

Flexible AC Transmission Systems (FACTS) Devices
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Lecture – 14
Static Var Compensator II

Welcome to our FACTS devices courses. We have we shall continue today with the FACTS var compensator, we have we are discussing that will be a continuation of the previous discussions.

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MSC-TCR SVC

- In this instead Fixed capacitor mechanically switched capacitor are used
- It is normally used, where less number of switching required
- like FC-TCR SVC a small inductance is connected series with capacitors and tuned for selected harmonics
- In this also high pass filter also used for mitigation harmonic

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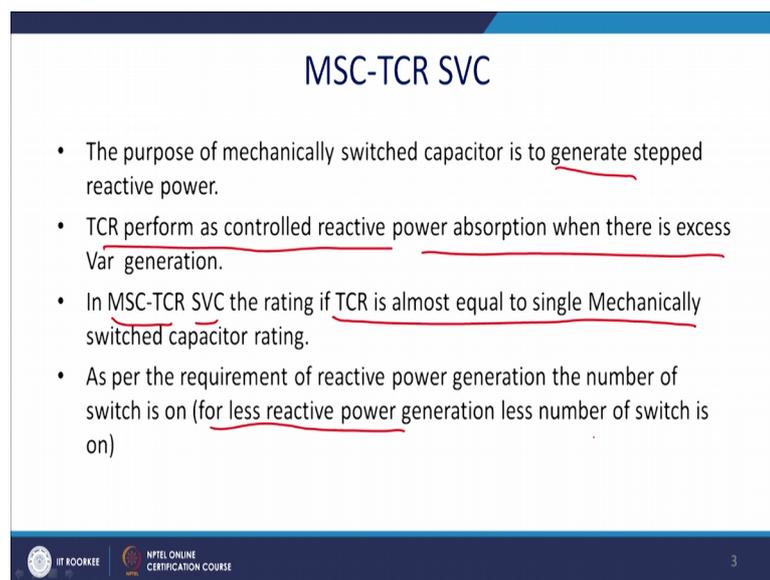
Now, first of all we will discuss about the MSC-TCR SVC. MSC stands for actually Mechanically Switched Capacitor and TCR is thyristor controlled reactor and that combinations will give you the actually the shunt compensations. Please understand it actually we this is a great connections and we require a step down transformer to match the rating of this TCR mostly.

So, we have a TCR and apart from that we have a mechanically switched constant capacitor and we will have a small value of the inductor. So, that it will actually prevent the inrush current so, the capacitor. And this is a harmonic because TCR will generate some amount of the harmonic that will be suppressed by this actually by this actually harmonic filter. So, this kind of combination is called MSC TCR SVC. Here instead of the fixed capacitor mechanically switched capacitor are been placed this is advantage of

it because you can connect and disconnect instead of connecting permanently with the voltage stress. And it is normally used why normal we require a less amount of switching. Because you know that there is a constant var let say around 14 MVA. So, you keep it is around fourteen MVA if at a moment it is 13.6 then you know it will have a capacity one TCR will have a capacity to actually inject one mega var negative.

So, you know actually it will inject actually minus 0.4 MVA. So, this is the concept of this MSC TCR. So, you would not be switching very frequently this capacitor for only for the maintenance or any isolation issues. It is same like fixed TCR is VCA small inductance is connected in series with a capacitor and tune for the selected harmonics and apart from that there should be a harmonic suppression filter. It is also a high pass filter used for the mitigations of the harmonic.

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The slide is titled "MSC-TCR SVC" and contains the following text:

- The purpose of mechanically switched capacitor is to generate stepped reactive power.
- TCR perform as controlled reactive power absorption when there is excess Var generation.
- In MSC-TCR SVC the rating of TCR is almost equal to single Mechanically switched capacitor rating.
- As per the requirement of reactive power generation the number of switch is on (for less reactive power generation less number of switch is on)

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Now, the purpose of the mechanically switched capacitor is to generate a stepped reactive power. Once it has we will show in the next slide, when it is been switched on. So, reactive power capability will change because you are actually in increasing the actually you are actually increasing the admittance of the line the small current will flow and the more MVR you will inject.

TCR perform as a controlled reactive power absorptions, because it will go to the highest numerical number highest unit of number; if it is every mechanical is mechanical switch may have a capacity of 2MVR. So, it will go to 7 and we require to select the

compensator 13.6 that 0.4 volt will come from the TCR power of this what it says that power absorption.

When there is a excess var generation in MSC TCR SVC, the rating if TCR is almost equal to the single mechanical switch rating of the capacitor. As per the requirement of the reactive power generation, the number of switch is on for less reactive power generation less number of switch should be on. Definitely if it is 10.4, then you will actually switch on something that I have rather switch on the other 12 because 6 and 1.6 MVA will has to be compensate by the TCR.

So, what are the advantage is definitely this is there is no complexity in it and we will switch it on when it will totally discharged and switch it off when it is at the zero crossing. So, there should not be any problem and it should be actually we will have a better resistance to actually dissipate the energy according to the system. That we will see in the last class in a actually in a practical quadrant injection control of the FACTS devices in a in a one case study.

So, advantage is a low loss and the low cost and disadvantage are definitely more because it is using put in practice before the FACTS devices.

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The slide is titled "MSC-TCR SVC" and is divided into two sections: "Advantage" and "Disadvantage".

Advantage

- Lower loss
- Lower cost

Disadvantage

1. Slow response due to mechanical switching, the switch closes in 2 cycles and open in 8 cycle. So it is not used for large dynamic reactive power variation.
2. If the Var demand would repeatedly change above and below those levels at which a capacitor bank is switched in and out. Then MSC-TCR SVC, cannot be used because the switching life limited by 2000-5000 times only.

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So, slow response due to the mechanically switching, the switching closes around 2 cycles. So, for this reason we require to inject or insert this in again inductor this actually

reactance very slowly, and that leads to the sub harmonic oscillation and open in 8 cycle. So, that is we have to check that we require to gradually dissipate the power and open it. So, it is not used for the large dynamic reactive power variation, and it is for the also for the fast the dynamic power reactive power variation.

If var demand, would repeatedly change above and below this level at which the capacitor bank is switched in and out, then the MSC TCR SVC cannot be used because switching life is limited to 2000 to 5000 cycles. So, we have to operate this actually operation very constraint manner so, that we can use it for the longer duration.

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MSC-TCR SVC

Disadvantage

3. Tapped energy in capacitor banks which results in transients. There for each capacitor has to be completely discharged through resistor (which make around 8 minutes) before being switch we use potential transformer(P.T) but it will increase the cost .
- The conclusion that, because of the much slower response and limitations in the execution of capacitor switching's, the output of the MSC-TCR combination would not be able to follow a changing reactive current reference
- It can be used in rate of change is very low, or it is a single step like change at a time when the capacitor is already discharged and ready for switching.

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And another issue is that the tapped energy in the capacitor bank which result in transients. So, capacitor always been a little nasty, when actually transient phenomena occurs. Therefore, each capacitor has to be completely discharged through a better resistor, which makes around 8 cycles you know you have to dissipate all the energies before being switched.

We use potential transformer P T also some kind, but generally it is it will also increase the cost of doing it. Thus we can conclude that because of much slower response and the limitations of the limitation execution of the capacitor switching, the output of these MSC TCR combination would not be able to allow to exchange the reactive current reference. So, we had to be fitted with the dynamically controlled TCR. It can be used in in rate of change it can be used where rate of change is very slow or a single step like

change must be taken place in time is already discharged, and we can go for the next switching stage.

The thyristor switch capacitor is another combinations. So, instead of the fixed is fixed with capacitor, we may have actually mechanical switch capacitor, you may put in on and off by mechanical switches.

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The slide is titled "TSC- TCR SVC". It contains four bullet points. The first bullet point is underlined and has a red arrow pointing to it. The second bullet point has a red circle around the word "branches" and a handwritten note "2 MVA → (13.6) MVA" below it. The third bullet point has a red underline under "maximum Var output". The fourth bullet point has a red underline under "to any maximum rating by". At the bottom of the slide, there are logos for IIT ROORKEE and NPTEL ONLINE CERTIFICATION COURSE, and the number 6.

TSC- TCR SVC

- The thyristor-switched capacitor, thyristor-controlled reactor (TSC-TCR) type compensator was developed for dynamic compensation with minimized standby losses and providing increased operating flexibility.
- A basic single-phase TSC-TCR typically consists of n TSC branches and one TCR.
2 MVA → (13.6) MVA
- The number of branches, n, is determined by practical considerations that include the operating voltage level, maximum Var output, current rating of the thyristor valves, etc.
- The inductive range also can be expanded to any maximum rating by employing additional TCR or TSR (Segmented TCR) branches.

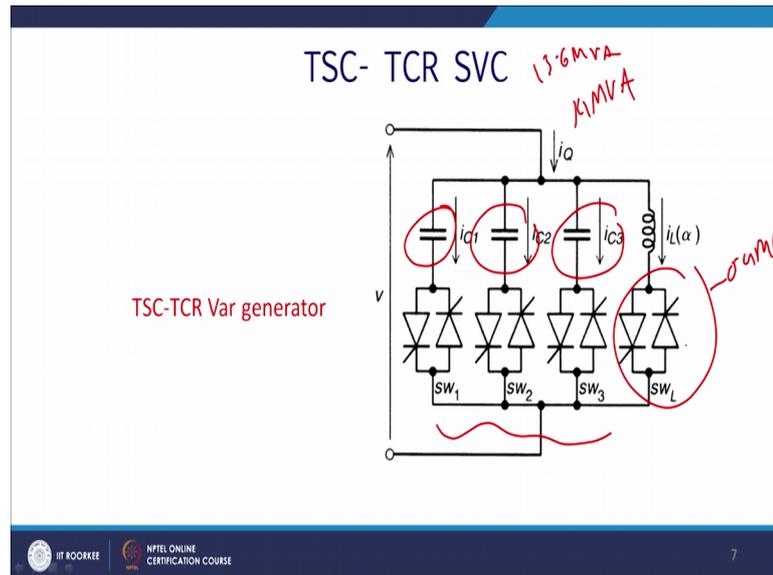
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Now, you may have a TCSC TCR is a combination. So, then you are also have a thyristor switch. So, it can manipulate turn on and turn off as well as you have TCR. So, thyristor switched capacitor and thyristor controlled reactor TCR are the type of combinations, actually compensator was developed for the dynamic response with minimized standby losses, provided providing the increased operating reliability.

Because you can also frequently turn on and turn off this TCR, that is already there and apart from that you have TCSC. So, that also can be turn on very frequently as a basic single phase TCSC TCR typically consist of n branches of the TCSC let us say have a rating of the 2 MVA. Again same example you require 13 dynamically you have compute that you have a 13.6 MVA. So, what you will do you know you will actually switch on the 7 such TCSC, and minus 0.4 var will be actually provided by the TCR, that is a principle of operation of this combinations is very simple.

Thus the n number of branches n, which is determined by the practical consideration that include the operating voltage level maximum var output current rating and the thyristor valve etcetera. The inductive range also can be expanded to any maximum rating by employing additional TCR is TSR segments of the branches. So, you can add on that is all.

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So, you know actually this is the one TCSC another TCSC and this is another SC. So, accordingly it will actually increase the var compensation and whatever the negative portion it will come. So, it will be actually making let say whereas, 7 such thing. So, that will be a 14 MVA capacitive and you require actually 13.6 MVA. So, minus 4 MVA 0.4 MVA will come from this TCR.

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TSC- TCR SVC

- The total capacitive output range is divided into n intervals.
- In the first interval, the output of the Var generator is controllable in the zero to Q_{Cmax}/n range, where Q_{Cmax} is the total rating provided by all TSC branches.
- In this interval, one capacitor bank is switched ON and, simultaneously the current in the TCR is set by the appropriate firing delay angle
- So that the sum of the Var output of the TSC and that of the TCR equals the capacitive output required.
- In the second, third, . . . , and n^{th} intervals, the output is controllable in the Q_{Cmax}/n to $2Q_{Cmax}/n$, $2Q_{Cmax}/n$ to $3Q_{Cmax}/n$, . . . , and $(n - 1) Q_{Cmax}/n$ to Q_{Cmax}

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The total capacitive output range divided into n individual. The first interval the output of the var compensator and the var generator is controlled to zero to $Q C \max$ by n . So, n is the actually the quantization, where $Q C \max$ is a total rating provided by the all the TCSC branches. In this interval, one capacitor bank is switched on simultaneously the current in the TCR is set to be set by the appropriate firing angle delay. So, that the sum of the var output of the TCSC and that of the TCS of the capacitive output is required.

So, it will compensate the negative var. The second third and the n th interval of the output controlled that is let us say this is actually $Q C$ by n . So, there will be $2 Q C \max$ by n and so on till $Q C \max$. So, you can have a step change in operation of compensating var we shall see in a wave form soon.

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TSC- TCR SVC

$\frac{Q_{max}}{M} = 2 \text{ MVA}$

- In all interval surplus reactive power absorbed by using the TCR
- So theoretically, the TCR should have the same Var rating as the TSC.
- But the switching conditions at the endpoints of the intervals are not indeterminate,
- So the Var rating of the TCR has to be somewhat larger in practice that of one TSC in order to provide enough overlap (hysteresis) between the "switching in" and "switching out" Var levels.
- The capacitive Var output (Q_C) is changed in a step-like manner by the TSCs

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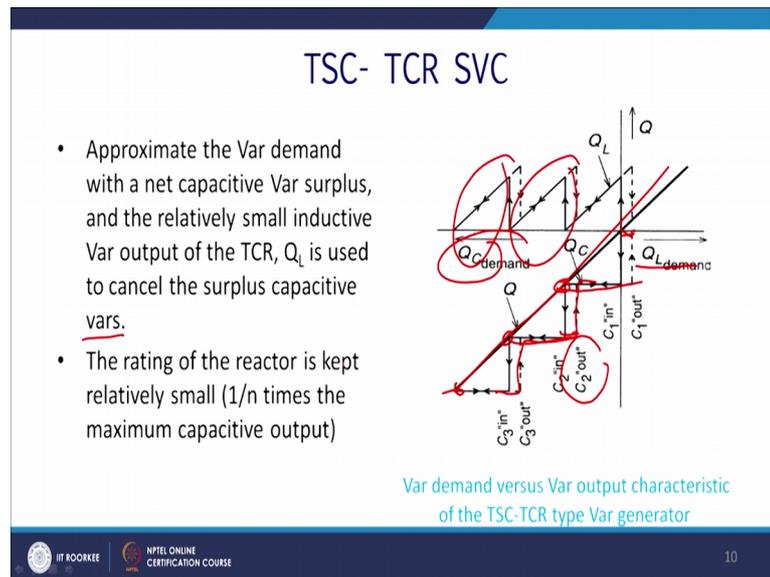
In all interval, surplus of the reactive power is absorbed by TCR that is what I was saying. So, theoretically TCR should have a same var rating as TCSC, but which will later provide little bit more, but switching condition at the endpoint of the intervals are not intermediate.

So, var rating of the TCR has to be somewhat larger even though you can say that since the Q_{max} by n you have chosen to be 2 MVA. That is a say rating of the single are TCSC branches, but here you know that is what it is saying it has to be somewhat larger in practice, that of the TCSC in order to provide enough overlap.

Because you know you require to have a hysteresis band otherwise you will unnecessarily switching this devices. So, for this reason overlap or the hysteresis band between switched in and switched out var level. So, we will decide. So, that is actually what is actually the window of hysteresis. So, whether it is 0.1 MVR or 0.2 MVR that something we require to decide and based on that we have to provide this.

The capacitor output var Q_C is changed in a step like the manner of the TCSC which we have discussed earlier.

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So, this is the wave form we require to explain this is the Q demand and this is the L demand; once you actually switch on this capacitor. So, you get this much of var, once you are this much of capacitor. So, you get a steps like compensations switch it on you get. So, you can convert into the ramp ultimately you will have this kind of ramp. So, that will p 2 operated, but you can operate only this point this point something like that. And accordingly that extra demand has to be compensated by the inductive var. So, you can inject a little bit of inductive var. So, you know actually you will have this is the dotted line.

So, once you like to go it back. So, once you come back you come with like that, and you know this is actually the ramp on in that way, this is for one TCR, this is for another TCR, this is for another TCR accordingly you can change the var ultimately you can make it also inductive var demand by switching only the TCR. Thus what we can can conclude from this discussions? The approximate var demand with a net capacitive var surplus and a relatively small inductive var output of the TCR and Q_L is used to cancels the surplus reactive var.

So, this is the actually small amount of the reactive var. The rating of the reactor is kept relatively small that is 1 by n times of the maximum rating of the capacitor voltage and the capacitive MVR.

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The slide is titled "TSC- TCR SVC" and features a handwritten diagram at the top left showing a circuit with a thyristor and a capacitor. The text on the slide is as follows:

TSC- TCR SVC

- Control scheme for the TSC-TCR type Var generator have to provides three functions $20\text{MV} \rightarrow 2\text{MVA}$
- 1. Determines the number of TSC branches needed to be switched in to approximate the required capacitive output current and computes the amplitude of the inductive current needed to cancel the surplus capacitive current.
- 2. Controls the switching of the TSC branches in a "transient-free" manner.
- 3. Varies the current in the TCR by firing delay angle control.

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The control scheme of scheme for TCSC TCR type generator and we will see that how it can be controlled. First of all we require to know that what can be the maximum var requirement of that particular side and we came across let us say we require let us say 20MV and from there we have to design the size of the modality. So, what should be the one branches capacity of compensation?

So, let us set we decide of the all the constraint, thyristor ratings transients all those consideration has to be put into the operation and we find out that actually the 2 MVA will be the suitable. So, thus it can compensate maximum capacity var of up to 20 MVA by switching 10 such TCSC. And you should have 1 TCR operating of around 2.5.

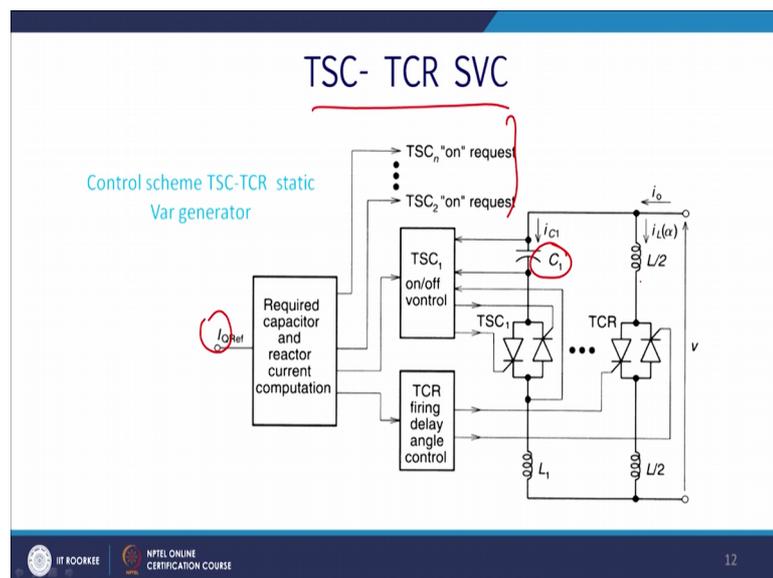
So, that there will be a little overlapping and you can able to compensate in the right manner and you can manage with the actually the combination of TCR and TCSC very well. The precision will be set by TCR that first source thus what happens? That determines the number of the TCSC branches detect to be switched on switched in to the in to the approximate required capacity output current of and compute the amplitude of the inductive current needed to cancel the reactive surplus var.

First of all you will compute let say 13.6 from 13.6 you will actually come down the number n that will be 7 here. So, you are compensating 14 MVA for exactly you require basically then TCR has to inject 0.4 MVA, and thus you compute the delay angle for it. Delay angle can be computed online by the processors or you may have a i prom. So,

that you have for every degree of alpha, for a particular voltage rating. So, you know this actually what should be the value of alpha, that you can put it into the e prom with some precisions of 180 degree or will 0 to 180 degree with the precisions of 1 degree or 2 degree. So, we have to see that what will be the change in current for the 1 degree and 2 degree, we will be in a prescribed limit we said choose the precision in that way we shall come this a little later next slide.

The control the a controls the switching of the TCSC branches in a transient free manner that is very important. Since you are inserting capacitor so, you have to do the 0 voltage switching that we have discussed previously; you know we require to insert a capacitor when you are inserting a capacitor ensure that voltage supply voltage and the capacitor voltages are same or when supply voltage is 0 you are going to switch on this capacitor; varies the current in the TCR by firing angle delay control.

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So, this is something the scheme of TCSC TCR SVC. So, you have m such TCS C's and you require the IQ Ref. So, thus you can find it out what will be the number of such element actually 123 to 7 is required. So, for this is you will turn it on those. So, 1 to n thereafter you know you will have this is on off control and there is see that you know actually you will sense the voltage of the TCSC that is very important of this capacitor, and accordingly you will give a pulse and this scheme we will discuss little later and we will give a triggering pulse of the thyristor to the TCR.

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TSC- TCR SVC

Determines the number of TSC branches needed to be switched

- The input current reference I_{Qref} representing the magnitude of the requested output current
- Find the ratio of current reference (I_{Qref}) to current (I_C) that a TSC branch would draw at the given amplitude V of the ac voltage.
- The result, rounded to the next higher integer gives the number of capacitor banks needed (TSC).

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So, the first of all first steps will be to determine the number of TSC branches needed to be switched from this actually I_{Qref} . The input current reference I_{Qref} is presenting the magnitude request of the output current. So, we have to find that find the ratio of the current reference and current I_C . So, then that gives you the number of n , then n comes out to be 13 actually 5.6, then you actually turn on 6 such things and that actually the fraction part will be compensated by the TCR and that a TCR branch will draw at the given amplitude V of the ac voltage. The result rounded to the next higher integer and this number of capacitor banks is switched.

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TSC- TCR SVC

computes the amplitude of the inductive current needed to cancel the surplus capacitive current

- The difference in magnitude between the sum of the activated capacitor currents $\sum I_{Cn}$ and the reference current I_{Qref} gives the amplitude $I_{LF}(\alpha)$ of the fundamental reactor current required

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Then compute the amplitude of the inductive current needed to cancel the surplus reactive current. You find it out actually I_{Cn} , from I_{Cn} actually you will actually compute the current required that will be $I_{Q\ Ref}$ and thus forms subtraction you get basically that the inductive current to the TCR that is $I_{LF\ \alpha}$. So, you required to compute the alpha from I_{LF} .

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TSC- TCR SVC

Switching of the TSC branches in a "transient-free" manner

- Switching of the TSC branches follows the two simple rules for "transient-free" switching summarized in TSC discussion.
- That is either switch the capacitor bank when the voltage across the thyristor valve becomes zero or when the thyristor valve voltage is at a minimum. (The first condition can be met if the capacitor residual voltage is less than the peak ac voltage and the latter condition is satisfied at those peaks of the ac voltage which has the same polarity as the residual voltage of the capacitor)
- The third function (TCR firing delay angle control) is identical to that used in the fixed-capacitor, thyristor-controlled reactor scheme.



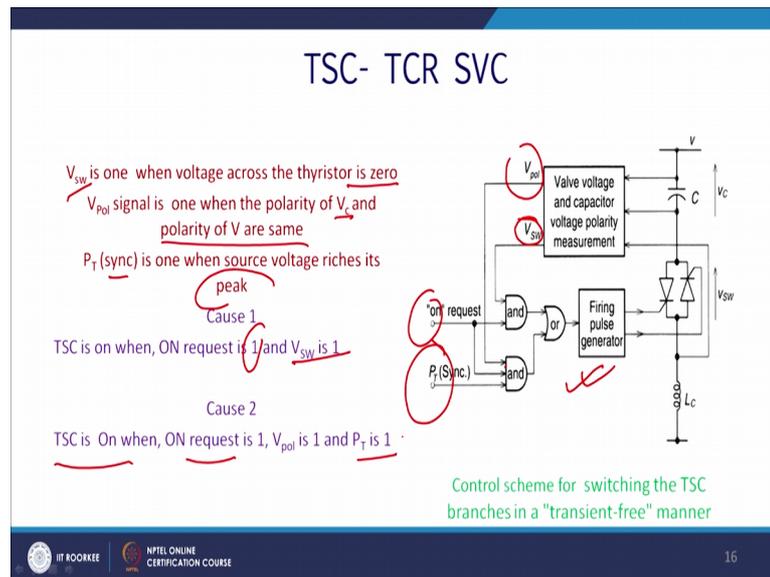
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So, what we can say the switching of the TCSC branches follow the two simple rule; one we require to our transient free operation and that is either switch the capacitor bank when voltage across the thyristor valve becomes zero or when the thyristor valve is a voltage, when it is minimum.

So, either of the circumstances you have you can trigger on to ensure that minimum transient into the system. The first condition can be made if the capacitor residual voltage is less than the peak voltage and the later condition is satisfied, those peaks of the ac voltage who has the same polarity of the residual voltage of the capacitor. For this reason you will sense this actually every moment the voltage across thyristor and also check the polarity of fit and then you actually design the triggering pulse in that manner, we shall come and see that actually triggering scheme for the TCR in next slide.

For the third function, TCR firing delay angle is identical to use for the fixed capacitor there is no change and thyristor control reactor scheme.

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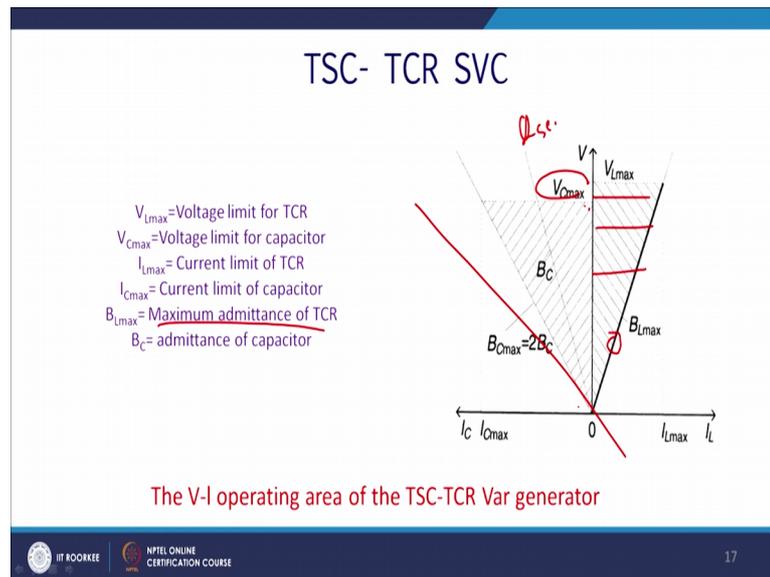


So, this is the actually the control logic, you have to sense this voltage first of all it will sense the pole voltage that is called pole voltage and also the we have to sense the voltage across the switch. So, we want have a minimum stress across the switch. So, what happen? So, if you have a on request then first of all you require to synchronization with the actually P T.

So, that is comes of the potential transformer essentially is a voltage template and it will end, and then it will actually also check the pole voltage, and then it will again what happen you have on request then you will check the switch voltage both. So, then it will end it and that or it you will give a triggering pulse because there is a two conditions so, clause 1 and clause 2.

When v_{sw} is high or one whatever voltage across this thyristor is zero that is something that information should carry. The pole voltage is signal is one when polarity V_c and a polarity of the phase a line voltage of the great voltage are same and PT is a actually synchronizes one when the source voltage reaches at its peak. So, TCSC is on when the request 1 and SW is 1; that means, switch across its thyristors is 0 or when TCS is on when the request 1 this pole actually potential is 1 and the PT is 1 in the circumstances also it will put the thyristor on.

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So, thus what happen you know, this is the actually the admittance curve you know what happen for this is actually you require to keep the rating of the TCSC little below than the TCR, because of the voltage swelling of the capacitor. So, for this maximum V_C max you can go little lower than the V_L max.

So, this is the this is actually compensation you can choose any compensation level for the V_L depending on this actually amount of the current you have passing through and that will depend on the voltage rating of the of the supply. And here if you wish to change it then you have to this is for actually TCSC 1 and this is for the TCSC 2 this is for the TCSC 3 this is for the TCSC n in that way this will go on.

So, this is basically the V_L max is the voltage limit for the TCR, V_C max is the voltage limit for the capacitor and I_L max is the current limit by of the thyristor and I_C max is the current limit to the capacitor and B_L max is a admittance of the TCR you can choose any value and B_C is a admittance of the capacitor and it will change in this way.

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The slide is titled "TSC- TCR SVC" in a large, dark blue font. Below the title, the text "The advantages of TSC-TCR type SVC over FC-TCR type" is written in red. A bulleted list follows, with red underlines and checkmarks under certain items. The list includes: "The reduction in the reactor size and consequently the harmonics generated" (with a checkmark), "Greater flexibility in control" (underlined), "Better performance under system fault conditions.", and "The power losses in the quiescent operating condition (with SVC output current close to zero) also tend to be less with TSC-TCR type SVC." (with "TSC-TCR" underlined). At the bottom left, there are logos for "IIT ROORKEE" and "NPTL ONLINE CERTIFICATION COURSE". At the bottom right, the number "19" is displayed.

TSC- TCR SVC

The advantages of TSC-TCR type SVC over FC-TCR type

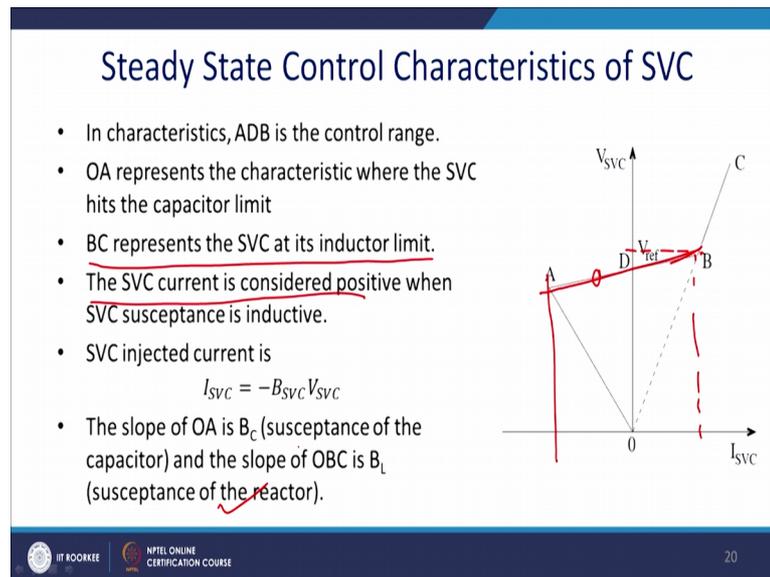
- The reduction in the reactor size and consequently the harmonics generated ✓
- Greater flexibility in control
- Better performance under system fault conditions.
- The power losses in the quiescent operating condition (with SVC output current close to zero) also tend to be less with TSC-TCR type SVC.

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Advantage of the TCSC TCS type SVC; Of course, you have a fully controlled unlike the fixed and the mechanical control.

The reduction of the reactor size because you can play around little bit with the modular type TCSC with consequently the harmonic is also generated, we require to suppress the harmonic. It got greater flexibility of control precision can be set by the TCR better performance under fault condition because you have a switched one and you can switch it off or switched in the impedance part of the it to damp out the oscillation, power losses in the operating conditions that is with SVC output current close to zero tend to be less with the TCR TCSC type SVC than the normal one.

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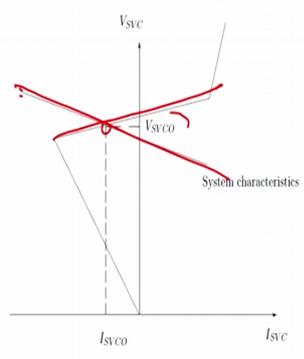
So, this is the actually the combination this is actually compensations, you know this value basically inductive value will be little bit more and you have a maximum value of the current can pass through the thyristors of the TCR. This portion is actually the TCR compensation and this portion AD is that portion basically that capacity combinations. So, the characteristics ADB is the control range you can actually have a this kind of control range, less current you can go to the little higher voltage inside the capacitive, but capacitive voltage when you have fully you have to little bit drooping. The voltage compensation the BC represents the SVC at its inductor limit.

The SVC current considered the positive, when SVC susceptance is inductive. SVC injected the current it is $I_{SVC} = -B_{SVC} V_{SVC}$. The slope of OA is B_c susceptance of the capacitor and the slope of OBC is B_l that is susceptance of the reactance.

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Steady State Control Characteristics of SVC

- The steady state value of the SVC bus voltage is determined from the intersection of the system characteristic and the control characteristic
- The system characteristic is a straight line with negative slope and is defined by
$$V_{SVC} = V_{TH} - X_{TH}I_{SVC}$$
- Where V_{TH} and X_{TH} Thevenin voltage and reactance viewed from the SVC bus.



Determination of operating point of SVC

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And what happens then the steady state value of the SVC bus voltage is determined from the intersections of the system characteristics and the control characteristics. So, this is basically the system characteristics that is a voltage and you will cut to this one point and generally when power factor increases I mean that is I mean gets better the plot will increase, and in a capacitive reason, but you have a just reverse characteristics compensation characteristics will be this. And system characteristic that is a voltage characteristic will be this and you will find the operating point that point you will operate.

The system characteristics is a straight line with a negative slope defined by SVC equal to V_{TH} minus Thevenin equivalent into SVC, where V_{TH} and the X_{TH} are the Thevenin voltage and reactance viewed from the SVC where the point SVC is connected.

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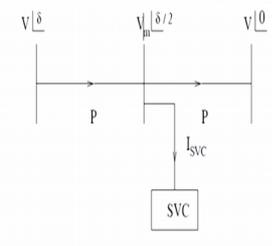
Steady State Control Characteristics of SVC

- For the modeled system

$$V_{TH} = V_{mo} = \frac{V \cos(\delta/2)}{\cos(\theta/2)}$$

$$X_{TH} = \frac{Z_n}{2} \tan(\theta/2)$$

Where Z_n is the surge impedance

$$Z_n = \sqrt{\frac{l}{c}}$$


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So, from there actually we can go to this calculation since it is a midpoint controller, we can find it out actually the actually $V \cos \theta$ by δ by 2 and so, from there this is the actually the X_{TH} and where surge impedance will be given by under root of l/c .

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Steady State Control Characteristics of SVC

Expression for voltage and power

control range

The SVC control rang is described by

$$V_{SVC} = V_{ref} + X_s I_{SVC}$$

where X_s is the slope of the control characteristics. V_{ref} is the SVC voltage when I_{SVC} is zero (point at D)

after solving the above equations

$$V_{SVC} = V_m = \frac{V_{TH} X_s}{X_s + X_{TH}} + \frac{V_{ref} X_{TH}}{X_s + X_{TH}}$$

the expression for power flow in the line is given by

$$p = \frac{V_m V \sin(\delta/2)}{Z_n \sin(\theta/2)}$$

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So, we can have a control range. So, we have a SVC plus V_{ref} plus this extra control current where X is a slope of the control characteristics and V_{ref} is the SVC voltage and I_{SVC} at the zero current. So, after solving you know you can get that is actually the voltage of the SVC at the midpoint on the sack compensator will be this value and

ultimately what you get actually V_m that is midpoint into $\sin \delta$ by $2 Z_n \sin \theta$ by 2.

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Steady State Control Characteristics of SVC

At SVC limits

- When the SVC hits the limit, then it can be represented as a fixed susceptance (B_{SVC}) where $B_{SVC} = B_C$ at capacitive limit. At the inductive limit, $B_{SVC} = -B_L$.
- Substituting I_{SVC} in this equation $V_{SVC} = V_{TH} - X_{TH} I_{SVC}$ then

$$V_{SVC} = V_m = \frac{V_{TH}}{1 - X_{TH} B_{SVC}} = \frac{V \cos(\delta/2)}{(1 - X_{TH} B_{SVC}) \cos(\theta/2)}$$
- Power flow is

$$\frac{V^2 \sin(\delta)}{Z_n (1 - X_{TH} B_{SVC}) \cos(\theta)}$$

So, by calculating it you can calculate the power flow and this power flow will be $V^2 \sin \delta$ by $2 Z_n (1 - X_{TH} B_{SVC}) \cos \theta$.

So, you can see that you can compare with that $V^2 \sin \theta$ by $2 Z_n \sin \theta$. So, you can see that you can reduce this the denominator by playing out this p_{TH} into a. So, this multiplication can be 0.5, thus you can have a actually power flow control increase to the two types. So, this is the our discussions of this actually TCR type SVC. So, we shall continue to discuss shunt type reactance in our next classes thank you for your attentions.

Thank you very much.