Control Engineering
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Lecture - 14
Models of Industrial Control Devices and Systems (Contd….)

Having given the examples of motion control systems using certain hardware you recall the hardware we have used. we have used at DC motor for the actuator, a DC tachogenerator for the speed sensor, a potentiometer for position sensor and other suitable hardware were used to give you examples of motion control systems. Under motion control systems we have taken position control systems and speed control systems. The objective for today's lecture is to reintroduce the same concept of position and speed control system but through different hardware. The merits of the hardware being presented today vis-à-vis the hardware already discussed should be clear from today's lecture. That is, the emphasis is going to be on AC components instead of Dc. I am going to have an AC sensor called a synchro, I am going to have an AC motor called an AC servo motor a two-phase servo motor and other appropriate devices to constitute an AC motion control system will appear today; an important class and its application also will be highlighted.

So, to get going I will like to first take up the actuator of such a control system the two-phase servo motor. The two-phase servo motor is an actuator which is going to produce the required torque to actuate the load. So as is the as it is evident from the name this is going to have a two-phase system; it is a two-phase stator and let me say that this is one phase and this is the other phase (Refer Slide Time: 2:50). I will call one of these phases as the control phase, the reason will become clear soon and this is my reference phase, fine. Now on this particular rotor is the load and whether the load is direct on the rotor or through the gear train I can model like this, now you know it very well.

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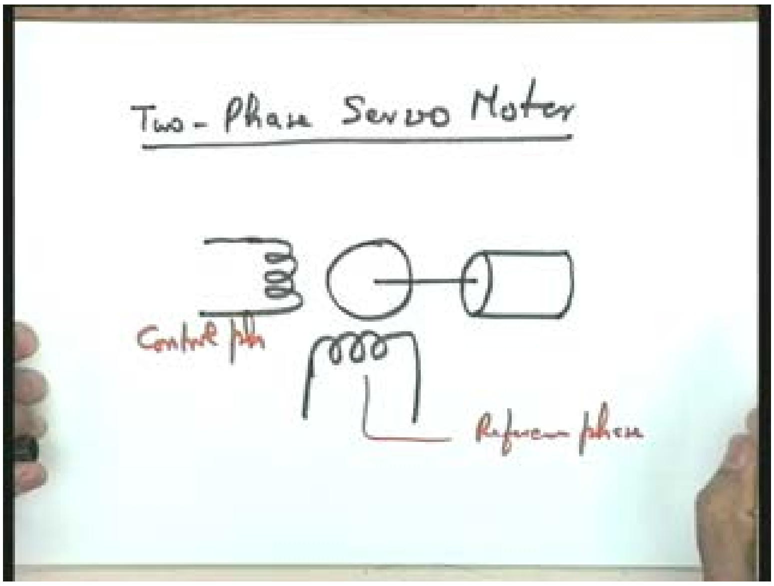

Let me say that J and B are the parameters of the load. I assume that the rotor produces a torque T M and T w is the disturbance torque on the motor which naturally opposes T M as per this schematic diagram. So, in this particular case now what I do is I put in this particular circuit a phase shifting capacitor. The idea is this that the two-phase apply I should be able to get through a single phase voltage supplier available to me. So if have a phase shifting capacitor here the natural consequence will be the phase difference between the two-phases here which is going to be 90 degrees.

So this reference phase let me say has got the voltage supply E r cos omega c t. omega c the name the frequency as you will see shortly is a carrier way frequency, the c is coming because of that reason; it is the carrier way frequency an E r stands for the reference voltage. For reasons to be made clear shortly I put a modulator here a modulator and this is the AC supply here (Refer Slide Time: 4:46) and what is the input to the modulator; the input to the modulator is the control voltage e c. I need your attention here that the input is control voltage e c taken over here which is always in a control system a low frequency voltage.

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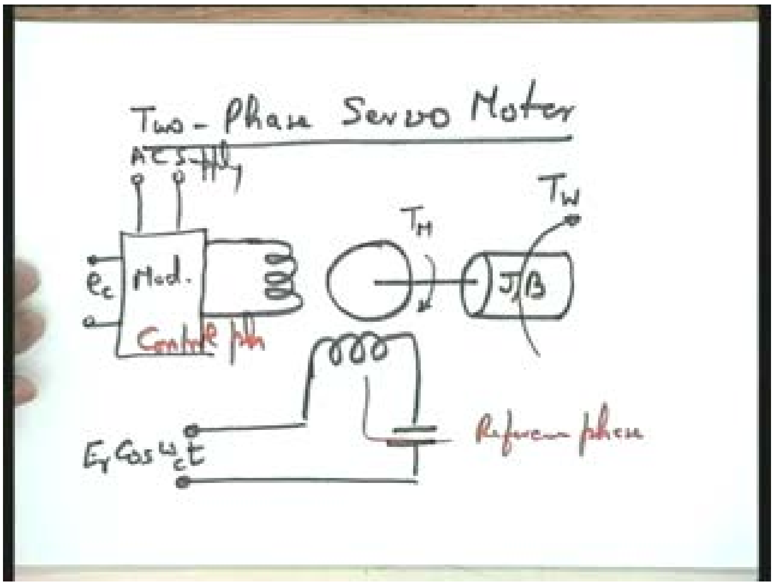

Recall the specific objective of e c what is e c? e c is an error signal, e c stands for an error signal in a feedback control system and the specific objective of the errors of the control system is to nullify this error to reduce this error to zero. So typically if a control system is functioning well this error e is going to be low a frequency signal it is going to be a small signal and let me take a typical error signal of this nature.

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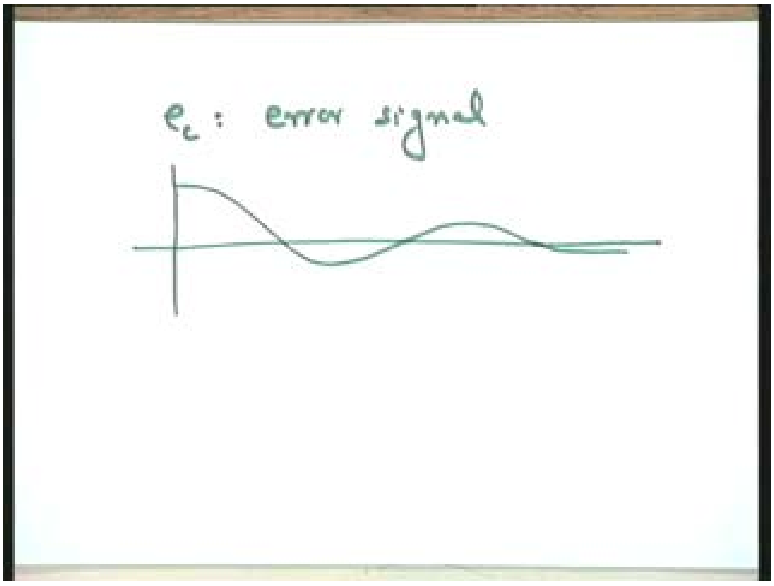

Let us say this is the error in the controlled position and the reference position or it could be the error in controlled velocity or the reference velocity. So in this particular case now if this e c signal is the input to this motor (Refer Slide Time: 5:59) I will like to modulate this signal. So, in this particular case the modulating frequency is going to be omega c which is the carrier frequency. So let me take the nature of the signal, let me see what the nature of signal will be when the signal reaches the control phase.

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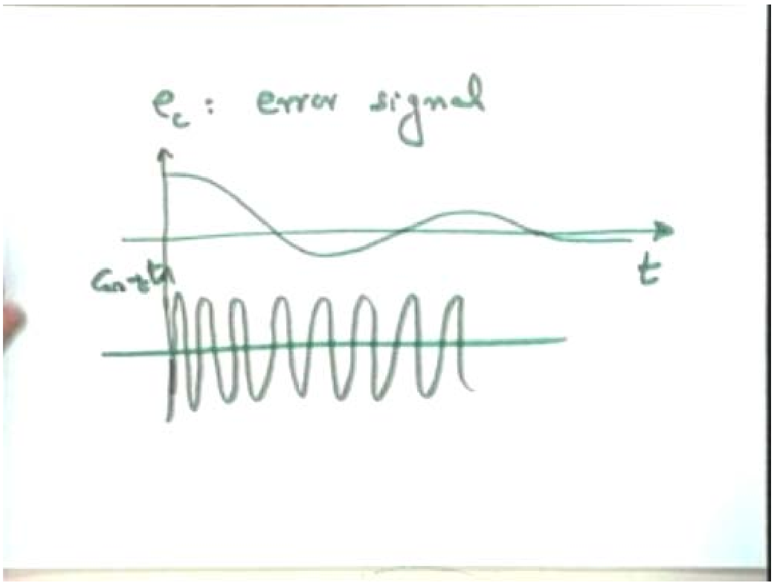

I take this as the carrier frequency for the modulator. So this is my omega c t cos omega c t signal, fine. Let us see what is the nature of the signal, I call that as e m applied to the control phase. This signal will look like, as you know already, a modulated way of this nature the envelop of this particular wave, this, I need your attention at this particular point I will be using this concept in the derivation. This is the envelop of this particular wave which is a low frequency signal e c.

How about this carrier?
now just see that when e c is positive, your attention here, when e c is positive I take this signal e m to the in phase with the carrier and therefore when the maxima of this comes the maximum of this will also come. My diagram may not be clear very clear because it is a rough diagram coming to you but you see that the maximum and this and the maxima of this coincide so that the phase of e m that is e m the modulated signal is in phase with the carrier signal.

Now, when the sign of e c changes in that particular case the phase reversal will take place. So it means in this part of the curve e m should be empty phase to cos omega c t. let me show it this way. This is the maxima (Refer Slide Time: 7:57) so let me show it just opposite, this is the minima so here is the maxima and so on. Now again the phase reversal is taking place at this particular point. So in this peak case again an e c becomes it positive and hence e m will be in phase with e c; so making e m will be in phase with e c is your responsibility to draw a suitable curve.

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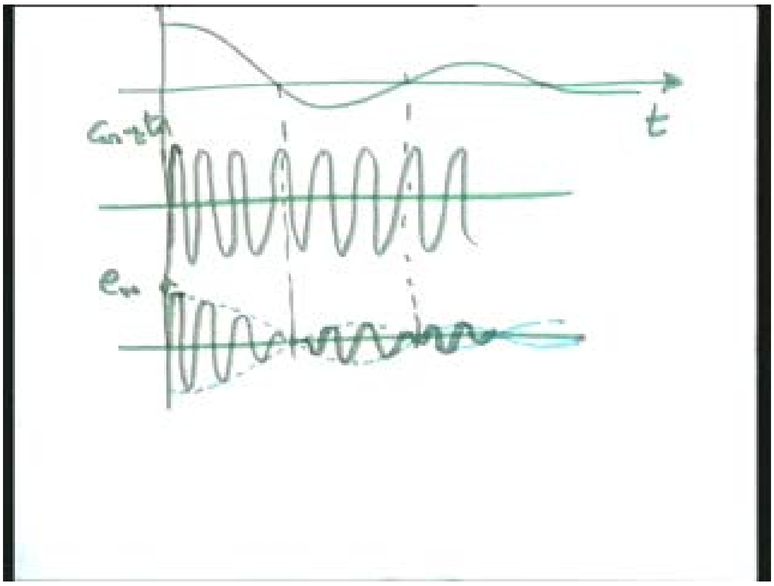

What I want to say is this that, at this particular point where the e c changes its sign the phase reversal of the e m signal occurs and it is because of this phase reversal the reversal in the magnetic flux takes place and hence the direction of the motor reverses. So this is a bidirectional control system bidirectional control motor wherein for e c positive the motor is moving in one direction and for e c negative equivalent effect being in the phase reversal of e m the rotation of the motor will be in the reverse direction. So that way e m is a carrier modulated wave at frequency omega c and the reference voltage is at frequency omega c. These two voltages (Refer Slide Time: 9:15) given to these two-phases will produce a torque on the motor and the torque naturally is going to be a function of the magnitude of the voltage e c E r being fixed; it is going to be a function of the magnitude of the voltage e c and its direction is going to be a function of the polarity of e c, this should be very clear.

Now let me see how this motor behaves. If I make a torque speed characteristic curve over here, this is speed on this axis and here is torque on this axis (Refer Slide Time: 9:49) and if an experiment is conducted the results will be of this nature. You will please note that I am very clearly showing here that the curves are nonlinear. So it means an AC motor is effectively a nonlinear device. There is a nonlinear relationship between torque and speed. recall the case of DC motor, in the case of DC motor, let me just show it in a separate window arrangement, in the case of the DC motor it is the speed it is the torque the torque speed characteristics are almost linear. So it means a DC motor is the linear device while an AC motor is a nonlinear device if positive point for selection of the DC actuators because your mathematical model will be linear in nature. I need this point should noted over here that the linear characteristics of a DC motor is a positive attribute because the mathematical model will be linear over a wider range of operation. While in this particular case the mathematical model may turn out to be nonlinear if the range of operation becomes too wide.

However, DC motors still have got certain advantages and these advantages will become clear. So, in this particular case the AC motor characteristics, if I linearize, a linear curve appears like this. But what should be the region of validity of this. Fortunately AC motors in position control systems are quite useful the reason being your normal operating point is this. Please see, in a position control system what is the steady state position? The steady state position means speed is equal to 0 that is the actual position of the load is equal to the commanded position and the motor is not moving; and under equilibrium state under the steady state the motor is at stand still and therefore speed is equal to zero is the equilibrium point of position control systems; and around this particular point you see even from the nonlinear characteristics you have more or less linear region and therefore for position control systems AC motors give reasonably accurate linear model.

Therefore, for the purpose of modeling I can forget about the nonlinearity, I can assume as if the characteristics are given by these linear curves. This point may please be noted. There is a strong assumption involved in it. You see, when I am writing a linear model the linear model is not valid for the entire region of operation; the linear model is valid under the assumption that this is my operating point which is speed equal to 0 and around this operating point the curves are linear. Therefore I am going to use AC motor as a linear device throughout my discussion under the assumption of this being the equilibrium point and which is hundred percent true as far as position control systems are concerned.

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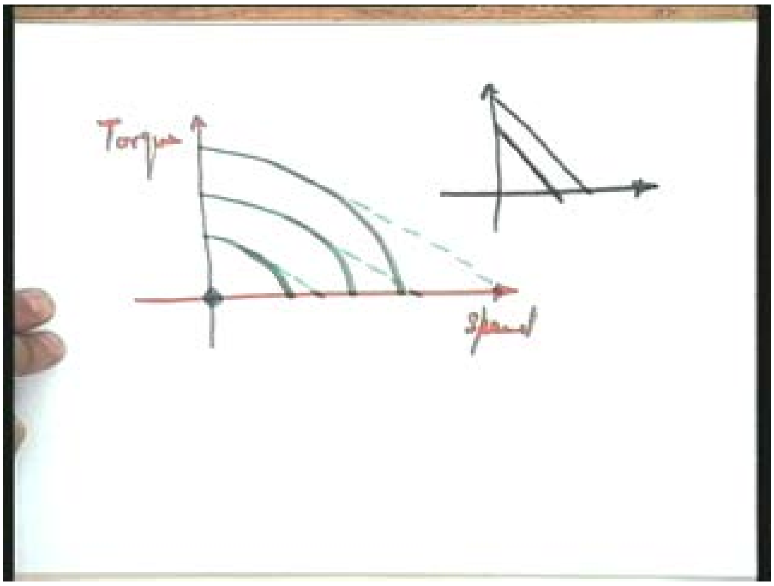

If that is the case what is the torque; let me write the torque equation. The torque equation becomes simple: K 1 T M should depend upon which factors please? It should depend upon speed. Obviously, as the speed increases the torque decreases and therefore the slope here is going to be the governing factor between among between the relationship between torque and speed. So this is slope K 2. What is the other factor? The other factor is going to be control voltage. Recall, e c is the input to the control phase. If e c is equal to E r than let me assume that this is the curve, let me call this as e c 1, this is e c 2, this is e c 3 (Refer Slide Time: 13:40). Please see that e c 1 is greater than e c 2 is greater than e c 3. So it means the torque is going to be a function of the control voltage and the speed. When the control voltage increases the torque increases, when the speed increases the torque decreases and hence as a perturbation model, mind the statement, a perturbation model means that in this is region around the equilibrium point I can write the equation as k 1 e c minus k 2 theta dot where theta dot is the position K 1 e c; k 2 is corresponding to the control voltage and K 2 theta dot corresponds to the speed torque relationship.

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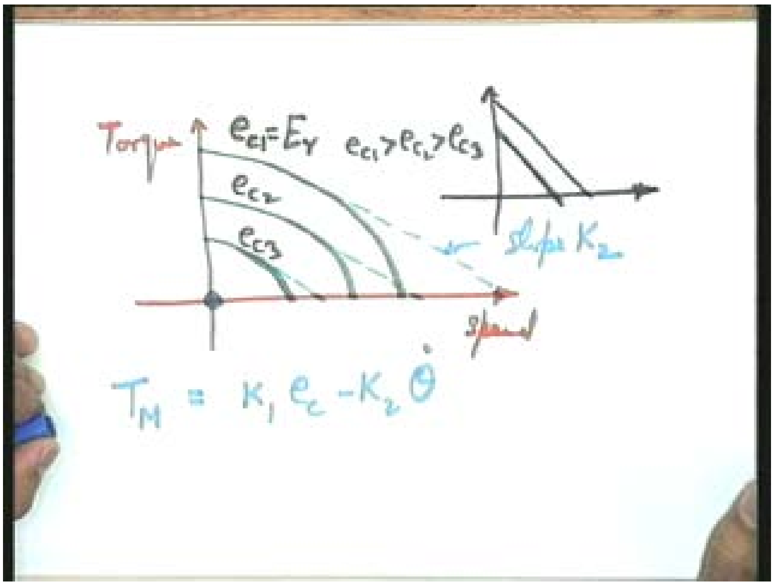

Once these curves are experimentally determined and given to you the mathematical model can easily follow from these experimental curves because K 2 you can determine from here; how about K 1 please; tell me how will you get the value of K 1? Very easily from this data itself you can make a different plot. That is, I can make a plot between control phase voltage e c on this axis and torque on this axis; let us say this is the curve for omega equal to 0 and for different values of omega you can take for omega is equal to omega 1 for example. So, in that particular case what is K 1; K 1 is going to be the slope of this particular curve, they will be more or less linear in a linear model but however, this is in assumption that the linearity assumption we are taking up for a nonlinear device which we know is true for a restricted range of operation. So, if I plot control phase voltage versus torque taking speed constant I get a line whose slope gives me the value of K 1; K 2 is directly available to me and therefore this becomes the equation for the torque developed in the case of AC motor.

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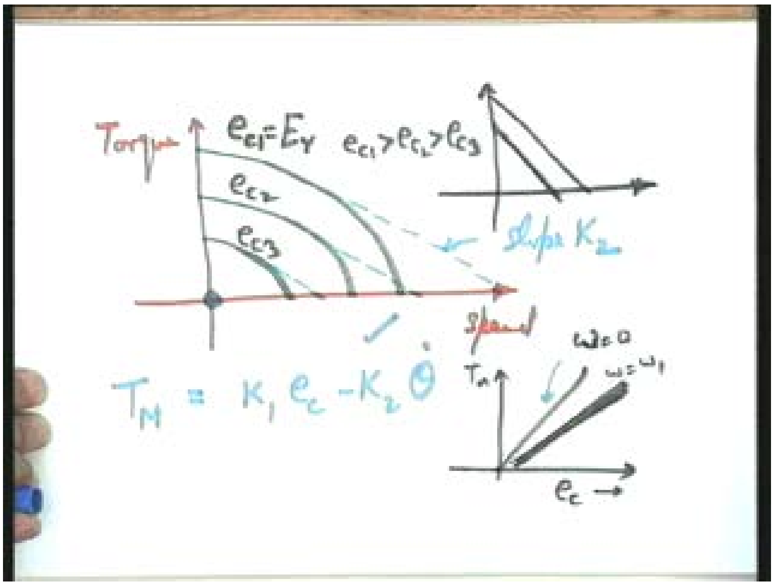

[Conversation between Student and Professor – Not audible ((00:15:44 min))]
I have never said that error signal is a constant. This is actually a torque speed characteristic you have experimentally determined for a motor. These are not the error voltages in a typical feedback control application. When you want to determine the mathematical model of a system you will conduct the experiments. so what you will do is you first give e c 1 is equal to E r a constant voltage to the modulator determine the torque speed characteristic for this, change the voltage, for a particular curve you are keeping this voltage constant. So when you are experimentally determining the torque speed characteristics then this is an applied voltage to the control phase and need not be the related to the error voltage because then you are getting these curves for different voltages. What is the effect of varying voltage is coming through this particular equation. is it alright please?

These are not the curves for a feedback control system; these are the curves you have obtained in the lab by experimentation and therefore keeping a voltage constant for a particular experiment is in your hand. Is it okay? Fine then.

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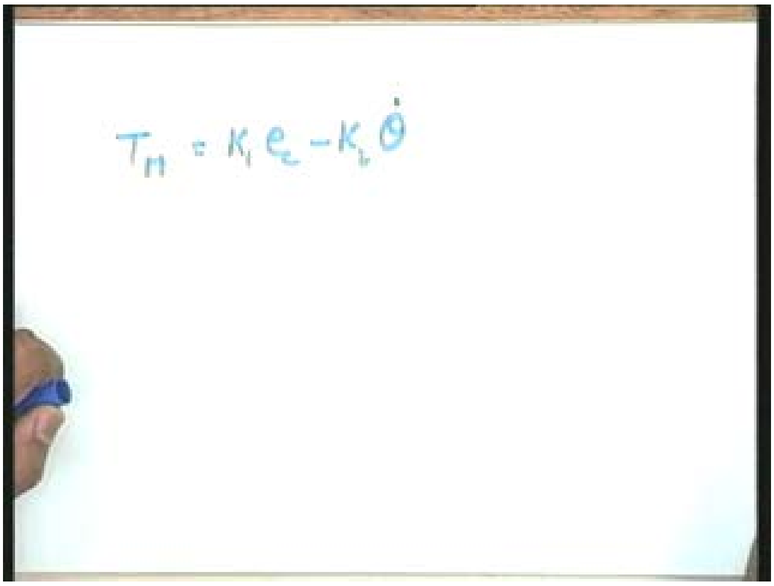

Going to this equation: T M equal to K 1 e c minus K 2 theta dot what is the load on the motor? The load on the motor is equal to J theta double dot plus B theta dot plus let me write T W this becomes the mathematical model of the motor under consideration. See this point: this can be written in the form k 1 e c equal to J theta double dot plus B plus K 2 theta dot plus T W. I can now write e c is my input, e c is equal to….. or well, probably we can directly take up the block diagram form that will be better; e c is the input you will help me here, what is the other signal coming? Between e c and theta if you are interested it this is given by this equation and T W is the disturbance torque on the system. So I can take over here a constant K 1 to generate the signal K 1 e c.

Now I can generate I can put a summing block over here and take a signal T W here. This is the net torque now which is driving the inertial load. And now I can put in inertial load over here; what is this value: 1 over Js plus B plus K 2 this is your omega here. So if I am interested in a transfer function between omega and e c the block diagram is complete. But if you want to bring the position into a picture put an integrator this is a position here (Refer Slide Time: 18:51). This becomes the block diagram of the total system, you will please note.

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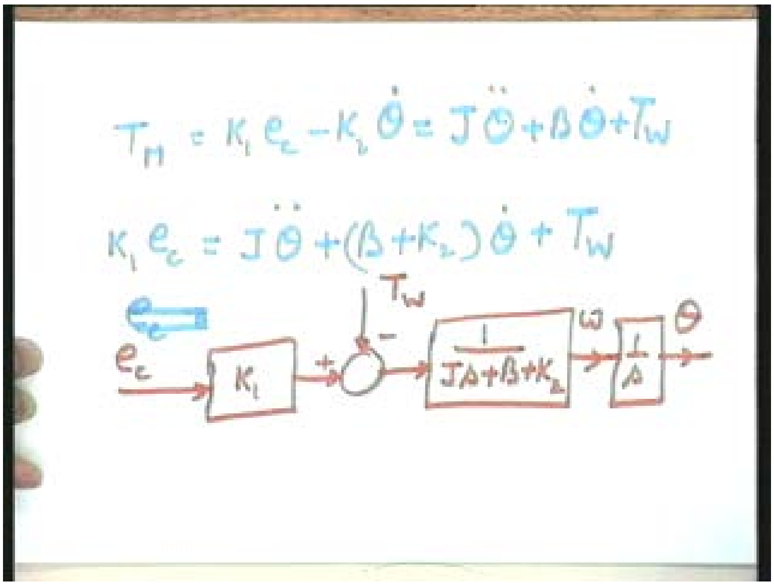

In this particular case if I am interested in the transfer function between omega and e c or between theta and e c the transfer function will look like……. help me please between omega and e c what is the nature of the transfer function? It is K 1 over Js plus B plus K2. I hope this is alright. K 1 over Js plus B plus K 2 this is the transfer function. Now can you show can you tell me what is the effect of K 2? Please see, K 2 is adding to the damping of the system, the mechanical damping of the system. So it means it is behaving, as far as damping is concerned, the way the DC armature controlled motor behaved. Please see, K 2 that is the AC motor is adding to the damping of the system and the time constant of the system becomes J divided by B plus K 2 where K 2 is a parameter of the system.

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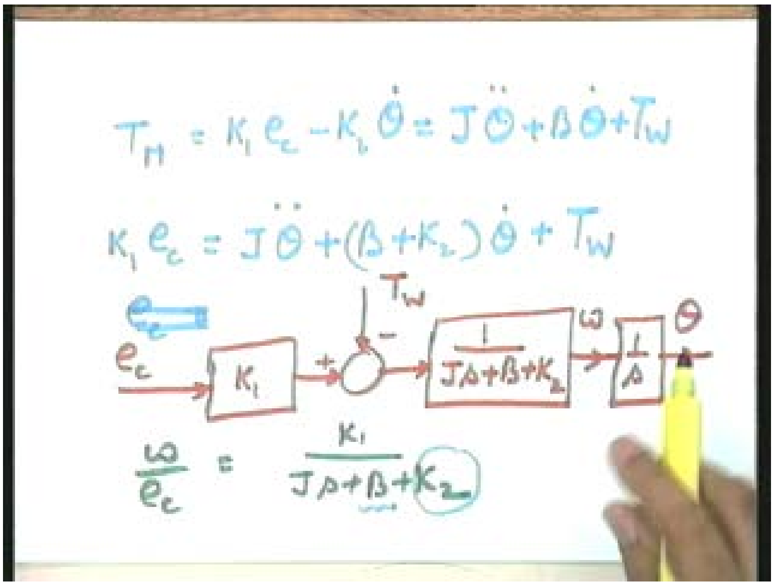

So I take this opportunity to explain one point to you; a typical induction motor a two-phase induction motor as you know has got this characteristics. My question to you is that can I use these two-phase induction motor for servo applications? I put my question again and really I am expecting an answer from you and to give you the hint I will tell you that concentrate on this equation (Refer Slide Time: 20:41) that the relationship between omega and e c is given by K 1 over Js plus B plus K 2 where K 2 edge to the damping.

Now if I take this characteristic this which is the characteristic of an induction motor that is if I use induction motor for servo application do you think there will be any problem or the system will behave appropriately as per your expectations? Yes, any answer please?
[Conversation between Student and Professor – Not audible ((00:21:02 min))] That is right. The answer is correct please.

In this particular case you will please note that for induction motor you are working at this particular speed but for a servo application you are working in this region. So, if the slope becomes negative in that particular case what will happen? If K 2 becomes negative (Refer Slide Time: 21:26) this amounts to negative damping and negative damping depends upon what is its magnitude in relation to B can even lead to instability or the hunting naturally will come, too much of oscillations naturally will come but it can even lead to instability because of this damping because K 2 has a negative sign.

Now it depends, what is the net damping will depend upon the magnitude of B. the magnitude that is the B value has to be extremely high to take care of this negative damping effect. It is because of this reason that this characteristic is never allowed in servo applications and hence an ordinary induction motor cannot be used for servo applications. By servo applications I mean position or speed controlled systems. What you need is you need this characteristic you will recall this is the characteristics we had drawn and in this characteristics the slope is always positive it is never allowed to be negative.

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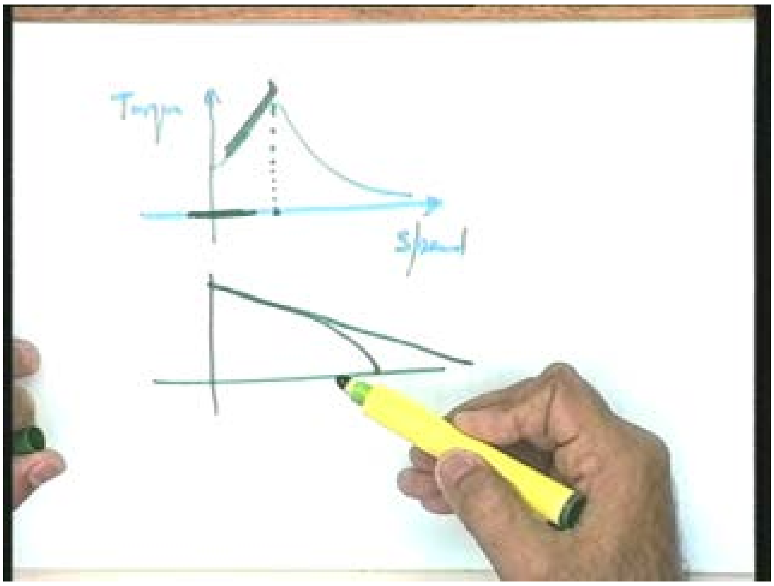

How do you get these characteristics?
These characteristics you directly get from the induction motor only by using high rotor resistance. So you see that a servo motor is nothing but an induction motor of high rotor resistance so that the characteristics of a servo motor always has a positive slope. So you are paying a heavy price as far as efficiency is concerned. High rotor resistance means net efficiency of the system is going to be low; the net efficiency of the motor is going to be low. But naturally

we cannot help it because our specific application is a servo application wherein the negative slope is not allowed. So in this case this point has to be kept in mind that an induction motor if you are using for servo application redesign it or take care of this point that it always has a positive slope. With this now I can go back to the motor model.

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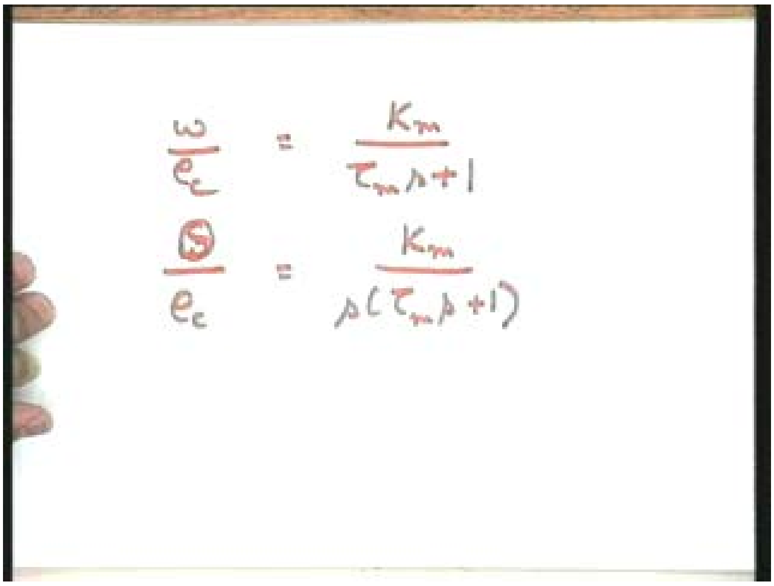

The motor model looks like this: Omega divided by e c is equal to K m the motor gain divided by tau ms plus 1 where tau m is the mechanical time constant of the motor. This is a first-order system between speed and the control voltage. Now, if you are interested in an equation between theta and the control voltage it is going to be a second-order system it is K m divided by s into (tau ms plus 1). This is the mathematical model which as you know is identical to an armature controlled DC motor a second-order model. I, at this particular point, will need your attention on this system block diagram once again.

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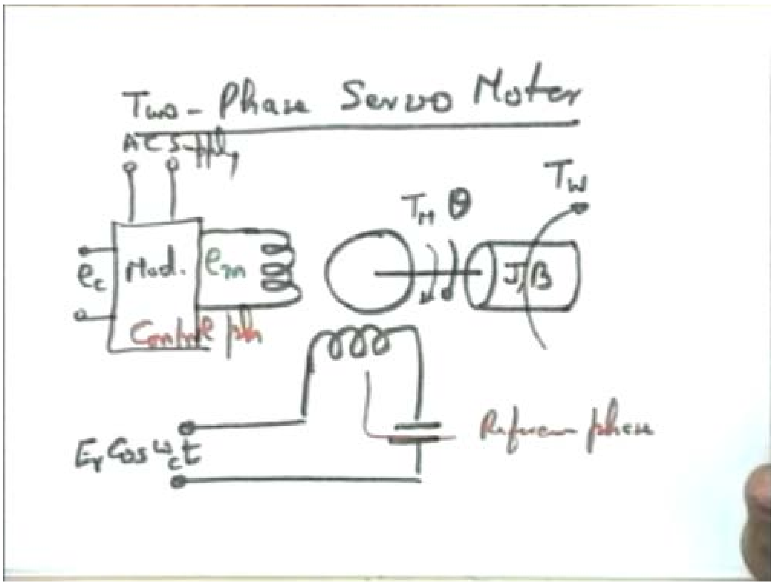

You will please note that I have taken a transfer function between e c the control voltage applied over here and theta M are theta which is the position of the motor shaft. What is this e c? e c is the control phase voltage which is a low frequency signal. Consider a situation, you see, consider a situation in a control system that the control phase voltage is directly a high frequency signal a modulated signal. Your attention here please. It means the input to the control phase is e m and the output is theta and you are interested in a transfer function between e m and theta. So now input output pair of the system could be taken as this way.

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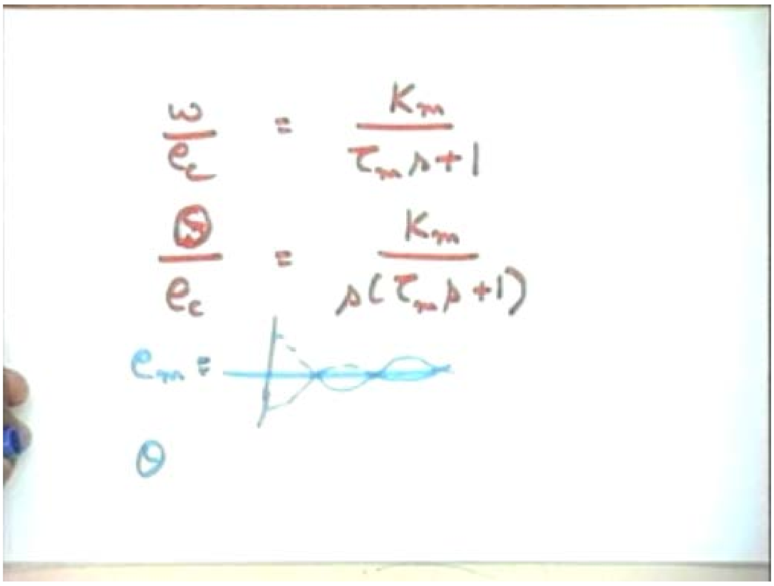

What is input?

Input is equal to e m which is of this nature and what is output; output is theta the position. Yes please.

[Conversation between Student and Professor – Not audible ((00:25:24 min))]

This is what I was going to say. I thought in that particular case I could have delayed this discussion but okay let me reemphasize this point. In a typical control system application……. this is fine as far as the motor model is concerned. In a typical control system application the input to this particular motor (Refer Slide Time: 25:47) is the signal which is going to the control phase.

Now I said that as I will illustrate it through applications in some systems there are devices which are connected on to the left hand side of the motor that is the devices whose output is given to the motor those devices may be directly producing a modulated signal. See this point please; I think I have confused you so I will like to make this point further clear by taking a feedback control system. I take this as feedback control system plus minus and amplifier or any other device and this is the motor; omega over here, 1 over s, theta over here, this theta is being feedback.

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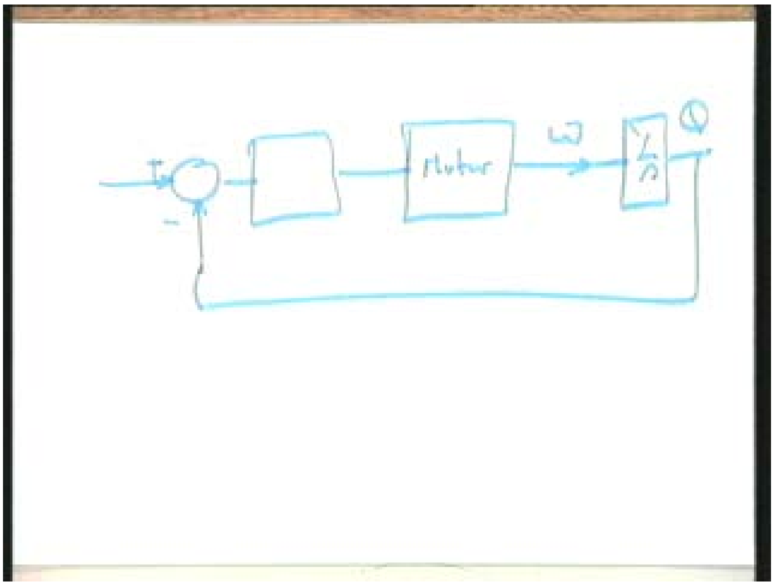

Now please note my point; what I want to say is that I have taken the transfer function between omega and the input to the motor; the input to the motor is control phase voltage. Now that will depend upon this device. I am going to tell you that there may be a device over here which is going to produce a low frequency signal in that particular case that e c is the input and the transfer function which we have derived should be use the wave we have already derived it.

Now, suppose I have a device over here this device which produces a carrier modulated signal is the signal which is being fed to the control phase of the motor. In that particular case as far as motor is concerned that motor is taking or getting a carrier modulated signal directly as an input signal. So it means as far as the transfer function is concerned it appears I should take the transfer function between omega and the carrier modulated signal. Here just I want it to convey this point here; (Refer Slide Time: 27:44) if this is the input signal coming from this particular device in this particular signal the actual information about the control is carried in the envelop only and this particular carrier signal is simply the operational frequency of the motor. What I want to convey to you is that this operational frequency may be 50 cycles per second may be 400 may be 1000 it simply depends upon the design of the motor it simply depends upon what the manufacturer has given to you. And as far as the system is concerned as far as the control information is concerned the control information is carried in this envelop and therefore the mathematical model of the system could be taken as the relationship between the speed or the position as the output signal and the envelop of this particular signal as the input signal.

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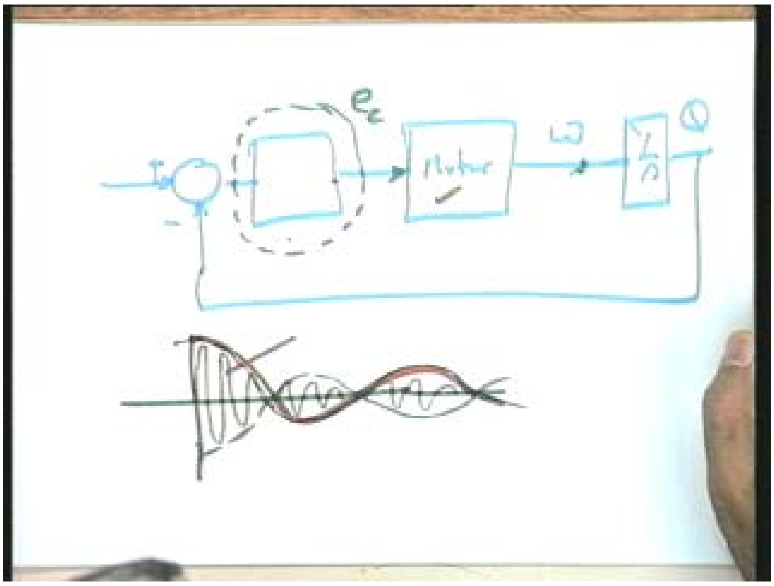

So my point is this that to the AC motor if the signal is directly a low frequency signal and is coming to the AC motor through a modulator in that particular case that low frequency signal will be taken as the input for the motor. But if to the AC motor a carrier modulated signal is coming as the input signal in that particular case I will take only the envelop of the modulated signal as the input to the motor as far as control application is concerned because this particular frequency is just an operational frequency of the motor and it simply depends upon the design of the motor. you may use a 50 cycles 50 Hz motor the operational frequency will become 50 Hz, you may use a 1000 Hz motor the operational frequency will be 1000 Hz but the envelop will remain the same because this envelop is a information carrying signal and this information is the information about the discrepancy between the commanded position and the actual position. Is it alright please?

This even if it is not very clear at this stage I assure you will become very clear when I take the control system applications; when you will see that there are devices which actually give you be carrier modulated signal directly to the motor and you will extract the envelop of this particular motor as far as the input output relationship is concern because this carrier frequency is not important.

Now, if the carrier frequency, I made a statement which is a week statement if not a wrong statement; I said carrier frequency is not important it is not that, it is important but the importance is taken care of in a different way. So, when do I select a motor of 50 Hz or a motor of 1000 Hz please see, if this is the question. What is the selection criterion? You see that AC motors naturally are not going to be susceptible for low frequency noises. So, if I assume or if in an application I expect that there will be low frequency noise I should take up a motor of high frequency that is why in aircraft and missile systems normally 400 Hz or 1000 Hz motors are used but for ground applications we use 50 Hz motor and not the high frequency motors. It depends upon the application.

In aircraft systems the low frequency noise is present abundantly and to filter that noise to reduce the effect of that noise we normally go for high frequency motors. So, whether this selection is

50 Hz of 1000 Hz, please see, it depends upon other considerations and therefore in modeling I will not like to bring this aspect at all. So I will say that as far as the information is concerned the information is carried in the envelop of this particular signal and therefore the motor model which I have written as omega over e c or e let me say or e c can be taken K m over tau ms plus 1 is the model between omega the speed and e c the information carrying signal to the motor. This is what I want to say.

There may be a difference between the actual signal going to the motor and the information carrying signal to the motor and my interest is about the control information and the carrier is not important to me in modeling and therefore I am extracting that information from the modeling and my mathematical model is between omega and the information carrying signal to the motor. I hope this point is well taken and I assure you that this will become more clear when I take this specific applications wherein you will see the information carrying signal to the motor could be a modulated signal. This is going to be clear later.

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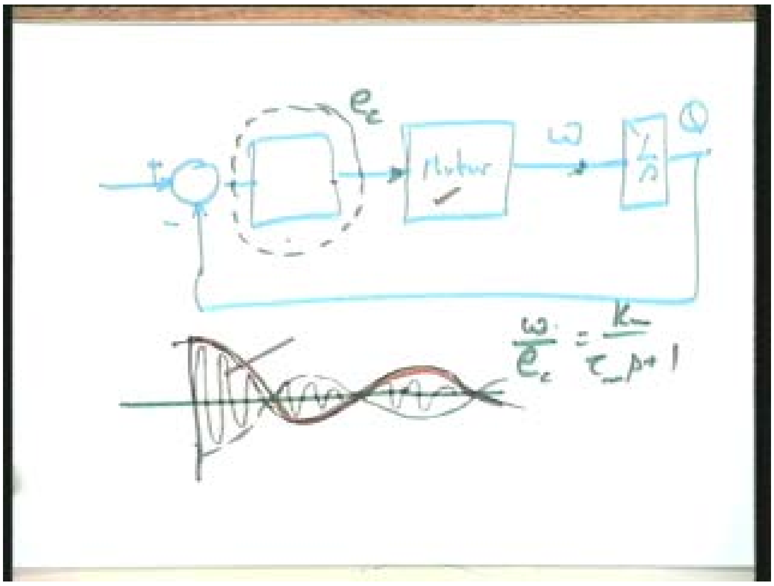

Now, before I come to an application a full-fledged application of a position control system I need one more device and that device is an AC error detector. With these two devices I should be able to give you an application with that application should make all these points also very clear. An error detector; now again your knowledge of AC machines will be utilized over here particularly transformer. Just see, in this particular case I take a device a schematic I am giving you. My diagram may not be good, you may not like it but at least you should convey the message.

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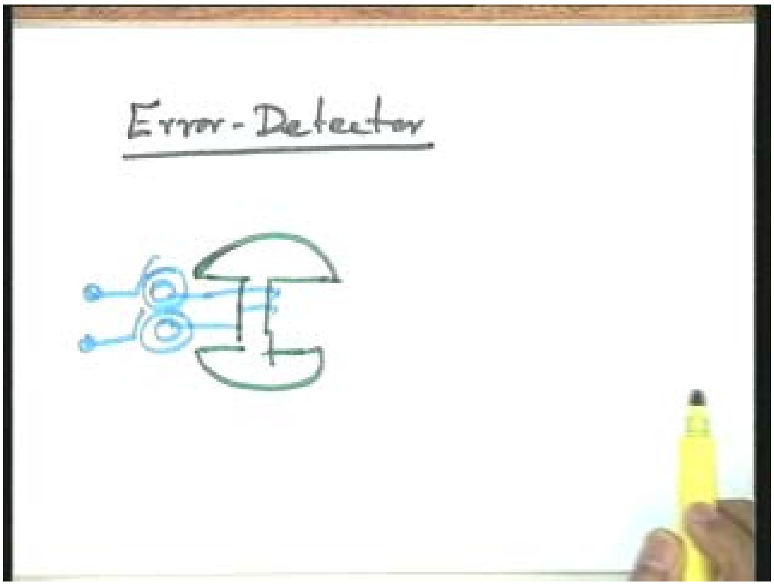

This is a dumbbell rotor a particular construction; on this particular rotor I show a winding through these slip rings I gave the supply. Now, on the stator, stator is a slocket stator but schematically if you do not mind I could show it this way this will make my derivation of the mathematical model more clear. So I am taking here three windings call it S 2 S 1 S 3 1 2 and 3; this is a stator, this is actually a connection this type in the winding, this is neutral (Refer Slide Time: 34:27) S 2 S 1 S 3 schematically I am showing it this way it will help me.

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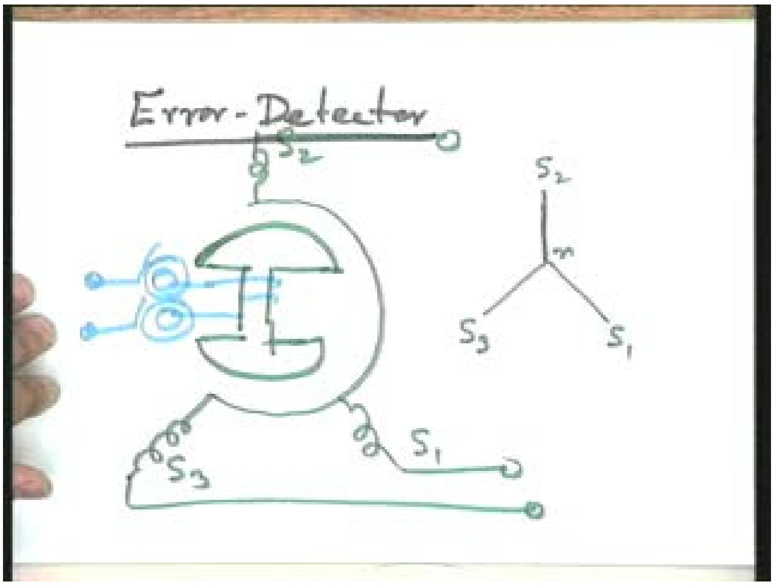

The winding arrangement in the stator is this way; space distribution is 120 degrees, neutral, however, is not available to me S 1 S 2 S 3 are the three terminals available to me. I want you to give me the mathematical model for this system or how this system behaves we want to see this point. Now see the linkages of the two fluxes. You see, in this particular case when you give this supply the rotor produce is a magnetic flux and this flux links with the stator windings and hence EMF is induced at the terminals 1, 2 and 3. So the output in this particular case is the EMFs available at S 1 2 3 and the input in this particular case is the rotor position.

Please see, I can change this particular position. So it is a device called a synchro transmitter the name of this device is synchro transmitter. In this particular case the input arrangement you must see. The AC voltage to the rotor is a fixed voltage, it is the auxiliary supply you are not changing this voltage; what you are changing is the rotor position. And in response to this particular rotor position the three voltages at the three terminals S 1 S 2 S 3 should change and the information about the rotor position theta should be carried in these three voltages.

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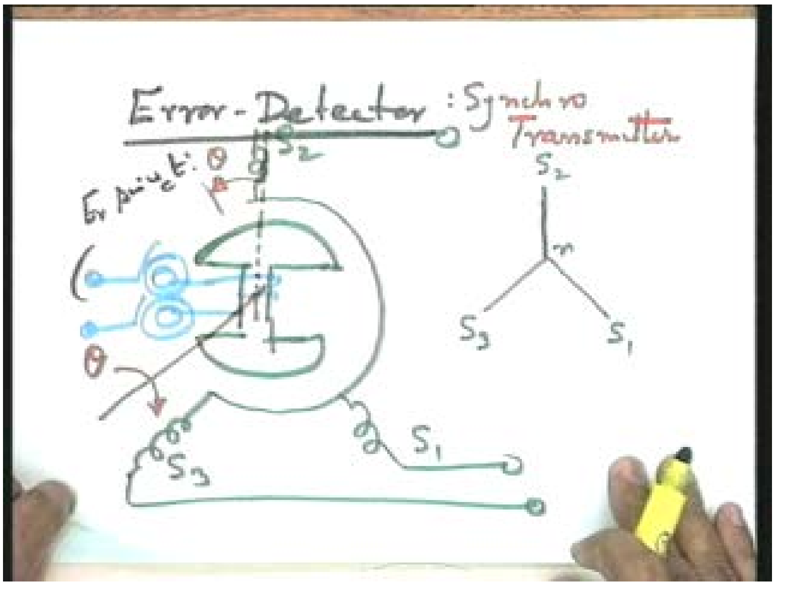

Now help me, how will these three voltages be linked to this particular theta or the relationship to theta is to be determined. in this particular case you will find that if this rotor angle (Refer Slide Time: 36:28) the rotor angle over here theta let me take with……… taking this as the reference I rotate this taking this axis S 2 axis as the reference and with respect to this reference I take theta. If theta is equal to 0 the maximum flux is linked with S 2 and therefore maximum voltage will appear over here. If I take this voltage to be E r sign omega c t what is the voltage across S 2 please? e S 2 n is equal to K E r you can say some K constant sin omega c t for theta is equal to 0; maximum voltage is induced.

Now tell me please what will happen if theta is equal to 90 degrees; what will happen as far as the voltage at the S 2 terminal is concerned with respect to neutral for theta is equal to 90 degrees. It is going to be zero and therefore I can say that at any position theta the voltage is going to be e S 2 n is equal to K E r cos theta sin omega c t. This is going to be the voltage between s two and n for any position theta. Similarly, with the same reason I can write e S 1 n this you can know verify very easily K E r cos theta minus 120 degrees sin omega c t and the third voltage e S 3 n is equal to K E r cos theta minus 240 degrees sin omega c t. These are the three voltages by transformer action.

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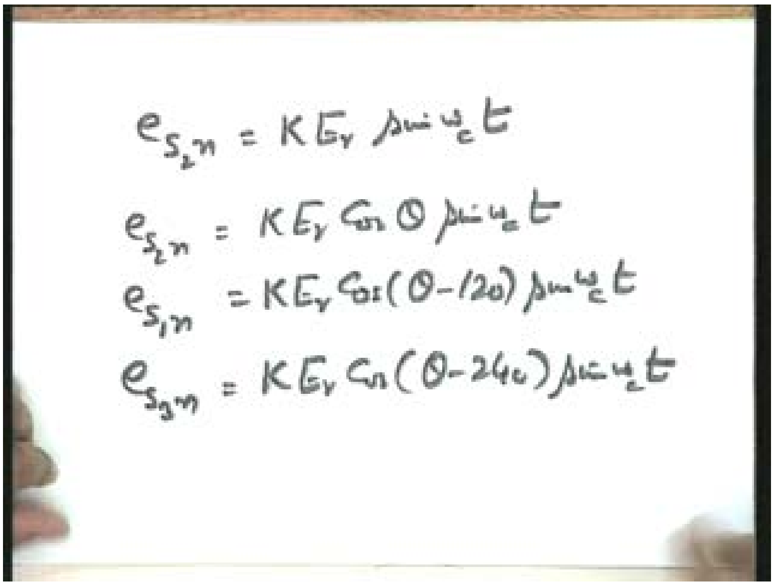

Now, since the neutral terminal is not available to me I will take only the terminal voltages and this is a simple exercise left to you to determine that e s 1 s 2 is equal to…… add up, algebraically adding the two voltages K under root 3 K E r sin theta plus 240 degrees sin omega c t e S 2 S 3 is equal to under root 3 K E r sin theta plus 120 degrees sin omega c t and lastly e S 3 S 1 equal to under root three K E r sin theta sign omega c t. This can easily be examined you see. Just for example, what is e S 1 S 2 equal to e S 1 n plus e n S 2 equal to e S 1 n minus e S 2 n just adopt the two voltages and you are going to get the three terminal voltages. I leave this as a simple exercise for you.

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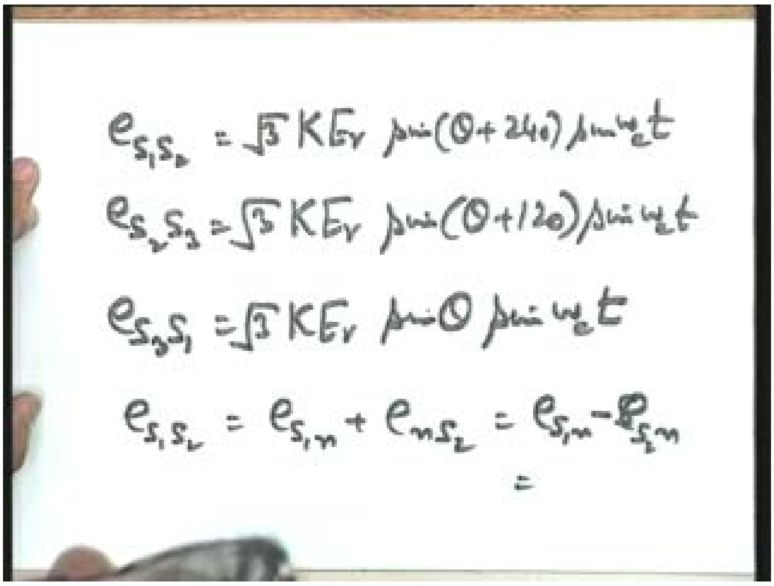

Now help me, just look at these three equations. What will happen if theta is equal to 0. Look at the terminal voltage. Suppose you have the measuring devices and you measure these voltages what will happen when theta is equal to 0. You recall, when theta is equal to 0 maximum flux is a link with the s 2 windings. Now look at the terminal voltages; what will happen to e S 1 S 3 you find that e S 1 S 3 becomes equal to 0. So at this particular position I give you a definition over here when the voltage across e S 1 S 3 is equal to 0 the corresponding position of the rotor is called its null position and your theta is equal to 0 reference is given by this null position; this you are going to conduct as an experiment also in the lab. So, if you have to determine the null position that is the reference position of the rotor you will measure voltage across S 1 S 3 and when this voltage becomes equal to zero mark that position as theta is equal to 0 and all the measurements of theta should be done with respect to that position.

So, in the null position keep in mind, in the null position maximum flux is linked with the S 2 winding and the voltage across S 1 S 3 is equal to 0. Yes please.
[Conversation between Student and Professor – Not audible ((00:41:13 min))]
No, the directions of theta are not opposite I am sorry then my diagram is….. this diagram is only to show you that you have a shaft by which you are rotating. I am sorry this should not confuse. Let me not put a theta over here in that particular case (Refer Slide Time: 41:34). This is only a mechanical arrangement to rotate your theta. That is, any device which rotates theta is given by the is shown schematically like this and with respect to null position this is the theta over here. Is it okay please? Okay. I hope your confusion is taken care of. This is only to show the prime mover for this you can say as if, fine.

Now tell me, one simple question I will ask you which I have been asking the students in the labs when they conduct the experiment on this. Is this device a three-phase device? Look at the three voltages e S 1 S 2 e S 2 S 3 e S 3 S 1. Is the device under consideration the synchro transmitter a three-phase device?
[Conversation between Student and Professor – Not audible ((00:42:14 min))]

Well, the device is a three-phase or single-phase is only with respect to time. You have very rightly answered it. Since it is in time they are in phase so it is a single-phase device surely because only the amplitudes are changing. You will see, all the three voltages are in phase only the amplitude of the three voltages are changing and therefore the device under consideration many a times it confuses with respect to the equations that is why I made a specific mention; some of the students have been answering it as a three-phase device, it is a single-phase device you have rightly answered it, its magnitude is changing but the phase all three voltages are in phase.

This is a synchro transmitter which has the input as the rotation of the shaft theta and the output are the three voltages and these three voltages carry the information about the device or about the rotation theta. Now, actually what my interest is in a control system application I think I should be able to complete this diagram as far as the discussion is concerned before I close today so that next time I give you directly the control system.

Let me say that this is the rotor slip ring arrangement (Refer Slide Time: 43:37), here I have three windings S 1 S 2 S 3, I have another rotor here, well again I said that, hopefully I should be able to draw a sensible diagram at least. This is a rotor; the construction is different than this rotor I am going to give you the reason and let me say that I have three windings here as well. I have two machines now; you please note that these are the two machines, here the rotor is a dumbbell construction, here I have tried to make it more are less cylindrical. You see that the diagram may not be the way I wanted to tell you but in words I want to explain that I just wanted to make it more or less cylindrical the reason being that the output of this particular rotor is going to a signal conditioning device an amplifier may be or a demodulator.

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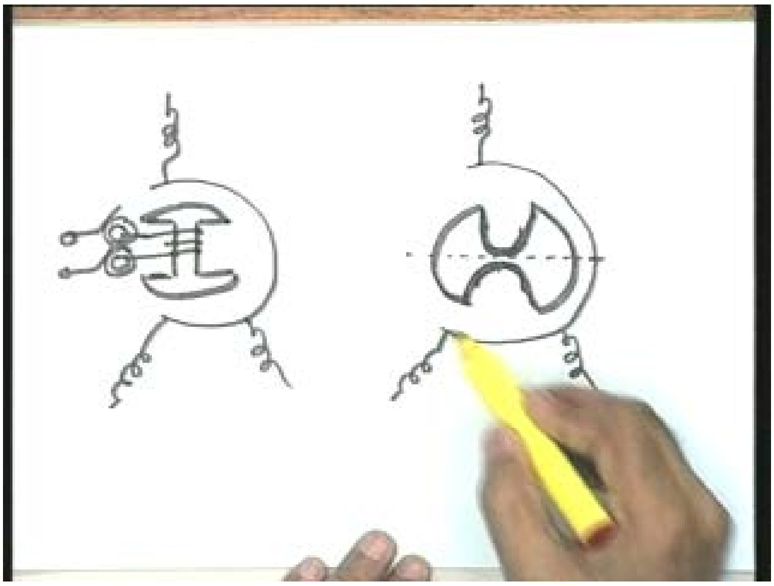

Here is a signal conditioning device and I really want that, this is signal conditioning device; I really want that this particular device should see a constant impedance. If the rotor is not cylindrical then the impedance as seen by the signal conditioning device will become a function of the rotor position. So I have made it more or less cylindrical so that the impedance as seen by the signal conditioning device is not a function of the rotor position. This requirement is not that stringent in the earlier case and therefore in the earlier case you can have a dumbbell construction.

You can have a dumbbell construction, no one prevents you in taking the cylindrical construction there as well but probably we save in cost and that is why in the synchro transmitter that is in this particular machine we can go for a dumbbell construction. Well, the construction has to be more accurate here; the rotor has to be more cylindrical here so that the impedance at these particular points as seen by the signal conditioning device is constant. So this let me say over here, signal conditioning, the output of this is going to a motor and this motor is going to control the position of this particular rotor. This motor is going to control through a gear train of course; if necessary it is the going to control the position of this particular rotor. this is the construction, this is the arrangement that is the two stator windings are joined this way (Refer Slide Time: 46:39) and here is the prime mover or the mechanism for moving this particular rotor and let me call this rotor as the this motion as theta R and let me call this motion as theta c. this is the device I am going to use in my servo applications, please see.

In this particular case this unit the two are identical you see, the two units are quite identical but for the rotor construction. this particular unit is refer to as a synchro transmitter and this unit is called a synchro Control Transformer, this may please be noted; a synchro transmitter here and a synchro Control Transformer here and the objective in this particular case, the input output you see, what is the input, the input in this particular case is the deviation of the two shafts theta R and theta c and the output in this particular case is the output voltage available across the rotor terminals of the control transformer here.

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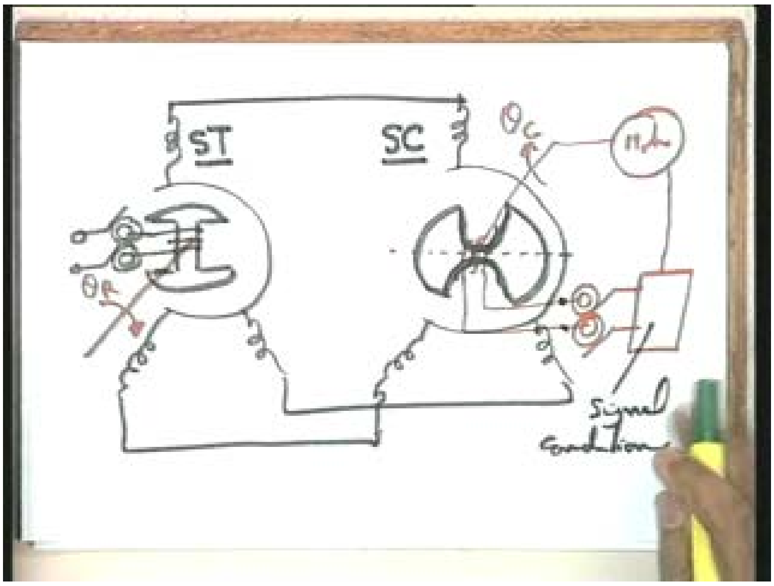

Well, unfortunately with the constraint of time I have not been able to complete it but next time I am going to start with this diagram only, thank you.