High Voltage DC Transmission

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Module No. #07

Lecture No. #03

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So, this lecture is the continuation of our previous lecture that is, lecture number 2 of the module 7. In this lecture that is, lecture number 3, I will be continuing our previous lecture and in that we discuss the voltage source converter based HVDC transmission system and also basically, the nickname given by ABB's HVDC light and by Siemen's HVDC plus. But, here the major difference between the conventional HVDC transmission and this is the VSC based HVDC transmission system. Here, we are using the voltage source converters and in the conventional we use the current source converters.

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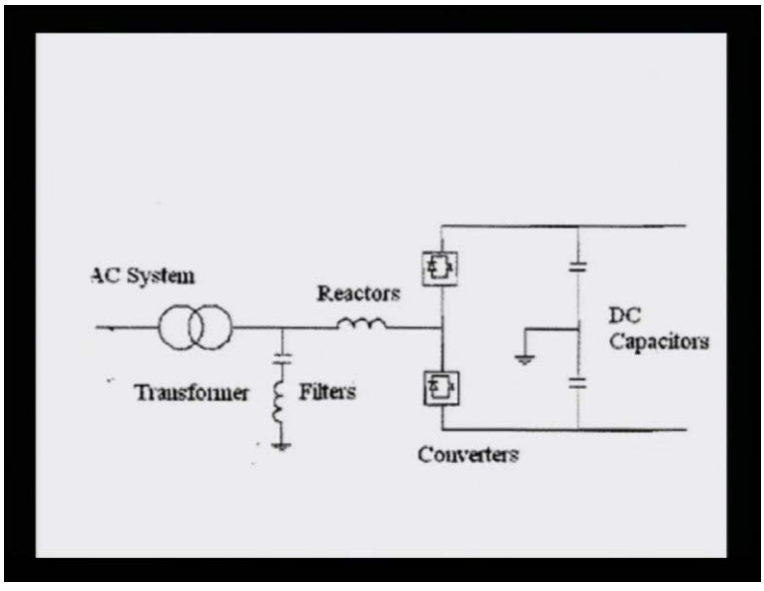

So, the diagram for the voltage source converter base HVDC system here you can find there is AC system is having this converter transformer. Then, we are having some filters to filter out the harmonics. Then, we are having the reactors and then, these are the

converters and these converters are basically based on the IGBT technology and we are using here the sound capacitors the DC capacitors for charging and discharging during that to maintain the voltage across this however in the c s c it was smooth reactors was in series with the line was used and that is why the current control we were making the voltage here the current the constant in the DC link.

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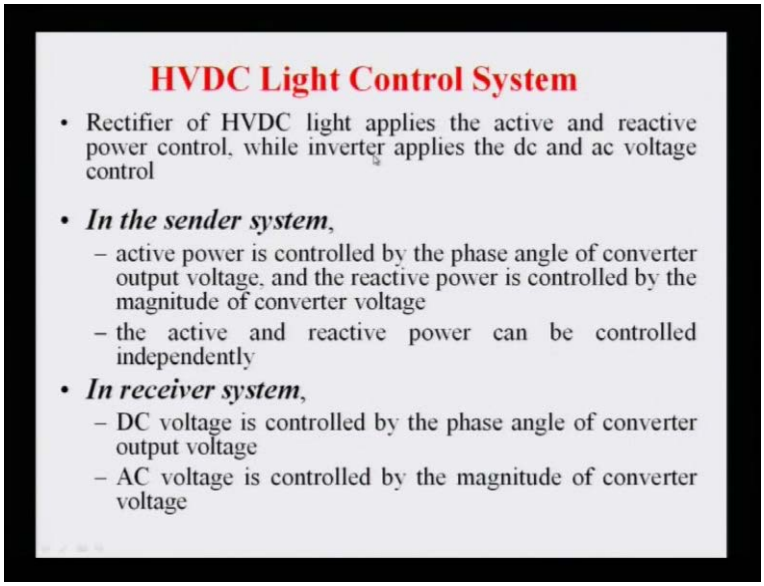

I will go for the some control philosophy already we saw the control philosophy for this conventional HVDC system. Here, for the HVDC light again repeatedly I am saying the HVDC light means the voltage source converter based HVDC transmission system and its control again you know there is there may be the two converters one will be your sending end and other will be your receiving end so the rectified of HVDC light applies basically usage the active and reactive part control while the inverter basically usage the DC as well as the AC voltage control AC of the AC side of the inverter and the DC is the DC link voltage.

So in any system you are having one sending system one is your receiving system i am not talking here the your rectifier and the inverter because there is a possibility this HVDC light can be used for the passive load than it is a sending and the receiving end the receiving may be your load and sending may be your rectifier, So similarly, we can if you are having the power you are having two converter 1 is a rectifier another your inverter so you can say the sending end is a rectifier and the receiving end is a inverter,

So in this sense we can say the active power that is a real power is controlled by the phase angle of the converter's output voltage and the reactive power is basically controlled by the magnitude of the voltage we know very well because the actives is sending end the voltage this the delta which is the phase angle basically it is the real power control however the reactive power is controlled by the voltage magnitude.

So this very well we know thus q b relation and the p delta relation very well and the same applies here as well although no doubt if we are changing the delta the reactive power also changes but, this change is very insignificant that is why we say that is the real power is directly controlled by the delta as well as the reactive power is directly related to the voltage as well if you are changing in on the converter voltage the active power also going to be changed and but, that change is not very significant.

So and another big advantage of your HVDC light control system is that we can have the both active that is a real power and the reactive power that can be controlled independently so we can control these 2 independently and that is the beauty of I g b t's based voltage source converter HVDC transmission system in the receiving side you will see the DC voltage in the receiving side we are having the DC link voltage you can see here this is your this DC here the DC voltage and the inverter is another side receiving end of that side so this voltage basically the DC voltage is controlled by the phase angle of the converter output voltage where the AC voltage is controlled by the magnitude of the voltage the converter voltage. So these are the as I said here in the beginning that say receiving at your inverter basically utilizes and it controls the DC as well as the AC voltage.

In the most detail we can see the rectifier controller what it does basically the rectifier controller consists of 4 part 1 will be your power flow control loop means power flow here we are talking about the real power here i am I want to say the real power flow control loop that is a p control loop and another we are having the q power that is a reactive power control loop then we are having the phase locked loop that is called PLL that is used to basically generate the firing pulse etcetera that is required and then we are having the pulse width modulated firing pulse firing schemes so all these 4 loops are there and they are having the control break individually and that be used for the simulation of the purposes.

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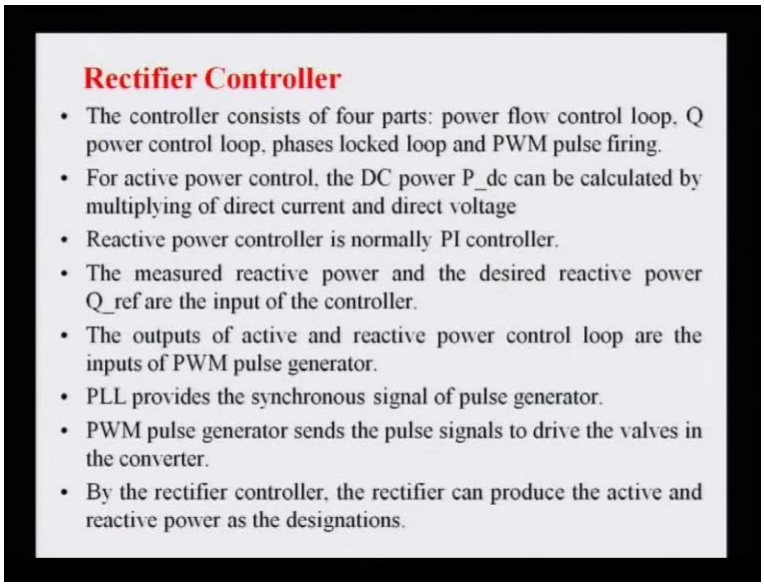

For active power here, for active power control, the DC power basically that is p DC can be calculated by the multiplying the direct current and the direct voltage it is very well known in conventional HVDC system are your the HVDC light are v s c based your HVDC transmission system the DC power it is nothing but, your this p is equal to your v DC multiplied by the I DC so the reactive power controller is normally a p I controller the proportional integral controller the p I controller are normally used for the reactive power control the measured cube reactive power and the desired reactive power are the input to the controller means another sense you can see for all this 2 points I can say our this p DC is a DC power it is nothing but, your v DC multiplied by your I DC so whenever you want to control the power you can control 1 of this (( )) quantity or both of them then you can control the p DC here I am talking for the controlling the reactive power here this is a control block here the q ref what is your reference reactive power you need and what is your measured value this is plus and minus here I can say q measured value then this is given to your controller so this is basically control block where we are trying to set means our intention is to try that this error should be minimized by this controller so we want that if this value will be 0 the error difference here this will be equal to this which is our intention.

So whatever the q you want you can fix and you can make your controller so that it can be equal to the q reference and that is basically input the difference here going to the controller so the outputs of active and reactive power control loops are the input to the

pulse width modulated pulse generator the output of this along with similarly, we can go for the real and reactive power this is a reactive power similarly, we can go for the real power and this 2 inputs are given to the your pulse with modulated pulse generator and then it is generating your firing angle and then your converter as well as your inverters here because we are controlling the real power and reactive power so this input is given to your these pulse with modulated control of your rectifier.

The PLL provides basically synchronous signals of synchronous signals of a pulse generators here phase locked loop provides the synchronous signal of your pulse generator pulse width modulated pulse generator sends the pulse signal to the drive the valves or you can say I g b t's in the converters and thereby we can control the quantities accordingly by the rectifier controller the rectifier can produce active and power reactive power as a designations means whatever you want as I said here you can have even though similarly, you can have your this controller this is your p ref means how much difference setting you are doing what is the p which is actually this is a measured value and then it is given to your controller.

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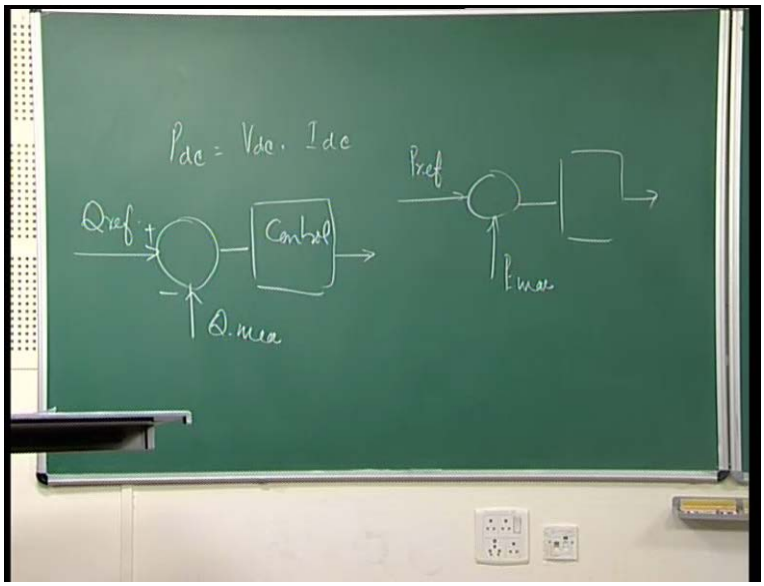

This output of this controller is as well as the output of this controller is going for the rectifier pulse width modulated scheme pulse generation etcetera similarly.

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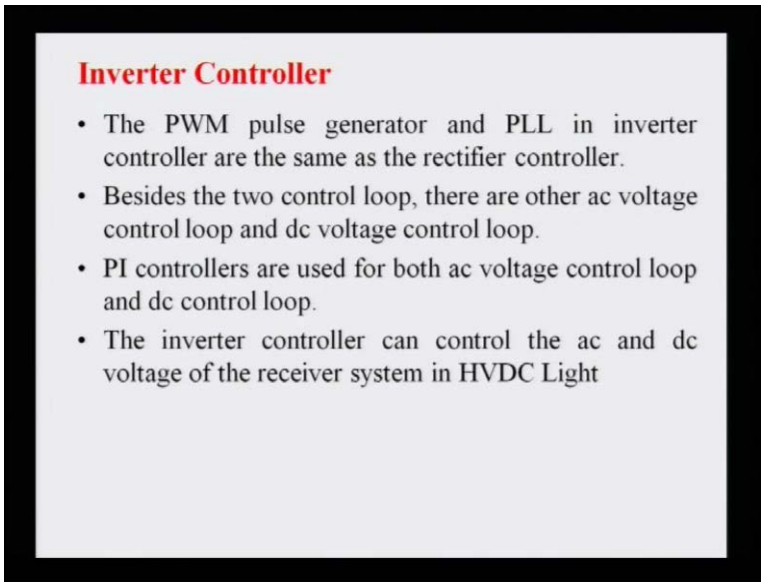

If you are going for your inverted control through in inverter side there is pulse width modulated pulse generator and the PLL in the inverter controller are the same as a rectifier because the pulse generation scheme as well as the PLL because this is used for the synchronous pulse generation both are the same similar whatever you are using in the rectifier circuit besides we require the 2 control loops here there are 1 is your AC voltage control loop and other is your DC voltage control loop whereas, there it is a real and reactive power control loop. So, in whole HVDC light scheme there is 4 control loops 2 loops for your rectifier and the 2 loops for your inverter and the inverter here it is we are controlling the AC voltage as well as the DC and that is why this is called AC voltage control loop and the DC control voltage loop.

D c the p I controllers are used here for both AC as well as the DC control loops here we are using the proportional integral controller however some people are doing some researches and some more advances or using some even the artificial intelligence based controllers along with the pi and when also people go for the other double derivatives here and they are control the people are trying to give the better and better performance the inverter controller can control the AC and DC voltage of the receivers systems because, it is receiving system in the HVDC light and this controller for use.

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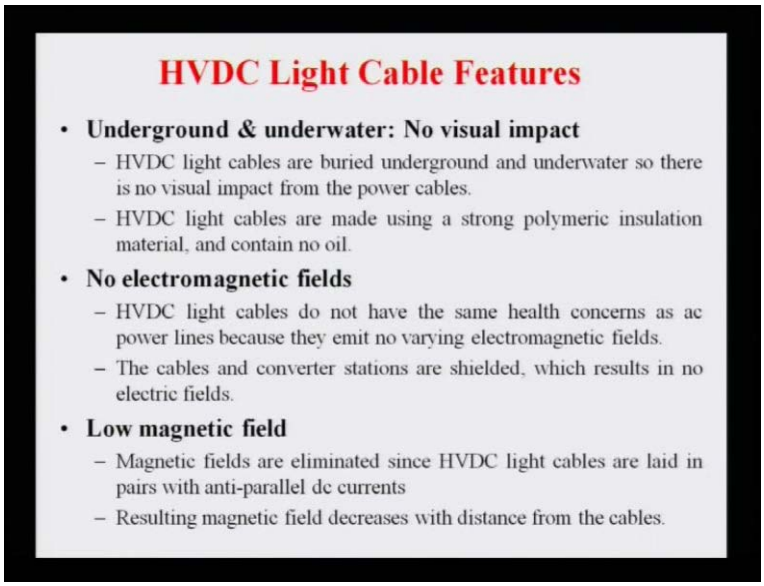

Now, one of the major advantage of having HVDC light in terms of cable because it is gives a lot of better features compare to the other cables that is AC cables and those differences that you can say the what are features are having the HVDC light cables you can see first 1 it is your underground and underwater there is no visual impact means the HVDC light cables are buried underground or underwater so there is no visual impact from the power cables no visual impact at all HVDC light cables are made using a strong polymeric insulation material contains no oil however if you are going for the larger cables you can put the some oil inside and that is the 1 of the big concern but, here it is not required you can use a strong polymeric insulation material and that will solve the purpose.

Another is said that is there is no electromagnetic field I mean to say that the HVDC light cable do not have the same health concern as the AC power lines because they emit no wiring electromagnetic fields no doubt you know the DC it also emit the field because once current is going you know the flux is around us so the magnetic fields are there but, it is not wiring however in AC it is alternating so the effect of this varying electromagnetic fields are more dangerous compare to the [reside/residual] state and also the cables and the converter stations are shielded normally and there was which results no electric field. So, electric field is almost 0 because, it is shielded and it is grounded so it is not coming out but, this your electromagnetic fields comes out even the DC case

also and this basically this is not varying so it has a less hazardous than compare to your the time varying so it is not a same health concern.

Another advantage of the DC cable this is HVDC light DC cable we are talking because it has a low magnetic field and how come this magnetic field are eliminated by having the HVDC light cables let it is the anti-parallel DC currents what we do normally your going and incoming both are if in 1 here itself then what will be at the resulting magnetic field will be decrease and it is with the distance from the cable means I want to tell you here that if your 1 cable here is going that I can say the current is going inside and if you are having 1 conductor it is coming out and this is in 1 so what will be the field of this and this will be going to nullified.

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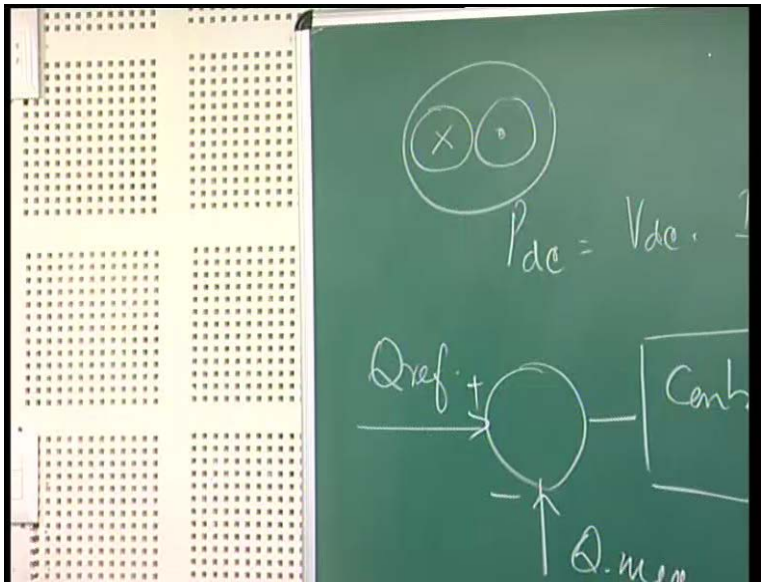

Finally, if you will say the wider range the electromagnetic field is going to be minimize so it is a low magnetic field so it is possible to have 1 conductor that is going go 1 is come so this can this field is going to be canceled by this field and that we have the minimum impact no doubt I cannot say that is the 100 percent eliminated that is why it is said here it has a low magnetic field.

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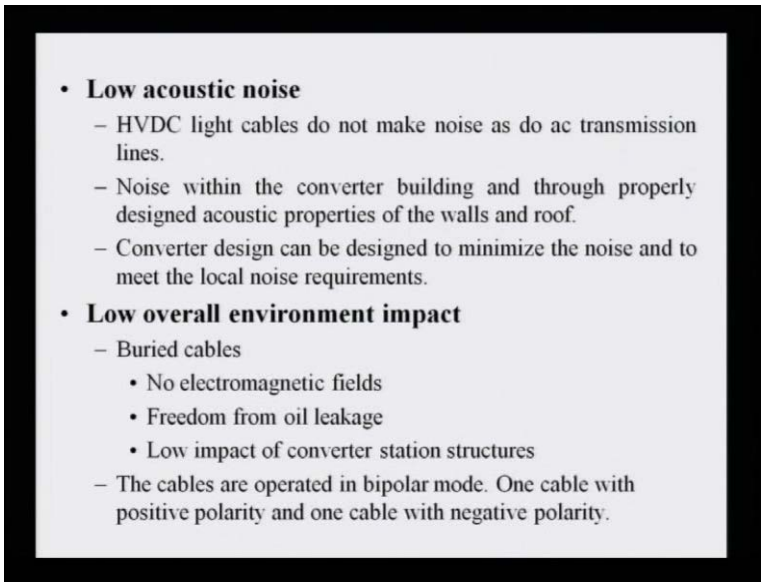

Another concern the feature that is advantage of HVDC light cable is that it do not make noise as do AC transmission lines are doing if you are having a transmission line so it is a lot of humming noise as well as the crooner noise you will find hissing noise etcetera that is not there in the cables noise within the converter building although, the properly designed acoustic property of walls and roof. Normally, we what we we noise are basically reduced if because, the converter stations are inside the building so it can have some acoustic, another property of the roof, etcetera, so that, noise cannot come outside and then we can eliminate or we can reduce that one.

The converter design can be designed in a such a way to minimize the noise and to meet the local noise requirement that can be done so that we can also reduce the noise generated by converter station itself and also by designing the roof and walls we can also reduce that noise level so it has a low acoustic noise compare to others.

Another it is said that it has a low overall environment impact mean to say that the buried cables there is no electromagnetic fields the freedom from the oil leakage there is no oil fields so there is no oil leakage it has a low impact on the converter station structure and also there no electromagnetic fields I mean to say that if it is buried inside and also if you are having the anti-parallel so minimum and also the it is impact of this electromagnetic radiation is going to be very less. The cables are operated in the bipolar mode as I said in the bipolar means 1 is go another is a ( ) conductor so 1 cable with the positive polarity

another with the negative polarity basically then it is happening this whole is magnetic field is going to be minimize.

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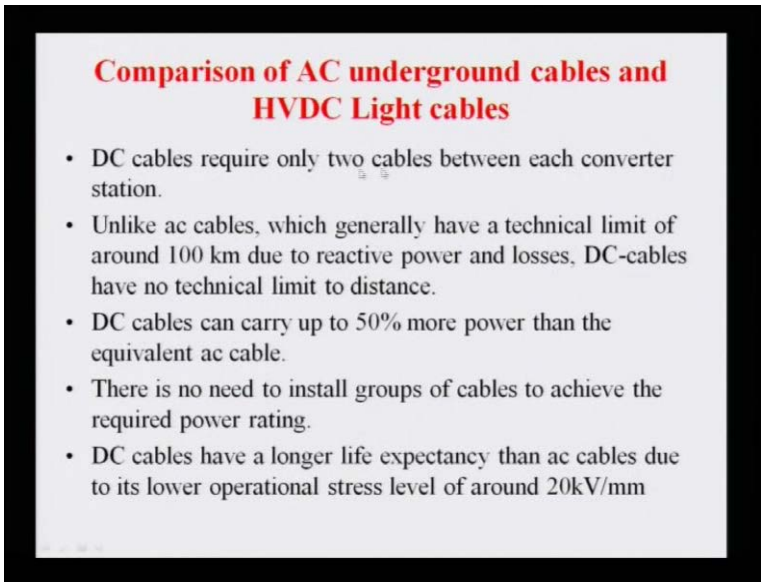

Now, here we can see now we are comparing that is AC underground cable with your DC light cables or HVDC light cables so you can see the DC cables require only the 2 cables between each converter station here 1 is the positive another negative if it is in bipolar operation if it is in monopolar operation 1 is the your go another is return conductor like that so you will be require only 2 cables even though we are going for the bipolar operation unlike the AC cable you know here in the AC cable we require 3 conductors if this 3 conductors may be in 1 cable the 3 core we can say 3 core cables or we can have the separate single core cables then we require 3 here we require only 2 cables and normally these 2 cables may be input in 1 and there is 2 core cables can be used unlike AC cables which generally have a technical limits of around 100 kilometers due to the reactive power charging and the losses that we cannot exceed this even though earlier it was not more than it was not more than 50 kilometers.

Now, it means with the help of various insulating materials and advances in those technologies people claim that even though they can construct the cable AC cables of approximately 100 kilometers and we cannot go beyond this because if we are going beyond this then what will happen even though your receiving end that is you are not taking a single ampere of current or a power the sending end current is the full load

rating of this cable and thereby if you are exceeding the receiving end power this cable will puncture and burst and also there is huge losses. So, the DC cables are having no such limits we cannot go up to its thermal limit so that is why the DC cables are more preferred especially if you are having submarine or you having the cables in the sea or you are going further longer distance. DC cable can carry up to the 50 percent more power than the equivalent AC cable means it can go up to a 50 percent more because as due to the charge in effects so it cannot load more and that is why it is more stable as well so there is no need to install the groups of the cable to achieve the required rating that is very clear that say you cannot so this no need of go for several cables so that you can achieve the same rating so that is why it is already is 50 percent higher than your AC cables so the DC cables have a long life expectancy than the AC cable due to its lower operating stress level of around 20 kilovolt per mm here you know if you are having a cable weighted for let suppose 500 kilovolt means it is a stress level is only that voltage if you are using the 500 k v a c. It means that the stress level is going to be multiplied by under root 2 because we have to see some stress at the peak value.

That is more stress and that is under root 2 times for the same voltage rating. So, the life expectancy is more because the stress is less and once stress is less then we can certainly say that your cable will have a more life compare to the AC life so the DC cables are known to be longer life compare to the AC cables for the same voltage rating because it has a DC cables DC cable has a lower operational stress compare to the AC one.

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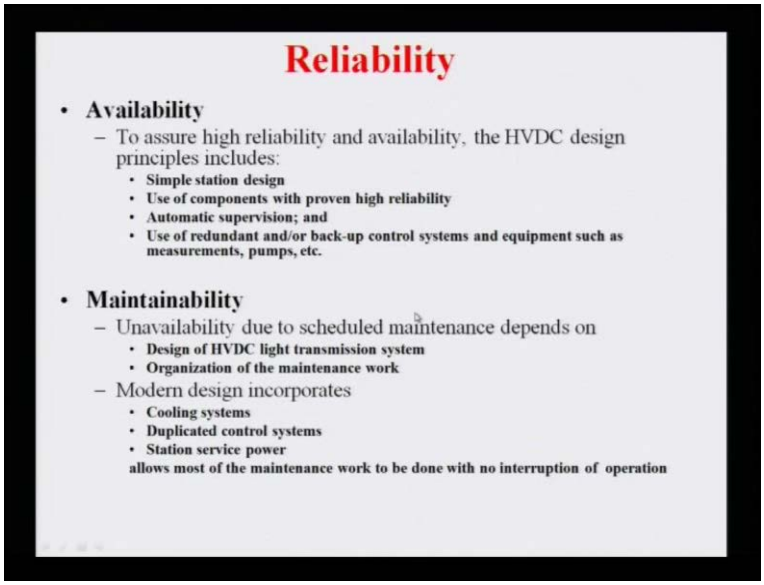

If we will talk about the reliability because that is also 1 of the big concern the major tension that is we can say based on your cost your operation your its life its reliability all the things are coming into picture and then that is, now I am talking about the reliability the reliability basically can be based and can be categorized in the 2 terms 1 is the availability another is a maintainability.

In availability to ensure the higher reliability and the availability the HVDC design principle includes normally with design in such a way that we can achieve the more reliable operation of HVDC system HVDC light system. So, it is a simple station design that the station should be very simple it should not very complex if complex is there so there is always possibility of the problems in the various elements of the system and then the reliability goes down so we want to design ours converter stations so, simple that is they should have the fewer elements and also they should of having more reliable.

The use of the components with the proven high reliability as I said if you are using the elements you should use the few elements as minimum as possible so that the design can be simple and whatever the elements you are using they should have a high reliability standards high reliability contents and then we can say on overall the system will be more and more reliable. Another is also because it is not also powerful that is manually every time you are inspecting so we should have some mechanics to have the atomic supervision and so that you can if there is some problem here and there then by automatically it should be corrected or you can know by sitting somewhere station somewhere far end you can see whole system where is the problem.

Another is to use the redundant are to the back of control system and the equipment says as the measurement pump etcetera because as I said there is a lot of heating problem is there because lot of heats are generated due to the switching here and there and the converter they are not a perfect switch they are having some resistances so there will be some active and reactive power losses in that and thereby we require some heating and for the cooling it we require some pumps and then if suppose 1 pump we are using and this fails then whole converter station must be stopped so what we do we go for some reliable operation means we shape some redundancy if 1 pumps goes off we can go for another pump and then we can start the operational problem without any delay or we can just even though continue with you help up another pump and what happens then then the later on we can repair 1 and then again put into the service so that we have to go for

the redundancy of the elements sometimes measuring device if 1 measuring device fails so you do not know what will be the temperature for measuring the device like temperature if the temperature meter fails and it show you a very high temperature what will happen then you have to stop your session.

So, we should have a second 1 so that we can verify it so redundancy and the sometime the backup control because if 1 control fails then also we need some secondary and backup control that will take care for the running operation of the system and later on that can be replace and that can be corrected so these are the basically the design principle it is not only for HVDC light but, also it is true for the conventional HVDC station so whenever you are having this criteria in your mind then I can say the availability of that station will be much more and that will be more reliable.

Another term that is the basically it is related to the maintainability in this basically you have to maintain in a such a way that easier way without interrupting without interrupting the supply or operation of the system so unavailability here due to the schedule maintenance system you know may be unavailable because if it is going for the maintenance and it is maintenance is 2 type 1 is the emergency maintenance, another is a schedule maintenance. Schedule maintenance are decided pre - in advance that you are going to maintain it in the future time, future date and time, etcetera and based on that you can operate your system in a such a way there should not be any clash or no any other problems.

So the design of HVDC light system here what we do it depends upon that how your HVDC light system is there because if your HVDC light only 1 2 zones are connected with the 1 system and once this line is hope and are it is gone for the maintenance i am sorry, what will happen then? It is possible that we cannot fit the power from 1 zone to another zone so it depends upon that is why it is and maintenance depends upon the design of HVDC light transmission system and also the organization of maintenance work so the unavailability basically decided based on this so modern design incorporates the very good cooling system we require very reliable cooling system and then also we go for the duplicated control system and also we require the station service power because sometime there suppose emergency power is gone or something some problems and the power is failed then, what will have done? So, we require some station service power that allows most of the maintenance work to be done without any interruption of

the operation means the main intention that we should operate whole system we maintain our system without interruption of the operation that is the major goal of improving the reliability of the system. now, let us see that we can go far if we are using the v s c based HVDC system in the hybrid HVDC AC system transmission system and that i am going to discuss cut.

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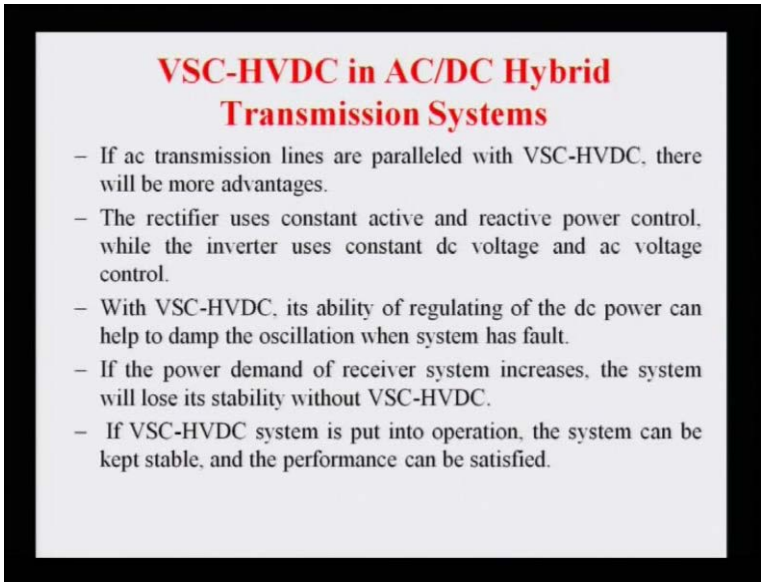

In this voltage source converter base HVDC system, if it is inbuilt in your AC DC system that it can solve a lot of problems it can improve the performance that is both static as well as your dynamic performance so here just I want to mention if a AC transmission lines are parallel with the voltage source HVDC system there will be more advantage and that advantage that I can say the rectifier usage the constant active and reactive power control while the inverter uses your DC and AC power that is a basic philosophy for your v s c based HVDC system with the v s c HVDC its ability of regulating the DC power can help to damp out the oscillation when the system has the fault what I want to say that if you are having let us suppose you are having this is your HVDC light system you are having this is the just i am talking with the single line anyway.

Now here this is your having a transformer and other things now if you are having your transformer and your are having the 2 parallel lines let suppose and then i am talking in this sense and this is also having a transformer of the different rating now what is having

this is your HVDC light this is I can say the v s c based HVDC system and this is parallel with the 2 lines if there is any problem here there is any fault in this of the line then we can control the as I said this is your HVDC light system you can control p and q independent from the rectifier side.

If there is any fault what happens the system will keep on oscillating here if it is not there if there is any fault in any of this line then there is power will be oscillating and there will be shrink and that if we are using here then you can modulate that power and that oscillations can be damp out and that is the beauty of this HVDC system here.

If power demand of the receiver system increases the system will lose its stability without this if there is a fault and suppose this line stripped and this is not there and the power demand this side there then system also becomes unstable but, if you are using this you cannot control the power you can send power from this HVDC light and this will improve basically if you are having this then it will be improving the system stability that is why it is said that is the v s c HVDC system is put into the operation the system can be kept stable along with the performance can be improve are satisfied whatever the performance you want what is your goal of the performance that can be met

HVDC light can improve the dynamic performance in the total I can say and keep the system stable for the power angle stabilities just like the conventional HVDC system and it also provides the damping for the system oscillations as already explained so it cannot damp out the oscillation if in the AC system by this we can damp out very easily for the conventional HVDC system the fault may cost the commutation failure here the major concern is this if you are not using this the option that you can have the conventional let suppose your HVDC system if there is some fault and this side here this voltage may go down and this inverter if it is a conventional based it is not a v s c then there there may be possibility there will be commutation failure and also that will may cause the your DC voltage going to down and it may be 0 and that may delay the your voltage recovery problem and then system may be you mean the its require some more time to get stabilize.

But if you are using the HVDC here the since there is no concern of your commutation failure so we can recover the DC voltage rapidly at the same time by constant AC voltage control in the inverter it can produce the reactive power and help the recovery of

the AC voltage as well and thereby we can very quickly we can restore the voltage beside and we can very your power system than makes your whole power system operation in this AC DC using the voltage source converter base HVDC is improving much better than your conventional HVDC system.

Another concern here this is we are talking you are having AC system and then you are having your HVDC light system now there is also possibility that is you are having the HVDC system conventional and then you are putting your HVDC light that it also improve your the performance of the system for example, if you are having HVDC system here let suppose I am having HVDC system here 1 parallel we are having the DC here and we are having another HVDC here let suppose a parallel to this we are having the HVDC this side this is your converter station I can say and here we are having and then we are having the transformers of course, connected with this now this is your HVDC 1 I can say this is a conventional HVDC system here I can say HVDC 2 and this is and parallel is also operating and this is connected with the 2 zones.

In this case what is happening that if HVDC light put along with the conventional system again the power system performance of whole operation of this system is improved significantly so that is why it is said that single phase to ground fault is set at the AC bus of HVDC 1 converter and the fault inception here during this if suppose you are putting some fault here at the point 4 steadily operating and the duration of this fault let suppose sustain for 5 cycles that is a point 1 second and then with this system HVDC light and without we can see if this fault occurs and you are not having HVDC light system then system becomes unstable.

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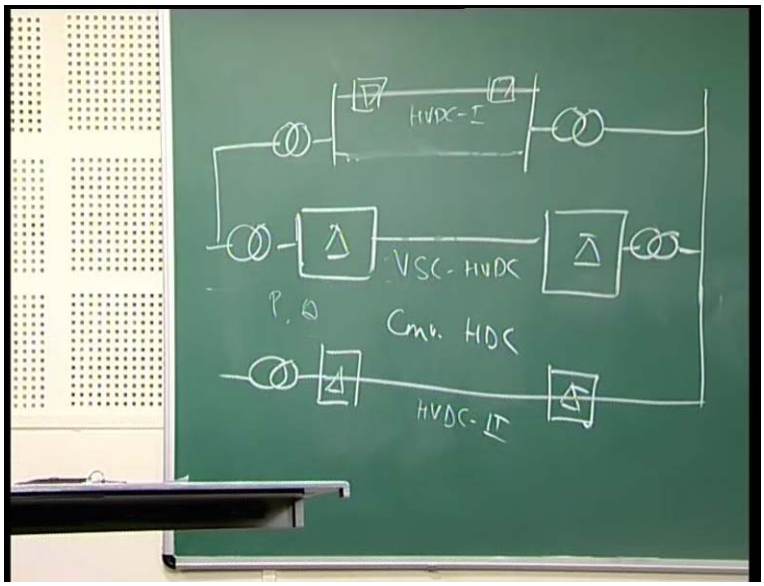

If we are putting HVDC light system here what happen then system becomes stable 1 conclusion here another without HVDC light here what will happen there will be problem of the commutation failure of the this 2 side here this is HVDC line we are talking so that also can be recovered by using the HVDC light.

So, with the HVDC light the converter 1 still have the commutation failure but, the DC voltage only decreases up to certain level that is 300 kilovolt this is operating 500 plus minus volt the HVDC 2 does not have any commutation failure and the DC voltage only decrease 2 point 8 if the fault is here there is a possibility of the commutation failure here in this fault if you across the AC side this but, this is not going to affect and the finally, with help of this if it is not there then, no doubt there will be also commutation failure but, with help of this voltage will go down because this is maintaining the reactive power injection here and then we can say that system can be stabilize much more faster.

So the constant AC voltage control makes the inverter that produce the reactive power to sustain the AC voltage of inverter side due to this HVDC light system and the AC voltage can be kept higher then point 9 per unit which prevent the commutation failure of the HVDC link 2.

Also, this HVDC light has the capability of controlling active and reactive power respectively and it can support the AC voltage and the DC voltage during the fault in the power system so in the multi feed HVDC system HVDC light can help the recovery of

the HVDC system and the prevent commutation failure of these HVDC systems so this is again if you are having the HVDC light in feed with the HVDC system that again also improving the power system performance and also it improve the performance of the DC links as well.

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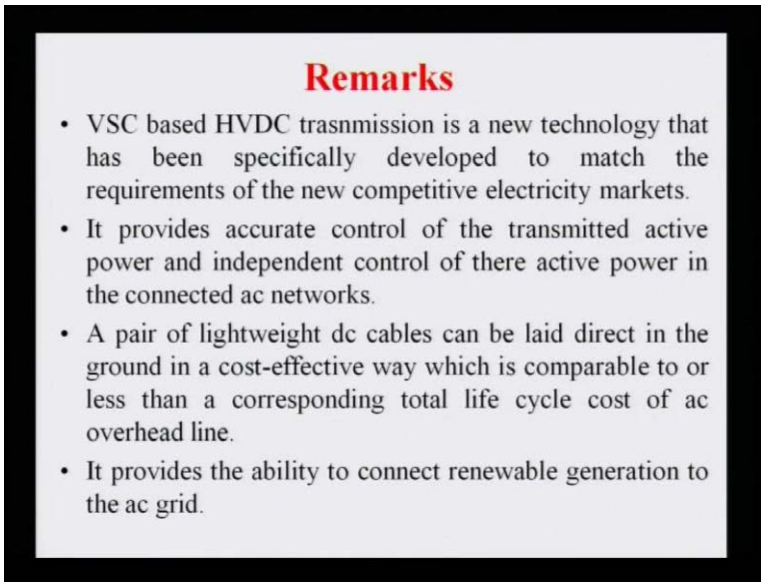

So, in the remark of this HVDC light I can tell you that the voltage source converter based HVDC transmission system is a new technology that has been specifically developed to match the requirement of new competitive electricity market. Now, the markets are appearing whereas, there is the every generator for computing with other generators and thereby this cost etcetera is basically the price based and the market is deciding the price of electricity so in that there is a lot of corridors basically be getting this congested some of the lines even though going to be over congested so what happens with the help of HVDC light or may be your transmission system based we can regulate we can control the power in the very effective way and then we can meet the requirements of this today's need that is in new competitive electricity market environment.

It also provides the accurate control of the transmitted active and independent control of the active as well as the reactive power as well and that is a big deal because we can both active and reactive power control which is not possible in the conventional HVDC system where the real power you can control but, the reactive power cannot be control

independently so a pair of light weight DC cables can be lay direct between the ground and in the ground in the cost effective way which is comparable to or less than the corresponding total life cost cycle of AC overhead line now no doubt the cable cost is larger compare to the AC overhead lines but, if we will see the life another things another advantages of the cables this cable may be even though in the that is called life cycle l c c is comparable to your transmission overhead transmission AC lines.

It also provides the ability to connect the renewable energy sources to the AC grid now this is 1 of the big challenge because now it is the due to the smart you can say smart grid initiatives all over the world now we are trying to integrate the smaller and smaller distributed energy resources into our conventional grids and those smaller normally they are the renewable energy sources may be your wind fordable tide and another bio gas another tide whatever this renewable and small energy sources are there along with the nonconventional as well like the c h p another micro turbines we are using so with help of HVDC light etcetera we can very effectively we can just integrate or connect these resources into the main grid without much determine because these energy resources are distributes in nature.

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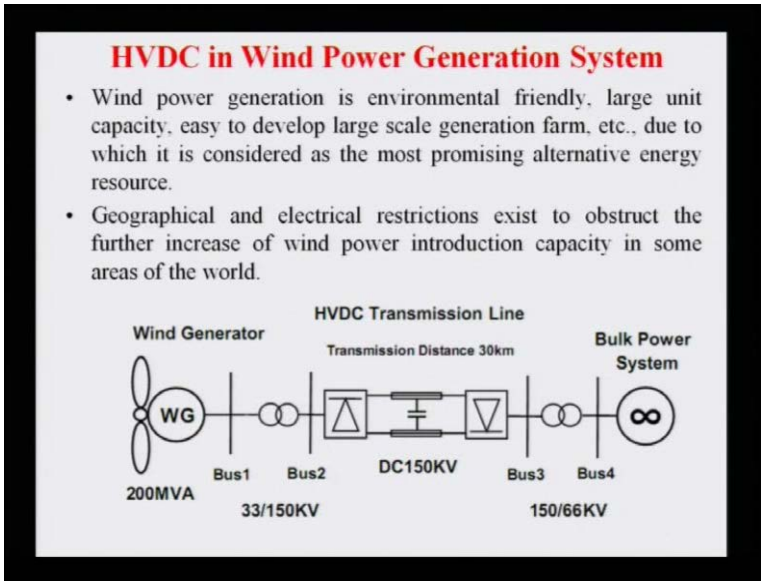

Let us see as already discussed the wind power generation that is this HVDC is going to be very popular in the wind power generation and let us go quickly because this is not the wind power generation is a part of this but, since wind powers are there so we are

using HVDC for this so I am going to quickly review the what is the wind power so wind power generation is environmentally friendly at you know it very well and the large unit capacity because now it is we are going for the larger and larger a single unit earlier it was very small in the kilowatt now we are having in the megawatt now it we have gone of the 6 megawatt and again the some of the r n d another activities I am going to be installed more than even though 7 point 5 megawatt in the future we will see it so we are going for the 1 unit is going to be larger that is in the megawatt or so and then if you are using a large number of wind units then it is going to be a wind mills or you can say wind farms so that is a easy to develop large scale generation farms and due to which it is consider as the most promising alternative energy resources compare to other one.

So now a days, only the 2 alternative energy sources are renewable energy sources 1 is wind another is a soul of our very promising nowadays and wind is 1 of them and that is more popular so already all over the world the integration of the wind power energy into the conventional grids is going to be more challenging and people are putting more and more into the system sometimes the geographical and the electrical restrictions exist to obstruct the further increase of the wind power introduction capacity in the some of the area of the world that is true why this we are talking the geographically because sometimes if you are having a location is some awkward that it is not possible to build the transmission line or maybe it is not possible to have the cable out so much that geographically and also you are having the line but, it is overloaded and another thing the network is not capable to sustain so that is why it is a geographical as well as electrical restrictions may do adjust and thereby, that may obstruct to increase of the penetration level of the wind power resources so you can see we will see some other wind power generation features but, here you can see a wind power generation which is we can say it is a wind farm it is not only 1 unit it is 1 unit cannot be a 200 m v a but, it is if we are having so many units together then it is called wind farm and that is capacity efficiency in this here it is shown this 200 m v a or 200 megawatt so it is connected the bus 1 then we are having the step of transformer and then we are going for the 150 and you can say this the DC cable because it is powerful that we can go for the AC overhead lines as well but, it is depends whether it is your offshore or it onshore in offshore we have to go for this cables because the construction of your towers and the overhead lines as very expensive.

So it is your transmission line and the distance it can be a DC cable very well we can use here HVDC light and then again step down or step up and then you can connect to this your other system may be your lower voltage medium voltage or may be h v or u h v high voltage depending upon the power injection into the system and that is allowed and you know this interconnection the p c c we called a point of common coupling it depends upon the great code of the respective country and that is a decided at which level how much power you can inject.

So beyond the some of the transmission distances I says if your distance is very far the 3 phase current network using submarine cables were no longer technically feasible and the 3 phase basically here talking the 3 phase means AC it is no longer technically feasible nor can the stability of the network concerned be assured in all control states of traditional means by rating involved.

So instead of traditional thyristors we can use the I g b t's component are now being used and the microprocessor based and the computerized control system have been replaced with your the old your analog controls and thereby we are having very fast and very efficient controllers and we can transmit power over the DC cables.

So the development basically process has given the new generation of the HVDC transmission equipment and it is branded as the voltage source base HVDC are called HVDC light or HVDC plus so the voltage source converter based already we saw the lot of advantage compare to the c s c base HVDC transmission and c s c base is nothing but, your conventional HVDC transmission system.

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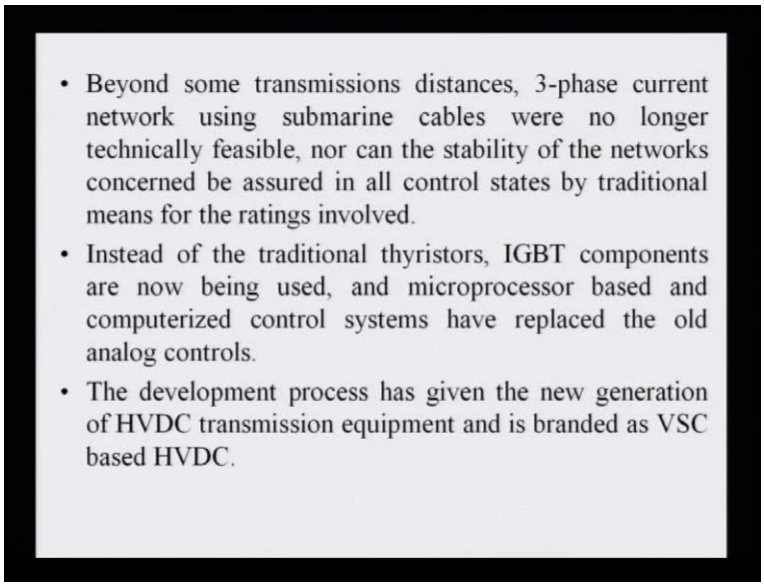

The VSC base HVDC system can be supplied up to the a unit of output of currently 5 100 megawatt and this power can be transported over long distance with the low loss using just 1 pole of the DC cable 1 wire that can be returned ground can be returned path can be used.

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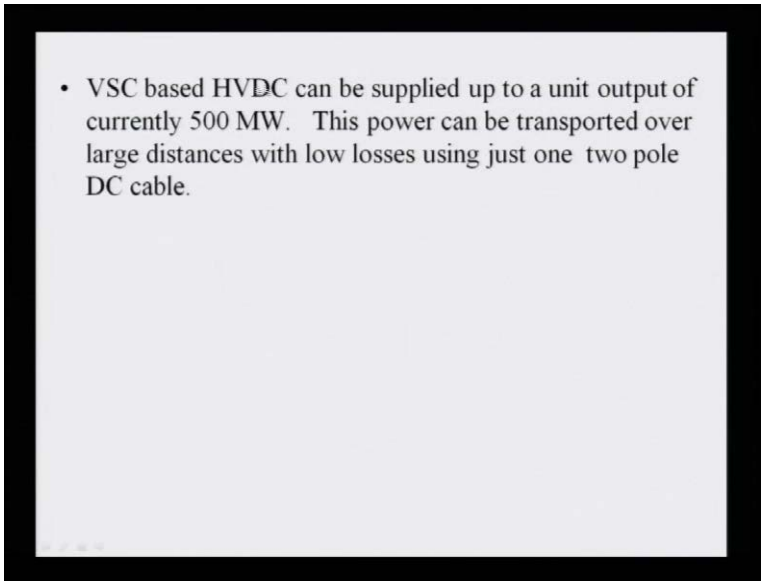

The property of wind farm here I have returned this offshore wind farm power generation you know offshore means it is some of the countries are having the sea and that sea is very shallow.

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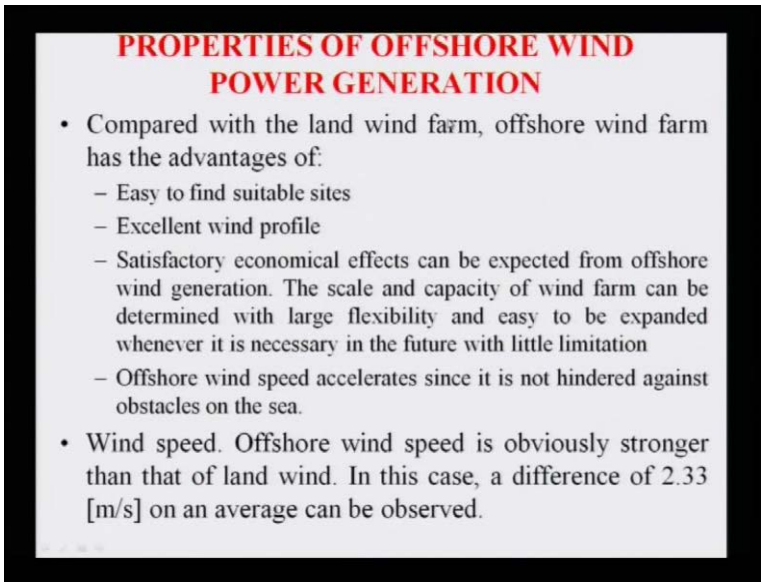

So, they can put there wind turbines inside the sea and it can go up to the 70 kilometers or 80 kilometers so that you can track the power and it has of main advantage you have to receive and collect the power and you have to send the line and thereby that can be utilize for the your load.

So compared with others here it is said in this in this slide that the compared with the wind farm that is onshore wind farm offshore wind farm has the many advantages such as easy to find the suitable sides because a land may be you are having trees you are having so many other obstacle your land is not uniform sometimes what clean wind also it is another concern no you can say here it and the excellent wind profile the wind you know you are having the wind almost longer duration compare to your land side and also you are having very constant speed that is required for the production of the power.

So, first one that we can get the site very easily because the land just sea we can use the no doubt the cost will be slightly high but, again the technology are improving for the offshore and the cost is not a big concern now so excellent wind power profile in the offshore and also the satisfactory economic affects can be expected from the offshore wind power generation the scale and the capacity of the wind farms can be determined with the large flexibility and easy to be expanded suppose you are having the certain units now due to the cost another criteria later on you can add and finally, you can transported.

So it is very easy to expand as well whenever it is necessary in the future offshore wind speed accelerate and since it is not hindered against the obstacle of the sea and that is why there is you know the speed accelerates and very easily we can just track the power the wind speed basically here the offshore wind speed is obviously stronger than the land speed it is the high speed and in this case specially the difference of 2 point 3 meter per second on average can be observed means you are having always 2 point 3 than the your land you can find it is average and then your output can be larger compare to that your land wind power stations.

Since the wind energy is a third power of wind speed I want to say that wind power or wind energy is proportional to the cube of the wind speed the energy obtained from the offshore wind is possibly 2 point 4 times more than your wind speed a land wind so whatever the power of the speed is more so it is cube of this so you are going to get more and more power but, no doubt you should not be not be confused that if your speed is very high then you can get more and more power so always but, we operate our wind turbines in the 2 speed 1 is called cut in speed if speed is less than that the output will be 0 if speed is very high then it is a cut off speed and then you cannot produce and you have to shut off your wind turbine so in between but, no doubt we can have the large energy power production and we will see something some slides and some figures in the our next presentation.

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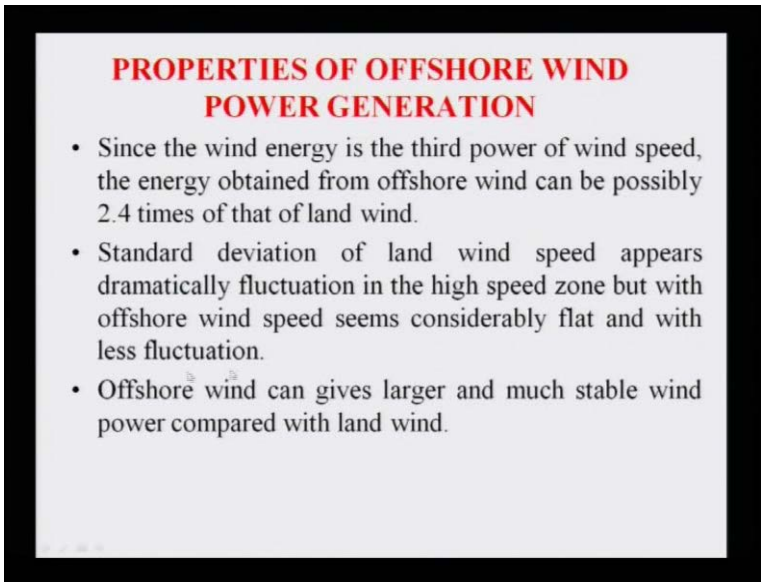

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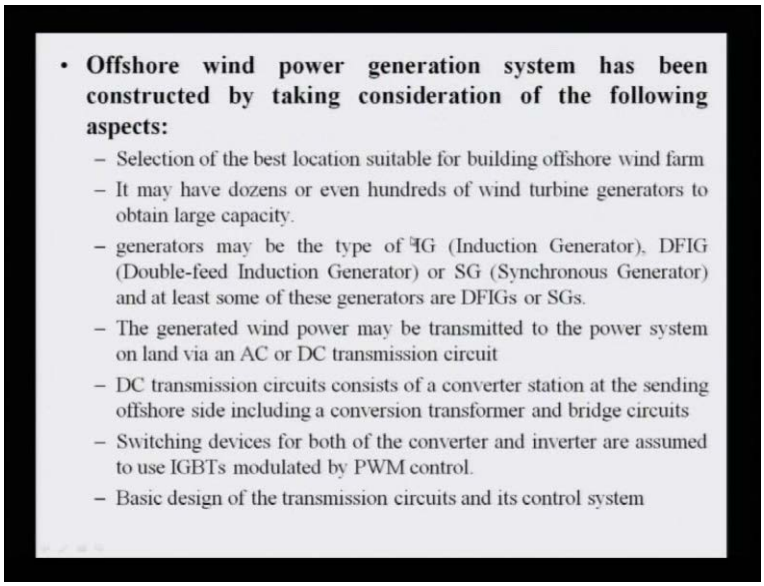

Standard deviation of the land speed appears dramatically fluctuating in the high speed zone. But, with offshore the wind speed seems considerably flat with the less fluctuation and offshore wind can gives larger as well as the most stable wind power compared to the land which you can see we can see in the our next slide basically as just I will show you can see this is wind power generator in the previous slide I also I show 1 figure but, here only I see this blade and the wind turbine but, we can say the wind turbine you have so many things you have beach angle control we are having the basically.

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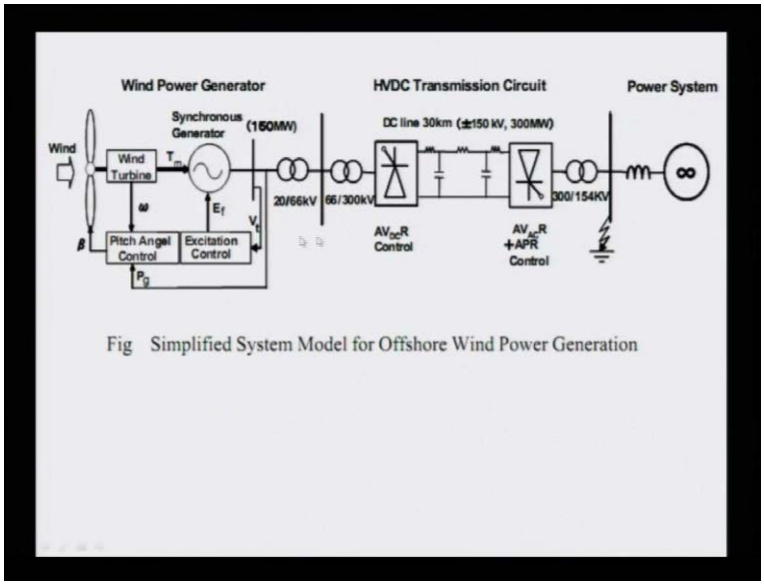

Now we require the maximum power tracking algorithms and also we are having the excitation control of the synchronous generator then here you are having so many things again it depend type of wind power generators are available you can have the induction generator you can have the double effect induction generator you can have even the synchronous generator so on these are using basically the power electronic based interface and then finally, it is coming into the picture and you can say this is your DC transmission circuit and finally, it is integrating with the grid and this is the system so it is simplified model for the offshore wind power generation which having the cable and along with your wind power system which is collecting so offshore wind power generation system has been constructed by taking consideration of the following aspects so various aspects are consider when you are going for the offshore wind farms.

So selection is the basically best the selection of the best location suitable for building offshore wind farm is to be first you have to select the good location you have to say the wind profile throughout the year so that you can see what is the cost how much your recovery is there and that must be very carefully designed.

So it may have the dozen are even 100 s of wind turbine generators to obtain the larger capacity as I said we are having still not going we can have a 100 megawatt of a single unit we are having a limited less than the tens and of the capacity and then we have to go for the so many units to be connected in series and the parallel so that we can have more and more power output.

So generator may be of type as I said the induction generator type we can have the double effect induction generator or we can have the synchronous generator normally the synchronous generator we use the permanent magnet synchronous generator so we call the p m s g and at least some of them should have the d f I g n s g because there is some problem in the induction generator you know all this is not it is not self excited however there is the d f I g n s g's are self excited and then we can do it so that is why it is said that you should have some of the units of d f I g r s g along with the I g.

If you are using the generated wind, power may be transmitted to the power system by are the land on the land by and AC and DC transmission circuit. So, if it is offshore then you should have the AC cable in offshore AC cables or the DC cable and the DC cables have a much advantages than to your AC cables so the DC transmission circuit consist of

converter stations at the sending offshore sides including a conversion transformer and the bridge circuit we also require the switching devices for the both converter inverters and normally we use if we are using IGBT then it is HVDC light and as a modulated by the pulse with control normally we use.

The basic design of the transmission circuit and its control is always 1 of the big concern and should be designed in the very proper way you can see here in this you can outline of a typical offshore wind farm wind farm you can see here we are having all this 1 2 to 10 units in 1 parallel then here again 1 to 10 and then 3 so we can say the here the 10 units 10 units and 10 units the 3 rows are there so totally we can say is 30 units are there and if you are having 1 unit of the 10 megawatt then you are having the 300 megawatt although this we do not have now 100 megawatt of unit 1 unit capacity but, you can say here again you can and 1 and 2 then it is going to be 2 suppose you are having 2 then it is going to be 10 megawatts.

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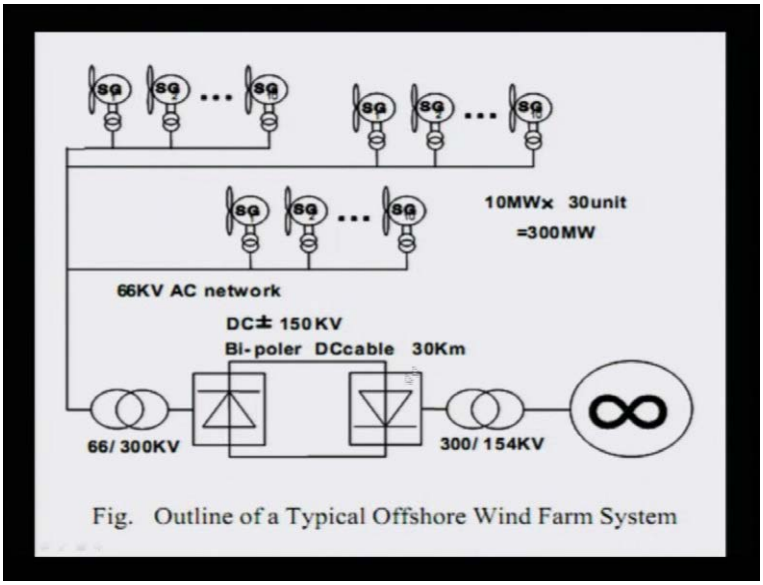

It is connected again the your DC cable and finally, it is connecting to your grid and that is the infinite here it so that you are having infinite bus basically it is showing your complete power system having huge inertia in the control side you can see the converter the control blocks what we do in the converter side you can see the dc voltage and the DC voltage reference is compared then we are having some phase angle of AC system

both are coming and this signals are given to the pulse with modulated control because we are generating here sine waves.

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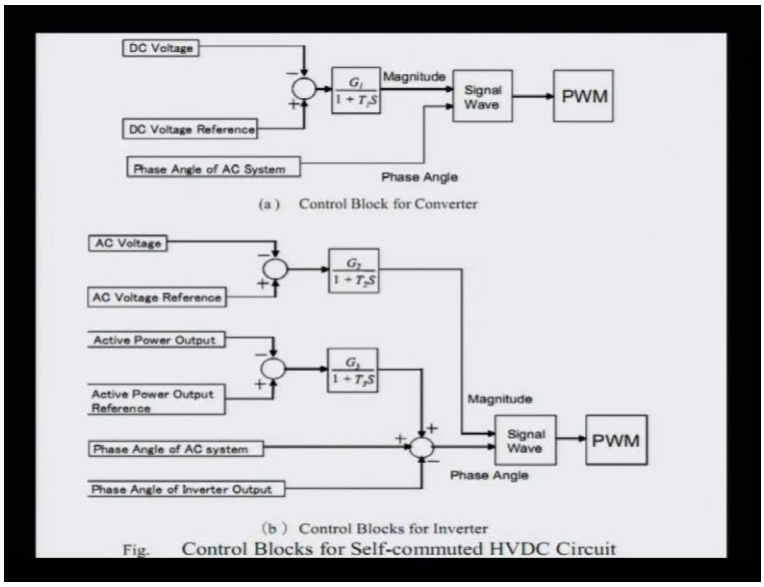

Fig. Control Blocks for Self-commuted HVDC Circuit

Similarly, if you are controlling the inverter here the voltage AC voltage is checked then we are also controlling the active and reactive power reference value here and the phase angle and the inverter output both are coming and then it is based on that we are generating the phase angle this is some schematic diagram diagrams that is normally use some people go for the different types of control structure; it depends upon the various type of control philosophy.

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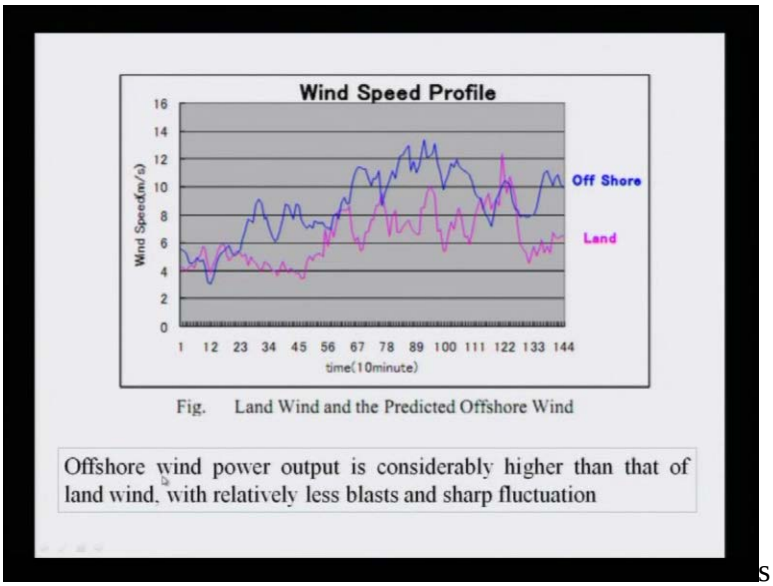

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Here as I was said telling that is you can see the offshore wind power output is considerably higher than that of land, with speed with the relatively less blush and the sharp fluctuation you can say this red one here. This is having the land wind turbine speed on the land you can say it is always less than your offshore wind and you are having more here you can see and also we will see here in this next slide you can see here is a this your this dark here black dark black and is light black here the dark black is from the your offshore all power output and you can see here is the onshore you can see up to here that is 24 here 24 to 52 this output is 0 because this speed is less than its speed of that is a cut in speed so your turbine should be off and there will be no power generated.

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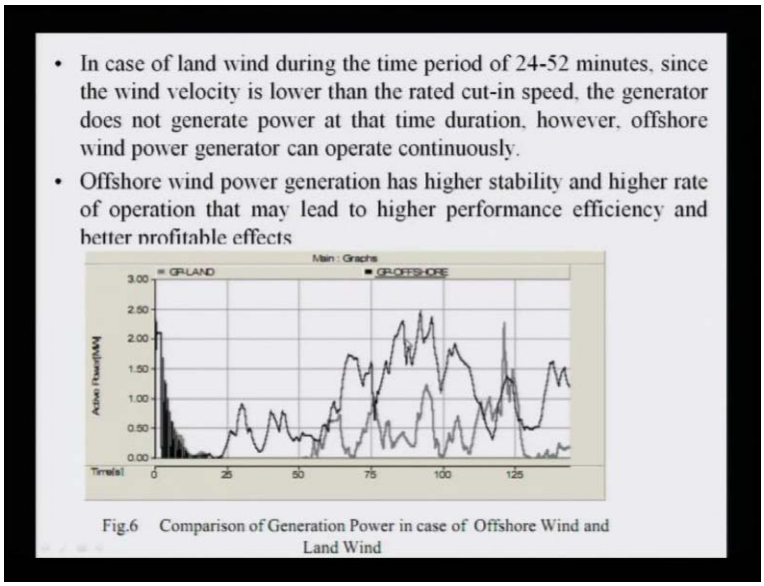

Fig.6 Comparison of Generation Power in case of Offshore Wind and Land Wind

However, you can see your offshore still even though that low speed on the land you are having some speed in the wind and you can generate some power and also you can see the fluctuation here is a huge fluctuation here compare to this land side and that is why we can say offshore wind power generation has much higher stability and higher rate of operation and that may lead to the higher performance of efficiency as well as the better profitability because you can generate larger power you can get maximum profit whatever the cost you can recover in the quick time and that is why we can say there is a profitability is there.

Here, I want to conclude that the wind power is 1 aspect that we can connect the wind power with help of your HVDC transmission system especially if you are having the offshore if you are having the onshore then it is possible that you can go for your AC transmission system that is overhead conductor that is possible and then you can construct and then you can connect with the main grid but, again if you are having offshore then it is not possible then you have to collect the power and then you have to use the cable and you know the AC cables are having lot of problem in terms of reactive power charging and the DC cables are 1 of the option that you can feed more power and also the cost can be minimized.

Among the various type of renewable energy sources the offshore wind power generation has the advantage of the large capacity excellent wind profile and the high

operational performance etcetera is possible in some of the country it is not possible that we can go for the offshore if your sea is not shallow then suppose is a very deep so you cannot your cost of the construction of a wind turbine that is a platform it is very expensive and this is not feasible.

But especially in the Europe the sea is very shallow and they are using lot of offshore wind power plants are coming farms are coming and thereby they are just injecting lot of wind power into the their grids and their basically breaking down the thermal power and using the renewable energy sources

So based on the prediction of the offshore wind data using the measure the land data a basic structure of this generation system with the self commuted HVDC transmission system is suitable self commuted here it means your HVDC voltage source voltage source converter based technology means that is HVDC light your line commuted means your conventional HVDC system so offshore wind is stronger and stable than the land speed it is very well known and this always and also the continuity and availability is much more in the offshore always you can experience this if you are going in the near to the sea you will find there is always breeze and always the wind is flowing and inside sea also have to 70 kilometer you find the constant almost speed although fluctuation is there but, it is very less compare to land side and also in the land side the speed may be with speed is there but, it is not curly or it may be some cost and something all the things are there which we cannot use our wind turbines.

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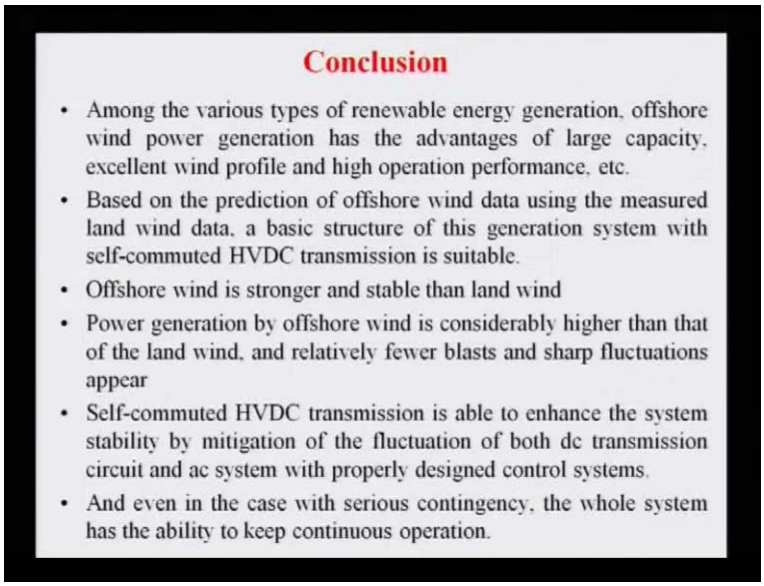

The offshore is one of the needs of the hour and it is going to be more and more added specially, if it is feasible. The power generation by offshore wind is considerably higher as I said because you are having the higher speed and then you can basically, you can generate higher as well and that is good enough. The relatively fewer blasts means a change - sudden change, sudden off and on and the sharp fluctuations are not there in the offshore. However, you will find in the land wind land or you can say onshore wind turbine system.

Self commuted HVDC transmission system is able to enhance the systems stability by meeting in the fluctuation of both DC transmission circuits as well as we are having the AC transmission system with the properly designed control schemes. Means, you are having the designed control systems; better performance can be achieved by this voltage source converter based HVDC system and even in the case of the serious contingencies means, the outages if there is some outage of any of the elements then, the whole system has ability to keep continuous operation by this system if you are having HVDC system. so, thereby you can improve the system operation as well and that is one of the option and that is very much desirable.

So, with this I can conclude this module 7 and this lecture number 3 and with this whole this HVDC system, this is the end of this lecture; end of this class; end of this course that is HVDC transmission system; thank you.