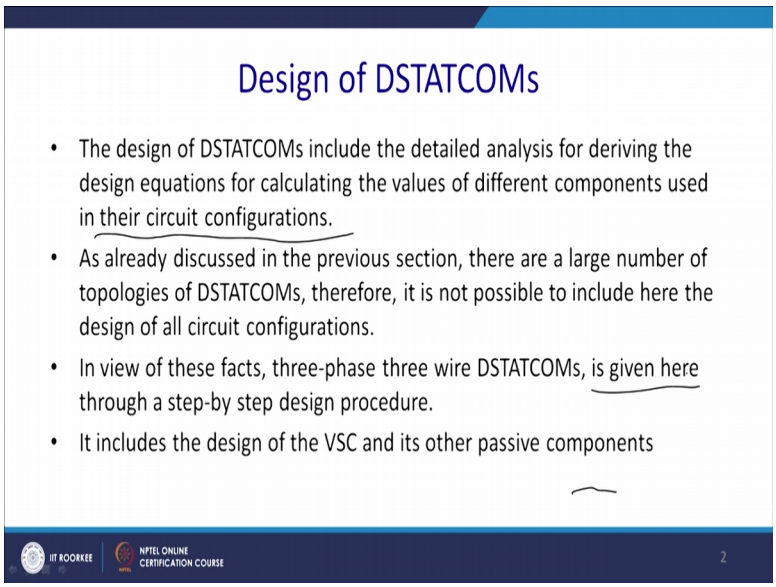
Flexible AC Transmission Systems (FACTS) Devices

Dr. Avik Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture – 20
Design of DSTATCOM

Welcome, to our lectures on Flexible AC Transmission System. We have already we had discussed we were discussing about the DSTATCOM. Now, in this lecture we shall see that actually how to design the DSTATCOM.

(Refer Slide Time: 00:49)

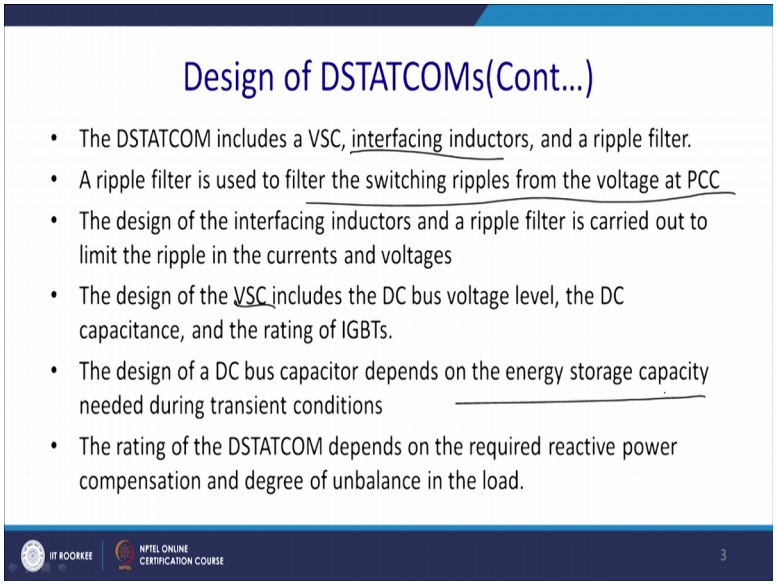


So, design of the DSTATCOMs include the detail analysis for deriving this eq design equations for calculating the values of the different component used for the circuit configuration. So, we require to see that how we can come out with the values of the capacitor, inductor and different component. Already as already discussed that in previous section there is a large number of topologies of the DSTATCOM. Therefore, it is not possible to include here design of the all circuit configuration on the topologies. So, few major and the commonly discussed topologies is been considered here.

In view of the facts this phase of the three-phase three wire DSTATCOM we have considered and the here we have considered the step by step design of this DSTATCOM. It includes the design of voltage source converter and other passive component, there is a

DC link volt there is a DC link capacitor and the couple inductor these are the also the component of it and we will see that how we will design it properly.

(Refer Slide Time: 02:32)

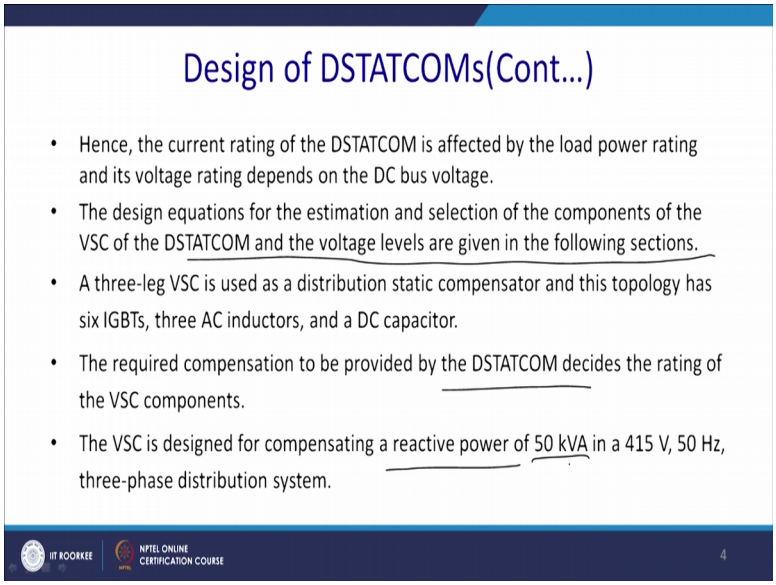


So, design of the DSTATCOM includes let us understand that how we will go by step by step interfacing inductor and the ripple filter. Please recall the circuits we have discussed in previous class ripple filter is used to suppress the switching frequency and the point of common coupling. So, switching ripples has to be mitigated by the ripple filters and accordingly it has the value has to be actually the cut off should be near to this actually the switching frequency. So, you require a very small filter to do that. The design of the interfacing inductor and the ripple filter is carried out to limit the ripple in the current and the voltages.

The design of the voltage source converter includes the DC bus voltage level which voltage will operate the DC bus capacitance and the rating of the switches if it is IGBT then it is IGBT. The design of the DC bus capacitor depends on the energy storing capability needed during the transient condition. So, there is a step change in the load. So, we cannot get instantaneous power from the supplying or you can throw back instantaneous power for the supply. So, that for this transient time so, this energy storing ability will be considered. Rating of the DSTATCOM depends on the required reactive power compensation and degree of unbalance will be present into the load because you

know that harmonics generally power is generally very less. So, these are the two dominating power that will actually ensure that power rating of the devices.

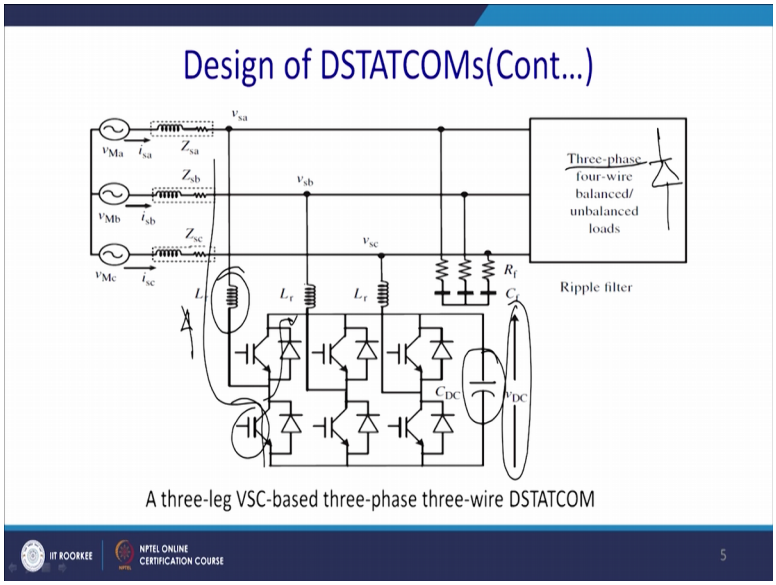
(Refer Slide Time: 04:31)



Now, hence, this current rating of the DSTATCOM is affected by the load power rating and the voltage rating depending on the DC bus voltage. The design equation of the estimation and the selection of the component of the VSC of the DSTATCOM and the voltage level are will be discussed in this session.

A three-leg VSC is used as the distribution static compensator of the topology has six IGBT minded it you may increase for the three-level inverter or the more level three inductor and a DC capacitor. The required compensation to be provided by the DSTATCOM decides the rating of the VSC components. The VSC is designed for compensating a reactive power of 50 kVA 415 volt, 50 hertz three-phase system this is been considered.

(Refer Slide Time: 05:34)

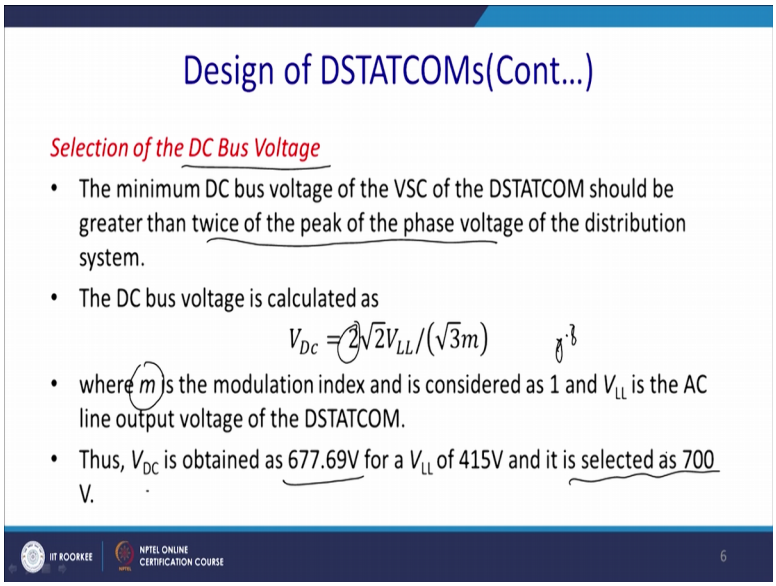


So, see that this is the again the STATCOM and it has it may also have a reactive power. So, we have considered the three-phase three-wire balance load, but it may have a non-linear load fitting at diode based rectifier depending on the different kind of possibilities. So, this is basically the L r we require to design and this is the value of the C DC actually we require to design the value of the capacitor and the value of this DC voltage to operate properly. Please note that since we require to we have seen in case of the statcom that it require to inject power current has to be this way.

So, for this reason DC link voltage has to be higher than the rectified DC bus voltage because it is of two quadrants which is ultimately due to this body diode it will acts as a rectifier once and it sees the inherently the boost topology. Please note that when this lower switch is on then current will flow through this in positive of cycle and thus when switch is off current will be actually flowing through this directions and thus it will boost the DC link voltage. So, it is this L r is the essentially does the two purpose, since this it is a PWM inverter. So, instantaneous pole voltage of the inverter will be different from the VSC and for this reason we have to put an inductor to block circulating current and moreover we require to actually boost up the DC bus voltage.

So, for this reason we require this inductor. So, see that how we will first will go by selection of the DC bus voltage.

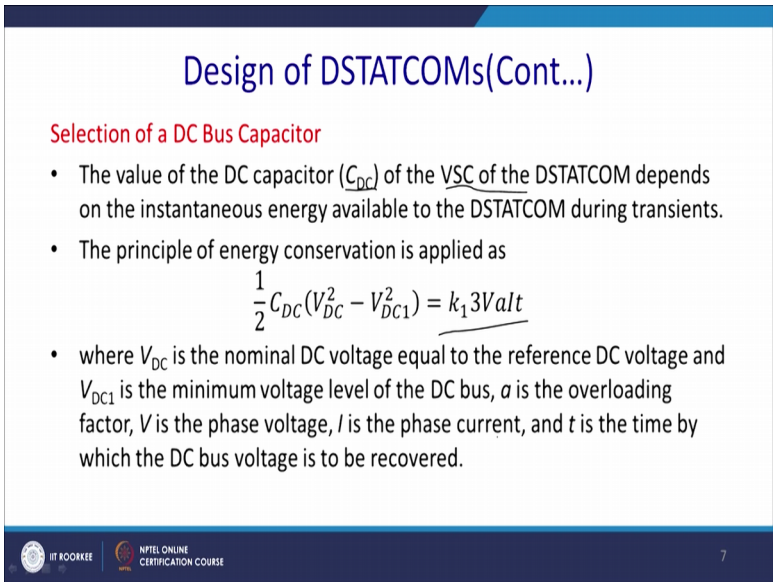
(Refer Slide Time: 07:44)



The minimum DC bus voltage of the VSC of the DSTATCOM should be greater than the peak of the phase voltage of the distribution system. The DC bus voltage is calculated as 2 into under root of root 2V by L by root 3m, where modula m is the modulation index and generally it is restricted to 0.8, please mind it.

So, where m is the modulation index and it is considered 1 and generally we do not consider 1 rather we consider it around 0.8 and V LL and the AC output voltage of the DSTATCOM. So, thus even if you consider that m value to be 1. So, V DC obtained to be 667.69 and you divide it by 0.8. So, it will be actually around 750 volt. So, for this reason we can select the DC bus voltage in an around 700 to 750 volt, this is the calculation.

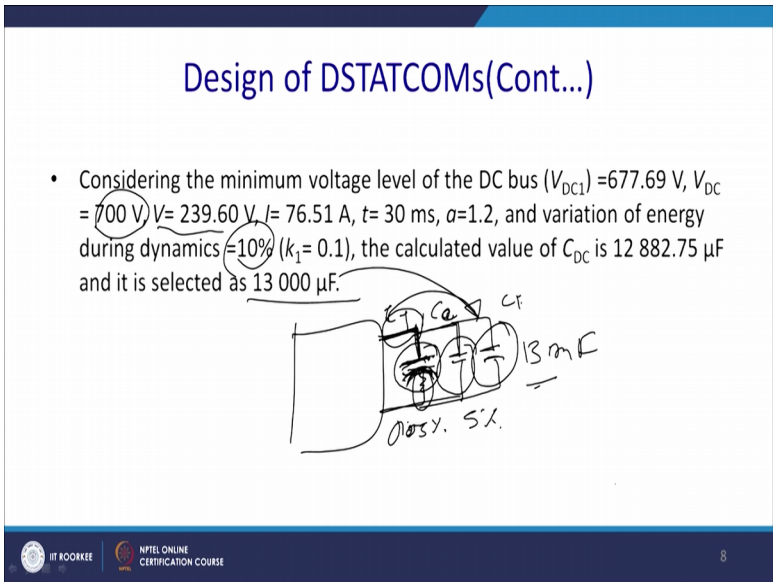
(Refer Slide Time: 09:05)



Now, we will talk about the selections of the DC bus capacitor the value of the DC bus capacitor C DC of the VSC of the STATCOM depend on the instantaneous energy available to the STATCOM during the transients. The principle of the energy conversion starts you know half CB square.

So, half C DC into Vg square minus VC 1 square equal to k 1 3V alt what is it, let us see, where V DC is the nominal DC bus voltage equal to the reference DC voltage and VC 1 is the minimum voltage level of the DC bus, a is the over loading factor, V is the phase voltage, I is the phase current and T is the time which the DC bus voltage has to be recovered. So, generally it will be some cycles. So, it will be around 2 cycles, 3 cycles, 100 milliseconds or one 150 milliseconds something like that.

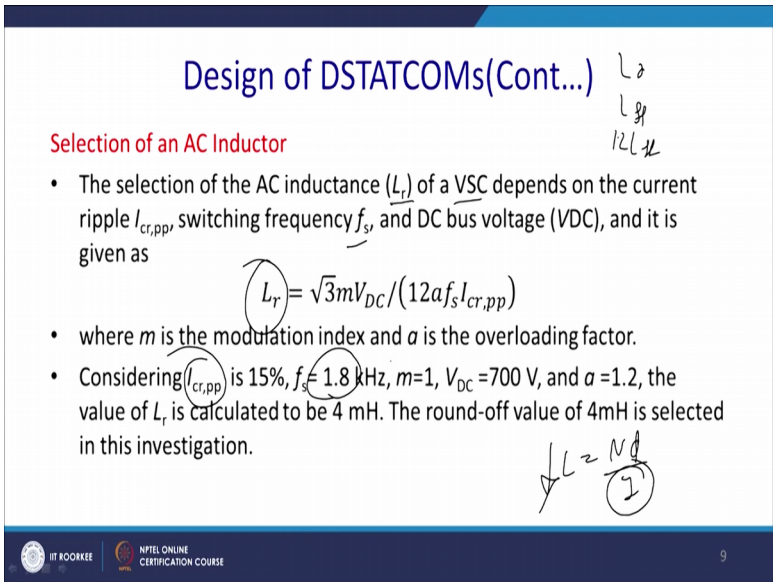
(Refer Slide Time: 10:31)



So, thus we can put this value let us consider that that the voltage is being kept to the 700 volt considering the minimum voltage of the DC bus voltage. So, V DC was actually 700 volt and V equal to then we can compute that actually the what will be the phase voltages that is 390 around 240 volt and I should be equal to 76 ampere and T equal to 30 milliseconds and a equal to 1.2, and variation of the energy during the dynamics is a k; k is assumed to be the 10 percent and from there we can calculate then what should be the value of the C DC and it is basically we come out to be this value. So, we can select in the range of that on 13000 microfarad or 13 millifarad.

So, let us then come to the next step of design. So, that is your design of the inductor.

(Refer Slide Time: 11:57)



Selection of the we please recall actually design of the inductor is a very important aspect of our design. So, selections of the AC inductance L r of voltage source converter depend on the current ripple switching frequency f s and the DC bus voltage and it is given as actually L r equal to root 3 V m DC by 12 af crr let us see what is it, m is the modulation index of the of a switching pattern and a is the overloading factor. So, how much you can overload. So, depending on you can overload. So, generally it has to be we have when we put a inductor specifications we put there are few values for what is it is no load value L 0 full load value f l 1.2 into full load value.

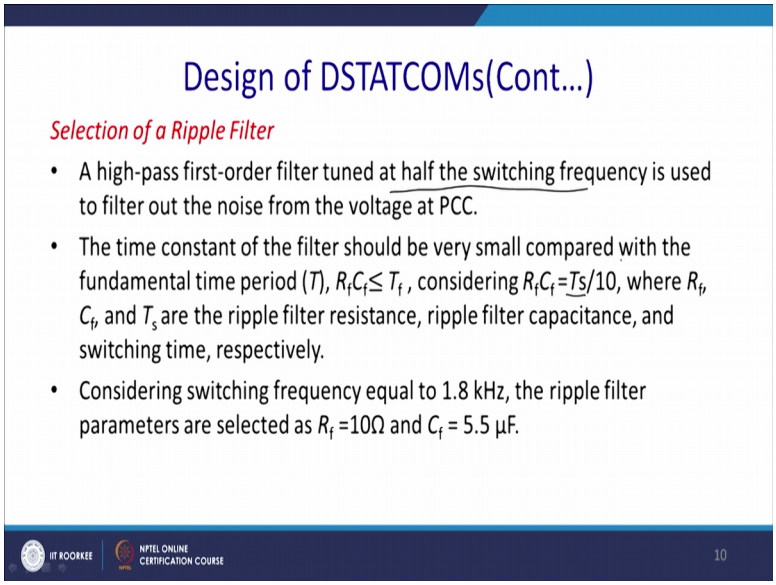
So, here actually it is considered to be the 20 percent mode of the full load value most of the cases what happen you know you know that L equal to N phi by I and if current increases thus the value of the inductor decreases and it has a different kind of material to be chosen accordingly. So, they comes after to the actually the power electronics engineering has to be very competent to design the inductor of for having this loading factor into the account.

So, let us consider it is a three-phase three-wire system and thus you know you got a this much of the current ripple for 6 pulse converter you can change this value also to 27 percent. So, crr, pp is around 15 percent and now the switching frequency of the IGBT or IGCT that is let us assume that it is operating at 1.8 kilo hertz and modulation index is assumed to be 1 and thus and V DC also 1, V DC also 700 volt and overloading factor

said to be actually 1.2 and the value of r is calculated to be the 4 millihenry. So, we can round it off the 4 millihenry. So, it is chosen for the investigation.

Now, next is the selection of the ripple filter. So, ripple filter is essentially high-pass filter it will suppress the switching frequency harmonic. Here switching is done at 1.8 kilo hertz. So, accordingly we require to design the ripple filters.

(Refer Slide Time: 15:17)

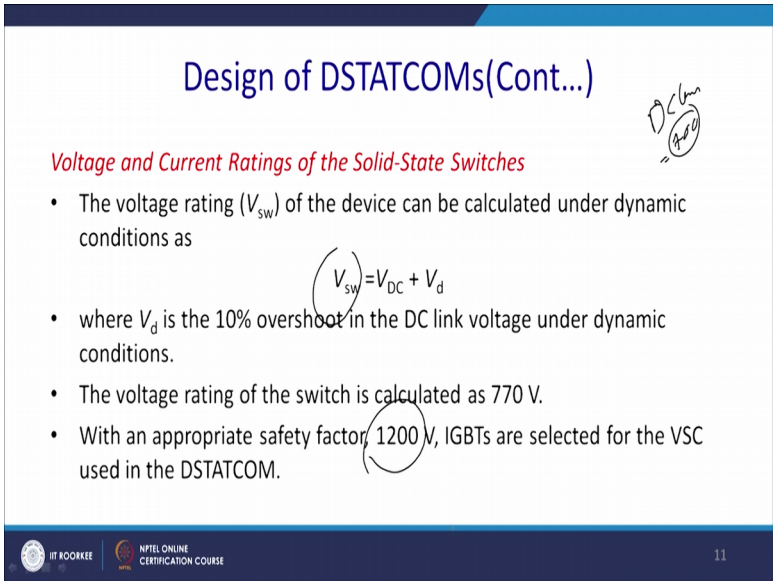


The high-pass filter in order to a high-pass filter tuned at half of the switching frequency is used to the filter out the noise or the switching ripples from the point of common coupling. Please note that you know actually power system is actually predominantly it is inducting the so, it is a low pass filter. So, it will be actually eliminate that high frequency high frequency noise system and while doing that we required to choose the time constant should be very small compared with the fundamental time period of T.

So, T should be actually much much greater than R f into C f and for let us consider that you know R f into C f will be T s by 10 where R f, C f and T r are the ripple resistances, the ripple the ripple filter capacitance and the switching time respectively. So, we have already chosen that switching frequency of switching frequency of this actually inverted is operating at 1.8 kilo hertz. So, thus parameter is selected to be actually R f equal to 10 and C f equal to 5 microfarad. So, this is the case, ok.

Now, let us come to the switching now we have to choose IGBT so, what should be the rating of it? Generally, we consider a factor of safety and with that there is some data available with the reliability studies with the reliability studies. There are more the factor of safety is used you got a more reliability. So, for this reason you know we have chosen this actually the DC link.

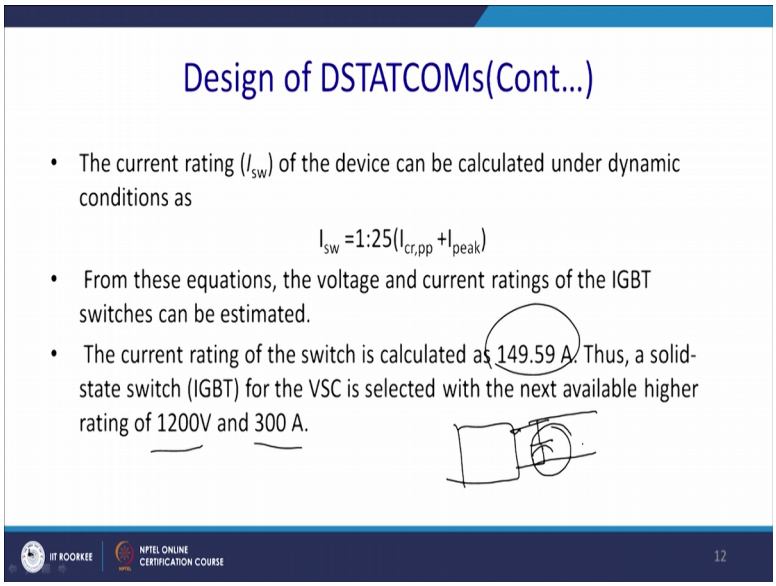
(Refer Slide Time: 17:44)



It is at two-level inverter and the DC link voltage is 700 volt. So, we choose 10 percent more as a search voltage rating. So, voltage rating of the device can be calculated in dynamic condition. So, what is it? So, SW will be equal to V DC plus V d, where V d is basically 10 percent overshoot of the DC link voltage and a dynamic condition and thus the voltage rating of this IGBT should be around 770 volt, but practically speaking you know you want an IGBT of the voltage level of around 1200 volt.

So, we will choose a factor of safety. Generally, you know we expect that this DSTATCOM will be actually will have a life span around 10 year and thus you know actually this STATCOM around choosing the safety factor of around one point around actually one more than 1.5 that will ensure that and we can choose closest to this value as 1200 volt IGBT is selected for its VSC rating what else and how will come down to the inductor rating.

(Refer Slide Time: 19:27)



Current rating also can be calculated it has few components of it the device can be calculated under dynamic conditions and that is basically SW equal to you have a ratio 1 is to 25 cp pp and the peak ratio and from this equations voltage and current rating of this IGBT can be estimated. So, current rating of the switching in this portion we have we can go back what is what was our value of the this values of this current. So, we have already seen that value. So, this is the value of the cr, pp and from there we can calculate that what is the value of cr, pp and the peak current rating and from this equation the voltage and current rating of the IGBT can be computed.

So, the current rating of the switches is found about to be the 149.59 ampere and we require to take a factor of safety in this case. Generally, we find that factor of safety require to be double and for this reason we choose the next available higher rating that is 1200 volt 300 ampere. So, these are few takeaways.

Now, we have to actually consider few aspects of it. Now, another aspect of it is in a STATCOM how you actually choose and you will find few practical aspect of it then generally what happen you have a DSTATCOM. So, this STATCOM generally have we have calculated a huge amount of capacitor this capacitor value has been calculated. Since it is a very large value then generally it will feeded with a electrolytic capacitor, but in practically you will find that with this and what was a value we have find found in the value of the capacitor let us cal do the calculation here itself.

So, this is the calculations we find that value to be the 13 millifarad. So, you have a two level inverter, thereafter you will find that there is a actually few capacitor; one is ceramic capacitor, one is tantalum capacitor, another is electrolytic capacitor this have been placed. So, you require to also calculate their values here. What happen, so, these value is corresponds to this electrolytic capacitor and you know ultimately you have a small tantalum capacitor and you have small ceramic capacitor. Generally, the ceramic capacitor will be just 5 percent of this big 13 millifarad capacitor, this very low and 0.5 percent of it should be the tantalum capacitor. What does they do?

Essentially there will be a lids and due to that they will remain inductor and thus even though you cut this lids practically have we have talking about this practical aspects this course is facts devices. So, you have to cut these lids at the junction. So, this lid may gives rise to the inductance, that inductance you know you require to be suppressed. So, for this reason you know we have a switching and these lids may be actually access the inductor as a switching frequency. So, to suppress those we have to parallely connect this ceramic capacitor C e and the C t and will what will be the placing? Generally, there is a way of placing this capacitor. Otherwise what will happen you know it has a track and thus it has got a resistance and it has got a also the value of the ESR. So, we can model it.

So, this track resistance and ESR should match otherwise there will be a reflections or EMIC problem with their and that is also nowadays has to be considered properly and generally what happen larger the value of the capacitor higher will be the CSR. So, for this reason even though in a same rating the value of the ESR is list in case of the in case of the actually the electrolytic capacitor, but in this case you know since the size of the inductor is biggest value of the ESR will be the least and for this reason you will find that the re-order will be reversed.

First we will put a electrolytic capacitor then it is triggered to the impedance matching of it. So, those whose actually design this actually the perusable layout this perusable layouts value of the resistances and the ESR value should match, that is the requirement. Then it will be ceramic will be at the midpoint, since it has got the ESR at the middle of the value and the tantalum will have a highest ESR rating since it is a smaller size and thus will be placed here. So, configuration will be changed. So, here it will be ceramic, here it will be actually you will have electrolytic capacitor this will be the ceramic

capacitor and this will be your tantalum capacitor. So, all those features has to be considered ultimately that will come completes your practical aspect of the designing.

Another aspect you require to consider while designing an inductor. So, what should be the material of the inductor. So, that also we require to consider if you think of. Generally, if we write it is chosen for the for the for farad is chosen for most practical purpose, but if you wish to have a lower losses and all those issues has to be considered because overlap will be one of the requirement because you have a overloading requirement for this reason sometime we chose to have inductor with the different material. So, practical aspects of DSTATCOM is a preview of the power electronic engineers and it has been successfully implemented in a distribution level.

So, thus I conclude our discussions on shunt compensations and we have discussed first SVC, thereafter compensation property of SVC then STATCOM compensation of the property of the STATCOM, then followed by the DSTATCOM – distribution STATCOM and its practical implementation of it in our courses. I hope that you will find this discussion is hopeful for your or for your better understanding of facts devices. Thank you so much, indeed for your kind attention.

Thank you.