Power Plant Engineering
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Lecture - 34
Photovoltaic Conversion

I welcome you all in this course on Power Plant Engineering. Today, we will discuss about the Photovoltaic Conversion. We will start.

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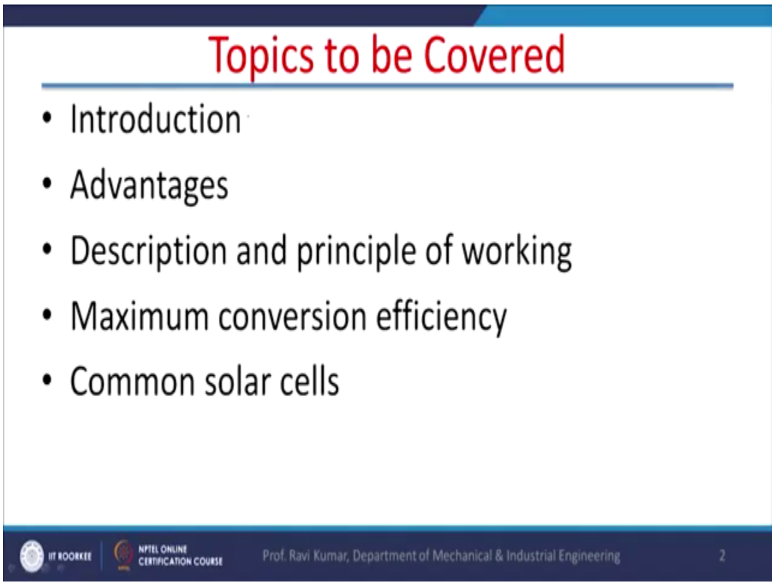

Topic to be covered in this lecture are first of all we will introduce what is photovoltaic conversion, advantages of photovoltaic conversion, description and principle of working of a photovoltaic conversion device, that is known as solar cell, maximum conversion efficiency to what conversion efficiency we can go for, and we will name some describes certain common solar cells, ok.

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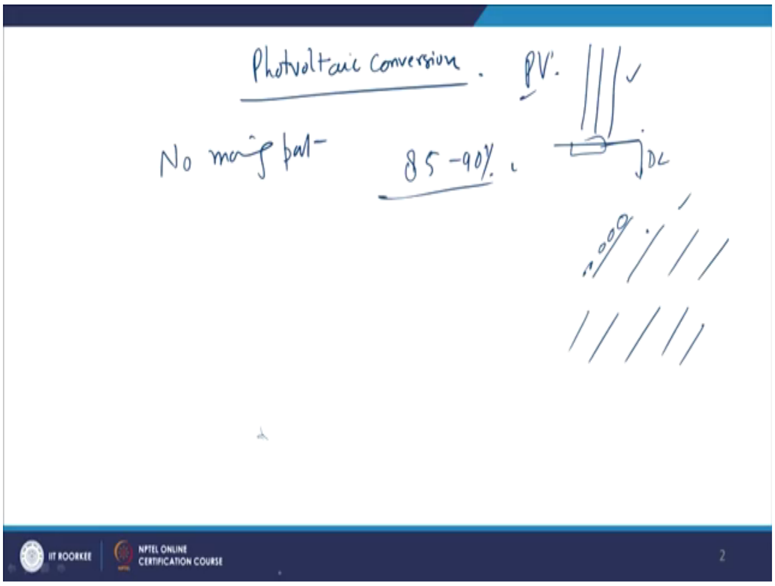

So, starting with the introduction the photovoltaic conversion. This photovoltaic conversion, why it is called conversion? It is called conversion photovoltaic conversion because of solar energy which is falling on the surface in converted to electrical signal or electrical energy. So, that is why it is called photovoltaic or it works on the photovoltaic effect.

And it is another way of trapping the solar energy. One is a solar thermal energy, solar thermal systems which can trap the solar energy, another is sort of photovoltaic conversion of PV photovoltaic system for trapping the solar energy. And these systems are becoming very popular nowadays, because they are direct conversion systems and the energy which is falling on the photovoltaic cell is directly converted into the DC and this DC can be used for running different appliances.

And you must have seen in the cities, in the rooftops, there are certain panels which are laid and the area of the panels, facing a particular direction these panels they contained PV cells, right and output of the panels is adjusted in such a way that we get desired voltage and current at the output, and this desired voltage and current output either we run the DC machines, right. Then DC fans are also available nowadays. So, we can run the DC machines directly from them.

Or we can send this energy to the main grid, but when we are sending this energy to the main grid the losses are high. Third option is we can store this energy and then charge the batteries and use the batteries for different applications, right. They have no moving part the. Beauty is no moving part. Little maintenance is required.

You have to clean, only keep the surface clean PV surface clean, otherwise the efficiency of the cell will go down drastically and the best part of it that it takes the diffused radiations also. If you look at the solar thermal type of systems, solar thermal type of systems they work on the direct radiation beam radiation, they do not take diffused radiations or they take diffused radiations, but the percentage is very insignificant. But here they take the diffused radiations also.

You must have seen those calculator which are running with the solar cell they do not require batteries, right and you can operate those calculators sitting in a room and the rooms we are getting only diffused radiations. We are not getting direct radiations. So, that is the advantage of these type of devices that they can take the diffused radiation. And for different power requirement you can simply adopt these devices. Just changing the arrangement the connections in an array you can have different combinations of voltage and currents. So, that is also in favor of the PV devices.

The main disadvantage is they are costly and because nowadays the companies are going for the mass production, so the cost is also coming down to a reasonable limit, and the government, in past the government was also giving subsidy on these devices PV devices, right. So, different governments are giving the subsidy on these devices. So, in all this is a very neat system for power generation, but still it is a nonconventional source it cannot be used as a base load power system.

So, this does not pollute, it is cheap, versatile and load factor is very high 85 to 90 percent, is a load factor for these type of devices.

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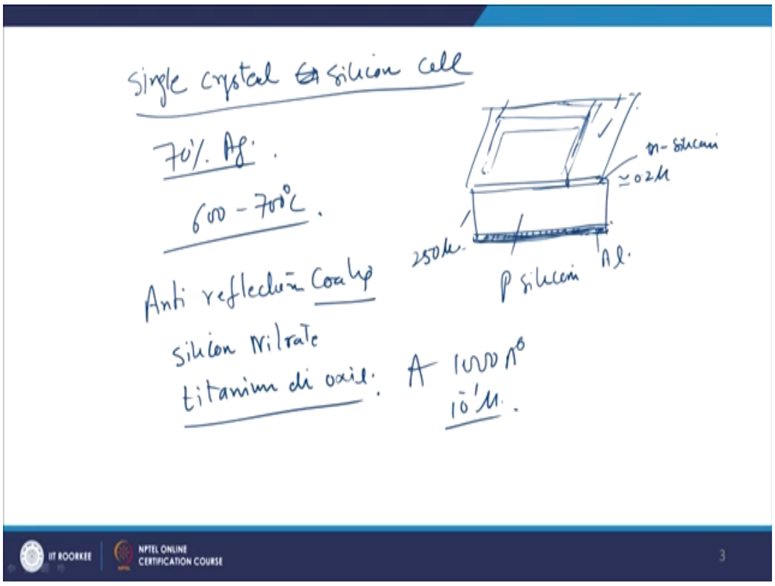

Now, description and the principle of working. Now, there is a crystal single silicon crystal, single crystal silicon cell. So, there is a wafer of single crystal entire crystal, we do not take we take a wafer of crystal of 0.2 mm thickness maybe of 0.2, just to give you an idea of 0.25 mm thickness we say 250 microns, right. Now, on the bottom side because top side is facing the sun.

So, bottom side it is covered with the metal, there is a metallic cover, right. On the top side there is the fob cover because if you completely cover the top side then the where the sun ray will fall. So, the top side cover is a fob type of cover just to hold the wafer on the surface, right. So, it has a junction there is a p junction and n junction. So, junction is formed here, the thickness of this junction is approximately 0.2 micron, very thin junction is formed here, right, and this is p silicon, right, and then this automatically become n silicon, right. This is metal electrode fingers which are holding the cell.

Now, how this front this screen the entire screen, it is painted with a paste with having 70 percent silver power (Refer Time: 06:57) binder and sintered glass, so that you must have seen on the solar cell there is a transparent coating. It allows the solar radiation to enter the to pass through the coating, so that through the photovoltaic effect the energy is generated. The backside is spray coated with aluminum spray painting, spray coating. So, this side is opaque and we do not require the side also. We for power generation, we are concerned with this side only.

Now, this cell is placed in the furnace, this after these coatings 70 percent silver coating at the top and the bottom this cell is placed in the surface at 600 to 700 degree centigrade. So, what happened? The metal paste it is it diffuses into the wafer. Connectivity is established, metal when metal paste when it is diffuse to the wafer the connectivity is established. So, there is no any resistance for the flow of the current.

So there is anti-reflection coating, you must have seen these cells are normally black in color. So, anti-reflection coating is also done. It is done with the silicon nitrate or titanium dioxide and the thickness of the layer is approximately 1000 Armstrong or 10 to power 1 micron, right. And this completes the cell.

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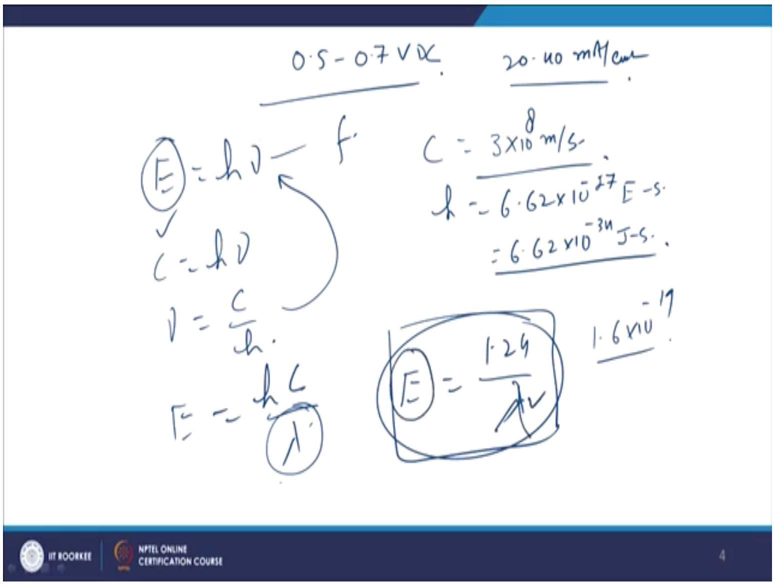

Now, output of the cell. A cell if you make a cell with the this silicon wafer it develops approximately 0.5 to 0.7 volt DC and current density is 20 to 40 milli ampere per centimeter square. So, nowadays amorphous cells are also used, multi layer amorphous cells also used, the single crystal cell was the basic cell to understand the functioning of photovoltaic cell. The amorphous cells are also available, they are they work more efficiently.

The cell must be made of the material that it should be able to absorb the energy, we cannot go for any material. The semiconductors are the best material for making a solar cell, right. And as you know the photon which is coming from the sun it has certain energy and the energy is h nu, nu is the frequency of photon. If you do not know the frequency then C is equal to h nu, C is equal to light speed, so nu is equal to C by h. Now, if you use it here that energy is equal to h C by lambda.

For a particular light wave we know the value of lambda. So, if you want to estimate the lambda or the frequency you would like to estimate the value of lambda. Now, C is you know that 3 into 10 to power 8 meters per second. This is the speed of light. h is equal to 6.62 into 10 to power minus 27 earths second earth let us (Refer Time: 10:30) in as a 6.62 into 10 to power minus 34 Joules second, right.

And then if we take the output in electron volts, right, so electron volts output will come is equal to 1.24 divided by lambda. 1 electron volt is 1.6 into 10 to power minus 19, the voltage of potential of electron, charge of the 1 electron. So, E is 1.2, this is simplifies form, simply when we know the value of lambda we can find the value of E.

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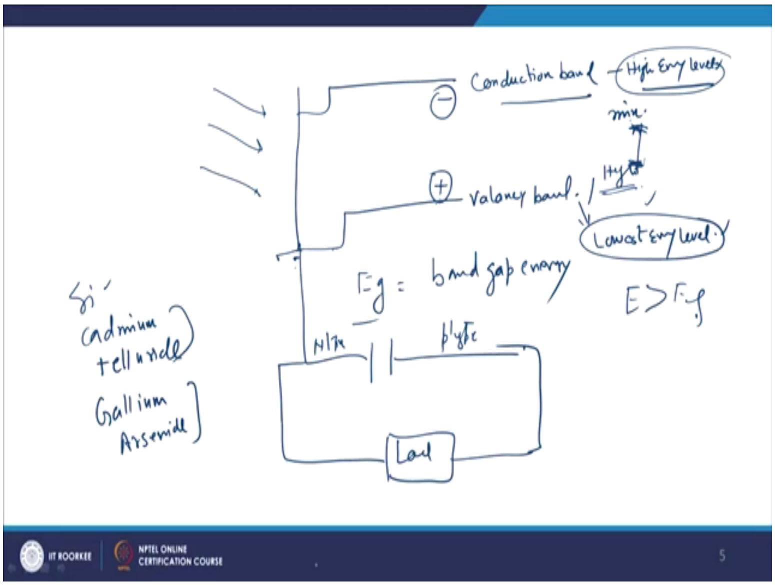

Now, suppose there is a photovoltaic cell and rays of sun are incident on it, diffused radiations are also coming, direct solar radiations are also coming. Now, in a semiconductor the two types of bands, one is conduction band, another is valancy band. In valancy band, the electrons are I mean lowest level, lowest energy level, lowest energy level here the electrons are on high energy level. So, this semiconductor can be made of silicon, cadmium, telluride, gallium arsenide, they are one cadmium telluride and gallium arsenide or silicon any I mean generalized crystal I am talking about.

Now, electron, so electron here they are very stable because it is in a low energy level, low energy level does not mean that it is unstable, it is quite stable, quite packed and here it is on high energy level. So, little energy will be required here to excite the electron, high energy will be required here to move the electron. And the difference between this conduction band, minimum energy in the conduction band this is the minimum energy electron and this is the high energy electron.

So, in the lowest energy levels there will be some electrons which are on high energy. In lowest energy level there may be certain electrons which are relatively on high energy. In conduction band there may be some electrons which are at lower level energy. Now, this gap energy gap is known as Eg, band gap energy.

Now, we are why we are taking this as band gap energy? This is the, because the gap cannot be less than this, highest is the minimum value and lowest is the highest value. So, this is the, but we cannot go, so the band gap energy cannot be less than this, right. So, Eg is the band gap energy. Now, the photon which is coming on the this cell should have E greater than Eg. In that case, the electron from the valancy band will be ejected. When the electron is ejected the hole will be created. So, electron will be go to the conduction band, so this will become negative and this will become positive.

Now, this hole and the electron they are free to move from outside circuit. So, your outside circuit will be made. So, there is a junction here, a junction will be here. So, p-type and this is n-type, right. This is front side, this is external load and this is the backside it is connected, right. And this is how the current is current move in the load, in this type of photovoltaic system.

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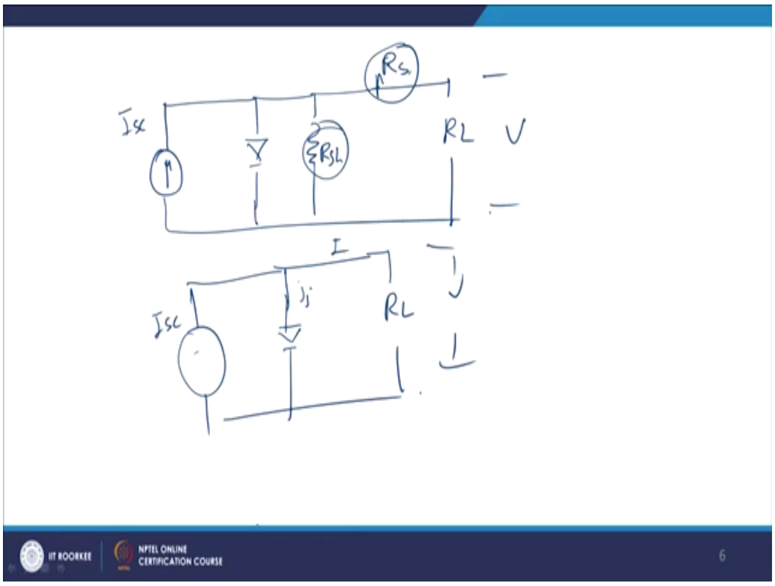

Now, the current which is coming to the cell can be simplified. If you draw the diagram it is something like this. This is short circuit current, this is your semiconductor device, this is common equivalent circuit is going to be like this, R shunt, R series, R load and this is voltage because this resistance of shunt and resistance of series is very low, it is not very high. So, that is why they we can do away with them, and if you want to have short circuit current then this is nothing, but i j and this is I and here is the voltage.

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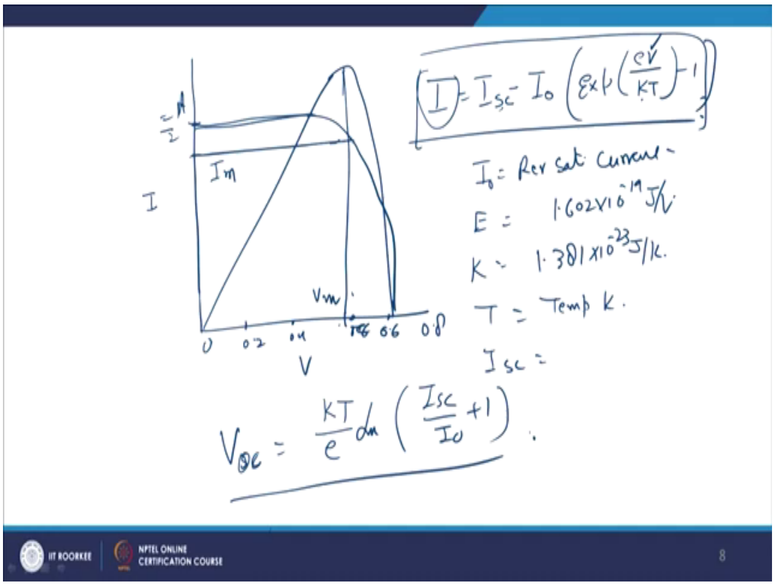

Now, if you look at the characteristics of the PV cell because any device we use we have to I mean well covers converse with the characteristic of device as well. So, if we draw a current and voltage, current and voltage for PV cell then, just a minute. Current voltage will vary from 0 to 0.8 let us say current in ampere it is going up to 1. If you keep on changing the voltage let us say 0.2, 0.4, 0.6 and 0. volt 8 volt DC.

So, short circuit current the current will remain constant, we keep on. So, it works in a different way from a resistance, because in a resistance if we keep on increase the voltage the current will automatically increase, but in a semiconductor it will not happen. The current will remain constant for certain voltage and then there is a sudden breakdown and this breakdown is approximately near 6, right.

So, from 0 if you so if initially if you start with 0.2, 0.4, 0.5 the current is fixed, it is approximately let us say 1. But when you cross certain voltage approximately 0.6 or 0.56 there is a sharp drop in the current. This is for short circuit when there is no load, right. But when you want to draw the power, when you are drawing the power then it will follow certain up to a certain extent it will follow this Ohms Law and straight way it will go up. And then again after attaining a peak value it will come down.

Now, when it is coming down this is the peak value and this current is I m and this is V m, maximum current and this is maximum current at maximum voltage. The current at maximum voltage is I m, otherwise maximum current is this, but we are taking current at maximum voltage. So, there is the relation, so there is the relation I current is equal to I sc short circuit minus I o exponential e V over KT minus 1.

This is the equation. I o is reverse saturation current, E is the charge of the electron that is 1.602 into 10 to the power minus 19 Joules per volt, K is this k is Boltzmann constant it is 1.381 into 10 to power minus 23 Joules per Kelvin, T is temperature in Kelvin, I sc is short circuit current, right. So, for that case we are getting this formula. So, for any moment we want to find I we can use this formula.

Now, when there is short circuit I is 0, when there is short circuit I is 0 and when this I is 0 then with the help of short circuit current we can find the value of V. So, V short circuit or open current open circuit is going to be equal to KT by E natural log I sc by I o plus 1.

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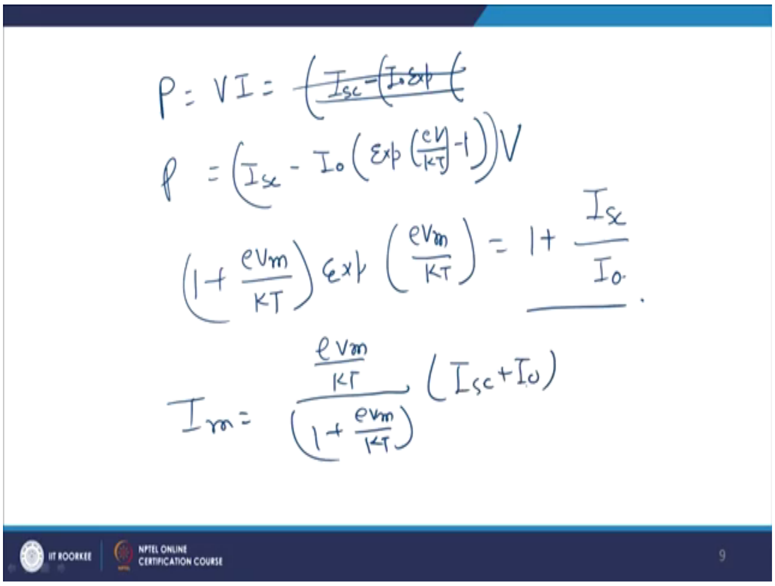

Now, V is known to us, then P is equal to power developed is equal to V into I, right. Now, in any device power is V into I. Now, I we can again take this short circuit minus I o exponential of sorry exponential of e V by KT minus 1, multiplied by this is current multiplied by V and this is power. And if you want to find the maximum power, maximum power, we should differentiate with respect to voltage and put it equal to 1.

Maximum power at what voltage? And when we do that we get the expression 1 plus e V m by KT exponential of e V m by KT and that is equal to 1 plus, that is the condition for maximum power and this gives the maximum current as e V m by KT.

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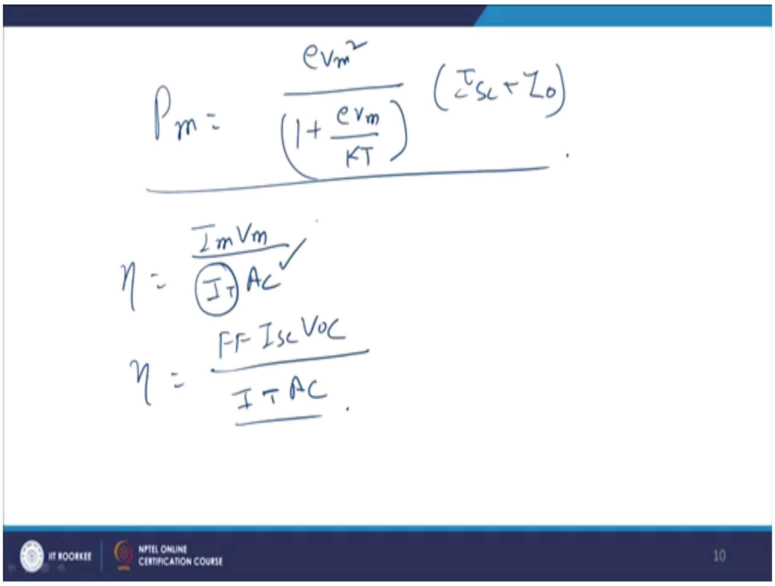

Once I m is known, we can go for the maximum power as, now e V this will be multiplied this. This e V m will be multiplied by e V m square. So, multiplied by e V m again, e V m again that is it. Now, this will be simply multiplied by V m. So, when this is simply multiplied by V m, the V m will it will become V m square and we will get this for the maximum power. So, this is how we can calculate the maximum power from any PV system.

Now, the efficiency maximum efficiency, the maximum efficiency is going to be the maximum power maximum voltage divided by I T and A C. And this is equal to; I T is a total solar flux and AC is the area of the cell, right and this will give you the maximum conversion power.

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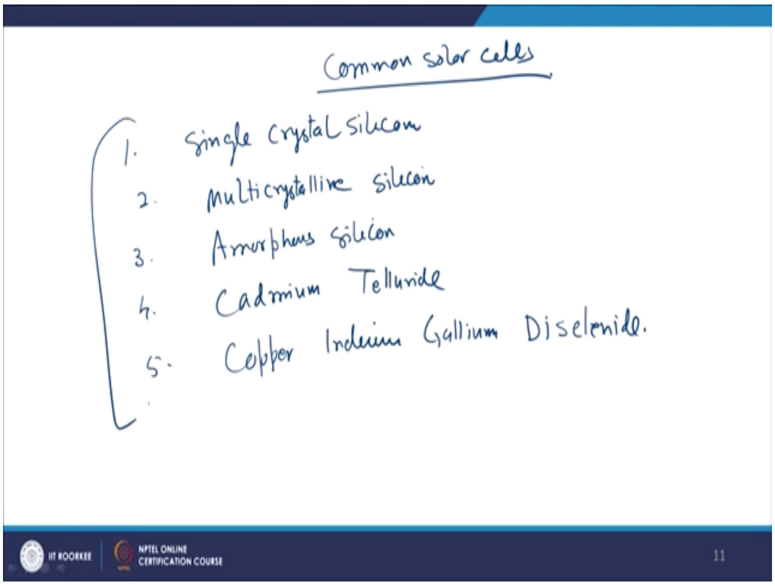

Now, there are different type of solar cells they are known as a common solar cells. Single crystal silicon, we have already discussed single crystal silicon, multi crystalline silicon, third is amorphous silicon, fourth is cadmium, fifth is copper gallium diselenide. So, there are 5, there can be other also.

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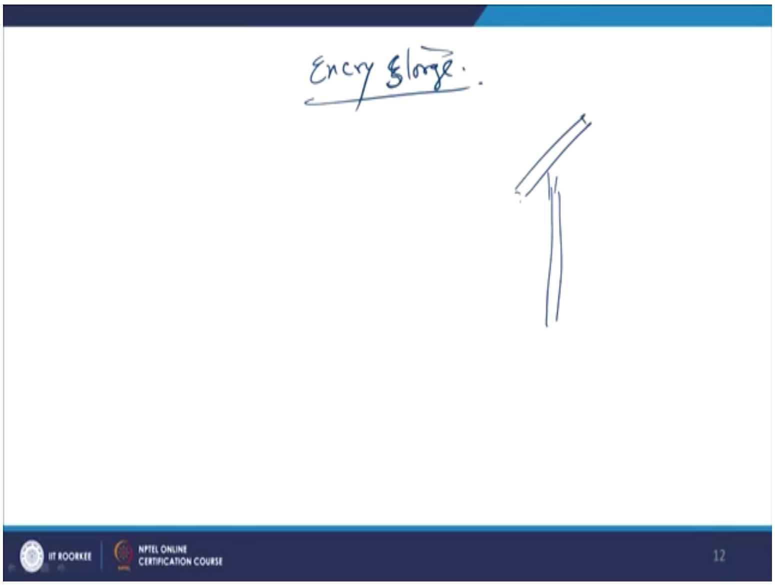

Now, the use of solar cell in the society is increasing in the individual persons they are putting solar cell in the rooftop and they are using this energy for different lamp appliances, but the cost, major cost is coming. Cost is not coming from the solar, cell it is coming from energy storage. Now, throughout the world there is a hot research topic, how to store the energy, right.

If we are able to store energy at the low cost the cost of the solar PV power generation will drastically reduce, and the benefit of this type of power is we can have this type of energy at the household level and we can go for the mega plants by putting solar panels on the field. It, because the power intensity is low per meter square is low. So, a lot of area is required for solar power generation. Now, and this is and this panel these panels are using the fertilizer this fertile land.

So, now, the ideas have come instead of putting on the ground the solar panel, they are put on the columns of the height of 20 or 25 meters, so that the field or fertile land can be used for the agriculture purpose. Because these type of cells they do not require any high order of maintenance, only cleaning is required. A lot of work is going on the cleaning of the solar PV also.

There are many ways, I mean you can just wash with the water, right. Nowadays, people are trying to develop the micro robots which can clean the solar panels. The micro robots are like bugs, so they will be traveling on the solar panels surface and the solar panel surface will be clean. So, there is a lot of scope of work in the area of cleaning of the solar panel and installation of the solar panels.

And now the energy developed in the solar panels can be used in many ways you can use it for the domestic purpose and you can have a I mean and energy, 0 net energy locality or 0 net energy building or this energy can be directly connected to the wind grid, that is also possible. So, when this energy in that case you do not have to I mean store the energy. So, this energy can be sold to the companies which are supplying the electricity and this DC, then convertor is required.

So, this DC which energy which is coming from the solar cell, it will be converted into the AC with the help of a converter and it will directly go to the grid. But this conversion process, the efficiency of the conversion process is not very high. So, that is why it is always recommended, so where you generate the solar energy you consume it there itself, until unless it becomes necessary to transfer transmit this energy to the grid.

That is all for today.

Thank you very much.