Power System Generation, Transmission and Distribution

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Lecture No. # 22

HVDC (Contd.)

Welcome to this lecture number 22. We will continue today HVDC that is High Voltage DC Transmission and the one of the major advantage of having HVDC is to unable the power, people to have back to back connection.

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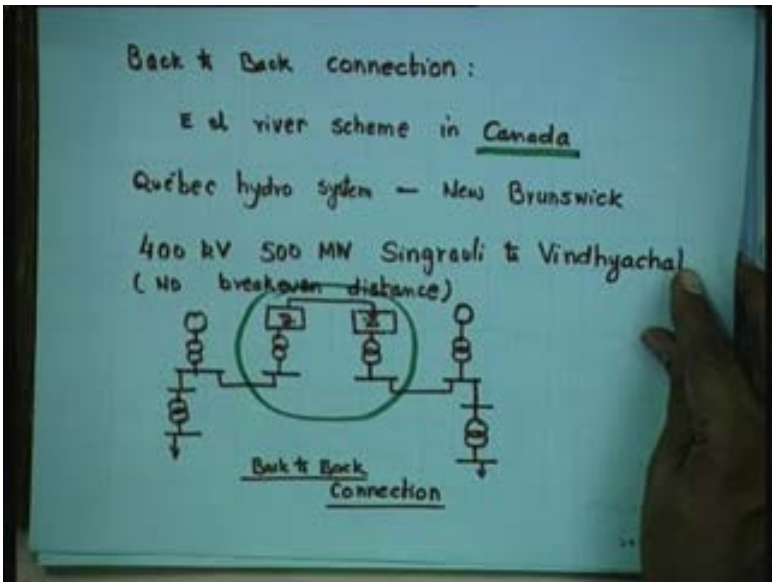

Now, what is this back to back to connection? For the first time, it was used in E el river scheme in Canada. It is Quebec hydro system which is perhaps one of the best hydro systems in the world at Montreal. So, from this 2 New Brunswick that was the back to back connection and in India, we have 400 kV 500 mega watt Singrauli to Vindhyachal. Now in, when is talk a back to back, there is no meaning in talking about break even distance, because distance is almost zero. Now you see a look at the diagram, which is shown in the green circle is the back to back connection and it can be housed in the same building. You even do not have to go to next building. Now, this is do not think that this is the only way we can use HVDC.

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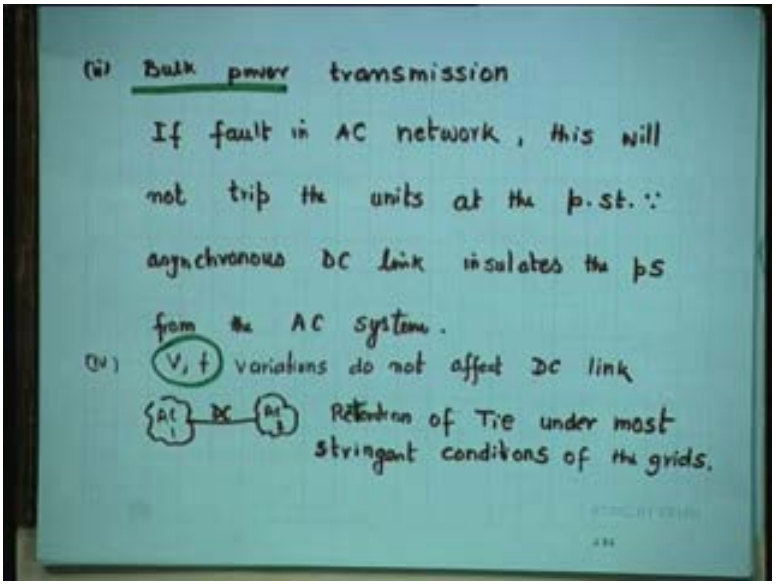

In fact, Bulk power transmission is another important application of HVDC. Now, why do you need bulk power transmission? There may be an area like North East, where there is a lot of hydro power generation available. However, there are not much industries, there are not many people there. So, we do not need power right there. So then, if you generate that power, it has to be taken to a place where it is required. Now, power is required in South, for example, lot of industrialization is there. So, what we do? We have a 2000 kilometer line built in 2002 which will carry almost 2000 mega watt from all the way from North East to South up to Bangalore, and there Bangalore and Hyderabad and Madras, being the industrialized highly industrialized places in South. They need power and they do not have local power available. There is a water problem. Everybody knows about Cauvery problem. So, there we need this bulk power transmission.

Another advantage is the fault is there in AC network, this will not trip the units at the power station, because asynchronous DC link insulates the power system from AC system. So, that it is you know something which will avoid fault to take place that it been AC link, the fault would have affected this as well. Again voltage and frequency variations in AC systems have absolutely no effects what is ever on this DC link. It is immune and this is what is shown in this figure AC one and AC 2 and this is the DC link. So, this DC link has no impact of anything wrong in AC 1 or anything wrong in AC 2. Retention of Tie under most stringent conditions of the grids is possible only if the tie is HVDC not HVAC.

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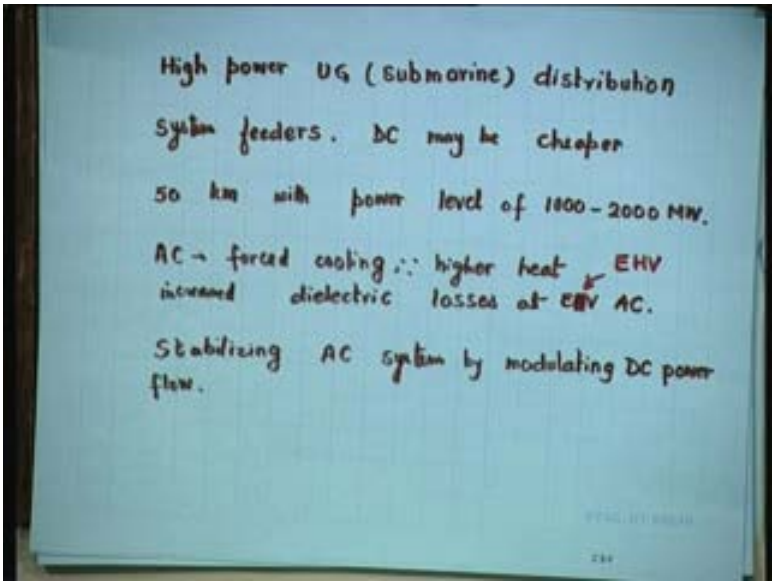

High power underground submarine distribution: now do not think that there is no underground under water transmission system. We do have at some places, power transmission being done under water submarine distribution system. DC may be cheaper, there 50 kilometer with power level of 1000 to 2000 mega watt. All of you must heard Bombay, where we have, we know the Indian Oil companies. So, you need power there is well.

Now for AC, you need forced cooling because the higher heat is generated. There is a I square x losses also, which not many people appreciate by losses. Everybody thinks normally I squared r losses, forgetting the x is a major component. Please remember r by x is very small. So, x is very high roughly it is 10 times r for a normal system. If x becomes closer to r, it becomes abnormal system, it becomes ill condition system. So, they we need better cooling, forced cooling, if it is a AC system because the higher heat is generated again due to dielectric losses which are much more in extra high voltage AC than in DC. Now a stabilizing AC system by modulating DC power flow, also it has a stabilizing effect is well. So there, these are the various advantages of having direct current, high voltage, a HVDC system.

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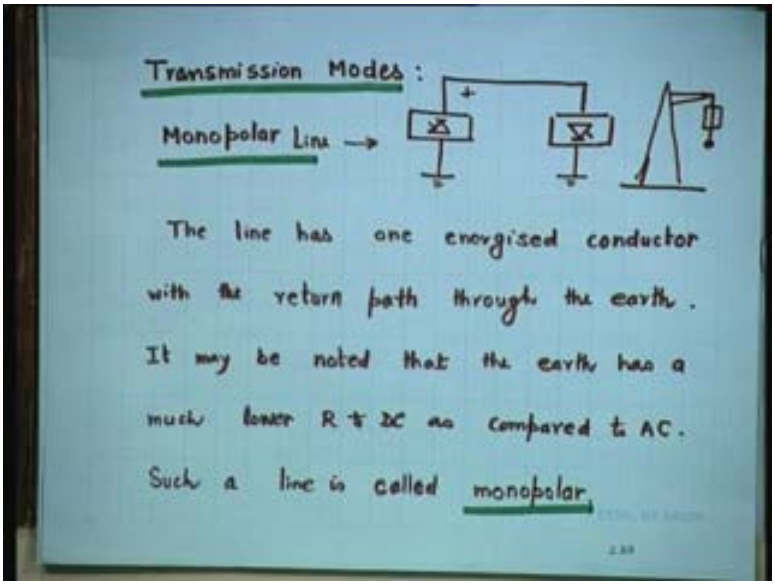

Now what are the different transmission modes Monopolar line, as you can seen a figure, it is just a line has one energised conductor just one with the return path through the earth. Earth is being used for return conductor. It may be noted that the earth has a much lower resistor to DC as compared to AC. Such a line is called monopolar. Bipolar 2 circuits means, the both the circuits are identical.

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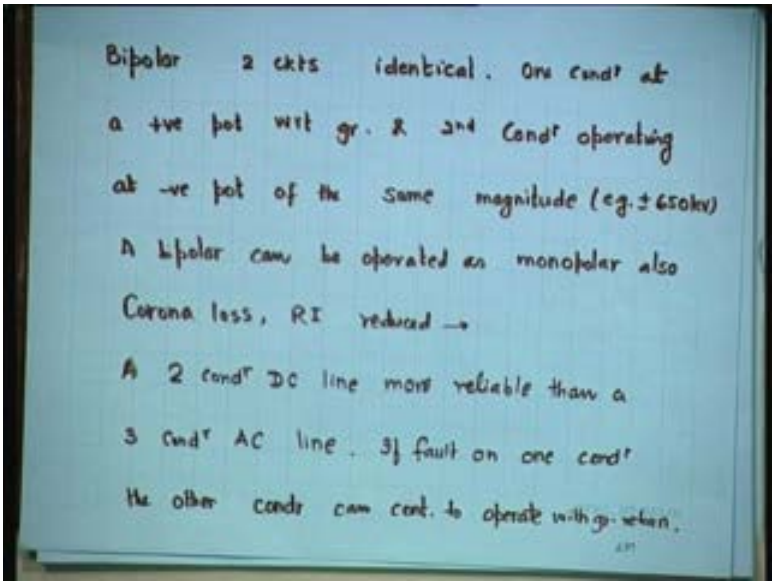

One conductor at positive potential respect to ground and second conductor operating at negative potential of the same magnitude. For example, when we talk plus minus 500 kV

or 650 kV, what is that means? It means 650 positive as well as 650 negative. So, this is bipolar. A bipolar can be operated as monopolar, suppose you do not need both. So, you can have as well one and it can work as a monopolar line. Monopolar cannot act as a bipolar, but bipolar can always act as a monopolar.

Also corona loss and radio interference are reduced in direct current. A 2 conductor DC line is more reliable than a 3 conductor AC line. Why? More the components chances of failure are more, fewer the components chances of failure are less. I hope you must have all studied reliability theory at anyone stage of your life so far. So, you know that system is less reliable, system is more reliable. Similarly, more components more chances of failure. A fault on one conductor, the other conductor can continue to operate with ground . That is monopolar operation, which is not possible in AC line. Of course, there is they, you cannot do everything positive in life in anything.

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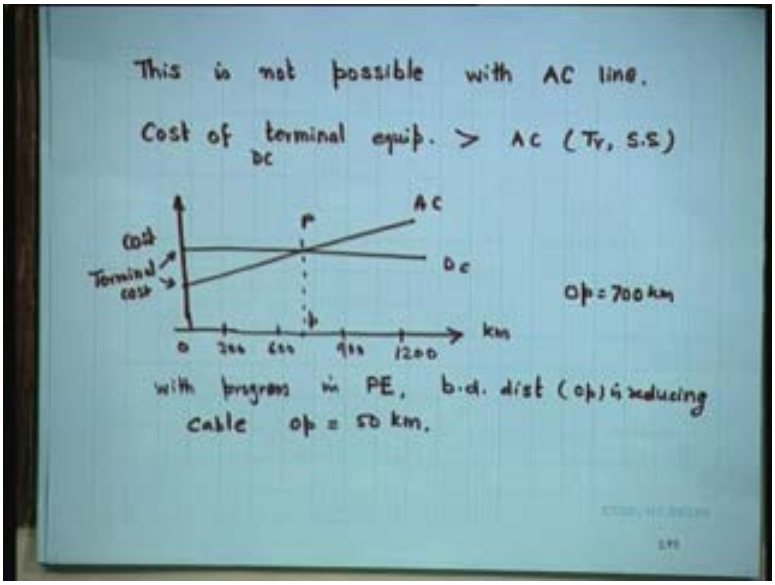

So, the problem is why so far HVDC has not been so widely used? Because the cost of terminal equipment were much much higher than that of AC. In AC, the terminal equipments are substation and transformer, in DC converter station. Now with the progress in power electronics over last three decades, this cost like computers. Computer whenever you buy next time, you it will be cheaper. So, is the power electronics devices IGBT, , all these things are lot lot cheaper. Then what they use to be few years back? Please give a attention on this diagram or a graph which are plotted. This is the x axis is

kilometers (distance). The y axis, there are 2 quantities for DC and AC plotted, the quantity plotted is cost. As you can seen the terminal cost is higher for DC lower for AC, you are just stated the fact minutes back. But the overall cost goes up after a point P and AC becomes costlier than DC. So, this point is called break even distance.

So, if it all, you have a HVDC line, it has to be longer than op. If it shorter than op then it is no point in using DC, you have to use AC and now this break even distance also keeps on varying, depending on the, you know the advantages the technology. Normally o p is around 700 kilometer. So, if it is more than 700 kilometer, it becomes advantages, cheaper, better, more reliable to use HVDC option. With progress in PE, break even distance is reducing every year, every day, cable this distance is just 50 kilometer. If it is underground or if it is even above an earth, under water, whatever, wherever you use cable, the corresponding distance is 50 kilometer.

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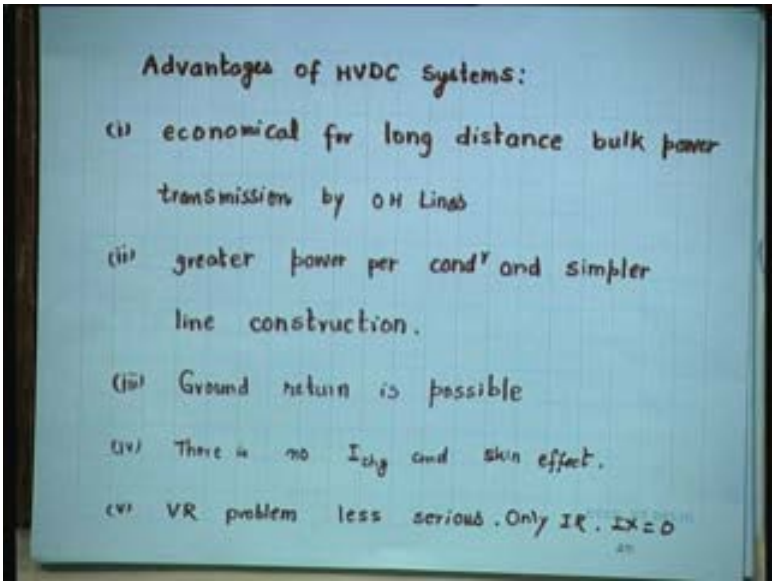

What are the advantages of HVDC system? We have been talking about advantages only, but let list them point wise. Economical for long distance bulk power transmission by OH Lines. We are just concluded when the distance is more than break even it becomes economical. Greater power per conductor and simpler line construction. Ground return is possible. There is no charging current, there is no skin effect. Voltage Regulation problem is less serious. Why less serious? There is nothing, called IX. This drop is totally upset, only IR drop is there.

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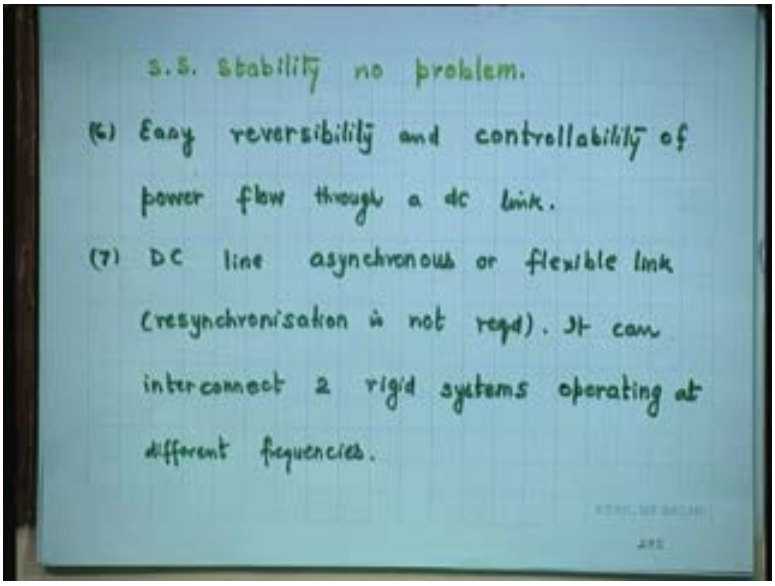

Steady state stability is no problem. Absolutely easy reversibility and controllability of power flow through a DC link, Control is lot easier. Only a 2 play with the 2 voltages is nothing call phase angle, nothing call route 3, no route 2 business, no errors, you likely to get full marks in numerical because normally you made a, you make errors in route 3, route 2 etc etc.

Well, we are now currently advantages, will come to disadvantages little later. Let us talk positive things first. DC line asynchronous or flexible link, resynchronization is not at all required. The AC is is resynchronize. It can interconnect 2 rigid systems operating at different frequencies. So, it can even make enemies talk that what it means. So, even France and England, if they are connected interconnected by DC line, whatever happens in those France and England is unaffected as far as DC link is concerned. So, 2 rigid systems operating at different frequencies can also be interconnected that is the real beauty of DC systems.

For a single DC line between 2 converter stations, circuit breakers not required, whereas circuit breakers is a big issue in AC because control of converter station can be used to block current flow during faulted conditions. The whole idea of circuit breaker is so that current does not pass. Well that can be achieved merely by controlling the converters.

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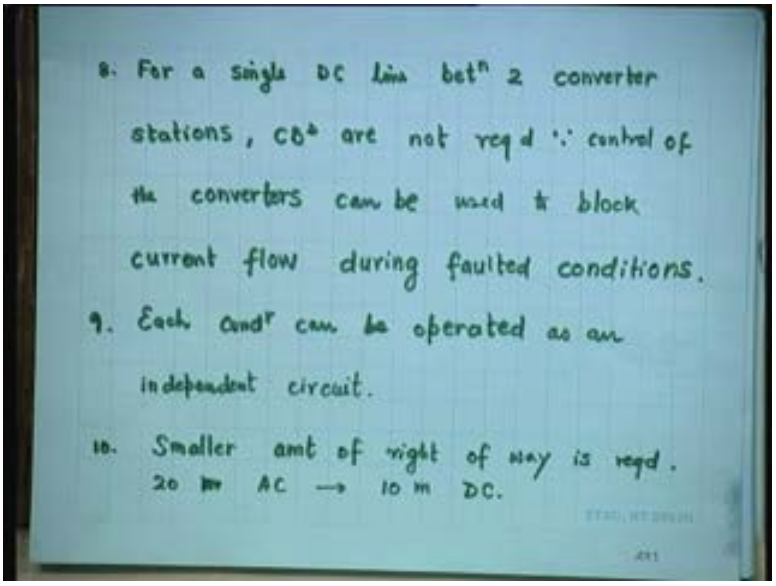

Each conductor can be operated as an independent circuit. So, the independence is there and in probability theory, independence is very easy. If you assume independence of events, the mathematics becomes lot easier than probability theory. Smaller amount of right of way is required because only 2 conductors. So, if it is 20 meter for AC, for DC it just half just 10 meters. Imagine how much more spaces available for use, if you have HVDC rather than HVAC and space is great premium, nowadays there is no space.

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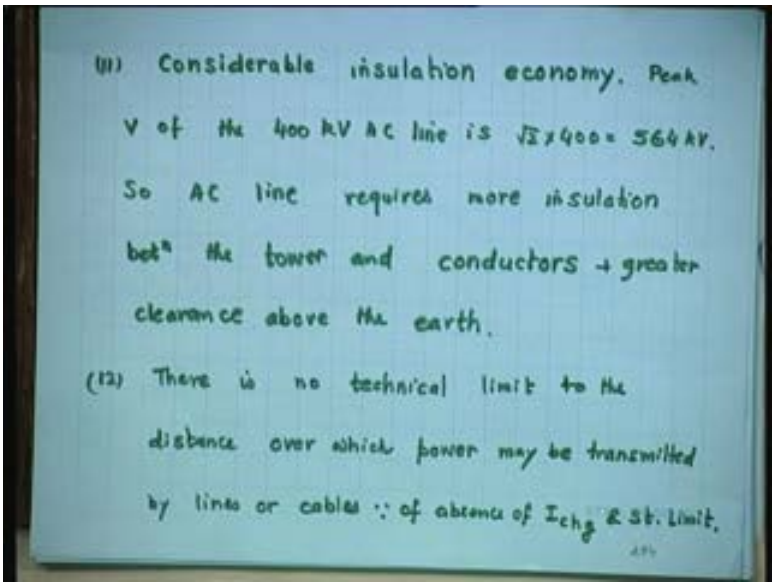

If you travel in Kerala, this is hardly a single foot available for doing anything, either this water or there is some considerable insulation economy, the point number 11, the advantage number 11. Peak voltage of the 400 kV AC line is root 2 times 400 564. Imagine how much extra insulation is required because of extra voltage. So, AC line requires more insulation between the tower and the conductors, greater clearance above the earth. There is no technical limit to the distance over which power may be transmitted by lines or cables, whereas AC, you must have remember when I talked you to power lines, there are not practicable because 4000 kilometers, where as in DC technically, practically, you may not need. Why transmit power to, let us say SriLanka from South and North Eastern unless settle paying money because charging current is totally up sent and stability limit, there is no such thing. That is right. No required. It is not required at all. Yeah. That is right. Line losses are smaller.

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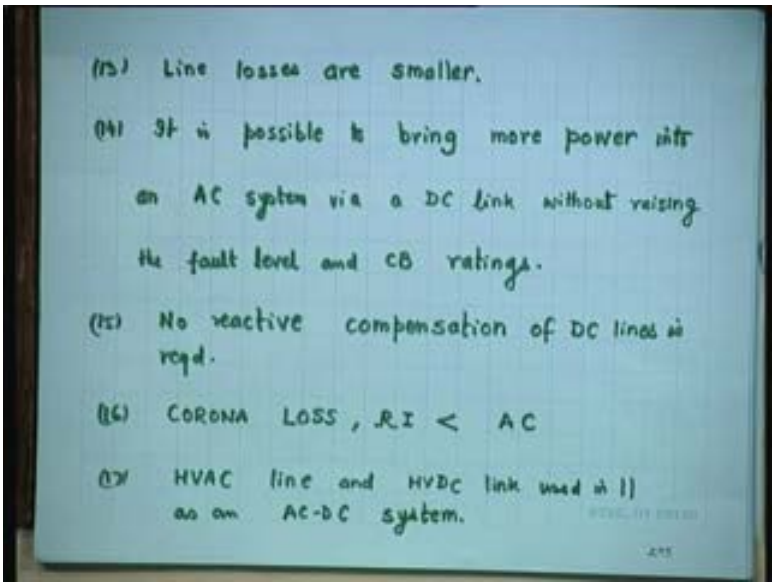

This point we are again and again , again and again repeating because it is so important. It is possible to bring more power into an AC system via a DC link without raising the fault level and circuit breaker ratings. No reactive compensation. This is wonderful point of DC line is required because it is not there. Corona loss, this we already said, and radio interference are lot lower, lesser than corresponding AC values. Well, you can have a hybrid system HVAC line and HVDC link can be used in parallel as an AC- DC system and that is why the whole power system modeling is revised.

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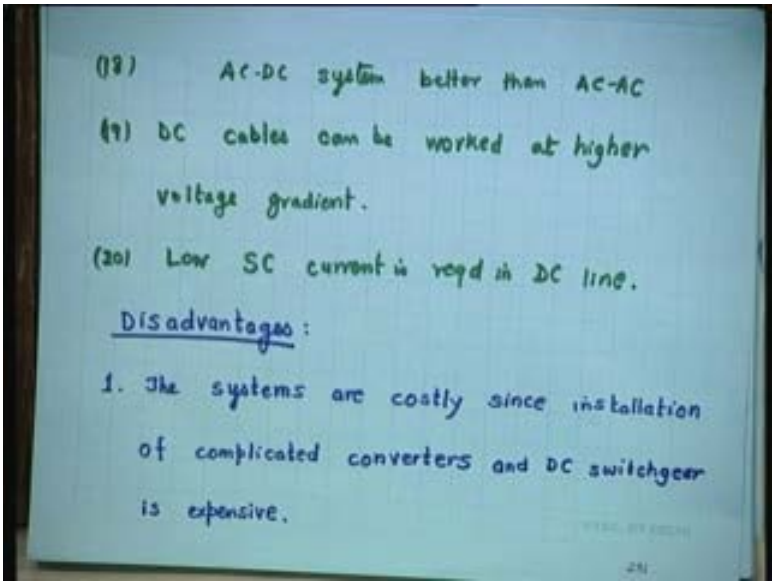

Of course, that is why the whole area fax system in, otherwise why do you need fax? Eighteen, AC-DC system is better than AC-AC. This is the conclusion. DC cables can be worked at higher voltage gradient. Low short circuit current is required in DC lines. So, these are ladies and gentlemen 20 advantages in HVDC system over HVAC system which is not a joke. It is a tremendous advantage.

Short circuit current, you know low lower short circuit current is required not a higher one and if in AC, the corresponding the short circuit , it is a fault issue. Disadvantages: Now, you cannot, all advantages in any system whether it is a, you know whatever point you may arise that has to be some plus points some negative points. Nothing is absolutely perfect.

What are the disadvantages? The systems are costly since installation of complicated converters and DC switchgear is expensive, even people are today working in RND, DC transformer, DC circuit breakers. So, these concepts are still being developed and no perfect circuit breaker or perfect transformer has been developed, but the efforts are on and they are certainly costlier. Now this is something which is a real disadvantage, the not only that DC cannot carry any reactive power, the converters required considerable reactive power.

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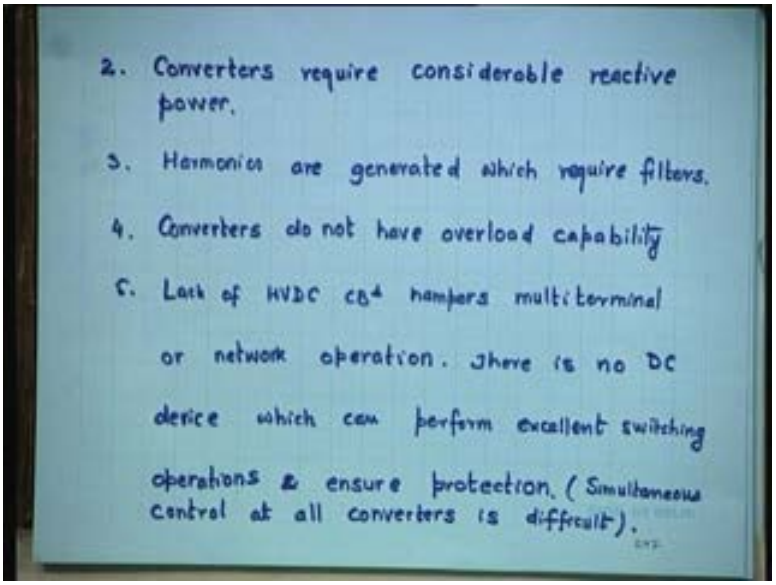

So, you have to not only supply the requirement, locally the total requirements because you cannot transmit any reactive power, but you to also supply to the converters which also need a reactive power. So, reactive power management is a real issue in HVDC. Harmonics are generated which require filters which is more and more power electronics is involved in the circuitry, it is harmonics problem.

No, reactive power is a load requirement. Only thing you to understand is AC you can transmit a part of reactive power whether you like it or not. Here zero that is all, that is the only point you have to seen in point number 2. Fourth, converters do not have overload capacity capability. Lack of HVDC circuit breakers hampers multi terminal or network operation. There is no DC device which can perform excellent switching. Why no natural zero error like AC we have? Here there is no natural zero. You to have a forced excellent switching operation and ensure protection, even protection there is a problem. Simultaneous control at all converters is difficult it is not impossible, but it is not easy.

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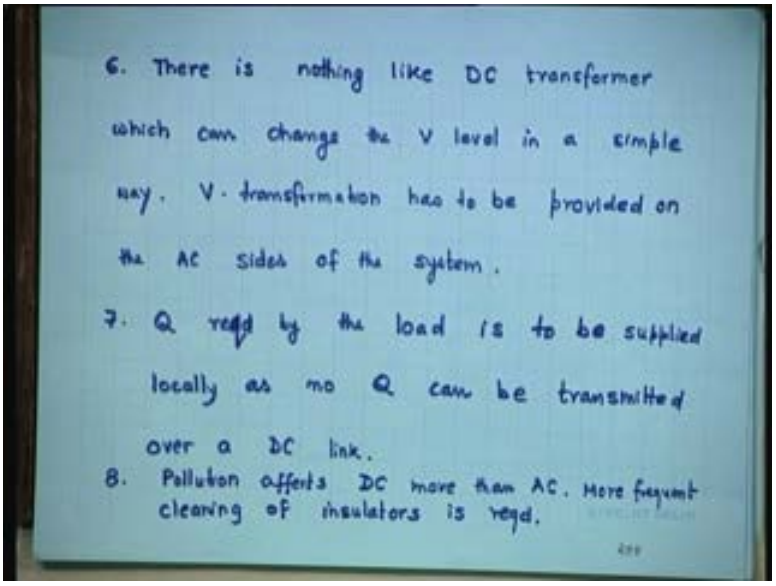

There is nothing like DC transformer as such, which can change the voltage level in a simple way. Voltage transformation has to be provided on the AC sides of the system. It will do it and then convert it. Yes, but then they are all you know extra, it is not as easiest transformer. It does not become that easy, like you need say AC or coolers, you can use is how long you go on doing like this. So, there is no cost there, but can. Seventh, the reactive power required by the load is to be supplied. This is what the point I was making again and again, locally. The word locally has to be underline twice as no Q can be transmitted over a DC line is still there is no solution to this. We have to only have a local control. Pollution affects DC more than AC. More frequent clearing of insulators is required is a atmospheric pollution. Future trends, this HVDC is a latest topic and lot of the research is going on Ph. D, M. Tech level and even in a institution like power grids, NTPC, BHEL, ABB all these you know CPRI. They are doing lot of . I do not know whether CPRI has it, you know, a test one kilo meter long transmission line in the field where you can go and do lot of experimentations.

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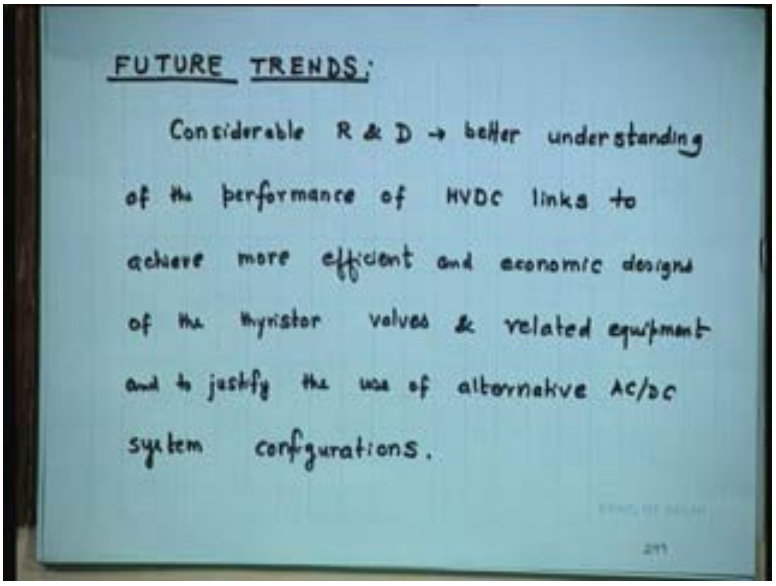

Considerable R and D is going on for better understanding of the performance of HVDC links to achieve more efficient and economic designs of the thyristor valves and related equipment and to justify the use of alternative AC/DC system configurations. So, future belongs to AC/ DC systems. Perhaps, there may not be any purely AC system in future, may be 10 years, hence, 20 years hence, how things will change. It is very difficult to predict any day, there can be break through any things can change. So, there can be quite revolution but it is in . When exactly it is going to happen, it is very difficult to predict like communication you know the cell modular. This might, this would calls cell phones have done a new revolution.

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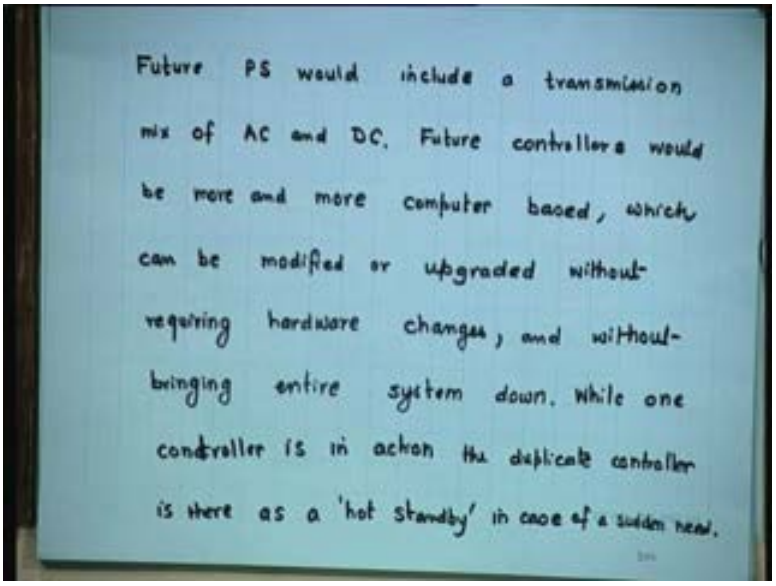

Future power system would include a transmission mix. This what I have said just now, mix of AC and DC. What percentage? I cannot said depends on needs, depends on place, depends on money and so, many factors. Future controllers would be more and more computer based that is very obvious unless should not have been there, which can be modified or upgraded without requiring hardware changes. So, mostly control is through software now and without bringing entire system down. So, it is in on load, on line connection, on line control, real time control, smart control, intelligent control, these are the things. You may have a card and that can bring you exist to a room, exist to a library, you can go to bank. It can, card can be know everything for you.

While one controller is in action, the duplicate controller is there is a hot standby. So that, if there is a failure, the system would not come to…. So, to avoid that will always have a backup. The backup protection idea will always be there. It will never go, come what may, whatever computers you may bring, but you will always fear, the man will always fear failure and that is why he is always ready to face that failure. Because failure is a probability you cannot the day when there will be no death, I do not think world will be worth living, you know.

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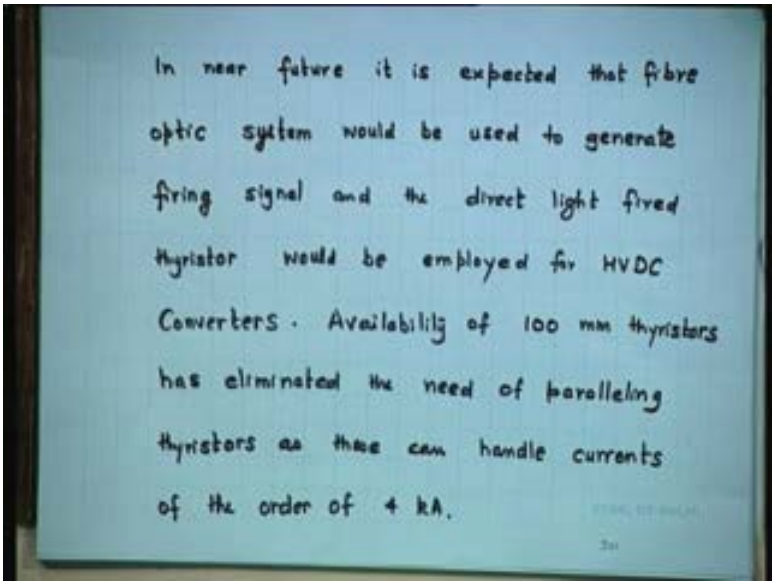

What will happen it will be… In near future it is expected that fiber optic system, everything is fiber optics now. Wireless, these are the know, he ADSL in the inventor connection sorry internet connection which no more dialup now in IIT. That fiber optic system would be used to generate firing signal and the direct light fired thyristor would be employed for HVDC convertors. Immense possibilities, availability of 100 millimeter thyristors has eliminated the need of paralleling thyristors as these can handle currents of the order of four kilo ams. So, this is the progress going on in power electronics area which will affect power systems as where. Now improvement in any area affects all the area, materials, bio, instrumentation, control, computer, building material, anything it will affect everybody. Ok, make it or you can have multiplied ten is to power something. As it is rightly saying this is the era of nano technology, nano materials everything nano.

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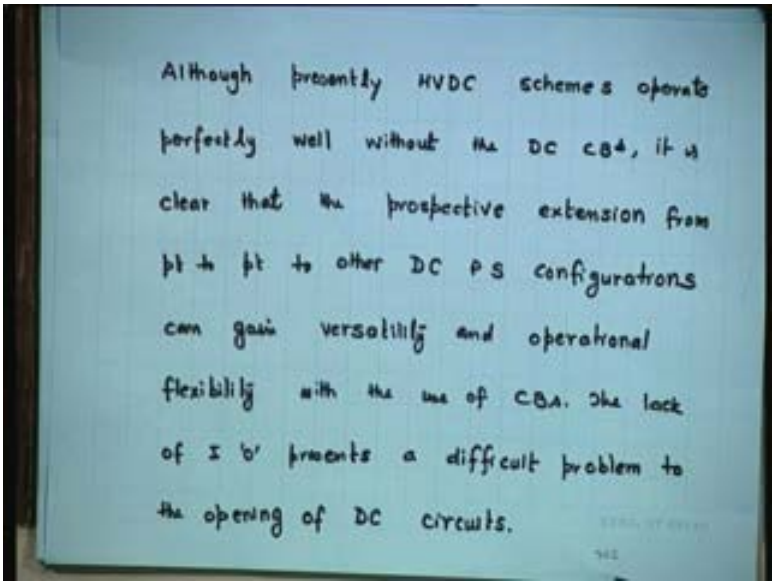

Although presently HVDC scheme operate perfectly will without the DC circuit breakers that does not mean we should not have one. It is clear that the prospective extension from point to point to other DC power station configuration can gain versatility and operational flexibility with the use of circuit breakers. If it is the more versatile, it will be more flexible. It will be better control level. It can handle more power. So, there is all the way we can gain by having DC transformer in DC circuit breakers. The lack of current zero presents a difficult problem to the opening of DC circuits, this I have already told you. This is a real problem because we do not have the natural zero occurring like AC.

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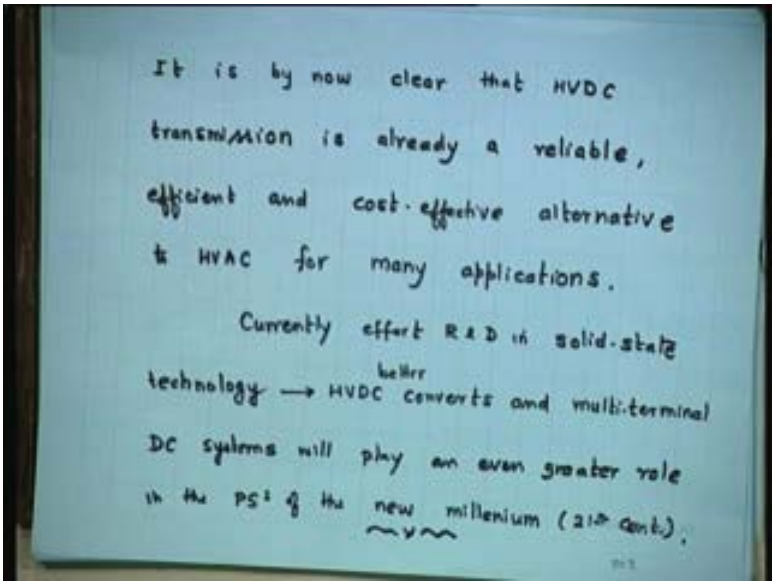

It is by now clear that HVDC transmission is already a reliable, efficient and cost-effective alternative to HVAC for many applications. I will only add that you cannot completely eliminate AC, in fact, AC will be a dominant partner in AC/DC system to my knowledge. As indeed, the conventional energy sources are in energy see. You cannot say, you cannot visualize that only solar power will supply the whole world or only wind power will supply to the whole world. Then it will always it will always remain an optimum mix and that mix will depend on a particular local place, local conditions and requirements.

Currently effort R and D, lot of effort is going on in solid state technology to develop better converters and multi-terminal DC systems will play an even greater role in the power system of the new millennium in which we have entered in 3 years back and twenty first century will definitely belongs to HVDC more than HVAC, then we have heard in last century 20th century.

I think with this, we finish the HVDC topic, anything you want to ask or any other point you want to know. Well, there are books on HVDC. So, sky is the limit. If you want to need more, the books are by, by KimbuRani and our own local Indian book by Pandiya, you can read it. There are chapters given practical in all power system books. You can read those chapters. If you are any difficulties, so far whatever you have done, you can please ask and next lecture and will be on distribution systems. Hopefully will finish that in 2 lectures and then will go to AGC that will the last topic of this semester, next week.