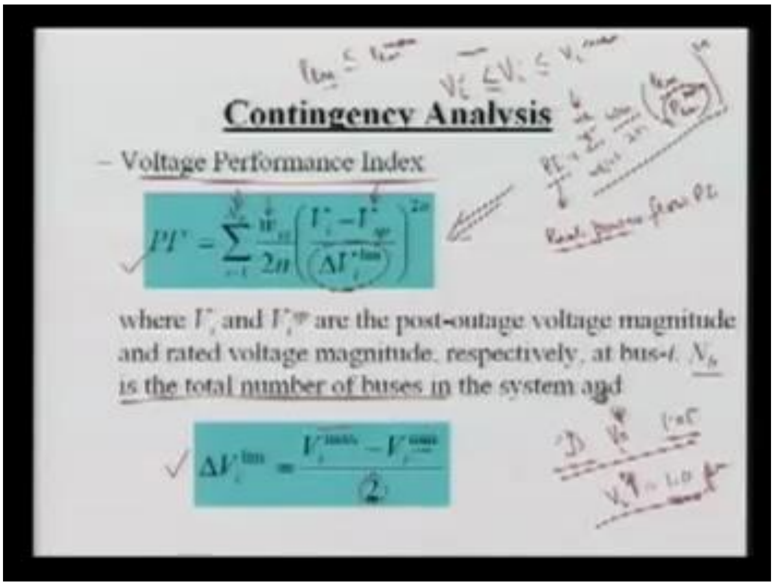
Power System Operations and Control
Prof. S.N. Singh
Department of Electrical Engineering
Indian Institute of Technology, Kanpur

Module - 5
Lecture - 2
Load Dispatch Centre Functions

Welcome to lecture number two of module five that is load dispatch centre functions. In the previous lectures, I explained about contingency selection reparative and emergency control actions. In the contingency selection that is a part of contingency analysis, our decision that we can go for this formation of performance indices those are useful for categorizing the critical contingencies in the system. So, in the previous lecture I discussed about the real power flow performance index. Now, here I will discuss your voltage or you can say reactive power performance index and which can be defined as follows.

(Refer Slide Time: 01:03)



This PI which I have written the PI v means it is for the voltage performance index and basically that is used for your MVR security or voltage security analysis.

Here, again this function is similar to your real power flow performance index and that if you can see I just define here the PI for that. You can say it is a real power flow that is equal to summation of your I equal to 1 to here all the number of lines here it was your omega m over your 2 n and here I was writing this P lm over P l m maximum value and then it was power 2 m here basically it was m. So, this function is almost similar to this function you can see, this is the power flow performance index that is it is a real power flow, real power flow PI.

Why it is real power flow? Because we are taking this here variable the P l m that is a power flow P l in particular line m divided by the rating of that line that is a P lm maximum value and then we are going for the 2 N that is n is your exponent. Here, omega m is given the relative importance as I explained yesterday in the previous lecture. Here, that is stabilized by 2 m, it is giving relative importance of that particular line, and normally this value is kept 1.

So, we are giving the relative importance for all the lines how to do this equally. Similarly, here in this voltage performance index here inside of in the voltage at particular bus. We are just taking the difference between the excess specified, the question here the P l m always we go for this equality, the P l m of any particular line should be less than or equal to this P l m of that line to this maximum value.

So, it should be always less than or equal to this value, so this side limit is again if you are taking mod, so it will 0 value. So, there is no problem, but the voltage if will see the V I here, it should be lie between the two limits here I can say VI maximum value and then here it is V I your minimum value. It means the voltage and any should lie between the two limits one is your its maximum value and another is your minimum value.

So, we have to now go for the different, how much this where you are operating what is your voltage. If it is only one value and there is no lower side value, then we can go for the similar expression, but here since this VI should lie between these two ranks, so we are talking about the difference. Now, the V is specify what should be the re-specification of any bus V 1 that suppose your bus voltage is 1.05 is upper limit and the lower limit is 9.5 V 1. The specified voltage here should be I that is specified it is the sum of these two divided by 2 means it is average of these two. So, VI is specified is equal to your 1 per unit.

So, here this V is specified even though sometimes it is a general value I am talking even though if you are not going for 1 per unit or else value, then you can specified how much you want and how much it is a deviation. You want that your voltage should operate here, it specified value. So, this will be 0 and this will not go in the PI addition because it is addition for all the buses.

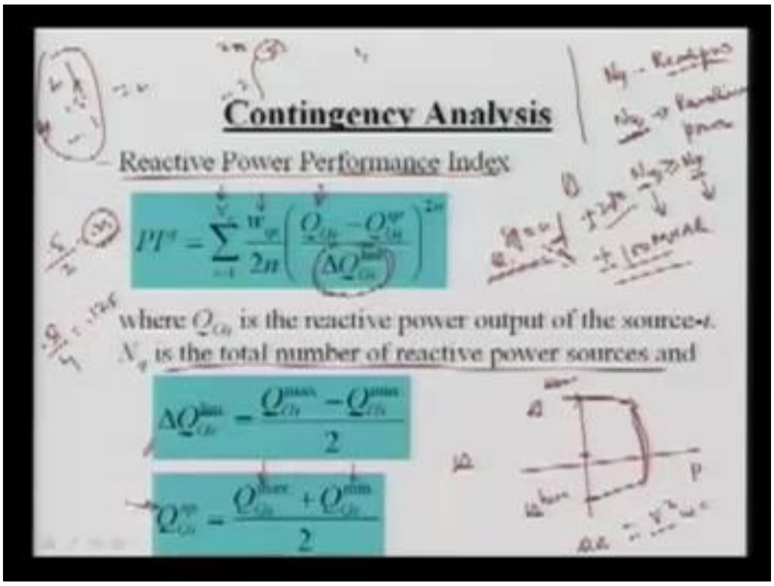
So, it all the bus voltages are equal to a specified voltage then this value will be 0, otherwise if variation deviation the voltage will be this PI value will be higher and that gives the relative severity of this. If this PI V is larger means I can say for that contingency our system is most critical and so on so forth. Now, again here this we are putting the wall that is a omega VI, which is also giving the relative importance of a particular bus in this PI contribution.

Why is it? So, because we know even though some buses even though violation, we can go even the more than that its eliminate it can cross, but that may not be so critical, but some busses even though a small deviation in that voltage is very critical. So, we can put some value more other than unity here means that will give the relative importance of that value, 2 n is divided here to normalize this almost so that we should not keep on anything in the value.

Another value here to make it what is the range of your the limiting value, here we were using this again here was also range, range means it was a P max minus 0 because the from 0 to P max it can go of course in any direction to here this value as P max. Here, we are taking the VI limit and this VI limit is defined as you are here the VI max means the maximum value at ith bus minus minimum at the ith bus divided by 2.

So, this value is kept here and then we can go for summation for all the busses here again n b here it was number of lines because we are talking the line slow. So, number of lines we are considering here, we are talking about the bus voltages. So, number of busses are keep are going to be added, so that is why here I have written the n b is the total number of buses in the system.

(Refer Slide Time 06:45)



Similarly, some people say that the voltages performance index may not be edited, then they define another write a reactive power performance in the similar to your real power flow performance index. Basically, this reactive power performance index is reactive power generation means how much reactive power you are putting into the system, how much requirement is there and there gives your relative criticality of the system. Similar to PI V, here we are adding number of n q means how much sources you are having in your system means how much reactive power? Again, just I want to give one example in your power system there maybe number of Ng number of generators means real power generators and there maybe your N q reactive power reactive power generators.

Now, this N q is always greater than R equal to n 0 why it is soon, for example some of the generators your real power generators or your alternatives. So, they are generating the real power and they can also generate the reactive power. So, this N g is also reactive as well as real power generation N q, it is not necessary, all this reactive power generators will generate the real power that is the reverse is not true because let us suppose you are having a static condenses. You are having fax devices you are having simple capacitors, they can generate reactive power, but they cannot generate the real power.

So, this N q just we are considering all the reactive power forces including your real power generators and synchronous condensers your fax controllers as well as the other capacitors are reactors in the system. So, always this N q is more than your N g, this is real power generator this is a reactive power generators. So, here we are adding the reacting power generated for all this N q in the number. So, I have written this N q is the total number of reactive power sources in the system.

Now, let us come to this point again here this W q y it also shows the relative importance of particular reactive power source. The difference here what is the reactive power generation of that ith just we are adding here? So, the Q g is the reactive power generation at I means ith bus minus Q gi is specified. This Q gi is specified how much you can generate this basically defined at the Q gi is specified here with this Q gi max plus Q gi min divided by Q is the specified means we have the some limit and then we are going to generate that.

You can also see already we discussed about the reactive power capability of alternative. So, remember what I did this I this is P and Q curve this I have drawn and we found this is your field hitting limit this is your armature getting limit and this is your end hitting limit. So, this was your reactive power capability limit, so this was your positive queue, it was your negative q. So, this was your q mean and this was your q max that you can generate.

So, this is the average of this, we can go for here, but some of the devices for your capacitor, it will generate because it has no limit it depends upon the voltage, how much capacitors? So, it is a value here V a square into omega c, it will be the reactive power generated by a capacitor, but if you are having a static compensators S vc also I have explained in S vc, it is a plus minus certain value you can say, let us suppose hundred NVR. So, it can go for both sides, so normally we want the static compensator should neither generate, so this is basically the specified value for this will be 0 Q specify for this Q is specified we can take care of this, it maybe this some positive value.

So, these are the basically that we have to see and what is specified, now question why we want this specified value change if you are putting a huge expense for putting a SBc in your system, it is very expansible device.

Of course, then if we want to operate this, then we will have the more margin whenever because these systems are used not for simply providing the reactive power support because the reactive power support can be provided by your capacitors and reactors. If we have a more margin here, then during the emergencies, we can control this very effectively and we can provide much more effective control to normalize the system. So, that is why we want here that it should in the yesterday state, it should not generate for example, we have one SVC in the Kanpur here that is a power grid.

Mostly, it is operating in the capacitive mode it is generating the reactive power every time because it is our system demands, but we want that it should generate very less amount of a reactive power or a job, otherwise we have a less small n. For example, this is this SVC which we have in our UP lets go. It is already generating, basically rating is plus minus 280 degree NVR, let us supposes it is generating to a TNBR in the condition if the faults come, there will be no margin. So, it already setting the limit and it has no control during the emergency because these devices basically you are used for the emergency control.

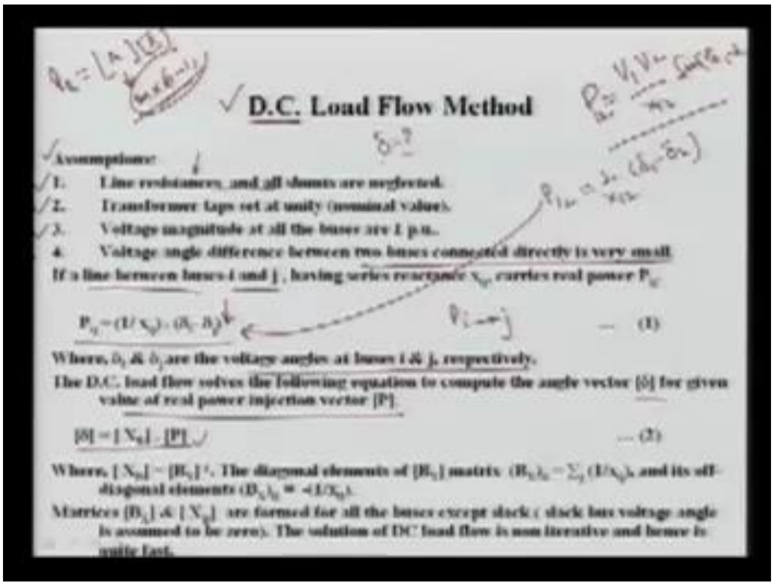
So, that is why this is the specified, we are adding the maximum to the minimum value and just we are taking between these two. Similarly, another is you are here, that is your change in your the reactive power limits that is we are dividing just value just we are lets making a significant amount because you are just you can see how much margin you are having what is your range here.

If you are having less range, then this value will be more means you are just operating how much closer to this limiting value. So, this limit is basically giving idea, for example the two systems you can see one is here the limit is let us suppose 1 plus 1 2, one you are having another reactive power generator you have a 2, 2 minus 2. Now, you can see here in this range you are having this value is 4, here you are having 2.

So, if you are dividing by 2 with the some here value means this value is very close to that. For example let us go this is operating at here 0.5 and this is also operating at 0.5 values for these will be 0 because a specified is if adding plus and minus here negative, so, it will 0. So, what we can get here 0.5 divided 2 g, it is generating this is your 2 g 0.5 divided by 2 for this case and for here, it is your four no 0.5 divided by 4 means you are here operating 0.1125.

Here, you are generating 0.25, so this value we can say it is very critical because you can see the range we are having 0.5 only margins to its filming, but here 0.5 we have a more margin. So, this case is less critical than this critical, so this gives basically the relative that is margin how much you are having. So, this is very important factor if you are not using then you can say then both will be equal here. So, it is showing that is the q limit is divided to take the importance of that range also and that range is defined by the change in the Q gi limit is equal to your Q gi max minus Q gi min divided by 2 just we are taking this.

(Refer Slide Time 14:56)



Now, let us go form some methods for the contingency selection in the contingency selection first and very simple method is your DC load flow method. This DC flow load flow method is basically used as I said it is only for the real power flow security analysis because it is DC here, it is not direct current, it should not consider. This is no doubt is load flow solution; it is called DC because we are ignoring the voltage system, only we are taking the delta I will just show you.

The agencies behind this program of this method are the line rate and all the sensors are neglected, you can see here first one, transformers step are ignored means you have to set at unity. This normal value, the voltage magnitudes at all the bus are assume to be unity while formulation we put in 0, 1 and then we go for calculation.

The voltage here angle are difference between the two buses is very small, with this agency we can write the power flow equation here discussion. You remember this expression very well that is a P at flow in the line is V 1, V 2 upon X 1 2 in that line sin delta 1 minus delta 2. This is basically power flow between 1 to 2 buses, now using this and this expression is only valid when R is 0. So, already we have taken in this expression, otherwise there will be some last term will be also appearing, it is said the taps already we have set unity voltage if it is 1, means V 1 V 2 is unity.

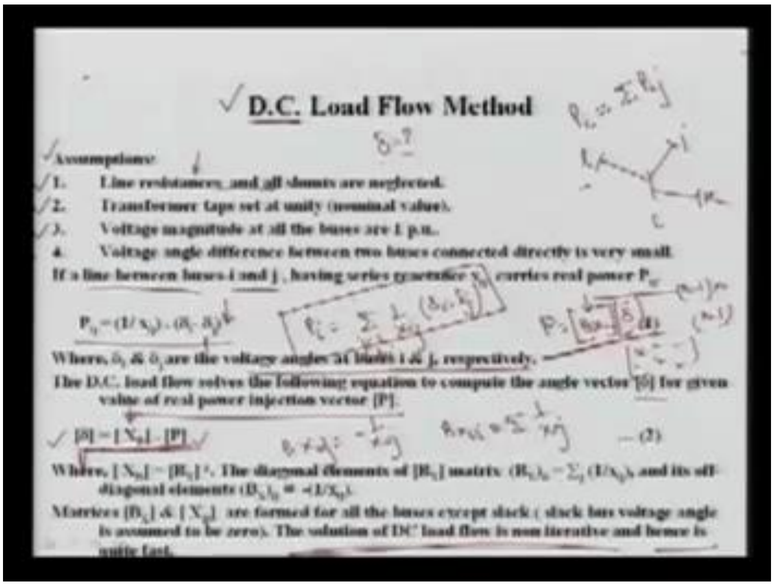
So, we are getting P 1 2 divided by X 1 2, here we are saying the angle is very small means the delta 1 minus delta 2 is also very small. Already, the angles are small delta 1 and delta 2 and once 2 is smaller quantity are going to be subtracted it become further is smaller. So, here and then if your sin theta now we can write at the theta for this small value. So, this is nothing but your delta 1 minus delta means we can in the radian, we can write this. So, this is present here you can see just I have written where x 1 to now it is a general way it is written that for any line which is connected between bus i and j we can write the P ij in that line that is equal to 1 over X ij multiplied by delta i minus delta j.

So, this source the power flow from i ti j, so it is just delta i minus delta j, we can write this where the delta i and j are the voltage angles at the bus i n here respectively as I told you. Now, the DC loads flows are the following equation to computer the angle vector this for the value of the real power flow injection. Now, we can use another expression if then remember that expression here we were using this expression that is a real time in terms of power injection means here in this one we cannot directly write this. Here, we can if you write here the general P l I can say we can write one matrix here and then we can write is a delta matrix.

Here, delta vectors are in and this matrix maybe your somewhere it I can say this is the some matrix we are here representing, let us suppose a matrix, this matrix is not a square matrix so that you can actually get the data. If you can get delta here in the DC load flow, what we do? We obtain the deltas and once you can get the delta, you can calculate the line flow and that is required in the real power security analysis because we required the line flows if the something some line is out, what will be the power flow? So, we required the delta C at from this expression here this matrix is this M cross N, N is number of buses and M is number of line.

Here, all the this delta one for the slack is always assume to be 0, so here I can say N minus 1 matrix. So, M is number of lines in the system that is always more than number of buses or equal to that and here n minus 1, so order here it is not a square, so you can at involve it, so you can and get the delta.

(Refer Slide Time: 19:42)



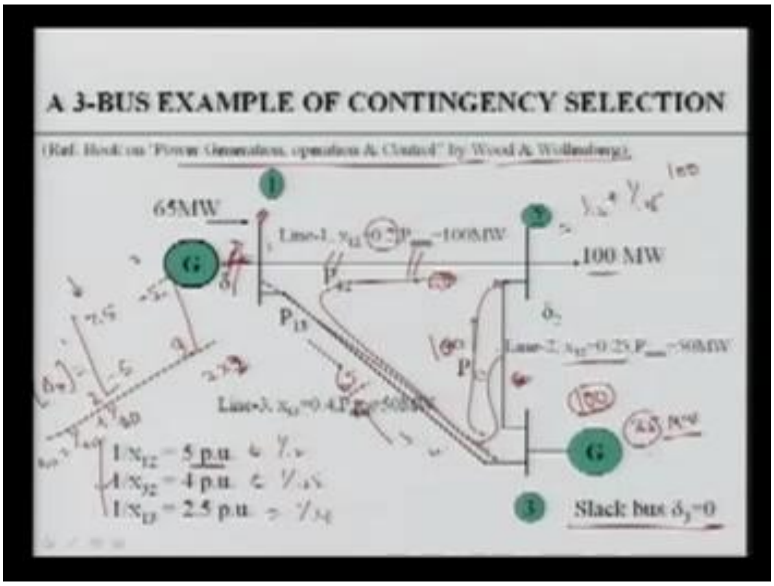
Now, we can use the some other expressions for calculating this, so here from this expression you know the injection at any bus that we can write the summation of this E ij and this is the all the lines that are connected with this bus I. For example, if you are this is the bus i here if you are having several lines here, so what will happen? This is your j, it may be your k it may be your l, so it is a summation of all the line that is here P ij, P ik P lk and then we can add together. So, here this from this expression I can write this PI at individual bus it is the summation of all the power flow that is one upon your x ij.

Here, delta I minus delta j here you are basically we are going to delta one to all this the connected lines means your j k what are the buses that it is, but it is not I and then we are keep on idle, so what we can do from this? We can form a matrix that is your P vector that is a injection at every bus in the system that can be form like a matrix here and here we can write that delta vector here. So, that matrix here is known as your B x matrix, this B x matrix again will take one example.

Then, that will be cleared to you in that this B x is the diagonal and off diagonal terms that can be defined in this D x that is a diagonal term here I can say the B x ii will be your summation of all this elements here that are connected at the bus i. So, here I can go for the B x ij it is nothing but negative of your x ij means the element between i and j of diagonal here on packing. You know the diagonal terms are these are the diagonal terms and off diagonal terms are there. Then, we have the negative sign X ij, why which negative sign coming? You can negative with the j here negative with the k will be coming and then it will be there we will just solve one example then it will be more clear.

So, what we can do? This, we can have this matrix, now we can exclude the select bus. So, delta at that bus is assume to be 0, so B also we can ignore because the last etcetera. So, this matrix is nothing but your n minus 1 cross n minus 1 and that is a square matrix it is a non singular matrix as well. So, we can invert this, so we can get the delta here, so delta can be calculated by the power injections, we know the load at each process. We can form this X V very clearly during the outage is another thing. Then, we can calculate the delta and that delta is used here then we can calculate the power flow. So this is basically the solution of this, it is non iterative and hence it is a quite fast to see this examples first I will discuss that example lets us see here.

(Refer Slide Time: 22:37)



This is a three bus example that is we are using the DC power flow and these references are taken from the power generation operation and control by Wood and Wallenberg book. Now, we are having here your three bus system and in this case just we are assuming the bus three is your selection means here angle is 0 and the lines 1 2, 1 3 and 2 3 are connected. The impedance of the line that is we are only ignoring the rest and of assumptions of this load flow. Here X 2 3 is 0.25 per unit on 100 MPA base. Here we are taking the MPA base is 100, now here also we have the X. So, 1 upon X 2, it is 5 X 2 is 0.2 here. So, 1 upon this means this is equal to 1.2, we are getting this.

Here, it is a 3 2, you can 3 2 its 0.25, so it is 1 upon 0.25 and here 0.25 means 0.4, so one upon 0.4, we are getting these values. Now, we have to form the matrix B first that is B x matrix we are going to form. Now, this B x matrix will be 2 cross 2 matrix, because this is your three bus system, so n minus 1 cross n minus 1 matrix are there. So, it will be your 2 cross 2, this 3 minus 1 is 2. So, 2 cross 2, sorry it is 2 cross 2 matrix will be there. Now, these are you are here and here, they are the diagonal element and as I said the diagonal elements are calculated the two. It is a summation of let us suppose I am talking about the bus 1 here at bus 1 it is the summation of all the lines that are going from that one.

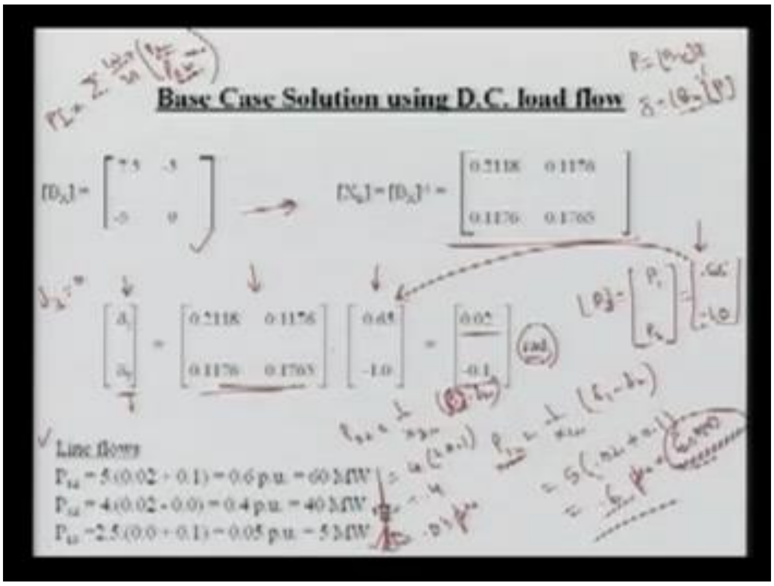
So, 1 over X means here this I can say B 1 1 will be your 1 over X 1 2 plus your 1 over 1 X 1 3 means admittances the some of the admittances that is the line which are connected as bus 1. So, here one upon 0.2, 1 upon 0.4, so how much this means? This will be added 1 2 and this will be added, so it will be your 7.5, now this diagonal of this first elements means we are talking 1 1. I am going for this is your 1 2 here 1 2, so this your 1, 1, 1, 2 is I as said it is the negative of first write negative of the admittance between 1 and 2 1 and 2 admittance is 5 because your 1 upon X 2 is 5, so it is 5.

Similarly, here 2 and 3 we are talking basically here we are talking one sorry here three is your select. So, we are talking the value between 1 and 2 again here, so it will be similar to with the negative 0.5, 1 and 2 here means 2, 1 this is your 2. So, 2, 1 we are calculating of course one way you can check this matrix is symmetric, so, this is a 5. So, it is a 5 between now here the value we are going to calculate that is a diagonal element and that diagonal element is nothing but here it is the summation of admittances of those lines. Those are connected at bus 2 to here 1 upon 0.2 means here 1 upon 0.2 plus 1 upon 0.25.

So, this will be equal to your 4 and here 4 and here 4 and 5, it will be a matrix, so this is your B x matrix. So, it is very easy to form without any doubt you can creative and your larger system is there. So suppose your several lines are there, so keep on going for this one, so you have you have to see your diagonal element of any for bus 1, and then it will be the sum of all the admittances of the line connected at bus 1. For 2, it is some of the admittances of the line connected at the 2.

Now, this diagonal elements if you are talking about 1 and 2, then we have to take the admittances negative of the admittances between bus 1, a 2 that is I have written here and similarly you can keep on going to for this. So, this is your B x matrix which I have seen I have written also here you can see what it is.

(Refer Slide Time 27:14)



Now, you have to invert this as I said this relation is showing your P is equal to B x delta, but we want delta. So, that we can have the B x inverse and then we can multiply P vector. So, the inverse if you are going to take and you can very easily you can take the inverse here you can take this changes this one change the sign here. Then, divided by determinant of this value you can get this it is very easy to cross two matches inverse. So, this will be now we have to calculate the P vector, P vector is nothing but the power injection at 1 and the power injection at 2. Again, you must always be very careful it is in for unit because admittances we have taken in the per unit.

So, the real power flow also we have to take per unit, also you have to very careful if the power at any bus is here the injected then this value is positive. If we are taking the bus power at that one, then it is taken as negative means load are treated as a negative injection and generation. Of course, they are injecting power into the system those are taken as your positive injection. Now, in this figure here you can see at bus one it is a 65 megawatt is injected, so 65 divided by 100 because we have to convert in the per unit this is the power divided by base. So, 0.65 here, 0.65 will be your value for 1, so it is 0.65.

Now, for this one, for the 2 it is a load and this load is 100, so 100 divided by 100 is 1 and since it is load, so it is a negative value we have to take and then it will be your minus 1.0. So, using this B x inverse use the P means I have just written here for calculating the delta 1 and 2 because delta 3 is 0. Already, we have assume it is a slight bus, this is the B x inverse XB here we are putting the P that is I have taken here you can say very easily and then you can multiply it. After multiplication, you will get the delta one is your 0.02 and delta 2 is minus 0.1 radial.

So, these angles are in radian we are getting always it is not, so now if you will get confused in the conversion of the per unit quantities treating this P values if you are taking actual value then everything its wrong. So, this is in per unit this matrix is on the per unit impedances of the line this is in radian. So, we are getting already radically, now we can calculate with help of lambda 1, delta 1, and delta 2, we can calculate the P 1 2. Now, the P 1 2 that is we can define as I said here this P 1 2 is nothing but 1 over X 1 2 here delta 1 minus delta 2.

So, we can 1 upon X 2 it is nothing but your 5 already we are calculate the 5 delta one is 0.02 minus 1.1. So, it is a plus 0.1 and then you are going to get here 0.6 per unit means it is your 16 megawatt. Similarly, you can calculate your P 3 2 basically 3 2 is we can say again 1 upon X 3 2 here delta 3 minus delta 2. So, this is the direction, which is showing from 1 to 2, so this value is 60 megawatt that is flowing from 1 to 2 in this diagram what is this? So, this is 1 2, it is your 60 megawatt showing from 1 to 2 if you are going to here already we have mark the sign. So, 3 2 just we are calculate here if it is a negative value is coming means your direction is reverse

So, here we can calculate P three two by putting these value three here delta three is 0, already we have assume because it is a slight bus. So, 1 upon here X 3 2 X 3 2 is 4 1, upon this we can see here value I have written and then I can just put here four into minus delta 2 and here it is a minus it is plus and then we are getting 0.4 means it is your 40 megawatt. Similarly, we can calculate the 1 3 and we will get point here we will get

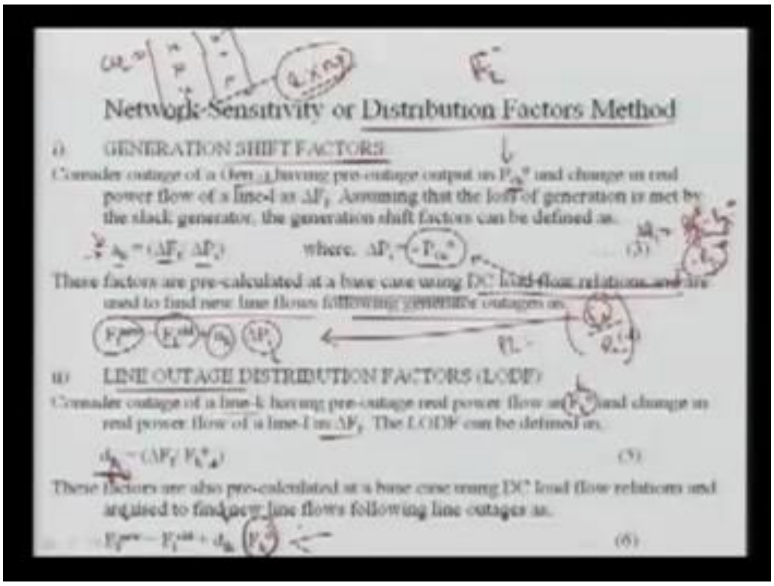
0.05 per unit or it is your 5? So, now you can see here in this direction is 65 here, it is 60 here pipe is flowing here and the 60 is going and this value is going to be 40 here.

So, this 65 is just divided into 60 in this line 1 to 2 pipe is coming from 1 to 3 and this here 40 is going means this generator is generating how much is 35 why? Because pipe is coming here, so remaining 35 is mid, the select bus select bus generation and then this is the generation of this megawatt. So, this is the application of you can say it is a non iterative, this load flow we can calculate the power flow variously by simply solving one iteration. You can say here what we are doing we are taking only one iteration for one contingency.

How were if you are going for the load flow? So, every time we have to this is four iteration of five iteration quantities are there then you have to iterate accordingly. So, this is we can calculate and this is one way that we can obtain this line power flows and again we can go. Another, I just I want to mention here in this power flow definition that is I use here PI for line flow I am talking it is a summation of here, I said omega m upon 2 n. Here the P lm upon P lm maximum, you can use here the P lm and P lm maximum value in per unit are in megawatt, but the proper case should be taken that if you are taking the line power flow in the actual value that is a megawatt or kilowatt, then you have to use this rating also in the same unit.

So, if there be no change if you are using per unit you can use both in per unit and when you can solve it without any problem. So, you can see how fast and it is called DC because we have no doubt it we are only taking this P deltas. These deltas giving directly power flow although these power flows are not so accurate because we have know the losses we have know the voltage, but for your ranking that is even though giving very good result for the real power flow security.

(Refer Slide Time 34:23)



Another method just I am going to discuss you is the network sensitivity are the distribution factor methods means here the distribution factors methods are very popular use for the contingency selection. In this, the basic principle basic motives behind this the generation ship we are having the different factors. The factors corresponding to the generator outers, so it is called generation shift factors and the factors corresponding to your line outages.

Then, it is called the line outage distribution factors and then those factors are stored those are calculated at the base case, what is the base case? It means actual operating system without any outage. So, we can calculate at the base case loading and then we can use the same factors with for the different loading again that loading should not be very high. Its loading is very high that factors in wrong or inaccurate results. So, first let us consider the outage of a generation means outage of generator I having a pre outage means it was generating the P g i naught value means it was given power to that and then it was outage.

After this outage, then we want to see what is the change in loading of your transition line earlier the power flow we are knowing that the line that is in the power flow in all the lines it was nothing but your this power flow I can say F, now here I defined. So, this was your not value when it was generating this once this generator was out we are keeping the load constant, what will happen?

That outage generator will supply power, means this power will be supplied sorry by other generator normally, let us take it us select power generation. So, there will be reducing of the power flow in the transition line to see what will happen? Just I will explain you, if we will take this example here, even though for this system let us suppose this generator is outage this generator is tripped what will happen? If the load is this is a constant, so this generator will be instead of this it will be generating 100 megawatt and if it is generating 100 megawatt, the power in this will be read.

The power will be totally different here, the power will be maybe the power, just we can calculate I am not sure how much value, but this 100 will be shared one will be flowing like this another will be flowing like this and then it will be this. So, since it is a having more impedance the compare to this here you can say 0.6 here 0.5. So, the most of the power will be flowing here compare to this. So, normally here it will be a 60 here, it will be a 140 megawatt unit. So, this is what happens now, the power is redo, there power is the different. So, here the same way just I am explaining that is one this was the earlier it was generating after outage of this there will be reducing of the power flows in the lines and then we can see how much change from the previous one.

So, the factors are defined by for line L for any particular line because we are having m number in the line. So, this factor is A l i is corresponding to outage of your I h generator is defined the change in the power flow in the L th line divided by the change in power at ith generation. In this case, what is happening, changes is your negative of this earlier it was injection final value is 0. So, what we can say final this delta PI is your P gi final minus P gi not means original old value. So, this value is 0 completely, so we are getting minus P gi not and you can say this value is this,

So, this is the element, so we can have the stores of all the lines for ith unit, so what we can do let us suppose this is a vector just we are considering this L this it is equal to you are here all the lines and that is outage of any particular highest generation. So, here for I here it is your all the values are stored here means line 1 2 3 4, all the lines for ith. Similarly, if you are having another generator, so we are going to another here column for this so that we can have here L cross number of real power outage matrix. So, all these factors are calculated and stored in the computer and they are calculated on the base scale means we are assuming the same loading.

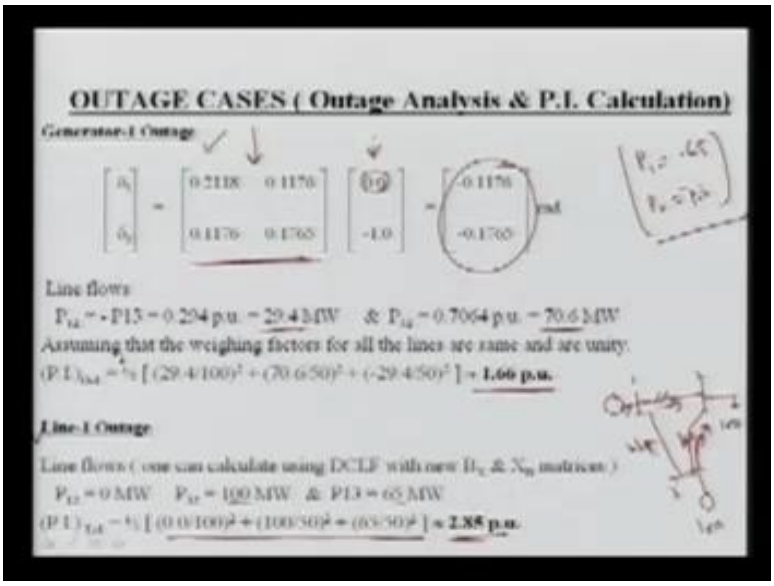
The loading can be changed once we are calculating you are going to use that one at that time the system loading will be different, but it is assumed that this will be giving although some inaccurate. This will be ranking the transition lines outage cases severity cases in the some reasonable accuracy. So, here as I said we can calculate these structure at the base case and we can stored and we can use now we can say how we can use. These factors are P calculated at this case using the DC load flow relations and are used to find the new line flows following the generators outage means here now the factors you are having.

Now, this value is outage with the some value here change in the PI you know this how much it is going to out one unit two unit you can utilize this. Then, with this you can ith then you can get new line power flows as then that can be used because we required then PI we require the Fl here divided by maximum value that is known. So, this value we know and we can calculate from here, similarly let us consider a line k which is out and it was flowing F k naught and early case and when it is going to out what will happen there will be change in other lines what could be the value.

So, this was the k of lines, so we are calculating power change in other line, so in that line, if it is out, it is 0 of course. So, we are going to calculate the change in power flow for example, let us suppose this line is out and this generator is active, what will happen? This whole 65 will be flowing here and then it will be going 65 plus here it will be 100, here it will be going this line is out. So, this line power flow the final value is 0, so what happens? Now, it is from initial it was 5 now it is 65, it has increased. So, how much change it is a 60 final minus initial, similarly we can calculate.

So, we can define the line outage distribution factor means L denotes the line where it is flowing K is due to the outage. So, we can change in L divided by FK not here and that is defined here. Similarly, we can again calculate these values and then we can use these factors knowing these factors with any change in the line power flow. We can get the new power flow and then we can calculate the PI value and the performance in that very clearly.

(Refer Slide Time: 41:39)



So, let us see the some using this distribution load flow, we can see some outage cases and using PI how we can reformulate. We can recalculate and we can rank them contingency for again three bus systems which I showed you here mean I am talking about this system again. So, here for this system impact, again you can consider the base case, now I am going to consider this outage of one line here we are outage of generators first means once generator is going to out. What will happen? This value becomes 0 because the P if you are remember I form this P 1, P 2 and the P n, earlier it was 0.65, now it is outage means 0.

So, we put 0 and now we are calculating the delta 1 and delta 2 we are getting this value. With this, what we can calculate? Now, we can calculate what will be the power this P one two lines flow, now after outage of these generator, we are calculating you can see in this diagram. Again, I can draw here, even this it is here and this is your load and we are having another generator here and this is generating power here and this is here. Now, this is out, what will happen? This is generating now 100 megawatt powers completely this is your 100 megawatt whole the power will be flowing here to here.

So, this is 1, 2 and here 3 means the power which is flowing from 3 to 1 will be equal to 1 to 2 or it is 1 to 3 will be negative of 1, 2 and that is we have written 1, 2 will be minus 1, 3.

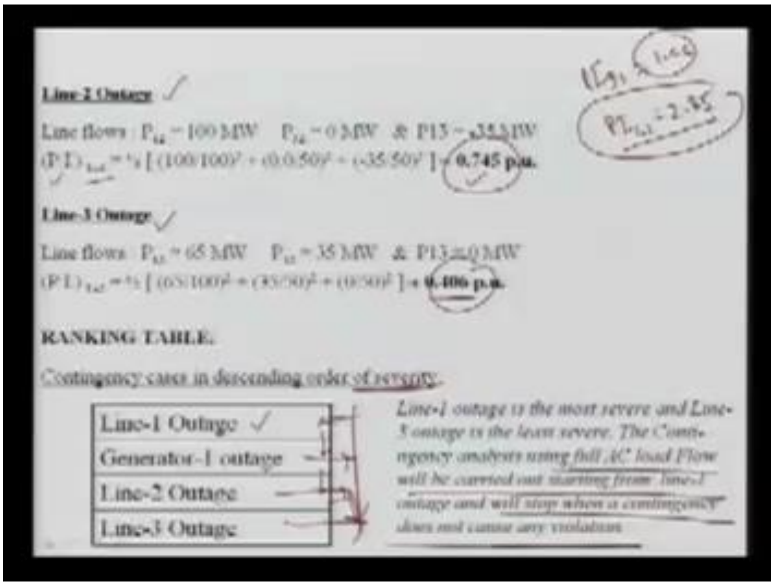
This direction is because the power will be flowing here and that we can calculate from this expression it is a 29.4 megawatt. Similarly, the remaining power of 100 will be going 70.6 here. So, this is rerouted and now what we can form? The PI again with the same real power flow performance index, we are using and we are using this Pm value is unity. We are using exponent n is equal to n means square term, so we are dividing here 1 number 2. Now, we are assuming the line rating already you can see the line ratings I have already explained here the line ratings are this line is 100 megawatt.

This line is having 50, this megawatt is this line having 50 means it is 1 per unit 0.5 per unit 0.5 per unit way. So, using this here it is divided by you can use the megawatt value or you can use per unit of course no difference. So, this divided by this square plus this divided by 50, this again minus value just we are taking square 50 and then you are getting 1.66 per unit. Now, let us say for the line one outage line one outage means this line is tripped, now this whole power will be flowing here 100 megawatt because the power will not going this will be coming 65 here and the 100 megawatt here.

So, again this means we can see this line will be 100, this will be 65 in this case even though there is no need to go for the delta calculations. Sometimes, you can see for this is very simple system, but if you have a more interconnected system, you have to again from this matrix this matrix is revised because this matrix is dependent on you are the line topology. So, if line is going to be change line, outage is going, then this matrix will be also change in the previous case this network was intact only generation was outage only we change here.

In this case, line outage here we are this value is same means we are going to take 0.65 here, we are getting point 1.0 with the negative. So, it is not going to change, now this is going to change. So, we can again from that B x matrix then we can go for the inversion and then we will find that is we are getting this power and then you can form this PI value. You will get again where the similar 1, 100 because 0 power and finally you are getting 2.85 per unit for this case for line one.

(Refer Slide Time 45:40)



Similarly, if you are going for the line two outage if you will calculate in long two outage you will find this type of concept because what is happening in this we can see line two outage means we are going to outline this 1 1 3. I think here 1 3 is going to outline, this line is going to out, so what happens? This 65 will be flowing here and the remaining 35 will be flowing here. So, in this case also, there is no need to go for the forming again the V max, we can simply see here using the simple Kirchhoff law. Then, using that we can just calculate and will find here the other value 0.745, again we are using the PI for outage this.

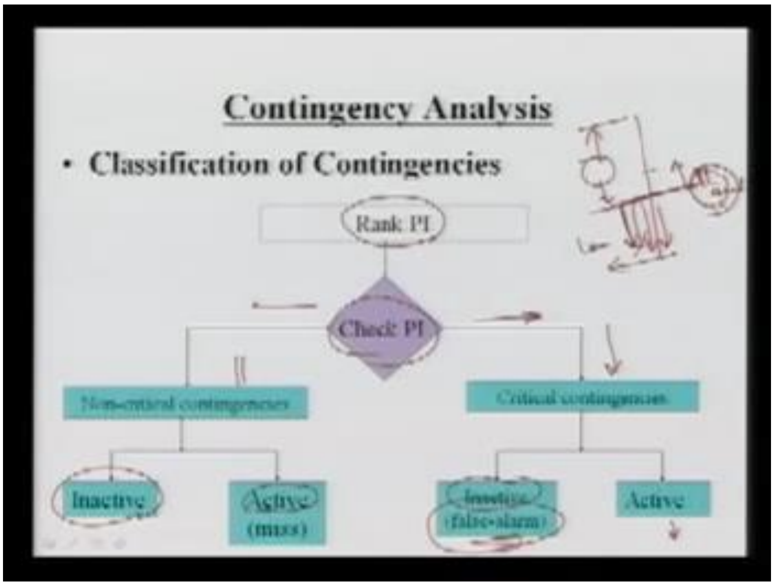
Similarly, for line outage three, we can form and will see this value is this, now you can see for the line this line outage PI this L 1, it was your this value you can see it was 2.85 and this PI for g 1 outage it was 1.66. Now, you can say which one is severe so that value which is giving highest that is more severe. So, this is your first severity, just we have rink the contingency cases in the descending order of severity line one outage is most severe because this value with the highest followed by generator one outage. This value is followed by line 2 outage this value, then followed by line 3 outage this value.

So, this is giving your relative order of severity for your outages and that PI giving the real power flow performance in this, and that can be used for your real power security analysis.

So, in this, contingency selection is just we have rank all these four contingencies in this system. So, line 1 outage is the most severe and line 3 outage is the least severe, the contingency analysis using the full load AC power flow will be carried out a starting from the line one here outage and will you stop when a contingency does not cause any violation. So, now we can run the lower flow, we can see whether this line flow limit or violating or the voltage limits are violating. Then, we can go for next, then we can go for next and then we will stop when there is a no violation or even we can go for one or two more because there is some error in the calculation here and then we can a stop.

So, the online full load AC load flow which used for the only the critical contingency those are rank in these severities. Now, let us see in the contingency selection algorithm what happens you have ranked up to what level you have to go that is basically the rank the PI based on the PI.

(Refer Slide Time: 48:22)



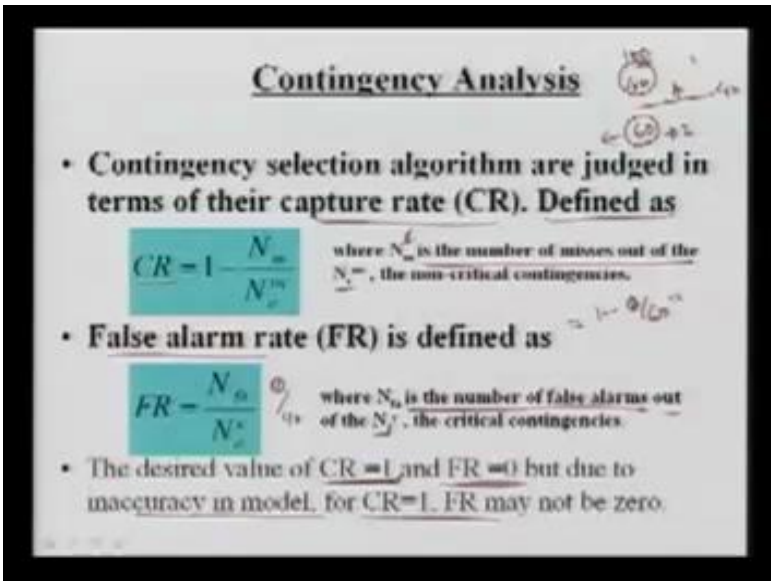
So, you have to have some cut off marks somewhere which PI just you have to go for. So, if you are going for the PI checking, the PI which is means at what level this is your ranking through somewhere based on the ranking, you have just taken this PI as a cut off mark. In that cut off mark, there is a possibility if this value is higher just you are check this PI cut off. So, the PI which is more than this cut off, that will be giving your critical contingencies and then the PI, which is less than that we can say these are non critical.

We want to have some cut of PI value so that you can say if it is more than that system critical and if it is less than that then those contingencies not critical. In that critical contingency here, those are ranked here the highest severity this is a cutoff this is a least in that critical contingency there is a possibility that some contingencies are of course that are active. That means they are critical, but some contingency maybe not critical because we are just making PI based on some approximate solution, so what is happening?

So, we can get some inactive contingencies, some least without critical contingency and we are getting some false which means it is saying that this line is critical with the help of this PI, but actually it is not. So, it is a false LR that is giving, so this PI is a cut off we have to decide and again that based on the fast here the fast LR we can say this method is accurate or not. Now, here just you can compare this cutoff and you said this between less than PI system is not critical, means not critical contingencies are there below this line, but there may be some inactive contingencies below this. Most of most of them will be non critical, but some contingency maybe critical.

Some violation some a small error will be there and that called is the misses so this side we are getting some missing this side we are getting some false along. Normally, we have to define what is your false along rate what is your capture rate and that is defined that this here in this formulation.

(Refer Slide Time 50:43)



So, the contingency selection algorithms are just in terms of their capture rate that is the CR rate and it is a defined as CR is 1 minus Nm divided by Nc n. here, N c means here this is saying NM is the number of misses out of this non critical contingencies as I said here you are having hundred contingencies. Let us suppose 100 contingencies and you have made some cut off of 14 means PI which is more than that then here your 40s or your critical and 60 or you are saying is a critical factor. So, in this non critical contingencies, how many are the misses? How much are the critical contingencies that given to N m?

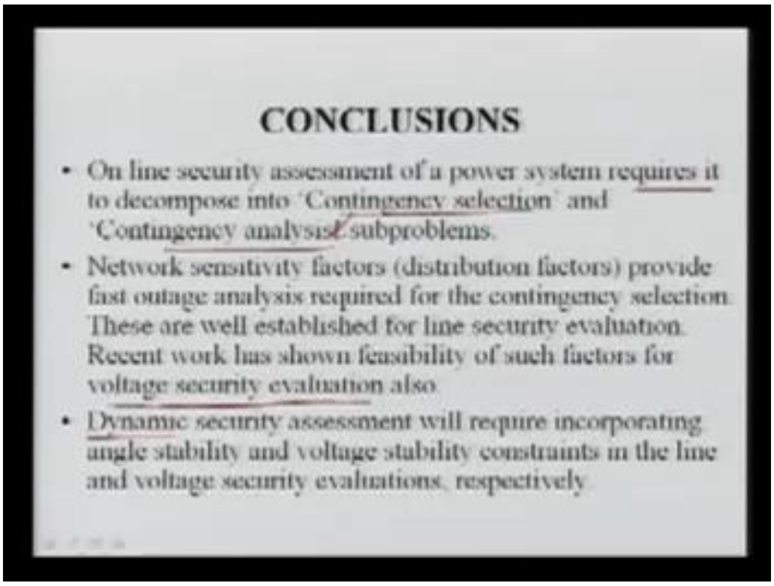
Let us suppose one two contingency here is your critical it is said using your PI ranking it is saying it is not critical, but it is actually a critical. So, it is a 2 here N m is 2 here is a 60, so we can say 1 minus 2 upon 60 and that it is basically you can calculate what is your capture rate. Normally, what we want we want this miss rate is 0, so the capture is it is unity, so the standard practice here always we want the capture rate is unity and the false LR rate should be 0, what is the false LR rate? False LR rate is defined as FR is equal to N f a and that is defined is N f a is the number of false alarms out of N c c means number of critical contingencies, here in this case 40.

So, if there is suppose one false alarms is 1, so it is 1 upon your 40 is your false alarms rate, V 1 this value should be 0. So, it is a 0 means there should not be any false alarms. So, our method we substitute means always due to the inaccuracy in the model it is a F CR is equal to 1 FR is equal to 0 is not possible. So, we have to see the methods various methods are there, so these are the basically false along rate and the capture rates those defined based on your the PI cut off value. So, always in the contingency selection we have to go for monitoring what is your capture rate what is your false alarms rate and based on that we can say this method is given very accurate result.

So, just we saw the various methods for the contingency selections already I defined the contingency definition. Now, once we have as I said we have rank then we can go for the contingency evaluation where we actually check using your aniline AC load flow that whether there is any violation in the operating constraints are not and then we can perform contingency relation. That consists of your complete contingency analysis part, in that contingency analysis part means this contingency definition contingency selection, then contingency evaluation.

That contingency analysis is next for either real power or reactive power voltage security analysis, but it is combined, we have to go for the real power security analysis as well as your voltage security analysis. So, now I can just conclude and then will give some more highlights that what are the next that we are going to higher in this contingency analysis.

(Refer Slide Time 54:07)



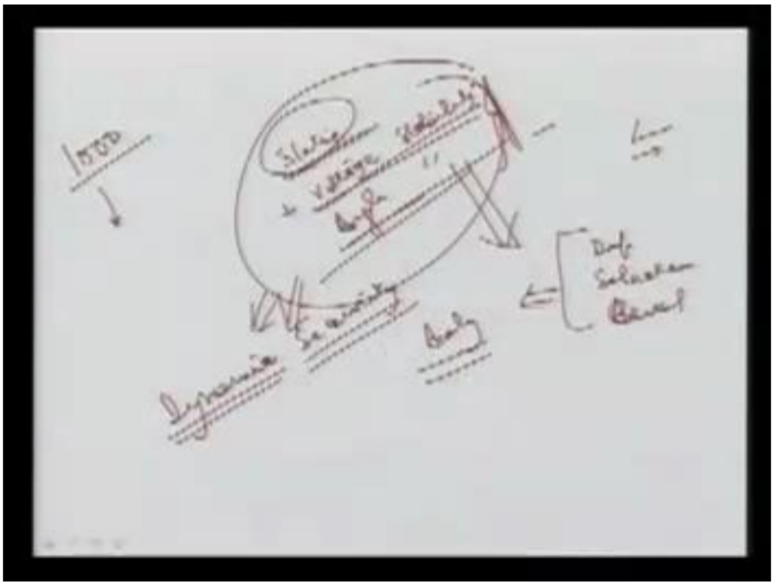
So, online security assessment of a power system requires it to decompose in the contingency selection and the contingency analysis sub problems were again. This contingency selection and contingency analysis problem can be combined together if you are having very fast computational algorithm along with you are having fast computational platform. Then, you can must this two and you can go for all this contingency selection, means contingency definition list, but we have some limitation and therefore, we go for contingency selection first, then we go for contingency analysis.

Network sensitivity factors is the distribution factors provides fast outage analysis required for the contingency selection. I listed several contingency selection algorithms both including ranking and the methods. So, this distribution factors are very fast; however, they are not used for high difference from the base case condition. If your base condition is change to much then these distribution factor will not give the accurate result, but here they are fast because this one inverse is required for all this analysis. These are well established for the line security evaluation resent work has shown feasibility of such factors for the voltage security as well.

Earlier, this distribution factors were very widely used for the line security analysis or 100 megawatt security evaluation, but now it is they are also used for the voltage security evaluation. I did not discuss how this distribution factors methods are basically thus we are going for the voltage security evaluation because the there is so many distribution factors methods are proposed in the literature. So, it is not possible to that, but you should know that these distribution factors are very widely used for both line as well as your voltage security evaluation purposes. Nowadays, another recent requirement that we should go for is the static security, so far, I was discussing that the static security analysis.

Now, the people are talking about the dynamic security assessment as well which will require the incorporating the angle stability and the voltage stability constraints in the line and voltage security evaluation respectively. What is that what we are going to do here in this dynamic security? We are doing nothing.

(Refer Slide Time: 56:42)



Here, the same this static security analysis plus we are adding some that is your voltage and your angle stability here problems means we are using some dynamics of the system, means here voltage and angle stability added. Then, if you are going for this then it is called your dynamic security, so this is very demand and it is very challenging here we required very fast computation you know the solving the dynamics of the power system requires lot of time.

So, we have to take care very carefully means we have to use very fast methods for this dynamic security as well, but so for although so many researches and papers are available for the dynamic security as well, but here this has a. So, many problem again to solve the power system dynamics along with static security limits and operating constraints. The system if you are operating the dynamically secure system it is very expensive, means we have to see that is one line is out now the fault duration at the dynamics again then you can see whether your system is stable or not.

So, in this module here only I took the two lectures already it is of four lectures, but the some of the part already I explained in the module first where about the security monitoring importance security optimization etcetera. Here, in this contingency analysis just we saw first we saw the various operation and control hierarchy then we also went for this some restorative emergency control. Then, in contingency analysis I discuss completely your contingency evaluation contingency selection and the your contingency analysis, means evaluation you can say to this analysis part is your definition selection and then it is your evaluation.

So, these three parts basically combined your security analysis that is analysis or sometimes it is called contingency analysis or security analysis both are the same term. If we are going to include the power system dynamics along with the voltage stability limits and the angle stability limits along with your static security limits then we can achieve here the dynamic security. That is again can be a further resource topics lot of resource already people are doing, but still we require very fast and accurate method for this because in the power system. Now, if you are including with as I said there are thousand conditions is more than that 1,000 contingency are existing.

Now, you are going to include the contingency with the critical clearing time how much it is which type of false you can using the how many false are there in one line. So, it is again number of whole set is enormous and then we are going for this again contingency selection and analysis for dynamic security it is very hot tasks. So, we require very fast, we require some sort of here fast calculation of this and so that you can go for the dynamic security analysis or assessment as well.