**Power System Analysis**
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**Lecture – 36**
**Load Flow Studies (Contd.)**

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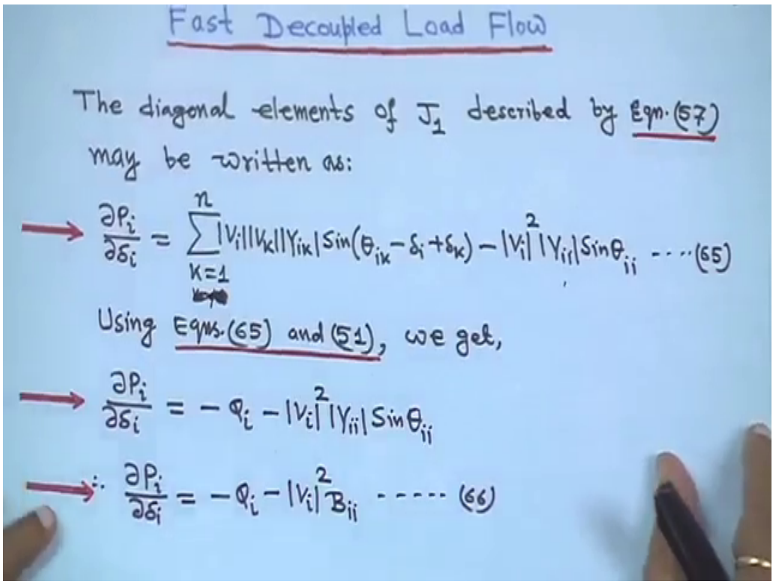


Next is that fast decoupled load flow. Here we cannot, will cannot solve numericals now. But we will tell you what is this one. Now the diagonal elements of J 1 described by equation 57, this is my this is equation 57.

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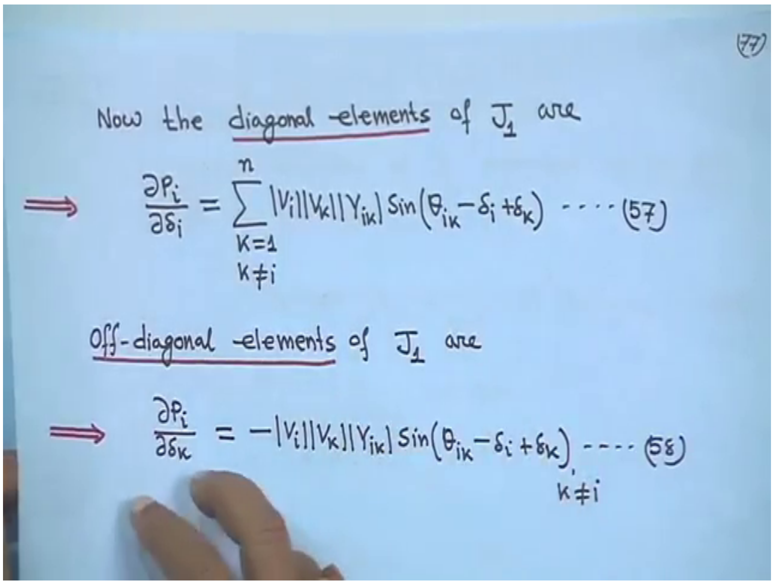


It can be written as delta P i upon delta, delta P i upon delta, delta i sigma k is equal to 1 to n V i V k Y ik sin theta ik minus delta i plus delta k minus V i square Y ii sin theta i; that means, this equation 57 this is your equation 57 right. This is 57.

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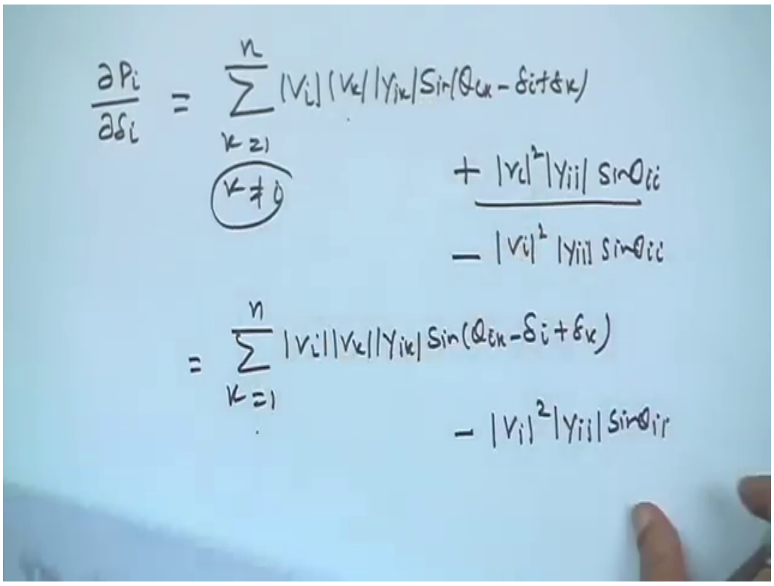

So, this one what you can do is, that delta P i upon delta, delta i is equal to sigma k is equal to 1 2 n right. This equation is k naught is equal to i this equation right. V i then V k then Y ik then sin theta ik minus delta i plus delta k this is the diagonal element right.

So, with that what you do you just look what I am doing add your V i square then Y ii right. Then sin theta ii minus again subtract V i square Y ii then sin theta ii right. If you if you do so, if you do so then these term you bring it to this into the summation has that k naught is equal to i, you remove, because the ith term when k is equal to i, for example, an k is equal to iit will V i square Y ii sin theta ii. So, V i square Y ii sin theta ii. So, that is why you bring this term into that; that means, this on it can be written as k is equal to 1 to n V i V k then Y ik then sin theta ik minus delta i plus delta k, then minus this is separate term V i square Y ii then sin theta ii, but k not is equal to i now is removed because this term as brought into the summation right.

If it is so, if it is so, then this fast decouple thing fast thing is that this term can be written as whatever I showed you that this term minus V i square Y ii sin theta ii; that means, delta P i upon delta, delta i right. It can be written as your sigma k is equal to 1 to n V i V k Y ik sin theta ik minus delta i plus delta k minus V i square Y ii sin theta this is equation 65 right.

Now, using equation 65 and 51 right, in equation 51, that equation 51 Q i is equal to actually minus of your k is equal to 1 to n V i V k Y ik sin theta ik minus delta i plus delta k up to this right. So, that expression these expression actually you put Q i is equal to that expression minus of that one; that means, these expression called minus Q i that is why these expression these expression you go to equation 51 then you will see that Q i is equal to minus of this whole expression up to this right; that means, these expression is go to minus Q i. So, I am not going to 51 it is understandable now. So, this term is written as minus Q i minus this term V i square Y ii sin theta ii this way you can write.

Or next is the delta P i upon delta, delta i then is equal to minus Q i and Y ii sin theta ii is equal to B ii. Because we have taken the convention once that Y is equal to g plus jd right. So that means, Y sin theta is equal to your B. So, Y ii sin theta i magnitude is equal to B ii right. This is actually your conduct an susceptance this is susceptance. So, on write B, B ii this is equation 66. So, this is minus Q i minus V i square B ii right. This is delta P i upon delta, delta i; that means, here I actually fast decoupled load flow means a several approximation right.

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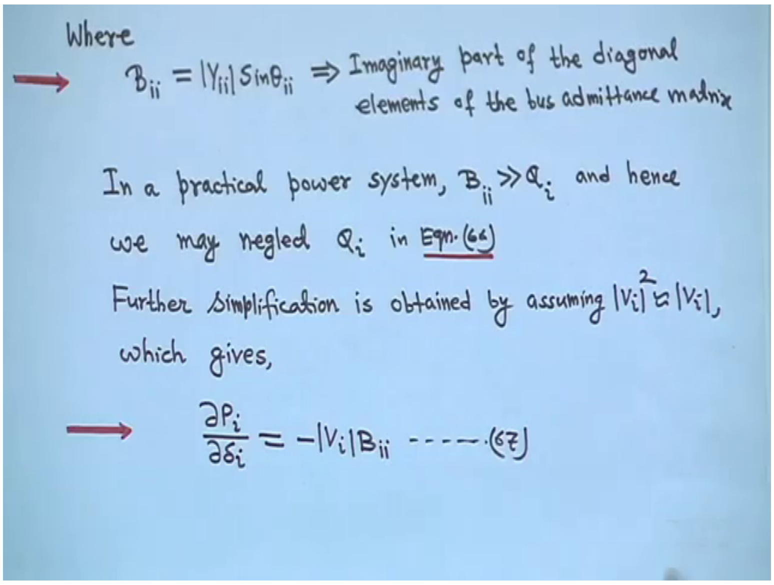


Then, this one then B ii is equal to Y ii sin theta I there is imaginary part of the diagonal elements of the bus admittance matrix that is capital Y right.

So, in a practical power system in B ii greater than much, much greater than Q i, remember, this is actually in power you need values. When you transform your Q i, i mean Y is in your Y is in your power unit Q also is in power unit at that time you will find that B ii is much, much greater than Q i. And hence we may neglect Q i in equation 66, that mean in this equation you neglect Q i; that means, drop Q i right. You will drop Q i right. If you do so then delta P i upon delta, delta i right. An another in another assumption we are making that this V i square this V i square approximately equal to V i, because voltage are very in a close facility of one per unit because slag bus voltage your taking one. So, this is another approximation V i square your taking approximately V i and this B ii much, much greater than Q i therefore, this Q i these term is much larger than this one. So, hence this term Q i is dropped and V i square taken as bi. So, delta P i upon delta, delta i is equal to minus V i B ii this is equation 67 right.

So, this is your what you call that delta P i upon delta, delta i right. Similarly just hold on.

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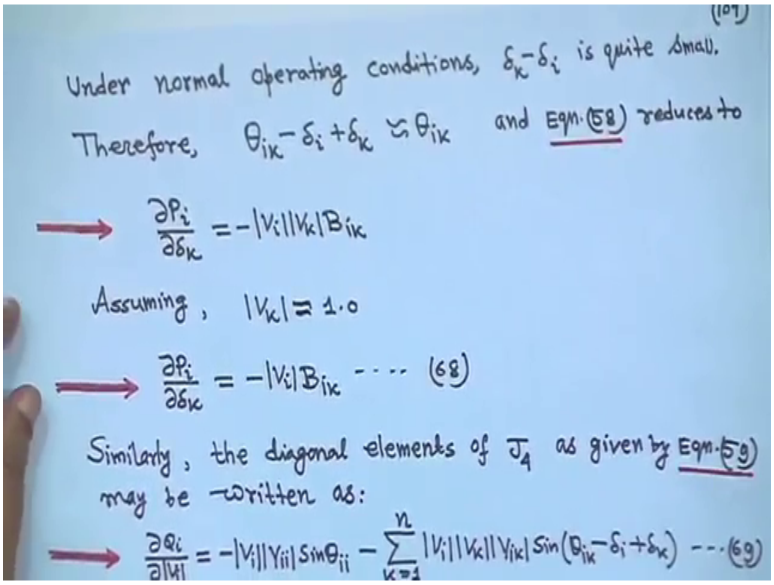


Similarly, under normal operating condition, under normal operating condition delta k minus delta k, k delta k minus is quite small therefore, theta ik minus delta i plus delta k approximately taken as theta ik therefore, in equation 58. In equation 58 you please put this condition that theta ik minus delta i plus delta k. I am not going to equation 58 because your I mean here right. In equation 58 right. So, in this is your what you call J 1 matrix, so this theta ik minus delta i plus delta k right. You just put a sin theta ik minus delta i plus delta k approximately to sin theta ik right.

So, with this assumption, with this assumption delta P i upon delta, delta k will become minus B i B k and if it is if it is Y ik sin theta ik.

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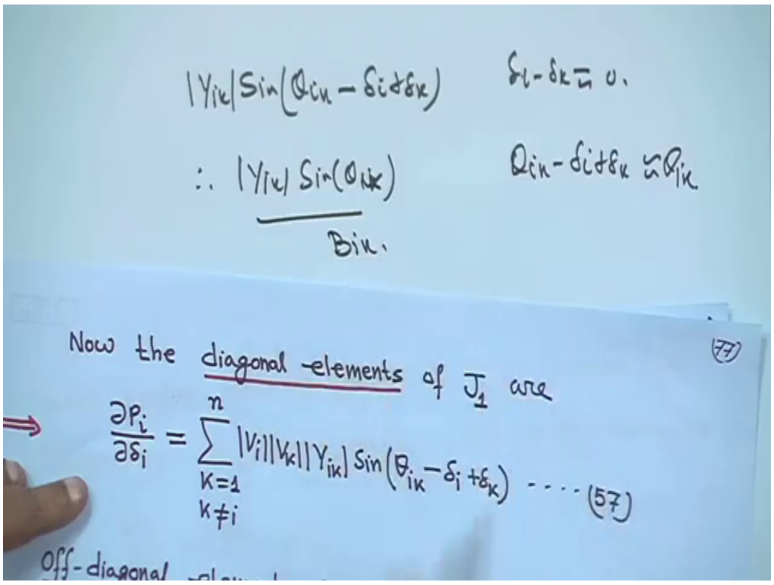


This one if you take I mean, this one for you are understanding that is Y, Y ik that is sin theta ik minus delta i plus delta k. So, you what you are taking that delta i that your what you call delta i minus delta k they are this thing they are very small approximately I mean difference is very small So that means, this Y ik that this can be taken as sin theta ik right. Because theta ik then minus delta i plus delta k approximately is equal to theta ik. This one Y ik sin theta ik is equal to your B ik right. So, this one your just hold down right. Is gone here it is therefore, this 1 minus V i V k B ik right. The V k is they can making an assumption assuming V k is approximately one right. Therefore, delta B i P i pi delta, delta k is equal to minus V i B ik this is equation 68 right.

Similarly, the diagonal elements of J 4 as given in equation 59 right, may be written as. So, diagonal elements that your delta Q i upon delta B i right. Let me see if I get your this thing this is equation 59 right. Let me see if I get fifty because I here it is right, this equation that 59 actually look at that very simple just try to understand.

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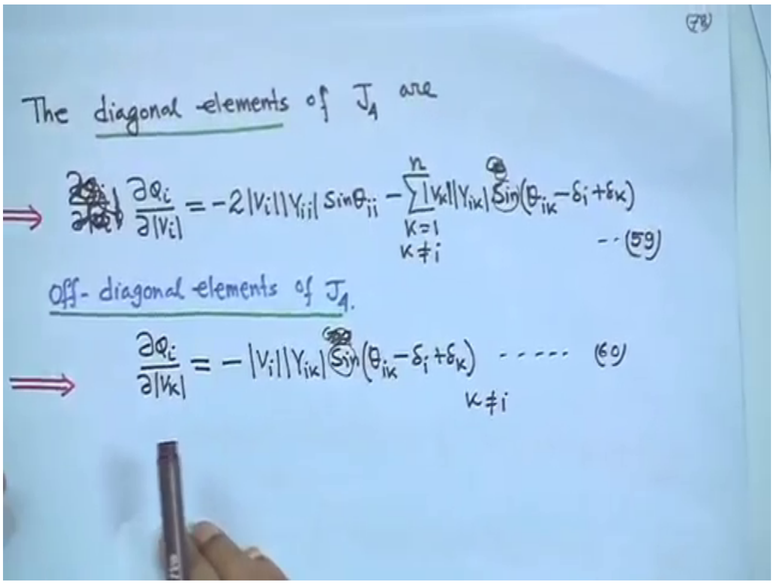


Delta Q i upon delta V i is minus 2 V i Y ii sin theta I, then minus k is equal to 1 to n k naught equal to iV k Y ik sin theta ik minus delta i plus delta k right.

Now, this is minus 2 V i vi Y ii sin theta i. So, take one out this is minus 2 V i y. So, what you do V i Y ii sin theta I you put one inside this sigma take in the summation such that k is not is equal to i should not be there and another minus V i Y ii sin theta will be outside right. Take one inside and one will be outside; that means, this delta Q i upon delta V i it can written as from this equation or it can written as right. That is written that minus V i Y ii sin theta I this will written and another V i Y ii sin taken in inside the summation and k is equal to 1 it as including the summation k is equal to 1 to n, but k not is equal to i that is V i V k Y ik sin theta ik minus delta i plus delta k. This is equation 69.

So, this is little bit mathematic per simple mathematics right, so using 69 and 51 right. Then you will get the same thing this 51 Q i is equal to actually minus k is equal to 1 to n V i V k Y ik sin theta ik minus delta i plus delta k. That is actually equation 51 Q i expressed is equal to minus of the whole term; that means, your delta Q i upon delta V i will be minus V i then Y ii then sin theta I plus Q i, because k is equal to minus of these thing.

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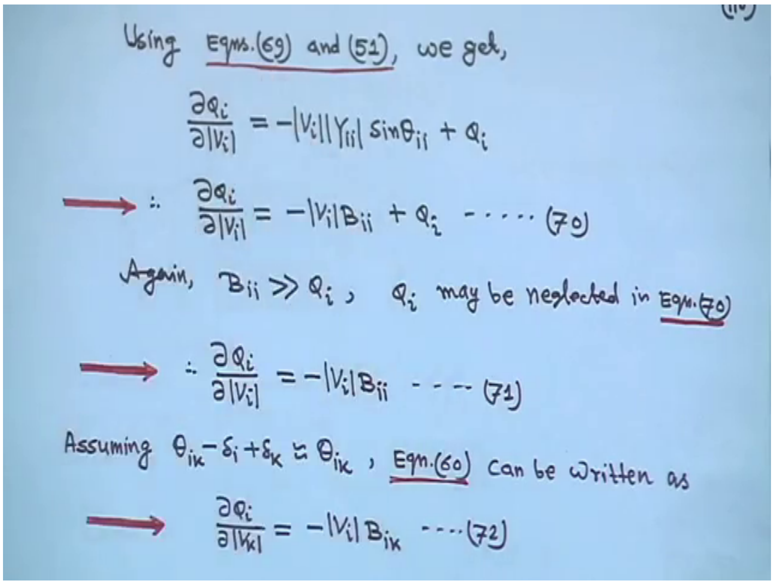


That means, this that means, I am writing equation 69 and 51 right. So, this is 69 and 51 I told you that equation already you have been give already those things have been given.

So, delta Q i upon delta V i will become minus V i vii sin theta ii plus Q i, but Y ii sin theta I is B ii. So, minus V i B ii plus Q i I wrote the same assumption, that B ii is much greater than Q i note that I told you earlier also that it is this values Q i and B ii both must be in power unit values. Then this condition hold B ii much greater than Q i right. And Q i may be neglected in equation 70. So, drop this one, you drop this one. If you drop this then delta Q i upon delta V i will be minus V i B ii this is equation 71.

Similarly, assuming again theta ik minus delta i plus delta k is equal to theta ik. So, equation 60 can be a written as right. So, this is your equation 60, this is your equation 60 with a same assumption this is equation 60, we will take this one as a sin theta ik, such that it will be minus V i V ik. That that is why these on delta Q i upon delta V k will become minus V i B ik, with this assumption and equation 60 can be written as this is equation 72.

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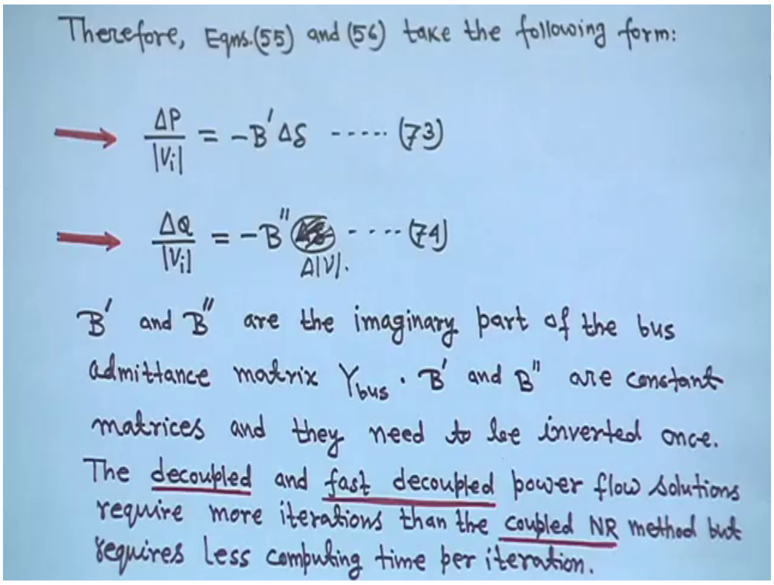


That means in general, in general. So, we have what we have seen is that delta P upon V i magnitude V i is equal to actually minus B as delta, this is equation 73 in matrix form. And delta Q upon V i is equal to minus B doubled as set delta B actually B as into delta B this is equation 74. So that means, this equation everywhere multiplied by V i vi and V i or V ik, that is why this is one set of equation this is another set of equation.

Now, this B dash and B doubled as actually this 2 matrices right. They are independent of any or what you call any, any your what you call, any variables like or it is a constant, it is a constant right, totally independent. So, you need not if an at them in every iteration right. So, it is a constant matrices and only if you invert them once and that is all, what you need not evaluated you can led Jacobean matrix right. So, this is your the decoupled and fast decoupled power flow solutions require, but in this case, fast decoupled case, that you need it is very fast computation, but perhaps takes more iteration it takes more iteration, then the decoupled Newton Raphson method right, but all the takes more iteration, but computationally this is very appreciate for transmission line right.

So, this was a proposed by Stott and Alsac if I recall, the year correctly probably it is 1974 right. So, this one your fast decoupled power flow. So, this is the matrix. So, numerical other things I cannot show you. Because already 2 examples are given right, time is permitted, but for small example or some other type of problems sometime fast decoupled it does not converge right. But for high power transmission line it is very efficient and commercial packages commercially pack packages are available right. So, this is equation 70, 74 and whole thing can be represented by matrix right. So, this is your fast decouple load flow. One this is done right.

Next we will come to that your what you call the tap changing transformers and rather, I will say that transformer representation transformer representation in the load flow studies that is the P i equivalent right. We have seen little bit tap changing transformer before right.

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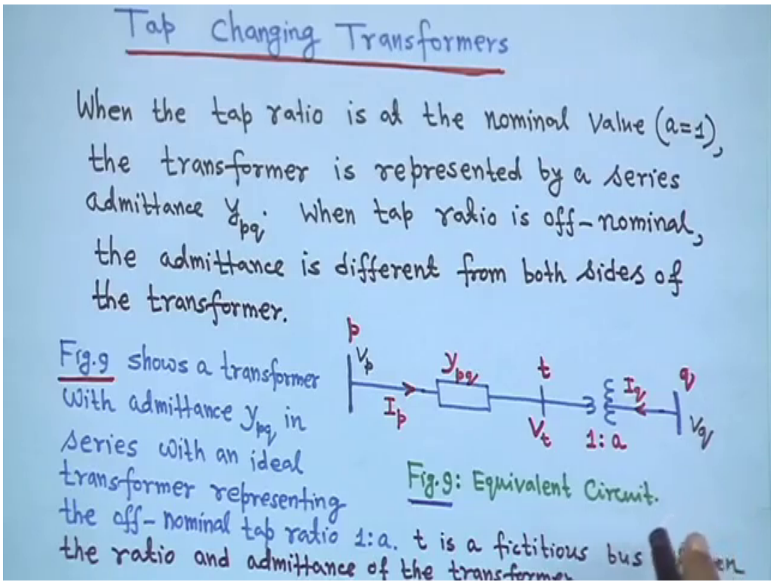


Little bit ideas are been given now when the tap ratio is at the nominal value that is have the a is equal to 1 right. At that time the transformer is represented by series impedance right. Series admitter rather right, Y P Q.

Suppose you have a tap ratio once. So, you are not changing the voltage level right. So, in that case it is it will be represented bias series admittances right. So, Y pq come to this one. So, this is your what you call the admittance the representation is something like this. First you have to understand this diagram. Suppose you have a transformer right. I will come to that another thing. So, suppose you have a transformer this is say, a P say this is we call bus bar P it is voltage is V p this is bus Q is voltage is B Q right.

So, transformer has impedance hence the admittance right. So, this is this is actually Y pq for example, this transformer this transformer has a admittance Y pq, but this a Y pq put in the line as if it is some kind of series connection Y pq and these are become ideal transformer right. And this bus bar take and this side right. This is a fictitious bus bar the mark is a t right. This mark is t this is a fictitious bus right. And actually this is one side away transformer right. And this is a another side of a transformer high voltage or low voltage or low voltage or high voltage does not matter, but a fictitious bus is taken and Y pq with the admittance of the transformer, and as this is an ideal transformer now and is it is one is 2 a and that is the your what you call trans ratio.

So, the actually the this side is a N t right. And this side is a nq. So, it is one is to N q upon N t right. That will come later. So, this is a transformer representation and this side current is goings I p and this side it is I q right. This side it is I q. So that means, before going to that that; that means, if you take that another the equation that is np into I your if this side is N t terms then N t into I p you will be minus N q into I q that will come later right. So, this is the direction of the current and this is P and Q this is the equivalent circuit of a transformer. And look how representation P i representation. So, that is why I have retained that figure line this figure 9 shows a transformer with admittance Y pq in series with an ideal transformer. Representing the off nominal tap ratio one is to a right. And t is a fictitious bus bar. Between that ratio and the admittance of the your and the admittance of the transformer. That mean between this one. In between this one and this side, this your what you call this fictitious bus bar we have assumed.

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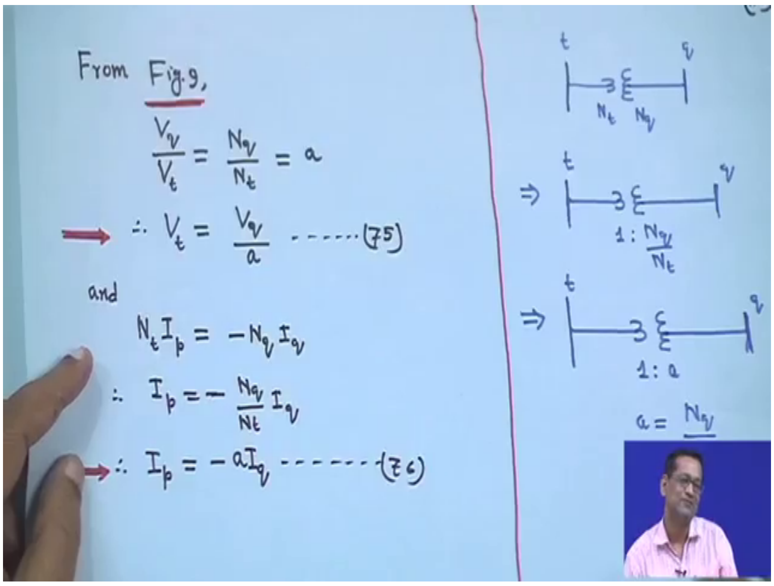

Next is, next is before coming to that right. This is t this side is t this side is Q right. So, we assume this side term is N t this side N q right. Therefore, N t N q that mean t N q you can right.

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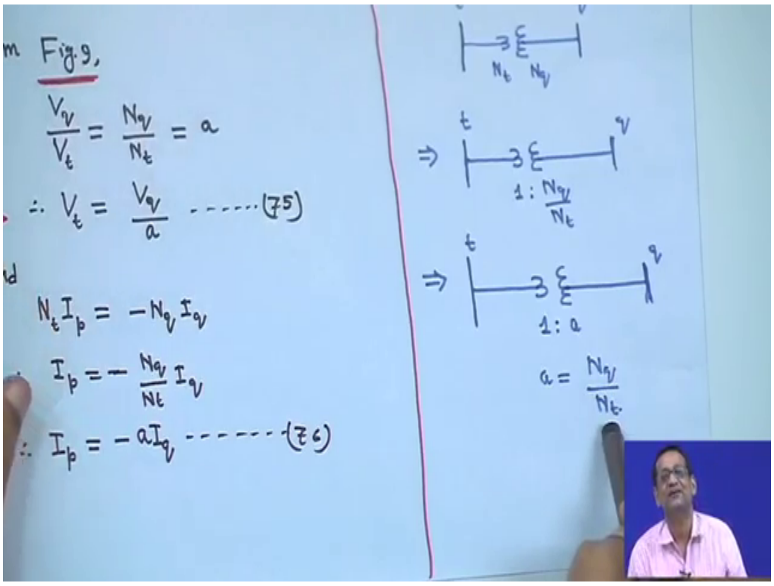


One is to N q N t; that means, it is one is to a; that means, a is equal to N q upon N t right. Therefore, in from figure line we can write V q by V t is equal to N q by N t; that means, from this figure you can write right. B Q by bt is equal to N q by this you know right. For example, generally for machine studies and these that your studied v upon v 2 or e 1 upon e to is equal to n one or a n 2 same thing right. So, V q upon V t is equal to N q it is a; that means, V t is equal to V q upon a this is equation 75.

Now, as I told direction of the current right. This is taken this way this is taken this way right. So, this side is a N t term this side is a N q term; that means, N t into I p is equal to minus N q I q right. Because this side is I p and this side is I q, so your N t into your N t into I p right. Is equal to minus N q into I q right. So, N t this side is a N t. So, N t into I p is equal to minus N q into I q right; that means, I p is equal to minus N q upon N t into I q, but N q upon N t is equal to a here also a in I p is equal to minus a into I q this is equation 76 right.

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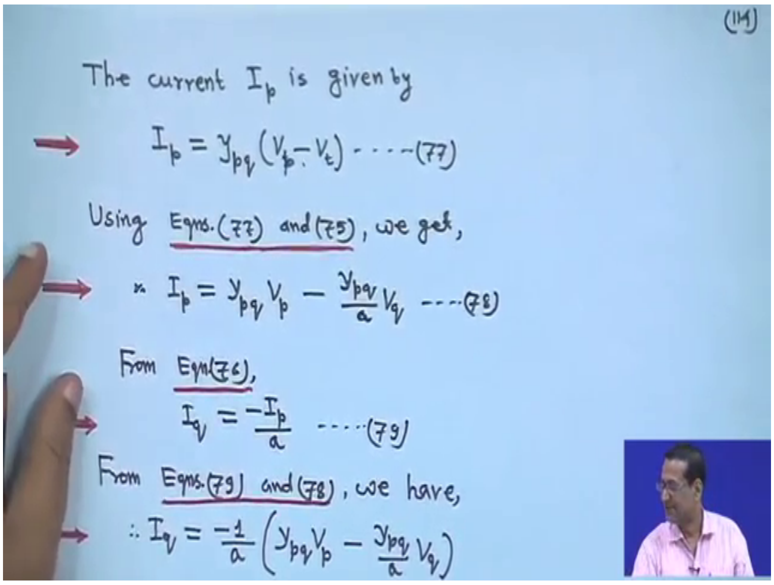


That means the current I p is given by, if you look at the diagram, the current I p is given by, this I p is equal to Y pq into V p minus your V t. Here if you one you can put this fictitious bus bar voltage is V t right; that means, that I p is equal to your Y pq into V p minus V t therefore, we write I p is equal to Y pq into V p minus V t right. Now using equation 77 and 75 right; that means, this is your 75 actually V t is equal to V q upon a right; that means, this V t is equal to V q upon a this one you substitute here you substitute here right. If you do so you will get I p is equal to Y pq V p minus Y pq upon a into V q this is equation 78.

Again from equation 76; that means, from these equation this equation 76 I q is equal to your minus I q is equal to minus I p by a from this equation right. Therefore, I q is equal to your minus I p by a this is equation 79. Now from equation 79 and 78; we have that I q is equal to it is minus 1 upon a this is minus 1 upon a and I p you substitute here. Y pq V p minus Y pq upon V q you substitute here right. If you upon substitution.

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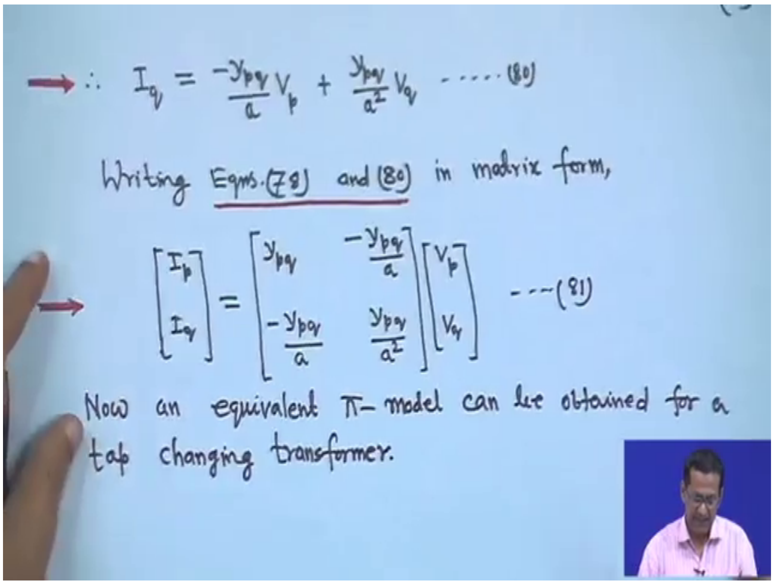


You will get you will get I q is equal to minus Y pq upon a V p plus Y pq upon a square V q this is equation 80.

Now, equation 78 and 80 put them in matrix form that is I p I q is equal to Y pq minus Y pq upon a minus Y, Y pq upon a then Y pq upon a square this is V p V q this is 81 equation 81 right. Now we have to obtain from this equation an equivalent time model for the transformer right. How we will do this? So, what one can do is this equation we have got right.

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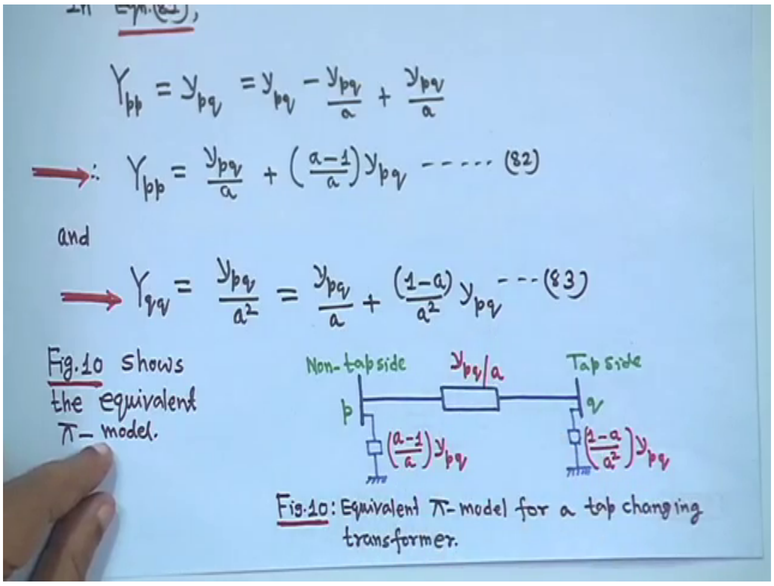

What one can do is look this Y pp that is a diagonal that Y pp diagonal element is equal to Y pq this diagonal element first one. So, Y pp is equal to Y pq, now what you do you subtract minus Y pq upon a, then add one Y pq upon a. So, in that case you will get Y pp is equal to this Y pq upon a plus this one you take a minus 1 upon a Y pq right. So, adding Y pq upon a subtracting Y pq upon from that from this thing. So, you will get Y pp is equal to Y pq upon a plus a minus 1 upon a Y pq this is equation 82.

Similarly, your Y qq is equal to Y pq upon a square this one, this is Y qq right. So, this one your Y qq is equal to Y pq upon a square, in that case also you add Y pq upon a subtract also Y pq upon a. So, in that case what you will get Y pq upon a plus 1 minus a upon a square Y pq this is equation 83 right; that means, what we are doing actually that; that means, Y pp will be Y pq upon a plus your a minus 1 upon a Y pq, and Y qq will be Y pq upon a plus 1 minus a upon a square Y pq right.

So, if you look like this then you can represent the transformer then this P side actually that is this is non tap side, and Q side actually tap side this P side right. Non tap side and Q side is the tap side right; that means, this is the non tap side the P and Q is the tap side. So, this is Y pp when you write it is Y pq upon a this is that your transformer your admittance, Y pq upon a and with that this is this is your some branch is coming for the transformer. That is this is the sand part, that is your a minus a upon a Y pq if you write Y pp this is Y pq upon a plus a minus a upon Y pq right.

Similarly if you go for Y qq that Y qq right. This side it will also Y pq upon a Y pq upon a is there plus 1 minus a upon a square Y pq 1 minus a upon a square Y pq. When tap ratio is nominal that a is equal to 1 that is equally is simply Y pq right. And when a is equal to 1 these term will not be there it will be 0, this term will be not there it will be 0 and transformer can be represented just is series admittance, if a is equal to 1 if it is not this is the P i equivalent of the transformer model right. I hope this equation you have understood this very interesting right.

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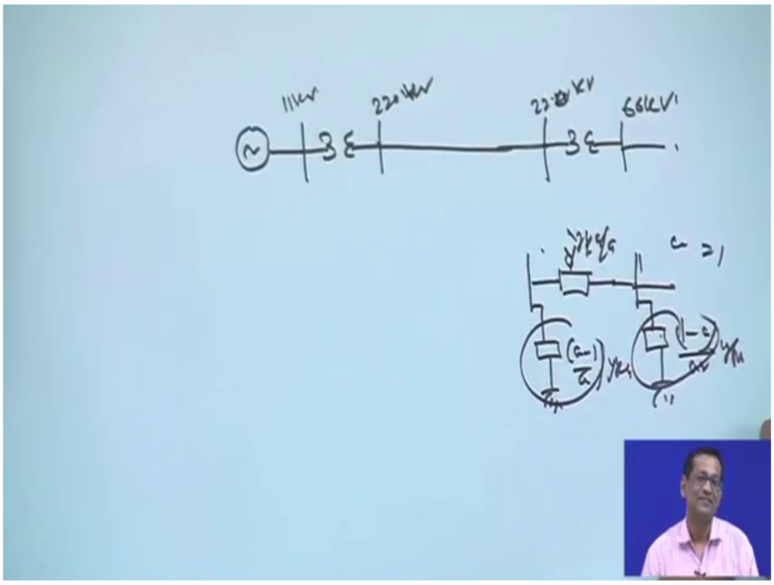

So, how was the, what way you have done it, right? So that means, suppose you have suppose you have, suppose you have generator. You have a generator for example, you have generator right. Then you have in your what you call transformer this is transformer right. Then it is going to transmission line your step up transformer say transmission line you have the transformer right. And transformer for example, suppose I am just showing transformer may be in your step down step down step up anywhere in the line right. For example, then again you have the transformer say your step down stepping down the voltage suppose this is 11 KV genres side.

So, this is 220 KV this is also said 220 KV, 220 KV. So, this is also and say this is your say 66 KV right. Suppose this task suppose for example, this transformer your representing right. See in that case this is your this is your this is your 2 bus bar right. This is your 2 bus bar. So, this is this will be your Y pq by a right. This side and this side is your that transformers side is there. This is a minus 1 upon a Y pq right. And this side also it is there this side also it is there it is 1 minus a by a square Y pq right. And in addition to that your what you call that other you have what you call line charge admittance san thing is also there right.

So, that why if a is equal to 1 then, simply it can take it can be taken as Y pq and that if a is not is equal to 1 right. Some other values it depending on the increase or the decrees of the tap or saver right. Then these branch this some branch also has to be considered right.

That is the idea of the your what you call that tap changing transformer right. As not tap change that is transformer P i represented sorry P i representation right. So, this is the idea and this is the P i equivalent representation of the transformer right.

So, with this, with this what we will do that just, today will discuss as just will discuss and after that will come to that generally.

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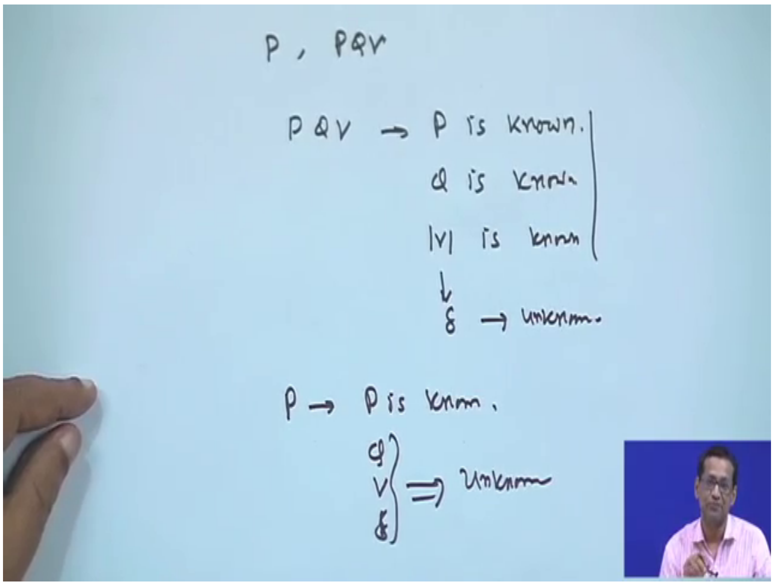


Now, at present in that power system that 2 new more bus have been introduce. That is called P bus and PQV bus right; that means, suppose these; that means, at bus for P is known for P Q v bus right. Here P is known that is real power is known very interesting it is your Q is known this is also known and voltage magnitude is also known. These 3 quantities are known for P Q V bus unknown is only that voltage angle delta this is actually unknown quantity right. And P bus, when you take the P bus that is only P is known right, but your Q then v and delta of the P bus they are actually unknown quantities right.

So, why will go for your P bus and t by I mean, P bus if you take PQV bus means P bus has to be there these 2 bus has to be there right. So, question is why will go for PQV bus actually when want to control a remotely located bus voltage. So, you can control it from another bus, but judicially as you have to take in network which one will take. For example, I am giving you a same for your understanding a simple diagram. Suppose you have this kind of network since as showing one generated right. You have this kind of network detail mathematics other thing will be given later right.

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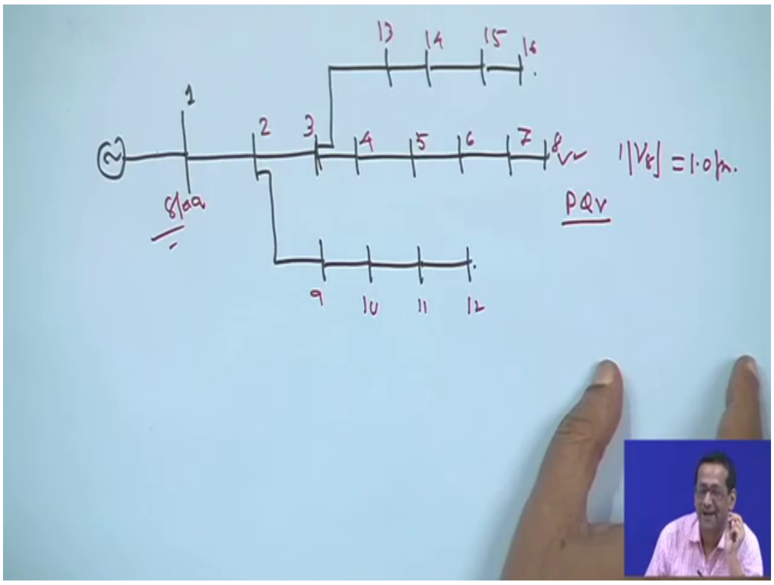

You have a just for the understanding right. Suppose you have a network like this you have a network like this, just I had made it like this right. So, this is say this is bus 1 right. Just hold on this is bus 1 just number it arbitrary numbering 2 3 4 5 6 7 8 right. 9 10 11 12 then 13 14 15 16 say it is a 16 bus problem. This is your a slag bus a right.

Suppose my bus 8 say my bus 8 if I make it as a PQV bus right. And I want to, I have to and from as P and Q both are known this is not a PV bus PQV bus as Q is known; that means, I cannot inject further Q one bus 8. So, I cannot control this voltage, but I want by bus voltage magnitude V i suppose I want to maintain at one point 0 per unit for example, say, but I want to control this bus voltage magnitude from remotely located bus; that means, not from this bus, but some other bus right.

For example I can call I will only one this network I will find out that which node from which node I want control this your what you call bus voltage magnitude right. So, what one can do is first I can choose say bus 2 is a P bus suppose this is PQV bus you have to choose one P bus, but which P bus will be a base bus based on your lost reduction you do not know. First we have how mathematic Jacobean can be formed will be see later. First I have suppose I have chosen bus to is a P bus right; that means, at this bus I have to inject

Q, such that I can maintain this voltage at one point 0 unit and I have to take the loss also right.

Similarly, I can choose the bus 3 right. So, in that case I have to also I have to find out what will be the Q injection such that I can maintain this voltage and such the same time of the power loss. So, similarly each bus I have to test and I have to see which one is giving the minimum loss this term that I choose the your what you call P bus. For example, suppose bus 3 is giving my best your Q injection for which my power loss of the network is minimum and I can maintain this voltage at one per unit; that means, instead of PV bus PQV bus; that means, this bus voltage magnitude or controlling from a remotely located bus. But if you try to make it from here I will control you cannot do that because it is a radial network. So, no connectivity or this no actually is not coming here. So, they you it is almost you will get some you know not desirable result.

So, it is a radial network I have taken just you make you things understand right. T bus and PQV bus if it is a transmission loop system your mesh distributed network transmission network, you have to see that which bus you choose a PQV bus, but which bus should we P bus accordingly you have to choose right. Based on many factors; that means, that P bus and PQV bus load flow studies you have studied, but these to bus receive have a studied because it is not available in the book right.

So, later we will discuss that formation of Jacobean matrix taking a small example that how PQV bus work, but so, I can tell you regarding this P bus and PQV bus we have made the simulation other things and your what you call using Newton Raphson method and result are very encouraging right. And some significance will be there for these P bus to will discuss later right, about this one.

Thank you.