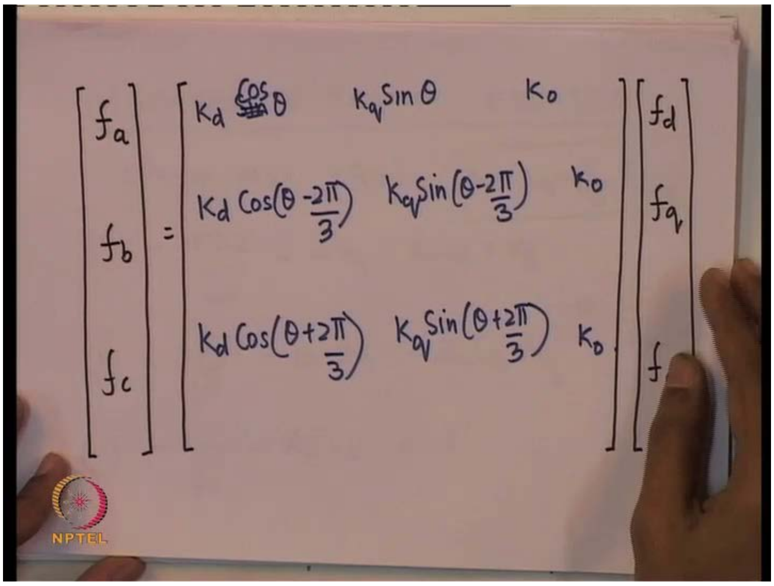
Power System Dynamics and Control
Prof A. M. Kulkarni
Department of Electrical Engineering
Indian Institute Of Technology, Bombay

Lecture No. # 15
Modeling of Synchronous Machines, Standard Parameters

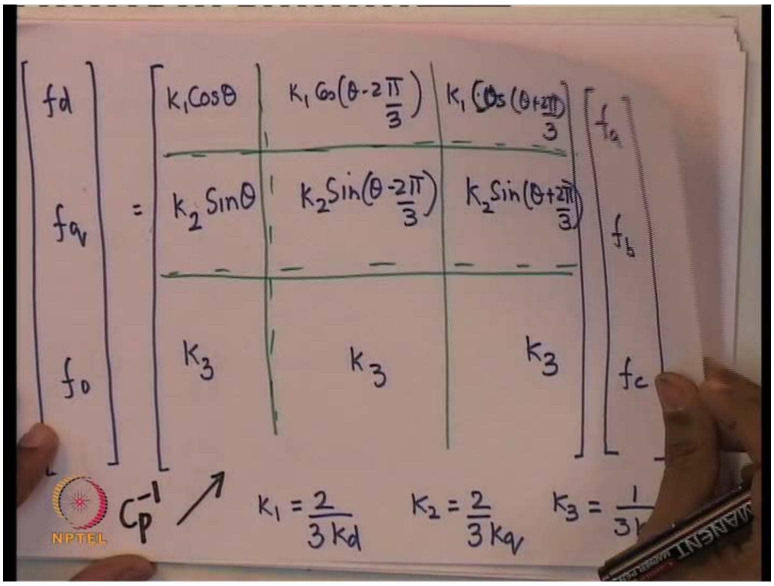
We are now in the position to write down the equations of a synchronous machine together and try to draw some inferences from the equations which we have derived in the d q variables. Remember that we have done time variant and theta variant transformation of variables from the a b c variables or the phase variables to the d q 0 variables. The transformation which we have used is defined using the rotor position theta, that theta is of course, the electrical angle and to be instructive to just look at the transformation once.

(Refer Slide Time: 01:00)



So we can express f d f q and f 0 in terms of f a f b and f c and vice versa in this case of course, this transformation is what we refer to as cp and this of course, is cos theta cos theta minus 2 pi by 3 and cos theta plus 2 pi 3 and similar things for sine.

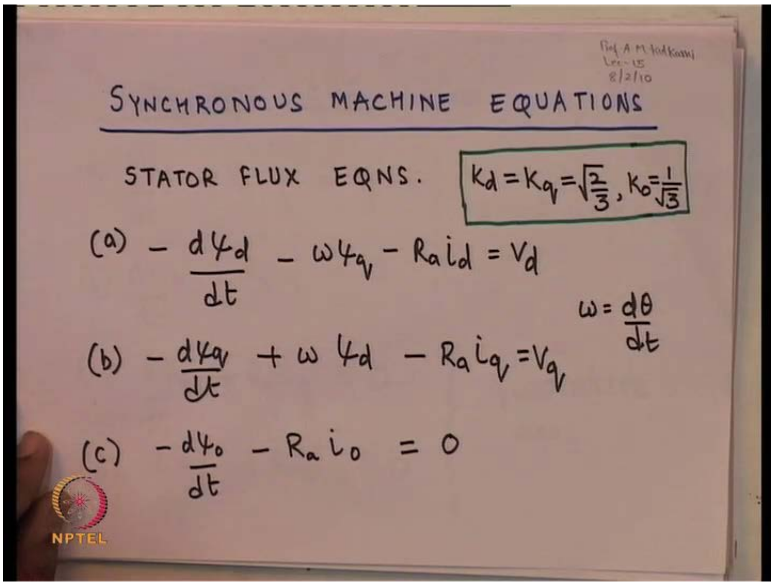
(Refer Slide Time: 01:33)



Now, the inverse transformation of course, given by this. So, the basic idea which we have tried to get is that we can do the analysis in the d q 0 variables and after obtaining the results in the d q 0 variables we try to move on and see what are the values in the a b c variables.

So, why do of course, we go to the d q 0 variables the reason is that the differential equations which you get in the d q 0 variables are in fact time not theta dependent that is one major advantage of using theta dependent transformation of variables.

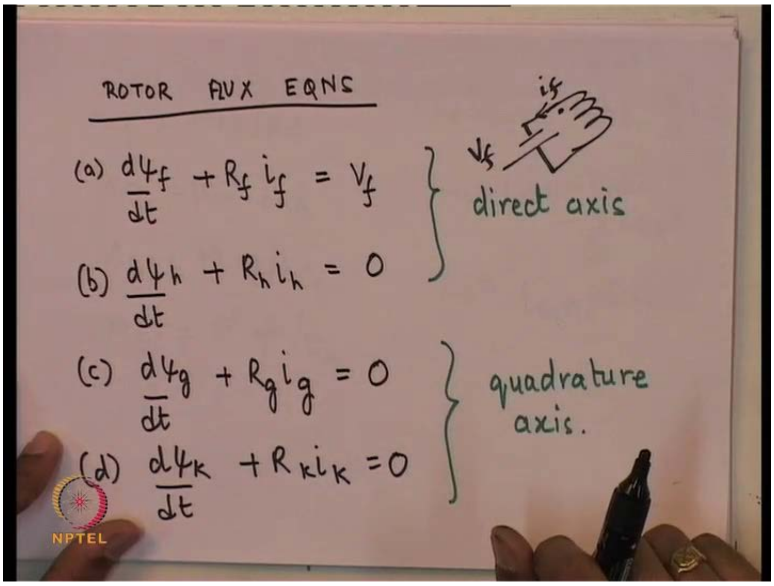
(Refer Slide Time: 01:57)



So, what are those equations the basic equations of a synchronous machine in the d q 0 variables are as follows. So, the stator flux equations are given by this d psi d by minus of d psi d by d t minus omega minus R a I d is equal to v d and similar equations for psi d and psi 0 omega here is of course, d theta by d t theta being the electrical angle and omega being the electrical angular frequency. Now, remember that these equations are obtained using the transformation as discussed before with k d and k q equal to root 2 by 3 and k 0 is equal to 1 by root 3 by doing this we make this transformation c p and this inverse transformation c p inverse transpose of each other that is c p inverse.

Becomes equal to c p transpose for this choice of d k q and k 0 of course, but of course, it is not necessary for k d and k q and k 0 to be these values in the sense that even if you choose a non 0 k d k q k 0 value absolutely arbitrarily still we will achieve one thing that is time variance of time invariance of the resulting differential equations. So of course what I will write here now, what we will do in this course will be for the specific choice of k d k q and k zero.

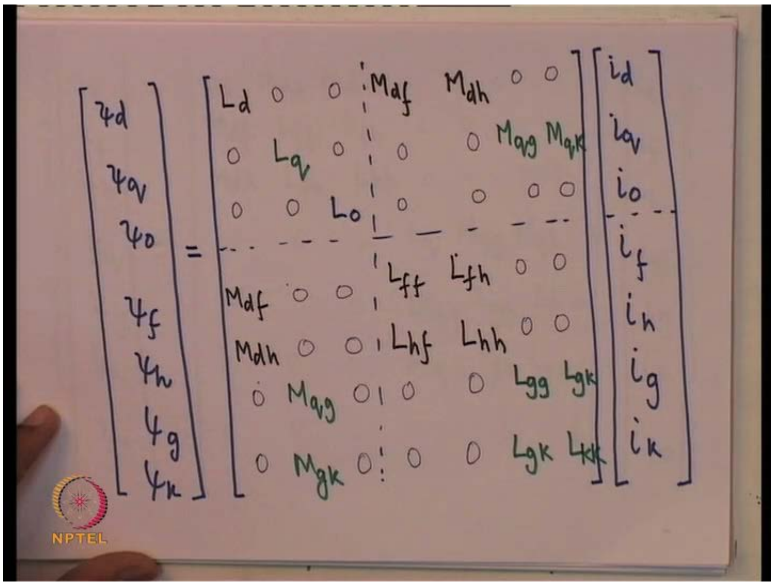
(Refer Slide Time: 04:29)



But you noticed the all the equations are time in variant theta invariant now, the rotor equations recall that we have represented the rotor as 2 coils on the d axis and 2 coils on the quadrature axis h g and k are representing the effect of damper bars as well as ready current effects in the machine.

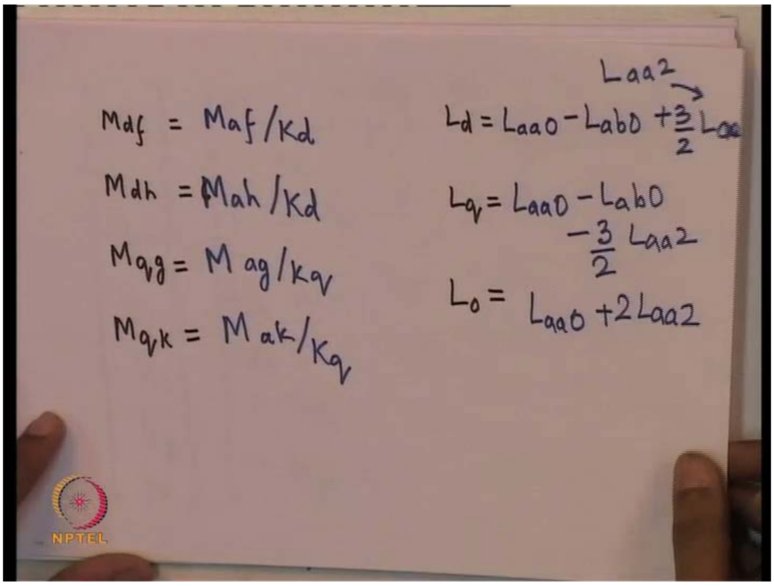
Now, v f is the applied voltage on the field winding if we recall an earlier diagram. So, your this is I f and this is v f so, this is the applied voltage on the field winding now of course, the equations which relate if you recall if you look at these equations they are not in pure state space form for example, they are differential equations are in psi, but you also have these terms id I q and I0 If Igand Ik If Ih Ig and Ik.

(Refer Slide Time: 05:37)



These are in fact related to the flux variables by this relationship which is of course, theta invariant. So, this is l d l q l 0 this is a diagonal matrix we have just shown the non 0 terms in bold this is of course, a symmetric matrix because we have chosen our k d and k q values such that we get this symmetry.

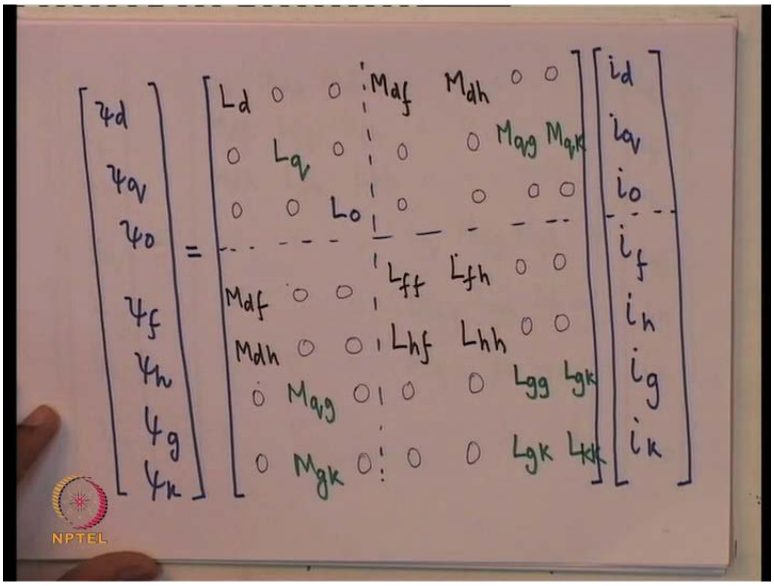
(Refer Slide Time: 06:23)



In fact the special choice of k d and k q was made in order to get this symmetry and of course, interesting property for c p and c p inverse in c p now remember that m d f here is related to m a f the mutual inductance coefficient by this formula. So, our m d f is m a f divided by k d m a f is in fact the mutual inductance between the a winding and the field a winding and the field winding in fact is the max value of the inductance.

Of the a winding and the field winding divided by k d of course, we have taken as k d by root 2 similarly, we can define m d h m q g and m q k and of course, remember that l d itself is can be written down as l a a 0 minus l a b 0 plus 3 by 2 times l a a 2 and similarly, l d l q and l 0 are defined.

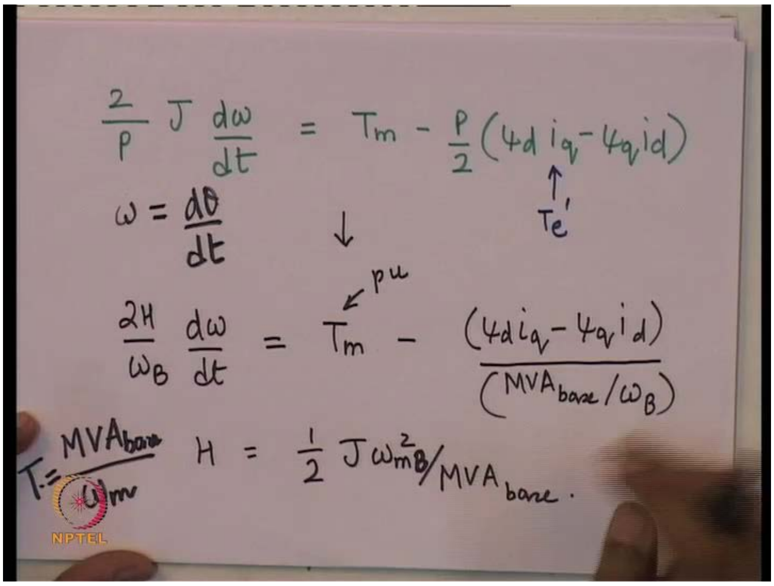
(Refer Slide Time: 07:20)



In this fashion so, these are of course, the original self and mutual inductance terms when written down using the a b c variables, but of course, when you go to the d q 0 frame of reference or the d q 0 variables this relationship is like this and of course, does not depend on theta. In fact you can aggregate all the windings on the d axis that is the d f and h winding around the d axis the direct axis.

Q g and k are on the quadrature axis and psi 0 is of course, the sequence flux. So, if you relate the d axis fluxes they are only dependent on the d axis currents similarly, the q axis fluxes are dependent on the q axis currents alone and psi 0 is dependent on I 0 alone. So I will just re arrange the equation and they will look like this of course, we remember that the d q variables are coupled, but via this differential equation.

(Refer Slide Time: 08:30)



Remember these differential equation in psi d has got this psi q term what we kind of inferred to be the speed e m f terms which comes because of taking the derivatives of the transformation. We have done of course, his in the previous class now our discussion would not be complete unless we talk about how omega or theta vary in fact omega itself is d theta by d t this psi the electrical angle theta.

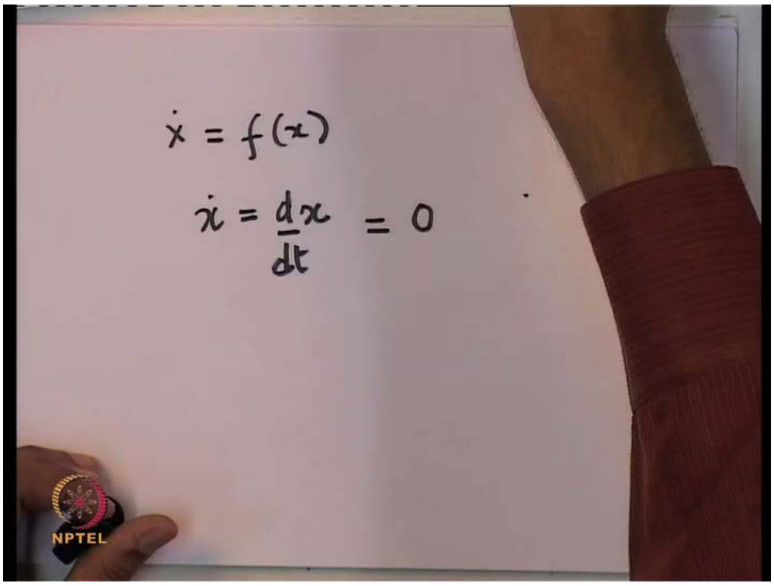
Omega is the electrical frequency so, we got this equation sometime back 2 by pi p is the number of poles j d by d t j d is the number of moment of inertia is equal to t m minus p by 2 into psi d I q minus Id psi d it is a very neat term for the t e dash. So, pi by two times the t e dash is actually the electromagnetic torque which we get now, we can write these in per unit by dividing the whole both the sides by the torque base torque base is nothing, but m v a base divided by the mechanical rotational angular frequency. So if you do that you can actually get this in this form where t m is the per unit torque mechanical torque the prime mover torque.

And h is nothing, but half of j omega mechanical base speed square divided by m v a base. So, this is basically if you divide both sides by the torque the mechanical torque base so, torque base is nothing, but note that we have not written down the synchronous machine equations in pure state space form that is x dot is equal to d x we have actually written it in a composite form.

We have written d psi by d t is equal to in terms of psi q if we for example, take fluxes as the states then we also use the auxiliary variables d Iq and I0 and similarly, if ig Ih and Ik, but then we relate the fluxes and current through an inductance matrix. So, we are not written this down in a pure state we are now in a position we are now in a position.

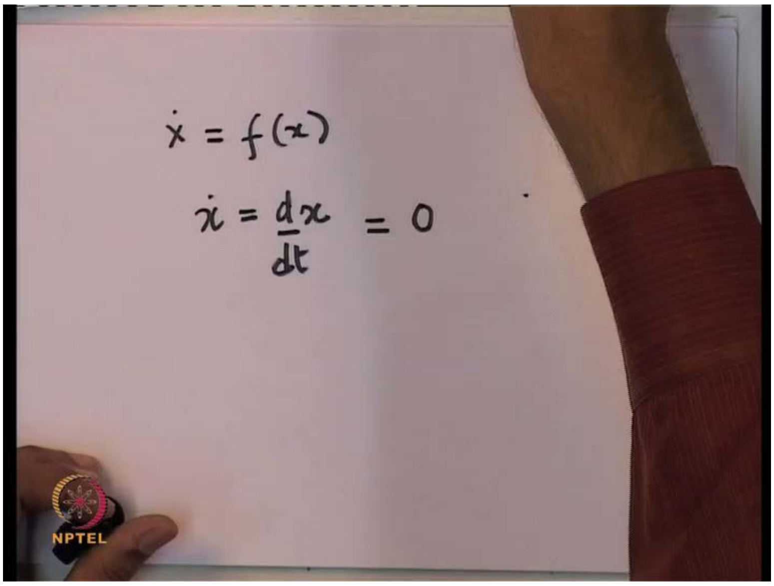
To actually draw inferences about the behavior of a synchronous machine that is how what we have doing this modeling after all we are trying to get how the synchronous machine behaves. So, what we will do is we will keep our ambition bit low at the present we will use these flux equations all the equations which you have written do to actually at least first infer the steady state behavior of a synchronous machine.

(Refer Slide Time: 11:21)



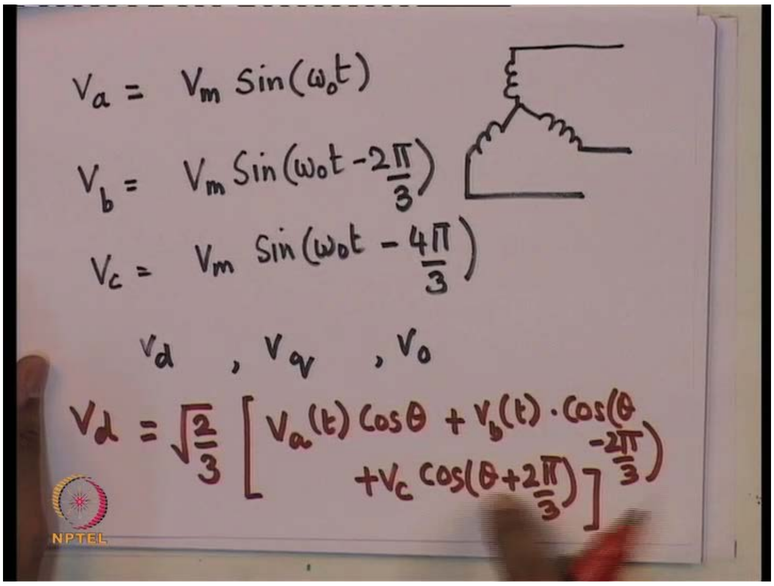
So, how do I infer the steady state behavior of a synchronous machine now the thing is that when do you say that a system x dot is equal to f of x is in steady state where x dot is equal to d x by d t we would say of course, the system is in steady state when this equals to 0 now.

(Refer Slide Time: 11:41)



The interesting thing about this whole set of equations in the d q frame d q 0 frame of references that although in the a b c frame. When we say we are in the steady state psi a psi b psi c are sinusoids it turns out if we are having a balanced system then psi b psi q and psi 0 in steady state become constant let me just give you an example.

(Refer Slide Time: 12:24)

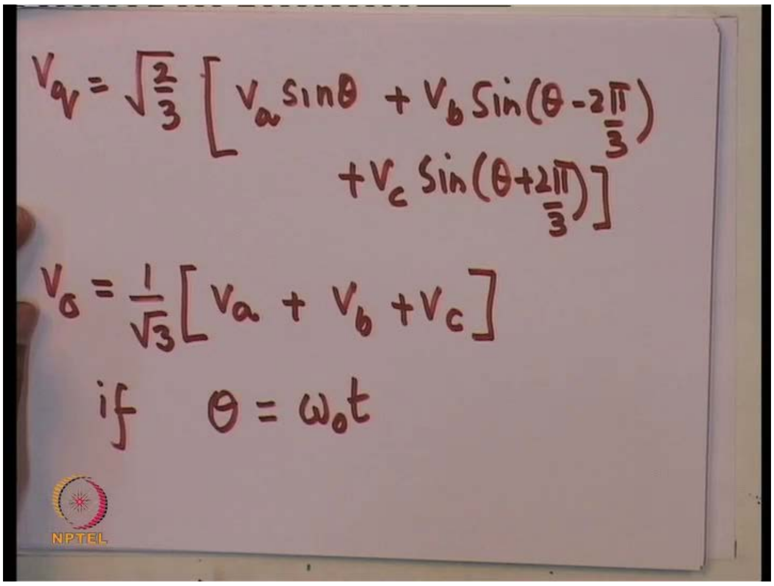


Suppose you have got a set of voltages v a, v b and v c and these are a balanced set of voltages. So, what I can write down v a as example of v a is equal to v max the phase to neutral max suppose have got a star connected machine.

The stator is connected to the same star then this is v sine and it is say the voltages applied to the stator have a frequency omega t n v b is equal to v m. Suppose this is a balanced set of voltages in that case what is v d and v q and v 0 v 0 is easy to get remember the transformation is.

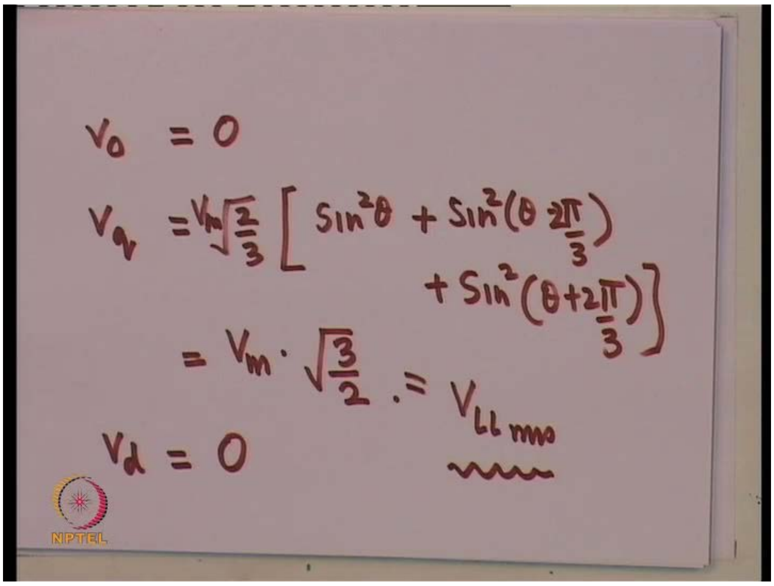
This of course, we are taking special values of k d and k q and k 0 k d and k q k are root 0 by 3 and k 0 is equal to 1 by root 3. So, I will just write down the expressions for v d so v d will be root 2 by 3 v a of t into I am sorry cos of theta plus v b of t into cos theta minus 2 pi by 3 plus v c into cos theta plus 2 pi by 3 plus 2 pi by 3. So, you have got v d is equal to this so of course, v a of t and v b of t and of course, t are like this the question is what is v d so what is v d.

(Refer Slide Time: 15:03)



And similarly, we have got v q is equal to root 2 by 3 v a v 0 is equal to. So, if the speed of rotation of the machine theta is equal to omega 0 t itself suppose the speed of the machine is omega 0 t. So, if theta is equal to the speed of the machine is omega 0 and theta is equal to omega 0 t.

(Refer Slide Time: 16:29)



In such a case we will have v 0 will be equal to 0 that is almost equal to v s its balanced set of sinusoids. So, you will have v a plus v b plus v c is equal to 0 and well have v q will be equal to root 2 by 3 into sine square theta plus so, it will be v m sine square theta plus sine square theta minus 2 pi by 3 plus sine square theta plus 2 pi by 3 and that will give you in fact this remember there is an identity which we discussed sometime back.

This this sum of these 3 terms is actually root 3 by 2 this is a trigonometric identity of course, multiplication factor of v m here we well have v m into root 3 by 2 and it is easy to show that v d will come out to be 0. So, in case v a v b v c are like this v 0 v q and v d are equal to 0 and in more importantly v 0 is equal to 0 v d is equal to 0 but, v q comes out to be v m into root 3 by two.

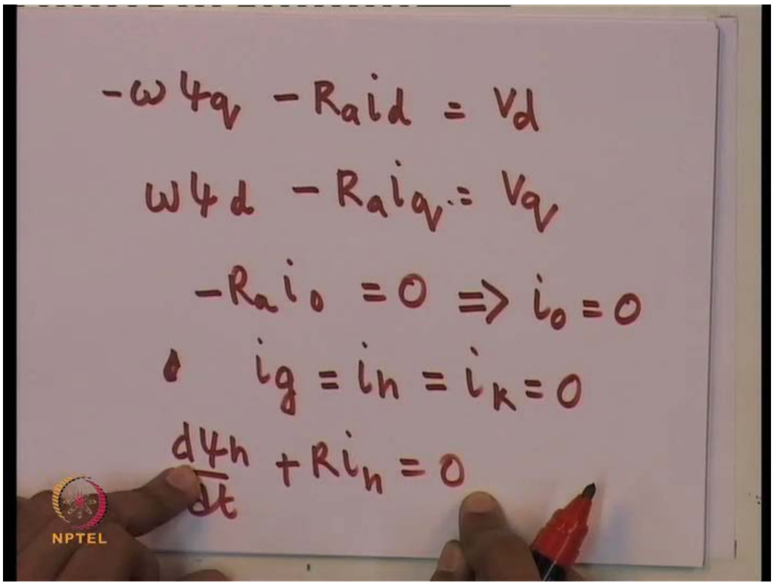
In fact this v m is nothing, but the maximum of phase the maximum of the phase to the neutral voltage for a star connected system here so, maximum of the phase to neutral voltage. So, it is easy to see that v q in this case is equal to the line to line r m s voltage of the system. So, actually what I wanted to show here is that if I got a balanced set of sinusoids then it turns out that v not v q and v d are in constants.

So, if you have got a if you are steady state in your system is a balanced 3 phasesinusoidal steady state it turns out that d q 0 variables act like constant. So, this is just simple example to prove that or show that actually now let us actually try to get some inferences from of the steady state behavior from our differential equation. So, one thing I showed you is that if you are in a balanced 3 phase sinusoidal steady state.

Then the d q variables become constant and if they become constants of course, the d by d t's of all the d variables are going to be 0 more over the field winding of a synchronous machine as well as the damper winding currents also, become constants in steady state in fact the damper winding currents are 0 so, Ig Ih and Ik are 0 in steady state.

So, if you have all these conditions it should be possible to infer the steady state behavior of a machine. So, what the first thing we will try to do is what if we want to see this what happens in case we have got a field voltage v f applied to the machine at the field windings in steady state what are the voltages induced on the stator so that is a very basic study that we can do so, what we do is take the differential equations of the synchronous machine set all the d by dt s equal to 0. So if you do that I will just draw few d by dts, so if for example, if we take the stator flux equations.

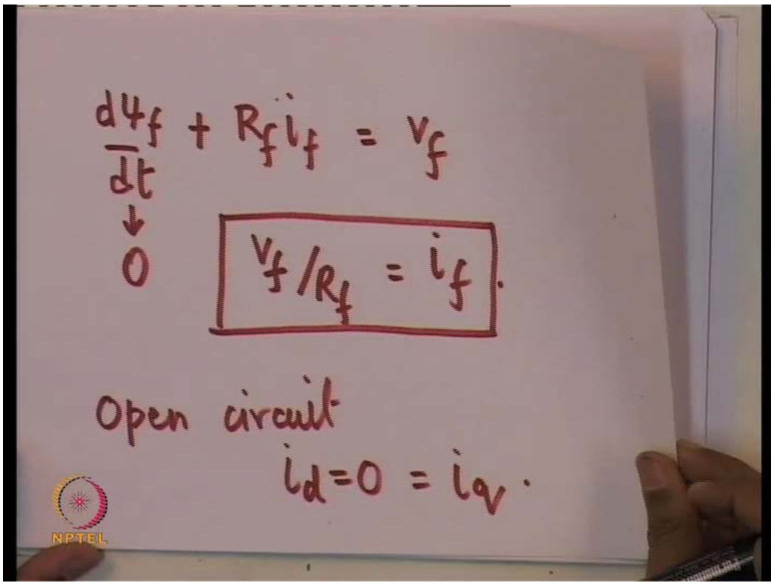
(Refer Slide Time: 20:21)



Since, d by dt is equal to 0 I have omega psi q minus r a Id is equal to v d and you will have omega psi d minus r a Iq is equal v q and of course, minus ra I0 is equal to 0 omega is of course, the electrical angular frequency please remember that now similarly, we have got i just mentioned some time ago so, this just implies that I 0 ids equal to zero.

You also have g these are the damper winding currents I h is equal to I k is equal to 0 this is of course, simply obtained by setting the d by dt is corresponding to the field windings equal to 0. So in fact what you have is d psi h by d t so, if we set this to 0 it automatically means that i h is equal to 0. So similarly, we can show that I g and I k also equal to 0 I f is not equal to 0 in steady state so, what we have is these two equations here and then well have.

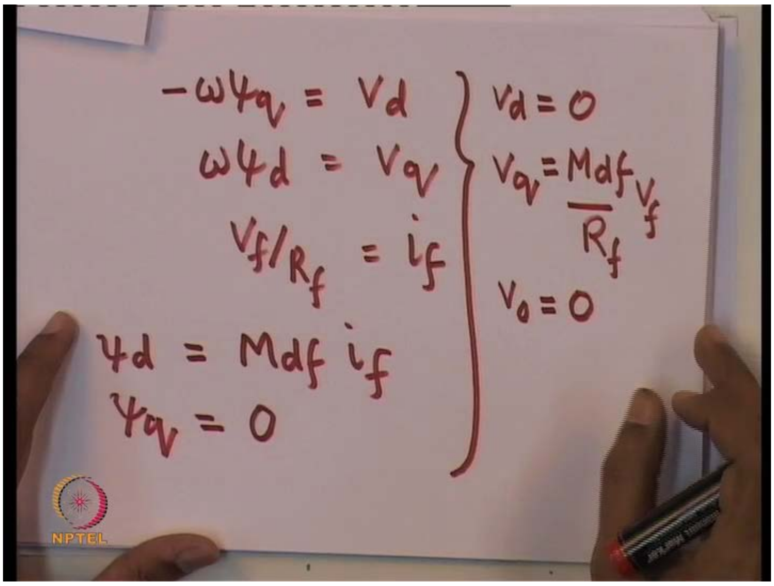
(Refer Slide Time: 22: 04)



So, we set this equal to 0 under steady state conditions so, that means that v f by r f is equal to I f. So, this is our second equation of importance now we also have from the flux current relationship if you look at this flux current relationship which we have we have got now this equal to 0 this equal to 0 and this equal to 0 and only non 0 currents are Id Iq and If.

But of you are also we are actually taking the open circuit voltages induced on the stator of a synchronous machine then we also have I d equal to 0 and I q is equal to 0. So, what we have under open circuit conditions the differential the algebraic equations which are there are very simple.

(Refer Slide Time: 23:22)

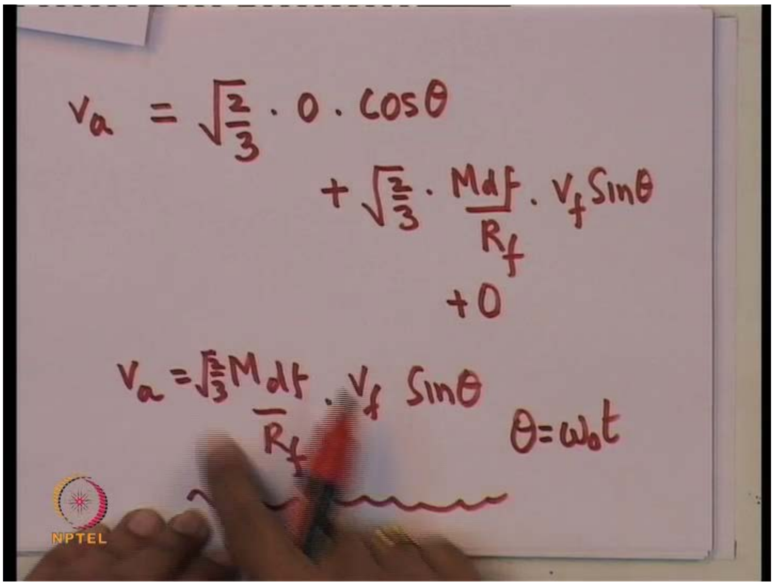


So, you have got omega psi q is equal to v d omega psi d is equal to v q v by r s is equal to if then we have psi d is equal to l d into i d, but of course, I d is equal to 0. So, the only term which comes is m d f into p I f all the other currents are 0 psi q turns out to be 0 because it is l q psi q is nothing, but l q into I q plus m q g into I g plus m q k into I k, but all these are in fact this is also 0 and this is also 0 under open circuit conditions I d and I q are also 0 under open circuit conditions so, what you have here is this is also zero.

So, under circuit conditions you will have from all this you can infer that you will have v d equal to 0 and v q is equal to md f by r f into v f there is a small correction here I have forgotten to multiply the term v q is equal to md f m d f by r f into v f I forgotten to multiply it by omega not.

Which is the speed of the rotational speed of the synchronous machine. So, v q the expression here md f by r f into v f has to be multiplied by omega not so, this is v q and of course, v 0 turns out to be equal to 0 is to so, what we have here.

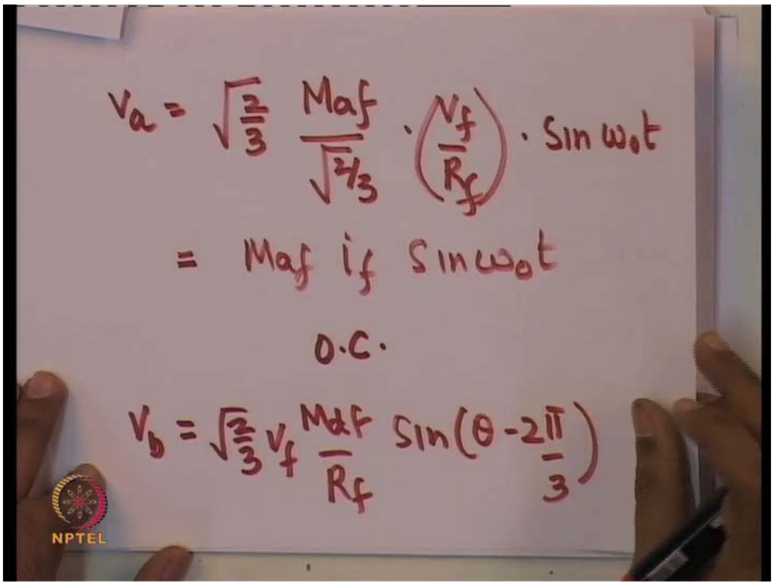
(Refer Slide Time: 25:41)



Eventually is a situation where we can find out v a from the value of v d and v q. So, what is v a from the transformation which we have defined v a is nothing, but root 2 by 3 into f v d so, v d is equal to 0 into cos theta plus root 2 by 3 into m d f by r f into v f into sine theta plus 0 so, if you have this.

It turns out that v a is m d f root 2 by 3 m d f by r f into v f sine theta. So, actually sine theta is theta if the machine is rotating at a singular frequency of omega not and suppose is equal to omega 0 t what you have is under open circuit conditions you will have a voltage induced which is nothing, but a sinusoidal voltage ad this is the coefficient corresponding to it.

(Refer Slide Time: 27:05)



Now, if you look at this expression v a is nothing, but root 2 by 3 m d f m d f is nothing m a f by k d, root 2 by 3 itself into v f by r f v f by r f is the current of course, into sine omega not t. So, if you look at this particular equation this is nothing, but m a f into I f into sine omega t. The expression for v a is m a f into if into sine omega not t has to be multiplied by omega not, there is a minor correction here.

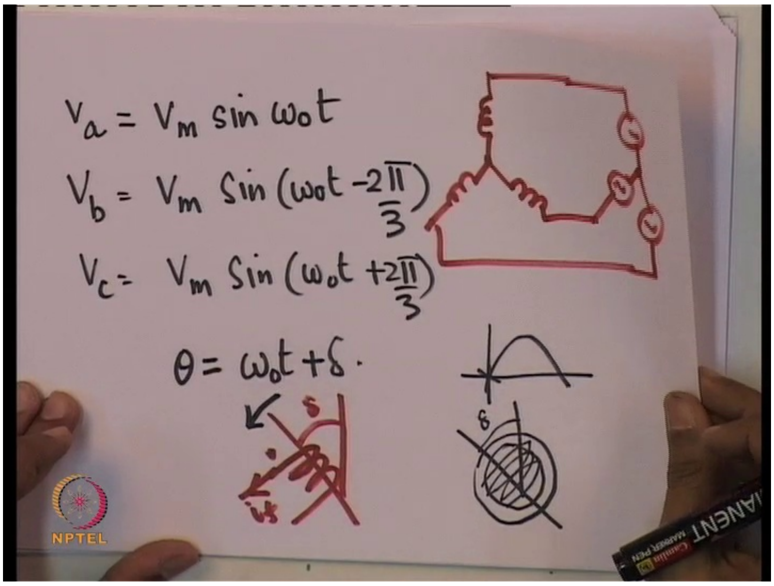
V a the expression for v a which is given as n a f into I f into sine omega not t has to be multiplied by omega not so, actually it is understandable why this is true. So, if you have got a current if in your field winding m a f I f is the flux link with the a winding because of the field winding and because of that we have got we are having this form.

So, this is the open circuit voltage on the a winding of course, b is equal to nothing, but root 2 by 3 in fact it is root 2 by 3 by m d f by r f into sine into v f sine theta minus 2 pi by 3 and similarly, we see it will be phase shifted by 2 pi by 3 so this is what we get when we apply the equations under steady state under open circuit conditions when v f is applied to this stator. So, let me just revise what are the steps we just put d by d t equal to 0 why do we put them to be equal to zero.

Because under balanced 3 phase sinusoidal conditions d q variables become constants in steady state. So, if they are constant d a by d tome equal to zero remember d psi a by d t is not constant in steady state. So, in fact the a b c variables are in sinusoidal steady state corresponds to the d q variables being in you can see d c steady state means the values become constant.

So, by d by d t has become equal to 0. So, that is one thing is one important thing now, well go one step further let us see what happens. When we connect the machine to a voltage source we are not having an open circuited machine we have connecting to a voltage source so, let us assume we have got a star connected machine.

(Refer Slide Time: 29:47)



So, the a winding b winding and c winding are connected to the voltage source there is a voltage source I have got a voltage source of this kind and let us assume that this voltage source is v a v max this is a constant voltage source three phase voltage source and a balanced one that too.

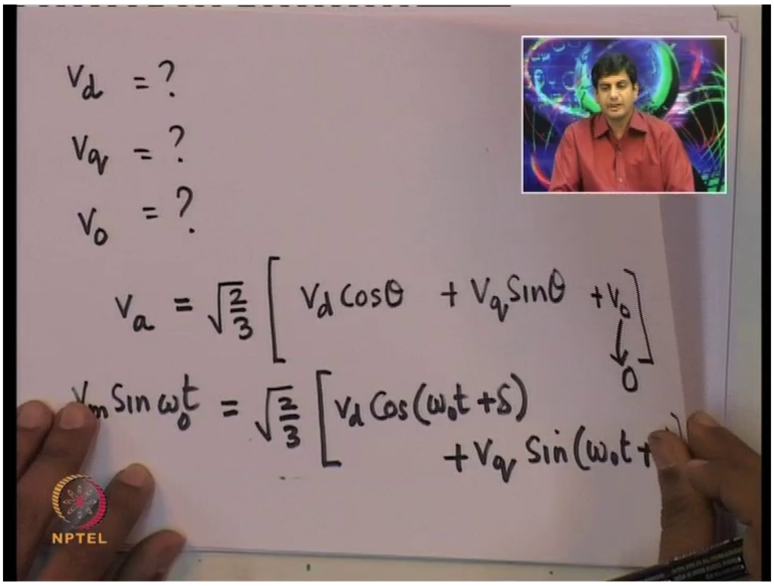
And v c is equal to v m sine omega not t plus 2 pi by 3. So, if you have got this voltage source balanced voltage source connected is a three phase balanced source connected here and let us assume that theta is equal to omega not t delta now, what I am trying to say here that, we let us suppose we are operating at a situation suppose we have we have got a steady state situation in which whenever this voltage v a n has a 0 crossing.

And I just take a quick snap shot of the machine I find that the filed winding which is here is at an angle delta let me repeat what I said suppose I am operating at such a steady state such, that if I take a snap shot of the machine when the phase voltage v a is crossing it is 0 has a 0 crossing here take a snap shot at that point I see that the field winding.

The field winding is aligned at an angle delta with the a axis winding. So, if this is your field winding remember this is your field winding. So, this is something I am telling you it is not something which is obvious I am just telling you that a situation I am studying is such that when the v a is having itI ,s 0 crossing this is at an angle delta that basically the speed of the machine is also omega not t omega not.

So, the voltages which are applied and the rotational speed of the machine are in fact the same only thing is that at time t is equal to 0 or whenever, v a hits the 0 if I take a snap shot this is at an angle delta so, such a situation suppose exists.

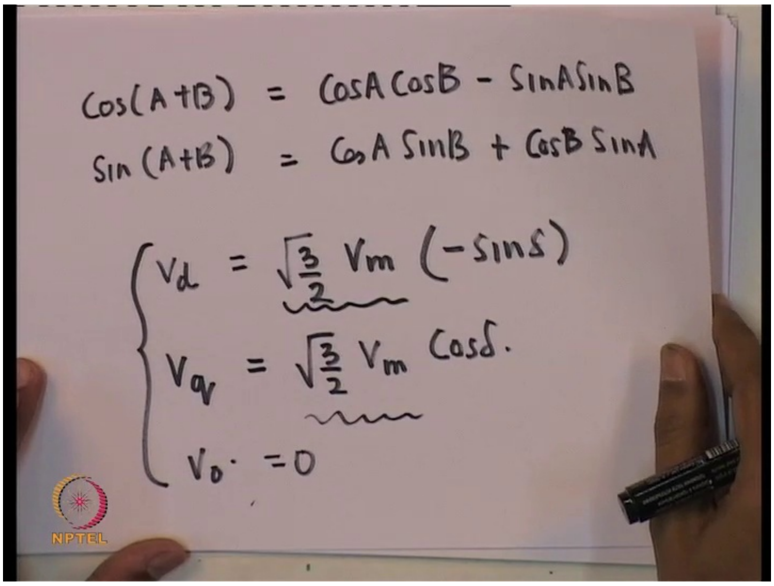
(Refer Slide Time: 32:58)



In such a case what will be v d v q and v not. So, we can apply of course, this transformation this transformation which you have studied with of course, k d and k q as root 2 by 3 and k not is equal to as 1 by root 3, but of course, I will not go through the complete manipulations let me try to just show by just show by inspection what you will get now you know that v a is equal from the c p transformation is nothing, but root 2 by 3 times.

V d cos theta plus v q sine theta plus v not v not of course, is 0 because v a plus v b plus v c is equal to 0 well this is 0 also since, v a is equal to v m sine omega not t is equal to t is equal to root to by 3 .So, we have v d cos theta I have told you is omega not t plus delta plus v q sine omega not t plus so, can you guess what v d and v q will be.

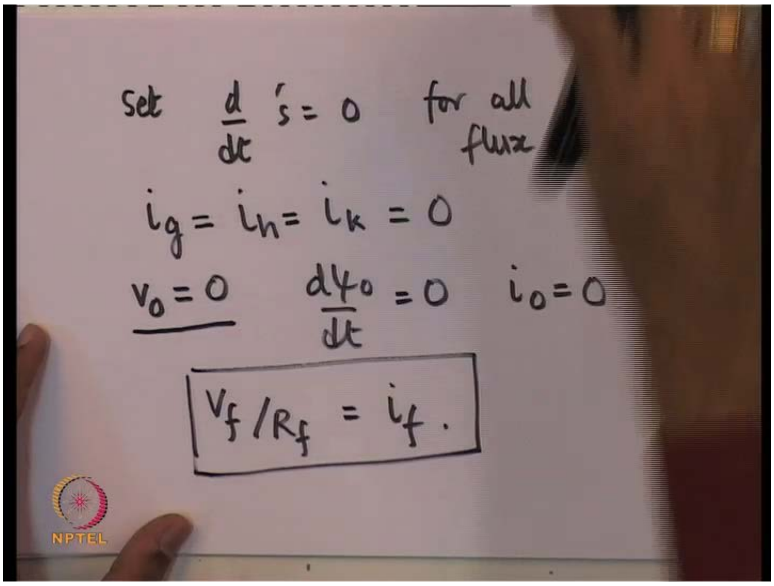
(Refer Slide Time: 35:03)



So, the question I am asking you is if I give you the right hand side and I tell you the left hand side is this can you find out what v d and v q are please recall the trigonometric identity cos a plus b is equal to cos a cos b minus sine a sine b and sine a plus b is equal to cos a sine b plus cos b sine a if you if you know this it is very easy to see that v d is if the left hand side and right hand side are to be equal then v d will be root 3 by 2 v m into minus sine delta.

And v q is equal to root 3 by 2 times v m cos delta. So, v d and v q become this in fact v m remember is the maximum voltage of the phase to neutral. So, if its star connected winding in fact this is the line to line r m s voltage this taken together is the line to line r m s voltage anyhow now that we have got v d v q and v not.

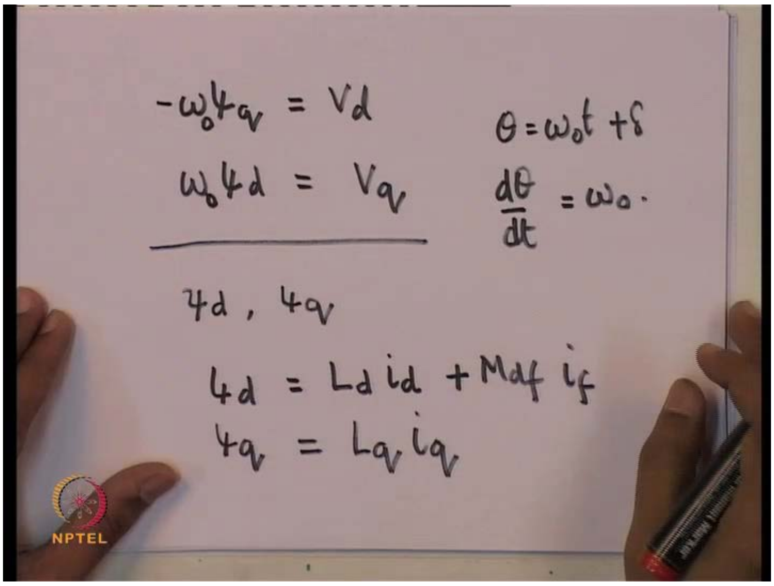
(Refer Slide Time: 36:48)



Can we take out again the steady state situation values of current and so on. Well in fact again we set the d by dt is equal to 0 set the d by dts equal to 0 for all fluxes because they become constants in steady state. So, remember of course, by doing this we will again get the same condition by damper winding.

And the fact that v 0 is equal to 0 v 0 is also equal to 0 and d psi 0 is equal to 0 also means I 0 is equal to 0 well also have from the flux differential field flux differential equations v f by r f is equal to I f. So, v f by r f is equal to I f this is another equation we have this is another important equation.

(Refer Slide Time: 37:53)

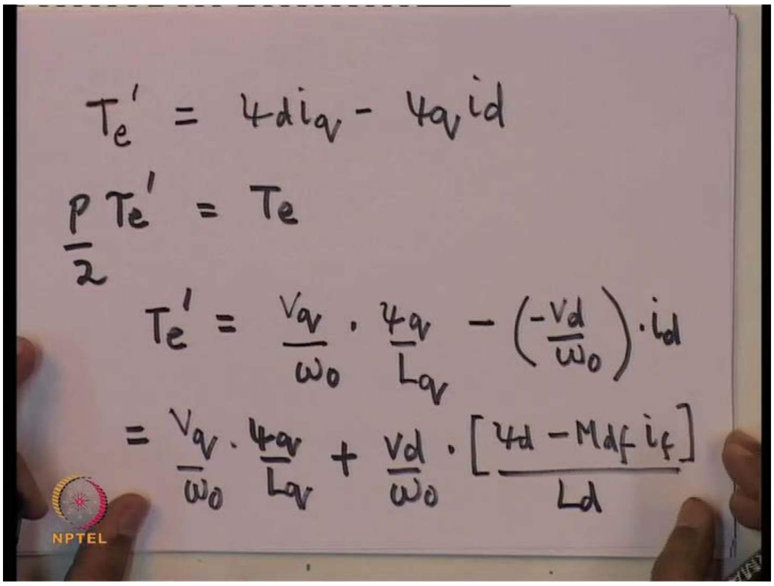


And if we neglect resistance of the stator then we also have minus omega psi q is equal to v d and omega psi d is equal to v q now, one of the things I mentioned sometime back is that theta is equal to omega not t plus delta. So, it follows of course, that this should be omega not because d theta by d t is equal to omega not is it.

I just discovered a small error in what we have done slightly earlier I will just write that down here too theta we have taken as omega not t this is the earlier example. So, in fact this should be into omega naught. So, this is a small error please note this small error what we did previously.

We continue our example of a synchronous machine connected to a voltage source. So, if we neglect the resistance of the stator in fact get this particular set of equations and because of this now we have got we can get the value of psi d and psi q how see remember that psi d equal to l d into I d plus m d f into I f.

(Refer Slide Time: 40:41)

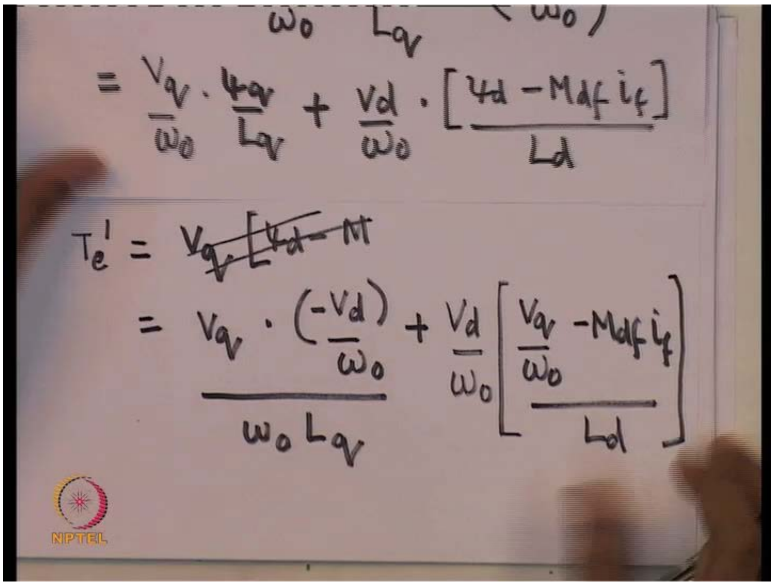


Psi q is equal to l q I q and of course, it is not related to since the other currents on the q axis are all 0 you do not have any other term. So, what we can do from all this is actually obtain the torque so, torque is equal to if you recall I am sorry electrical torque that is actually t dash actually is equal to psi d q minus psi q I d and this is in fact the electrical torque for the two pole machine for in general the electromagnetic torque is p by q times.

T dash this is something you should remember. So, if you are working with the 2 pole machine then of course, we finally, have if you want to take out t dash it will turn out to be psi d psi d is nothing, but t q divided by omega not v q divided by omega not into I q I q is nothing but, psi q by l q and psi q minus I q psi q is nothing but.

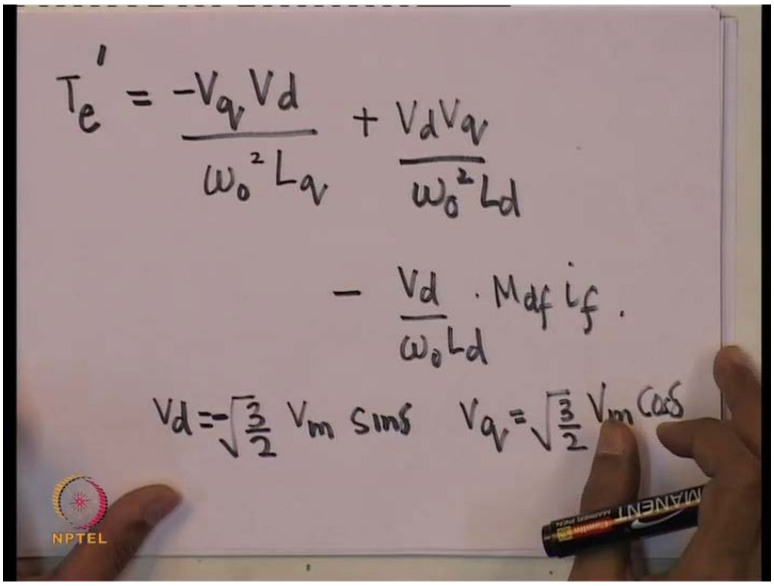
Minus of v d by omega not you can actually have a look at this these equations which we have just done in the previous slide into I d I d is nothing, butI will just rewrite this t dash is equal to v q by omega not into psi q by l q minus or we say we can call it plus v.

(Refer Slide Time: 42:49)



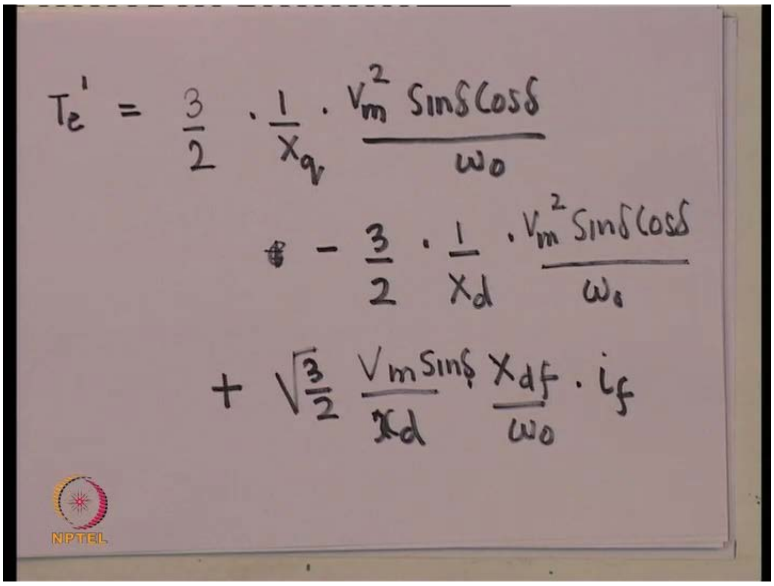
So, if we just continue with these manipulations well get t e dash is equal to you can substitute for psi q again here. So, well that is all v q into psi q psi q is nothing, but minus v d by omega not l q. so, plus v d by omega not psi d is nothing. So, if we gather all these terms again it is turning out to be quite an avalanche of equations.

(Refer Slide Time: 44:07)



We just be steady. So, minus v q v d by omega not I think there is omega not square is there l q plus v d v q by omega not square ld minus v d by omega not l d into m d f into i f. So, these are the expressions which we will get finally, form this actually v d and v q have already computed form previous manipulations there nothing, but v d is equal to root 3 by 2 v m sine delta minus of it and v q is equal to root 3 by 2 v m cos delta cos delta.

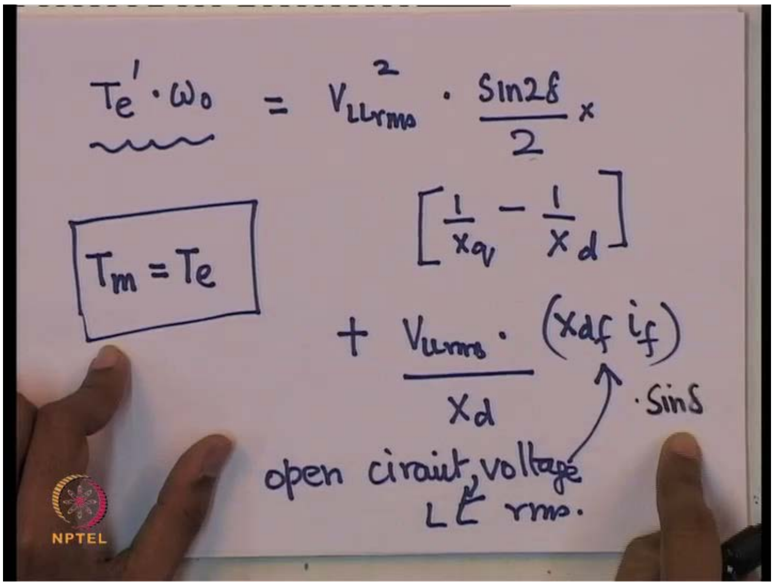
(Refer Slide Time: 45:32)



So, we can substitute this onto this and finally, obtain the electrical torque. So, what we get essentially t dash is equal to its it will by 3 by 2 one upon x d x q omega not into l q is x q you have into v m square sine delta cos delta plus that will have here by 2 times 3 by 2 times one upon x d into v m square sine delta cos delta divided by omega not minus.

Root 3 by 2 it is actually plus we are evaluating this expression please remember that, so i am evaluating now, this expression here. So, it will be root 2 by 3 root 3 by 2 , v m its d into x d f by omega not into if into sine delta now does this expression look familiar to you this expression in fact is something we probably done in our under graduate here.

(Refer Slide Time: 47:46)



What we are having here I will just re write this is nothing ,but t dash is nothing, but t dash or t dash into omega not this is power you can say. So, if you look at the power it is nothing, but 3 by 2 times v m square so, if you look at this 3 by 2 v m square we actually v m is the phase to neutral peak value so, 3 by 2 times the phase value of the peak by neutral is the fact is rather root 3 by 2 times the peak of the phase to neutral is in fact the line to line r m s voltage.

So actually we can write this as v line to line r m s square into sine 2 delta by 2 cos delta sine delta the product is sine delta by 2 into one upon x q into minus one upon x d plus v line to line r m s into by x d into x d f into i f, so in fact x d f into i f is the open circuit voltage I should say line to line r m s voltage we have just done this few minutes ago in fact when we had.

Obtained our open circuit voltages formula in fact v a is nothing, but omega not m df into I f sine omega t which is which also means open circuit line to line voltages is this this should have sine delta into sine delta here which was missed out.

So, what we have obtained is the steady state let us say it is called a power angle characteristic. So, the power angle characteristic of a steady state characteristic is given by these equations, but of course, if you are going to do only a steady state analysis to some extent that is keeping our ambitions too low as far as this course is concerned what we will do in the next lecture is try to build a ground for doing.

Transient analysis of a synchronous machine we will be not setting the derivatives of the d q 0 as well as, the filed flux and the damper winding fluxes equal t 0 well we will not be doing that, but one step which we need to take before we actually start getting the transient analysis of a synchronous machine is try to you know kind or rephrase or write your synchronous machines in a more user friendly or engineer friendly format.

What I mean is that that the synchronous machine equation as they have been written now are in terms of inductances and resistances these often are not easy to obtain the values of the inductances and resistances themselves are not easy to obtain by simple tests what we instead can do is prescribe a few tests from which we can back calculate these inductances and resistances.

So, let me repeat although we have obtained the synchronous machine equations we need to obtain synchronous machine parameters form a real machine. So, if I want to do the analysis somebody has to give me the parameters. So, i should define some tests and methods to back calculate the inductances in fact.

You may argue of course, these inductances can be analytically derived well while that is to some extent true form electromagnetic analysis you can actually compute fields and compute the mutual inductances and self inductances and so on. It is in general quite a difficult process more over remember that we have actually represented a synchronous machine.

By windings and sometimes the windings are actually representing the effect of eddy currents so, they are not actual they are actually no windings in some cases in such a case to obtain the mutual of the self inductances analytically it is going to be tough. So, as i mentioned back we have to prepare a ground for inferring these values from measured tests. So, whatever, tests we do we try to infer from these values and we will find out a way to fit the measured you know responses into this model remember that whatever model we make this is obviously something which is very important in engineering whatever model we have made it is based on a some assumptions, so we for example.

As I mentioned, in the beginning of synchronous machine modeling that our assumption that we can represent the synchronous machine effects by 2 windings on the rotor and 2 windings on the rotor and d axis and 2 windings on the q axis in addition of course, to the stator winding was an assumption we assume that we well be able to fit our results or rather well be able to fit the results in obtained tests to our model.

That is the basic point which is implicit in all our model derivation. So, in the next class we will try to actually take this a bit forward try to see how we can measure parameters and fit them into our model or rather obtain the parameters in our model from the measured tests.