High Voltage DC Transmission

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Module No: # 01
Lecture No: # 01
Evolution of HVDC Transmission

Welcome to this HVDC transmission video course in NPTEL program, phase 2. The first lecture I will be discussing about this evolution of HVDC transmission system. First, I will discuss what are the various contents in the various modules and then, I will discuss about the first module and contents, one that is the evolution of HVDC system.

So, this HVDC transmission system course is divided in 7 modules and the first module basically, it is including the evolution of HVDC transmission system and then, in this evolution of HVDC system.

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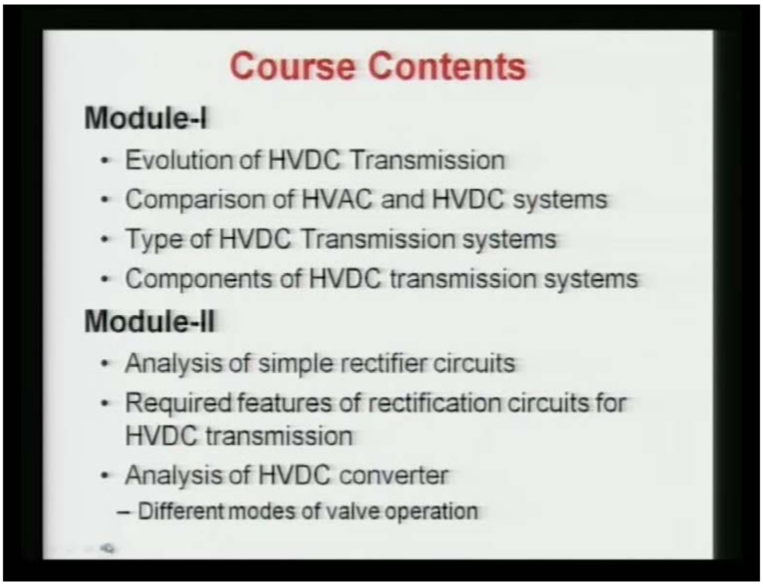

Before that I will discuss about the evolution of power system then we will see how this HVDC came into the picture along with the AC transmission system. Then, I will compare the HVAC and the HVDC systems together and we will see the various problems in HVAC system and then HVDC systems, already and also, their advantages and the system. Then, I will discuss about the various types of HVDC transmission systems; that is, various links and then in that module, the last lecture is lecture number 4, will be dedicated to the components of HVDC transmission system including converter DC lines; your trans converter transformers and other filters and snooping vector, etcetera. In module 2, it will be devoted to the analysis of the converter circuit and you know the converter it is a very important in HVDC transmission system; that is, we are having rectifier site as well as the inverter operations as inverter end. So, these converters are very important in HVDC transmission.

So, module 2 is completely dedicated for the analysis of the converter circuit and this HVDC converter circuit will be represented by the equivalent electrical circuit at the end to start with first I will discuss in this module that is a analysis of the simple rectifier circuit it may be the single phase rectifier circuit and also along with will see the 3 phase circuits then we will go for the variousconfigurations and we will see what are the advantage and the we will see the various terminologies those will be used like the DC output voltage peak inverse voltages and commutation group as well then with this terminology I will jump to the required feature for the rectification operation or rectifier circuit operation in HVDC link. So, we will see the various requirement that we required the high output DC voltage for a given input AC voltage we required the better utilization we will also see the less peak inverse voltage also we will be requiring that the harmonics should be minimum. So, these are the basically desired features and based on that we will arrive the should be the optimal configurations for this HVDC converts

After deciding the converter circuits that is the 6 pulse converter circuit will be analyzed for the different modes of the operation different modes I mean yeah basically the overlap angle I will be discussing overlap angle means the one wall or one twister is taking current and then it is a another is going to be turn on then how the current is going to shifted it is instantaneous that is ideal case then we will say the value of u that is a overlap the current shifting from one wall to another wall the values u angle if it is a less the 60 then it is mode one if it is a 60 then it is mode 2.

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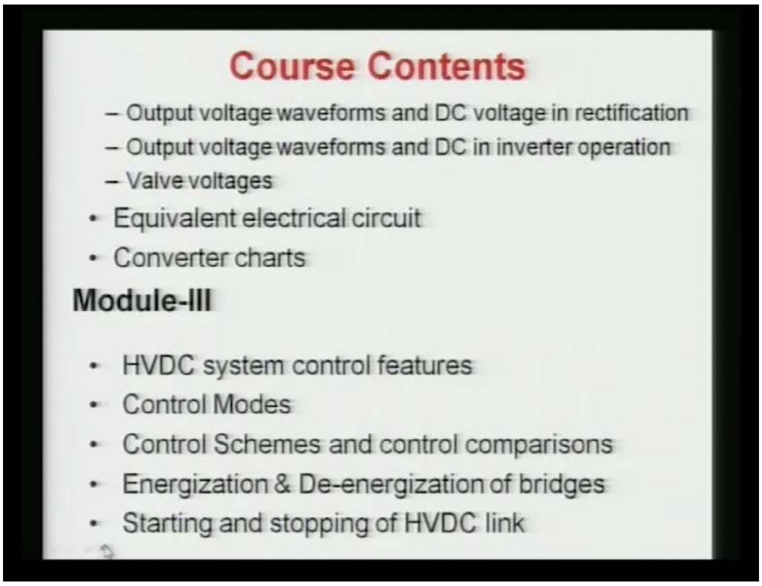

If it is more than 60 then mode 3 and 4 operations, we will say based on that the output voltage as well as the way form will change and then we will analyze detail about the circuit. So, in both output way forms of various modes we will analyze both way forms like it the valve voltage the DC output voltage currents in the phases of the transformer and also we will see this what will be the DC average value of the rectification operation and the similarly we will see for the inverter operation as well now we will also as here already have. Thus, we have also going to discuss the valve voltages this is the very important because if the voltages of the valve should be known then we can see what are the various mal-operation of the valve and based on that we will design some circuit to avoid the mal-operations of the valve.

After this once you are having the complete analysis we can form means we can substitute this HVDC link by simple equivalent circuit electrical circuit having a variable about a source and with the some commutation resistances and the line resistances and then we can calculate the current in the DC link. Another part of this module 2 is basically, analysis is based on the converter charts; we will see the converter charts. Basically, the DC variables we are having alpha delta and gamma and the beta are the DC variables. So, we are going to draw and the 2 planes; one is the DC voltage and the DC current. Then, we will see the DC variables impact and the current converter chart will be draw and another one we will see the AC variables like P and Q will be your accesses and then we will see your power factor apparent power AC current, etcetera, will be and recti-power as well and in another chart. So, this 2 variety of charts will be discussed and then we will see based on that how that we can analyze for particular current we can get the voltage u and another angles as well.

So, third module basically, now is a dedicated for the converter control in the first lecture I will be discussing about this; what are the desired features of HVDC control and then we will go for the various control modes. We will derive the control characteristic that should be the suitable for the HVDC transmission operation and then we will discuss the various types of control schemes for the firing of the valves because, in HVDC this is a main. We are, what we are doing? We are generating the gate pulses to turn on the your valves or thiesters and then we will see the various comparisons of various schemes suggested by various inventors and we will see which are the bad and which are the miss say, we are going for a demerits and the merits of the various control schemes. Another lecture will be dedicated for the energization and de-energization of bridges. If your HVDC link is having the many more than 2 bridges in converter side or inverter side and if you want to take one bridge out of operation for the maintenance other purposes then, how you are going to de-energize? How you are going to bypass that bridge? Again, once it is a repaired then, how you are going to put into the HVDC link again? So, energization and de-energization are discussed in detail in this module 3 as well. Another aspect here, even though if suppose your HVDC link is down for some maintenance or some problems in the fault in the DC line we have to start the HVDC line then how to start it. So, the starting concept will be discussed and also if you want take whole HVDC link down for any maintenance another repair or any other purposes then what should be the stopping way procedures is basically discussed in your starting and stopping of HVDC link.

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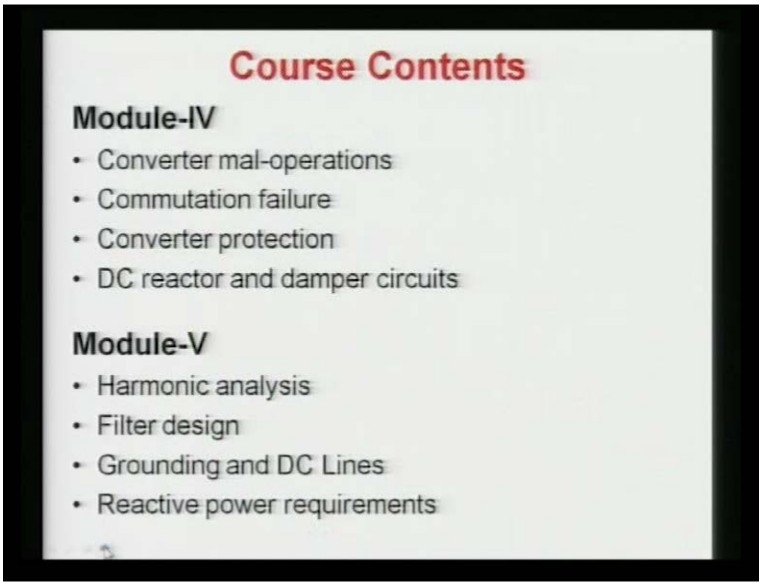

In module 4 basically, it is dedicated for the protection as well as the mal-operation of the converter circuit. So, the malconverter circuit maloperations the various mal-operations in the converter circuits are discussed including your ark back ark through misfire commutation failure, quenching all will be discussed in detail along with the web snips of your output voltage; other of the valve voltages but, the commutation failure which is only occurring in your inverter side. It is a very frequent phenomena; it is discussed again in detail for the single commutation failure or it is a double commutation failure. Single commutation failure means in one cycle it is only one commutation failure if it is happening more than one, it is called multiple commutation failure. So, in this module the first and second commutation failures are discussed and we will see what will be the voltages; what will be the impact of the wall voltages, etcetera will be analyzed. Then, we will see how to protect overall converter circuit; that is we want to protect the converter circuit; we want to protect our HVDC lines. So, we are going for the over voltage protection; we are going for the over current protections similar to your AC current. Now also we are going to have the differential protections for the checking the link differential current. So, the complete inverter as well as your rectifier side system protection is discussed.

Another discussion here is this smoothing reactor. Basically, the DC reactor I am discussing and this DC reactor is if it is used to limit the rate of rise of voltage or current. So, what will be the inductance values? This is basically it is discussed and the one problem is also solved. Then, in this module as well the damper circuit because, we are having the various type of dampers like the voltage oscillations. If they are there then we are going to have the inner dampers if you are going to have the current oscillation if you are going to have a line oscillation. So, we are having the various r c and r l cider dampers are used and they are discuss in detail in this module.

Module is basically dedicated to design the various aspects because, we have to design the filter circuit we have to design the grounding and the DC lines. So, to design the filter we have to analyze the whole converter operation and it is. So, we want to know what the various types of harmonics are. So, various harmonics that are a characteristic and harmonics are discussed and analyze for the 6 pulse operation as well as the twelve pulse operation of the HVDC link and based on that we are going to design the filter circuit. So, we will see the various option for the is a tune seal filter circuit or it is a bypass band pass filter circuits design. So, the design of the filter will be done in this Another aspect of this module that it will be also analyze the reactive power requirements and we will analyze even the filter circuit if it is designed for particular harmonics to provide the minimum impedance for that harmonics. But, this filter circuit provides the reactive power support to the converters for the fundamental components and that will be analyze and we will see the requirements of your reactive power.

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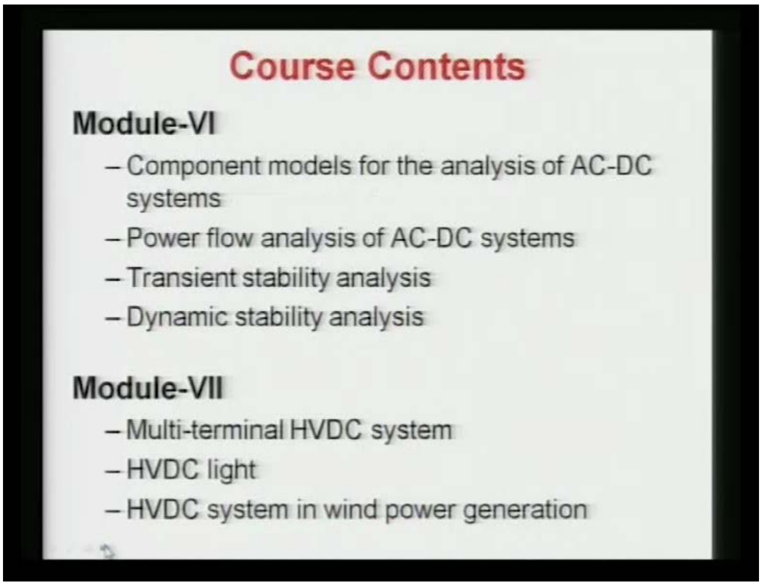

In your module 6 is completely dedicated for the power system analysis aspect. So, here first I will model the various components of ac-dc systems including your DC the base powers etcetera, for AC and DC completely we have to match the AC base powers and the voltage and also the DC base power as well the voltage and then we will model them in detail and later then we will go for the AC DC load flow. Various techniques are already suggested that is a sequential basedAC DC power flow analysis or it is a elimination based or unified schemes they are discussed much in detail in this module 6

After the modeling, this module also will be discussing here. The various stability analyses like the transient stability analysis as well as we will also discuss about the dynamic stability analysis in this module. The last module that is module 7 is basically dedicated for the diverse aspect like new concept is arising this HVDC light is basically using the transistor technology. It is very fast as well as the communication requirement is reduced it has a various advantages. So, that will be discussed; also, we will discuss about the multi-terminal HVDC link because till now up to the module your module fifth I discuss about only the 2 terminal HVDC. So, in this 7 will discuss the aspects problems and what are the advantage of multi-terminal HVDC links then the last lecture will be dedicated for this HVDC system that is used for the wind power generations in the wind generations you know the wind form may be located very far from the actual load sent is it may be even though in outsource. So, it may be see, we have to see how this HVDC system is useful and a beneficial for the wind power and the green power generation in whole power system. So, these are the brief course contents of this HVDC transmission system video course that is NPTEL phase 2.

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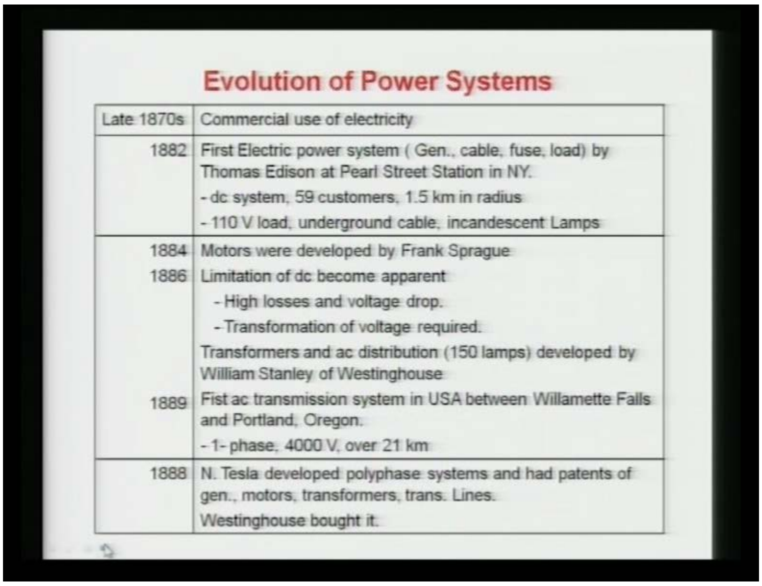

Now, as in the first part of this lecture I will be discussing the evolution of the power system then we will move that and we will see how the HVDC system came. So, to start with you can see the slide here the commercial use of electricity; basically, started in late 1870s, but the first power system was developed by Thomas Alva Edison. It was at a pearl street of New York station and it was commissioned and operated in1882.

This was the DC system it is surprising, but it was the low voltage DC system, but how about this course is devoted for the high voltage system. So, that time the high voltage DC system was not possible because the several problems like your generations because it was the DC generators it was used and also to transmit the power the insulation another problems were there. So, this power station, the first electric power station which was the DC it was consisting of a DC generators then it was using cables fuses were use for the over current protection and it was providing the load and this load was nothing, but it was simple incandescent lamps were there the simple bulb loads were there and it was feeding to only 59 customers in the radius of 1.5 kilometers. So, it was a small system, but it was a complete in the sense and it is said the power system because a power system should comprise of generation transmission as well as the distribution. So, it was consisting all. So, that is why it is called it is a first electric power system.

It was the DC system because, the DC generators were used that time AC power was not even though invented. So, the DC system was there in 1884 the motors were developed by the Frank Sprague and with the addition of this motors in the DC system make the electricity more and more useable and people were more preferring this electricity because, now for using the electricity only for the lightning propose is not very much appreciated. But, the using the load you know the motors load and these motors loads the mechanical load you can just connect it that means you can achieve various applications in normal human life you can say.

So, the motors were added in the system but in 1886 the limitation of DC system is becomes apparent with the 2 aspect that one is the voltage drop and high power loss. To minimize this we require some transformation of the voltage which was not possible by the DC system. So, people were starting thinking for the new one. At the same time, the transformers and the AC distribution system of one 50 lamps developed by the William Stanley for the wasting house was developed at the same in 1886 nearby. So, the limitations of the DC was arising and the AC and DC system, this started arguing to each other because the DC system was advocate by the Thomas Alva Edison and AC system was advocated by the wasting house because, this wasting house purchase all the patents of the AC we will see the later on. So, this is the first AC transmission system was basically commissioned and operated between the Willamette fall and the Portland. This was the single phase it even at that time the 3 phase AC was not invented and it was having the 4 kilo volt and it was feeding the power over 21 kilometer.

It was bigger because, AC system DC system was not feasible; because this much distance if you are going then you are incurring more loss and high voltage drop. So, in 1889 the first AC transmission system was operated in 18 before that even the teals this Nicolas Teals developed. So, many poly phase AC systems basically, he had the patents of generators, AC generators, motors, transformers, transmission lines, etcetera and all these patents were basically purchased by the wasting house. So, the wasting house now started developing the AC system - AC power system. I can say and Thomas Alva Edison always advocated for the DC system. So, the parallels AC and DC systems were existing for the different pockets of the all over the word and the fight started that whether we should go for the AC system or the DC system and due to the limitation of the DC system, AC won the race and DC system slowly and slowly faced out, that is here already.

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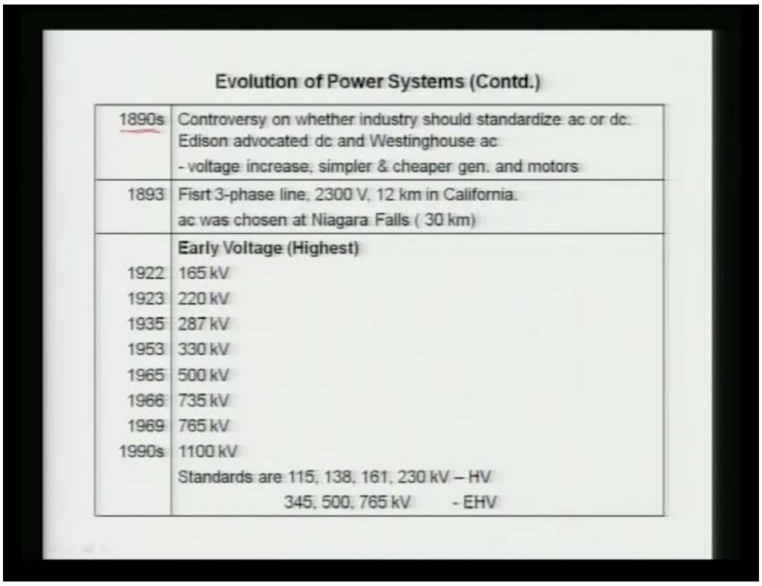

In 1890 it is said the controversy whether the industry should waste and raise AC or DC edition who advocated DC was favoring the D C. However, the wasting house who had the lot of patents of AC system advocated for the AC systems. So, AC basically becomes more and more feasible because the it was possible to increase the voltage by the transformer actions and also it is a simpler in terms of generation and the motors and it is a rugged and very versatile and then it was the DC system was slowly and slowly the dismantled and the AC systems becomes very popular.

First 3 phase power system that was operated here in 1893 and the voltage was 2 point 3 kilo volt, it was in California. It was basically chosen for the Niagara fall which is 30 kilometers away from this Niagara falls. AC system becomes very popular but, the voltage at the beginning very less due to the various problems in the design and availability of the insulating materials due to the various advancement in the insulating materials the voltages you can see now is a various voltages keep on increasing it was 1992 it was 165 k v in 1923 it went to 220 k v in 1935 it was 287 k v and in 1953 is 330 and so on. In 1990 it went up to 1100 kilo volts the transmission level.

Similarly, there are also improvements or you can say new developments in the generation side. So, we also increase our generating voltage up to 33 k v. So, it was and also in terms of megawatt more and more power generation for the single units. So, the standards basically adopted EHV system when it is more than 300. Then, it went through

EHVsystem high voltage and it is less than 300 then it became high voltage that is the various voltage levels.

Now, these voltage levels are the different for the different countries and the each country are having the different sets of the various voltages because they have to use transformers. So, it is not that we can have the n number of the transformations and the volt transformers. So, all the countries they standardize the various voltage levels to have the interconnections because the interconnections also had a lot of advantages when we keep on growing the AC system DC system AC system sorry and then we keep on interconnecting them to make better and better reliability and also to decrease the cast and. So, many other advantages as you know the interconnections advantages.

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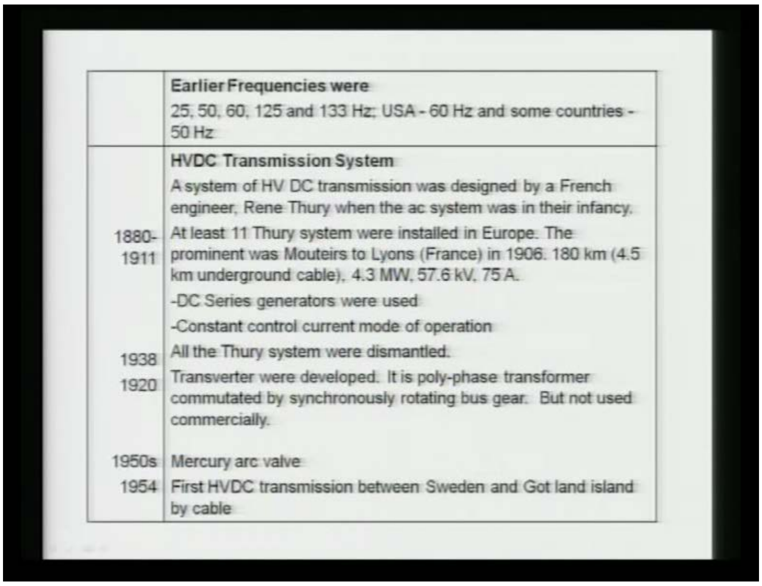

To have the interconnections, we know require the single frequency of the system in the beginning it was witnessed that various frequencies were existing all over the word and now due to the interconnection problem it was realized that there should be the single frequencies and then the 2 frequencies after that were standardized like the 60 hertz came to the us and the Canadian countries and the 50 hertz came to the Europe and the Asian countries. So, we are operating our system at the 60 hertz and they are operating system at the 60 hertz.

Now, here if you will see the HVDC transmission system because I just explain how the HVAC system how it is grown to 1100 k v no doubt the beginning the DC was there then there was a limitations of the DC was experienced then AC people started thinking out the AC power system, but at the same time this people will also started thinking if any how we can increase the voltage. So, that we can have the minimum loss and also the minimum drop. So, people are started thinking and developing the various systems. So, the HVDC DC transmission system first designed by the French engineer that is a renethury here when the AC system was in their infancy because AC system was also developing slowly and slowly. So, between 1880 and 1911 at least 11 theory system because the theory system was given based on his name renethury was installed in Europe and the prominent was the Mouteirs to Lyons in France in the 19 106 it was 180 kilometers and I mean having 4.5 underground cables it was only carrying 4 point 3 megawatt power, but the voltage level was 57.6 kilo volt and the current was 625 MPH the main features of theory system was that it was having the DC generator and this is a series DC generators and it was operating at the constant current control mode because the current control here the current in this DC system here the current was fix; however, we will see in the AC system the voltage is fix and the current is changing depending by the load, but in this DC system he preferred current should be constant and the voltage changed to control the power and feed the power, but in here 1938 all the theory systems were dismantled because there was several problems in this system because the safety problems was once concern.

Also, there was another problems here that we are adding the more and more series and data's there was maintenance the cost other problems were experienced and at the same time the ac development was there and it was felt that AC system is the better than the DC system even though it was also witnessed that the tour in 1920 the transverses it is a similar type of mechanical converters were developed and it was using the poly-phase transformer commutated by the synchronously rotating bus gear, but it was not used commercially it was only used the for the experimental another purpose.

So, once the theory died basically then whole the theory system was vanished and the people started talking about only the AC system. So, till 1950 when the mercury arc walls were developed and the designed then before that we were having only the AC DC AC systems with the development of the mercury arc valves it was possible to convert the AC to DC. So, in 1954 the first HVDC it is not DC it is high voltage DC transmission between the Sweden and the Gotland is land of the Sweden itself was connected by the cable it was the 7ty kb approximately 7ty kilometers away and the AC cables were not. So, feasible. So, it was decided to go for the HVDC transmission in terms of cable in the sea and mercury arc valves were used. So, this was the beginning of again starting to think of HVDC system now the question again arise why people started to think for the HVDC system because there was. So, many limitations HVAC systems. So, we will see in the next lines.

So, in AC systems here before this end this I will discuss this what is the problem in HVDC and AC systems in detail basically in this AC system the major problem in the AC system is that we do not have the power control.

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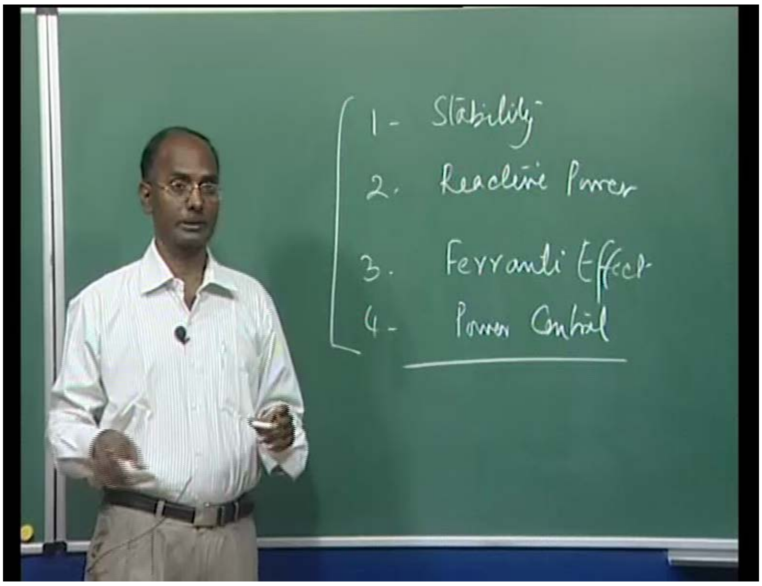

I can say the stability problem stability is the one concerned if you are going more and more power transfer. So, this stability issue another is your reactive power requirement then third is your the Ferranti effect Ferranti effect also it will be discussed the Ferranti effect is nothing, but your receiving end voltage sometimes become higher than your sending voltage. Specially due to the charging or the capacitance between the line to ground and the line to line and 4 that we do not have the power control facility power control. So, the power control is not possible here. So, this is the one of the big problem in the AC systems in awhile your AC system if this is your control is not possible because, nowadays we are also thinking to be provide the AC control if the AC control is possible then we can operate our power system in a much better and in the efficient manner.

So, these 4 are the major reasons for people are start to thinking to go for the DC transmission system these are basically problem which I am discussing in terms of the HVAC transmission system. So, to avoid these the DC transmissions were there because the reactive power you been see the first HVDC transmission system which came in the Sweden and the Gotland island it was basically due to the charging because the 7ty kilometers cable it was at that time it was not feasible 7ty kilometer. So, then it was realized that we can go for the DC cables and these DC cables were feasible. So, then what they did here? This system you are the Sweden and this was your island and they connected by your the DC system here and they operated and this was your cable. So, this first HVDC basically, your them for was developed to reduce the charging effect of the system.

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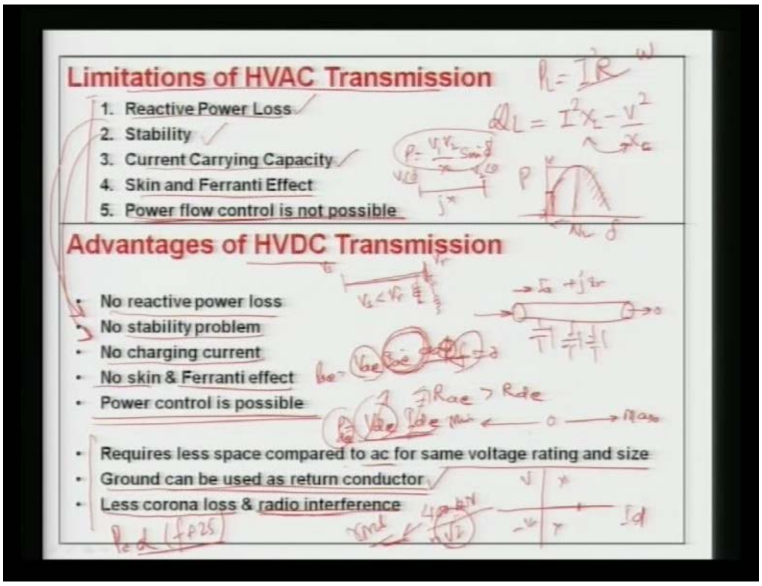

Here, in this you can also see that is I have summarized the 5 major problems limitations are HVAC transmission system that is a reactive power loss the stability concern the current carrying capacity that is the charging skin and the Ferranti effect the power flow control which is not possible in the AC system.

Reactive power loss we know it very well because the reactive power loss can be define that is a Q loss you knowreal power loss it is very well that is I square r here whatever the resistance and that is flowing in this your line it is having resistance it means not only line in the transformer as well. So, in all operators if are having the resistance r and current is this. So, I square r loss that is it is basically in watt it is your real power loss reactive power loss basically some people talk about here I square into x is the reactance of that element, but it is not only this loss because we are having another component that is a it is I can say x l it is a reactive component that is a inductive part and we are also having some charging part. So, that is basically I can say v square over x c here that is the capacity part. So, the reactive power loss is basically total of the that reactive power consumed in the element and some of the elements they generate the reactive power. So, the total sum of this is treated as the reactive power loss.

And this concept is only happening in HVAC because this x components that is here is only is occurring in AC and the DC only the resistance is there. So, this reactive power loss has no impact because this does not exist at all in the HVDC transmission system. So, this is does not this Q loss does not arise and thereby why what happens if your line which is carrying the current of both active and reactive components. So, here you can see if we can there is no reactive component though line can can carry both active power and then we can improve the performance of the systems.

Stability is the one of the concern to explain the simple way of the stability here you know this p angle this curb here this is a delta this a power that is a flowing between the 2 notes of the element. So, here this is the maximum power that at the delta pi by 2 the maximum power that can be transported through that element we never go for this always we go for the lesser one due to the various reasons if there is some disturbance then we go the unstable reason this is unstable area and this is your stable. So, we have to operate our system in a way that the power flow in that line should be less than here this is a p max and here this is 0 in between. So, normally we operate our element that angle different between the 2 adjacent note not should exceed more than 20 to 30 degree. So, that whenever there is any disturbance we can go here and our system cannot lose a synchronous.

So, the stability concern here basically this expression is the p is derived your v one v 2 by x sign delta here and this is basically the 2 elements this is your delta if this is angle 0. Here, I can say v 2 here v one and this is your x of the line. So, the power flow can be simplified if you are assuming this line is loss less I can just get this power flow and we will see here we can go for the minimum delta. So, this stability concern again does not arise in the DC system because the delta has does not derived because we only talk about the voltage and the resistance. So, no x nothing. So, this concept does not in that your DC system another is a current carrying capability here because the current carrying capability is basically the if any wire or cable here which is there the current is I is flowing inside this here this is called the current carrying capability now this current is if it is AC system it is having 2 component one is it is a active and another is your reactive components are there.

Now, it is the total current which is flowing, but if your here element is having more charging. So, what happens it is a more let us suppose capacity here elements are there like cable. So, even though you are not taking here any active power here this there is a possibility the current which is drawn here it will be the rated of this cable because due to this current which is flowing here in the charging. So, the current carrying capability of the AC elements or transmission line or your cables are very less compare to your DC because there is a no reactive component of current flowing over the cable or the transmission line. So, that is why here as mention. So, this if you are going for the cable longer than 50 kilometer is very costly and it earlier it was not possible now it is possible and it is not very much feasible, but it is better to go for the DC system.

Another here that is your skin effect skin effect is nothing, but if it is a AC system here the current this is your complete conductor area current will try to go from outer side due to the again the frequency of the system is some more frequency current will go more outer side. So, here the current is non-uniform because the inn in at center current will be less outside it will be more. So, what happen the density of the current in this over this area of the conductor is the different and that is why the resistance effective resistance will be more and there by the loss will be more. So, this skin effect only arise in your AC cable AC lines because AC has a some frequency f and that is why it is having if f is 0 it is a DC and finally, it will be the current will be the uniform and therefore, that is why always we say r AC is always greater than your r DC means thus resistance if you’d measure the AC resistance will be more than your the DC resistance due to your skin and the plasmid effect if another conductor there again there is flux linkage the Ferranti effect which is basically if this 2 system here the big transmission line is there and this is called v sending end voltage and this is your receiving end voltage at the lightly loaded or no load condition you are the v s magnitude here I am talking it is less then sometimes it is your v r and this is called Ferranti effect and this is due to the charging basically charging of the on the capacity of form due to this conductor with this to ground.

So, what we do we go for the various mechanisms to limit this voltage especially if you are charging the line there is no load and then the high voltage will be there at the scent and there will be again tripping of the system? So, we put the various here the reactors we put the line reactors if the line is very long and then if still you required more reactive powers then you can put the bus reactors and sometimes also we use the tertiary reactors as well.

The another major concern here the power flow control is not possible power flow control I mean that we want the power flow control in the smooth manner sometimes we also want the power should be reverse from one direction to another direction which is not feasible not possible in the AC system unless until you are putting another device nowadays again the flexible AC transmission systems are invented they are in the place in the system now with help of them we can control the power in the AC system as well, but at that time it was earlier it was not possible before 90 it was not possible and HVDC control was only possible. So, that why the various types of links were developed and based on those links we were controlling the power flow as well in the lines as well as very neighboring areas.

So, to avoid these 5 limitations it was found the HVDC is better in terms of problems of the HVAC transmission first you will see the reactive power loss here you can say there is a no reactive power loss at all as I explain it is true the stability concern you can say there is no stability concern in HVDC system no doubt we are it is not mean that we can flow up as much as power in any transmission line HVDC transmission line it has some limit, but that limit now is your thermal limit; however, in the AC system we are having thermal limit and stability limits and the voltage regulation limits as well, but it depending upon the length of line which limit is coming first is basically decided by the length of line if is very long your stability limit is the governing criteria than the thermal limit because thermal limit value is very high if line is less then stability concern is not there very less. So, the thermal limit will be governing criteria, but here in HVDC only the thermal limit is the governing condition you can load your transmission line up to it is a thermal limits where it is designed, but the stability problem is not a concern of

HVDC transmission no charging current because the if there is no change smooth here the perfect DC voltage and perfect current flowing. So, there is no charging here and this no capacity and the charging current is not there because once it is the capacitance will be formed once you are having the 2 potential difference medium is the directing medium air is a also a directing medium. So, capacitance is form, but are the constant and the snow charging.

Here no skin effect no Ferranti effect because the charging is not their skin effect is not there because again the frequency is 0 here in the DC system and the power flow control is possible that we can control our in a such a way that we can control the power because the DC power here it is a p DC is your v DC into your I DC means the DC current multiplied by the simple DC current, but and this is called your p d c; however, your p AC is your the voltage AC voltage and your AC current into the cosine theta then theta are here I am writing theta is the power factor between voltage and current and the cosine of this is a power factor here the p DC can be control by the voltage control can be control by current control or can be control by both, but we prefer the current should be the constant and the voltage can be varied and thereby we can varied here the DC power.

So, here basically what this your DC power is very effectively controlled even though it is not only controlling from 0 to it is maximum value it is also possible that we can control it is the minimum value in the negative direction means because the voltage can be vary from minus v to 0 to plus v. So, that we can have the power reversal also with the help of this HVDC link and that is means you can have a full 2 quadrant operation because the 2 quadrant which I mean here this is your id we had as I said it is a constant and your voltage here the positive voltage here negative voltage you can operate this and this co-ordinate very effectively and then you can basically control the power from one end to another end and as well as you can return it back.

So, the controllability here is very better and very effective, but some other advantages minor advantages are also there with the your HVDC transmission system that it is said that it requires less space compared to the AC system for the same voltage rating and the size because the same voltage here you know if you are having let us suppose 400 kb system 400 kb system means you have to design this 400 kb is your r m s value. So, you have to design your system for it is peak value and peak value here is nothing, but multiplied by under root 2.

So, you are going to multiply this design is basically, but in the power here calculation is a 400. So, what happens? You require less space in terms of suppose you are having the insulators if ( )arms and also in the substations clearance here and there we require the less space in the DC due to this factor as well because we always see the peak inverse peak voltages for the AC system.

Another advantage here that the ground can be used as the return path in as I will discuss in the next and other lectures, that the various type of links are feasible. It is called mono polar by polar and homo polar in the mono polar. Only one pole, only one wire is there and the ground is used as a return path. So, we can use the ground as a return means we can minimize we can reduce the cost of the conductor. But, it is not very practical because the if you are using ground current then there are. So, many others like the communication interference there will be some erosion there may be some if some there is some potential is developed and there is shock conceptive major as well. So, ground is used as a written path is especially in the emergency conditions when there is one problem in the one pole. Then, we can use the ground as far providing the power for the limited period of time especially in the bipolar. If one pole has gone then we can use another pole as the mono polar operation and we can operate we can give the 50 percent power transfer from one area to another area. So, this is another advantage that we it is possibly for AC system phase you have to completely shut down; then, you have to maintain it.

Another advantage is the less corona loss because, the corona loss you know it is the always this proportional to f plus 25. Here, that is I can say p c corona loss is a proportional to this you know the in DC if is 0 and your AC is a here f is 50 or 60 hertz. So, it is the more loss in AC system compared to your DC system. So, what happens here, the corona loss in HVDC system is less compared to your DC system. Another is radio interference here the r I if frequency is 0. So, radio interference is 0 but, due to the some harmony, some other thing there will may be some radio interference, but this value is very less.

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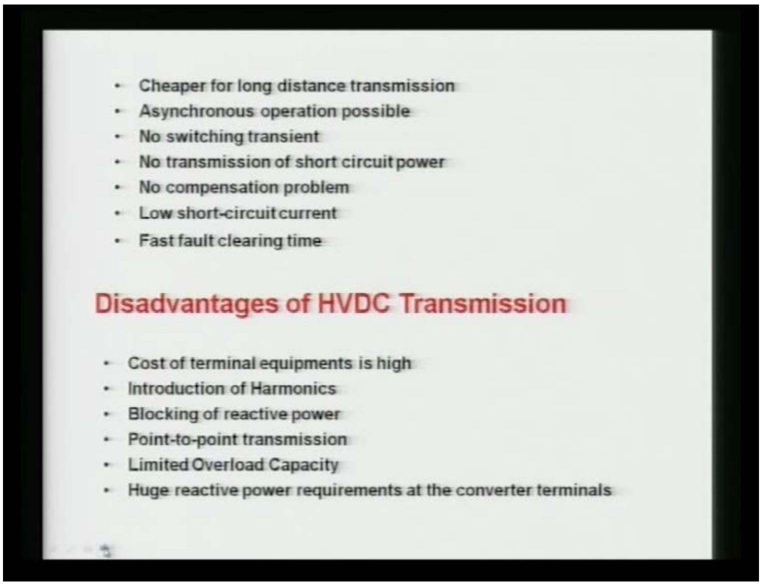

Overall, we can see here that the advantage of HVDC is basically taking place and it is trying to minimize the limitations of HVAC transmission system but, it is not HVDC is not having limitations. It is also having the various limitations in terms of it is cost in terms of generating harmony in terms of tapping of the power and in terms of some other limitations like here you can say the overload capability we can the blocking of the reactive power a and some are all other things there. So, advantages here some other various minor advantages are listed here you can say the fault clearing time the compensation problem no compensation is required for the capacitance low short circuit. No, transmission of short circuit power it has a less and no switching transient or synchronous operation problem is possible and it is a cheaper for the long distance problem.

So, all these again I will discuss the next lecture, but in this lectures my main intension is to give you a concept. Why this HVDC transmission system is taking place all over the world specially for the long distances transmission in the those countries, which is very small in the geographical area HVDC is not very feasible for the long distance transmission.

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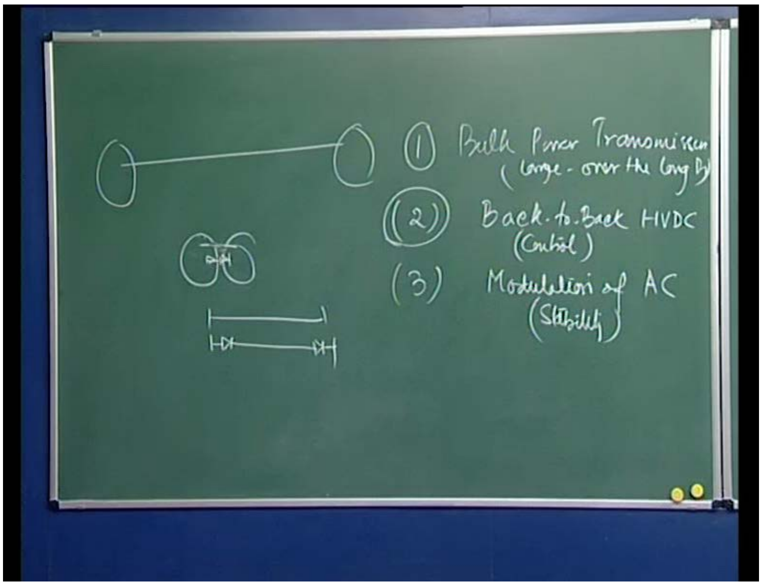

We are having basically the 2 types - 3 types of HVDC links for this control of AC DC power system. One is called if you want to have a bulk power transmission and second is you want it is called back to back concept. Back to back modulation of AC network basically, here in the bulk power transmission. What I want to say if you want to transmit the power from one region over a long region without tapping power in between, it is called bulk power transmission.

Here the concept that the generation if suppose in this area is very high, load demand in this area is very high we want to transmit power without tapping in between the DC is the best and the cheap option. But, that is I mentioning if area is small then it is possible that you can go for the AC system and then you can transmit the power but, those country is a very long and you want to transfer for the long distance. There is no other option; you have to go for the DC system at all. So, we have to use the HVDC bulk power transmission specially in India, it is very important if you are trying to trap power from north east and taking it to the central part of the India. We require huge HVDC links to transmit the power but, this concept is now common not only here at the basis of here to control the power, here the concept was to transmit the power here this control aspect even though if you are having the 2 regions very nearby.

Here, you can have your the DC here back to back even those converter and inverter stations are put together very near to each other may be less than one kilometers away even the one substation and the purpose here that we can monitor how much power is flowing from one region to another region. So, that is it is called back to back because inverter and converter are same back to back here only. We do not want to transfer bulk amount of power here. We want to control the power because it is based on the contract; it is based on some negotiations and also in terms some sort of the emergency you know, if there is some problem this region this link is there. Then, we can open this and the disturbance cannot be propagated in another region. But, if you are having a AC line here certainly the disturbance can go there. If it is not protected well then both system be the collapse. So, it has various advantages here we want to control, we want to provide the emergency support and also we can just meet our contractual requirement. So, the back to back connections are there.

Here, the modulation of AC DC system basically is mini; that if you are having some here AC line and this line is very weak. Sometimes, there is some problem here due to the power isolations or you can say power swings are there. We can have another here HVDC link small HVDC link that can support this one means whenever there is a problem we can just control in a such a way that we can moderate the power over this AC line means it is use to improve the stability of the system. So, you can see these 3 objectives are for the HVDC transmission system. Here, it is basically to feed the power over the long distance means, large power over the long distance. This is also control we do it control no doubt but, the basic is huge power which is fed from one area to another area. Here, as I said this one is the control of power; is the primary objective. That is, we can control the power. How much it is going if it is AC system is there? So, if this area is drawing more power it will be flowing here without any control you cannot control here, but the DC here connection is there you can fix the power it cannot take more power from this area unless and until this controller or tune for this one is basically used for your stability of the system.

Basically, it is used in this AC system to stabilize the AC DC system as well. So, that is why here the transmission part is now going. If your objectives are these then, you have to go for your DC systems and it is we are talking about the high voltage DC system. So, now days that is why we are having the AC generation; we are having the AC distribution system. of course, the utilization now we are again shifting from the AC to the DC because, we are having lot of power electronics based devices those are giving and also communication mobiles and another DC power are required in the houses, but the transmission distribution is AC and after that again people are using some converter conversion technology to get the DC power for the charging of the batteries here and there generation is still your conventional generators; they are AC. We are also generating some part of the DC power based on your photovoltaic but, if you want to connect in the system then you should require some converter and then you convert to the AC system and then you can connected it to the ( ) but, the transmission if this transmission is the combination of your AC and DC system, specially based on the various objective, it is believed that your transmission part will be the mixture of your AC as well as the DC system. here, the DC system we are talking high voltage DC we do not have the DC low voltage DC because, again the problem of high loss and the voltage drop will be there.

So, high voltage DC transmission along with the AC transmission it includes both your high voltage EHV and the low voltage AC transmission as well. This is the scenario which is emerging all over the world. To conclude in this whole lecture number one basically I discussed the course contents which will be the giving the basics that what we are going to discuss in the various modules various lectures and it was decided in based on that. So, the total this whole course will be basically schedule for 35 to 40 lectures based on the various contents and also some numerical problems will be solved and will be showed so that the students can get benefited. Even the teachers also they can be benefit from this and here, in the first lecture I had just summarized the evolution of the power system along with the special emphasis was your DC system from your small high voltage DC systems. Then, we went for the large DC system and then we discussed some of the limitations of HVAC system and then, along with it we discussed that how this DC system will be advantageous to remove the limitations of HVAC system.

So, the various disadvantages are also there that will be discussed in the next lecture and also we will discuss the various types of links in this module and also the several of components the basic background will be given in this module so that, we can move to the various modules. Then, it will be analysis control the protection; then, analysis and then, we will see the total performance of HVDC, AC, DC and the AC system as well. So, with this I should stop this; thank you.