Computer Aided Power System Analysis
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Lecture – 47
Power System State Estimation (Contd.)

Hello friends, welcome to this lecture on computer aided power system analysis, we have been discussing about power system state estimation, so let us process this this, so we are talking about the algorithm.

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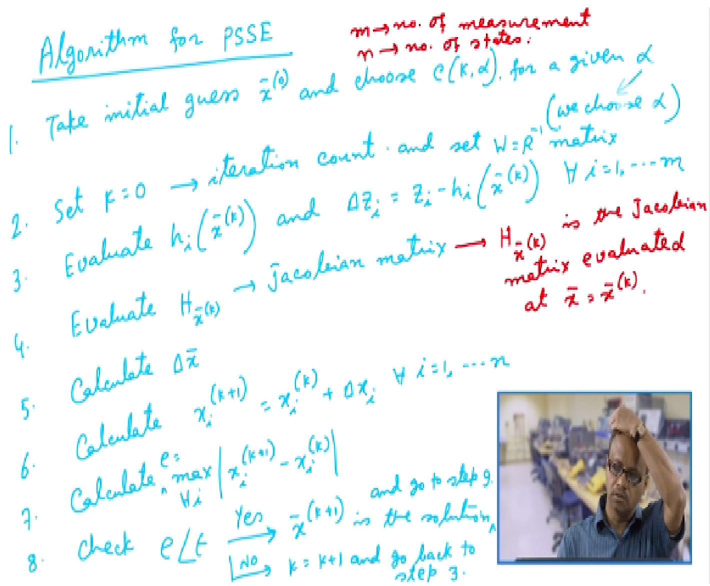

So, let us just very quickly recapitulate the algorithm and then we will algorithm for very quickly we have already seen it but just to recapitulate algorithm for PSSE, so we first have taken initial guess, x0 and choose ck alpha, ck alpha is nothing but a threshold as obtained from the chi squared distribution for a given value of alpha; for a given alpha, we should also say that I mean this alpha is also we choose, we also choose actual alpha, we actually choose alpha, so we must also know that we choose alpha.

So then after that set k = 0, this is the iteration count, then what do we do; we evaluate hi at xk, right and from that and zi; delta zi; delta zi = zi – hi xk for all i = 1 to m, m is the number of measurements, then what do we do; evaluate Hxk, now what is Hxk that is the Jacobian matrix, this is the Jacobian matrix, so and then after that we and we also set W = R inverse matrix; W = R inverse matrix is nothing but the weight matrix.

So, I mean in this particular W matrix is this weight matrix calculate delta x vector, then we check calculate xi k + 1= xi k + delta xi, this is for all i = 1 to n, n is the number of states, so n is the number of states, then calculate max of absolute xi k + 1 – xi k for all I, let us say this is epsilon, let us say this is e, we should write it more clearly, e = this, then what we do; check whether e is < epsilon.

If yes, states are estimated, xi xk + 1 is the solution, if not; no, if not, then what we do; we simply k = k + 1 and then go back to step 3, so this is the basic algorithm.

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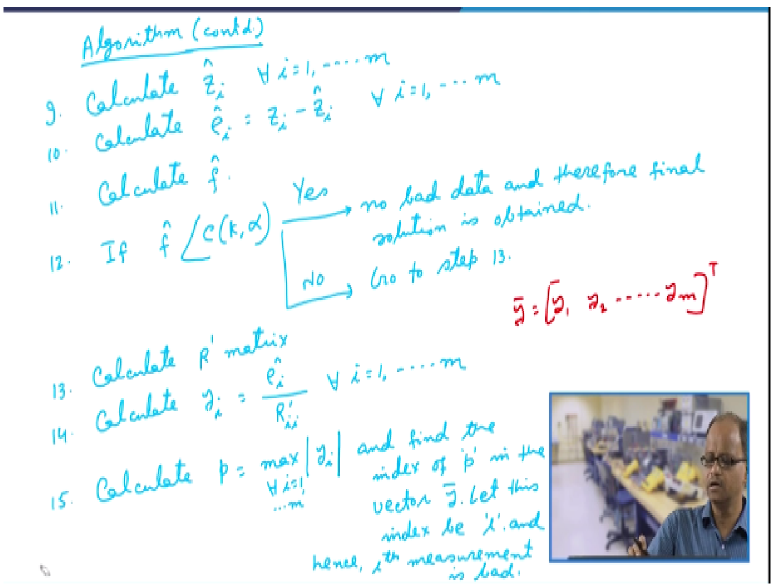

Now, after this also, so algorithm continued, so here also is the solution and from then and we should write here and go back to step 9, so this is actually go to step 9, what do you do in step 9, we calculate, in step 9 calculate zi hat overall i = 1 to m, then step 10 calculate ei hat = zi – zi hat, this is for all i = 1 to m, then we calculate f hat, then what do we do; if f hat is < ck – alpha is no bad data and then therefore, final solution is obtained.

If no; if it is no, so then what happens; if no go to step 13, what do you do in step 13; calculate R dash matrix, we have already seen how to calculate R dash matrix, then what do we do; calculate yi = ei hat/ Rii dash for all i = 1 to m, then we calculate position P as max of yi, this is for all i, for all i = 1 to m and find the index of P in the vector y. What is this vector y; this vector y is actually, this vector y is nothing but y1, y2 to ym transpose, so this is the vector y.

Now, after that what you do; we find the location, let this index be l, so therefore and hence lth measurement is bad, so after that what do we do; index and vector, let this index be l and hence lth measurement is bad.

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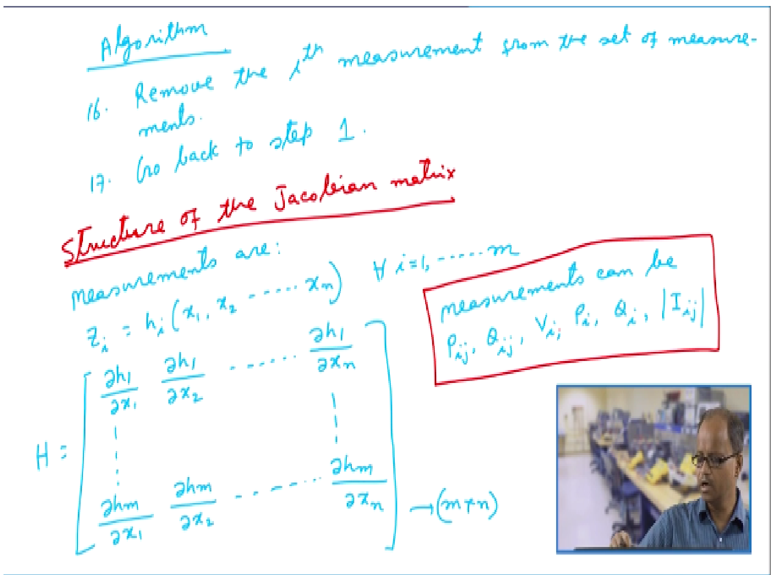

So, then therefore what do we do; remove the lth measurement from the set of measurements, right, go back to step 1, so this is a complete algorithm of the state estimation which includes also the process of bad data deduction now, here, now we have to look into this basically, the structure of this Jacobian matrix, so now let us look at the structure of the Jacobian matrix, so now we are looking at the structure of Jacobian matrix.

Now, here also we must do one thing, now this Hxk we must note that Hxk is nothing is actually the Jacobian matrix, you must note it, evaluated at x = xk, so that is what is Jacobian matrix, so now what is the structure of the Jacobian matrix; so now let my measurements are let us zi = hi * x1 x2 up to xn for all i = 1 to m, right, we just for the sake that m is the number of measurements, n is number of state.

So, now therefore, what is this H matrix; so then therefore H matrix is nothing but del h1 del x1 del h2 del x2 dot dot dot del h1 del xn and this will go up to del hm del x1 del hm del x2 dot dot dot del hm del xn, so this is an m cross n matrix, this is straight forward m cross n matrix, now as we said that our measurements can be now we said that our measurements can be let us say Pij, I have already defined what are these quantity Qij, Vi, Pi, Qi, mod Iij, anything can be this measurement.

So our overall set of measurements, set is like this, we already know what is the; what are the expressions of Pi and Qi that we already know and similarly, this Vi is also already know, so now let us look at that I mean what are the expressions of Pij and Qij.

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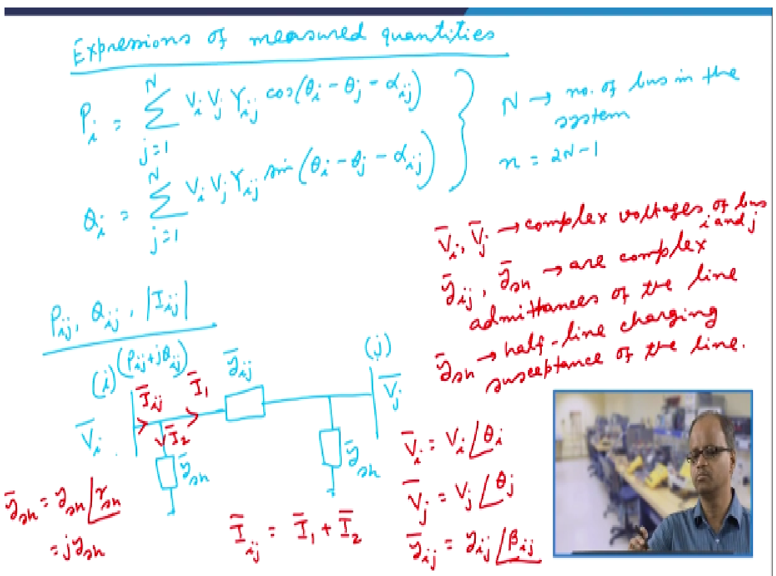

So, now let us look at some expressions, so now look expressions for different quantity, expressions of the measured quantities, so we first note that Pi is simply i = j = 1 to capital N Vi Vj Yij cos theta i – theta j – alpha ij, similarly Qi is j = 1 to N Vi Vj Yij sin theta i – theta j – alpha ij, you should note here that N is the number of bus in the system and we also note that n that is the number of state would be 2n – 1, Vi is already known, so Vi = Vi, now let us look at Pij Qij and Iij.

To know that let us consider a transmission line, this is bus i, this is bus j, in between there is a line, let us say this has got an admittance Yij, this is an complex quantity, this is y shunt, this is also y shunt, so it is a standard pi model, these are all complex admittances, so we must write that these are not vectors, Yij, y shunt are complex admittances of the line, must write admittances of the line and what is y shunt?

And y shunt is actually half line charging susceptance of the line, so if that is the case, so then this current Iij, so we are not trying to find out what is the current Iij, so this current is nothing but this current plus this current, so Iij = I1 + I2, so this is I1, I2.

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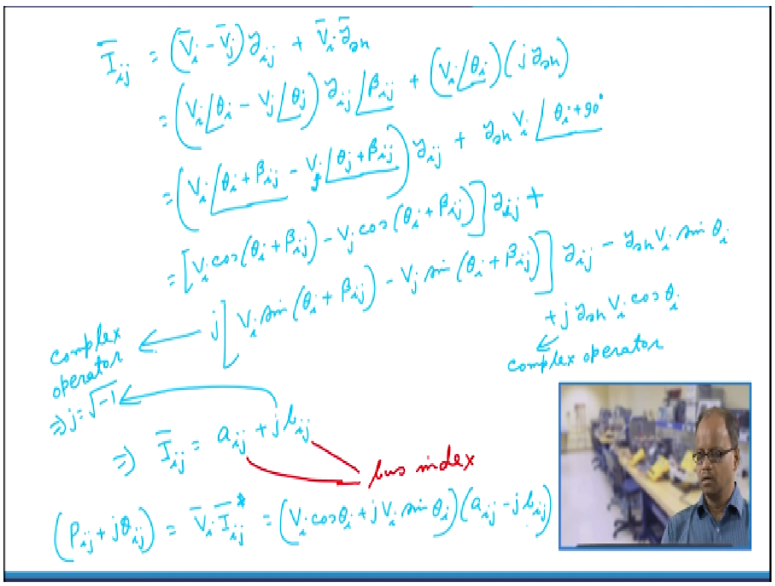

So, then therefore Iij is actually Vi – Vj * Iij, Vi, Vj are the complex voltages, Vi; so it has got a voltage Vi, this is got a voltage Vj, and we must also write that Vi, Vj complex voltages of bus i and j, and we also should write that Vi = Vi angle theta i and Vji is also be Vj angle theta j and let us say Yij is Yij angle alpha ij, we should not write alpha allowed because we are already utilising alpha, sp something else we should write, should write beta ij.

And let us say y shunt = y shunt angle let us say gamma shunt, actually gamma shunt would be = 90 degree but just for the sake of it is actually should be = j gamma shunt, it is actually j y shunt because I mean gamma shunt would be = 90 degree, so jy shunt, so then therefore, + Vi * y shunt, so this is Vi angle theta i - Vj angle theta j * yij angle beta ij + Vi angle theta i * j y shunt, so it would be Vi angle, sorry, theta i + beta ij – Vj angle theta j + beta ij whole of Yij + y shunt Vi angle theta i + 90 degree.

So, then therefore it would be Vi cos theta i + beta ij – Vj, so it should be Vj; Vj cos theta j + beta ij whole of Yij + j, now this is the complex operator, this j is complex operator, so that means j = root over -1 * Vi sin theta i + beta ij – Vj sin theta i + beta ij * Yij – ysh Vi sin theta i + j ysh Vi cos theta i, please note here also this j is also the complex operator, so this is also complex operator.

So, then therefore I can write down that Iij = let us say something i real part + j bij, again I note that these j is actually the complex operator and these j; these 2j's are the bus index, so then from here, I can write down that Pi + j Qij that is if I am measuring Pij and jQij at this point, so I am actually measuring here, Pij + jQij, this is at this point at that is at this point I am measuring that means at the outgoing point from bus i.

So, then it would be Vi star, sorry, Vi * Ii star, sorry, Vi * Iij star, so then therefore, this is Vi cos theta i + j Vi sin theta i * aij – jbij.

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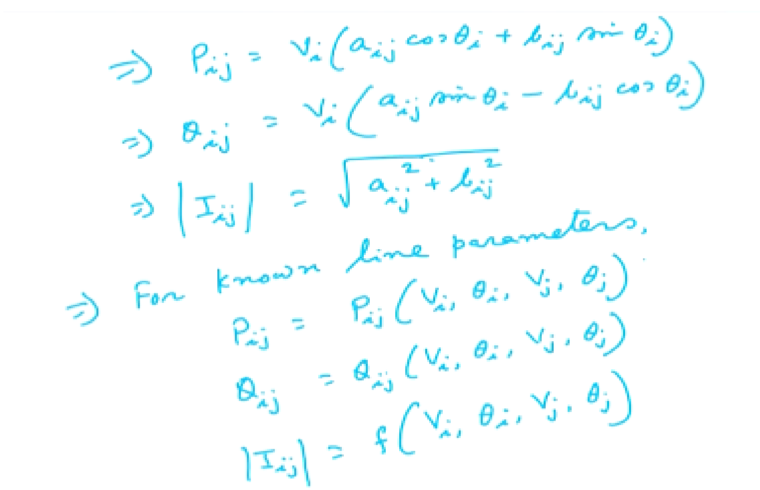

So, then therefore, from here, I can write down Pij = aij Vi cos theta i, so Vi aij cos theta i + bij sin theta i now, if I look at this expression and similarly, Qij would be Vi -; Qij sin theta i – bij cos theta i, so now if I look at that these 2 expressions; aij is nothing but this plus this and these are all only, this is j, I am sorry, this is j, this is also j, this is also j, snow aij = this + this and bij = this + this and all these are only a function of Vi Vj theta i theta j.

Of course, here we are assuming that this quantity is a beta ij and I mean we are assuming that this all this line parameters are known, so then therefore and also I can write down that I ij mod = root over aij square + bij square, right, so then therefore I can write down that for all for known line parameters, Pij is some function of Vi theta i Vj theta j, similarly Qij is some other function Qij Vi theta i Vj theta j and mod iij is also some other function and let us this call this function f.

This is also be would be functions of will be Vi, Vj, theta i, theta j, so all these quantities corresponding to line would be only the function of the terminal voltage magnitudes and angle of that corresponding line. So, with this we now ready to look at the structure of the Jacobian matrix which we will do in the next lecture, thank you.