Control Engineering
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Lecture -13
Models of Industrial Control Devices and Systems (Contd….)

Well friends. Under discussion was a DC position controlled system. I think it will be in order if I review the DC position controlled systems, this being a very important plant a very important system as far as controlled system are concerned. Because many of the loads are actuated by a DC motor and a position or a speed controlled system becomes important. So let us see what are the what were the basic components of a DC position controlled system.

The basic component we have taken a motor, let me say that here is a motor which is producing a torque T M. Now this motor is driving a load and I had taken the load through a gear train. This is my gear train (Refer Slide Time: 1:51). By gear train I mean that it could be more than a set of gears. I have taken two gears pictorially but it depends upon the torque magnification and speed reduction requirements so naturally it could be more than a pair of gears, it could be two pairs and so on. So, on this particular gear I have the load and the two parameters of the load we had taken were J L and B L.

Let me say that as far as this system is concerned theta M, omega M is the velocity and theta M is the position of the motor shaft and here in the opposite direction obviously theta L is the position of the load shaft and the disturbance torque is going to oppose the motion and therefore T W I am giving in this direction.

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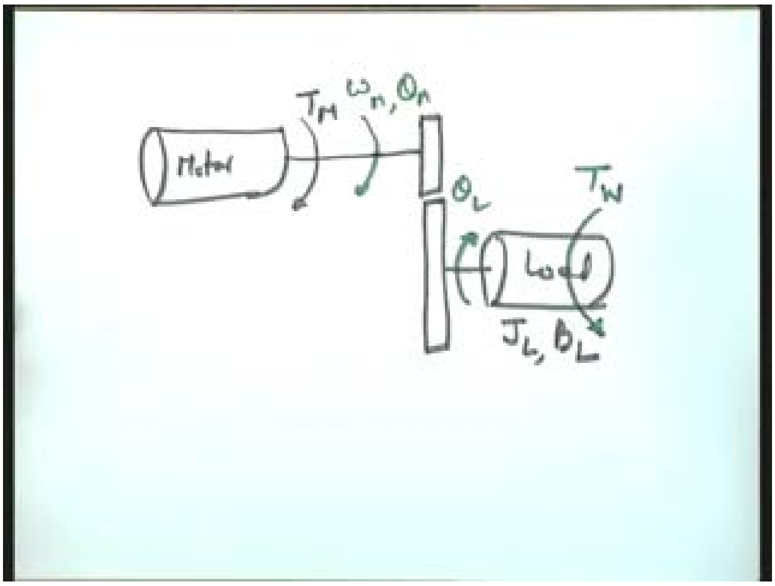

So, in this particular case the conclusion of our earlier discussion was that the load parameters could be reflected on to the motor shaft. I will revise the result for you directly, hopefully you recall the derivation. This system as far as mathematical equations are concerned is equivalent to the system I am going to draw here. This is the motor, motor produces the torque T M and the position is theta M. You can equivalently couple a load directly to the motor instead of showing through the gear train.

I take this as the direct load. Now what are the parameters of this direct load? Recall our derivation I call it as J equivalent is the equivalent inertia on the motor shaft, B equivalent is the equivalent frictional coefficient on the motor shaft. In that particular case these two will become similar that is the mathematical equation describing the system will be the same if I write J equivalent as a function of J L and let me say that the motor shaft has got the parameters J M and B M where J M is the friction of the B M is the frictional coefficient on the motor shaft and J M is the inertia due to rotor, gears and other things.

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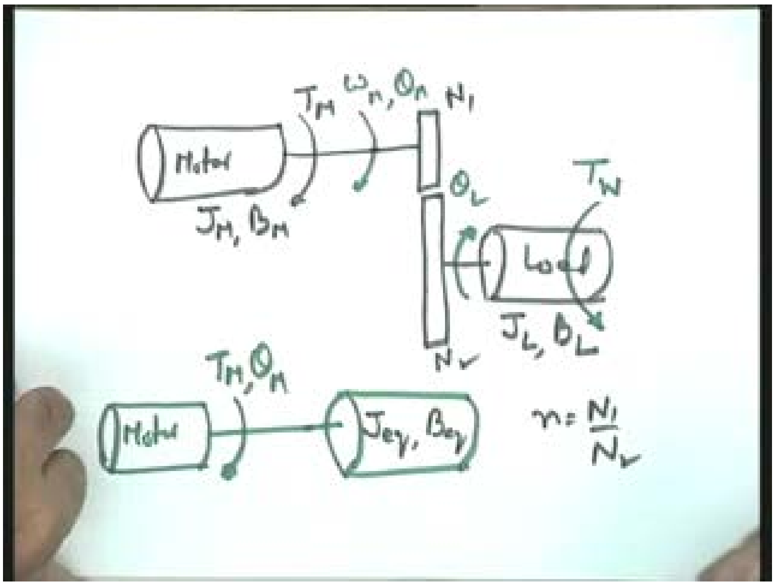

So, if I take N 1 and N 2 as the teeth and small n is taken as equal to N 1 by N 2 as the gear ratio, in that case please recall the result, J equivalent on to the motor shaft will be given by J M the movement of inertia on the motor shaft plus an equivalent portion reflected from the load shaft and that value is n square J L. So it means the equivalent movement of inertia on the motor shaft could be taken as J M plus n square J L. Similarly, equivalent viscous frictional coefficient could be given as B M plus n square B L and the motor equation than can be written as the motor equation the torque developed by the motor equal to the inertial torque J equivalent theta M double dot plus B equivalent theta M dot.

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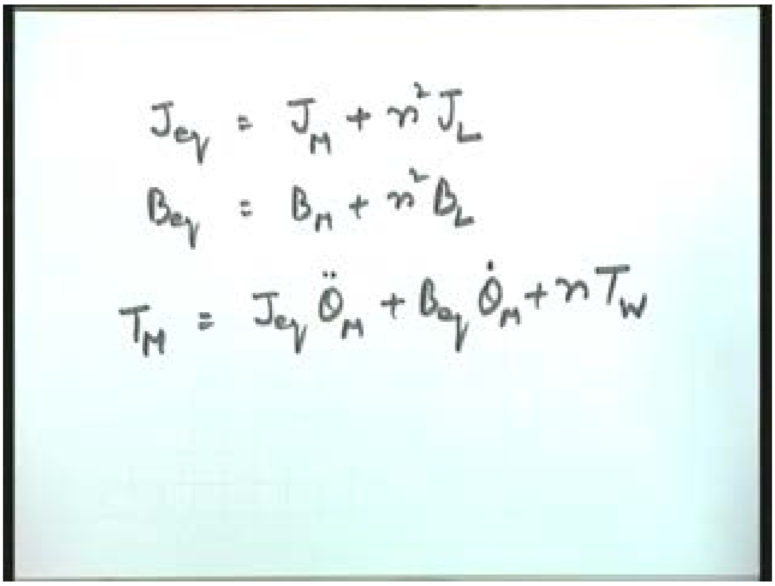

Now you see that theta L is not appearing in the equation at all. If you want to get the value of theta L then naturally theta M and theta L are related by the gear ratio. So, from theta M you can go to theta L but as far as the basic equation is concerned the basic equation is available in terms of theta M which is the displacement of the motor shaft. Now, if you remember the derivation I pose a question to you.

Tell me what will happen to this particular load torque on this equivalent model?
[Conversation between Student and Professor – Not audible ((00:05:53 min))] n T W, this please note that if T W is the torque on the load this is the actual torque the disturbance torque on the equivalent model we have seen, you will naturally write it opposing the motion it is n T W where n is the gear ratio and therefore the complete mathematical model becomes T M is equal to J equivalent theta M double dot plus B equivalent theta M dot plus n T W. You will please note that T W is the actual disturbance on the load shaft and n is the reflection factor of that disturbance on to the motor shaft.

This is very convenient and in modelling normally we will do in that way only. That is all the load parameters, all the parameters of the gear train will be reflected on to the motor shaft and a mathematical equation on the motor shaft will be written. Now, in addition to this last time I had taken up the derivation of the DC motor. I think a review of that also will be in order before I take a complete position controlled system and this is my target for today. I am going to explain a complete position controlled system to you.

So now, again you take the motor. Some newer points, some points will have not been covered in the last lecture. I had taken this as an armature controlled motor. So, in this particular case the control variable is the armature voltage e a. I had directly neglected the armature inductance because this is usually the case. In the approximations which we make in modelling the armature inductance is normally neglected so I have not included it right in the beginning in my mathematical model. So e b is going to be the back EMF on this. Now let me write directly assuming that on this motor there is a load through the gear train. However, now I am equipped to write this load directly over here and I can drop the letters equivalent also if you understand. I will say that J and B are the parameters of the load on the motor shaft; equivalent word equivalent subscription I am avoiding because now it is clear to me, if I am taking a load on the motor shaft naturally if the load is through a gear train the reflection on the motor shaft will have to be taken. So J and B are the equivalent parameters and as far as disturbance is concerned let me take this as the disturbance as n T W

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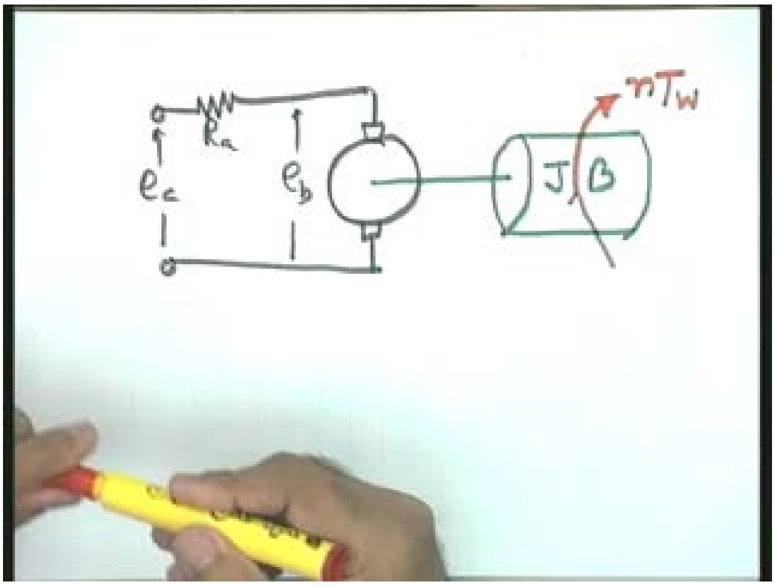

So, in this case T M and theta M are the two parameters of interest because this is the torque produced and this is the displacement of the motor. I tell you that after some time you will really not require the differential equations. You will be able to write the block diagram model directly from this schematic diagram of a system. Make an attempt here itself.

Just see that your input is e a the armature voltage and this is being opposed by the back EMF and therefore let me use an error detector here to represent this particular phenomena that is the back EMF opposes the applied voltage (Refer Slide Time: 9:28). The net voltage appearing across the resistor is e a minus e b so naturally 1 over R a if I put a block over here this gives me armature current so let me call it i a. Now this action plan is coming directly through a block diagram, this may please be noted. This is armature current and if I multiply it by a torque constant K T, you recall, your torque is proportional to the product of armature current and field current. So in this case what I am doing is I am taking the field constant.

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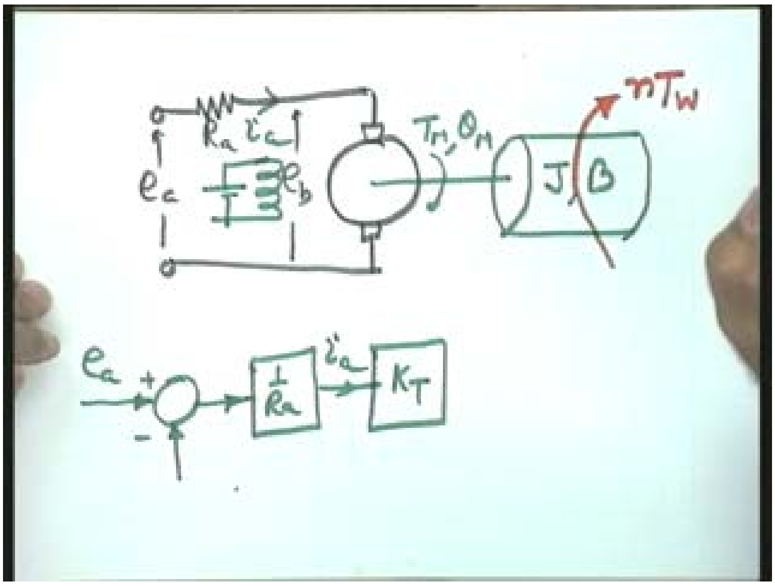

You will note this point please here; you have motors DC motors which are permanent magnet motors or round field motor. So, if in the round field motors if I give a constant voltage supply the field is constant and for the permanent magnetic motor you can naturally take that the torque produced is directly proportional to the armature current. So the block diagram I am doing to give you is valid for both the round field motor with constant field current or a permanent magnet motor, this point may please be noted.

So, after this particular block I have got the torque so let me take this variable as T M (Refer Slide Time: 10:42) so this T M variable is going to be opposed by the disturbance torque so let me put a plus sign here and a minus sign here because it is in a position. This again I think I have over emphasised my point that this is only an algebraic quantity, it could even at to TM it depends upon the nature of disturbance. Even if it adds to T M it is a disturbance because we have not designed our system with that objective in mind or with that variable taken in that way that it adds to the it adds to the applied torque T M.

So let me write here n T W and therefore this becomes the total torque available for driving the motor for driving the rotor of the DC motor. So here the opposition is coming from the load and let me say that 1 over Js plus B is the load transfer function where J and B well, obviously it should be clear now, are the reflections on the motor shaft. So the output here is omega the speed. now this omega you have to lift from here because there is a feedback and the feedback phenomena is through the back EMF and therefore let me put a constant K b here. So this is going through the constant K b into this error detector.

Now, if the output of interest is position and not speed in that particular case you will put a block here and integrator 1 over s and therefore the output in this particular case will become theta M. Theta M is the output the position and e a is the input armature voltage and there is a loop inherent in the system because of the back EMF and this loop is through the back EMF constant K b.

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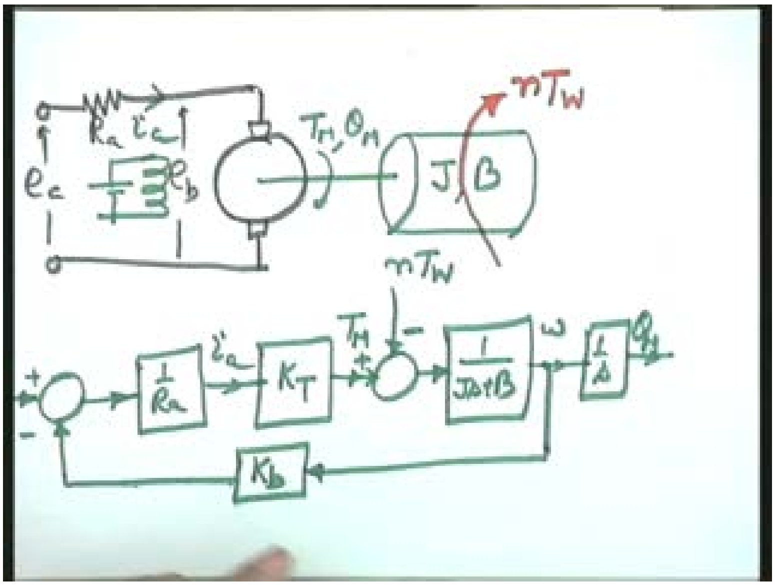

Now, if I take up this particular block diagram and I am interested in the transfer function model of this system you see that it is a two input and one output system. let me take Let me apply a superposition and set one of the inputs equal to zero, let me set disturbance equal to zero so I have a transfer function between omega and ea or between theta M and e a. so between omega and e a please help me, I am sure you are equipped with this now. Yes, can you give me directly? See, if I can write directly: K T by R a divided by Js plus B plus K T K b by R a. This, I am writing after using the basic block reduction rule to this particular loop. Just see that it is between omega and e a. The point to be noted here, that is why I am repeating this point; you see that K b is adding to the B term; B is the mechanical friction in the system due to bearings, due to gears or due to any other mechanism and K b is adding to this term and K b it means, really you can say that is adding or giving damping to the system.

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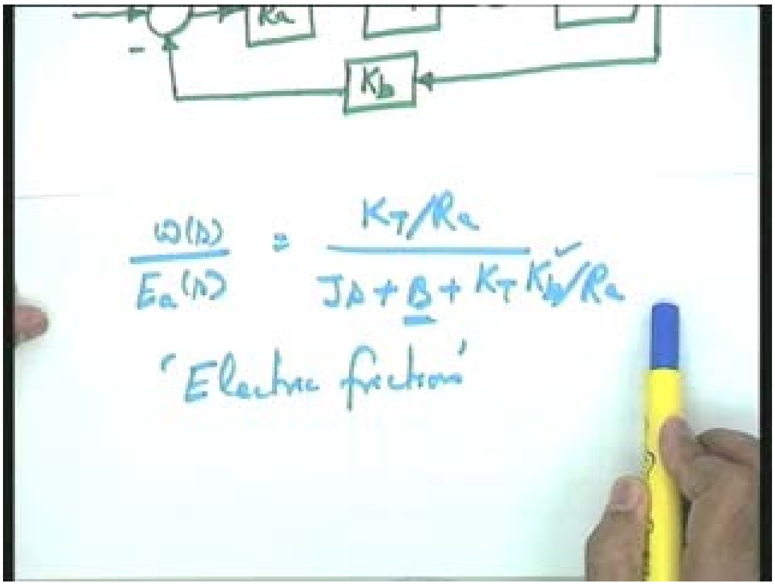

More or less can we use the word as if it is electric friction because if you require damping in the system K b is helping in that, it is adding to the damping and equivalently I say as if K b is providing the electric friction so that the total friction is given by this B plus K T K b by R a and this particular transfer function I can now interpret in the standard form, in the standard form, this being a first-order system in the standard form this is going to be equal to K m the gain of the system divided by tau m(s) plus 1 where tau m is the mechanical time constant and that will turn out to be J divided by this quantity which can easily be calculated.

So this is the transfer function model and now if you want the transfer function between let us say theta M(s) over E a(s) between the position and the input voltage what will happen, a factor (s) will come over here so this theta M(s) over E(s) will become equal to K m divided by s into (tau m s plus 1). This becomes the transfer function if position is taken as the variable of interest.

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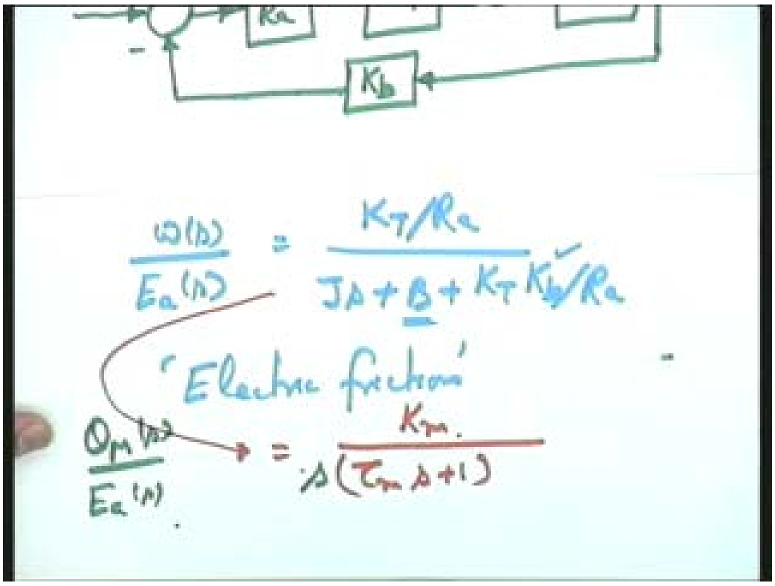

Now a point in this particular case which needs mention is the correlation between the variable K T and K b an important point please. K T is the torque constant and K b is the back EMF constant. I want to establish a relationship between the two and what is the use of that relationship. That also we will see.

Look at the power developed power P is equal to e b into i a watts this is the power developed in the machine, e b is the back EMF and i a is the armature current. Now let us look at the units: This I can write as K b omega into i a. What is K b? K b is volts per radian per second into radian per second into amps, well, the unit is watts. Now give me the equivalent expression of power developed please. power developed is also given by, assuming that there is no loss, assuming neglecting losses is also given by the torque T M into the speed omega again the units watts; the torque T M developed by the motor into the angular velocity omega. Now let us look at the units. The units in this particular case are Newton meter into radian per second this is in watts.

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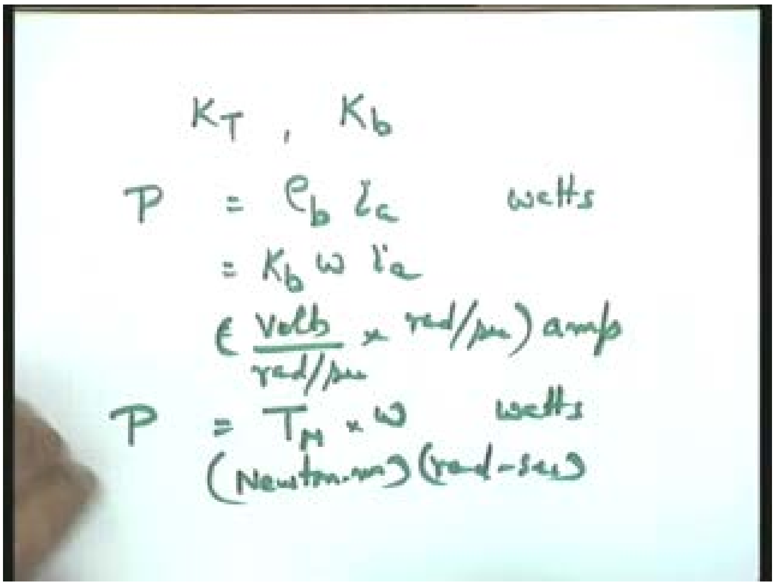

Now interpret this, I will keep it here, interpret this in K T terms this can be equal to K T into i a into omega, this is equal to what is K T? K T is Newton meter yes per amp this is your K T Newton meter per amp. You can look at the block diagram also that will also give you the same thing into amp into radian per second. This is in watts. Now please see that in this particular case if you compare this I hope this is also available on the screen this expression (Refer Slide Time: 17:50), this expression volts upon radian per second into radian per second into amps is watts, Newton meter per amp into radian per second into amps is also watts so naturally if I take K T in the units Newton meter per amp this becomes equal to K b when taken in units volts per radian per second. This point may please be noted.

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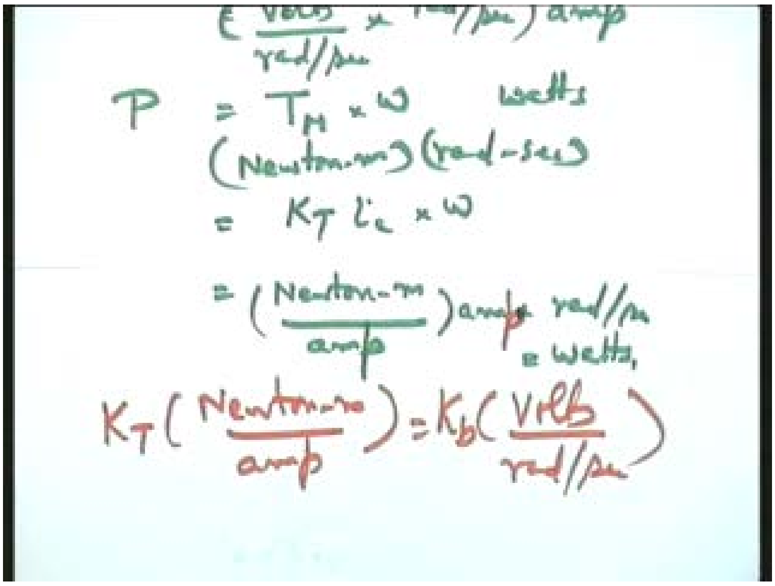

This point needs your attention, that, if K T is taken in Newton meter per amp and K b is taken in volts per radian per second then the numerical value of K T must be equal to that of K b. The units I am stressing because if you take different units in that particular case the two may be related through a constant. It is not necessary that K T is always equal to K b it depends upon the units; consistency of the units, compatibility of the units has to be observed. So, if I take these units I have proved to you that if K T is in Newton meter per ampere and K b is in volts per radian per second in that particular case numerically the value of K b will turn out to be equal to K T. It is a very important result in the sense that if you are modelling a motor experimentally you can visualise this situation conducting an experiment to measure K b is much easier and more accurate than that to measure K T.

I think, well, you can think what type of experimental setup will be required to measure K b it is so simple; you will be measuring the back EMF and the speed to get you the value of K b. Well, in this particular case torque measurement will be required and therefore naturally the measurement of K b is more easier and may turn out to be more accurate and therefore even to get the value of K T you will conduct an experiment for measurement of K b and use this relationship to get the value of K T. This is an important point and you have to keep in mind that with suitable units taking consistent units the two constants are equal numerically.

Now well, armature controlled motor we have taken. Just for the sake of completeness a quick result on the field controlled scene could also be given. What would be the field controlled scene? i a is equal to constant, you will like to keep the armature current constant and you will vary the field current i f to control this particular motor or to control the torque developed by the motor. you can take the same scene here (Refer Slide Time: 20:46) sorry, you could take, yes, you could take this way the load and there may be a disturbance on this particular thing on this particular load T W or n T W as you may like to take, this is T M the torque developed by the motor.

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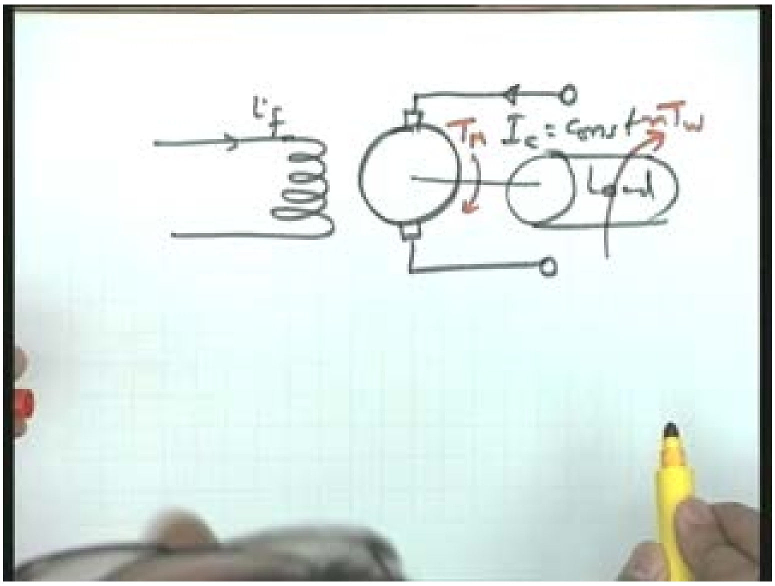

So, in this particular case this torque (Refer Slide Time: 21:05) is dependent on the field current since I am keeping the armature current constant. I am giving this particular derivation to highlight as to what are applications of field controlled motor vis-à-vis armature controlled motor. If you have to make a selection for a particular application, if you have to make a selection of an actuator which of the two you will select; this is an important point and I need your attention on that point. But before I discuss that point a quick derivation of the mathematical model of this. I will not write the equations now. I hope I can give the block diagram directly. So, in that particular case the armature resistance, the field resistance and field inductance both the parameters I am taking because the field inductance is not negligible. So, in this case both the parameters are being taken and e f is the voltage which is the controlling voltage which controls the torque.

So, come on, make a diagram: e f is the variable here there is no back EMF facing e f so I can put a block directly that block is 1 over R f plus s L f this gives me if the field current here, now this i f multiplied by a torque constant let me put a K T dash only to differentiate it from the earlier torque constant and since in this particular case the armature current is constant so the torque is directly proportional to the field current so this gives me the value of the torque T M. At this particular point (Refer Slide Time: 22:48) I can add n T w algebraically which is the disturbance torque, this is the net torque available for driving the load and here I can put the load parameter 1 over Js plus B I get the value of omega.

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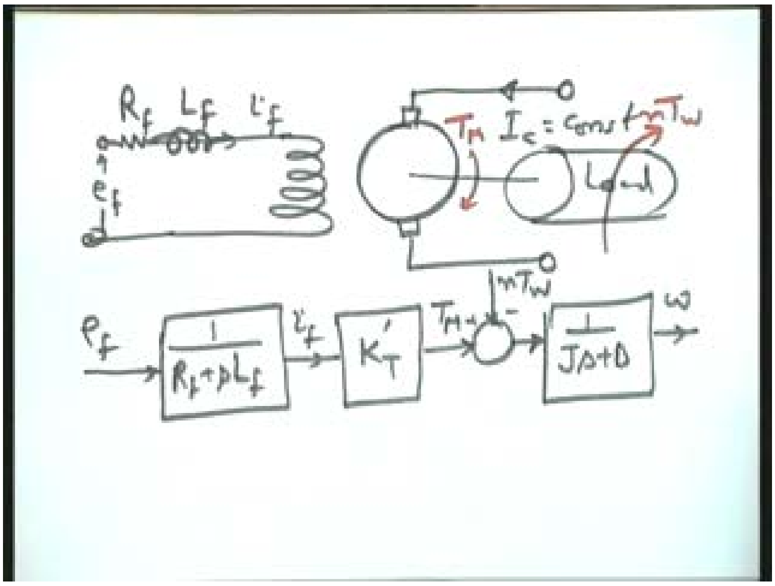

You will please note that in this particular case the so-called electric friction effect is not available. The electric friction effect, the damping effect you had in the armature controlled mode is now not available you are controlling it through the field current and in this particular case, the mathematical model, one more point, turns out to be a third-order model. Between omega and e f what is the model? Between omega and e f please note that I can write this as K m dash only to differentiate it from the earlier value K m divided by, I think it can be directly written now, tau f s plus 1 into tau ms plus 1. This is a second-order model. But if I take the relationship between the position theta M and the voltage e f it becomes a third-order model. You see that higher the order of the model more complex will become the design as you will see later. In this case L f cannot be neglected. So, between omega and e f it is a second-order, between theta M and e f it is third-order.

tau f as you see in this particular case is L f upon R f which is the field time constant which is not negligible while the armature circuit time constant was negligible and tau M is identically the same that is it is the mechanical time constant as you had in the earlier case. But now in this particular case in the mechanical time constant the K b term is not coming. So this becomes the mathematical model.

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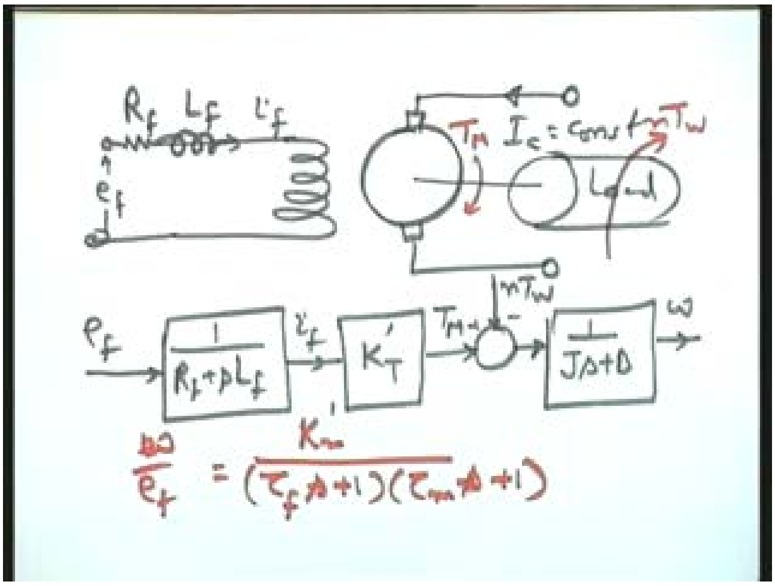

Now, as I said, that I will like you to understand the point as to how the selection is made, as to which motor you should take for the purpose of control when a particular application is given to you. So, as far as the field circuit is concerned you see the great advantage is this that the power amplifier in this particular case will be……. the requirement on the power amplifier will be low because the total amount of power required to drive the field circuit is lesser than that required for the armature circuit. So the controlling unit the power amplifier in this particular case is going to be less costly. So the price you are going to pay in terms of the performance of the system is when you look at this circuit. You see it requires an armature current constant.

Now, keeping in armature current constant, if there is a requirement of high armature current is very difficult. What you will normally do, what you will do in a circuit, how will you keep the armature current constant? You can keep the armature current constant by using a high constant voltage source. If the resistance of this circuit R is reasonably larger than the resistance of armature circuit and this voltage source is high in that particular case, please note that your i a is more or less constant; why the i a should change? The i a changes because of the back EMF effect. This back EMF effect is going to appear as far as the armature side is concerned and because the back EMF will change with speed the armature current cannot be kept constant. But if you take a large voltage source here and a large resistance here in that particular case the armature current can roughly be kept constant.

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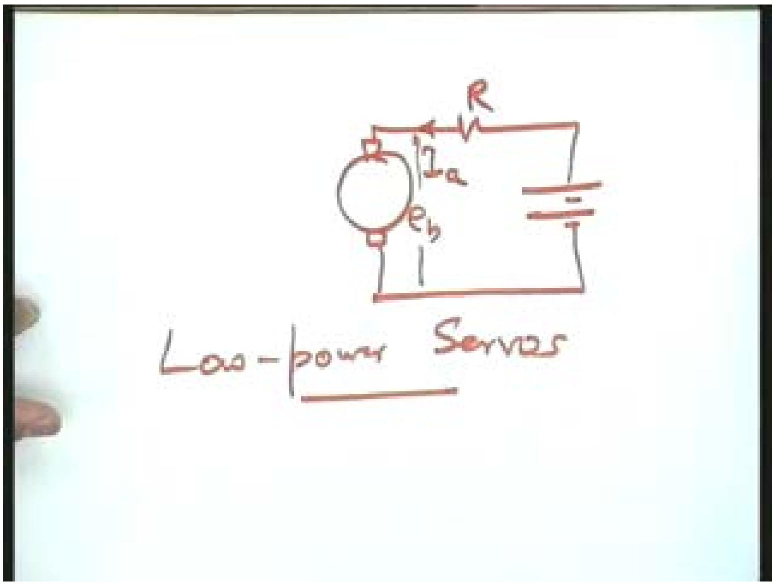

However, this particular approximation will be more correct if the requirement of the armature current is not very high and therefore I can conclude my discussion with the statement that field controlled motor is a good competitor for selection as far as low power servos are concerned. Wherever there is a low power requirement so that the armature current i a will be low in that particular case and it will be possible to maintain that current at a constant value reasonably well.

For a high power servo, you see, it is the armature controlled motor which is used and I can conclude my discussion on the motor with the statement that in most of the industrial control applications it is the armature controlled motor which is used and not the field controlled motor because of its other advantages also you have seen that it gives you the advantage of damping as well and a proper control is possible in the armature controlled mode.

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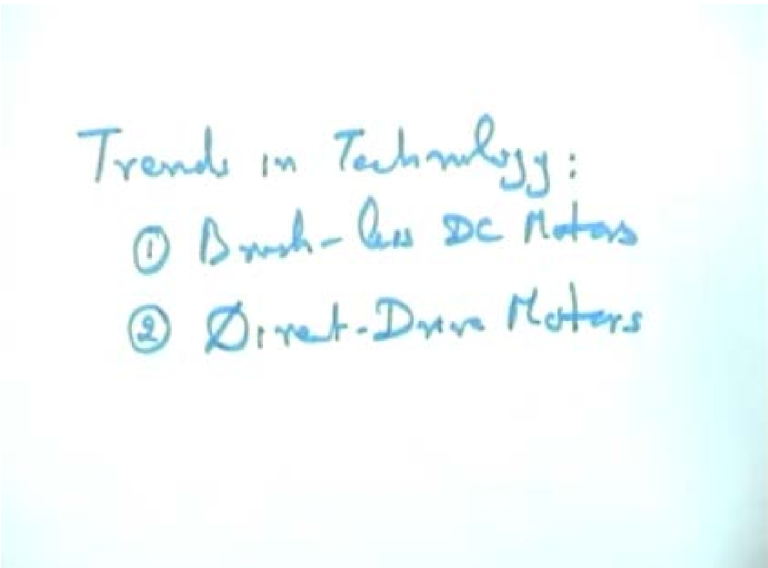

The Trends in Technology I think it is quite appropriate I could mention here as far as the motor drives are concerned. Though I will not go to the details of this, the Trends in Technology are to take care of the problems associated with these motor drives.

Come on, can you suggest what could be the problems associated with these motor drives?
Well, one of the problems, the major problems which have not been visible in our discussion is because of the brush friction. You see that that brush friction will make your mathematical model a nonlinear model. You have happily taken it to be a linear model taking the friction to be viscous friction only but the brush friction is a constant frictional source. And if you add a constant friction into the system which is independent of speed your mathematical model becomes a nonlinear model and the total analysis which you are going to make on the assumption of linearity may not be valid and therefore this is one of the great assumptions we are going to make in using this particular model and the latest Trends in technology are to give you brush-less DC motors. In that particular case the commutation is electronic.

So it means now brush-less DC motors are available so that the linear mathematical model is valid and nonlinearity due to the brush friction are taken care of. One more problem you see which we have happily ignored and that problem is associated with the gears. We have taken the gears to be simply a linear relationship given by the gear ratio. Unfortunately this situation is not that simple. You see that the two gears are in mesh. When the speed reverses what will happen, the reversal of the gears will not take place instantaneously there will be a backlash and the backlash and the gear reversals is going to introduce another nonlinear term and therefore in the gear drives the mathematical model which we have derived is not again applicable it is only an approximate analysis. That is, the equivalent reflection on the motor shaft is based on the assumption that the backlash is zero which is never the case. So it means, well, you should understand the limitations of our mathematical model.

Well, nonetheless still the mathematical model which we are going to use are giving useful results even under these assumptions. But the technology is taking care of these problems. Now the direct-drive motors are available. In this particular case the requirements of torque and the speed are taken care of in the motor construction itself. You recall my statement that we required gear train for torque magnification and speed reduction. These requirements are taken care of in the motor construction itself so that the direct-drive motors directly can be interfaced to the load without the need of gear trains in between. The advantage is being very clear. In that particular case the nonlinear problems of backlash or friction in gears etc will not appear.

Yes please………
[Conversation between Student and Professor – Not audible ((00:31:21 min))]
Right……..
[Conversation between Student and Professor – Not audible ((00:31:28 min))]
Well, when will that happen will depend upon your application. Will you not require the bidirectional control? You see, you think of antenna control; your motor is controlling antenna so your antenna control will require…… you see your motor is moving in one direction, your control signal now requires that the antenna should track the torque in the reverse direction. So it means immediately the motor will have to reverse its speeds and hence a bidirectional control will be required. So there are applications in industry: Unidirectional control and bidirectional control both the applications are there. Wherever bidirectional control is required the reversal in the direction of motor rotation will be required

and that reversal will be provided by the controlling voltage and hence the backlash will appear. Is it okay?
[Conversation between Student and Professor – Not audible ((00:32:14 min))] Okay, with this now I think I can come to the position controlled system. With this introduction about the motor I can come to the position controlled system

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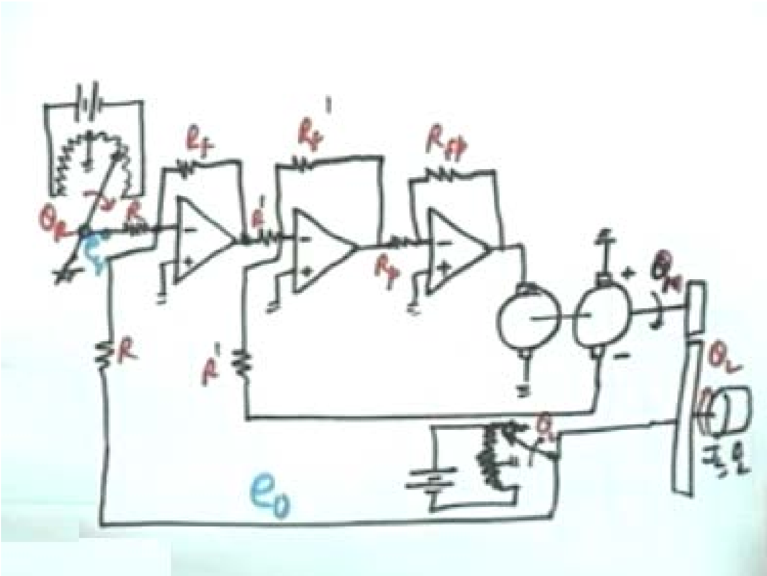

Now, look at this system this position controlled system in idea of the position controlled system that was given last time also. But now let us have a complete discussion how the system works. In this particular case you will note theta L is the attribute of interest this is the variable you want to control. Look at the arrangement I have shown which is not a unique arrangement; it is symbolic of the arrangements normally employed in industry, you can use different hardware as well. Theta L is the attribute of interest let us say it is the antenna position. Theta R is the position is the command signal in this particular case; symbolically the command signal is being given by setting a wiper on the potentiometer but in an actual practice this command signal may be coming digitally or may be coming through any other device. You see that it is a symbolic arrangement that you are changing the wiper on the potentiometer and hence a voltage here (Refer Slide Time: 33:29) which is proportional to the position theta R is coming at this particular point and let me call this voltage as e r which is the reference position. So the relationship you see, in your minor also these relationships were required.

Relationship between e r and theta R is through a potentiometer constant and that constant depends upon the voltage source over here that constant depends upon the resistor used over here. But let us capture it in a single constant K p so that e r is equal to K p into theta R a voltage proportional to position is available. I am mentioning this point again. I am worried about e r and not the way it is generated, it is only a schematic arrangement to generate it, it will depend upon the application and the way the signal is being generated.

Similarly, the output, well, the output simply I am showing it here through a potentiometer. You will please note that a potentiometer again leads to nonlinear problems because it has a finite resolution. A wire-wound potentiometer for example will only change step by step and will not give you a continuous movement. So, in that particular case a potentiometer is also adding to nonlinearity. But in my mathematical model at this point I am neglecting that nonlinearity and I am assuming a linear relationship between this voltage and this particular position theta R. at a later stage I will come to other devices which are better than potentiometer in terms of the linear behaviour and which are more extensively used than the use of potentiometer in industry.

But a symbolic arrangement a schematic diagram could be taken at this stage as if I have a device for generation of the reference signal and I have a device for the generation of a feedback signal and these two devices these two potentiometers could be replaced by better devices those better devices will come up later in our discussion. But at this point now I have a voltage e 0 which is the feedback voltage which depends upon theta L and I have a voltage e r which is the reference voltage which depends upon your command.

Now look at this Op-Amp circuit (Refer Slide Time: 35:47). This particular Op-Amp is giving you a voltage which is proportional to e r minus e 0 so it means it is acting as a differential amplifier with gain R f minus R. I will give you the block diagram but first let me scan it all through. The gain is minus R f by R and it is a differential amplifier because it is giving you a signal e r minus e 0. Well, one point, at this at this stage itself you may please note, here as far as this wiper is concerned this is on the negative side and as this wiper is concerned I have deliberately connected it on the positive side. you will please note in that case: e r is a negative voltage and e 0 is a positive voltage and this particular gain is minus R f by R, I hope you will not mind if instead of showing negative sign signs with e r and e 0 I take this block diagram: E r plus minus e not and here I am putting R f by R it is an equivalent scene.

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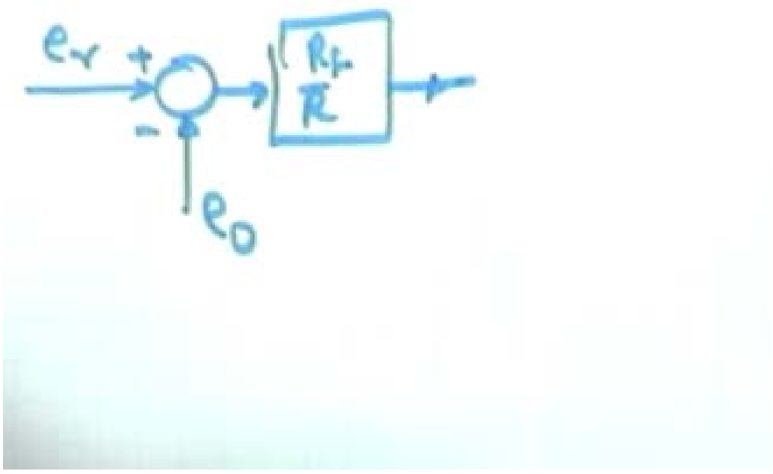

Please see, I have taken this particular block diagram to represent the phenomena e 0 I have taken on to the positive side, e r I have taken on to the negative side and this differential amplifier has got the gain minus R f by R. So minus signs appropriately taken care of, this gives you the block diagram. I hope this is okay, Fine?

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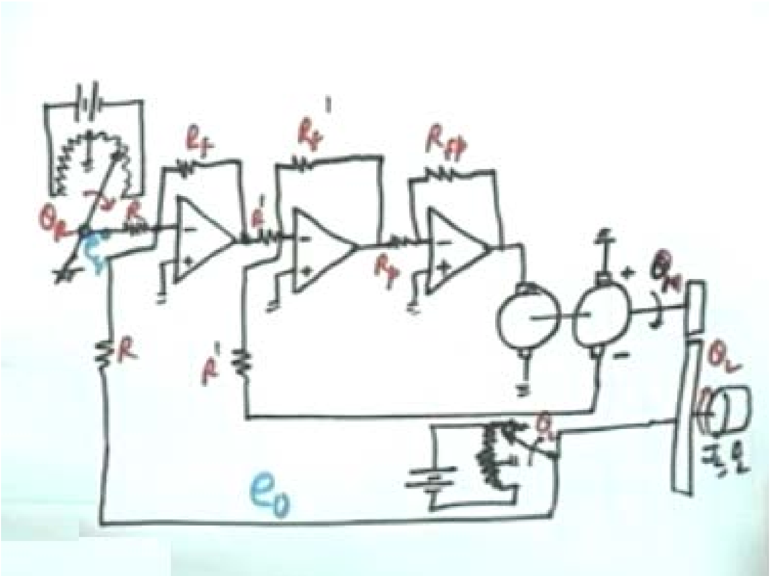

In this case now let me put a K P here a potentiometric constant and therefore this becomes theta R. Let me put a K P here a potentiometric constant and here is the value theta L. So I will connect theta L to the circuit but this theta L into K P is e 0 and this can equivalently…….. this K P can be taken in to the system so that your input is theta R here directly plus minus this is theta L here (Refer Slide Time: 37:54) so that this becomes system error so I am heading towards a unity-feedback system if I take this arrangement and your K P in that particular case can be taken as K P R f by R. This, if I complete the block diagram is going to give me a unity-feedback system. Okay, I hope this point is very well understood.

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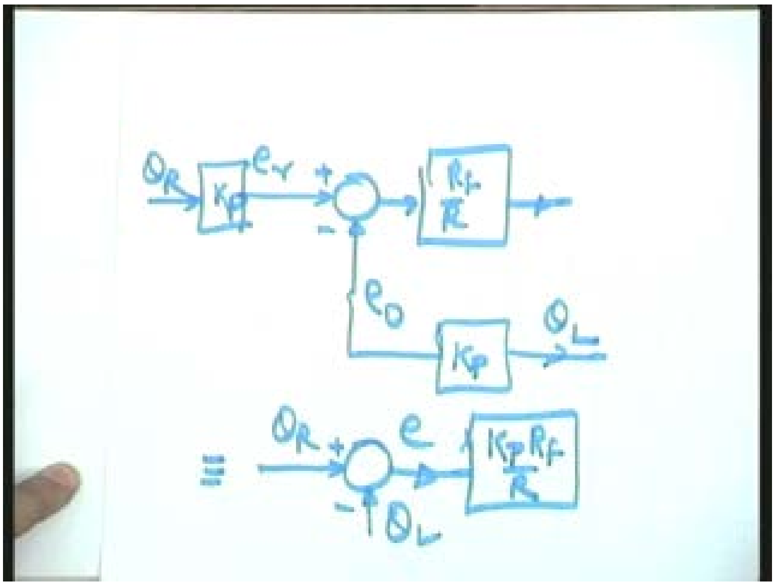

Okay let us go back to the diagram. So it means I have reached this point. At this particular point (Refer Slide Time: 38:24) I have a signal e r minus e 0 multiplied by a constant that is the gain of this differential amplifier. Now, I need your attention at this point. What I am doing here is that, in addition to this signal I am taking another signal which is coming from a tachogenerator. This tachogenerator…….. again the signs, I need your attention on the signs also; this tachogenerator voltage is e t with a negative sign. So it means this particular amplifier is again working as a differential amplifier with gain minus R f dash by R dash.

What is the input?
The input to this amplifier is this voltage. this voltage you could name you could give some name to this particular voltage let us say e dash I say; this e dash minus e t multiplied by R f by R dash with a negative sign will be the voltage available at this particular point. So it means now you are going to have two loops, it should be clear. One is the primary loop which is the feedback of the position and this is the secondary loop or the minor loop which is the feedback of the velocity. So it means I am feeding back the velocity in addition to the position as far as this total feedback controlled system is concerned.

Now you will note again the manipulation so that the negative sign is taken care of. This is my power amplifier (Refer Slide Time: 39:57) what is the gain of the power amplifier; the gain of the power amplifier is a gain with the minus sign R fp divided by R p. So what I can do is I can take the total gain here as the two gains multiplied and the negative sign is automatically taken care of and hence I take you to the block diagram. the minor loop side I completed this way now, this was the signal we named it as e dash, let me put it a plus here, a minus sign here, this is the signal e t coming from the tachogenerator this particular signal I multiply it by R f dash R fp divided by R dash into R p so that this becomes e a the armature voltage.

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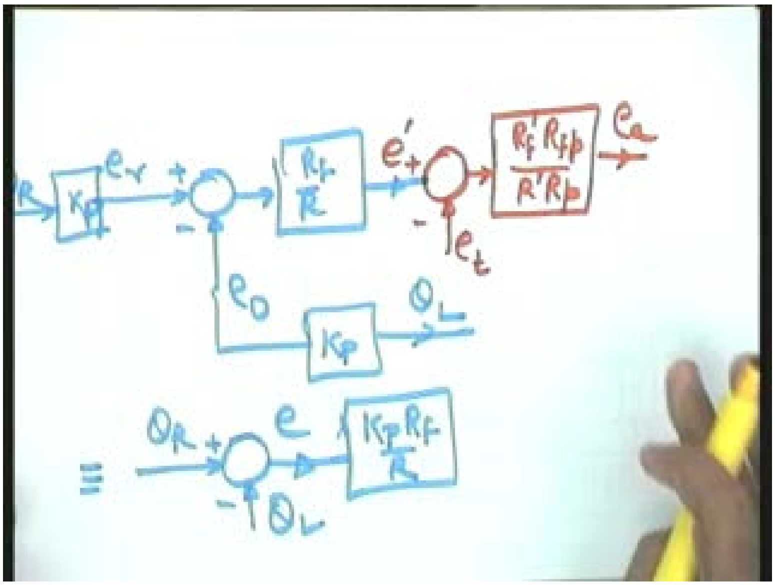

Since on this slide there will not be a space so from this armature voltage I will continue with my block diagram. But keep in mind that I will have to generate signals e t and theta L so that the complete block diagram can be drawn. So, e t and theta L I will generate from a block diagram which I take as a continuation from e a.

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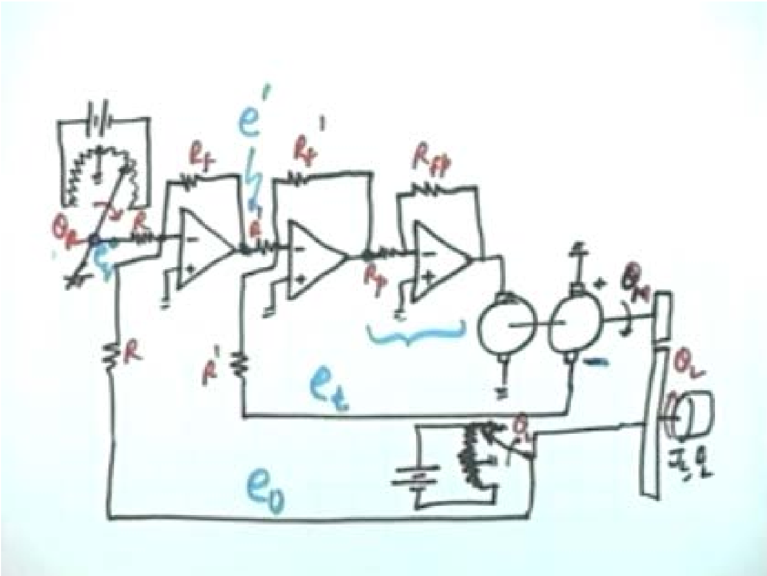

So this e a has come at this particular point, now I am here, e a is the voltage which is available to the armature. This particular voltage the complete block diagram can be drawn and hence I think yes this will be appropriate here theta R, theta L, a constant K 1 plus minus another constant K 2, here let me take motor. I think this now can be drawn this way without any problem and this is theta M.

The motor relationship you will be able to draw and this you know that, as far as the transfer function of the motor is concerned the transfer function of the motor is K m divided by s into (tau m s plus 1). You can complete this block diagram through the feedback loop which is the back EMF loop. So I am not taking that, I am taking this as a motor and generating K t and generating K b and theta L.

Help me please; how do you how do I get this value e t from theta M?
Give me the value of this block; I need your help now. Give me the value of this block (Refer Slide Time: 42:31) so that I get e b here the back EMF oh I am sorry I need e t here the tachogenerator voltage. Yes, what should be the value?
[Conversation between Student and Professor – Not audible ((00:42:44 min))]
s K t K t is the tachometric constant because the tachometer output e t is proportional to speed and in the block diagram I am tapping my signal from theta M so this becomes theta M into s K t, this is e t and this is the feedback signal available over here. Now you want a signal theta L as well. So, if I want a signal theta L so in this particular case what I will do is, yes, give me the value here as well please;
[Conversation between Student and Professor – Not audible ((00:43:17 min))]
n is the gear ratio, what should I put over here?
Should it be n? Yes, n we had taken if you recall theta L by theta M that is right, it will be n. n we have taken as theta L dot over theta M dot so I am writing it here there is no confusion, n I am writing it as theta L dot over theta M dot this is the ratio; if I take this as the gear ratio then it will be n and here it is the load position theta L. From theta L you tap your signal and take it to this particular point this becomes the complete diagram where the motor block could be again written in terms of the total feedback loop and therefore this motor block will

give you one more feedback loop. However, that feedback loop is not because of us; that is, we have not added a component there, that feedback loop is because of the inherent nature of the motor which is through the back EMF. So, if I want to take this feedback loop also from theta M, if I tap a signal, s into K b I will put and suitably that particular block will be completed over here.

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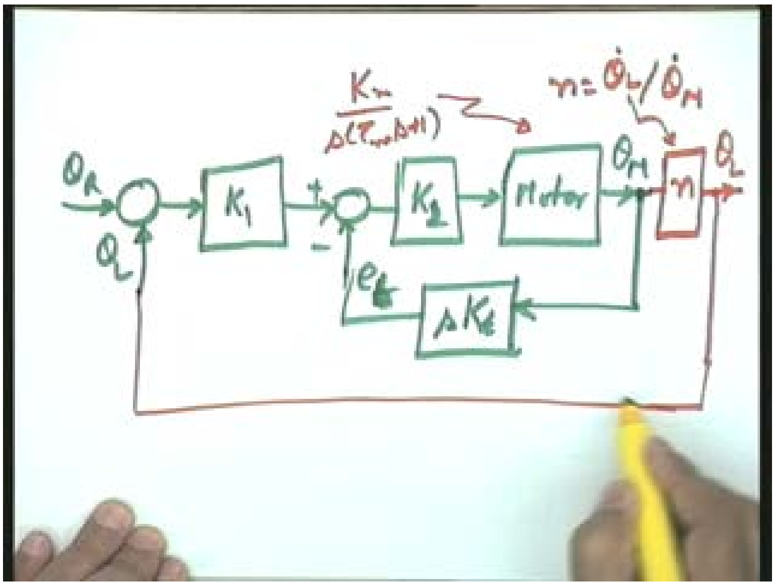

Now, here, before I let you go I like to pose a question. If I break this particular loop what will happen as far as the functioning of the system is concerned? If I break this loop what'll happen to the performance of this particular system? Yes, I will need a replay from you only. You just see that there are two loops: One loop is through the position and the other loop is through the velocity. That is, you can say as if this particular loop is the derivative of the position. So it means as if, in addition to the output signal you are feeding back the derivative of the output signal as well. So, if this derivative is removed if only the output signal is fed back what will happen to this particular system?

[Conversation between Student and Professor – Not audible ((00:45:24 min))]
It means basically, I think the point is right; basically it will continue to act as a position controlled system. The only thing is this that this K t by proper use of K t you are controlling the damping of the system because this is also controlling the damping. A derivative feedback, please see, like back EMF the derivative feedback is also controlling the damping of the system because after all you are giving a signal which is proportional to speed; back EMF is also a signal which is proportional to speed. The only difference between back EMF K b and K t is this that the back EMF K b is beyond your control. Once the motor is selected you cannot change the value of K b. but K t signal is in your control because once the motor is selected the selection of a tachogenerator is in your hand and therefore the signal K t can be controlled. but you please note that in this particular block diagram K t serves the same purpose as K b the only different being that K b is not in your control once the actuator has been selected while K t is in your control because the feedback measurement device you can appropriately select. So it also provides damping.

As he has rightly pointed out if I remove this particular block, that is if I do not give the feedback signal from the tachogenerator the motor still acts as a position controlled system the only thing is that the performance of the system may get deteriorated.

The last question. Let us restore this particular block, restore this and break this, yes very important point, break this. Keeping this in mind actually it is a voltage e r and this of course you have broken so this signal is not coming. The reference signal is actually a voltage which has been appropriately interpreted as proportional to the required position.

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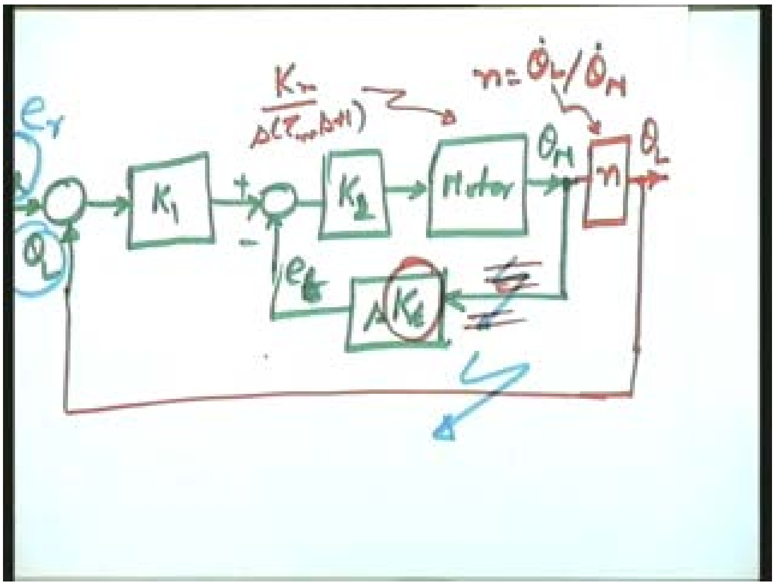

Now this is the last question; answer this question and go. That is, if I break this loop and this loop is there in the system the same system was there as how would this system will work and what will be the nature of the performance of the system. Yes, [Conversation between Student and Professor – Not audible ((00:47:38 min))] Yes please it is right. Please see that your original position controlled system now is a speed controlled system. This theta R is not important you see this is the voltage which earlier was interpreted as a signal proportional to position because a feedback of position signal was coming. Now this particular voltage is actually representative of speed because there is no position feedback loop. So this particular voltage e r (Refer Slide Time: 48:06) which is going in the forward loop is a representative of speed now and a speed feedback is coming in this particular case.

Please see, if this loop is broken in that particular case the primary feedback loop is that of speed and therefore the system acts now as a speed controlled system. In this particular case this theta M into s K t is actually coming as from omega M that is the motor velocity and this particular signal is K t in this particular case therefore your K t into omega M becomes the feedback as far as the speed controlled system is concerned. So, once this primary loop is broken the feedback is that of speed and this voltage is interpreted as a signal proportional to speed and hence the resulting system becomes a speed controlled system that is all, thank you.