can still exert some influence the fountain performance. The fact is that the purer water enables more efficient pumping. The tap water which seems to be quite pure can also produce some minerals from the water in the pump. To prevent this, the distilled water can be used, which however would cost more. On the other hand, you can also change the water more frequently and pay more attention of the water cleaning.

Q58.What are typical characteristics of PV module?

A **photovoltaic system** (or **PV system**) is a system which uses one or more solar panels to convert sunlight into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.

Due to the low voltage of an individual solar cell (typically ca. 0.5V), several cells are wired in series in the manufacture of a "laminate". The laminate is assembled into a protective weatherproof enclosure, thus making a photovoltaic module or solar panel. Modules may then be strung together into a photovoltaic array. The electricity generated can be either stored, used directly (island/standalone plant)or fed into a large electricity grid powered by central generation plants (grid-connected/grid-tied plant) or combined with one or many domestic electricity generators to feed into a small grid (hybrid plant). Depending on the type of application, the rest of the system ("balance of system" or "BOS") consists of different components. The BOS depends on the load profile and the system type. Systems are generally designed in order to ensure the highest energy yield for a given investment.

Q65.Write equation for overall efficiency of solar water system.

To calculate BTUNeed, use the following formula:

BTUNeed = 8.34 X Gallons X (122 – Coldtemp) X Standby loss factor

ULTIMO COLLEGE OF TAFE

Course name	:	Advance Diploma in Electrical engineering
Course no.	:	17794
Student name	:	THI TRUONG
Student number	:	210182527
SUBJECT	:	ASSIGNMENT KO35
		DESIGN GRID CONNECTED POWER SUPPLY SYSTEMS
TEACHER'S NAME	:	KYAW NAING

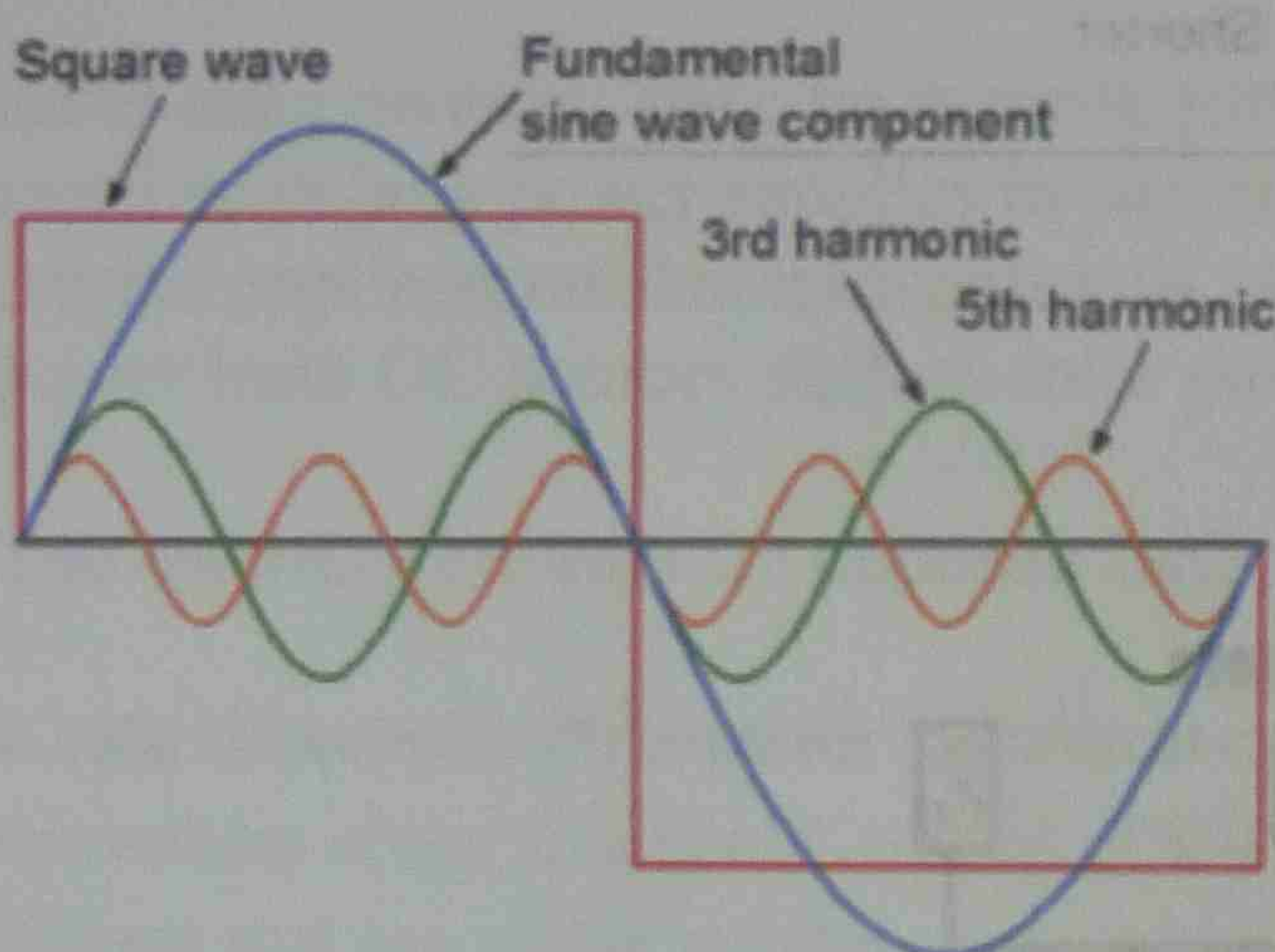
ASSIGNMENT K035

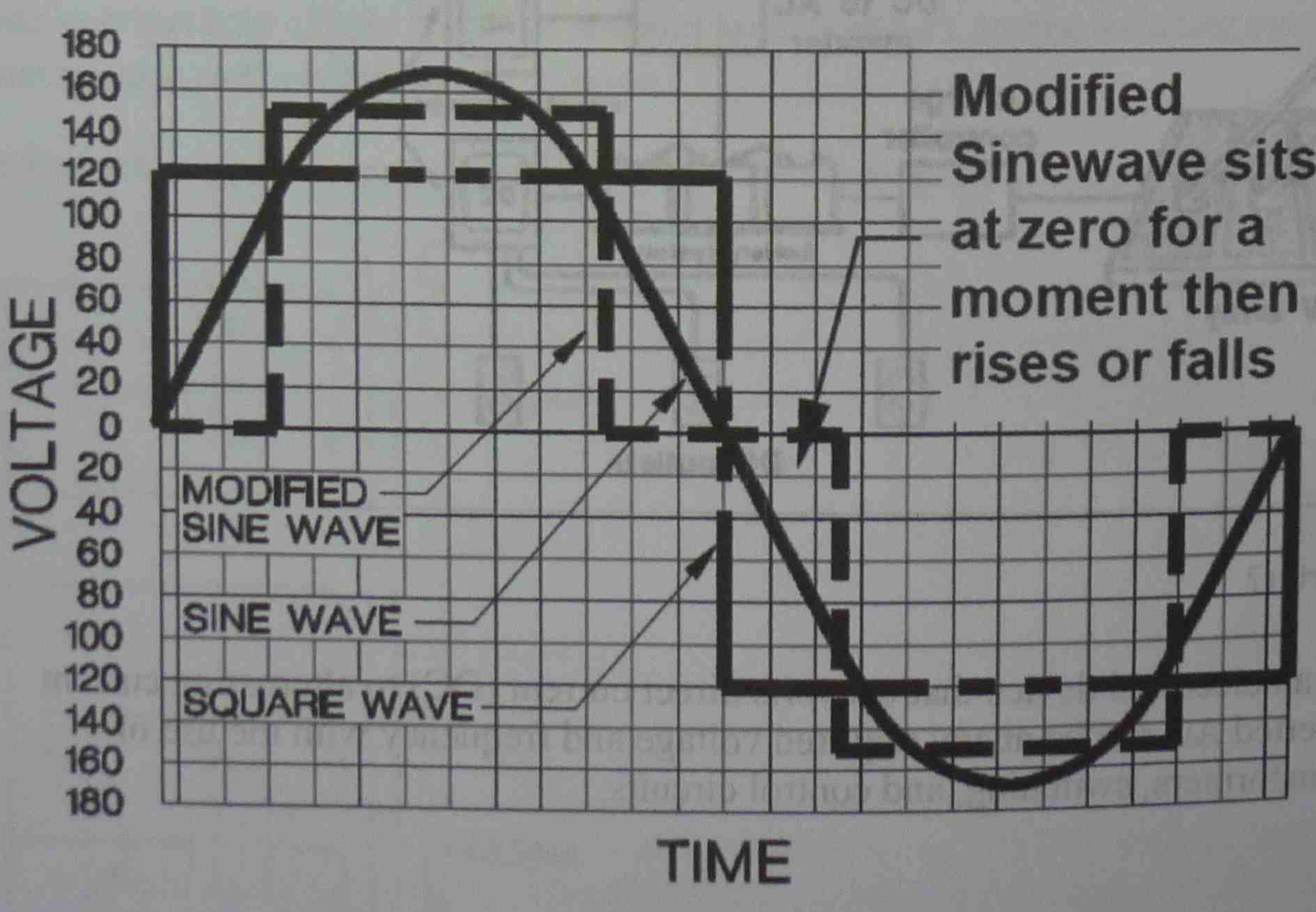
Q1.Sketch the waveforms for (a) DC to pulsating AC inverter (b) Modified sine wave , step sine wave inverter (c) PWM inverter.

An **inverter** is an electrical device that converts direct current (DC) to alternating current (AC) the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

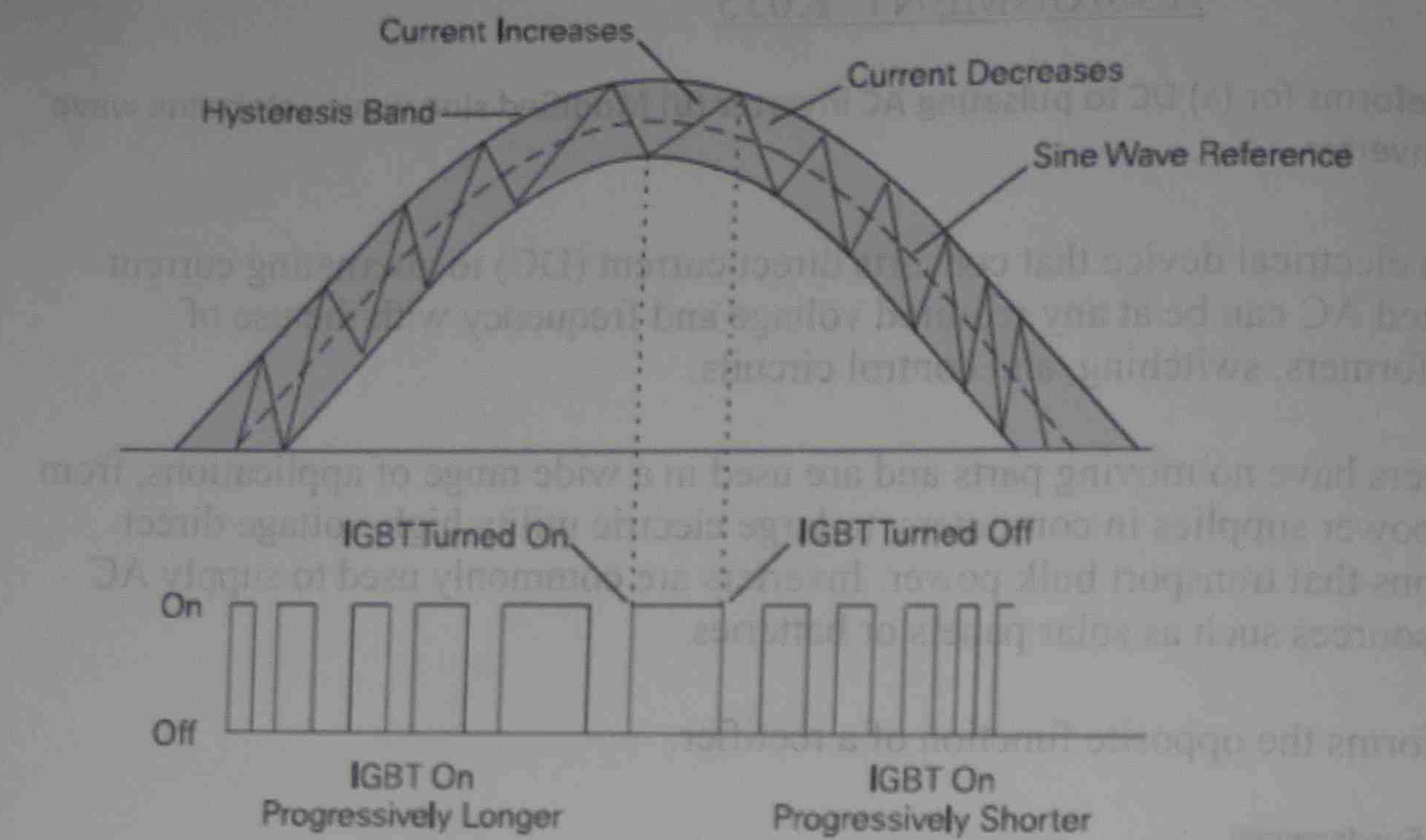
Solid-state inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries.

The inverter performs the opposite function of a rectifier.



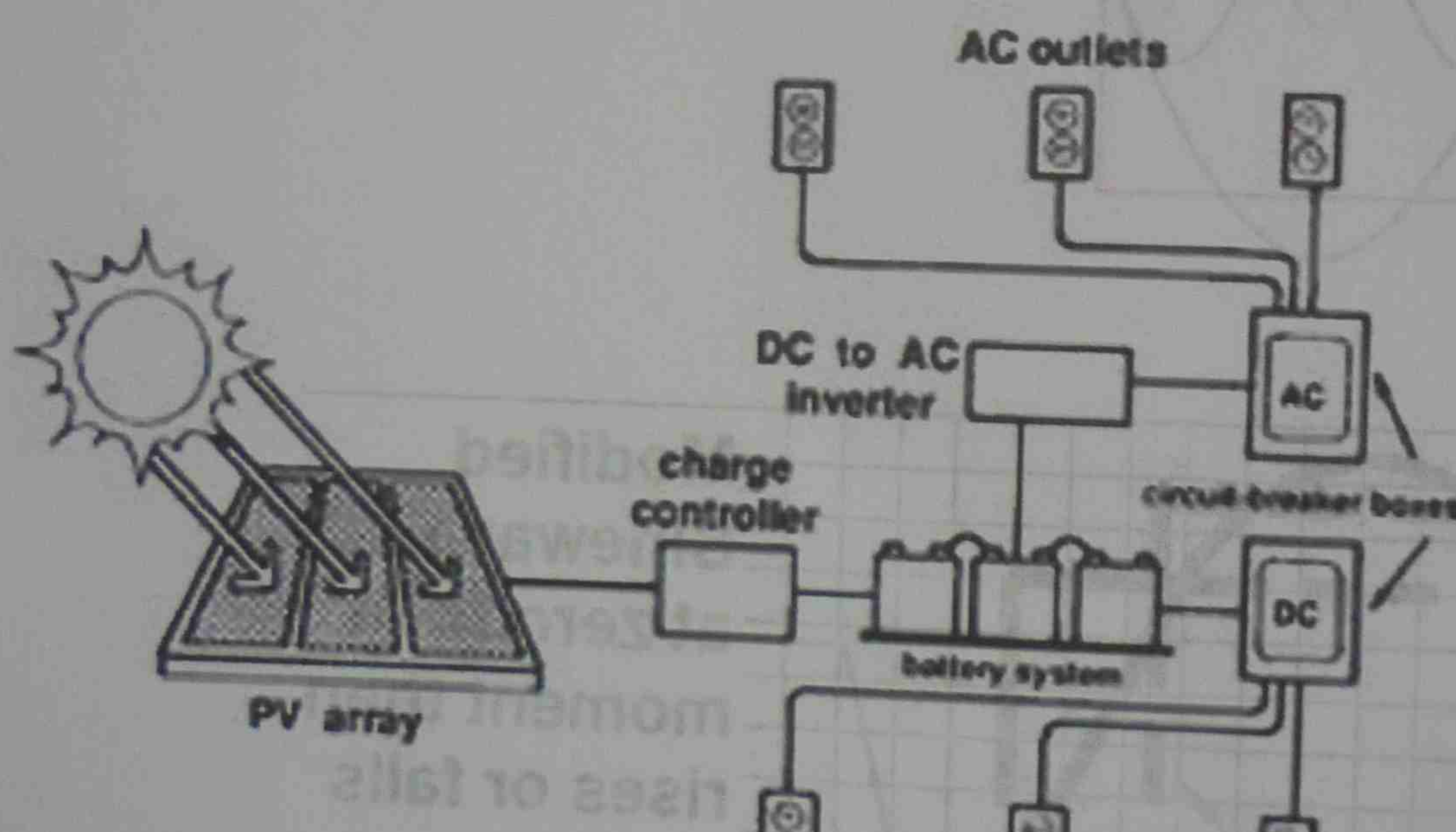


Square, Modified, and Pure Sine Wave



PWM inverter

Q2.Sketch the block diagram for stand alone PV system.



Q3.What is inverter?

An **inverter** is an electrical device that converts direct current (DC) to alternating current (AC) the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

Q4.What is grid tie inverter?

A grid-tie inverter (GTI) is a special type of inverter that converts direct current(DC) electricity into alternating current(AC) electricity and feeds it into an existing electrical grid. GTIs are often used to convert direct current produced by many renewable energy sources, such as solar panels or small wind turbines, into the alternating current used to power homes and businesses. The technical name for a grid-tie inverter is "grid-interactive inverter". They may also be called synchronous inverters. Grid-interactive inverters typically cannot be used in standalone applications where utility power is not available.

Q5.What are the applications of inverter?

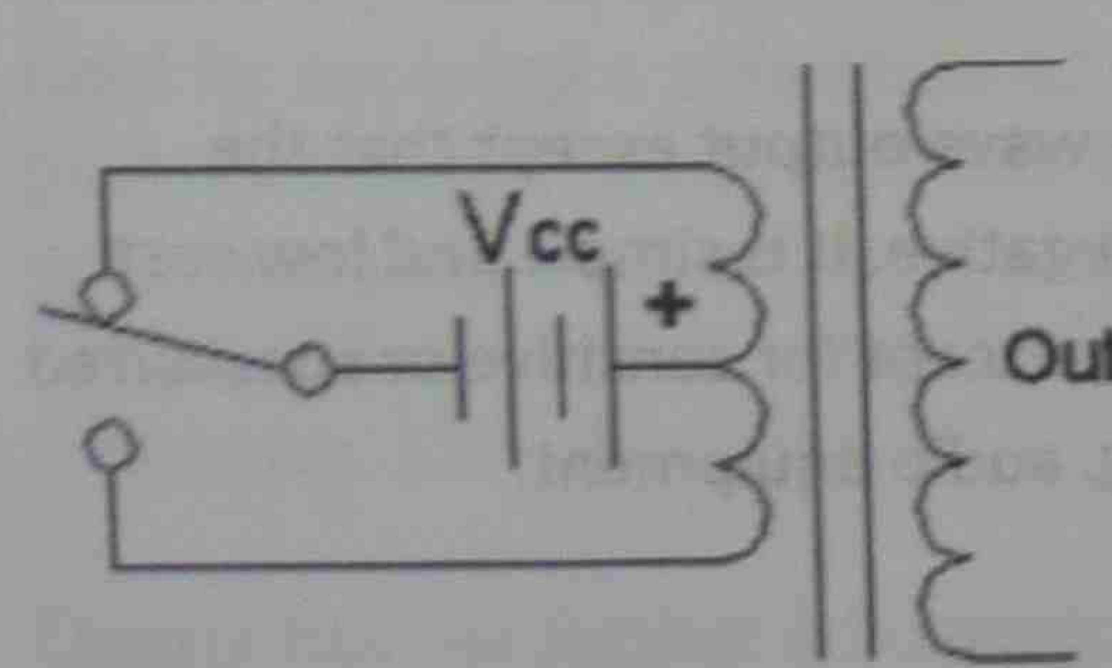
An **inverter** is an electrical device that converts direct current (DC) to alternating current (AC) the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

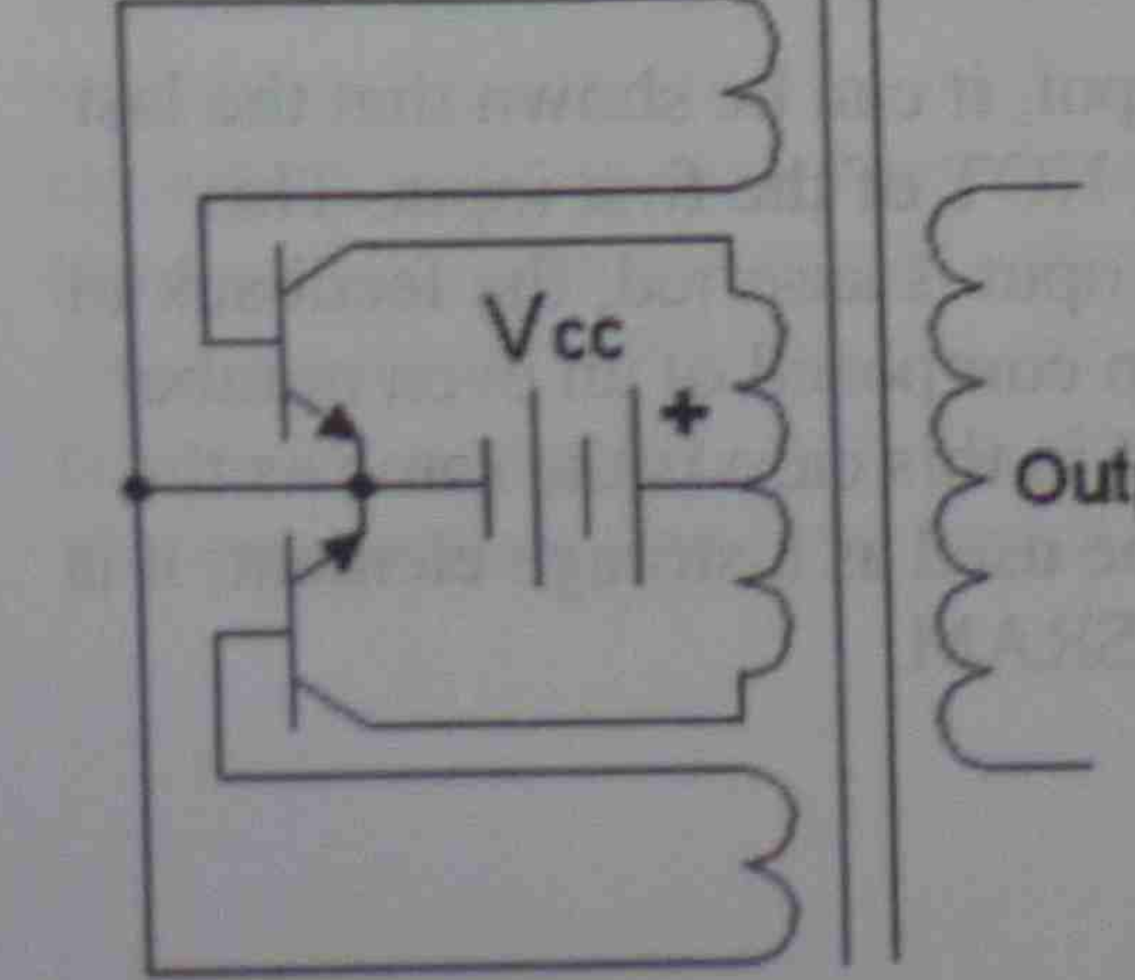
Solid-state inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries.

The inverter performs the opposite function of a rectifier.

A **solar inverter** or **PV inverter** is a critical component in a solar energy system. It performs the conversion of the variable DC output of the Photovoltaic (PV) modules into a utility frequency AC current that can be fed into the commercial electrical grid or used by a local, off-grid electrical network. An inverter allows use of ordinary mains-operated appliances on a direct current system. Solar inverters have special functions adapted for use with PV arrays, including maximum power point tracking and anti-islanding protection.

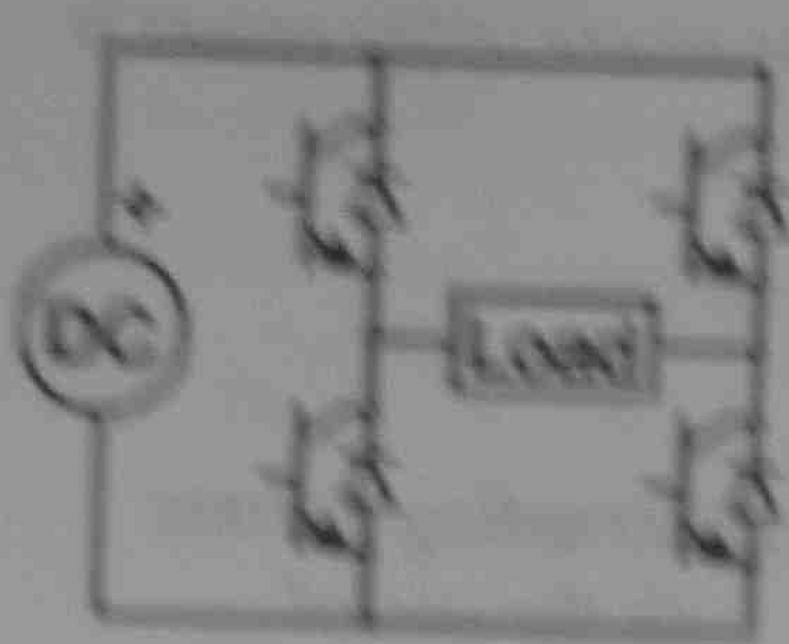
Q6.Sketch basic inverter principle circuit and operating principle.



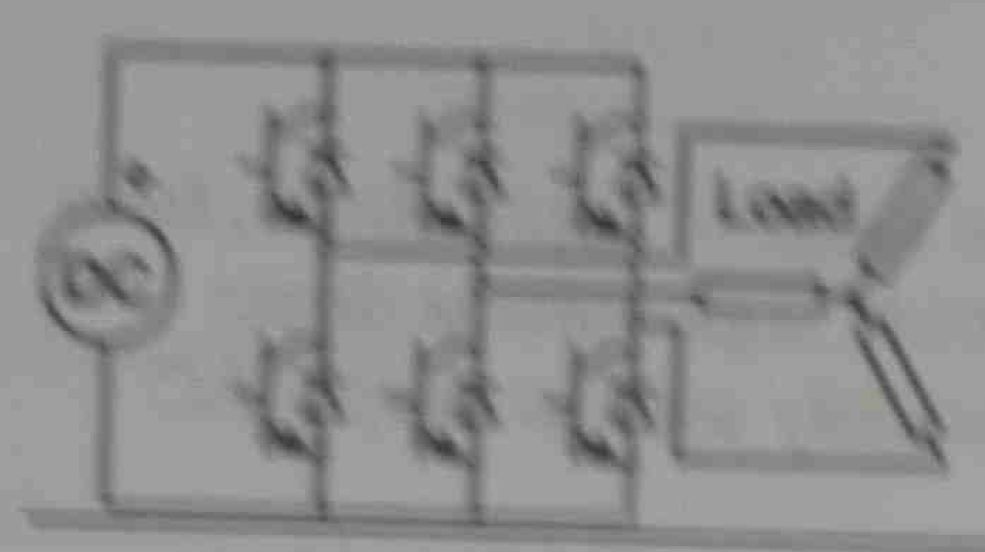


In one simple inverter circuit, DC power is connected to a transformer through the centre tap of the primary winding. A switch is rapidly switched back and forth to allow current to flow back to the DC source following two alternate paths through one end of the primary winding and then the other. The alternation of the direction of current in the primary winding of the transformer produces alternating current (AC) in the secondary circuit.

Q7.Sketch (a) H bridge inverter (b) Three phase inverter.



H bridge inverter,



Three phase inverter

Q8.Explain PWM technology and inverter circuit used with PWM technology.

PWM or **Pulse Width Modulation** is the technology to generate a steady output voltage from inverters. When compared to the conventional **Semi Sine wave** and **Pure sine wave** inverters, PWM Inverter offers superior quality. PWM Inverters use **MOSFET** technology at the output stage, so that any type of loads can be connected to the inverter. These inverters also have voltage control and load protection circuits.

Q9.Explain modified sine wave inverter.

The output of a **modified sine wave** inverter is similar to a square wave output except that the output goes to zero volts for a time before switching positive or negative. It is simple and low cost (~$0.10USD/Watt) and is compatible with most electronic devices, except for sensitive or specialized equipment, for example certain laser printers, fluorescent lighting, audio equipment.

Q10.Explain the oscillator for inverter circuit.

Because a single inverter computes the logical NOT of its input, it can be shown that the last output of a chain of an odd number of inverters is the logical NOT of the first input. This final output is asserted a finite amount of time after the first input is asserted; the feedback of this last output to the input causes oscillation.A circular chain composed of an even number of inverters cannot be used as a ring oscillator; the last output in this case is the same as the input. However, this configuration of inverter feedback can be used as a storage element; it is the basic building block of static random access memory, or SRAM.

A real ring oscillator only requires power to operate; above a certain threshold voltage, oscillations begin spontaneously. To increase the frequency of oscillation, two methods may be used. Firstly, the applied voltage may be increased; this increases both the frequency of the oscillation and the power consumed, which is dissipated as heat. The heat dissipated limits the speed of a given oscillator. Secondly, a smaller ring oscillator may be fabricated; this results in a higher frequency of oscillation given a certain power consumption.

Q11.A crystal oscillator has the following parameters C_p =50PF C_o = 10PF R = 100Ω at 10MHZ for a CMOS inverter with an open loop gain a =200 calculate the value of feedback resistor.

Q12.Explain the operational requirement of crystal oscillator for inverter.

A **crystal oscillator** is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time (as in quartz wristwatches), to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits designed around them became known as "crystal oscillators."

A crystal is a solid in which the constituent atoms, molecules, or ions are packed in a regularly ordered, repeating pattern extending in all three spatial dimensions.

Almost any object made of an elastic material could be used like a crystal, with appropriate transducers, since all objects have natural resonant frequencies of vibration. For example, steel is very elastic and has a high speed of sound. It was often used in mechanical filters before quartz. The resonant frequency depends on size, shape, elasticity, and the speed of sound in the material. High-frequency crystals are typically cut in the shape of a simple, rectangular plate. Low-frequency crystals, such as those used in digital watches, are typically cut in the shape of a tuning fork. For applications not needing very precise timing, a low-cost ceramic resonator is often used in place of a quartz crystal.

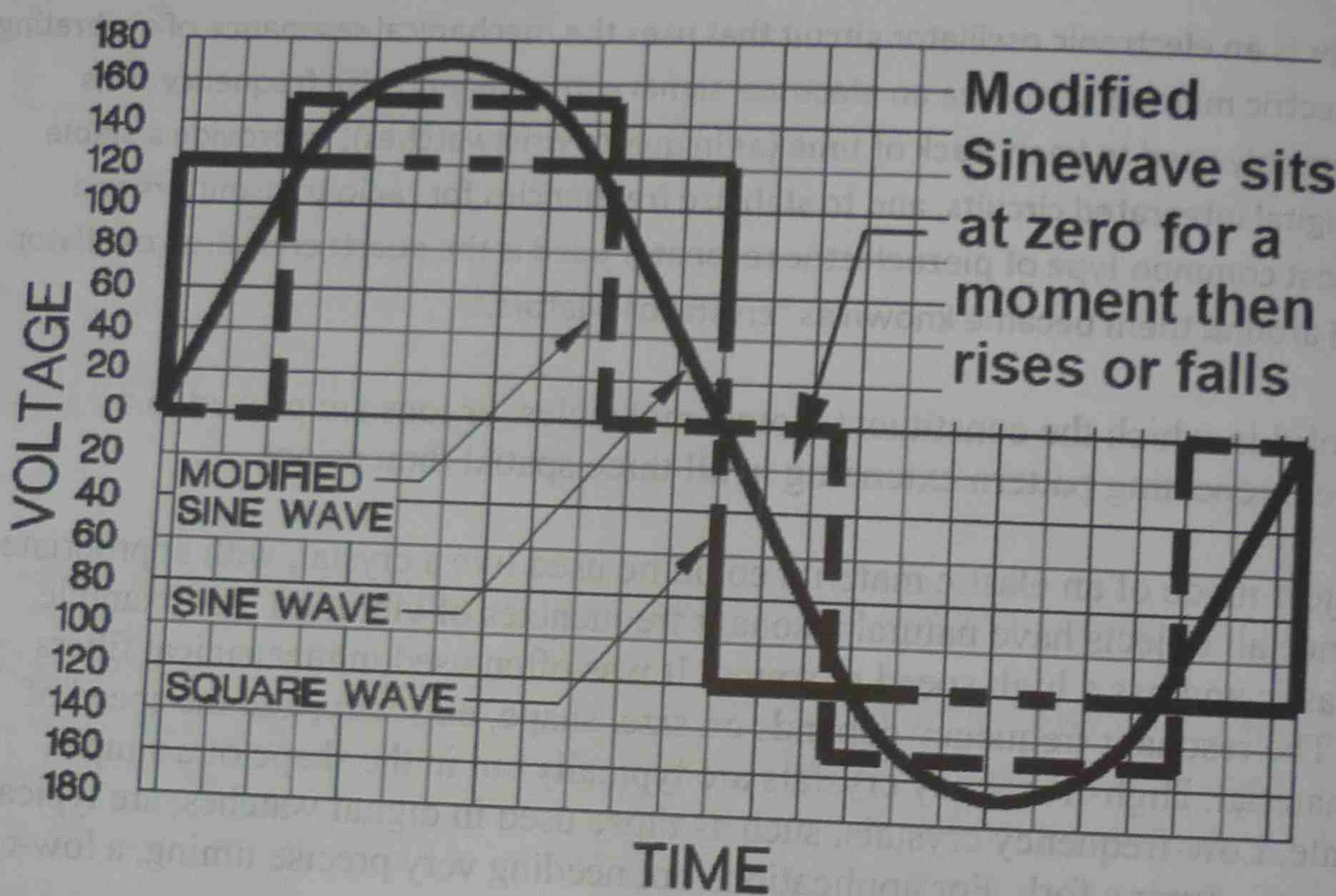
When a crystal of quartz is properly cut and mounted, it can be made to distort in an electric field by applying a voltage to an electrode near or on the crystal. This property is known as piezoelectricity. When the field is removed, the quartz will generate an electric field as it returns to its previous shape, and this can generate a voltage. The result is that a quartz crystal behaves like a circuit composed of an inductor, capacitor and resistor, with a precise resonant frequency. (See RLC circuit.)

Quartz has the further advantage that its elastic constants and its size change in such a way that the frequency dependence on temperature can be very low. The specific characteristics will depend on the mode of vibration and the angle at which the quartz is cut (relative to its crystallographic axes). Therefore, the resonant frequency of the plate, which depends on its size, will not change much, either. This means that a quartz clock, filter or oscillator will remain accurate. For critical applications the quartz oscillator is mounted in a temperature-controlled container, called a crystal oven, and can also be mounted on shock absorbers to prevent perturbation by external mechanical vibrations.

Q13.Explain the basic principle of sine wave inverter.

A **pure sine wave** inverter produces a nearly perfect sine wave output (<3% total harmonic distortion) that is essentially the same as utility-supplied grid power. Thus it is compatible with all AC electronic devices. This is the type used in grid-tie inverters. Its design is more complex, and costs more per unit power. The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters were made to work in reverse, and thus were "inverted", to convert DC to AC.

Q14.Sketch the graphs for square wave , modified sine wave & pure sine wave.



Q15.Explain pulse width modulation.

Pulse-width modulation (PWM), or **pulse-duration modulation (PDM)**, is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is.

The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switchings have to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

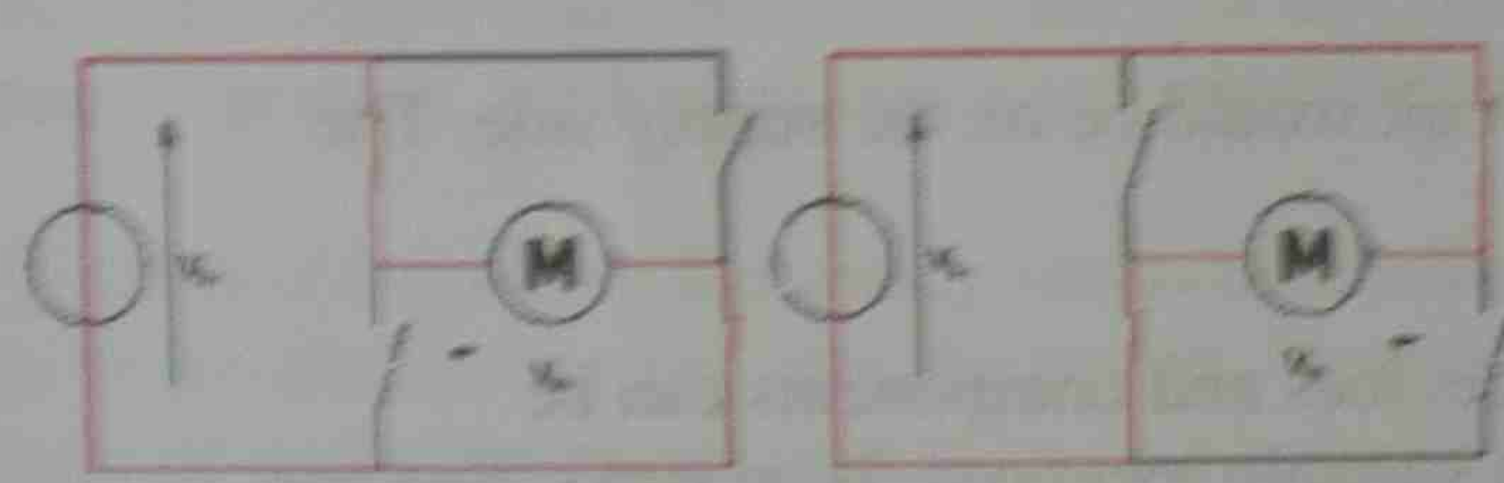
The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

Q16.Explain the operation of Bubba oscillator.

The design starts with a DC voltage input that powers all circuits. From here, our circuit is broken into three sequential phases. In the first phase we use a loop of operational amplifiers to generate a perfect sine wave called the "Bubba Oscillator." We also tweak the elements of this oscillator so that the sinusoidal wave travels at 60 Hz or approximately what is coming out of a wall outlet. We tap this circuit at two points to obtain two complementary sine waves. We are not using these voltages to power anything; they are used as what are called "reference voltages" or voltages that guide the operation of another part of the circuit. Because we cannot allow our circuit to use a negative rail (only have one power source), at this stage, our sine wave clips, and we have only the top half of both a sine wave and a –sine wave.

Q17.Sketch H bridge construction & operation table.

Operation

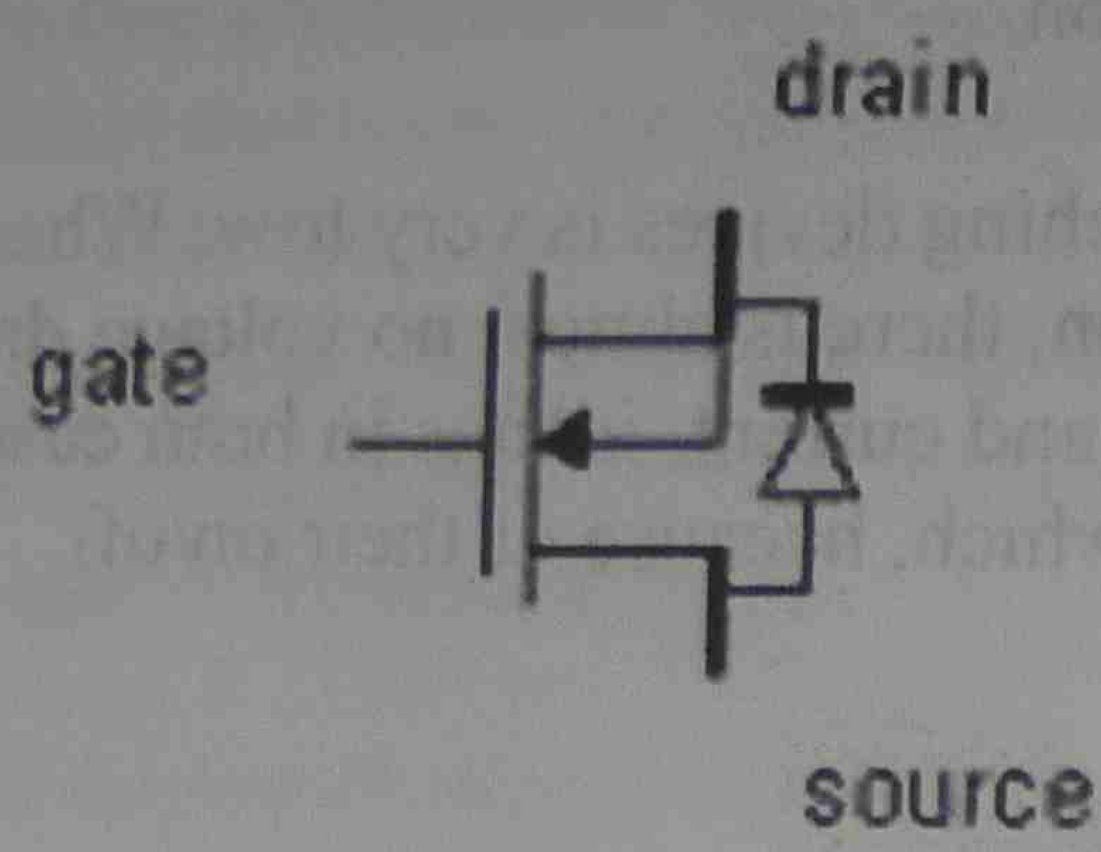


The two basic states of an H bridge

The H-bridge arrangement is generally used to reverse the polarity of the motor, but can also be used to 'brake' the motor, where the motor comes to a sudden stop, as the motor's terminals are shorted, or to let the motor 'free run' to a stop, as the motor is effectively disconnected from the circuit. The following table summarises operation, with S1-S4 corresponding to the diagram above.

S1	S2	S3	S4	Result
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
0	0	0	0	Motor free runs
0	1	0	1	Motor brakes
1	0	1	0	Motor brakes

Q18.Explain MOSFET driver with sketch.



The source terminal is normally the negative one, and the drain is the positive one (the names refer to the source and drain of electrons). The diagram above shows a diode connected across the MOSFET. This diode is called the "intrinsic diode", because it is built into the silicon structure of the MOSFET. It is a consequence of the way power MOSFETs are created in the layers of silicon, and can be very useful. In most MOSFET architectures, it is rated at the same current as the MOSFET itself.

The power handling of the package without an extra heatsink is very small. On some MOSFETs, the metal tab is connected internally to one of the MOSFETs terminals - usually the drain. This is a disadvantage as it means that you cannot fit more than one MOSFET to a heatsink without electrically isolating the MOSFET package from the metal heatsink. This can be done with thin mica sheets placed between the package and the heatsink. Some MOSFETs have the package isolated from the terminals.

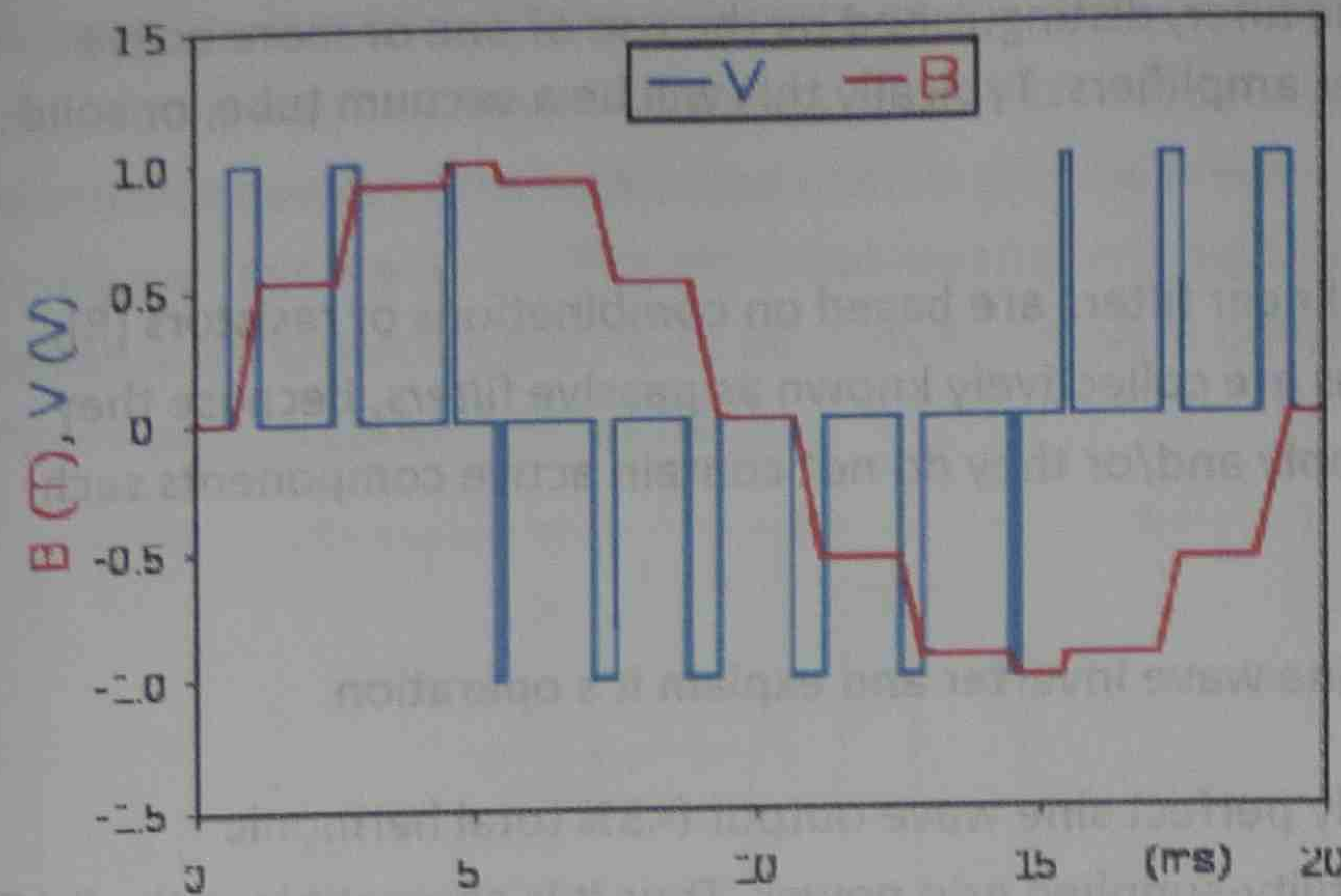
Q19.Explain inverter circuit protection and snubber.

The only way an Inverter could overload a circuit would be on the supply side. The fusing/protection for the inverter is incorrect.

Power electronic circuits and their switching devices and components can be protected from overcurrent by placing fuses at suitable locations. Heat sinks, fins and fans are used to take the excess heat away from switching devices and other components

Protection of switching devices and circuits: Switching devices and circuit components may fail due to the following reasons.
1. Overheating – thermal failure
2. Overcurrent
3. Overvoltage – usually happens during turn-off
4. Excessive
dt
di
5. Excessive
dt
dv
6. Switching loss –excessive switching loss is a major contributing factor of overheating.

Q20.Explain PWM with sketch.



An example of PWM in an AC motor drive: the phase-to-phase voltage (blue) is modulated as a series of pulses that results in a sine-like flux density waveform (red) in the magnetic circuit of the motor. The smoothness of the resultant waveform can be controlled by the width and number of modulated impulses (per given cycle)

Pulse-width modulation (PWM), or **pulse-duration modulation (PDM)**, is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is.

The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switchings have to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

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The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications.

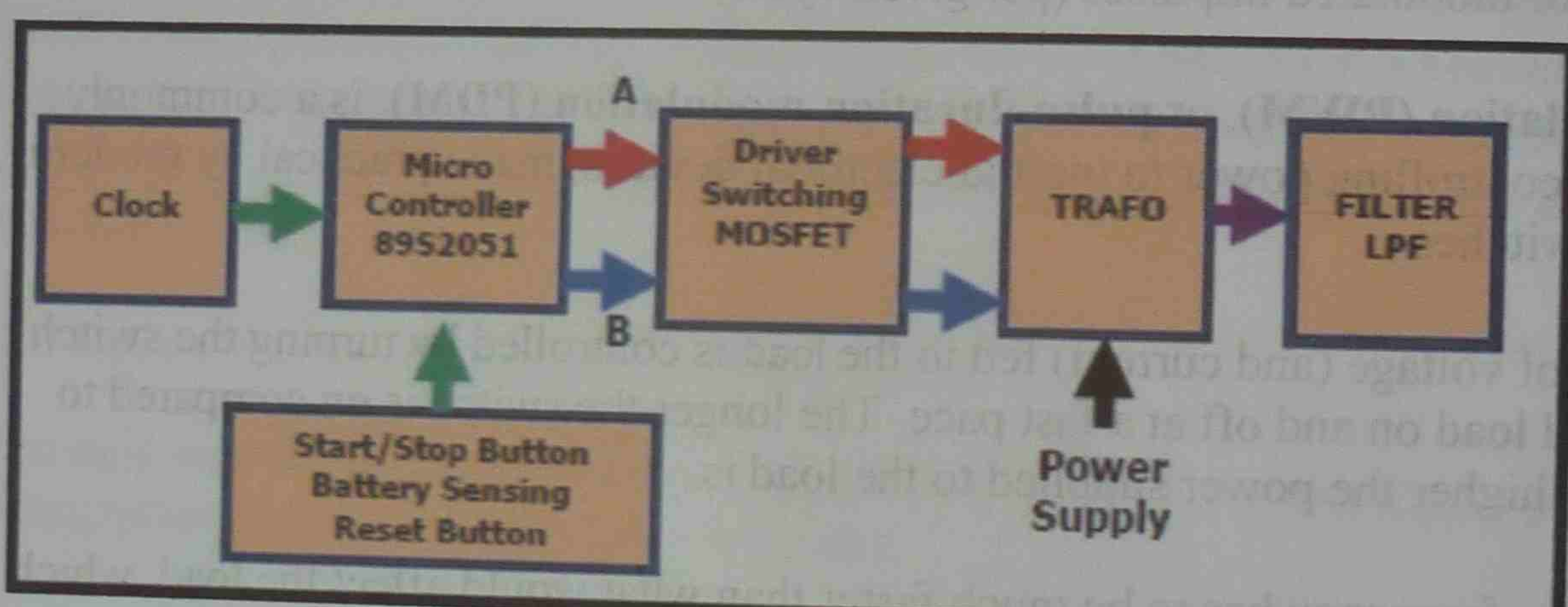
Q21.Explain active filter and passive filter.

An **active filter** is a type of analog electronic filter, distinguished by the use of one or more active components i.e. voltage amplifiers or buffer amplifiers. Typically this will be a vacuum tube, or solid-state (transistor or operational amplifier).

Passive filters: Passive implementations of linear filters are based on combinations of resistors (R), inductors (L) and capacitors (C). These types are collectively known as passive *filters*, because they do not depend upon an external power supply and/or they do not contain active components such as transistors.

Q22.Sketch the example diagram of pure sine wave inverter and explain it's operation.

A **pure sine wave** inverter produces a nearly perfect sine wave output (<3% total harmonic distortion) that is essentially the same as utility-supplied grid power. Thus it is compatible with all AC electronic devices. This is the type used in grid-tie inverters. Its design is more complex, and costs more per unit power.[3] The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters were made to work in reverse, and thus were "inverted", to convert DC to AC.



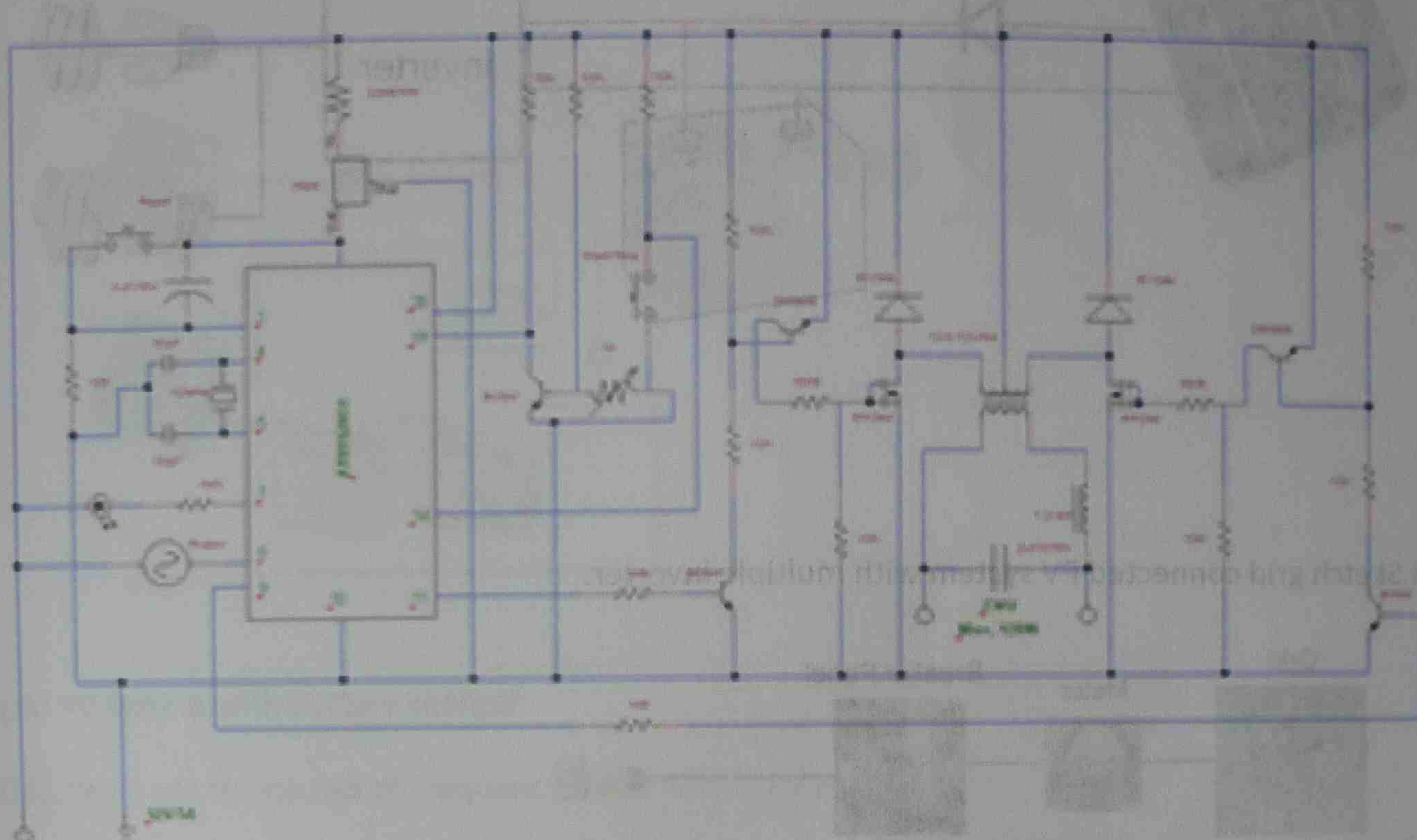
Q25.Explain filter design.

Filter design is the process of designing a filter (in the sense in which the term is used in signal processing, statistics, and applied mathematics), often a linear shift-invariant filter, that satisfies a set of requirements, some of which are contradictory. The purpose is to find a realization of the filter that meets each of the requirements to a sufficient degree to make it useful.

The filter design process can be described as an optimization problem where each requirement contributes with a term to an error function which should be minimized. Certain parts of the design process can be automated, but normally an experienced electrical engineer is needed to get a good result.

Q26.Sketch pure sine wave inverter circuit and explain the operation.

A **pure sine wave** inverter produces a nearly perfect sine wave output (<3% total harmonic distortion) that is essentially the same as utility-supplied grid power. Thus it is compatible with all AC electronic devices. This is the type used in grid-tie inverters. Its design is more complex, and costs more per unit power.[3] The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters were made to work in reverse, and thus were "inverted", to convert DC to AC.

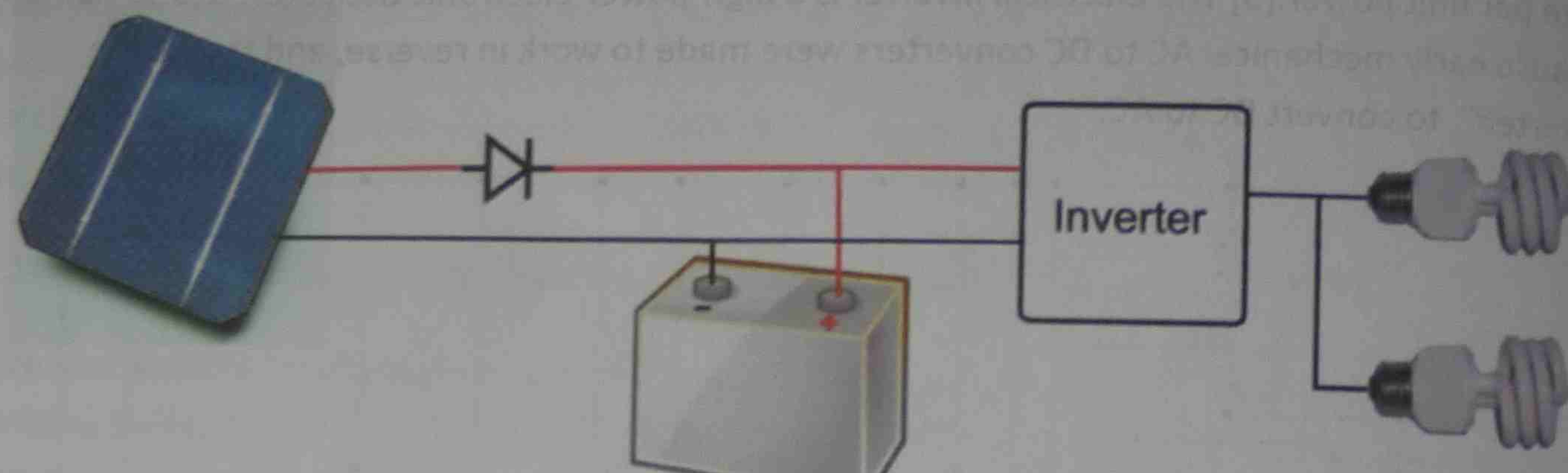


Q27.Sketch overview of grid connected inverter system and explain it's operation.

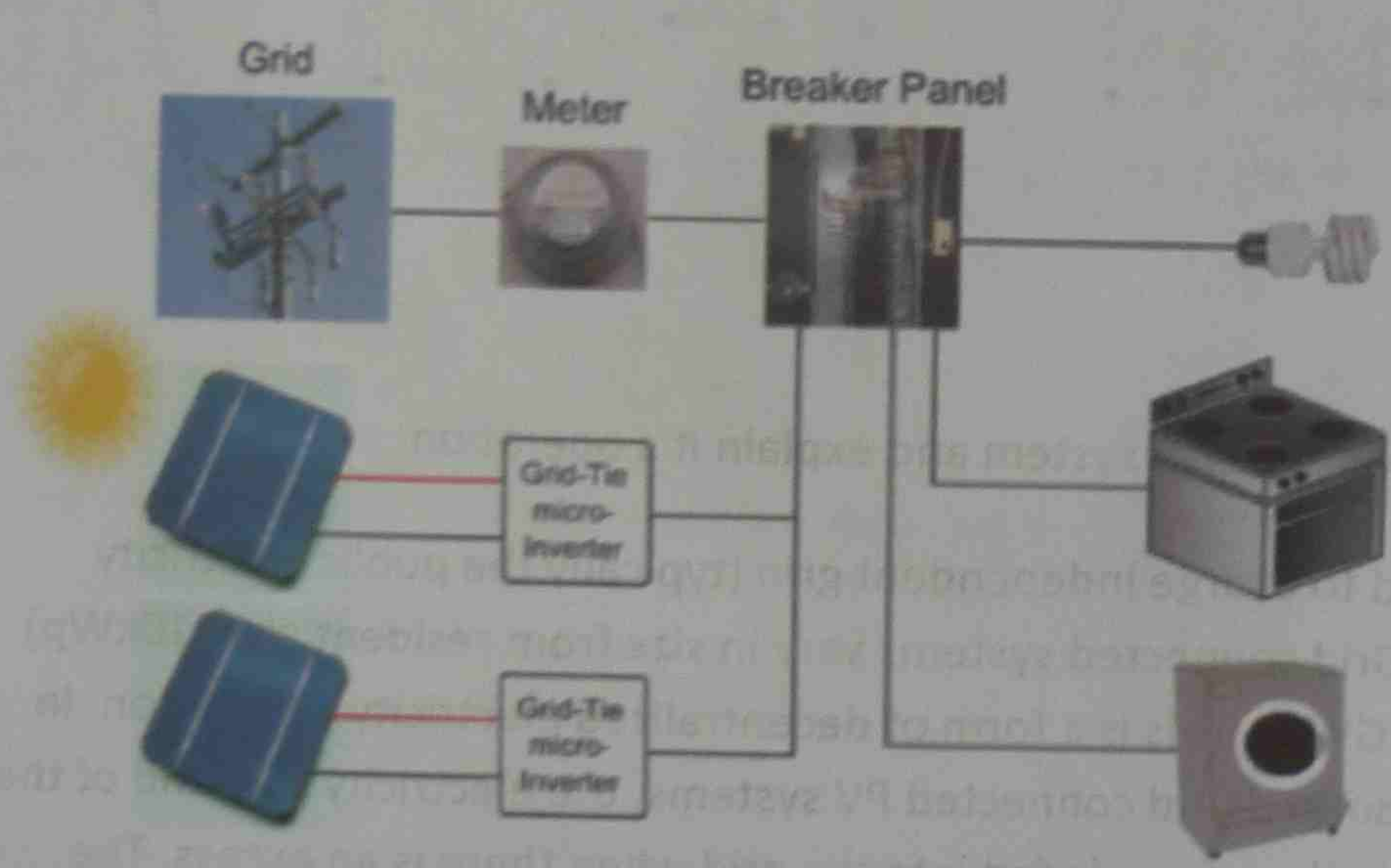
A grid connected system is connected to a large independent grid (typically the public electricity grid) and feeds power into the grid. Grid connected systems vary in size from residential (2-10kWp) to solar power stations (up to 10s of GWp). This is a form of decentralized electricity generation. In the case of residential or building mounted grid connected PV systems, the electricity demand of the building is met by the PV system. Only the excess is fed into the grid when there is an excess. The feeding of electricity into the grid requires the transformation of DC into AC by a special, grid-controlled solar inverter.

A grid-tie inverter (GTI) is a special type of inverter that converts direct current(DC) electricity into alternating current(AC) electricity and feeds it into an existing electrical grid. GTIs are often used to convert direct current produced by many renewable energy sources, such as solar panels or small wind turbines, into the alternating current used to power homes and businesses. The technical name for a grid-tie inverter is "grid-interactive inverter". They may also be called synchronous inverters. Grid-interactive inverters typically cannot be used in standalone applications where utility power is not available.

Grid-connected photovoltaic power systems are power systems energised by photovoltaic panels which are connected to the utility grid. Grid-connected photovoltaic power systems comprise of Photovoltaic panels, MPPT, solar inverters, power conditioning units and grid connection equipments. Unlike Stand-alone photovoltaic power systems these systems do not have batteries. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid.



Q28.Sketch grid connected PV system with multiple inverter.



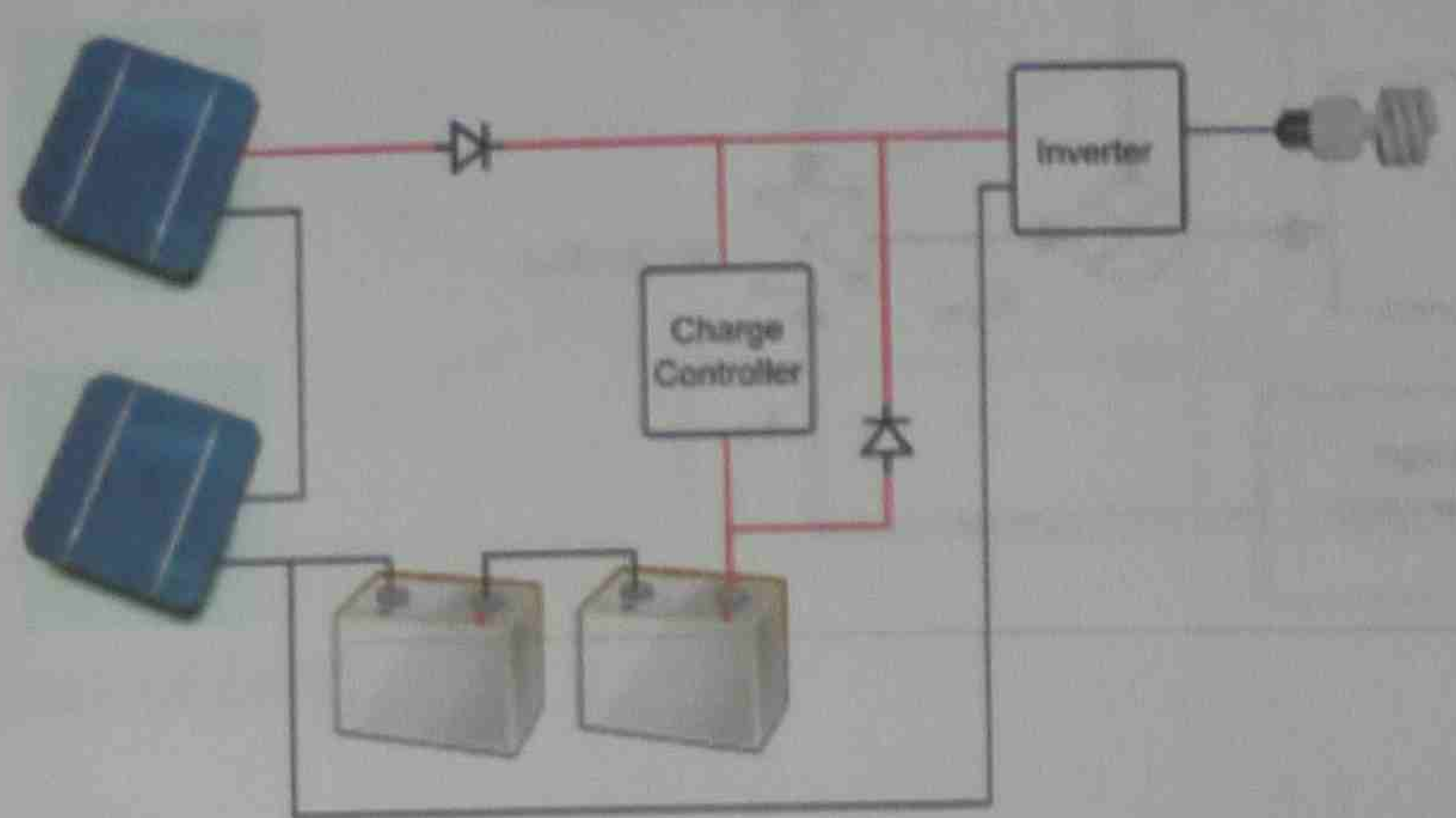
Q29.Explain the energy saving aspects of solar electrical system.

The average household today pays nearly $170 each month in home energy costs. Some estimates have energy costs pegged at almost $200 per month, a cost of $2,400 for the entire year.

It's important to look at the long term picture when evaluating the amount of savings the addition of a solar panel system to one's home will bring. With energy expenses rising each year of due to rising utility rates it's easy to see how fast the money saved builds up.

Q30.Explain PV inverter system with sketch.

A **solar inverter** or **PV inverter** is a critical component in a solar energy system. It performs the conversion of the variable DC output of the Photovoltaic (PV) modules into a utility frequency AC current that can be fed into the commercial electrical grid or used by a local, off-grid electrical network. An inverter allows use of ordinary mains-operated appliances on a direct current system. Solar inverters have special functions adapted for use with PV arrays, including maximum power point tracking and anti-islanding protection.



grid PV system with battery charger.

Q31.What are the causes of frequency distortion to PV inverter?

An inverter selected for in grid-connected PV applications has to meet the requirements of a relevant standard that specifies distortion limits. In Australia this would be AS4777.2. The question is whether the levels of low frequency harmonics in the output of unipolar inverters fall within the limits specified by the standard. This question is best answered on a case by case basis. For the inverter considered in section 3 above, the third harmonic is the worst one and its levels are shown in figure 10.
Total harmonic distortion is shown in figure 11. It has been assumed that non-zero switching delay is the only reason for the generation of low frequency harmonics. The inverter is designed for a rated output of 4 A, therefore it would satisfy the requirements of AS4777.2 even if switching delay is as high as 8 μs. Individual levels for the second to the ninth harmonic should be limited to 4% whereas total harmonic distortion should be limited to 5%

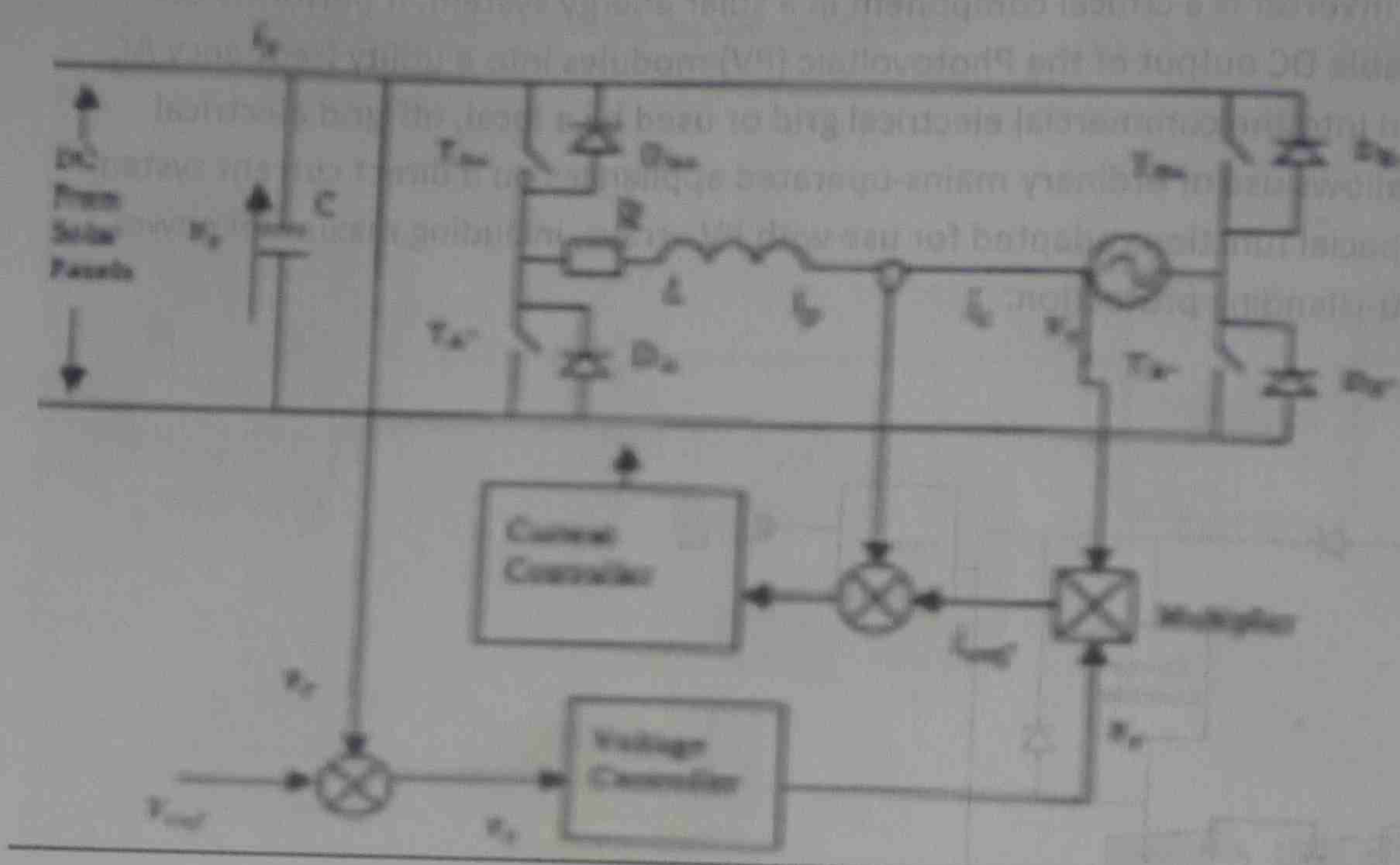
Q32.Write the equation for switching delay.

It is given by the following formula:

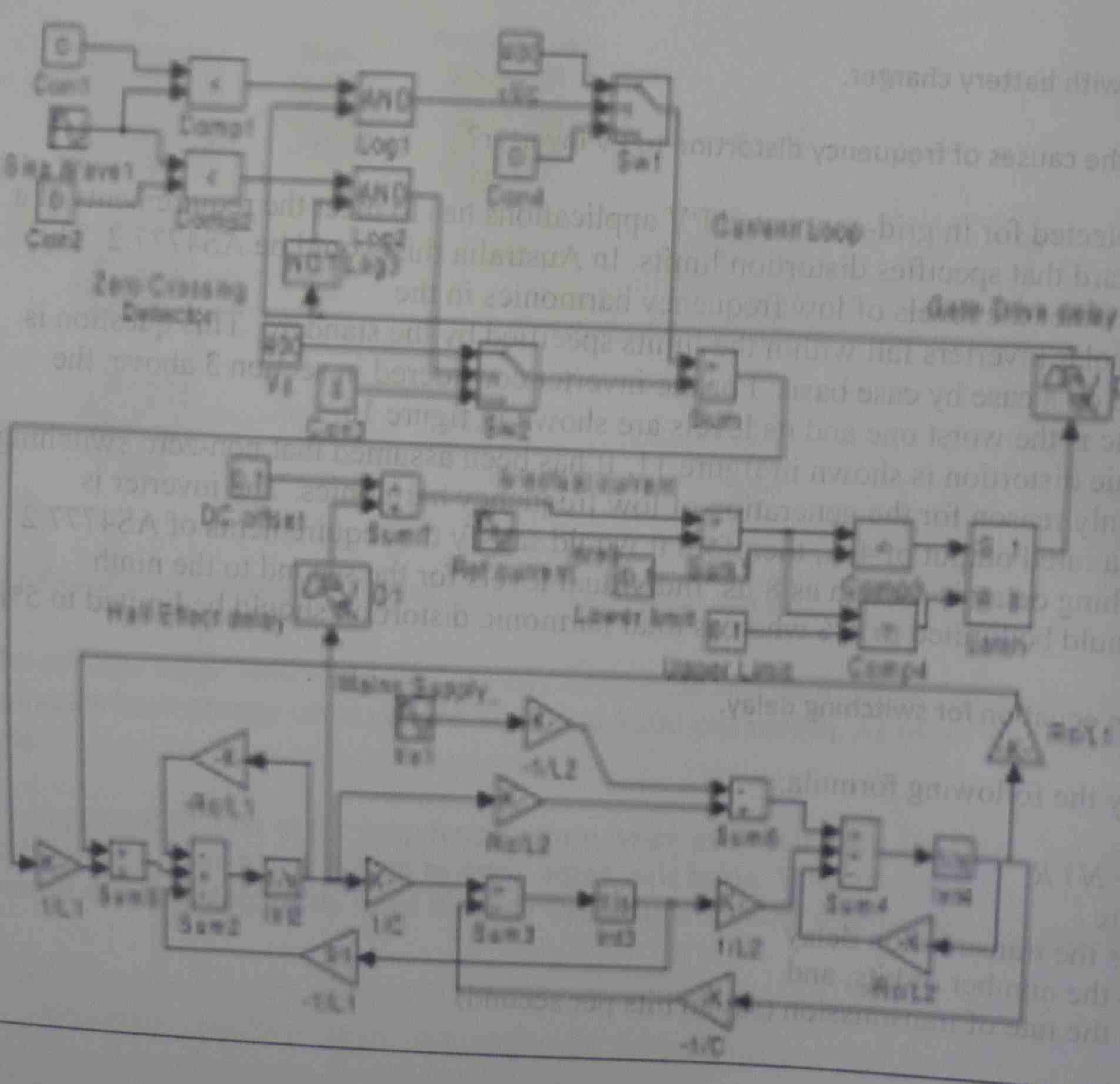
$$D_T = N / R$$

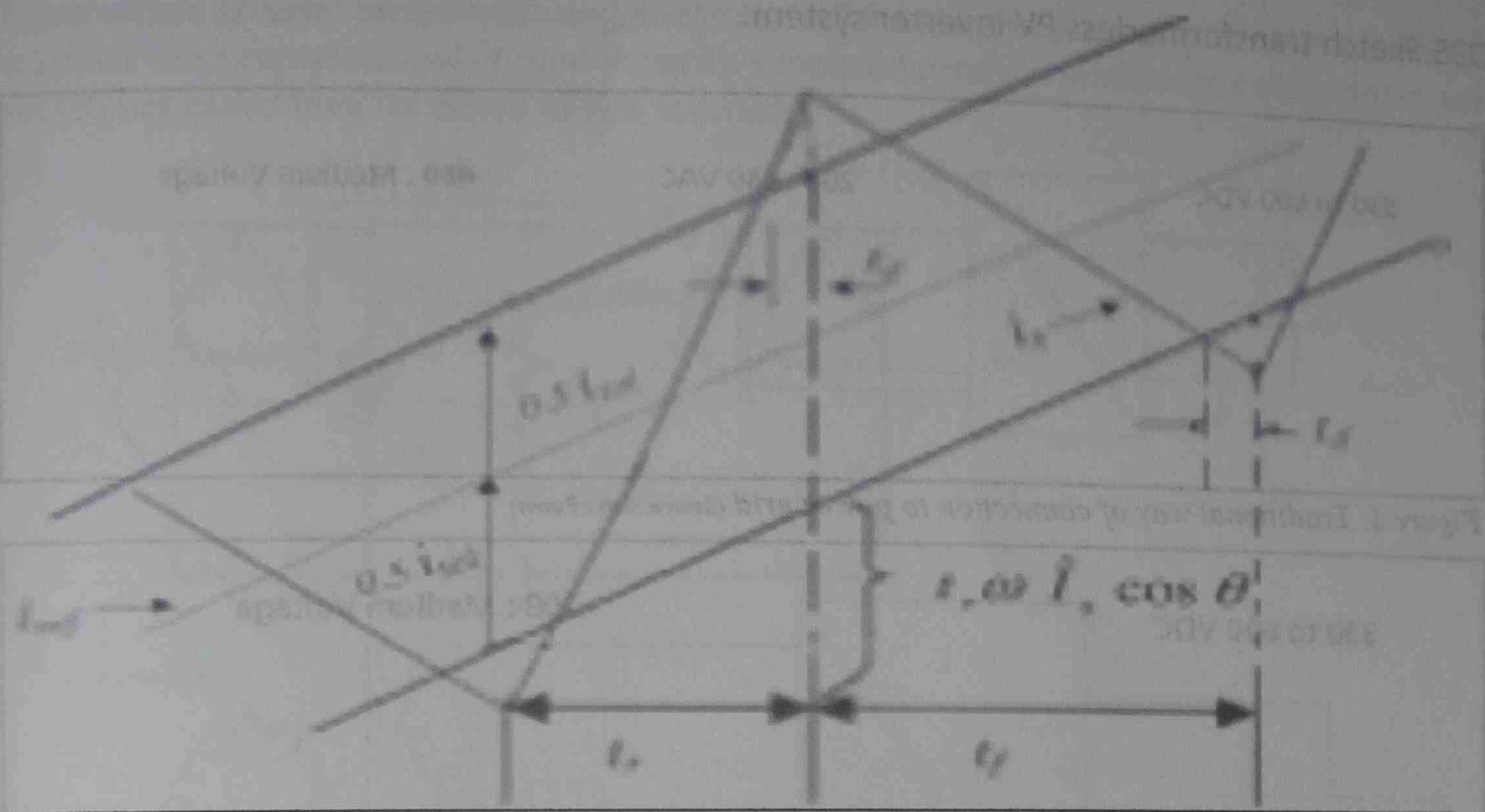
where
D_T is the transmission delay
N is the number of bits, and
R is the rate of transmission (say in bits per second)

Q33.Sketch inverter output current diagrams & total harmonic distortion for unipolar switching & bipolar switching.



Single-phase grid connected PV inverter system.





(Is = peak of $isref$)

Bipolar Mode

Q34.What are the topologies of grid connected inverter?

Grid-tie inverters that are available on the market today use a number of different technologies. The inverters may use the newer high-frequency transformers, conventional low-frequency transformers, or without transformer. Instead of converting direct current directly to 120 or 240 volts AC, high-frequency transformers employ a computerized multi-step process that involves converting the power to high-frequency AC and then back to DC and then to the final AC output voltage.[1] Transformerless inverters, which boast lighter weight and higher efficiencies than their counterparts with transformers, are popular in Europe. However, transformerless inverters have been slow to enter the US market. Until 2005, NEC code required all solar electric systems to be negative grounded, an electrical configuration that interferes with the operation of transformerless inverters. The issue at stake currently is that there are concerns about having transformerless electrical systems feed into the public utility grid since the lack of galvanic isolation between the DC and AC circuits could allow the passage of dangerous DC faults to be transmitted to the AC side.

Most grid-tie inverters on the market include a maximum power point tracker on the input side that enables the inverter to extract a maximum amount of power from its intended power source. Since MPPT algorithms differ for solar panels and wind turbines, specially made inverters for each of these power sources are available.

Q35.Sketch transformerless PV inverter system.

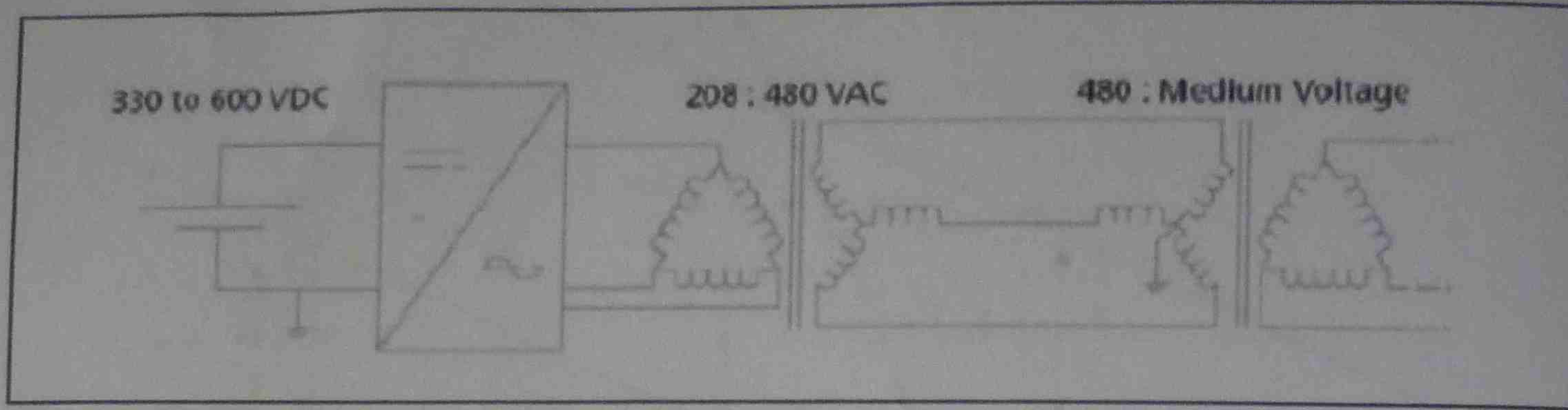


Figure 1. Traditional way of connection to power grid (Source: Samil Power)

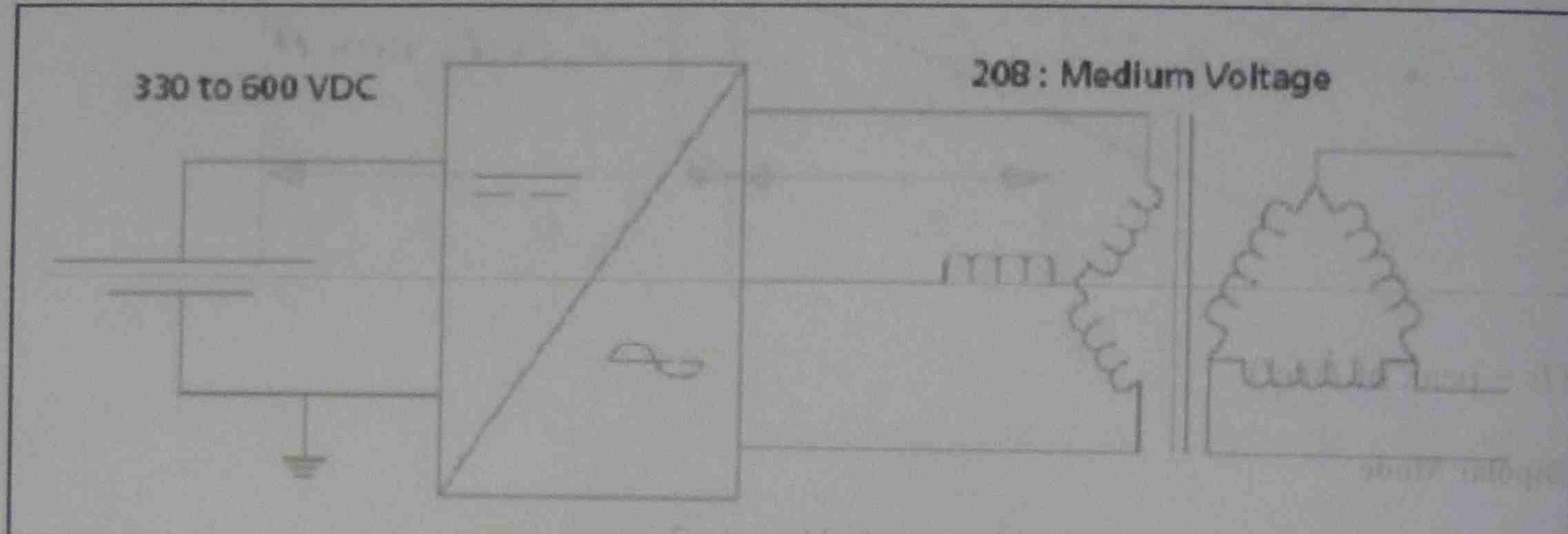
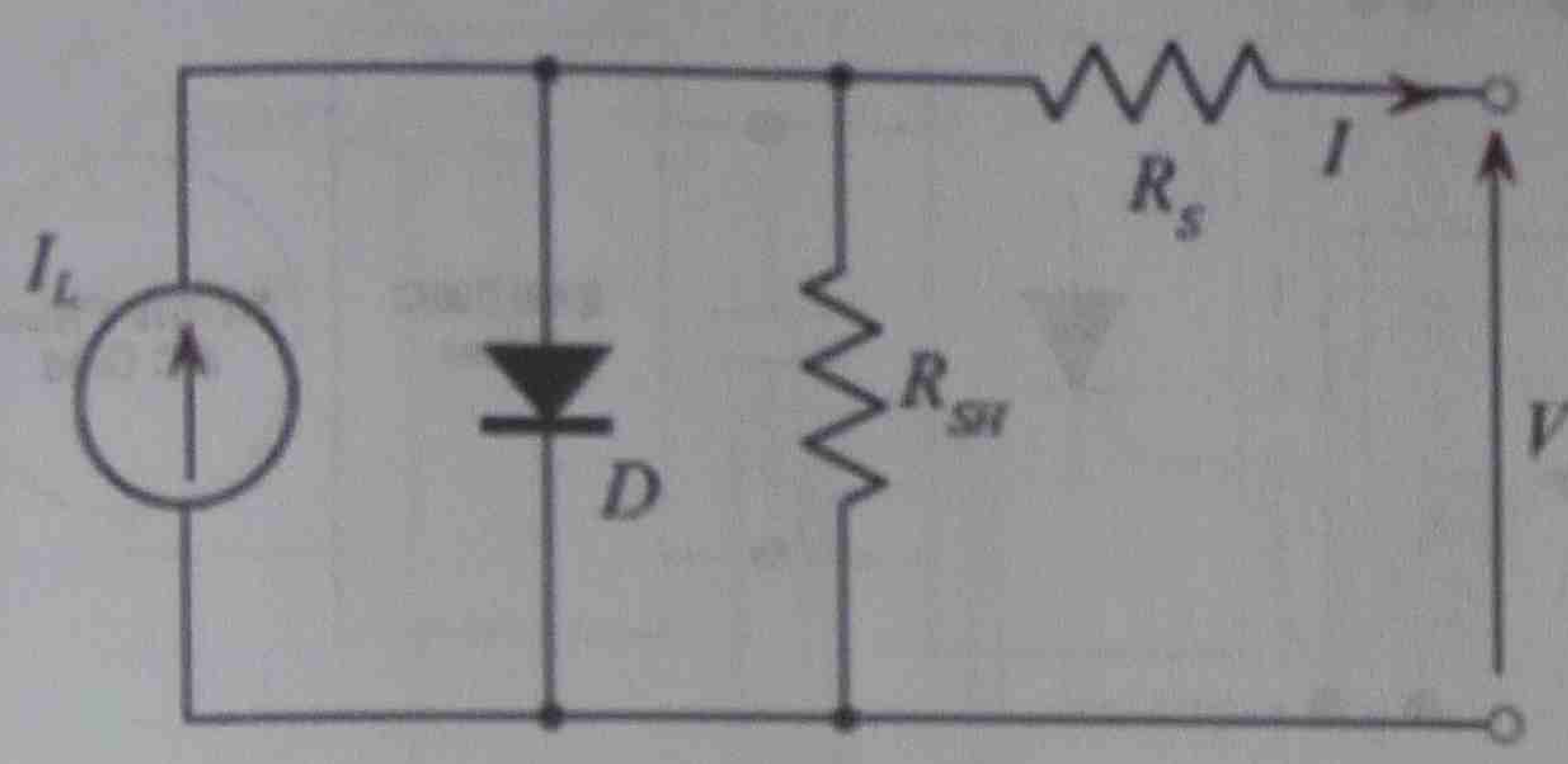


Figure 2. New way of connection to power grid (Source: Samil Power)

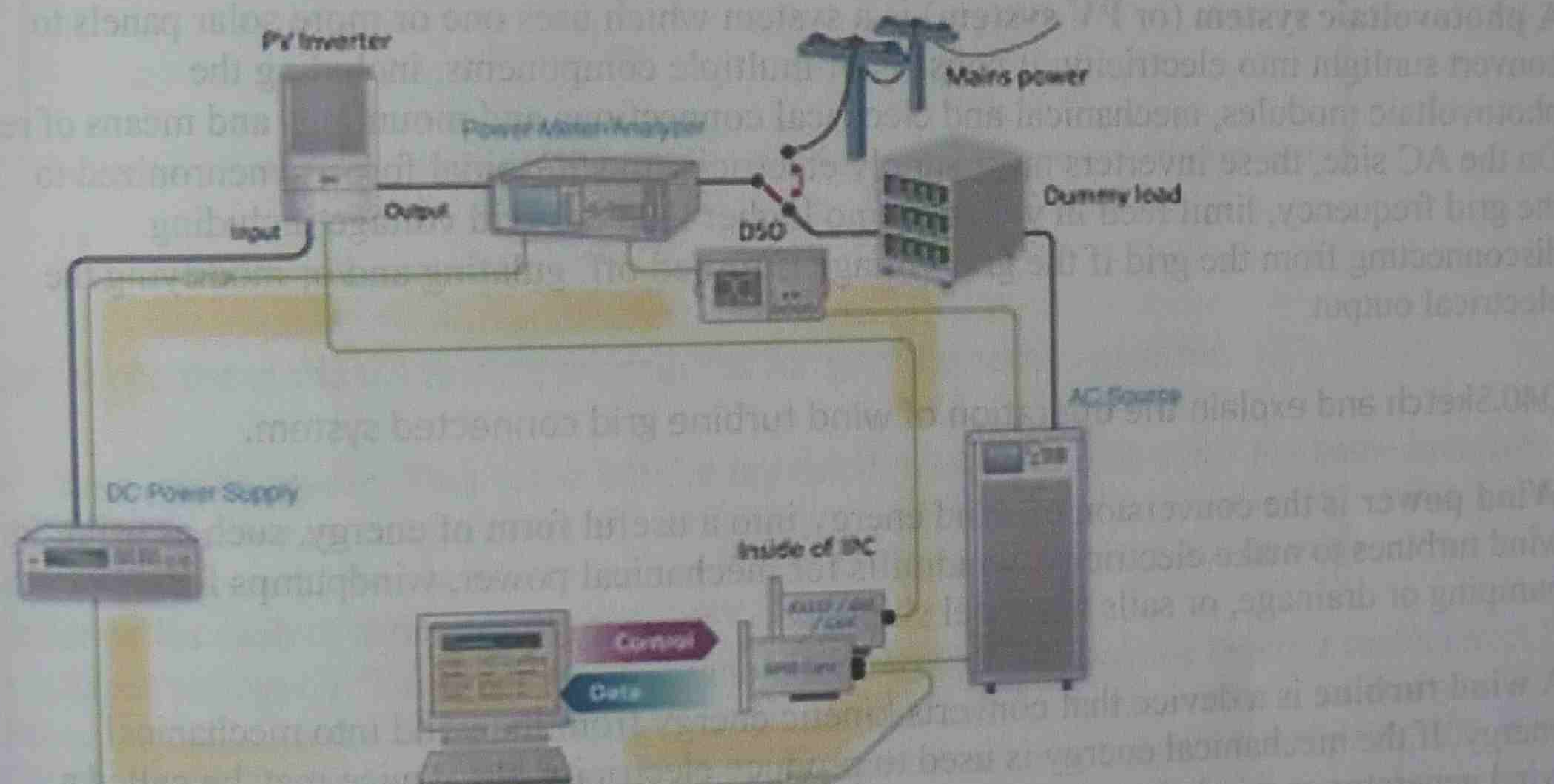
Q36.Sketch PV inverter with frequency transformer .

A variable-frequency drive controls the operating speed of an AC motor by controlling the frequency and voltage of the power supplied to the motor. An inverter provides the controlled power. In most cases, the variable-frequency drive includes a rectifier so that DC power for the inverter can be provided from main AC power. Since an inverter is the key component, A number of political, environmental and technical factors have resulted in the increase of implementation of renewable technology including grid connected photovoltaic inverters. As a result, new topologies for grid connected inverters providing higher efficiencies and lower manufacturing costs have been developed. In particular, designs utilising transformerless topologies have steadily increased. While there are clear associated advantages of implementing these new transformerless topologies, new potential issues such as DC current injection and capacitive leakage currents are introduced. Part A of this report presents a clearly defined test circuit setup and procedure for testing DC current injection for grid-connected single-phase photovoltaic inverters implementing both transformerless and high frequency transformer topologies. The results demonstrated that the test circuit setup and testing procedure is suitable for inclusion in a future amendment to AS4777.2. It is however proposed that before these amendments are recommended, further investigation is required to determine what power levels all inverters are required to be tested at and how many tests per inverter are required. Part B of this report defines and models a variety of transformerless inverter topologies, switching schemes and output filter configurations and clearly defines their operation. All of these various models have been simulated to determine which designs are suitable for applications in regards to reducing capacitive leakage currents in an effort to eliminate potential risks to users and to ensure electromagnetic compatability. Two commercially available and one anonymous Grid-connected Transformerless Single-phase

Photovoltaic Inverter models utilising a selection of the simulated topologies and switching schemes were experimentally tested to verify simulated results. variable-frequency drives are sometimes called inverter drives or just inverters.



Q37.Sketch PV inverter with several conversion stage & high frequency transformer.



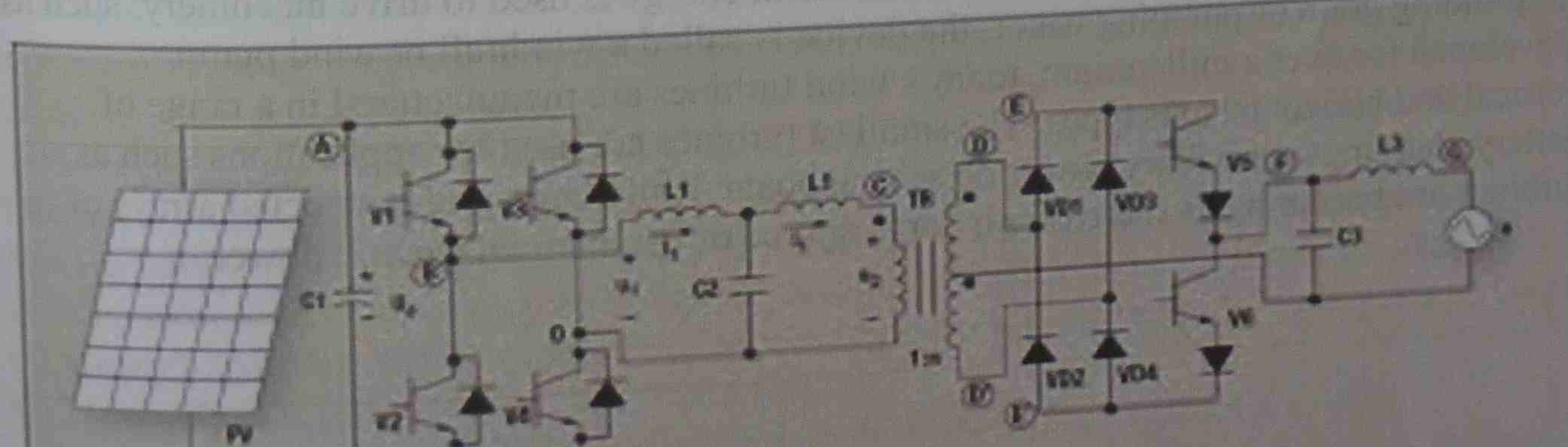
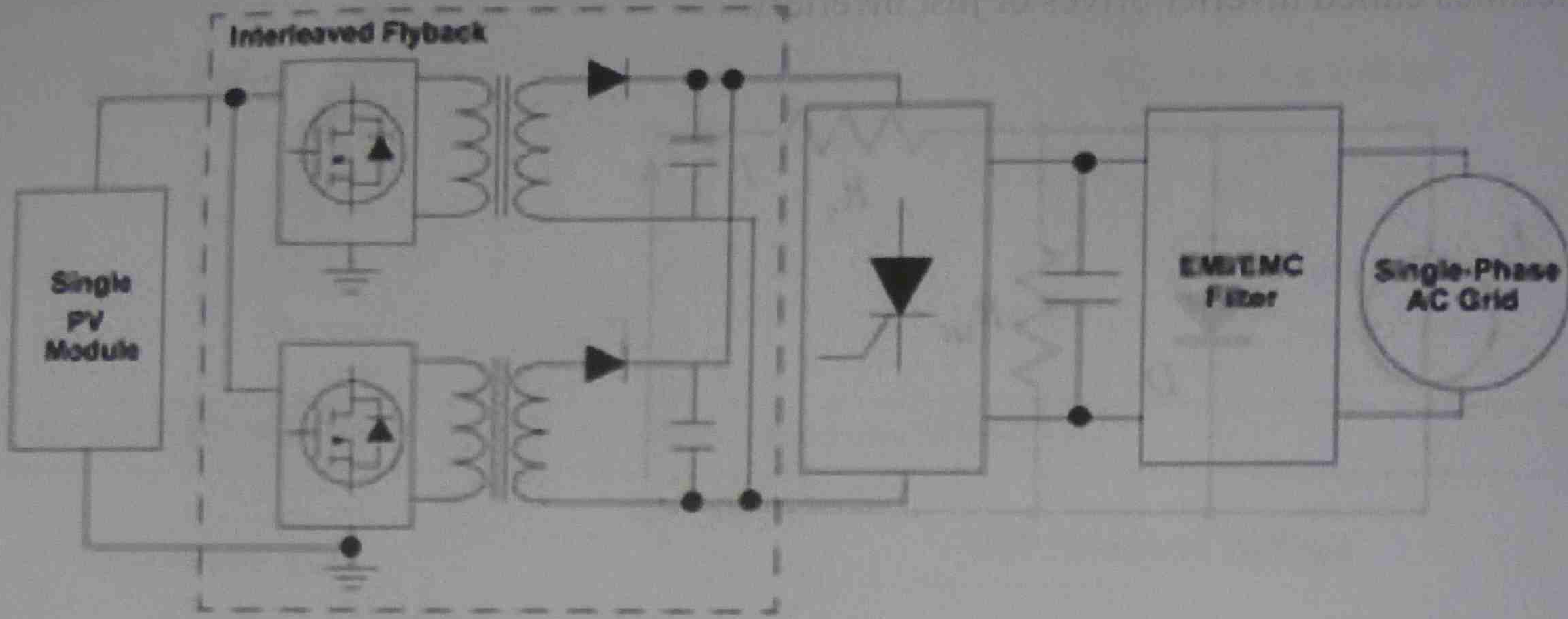


Fig. 1. System topology of the proposed single-phase current-source grid-connected inverter that consists of a high-frequency full-bridge inverter, immittance converter, center-tapped transformer, high-frequency bridge rectifier, power-frequency inverter and low-pass filter.

Q38.Sketch PV inverter with several conversion stages including boost stage



A single-**stage microinverter** performs DC **boost** and AC waveform

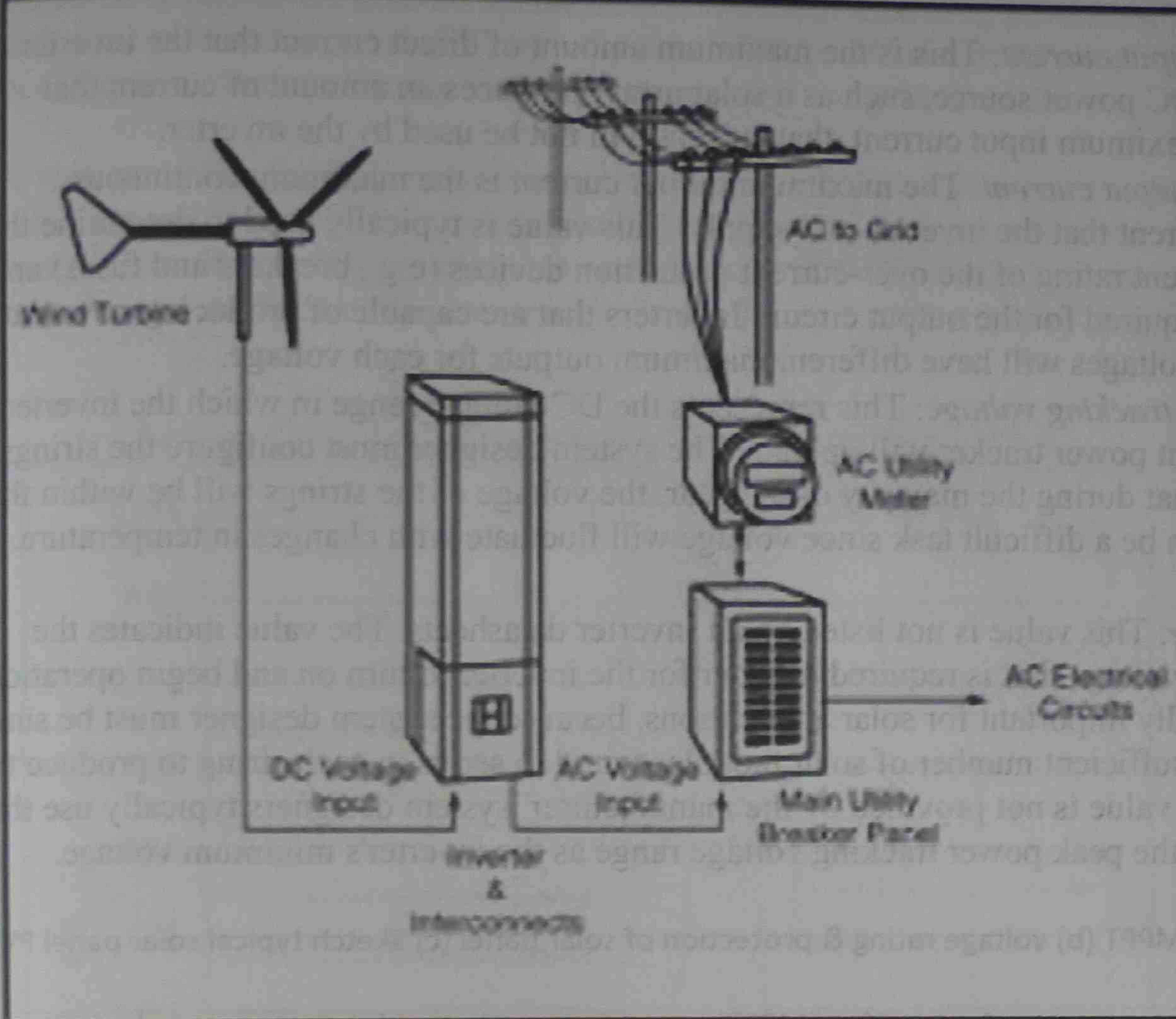
Q39.Explain the configuration and standards for grid connected PV system with diagram.

A **photovoltaic system** (or **PV system**) is a system which uses one or more solar panels to convert sunlight into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of re On the AC side, these inverters must supply electricity in sinusoidal form, synchronized to the grid frequency, limit feed in voltage to no higher than the grid voltage including disconnecting from the grid if the grid voltage is turned off. gulating and/or modifying the electrical output.

Q40.Sketch and explain the operation of wind turbine grid connected system.

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electricity, windmills for mechanical power, windpumps for water pumping or drainage, or sails to propel ships.

A **wind turbine** is a device that converts kinetic energy from the wind into mechanical energy. If the mechanical energy is used to produce electricity, the device may be called a wind generator or wind charger. If the mechanical energy is used to drive machinery, such as for grinding grain or pumping water, the device is called a windmill or wind pump. Developed for over a millennium, today's wind turbines are manufactured in a range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging or auxiliary power on sailing boats; while large grid-connected arrays of turbines are becoming an increasingly large source of commercial electric power.



Q41.Write the standard testing procedures for grid connected inverter.

• *Rated output power*: This value will be provided in watts or kilowatts. For some inverters, they may provide an output rating for different output voltages. For instance, if the inverter can be configured for either 240 VAC or 208 VAC output, the rated power output may be different for each of those configurations.

• *Output voltage(s)*: This value indicates to which utility voltages the inverter can connect. For smaller inverters that are designed for residential use, the output voltage is usually 240 VAC. Inverters that target commercial applications are rated for 208, 240, 277, 400, or 480 VAC and may also produce three phase power.

• *Peak efficiency*: The peak efficiency represents the highest efficiency that the inverter can achieve. Most grid-tie inverters on the market as of July 2009 have peak efficiencies of over 94%, some as high as 96%. The energy lost during inversion is for the most part converted into heat. This means that in order for an inverter to put out the rated amount of power it will need to have a power input that exceeds the output. For example, a 5000 W inverter operating at full power at 95% efficiency will require an input of 5,263 W (rated power divided by efficiency). Inverters that are capable of producing power at different AC voltages may have different efficiencies associated with each voltage.

• *CEC weighted efficiency*: This efficiency is published by the California Energy Commission on its GoSolar website. In contrast to peak efficiency, this value is an average efficiency and is a better representation of the inverter's operating profile. Inverters that are capable of producing power at different AC voltages may have different efficiencies associated with each voltage.

- *Maximum input current*: This is the maximum amount of direct current that the inverter will use. If a DC power source, such as a solar array, produces an amount of current that exceeds the maximum input current, that current will not be used by the inverter.
- *Maximum output current*: The maximum output current is the maximum continuous alternating current that the inverter will supply. This value is typically used to determine the minimum current rating of the over-current protection devices (e.g., breakers and fuses) and disconnects required for the output circuit. Inverters that are capable of producing power at different AC voltages will have different maximum outputs for each voltage.
- *Peak power tracking voltage*: This represents the DC voltage range in which the inverter's maximum point power tracker will operate. The system designer must configure the strings optimally so that during the majority of the year, the voltage of the strings will be within this range. This can be a difficult task since voltage will fluctuate with changes in temperature.

- *Start voltage*: This value is not listed on all inverter datasheets. The value indicates the minimum DC voltage that is required in order for the inverter to turn on and begin operation. This is especially important for solar applications, because the system designer must be sure that there is a sufficient number of solar modules wired in series in each string to produce this voltage. If this value is not provided by the manufacturer, system designers typically use the lower band of the peak power tracking voltage range as the inverter's minimum voltage.

Q42.Explain (a)MPPT (b) voltage rating & protection of solar panel (c) Sketch typical solar panel PV curve.

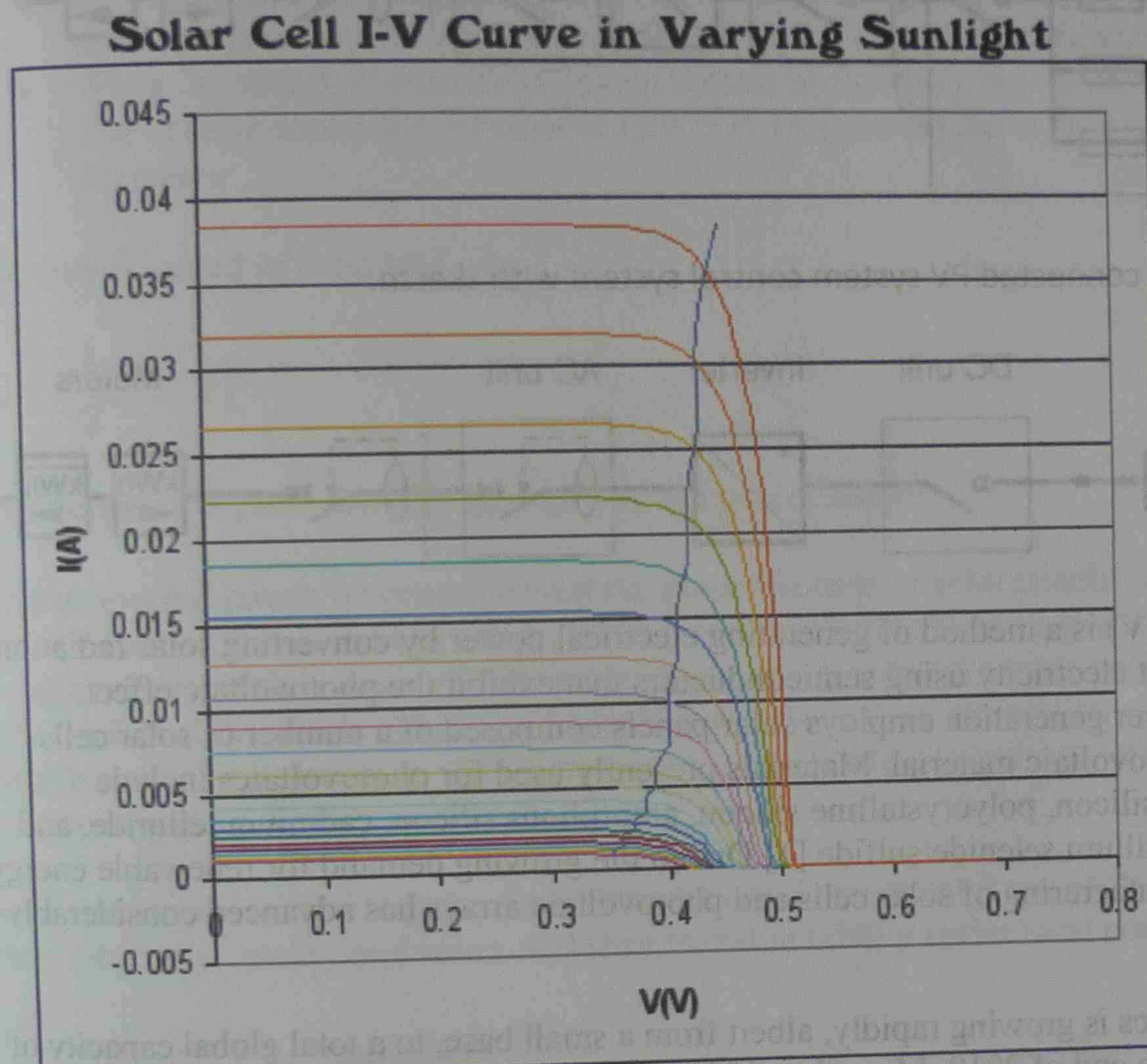
a) **Maximum power point tracking** (MPPT) is a technique that grid tie inverters, solar battery chargers and similar devices use to get the maximum possible power from the PV array. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency known as the *I-V curve*. It is the purpose of the MPPT system to sample the output of the cells and apply a resistance (load) to obtain maximum power for any given environmental conditions. Essentially, this defines the current that the inverter should draw from the PV in order to get the maximum possible power (since power equals voltage times current).

This method makes use of the fact that the ratio of maximum power point voltage to the open circuit voltage is often close to a constant value, with 0.76 being a common estimate. One problem with this method arises from the fact that it requires momentarily setting the PV array current to 0 to measure the array's open circuit voltage. The array's operating voltage is then set to (for example) 76% of this measured value. But during the time the array is disconnected, the available energy is wasted. It has also been found that while 76% of the open circuit voltage is often a very good approximation, it does not always coincide with the maximum power point.[5] Thus this method may not give as much efficiency as others, especially if conditions are highly variable or the physical behavior of the cell deviates from expectations. Its main advantage is that it is relatively simple to implement and thus usually less expensive.

Normally, grid-tied inverters will shut off if they do not detect the presence of the utility grid. If, however, there are load circuits in the electrical system that happen to resonate at the frequency of the utility grid, the inverter may be fooled into thinking that the grid is still active even after it had been shut down. This is called islanding.

An inverter designed for grid-tie operation will have anti-islanding protection built in; it will inject small pulses that are slightly out of phase with the AC electrical system in order to cancel any stray resonances that may be present when the grid shuts down.

The voltage and/or the frequency change during the grid failure is measured and a positive feedback loop is employed to push the voltage and /or the frequency further away from its nominal value. Frequency or voltage may not change if the load matches very well with the inverter output or the load has a very high quality factor (reactive to real power ratio).

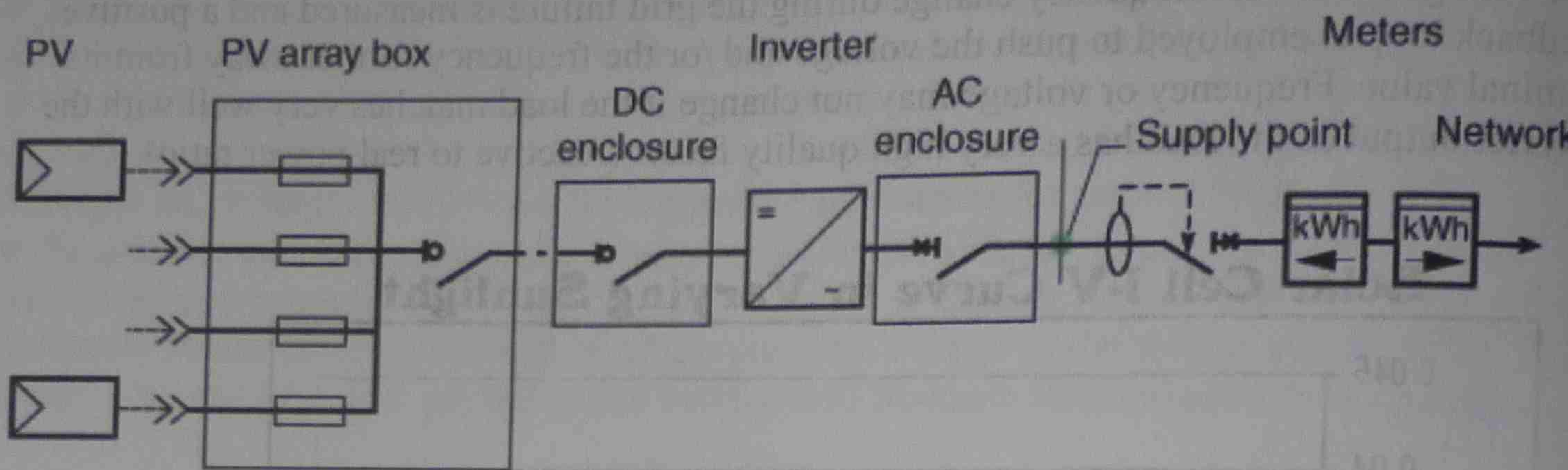


Q43.Sketch multi string PV inverter system.

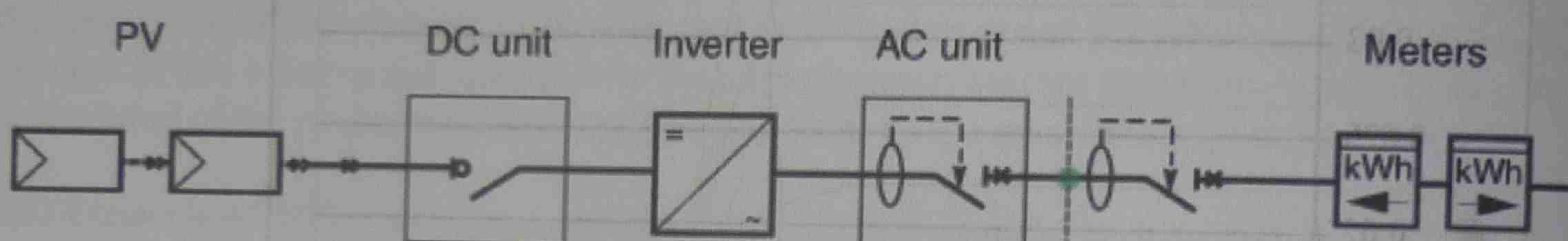
A **solar micro-inverter**, also referred as microinverter or micro inverter, converts direct current (DC) from a single solar panel to alternating current (AC). The electric power from several micro-inverters is combined and fed into an existing electrical grid. Micro-inverters contrast with conventional central inverter devices, which are connected to multiple solar panels.

Micro-inverters have several advantages over conventional central inverters. The main advantage is that, even small amounts of shading, debris or snow lines in any one solar panel, or a panel failure, does not disproportionately reduce the output of an entire array. Each micro-inverter obtains optimum power by performing maximum power point tracking for its connected panel.

Their primary disadvantages are that they have a higher equipment initial cost per peak watt than the equivalent power in a central inverter, and are normally located near the panel, where they may be harder to maintain. These issues are however surpassed by micro-inverters having much higher durability and simplicity of initial installation.



Q44.Explain grid connected PV system control system with sketch.



Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide.[1] Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

Solar photovoltaics is growing rapidly, albeit from a small base, to a total global capacity of 40,000 MW at the end of 2010. More than 100 countries use solar PV. Installations may be ground-mounted (and sometimes integrated with farming and grazing) or built into the roof or walls of a building (building-integrated photovoltaics).

Q45.Write the mathematical modelling for switched mode inverter.

A **switched-mode power supply (switching-mode power supply, SMPS,** or simply **switcher)** is an electronic power supply that incorporates a switching regulator in order to be highly efficient in the conversion of electrical power. Like other types of power supplies, an SMPS transfers power from a source like the electrical power grid to a load (e.g., a personal computer) while converting voltage and current characteristics. An SMPS is usually employed to efficiently provide a regulated output voltage, typically at a level different from the input voltage. Unlike a linear power supply, the pass transistor of a switching mode supply switches very quickly (typically between 50 kHz and 1 MHz) between full-on and full-off states, which minimizes wasted energy. Voltage regulation is provided by varying the ratio of on to off time. In contrast, a linear power supply must dissipate the excess voltage to

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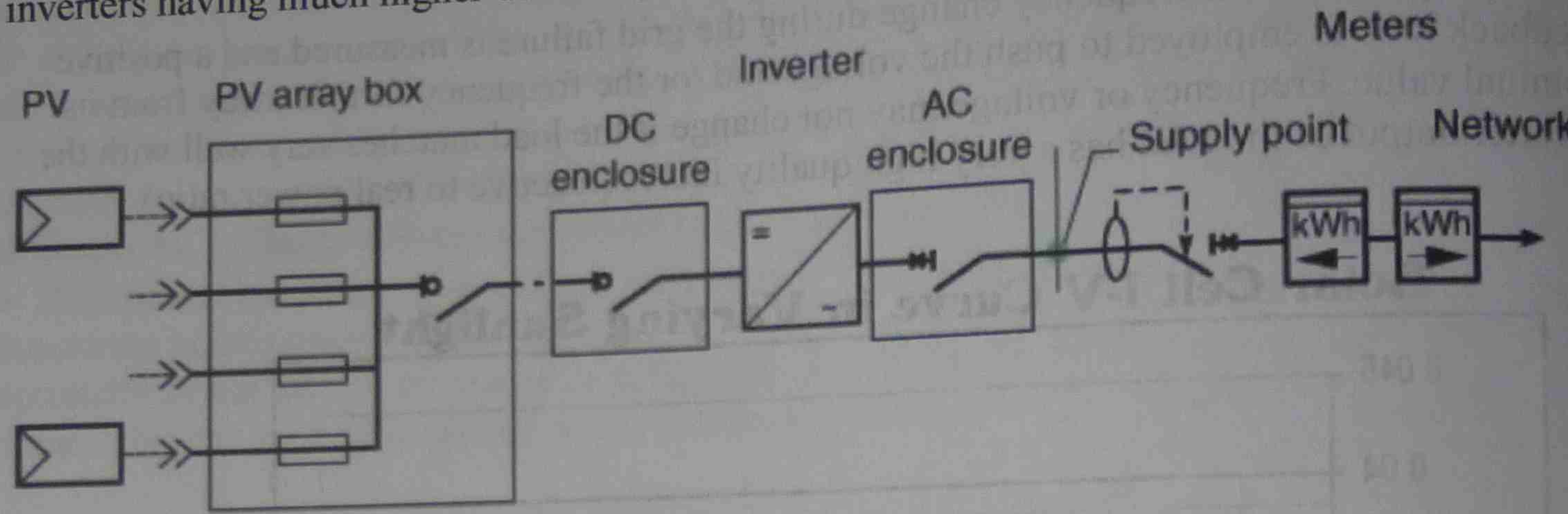

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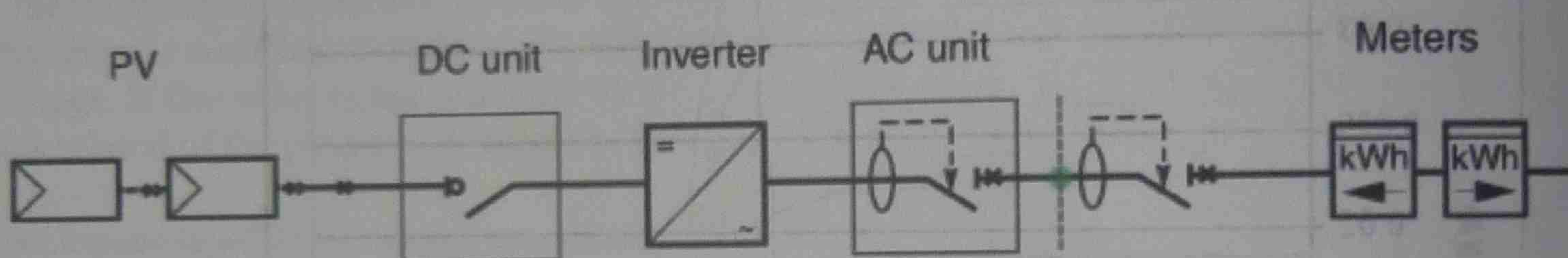

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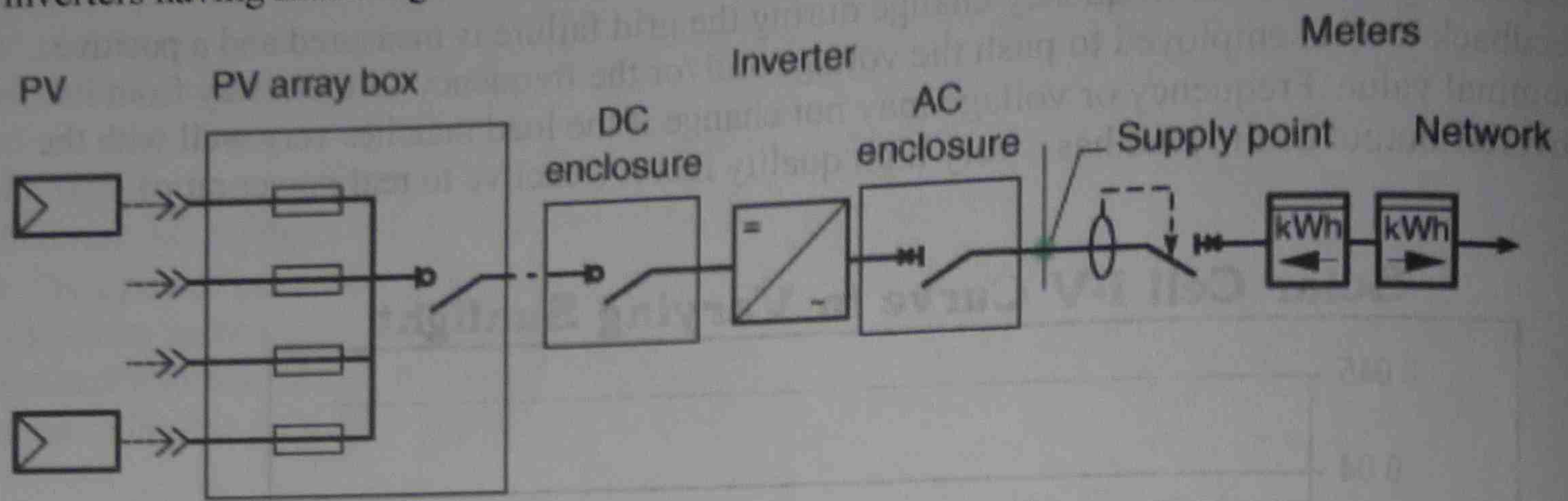

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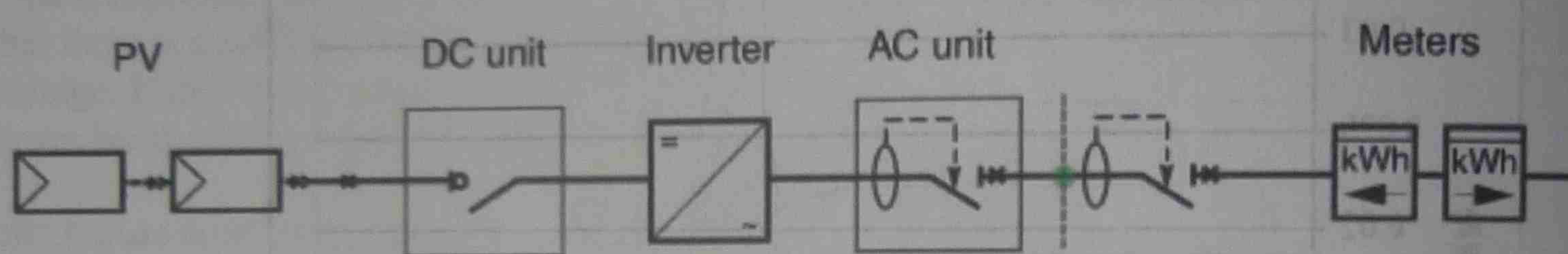

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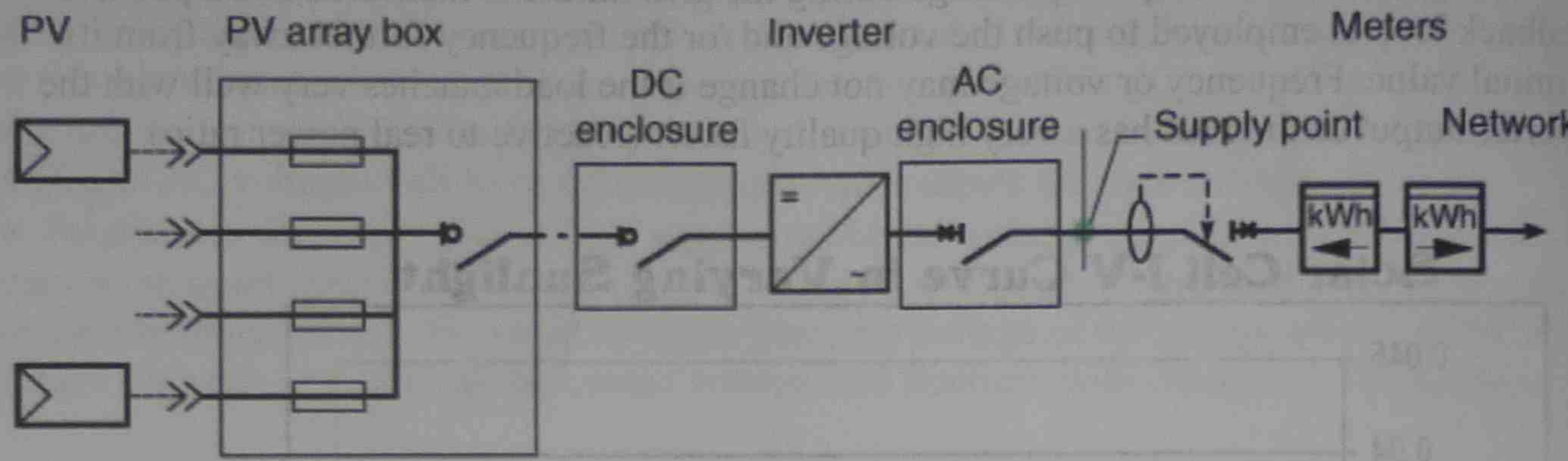

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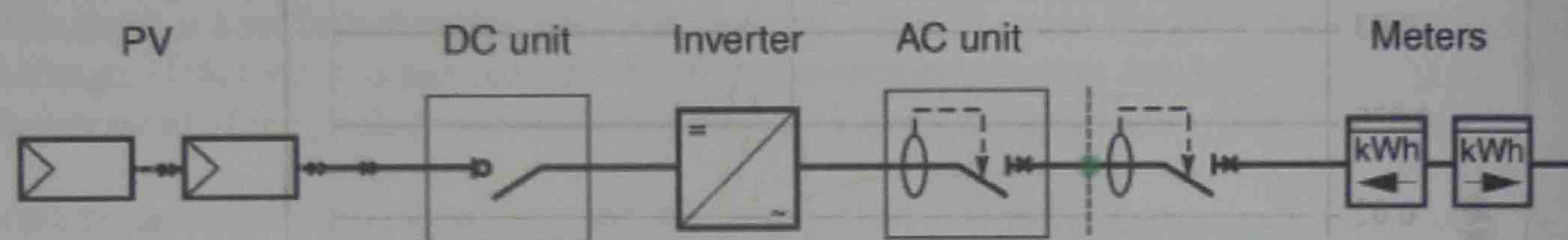

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Switching regulators are used as replacements for the linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated, their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor.

- When the switch pictured above is closed (On-state, top of figure 2), the voltage across the inductor is $V_L = V_i - V_o$. The current through the inductor rises linearly. As the diode is reverse-biased by the voltage source V, no current flows through it;
- When the switch is opened (off state, bottom of figure 2), the diode is forward biased. The voltage across the inductor is $V_L = - V_o$ (neglecting diode drop). Current I_L decreases.

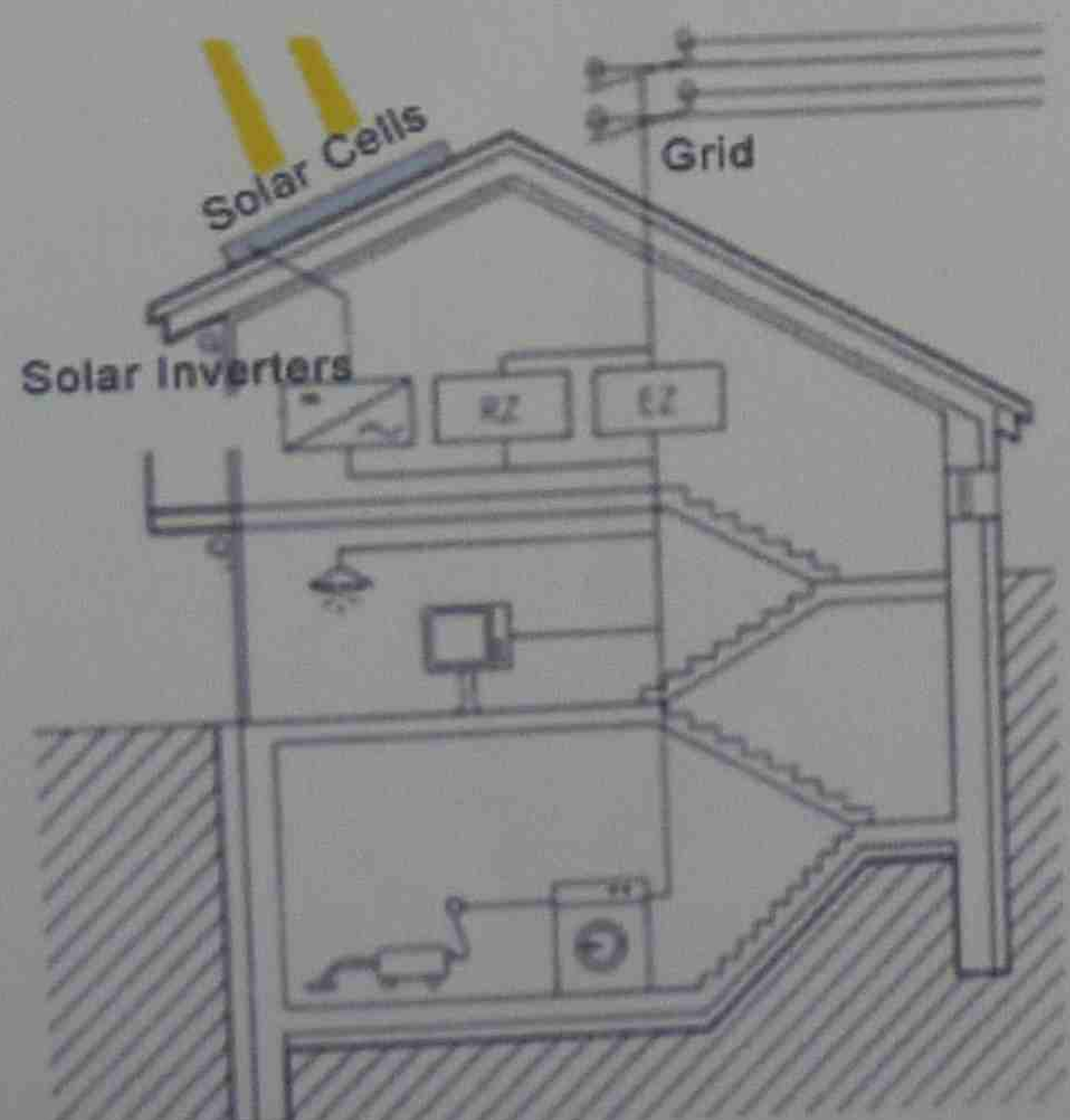
The energy stored in inductor L is

$$E = \frac{1}{2} L \times I_L^2$$

Q46. Express the parameters of grid connected power inverter.

Grid-connected power inverters convert the power from your solar panels into electricity suitable for use in the home or office, when it is connected to the power grid.
Here, a battery bank is not needed to store any excess generated power, as that can be delivered directly into the power grid for someone else to use, giving you a credit. At times of insufficient solar power (e.g. night time), extra power that's needed may be drawn back from the power grid.

Solazone supply several brands of grid inverters, and recommend any of these models for their reliability, quality and value, and their tested reliability under local conditions.



ULTIMO COLLEGE OF TAFE

Course name : Advance Diploma in Electrical engineering

Course no. : 17794

Student name : THI TRUONG

Student number : 210182527

SUBJECT : ASSIGNMENT KO25

SOLVE BASIC PROBLEMS IN PHOTOVOTAIC ENERGY APPARATUS

TEACHER'S NAME : KYAW NAING

Q16.Explain (a) Characteristics of sunlight (b) black body (c)emergency density of black body radiation distribution of sunlight.

The Earth's most important energy source is the Sun. Thanks to the sunrays the surface of the Earth and the air right above the surface warms up, therefore the Earth's average temperature reaches +17°C even though it is in the outer space which is -270°C. This way life can develop and be maintained on the Earth.

Inside the Sun there is thermonuclear fusion, thanks to which heat is produced, while Hydrogen is transformed to Helium.

Due to the nuclear fusion the temperature of the Sun's surface approaches the 6000°K.

As a consequence of this high temperature the Sun emits short waves of electromagnetic rays of light.

From the sun-radiance power of $(4x10^{23}$ kW) the surface of the Earth reaches 173×10^{12} kW.

From the sunrays approaching the edge of the atmosphere only some proportion reaches the surface of the Earth. According to the calculations out of the total sunrays 23% is absorbed by the gases in the air, transforming it to heat, 26% is reflected or radiated back to the space in the form of stray rays.

This way only 51% reaches the surface of the Earth, 33% as direct shortwave radiation and 18% as diffuse radiation. Out of this proportion the Earth's surface reflects 10%, 5% is absorbed in the atmosphere, and 5% exits to the space.

The sunray household of the Earth – **which exceeds the energy needs of the humanity more than thousand times** – is constantly balanced in average, but the value is variable with the weather changes. The main cause of this phenomenon is the Earth's geometrical relationship to the Sun.

The proportion of the sunrays at the edge of the atmosphere can be divided in the following matter:

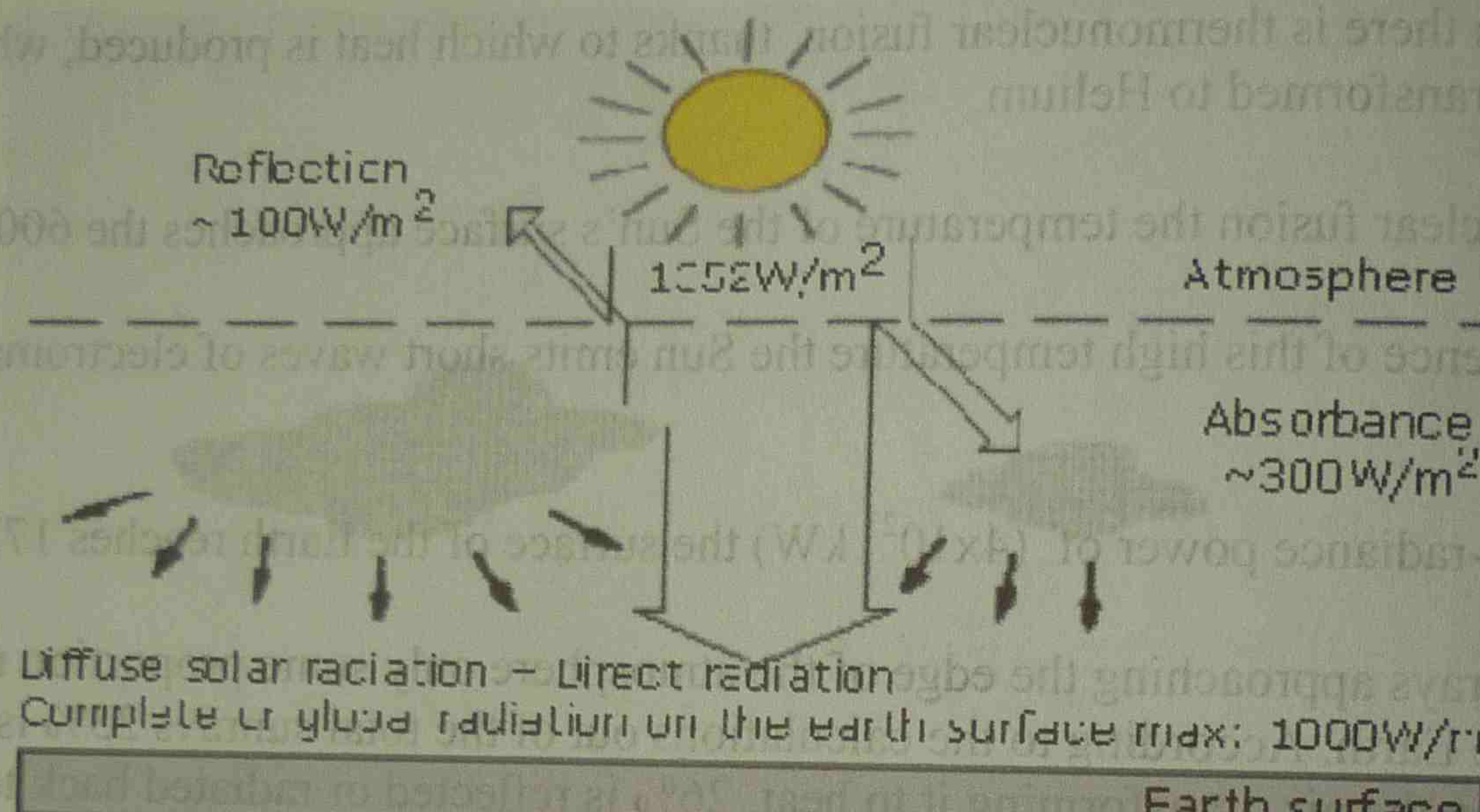
- Ultraviolet radiation 9%.
- Visible light 49%.
- Infrared (heat-) radiation 42%.

According to the data described above the atmosphere weakens the sunrays arriving to the Earth surface, which is highly effected by the clouds and fog present, due to the weather changes.

These clouds reflect or absorb most of the sunrays. Between the axis of the Earth and its circle around the Sun there is 23,5° difference, therefore the visible orbit of the Sun on the

sky is different every day.
naturally influences the usable energy.

Since Hungary can be found in the north tempered zone, on the north latitude between 45,8° and 48,6°, the number of sunny hours is approximately **2100 hours/year**, the heat quantity of the arriving sunrays is ~**1300 kWh/m² year**, the highest peak summertime, at noon, in case of clean sky can reach, or exceed the **1000 W/m²**



A **black body** is an idealized physical body that absorbs all incident electromagnetic radiation. Because of this perfect absorptivity at all wavelengths, a black body is also the best possible emitter of thermal radiation, which it radiates incandescently in a characteristic, continuous spectrum that depends on the body's temperature. At Earth-ambient temperatures this emission is in the infrared region of the electromagnetic spectrum and is not visible. The object appears black, since it does not reflect or emit any visible light.

The thermal radiation from a black body is energy converted electrodynamically from the body's pool of internal thermal energy at any temperature greater than absolute zero. It is called blackbody radiation and has a frequency distribution with a characteristic frequency of maximum radiative power that shifts to higher frequencies with increasing temperature. As the temperature increases past a few hundred degrees Celsius, black bodies start to emit visible wavelengths, appearing red, orange, yellow, white, and blue with increasing temperature. When an object is visually white, it is emitting a substantial fraction as ultraviolet radiation.

Blackbody emission provides insight into the thermodynamic equilibrium state of cavity radiation. If each Fourier mode of the absolutely stable equilibrium radiation in a cavity with perfectly reflective walls were considered as a degree of freedom, and if all those degrees of freedom could freely exchange energy, then, according to the equipartition theorem in classical physics, each degree of freedom would have one and the same quantity of energy. This approach led to the paradox known as the ultraviolet catastrophe, that there would be an infinite amount of energy in any continuous field. The study of the laws of black bodies helped to establish the foundations of quantum mechanics.

Q17.Describe solar insolation measurement.

Insolation is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed as average irradiance in watts per square meter (W/m2) or kilowatt-hours per square meter per day (kW·h/(m2·day)) (or hours/day). In the case of photovoltaics it is commonly measured as kWh/(kW_p·y) (kilowatt hours per year per kilowatt peak rating).

The object or surface that solar radiation strikes may be a planet, a terrestrial object inside the atmosphere of a planet, or any object exposed to solar rays outside of an atmosphere, including spacecraft. Some of the solar radiation will be absorbed, while the remainder will be reflected. Usually the absorbed solar radiation is converted to thermal energy, causing an increasing in the object's temperature. Some systems, however, may store or convert a portion of the solar energy into another form of energy, as in the case of photovoltaics or plants. The proportion of radiation reflected or absorbed depends on the object's reflectivity or albedo.

Q19.Explain solar geometry.

The solar geometry model takes input of date, time and location of an observer on the earth and returns information about the location of the sun. The model can work in two modes: as a single shot calculation which is carried out each time an input variable is changed or it can be set so to automatically increment time and will run continuously.
User Input
The model takes the following inputs:

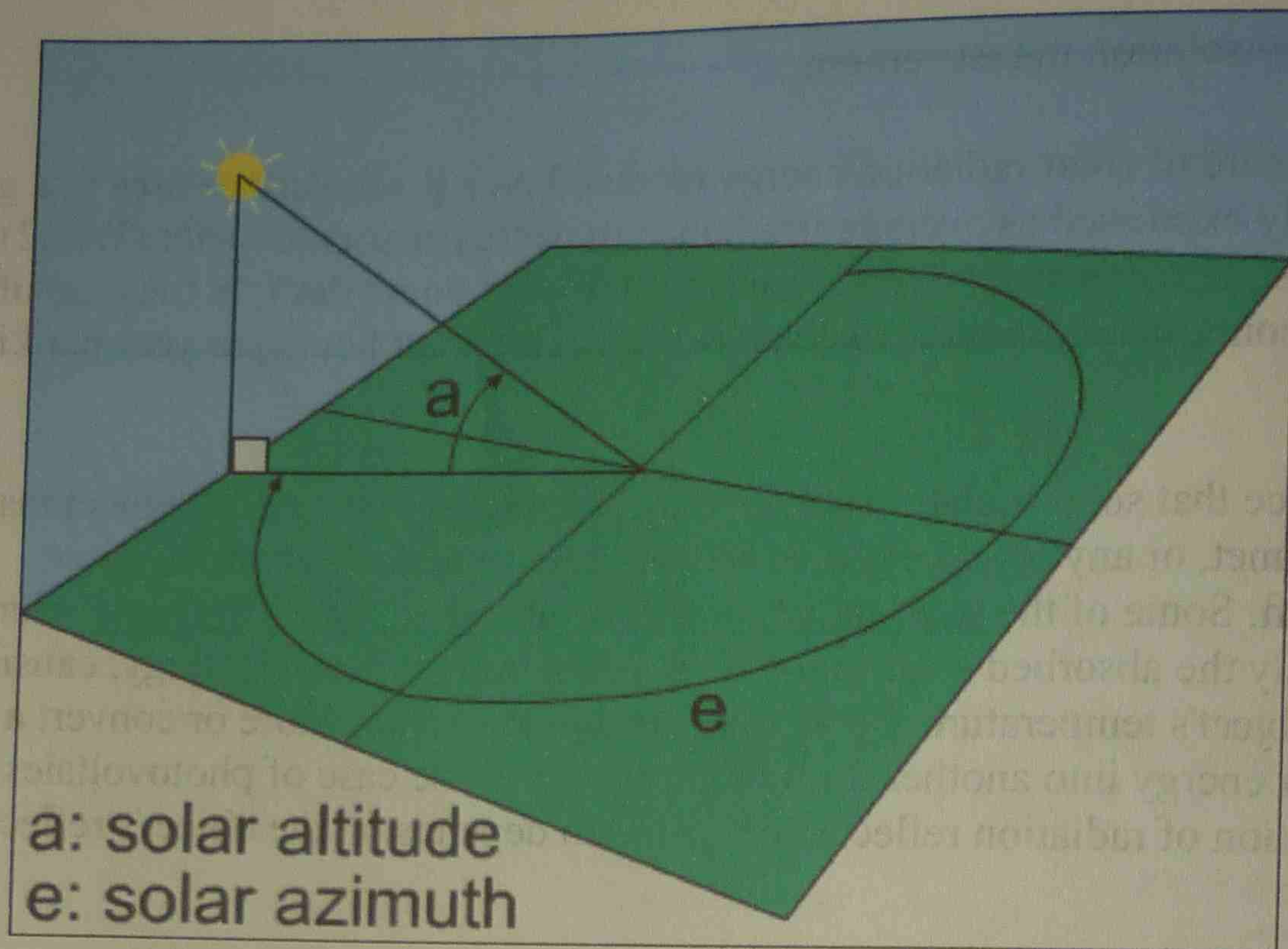
- **The date**
    - a year in the range 1800 - 2100,
    - a month
    - the day of the month
- **The time of day:**
    - hour (24 hour clock),
    - minute
- **Location on the earth**
    - latitude (degrees),
    - longitude(degrees)
- **The orientation and tilt of the surface of any building**

Q20.Explain altitudes and azimath angles

Model Output
The model provides the following outputs.

- the **altitude and azimuth** (see figure below) of the sun at that time and location,
- **the geometry of the sun with respect to any specified building.**
- the **length of a shadow** cast by a 1 metre pole

- tables and graphs of the monthly and diurnal ... and azimuth



Q21.Write the formula to calculate standard solar time.

The Local Standard Time Meridian (LSTM) is a reference meridian used for a particular time zone and is similar to the Prime Meridian, which is used for Greenwich Mean Time. The LSTM is illustrated below.

The (LSTM) is calculated according to the equation: $LSTM = 15° \times \Delta T_{GMT}$

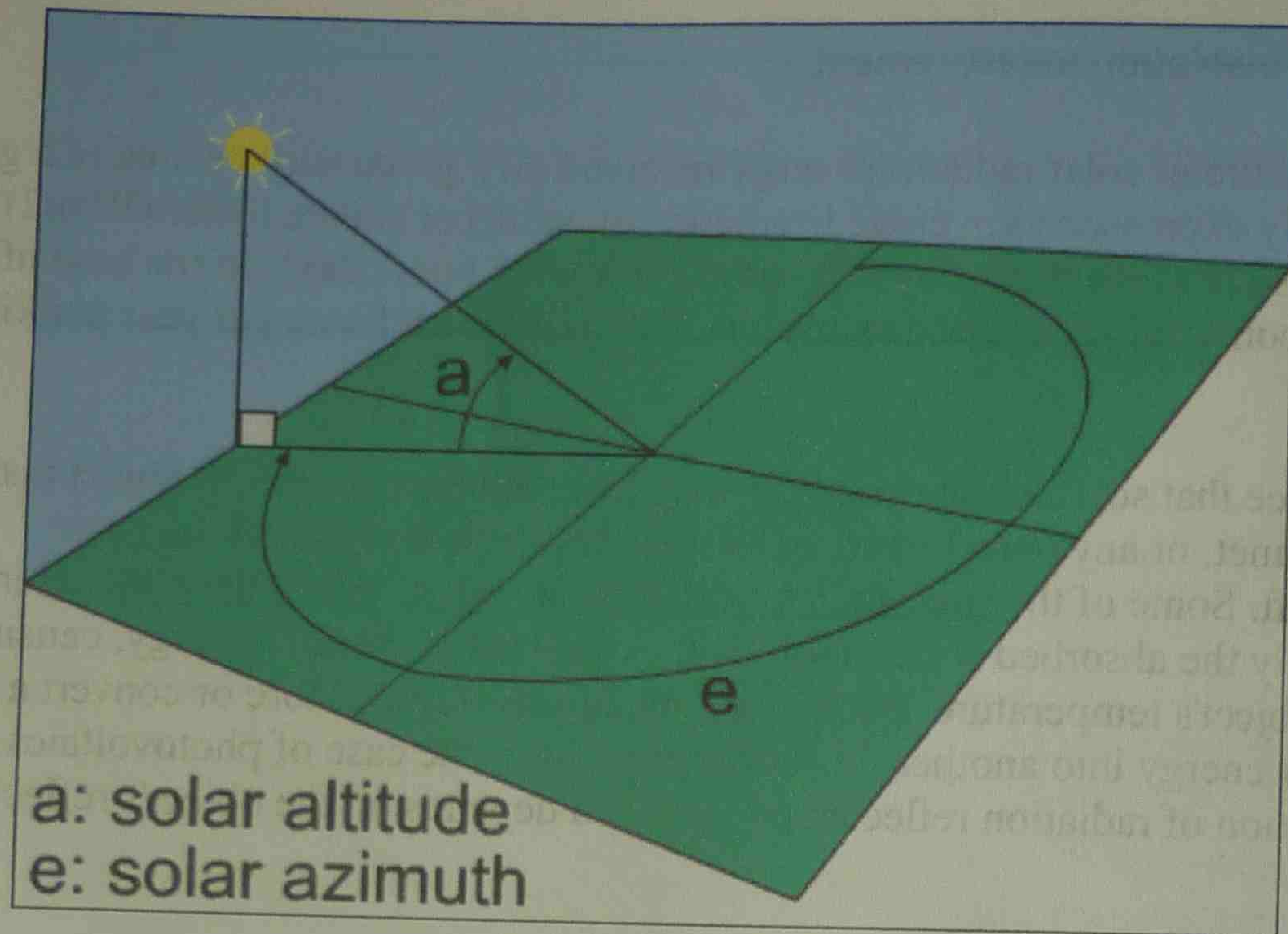
where ΔT_{GMT} is the difference of the Local Time (LT) from Greenwich Mean Time (GMT) in hours. 15°= 360°/24 hours.

Q22.What are the properties of semiconductor.

A **semiconductor** is a material with electrical conductivity due to electron flow (as opposed to ionic conductivity) intermediate in magnitude between that of a conductor and an insulator. This means a conductivity roughly in the range of 103 to 10−8 siemens per centimeter. Semiconductor materials are the foundation of modern electronics, including radio, computers, telephones, and many other devices. Such devices include transistors, solar cells, many kinds of diodes including the light-emitting diode, the silicon controlled rectifier, and digital and analog integrated circuits. Similarly, semiconductor solar photovoltaic panels directly convert light energy into electrical energy. In a metallic conductor, current is carried by the flow of electrons. In semiconductors, current is often schematized as being carried either by the flow of electrons or by the flow of positively charged "holes" in the electron structure of the material.

Common semiconducting materials are crystalline solids, but amorphous and liquid semiconductors are known. These include hydrogenated amorphous silicon and mixtures of arsenic, selenium and tellurium in a variety of proportions. Such compounds share with better known semiconductors intermediate conductivity and a rapid variation of conductivity with

- tables and graphs of the **monthly and diurnal variation of the solar altitude and azimuth**



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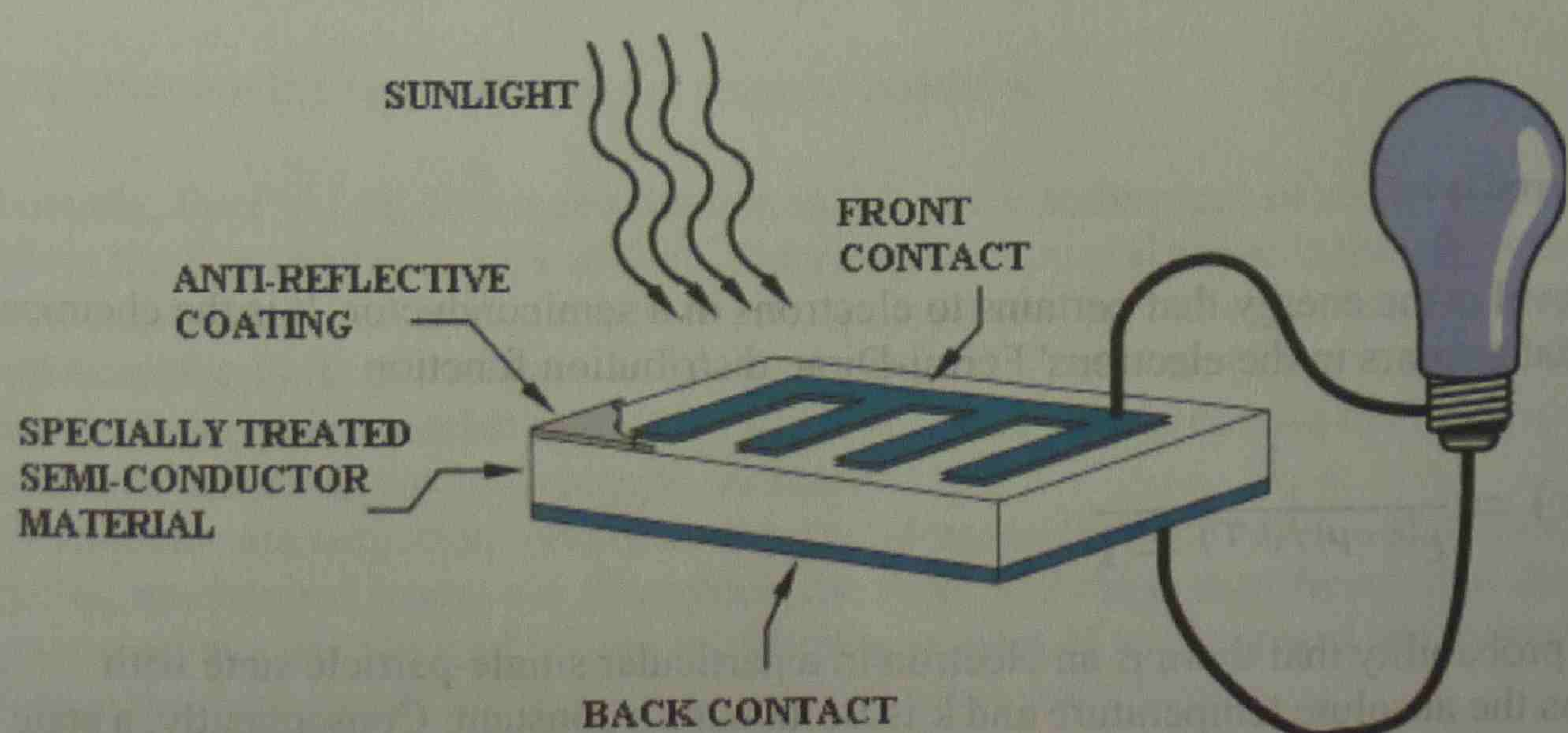
Common semiconducting materials are crystalline solids, but amorphous and liquid semiconductors are known. These include hydrogenated amorphous silicon and mixtures of arsenic, selenium and tellurium in a variety of proportions. Such compounds share with better known semiconductors intermediate conductivity and a rapid variation of conductivity with temperature, as well as occasional negative resistance. Such disordered materials lack the rigid crystalline structure of conventional semiconductors such as silicon and are generally used in thin film structures, which are less demanding for as concerns the electronic quality of the material and thus are relatively insensitive to impurities and radiation damage. Organic semiconductors, that is, organic materials with properties resembling conventional semiconductors, are also known.

Silicon is used to create most semiconductors commercially. Dozens of other materials are used, including germanium, gallium arsenide, and silicon carbide. A pure semiconductor is often called an "intrinsic" semiconductor. The electronic properties and the conductivity of a semiconductor can be changed in a controlled manner by adding very small quantities of other elements, called "dopants", to the intrinsic material. In crystalline silicon typically this is achieved by adding impurities of boron or phosphorus to the melt and then allowing the melt to solidify into the crystal. This process is called "doping".

Q23.Sketch the atomic structure of photovoltaic material & explain the construction & operation.

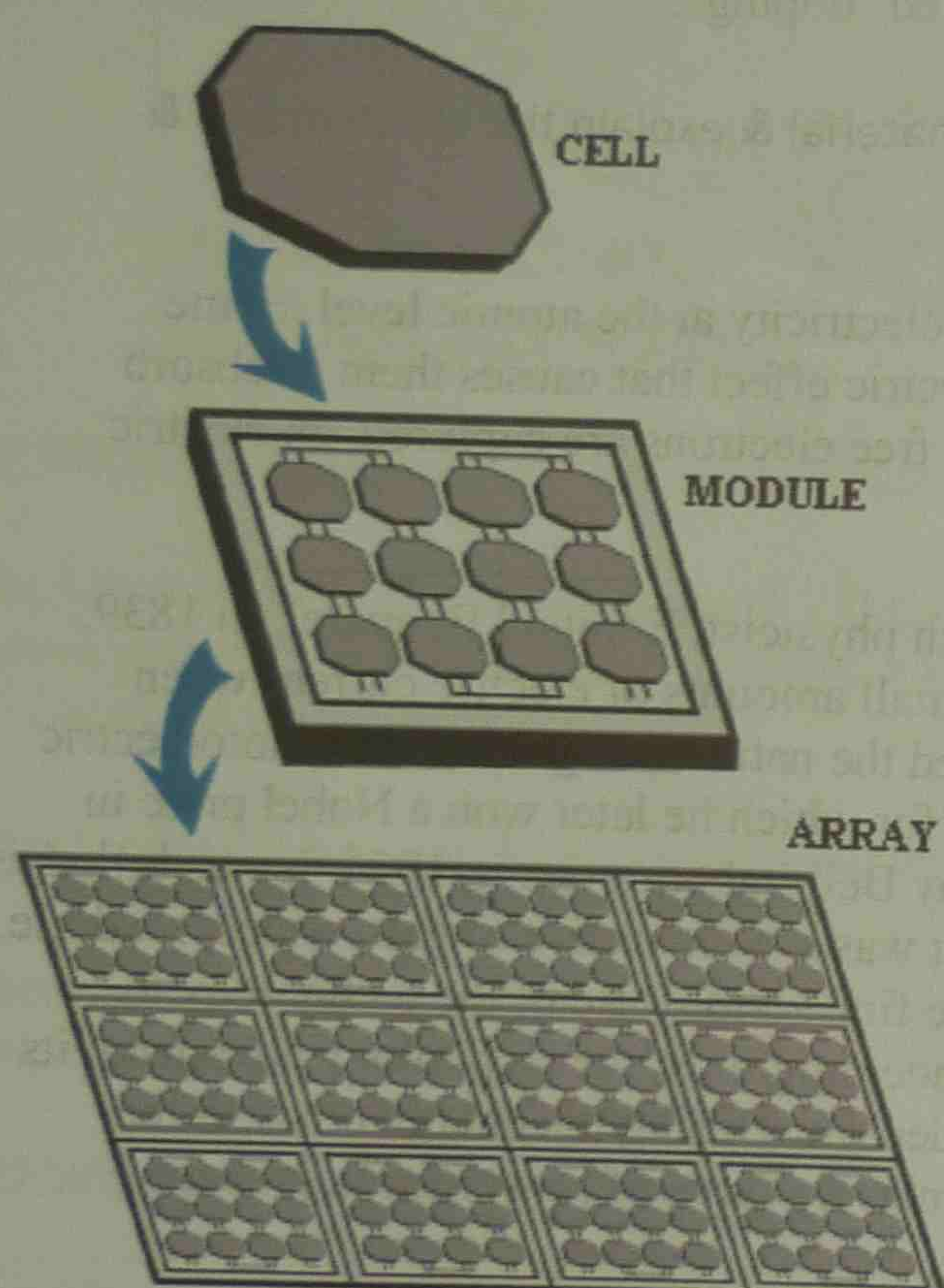
Photovoltaics is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity.

The photoelectric effect was first noted by a French physicist, Edmund Bequerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel prize in physics. The first photovoltaic module was built by Bell Laboratories in 1954. It was billed as a solar battery and was mostly just a curiosity as it was too expensive to gain widespread use. In the 1960s, the space industry began to make the first serious use of the technology to provide power aboard spacecraft. Through the space programs, the technology advanced, its reliability was established, and the cost began to decline. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications.



The diagram above illustrates the operation of a basic photovoltaic cell, also called a solar cell. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current -- that is, electricity. This electricity can then be used to power a load, such as a light or a tool.

A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module. Modules are designed to supply electricity at a certain voltage, such as a common 12 volts system. The current produced is directly dependent on how much light strikes the module.



Q24.What is fermi level?

The **Fermi level** is the energy that pertains to electrons in a semiconductor. It is the chemical potential μ that appears in the electrons' Fermi-Dirac distribution function

$$F_o(\epsilon) = \frac{1}{e^{(\epsilon-\mu)/(kT)}+1}$$

which is the probability that there is an electron in a particular single-particle state with energy ϵ. T is the absolute temperature and k is Boltzmann's constant. Consequently, a state at the Fermi level has a 50% chance of being occupied by an electron.

Q25.Explain fermi conductor.

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Q26.Explain poly crystalline silicon.

Polycrystalline silicon, also called **polysilicon**, is a material consisting of small silicon crystals. It differs from single-crystal silicon, used for electronics and solar cells, and from amorphous silicon, used for thin film devices and solar cells.

Q27.Write the process to manufacture solar module.

Solar cells are often electrically connected and encapsulated as a **module**. Photovoltaic modules often have a sheet of glass on the front (sun up) side, allowing light to pass while protecting the semiconductor wafers from abrasion and impact due to wind-driven debris, rain, hail, etc. Solar cells are also usually connected in series in modules, creating an additive voltage. Connecting cells in parallel will yield a higher current. Modules are then interconnected, in series or parallel, or both, to create an **array** with the desired peak DC voltage and current.

To make practical use of the solar-generated energy, the electricity is most often fed into the electricity grid using inverters (grid-connected photovoltaic systems); in stand-alone systems, batteries are used to store the energy that is not needed immediately. Solar panels can be used to power or recharge portable devices.

Q28.What are the types of stresses on solar modules?

Recently, the PV-Lab developed competencies in the techniques of solar cells encapsulation. While the front end activities of the Laboratory are directed towards the performances, the back end is more in relation to the industrial world. We aim to understand the requirements and needed criteria of each part of a photovoltaic (PV) module (front and back sheet, encapsulants, paint, mechanical constraint, etc.) to be able to choose the most adequate materials according to the European standards.
PV modules are subjected to various types of stresses, like humidity, UV radiation, thermal cycles, mechanical stress, etc. Therefore, the study and the comprehension of the phenomena governing this last stage of the manufacturing process of a solar panel are indeed essential to ensure the final quality of the modules and lifetime over 25 years.

The encapsulation (polymers) materials of a PV module aim at:

- ensuring a high optical transmission,
- ensuring a good electrical insulation,
- being highly stable under UV radiation,
- acting as a barrier against water vapour and oxygen transmission,
- presenting an adequate interfacial adhesion to prevent delamination process,
- providing a structural support.

Q29.Explain solar cell semi conductor dark and illuminated current

In a traditional solid-state semiconductor, a solar cell is made from two doped crystals, one doped with n-type impurities (n-type semiconductor), which add additional free conduction band electrons, and the other doped with p-type impurities (p-type semiconductor), which add additional electron holes. When placed in contact, some of the electrons in the n-type portion flow into the p-type to "fill in" the missing electrons, also known as electron holes. Eventually enough electrons will flow across the boundary to equalize the Fermi levels of the two materials. The result is a region at the interface, the p-n junction, where charge carriers are depleted and/or accumulated on each side of the interface. In silicon, this transfer of electrons produces a potential barrier of about 0.6 to 0.7 V.

When placed in the sun, photons of the sunlight can excite electrons on the p-type side of the semiconductor, a process known as photoexcitation. In silicon, sunlight can provide enough energy to push an electron out of the lower-energy valence band into the higher-energy conduction band. As the name implies, electrons in the conduction band are free to move about the silicon. When a load is placed across the cell as a whole, these electrons will flow out of the p-type side into the n-type side, lose energy while moving through the external circuit, and then back into the p-type material where they can once again re-combine with the valence-band hole they left behind. In this way, sunlight creates an electrical current.

In any semiconductor, the band gap means that only photons with that amount of energy, or more, will contribute to producing a current. In the case of silicon, the majority of visible light from red to violet has sufficient energy to make this happen. Unfortunately higher energy photons, those at the blue and violet end of the spectrum, have more than enough energy to cross the band gap; although some of this extra energy is transferred into the electrons, the majority of it is wasted as heat. Another issue is that in order to have a reasonable chance of capturing a photon, the n-type layer has to be fairly thick. This also increases the chance that a freshly ejected electron will meet up with a previously created hole in the material before reaching the p-n junction. These effects produce an upper limit on the efficiency of silicon solar cells, currently around 12 to 15% for common modules and up to 25% for the best laboratory cells (about 30% is the theoretical maximum efficiency for single band gap solar cells, see Shockley-Queisser limit.).

By far the biggest problem with the conventional approach is cost; solar cells require a relatively thick layer of doped silicon in order to have reasonable photon capture rates, and silicon processing is expensive. There have been a number of different approaches to reduce this cost over the last decade, notably the thin-film approaches, but to date they have seen limited application due to a variety of practical problems. Another line of research has been to dramatically improve efficiency through the multi-junction approach, although these cells are very high cost and suitable only for large commercial deployments. In general terms the

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Q30.What are the output parameters of solar cell?

I_V measurements are performed to characterize solar cells. Figure 4 shows a typical I_V curve with some of the following solar cell output parameters indicated

_ Short-circuit current, I_{sc}, is the maximum current at zero voltage. The short-circuit current density, J_{sc}, is often used (see Section 2.3.2).
_ Open-circuit voltage, V_{oc}, is the maximum voltage at zero current.
_ Maximum power point, P_{mp}, is the maximum power output at optimal

operating condition, i.e. $P_{mp} = V_{mp}I_{mp}$.

A realistic distributed equivalent circuit for the buried emitter silicon solar cell is presentedtaking into consideration the carriers paths through the planar and vertical junctions. In addition, a new theoretical model for the cell characteristics including the cell's mismatching, series resistance, different junctions (planar and vertical) and junctions geometry is considered in this work. The results are compared with the published data.

Q31.What are the production steps of solar cells?

A typical representative of a silicon solar cell consists of a photoactive p/n junction formed on the surface, a front ohmic contact stripe and fingers, a back ohmic contact that covers the entire back surface, and an antireflection coating on the front surface.

For silicon solar cell production either poly-crystalline or mono-crystalline material is used. Poly-crystalline silicon for photo-voltaic applications is normally produced by casting methods while mono-crystalline silicon is prepared in a Czochralski growing process.

The poly-crystalline or mono-crystalline ingots are cut to wafers. Poly-crystalline material is mostly cut to square wafers with a side length of 125mm or 150mm while mono-crystalline material is used to produce round wafers of 100 - 150mm of diameter. Sometimes square material with rounded edges is prepared from round wafers (125mm side length) in order to get a denser packing of the solar c The main process steps in solar cell production are the preparation of the p/n junction by doping and the metallization or contacting of the photovoltaic cell. Beside that, further deposition processes are used to establish an antireflection coating or to improve the solar cell setup. ells in the solar module.

Q32.Write the equation for the cost of electricity by using solar cell.

Assume that we have a time series of system wholesale prices, w_t, and system demand quantities, Q_t, and that those system demand quantities were generated by a flat retail price that covered wholesale energy costs. That flat retail rate for energy (excluding capital costs of transmission and distribution, taxes and other fees) would be

$$\bar{P} = \frac{1}{1-\phi} \cdot \frac{\sum_{t=1}^{T} Q_t \cdot w_t}{\sum_{t=1}^{T} Q_t}$$

Q33.What is optical loss?

In metallic conductor systems, reflections of a signal traveling down a conductor can occur at a discontinuity or impedance mismatch. The ratio of the amplitude of the reflected wave Vr to the amplitude of the incident wave Vi is known as the reflection coefficient Γ.

$$\Gamma - \frac{V_r}{V_i}$$

Q34.Write the equation to calculate dark cell current.

Unstimulated (in the dark), cyclic-nucleotide gated channels in the outer segment are open because cyclic GMP (cGMP) is bound to them. Hence, positively charged ions (namely sodium ions) enter the photoreceptor, depolarizing it to about −40 mV (resting potential in other nerve cells is usually −65 mV). This depolarizing current is often known as dark current.

Two important quantities to characterize a solar cell are

- Open circuit voltage (V_{oc}): The voltage between the terminals when no current is drawn (infinte load resistance)
- Short circuit current (I_{sc}): The current when the terminals are connected to eachother (zero load resistance)

The short circuit current increases with light intensity, as higher intensity means more photons, which in turn means more electrons. Since the short circuit current I_{sc} is roughly proportional to the area of the solar cell, the short circuit current density, $J_{sc} = I_{sc}/A$, is often used to compare solar cells.

When a load is connected to the solar cell, the current decreases and a voltage develops as charge builds up at the terminals. The resulting current can be viewed as a superposition of the short circuit current, caused by the absorbtion of photons, and a *dark current*, which is caused by the potential built up over the load and flows in the opposite direction. As a solar cell contains a PN-junction (LINK), just as a diode, it may be treated as a diode. For an ideal diode, the dark current density is given by

$$J_{dark}(V) = J_C(e^{qV/k_BT} - 1)$$

Here J_0 is a constant, q is the electron charge and V is the voltage between the terminals. The resulting current can be approximated as a superposition of the short circuit current and the dark current:

$$J = J_{sc} - J_0(e^{qV/k_BT} - 1)$$

Q35.Write the equation to calculate solar cell current.

$$J = J_{sc} \quad J_0(e^{q(V+JAR_s)/kT} \quad 1) \quad \frac{V+JAR_s}{R_P}$$

Q36.Write the equation for maximum power output related to series resistance.

$$\eta = \frac{R_{\mathrm{load}}}{R_{\mathrm{load}} + R_{\mathrm{source}}} = \frac{1}{1 + \frac{R_{\mathrm{source}}}{R_{\mathrm{load}}}}$$

The theorem was originally misunderstood (notably by Joule) to imply that a system consisting of an electric motor driven by a battery could not be more than 50% efficient since, when the impedances were matched, the power lost as heat in the battery would always be equal to the power delivered to the motor. In 1880 this assumption was shown to be false by either Edison or his colleague Francis Robbins Upton, who realized that maximum efficiency was not the same as maximum power transfer. To achieve maximum efficiency, the resistance of the source (whether a battery or a dynamo) could be made close to zero. Using this new understanding, they obtained an efficiency of about 90%, and proved that the electric motor was a practical alternative to the heat engine.

Q37.Explain solar radiation and shading assessment procedures.

Sunlight, in the broad sense, is the total frequency spectrum of electromagnetic radiation given off by the Sun. On Earth, sunlight is filtered through the Earth's atmosphere, and solar radiation is obvious as daylight when the Sun is above the horizon.

When the direct solar radiation is not blocked by clouds, it is experienced as **sunshine**, a combination of bright light and radiant heat. When it is blocked by the clouds or reflects off of other objects, it is experienced as diffused light.

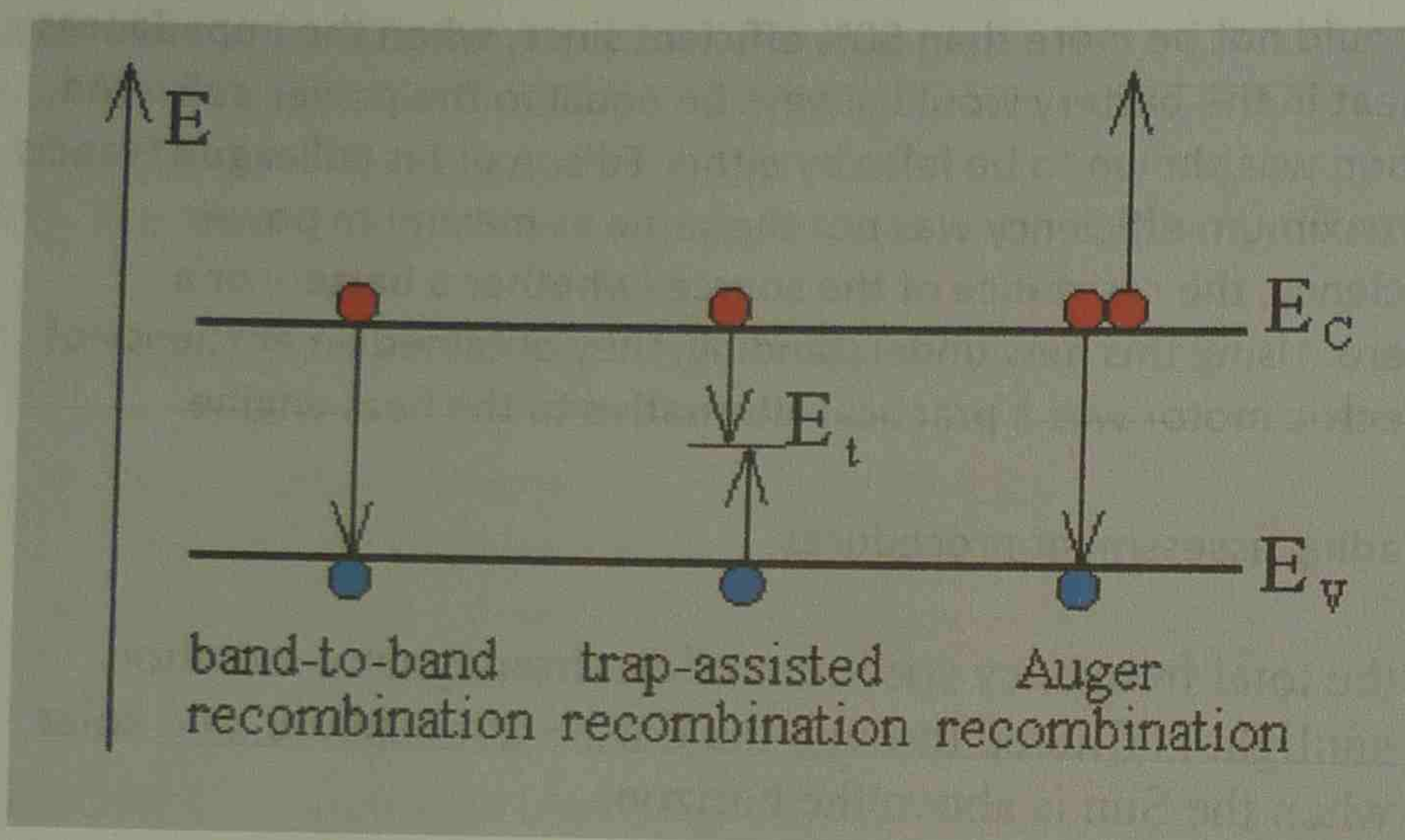
shading assessment procedures

If the location for your planned PV array has trees, chimneys, dormer windows, tall buildings next door, or other features that may shade the system either now or in the future this can have a major impact on the performance of the system.

In these situations the standard SAP2005 method of assessing the performance of the system isn't particularly accurate, and we'd strongly recommend that you ask us to produce a proper Shading Impact Assessment for you so that you can accurately assess the implications of this shading for the long term financial returns from the system.

Q39.Explain (a) Recombining process (b) Radiative recombination (c)Auger recombination (d)Recombination through traps (e)Recombination at surface (f)electronic matching.

Recombination of electrons and holes is a process by which both carriers annihilate each other: the electrons fall in one or multiple steps into the empty state which is associated with the hole. Both carriers eventually disappear in the process. The energy difference between the initial and final state of the electron is given off. This leads to one possible classification of the recombination processes: In the case of radiative recombination this energy is emitted in the form of a photon, in the case of non-radiative recombination it is passed on to one or more phonons and in Auger recombination it is given off in the form of kinetic energy to another electron. Another classification scheme considers the individual energy levels and particles involved. These different processes are further illustrated with the figure below.

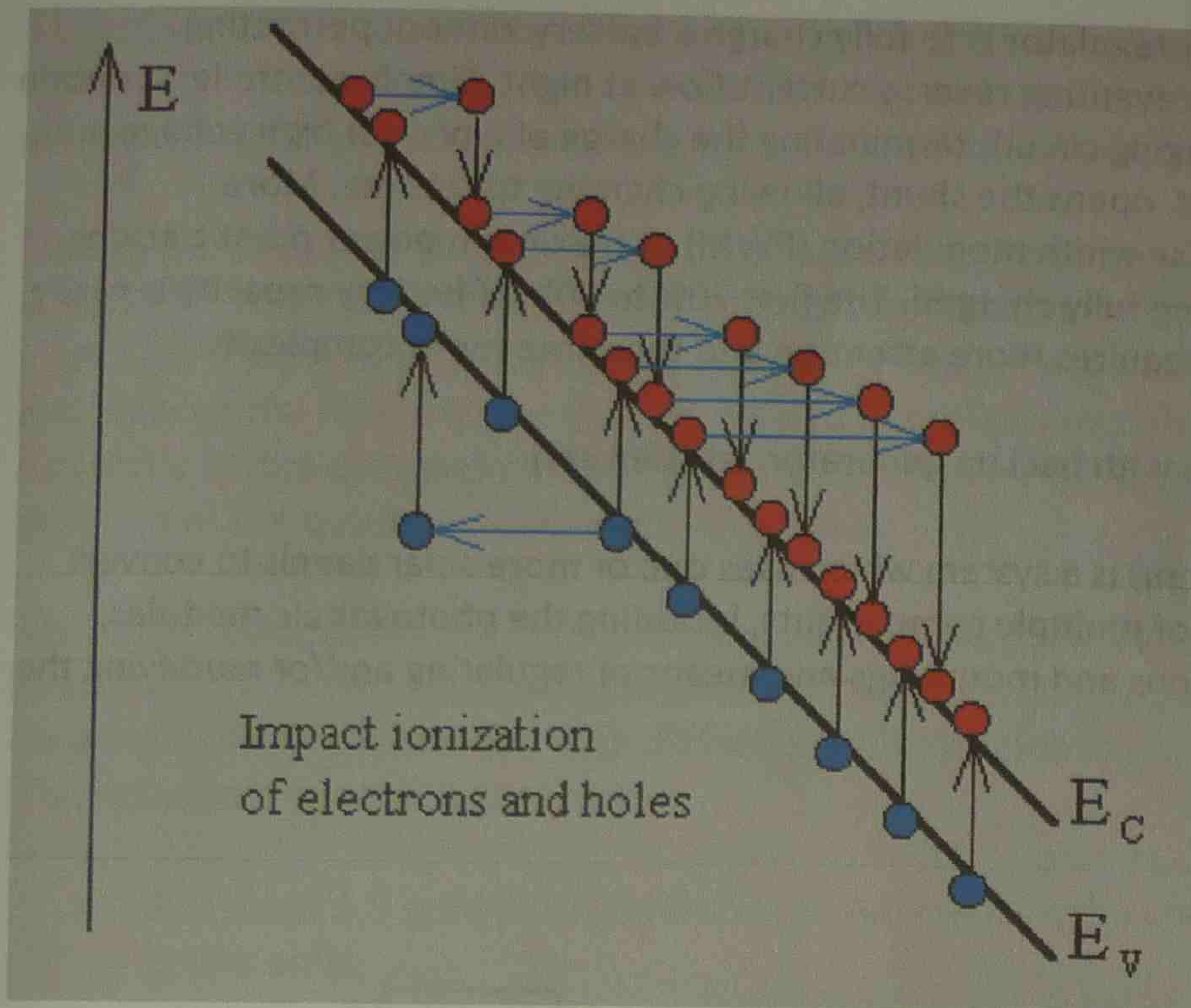


[Trap-assisted](#) recombination occurs when an electron falls into a "trap", an energy level within the bandgap caused by the presence of a foreign atom or a structural defect. Once the trap is filled it can not accept another electron. The electron occupying the trap energy can in a second step fall into an empty state in the valence band, thereby completing the recombination process. One can envision this process either as a two-step transition of an electron from the conduction band to the valence band or also as the annihilation of the electron and hole which meet each other in the trap.

Carrier generation due to light absorption occurs if the photon energy is large enough to lift an electron from the valence band into an empty state in the conduction band, generating one electron-hole pair. The photon energy needs to be at least equal to the bandgap energy to satisfy this condition. The photon is absorbed in this process and the excess energy, E_{ph}-E_g is added to the electron and the hole in the form of kinetic energy.

Carrier generation or ionization **due to a high energy beam** consisting of *charged* particles is similar except that the available energy can be much larger than the bandgap energy so that multiple electron-hole pairs can be formed. The high-energy particle gradually loses its energy and eventually stops. This generation mechanism is used in semiconductor-based nuclear particle counters. As the number of ionized electron-hole pairs varies with the energy of the particle, one can also use such detector to measure the particle energy.

Finally there is a generation process called **impact ionization**, the generation mechanism which is the counterpart of Auger recombination. Impact ionization is caused by an electron (hole) with an energy which is much larger (smaller) than the conduction (valence) band edge. The detailed mechanism is illustrated with the figure below:

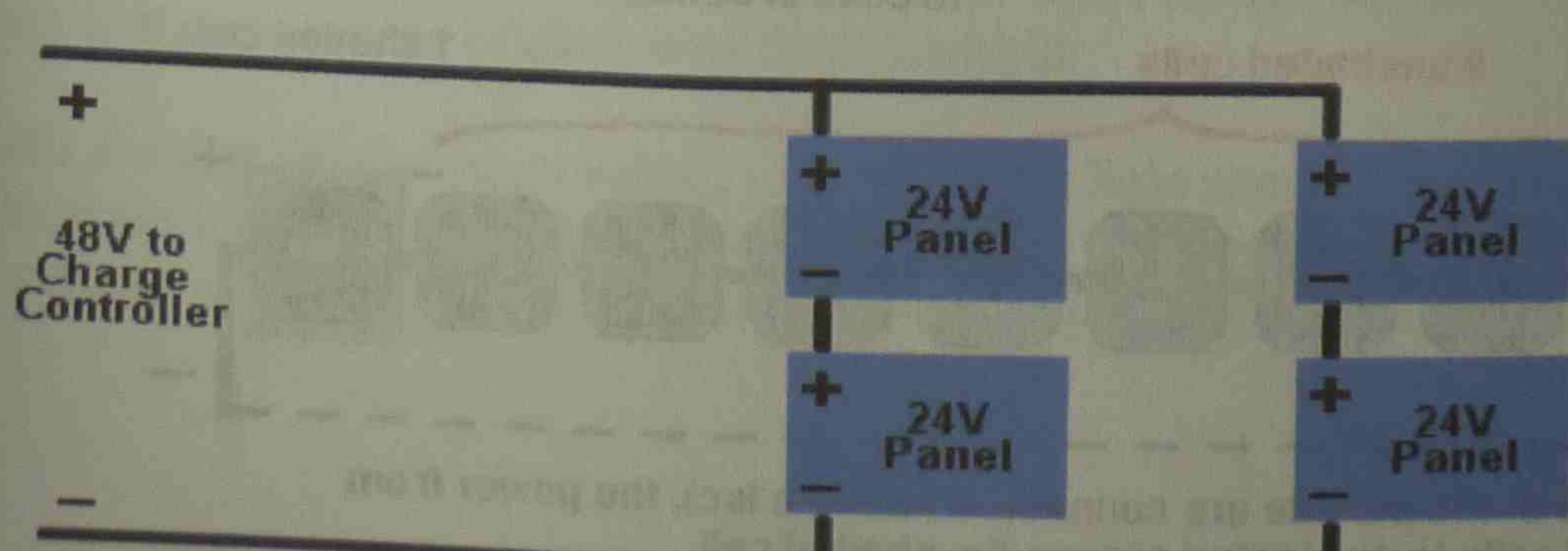


Band-to-band recombination depends on the density of available electrons and holes. Since both carrier types need to be available in the recombination process, the rate is expected to be proportional to the product of *n* and *p*.

Recombination at semiconductor surfaces and interfaces can have a significant impact on the behavior of devices. This is due to the fact that surfaces and interfaces typically contain a large number of recombination centers because of the abrupt termination of the semiconductor crystal which leaves a large number of electrically active dangling bonds. In addition the surfaces and interfaces are more likely to contain impurities since they are exposed during the device fabrication process.

Q40.Sketch PV system configuration circuits.

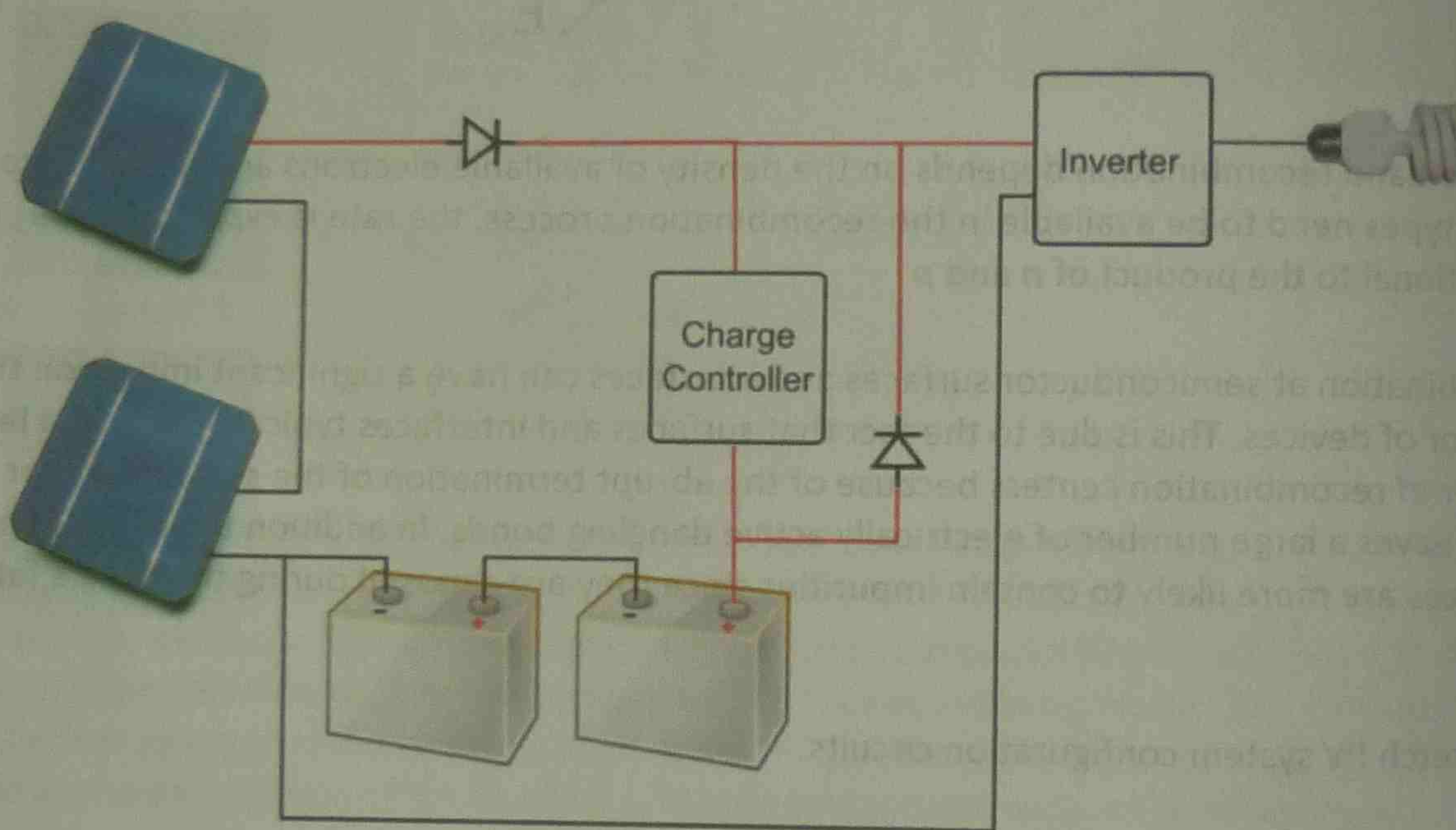
Q41.PV only system using integrated charge regulator, load controller.



The main function of a controller or regulator is to fully charge a battery without permitting overcharge and at the same time preventing reverse current flow at night. Simple controllers contain a transistor that shunts the PV charging circuit, terminating the charge at a pre-set high voltage and, once a pre-set reconnect is reached, opens the shunt, allowing charging to resume. More sophisticated controllers utilize pulse width modulation (PWM) or maximum power point tracking (MPPT) to assure the battery is being fully charged. The first 70% to 80% of battery capacity is easily replaced, but the last 20% to 30% requires more attention and therefore more complexity.

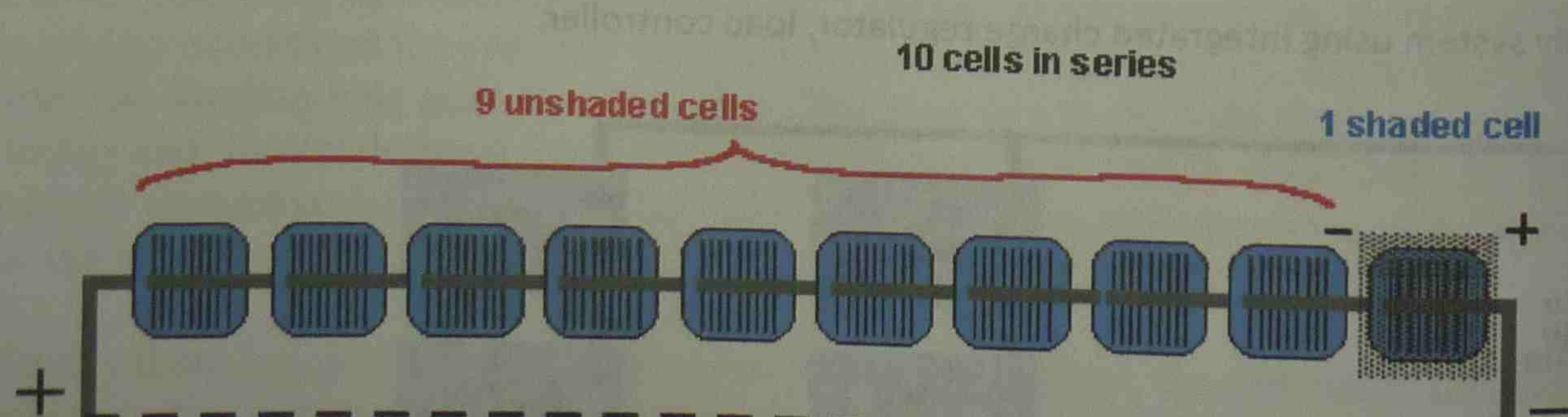
Q42.Sketch & explain dc PV system with backup generator set (Gen set)

A **photovoltaic system** (or **PV system**) is a system which uses one or more solar panels to convert sunlight into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.



Q44.Explain (a) Hot spot heating (b) Efficiency limit losses & measurement

Hot-spot heating occurs when there is one low current solar cell in a string of at least several high short-circuit current solar cells.



If the teminals of the module are connected (module Isc), the power from the unshaded cells is dissipated across the shaded cell.

The efficiency of a solar cell may be broken down into reflectance efficiency, thermodynamic efficiency, charge carrier separation efficiency and conductive efficiency. The overall efficiency is the product of each of these individual efficiencies.

Due to the difficulty in measuring these parameters directly, other parameters are measured instead: thermodynamic efficiency, quantum efficiency, V_{OC} ratio, and fill factor. Reflectance losses are a portion of the quantum efficiency under "external quantum efficiency". Recombination losses make up a portion of the quantum efficiency, V_{OC} ratio, and fill factor. Resistive losses are predominantly categorized under fill factor, but also make up minor portions of the quantum efficiency, V_{OC} ratio.

The most fundamental of solar cell characterisation techniques is the measurement of cell efficiency. Standardised testing allows the comparison of devices manufactured at different companies and laboratories with different technologies to be compared.
The standards for cell testing are:

- Air mass 1.5 spectrum (AM1.5) for terrestrial cells and Air Mass 0 (AM0) for for space cells.
- Intensity of 100 mW/cm^2 (1 kW/m^2, one-sun of illumination)
- Cell temperature of 25 °C (not 300 K)
- Four point probe to remove the effect of probe/cell contact resistance

Q45.Explain PV cell interconnection & module fabrication.

In one aspect, the invention provides photovoltaic modules. In one embodiment, a photovoltaic module includes a plurality of photovoltaic cells, at least two of which include a photosensitized nanomatrix layer and a charge carrier media. Preferably, the cells further include a catalytic media layer. The photovoltaic cells are disposed between a first electrical connection layer and a second electrical connection layer. In one embodiment, the cells are interconnected in series and the electrical connections layers each include conductive and insulative regions.

A **solar cell** (also called **photovoltaic cell** or **photoelectric cell**) is a solid state electrical device that converts the energy of light directly into electricity by the photovoltaic effect.

Assemblies of cells used to make solar modules which are used to capture energy from sunlight, are known as solar panels. The energy generated from these solar modules, referred to as solar power, is an example of solar energy.

Photovoltaics is the field of technology and research related to the practical application of photovoltaic cells in producing electricity from light, though it is often used specifically to refer to the generation of electricity from sunlight.

Cells are described as *photovoltaic cells* when the light source is not necessarily sunlight. These are used for detecting light or other electromagnetic radiation near the visible range, for example infrared detectors, or measurement of light intensity.

Q46.What is efficiency limit for black body cell?

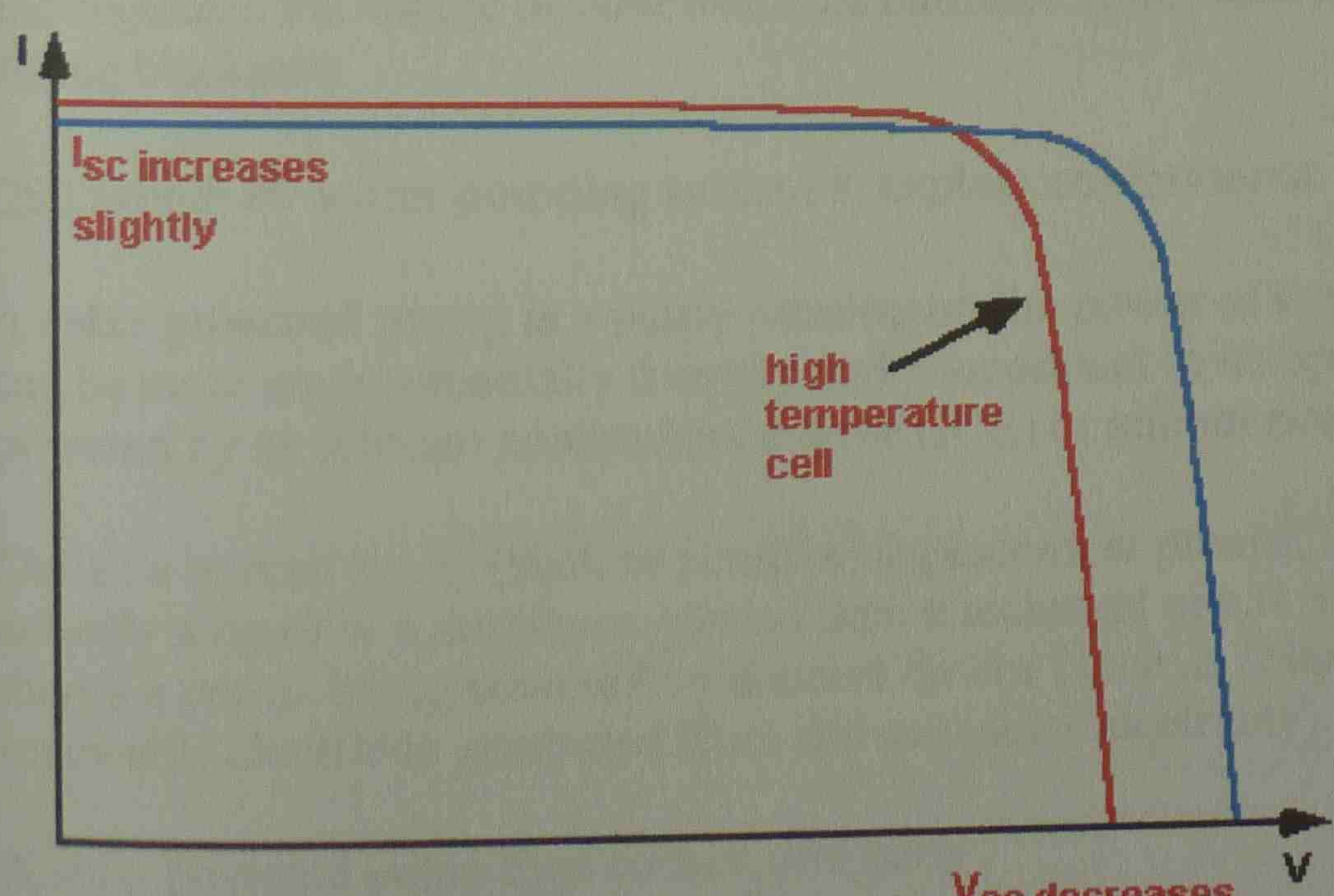
Any material above absolute zero temperature will emit radiation through blackbody radiation. In the case of a solar cell at ambient room temperature, at 300 Kelvin, a baseline energy is always being emitted. This energy cannot be captured by the cell, and represents about 7% of the available incoming energy.

This radiation effect is dependent on cell temperature. Any energy lost in a cell is generally turned into heat, so any inefficiency in the cell increases the cell temperature when it is placed in sunlight. As the temperature of the cells increases, the blackbody radiation also increases, until an equilibrium is reached. In practice this equilibrium is normally reached at temperatures as high as 360 Kelvin, and cells normally operate at lower efficiencies than their room temperature rating. Module datasheets normally list this temperature dependancy as T_{NOTC}.

Q47.What is the effect of temperature?

Like all other semiconductor devices, solar cells are sensitive to temperature. Increases in temperature reduce the band gap of a semiconductor, thereby effecting most of the semiconductor material parameters. The decrease in the band gap of a semiconductor with increasing temperature can be viewed as increasing the energy of the electrons in the material. Lower energy is therefore needed to break the bond. In the bond model of a semiconductor band gap, reduction in the bond energy also reduces the band gap. Therefore increasing the temperature reduces the band gap.

In a solar cell, the parameter most affected by an increase in temperature is the open-circuit voltage. The impact of increasing temperature is shown in the figure below.



The effect of temperature on the IV characteristics of a solar cell.

Q48.Explain the interaction of light with semi conductor.

In a traditional solid-state semiconductor, a solar cell is made from two doped crystals, one with a slight negative bias (n-type semiconductor), which has extra free electrons, and the other with a slight positive bias (p-type semiconductor), which is lacking free electrons. When placed in contact, some of the electrons in the n-type portion will flow into the p-type to "fill in" the missing electrons, also known as an electron hole. Eventually enough will flow across the boundary to equalize the Fermi levels of the two materials. The result is a region at the interface, the p-n junction, where charge carriers are depleted and/or accumulated on each side of the interface. In silicon, this transfer of electrons produces a potential barrier of about 0.6V to 0.7V.

When placed in the sun, photons in the sunlight can strike the bound electrons in the p-type side of the semiconductor, giving them more energy, a process known technically as photoexcitation. In silicon, sunlight can provide enough energy to push an electron out of the lower-energy valence band into the higher-energy conduction band. As the name implies, electrons in the conduction band are free to move about the silicon. When a load is placed across the cell as a whole, these electrons will flow out of the p-type side into the n-type side, lose energy while moving through the external circuit, and then back into the p-type material where they can once again re-combine with the valence-band hole they left behind, producing a lower-energy photon. In this way, sunlight creates an electrical current.

Q49.What are the components of PV electrical system?

Solar Electric (or Solar PV) systems convert sunlight to electricity. The systems consist of modules - or solar panels - inverter, charger and batteries. The PV modules generate DC electricity and send it to the inverter, the inverter transforms DC power into AC electricity and regulates the charge of batteries. The batteries store electricity that can be used at night or during blackouts.

Q50.Sketch PV water pumping system & explain components.

A **solar powered pump** is a pump running on the power of the sun. A solar powered pump can be more environmentally friendly and economical in its operation compared to pumps powered by an internal combustion engine (ICE) or animal power.

Unlike a normal pump (such as positive displacement pumps, ...), the solar powered pump is actually a more of a dictionary phrase than a technical one.It is only used to describe that there's a pump, being powered by another device (such as solar panels), being powered by the renewable electricity generated from the sun (solar electricity).

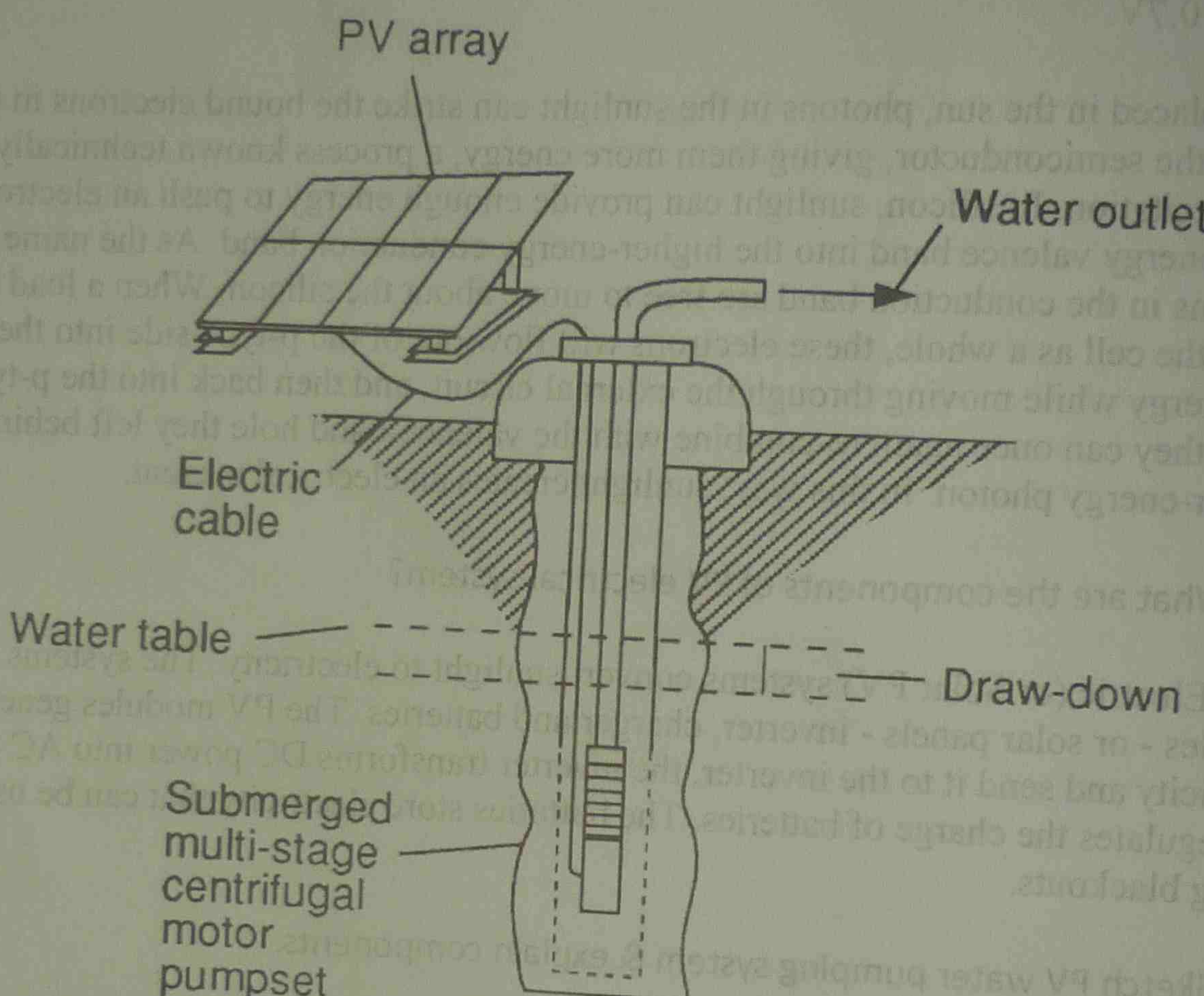
A solar powered pump thus consist of 4 parts :

- the actual fluid pump (that actually moves (pumps) gases or liquids under pressure)
- the controller (adjusting speed and output power according to input from solar panels)
- the engine (usually an electric motor)
- the energy source being powered by the sun (usually photovolatic cells (solar panels))

Solar array (photovolatic cells, solar panels) takes up 50% - 80% of the whole setup cost, which is the most expensive part.

There are two major types of solar pumps, DC (direct current) and AC (alternating current).
DC solar pump:

- power output up to 2kW
- suitable for small applications (garden fountain, landscaping)
- relatively low-priced (require slightly less solar panel)
- low compatibility (only selected controller work selected motor)



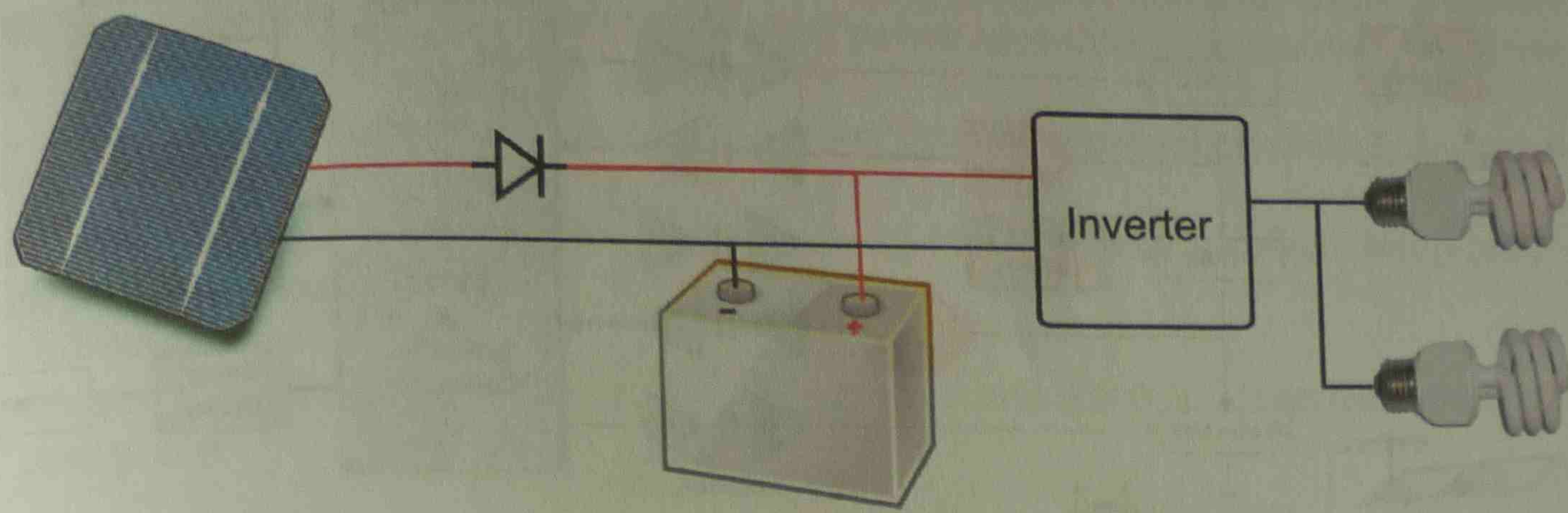
Q51.Exelectrical system plain power conditioning circuitry of solar water pump.

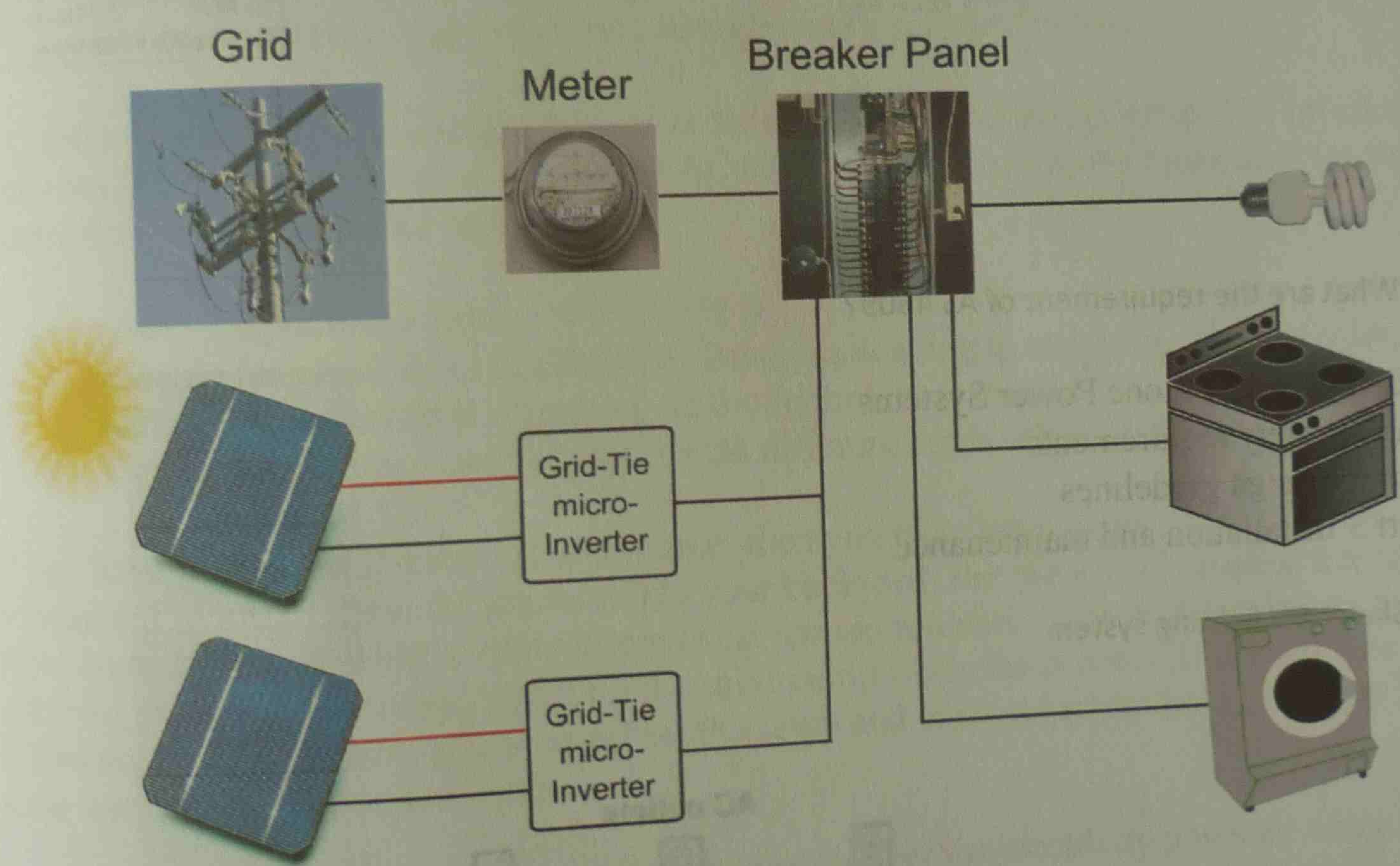
Photovoltaic pumps are made up of a number of components. There is a photovoltaic array which converts solar energy directly into electricity as DC. The pump will have an electric motor to drive it.. The characteristics of these components need to be matched to get the best performance. The pump motor unit will have its own optimum speed and load depending on the type and size of the pump.

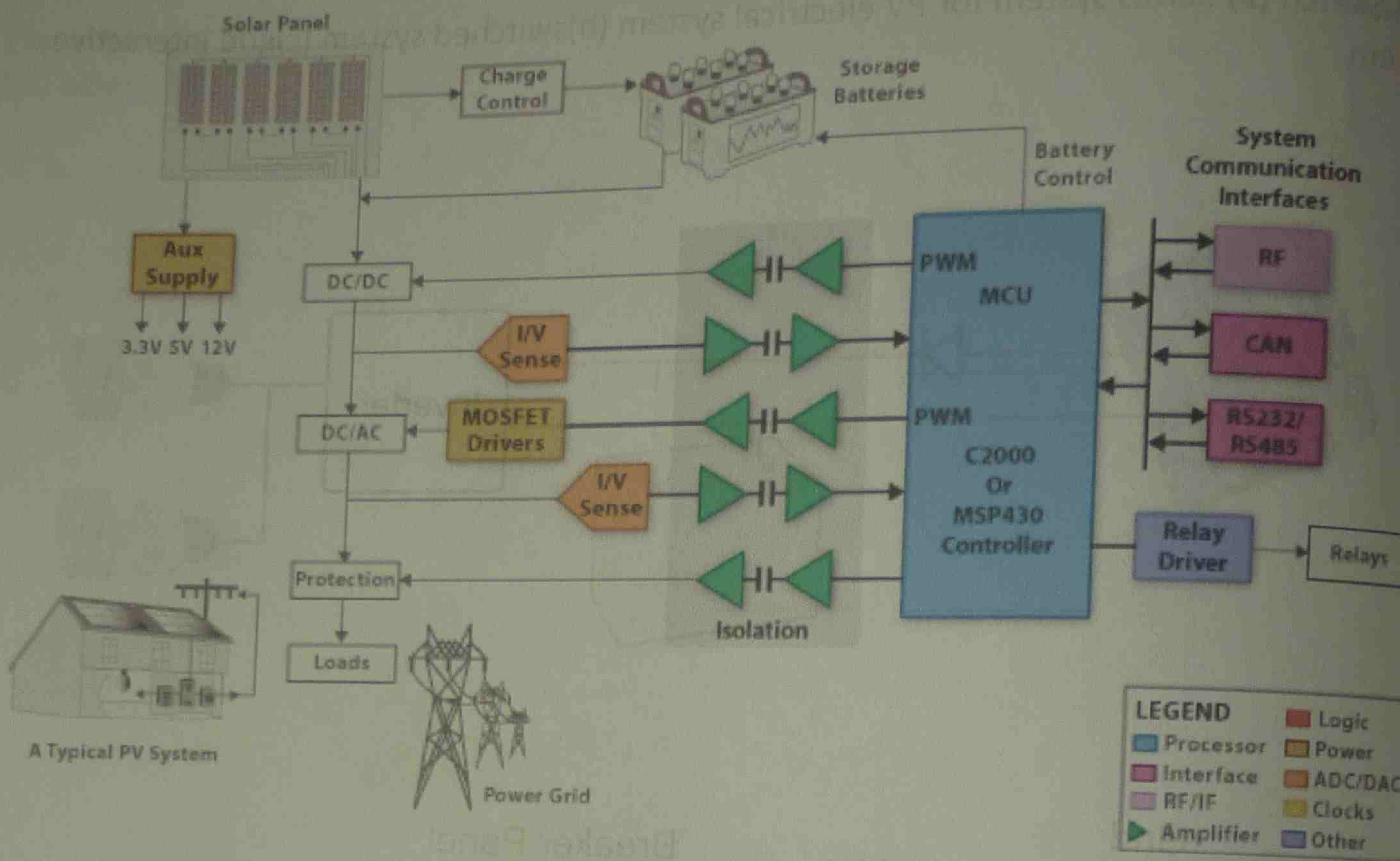
Q52.Write the equations for PV water pumping.

$H(S,p) = U + pV$

Q53.Sketch (a) Series system for PV electrical system (b)switched system (c)grid interactive system.



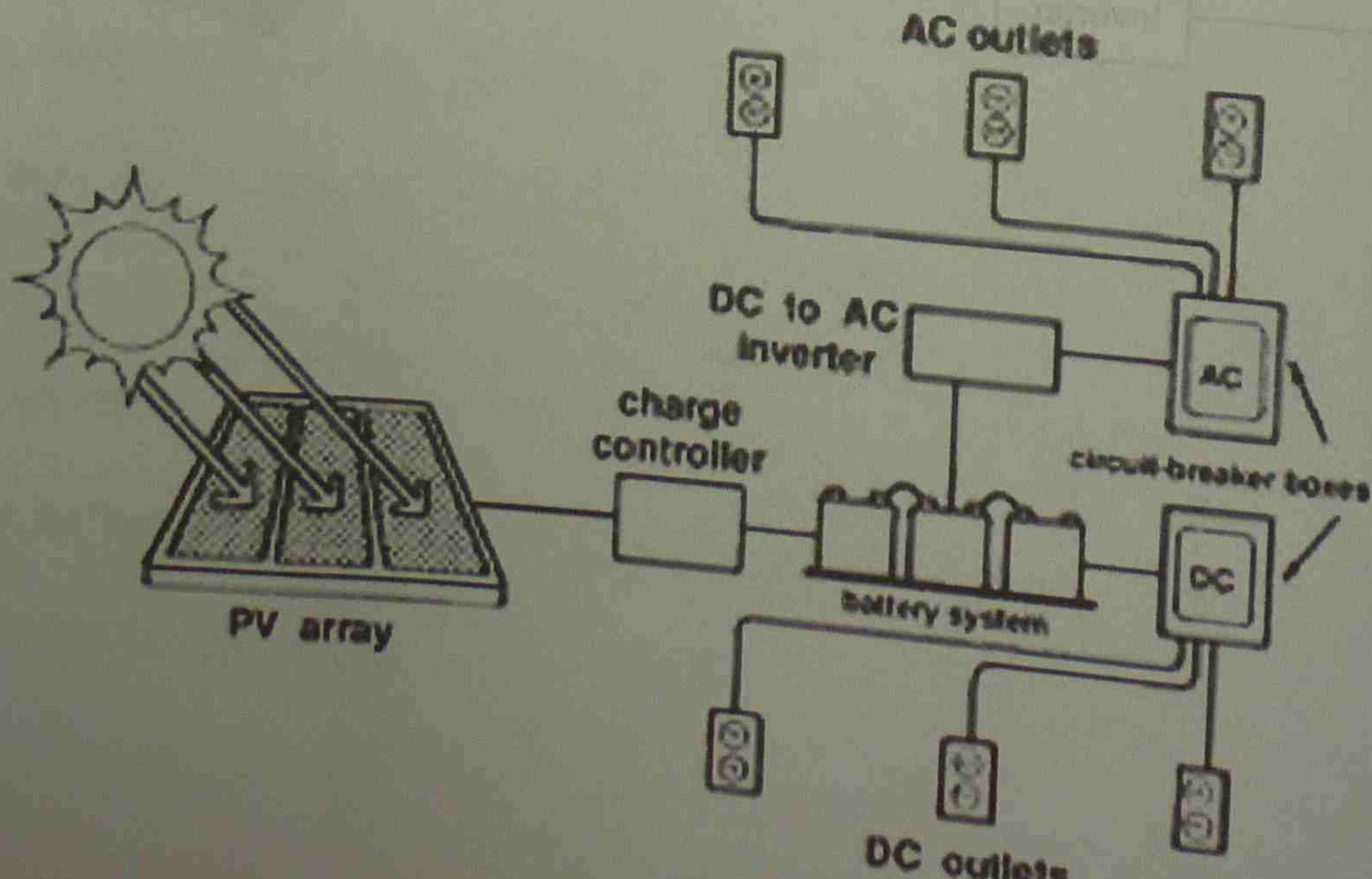




Q54.What are the requirement of AS 4509?

- AS 4509 Stand-alone Power Systems
- Part 1 Safety requirements
- Part 2 Design guidelines
- Part 3 Installation and maintenance

Q55.Sketch PV lighting system



Q57.Explain PV water system for water pumping.

A solar powered pump thus consist of 4 parts :

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- the controller (adjusting speed and output power according to input from solar panels)
- the engine (usually an electric motor)
- the energy source being powered by the sun (usually photovolatic cells (solar panels))

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There are two major types of solar pumps, DC (direct current) and AC (alternating current).
DC solar pump:

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- suitable for small applications (garden fountain, landscaping)
- relatively low-priced (require slightly less solar panel)
- low compatibility (only selected controller work selected motor)

AC solar pump: A solar pumping inverter is needed in AC solar pump setup. The inverter converts DC generated from solar array to AC to drive the pumps in the mean time (as the controller) to control output and speed.

- power output range from 150W to 55kW
- suitable for all kinds of applications from landscaping to irrigation, especially large scale such as farmland irrigation, desert control, etc.
- high compatibility (inverter works with different kinds of AC motor and pump)

If you have got a solar fountain at your home, then you must have learned that it is very convenient to install the solar fountain into your backyard. But the actual situation may be that you do not know what to do with your soar garden fountain or the tabletop fountain. After all, why should you pay to set up the solar pump while the process is so easy? The following 3steps will help you accomplish the setup and then just enjoy the beauty your new solar water fountain brings to you.

1. Initiate the pump All kind of water pump, regardless of the electricity powered water pumps or solar powered pumps can not have a good performance if it is pumping air. To initiate the solar pumps, you need to put the body into the water so that the intake can fill with water and the air inside can be removed at the same time. This process takes little time but is quite essential. This step should be every time when is has ever been detached from the solar water fountain and has not worked for a period of time.

2. Expose the solar panel to sunlight With the solar power as the energy source, you can place the solar powered fountain anywhere as you like, however be sure the solar panel must be located where the panel can receive maximum sunbeam. The longer the solar panel is exposed, the more power it will get for the fountain to work.

3. Get the debris out of the water Though most solar powered pumps are equipped with a filter to prevent dust and waste from block the solar fountain intake, the choice of water type