Computer Aided Power System Analysis

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Lecture - 20
Fast Decoupled Load Flow (FDLF)

Welcome to another lecture of this course of computer aided power system analysis. Till the last lecture we have discussed about the Newton – Raphson load flow both in polar coordinate as well as in the rectangular coordinate. We have seen that both in polar coordinate as well as in the rectangular coordinate all the equations are coupled with each other. Not what do we mean by this statement. So let us look at that.

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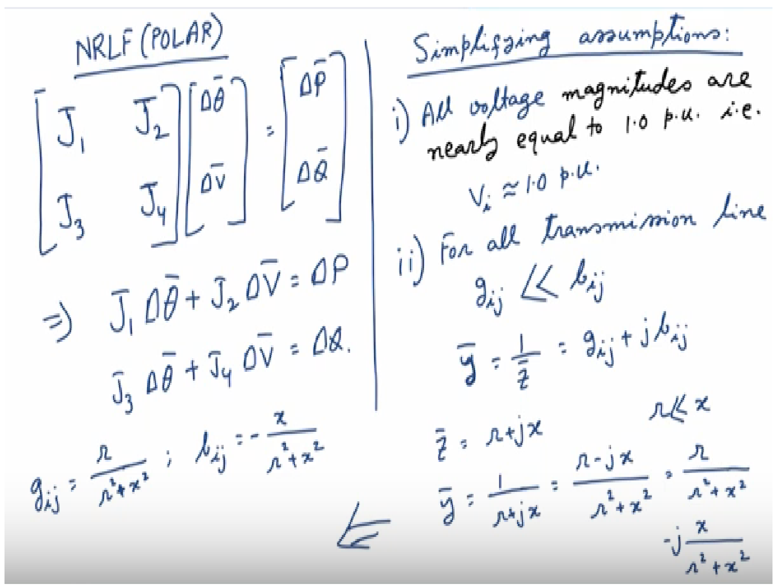

So in the polar coordinate for example NRLF polar, the equations we have is J 1, J 2, J 3, J 4 and then it is delta theta, delta V. Please note that this J 1, J 2, J 4 all are matrices of appropriate dimensions. Then we have delta P, delta Q vector. So then if we do expand this what equations I get? I get J 1 delta theta + J 2 delta V = delta P and we get J 3 delta theta + J 4 delta V = delta Q.

So if we solve them what we get? We would be able to solve for theta and V but then what I can see is that both theta and V they are actually dependent on both P and Q which is obviously the case. But then for all practical purpose we can show which we will actually show that with some simplifying assumptions it can be shown that the variation of theta is largely dependent on the variation of P that is the real power.

While the variation of voltage magnitude that is this vector delta V is largely dependent on the variation of Q that is the reactive power. In other words, the variation of theta is not dependent on Q while the variation of V is not dependent on P. So it will actually help us to expedite the solution. Now, to do that we have some simplifying assumptions. So we have some simplifying assumptions.

So let us look at those simplifying assumptions, under which assumptions this is true. So first look at this simplifying assumptions. So first assumption is all voltage magnitudes are nearly equal to 1.0 per unit. That is we should say that all V i is roughly 1.0 per unit which is almost true because we have already seen in our example that for this 5 bus system for example we have seen that all this voltage magnitudes are more or less equal to 1.0 per unit.

That is they are very close to 1.0 per unit. We may ask the questions that is it a kind of general situation. To some extent it is because in any power system you would like to maintain the voltage magnitudes at all the buses equal to their nominal voltage, nominal voltage means nothing but this rated voltage which in turn in per unit is nothing but equal to 1.0 per unit.

So then therefore because we wish to maintain the voltage profile of any power system network at the rated voltage so then therefore we can say that all the voltage magnitudes are more or less equal to 1.0 per unit. Second simplifying assumptions is for all transmission line g ij is << b ij. What is g ij and b ij? g ij and b ij are nothing but the conductance and the susceptance.

That is if we take the inverse of the impedance that is y so that is if we compute y that is the line admittance that is 1/z so that is = actually g ij + jjb ij. Now what is the justification of this? Now we have that J = r + jx where r is the resistance and x is the inductance and in a transmission system usually the realistic part is much less than reactive part. So then therefore we know that r is much less than x.

Usually r is much less than x. Now y is 1/r + jx. So you have got r – jx/r square + x square. So it is r/r square + x square – jx/r square + x square. So then therefore we can write down that g ij = r/r square + x square or rather this magnitude of g ij and b ij is –x/r square + x square. As r is very less than x so then therefore g ij would be very less than b ij because this denominator is same for both g ij and b ij.

And as r is very less than x so then therefore g ij would also be much less than b ij. So this is the second assumption.

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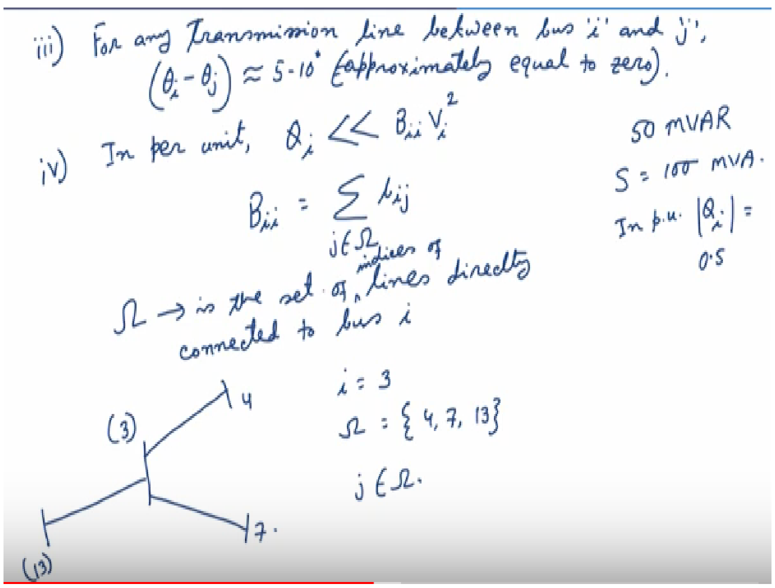

Third assumption is for any transmission line between bus i and j the angular difference between them theta i – theta j is quite small. So we say that it is roughly 5 to 10 degree. We say that is in all parlance we say that is approximately equal to 0. Now what is the justification for this? We know from our equal area criteria that for maintaining stability the angular difference between two terminals of a line must be as small as possible.

Because if the angular difference of the voltages between the two terminals of a line is increased so then therefore the possibility of instability for any fault in that line increases severely. So then therefore for maintaining the stability of the system we need to maintain the angular difference between the two terminal voltages as low as possible.

So then therefore according to that so we take that assumption and we say that for any transmission line between bus i and j the angular difference of the voltages between two terminals are approximately equal to 0. It is not equal to 0, it is approximately equal to 0 and the fourth one is in per unit Q i that is the injected reactive power at bus i is much less than B ii V i square. Now what is the justification for this?

Please note that it is in per unit. So Q i is much less than as compared to B ii V i square. Now what is the justification for this? The justification is that in per unit for example at any bus let us say the reactive power load is 50 MVR at a bus the reactive power load is 50 MVR. Let us say our base MVA S is 100 MVA. So then therefore in per unit Q i that is magnitude = 0.5. So this is basically the numerical value, 0.5 in per unit.

Now we know that B ii is nothing but the sum total of all b ij where j belongs to the set omega where omega is the set of lines directly connected to bus i, right? So then therefore j is actually basically or rather we should say that omega is the set of the indices of the lines directly connected to bus i. For example, just to give an example. Suppose I do have bus, let us say bus 3 in some system.

And let us say this bus 3 is directly connected to bus 4 and let us say this is bus 7 and here it is connected to let us say bus 13. So then therefore in this case i is 3 and set omega would be 4, 7, and 13 and J is omega and J belongs to omega. So then therefore here in this case this J would be 4, 7, and 13. And then therefore this B ii which is nothing but the imaginary part of the diagonal element corresponding to bus i.

That would be nothing but we know from the basic formulation of the Y- Bus matrix that this any diagonal element is nothing but the sum total of all the admittances of the lines directly connected to bus i. So then therefore the imaginary part of the admittance corresponding to the diagonal element would also be nothing but the sum total of the imaginary part of the admittance of all the lines directly connected to bus i.

So then therefore now from this, now if we look at this expression b ij, if I just look at this expression b ij, r square is quite less in per unit. Please note that all this calculations are being done in per unit. So then therefore r is a value which is small in per unit, let us say 0.03 or let us say 0.0023, something like that; x is also a value which is also pretty less. So then therefore r square would be even reduced; x square would be even reduced.

So then therefore r square + x square would be an very small quantity and x although it is a small quantity but because this is square so then therefore this divided by this would be actually a very large quantity. Now because this b ij in numerical value would be a large quantity so then therefore in numerical value numerically B ii would be also a very large quantity.

And even though if we do assume that this V i is almost equal to 1.0 per unit so even then, even if we take that this V i = 1 so even then because B ii numerically is very large value so then therefore numerically B ii V i square would be pretty large as compared to Q i in per unit because of this numerical value. So with this 4 assumptions now if we apply this 4 assumptions to our equations of Newton – Raphson polar coordinate some very interesting results can be obtained.

So let us look at that. So we will apply this 4 simplifying assumptions one by one and we will see that what conclusion is drawn.

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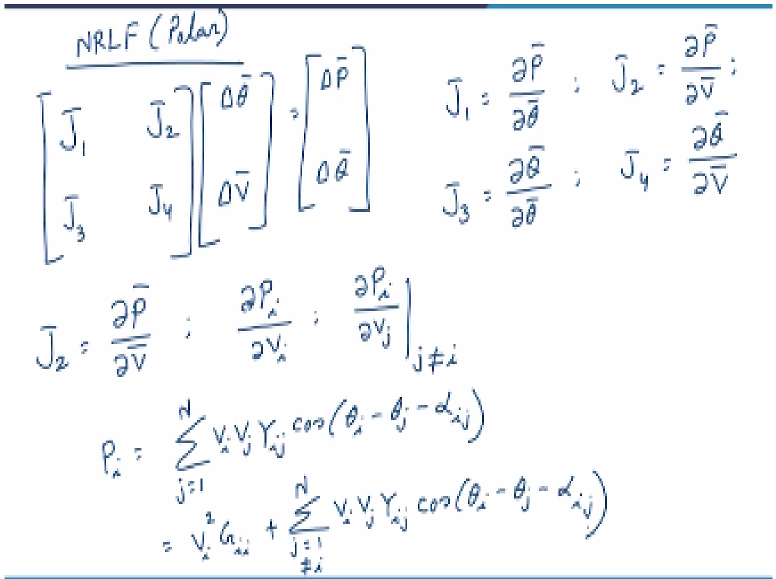

So again we write. This is again we discuss about NRLF polar. And we again just it is recollection. So delta that delta V delta P delta Q. Now what is J 1? J 1 we know that it is del P/del theta. We have already defined what is meant by del P/del theta. J 2 is del P/del V. J 3 is del Q/del theta and J 4 is del Q/del V. So first let us look at this two off diagonal sub matrices. If we think of this particular big matrix J constituting of 4 components J 1, J 2, J 3, J4. So first let us look at J 2 and J3.

So J 2 is del P/del V. So we have got, as we have seen so I have got two general expressions. One is del P i/del V i and another is del P i/del V j; j not equal to i. So these are the two expressions we have. We have P i is equal to we know that V i V j Y ij cosine (theta i – theta j – alpha ij) j = 1 to N. N is the number of bus. So it is we know that it is V i square G ii. We have already done it, we are just merely recapitulating it.

J = 1 not equal to i goes up to N V i V j Y ij cosine (theta i – theta j – alpha ij). So this is the expression. So now again let us do this two and then we apply these 4 assumptions one by one judiciously. So let us start.

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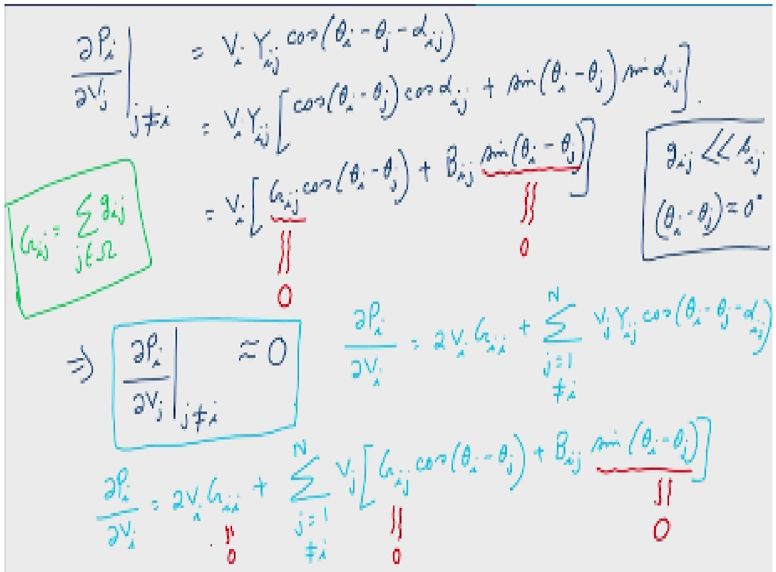

So first we look at the simpler one. So del P i/del V j with the condition that is j is not equal to i. So what it would be? So it would be basically we have already seen. So this will go and there will be only one term of V j. So it would be V i Y ij. So it would be V i Y ij cos (theta i – theta j – alpha ij). So now V i Y ij cos a cos b cos (theta i – theta j) cos P; cos a –b. So cos a cos b + sin a sin b sin (theta i – theta j) sin alpha ij.

Now you know that Y ij cos alpha ij is nothing but g ij. So we write V i g ij cos (theta i – theta j) and we know that Y ij sin alpha ij is B ij. So we write B ij sin (theta i – theta j). So this is the expression. Now we apply this simplifying assumptions. The simplifying assumption is we apply two assumptions. One is that g ij is much less than b ij and another assumption is theta i – theta j is approximately = 0.

These two assumptions we apply. If we do apply this assumptions, so what do we get? Sin theta i – theta j because theta i – theta j is approximately = 0 so then therefore sin theta i – theta j is also equal to approximately = 0. So this is 0 this part. And because g ij is much less than b ij we can say that this part g ij is also approximately = 0.

But remember because theta i – theta j is approximately = 0 so cos theta i – cos theta j would be approximately = 1 but because g ij is very small so we can neglect it as compared to b ij. So then therefore for all practical purpose we take g ij to be = 0. So this part becomes approximately = 0 and because of this assumption that theta i – theta j is approximately = 0 so then therefore sin theta i – theta j becomes = 0.

So then therefore this term becomes = 0, this term becomes = 0. So then approximately del P i/del V j where j is not equal to i becomes = 0. So this is a very interesting result. So we get this result. So this is the first result. Now look at this one. So it would be 2V i G ii + j = 1 to N not equal to i. It would be V j Y ij cos (theta i – theta j – alpha ij) because we are taking the derivative with respect to V i and from this expression V i would be everywhere.

So then this summation term will come. We have already looked into this. So now if we expand this part as we have done here, so we can write straightaway without any problem. This is 2V i G ii + j = 1 not equal to i = N V j then G ij cos (theta i – theta j) + B ij sin (theta i – theta j). So this part is identical of this. So we have just taken this result as it is. So as usual as before what we get? As before we get that this is almost = 0.

This part is almost = 0 and G ii because all G ij is much less than B ij so then therefore G ii which is nothing but the sum total of all G ij, we again repeat. We write that we again note that G ij we write it here, just G ij is sum total of g ij where j belongs to the set omega. So then therefore because all g ij's are very negligible so then therefore their sum total would also be very small.

So then therefore G ii would also be very small. So then for all practical purpose G ii would also be 0. So then therefore del P i/del V i would also be 0.

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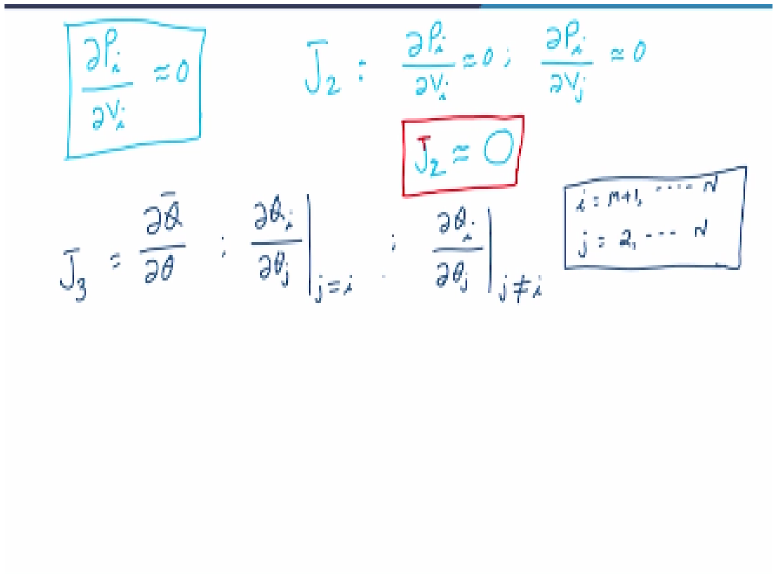

So then therefore what we get is we get del P i/del V i is also = 0. So then for this matrix J 2 we have terms del P i/del V i which is 0 and del P i/del V j that is equal to 0. So then therefore we can straightaway say that J 2 matrix is a null matrix. So this is a very interesting result. So matrix J 2 becomes a null matrix. It becomes simply a null matrix. Now let us look at this matrix J 3. So we have matrix J 3 that is basically del Q/del theta.

So we know that it has got two del Q i/del theta j. So one is j = i and another is del Q i/del theta j, j is not equal to i. We all know that how Q i varies and how j varies. For example i would be varying from M + 1 to N and j would be varying from you know 2 to N and etc. etc. all this are known. So this is it. So then we have these two terms. So then therefore when i varies from N + 1 to N and j varies from 2 to N.

So then therefore there will be some occasion where j would be = i and also there would be some occasion and in basically most of the occasions j would be not = i. So then we again need to look at this 2 expressions as we have looked into j 2 and then deduce what happens to this matrix J 3. So this we will look into this next lecture and also along with the other lectures. Thank you.