Power System Dynamics

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Lecture - 39

Methods of Improving Stability

Today, we shall study the methods of improving power system stability. We have so far studied the modeling of the system and various techniques for analyzing the stability of the system. We also examine the techniques which are suitable for analyzing transient stability and small signal stability and we also studied the voltage phenomena in a power system. Today, we will discuss certain special methods which are used for improving stability or enhancing stability of the system.

The several methods have been evolved over the years for enhancing the stability of the system and whenever you apply certain techniques or methods for enhancing stability only one method is not adequate judiciously chosen a combination of several methods may have to used. Today, we shall try to examine the techniques for transient stability enhancement.

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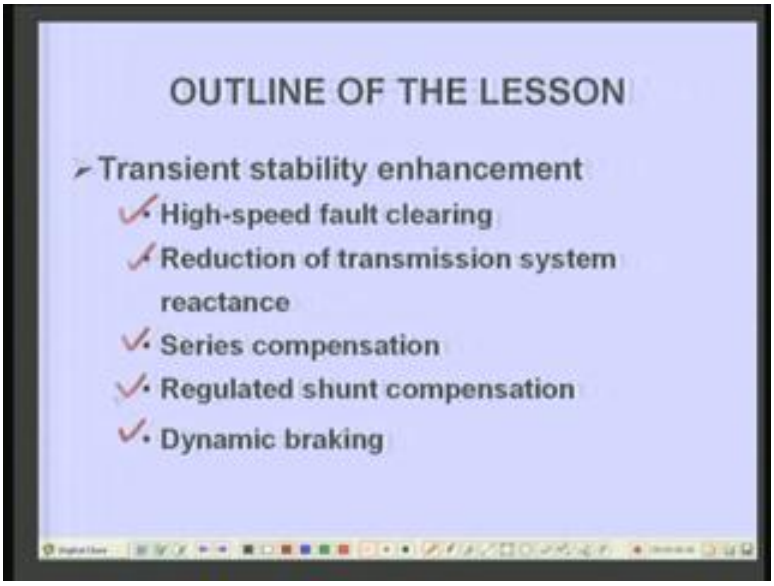

Under this category we will study importance of high speed fault clearing reduction of transmission system reactance under this category we will study how we can use series compensation to enhance the enhance the stability of the system by reducing the transmission line reactance then we shall also study about the affect of regulated shunt compensation on the stability of the system.

By applying regulated shunt compensation, we will be in a position to maintain voltage at a desired level at certain points in the system and hence we can improve the power transfer capability of the system. Then we will also study very special technique which is suitable for improving the transient stability it is called dynamic braking.

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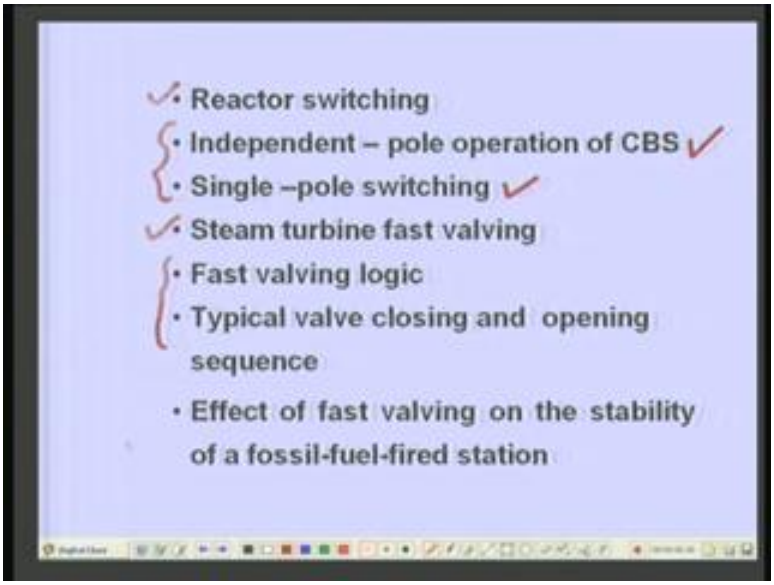

Another techniques which can be useful for enhancing the stability are the reactor switching then in terms of operation of the circuit breaker, there are two ways which can be used for enhancing the stability one is the independent pole operation of circuit breaker and the single pole switching these are the two different approaches for clearing the fault by operating the circuit breakers. In the independent pole operation as we will see the 3 poles of the circuit breaker are independently opened and closed that is there is a mechanism is so that we can independently open and close.

One arrangement maybe that all the three poles have one common mechanism to open and close but here the independent pole operation means we have 3 separate mechanisms for closing and opening the circuit breaker. However, however the whenever fault occurs irrespective of type of fault all the three poles will be open. In single pole switching arrangement the as we will see the 3 poles have separate independent mechanism for opening while whenever the fault occurs that is line to ground fault then only that faulted phase pole will be open.

In case any other type of fault occurs then all the 3 poles will be open this is what is the basic different between the independent pole operation of circuit breaker and single pole switching. We will see actually in detail under what circumstances the these techniques are suitable for enhancing the stability. Then the next important method for improving stability is steam turbine, fast valving this technique we try to control the mechanical power delivered by the turbine. We will see actually how we control the mechanical power.

We will discuss under this technique the fast valving logic and typical valve closing and opening sequence, how the valve is closed, how it is opened this sequence we will see. Then we will see what is the affect of fast valving on stability of fossil fuel, fired, fossil fuel fired station that means basically coal fired thermal power plant although the fast valving can be used for nuclear power plants also.

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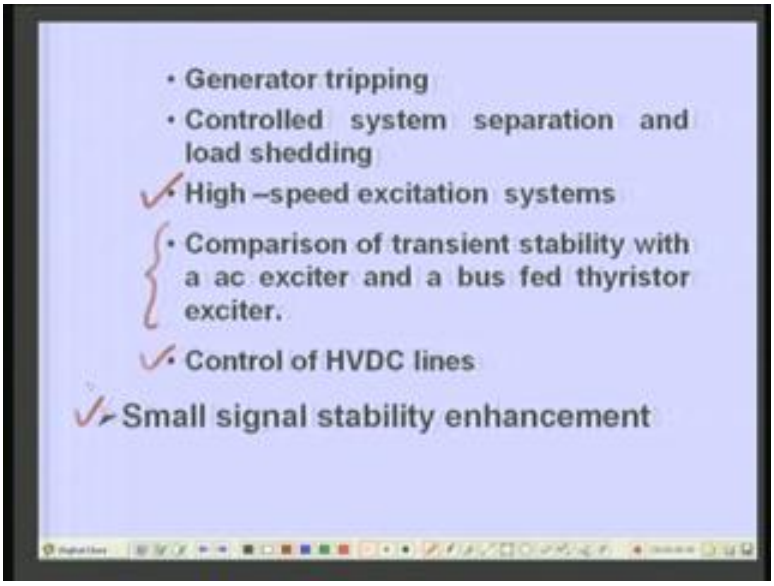

Then there are some other techniques which are suitable for enhancing stability are generator tripping, controlled system separation and load shedding, high speed excitation systems or high speed control of excitation. Then we will examine the performance of two types of excitation systems from the point of view of transient stability enhancement and at the end I will talk about the control of HVDC lines for improving the stability of the system these are several these are the large number of alternative approaches which are available for enhancing the system stability.

However, as I mentioned that for any particular system for a particular contingency one has to analyze the system in advance and and incorporate a set of techniques or set of devices which can be operated to enhance the stability of the system, these all these techniques are primarily for enhancing the transient stability or we can say the large perturbation stability of the system, small signal stability enhancement is done by by in installing the power system stabilizers and I have discussed about the designed and application of power system stabilizers for enhancing small signal stability in detail earlier we will not go into details about this small signal stability enhancement now.

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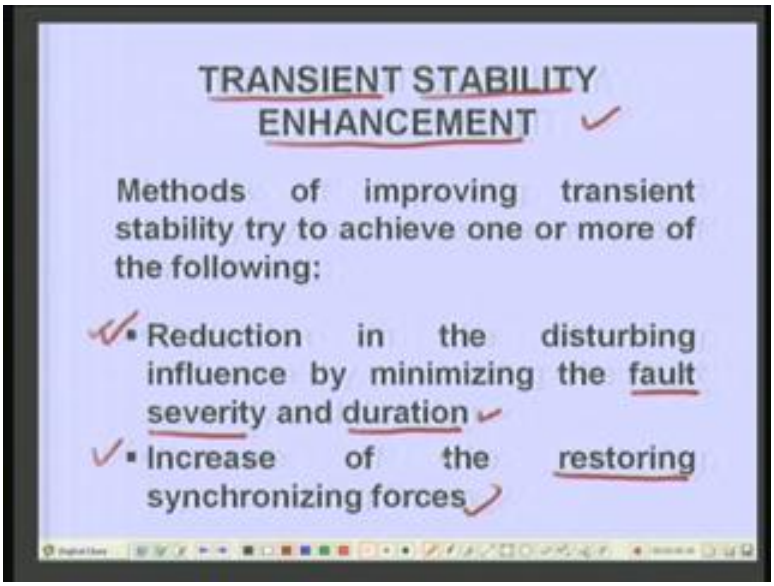

Now let us discuss these techniques one by one and see their effectiveness in enhancing the transient stability. Now when we try to see enhancement of transient stability or transient stability enhancement all the methods all the methods which are which have been evolved over the years all the techniques which have been evolved over the years are primarily aimed at achieving the following following affects, one is reduction in the disturbing influence by minimizing the fault severity and duration.

Normally you know power system instability occurs occurs when this faults occurs in the system and as we see that if the duration of fault can be reduced then then the the affect of disturbance is minimized because after all what happens is the when the fault occurs in the system during the faulted condition, the power output from the machines decreases, electrical power output. However, the mechanical input remains same and therefore all these machines where electrical output has decreased experience accelerations and they gain certain amount of kinetic energy. The amount of kinetic energy gained depends upon the duration of the disturbance duration for which the system is under fault condition and therefore one of the approach is to reduction of disturbing influence by minimizing the fault severity and duration, the one is the fault severity another is the duration over the years lot of efforts have been made to to reduce the fault severity and its duration, second is I will talk about what technique can be used but second is increase of restoring synchronizing forces. See the system is subjected to disturbance and then when has to be restored back to the initial operating condition or to the new operating condition right for that we need synchronizing forces.

Therefore the first is the reduction in disturbing influence and second is increase of restoring synchronizing forces, all the techniques we have to do is that we have to restore. We have more synchronizing forces that system is brought back to the new operating condition or the previous operating condition depending upon the the system.

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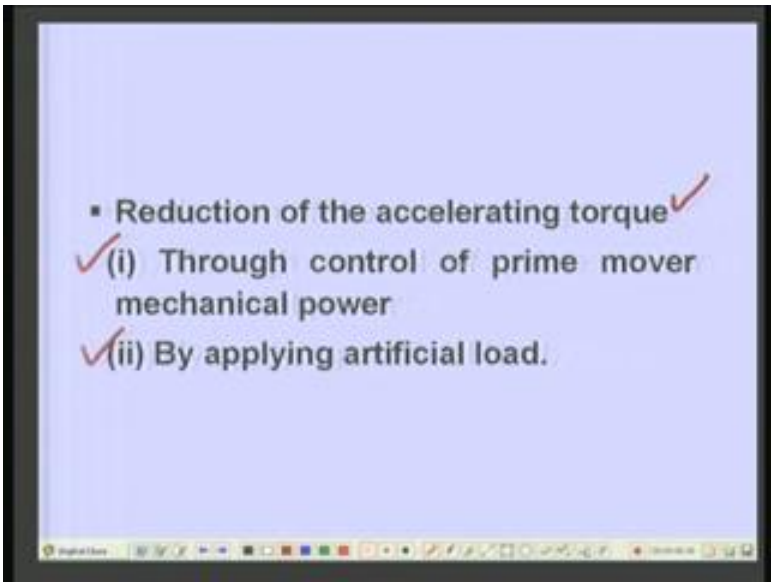

Another very important approach is reduction of accelerating torque that is we want to reduce the accelerating torque this can be reduced by by prime mover mechanical power control or through control of prime mover mechanical power you control this prime movers so that the mechanical power is is reduced when system is accelerating another is by applying artificial load.

Now here when I talked about this mechanical power the technique is called fast valving where we operate the valves to reduce the mechanical power output from the turbines in a very special manner I will discuss the fast valving in detail. Similarly, another approach is that we apply artifical load that is called braking we apply actually at the generator terminals, the braking resistors and the resistors are applied in a very judicious manner so that the the transient stability of the system is enhanced. We will talk about this braking resistors in detail.

Therefore, let me sum up the basic approach are is like this one is that you reduce the reduce the severity of the fault, duration of the fault, increase restoring forces, control mechanical power you reduce actually the acceleration accelerating torque or apply artificial load to reduce actually the electrical to increase the electrical power output and to enhance or enhance stability that is to to reduce the gap between the mechanical power and electrical power or say accelerating power that is accelerating power can be can be reduced by either reducing the mechanical power or increasing the electrical power.

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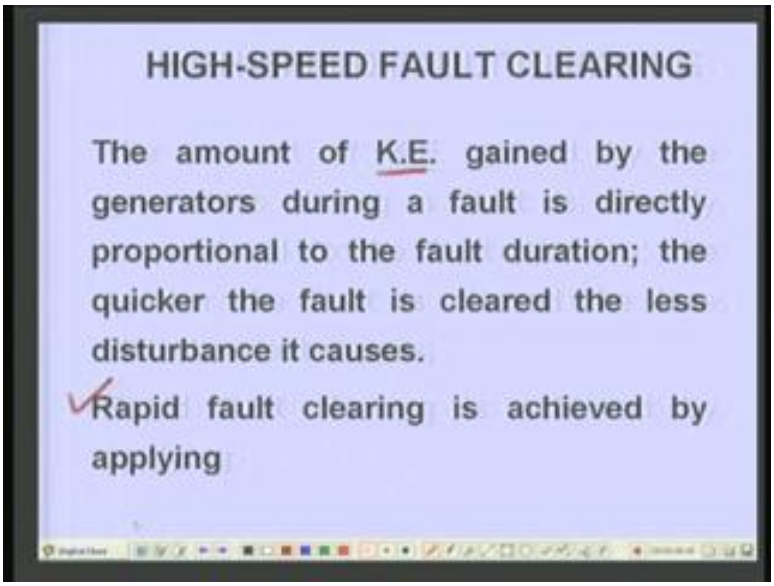

Now here let us talk about high speed fault clearing which is primarily for for reducing the duration of fault on the system enhance the hence the affect disturbing affect the amount of kinetic energy gained by the generators during fault is directly proportional to the fault duration the quicker the fault is cleared the less disturbance it causes this is very very fundamental you can say concept here right and all the efforts have been directed towards rapid fault clearing of the system. So for the severity of the fault is concerned, the severity of fault will depend upon the type of fault location of fault right.

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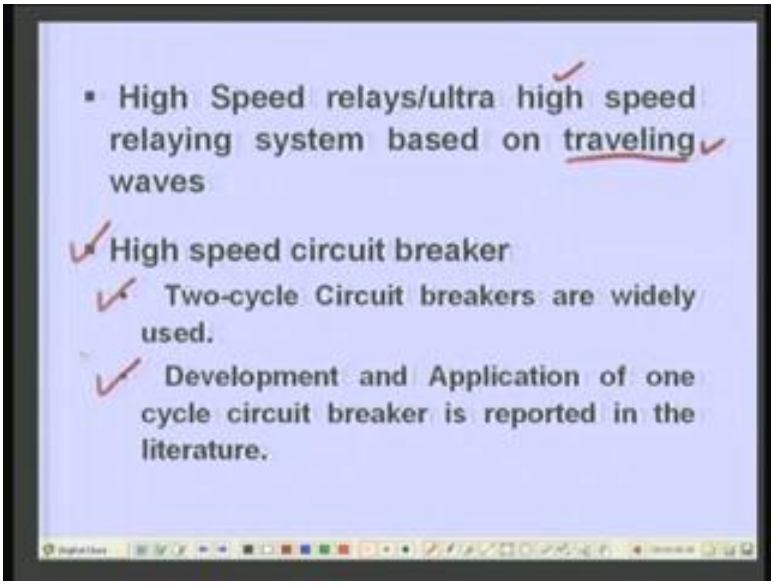

But the by by first fault clearing or high speed fault clearing we can reduce the duration of fault. So that the total duration for which actually the disturbing affect is there on the system is reduced as it has been discussed actually when we discussed the course on power system protection, our intention is to reduce the fault clearing time by reducing the operating time of the protective system and reducing the operating time of the circuit breakers because the fault clearing time is sum of the relay time, relay operating time plus the circuit breaker operating time.

The relays which we use in the power system today, particularly on EHV system or high voltage system these are high speed relays and as we know actually that whether you use a distance protection or whether you use actually the unit protection system for the feeders particularly the important feeders we use carrier protection system right under this case actually the operating time of the relay is very low may be of the order of half cycle right some ultrahigh speed relaying systems have also been reported which are best upon traveling waves where the operating time of the relays is even less than the 10 milli second which I have just now mentioned therefore this the high speed relaying is one of the very important aspect or important technique for enhancing the stability.

So far the circuit breakers are concerned over the years there have been developments in the circuit breaker technology to reduce the fault clearing time. Today we have circuit breakers where the total operating time or fault clearing time maybe of the order of two cycles means in 50 hertz system, 40 milli seconds and there have been certain reports where one cycle circuit breakers or the circuit breakers which operate or complete their fault clearing in one cycle time are reported and therefore, we can see actually that the so far, so far actually the high speed fault clearing is concerned, the high speed relay operation and high speed circuit breaker operation is used for for enhancing the speed stability of the system.

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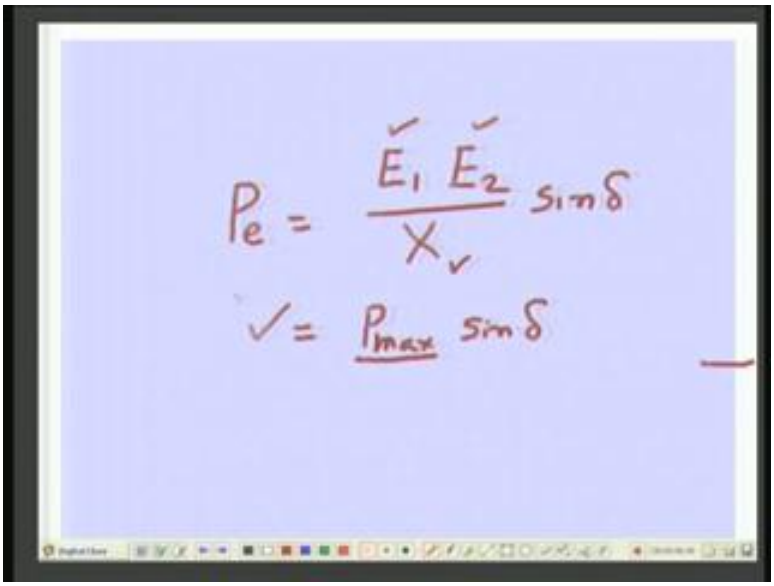

The next important aspect is that is from the design point of view how you design your system right from beginning so that the system has has high power transmission, power transmission capability. If you see the power angle characteristic, power angle characteristic of a machine a simple machine connected to infinite bus, a simple power angle characteristic we plot, then this power angle characteristic is given by this equation, electrical power output P_e is equal to E_1 E_2 divided by X sin delta or we say this is equal to P_{max} sin delta where, we know actually that this P_{max} this is the this is the maximum power which can be transferred over a transmission line if you increase the load in small steps right. Therefore, this P maximum becomes the actually the steady state stability limit now by increasing this P_{max} this can be increased by increasing E_1 E_2 or reducing X therefore if we reduce X or actually the transmission line reactance then we have a higher power transfer capability in the system that is the steady state stability limit is high and then correspondingly the transient stability limit will also be high.

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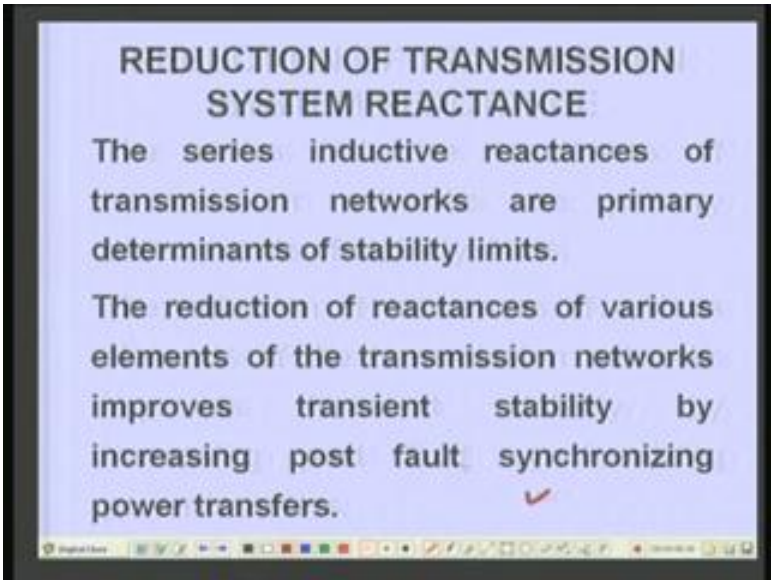

The reduction of transmission line or transmission system reactance we are talking of transmission system reactance. Now here the point is that series inductive reactance of transmission networks are primarily or primary determinants of stability limits the reduction of reactance is of various elements of transmission networks improves the transient stability by increasing post fault synchronizing power transfers right.

The reduction of transmission network reactance is achieved by reducing the transmission lines reactance by itself. Generally, generally when you design the transmission line right this will not be the only criteria for for or reducing the transmission line and reactance may not be the primary criteria of transmission line design but we know that in EHV transmission systems, if we use the bundle conductors the the line reactance reduces right and therefore these are the certain steps which can be used actually to reduce the line reactance or the bundle reactance is bundle conductor is required for for EHV transmission lines from the consideration of corona losses and

but the byproduct of this use of bundle conductor is that it reduces the transmission line reactance and hence it helps in improving the the power transfer capability of the lines then in all transmission system, we will have transformers and therefore you design the transformer use transformers of low per unit reactance.

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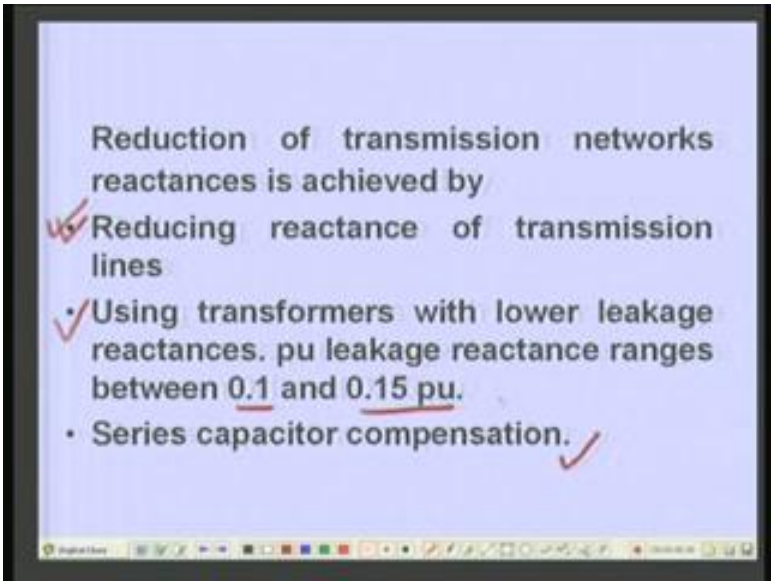

The transformers of per unit reactance will be of .1 to .15 are normally used in the EHV systems and then wherever, you find that length of transmission line is high or a long transmission lines are involved then series compensation is used for for reducing the line reactance. Now today there has been a lot of lot of you can say thrust on this aspect one is you have a fixed series compensation another is by using FACTS technology, you can go for for control series compensation by using control series compensation like thyristor control series, compensator and capacitors or static static synchronous series compensator the SSSC right.

We are in a position to control actually the line impedance in a dynamic fashion and improve the transient stability this is what is the normal technology here therefore most promising technique for improving stability is to make use of either fixed series capacitors or sometimes we may use switch series capacitors or the most suitable is actually the continuous control series capacitors. Now here, when we go for series compensation one has to one has to study or learn some important aspects one is one is that generally whenever the fault occurs in the system system the series series capacitors need to be bypassed during the fault the series capacitors need be bypassed reason is actually that when a fault occurs in the system the voltage across the series capacitor becomes very large and to protect this capacitors.

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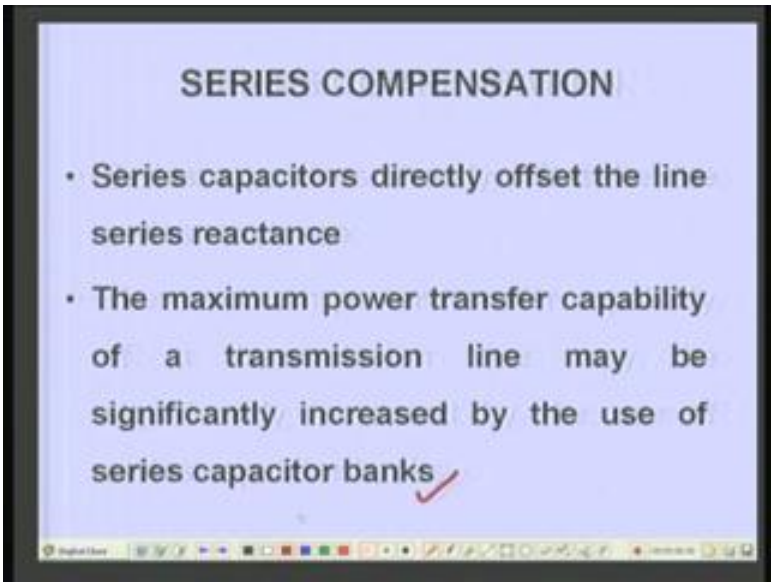

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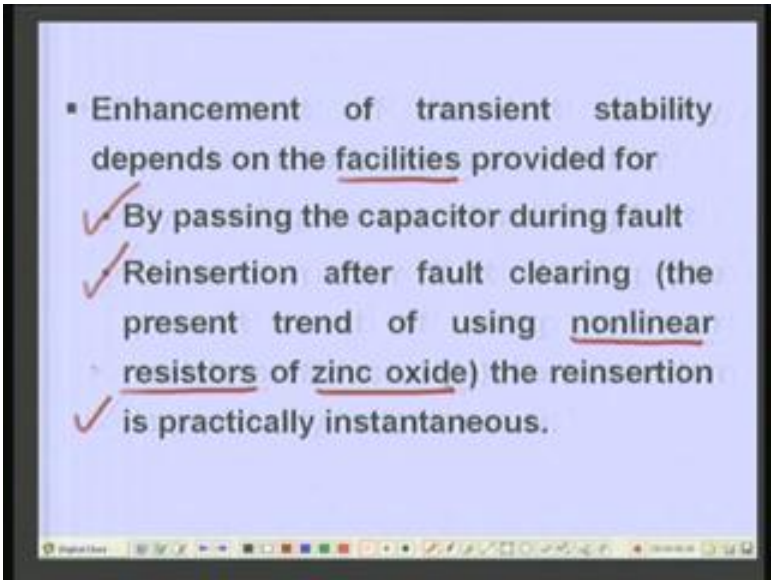

The capacitors need to be bypassed and then the when the fault is cleared, we have to reinsert this series capacitors if you can reinsert quickly then only then they will be effective that is the series capacitors need to be present in the post fault system for enhancing the system stability. This point is that for for enhancement of transient stability depends on the facilities provided for bypassing the series capacitors during fault and then reinsertion after fault clearing earlier earlier simple approaches were used where they were using actually the spear gaps across the series capacitors to bypass the series capacitors but there was the problem with this spear gaps is that

yes they when voltage across the gap increases it will spark over and bypass the series capacitor but till the till the ionized space between the air gap is you know cleared or it recovers its strength the series capacitor is not reinserted

Therefore, the new technology which is used today is the use of non-linear resistors which are basically the zinc oxide non-linear resistors and the terminology used is called metal oxide varistors MOV's, MOV's are used across the capacitors and whenever fault occurs depending upon the voltage which is developed the MOV's will bypass this circuit the capacitors but so far actually the MOV's are concerned the the voltage drop across the MOV will will not become 0, it is not going to completely bypass but it will shunt this capacitor and the voltage across the capacitor is restricted or limited to safe value right but the interesting thing is that the reinsertion time is instantaneous.

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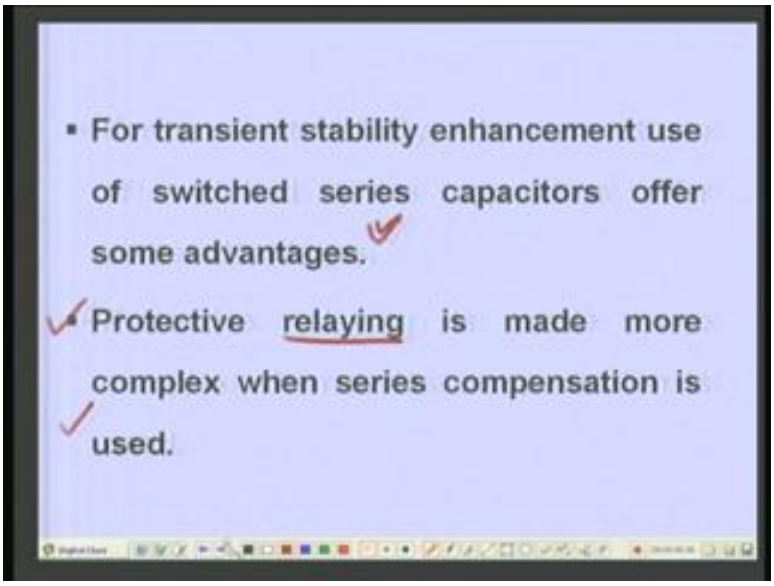

The movement the fault is cleared the MOV recovers its original high resistance condition and the capacitor is reinserted instantaneously therefore this this technology is very you know prevalent in all systems wherever we have series compensation I would mention that even if you use fixed series capacitors we require protection system for the series capacitors that is MOV's even when we use the FACTS devices like thyristor control series capacitors or SSSC, SSSC, S cube C or we use UPFC then we have to can say have an arrangement.

So at the voltage drop across these series component is reduced right and is safe that is series compensation MOV's are always provided but the advantage of MOV is that you you you can quickly reinsert them, re insertion re insertion time is practically negligible. As I have mentioned here the series capacitors directly offset the lines is reactance, the reactance becomes small the maximum power transfer capability of a transmission line may be significantly increased by use of series capacitor banks. Then the transient stability enhancement depends upon upon how

quickly you reinsert the capacitor when it is bypassed by by bypassing devices under fault conditions.

For transient stability enhancement one can used switch series capacitor I just now mentioned either it can be switch series capacitor so that some of the capacitors is a fixed one some is switched one but this switch series capacitors were considered attractive when the FACTS technology was not available but with the FACTS technology available available the same thing is achieved using the FACTS technology. Now when you go for series compensation there are some problems and one of the important problem is the the protective relaying for the transmission system becomes more complicated because the distance relay which we normally use where we we measure the impedance of the transmission line between the relay location and the fault point to find out the distance of the fault from the relay location.

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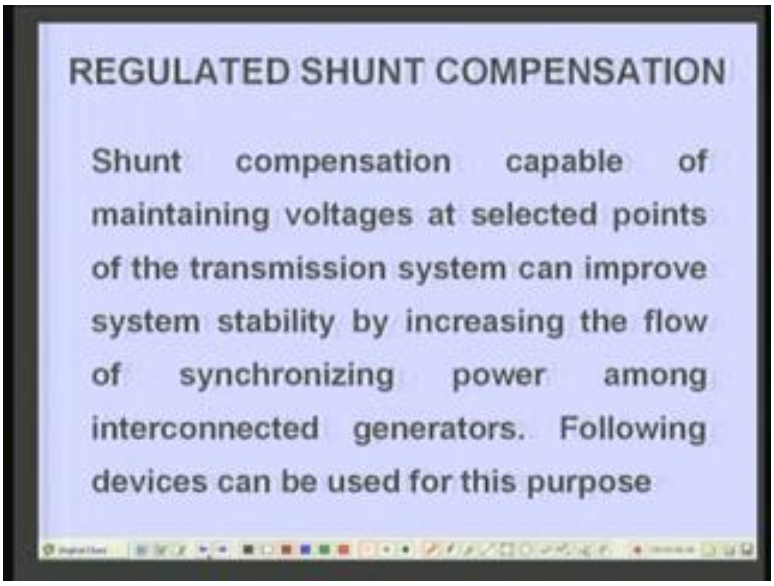

Now here this this simple approach cannot be used because because part of the line reactance is compensated by the series capacitor therefore this is a subject of research and many people are pursuing research on this subject that is the protection of series compensated transmission lines. Next is we go for regulated shunt compensation, the shunt compensation capable of maintaining voltages at selected points of the transmission system can improve system stability by increasing the flow of synchronizing power among interconnected generators following devices have been popularly used.

I will explain this point slightly in more detail that is for for regulating the voltage at selected points in the transmission network. The devices available are are synchronous condensers which has a rotating device but it is very fast in response and it is capable of maintaining the voltage at the certain locations. Another new technology is we use the static VAR compensators, the SVC we call it SVC static VAR compensators this is part of the FACTS technology and the next is the

STATCOM which is actually the voltage source converter based technology which can be used to inject the controlled reactive power in the system and maintain the voltage constant.

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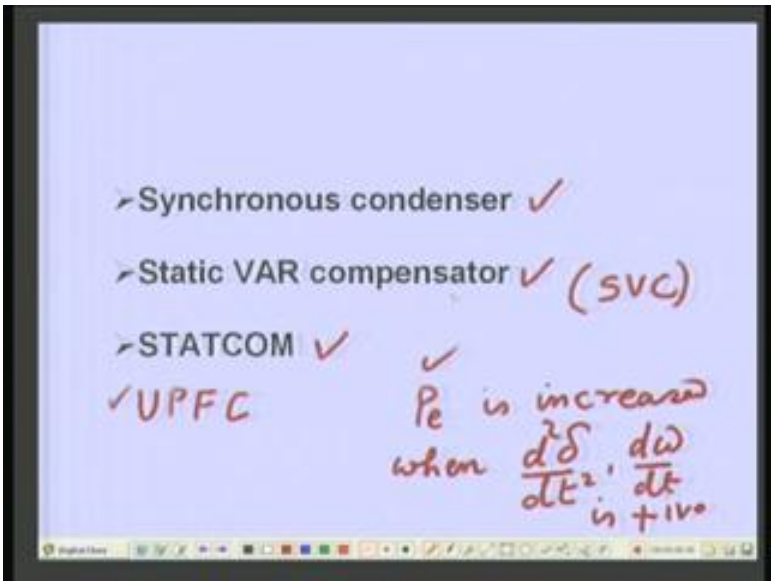

I have not mentioned here UPFC but unified power flow controllers also have a capability to maintain the voltage constant at a certain bus in addition to controlling the power flow on the line. In fact each of these techniques are very very powerful and lot of research work has been done to understand how much how much transient stability enhancement can be done but here here the capability of these devices can be harnessed by appropriately designed controllers.

So that during the dynamic condition whenever the system is accelerating we we reduce mechanic we reduced we increase electrical power output when the system is accelerating and when the system is decelerating we we we reduce electrical power output that is the approach basically for all these devices is this electrical power output P_e is increased, increased when d delta by dt this is the or you can say d_2 delta by dt_2 that is the acceleration or you can call it d omega by dt is positive whenever, you find that this system is accelerating means acceleration is positive what we have to increase P_e, so that we have to reduce the acceleration and therefore we require actually the controllers which will sense the acceleration and accordingly act, so that we can reduce the or increase the electrical power in response to whether the system is accelerating or decelerating.

Now here I will discuss the two important techniques one suitable for artificially increasing the electrical power output of the machines during during dynamic conditions, another is dynamically controlling the mechanical power input, dynamic braking is a technique which is used for for artificially controlling the electrical power output from the machine during the dynamic conditions, during the during the condition when this machine is oscillating dynamic braking uses the concept of applying artificial load.

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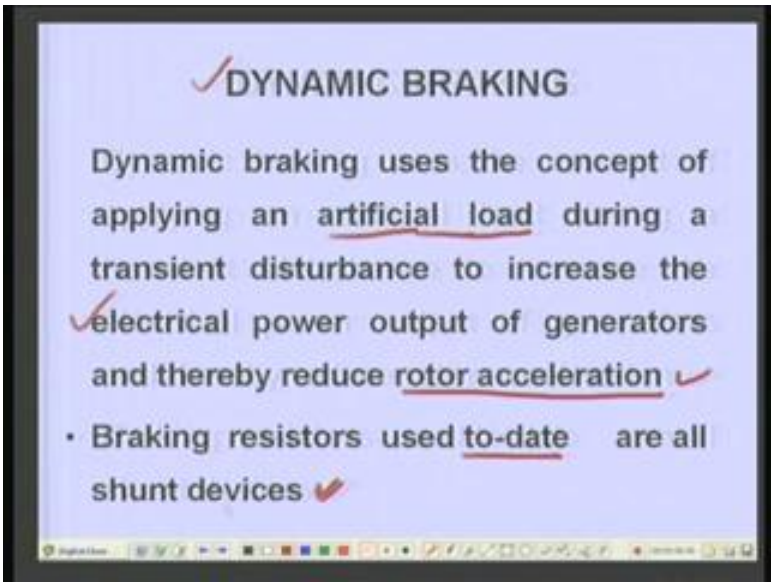

Now here because we have to understand load is anyway it is a load but it is not the normal load put on the system by the consumers we have a load actually which is specifically put to to observe certain electrical power from the machines it is why it is called artificial it is it is not actually there useful power, it is not going to do any useful work for us it is going to help in improving the stability that is why the word is used is artificial load during a transient disturbance to increase electrical power output of generators and thereby reduce the rotor acceleration.

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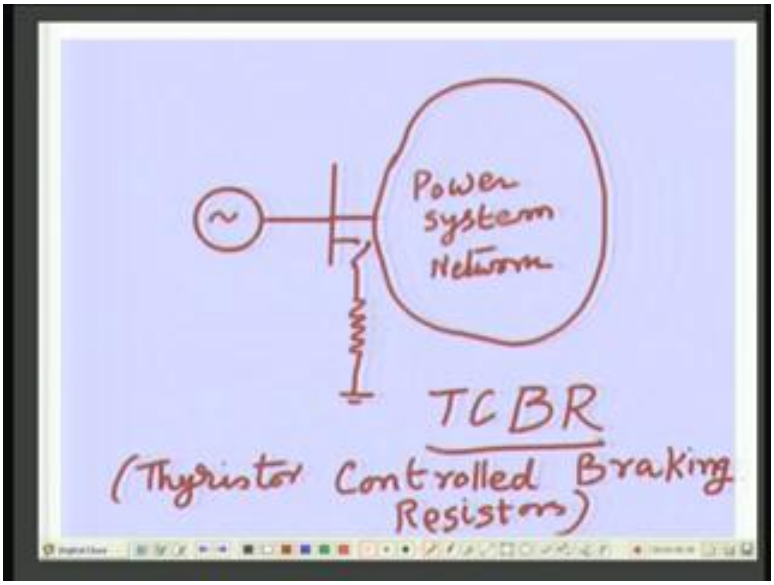

Now here actually I will just discuss slightly in detail about these braking resistors, braking resistors used to-date are shunt devices although one can use series devices or series connected braking resistors for enhancing the stability but most convenient method or what technology which has been used is is a shunt connected devices this point I will explain slightly in detail here. Let us look let us look at a synchronous machine. This machine is connected to a large network, external portion of this system to be generator or to which it is connected I will not show in detail but let us say that this is the power system network with all loads and generating only I have taken out one particular machine at the terminal of this machine what we do is that we keep a bank of resistors which will be connected connected by switching on this switch that is what we have is that in the generating plant we have a bank of resistors and these resistors are connected through through a some switching arrangement.

Now here first I will tell how this helps in improving stability and then I will talk about the the new technology which is used for switching. Here basically these resistors are switched on only when the machine is accelerating that is you sense the acceleration and when the machine rotor is accelerating it means electrical power output is less you close the close the switch. So that this resister absorbs power we usually that when the system is under fault condition the voltage at the bus of the generator becomes low therefore, normally during fault condition the these resistors are less effective but when the fault is cleared the terminal voltage is restored and the system is swinging right during that period you switch on so that this resistance will absorbs observe power right and the power which is absorbed by the resister will apply electrical artificial electrical load, you can consider it and reduce the acceleration right.

Now the movement actually the system is decelerating you disconnect this resister. Now today, today the improvement here is that instead of using a mechanical switch for closing the braking resistors or inserting the braking resistors, we use what is called actually the thyristor controlled braking resistors, the terminology is called TCBR, thyristor controlled braking resistors are used. You can put it here in thyristor controlled controlled braking resistors. On this braking dynamic braking this is called dynamic braking where we we is make use of actually thyristor controlled braking resistors people have done lot of research work, the research is basically in terms of designing the controller so that what signal we what signal is to be sensed so that these resistors are inserted in proper time and taken out.

Then another point which is very important here is that what should be the dose of braking dose of braking in the sense actually that how much power this resister should absorb, on that also a lot of research has been carried out generally these resistors are short duty resistors because these resistors are used only for a fraction of second and therefore these resistors are capable of absorbing huge power with their small size. Generally, today they use actually the stainless steel strip of large size right and that is capable of absorbing huge amount of power because they they are switched on only for a very short time of the order of fraction of a second right. Now when you use this thyristor controlled control then by adjusting the firing angle you can you can control the dose of braking and therefore, today is technology is that we can use actually the thyristor controlled braking resistors and they are very effective.

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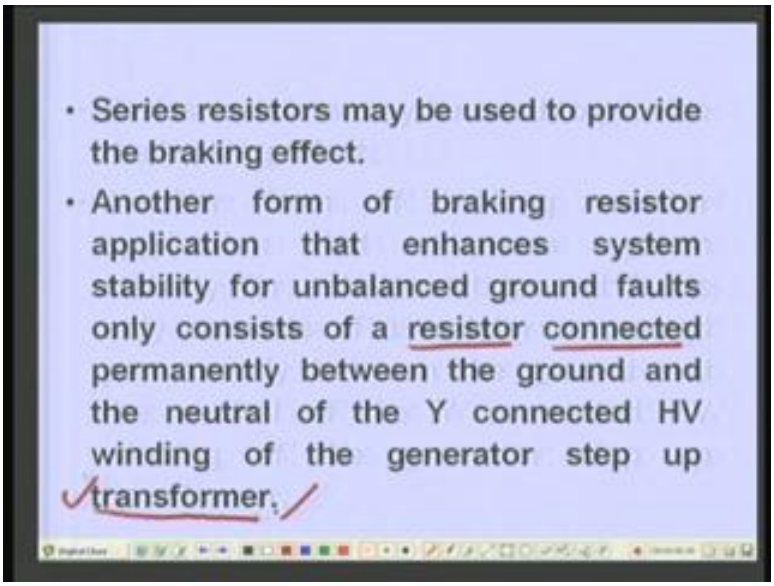

Now let us talk some few aspects about this. The series resistors may be used to provide the braking effect this point i will explain separately, another form of braking resister application that enhances system stability for enhanced for unbalanced ground faults only consist of resistor connected permanently between the ground and the neutral of the Y connected high voltage winding of the generator step up transformer.

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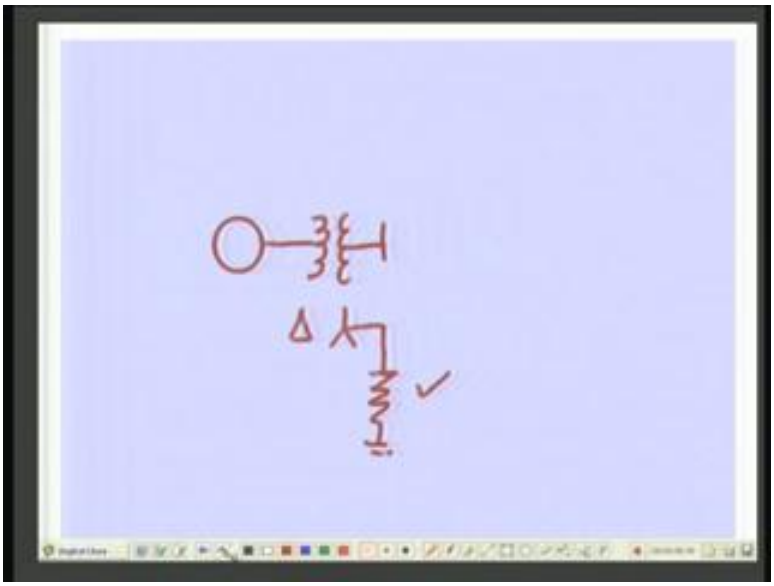

In fact here this point can be understood say you have a generator then at the generator, we put output of the generator straight away comes to a high voltage or you can say step up transformer and then it goes to the transmission network. This transformer is delta Y transformer, you you can ground this through a resistance, now this resistance remains permanently right. So that whenever there is a ground fault right the fault current flows through the resistor and when this the because of the fault current is flowing through the resistor certain amount of power is dissipated in this resister and this will act as a load on the system and generator will be decelerated when it is trying to accelerate it because when fault is occurred right the the power output from the terminal of the machine is reduced but now we are increasing the power loss in the neutral connected resistor, this is permanently connected right.

So that you certain amount of power is absorbed here this is called actually the neutral braking resistor, you can call that neutral resistor. This is what the point here another form of braking resistor application that enhances system stability for unbalanced ground faults only, there should be ground faults right consist of a series connected permanently a resistor connected in series permanently between the ground and the neutral of the Y connected high voltage winding of the generator step up transformer. This is a very import technique which has been used actually, series resistors the approach is like this.

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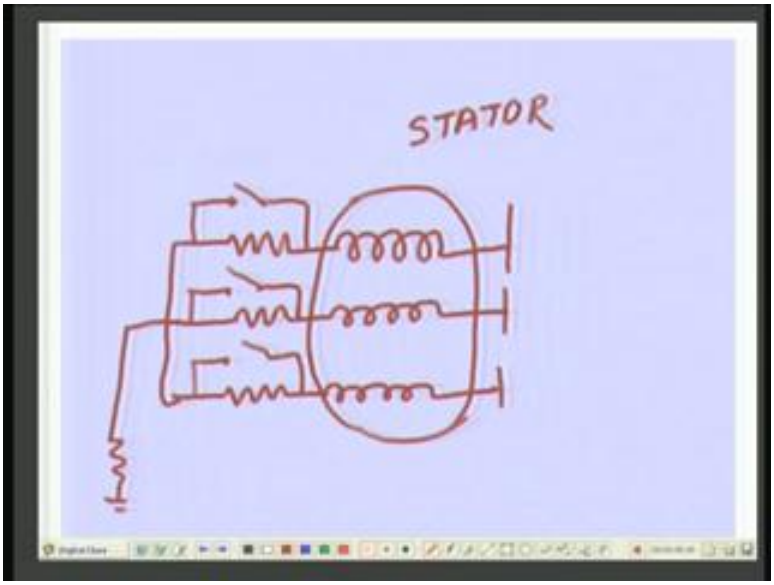

To understand this concept of series resistors I will draw a simple diagram, I will draw a single line diagram only but let me just this is the stator of the machine, in series with this you connect on the neutral side these resistors and these resistors will have a permanently by passed by putting a by passing switch that is this switch is closed here this switch is permanently closed and this neutral is of a grounded one right you can understand. This is the these are the buses terminals of the generator.

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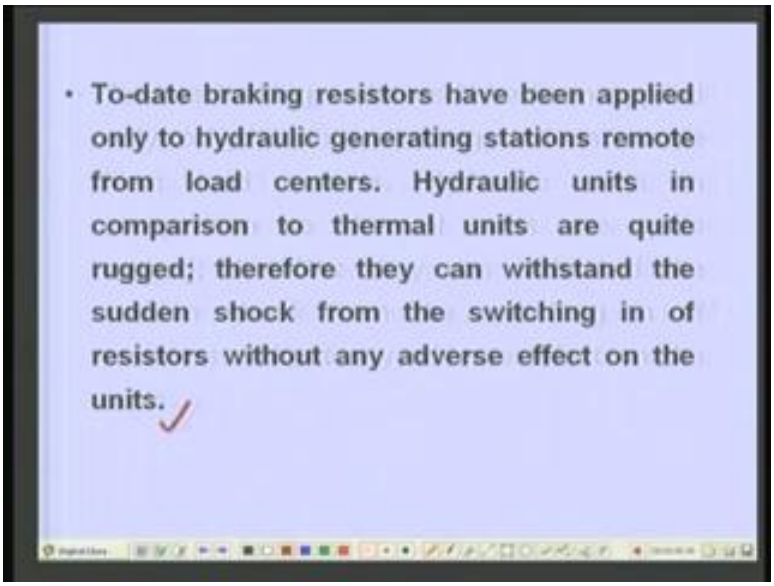

So that under normal conditions this series connected resistors are bypassed but whenever you find actually the machine is accelerating you you open these switches which are bypassed switches. So that this resistance are inserted in series with the stator winding and so that these are very effective during the during the fault condition, when the fault is on right when the system output becomes very low right at that time the fault the fault current flows through these resistors and a huge amount of energy can be absorbed but this alternative arrangement has been talked about but it is not very popular from the application point of view.

The another point here is these braking resistors have been applied only to hydraulic generating stations which are remote from load centers the hydraulic units in comparison with thermal units are quite rugged therefore they can withstand the sudden shock from the switching in of in of resistors without any adverse effect on the units. In fact what is actually is actually happening is that you you you just close them switch right then suddenly the electrical power output will increase and this causes actually a what we call actually the transient break on the system and in for so far this thermal units are concerned there is a danger actually so that the the shaft may get damaged because of frequent stroke with the which which may occur on the shaft by by closing and opening the circuit resistors.

The braking resistors are applied to thermal units, then this shaft fatigue life must be carefully examined that is before you apply apply these braking resistors for the thermal units you must examine this thing that what will be the effect of these braking resistors on, on shaft fatigue life there is certain life of the shaft and due to this phenomena its life gets reduced. With the switched form of braking resistors the switching time should be based on detailed simulation that is how you switch on how you switch off duration of the time for the switch is on then off this all has to be done by doing lot of simulation studies and then designing the appropriate controllers.

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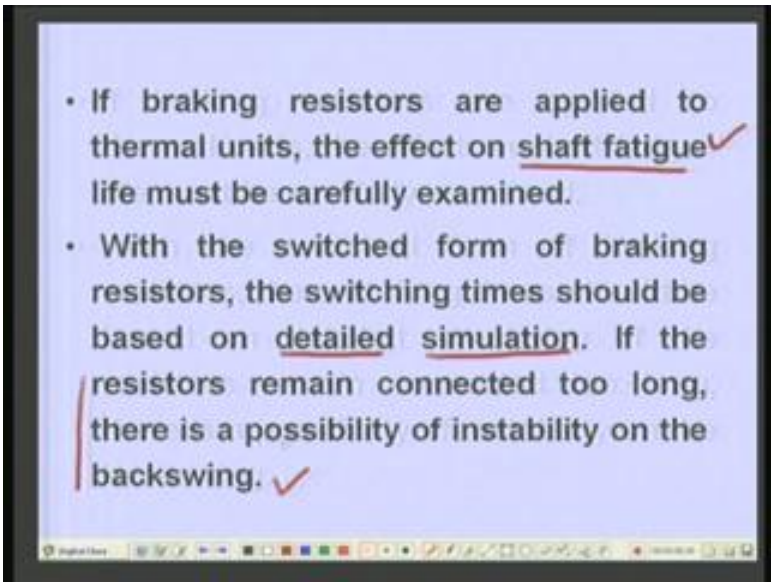

Now this this is a danger if the resistors remain connected too long there is a possibility of instability on the back swing. This can be this is a self explanatory that is if the resistors remain when when the system is no more accelerating right then this is putting additional load on the system and therefore system will decelerate backswing that is why actually the whenever you use this type of sophisticated techniques sometimes they use the word heroic techniques and this heroic measures when you want to apply you have to take special precautions.

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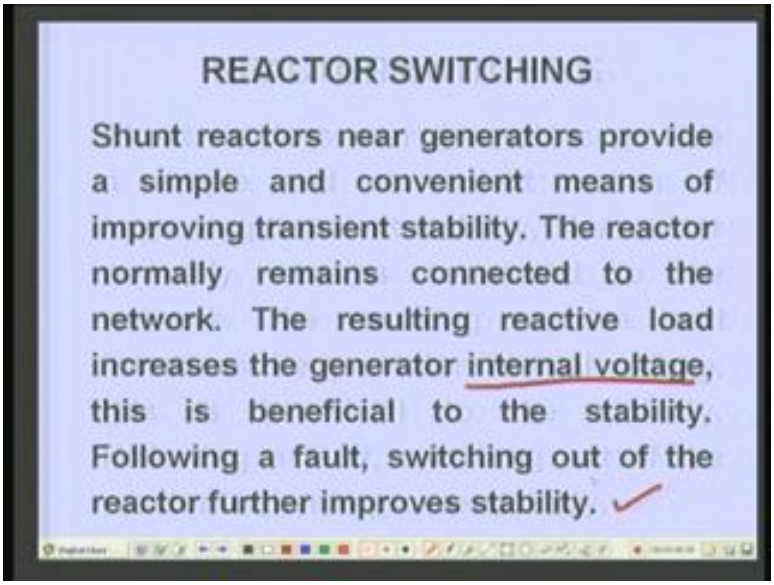

This is a very simple approach for enhancing stability that is reactor switching, shunt reactors near generators provide a simple and convenient means of improving transient stability. The reactor normally remains connected to the network the resulting reactive load increases the generator internal voltage, this is beneficial to the stability in a sense what happens is that you have at the terminal of the generator a reactor connected right it means actually the the generator is seeing a low power factor at its terminals and therefore to maintain the terminal voltage at the desired level desired level the internal voltage is large excitation will be more internal voltage is high and when the internal voltage is high right and the system is subjected to disturbance what we do is that we disconnect actually the reactor and because of high internal voltage the synchronizing power becomes more and that is following a fault switching out of the reactor further improves the stability. Then let us talk about the independent pole operation of circuit breakers.

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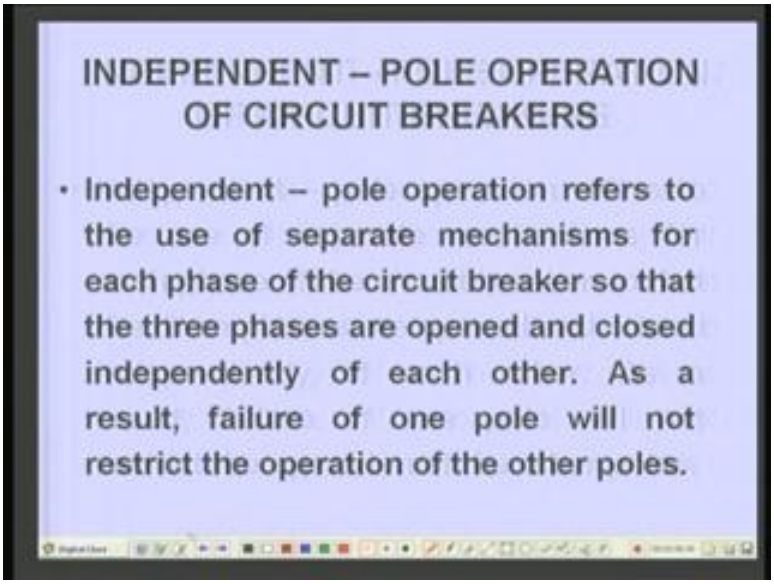

Now this is again a measure which is used for enhancing the stability as I have mentioned actually that high speed fault clearing is the target or aim. Sometimes what happens is that due to some failure in the in the circuit breaker mechanism right the circuit breaker may remain struck right. Now suppose you have a arrangement arrangement where all the three poles are controlled by one common mechanism if the circuit breaker one pole gets struck the complete circuit breaker remains struck, closely struck right therefore and and actually the stability design of the system considering a three phase fault with a struck circuit breaker is considered to be the most severe contingency.

Suppose, you design your system that how I should load the system, so that my system remains stable with three phase fault with a struck circuit breaker right that is very very onerous condition for which system may be designed. Now, generally independent pole operation refers to the use of separate mechanisms for each phase of the circuit breaker so that the three phases are opened

and closed independently of each other. As a result failure of one pole will not restrict the operation of other poles this is what I was telling you that this is the that there maybe some mechanical failures right and if all the poles remain struck right then the the fault is not cleared 3 phase fault still remains therefore if suppose actually if you have a independent pole operation, if one pole remains struck other two poles clear then the fault fault actually severity is reduced.

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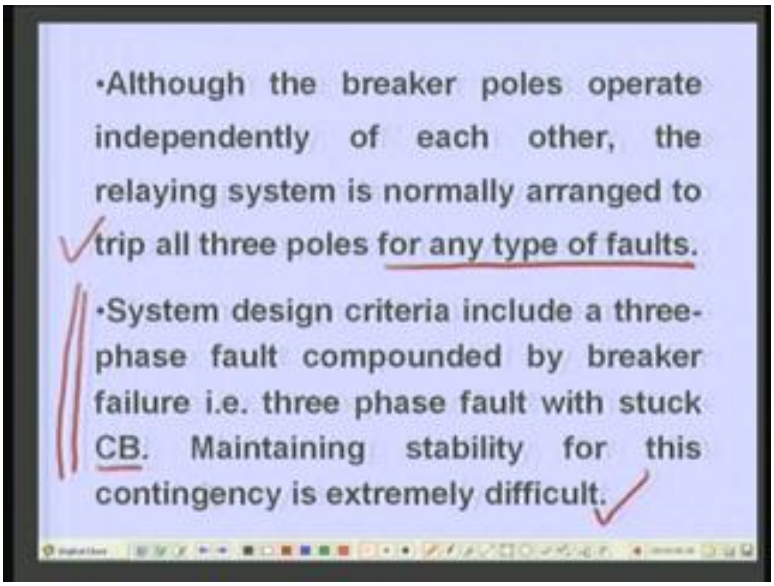

Although the break is another important point although the breaker poles operate independently, the relaying system is normally arranged to trip all 3 poles for any type of fault this was again this was mentioned earlier also when I talked about the outline of the lesson that in this independent pole operation although the mechanism for opening these poles are independent, 3 separate mechanisms but the relaying system is such that such that for any type of fault whether it is line to ground fault or three phase fault or any type of fault all the poles are opened simultaneously right this is what is the meaning of independent, operation is independent but the all these poles are opened that is line is completely opened.

The system design criteria include three phase fault compounded by circuit breaker or 3 phase fault with a stuck circuit breaker suppose you have designed a system with this as the criteria design criteria is is a 3 phase fault compounded by stuck circuit breaker right. Maintaining stability for this contingency is extremely difficult in generally you will find actually that we are not in a position to design the system with this type of contingency, if you design the system with this type of contingency means the system system loading will be very low for a given for this type of contingency, you have to very low loading .Otherwise, this type of contingency when it occurs system will lose stability but since this type of situation is 3 phase faults are very rare in the occurrence and the possibility of the circuit breaker poles getting stuck right. Looking into the probability and using independent pole operation we can we can mitigate this type of situation that is that is we can design the system for lesser or less severe contingency.

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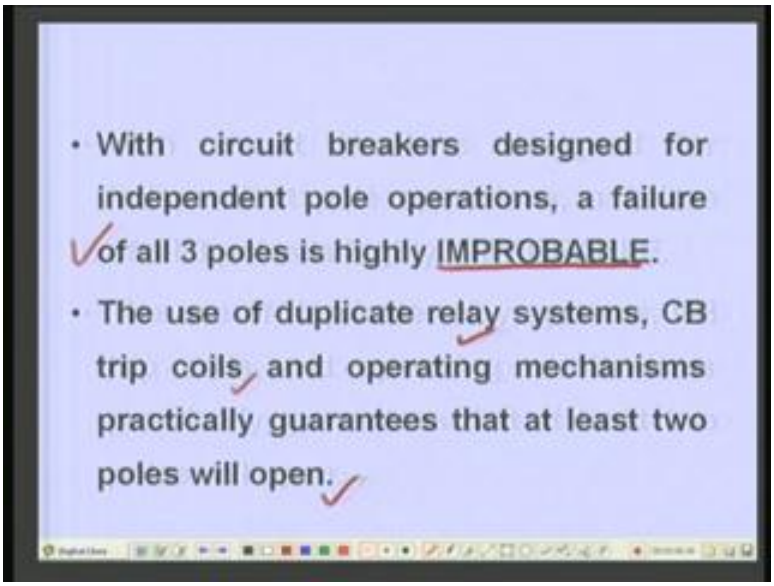

With circuit breakers designed for independent pole operation a failure of all 3 poles is highly improbable, it all the three mechanisms will fail. Simultaneously, that is very that probability is very low that is called it is why it is improbable and used the another is actually that as we have discussed when we talked about the protection system to increase the reliability of the protection system, we make use of duplicate relays or duplicate protection systems right and lot of you can say features are added.

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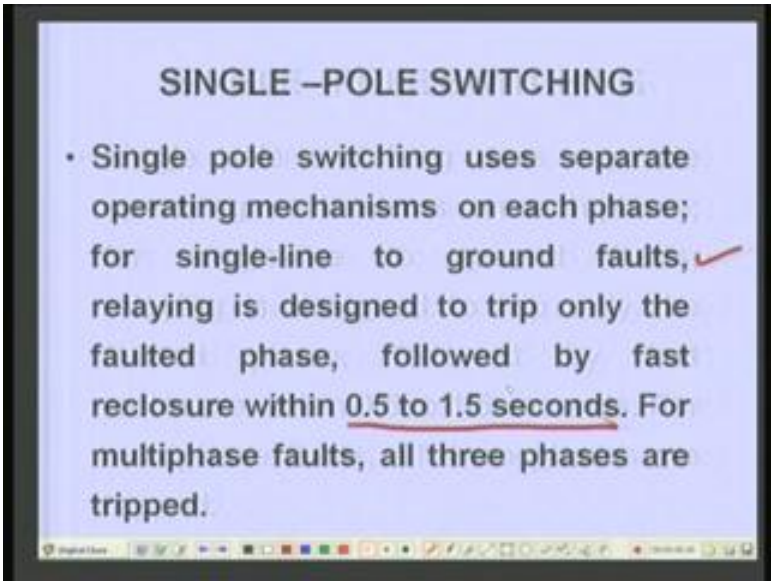

So that the failure of relays and the failure of circuit breaker is reduced, use of duplicate relay systems duplicate circuit breaker coils, tripping coils guarantee is actually that at least two poles will open that is you use certain certain features. So that actually whenever some some defects develop in the system possibility of all the three poles getting struck is very low and at least two poles will open. In fact actually one need to examine how the how this independent pole operation with actually one pole remaining closed and two poles open will help in improving the stability can be easily examined because what happens is that three phase fault has reduced to a single phase fault and the next is the single pole switching this is different from independent pole switching in single pole switching uses separate operating mechanisms for each phase for single line to ground faults relaying is designed again.

Now the relaying relaying is designed to trip only the faulted phase followed by fast reclosure in .5 to 1 point second for multiphase faults all 3 phases are tripped this is what is the mechanism that in single pole switching when there is a line to ground fault may be on a phase or b phase or c phase whichever phase is faulted you open that pole and then reclose it because many of manlier faults many faults are transitive in nature and the reclosure will be successful right therefore the this by using this single pole switching with the reclosure facility, we can enhance the transient stability to a great extent this is very important practice used actually in all EHV transmission network today.

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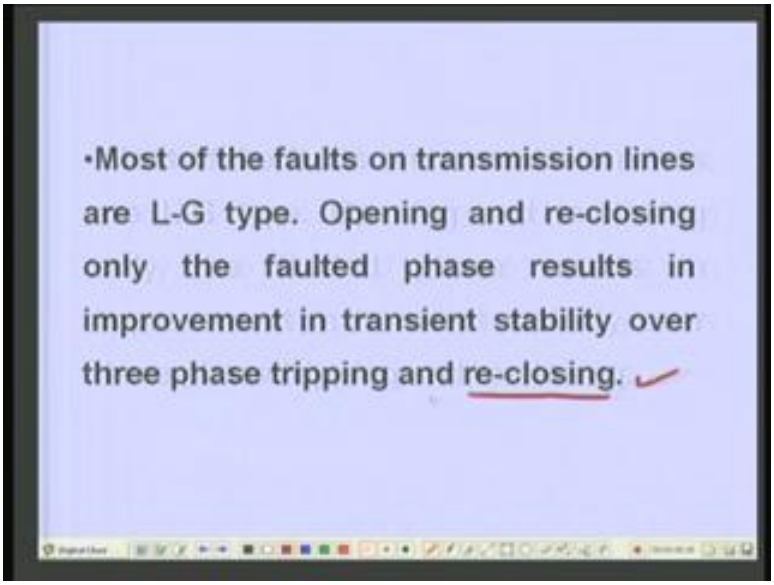

The reason is I have again let me reiterate most of the faults on transmission systems are line to ground faults opening and re-closing only the faulted phase results in improvement of transient stability over 3 phase tripping and re-closing. I think I will just mention about the steam turbine fast valving this is very promising technique for improving the stability of the system, we will discuss this remaining methods for enhancing transient stability in the next lecture.

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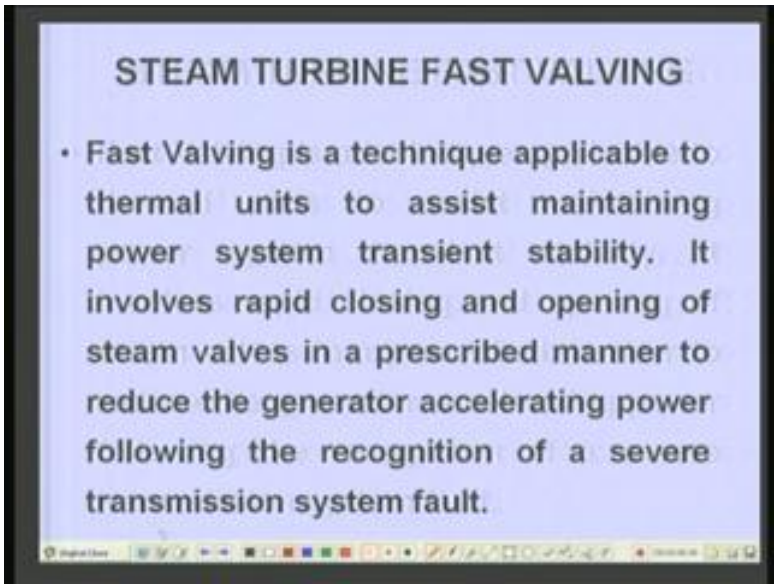

Let me sum up the points which we have discussed today. We have discussed the basic philosophy of improving the transient stability then we have talked about high speed fault clearing system, then design aspects to reduce the reactance of the transmission system, transmission network, one can reduce this by using series compensation or one can go for a controlled series compensation, a very powerful techniques.

I talked about the shunt compensation and particularly the controlled shunt compensation which maintains the voltage at certain points and increase the power transfer capability of the system by increasing the the synchronizing torque of the system and then we have discussed about braking resistors, application of braking resistors and particularly the the thyristor control braking resistors are very suitable today for enhancing the stability and then I have discussed about the two different mechanisms of opening this operating the circuit breakers, one is the independent pole operation and another is the single pole switching.