Flexible AC Transmission Systems (FACTS) Devices
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Lecture – 17
STATCOM/SVC Comparison

Welcome to our lecture on FACTS Flexibility AC Transmission System. We shall continue with our SVC versus, we have discussed already STATCOM as well as SVC, now comparison of both the system we require to discuss in subsequent section; So, on the basis of the explanations provided by the various sections that we have already discussed.

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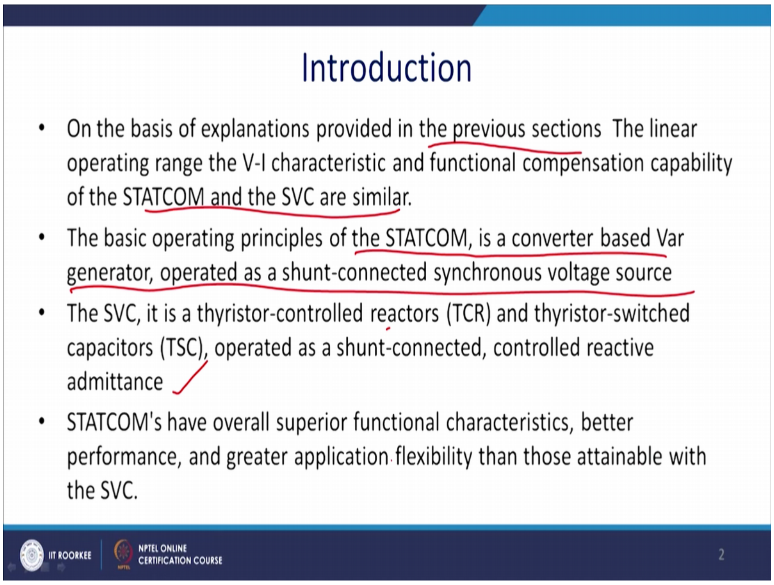

The linear operating range of the V I characteristics and the functional compensation capability of the STATCOM and SVC are similar. This is the actually the we can use STATCOM as well as SVC both, but there is a ifs and buts. The basic operation principle of the STATCOM is a converter based on the Var generator acting as a shunt connected synchronous voltage source essentially it is a voltage source and SVC actually the impedance.

So, there is a basic philosophical difference between this two. SVC is a thyristor controlled reactors thyristor switched capacitor operated as shunt connected controlled reactive admittance. So, one is source another is admittance. And thus STATCOM have overall superial functional characteristics better performance and greater applicational flexibility and those who attainable with the SVC we shall establish this consequences with this discussion.

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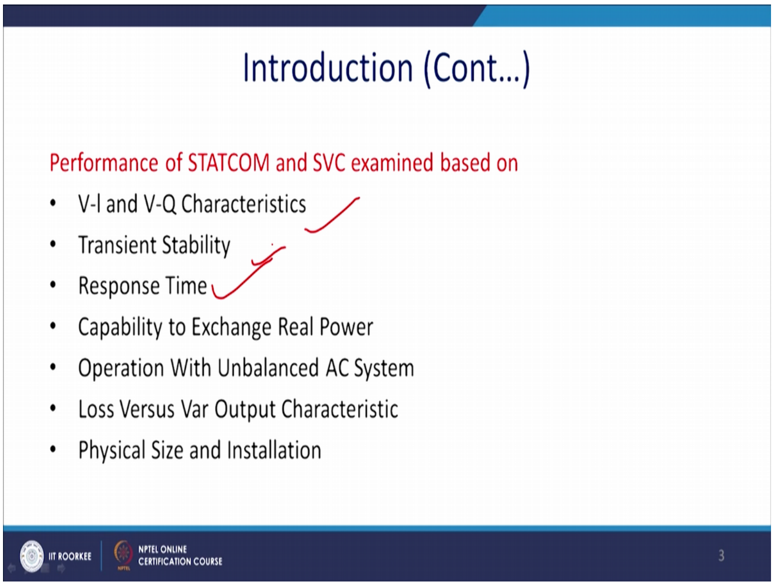

So, we shall continue with this presentation layout, that is what is the V I characteristics of SVC and V Q characteristics such as reactive power handling capability of the both SVC and the STATCOM.

Then how will see that how it handles or ensure the transient stability, how fast it reacts the response time, capability to exchange the real power whether it can be added to compensate the reactive power will some add on or the rate preferring purpose. Operation with the unbalances system if there is a source unbalanced or due to some switching or anything may be inductance value is different some low thermals may also be there losses versus Var output characteristics.

And you will your physical size and the installation these are the practical features we require to consider while you are and another is basically the cost I am silent about it. So, you will conclude yourself what should be the cost. So, this is the voltage rating and the this is 0 current rating.

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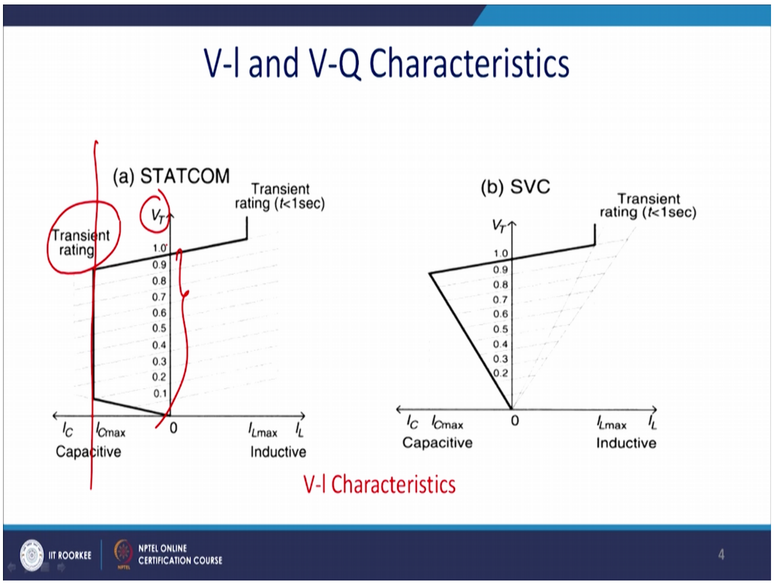

And you can see that it has a wide range of compensation, it can inject c max with any value of the voltage sac. So, voltage can be 0.2 0.3 it can start and it can go to any voltage. So, this actually this reactive power handling capability is constant with the supply voltage is a STATCOM. So, STATCOM can perform wide range of operation while a disrupt voltage source, but in case of the STATCOM SVC, you can see that it will be linearly increasing with the voltage. So, it is a maximum voltage sac handling capability and around 0.1 and what and this is a transient rating both will have a transient rating is less than one second. So, this is the V I characteristics of STATCOM and SVC.

So, what we can conclude? This shows that STATCOM can be operated over full output current range and of very low voltage theoretically it is 0, but generally it is 0.2.

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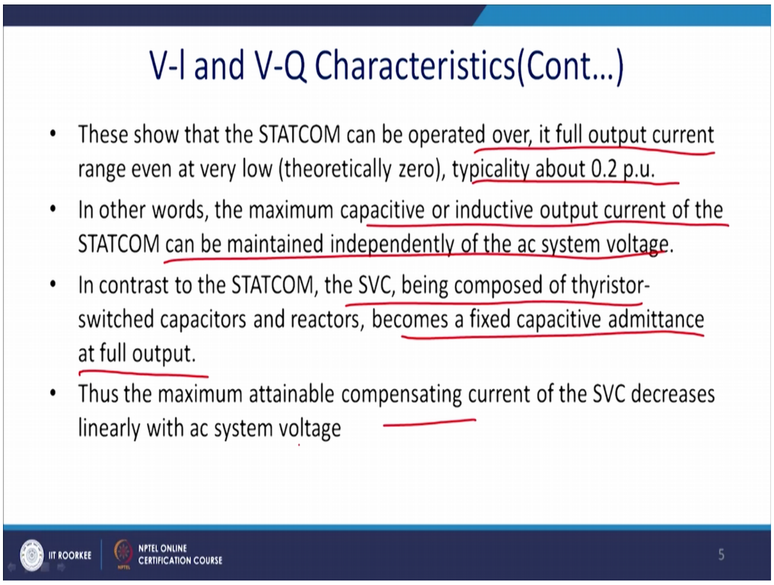

Theoretically zero typically at about 0.2 per unit of the voltage. So, it can compensate the reactive power when voltage sac has occurred. On the other hand the maximum capacity or the inductive output current of the STATCOM can be maintained independently of the system voltage is a biggest advantage of STACOM.

But on the contrary or contrast this is the STATCOM, the SVC being composed of thyristor switched capacitor and the reactor becomes a fixed capacity admittance with a full output, the reactive power handling capability is totally depending on the source voltage. Thus maximum attainable compensating current of the SVC decreases linearly with the ac system voltage and thus the capability handling capability of Q also decreases.

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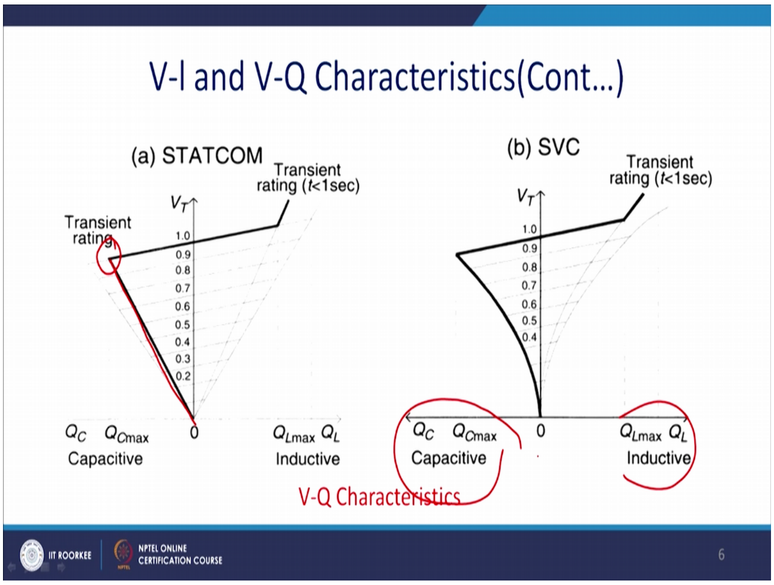

So, and you know this is the this curve corresponds to their actually the Q and V and essentially the it is an admittance curve. You can see that the reactive power handling capability of the STATCOM is V Q characteristics and here it will be 1.

And this is the transient rating and this is actually the curve of the inductive pattern, and this is basically something like non-linear, but here you can see that it is linear. So, you your operation is more predictable with the STATCOM and this is the capacitive region and this is the inductive region. So, what we can conclude from this figures?

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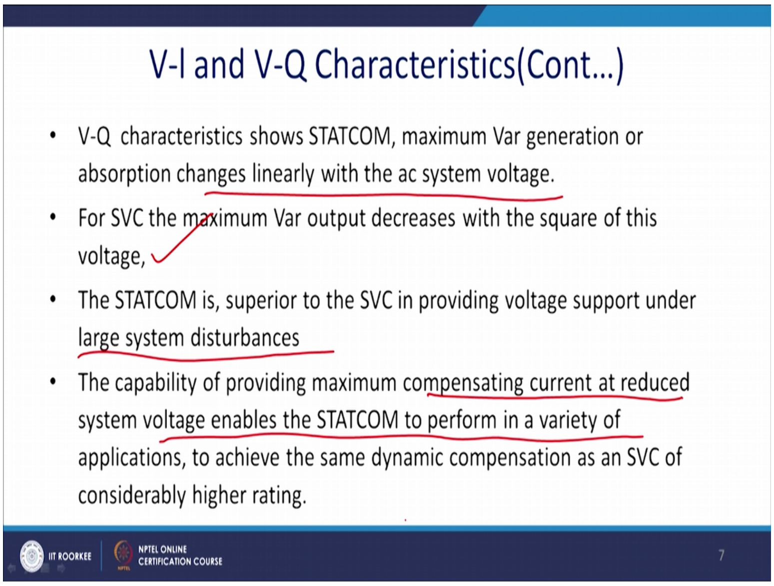

V Q characteristics shows in case of STATCOM, maximum Var generation or absorption changes linearly with the system voltage see that this changes linearly the system voltage, but it is in quadratic in nature. SVC the maximum output decreases with the square of its voltage.

So, it is in quadratic in nature for this reason what we can say STATCOM is the superior to SVC providing the voltage support under large disturbances. Since if there is a voltage fluctuation 20 percent. So, it will be directed by 40 percent SVC, but there will be directing of STATCOM will only by 20 percent.

The capability of providing maximum compensation current at reduced system voltage, enables the STATCOM to perform in a variety of application. To achieve the same dynamic compensation as an SVC we thus require a higher power rating. So, here in this case also STATCOM is also superior to compensate the more reactive power now what else?

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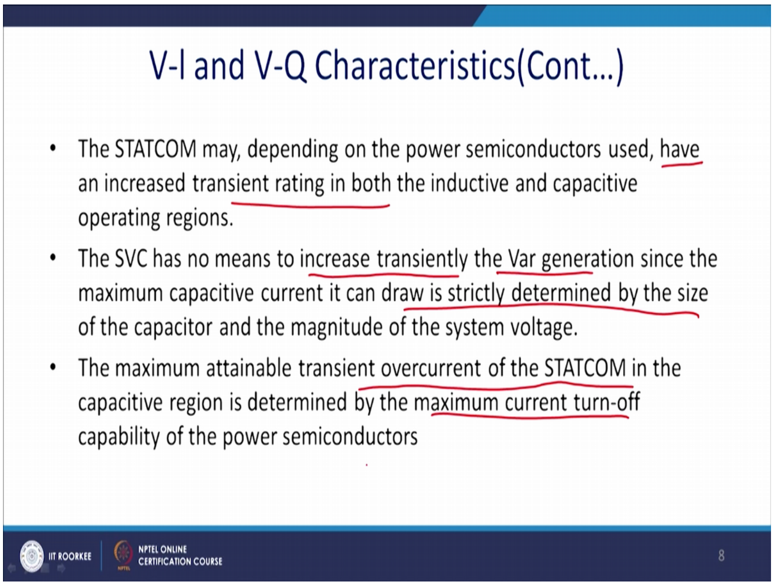

STATCOM may depending on the power semiconductor used have increased transition rating in both inductive and the capacitive range. Because you know you can depending on the rating you have a limitations on the switches because in case of the SVC you are strictly using the thyristors, but you have actually the choice you can use IGBT, you can use IGCT, you can use GTO depending on the rating and the switching frequency; So, GTO so, device compared to the IGBT or IGCT. SVC has no means of increase in transient or the Var compensation. Since the maximum capacitive current can draw is directly determined them by the size of the capacitor and the magnitude of the system voltage.

So, thyristor is the almost a passive device here. Maximum attainable transient over current of the stat STATCOM in a capacitor region is determined by the maximum current turn off capability of the power semiconductor, it will be determined by the most of the cases by the capacitor rating and the voltages.

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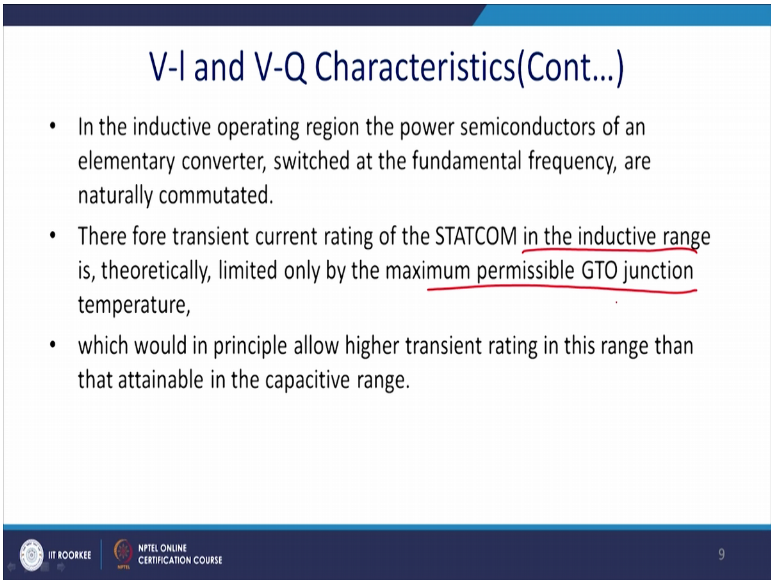

The inductively operating region the power semiconductor of an elementary converter switches the fundamental frequency are generally naturally commutated. So, therefore, transient current rating of the STATCOM in the inductive current range is theoretically limited by only the permissible GTO or IGBT or IGCT junction temperature.

So, whatever the current rating for the devices, that will determine what should be the transient current limit. Thus we should principle allow the higher transient rating and this range than the attainable capacitive range. So, it can handle more inductive power than the inductive Var than the capacitive Var. Now, let us come to the transient stability we will consider the two machines small actually you have put a shunt compensated at the midpoint.

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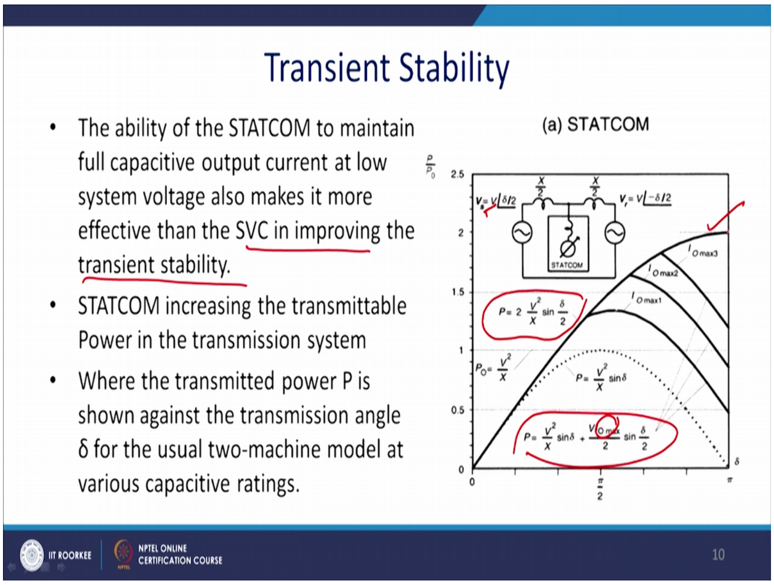

So, we have a angle V s and delta by 2 and this is the curve; previously your curve was basically V square by X sign delta. Now, with the shunt compensation we have derived that this changes to V square by X sign delta plus V into I 0 by 2 max into sign delta by 2. So, thus you know by changing the value of the current you can have a different curve.

So, this is the case of it becomes 2 V square by X sign delta by 2 this curve and so, on you can change it and, but this is limited by the amount of the current actually you supposed to get this curve, we have derived this equation, but essentially there is a limitation of the I 0 that will be put by the device. The ability of the STATCOM to maintain the full capacitive power current at low system voltage also make more effective than the SVC, in improving the transient stability.

Because it can you have a huge area accelerating area to compensate. STATCOM increases the transferable power in the transmission system. So, this equation becomes 2 V square by X sign delta by 2. Whereas, the transmitted power is p shown against a transmission line angle delta for the usual two machine model versus the capacitive rating, this is the model. So, we can conclude that it can handle better transient stability; now for comparison and equivalent p versus delta relationship shown for the also the SVC, where you have put the different value of X as the midpoint.

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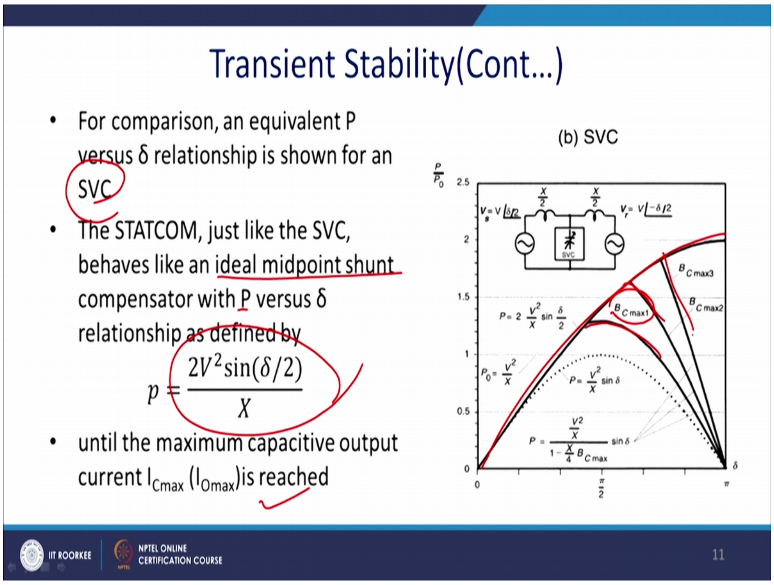

The STATCOM just like SVC behaves like a ideal midpoint shunt compensator with p verses delta and this equation becomes this, but there is a limitation until the maximum capacitive output power current IC max is reached. So, you are going to this, this is the ideal shunt compensation and the midpoint and ultimately what should be the value of the B C max, that admittance that will determine either you will follow this curve, this curve or this curve and you can see that drop is very steam just go back to this thing. So, it is quite smooth and here it is quite sure.

So, for this reason I you have a limiting condition, you should not go this point you will drastically fall after that. So, what should be the conclusion from this observation?

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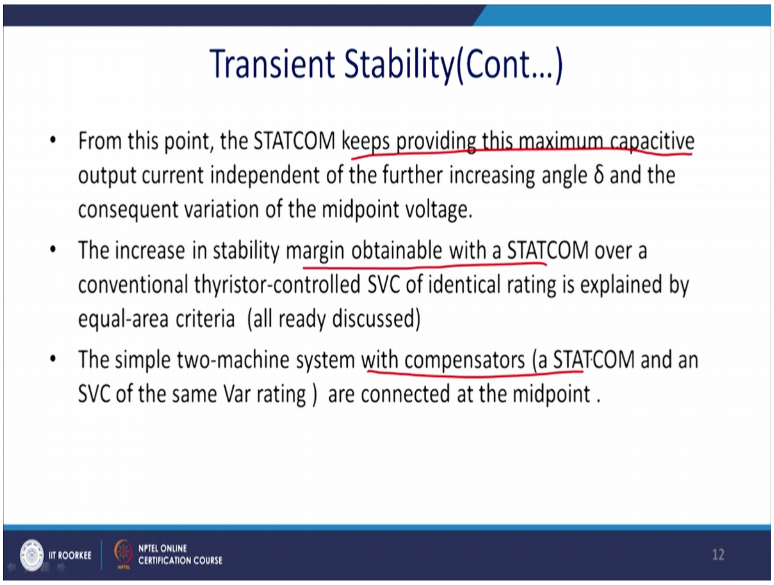

From the midpoint of the STATCOM keeps providing the maximum capacitive output current independent of the further increase of delta, and the consequent variation of the midpoint voltage.

The increase in stability margin obtained by the STATCOM over a conventional thyristor SVC of identical rating is explained, by the equal area criteria. The simple two machine system with the component of the STATCOM and a SVC Var rating can be connected at the midpoint and let us see what is the conclusion.

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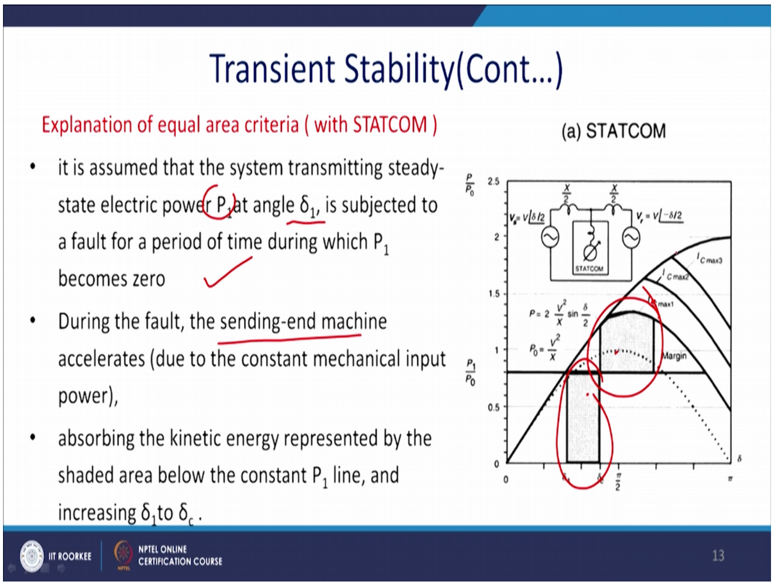

So, let us go back to the again our two machine model and this is the case of the STATCOM equal area criteria. So, this one is an accelerating area and this one is your decelerating area. So, this is the margin, you can change this margin by changing the value of IC max.

Thus we have already explained the equal area criteria explanation of the equal area criteria this assume that the system transmitted to steady state electric power P 1 at angle del 1 and is subjected to the fault for the period during which the P 1 becomes zero. Thus, you got an acceleration power during the fall the sending end machines accelerates due to the constant machine output voltage, absorbing the kinetic energy presented by the shaded area below the P 1 line and increasing to delta 1 to delta c.

So, you can see that this will increase like that.

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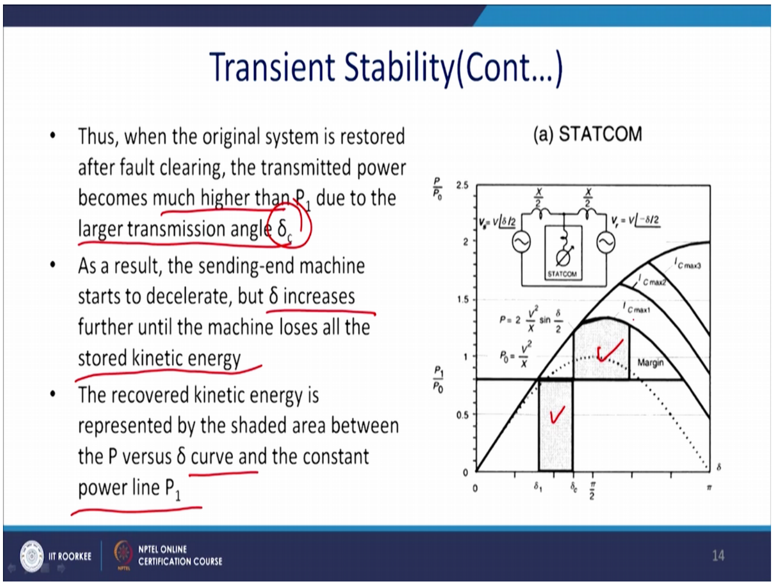

So, thus what happen? When original system is restored after fault clearing, the transmitted power becomes much higher than P 1 due to the larger transmission angle delta C. As a result the sending end machines start decelerating, but delta increases further until the machine losses all the stored kinetic energy the recovered kinetic energy is represented by the shaded area, between the P verses delta curve and the constant power line P 1. So, this is your accelerating area this is your decelerating area. Now what happen to the SVC same thing this is accelerating area.

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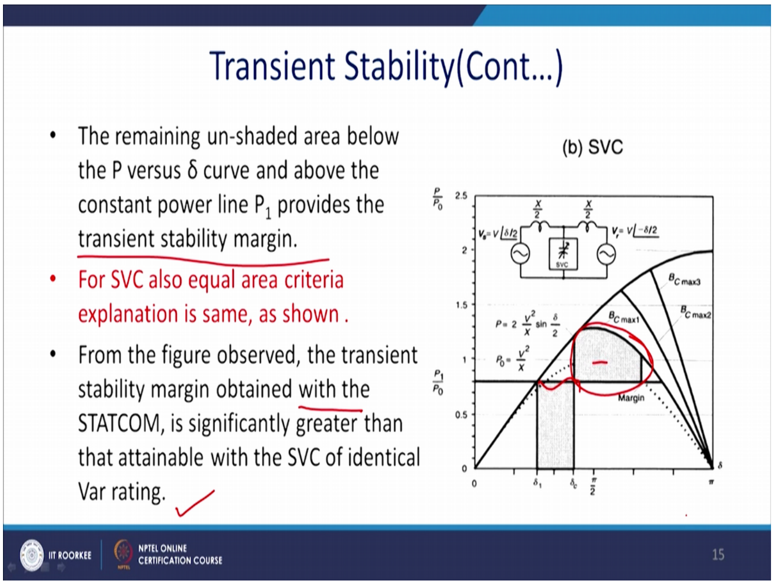

The remaining unshaded area below the P versus delta curve and above the constant power line P 1 provides the transient stability margin. So, this is your transient stability margin. From this figure observe that transient stability obtained with the SVC is significantly greater than obtained with the STATCOM is significantly greater than attainable with the SVC for the identical rating, because please go through this a. So, this is your margin and here this is your margin since this curve is quite deep.

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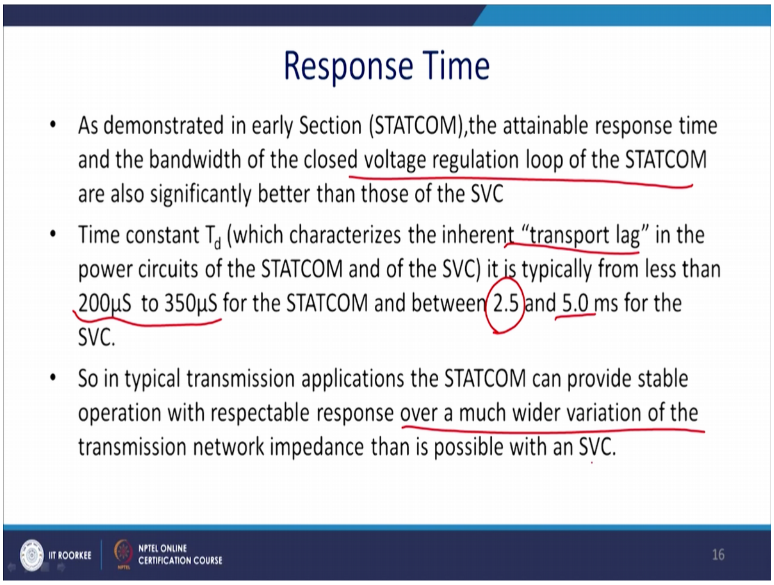

As demonstrated by this section earlier, the attainable response time of the bandwidth of the closed voltage regulation loop of the STATCOM is also significantly better than SVC; because you have we have discussed that it has to wait for the cycles to start and all those things.

But you can change the modulated index very fast for this reason the time constant T d which characterized by the inherent transportation lack in the power circuit of the STATCOM and SVC is typically less than 200 micro second to 350 micro second in case of the STATCOM. But it is an on ten times or fifteen times more in case of the SVC. So, it is actually 2.5 to 5 milliseconds that is actually the P i by 21 pic delay of SVC because you may have to have a transient operation for this you know you may have to wait total cycle total quarter cycle.

So, the typical transmission the STATCOM can provide a stable operation with respectable response over much wider variation of the transmission network impedance then this possible in this SVC. So, of course, that we can say that in transient stability entity also STATCOM supersite SVC. Now, let us come to the next topic that is exchange capability of exchange real power.

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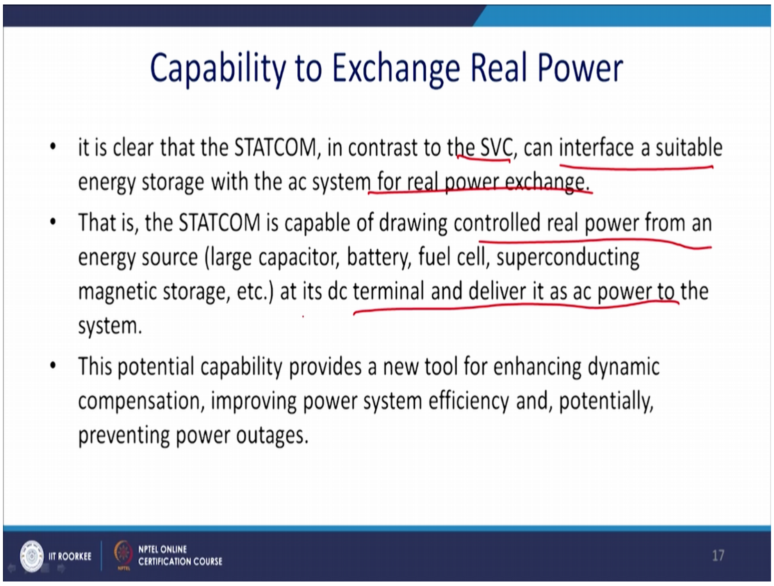

Though we have considered that STATCOM shunt compensation does not hold any real power. It is clear that STATCOM in constant to SVC can interface with the suitable storage element if you can provide to the ac system for the real power exchange. That is

STATCOM is capable of drawing controlled real power from an energy source like large capacitor, battery fuel cell, superconductor, solar cell, magnetic storage super conducting material and its dc terminal and deliver its ac power to the system. This potential capability provides a new tool of enhancing the dynamic compensation and it also provides and improves the power system efficiency potential and prevent the power losses or loss of synchronization or the catastrophically or the power system.

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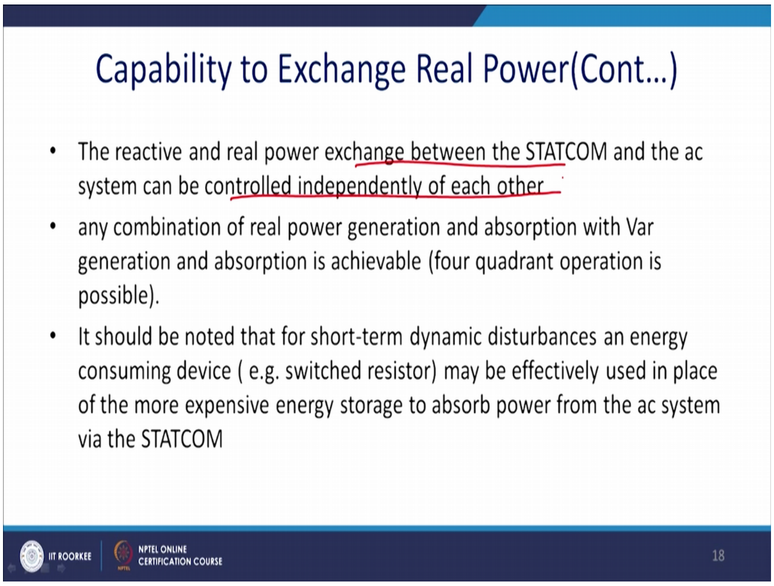

Thus capability to exchange power will have this merits real power. reactive power and the real power exchange between the STATCOM and the ac system can be controlled independently to each other.

This is the one of the feature we have seen that for quadrant operation of the STATCOM with the real with the power storing devices. Any combination of the real power generation and absorption with the Var generation and absorption is achievable and it is a four quadrate operation, four quadrant operation is possible. It should be noted that the short term dynamic disturbance.

An energy consumed by the devices like switching resistance switching losses of the devices may be effectively used in place of the more expensive storage to absorb power from the ac system by a STATCOM now what about its performance,, but in while handling, the unbalanced power system due to lower or resource for SVC normally means that.

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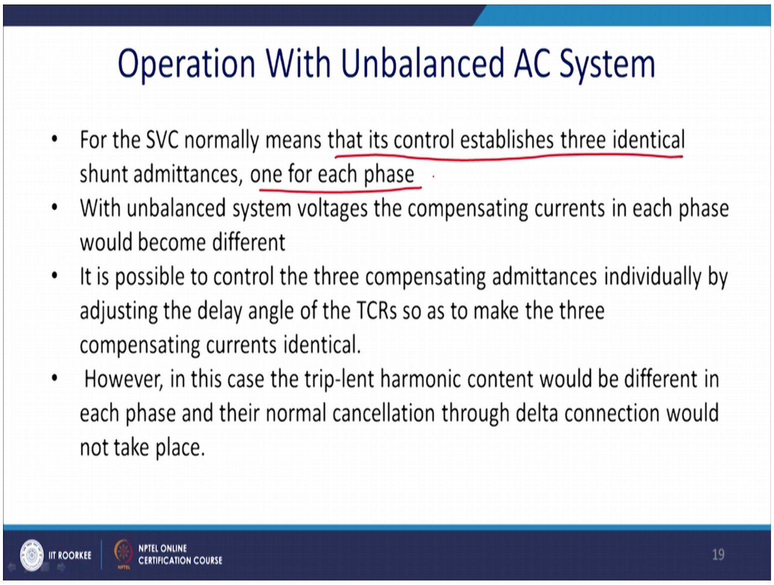

This control establishes three identical shunt admittances for each phase. So, while discussing we have assumed that the system is balanced. With unbalance system voltage compensation current of the each phase will be different. And it is possible to control the three compensating admittance individually by adjusting the delay angle of the TCR. So, as to make the three compensating current identical, we can of course, change alpha and by changing it.

However, in this case the triplet harmonic will be different in the three phases, and the normal cancellation through the delta connection would not takes place. So, we have discussed that how to compensate that triplet harmonic discussing SVC. So, if you have a this unbalanced in to the system. So, that method will have a will not give any fruitful results.

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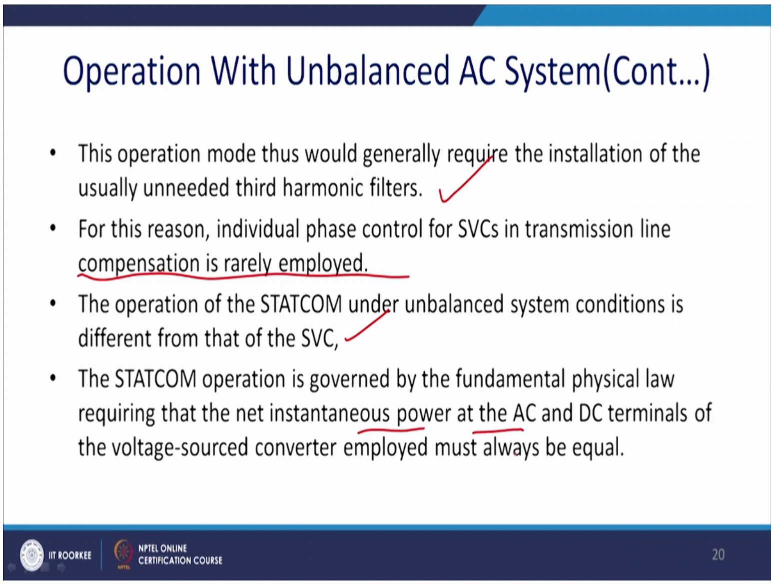

These operation more thus would generally require any installation of the usually unneeded third harmonic filters. You have to put another bulky third harmonic filter because it is a low frequency so, this filter will be very bulky.

For this reason individual phase control of the SVC transmission line compensation is rarely employed please note that point. The operation of the STATCOM under unbalanced condition is different from SVC. The STATCOM operation is governed by the fundamental physical law recovering that the net instantaneous power at the AC and the DC terminal of the DC voltage sourced converter employed must be always be equal.

Thus you can have a unbalanced power or the balanced power it does not matter. So, it can better handle the unbalanced. Assume that the dc terminal voltage of the STATCOM is supported entirely by an appropriately charged dc capacitor and a loss of the converters assumed to be 0 for sake of establishing the case.

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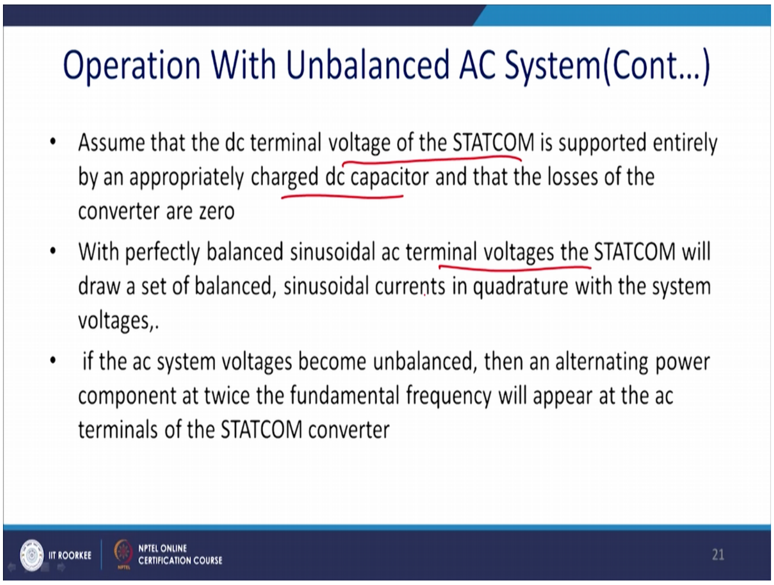

With perfectly balanced sinusoidal ac voltage STATCOM will draw the set of balanced sinusoidal current in quadrate with the system till 90degree phase shift. But if it is not balanced they would be not phase shift another phase shift. If the system becomes unbalanced then what will happen? Then the alternative power component of the twice of the fundamental frequency will appear in the ac stand bell of the STATCOM converter.

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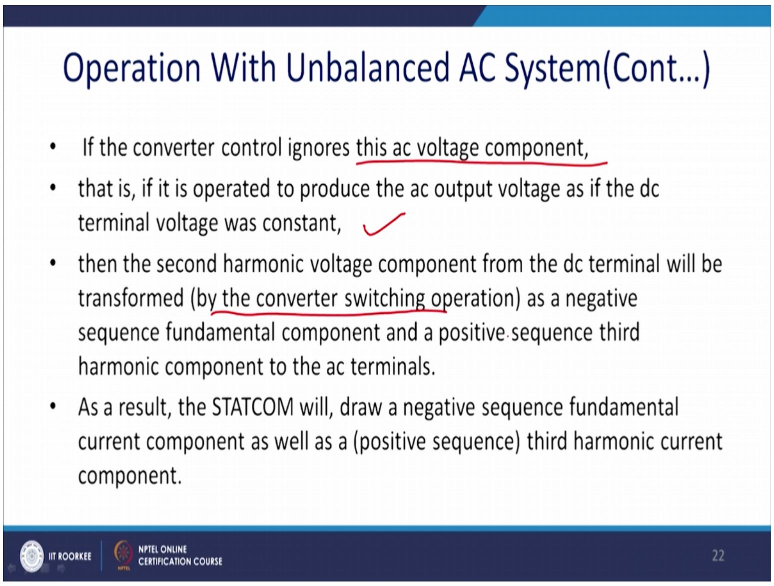

Now, if the converter control ignores this ac voltage component, thus if it is operated to produce ac output voltage, as if the dc terminal voltage was constant. Then the second harmonic component from the dc terminal will be transformed by the converter with switching operation as a negative sequence of the fundamental negative and the positive sequence of the fundamental components. As a results it will draw the negative sequence from the fundamental component as well as the positive sequence, and the third harmonic component from the source.

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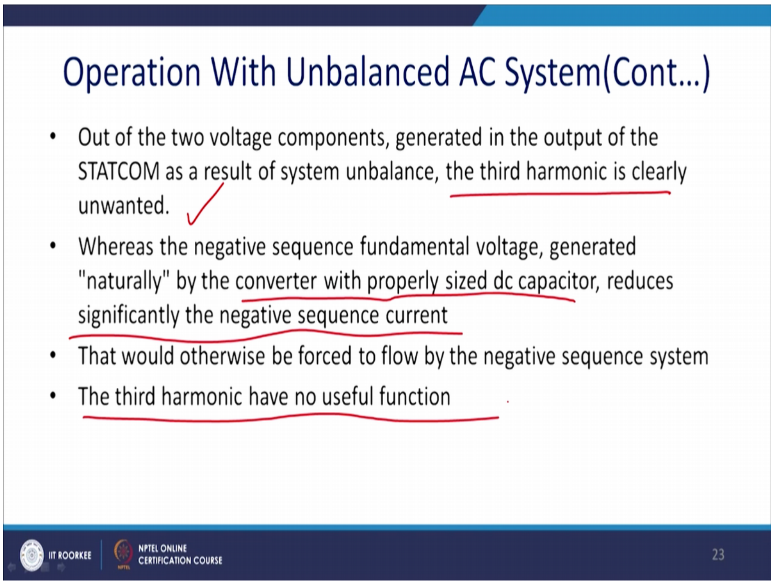

Out of this two components generated in the output of the STATCOM as a results of the unbalanced. The third harmonic is clearly unwanted please note that this will be circulating. Whereas, that the negative sequence generated naturally by the converter with properly sized dc capacitor reduces the significantly the negative sequence current that would otherwise be forced to flow by the negative sequence system and the third harmonic have no useful function.

So, it does not provide any sinkage for the third harmonic, what will happen then? The overall loss verses reactive characteristics of this STATCOM is already discussed.

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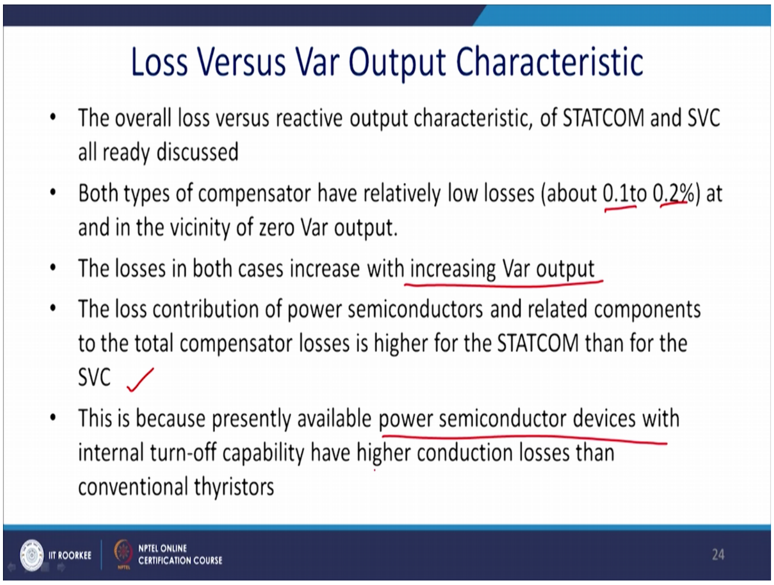

Both type of compensator have relatively low losses, 0.1 to 0.2 in the vicinity of the zero Var output. Losses in the both the cases increases with the increasing the Var output currently increases conduction loss increases. The loss contribution of the power semiconductor related to the component to the total compensated loss is higher for the STATCOM than for the SVC.

So, please note this point this is the one of the demerit of the STATCOM. This is because presently available power semiconductor devices with internal turn on capability have higher conduction loss than the thyristors, but we have a now a materials comings with the silicon carbide and all those things there we may this situation may change soon. Also the switching losses with the forced and the current intersession tend to involve more loss then the natural (Refer Time: 26:28). So, turn off loss will be there it is reasonably is reasonable to expect.

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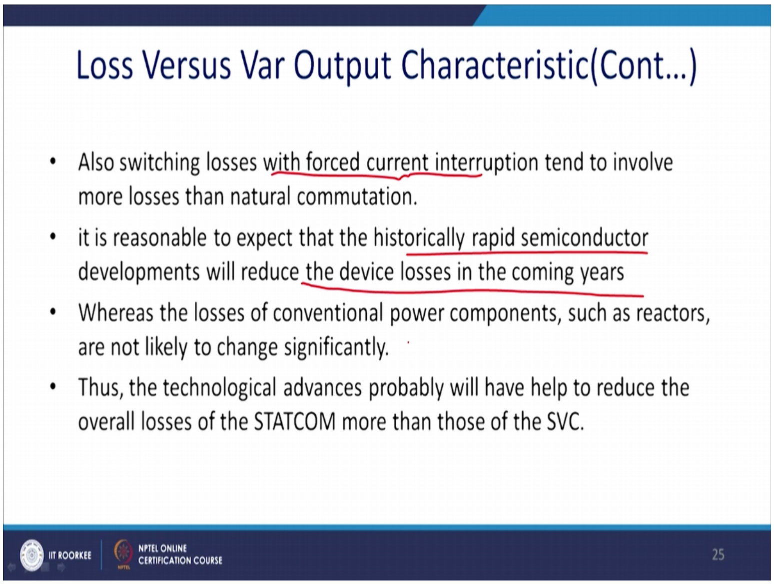

That historically rapid semiconductor development will reduce the device losses in the coming years. That is what I was saying, that we may have a actually silicon carbide device and all modern devices, that may change this statement whereas, that losses conventional power components such as reactor are not like to change significantly.

So, what we can say that STATCOM has a future, thus the STATCOM technological advantage probably will help reduce the overall losses of the STATCOM more than the SVC.

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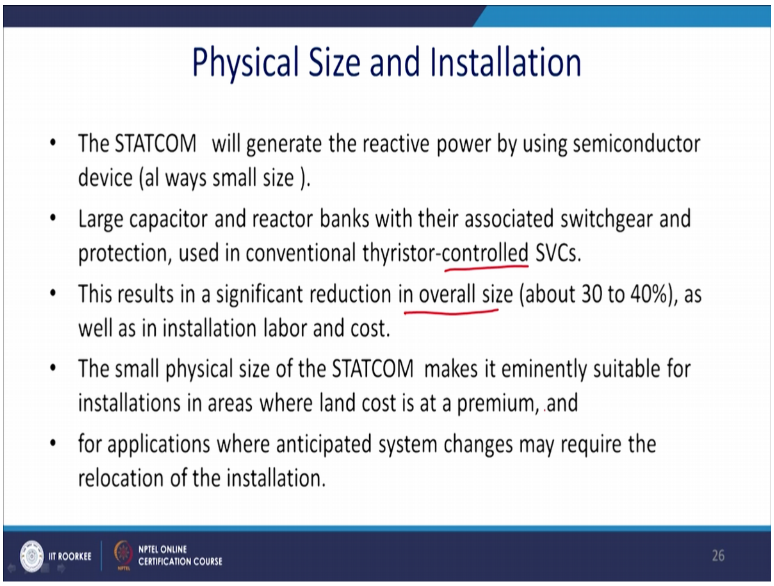

And what about a physical installation; STATCOM will generate the reactive power by using the semiconductor and that is how a small size. Large capacitor large reactor with associative with the switch gear and protections and all those things and used in a thyristor control SVC's, thus system is bulky. As a result the significant reduction of the overall size is about 30 to 40 percent is possible in case of the STATCOM. Small physical size of the STATCOM makes it eminent for suitable for the installations in areas where land cost is premium; that is also an important things say you are putting a STATCOM in Bombay. So, you require to consider it.

For the application where anticipated changes may require a relocation of the insulation, that is also something you have to give in mind. Today you may it may be a load center, tomorrow it may be that is a that point may change. So, you may have to reinstall somewhere else. So, retropetic and all those issues will have advantage on STATCOM.

Thank you for your attention we shall we have concluded the actually the compressor or the STATCOM on the SVC.