Power System Dynamics
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Lecture - 38
Voltage Stability (Contd…)

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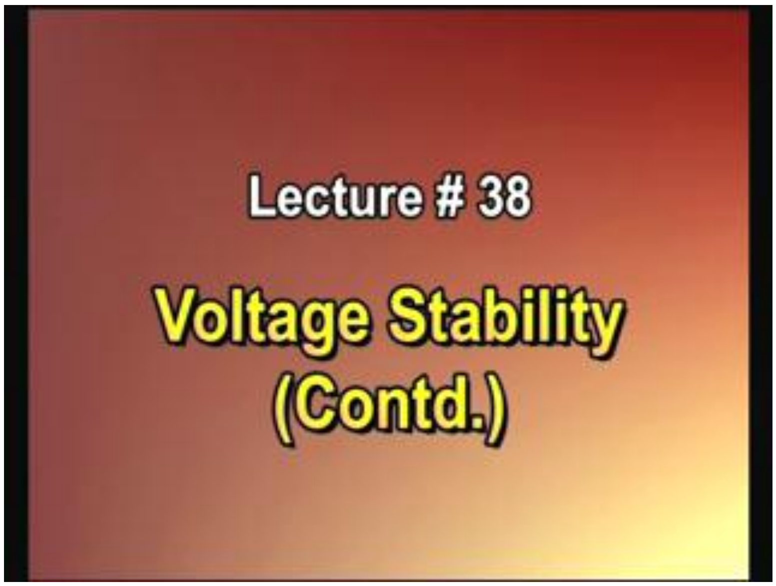

Friends, we continue with the study of voltage stability.

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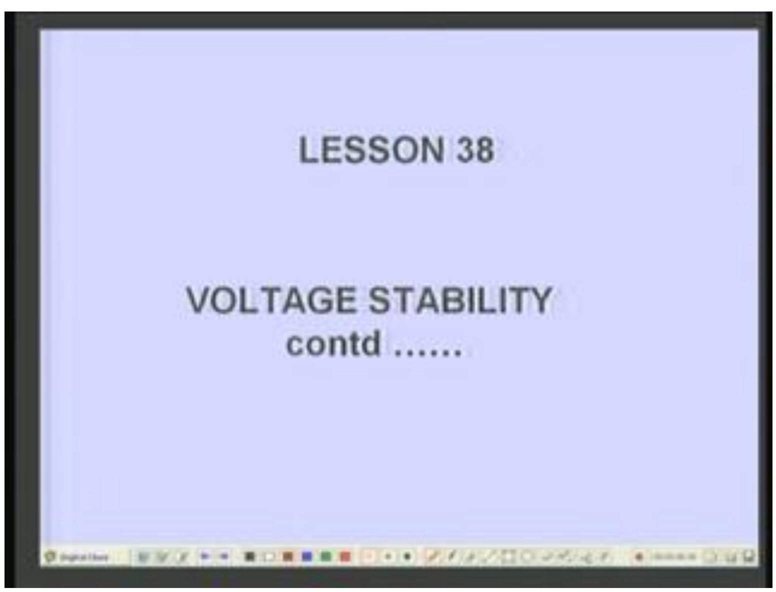

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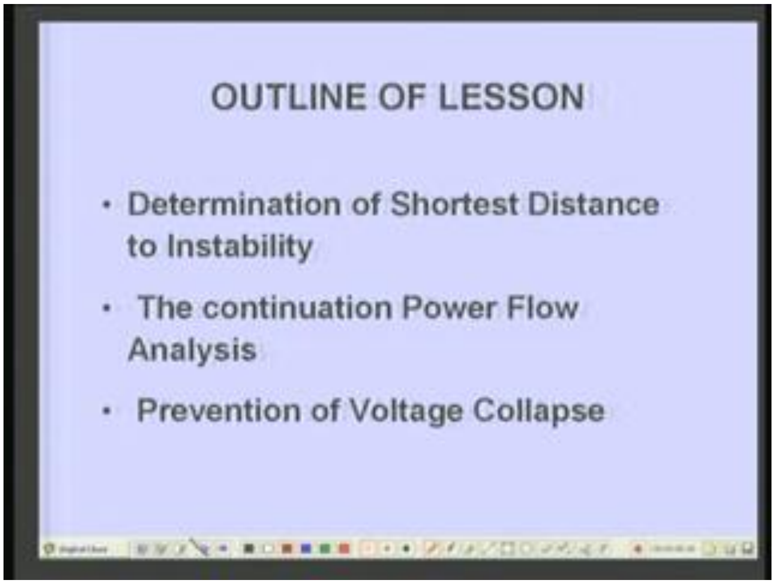

Today, we shall studythe determination of shortest distance to instability, the continuation power flow analysis and at the end we will study the techniques which can be used to prevent the voltage collapse or voltage instability. Now let us try to understand briefly what do we mean by the shortest distance to instability.

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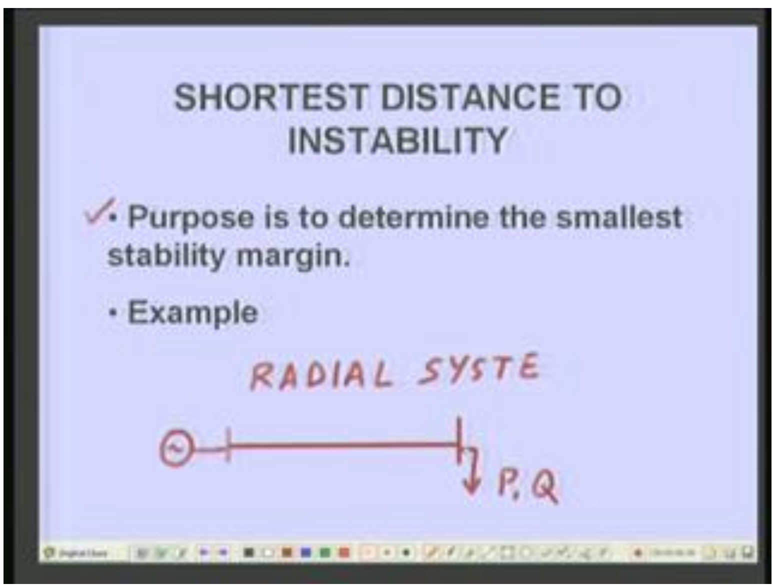

The purpose of this study is to determine the smallest stability margin that is whenever you are operating at a certain loading condition then we would like to know that how much increase in load can be made made so that the system becomes unstable that means how far we are from the from the instability but our interest is to find out the shortest distance.

In fact actually suppose you are operating at a certain loading condition then then the load can vary in a variety of manners right. Then for each particular combination of loading if you in stretch the load in a particular direction then you will reach even particular point where the system becomes unstable. We want to know what is the direction in which when we stretch the loading so that the instability occurs with the minimum distance.

Now to understand this basic point, we consider here a simple radial system radial system. In this radial system you have one source, one transmission line and say let us say the load here, we will call it P, I am considering there simplest system but any multi machine system and large system the there are several loads connected at various buses and and therefore whenever you want you can say increase the loading, the loading can be increased in variety of manners right. But we know actually that when you increase the load at a one particular loading condition condition the system becomes voltage instability occurs. So system becomes voltage instable and at that loading condition if you find out the Jacobian of the matrix then that Jacobian becomes singular right.

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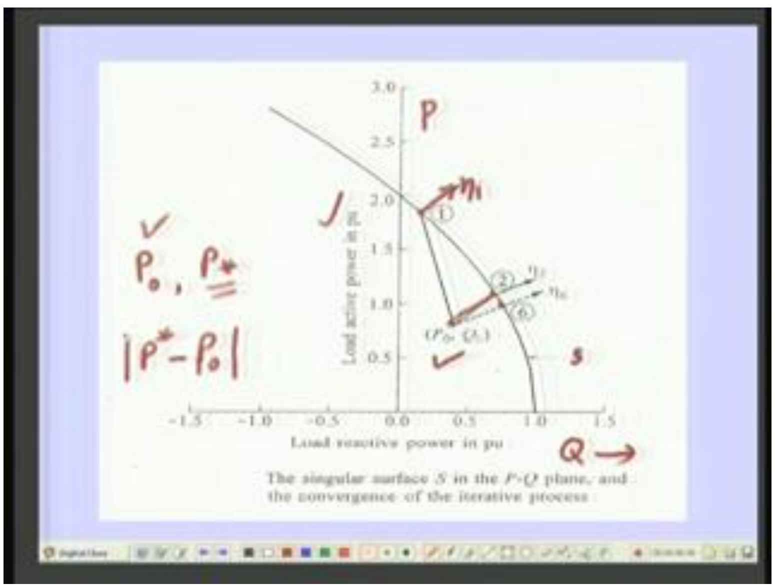

Now here for this simple radial system we plot here actually in the PQ plane. This is the load reactive this is the load in per unit that is the active power P on this side is the reactive power that is you put P on this side P here and the reactive power Q on this axis. Now we can find out one one surface if you any point on that surface surface will lead to if you operate at that point then it will lead to voltage instability. In case it is a large system with number of buses right that surface comes out to be a hyper surface right and in this particular case the the simple radial system right the we get actually a curve right.

Now this is the curve, now suppose you are operating initially at this point called P_o Q_o that is initial loading condition is denoted as P_o Q_o and suppose you increase the load P and Q in at random. Let us say you increase in this direction, so that you come and reach the this this surface as or actually the the curve as this you call as surface S or curve S right. Now at this point the system becomes unstable.

Now suppose now the question is actually that what is the shortest distance to instability to find out the shortest distance, obviously in this particular case the shortest distance one can find out first you find out the normal at this point one to the surface, let us call this is the normal at this point call it say eta 1 then the again go back to the initial loading condition and stretch the load in parallel or in the direction of this normal that is second time when you are stretching you are stretching in this direction this is parallel to this you reach this .2.

Then once you reach the point two again you find out the normal at this point eta 2 and then again go back to the initial condition and stretch the loading in the direction parallel to the normal. Then you will lend to a point where the distance between the operating initial operating condition and the new operating condition will be minimum that is one can find out, suppose you you represent actually the initial operating condition by as a vector rho, a parameter vector rho.

Now this parameter vector rho is the initial operating condition and let us say rho psi is the final operating condition then our interest is to find out this distance that is the rho psi minus rho norm norm of this quantity. This will be minimum right and the for a simple two machine system not two machine systems for a single radial system I have illustrated that you start from initial condition stretch the loading in any direction. Here, P is increasing while Q is decreasing like that and you reach to a new point then at this point one the see this point one lies on this surface this is the which represent the unstable operating condition then the then the normal which you find out at this point right. Now you stretch the in the direction of the normal and therefore you keep keep on doing this till you get the minimum distance therefore in the multi machine system. We denote actually the the loading condition loading condition in terms of initial P and Q through a parameter and we find out the final as rho star and in case the rho star is such a loading condition.

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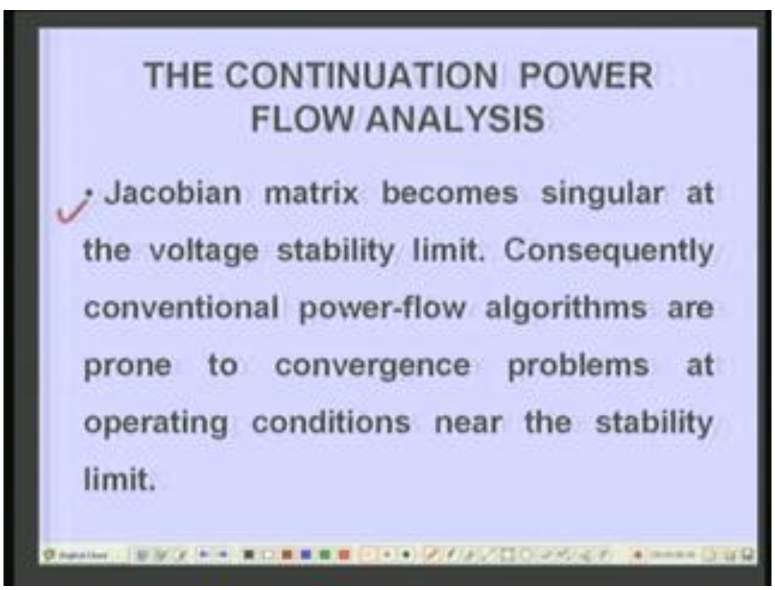

So that the moment you are operating this rho star lies on the hyper surface which is which represent the unstable operating condition and and that our objective is to find out the the norm of this quantity that rho naught minus, rho star minus rho naught norm of this line and this rho minimum and this process is a documented in various papers, how to find out for a multi machine or a large system this node, the purpose of this obtaining the shortest distance is to to note that at what stability margin we are operating because whenever you are operating system you would like to maintain certain stability margin all the time.The next point we will study is the continuation power flow analysis. The continuation power flow analysis is very important and is a very important tool which has been developed for for obtaining the critical operating conditionin. In fact as we know that if you operate if you operate near the critical point or at the critical point then the Jacobian becomes singular that is the Jacobian matrix, the Jacobian matrix becomes singular at the voltage stability limit.

Consequently the conventional power flow algorithms are prone to convergence problems that is the the moment the Jacobian becomes singular right the convergence problems arises and therefore if you try to plot actually the um we call PV curve right then we will be in a position to get certain points on the PV curve by conventional load flow analysis but the moment you reach closer to the instability poin, you will find the Jacobian becomes singular.

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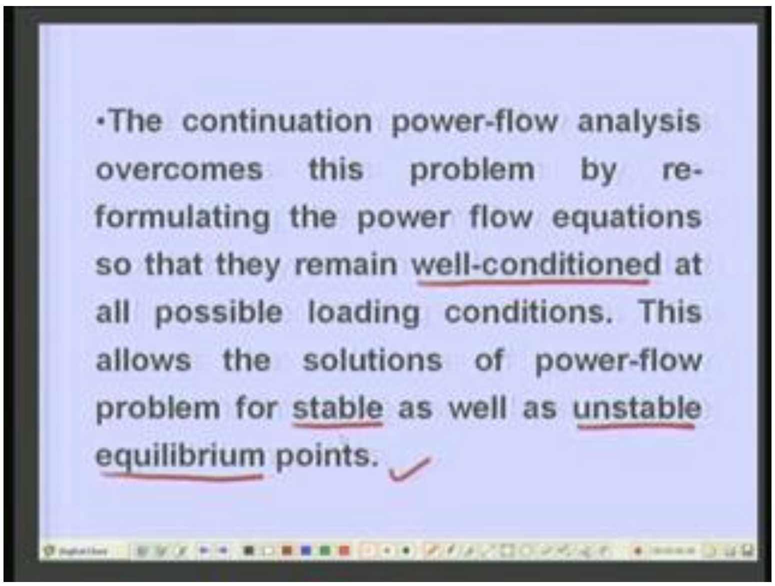

Therefore to solve this problem the continuous power flow algorithm has been developed that is the continuous power flow analysis overcome this problem by reformulating the power flow equations. So that they remain well conditioned at all possible loading conditions this allows the solution of power flow problem for a stable as well as unstable equilibrium points that is when you look at the at the PV curve right then the upper portion of this PV curve represent this stable operating points or equilibrium points but the lower portion right, they are the unstable. Now this these points when you cannot compute or we cannot get by conventional power flow equations or conventional power flow algorithm.

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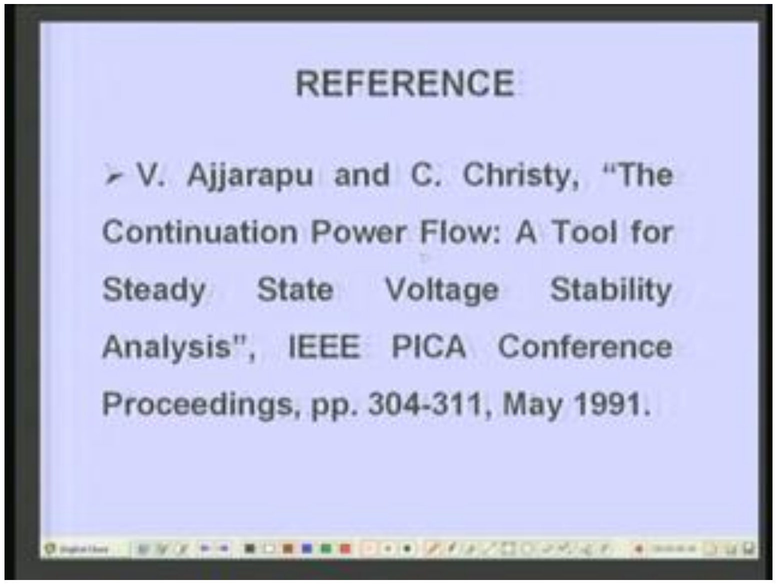

Now this continuation power flow approach has been well documented and the most important research paper where this continuation power flow has been discussed is written by V. Ajjarapu and C. Christy. The continuous power flow, the continuation power flow a tool for steady state voltage stability analysis. IEEE PICA conference proceedings page numbers 304 to 311, it appeared in may 1991 these very standard reference paper for understanding the continuation power flow algorithm. We will briefly briefly study the salient features of this continuation power flow algorithm basic principle.

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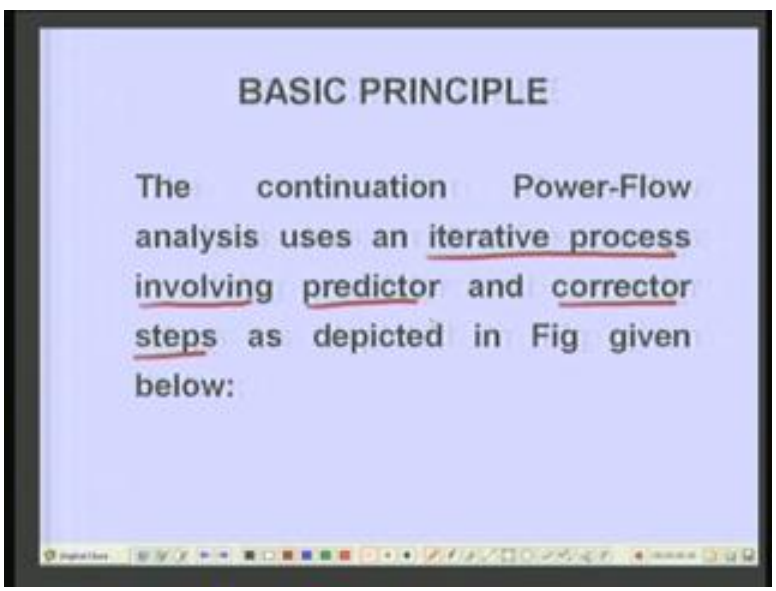

The continuation power flow analysis uses uses iterative process involving predictor and corrector steps as we will discuss just now that is the if the basic principle in this continuation power flow is that the two steps. First is suppose we are operating at a initial point, first we find out through the predictor step right the and then from that predictor step we go to the into the character step that two steps involved and these steps are followed attentively to get the solution.

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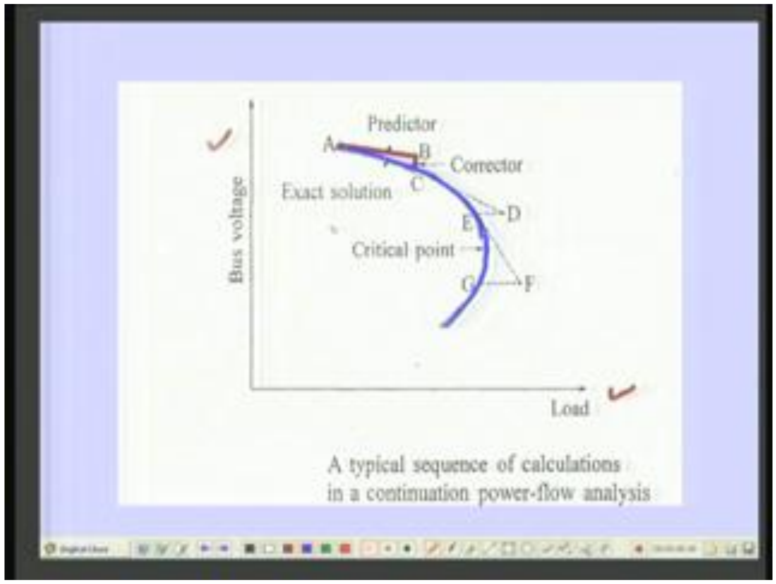

To understand basic concept let us look at this graph, this graph shows actually the the load on this axis and the bus voltage on this axis now this is a PV curve which is plotted in plotted part of it can be plotted by repeated application of load flow analysis right. Now suppose we are operating at this initial operating condition at A, the first step will be we we find out at this operating condition A a tangent vector that is there is a tangent vector which we find out, for example this is the tangent vector at this operating condition. Then the next step is persue you find out the tangent vector we want we want to find out what is the step length therefore the step length for example in this case shown is A to B therefore the step length is also a important decision to be taken.

Now once you come to this point B, next step is at this from this point we come to the actual solution C that is called character step from B to C that is at this if you see here actually that this graph which is the firm graph that shows the actual solution that of this is the exact solution, this graph shows the exact solution I will just draw it with the different color to make it more clear that is this blue graph is I have shown here is the exact solution that is we want to come from A to C but how do we come from A to C the step is at A you find out a tangent vector then you select a judiciously the step length then from this point B is not on the solution exact solution. At point B you apply character step and come to point C right.

Now this this approach is to be applied to find out the solution for different points on this graph here it is possible to get solution so that we can get the critical point. For example this is the critical point and then you can get points which are below the critical point also that is the complete part of the complete you can say PV curve can be obtained for a particular bus in the multi machine system.

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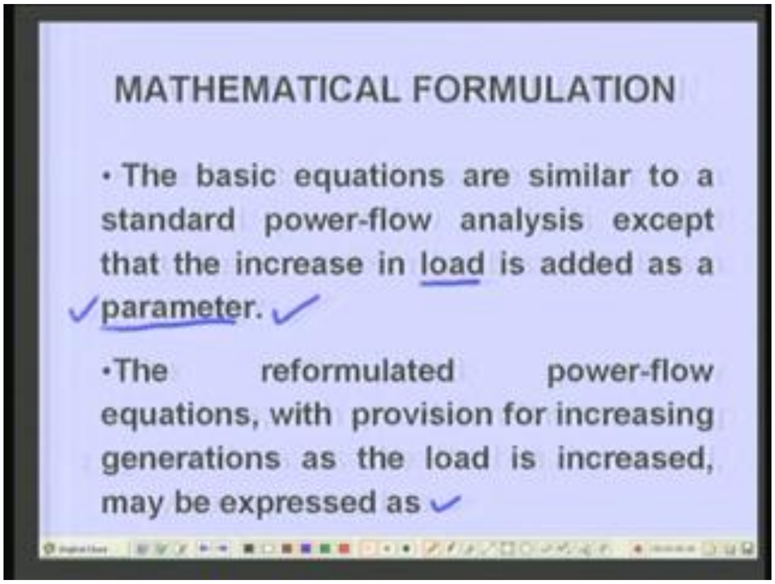

Now let us study actually the algorithm the mathematical formulation the basic equations are similar to standard power flow analysis except that the increase is in load is added as a parameter. Generally, in a conventional power flow what we really do is that loads are known to us and we solve the problem. Now here what we do is that increase in load is added as a parameter that is increase in load is added as a parameter this is one difference here the reformulated power flow equations with provision of increasing generations as the load is increased may be expressed as.

Now the point here is that is any system when I increase in the load right then I may have to increase the generations also right. So that the load generation match is achieved right therefore whenever you increase the load in a particular fashion then you have to increase the generations also that is the what it writes here is the you reformulate the power flow equations with provision of increasing generations as the load is increased. The the load flow equations can be formulated in this fashion F theta V equal to lambda times K where, F is a non-linear function of theta and V it means F theta V is represents actually F theta V equal to lambda K, it represents the set of non-linear algebraic equations okay. Here here F is a function in fact general F is a function and this equation is a is actually a vector equation a large number of equations are there in vector equation.

Here lambda is called the load parameter, theta is the vector of bus voltage angles, V is the vector of bus voltage magnitudes and K is the vector representing percent load change at each bus that is K is the vector representing percent load change at each bus. In fact here here when you look at the equations what you find here is that is lambda into K. We can fix actually some percent load changes and multiply by a parameter lambda. The magnitude of lambda varies from 0 to some critical value right. It means this the amount of load change which we put here can is adjustable.

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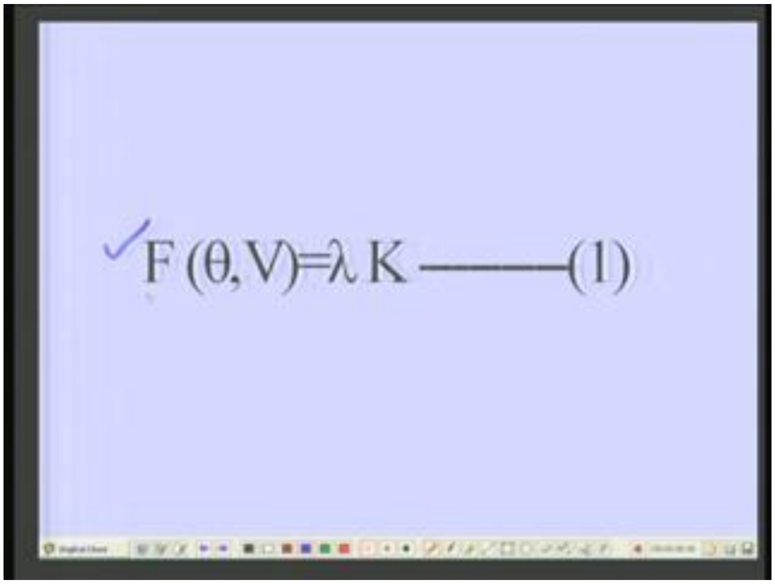

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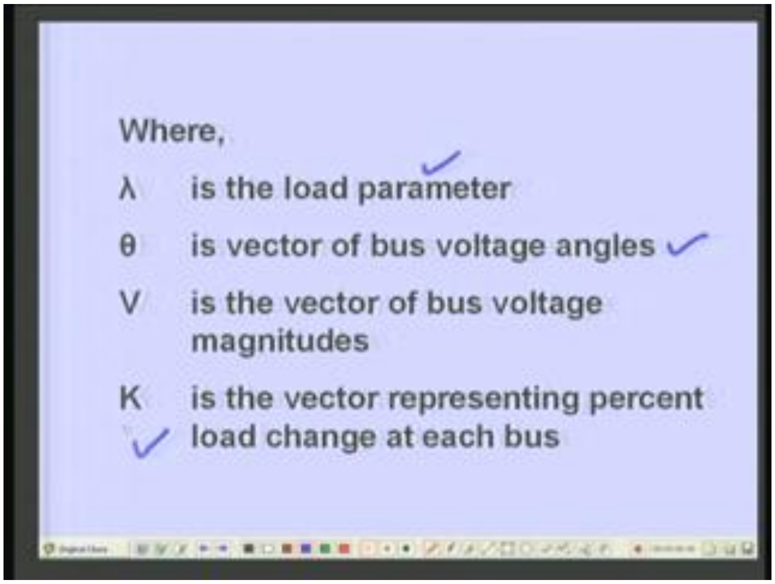

The above set of non-linear equations is solved by specifying a value for lambda such that lambda is between 0 and lambda critical where, lambda 0 stands for base load condition, when lambda equal to 0 it means we are not giving any increment in the loading condition and lambda equal to lambda critical deposit at the critical load that is they may be value of lambda is equal to lambda critical then we have reached the critical loading condition.

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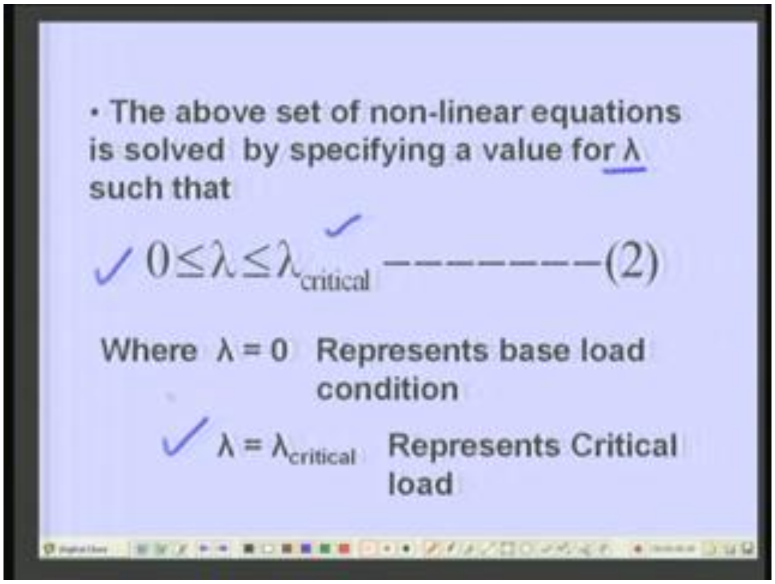

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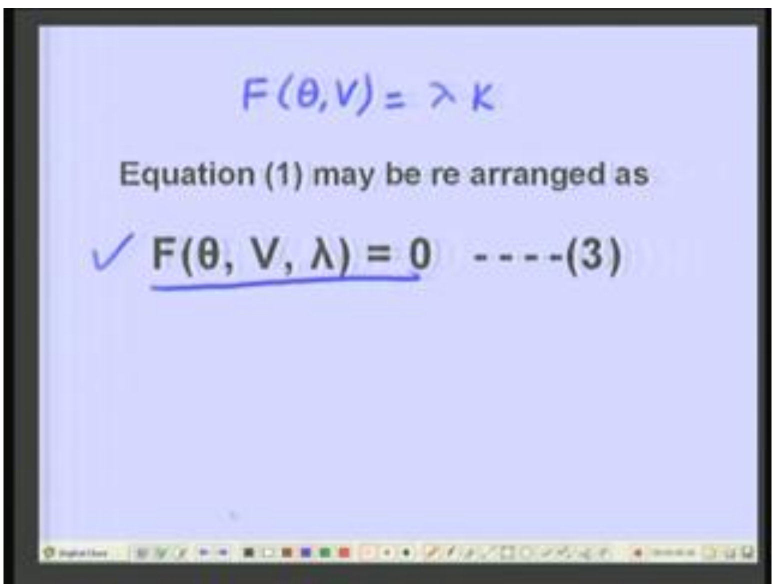

The equations which we have reforming for put here that is the equations which we are put as F of theta V equal to lambda K right. This equation can be reformulated or re arranged in the form F F theta V lambda equal to 0, K is a constant lambda is a variable parameter right these are the set of non linear algebraic equations. Now here to apply the continuation load flow algorithm as I have discussed they are two steps, one is called predictor step, another is called corrector step. First, let us examine the predictor step once a base solution has been found lambda equal to 0.

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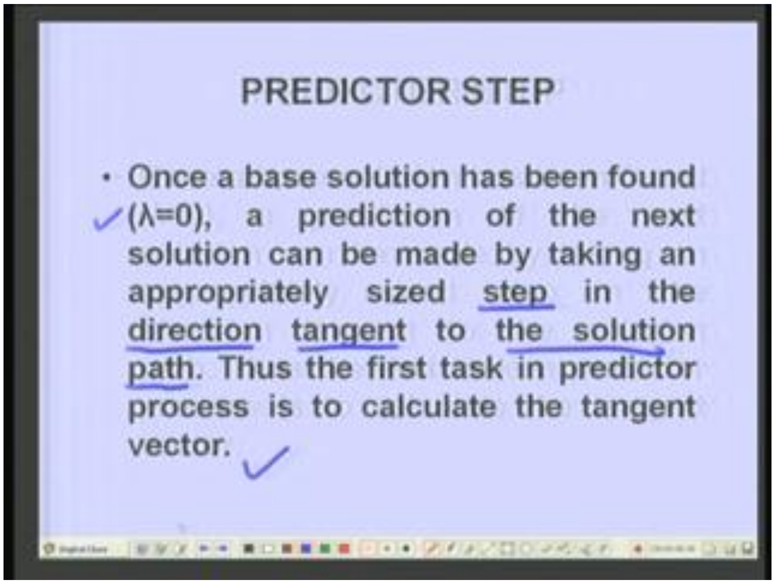

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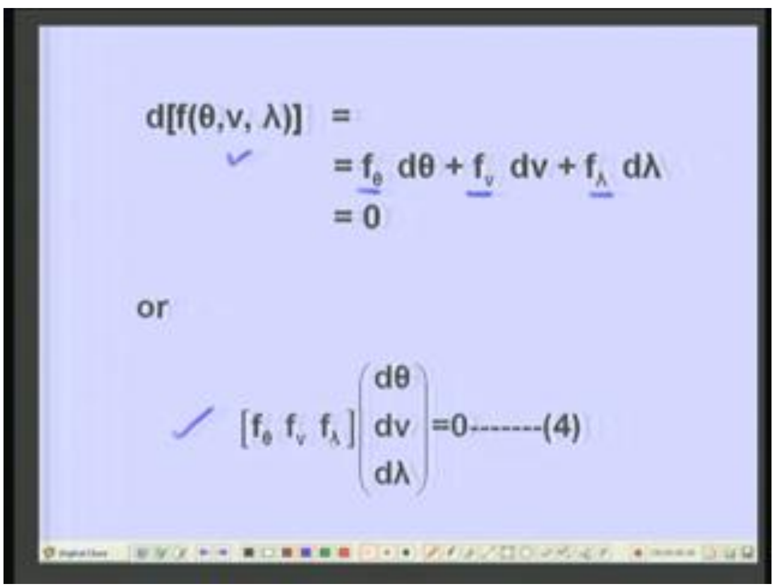

A prediction, a prediction of the next solution can be made by taking an appropriately sized step in the direction tangent to the solution path that is our interest is to find out find out actually the predictor step it is, let us find out next solution, next solution find out next solution a prediction of the next solution can be made it is a prediction by taking an appropriate sized step in the direction tangent to the solution path that is we start one initial condition, find out the tangent that is the direction that is the first task in predictor process is to calculate the tangent vector. It is the what we have discussed here the tangent vector is very important in and therefore deep in the predictor step the step is how to calculate the tangent vector the approach is very straight forward. We we have obtained the differential of this equation that is d of f theta v lambda, this function can be written as f naught d theta plus f_v d_v plus f lambda d lambda, this is equal to 0.

Now here this f theta, f_v and f lambda these are the the matrices of partial derivatives and this equation can be arranged in this form f theta, f_v, f lambda that is this matrices of partial derivatives are arranged and into this vector d theta, d_v, d lambda equal to 0. Since actually we have theta the dimensional of theta is equal to number of buses in the system right similarly or you can say actually d theta and d_v right these are n vectors and lambda is of course one scalar quantity.

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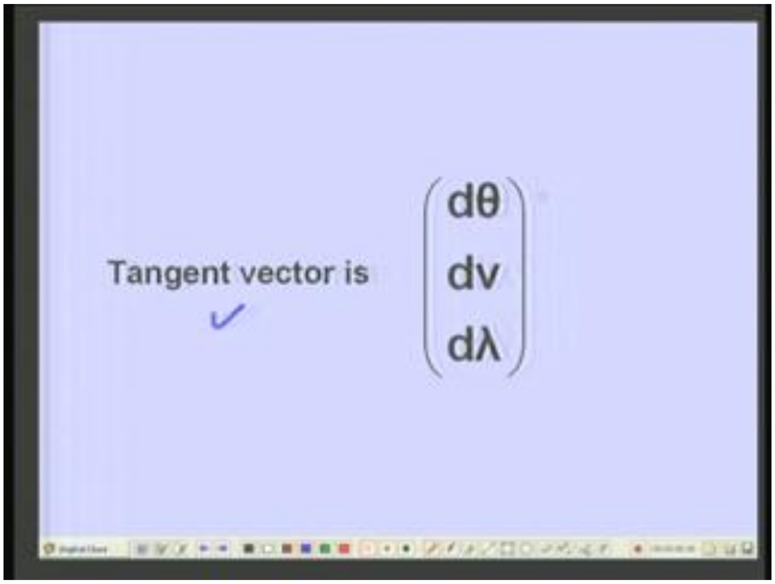

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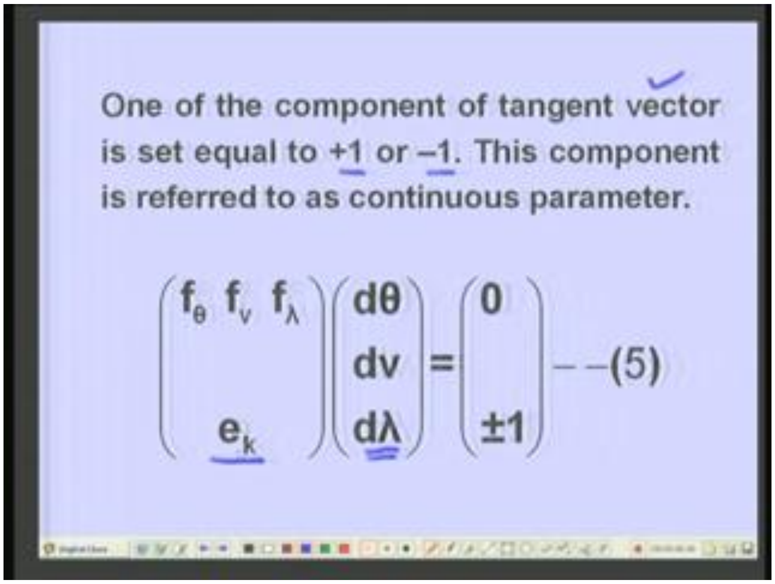

Therefore, this vector d theta, dv and d lambda this vector is given the name tangent vector that is tangent vector is defined as d theta, dv, d lambda. Our interest is to find out this tangent vector to find out the tangent vector we have just now seen what we really do here is this is the case but now the question is how to solve this problem. Now if you look here here so far the partial derivatives are concerned right this there are the number of unknowns I have now increased by one lambda is the additional parameter which we have added and therefore there is a necessity to add one more equation here.

So that you can solve this for this tangent vector that is one of the components of tangent vector is set equal to plus 1 or minus 1 that is we have first our step is how to solve this problem how to get the tangent vector right therefore the approach is that first we we add a rho vector e_k e_k to the set of differential equations or do this Jacobian matrix e_k. This vector e_k accept the k th element all other elements are 0 this is a rho vector and and our interest is that we want to make one of the component of the tangent vector equal to plus 1 or minus 1.

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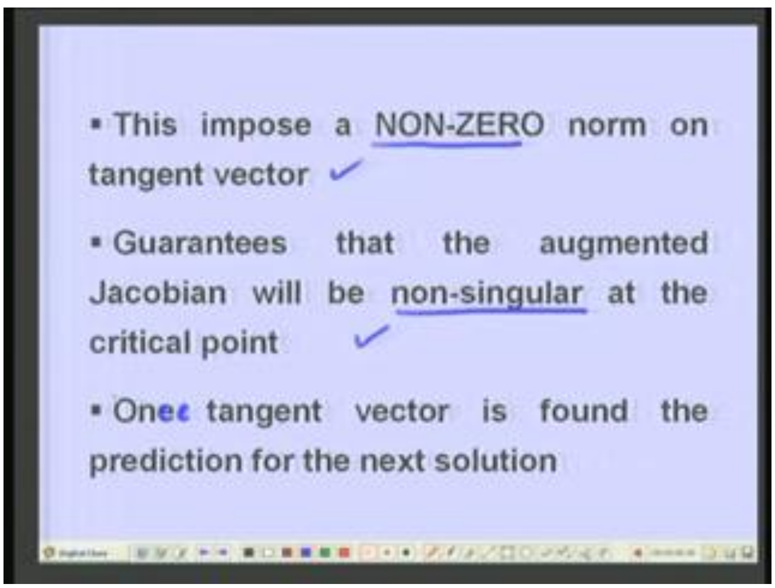

So that when this rho vector accept one quantity others are all 0 certain when you multiply this you will find actually that the delta lambda will come out to be equal to plus 1 that is here we are making actually this ek ek in such a fashion so that the you get d lambda. One of the elements of one of the elements of the tangent vector equal to one, for example if you want to make one of the elements of voltage component right that is say let us say the voltage of bus 1 d_{v1} or d_{v2} any one or similarly phase phasing allot any of the bus voltages that is in this you can make one of the elements equal to 1, it may plus 1 or minus 1, plus 1 is corresponding when you are operating on the upper part of the PV curve and minus 1, when you are operating on the lower part right. So in this reformulated equation we have now, we have now a situation where where we can compute this tangent vector okay.

Now the this imposes a non-zero norm on the tangent vector is that by by this approach by adding this rho vector e_k and making one of the elements as plus minus 1 right what was have achieved is that two things which you have achieved first thing is that this rho vector right. It it becomes a non-zero norm tangent vector that if a find a find in norm of this tangent vector then it will come out to be non-zero, it will not become zero right. Second is guarantees the augmented Jacobian will be non-singular that is the all Jacobian which you have augmented. Now this Jacobian becomes non-singular and you can find out the tangent vector that is one tangent vector is found once not one once once tangent vector is found.

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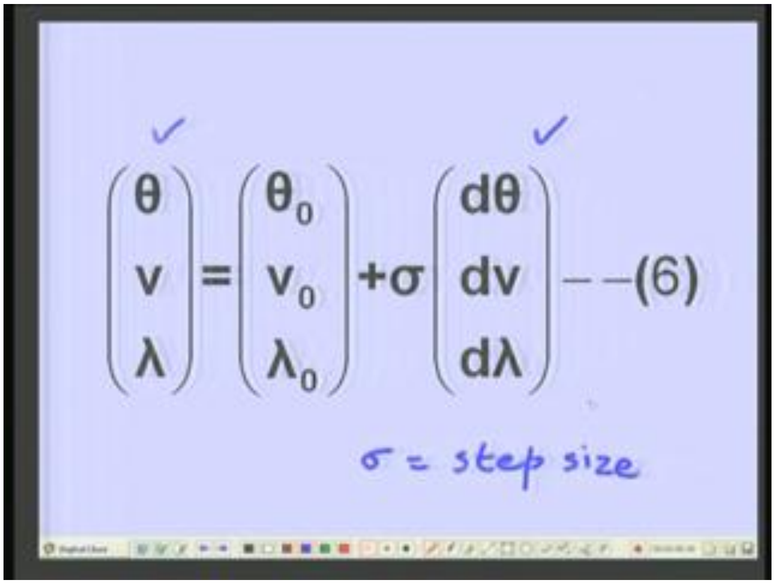

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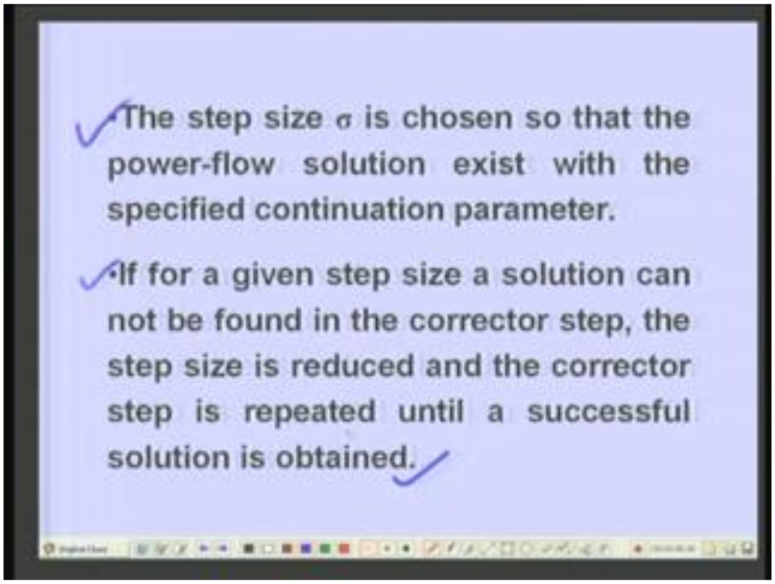

The prediction of the next solution is as follows that is what we really do is that we first compute the tangent vector and the moment you compute the tangent vector the new tangent vector is obtained as theta not not tangent vector this is the tangent vector d theta, dv and d lambda, this is the tangent vector. The new operating condition that is theta v and lambda obtained as the initial values of this vector plus sigma times the tangent vector this sigma is the step length sigma is the step length step size okay.

By step size sigma is chosen so that the power flow solution exist with the specified continuation parameterthe idea here is that the step size sigma should be such that such that now you can perform the normal power flow solution and obtain the obtain the complete solution that is you can find out the all the voltages and their phase angles. I will just see here, generally you will find out actually that in case suppose the step size is large then from that predicted solution you will not be in a position to get the corrected that is actually the low power flow solution when you try to perform right the solution will not give actually this the the exact solution or the required solution.

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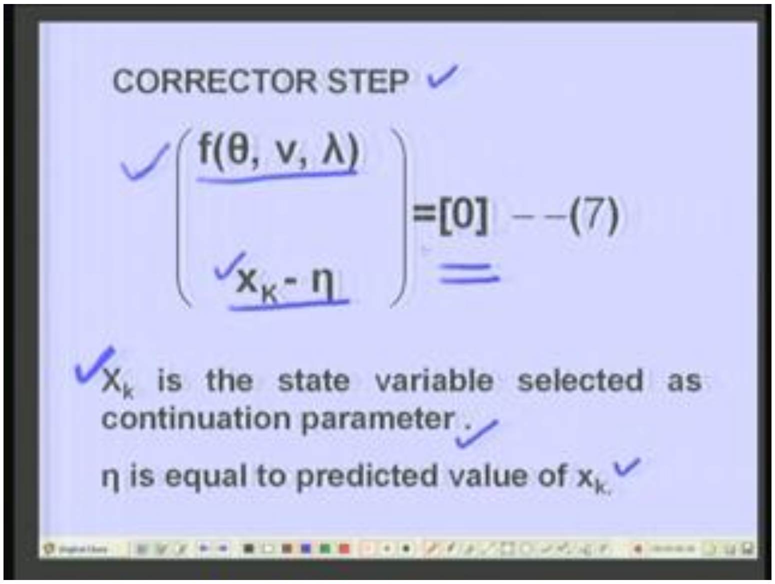

In that case we we reduce the value of sigma again repeat till we find out actually that in a character step. We get the solution if for a given step size a solution cannot be found in the character step the step size is reduced and the and the character step is repeated until a successful solution is obtained. This is actually a very important at what should become we do not know what should be characterized the what should be the step size. Suppose you take a very small step size then you will require large number of repetitions due to a large step size, it will not converse and therefore one has to take very judiciously these a step size next step step is the character step the character step is idea of the character step is to really perform actually the load flow and get the solution.

Now again the, if you see here actually this function f theta, v lambda right. The number of unknowns are theta v and lambda right but the number of equations will be one equation less because the the when you have formulated the number of equations you have added a term lambda into k but number of equations were still the same. Now to get the solution what is to be done is we add one more equation this equation is written as X_k minus eta equal to 0 that this X_k this is very important point here the X_k is the state variable selected as continuation parameter what are the state variables all the all the phase angles, all the bus voltages right and lambda they are the state variables here right and therefore what we do is that X_k is one of the state variables and this is chosen as a continuation parameter and and eta stands for value of X_k value of X_k that is the predicted value of X_k because X_k is one of the one of the state variables right and therefore if you look here which is our process then we start from the initial operating condition there we find out the tangent vector and suppose you start from point A and go to B, B is the predicted solution therefore at this B we know all the values of we know the value of the complete state vector right and therefore X_k, X_k is is the continuation parameter which is chosen and it is one of the state variables and value of X_k is chosen equal to equal to lambda which is the which is the predicted value of X_k predictor value of continuation parameter.

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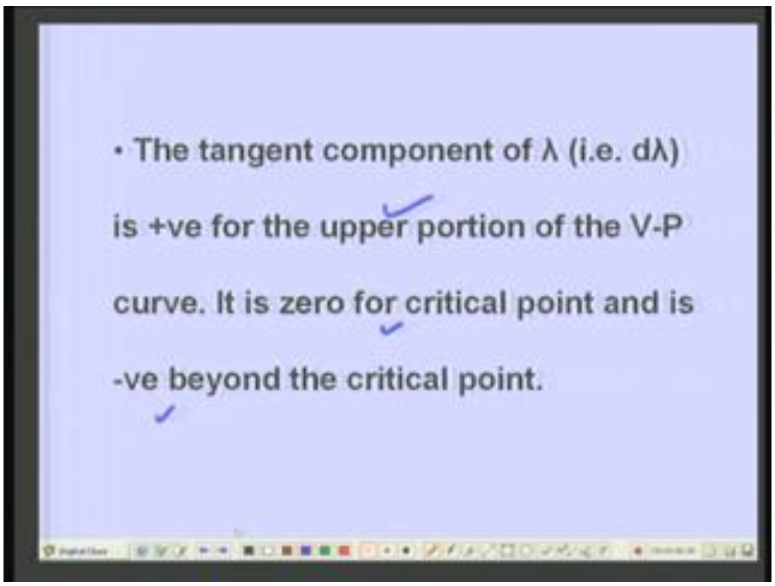

Therefore, the number of equations which now we have will be one more additional equations you added and therefore this set of equations can be solved by a normal normal load flow and you will get the solution therefore this is what is called character step. Now the question basically is that how to solve this problem, how to choose actually the continuation continuation parameter or continuation variable the X_k that is because X_k is one of the state variable to be chosen as the continuation parameter the tangent component of lambda d lambda is positive for the upper portion of the VP curve 0 for the critical point and negative for the lower point, so to be already mentioned.

The question is how to select the continuation parameters right obviously one can choose some some any one of the any one of the state variables as continuation parameters but the but the for optimum solution the approach is a good practice is to choose the continuation parameter as the state variable that has the greatest rate of change. In fact for to find out what we do is that we find out the the tangent vector and in this tangent vector the element which has highest value is chosen corresponding to that the chosen as the continuation parameter or that state variable which is highest or greatest rate of change is chosen as the continuation parameter.

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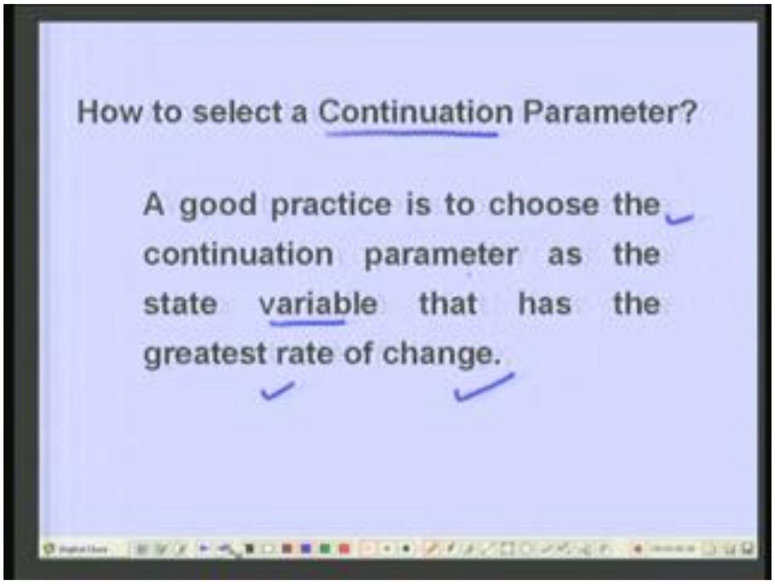

Let us look at the a flow chart of this continuation power algorithm. The flow chart is as usual you start your problem. First step is run the conventional power flow on base case, run the conventional power flow and the on the base case and find out actually the initial solution then specify continuation parameter. Now here at this stage how to specify the continuation parameter we have not calculated the tangent vector and therefore the suggestion is you can choose lambda itself which is the which is the load parameter as a continuation parameter right.

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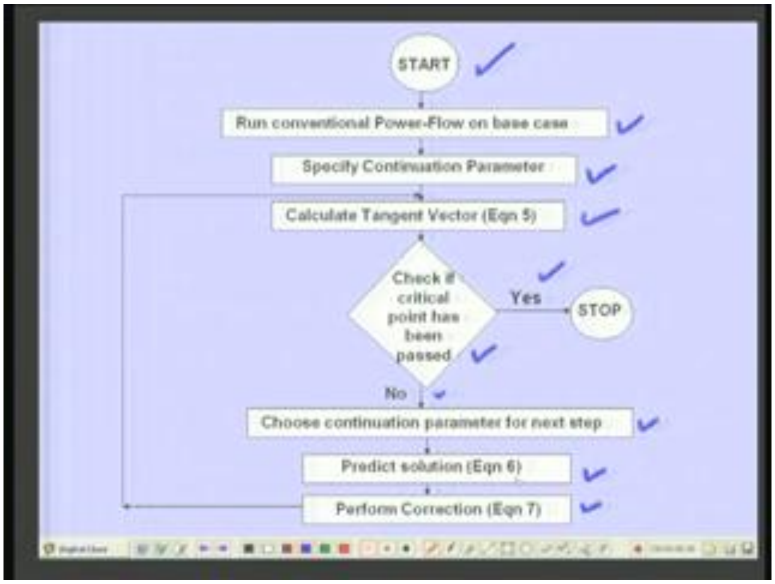

The next step is calculate tangent vector for which the equation has already been specified that is you calculate the tangent vector, next is if critical point has been reached that is you have to check whether you have reached the critical point or not if we at if you have reached the critical point you stop there. Otherwise, otherwise choose continuation parameter for next step.

The first step the continuation parameter was chosen arbitrarily and I told you that we can choose the log parameter as the continuation parameter. But here, now we once you have this tangent vector we can choose the continuation parameterthen after choosing this continuation parameter do the complete the predict the solution out of this prediction you go for the correction that is perform the correction part and then return back to this point again and this process continues till you reach the critical point and you can go below the critical point also and got get the other points operation. This is a very important algorithm which we have discusses.

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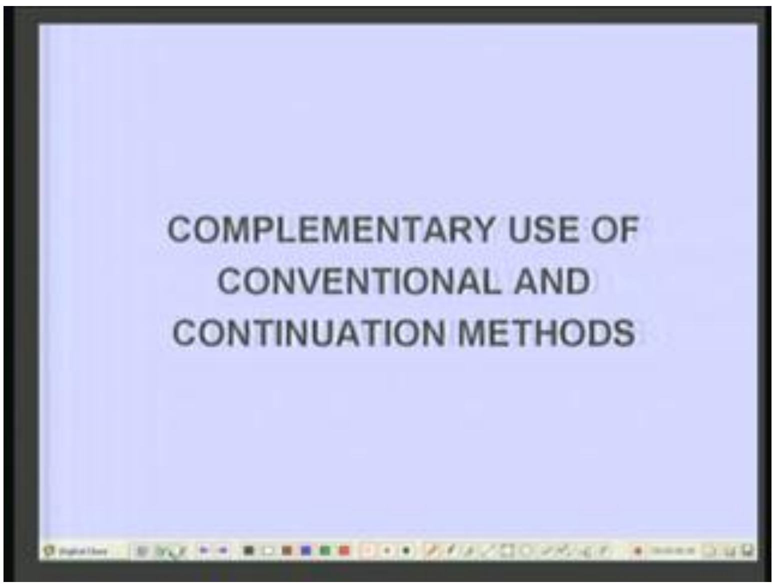

Now the problem here is that should we use the continuation load flow algorithm right from beginning or should we use it actually when we reach the near the critical point thus the answer is obviously, you first solve this continuation solve this problem by normal conventional load flow that is you are operating at initial condition, you give increment in load again perform the load flow analysis find out the new solution and till you come very close to the critical point, you can keep on using the conventional load flow but the moment you reach the critical point or near the critical point the Jacobian becomes so at critical point become singular and therefore both or or closure to the critical point you can now resort to the continuation load flow algorithm and obtain the points operating points which are the critical operating points.

The the idea here is that the continuation load flow algorithm it takes more time to get the solution because it has two important steps the predictor and corrector steps and so far the the conventional load flow is concerned you can you can increase the load in a particular direction and find out the solution.

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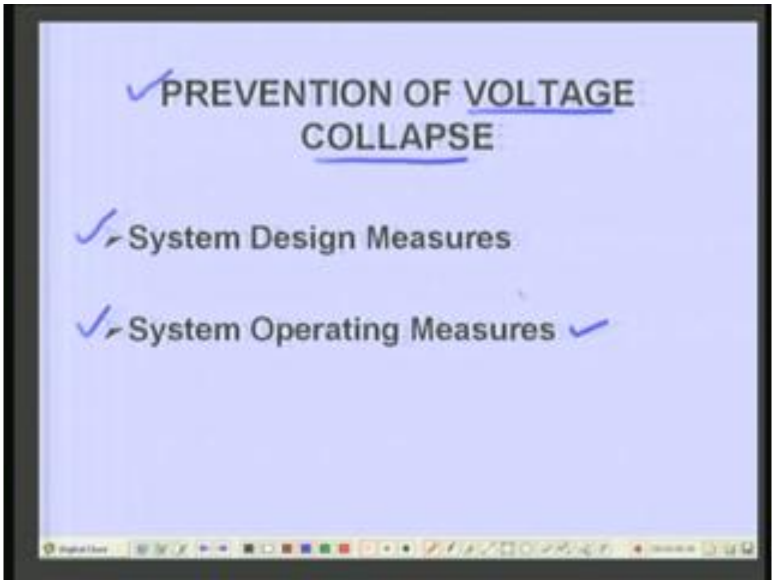

Next point, we will discuss is what can be done and how the system can be designed and operated. So that we avoid the voltage collapse situation that is we want to operate the system so that the we can prevent the voltage collapse. Now here we will divide this our discussion into two different headings one is the system design measures that is when you design the system you you take care so that it has a inherent stability margin right and then next is operating measure that is when your system is already there how to operate the system, so that the voltage collapse is avoided.

System design measures what are the design measures which can be adopted for for having a system which will have a large so voltage stability margin and voltage collapse would not take place there. Obviously, when we have discussed this voltage stability problem, the voltage stability problem is basically the problem of inadequate reactive power supply. It is a situation where the system has has less reactive power supply capability, it cannot supply the required amount of reactive power and the voltage collapse takes place therefore obviously the first solution or first design the approach should be design measure should be have apply apply reactive power compensating devices or adequate reactive power compensating devices, apply we should have various sources of reactive power and that these reactive power sources should be applied very judiciously.

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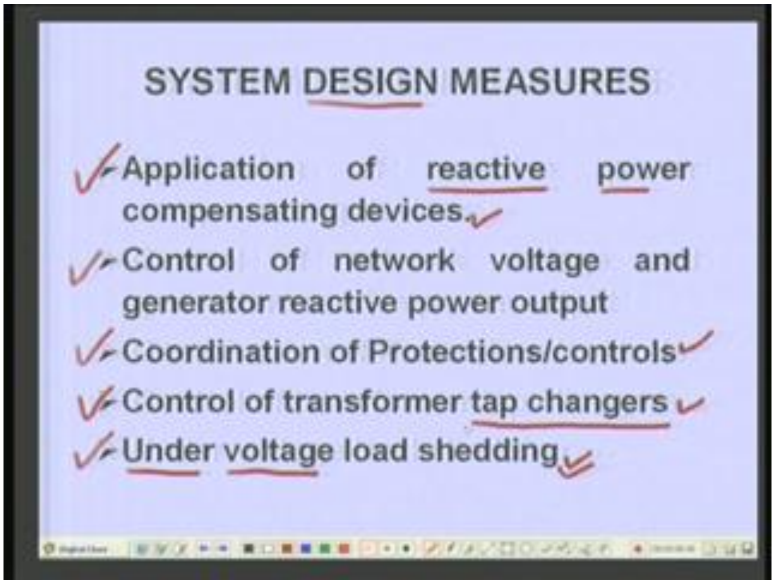

We will discuss this application part in the next step second will be control the network voltage and generator reactive power output that is that is when a system is under the design stage design measure itself right you provide certain certain controls which can be used for for controlling the network voltage and the generator reactive power output that is you should have the controls so that you can increase or decrease the reactive power output from the generating devices then there may be certain certain protections and controls we should have proper coordination, sometimes the protection there was use when they are controlling a load let us say right and when the arrangement is there whenever the voltage is decreasing you can do load shedding and voltage will recover.

Therefore, load shedding is one of the controls and therefore whatsoever protection and control devices you incorporate in the system, load control devices or voltage control devices all should be properly have proper coordination with the protection systems then also have proper control of the transformer tap changers where they are the voltage control devices you have to provide certain arrangements so that you can control actually the control the tap changer positions. Then next is under voltage load shedding if there is a last resort in case you find their voltage is sinking voltage is going low you you do that load shedding.

For example, under frequency load shedding all of you know right when the system frequency is going down we do load shedding so that the frequency is recovered right. Similarly, when the voltage is low one can resort to what side call under voltage load shedding but this this should be done very judiciously and this should be neither than last resort for for for saving the system from voltage collapse right therefore the point is that these measures which I have put here as design measures and therefore you should have a provision in the system so that you have a provision of under voltage load shedding.

As a as a built of strategy to to avoid voltage collapse phenomenon are voltage instability phenomenon. In case suppose it is provision is not exist it will not work right and generally you will find that the that the human intervention may sometime success be successful there will not be successful but here when I talk about this this is the automatic under voltage load shedding scheme.

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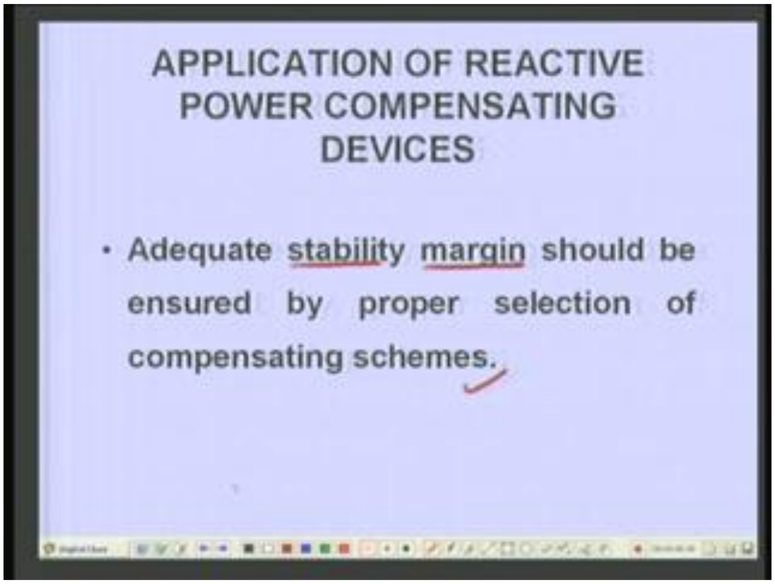

Now let us discuss this things in slightly more detail, application of reactive power compensating devices. We know that we have the various reactive power sources our interest here is that you should design your system so that you have adequate stability margin that is that is when you plan for the reactive power sources, you plan in such a fashion so that adequate voltage stability margin by proper selection of compensating devices.

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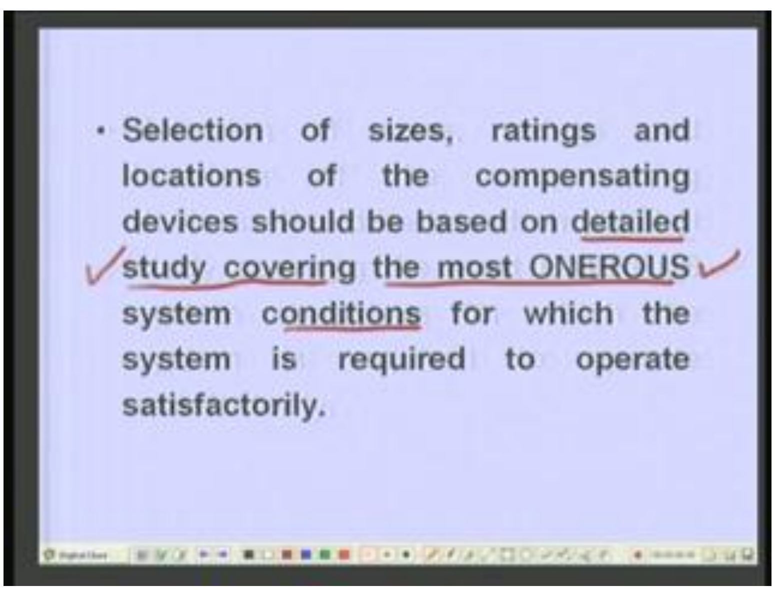

In fact here the selection of sizes what should we size of the compensating devices what should the ratings, what should be the locations all these things should be done by by a detailed system study covering the most onerous system condition for which the system is required to operate satisfactorily, idea here is idea is that when you are doing this design you have to you can say determine what should be the location of the reactive power sources what should be their sizes and what should be the type in the sense that is if control or is it fixed or whether is way which should be continuously control or else we discrete control that the idea here is that when you right at the design stage you have to perform a detailed system study or detailed system optimized study you have to be done. So that you find out actually the sizes locations type of devices and that should all include the most onerous or most most actually the most heavily loaded condition right.

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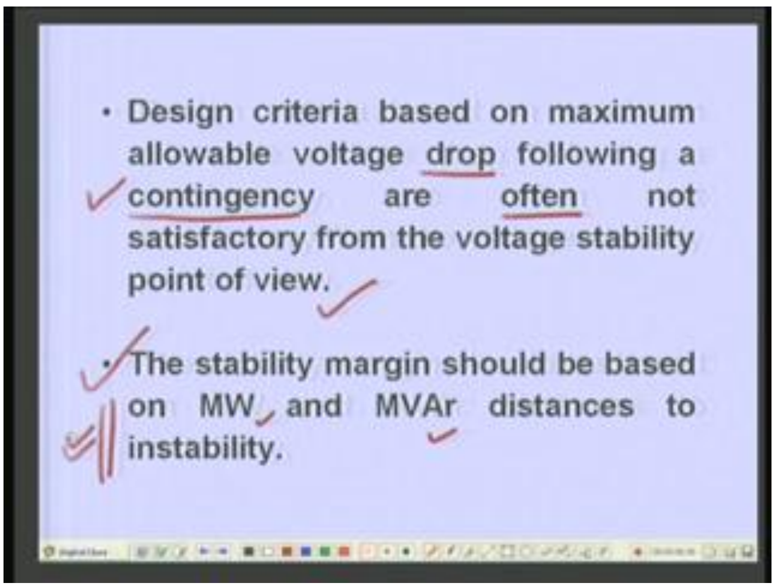

We wanted at that condition system should be stable, third is design criteria on maxim allowable voltage drop following a contingency are not often satisfactory from voltage stability point of view. Sometimes whenever, we design the application of reactive power sources the one approach will be that okay suppose the certain contingency occurs right what is the maxim permissible voltage drop and based upon that you design the reactive power sources but the suggestion is that instead of going for this type of situation one should design from the point of view of stability margin that is the stability margins should be based on mega watt and MVAr distances to instability that is how much real power, inductive power increment can be put on that system right till instability occurs that is what is that point actually I have already discussed the minimum distance to instability therefore that criteria should be we must we must design our system. So that there is a minimum inbuilt voltage instability.

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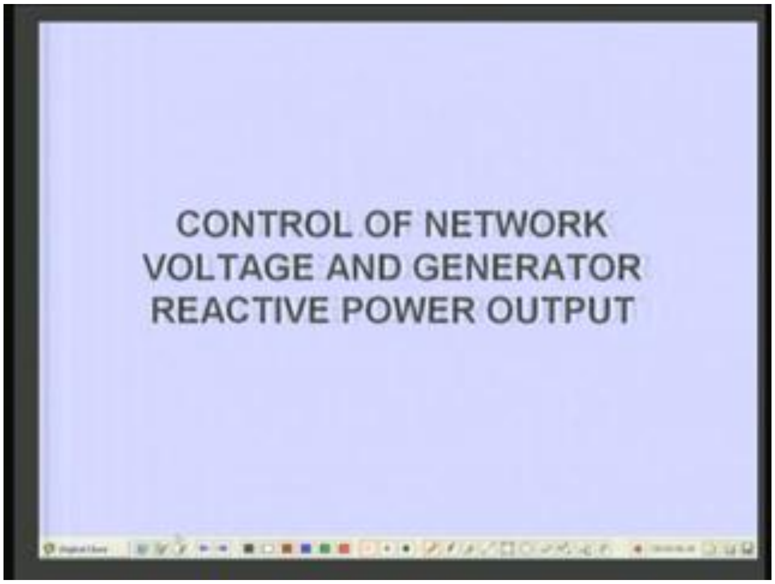

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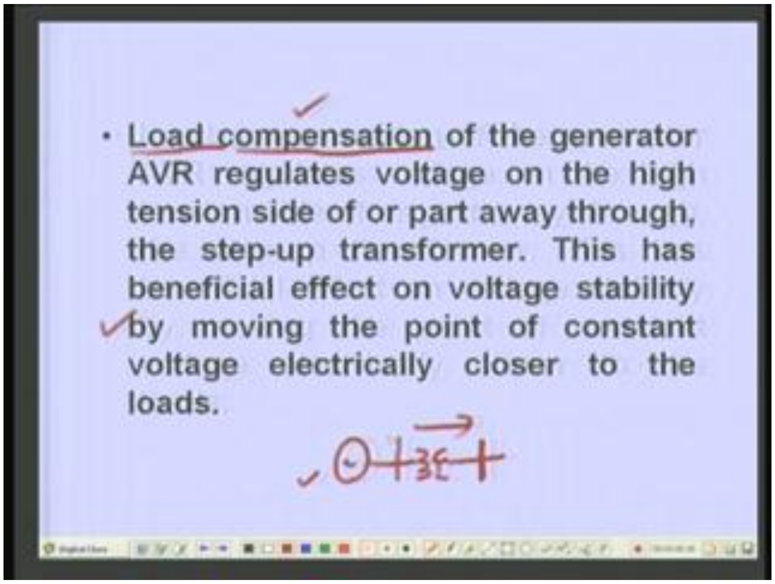

Next the control of network voltage and generator reactive power output again the design step. Now here, so far actually the reactive power sources are concerned the generator is one of the most important reactive power source and the generators have automatic voltage regulators, one way is that you you a regulate the voltage at the terminal at the generator, another way is that using load compensators you you regulate the voltage at a point away from the generator terminal that is the point which you choose for regulation may be not the terminal voltage of the generator suppose this is generator, this is the step of transformer that is you can regulate actually the field current of the generator through AVR. So that you maintain the voltage on the high voltage side of the transformer constant this is normally done with the help of load compensation devices the load compensators are provided to take care of this, this the AVR regulate the voltage on the high tension side of or part away through the step of transformer.

You can always regulates through that some voltage may not be at this point may not be at this point but in between that what you manage to decide that is the load compensation of the generator AVR regulate the voltage on the high tension side or part away through the step of transformer. This is beneficial effect on voltage stability by moving by moving the point of constant voltage electrically closure to the loads, in the sense that what is happening that this constant voltage point is now coming closure to the loads right. This is one approach that this instead of regulating the terminal voltage you regulate the voltage at some other point using the AVR load compensation devices.

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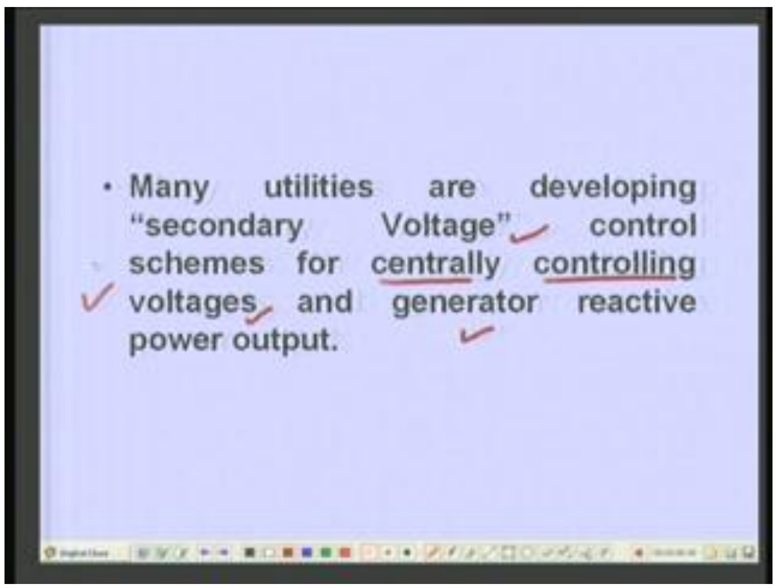

Then many utilities are developing secondary control or secondary voltage control schemes for centrally controlling voltages and generator reactive power output. In the sense that instead of actually having the this they dis-analyzed voltage controlled you an take this system as a whole right and monitor the system and control the voltages of the network from a central point of view, control all the generators all actual the reactive power sources centrally, so that you maintain actually a good voltage profile and maintain a voltage stability margin. This is this is a new modern approach where we go for system wide control.

The next is the coordination of protection and controls because we have provided certain protections so that when is suppose system is overloaded the protections will will trip the equipment right. Therefore, tripping of equipment to prevent an overload condition should be the last resort not in the necessary that suppose system is operating and there is a transmission line is the overloaded right the protection system look at the overloading and may trip the line but this it should be considered as a last resort that is your protection particularly the tripping or protection system wherever possible adequate control measures, automatic or manual controls may be automatic or manual. So the provided for relieving the overload condition before isolating the equipment from the system this point is very important here idea is that here is a system which is operating.

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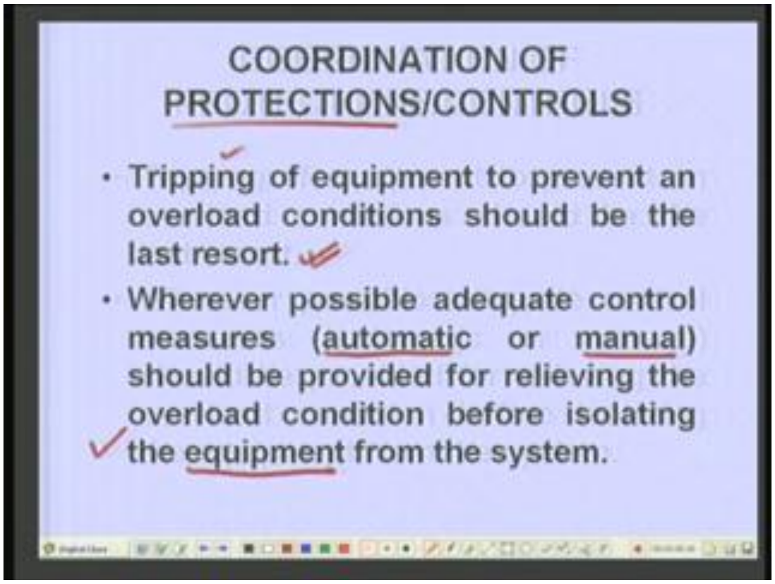

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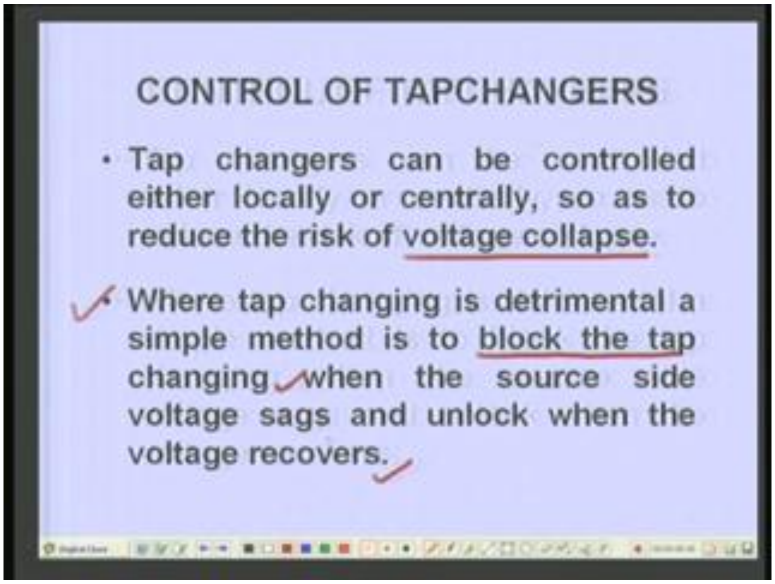

Let us say overloading takes place the protection system will try to look at the overloading and trip the line. Our interest is that we should try to relieve the overload by say by say tripping some loads before before tripping the generator or transmission line or so on that is the equipment before isolating the equipment here the equipment means basically is the generator transformer and transmission lines. This is what is the meaning of coordination of protection and controls.

Next about the control of tap changers but this is also playing very important role tap changers can be controlled either locally or centrally so is to reduce the risk of voltage collapse in fact what happens is that under certain situation the operation of tap changer is helpful under others operating condition of situation right the tap changer will not be in a position to increase the voltage but but that is going to reduce the voltage on the contrary that when you tried to you can see increase the voltage the reactive power flow increases voltage drops right therefore idea here is that where the tap changing is detrimental.

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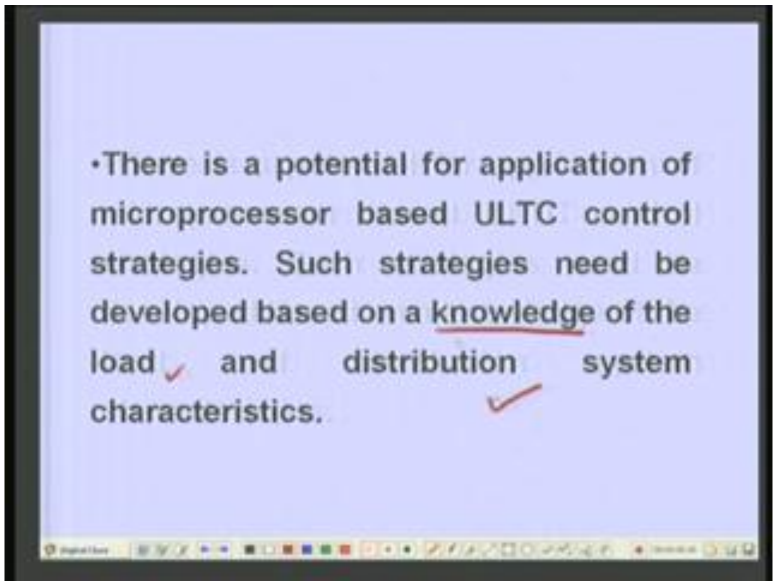

So detrimental a simple method is to block the tap changing when the source side voltage sags and unlock when the voltage recovers right that is again actually very centralized control we have to, there is also potential for the application of microprocessor based ULTC control strategies such a strategies need be develop based on the knowledge of the load and distribution system characteristic that is here microprocessor base means basically it is going to be intelligent type of control systems right. The next step is discussed was the under voltage load shedding.

Now to cater to unplanned or extreme situations it may be necessary to use under voltage load voltage load shedding schemes. The load shedding provides a low cost means of preventing widespread system collapse in the sense the before before the system collapse is right it is better to can say do some load shedding and rely the system from the overloading. The main cause of you can say the collapse is again the overloading more reactive power demand than what can be supplied and therefore if you reduce some of the loads or if you disconnect some of the non-critical loads right then one can save the system this approach is also used actually even for our a for improving the angle stability of the system under load, under load shedding.

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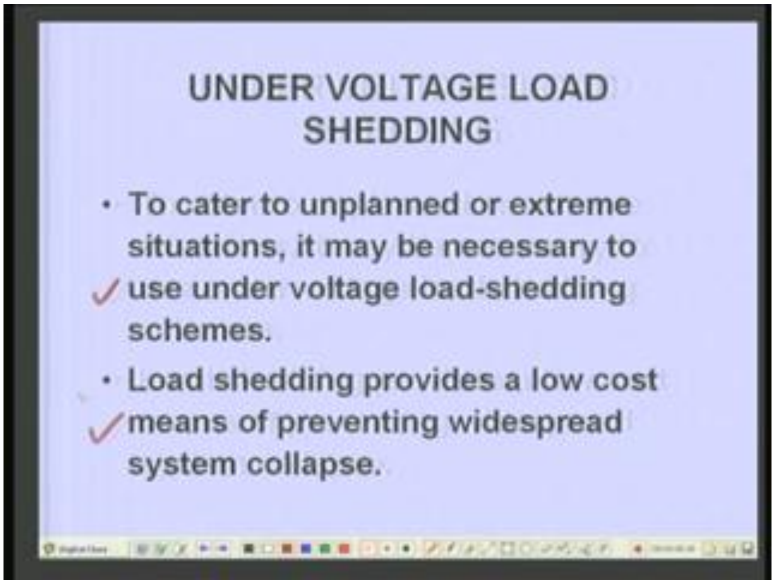

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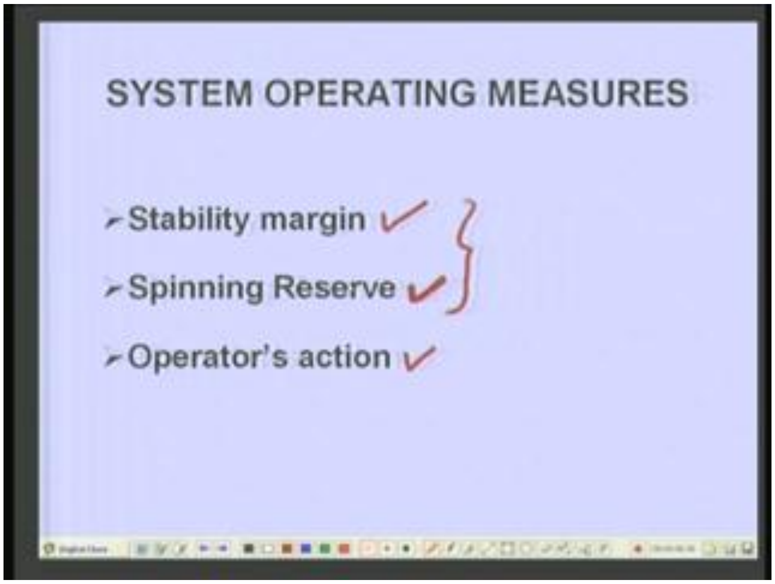

Then we talk about the system operating measures, what measures can be adopted so that when we operate the system, operate the system right the system will not go into into voltage collapse phenomena. The approach is very simple you operate the system so that it is a sufficient stability margin it means right now at the operating stage you design that yes loading should not go below a above a particular limit so that you have sufficients voltage stability margin. This point is also very important is called the spinning reserve, the spinning reserve the concept is the generators generators are the reactive power sources right and this reactive power can be obtained quickly by regulating the excitation right and therefore what is said is that you should you should operate initially the system.

So that other reactive power sources are used and the reactive power capability of the generator is kept reserve because you have various reactive power sources like shunt capacitors, synchronous condensers, may be SVC, may be state comment so on right, use then first and the load the generator. So that generator is operating at nearly the very use the power factor condition is supplies the real power so it has a reactive power capability and use this reactive power capability to save the system from voltage collapse that is actually the right at the design steps. Next is operator's action, idea here is that these are the two which you can plan at the at the operating stage when you operate your system, next is the operator's reaction, operator's intervention, how the operator can can actually monitor the system, look at the complete system as a whole and take necessary action.

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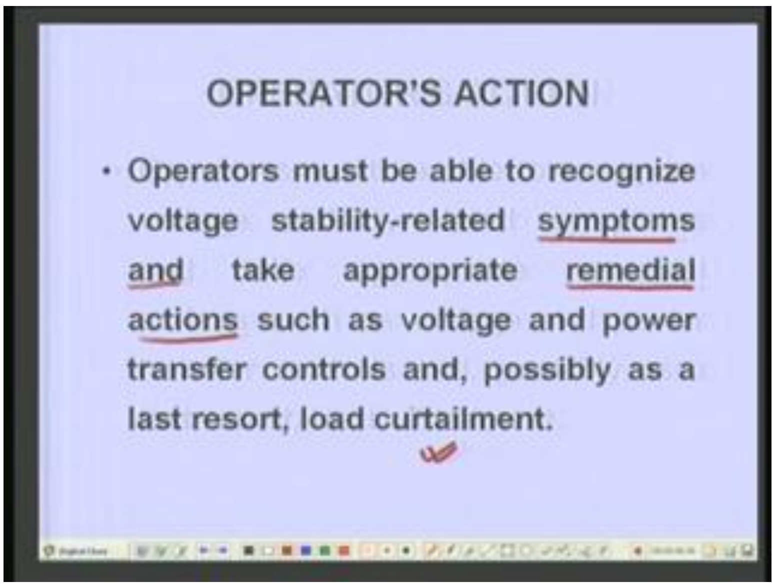

I will talk about the operator reactions slight in more detail, the operators must be able to recognize voltage stability related symptoms and take appropriate remedial action such as voltage and power transfer controls and possibly a last resort load curtailment. This is the most onerous task which is put on the operator that is the operator should be in a position to to recognize the voltage stability related symptoms the, right. So that this operator will take remedial action before the voltage instability occurs, it means the operator has to be well trained and he can find out that yes there is a possibility of voltage instability which may take place and therefore he takes certain measures and it should have certain certain authority to take those measures. Of course the last resort is the load curtailment if you feels that yes without load curtailment the system cannot be saved he should have the authority to do the load curtailment and he should have that type of experience and training.

So that he can make out actually that yes yes at this parse at this operating condition system is vulnerable is prompt to voltage instability and you should know the load remedial measures to be taken to save the system. It is very difficult task and that is why actually we require a highly trained personal to operate the system, operating strategy that prevent voltage collapse need be established in the sense here here the meaning of this is the operating strategies that prevent voltage collapse need be established.

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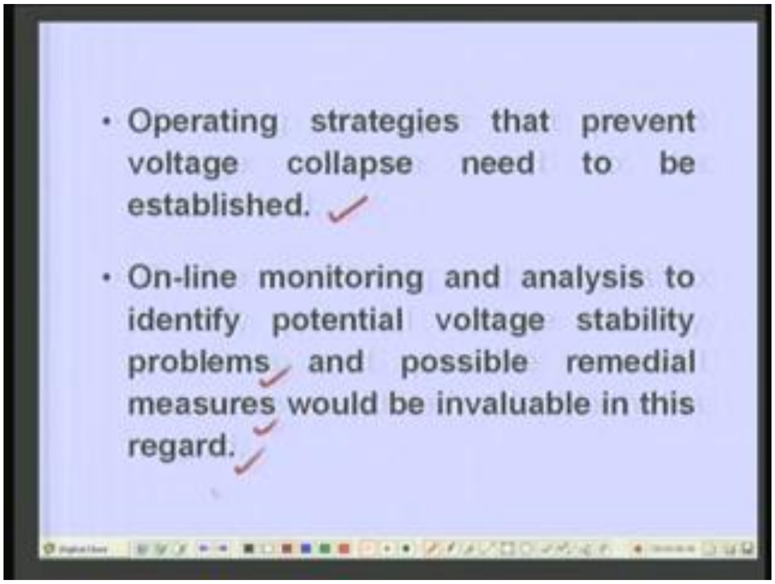

Right at the beginning when you are operating your system you have to establish that what should be the what should be the strategy so that we if this happens this measures should be taken that should be available to the operator an online monitoring and analysis to identify potential voltage stability problems and possible remedial measures should be invaluable in this regard is always online monitoring. With this I have I have completed the discussion on voltage stability what we have discussed in the voltage stability the how to analyze the dynamic stability problem this is done by complete time domain simulation then one can apply the certain tools static tools to to analyze the voltage instability problem.

We have seen the PQ sensitivity analysis, we have also seen the QV model model QV analysis i have also discussed the continuation load flow for so and so forth. At the end we have discussed the various measures that can be taken to prevent the voltage collapse in the system. Thank you very much!