Power Plant Engineering
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Lecture - 35
Problem Solving - IV

Hello, I welcome you all in this course on Power Plant Engineering. Today, we will solve a few numericals based on our previous lectures.

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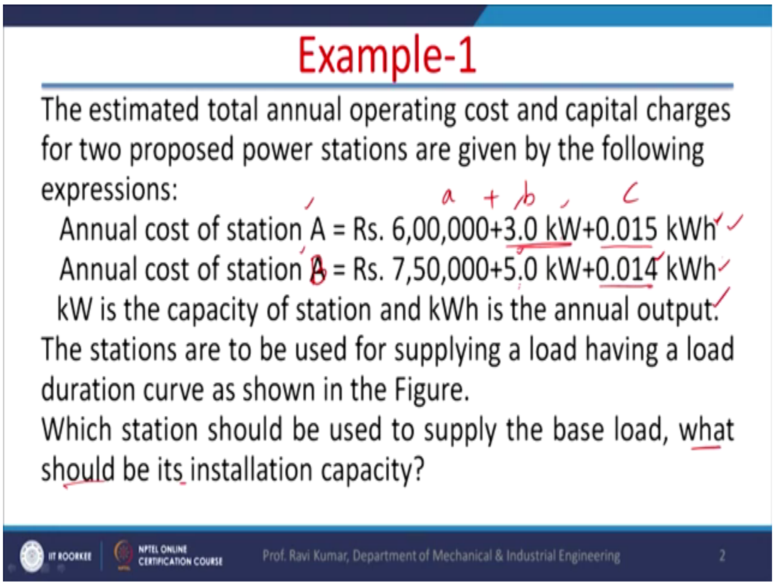

First example is, the estimated total annual operating cost and capital charges for two proposed power stations are given by the following expressions. So, there are two stations and annual cost of a station, this is station B annual cost of the station A and annual cost of a station B is given. So, fixed annual cost is 600000 rupees, for B it is costlier 750000.

Then capacity base multiplying factor for station A it is 3, for station B it is 5 that is known as B, this is a, plus b and this one is c. Then c is unit power generation cost that is 0.015 rupees for a station A and for station B it is a little cheaper, it is 0.014 kilo Watt hour. Because the power generation is used, so this difference also is substantial is it has substantial effect on the output or output of the cost.

Kilo Watt is the capacity of the station and kilo Watt hour is the annual output, right. The stations are to be used for supplying a load having a load duration curve as shown in figure. I will show you a figure that is the load duration curve which station you should be used to supply the base load and which should be which should be it is installation capacity, and what should be installation capacity.

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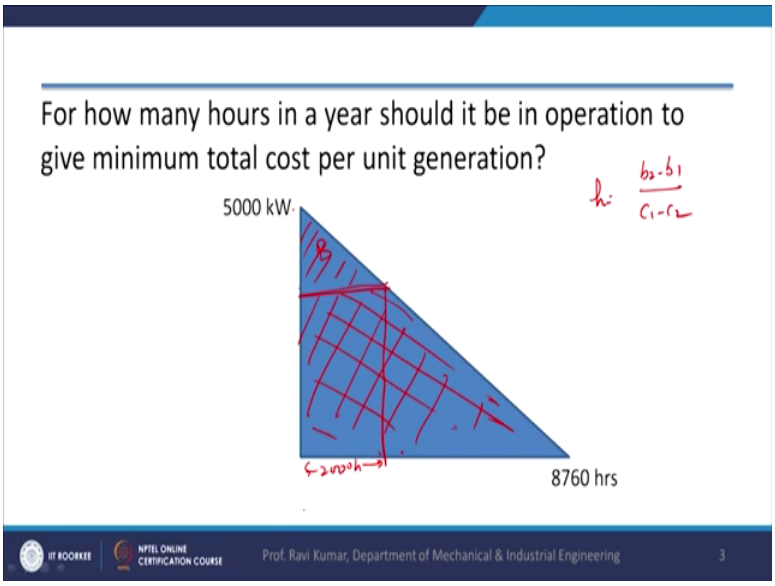

So, we have to decide this is a load curve is here, this is the load curve, this is a straight line, right. So, we have to take a combination suppose we take entire power 5000 kilo Watt from B, right. If we take entire 5000 kilo Watt from B this the fixed cost will increase, this capacity wise cost will be high.

Now, if you take a 5000 kilo Watt from A then this cost is going to be high, right. So, we have to find one optimum value and we have already done this, we have already carried out one derivation that we find the value of h, h is b 2 minus b 1 divided by c 1 minus c 2.

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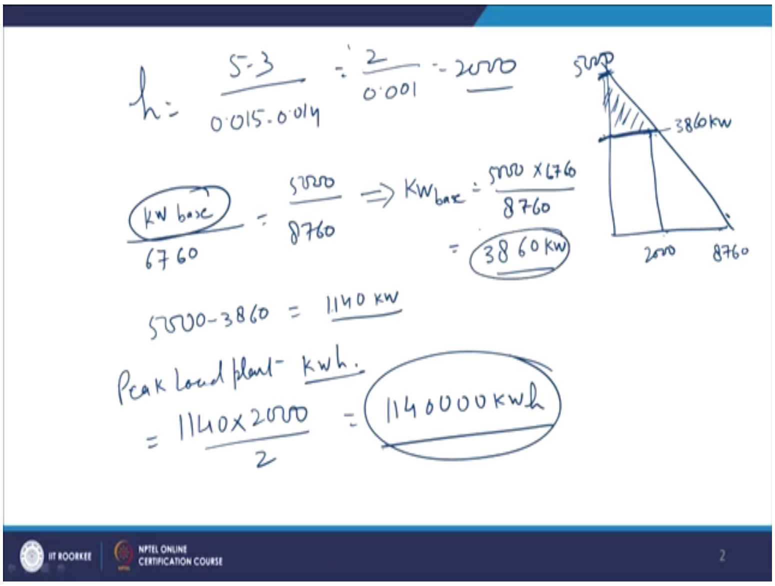

If you take h here in this case, then this is b 2 minus b 1, c 1 minus c 2. So, b 2 is b 2 is 5, b 1 is 3, c 1 is 0.015, c 1 is 0.015 and c 2 is 0.014, right. So, here h is equal to 5 minus 3 divide by 0.015 minus 0.014.

Now, this will give us two divided by 0.001 or 2000. So, for getting a for minimizing the cost of power generation we should have 2000 hour top of, 2000 come somewhere here. So, 2000 this is a line for 2000, so this is the energy which has to be supplied by a top plant, top of plant and this is for the base plant, right. Now, the value the plant which has cost c is minimum shall be the base one. So, this will be the base one, this will be the top of plant, right.

So, now, the base energy plant is this one and it will and this one this plant b will run for 2000 hours only. Now, when it is running for 2000 hour we can always find this value how much power will be required. Now, in order to find that, so kilo Watt of base you can draw it here. So, this is 8760, this is annual 8760, this is 2000, this is 5000, right. So, this kilo Watt is going to be equal to base, but now this is 67, 8760 minus 2000, 6760 is equal to 5000 divided by 8760.

So, this will give the base kilo Watt. From here we will get the base kilo Watt and the base kilo Watt is 5000 multiplied by 6760 divided by 8760 and the base kilo Watt is going to be 3860 kilo Watt, right. So, now we have the base kilo Watt also this is 3860 kilo Watt.

Now, for this part of the triangle 5000 minus 3860 is equal to 1140. So, this part is only 1140 kilo Watt. So, the capacitor of this is required is 1140 kilo Watt, capacity of the base load plant peak plant is 1140 plant, capacity of the base load plant is 3860 kilo Watt. So, now, we have decided this, right for the optimum value; now, the cost of generation.

So, for peak load plant, what is the cost of generation? The cost of generation is or first of all we will have to find how much energy is generated annually in the peak load plant. So, in the peak load plant kilo Watt hours, there is total energy generated will be the area of this triangle.

So, area of this triangle is going to be 1140 multiplied by base, base is 2000, 2000 divided by 2 and this will give the annual energy generation as 114 kilo Watt hours, this much of unit, that is what I said even one paisa makes a lot of difference, right; so, this much of kilo Watt hour will be generated by the peak plant.

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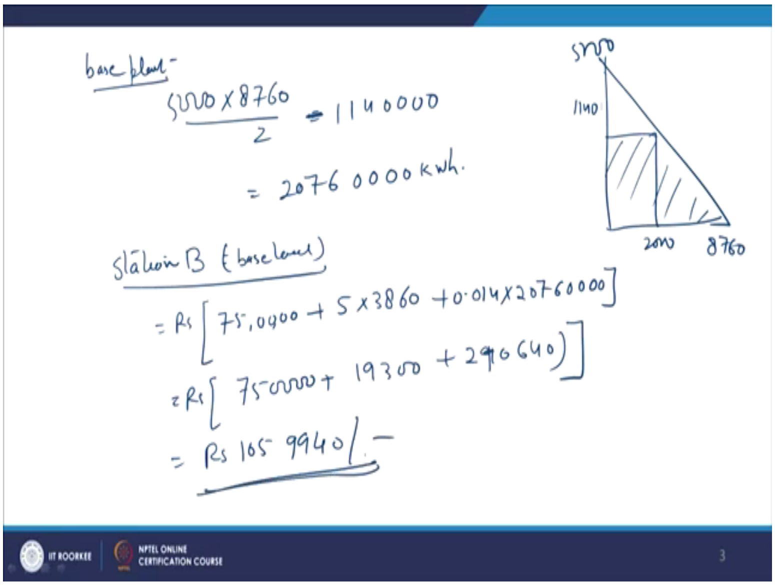

Similarly, for the base plant for the base plant, base plant we can find either we take area of this or area of this triangle minus area of this triangle. Area of this triangle we have already calculated. So, area of the bigger triangle is going to be 5000 multiplied by 8760 divided by 2 and it is going to be 114 minus sorry base plant minus this one, previous one, this, right and this will give us 2076 kilo Watt hour.

Now, we know the output of the both the plants, right uh. We know the output of this, we know the output of this, right. Now, after this two things rest of the information is already with us. We know the value of in kilo Watts it is 1140, 3860 for the base load and 1140 for the peak load plant, right. So, we know the value of kilo Watts, what is the power generation capacity of the both the plants, we know the annual energy generation also.

Now, we can find the annual cost of a station B and annual cost of station A. So, annual cost of a station B, station B that is base load, B is base load, right. It is going to be rupees in rupees 75 plus 5 into 3860, 3860 is the peak is the capacity of the plant plus 0.014 multiplied 2076 that is going to be equal to rupees plus 19300 plus 290640. So, just a difference of 0.1 paisa you can see how much difference is show I mean just leave it. So, this is going to be equal to total cost has rupees 1059940.

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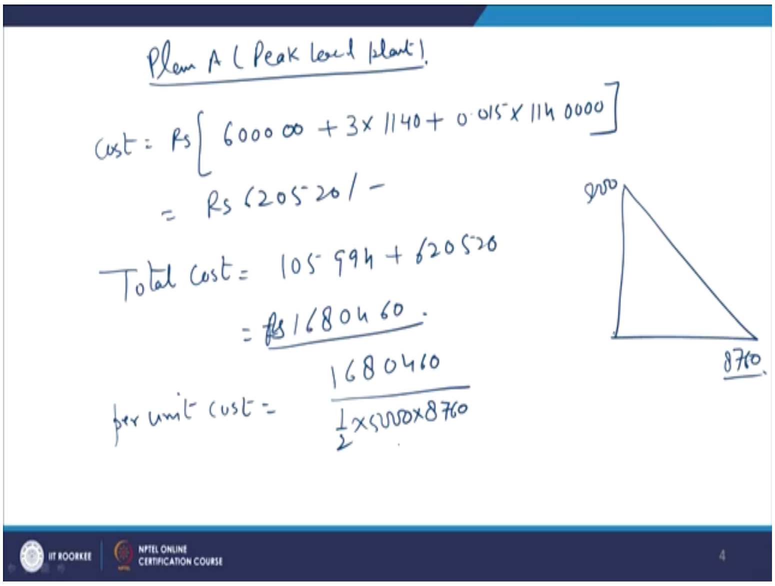

Now, cost of generation of plant B that is peak load plant, Plant A that is peak load plant. Now, for the peak load plant the cost is rupees plus 3 into maximum power generation capacity that is 1140 plus 0.015 into 114 and that is going to be equal to rupees 620520, right and for this one it was 1059940, right. So, total cost is going to be total cost, minimum cost is going to be 105994 plus 620520 is equal to 1680460, this is rupees, this is the total cost of energy generation, annual cost, this is the total annual cost.

Now, you want to have cost of generation of per unit per unit, right. So, this is the total cost. So, for per unit cost, again we will have to divide this by this area, right. So, the per unit cost is equal to total cost plus divided by all divided by the area of the triangle 5000, 8760. This figure 8760 is there because this is the total number of hours in a year, right.

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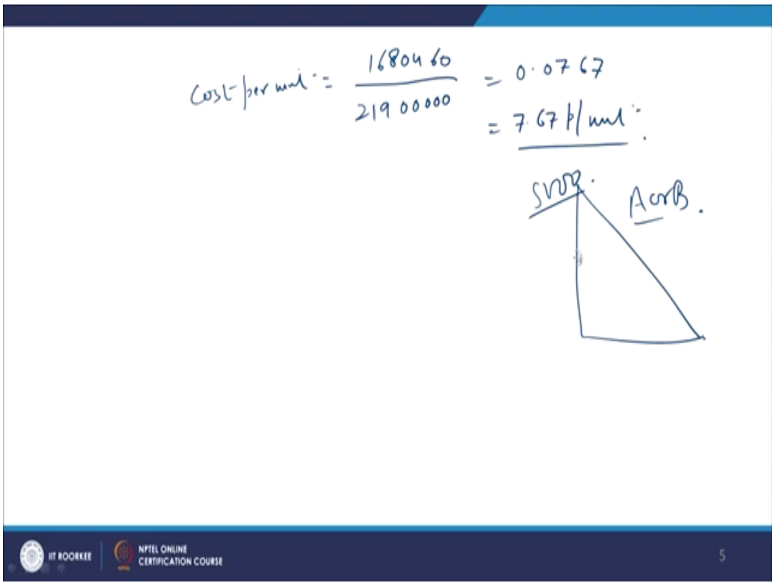

So, this is going to be half into 5000 into 8760 and this is going to be equal to cost per unit as 1680460, 219 is equal to 0.0767 or 7.67 paisa per unit. This is this is how the cost is calculated, because if we take it this case, if we take the entire generation by one plant the cost will be high, if you take entire generation by A or B the cost will be high.

So, what we have done, we have taken part this is a base load plant which has lesser value of c there is a base load plant and this is the peak load plant, right and we have taking the combination of these two and that has given the final minimum cost per unit energy generation, ok.

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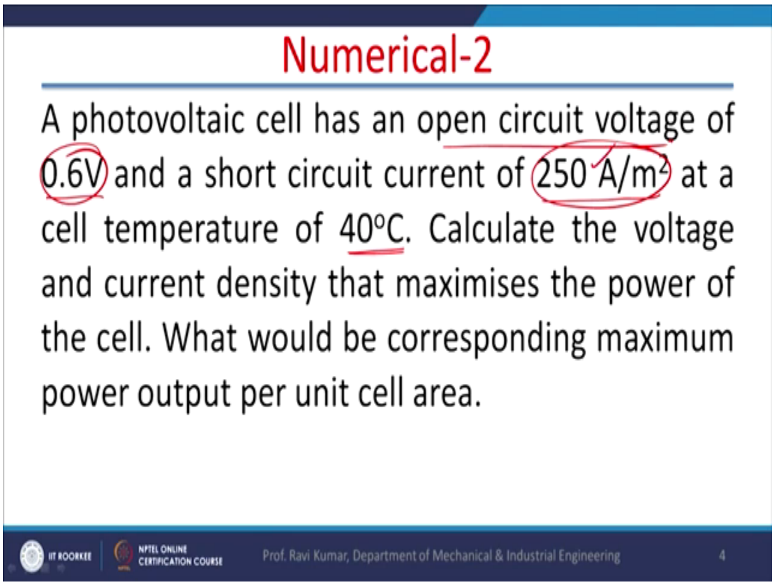

Next is, we will take another numerical it is about the photovoltaic cell: Photovoltaic cell that we have taken already lecture on the photovoltaic cells. So, there is a photovoltaic cell photovoltaic cell is a device for direct energy conversion. So, what happens? In normal energy, energy conversion means converting available energy into electricity. So, there is normal energy converse.

So, or what that for that what we do? We burn the coal, generate the power, right, power in the form of a shaft work and that shaft rotates the generator and that is how the electricity is generated. But here in this case whatever available energy is there it is directly converted into the electricity. So, that is why it is called direct energy conversion.

So, there is the photovoltaic cell which is an open circuit voltage of 0.6 volt, right. Short circuit current is 250 Amperes per meter square at cell temperature of 40 degree centigrade. Calculate the voltage and current density that maximizes the power of the cell. So, we have to find the voltage and current density two things that will maximize the power of the cell. What would be the corresponding maximum power output per unit cell area?

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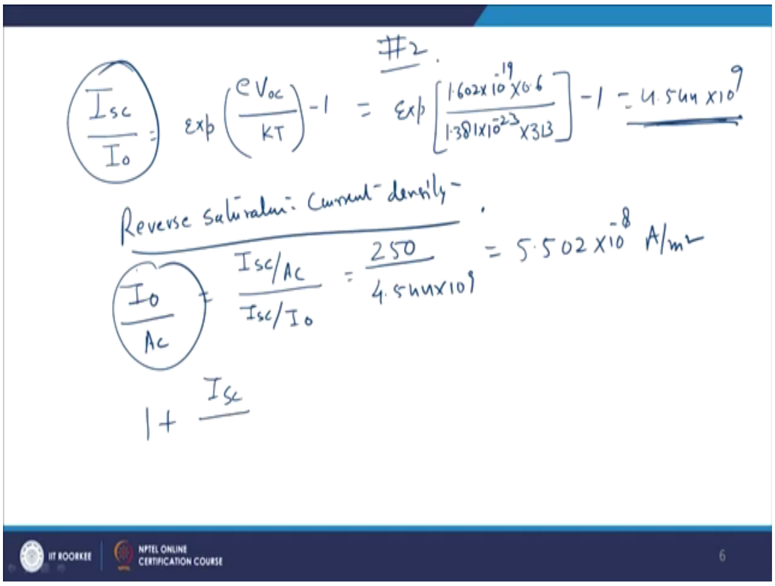

So, for this numerical number 2, we will start with the formula the ratio between short circuit and I o is equal to exponential of e V open circuit divide by KT minus 1. Now, K is Boltzmann constant, right. So, it will remain constant. So, this is going to be equal to exponential of this, e is charged on electron that is also constant 1.602 into 10 to power minus 19. V oc is given that is 0.6 volts.

So, here we will write 0.6 volts. Boltzmann constant is also given it is 1.381 into 10 to the power minus 23, right and temperature, temperature in Kelvin, so 273 plus 40 it is going to be 313 minus 1, right. So, this will give a the expression will be as 4.544 into 10 to power 9.

Now, reverse saturation current density I o by A c, it is equal to I sc by A c divided by I sc by I o, we have simply manipulated this ratio. I o by A c it is I sc divided by A c I sc divided by I o, so the I o will go up. So, then again if you simplify this you are going to get this expression, ok.

Then I sc by A c is given 250, it is given here 250. So, this is going to be 250, right. And I sc by I o this we have just now calculated, it is going to be 4.544 into 10 to power 9 and this will give the final explanation as 5.502 into 10 to power minus 8 Amperes per meter square, this is I o by A c.

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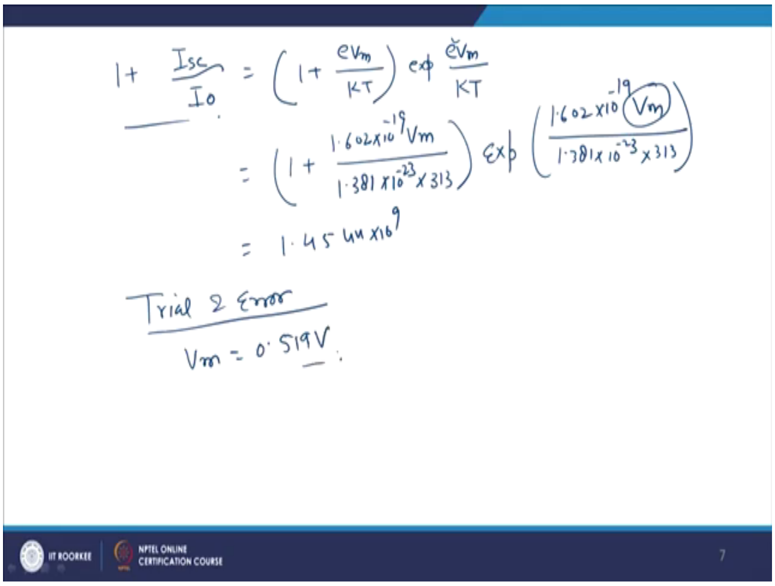

Now, again we will use the formula well I have taken, 1 plus I have dragged all these formulas in my lecture on the photovoltaic cells, right. So, from this we just simply put on the values, it is going to be equal to 1 plus 1.602 into 10 to power minus 19 V m; V m is not known divided by K 1.381 in to 10 to power minus 23 into temperature 313, right.

And Exp, exponential of again e voltage on electron 1.602 10 to power minus 19 V m divided by K 1.381 into 10 to power minus 23 into 313 is equal to 1.4544 into 10 to power 9 that is this one. Now, here only unknown is V m, right and in order to find the value of V m we will have to use the trial and error method because it is an exponential from here. So, by trial and error, we get the value of V m as 0.519 volts, right.

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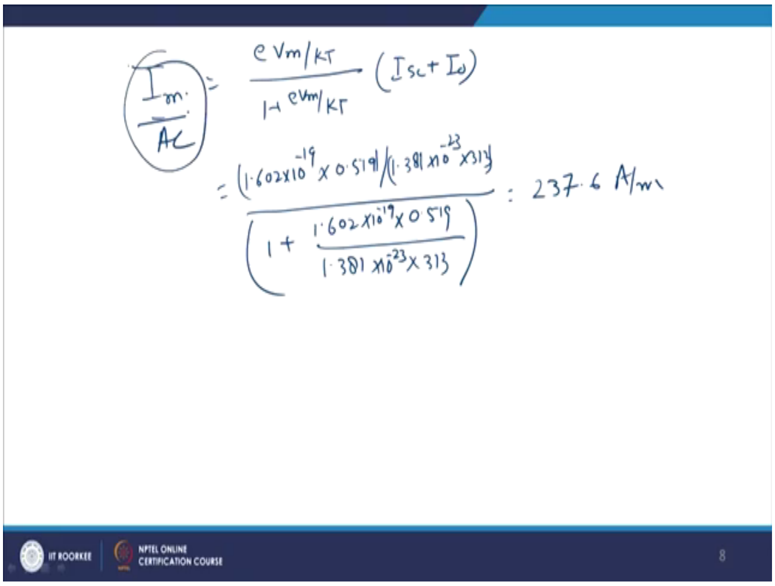

Now, after this V m is known now we have to find the value of I m, now, I m is equal to e V m by KT divided by 1 plus e V m by KT, I short circuit plus I o. Now, again we will keep on putting the values e is equal to 1.602 into 10 to power minus 19. Now, the value of V m is also known to a 0.519 divided by KT K is 1.381 into 10 to power minus 23 into 313, right divide by 1 plus again 1.602 into 10 to power minus 19 into 0.519 divided by 1.381 in to 10 to power minus 23 and T is 313, right.

And this will give the final expression as; so, this is going to be equal to 237.6 ampere per meter. This is a I m by A c actually, this is not I m, this is I m by A c.

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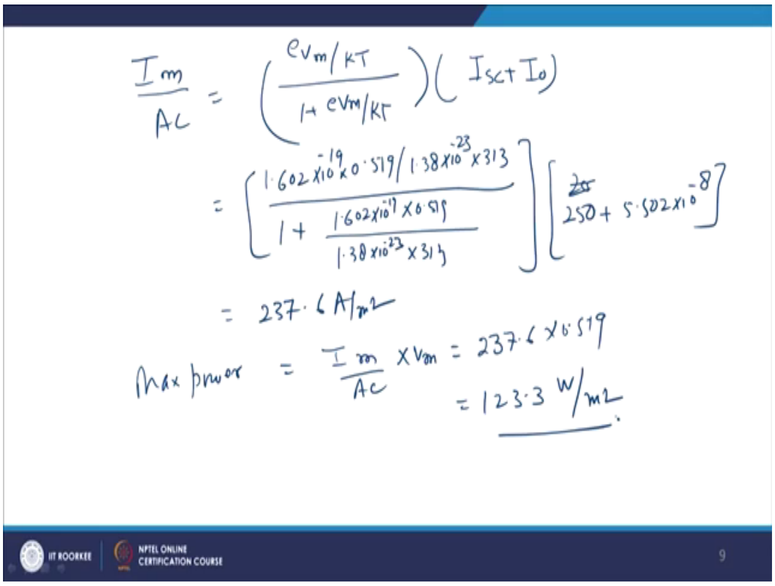

So, I m by A c is equal to e V m by KT divided by 1 plus e V m by KT I sc plus I o, right. Now, here we will keep on putting the values, 1.602 into 10 to power 19 minus 19, V m is 0.519 divided by K, K is 1.38 into 10 to power minus 23 and T is 313 divided by 1 plus 1.602 into 10 to power minus 19 into 0.519 V m divide by again K 1.38 into 10 to power minus 23 into 313.

I sc plus I o is 250, 250 is already given somewhere 250 plus 5.502 into 10 to power minus 8. Now, this will give the final expression as 237.6 Amperes per meter square, right. So, that is the current density. So, maximum power is equal to I m divided by A c into V m is equal to 237.6 into 0.519 is equal to 123.3 Watts per meter square, right.

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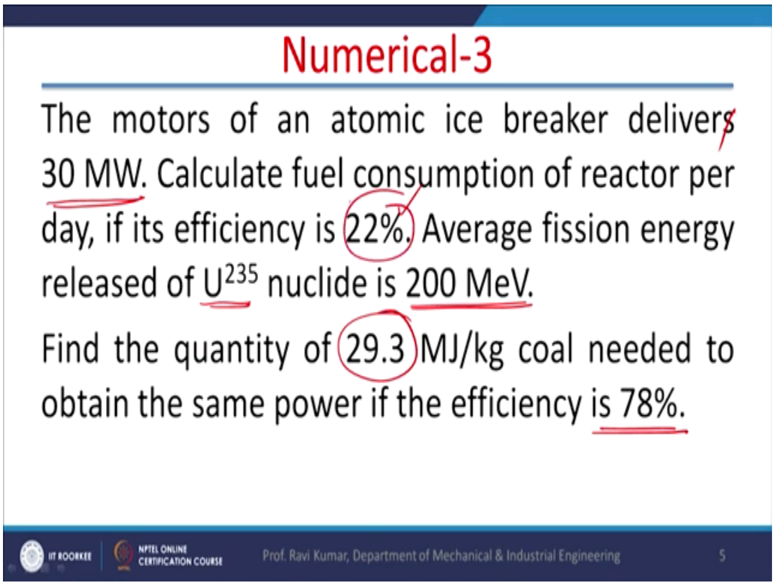

So, after this we will take a another numerical, is a short numerical. It is about the motors of an atomic ice breaker which deliver which breaker deliver 30 mega watt calculate the fuel consumption of reactor per day. If its efficiency is 22 percent, the reactor efficiency is to 22 percent.

Average fission energy is released of uranium 235 nuclide is 200 million or molecules is 200 million electron volts. Find the quantity of 29.3 mega joule per kg. So, this is calorific value of a coal, 29.3 mega Joules per kg coal needed to obtain the same power if the efficiency of this thermal power plant is 78 percent.

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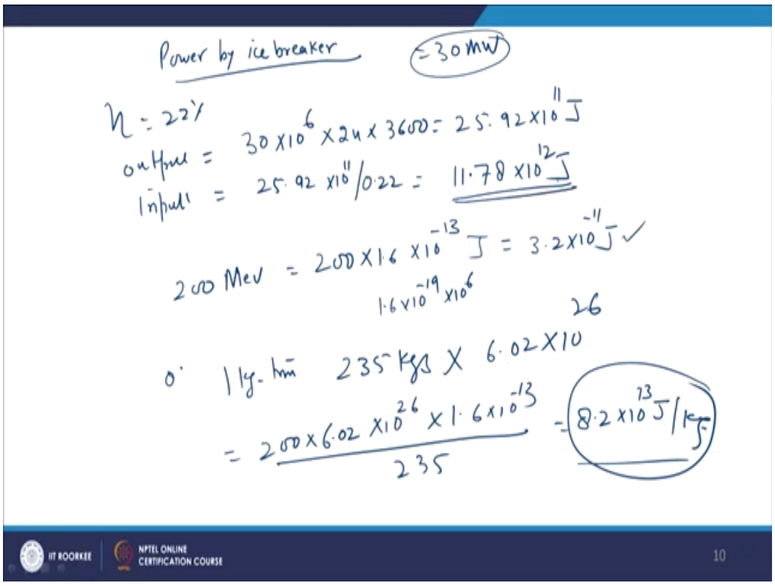

So, here power by ice breaker power by ice breaker, right is 30 megawatt, efficiency 22 percent. So, output is 30 megawatt, right into 24 into 3600 per day that is energy and it is going to be 25.92 into 10 to power 11 Joules.

Now, input, input is going to be 25.92 into 10 to power 11 divided by the efficiency of the plant, the efficiency of the plant is 22 percent, right. So, it is going to be 0.22 and that is going to be equal to 11.78 into 10 to power 12 Joules. This much of energy is has to be generated in nuclear plant and that will be sufficient to meet the output of 30 megawatt, right.

Now, let us talk about the how much fuel is required. So, 200 million electron volt per nuclide, it means 200 into 1.6 into 10 to power minus 13 million, ok, Joules, because 19 and this is actually it is 1.6 into 10 to power minus 19 into 10 to power 6 this is million, right. So, it is equal to a 3.2 into 10 to power minus 11 Joules. Now, if you take 1 kg, 1 kg, 1 kg atom or 1 kilo moles of a uranium, right.

1 kilo moles will count around 235 kgs, right. In 235 kgs how many nucleons will be there? This multiplied by 6.02 into 10 to power 26 by Avogadro number and each nucleon is producing this much of energy, right. So, the total energy released is 200 into 6.02 into 10 to power 26 into 1.6 into 10 to power minus 13 divided by 235 is equal to 8.2 into 10 to power 13 Joules per kg of uranium.

Now, how we have done? I am repeating. 1 molecule is releasing 200 million electron volt that is converted into the Joules, 1 kilo volt will consist of 235 kilo kilograms of uranium consisting of this much number of molecules, right and if we multiply this number of molecules by the energy generated per molecule and divided by 235 we will get the energy generated per kg of uranium.

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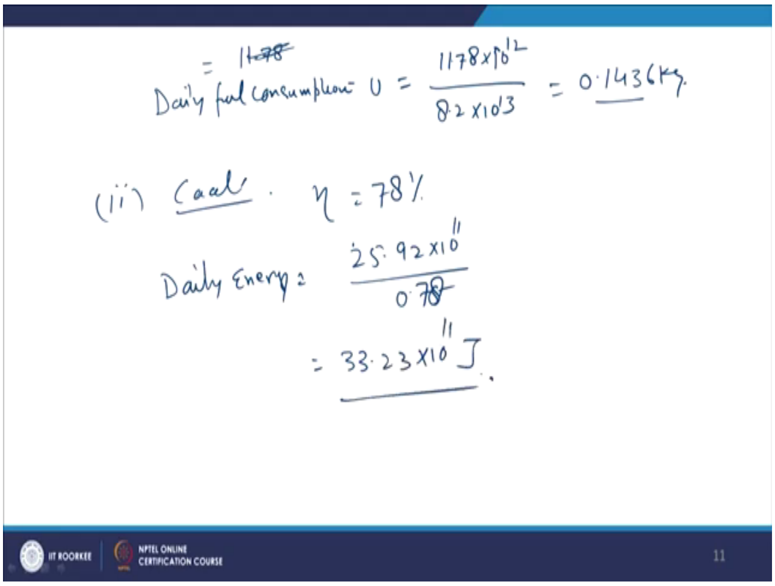

Now, for calculating fuel that is coal, for coal it is 11.78, ok. Now, daily fuel consumption of uranium is 11.78 into what is that; 10 to power 12, 10 to power 12 divided by 8.2 into 10 to power 13. Because this 8.2, 10 to power 13 is the energy released per kg of uranium and this is the total amount of energy which is required.

So, total amount divide by the energy release per kg and it is going to be equal to 0.1436 kg, 143 grams, 143.6 grams. Now, for coal, efficiency is 78 percent, daily energy is equal to how much 25.92 into 10 to power 11 divided by 0.75, sorry 78, not 75, 78. So, daily energy input is going to be equal to 33.23 into 10 to power 11 Joules, right.

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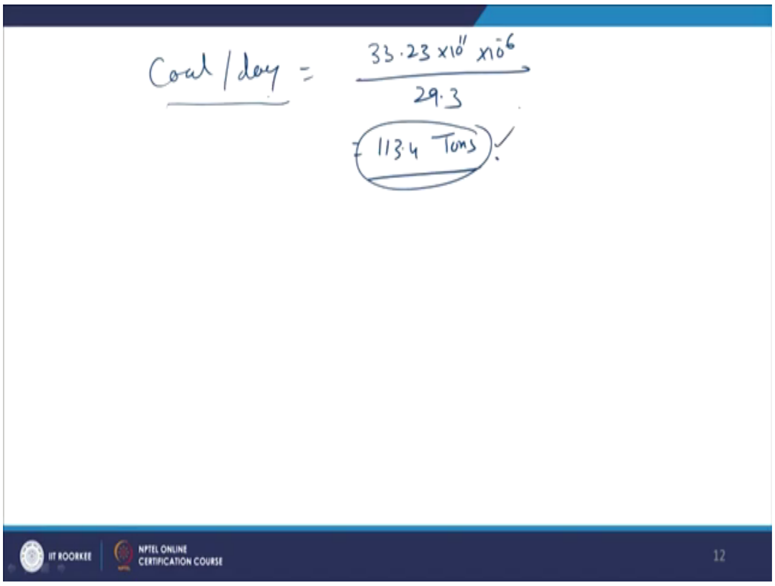

Now, coal required per day, total energy requirement 113.4 tons. So, you can compare the quantity of fuel required here, there only require 143 grams of uranium to produce the same power and for matching the power we need 113.4 tons of coal, right. That is all for today, right.

Thank you very much.