Computer Aided Power System Analysis

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Lecture - 32
Introduction to Contingency Analysis

Hello, welcome to this lecture on the course of computer aided power system analysis. From today onwards we would be starting the discussion on the topic of contingency analysis. Now before going into the detail of this contingency analysis let us first try to understand what a contingency means. So we are talking about contingency analysis.

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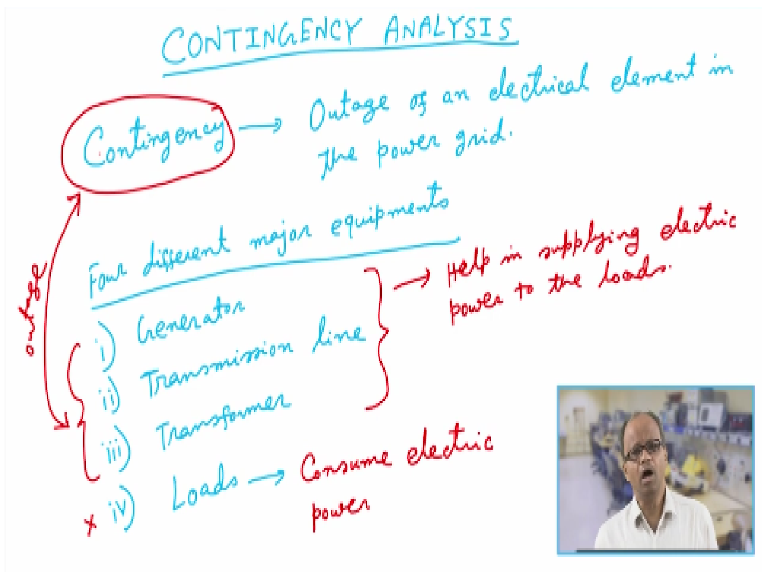

So we are discussing contingency analysis. Now, before we go into the detail of contingency analysis we need to first understand what contingency means. Contingency basically means in the context of our system. Of course we are talking about here in the context of our system what is meant by contingency, this term contingency and which is meant by actually outage of an electrical element in the power grid.

So this outage of an electrical element in the power grid. Now what is meant by outage? Outage means that this particular element is going out of operation. Now here what are the elements we are actually talking about. Now, essentially in any power grid there are more or less basically there are 4 different types of major equipment. So there are 4 different major equipments.

And these 4 major equipments are one is generator two is transmission line three is transformer and four is loads. Now out of this 4 different major equipments, so this is basically consume electric power and these 3 they actually help in supplying electric power to the loads, right? Now when we are talking about this term contingency, this contingency is actually means that outage of any electrical element which are used to supply electric power.

So then therefore when u are talking about contingency, outage of loads that is basically whether any load has got connected or disconnected or not that is not considered to be a contingency. So when we are talking about contingency it is basically the outage of an electrical element which helps to supply electric power to the loads. So essentially when u are talking about contingency we are talking about contingency of these 3 elements only.

So contingency is actually outage of these 3 elements. So this is outage of these 3 elements. Now for the purpose of analysis, transformer and transmission line are taken actually equivalent, for the purpose of analysis transformer and transmission line are taken to be equivalent. So why it is so?

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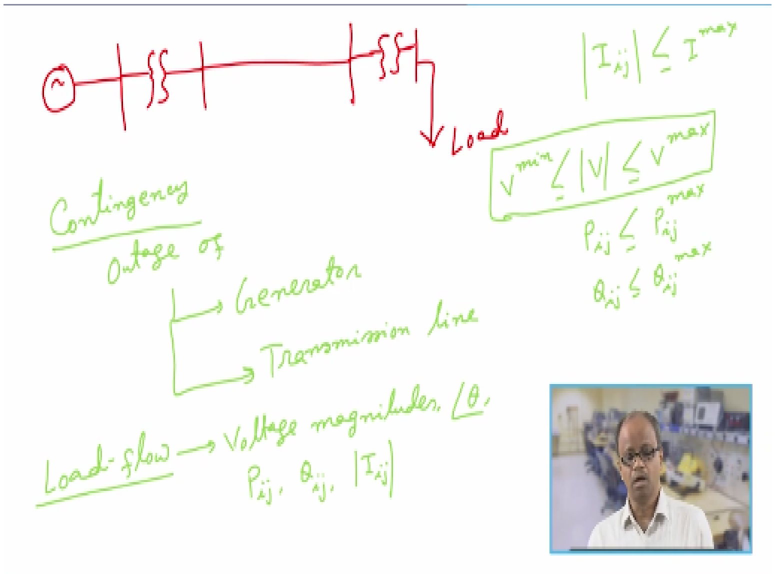

Because if you see so if we have just looked into a very simple power system grids so what I have got that I have got a generator say and then I have got a transformer and then I have got some transmission line. Then I have got another transformer and then I have some loads, right? So this is load. So as we have just now discussed this does not come under the (()) (05:44) of contingency analysis.

Only this generator, transmission line and this transformer come under the (()) (05:50) of contingency analysis. But as far as this transmission line and transformer are concerned they are actually sort of connected in series with each other. So then therefore for the purpose of analysis we only talk about this outage of either generator or a transformer and we also consider the outage of a transformer also equivalent to an outage of an transmission line.

So then therefore whenever you are talking about contingency we are essentially talking about, contingency, we are essentially talking about outage of generator and transmission line. We note here that outage of transformer is also taken to be equivalent to the outage of a transmission line.

So then therefore this transmission line outage can be either basically the outage of a physical transmission line or it can be also outage of a transformer but for the purpose of analysis you would be simply talking about that outage of a line, right? That line could be physically a transmission line or could be a transformer. So contingency means basically outage of generator and transmission line.

Now the question is that why this contingency analysis is important and why should we really talk about it. Now to answer that first let us recollect that what we do in the case of load flow? In the case of load flow what we do? We simply compute the current operating point that is basically voltage magnitudes, we compute voltage magnitudes, angles theta. Then power through a line, real and reactive power through a line.

Magnitude of current, anything and everything we simply compute; anything and everything. And we assume that all these values are actually within their certain bound. For example although we do not put certain bound on the angles but we have already seen or rather we have already discussed that for the purpose of stability this angle should not be more than basically this I mean difference of this angle should not be more than 30 to 35 degree.

But even that is beside the point. But the more important is that we say that any voltage magnitude V should be V min V max and V min within some V max and V min actually for the purpose of the practical operation of any power system when we do this load flow analysis we only compute V, theta, P ij, Q ij, I ij. We really do not check whether this voltages are within their respective limits or not.

Similarly, P ij also should be less than some P ij max. Q ij also should be less than some Q ij max and I ij also should be I ij is nothing but the magnitude of I max. So they actually should be within this limits. And these limits are imposed, these limits is imposed to enable the system to operate with a healthy voltage profile such that all this loads connected in the system they do not suffer major setback.

Because we already know that if our voltage profile in the system either goes up or goes down by a large extent so then all the loads connected to our system will face lot of problem because all this loads or rather this electrical appliances whatever we connect to our system they are only meant for certain rated value plus minus some tolerance.

So then therefore if this voltage impressed across them even goes beyond those tolerated value so then obviously they will cause damage and of course this value of current magnitude real power flow as well as the reactive power flow if they do go beyond their maximum limit so in that case this line would simply burn. So then therefore for all practical purpose these values should be within this respective limits.

But when we calculate load flow, when we perform load flow we only compute these values. We do not really crosscheck that whether these quantities are really within their limits or not. Usually we assume that these values are within their limit. Generally because we always try to operate our power system at some healthy operating point and when we talk about healthy operating point we mean that well all these parameters are within their respective limits.

But then, unfortunately there can be some outage of any element. For example if we take a very simple system.

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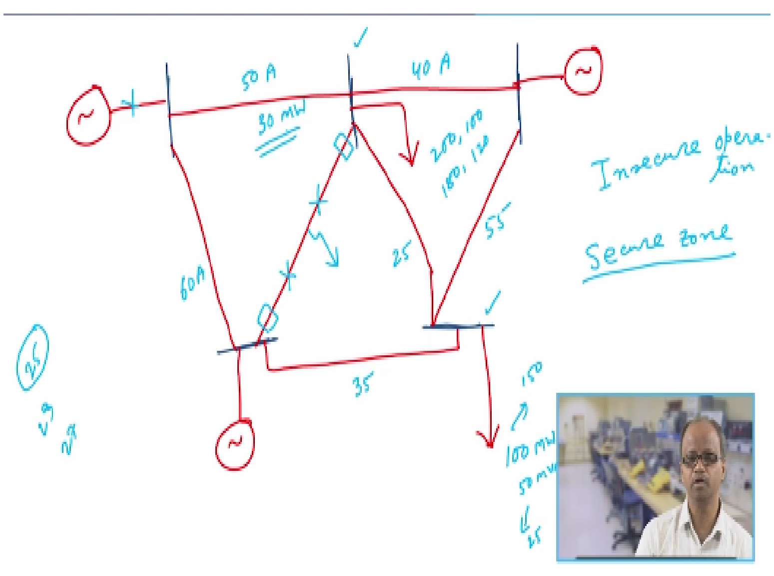

Now let us take some, a very simple system say a 5 bus system. I am just taking a 5 bus system. So these are buses. This blue lines are buses, blue lines are buses. And this red lines are you know transmission line. Remember please note that this transmission lines can also be transformers. That is beside the point, let us say this. Something like this. They are all interconnected, something interconnected.

And we have let us say one generator here and let us say we have got one generator here and let us say one we have got another generator here. And let us say these are, here we have got loads and let us say we have also got loads. We can also have loads at this point and this point. That is beside the point. So now what I have got? That we have got a 5 bus system, bus 1, 2, 3, 4, 5 and some lines, some loads connected.

And let us say that at the initial operating point that when we are connecting and we are doing this load flow analysis everything is in order. That is none of the parameters is beyond their safe operating limit. But now suppose, for due to some reason for example there is a fault. Now we know from our basic understanding of the protection system which we imply in our grid.

We know that each and every line is basically installed with some relays. In fact all this generators are also installed with some relays. So then therefore in case there is some fault or some abrupt operating condition so then these relays will simply trip this particular element to help the system to maintain, to basically to help the system to operate.

That is to basically protect this particular element from let us say burning down. Now suppose in this line, suppose for example in this line just in this line suppose there is a fault somewhere. So then therefore now there are relays at these two sides. These are the relays. So then if there is a fault at this line at some point. So let us hope and let us say that this relays they have done their job properly.

So as a result this line is gone. So this line is simply gone. Now when this line is gone, so then therefore what will happen? The same load will have to be supplied by this generators. So then therefore there will be redistribution of power flow as well as the current flow over all these lines, right? So then therefore this line current, this, this this, this, all this remaining line currents will have some new values of real and reactive power flow as well as the current flow.

So then what will happen in this? Now because there will be new values of real and reactive power flow as well as the current flow over all the lines, so then therefore these bus voltages will also vary. Even if we do assume that these bus voltages, that this bus voltage, this bus voltage, and this bus voltage even if we do assume that they are still being able to maintain at their respective specified quantities by this generator action.

But even then because there is now redistribution of power flow over the lines, this bus voltage and this bus voltage they will be certainly changed. And also because this line is gone, so then therefore some line, some of the remaining lines in the system will have definitely some higher values of current or rather real power flow.

So then therefore there is a change that this bus voltage or this bus voltage may go beyond their limits or some line through some line the current flow or the power flow both real and reactive, either real or reactive or both they may also go out of their limit. So if any of this quantities they go out of their limit we say that the system enters into an insecure operation.

We call insecure operation. Insecure operation means where there is the violation of some electrical quantities either voltage or current magnitude or real power flow or reactive power flow. On the other hand if even in the face of this outage of this transmission line so then what even if in the face of outage of this transmission line if none of this voltages or current flow or power flow go out of their limits we say that the system is still operating in the secure zone.

Now similarly instead of let us say this line going out of order, suppose due to some reason this generator goes out of order. So then if this generator goes out of order so now entire power will now have to be supplied by this generator and this generator only. So then therefore again there would be some kind of redistribution of current flow as well as the real and reactive power flow over the lines.

So then therefore again these voltage magnitudes will change. And again also some current power flow or some real power flow or some reactive power flow they may go out of their limits. If they do, then in that case again there is a chance that the system is going into the insecure operation zone but if they do not then we say that this system is going, then we say that this system is operating into the secure zone of operation.

That means even if there is an outage of any element we still do not run any risk of my entire system going down. Obviously, for all practical purpose we wish to ensure or rather we wish that my system will operate in a secure zone even in the presence of outage of any single element.

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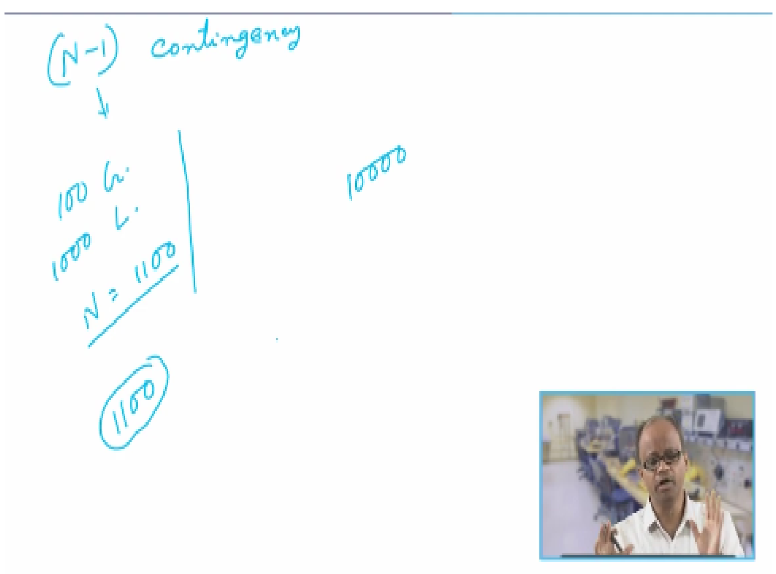

So this we call something called (N – 1) contingency, which we call (N – 1) contingency. (N – 1) contingency means that if there are let us say N elements comprising of generator and transmission lines and transformers. (N – 1) contingency is that outage of any element one at a time. So then what we wish to know that whether my system will operate in the secure zone even in the face of (N – 1) contingency or not.

That is the primary requirement. Now the point is, so then therefore now suppose in any system N can be any large. For example if suppose I have a system. Let us take a medium size system. Let us say that there are 100 generators or let us say there are and let us say 1000 lines. So then therefore N = 1100 suppose. So then therefore if we wish that my system should operate in the secure zone even in the face of (N – 1) contingency so then therefore what we have to do?

We have to check the system operation numerically, check the system operation or rather basically all this voltages, angles, real power flow, reactive power flow, current flow for all the lines, for each and every 1100 case, outage case so therefore if I have got total number of elements is 1100 so then therefore when we are talking about (N – 1) contingency we will consider that these 1100 elements will go out of order one by one.

So then therefore we will have a total of 1100 cases and then for each of this case we will calculate that what will happen to this voltage magnitudes, voltage angles, current magnitude, real power flow, reactive power flow through all the remaining elements if any one of this element is going out of order. Now the point is how do I calculate the voltage currents, real power flow, I mean real power flow, reactive power flow over the remaining elements in the face of an outage of a given element.

We can simply run the load flow. That is for example in this system if I consider that this particular line is out so then what we will do is we can simply run the load flow in which we will simply remove this line data from my data file and we will simply run the load flow and then we will find that what would be the voltage current, power etc. over all the lines and at all the buses. So this is simple.

So then therefore here in this case, if we wish to analyze the performance of the system for this each of this 1100 contingency case we can simply run 1100 load flow analysis. So then conceptually this is very simple. So there is really nothing much. It appears that there is really nothing much. So we have to simply run 1100 load flow which is pretty simple. Because if u have got a program which is running well there is no problem.

We can simply run them in a batch mode and this computer will simply give me the answer in some time. So conceptually this is very simple. Even if my system is very large, let us say there are 10000 lines and 1000 generators even then it does not matter. conceptually it does not matter. We will simply run this let us say 11000 load flows by the computer. It will run in the batch mode and it will simply give us the answer.

So conceptually it is very simple. But the catch is, the catch is that the operating point in the system changes quite periodically. For example if we look at the system and we are saying that here we have got this two loads just here. At this instant these two loads have let us say this loads has got 100 MW 50 MVR and let us say this load has got 200 MW 100 MVR. Suppose just after 5 minutes this is changing to 150 and this is changing to 25.

Suppose after 10 minutes, although this remains as 150, 25 this is changing to let us say 180 and let us say 120. So then therefore this loads they can keep on changing period to period, periodically. So then therefore whenever there is any change in the load the system is entering into new operating condition even in the absence of any contingency.

So then therefore when the system is entering a new operating condition so at that new operating condition also we have to crosscheck that whether the system would still remain secure in the face of (N – 1) contingency or not. So then therefore if in my system let us say there are 11000 elements. This is transmission line and this is generators and let us say so then therefore total 11000 elements, N = 11000.

And if I say that my system enters into new operating point every 5 minutes so then therefore every 5 minutes I have to run 11000 load flow analysis, right? Now this becomes computationally quite intensive. So every 5 minutes you have to run 11000 load flow analysis. Now if my computer is powerful enough probably I can still do it. But if my system is becoming larger and larger because nowadays the trend is that this electrical grids are getting more and more connected.

For example nowadays in India, India operates in only one single large grid. So then therefore there are thousands and thousands of buses and then thousands and thousands of lines. So then therefore if we have to crosscheck for (N – 1) contingency for let us say in the N grid so then and if we assume that every 5 minutes this system enters into new operating point.

So then therefore every 5 minutes we have to run thousands and thousands of load flow. So then therefore computational burden is quite extensive if we have to analyze this (N – 1) contingency every 5 minutes by the full AC load flow. So then computation burden becomes pretty high. So then therefore we need to look into something where I can probably reduce my computational burden.

Now here one very important concept we need to understand. The purpose of contingency analysis is to estimate or assess that whether my system will be in the secure zone or not in the face of any (N – 1) contingency. So then therefore for example if in this system, suppose for example that this line has got a limit of let us say 50 ampere.

That is what we are talking about maximum and let us say this line has got a limit of 40 ampere just as an example. This line has got a 60 ampere and this line has got let us say 35. I am just taking some example, 25 and let us say 55 suppose. These are the maximum. And then what we wish to assess that if this line goes out of operation at a particular operating point whether the current through them would be more.

Whether the current through it would be more than 50 ampere or not, whether the current through it would be more than 40 ampere or not, current through it would be more than 60 ampere or not and etc. etc. We are not really much interested to know the precise value, right? Till we can assess that whether I mean till if we can assess somehow that this new value of current would be less than 50 ampere whatever its value.

It could be 40, it could be 30, it could be 10, it could be 20, but till we can assess that this new value of current through this line would be less than 50 and similarly for all the other lines let us say till we can assess that this basically this new value of currents would be less than their corresponding maximum limits we say that the system is operating in a secure zone. We are not really interested into their actual value, right.

So then therefore here because we are not interested in any actual value so then therefore we can possibly make some assumptions to make our calculation procedure faster. Similarly, if we say that this line has got a let us say maximum real power carrying capacities let us say 30 MW suppose for example so then we only wish to assess that if whether in the case of outage of this line whether the new value of real power flow flowing through this line would be more than 30 MW or not.

If our new assessment is less than 30 MW we say that my system is operating in the secure zone irrespective of this actual value of this. So for example if this accurate value through this line in the face of outage of this line if the accurate value obtained after load flow is let us say 25 and if my assessment and let us say if somehow I can assess that this value would be around 25, not exactly 25, it could be 23, it could be 27 anything.

But it would be around 25 but still less than 30 as far as our concern is that basically we would be still saying that yes this system would be operating in a secured zone. So then we are not really interested in the precise value. We are only interested to know whether this new value of current is less than the maximum value or not.

Because we are not interested into the accurate new value of the real power flow, reactive power flow, the current flowing through the lines or the voltage magnitudes of the buses so then therefore it follows that it is not always necessary to perform these many number of load flows because AC load flow gives us the most accurate value but for the purpose of contingency analysis accurate value is not important.

What is important is the assessment whether the new values in the face of outage of any element whether the new values would be less than their corresponding limits or not. If our assessment give us a reasonably confident value of the new quantities with some plus minus error that yes that this new values would be less than their corresponding maximum values we would be secure in our knowledge that yes my system would not enter into an insecure zone.

So then therefore because we do not need the accurate values so for the purpose of contingency analysis we usually do not perform AC load flow analysis but we take some simplifying assumptions such that to make our calculation faster. So that for each and every operating point as and when this operating point changes we can immediately very quickly analyze all this (N – 1) contingencies maybe within next 1 to 2 minutes.

And then simply assess whether this system would be operating in a secure zone or not. If by our assessment we find that the system will not operate in a secured zone in the face of the outage of any element, one or two element or any element so then what we can do. Then we can take some corrective action right now.

That is just by altering some value of let us say I mean generator pattern or maybe changing some transform tap positions or maybe or let us say maybe taking some control actions or whatever such that my present operating point shifts and then again we will do again this contingency analysis at that new operating point to assure ourselves that yes in this new operating point which we have obtained by applying some control actions

This new operating point is now secure operating point in a sense that if at this new operating point any particular element goes out of order that is if (N – 1) contingency takes place then this system will still operate in the secure zone, right? So this is the basic purpose of contingency analysis where we try to assess whether my system would be operating in a secure zone or not and for that we really do not need accurate value.

Some amount of assumptions will do and we take those assumptions so as to enable us to do this assessment of the post contingency analysis. We are actually when we would say that we are doing contingency analysis we are actually talking about post contingency analysis that what will happen to the system in case this element between bus 5 and 13 goes out.

So we are just trying to assure ourselves that in the case of any outage of any element my system will still operate in the secure zone. So for that we take some simplifying assumption so that we can do this post contingency analysis very quickly and the whole purpose of doing this analysis quickly that is if I find that my system is going to be insecure at the present operating point then we can apply some control action to take this present operating point to some other operating point.

And again do this contingency analysis at that new operating point to assure ourselves yes we have achieved our objective of operating the system in a secure zone. So this is the basic philosophy of contingency analysis. So from the next lecture onwards we will be looking into the assumptions and we will see that how do we do this contingency analysis without resorting to this accurate load flow.

Please remember because we are not doing accurate load flow analysis so then therefore this resulting values would have some error. But fortunately these errors are not much as we will see at some future lectures. Thank you.