Power Electronics and Distributed Generation

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Lecture - 22
Design for Effective Initial Cost

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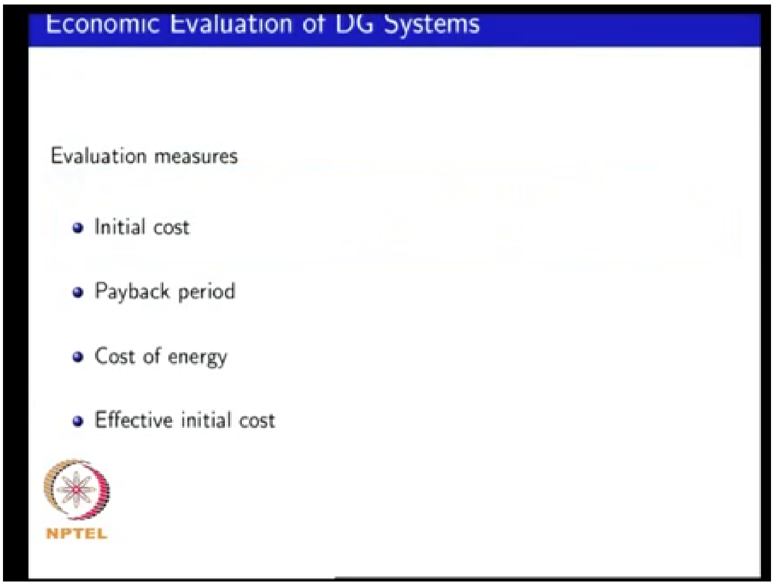

Welcome to class 22 on topics in Power Electronics and Distributed Generation. We were looking at economic matrix for evaluating distributed generation systems and we are talking about four of them initial cost, payback period, cost of energy. So, we have been discussing the payback period, examples of payback period and cost of energy in the last class.

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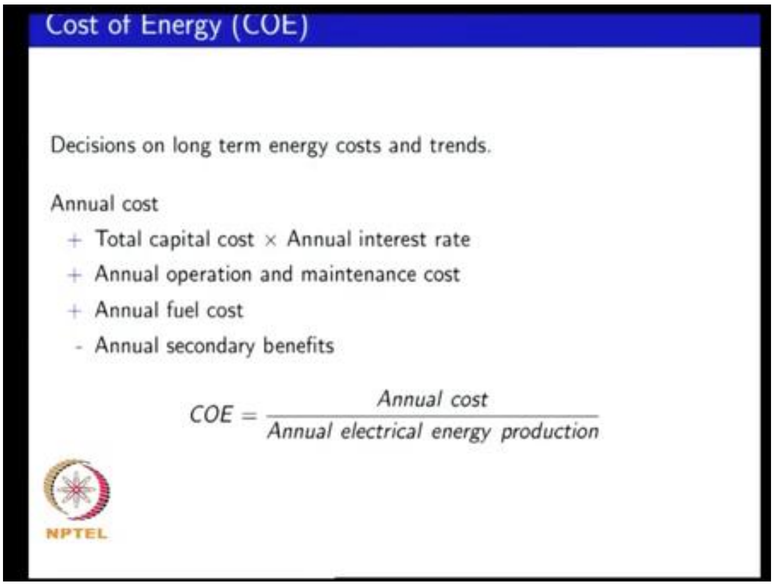

So, one way of looking at cost of energy is your purchasing some equipment installing it and you are getting energy out of it, and you are operating the equipment over a long time frame maybe multiple years. And so you want to look at the cost on a annualized basis for which you make use of things like interest rate, annual maintenance cost, annual fuel cost, the secondary benefits you look at it as a negative cost on annualized basis. And then you look at what is the energy produced on a annual basis, and you can calculate the cost of energy.

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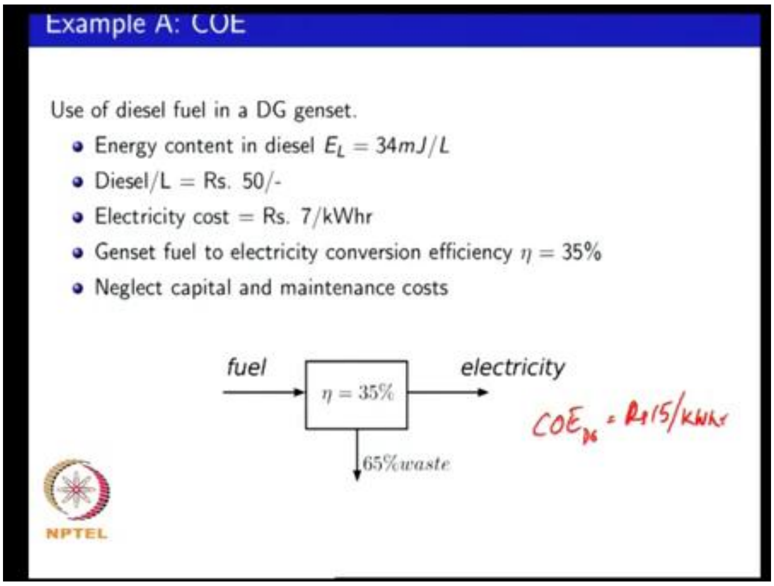

So, we looked at started with a simple example of a cost of energy for a diesel generator, producing electricity, and we looked at the cost of the fuel to be diesel fuel to be 50 rupees a liter. And the cost of electricity from your distribution supplier to be 7 rupees per kilo watt hour, and when work through the example, we found that the cost of energy in this particular case from your DG set would work out to be rupees 15 per kilo watt hour, so which is much greater than 7. So, it does not make sense to produce electricity in this manner except when absolutely necessary.

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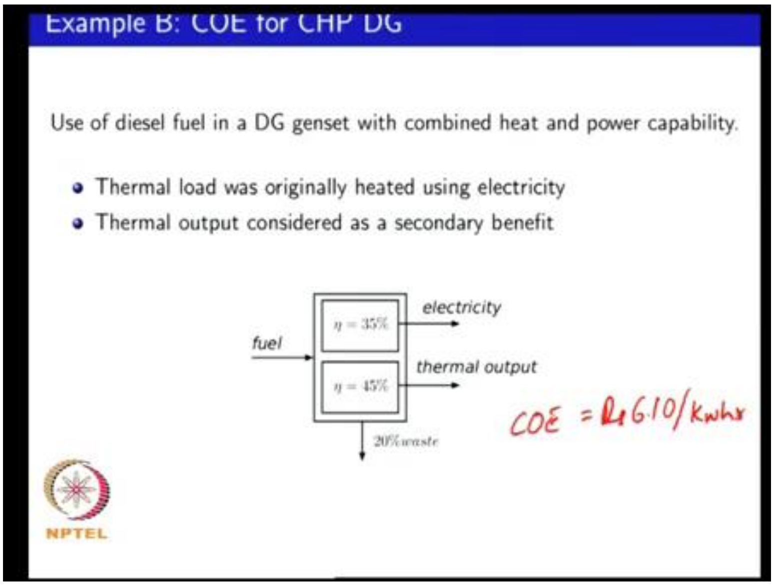

So, in a second situation we looked at, when your operating this genset as a combined heat and power unit, where fuel in the diesel is being converted into electricity with a given efficiency, and the waste heat is also being captured with some given efficiency. And then, based on the fact that, you could make use of this thermal output which might potentially be originally be heated from electricity, you can then calculate what your benefit is.

And in this particular case, your the cost of energy we worked out a example worked out to be rupees 6 rupees 10 paisa per kilo watt hour, which is less than 7, so potentially this is ah can be a situation where your producing electricity in this manner might, brief economically feasible. But, we have neglected capital equipment cost, there is a cost in the internal combustion engine, the alternator, the heat exchangers etcetera, the control system.

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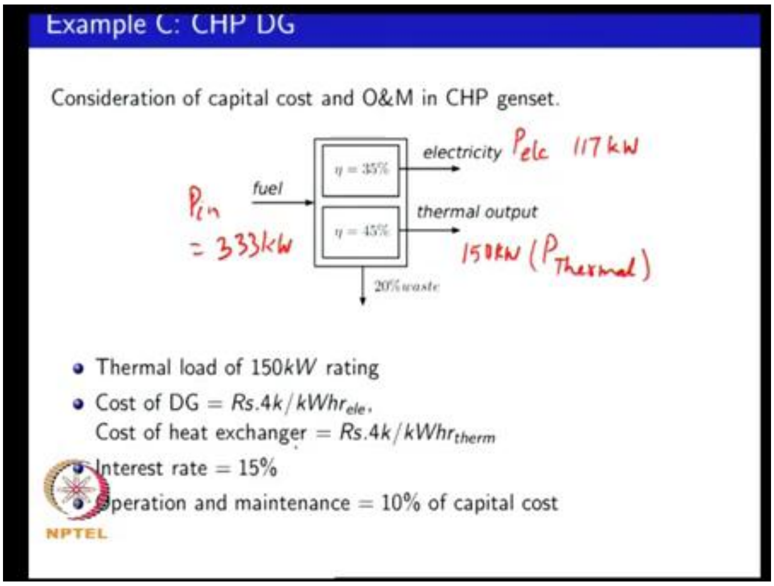

So, we will look at an example, we will start with an example where we are looking at capital and the operation and maintenance cost. So, in this example we are given the thermal load is 150 kilo watt thermal and the cost of your electrical part of your DG system is 4000 rupees per kilo watt hour, kilo watt rating of the system. And the cost of the heat exchanger part is again 4000 rupees per kilo watt thermal; and we are assuming a interest rate of 15 percent.

And we will assume that the operation maintenance cost is 10 percent of your capital cost of the equipment that you are purchasing. So, in this example we can calculate what would be the energy required to at the input, because we know the fuel to thermal output efficiency is 45 percent, so we can then calculate what your P input is, because this is P thermal which is given.

So, your P input is P thermal divided by 0.45, so that works out to be your 333 kilo watt and then, you can calculate your efficiency from your input fuel to electricity which is 35 percent. So, your electrical output power electrical, which is 0.35 times 333 this is 117 kilo watts. So, now your rating of your electrical system is 117 kilo watts, your rating of thermal system is 150 kilo watts, the cost per kilo watt rating of your electrical and thermal system, so you can calculate the capital cost.

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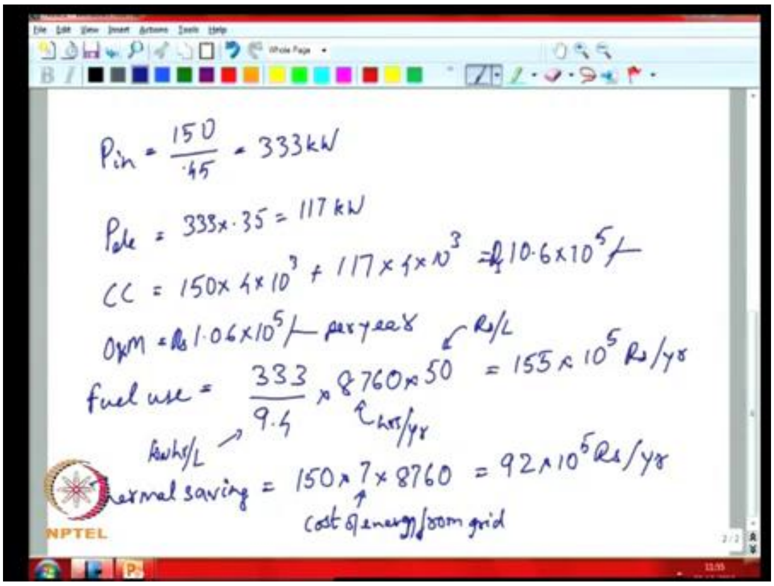

So, we worked through the example, so your capital cost is you have a system which is, your thermal system is rated at 150 kilo watts and the cost of the heat exchanger equipment is 4000 rupees per kilo watt and your electrical system is 117 kilo watts and it is cost is also 4000 rupees per kilo watt, so you get 10.6 into 10 to the power 5 rupees. And your operational maintenance cost is 10 percent of your capital cost, which is as which is your assumption 1.06 per year and then, also calculate your fuel use is 333 kilo watt is the energy in the fuel, that is used on a kilo watt into per second basis.

So, if you divide it by 9.4 kilo watts hour per liter into 8760, which is the number of hour per year and multiply it by 50 rupees which is the rupees per liter this is, so this works out to be 155 into 10 to the power 5 rupees per year. And if you look at the number over here 155 in to 10 to the power 5 is a fuel cost per year is much larger than the capital cost, which is just 10 point 6 into 10 to the power 5, so you will see that the fuel cost is much larger than the capital cost. You could also calculate your thermal saving, so 150 kilo watt is a thermal output and if it was being formally heated at 7 rupees per cost of power from the grid, which was 7 rupees per kilo watt hour into 8760, so this was 92 into 10 to the power 5 rupees per year.

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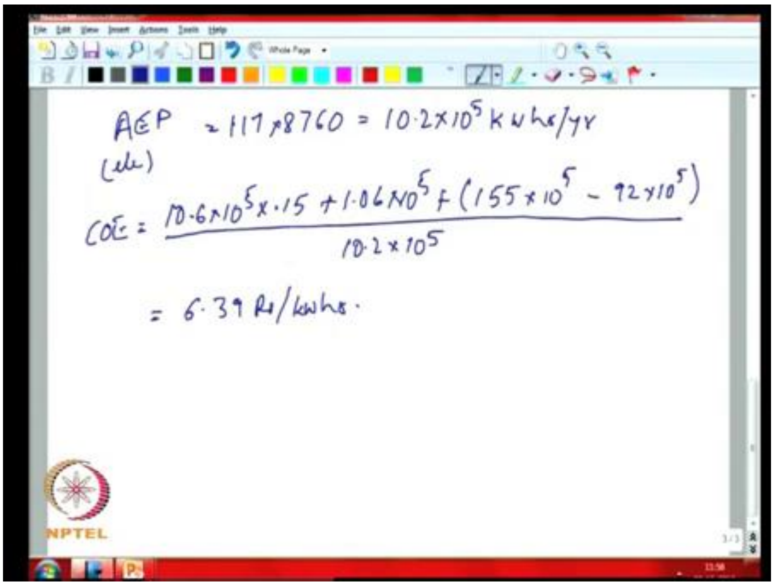

So then, you could then calculate your annual electrical production, electrical energy production which is 117 into 8760 is 10 point 2 into 10 to the power of 5 kilo watt hours per year. So, then you can calculate your cost of energy, capital cost into interest rate which is 15 percent plus 1.06 into 10 to the power 5, which is your annual operation maintenance cost and 155 into 10 to the power 5, which is your fuel cost and 92 into 10 to the power 5 which is your thermal saving divided by 10.2 into 10 to the power of 5, so this works out to be 6.39 rupees per kilo watt hour.

So, you can see that even when adding terms for capital cost, the cost of energy will increase significantly over the fuel cost which, so you are here in the capital cost it was 6 rupees 6 paisa with the capital cost operation maintenance moved up to 6 rupees 39 paisa. And in many fuel intensive technologies one may observe that the cost of fuel can be a major aspect of operating a system, whereas if you look at a comparative say other technology like renewable energy.

There the fuel cost is essentially 0, but then your capital cost would be the dominant one. So, also this implies that say in this example, we have seen that the diesel cost is 50 rupees per liter, suppose a diesel cost went up by some amount, then that would reflect the quite dramatically the cost of energy. So, when your generating power based on fuels, you have to be having a control over the risk of fuel cost going up and down.

Whereas, if you look at a system such as renewable energy system, the risk of operation over time is lesser, the risk has to be evaluated up front, whether capital can be invested. But, once done you have a fixed rate of return over a longer time frame, assuming that the reliability etcetera are as per design.

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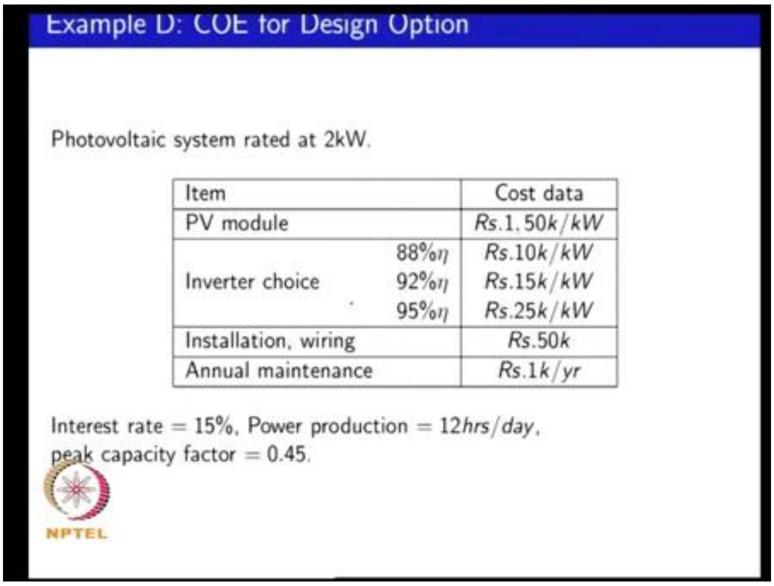

Next what we will look at is an example of making use of this cost of energy concept in designing a DG system, in this case example of a photovoltaic system, we will assume that these a 2 kilo watt photovoltaic system, the module cost, the PV module cost one and half lakhs per kilo watt. You have a choice of power electronic inverters, so you might have choice of which might be a older design, a current design, maybe a more futuristic design, it might have different efficiencies, it might have different performance capabilities.

And also it might have different cost, something which might be lower performance might be lower cost, the 92 percent of efficiency low per cost is 15 rupees per kilo watt and the 95 percent efficient inverter, cost of 25 rupees per kilo watt. And the question is which inverter would be an appropriate choice for your design, and could you make use of cost of energy as a possible basis for making a design decision.

We will also assume that, the installation and wiring cost for installing this photovoltaic system cost 50000 rupees and there is no major annual maintenance you might have to clean the PV panels and we will assume that cost 1000 rupees a year to for us the annual maintenance cost. We will assume the interest rate of 15 percent, we will assume that the power is being produced by this panel 12 hours a day, obliviously it is not going to produce 2 kilo watts early morning late evening. So, we will assume that there is a peak capacity factor of 0.45, so on a overall day basis 0.45 of the peak power is being produced. So, the question is can we make use of the cost of energy calculation in making a design and decision.

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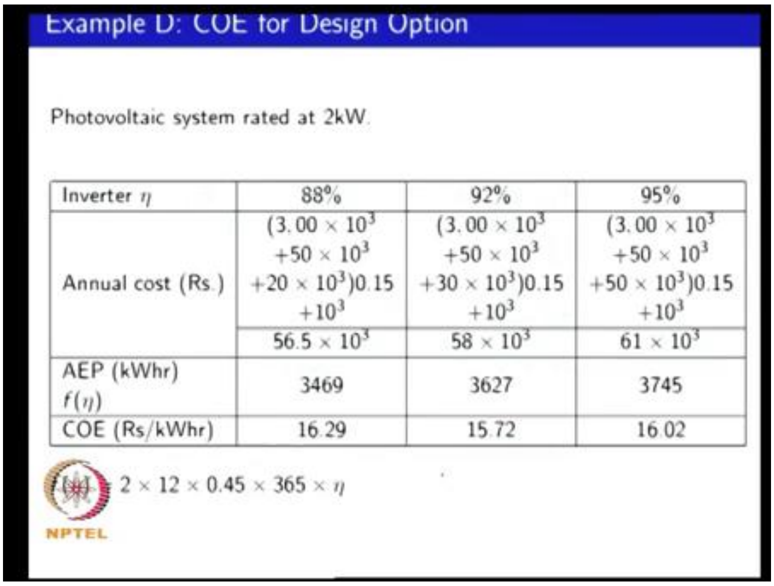

Example D: COE for Design Option

Photovoltaic system rated at 2kW.

Inverter η	88%	92%	95%
Annual cost (Rs.)	$(3.00 \times 10^3 + 50 \times 10^3 + 20 \times 10^3)0.15 + 10^3$	$(3.00 \times 10^3 + 50 \times 10^3 + 30 \times 10^3)0.15 + 10^3$	$(3.00 \times 10^3 + 50 \times 10^3 + 50 \times 10^3)0.15 + 10^3$
	56.5×10^3	58×10^3	61×10^3
AEP (kWhr) $f(\eta)$	3469	3627	3745
COE (Rs/kWhr)	16.29	15.72	16.02

$2 \times 12 \times 0.45 \times 365 \times \eta$

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So, we could actually go through the calculation of what would be the annual cost for these three technology options, so you have to panel cost which is 2 into one and a half lakh per kilo watts to 3 lakhs would be the panel cost is 2 kilo watt rated unit. And the panel cost is the same for the three inverter charges, the installation com commissioning cost is also the same, it is largely wiring, how we mount the panels, the civil works, the frame the mechanical structures etcetera, associated with it, we will assume it is the same.

Then if you look at the inverter cost for the 88 percent inverter, it is 10000 rupees per kilo watt, so your 2 kilo watt is 10000 rupees for the 92 percent efficiency, it is 30 kilo watts for the 95 percent is 50000 rupees. So, you take the capital cost and multiply it by your rate of interest, which is 0.15 and then, you add your annual maintenance cost which is thousand rupees to calculate your annualized cost.

So, the annualized cost for the three options works out to 6000 rupees for option 1, 58000 for option 2 and 61000 for option 3 and then, you can also calculate that is a annual energy production from these 3 units. So, we will assume that the panels from these 3 units are identical what is different is just the inverter, so far the energy production it is 2 kilo watt is the rating of the unit it is working for 12 hours a day with a peak capacity factor of 0.45, 365 days a year and there might be some losses in the inverter, so you multiply it with a efficiency.

So, you can calculate what the annual energy production is, it is 3469 units for option 1, 3627 units for option 2 and 3745 units for option 3, when you do cost of energy calculation you get 16 rupees 29 paisa for option 1, 15 rupees and 72 paisa for option 2, 16 rupees and 2 paisa for option 3. So, if you are looking at what is the lowest cost of energy, you would find that just going with the lowest cost unit or the highest performance unit may not be the most appropriate.

Something appropriate might be what gives you most value for the technology that is being introduced, again the numbers like the one and a half lakhs per kilo watts for the photovoltaic panel, might be a little bit updated number, if the cost might be actually lower today. So, these are numbers, but some of these numbers change to a time you could see a trend, but then you could see what would be an appropriate design decision, based on what power electronic technology your adopting.

So, again you can see from the cost of energy calculation, there is no fuel cost reason why you are having numbers like 15 rupees to 16 rupees per kilo watt hour is actually the capital cost. So, capital cost is critical for renewable energy or also true for things like nuclear technology, where the cost of construction is quite massive, your fuel cost is 0 in this case, also your important factor is the interest rate, if the interest rate is lower your cost can come down quite drastically.

So, when on policy towards these technologies is a important factor, because the interest rate can be affected by larger society policies. A drawback with the cost of energy approach when you are doing such a design is that, the differences between the performance matrix is really small, you are trying to make use of make a power electronic design, but then the power electronic numbers are borrowed by the larger numbers of the overall system.

So, the differences appear to be quite small, when your looking at it from a cost of energy perspective, and the cost of the power converter is actually a small fraction of the overall system cost. But, you can see another factor here, if you look at the annual energy production for the 95 percent unit and compare it with this particular unit, you have about plus 3 percent, 3.25 percent energy production in this particular unit.

So, you may not need a 2 kilo watt panel you can actually reduce the size of the panel by 3 percent, and you can see that the panel cost is quite significant. So, there is benefit from other balance of system, because of the power electronic unit, because it is actually sitting closest to the point of common coupling where the energy is being sent out. In this particular case even though the cost of the inverter is low, you are actually producing 4 percent lower power in this particular case, in which case to get the same 2 kilo watts you need 4 percent more panel area.

So, your panel cost would go up proportionately, so you can see that there can be a system implications for power electronic choices. And it would also be good to have a method for evaluating a power converter choice, which take into balance of plant benefits, rather than just a power electronic cost; so if you look at a few examples of a say balanced of plants benefits.

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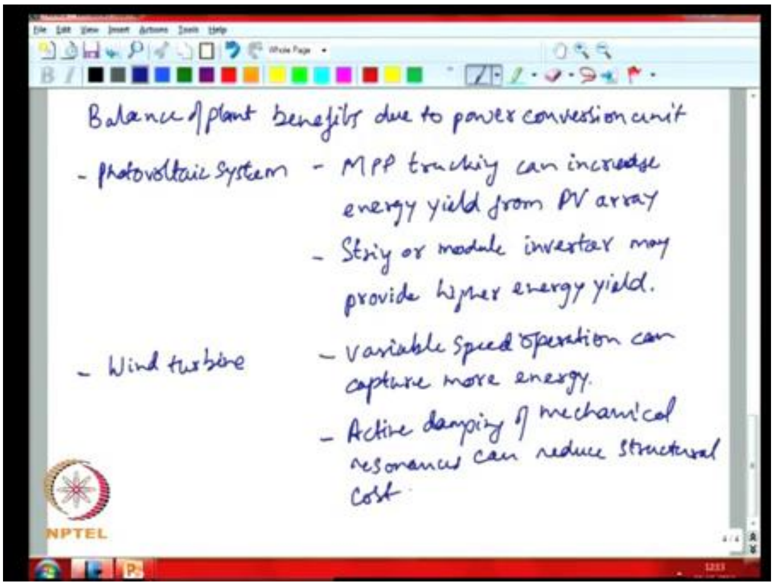

Say for example, in a photovoltaic system within a power conversion unit, say for example, in a photovoltaic system, you might have a power converter which has say

MPPT that can be incorporated in it. And because now, because of your power converter with the MPPT, you might be able to produce more energy which means again it reduces the size of the energy required, so you have balance of plant benefit.

Also you might have a situation where maybe, because of you are a topology choice maybe a string inverter or a module inverter rather than a centralized inverter, can actually have us more power, which means again you can have a smaller array which is producing more power. So, you might in a similar way, if you take a wind turbine some of the early wind turbines were fixed speed just like a induction machine connected to the grid, maybe with some power factor correction.

They were operating at fixed speed based depending on what the grid frequency is and maybe some limited speed change based on your pole number changes in your machine. But, if you are able to operate at it a variable speed with a power converter you could actually operate your wind turbine at the maximum power point and harvest more energy. So, if you asre able to capture more energy for a given size blade, it might keen that a fixed power output, you can maybe reduce the size of the blade height of the tower etcetera, which can actually give you a cost benefits.

Also say if you have a power converter, which can have a high say rate of change of power can be set quite rapidly, because of higher bandwidth etcetera, then you might be able to damp out resonances in the blades, tower etcetera, which means that your you can have lesser margin than amount of steel, required the tower etcetera and come down. And you can actually reduce the cost of structural cost, which is a major cost in things like wind turbine applications.

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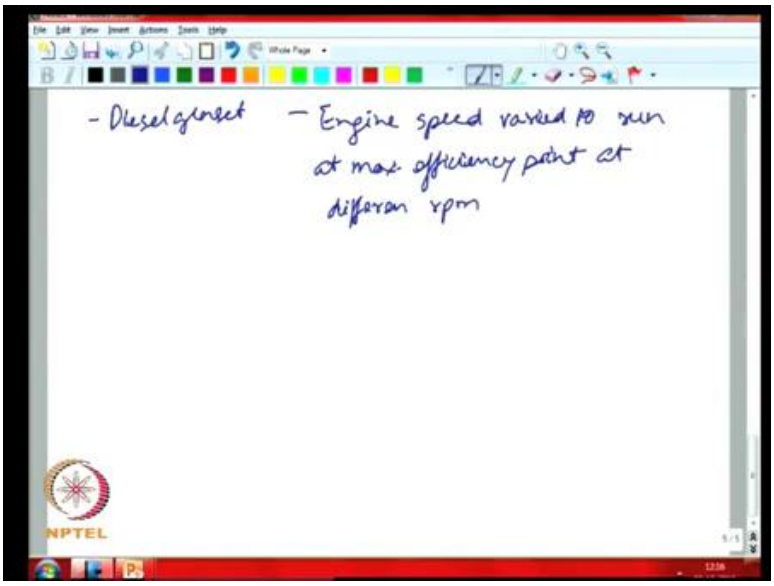

Or if you take an example of a diesel generator, if you look at the traditional gensets that will be running at constant speed irrespective of the load, so to produce a 50 Hertz output at providing 230 volts or 415 volts. You might operate at the same speed irrespective of you are the genset is fully loaded or half loaded or at no load, which means that you are consuming quite a bit fuel and be operating a genset at a not the most optimum point.

Whereas, if you have power converter in between which allow you to slow down a genset and your inverter is providing you are your output waive forms, then you can arrive your genset to use it is speed, when the load goes down, which means that now your fuel consumption can potentially come down. And we saw that in system such as gensets, the fuel cost is a major cost, so because you are now adding a power converter, you can reduce a major cost such as fuel, which can be attractive.

So, such a systems are also used in hybrid vehicles etcetera, where your genset, your actually IC engine might operate at the maximum efficiency point. And the additional torque required might be provided by a electric motor over and above, your average torque level that needs to be produced. So, that way you can operate your combustion engine at best efficiency point and giving you the over fuel consumption, so similar principle applies to vehicles also.

So, one would definitely like to incorporate some of these benefits to the larger systems, when you are considering whether to take one particular power conversion technology or some other power conversion technology. Because, one particular technology might be more efficient at capturing some of these benefits, so we will just look at a quick number of say an example of a wind turbine blade.

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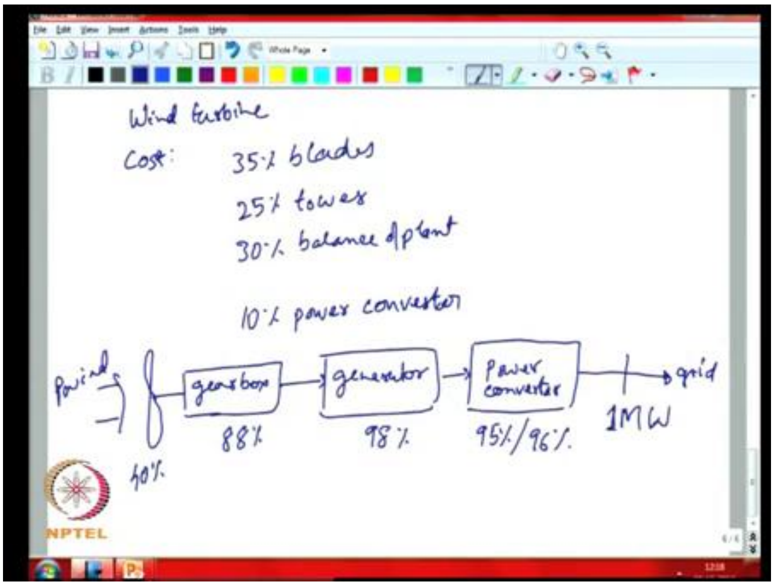

A wind turbine, if you look at cross cost breakdown say we assume say 35 percent of cost of a turbine maybe your blade cost, they might be some composite materials, carbon-fiber possibly, your tower cost is a major cost, balance of plant here, you are looking at a gear box, the generator, the yard pitch system, transformer etcetera. Your power converter might be just a 10 percent of the cost, but then if you look at the flow of energy in such a system, say you have the blades maybe your gear box.

So, your objective is to generate 1 mega watt being injected to the grid and then, we can calculate what would be the power input we will assume that 40 percent of the energy in the wind is being captured by the blade. Say 88 percent efficiency in your gearbox, 98 percent efficiency in your generator and you have say a couple of converter options one maybe 95 percent, the other might be 96 percent, And you can see what would be the energy in the wind, that needs to be captured corresponding to the 1 mega watt output for these two options.

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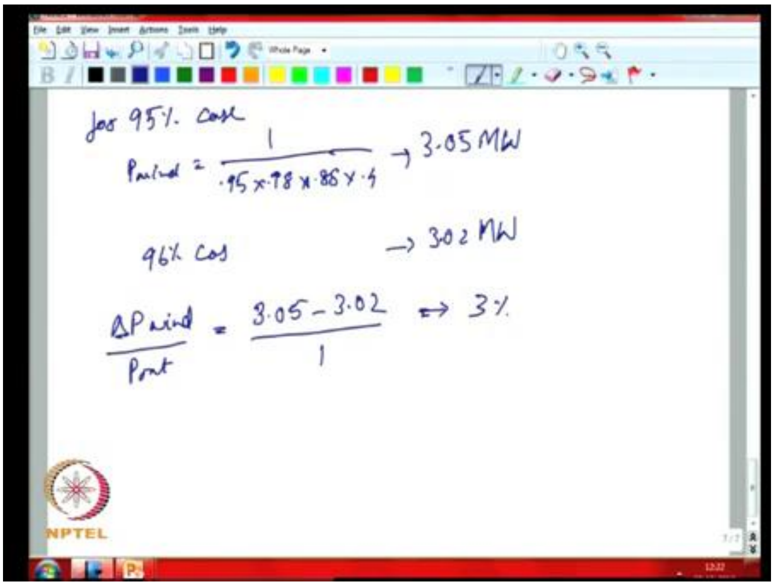

And so far, for the 95 percent efficient case, your P n ((Refer Time: 33:15)) is 1 mega watt divided by 0.95, 0.98 into 0.88 into 0.4, so you are talking about 3.05 mega watts. And if you are looking at the 96 percent of case, the number corresponds to 3.02 mega watt, so if you look at a delta P in your wind divided by P output, so you get the difference which is 3.05 minus 3.02 by 1, which is your output.

So, this corresponds to about 3 percent, so your one percent of efficiency difference in a inverter implies a abstain efficiency difference of about 3 percent, so it is magnified by 3. So, the amount of stresses in the blades etcetera can be reduced, and because your power converter is now sitting at the end of a chain right next to the point of common coupling, it forms a crucial cheer part in the overall system and that can be significant upstream benefits.

Even though your cost of the power converter is only 10 percent, it can implications on the balance of plant which is 90 percent of the cost. And another aspect of issue with the cost of energy approach is when you do the cost of energy, you may not know your overall system cost upfront. So, you are designing a power converter for a wind turbine, you might know the power converter roughly, but you do not know your wind turbine cost which it is displacement will be happening in parallel.

So, your overall cost to evaluate cost of energy may not be accurately known, but the power electronic designer might be aware that by adding some particular feature in the power converter operation, you can get benefits in the barrels of plants, and that might be easier to quantify. Also as we mentioned, we do not want to get buried by the cost of the overall system which is much larger than the cost of the power conversion unit. So, before we look at the effective initial cost, we look at what would be the ideal characteristics of say your power converter.

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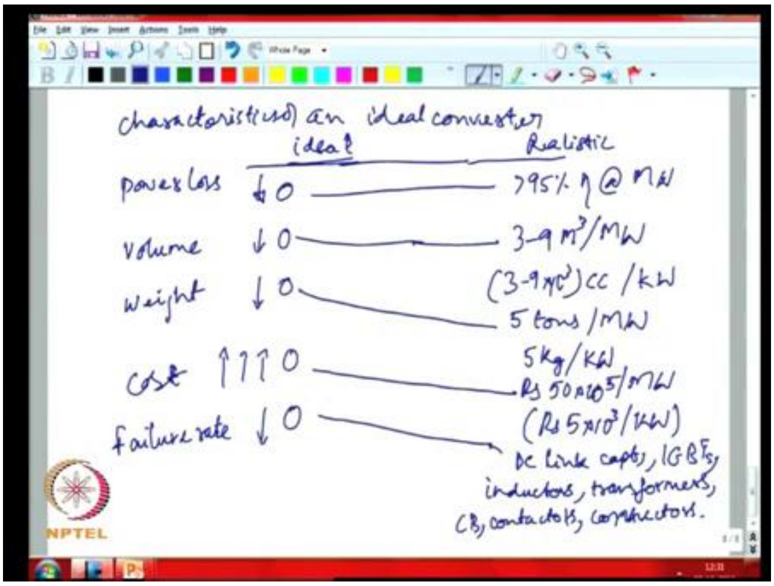

So, if you look at the ideal power converter, if you look at power loss, the ideal converter should have a 0 power loss in validity you might be talking about a converter, which might be 95 percent efficiency or something in that range. So, we are talking about power ranges of 100 kilo watts to mega watt level, if you are talking about converters which are maybe 10s of watts 100 watts your efficiency numbers maybe lower.

And if you are talking about a power converters, which are used in larger transmission systems in HVDC, start com type of applications, your efficiency might be as far as 99 percent. But, here we are looking at an application which might be used in a distribution system, so we are talking about something of the range of 95 percent, if you look at the ideal volume, your ideal volume is 0, your ideal power converter should not occupy any space.

Say assuming that a volume of the converter depends largely on the type of cooling that you are going to use, whether its natural cooling, liquid cooling, forced air etcetera, we will talk about say 3 to 9 into cube per mega watt. So, you are talking about on a 3 to 9 into 10 to the power of 3 CC per kilo watt, you know that 1000 CC is 1 mille liter, so it is about 3 to 9 liters per kilo watt.

So, you might look around say maybe have seen UPS sitting next to your computer and you may have a 1 kilo watt UPS and it is volume may not be much larger than 3 liters in the cabinet, if you exclude the battery. So, you can get a range for or what the volume would be of typical equipment around you, and also depends on the type of enclosure weather it is best proof open frame etcetera.

If you are looking at weight, your ideal power converter has 0 weight whereas, your realistic converter, we are talking about 5 tons per mega watt again this one making assumptions of say typical forced air cooling, filters being present in the converter etcetera. So, you are again you are talking about a kilo watt, you are talking about 5 Kg’s kilo watt, again you may not be familiar with the mega watt power converter and not definitely not lift it single handedly.

But, you could try lifting a UPS, which is there next to your computer and you would, say if you ignore the batteries it would cost maybe weight maybe 4 or 5 Kg’s . If you look at the cost, your ideal cost is 0, so if you look at again the cost which might be realistic, again it depends on the application, you might have applications where the cost it might be of the form of some considered goals which is being mass produced.

So, the cost might be lower or it might be some custom made product for space application or some strategic military type of application, whether cost might be higher, but we are talking about something typical for a mega watt range, commercial type of system. You are talking about being rupees 50 into 10 to the power 5 per mega watt, so again to scale up down you might say on a per kilo watt basis, you are talking about 5000 rupees per kilo watt.

Again if you look at a UPS that you might purchase with a for your computer in your lab, you are talking about 5000 rupees you might be able to purchase an UPS, in roughly in that range with some variation around it. We again another important aspect is a failure rate and ideal power converter never fails, so it is always working, whereas your practical power converter it is failure rate depends on components that application in which is being used.

So, we will look at the you might have components such bc link capacitors you might have IGBT is which are being cycle thermally, you might have inductors, transformers etcetera, which whose installation might degrade at high temperature. You might have a circuit breakers contactors, you have different number of cycles before it needs servicing, you might have connectors which might experience fatigue after so many mechanical cycles.

So, you have equipment where the failure rate is not 0 it is finite, so depending on the particular application one can actually try to back calculate, what your failure rate is and what could be potential replacement durations of within your equipment. So, if you look at the ideal power converters is ideal middlemen who provides all the service, that is a invisibly it does not take cost and money at is always available there is no failure etcetera.

But, you are trying to achieve that ideal, but it may not be possible to meet that ideal condition requirement in all situations, but as an engineer you are trying to make these numbers to get to the as closed to 0 as far as possible. And one thing to also keep in mind is some of these numbers are actually present in a trade off form for example, if you try to in reduce your power loss, your cost might increase. Similarly, if you try to reduce your power failure rate again cost would increase, if you try to make it more compact by reducing your weight and volume, so again potentially your cost can increase.

So, there is a tradeoff between cost and the performance numbers, so just trying to make it ideal in terms of performance, then magnify the cost and that may not be your always going further highest performance. Or conversely going for the lowest power cost or the power converter may not be the ideal situation.

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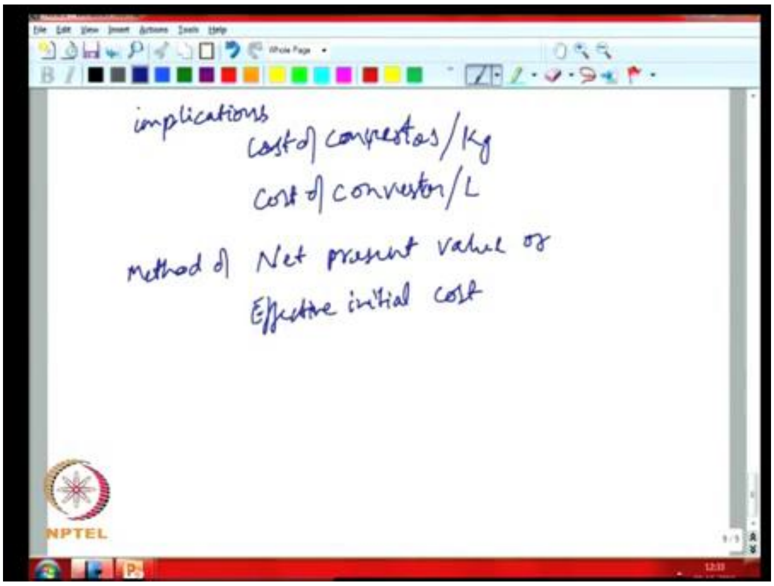

You could also look at now given this previous numbers, what these are fun exercises to carry out, here you would know the cost per kilo watt of a power converter and you also know the weight per kilo watt of the converter. So, you could ask what is the cost per Kg of a converter and we may not think of power converter as you purchase in Kg's, but you could look at it, if I purchase equipment what would be the cost per Kg or cost per volume.

And these are fun exercises to do, you could look at equipment that are available around you, electrical equipment that are there in your house say consumer items, microwave and mixer and grinders, look at their weight their cost etcetera and look at the cost per Kg number. And see whether they correspond to the sum of they be 10 towards number that you could actually make use of in making rough engineering decisions.

So, next we will look at making use of some of these characteristics in a deciding to look at it from you effective implications from a effective initial cost prospective, when you are looking at discussion to take a particular approach and we will look at a simple example of maybe a purchasing a vehicle.

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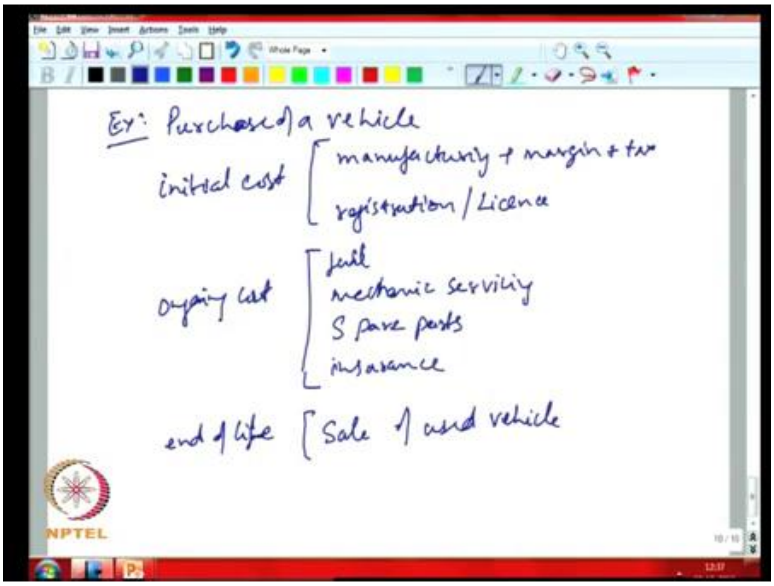

If you look at purchasing a vehicle, you might have a initial cost, the initial cost might be what is the cost of the vehicle in the showroom. So, the cost of the vehicle in the showroom might have a manufacturing cost, the margins that the manufacturer wants for producing the equipments, it might have some tax element that you have to add, you might have some cost, initial cost associated with a registration of the vehicle getting license etcetera.

So, you might have ongoing cost, there can be a number of ongoing cost, major one would be your fuel, your petrol cost you might periodically meet to go to a mechanic for maintenance, you might need spare parts, you might have a annual insurance payments. So, you would have a things that are done on a annual basis, and you might also have a end of life cost in which case, here it might not be a cost, you might get some money back when you sell the vehicle after so many years of operating it.

So, you would like to reflect all these cost to your initial point when you are making a decision, rather than just making a decision based on what the initial cost is. Because, in fact, when your making a decision you are actually not just connecting to the initial cost, but actually all the other cost associated with it. So, people talk about it as a net present cost or a net present value, effective initial cost etcetera, you all imply the same thing.

And the design methodology by which these cost are evaluated, people call it as creedal to creedal design, where you are not just looking at the initial upfront cost or the manufacturing cost. But, also eventually you might not just sell the used vehicle, eventually after a number of years, it might had to be a recycled or dismantled or disposed in some manner. So, if all the cost can be put together that particular way of looking at a design is what the effective initial cost is trying to approximate.

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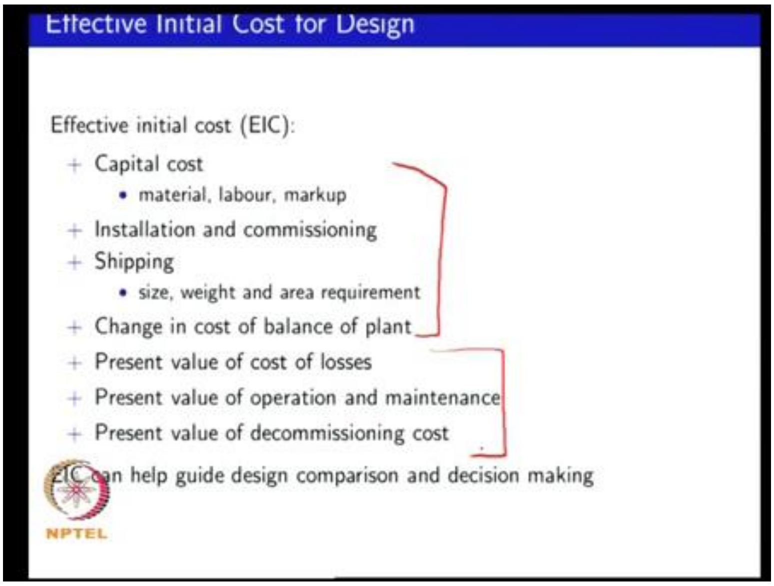

So, if look at what goes into the effective initial cost calculation, you might have your capital cost, which might have the material, labor, markup etcetera. You also have a option cost corresponding to installation, commissioning of a DG unit, you might also have shipping cost, say your wind turbine might be produced somewhere in Goa, it might have to be installed in Tamil Nadu.

So, depending on, if you want to ship huge towers blades across multiple states, it depends on how big it is, how much it weight, if you are trying to install something in a urban area, the cost of land in a urban area might be quite high, so the size weight area etcetera can actually reflect on the initial cost. You might also have change in balance of plant cost as we discussed earlier, you might have benefits in balance of plants which has to it should be reflected in your effective initial cost.

Also we know that practical power converter has losses, so an ideal power converter would have loss of 0, so whatever loss is being encountered in the power converter, you could look at it as one way as that is a loss that you are incurring or the cost that you are incurring by operating the power converter, you are having a fixed annualized loss cost associated with a loss in the power converter. Also you would have the operational maintenance, which can be reflected, which might be on an annual basis, it can be reflected to the present time. Also depending on the power plant or the type of plant you might have a decommissioning cost for example, as I mentioned if you have wind turbine, you might be able to get some value above from the scrap steel or copper in the generators etcetera.

But, you may not be able to get a value from say old electronic e-waste, which might be there in your system or suppose, if it is a nuclear power plant if you want to decommission, some part that is radioactive that might be a lot of expense in disposing say something which is radioactive.

So, depending on what you are trying to dispose might be different types of decommissioning cost, and the idea is that effective initial cost does not reflect actual physical amount spent. For example, you are not spending on amount, because of cost of losses it is unearned, you could have earned more it was better that is the idea behind it. So, it can be used for a design comparison or making a design and is not actual number where you can say this is the actual so many lakhs or some amount is the actual physical amount that is there. So, some of these values that are available upfront these might be ongoing or future values, which are reflected back to the present.

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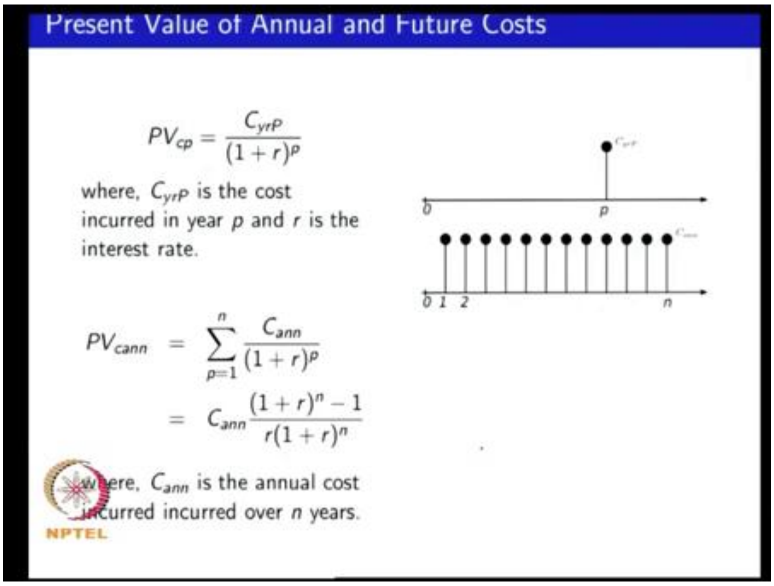

And then, you could save your how could one reflect the cost to the present, say if you have a amount C today and you are assuming interest rate r, then at the end of 1 year you have C into 1 plus r, at the end of the 2nd year you might have C into 1 plus r into 1 plus r. So, it should be seen to 1 plus r the whole square at the end of your P it would C into one plus r to the power of P, so if you have a cost C of P on your P, if you want to reflect it to the present you just to divide it by 1 plus r to the power of P.

And if you have a annualized cost every year you have an equal cost of C a n n and your assuming that is going to operate for n years, you can reflect the first years cost as C a n n by 1 plus r, 2nd year is by 1 plus r square. So, we have a summation where 1 to the n years which you are operating the equipment and the summation can be simplified to a fairly simple expression such as what is shown over here. And then, one could also look at the how to incorporate other factors, so we will consider a simple interest, rate number r which reflects on a on a annualized basis.

But, you could also include terms for deprecation and inflation rate, taxes etcetera, which can be captured by using appropriate values for r, depending on a particular application that you are dealing with. So, you with this framework, in the next class we will look at an example of how to use the concept of effective initial cost, in making use of it in deciding a power converter. Whether, it is appropriate what could be as if a design method energy to make a decision of what power converter use would be appropriate.

Thank you.