DC Power Transmission Systems
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Lecture - 67
Comparison of AC and DC transmission

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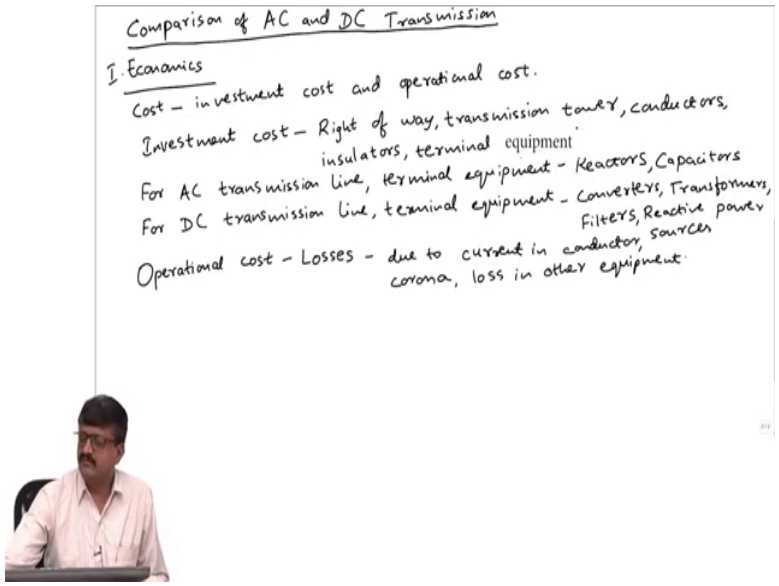

Now, we will come to the last part of this course. Now, we are in a situation to compare the AC and DC transmission; Comparison of AC and DC transmission. Now, whenever we get into comparison there are there is one aspect that is very important that is cost the other one is performance say comparison can be broadly based on cost and the technical performance. Let us look at first cost or economics ok.

Now, if I take the cost, cost will first of all include investment cost and the operational cost. So, the investment cost is the initial cost of that you need to set up the equipment; operational

cost is once the equipment is there and it is in operation what is the cost incurred. So, let us look at the component investment cost. So, investment cost is incurred on what? Suppose I take AC or DC; AC transmission line or DC transmission line what I mean what are the different components on which I have to spend or I have to invest?

Student: Conductors.

Yeah, now, before that when you were when I am talking about AC or DC transmission, let us assume that it is over a transmission line ok. So, if there is over a transmission line, the land below the line cannot be used for any other purpose; I mean one as to buy the right of way. So, first of all there is a land required for laying the transmission line. So, cost of right of way. Then what?

Student: Insulation.

Yeah, before that before coming to conductor and insulator I mean and I say over a transmission line, they how to be suspended from.

Student: Towers.

Tower; transmission tower, then conductors, then of course, insulators because the conductor is not just connected to the I mean it is not hanging from the tower, it is there is an insulator. It is of course, hanging from the tower, but there is an insulator between the conductor and the tower insulators. Then what?

Student: (Refer Time: 03:19).

Yeah, now, there are so many things at the two ends. So, these things are only for the transmission line. At the two ends, there may be many other equipment. So, we will call that as terminal equipment; terminal equipment.

So, if I look at the other components I mean components other than terminal equipment, they are same I mean right half ways therefore, both AC and DC transmission line, transmission tower, conductor insulators are required for both AC and DC transmission line. But terminal equipment are different for AC and DC ok. So, for AC transmission line, what are the possible terminal equipment; possible, what are the possible terminal equipment?

Student: After that (Refer Time: 04:24).

If I take see if I take AC network, there are many transmission lines ok. I take one particular transmission line, I can I could have used DC for that instead of AC I could have used DC. Suppose it is AC, what is the terminal equipment? What are the possible terminal equipment? If it is DC, we will come to what are terminal. See transformer is usually an equipment that is required if I want to connect generator to the network or load to the network.

See, if I take one transmission network consisting of many transmission lines at the same voltage level, there is no voltage transformation anywhere. Say we need transformers for many purposes. One example is if I want to connect a generator to the transmission network, I need invariably a transformer. Now, I am not considering that part here what I am trying to say is in a network AC network, take one particular transmission line ok.

So, it is not necessary that I mean I will have a transformer in any transmission line take a arbitrarily any transmission at both ends, I will not have a transformer it is not necessarily ok. So, and if I want to connect load also I will not to use the load at such a high level high voltage level. So, I use a step down transformer ok. Now, what I am trying to say is take any network at the same voltage level, take one particular transmission line ok.

So, now, if I take the transmission line, what are the possible terminal equipment? So, if I take a long transmission line where you a long transmission line say 300 kilometer line, what is there at the two ends?

Student: (Refer Time: 06:02).

Yeah, there is circuit breaker fine, yeah circuit breaker is one thing. What else? Yeah circuit breaker is correct; yes what else? Now, what I will do is I am trying to compare AC and DC even if you have DC, there will be a circuit breaker. So, common things I will remove. See if I have a DC line, I need a transformer and then a converter. Now, before the transformer, there is circuit breaker. Now I will try to just list items which are unique to AC and unique to DC. So, if I take along I am giving a hint if I take a very long transmission line invariably, we need something at the two ends.

Student: Reactors.

Student: Reactors.

Yeah, indicative reactors indicative reactors that is because under light load conditions it will cause over voltage if you do not have that ok. So, there are reactors. Now, a reactor means inductive reactor in power system terminology we use the word reactor to mean indicative reactor. In circuit theory of course, reactor can be inductive reactor or capacitive reactor. Then what else?

Student: (Refer Time: 07:18).

Sorry.

Student: Why do we need reactors?

Yeah, why do we need reactance? Yeah, see the this is normally taught in a very basic course. If I have a transmission line, there is a shunt capacitance ok. Now, if I take long lines, there is an effect called what?

Student: Ferranti.

Ferranti effect, are you have you heard of that? So, this Ferranti effect is coming to picture when there is no load. So, when there is no load the voltage can shoot to a large value beyond the value for which the line is designed the insulators are designed. Now, it is not only for no load, it can cause problems even under light load. So, to minimize that over voltage we nullify are at least to some extent take care of the effect of capacitance by putting a an inductor.

So, the inductor will nullify the effect of capacitor at least to some extension that is all. So, that is the point. Now, this problem becomes a um actually very significant when I have long lines longer the line more is the capacitance more is the Ferranti effect ok. Yeah, any other terminal equipment possible terminal equipment? Now, you use reactor for avoiding over voltage at the same time when there is heavy load there can be.

Student: Under voltage.

Under voltage, So, what one can do is one can put capacitor may see the point is at some point I may connect reactor at some point I am a remove reactor and put capacitor ok. If you put both, then it is there is a no use one is having a effect of nullifying the other. So, I do not want to load both. So, at one time I can use reactor for other times I can use capacitor ok. Now, these are the two major terminal equipment.

Now, let us come to DC for DC transmission line. What are the possible terminal equipment? Yeah, what are the terminal equipment? Say I take one possible AC transmission line in a network; I want to replace it by DC. I remove AC and replace it by DC. So, what all terminal equipment come where?

Student: Convertor comes.

Convertor comes convertor then ha.

Student: Filter.

No, before that say converter means suppose I say 12 pulse converter ok, it includes transformer also. But to stress that there are transformers also, I will explicitly state transformers ok. So, in addition to the power electronics circuit converter, we have transformers also then filters.

So, as I said fillers are of course, invariably used on the AC side they are also used on the DC side along with smoothing reactor. So, I call all these things as filters. Then just now we will discussed about reactive power sources; reactive power sources ok.

So, the now, we have seen what is the investment cost due to ok. So, I just said terminal equipment which is there for both AC and DC and we have listed what are the different possible components of the terminal equipment. These are all towards the investment cost of course, when it comes to operational cost; I mean what is the operational cost? What is the operational cost? Ha.

Student: Losses.

Losses mainly losses ok. So, operational cost is losses. Where are the losses?

Student: Conductors.

In the conductor due to flow of current and any other any other loss ah loss due to current in the conductor and corona and of course, one can also say the loss in the converter and other equipment. So, we can in include of course, loss in the other equipment together.

So, they are very small compared to the loss in the transmission line. One the major loss is the current loss due to the current flow i squared r loss the other loss is the corona loss due to that

is dependent on the environment of course, ok. Now, if I want to compare the two. So, that is our purpose now if I want to compare these two DC transmission line and AC transmission line.

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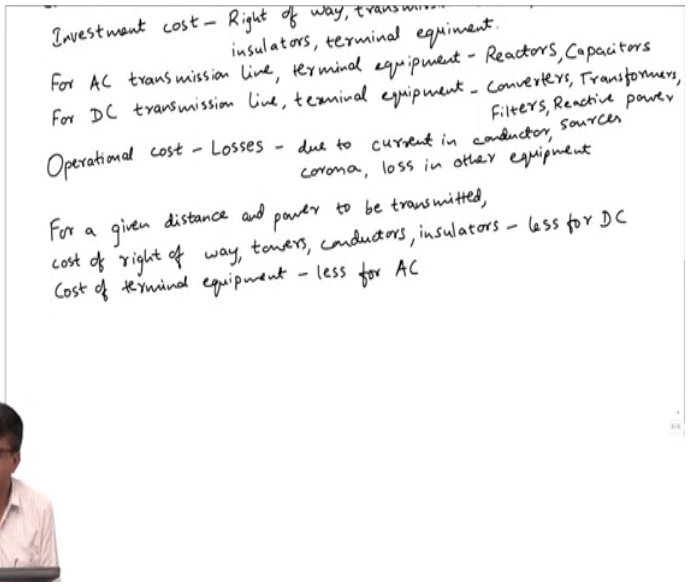

So, suppose I say that there is a fixed distance whether it is DC or AC for a given distance and for a given power to be transmitted.

Now, if I look at the investment cost. So, for the time being I will just look at the investment cost. So, if I look at the investment cost, there are two categories one is right of way, transmission tower, conductor, insulator the other one is terminal equipment. So, if I take a the cost of right of way, transmission tower, conductors and insulators; I will consider terminal equipment later ok inductor insulators. Now, which one has less cost DC or AC?

Student: DC.

Ha.

Student: DC sir.

Dc now, right of way it is dependent on the number of conductors ok. So, though we are not get into we do not get into the details of the design, I mean one can try to see that the right of way depends on the number of wires that you need. And I mean the less the number of wires less, I mean we need less investment on the tower from which the wires are suspended and of course, conductor materials is also less and less conductor means less insulators.

So, DC is less expensive. So, ok let me write it as this is less for DC, then that for DC AC. Now, when it comes to cost of terminal equipment; now, without even getting into the exact values of the cost, we can make a statement about the cost of terminal equipment which one I mean it appear which one appears to be.

Student: (Refer Time: 15:05).

Expensive.

Student: Expensive.

Dc is expensive right. So, you need so many things ok. So, without even knowing the values of the cost of different equipment, we can easily say that DC is more expensive here ok. So, this is less for AC.

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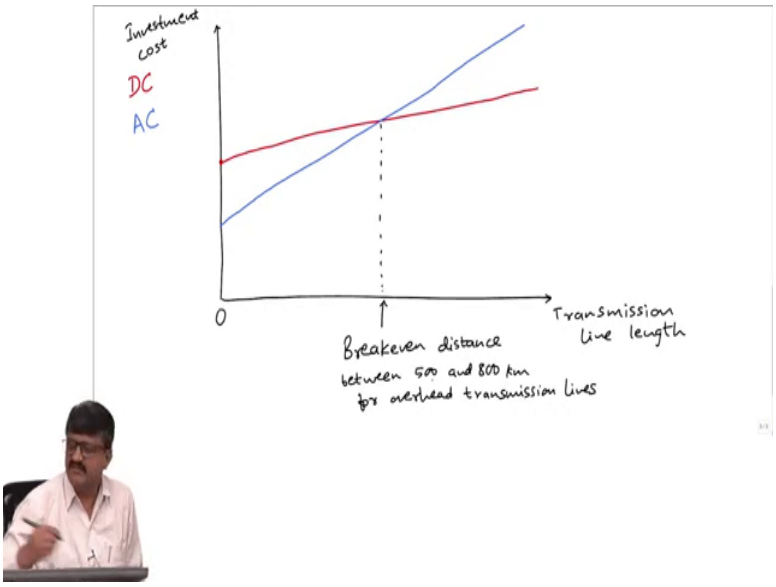

So, if I plot a graph ok so, I will plot a graph where on the abscissa I have transmission line length. And in the ordinate I have the investment cost ok.

So, I will use say red for DC and say blue for AC. So, I need to plot the curve of investment cost for AC and DC as a function of transmission line length. Now, when I say the transmission line length is 0 if I say transmission line length is 0 say if it is actually 0 for in the case of DC if I have back to back if I have back to back ok. Now, what is the cost incurred for DC when the transmission line length is 0? It is only on the.

Student: (Refer Time: 17:01).

Terminal equipment only on the terminal equipment, so, I at 0 length I have something here I have some nonzero value for reinvestment cost because it is on the terminal equipment. Now,

as I increase the transmission line length, then how does the investment cost vary as a function of transmission line length? Say, the other costs say I have considered already one cost that is the terminal equipment cost.

The remaining cost right of way towers, conductor, insulator; they are proportional to line length they are proportional to line length. So, it is actually a straight line with a positive slope. So, it is like this. Now, if I take AC if I take AC how does the investment cost vary as a function of transmission line length? So, here also it is.

Student: (Refer Time: 18:00).

It is dependent on the right of way conductor, insulator, tower say the I mean the all these are actually proportional to the transmission line length, but the slope is.

Student: Less more.

For AC.

Student: For AC more.

More slope is more. So, the slope is like this. So, I have now, I do not extend it to till the investment cost access because in the case of DC it makes sense because there is a 0. Yes.

Student: Slope for DC is.

Slope for DC is.

Student: Yes sir (Refer Time: 18:42).

Oh, sorry sorry yeah I made a mistake sorry I made a mistake both are straight line segments this is ok. Now, the point is even if I extend this straight line segment till the investment cost

axis the intersection is lower than that for DC because the terminal equipment cost is actually less for AC compared to DC is that ok. Now, what does this what do these two curve say? The total investment cost. So, there is one particular value of transmission line length below which AC is less expensive.

Student: (Refer Time: 15:53).

And beyond which are if I take any length greater than this then DC is less expensive ok. So, this is called breakeven distance breakeven distance. Now, this is I mean dependent on the system dependent on the voltage level power level.

So, based on all these things one can actually get a range of breakeven distance it is between 500 and 800 kilometers this is between 500 and 800 kilometers of course, I am talking about only overhead transmission lines for overhead transmission lines. So, in practice it is somewhere it is somewhere within this range 500 and 800 kilometers ok.

Student: (Refer Time: 20:52).

Sorry.

Student: (Refer Time: 20:54).

Yeah, I am I have drawn this for a general voltage level. What I am saying is we can arrive I mean typically it is between 500 and 800 which is dependent on the voltage level the power level and so on. Mainly its voltage level and power level which decides this breakeven distance.

Student: (Refer Time: 21:12).

Voltage level yeah, see voltage level is 100s of kilovolt see when it come to DC transmission its 100s of kilovolts power level is 100 1000 of megawatt you are talking about what your

question is what is the voltage level that is irrespective of this. Yeah irrespective of the the voltage levels are similar to the voltage level of AC transmission. Where this was something which we discussed long back when I say thyristor valve why do I say valve why not just thyristor?

Student: (Refer Time: 21:46).

We have to connect we do not have thyristor for that voltage rating. So, we need to connect many things many thyristor in series to get the required voltage rating ok. So, the voltages are in the range are of the order of 100s of kilovolt ok. So, the breakeven distance decides with I mean. So, depending distance is given to us.

So, if the distance is below breakeven distance we go for AC if it is above that we go for DC as far as economics is concerned.

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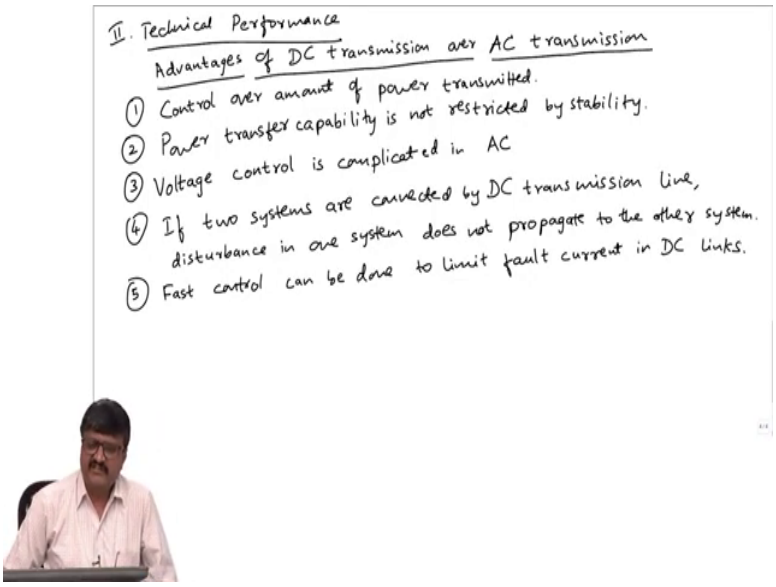

Now, let us do a comparison based on the performance. So, if I take technical performance. Now, when it comes to performance actually DC has many advantages over AC. So, let us look at the advantages advantages of DC transmission over AC transmission.

Yeah, whenever we talk about DC invariably there is a converter there is a power electronics circuit there at the rectifier side and the inverter side ok. So, there is some control that is possible in a DC transmission line which is not there in AC. So, in AC the amount of power flow or for that matter the amount of current flow is decided by Kirchhoff's law ok. There is no I mean in a conventional system there is no control there is a mesh network. And the amount of power and current that flows in a wire or in a particular transmission line is decided by Kirchhoff's law that is all. The user the utility does not have any control over the amount of power that is flowing in a particular transmission line ok.

So, the major advantage is there is control over amount of power transmitted. So, this is just comparison of DC transmission and conventional AC transmission ok. Of course, there is possibility of controlling AC if we bring in power electronics there we give a special name for that facts flexible AC transmission system means use of power electronics circuits for the purpose of control in AC transmission line also ok.

Now, when it comes to AC system always the amount of power is restricted by stability. So, you may be familiar with an undergraduate a notion of stability where you would have studied SMIB systems Single Machine Infinite Bus system. What is the maximum amount of power that can be transmitted? There is a power angle curve which the sin curve the theoretical maximum occurs at delta equal to 90 degrees. So, such things so, there is a limit. So, that limit is actually the stability limit it is not the thermal limit; see thermal limit means the limit which is introduced due to the amount of current that flows in a wire.

So, the thermal limit may be much larger; thermal limit are usually larger because we design the wire diameter such that the corona is minimized. So, for minimizing corona the wire diameter has to be much larger. So, the; that means, the thermal limit is much higher than the stability limit. So, we cannot use the full thermal limit in the case of AC because of stability reasons. So, there is an advantage in DC power transfer capability is not restricted by stability.

Now, again the presence of converter will not only help in power control it will also help in control of the voltage. Now, when it comes to transmission line the voltage is needs to be controlled because there is a sag and a swell. If you are familiar with sag and swell under light load conditions we have a swell. Even if I keep the some of the terminal voltage I had the desired value the voltage along the line cannot be control all along the line.

So, there will be a swell whenever there is light load and there is a sag whenever there is heavy load. So, such problems are not there in the case of DC because the sag and swell are essentially due to the inductance and capacitance. So, the inductance and capacitance do not have any effect in DC. Yes.

Student: This is sag and swell is (Refer Time: 26:49) voltage (Refer Time: 26:51).

It has nothing to do with the sag of the wire that is always sagging ok. I am talking about the voltage magnitude if I look at the voltage magnitude.

Yeah, that is another sag the sag you are talking about is the wire sag of course, that actually when there is low more loading the sag actually the sagging increases there is no swell there ok. So, when you talk about sag and swell both we are talking about voltage magnitude. Yeah, that point is also relevant what you are saying the wire sag increases when the load increases.

Because there is more expansion due to more heating and due to which the sag increases ok. So, voltage control is actually complicated in AC. So, again I am talking about the conventional AC transmission without use of any power electronic equipment in the AC system. Voltage control is complicated in AC.

Yeah, then there is one major advantage of DC. Suppose I have two systems I have two systems independent systems I want to interconnect for sharing of power. Then if I have the option of AC and DC I can choose based on various reasons. If I use AC, then there is one disadvantage a disturbance in one system will propagate to the other system through this AC wire to the AC transmission line on the other hand if DC is used the disturbance propagation is actually minimized to a great extent ok. So, if two systems are connected by DC; DC transmission line.

So, for all practical purposes we can say that disturbance in one system does not propagate to the other system ok. Now, there is just one more advantage that I want to point out here suppose there is a fault in an AC system, I mean we clear the fault by relieve in the sensitive fault and the circuit breakers are given a signal to trip ok.

Now, in the case of dc there is a possibility of controlling the converter itself to limit the fault current. Now, such I mean facilities not there in AC. So, fast control of I would say fast

control can be done to limit fault current in DC links ok. So, these are some of the major advantages of having DC transmission over AC transmission.