our system. This device is called a regulated power supply.

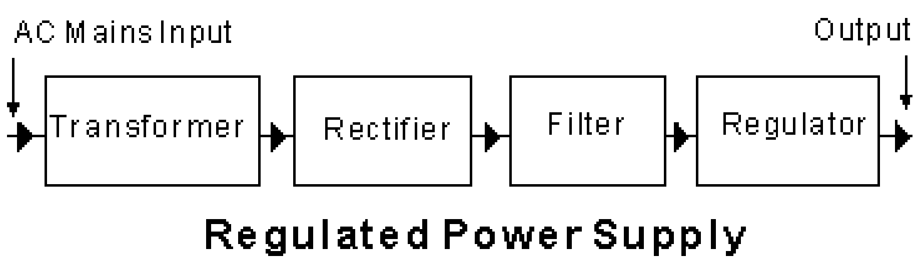

Fig: Components of Regulated Power Supply

In the figure, the components of a regulated power supply is shown. The goal of the device is to attain a DC voltage which would be the desired input for our electric devices or circuits. As we can see, AC current is given as the input to the unit. The value of this AC current frequency varies country to country. It is usually 240V with a frequency of 50Hz. Again in countries like

USA, the value of the frequency is 60Hz. This high voltage is then transformed to an input suitable for our unit. The current input is rectified and filtered. Finally, an IC voltage regulator unit will regulate the value of the DC output to a particular amount.

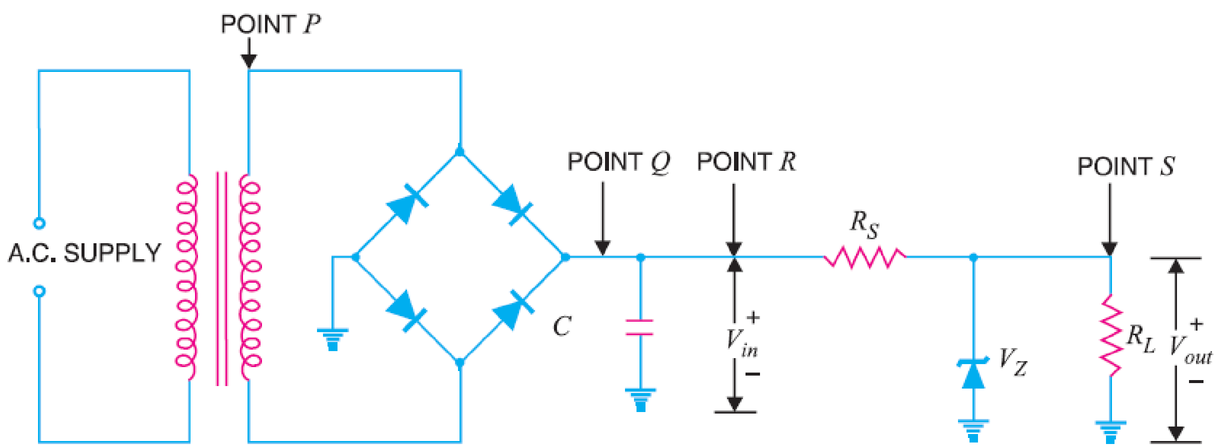

Fig: Detailed Circuit Design of Regulated Power Supply

In this figure, we can see the detailed circuit design of each of the components of our power supply. At the end of the circuit the load is given which takes the output DC current.

We use devices like these in our daily lives. From charging our phone to using our computer, there's always a power supply unit present in the circuit. Personally, I had a lot of experience with power supplies when working with Arduino (microcontroller) in robotics. I had to use a power supply to power my microcontroller, motors and other components of the robot. Each component has a particular value for the power input, for instance, the motor takes 5V as the input voltage; giving a higher voltage as input might potentially harm the device. Now, let's take a detailed look at the individual components of our regulated power supply.

Transformer:

A transformer is a passive electric component and is the first component of our power supply. It converts a power input of certain voltage and current to a power output of a desired voltage and current. A transformer consists of a primary coil and secondary coil. Current passes through the primary coil and by following Faraday's Law of Induction, output voltage and current will be produced.

Transformers can be classified into two types - (I) Step-up Transformers (which increases the output voltage and decreases the output current) and, (II) Step-down Transformers (which decreases the output voltage and increases the output current).

Ideal transformers follow Faraday's law of induction as:

$$\frac{V_P}{V_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S}$$

Where, V_P and V_S are Voltages of Primary and Secondary Coil respectively, N_P and N_S are the number of turns in those coils and I_S and I_P are the current flowing through those coils respectively.

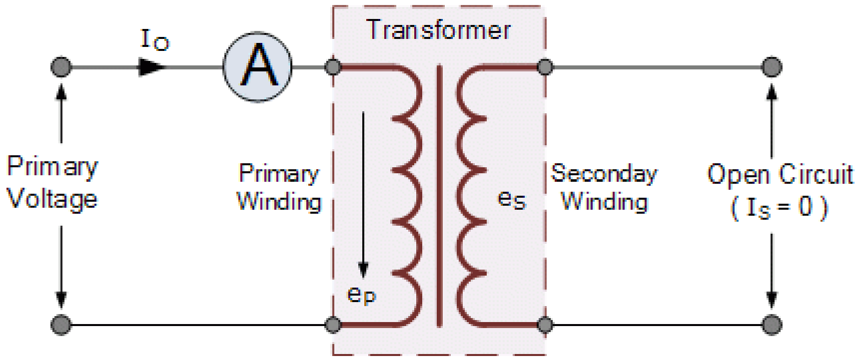

Fig: An Ideal Transformer

Rectifier:

A rectifier is an electric device and component of a regulated power supply which would take AC current as the input and convert it to DC current. An AC current signal changes its direction with time – sometimes it has a positive value and sometime it has a negative value. A rectifier tries to produce an output signal with a single positive value. Rectification is usually done using diodes.

Like transformers rectifiers are also divided into two categories – (I) Half Wave Rectifier and (II) Full Wave Rectifier. Half wave rectifiers can only retrieve half of the input AC current. The other half cycles are wasted in this case. The full wave rectifier rectifies both positive and negative half cycles.

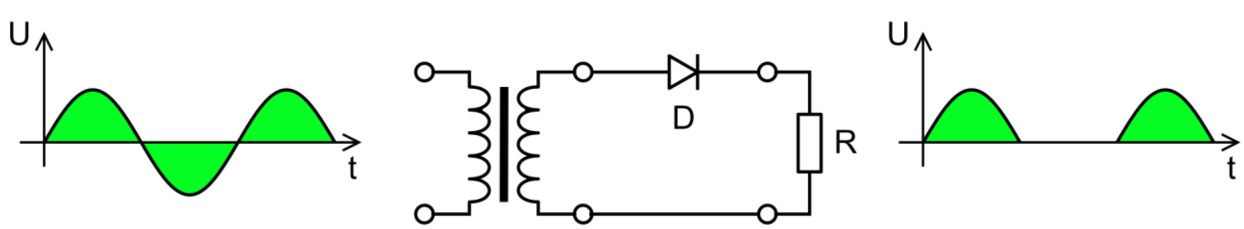

Fig: Half-wave Rectifier

As we can see from the figure a simple diode can be used to perform half-wave rectification. The diode blocks the negative values of the AC signal and thus produce a positive half output only.

Full-wave rectifiers are further divided in two types – (I) Bridge Rectifier and (II) Center Tap Transformer. The circuits are constructed using a four and two diodes respectively. Both rectifiers try to retrieve both half cycles of the AC current but the Bridge rectifier has a higher efficiency and hence, widely used.

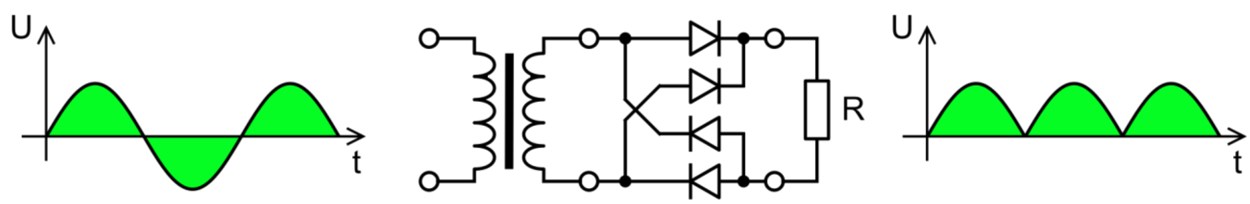

Fig: Bridge Rectifier

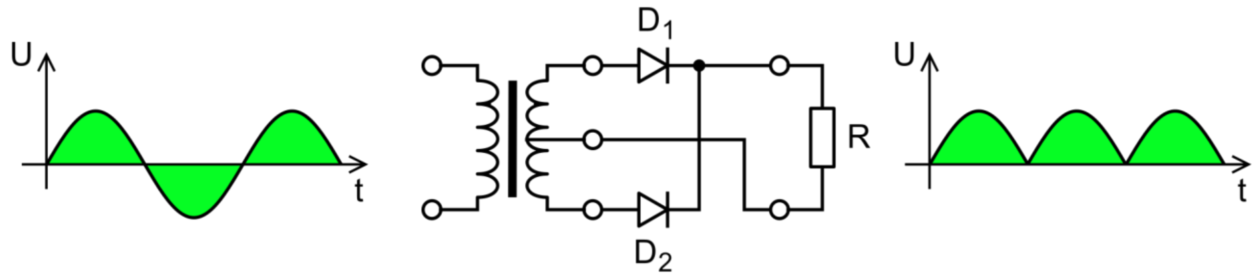

Fig: Center Tap Transformer

The output generated after rectification is in the positive side only but it’s still not a DC signal. The curves need to be straightened and that brings us to our next component.

Filter:

In electric circuits, filters are used to remove/block unwanted signals from our circuits. In our regulated power supply, the filter is used to smoothen the curves in the output from the rectifier. By smoothening the curve the signal will look closer and closer to a DC signal.

As we can see from the figure that the output from the full wave rectifier passes though the filter and produces the ripples. The ripples are periodically varying electric signals which are close to DC output but not quite. The filters can also be categorized into 4 types – (I) Shunt Capacitor, (II) Series Inductor, (III) L-C Filter, (IV) Pi Filter. Based on the type of output, the filters are also classified as low-pass filters, high-pass filters, band-pass filters and band-stop filters.

The working mechanism of filters vary based on the type of filter we use and its functionality. But for our regulated power supply, we usually use a shunt capacitor. At peak voltage the filter stores the voltage and then slowly discharges it as the voltage begins to decrease. So, instead of decreasing sharply, the voltage decreases in a much lower slope and thus the voltage stays in the higher region and doesn't fall too low. In this way, a ripple signal is generated which would be the output of our filter circuit component.

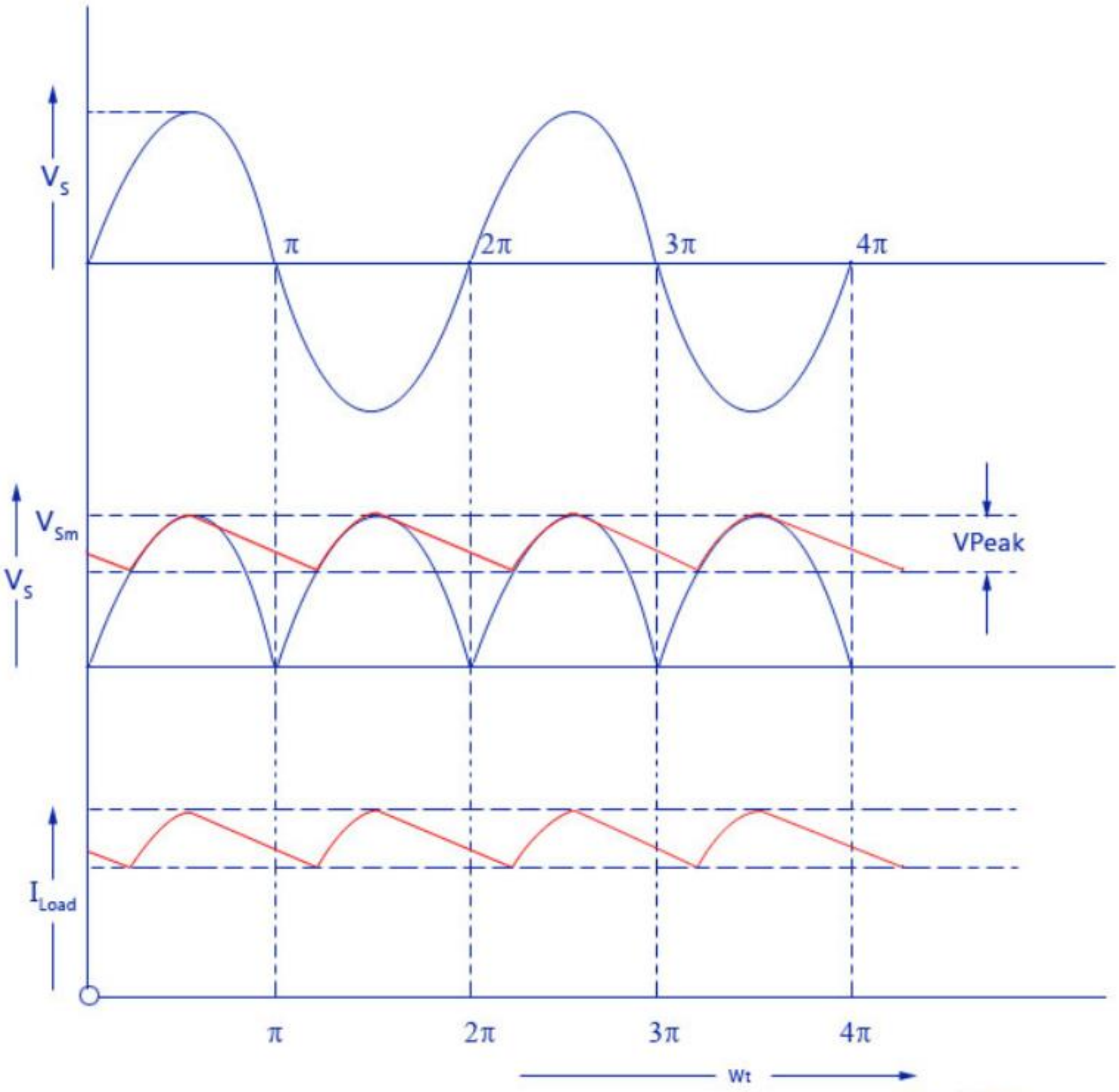

Fig: Wave output of Filter

The ripple current here is still not suitable as a DC output. By changing the value of capacitance, we can try to smoothen the ripples even further and make it look like an actual DC signal.

The ripple factor is usually denoted as

$$\text{Ripple factor} = (V_{Ripple(rms)} / V_{dc})*100$$

Regulator:

The smooth DC signal is now passed to our regulator or voltage regulator. Our electric devices use voltage of various values. Some devices are small and need low voltage. While other devices might require a lot of it. The power supply to our houses is usually 240V. But the whole peak voltage can't be fed to our devices. That's why we need to regulate the voltage using a component called voltage regulator. The function of this component is to change the voltage to such a value which is safe and suitable for our devices.

The voltage regulator is used as an integrated circuit. Usually fixed out voltage regulators are used.

Fig: A voltage regulator IC

The output from the voltage regulator will be the final output of our power supply. In this way a regulated power supply provides us with electric power in a particular voltage which can be directly used in our electric devices.

Stabilizer

What is stabilizer and why do we need it?

When we get our supply voltage it often differs in value. Sometimes in increases and sometimes it decreases. This shift in value can often harm our connected electric components. The drastic change can potential damage out devices. In order to avoid such a circumstance we use an electric component called Stabilizer which creates a steady output of the unstable voltage. The output is a voltage in a desired range which is suitable for our connected electric components.

The stabilizers act as the intermediary device between the supply voltage and the load. Now it is to be noted that the stabilizer can't supply a consistent voltage output. But it can change the drastic change in voltage which might be harmful to our devices. And thus it can give us an output within an acceptable voltage range which won't be detrimental to our devices.

The AC voltage stabilizers high efficiency digital control circuits to check the input voltage and produce a stable output. We can find various kinds of voltage stabilizer. The one in the figure is a single phase stabilizer. A three phase power supply is also available which are more efficient and can transmit thrice the power as the single-phase one. In out general uses, an automatic voltage regulator (AVR). Unlike the manual ones we used to use in the early days, the automatic stabilizers don't need switches or any human intervention to function properly. The manual ones were build using electromechanical relays but now the automated ones use digital circuitry.

Types of Stabilizers:

The most common types of stabilizers are:

(I) Relay Type Voltage Stabilizers
(II) Servo Controlled Voltage Stabilizers
(III) Static Voltage Stabilizers

Relay type Stabilizers switch relays and make a connection with a tapping to the transformer. There can be many tappings and only one of them has to be selected. There are also electric circuits like rectifiers, OP-amps, microcontrollers and so on. The input unstable voltage is compared to a built in reference voltage source and the switching is done whenever a difference in value is found. With an accuracy of plus-minus 10 percent, this cheap device can be used to protect lower end devices from harmful unstable voltage. But as it cannot detect minor fluctuations, it shouldn't be used for sensitive devices.

Servo stabilizers on the other hand, use a servo motor instead of the relays. Now what is a servo motor? Like the normal motors it is a rotatory motor but it allows us to control it using various inputs. The controls can be angular velocity change, direction change and so on. Now this servo motor is connected to the transformer. Judging by the name we can understand that in this device the servo motor is used to stabilize our voltage. Here the fluctuation in the output voltage is much lower and is close to plus-minus 1 percent making it far more efficient in the output department. But the input voltage shouldn't fluctuate higher than fifty percent or else the stabilizer might get damaged. The load capacity also differs from the relay type and this one offers various forms of cooling. It is also used in homes and small offices.

Fig: Relay stabilizer (left) and Servo stabilizer (right)

Static Voltage Stabilizers don't use servo motors or relays. Instead they use a type of transformer called buck boost transformer. The working mechanism is much different as an AC to AC transformer is used to supply the power to our transformer and is controlled using a microcontroller.

These stabilizers are far more efficient than the previous two and really compact in size. This made them popular and are being widely used in a variety of fields along the other two.

Fig: Static Voltage Stabilizer

Working Mechanism:

The whole procedure can be divided into two primary operations called boost and buck. Let’s think of stabilization for a moment. If we want get a high voltage, we need to reduce and if we get a low voltage we need to add something to it. The voltage stabilizer does these tasks exactly. Depending on the type of stabilizer we are using this “boost” and “buck” are performed to produce a stabilized output.

Boost: Boost has the task to add the voltage from the transformer when the input voltage is lower than our desired value. Both parts of the transformer coil can be accessed to do so. By adding this primary voltage our output can be increased to our desired value.

Buck: Buck does the opposite task but it will work when the voltage increases above the desired value. The buck is done in a serial connection with the positive sides of both our coils and this subtraction is done to lower the values.

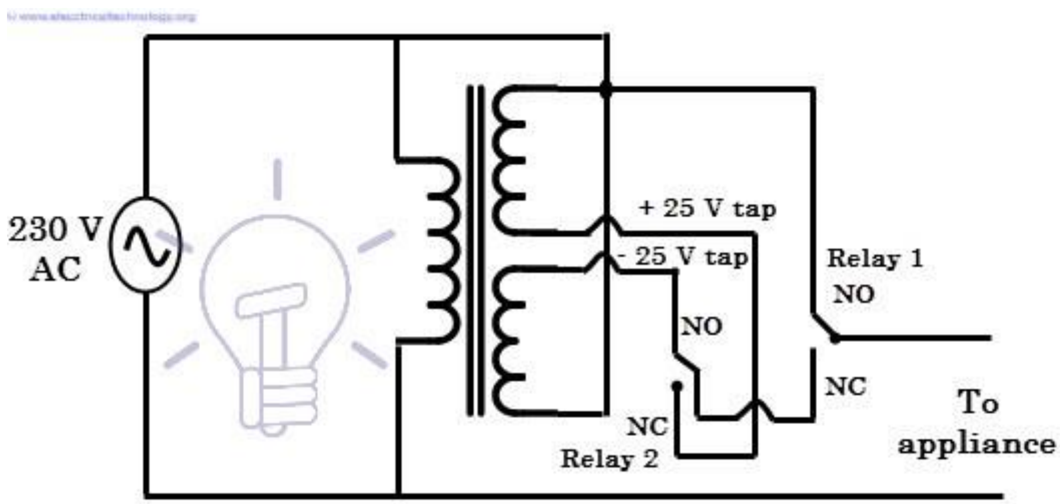

Fig: Mechanism of Relay type Stabilizer

This is a common mechanism where relays are used to stabilize the voltage. The routes are selected depending on the plus or minus 25V tap and finally the output is transferred to our appliances.

In case of our servo stabilizer instead of relays a servo motor is used.

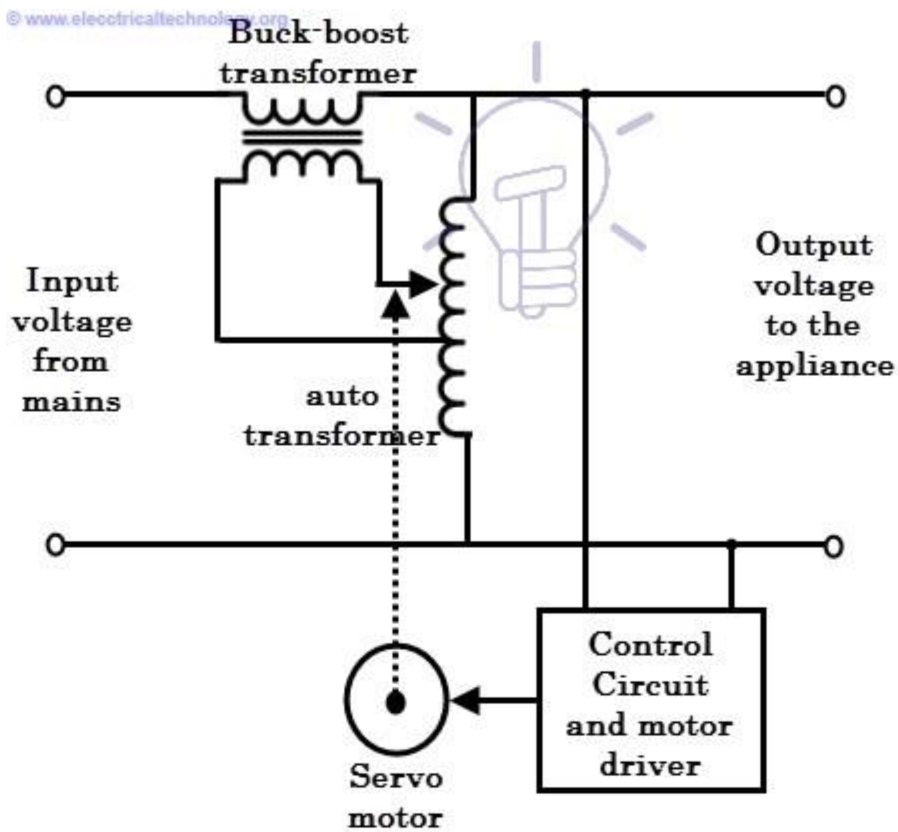

Fig: Mechanism of Servo Stabilizer

UPS

UPS or uninterrupted power supply is a commonly used device to get a consistent power signal even when the supply is turned off. In many countries, load shedding is a common problem and devices like server computers, desktops need constant power supplies. When the load shedding occurs then this devices would instantly turn off and thus a lot of unsaved work might get deleted. In order to avoid circumstances like these, a UPS is connected to such devices which can even supply power for a short amount of time when the actual supply is cut off.

Fig: Uninterrupted Power Supply (UPS)

Categories of UPS:

Generally used technologies of UPS are –

(I) **Standby/Offline/Battery Backup UPS:** It is used for small scale environments are really cheap. It has its own battery to generate power in order to add power to weaker voltages. Here excess power is clamped while lower power is clipped using the battery input. They can usually supply for a short amount of time and can only change the supply to battery within the 6-8 millisecond power break. This is widely used in home computers.

(II) **Line Interactive UPS (Battery backup)** – also used in homes and small offices. This device not online provides battery backup but also provides power conditioning. It can detect the power fluctuations easier than the previous offline models and can switch much quickly at a 4-6 millisecond when the power is absent. This is a little bit more expensive than the offline versions and act as moderately systems between the online and offline ones.

(III) **Online UPS** – This provides the higher level of protection against unstable power supply and are used in large scale programs and offices only. The online UPS charges its battery by rectifying the AC signal and the DC signal is also fed to the load using an inverter. Then the DC signals are converted to AC and given out as a stable output. For this reason it is often called Double Converter as it does AC-DC and DC-AC conversion in the same time. The output can be as good as perfect sine waves. The device can provide a hundred percent power conditioning and are the most reliable technology when it comes to choosing a UPS. For this reason it is a lot more expensive than the previous entries and are used in large data centers and special use only.

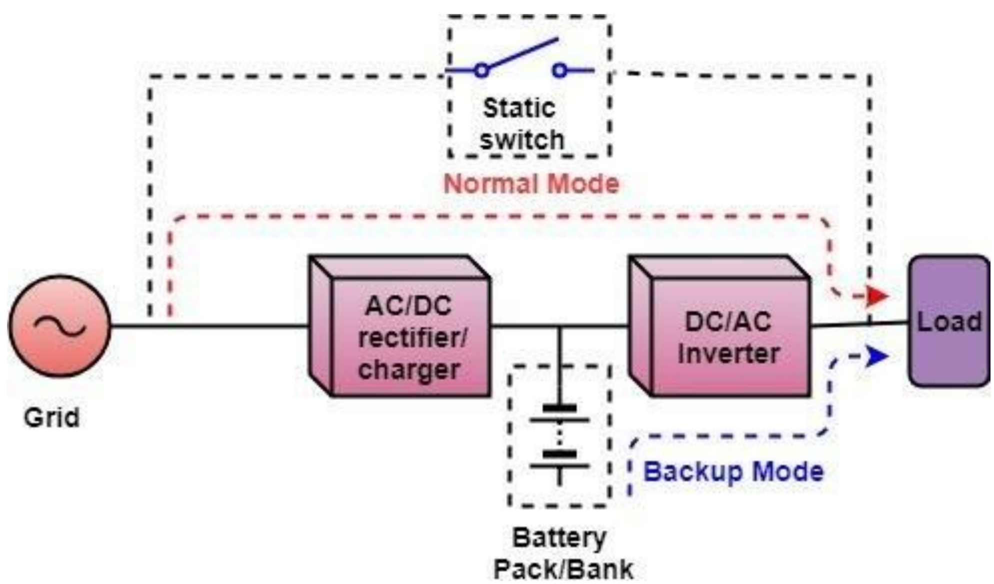

Fig: Working mechanism of Online UPS