Solar Energy Engineering and Technology
Professor Doctor Pankaj Kalita
Centre of Energy
Indian Institute of Technology, Guwahati
Lecture 13
Standalone Photovoltaic System

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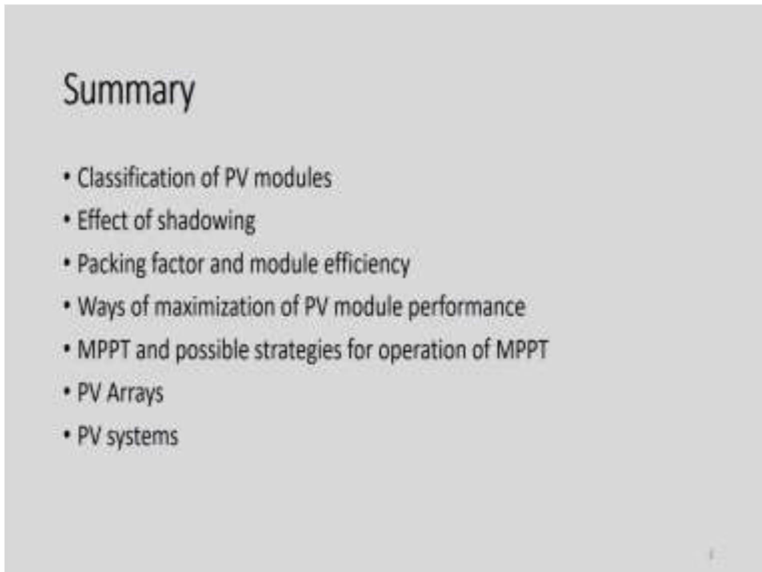

Dear students, today we will discuss about standalone photovoltaic system is designer pros and before we starts today's discussion, let us summarize what you have discussed in the last class, okay. So, we are mostly discussing about PV modules its classification, effect of shadowing, packing factor and module efficiency, ways of maximization of PV module performance, maximum power point tracking and possible strategies for operation of MPPT ,PV arrays and PV systems. So, knowledge of these PV module is very very important while selecting a best module for standalone PV system applications.

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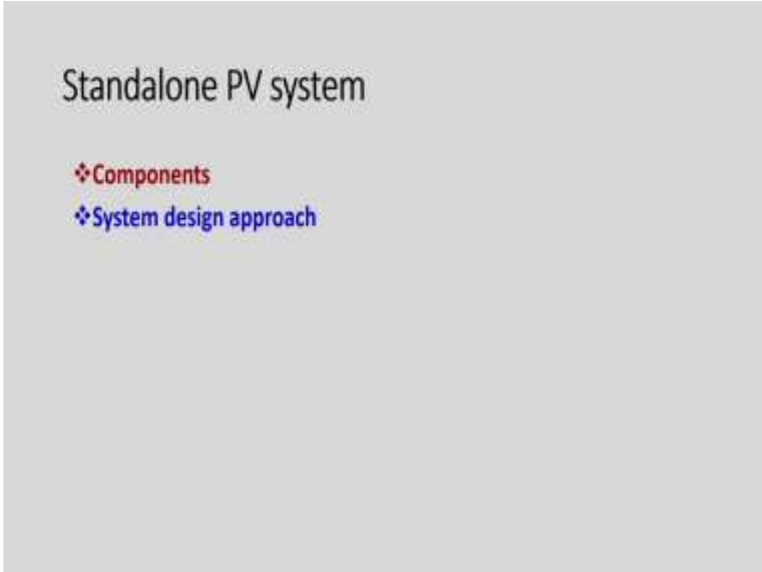

So, without delay let us start our todays discussion. So, mostly today we will be covering about the components of standalone PV system and system design approaches.

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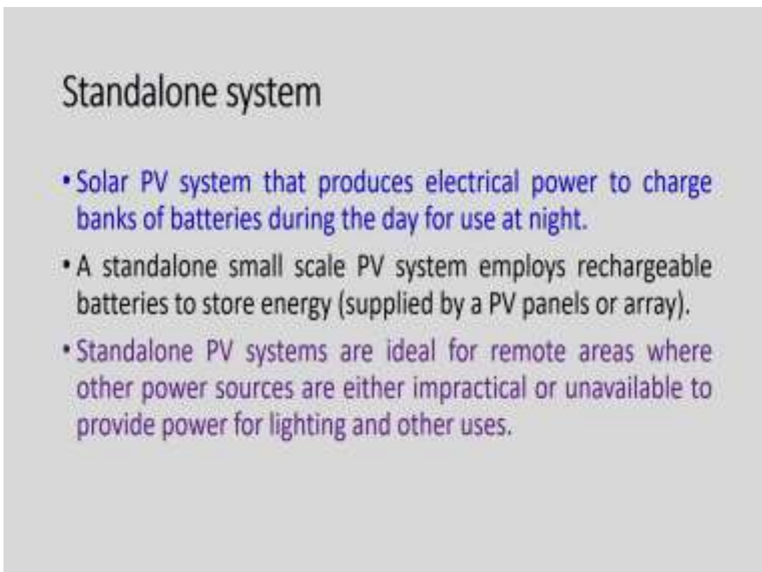

So, what is standalone system, the standalone system is a solar PV system that produces electrical power to charge banks of batteries during the day for use at night. A standalone small-scale PV system employs rechargeable batteries to store energy which is supplied by a PV panels or arrays. The standalone PV systems are ideal for remote areas where other power sources are either impractical or unavailable to provide power for lighting and other uses.

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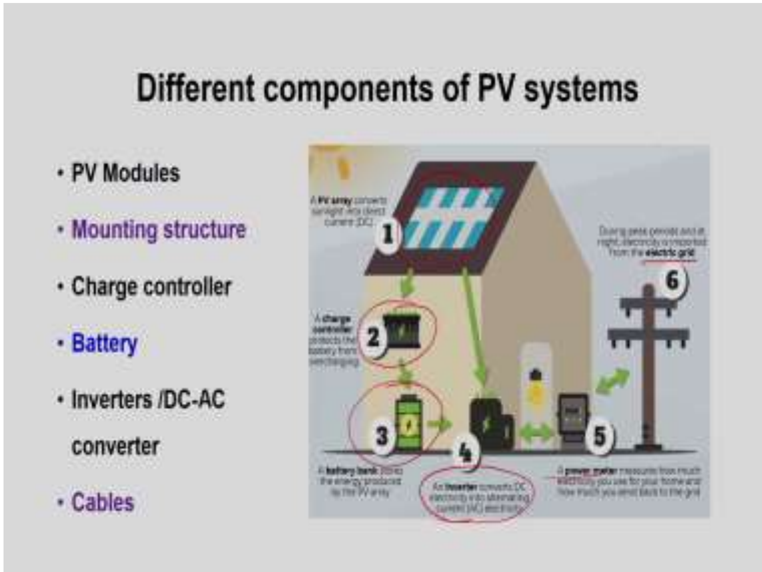

So, different components of a PV systems are PV modules which is the primary component then mounting structures then charge controller, battery, inverter, then DC AC converter and cables. So, as you can see here in the figure, so, PV modules are installed on the rooftop okay. So, this PV array converts sunlight into direct current right and we need to have a charge controller to protect the battery from the overcharging, right.

So, we need battery banks which stores energy produced by the PV arrays, okay. And then if we have AC load or alternating current load then we have to convert this direct current which is generated by PV arrays to the alternating current by an inverter and we need power meter and then electric grid sometimes or sometimes we can use the genetic energy locally right.

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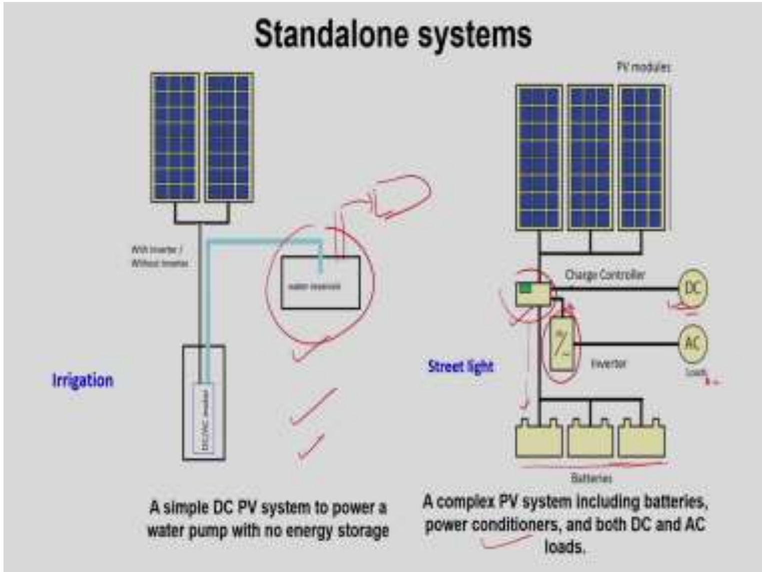

So, what you can see here, they are two configurations of a standalone system. So, first configuration where there is no charge controller and battery bank and the second configurations will have charge control and then battery banks okay. So, here this is an example of lifting water from the ground and storing in a reservoir and then finally we can use this reserve water for irrigation applications, okay.

Because in irrigation you need huge amount of water okay this is something like solar powered water pumping systems which is used in irrigation and these configurations what we have shown, there are many modules are connected and we will have a charge controller to protect these batteries for overcharging. Okay, the batteries here.

So, we will study how many batteries are required for a single applications and we need to have inverter to convert this DC current to AC current okay. So, if load is DC then straight way you can use from the charge controller. Okay, so these are the two extensively used configurations, okay. So, this is somewhat complex okay where we have many components and these are very simple configurations.

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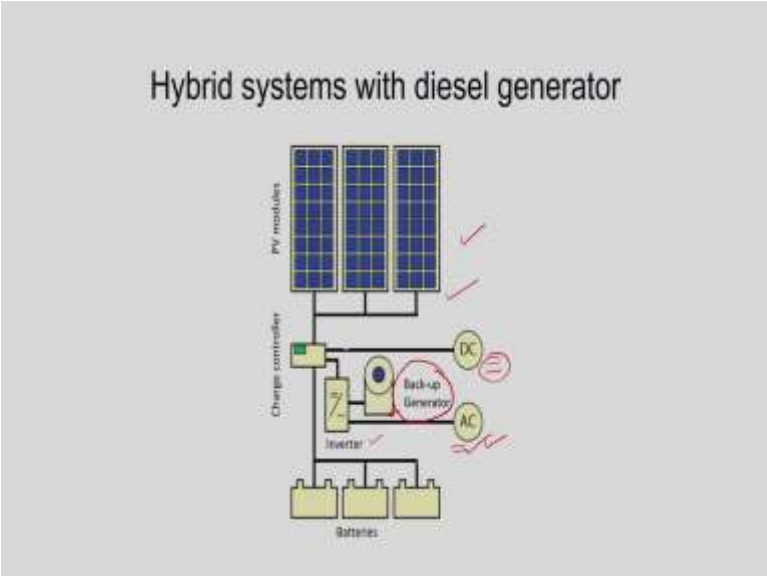

One more configuration we have, suppose in a single day we do not have enough sunlight, okay then amount of energy generation by this PV module will be very very less okay then under the conditions in order to meet the demand then we need some kind of backup system, okay. So, here what we have shown this is a generator backup system and this is coupled with that existing connections right.

So, that we can meet the demand during those cloudy days or rainy days, okay. So, primarily what we have understood there are components like solar PV which converts sunlight to electrical energy and we need to have a charge controller okay to protect these batteries from overcharging okay and if we have AC load then of course, we need an inverter to convert direct current into alternating current and sometimes there are some loads where we need only DC current. So, under that conditions, we do not need inverter okay.

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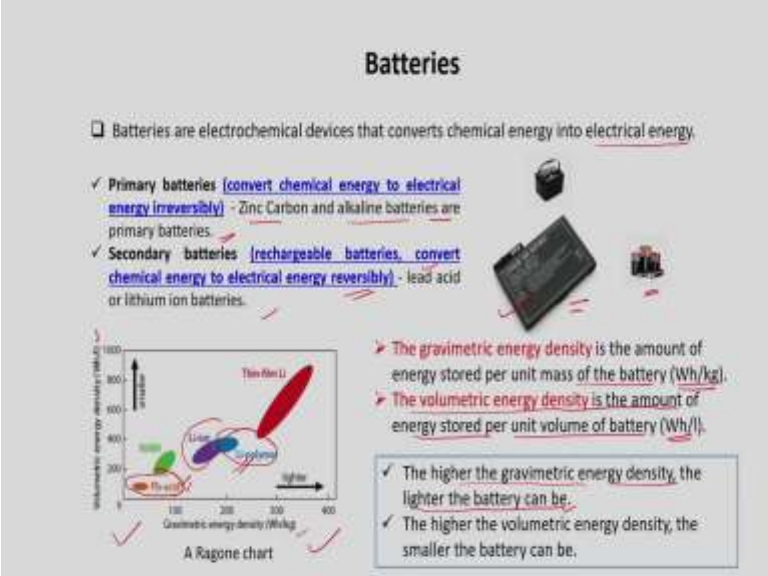

So, we will study one by one those components which constitute a standalone PV systems. So, let us first study the batteries okay. So, batteries are electrochemical devices that converts chemical energy into electrical energy, okay. So, there are two kinds of batteries normally used primary batteries and secondary batteries, what is primary batteries? Which convert chemical energy to electrical energy irreversibly, okay. So, for example, we have zinc carbon and alkaline batteries are primary batteries okay, we cannot recharge again and again.

But in case of secondary batteries, that is called rechargeable batteries, which convert chemical energy to electrical energy reversibly, okay. So, example is something like lead acid batteries, lithium ion batteries, okay. So, these are some of the examples right. So, if you look into this chart, this chart is known as a ragone chart which is used for comparision of different batteries. So, you can see the position of Pb acid batteries is here and lithium ion batteries and lithium polymer batteries are here okay.

So, in the vertical axis it shows volumetric energy density and in the horizontal axis it shows gravimetric energy density, okay and gravimetric energy density represents watt hour per kg and volumetric energy density represents watt hour per liter okay. So, what does it mean? So, gravimetric energy density is the amount of energy stored per unit mass of the battery, okay.

And volumetric energy density is the amount of energy stored per unit volume of the battery, okay, already we have defined those units and as you can see, if volumetric efficiencies increases what does it mean, higher the volumetric energy density the lighter the battery can be, that is why we know, this lithium ion and lithium polymer batteries are lighter than lead acid batteries and higher the volumetric energy density smaller the battery size at the same time the size of these lead acid batteries are higher compared to lithium ion batteries okay as you can see here, right. So, this art is normally used to compare character of the different batteries.

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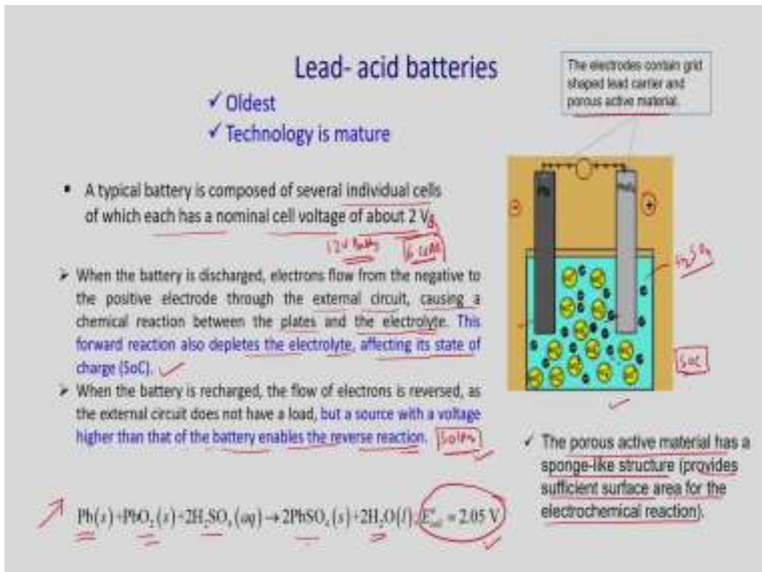

Now, let us learn something about lead acid batteries which is the oldest batteries and technology is quite mature. A typical battery is composed of several individual cells of which each has a nominal voltage of 2 volt, okay. So, what happens if we look for 12 volt battery then how many cells are required, it will be 6 cells right each cells will give 2 volt okay. So, for cell it works something like this okay. 2 metal electrode will be there and electrolyte will be there. So, electrolyte is nothing but diluted sulfuric acid and this electrode contains grid shaped lead carrier and porous active material okay.

So, this porous active material has a sponge like structure which provides sufficient surface area for electrochemical reaction, okay normally this Pb in one electrode is in negative and then Pb O2. So, lead oxide is positive okay when an external load is connected electron will flow from negative to the positive terminal okay. So, when the battery is discharged the electron flow from negative to the positive electrode through the external circuit okay which causing a chemical reaction between the plates and the electrolyte, okay.

Now, these are the electrolytes here and these are the plates okay this forward reaction also deflects the electrolyte affecting the state of the charge, okay. So, SoC we will define what is SoC. So, it affects the state of the charge okay and when the battery is recharged the flow of electrons is reverse of course, as the external circuit does not have a load okay but a source with a voltage higher than that of the battery enables the reverse reaction okay.

So, this external source is nothing but solar source okay. So, this is also known as solar battery because lead acid batteries are used in solar research okay. So, overall reaction will be something like this. So, lead and the lead oxide reacts with sulphuric acid and then we will get $PbSO_4$ and then H_2O and each cell will give about two volt of energy generation okay. So, this is how a lead acid battery works.

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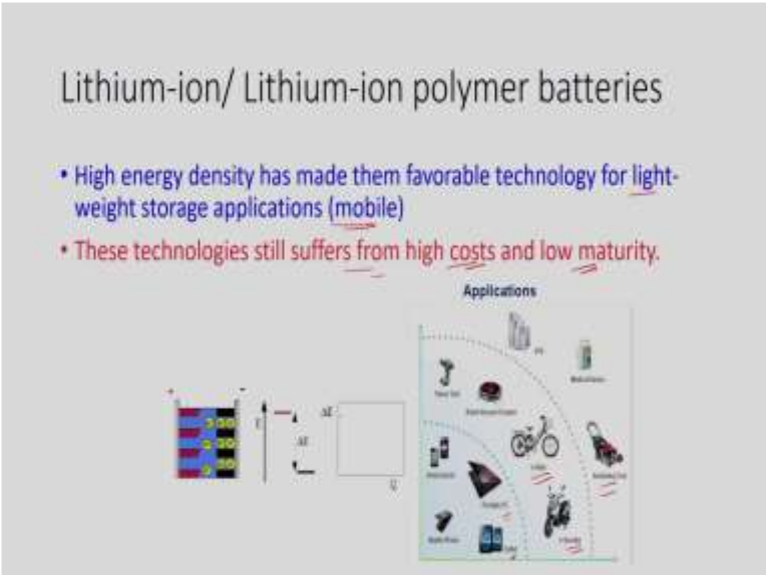

And if we talk about lithium ion and lithium ion polymer batteries as we can see from the ragon charts that high energy density has made them favorable technology for lightweight storage applications like mobile communications okay and these technologies still suffer from high cost and low maturity okay. So, this is the reason why this cannot be used in solar research or solar photovoltaic applications. So, as you can see, there are many applications of lithium ion and lithium polymer batteries. So, e-bikes are there, scooters are there, gardening tools, tablets, mobile phone, everywhere these lithium ion batteries are used.

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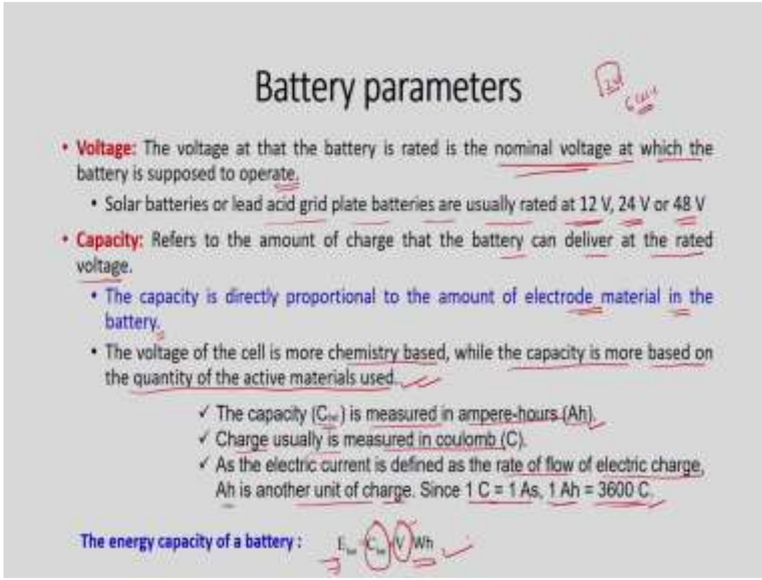

So, let us learn something very important aspects of batteries. These are called battery parameters. So, voltage capacity then energy capacity of the battery then SoC and in depth of the discharge all those parameters. So, start with voltage, the voltage at that battery is rated is the nominal voltages at which the battery is supposed to operate the solar batteries or say lead acid grid plate batteries are usually rated at 12 volt 24 volt or 48 volt that is what I said the number of cells required if single cell is giving 2 volt then number of cells required to get 12 volt will be 6 cells okay. So, that has to be connected in series.

And capacity refers to the amount of charge that the battery can deliver at the rated voltages , okay. So, this rated voltage is very very important this rated voltage nothing but nominal voltage, right. The capacity is directly proportional to the amount of electrode material in the battery that is why no smaller size battery if we compare it with the bigger size batteries then what will happen? The smaller size batteries capacities will be lower compared to larger size batteries, okay.

But the voltage will be constant the voltage of the cell is more chemistry based while the capacity is more based on the quantity of the active material use which is very very important, okay. The capacity which is also represented as C_{bat} okay is measured in Ah okay. So, charge usually is measured in coulombs that we all of us know As. Electric current is defined as the rate of flow of electric charge ampere hour is another unit of charge, right?

Since 1 coulomb is 1 As, right, and if we multiply these with 3600 then it will become 1 Ah which is nothing but 3600 coulomb right also, we are interested to calculate the energy capacity of a battery. So, how to get it? So, energy capacity of the battery can be calculated by multiplying this C_{bat} with this rated voltage, okay.

So, if we know the C_{bat} and rated voltage if we multiply what we will get is a energy capacity of a battery which is very very important and it is represented in terms of watt hour okay so capacities is now measured in ampere hour and energy capacity of the battery is measured in watt hour right.

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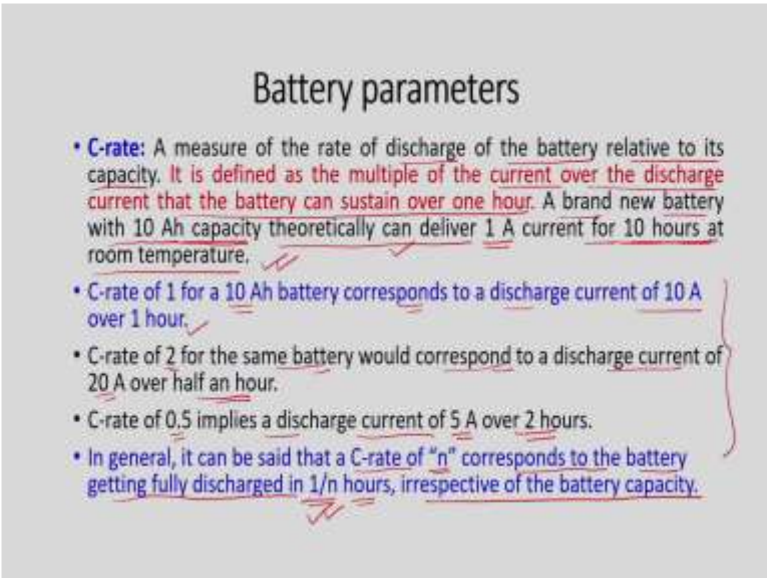

Now, one more very important parameter called C-rate, okay this C-rate is a measure of the rate of discharge of the battery relative to its capacity right. So, it is also defined as the multiple of the current over the discharge current that the battery can sustain over one hour, okay. Suppose for example, a brand-new battery with 10 Ah capacity already we have defined what is capacity theoretically can deliver 1 ampere current for 10 hours at room temperature okay that you should keep in mind.

So, a brand-new battery with 10 Ah capacity theoretically can provide 1 Ah current for 10 hours at room temperature okay it is related to temperature at which the system will operate, okay. For example, C-rate of one for 10 Ah battery corresponds to a discharge current of 10 ampere over one hour okay. So, same battery if we consider for the case two like C-rate of two for the same battery would correspond to a discharge current of 20 ampere over half an hour Okay. And then one more example, if we take C-rate of point 5 implies a discharge current of 5 ampere over 2 hours okay. In general, it can be said that C-rate of n corresponds to the battery getting fully discharged in 1/n hours irrespective of the battery capacity okay. This we should keep in mind okay.

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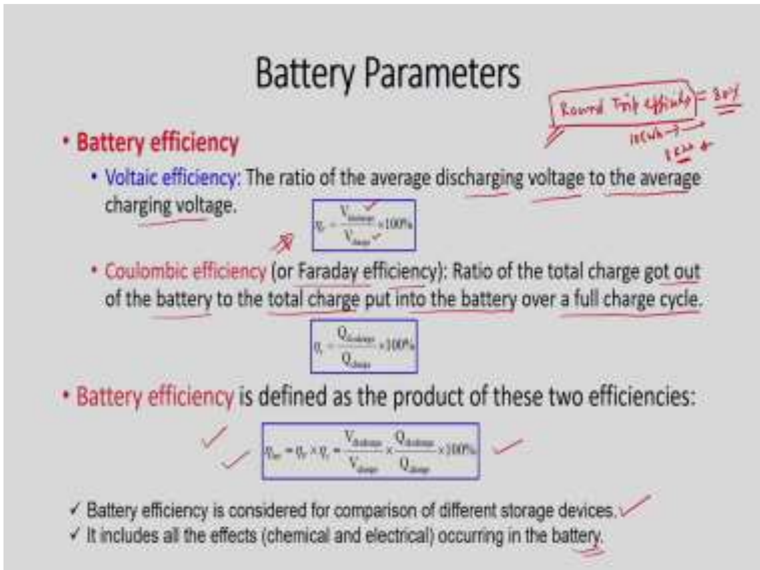

And this example will be very much helpful to understand how C-rate is defined also, we must know what is battery efficiency, battery efficiency also sometimes known as round trip efficiency, round trip efficiency. So, for any storage system we must know what is round trip efficiency okay. Suppose for example, if we have to say pumps amount of energy maybe 10-kilowatt hour of energy we are pumping, okay in a charging process and maybe eight kilowatt hour of energy we are retrieving in the discharge process. Then what will be the round trip efficiency, it will be 80% Okay. So, eight by 10 will be 80 percent.

So, in case of battery, so, this round trip efficiency is connected with voltaic efficiency and coulombic efficiency and finally, we will have a combined efficiency okay that is called battery efficiency and that take care of this round trip efficiency right. So, what is voltaic efficiency the ratio of the average discharging voltages to the average charging voltage okay.

So, we know that discharging voltage and charging voltage that ratio will give you voltaic efficiency okay and second efficiency is coulombic efficiency okay, or it is also known as

Faraday efficiency, which is the ratio of the total charge got out of the battery to the total charge put into the battery over a full charge cycle, okay, and this is defined as Q discharge by Q charge, Okay?

So, if we combine both the efficiency what we will get is a battery efficiency. So, if we multiply these two then what we will have is a battery efficiency. So, this battery efficiency is considered for comparison of different storage devices, okay and it includes all the effects like chemical and electrical occurring in the battery right. So, these efficiencies are important evaluating a battery.

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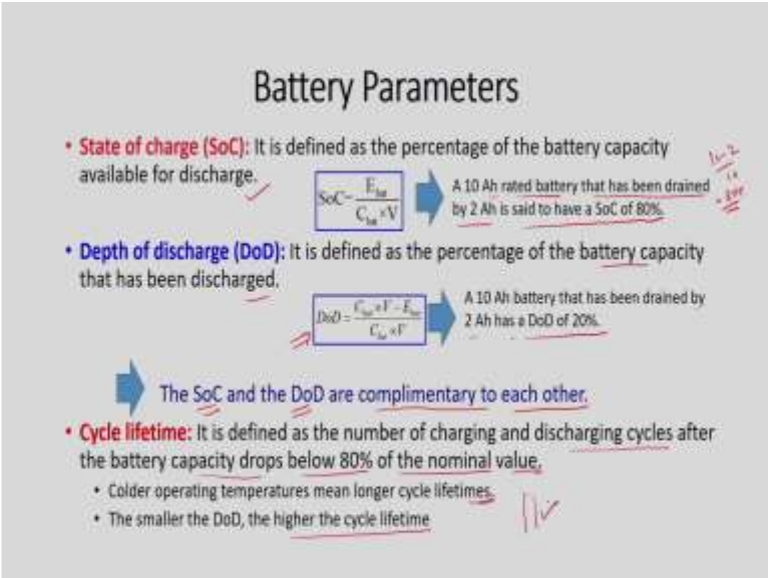

Also, we must know what is the state of charge of a battery which is defined as the percentage of the battery capacity available for discharge, okay. So, what we see in the mobile phone what we use nowadays, so, it shows like eighty percent 70 percent but these are remaining in the battery that means that SoC is 70 percent, okay. So, $SoC = \frac{E_{bat}}{C_{bat} \times V}$ okay.

So, for example, a 10-ampere hour rated battery that has been drained by two ampere hours is said to have a SoC of eighty percent, okay. So, this is something like 10 minus two divided by 10 okay it will be 80 percent and also one more parameter we must know when we talk about battery parameter is called dept of discharge. So, it is defined as the percentage of battery capacity that has been discharged okay. So, it is represented by DoD which is $SoC = \frac{C_{bat} \times V - E_{bat}}{C_{bat} \times V}$ okay.

So, same problem if we have to define in terms of DoD it is something like a 10-ampere hour battery that has been drained by two ampere hours has a DoD of 20 percent, okay. So, this SOC and DoD okay state of charge and depth of discharge are complementary to each other we should keep in mind. Also, we need to define one more terminological cycle lifetime okay which is defined as the number of charging and discharging cycles after the battery capacity drops below 80 percent of the nominal value, okay.

So, this battery cycle again depends on the operating temperature right. So, colder operating temperature means longer cycle lifetimes okay and the smaller the DoD means depth of discharge, the higher the cycle lifetime okay. So, these are important observations and how the cycle lamps are affected by temperature and DoD.

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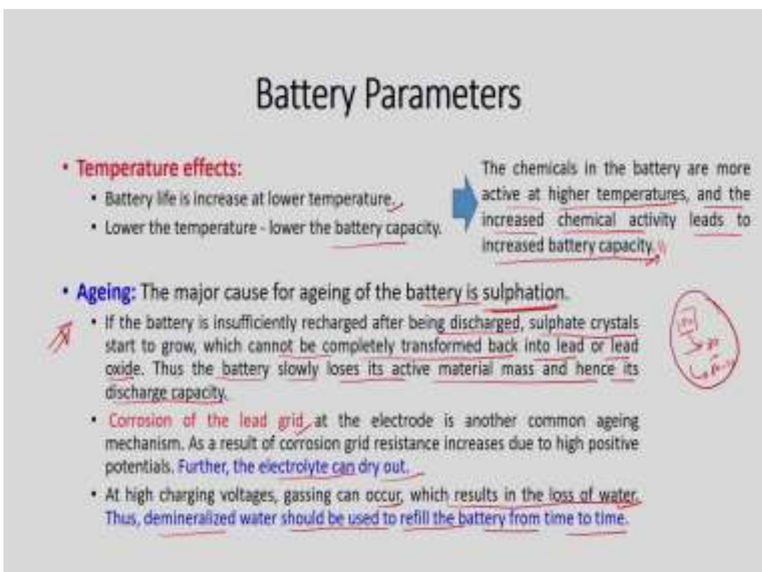

And how temperature affects the battery life. So, this battery life is increased at lower temperature okay if you can keep at low temperature or room temperature then battery life is expected to be higher and lower the temperature, lower the battery capacity again okay. So, what happens the chemicals in the battery are more active at a higher temperature okay and the increase chemical activity leads to increased battery capacity okay. So, by increasing the temperature we can increase the capacity of the battery, but now if increased more than a specified below then it will give a detrimental effect to the battery health, okay.

And also we have is ageing Okay, so major cause for ageing of the battery is sulphation. So, what is sulphation? So, if a battery is insufficiently recharged after being discharged Okay, suppose if I am using a mobile phone if it is no 50 percent charge available or SoC is fifty percent and we are charging it for eighty percent 50 percent 80 percent and then stop it again we use it for 80 percent 90 percent so that way if we make then know we are reducing the efficiency because of this sulpahte crystal generation's okay.

So, sulphate crystals start to grow which cannot be completely transformed back into lead or lead oxide, okay, so thus battery slowly loses its active material mass and hence it's discharge capacity okay and corrosion is also one of the problems and because of this corrosion electrolytes may dry out and at a highest charging volt is if the battery is charge at a very high voltage gassing can occur, okay.

So, gas will be generated which results in the loss of water as you can see in the overall reactions water will be there at the product side so that water losses will be there. Okay, so thus demineralized water should be used to refill battery for time to time, that is why you know we have to buy demineralized water okay to be used in those lead acid batteries for proper functioning.

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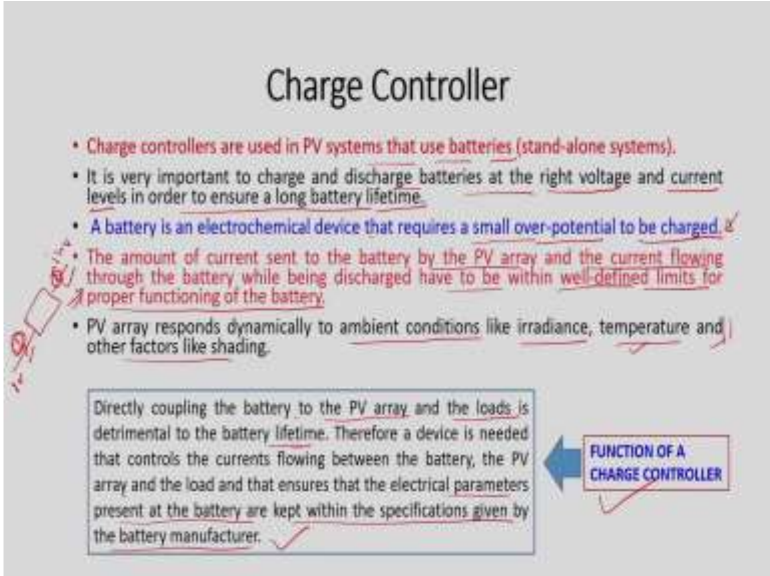

Now, let us discuss something about charge controller, which plays a key role in a stand-alone system where a battery is involved, okay. So, charge controllers are used in PV systems that use batteries okay. So, it is very important to charge and discharge batteries at right voltages and current levels in order to ensure the longer battery life time, okay.

A battery is an electrochemical device that requires small over potential to be charged that we should keep in mind. So, we need some kind of over potential for charging. The amount of current sent to the battery by PV array and the current flowing through the battery. So, if we consider this a battery, the amount of current flows from the PV and then going out from the battery okay. So, this will go to maybe inverter okay.

So, I am talking about this and this okay, this current and this current, so, this is for discharge and this is for charging have to be within the well-defined limit for proper functioning of a battery. So, that is very very important this current no charging current and then no discharge current has to be at the proper level as described by manufacturer okay.

This PV array corresponds dynamically to ambient conditions like irradiance, temperature, and other factors like shading what we have discussed in the last class. So, these are very very important things because every time we are not going to get the same solar irradiance okay. So, it will vary with time okay and also, when solar radiation increases then temperature also increases.

So, we need to think many parameters for proper functioning of a solar PV stand-alone system, okay.

So, this direct coupling of battery to the PV array and the load is detrimental to the battery lifetime okay. Therefore, a device is needed that controls the current flowing between the battery and the PV array and the load and that ensures that the electrical parameters presented the battery are kept within the specifications given by the battery manufacturer. So, that is the function of a charge controller.

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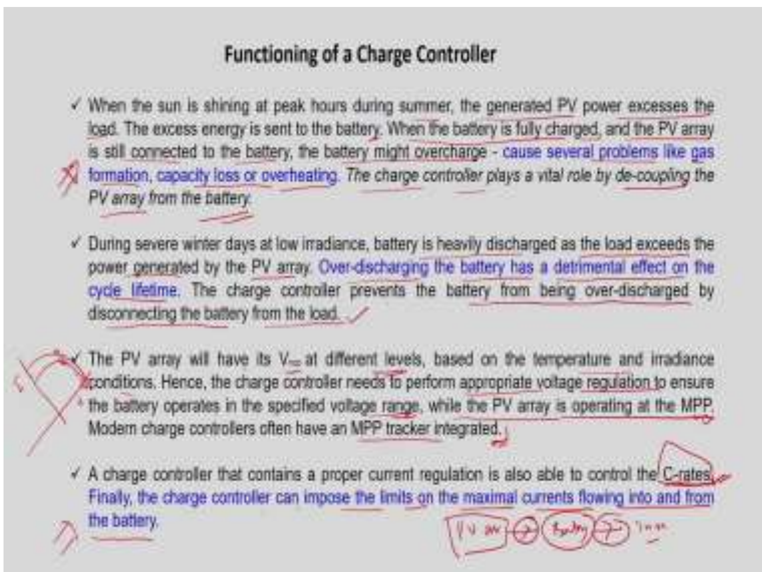

Let us learn more in depth about this charge controller how it works in a PV system. So, when the sun is shining at peak hours during summer the generated PV power excess the load okay. The excess energy is sent to the battery when the battery is fully charged and a PV array is still connected to the battery, the battery might over charge, okay, which may cause several problems like gas formation, capacity lost and overheating, okay. So, this is one concern, but if we have a proper charge controller, which plays a vital role by decoupling the PV array from the battery, right that is how this charge controller is useful in maintaining the proper life of a battery in stand-alone PV system.

So, during severe winter and now second cases when solar irradiation is very, very low and batteries heavily discharge as the load exceed the power generated by the PV array okay. So, over discharging the battery has a detrimental effect on the life cycle okay. The charge controller prevent the battery from being over discharge by disconnecting the battery from the load okay, this is the second function of this charge controller, okay.

Now, this PV array will have its V_{mppt} maximum power point at different levels as you can understand if we remember this IV characteristics curve, okay. So, this is maybe one irradiance and this may be other irradiance value okay. So, these value will change as irradiance will change right this is what it is mentioned.

So, PV array will have its V maximum power Point okay. So, this is V_{mppt} at different levels based on the temperature and irradiance conditions, hence, the charge controller needs to perform appropriate voltage regulation to ensure the battery operates in the specified voltage range, while the PV array is operating at maximum power point, okay.

So, of course this modern charge controllers often have an MPPT trigger integrated, okay. So, if this MPPT is integrated then it is not a problem it will operate at the maximum power point. So, a charge controller that contains a proper current regulation is also able to control the C-rate okay. So, this charge controller also controls this C-rate, okay. Finally, this charge controller can impose the limits on the maximal current flowing into and from the battery okay.

So, if we consider this is PV array okay this is PV array and we have battery and we have maybe inverter or may be utility okay. So, maximum current flows from here to here and maximum current flows from battery to the inverter or maybe some utilities right.

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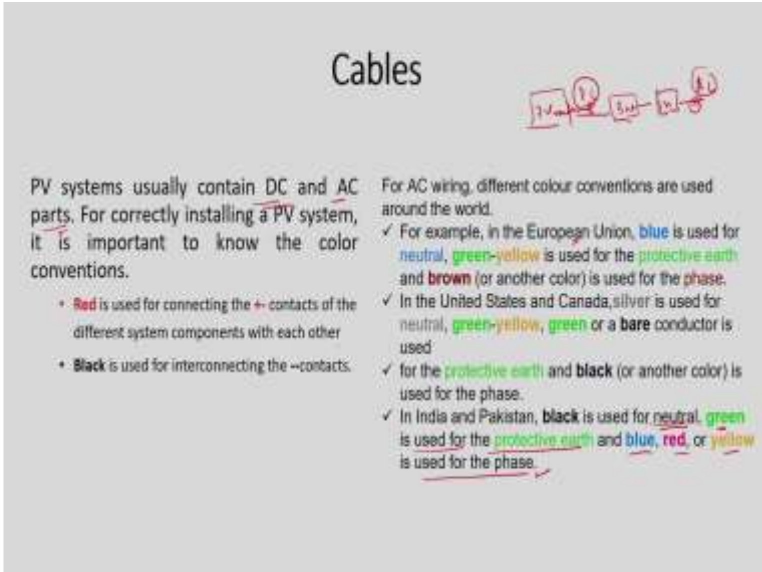

Now, we need to also learn the cables, cable plays an important role in the functioning of a PV system right. So, PV system usually contains DC and AC part as you can understand, so, when we are talking about PV modules, okay, or arrays so, power generated here will be DC then we will have okay battery we can write and maybe inverter here, okay? Then we will have AC okay.

So, we need to know the cables used for this and we need to know the cables used for this okay. So, that is how it is mentioned PV systems usually contains DC and AC parts for correctly installing a PV system it is important to know the color convention okay. So, red is used for connecting the plus minus contexts of the different system components with each other and black is used for interconnecting the negative negative contexts okay and for AC wiring.

So, different color codes are used around the world. So, kind of color code used in European Union is different than the kind of color code used in other countries okay. In case of India and Pakistan, black is used for neutral and green is used for protective art and blue, red and yellow is used for phase okay. So, this kind of color conventions are used.

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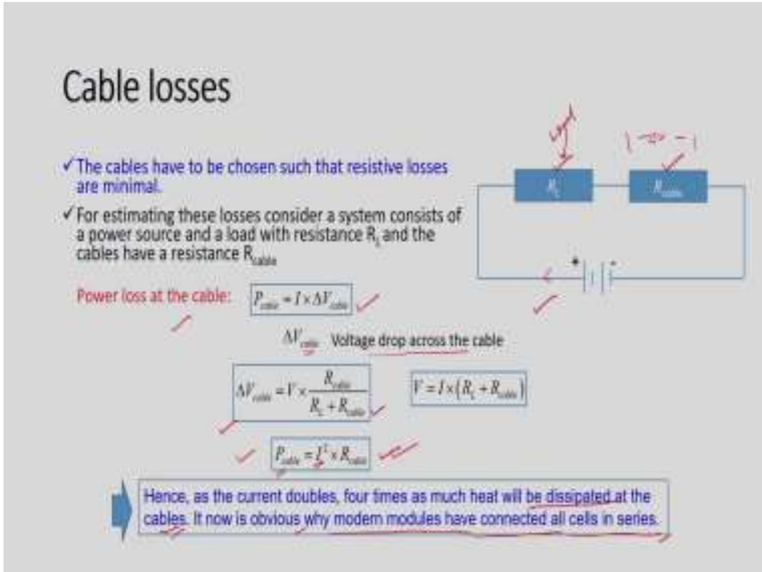

So, now, let us have a look about the cable losses okay. So, these cables have to be chosen such that resistive losses are minimal, okay. So, in order to understand this let us take an circuit which constitutes a supply voltages okay and then we have load and then maybe cable resistance are included, okay. So, R_L represents the load having resistance R_L okay and this R cable is the resistance of the cables right.

So, power loss at the cable can be calculated by using this equation $P_{cable} = I \times \Delta V_{cable}$ okay. See ΔV_{cable} is the voltage drop across the cable okay is the voltage drop across the cable. So, this can be calculated by using this and this is something like $V = I \times R$ right, this summation of (R_L + R_{cable}) and then finally, what we would like to show is power of the cable which is dissipated is equal to $I^2 \times R_{cable}$ right.

So, what we can say so, as the current doubles then what happens this power will be four times okay. So, what does it mean as the current doubles the four times as much heat will be dissipated at the cable, right. So, it is now obvious why modern modules have connected all the cells in series because of these losses okay power distribution is very very high because I^2 R losses will be there okay. So, we have to be very particular about the kind of cables to be used for this kind of standalone system okay.

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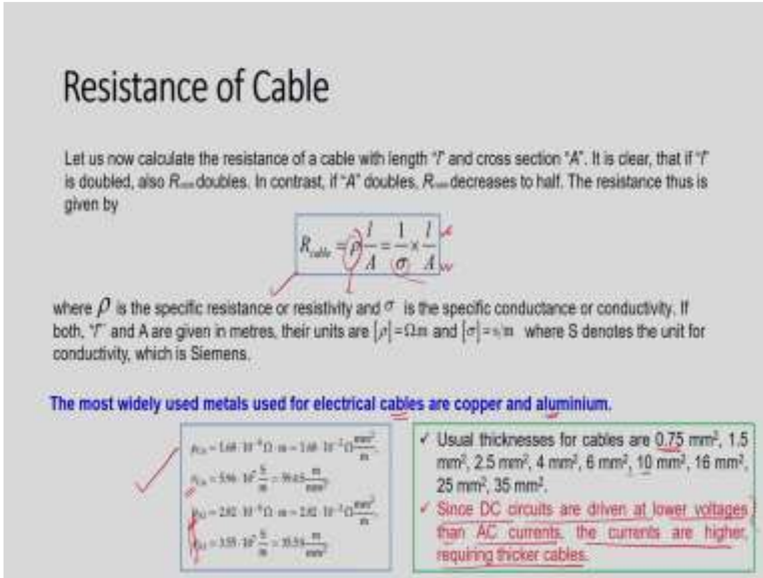

So, also we know this R_{cable} is function of row $\rho\frac{l}{A}$ and also $\frac{1}{\sigma}$ is $\frac{l}{A}$ right. So, this row is nothing but resistivity and also we can express in terms of conductivity okay this is conductivity, right. Normally this l will be in meter and a is normally in millimeter okay. So, this block shows about the no values of this row for copper and aluminum because mostly copper and aluminum cables are used in applications.

So, what will be the resistivity of copper we can say $1.68\times10^{-8}\Omega m$ okay and you can see the values of copper for conductivity as well as resistivity and then the connectivity for aluminum okay because these values are given as most of the times these values are used for calculation of this resistance of a cable okay and usual thickness for cables are about 0.75 square millimeter 1.5 square millimeter 2.5 square millimeters and so on okay. So, one very important observation is since DC circuits are driven at lower voltages, than AC currents the currents are higher requiring ticker cables. So, that you should keep in mind for DC we need a thicker cable right.

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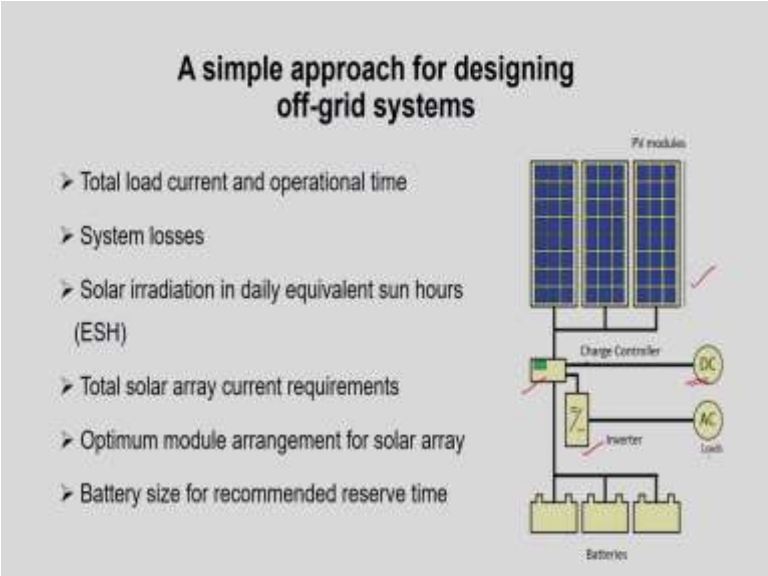

Now, let us see the simple approach for designing an off grid systems or stand-alone system. So, it includes the determination of total load current and operational time okay then determination of system losses then we need to determine solar irradiation in daily equivalent sun hours it also known as ESH that is equivalent sun hours and then we need to determine total solar array current requirements and then we need to determine the optimum module arrangement for solar array and then finally, we need to determine the battery size for recommended reserve time okay.

So, configurations are something like this okay module such there we have charge controller then DC load, AC load then we have inverter and then batteries right. So, this kind of configurations we are talking about okay. So, let us take a small example and try to understand the simple approach for designing of off-grid system okay.

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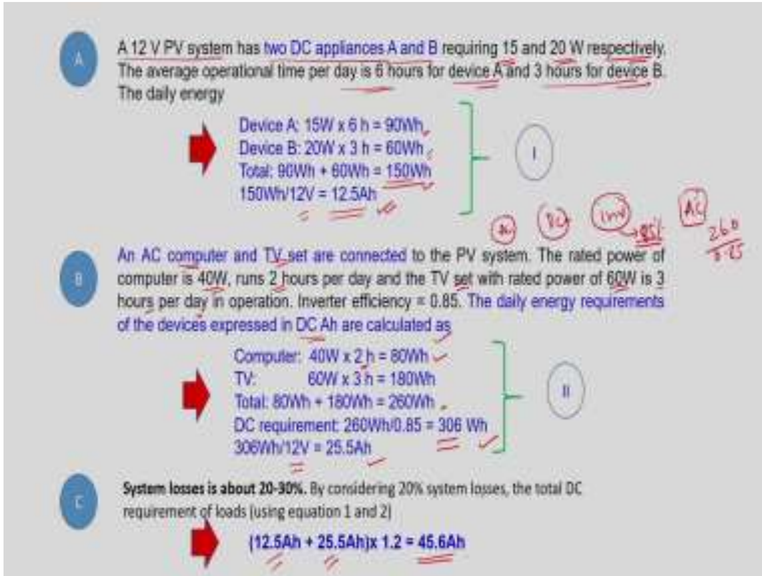

So, the example goes something like this a 12-volt PV system, we are considering very basic PV system has two DC appliances A and B. So, two DC appliances we are considering maybe A and B that may be anything requiring 15 and 21 watt respectively okay, the average opertional time per day is six hours for device A and three hours for device B right.

Maybe you know device A maybe fans and maybe you know tube lights or device B maybe mixer grinder or maybe something like that. So, now the daily energy requirement will be for device A is 15 watt multiplied by six hour. So, it will be 90-watt hour for device B it is 20 watt multiplied by 3 hours it will be 60 watt hour. So, these are DC appliances okay we are not talking about the AC appliances right.

So, the total energy daily energy requirement will be 90-watt hour plus 60-watt hour it will be 150-watt hour okay. So, as we know this rated voltage is 12 volts then if we divide this total daily energy by 12 volts then it will be 12.5 ampere hour, okay. Now, next step is for example, if we have AC load, okay. So, maybe computer is one item and TV set is another item okay which are connected to that PV system. So, as we know this will work in no AC condition means alternating current. So, we need to have inverter okay.

So, if we consider an inverter, so, in order to have AC then we need inverter okay from DC okay and we need to know what is the efficiency let us consider the efficiency of this inverter is 85 percent, okay. So, under that condition the daily energy requirements of the device express in DC ampere hour can be calculated, okay. So, in this case rated power of the computer is 40 watt and it will run for 12 hours per day and for TV sets, rate power is 60 watt and it will run for 3 hours per day okay.

So, if we talk about computer so what it will run for two hours so it will be 80-watt hour okay that is the AC requirement and for TV it is 60×3 so 180-watt hour right and total it will be 260 watt hour okay. So, as we know this efficiency of the inverter, so, what we can do we can divide this because we need to convert to DC. So, we have to divide it okay. So, $\frac{260}{0.85}$ will be 306-watt hour right.

So, if we divide this rated voltage it will be 25.5 ampere hour Okay, the next step as per our design methodology, we need to add some kind of losses Okay, this may be cable losses or any other losses encountered during operation. So, it is considered to be about 20 to 30 percent. So, if we consider 20 percent so, then what will happen this DC requirement will increase by 1.2 times so it will be 45.6 ampere hour. So, now this all the things are DC okay and then we multiply by 1.2 it will be 45.6 ampere hour, okay.

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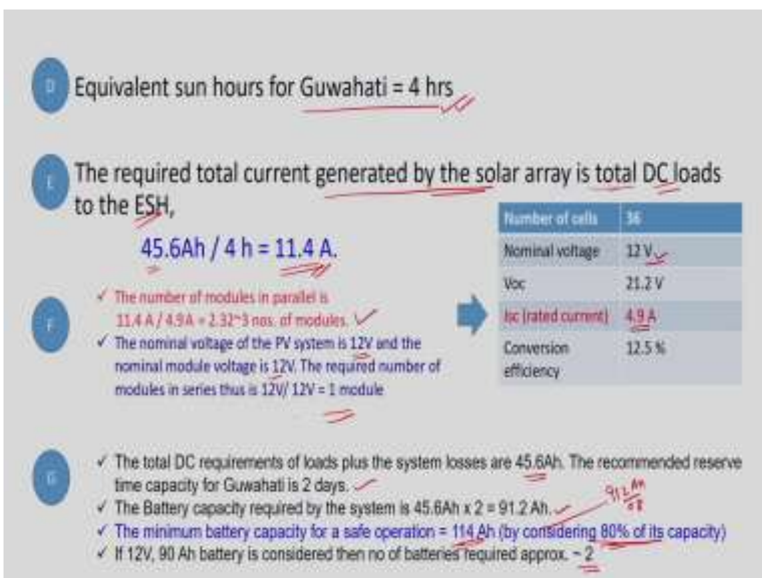

Let us move to the next step. So, equivalent sun hours if we consider a place in Guwahati so it may be four hours okay. So, required total current generated by the solar array is total DC load to the ESH okay equivalent sun hour. So, equivalent sun hour is four and then total DC load is 45.6 then what we will get is 11.4 ampere, okay.

Now, we are interested to know the number of modules to be connected in parallel. So, how to do that if we consider a module having I_{SC} value or rated current is 4.9 ampere then we can divide this current okay that is no current generated by DC solar array. So, this is 11.4 divided by 4.9 is 2.32 which is equivalent to three numbers of the modules okay to be connected in parallel right the nominal voltage of the PV system is 12 volt and the nominal voltage of the module is also 12 volt, here is the 12 volt for the module and then the PV system is also 12 volt. So, required number of modules to be connected in series is just 12 volt by 12 volt is equal to one module, right.

The total DC requirement for loads plus the system losses are 45.6 ampere hour the recommended reserve time capacity for Guwahati is said two days okay. So, battery capacity required by the system is if we multiply this by two so, it will be 91.2 ampere hour and minimum battery capacity for safe operation will be 114 because we know 80 percent capacity if we consider then this divided by 91.2 ampere hour divided by 0.8 will give you this 114 ampere hour, okay.

So, if we consider 12-volt 90 ampere hour battery then the number of batteries requirement will be approximately two numbers, okay. That way we can do the calculations. So, we will be discussing detailed design methodology in the next class, okay where we will understand the relationship between the kind of current goes from the battery to the inverter and then to the load and everything will be considered and we will study the clear-cut steps for designing a complete stand alone PV system.

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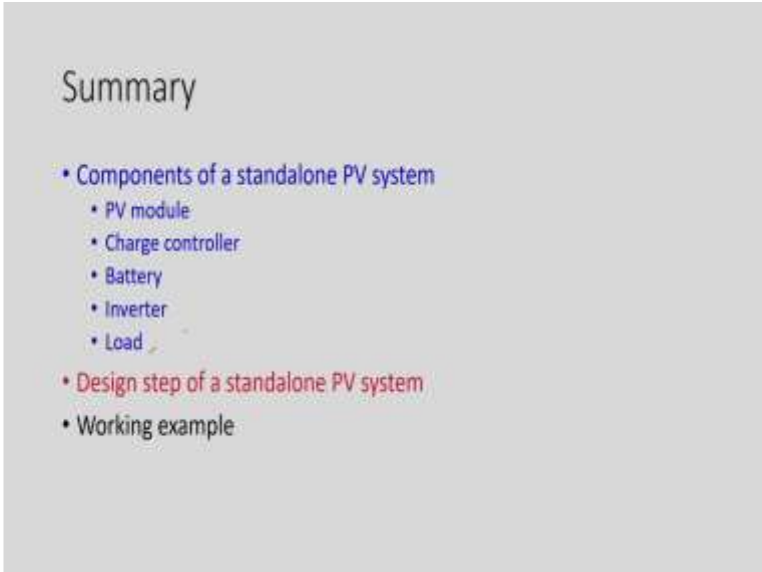

So, now let us summarize what we have discussed today about the different components of a standalone system like PV modules, charge controller, battery, inverter and load. We have not given more about the inverters because we will be covering these things when we discuss the grid connected PV system, okay. There are different kind of inverters are there which inverter to be selected for what application that will be discussed and also, we have studied the loads.

There are cases where DC loads are there, there are cases where AC loads are also there. So, what we need to do in case of AC and what we need to do in case of DC load that we have discussed. Also, we have discussed design step for a standalone PV system and also, we have discussed small numerical exercise to strengthen your understanding of design of standalone PV system, okay. So, thank you very much for watching this video, thank you.