Industrial Instrumentation

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Lecture - 30
Synchro

Welcome to lesson 30 of industrial instrumentation. In this particular lesson, we will synchro, which is basically inductive based devises. And this can be used as an error detector or position sensors, not the linear position rotary positions can be can be rotary position can be detected can be measured and we will get the voltage output. As well as synchro is widely used for the feedback, control systems in AC position control systems. And also in continuations with the synchro, we will consider the micro synchro or which is called more popularly named as microsyn. That is also will be covered in this particular lesson.

Synchro is actually a steel now, you will find it is used though there are digital shaft encoders, which is used for knowing the position of the system positions of the rotary shaft. But the synchro along with the servo mechanisms where that means, where the 2 phase servo motors can be used for position control system that means, I will give some particular position. That can be easily attained by the use of synchro when the synchro is used as a error detector. As well as for remote transmissions of the synchro some synchro is also can be used, over a long distance synchro can be used.

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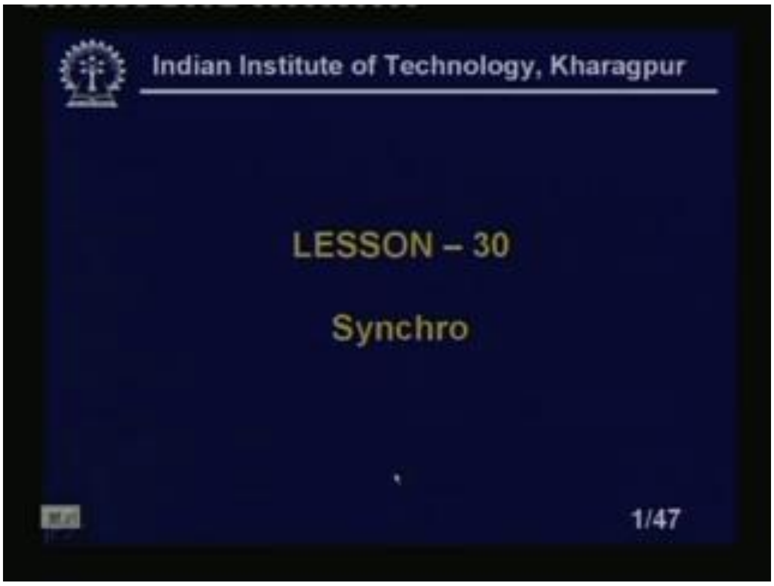

So, let us look at the contents of this particular lesson. Lesson 30 - synchro.

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Contents are the synchro as well as you know that it has a transmitter and it has a receiver. So, we will consider the transmitter first as well as receiver the 2 are almost same thing. I mean it has 1 rotors and stator, both in the case of transmitter and the receiver we do not call it, we call it control transformer in the case of synchro. So, it is always is to be used in the pair form; that means, transmitter cannot be used alone or receiver cannot be used, alone which is called as a control transformer. So, this always is to be used in pair. So, that is the reason sometimes we call it always or sometimes we call it synchro pair, instead of calling just synchro, because synchro alone 1 transmitter or 1 receiver will not work, right.

So, keeping that in mind, so always please note that the synchro always see whether it is error dedicator systems or reciprocation control systems or as a mechanical shaft error measurements. I mean all these things, I mean involved with the synchro pair; that means, one transmitter and one control transformer. So, we will discuss these details, this transmitter and control transformer. The first we will discuss the transmitter then we have control transformer which is nothing but a receiver, but what we are calling it control transformer, because the there is a transformer action. The transformer action is also there in both in the transmitter and the control transformer, but we are calling it control transformer.

Then we will discuss the synchro error detector. Synchro can be used as the error detector, because there is a misalignments of the 2 shaft can be detected. Because we will get a professional output voltage from the misalignment of the shaft that we utilized to use in control systems. We will also discuss the microsyn or micro synchro which is a, which is a smaller versions of the synchro with it is also synchro; that means, it can be also used as a position sensor. But the advantage of the microsyn is that it is a basically used for a low torque devices and you will get the there is no winding on the rotor of the microsyn. Whereas, in the case of is synchro we have windings; that means, coil windings both in the case of rotor as well as in the stator. Because since it is a motor devices you it must have sub stator and it has a rotor also I mean stator and rotor.

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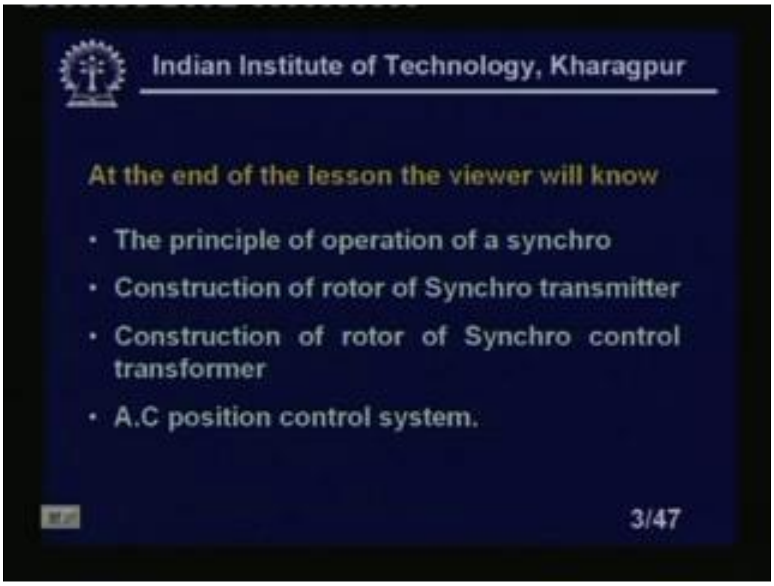

At the end of this lesson, the viewer will know the principle of operation of a synchro, the construction of rotor of synchro transmitter. The construction of rotor of synchro control transformer, AC position control systems. We will see that AC position control systems can be used that we will discuss in details here.

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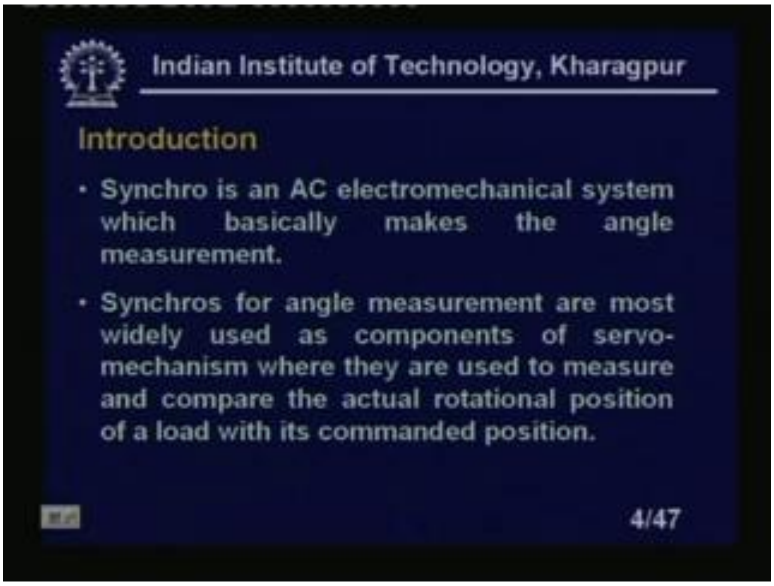

Introduction let us look at synchro is an AC electro mechanical system which basically makes the angle measurements. Angular measurements of the shaft can be detected thus I mean rotor it sense it is not actually for the linear measurement, but it is a angle measurement devices, right. This is slightly differing I mean, so for the in the all the 39 lessons we have not discussed anything on the angle measurements. Now, with the rotary angles measurement is possible; that means, if there is a misalignment of the shaft that can be I mean that can be detected by the help of synchro.

Synchros for angle measurements are most widely used as a components of servo mechanism. Servo mechanism is nothing but a feedback systems automatic feedback control or automatic control systems in short form we call it servo mechanism where they are used to measure the compare the actual rotational position of a load, with its commanded position. Why there will be some difference, because of we have some desired position of the load rotary position angle position that can be achieved with the help of synchro and in conjunction with the servo mechanism if the torque is large, right. Otherwise, we can use a synchro pair we will discuss all these in details.

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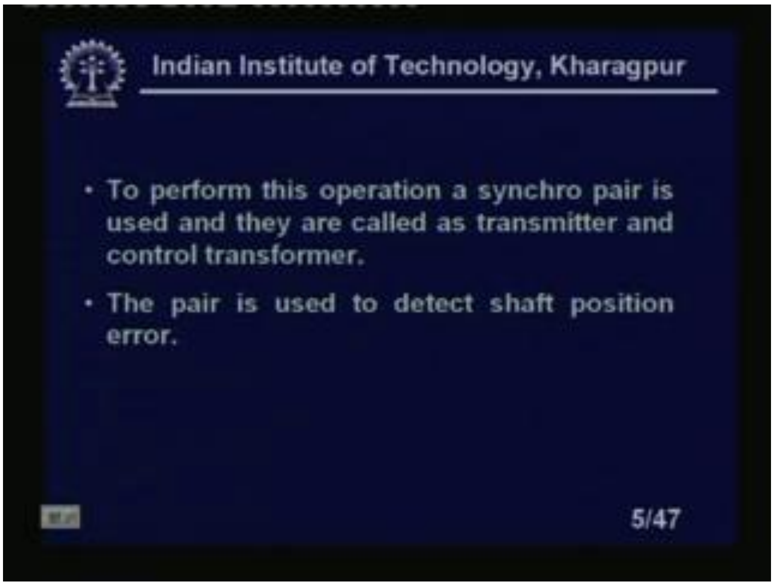

To perform this operation a synchro pair is used, and they are called transmitter and the controller transformer. Construction is almost same stator construction is almost same the rotor constructions are different, we will look at. The pair is used to detect shaft position later synchro pair as I told you, sometimes we are just calling it pair is used to detect the shaft position error.

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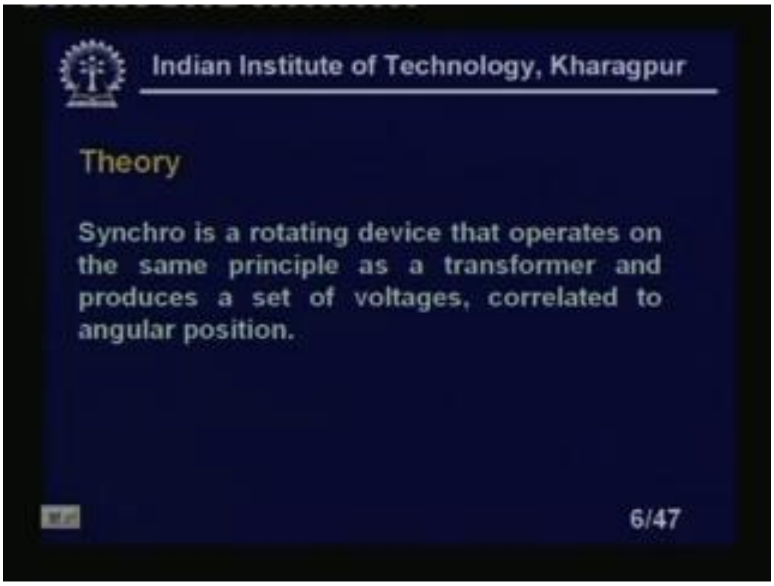

Theory: synchro is a rotating device that operates on the same principles as a transformer. And produces a set of voltages is correlated to angular position. There are 3 stator, so from each stator across the each 2 stators; that means, if you have a 3 stators between the stator 1 and stator 2 stator 2 and stator 3 stator 3 and stator 1. We will get some voltages that can be calibrated in terms of the position of the rotor right. So, as the rotor position changes the voltage output also will change.

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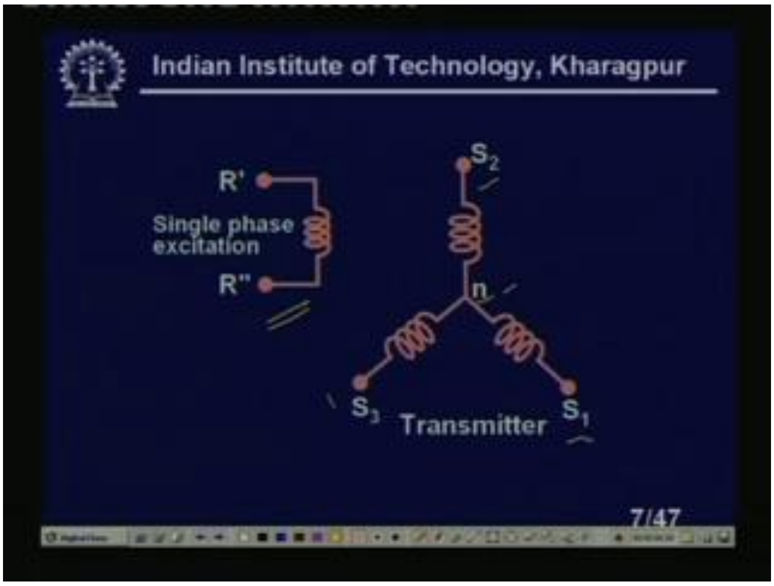

This is the diagram of a symmetric diagram of synchro, I mean transmitters. Because it is in I mean it is a big diagrams we cannot accumulated in a single slides. So, in the it is splinted over in the 2 you see this is a single phase excitations, we are giving here this is a rotor. So, this is a rotor, this is the rotor, and this single phase excitation goes to the rotor. Through a slip rings; obviously, we need slip rings because rotor; obviously, we do not need in any slip rings in the stator. So, we will get some voltages across the stator; that means, between S 2 and neutral and between S 3 and neutral as well as this 1 S 1 and neutral, right. We will get a voltage let us look at the second slide.

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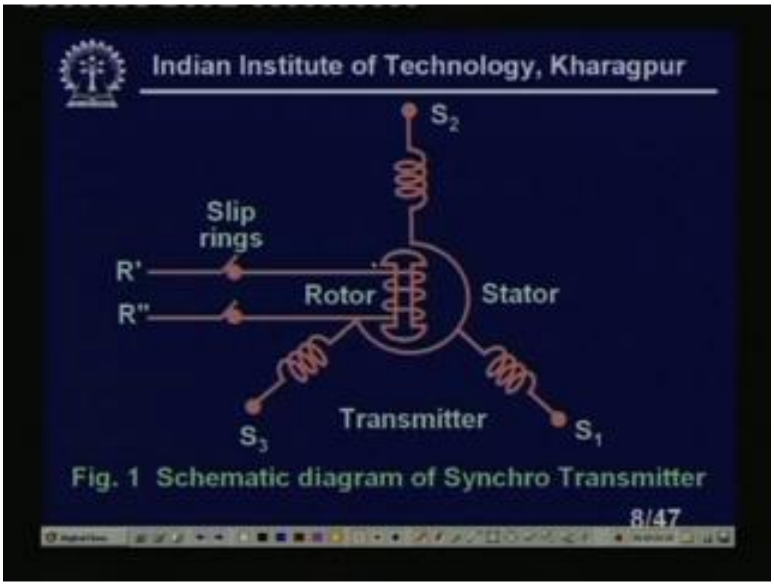

You see here, this is completes schematic diagram of the synchro transmitter. That is as just diagram this is a complete diagram of the synchro transmitter. Let us look at, here I am giving between the R dash R double dash since it is rotor. So, I am giving the name R dash R double dash through slip rings and to the rotors of the synchro. We have 3 windings in the stator which is which is in this complete systems. We call it the transmitter this is the rotor of the transmitter it is slightly difference, if you can look at this is the dumbbell shape we will discuss all this details. Why it is dumbbell shape? Because actually the command we will give to the, this rotor.

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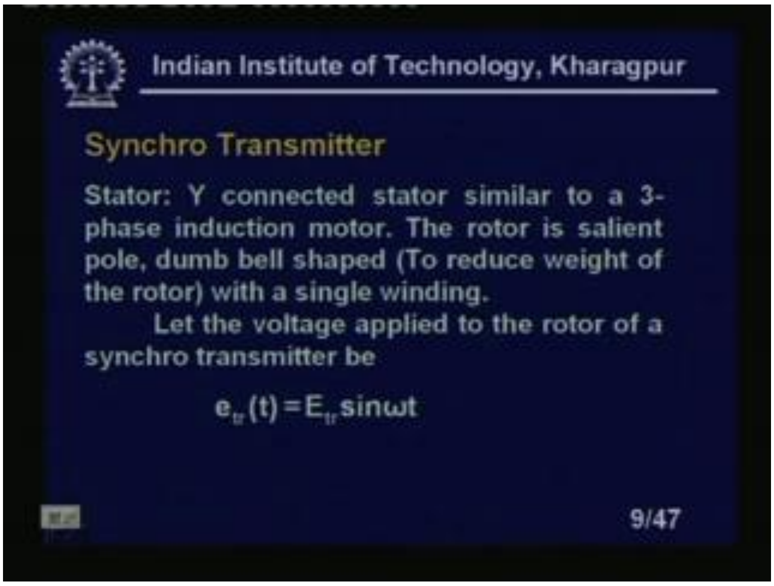

So, it should not roll actually the system in which we are connecting this shaft whereas, the control transform rotor which is typical cylindrical shape that we will see later on. Synchro transmitter; let us look at stator is Y connected stator similar, to a 3 phase induction motor. Though it looks like a 3 phase induction motor, but we will see that we will get a single phase output, at the stators of this synchro transmitter. Rotor is salient pole, dumbbell shaped. Why to reduce the weight of the rotor? Because if the there is a mechanical loading will not be there if the weight of the rotor is less with a single winding. Where the single winding, on the rotor of the synchro where the excitation single phase excitation is going through slip rings. Let the voltage applied to the rotor of a synchro transmitter be Etr time domain, Etr this is the magnitude of the signal ((Refer Time: 10:11)) into sin omega t. This is the omega is the excitation, frequency of circular frequency of excitations of a single phase excitations which we are giving to the synchro rotor, clear?

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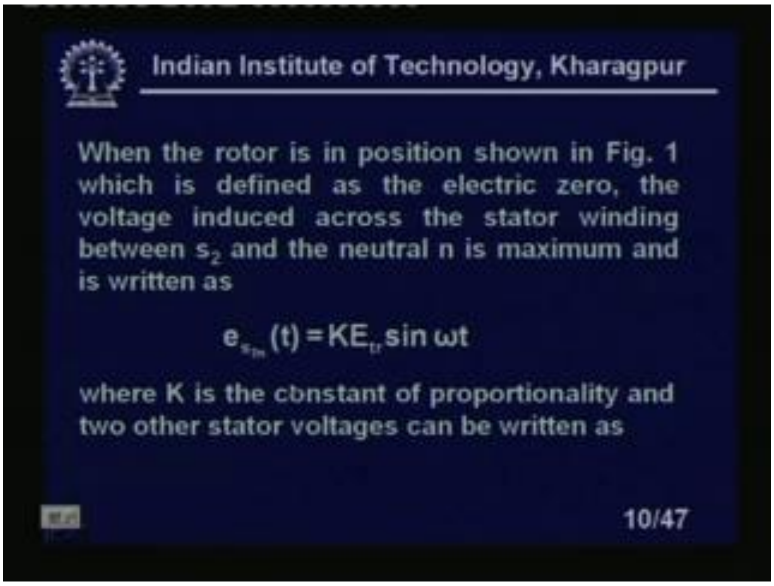

When the rotor is in position as shown in the figure, let us go to the figure. This is the rotor position when the rotor is aligned with S 2 if the position is something like that, when the rotor is in position shown in figure in one, which is defined as the electric 0. The voltage induced across the stator winding between S 2. And the neutral n is maximum, in this particular position rotor or the output voltage will be maximum. The induced voltage across the stator windings between S 2 and the neutral is n is maximum.

And is written as this is the neutral; neutral we are abbreviated as S. Please note this is the neutral we had abbreviated as S. S means this is a neutral we had been abbreviated as n, and is written as e S 2 n between the stator winding 2 and the neutral is K the factors we are introducing into Etr sin omega t no phase shift nothing, where K is the constant of proportionality and 2 other stator voltages can be written as these are the constant of proportionality. And the 2 other stator volt, there are 2 other stator voltage between the stator 1 and neutral and stator at the 3 and neutral.

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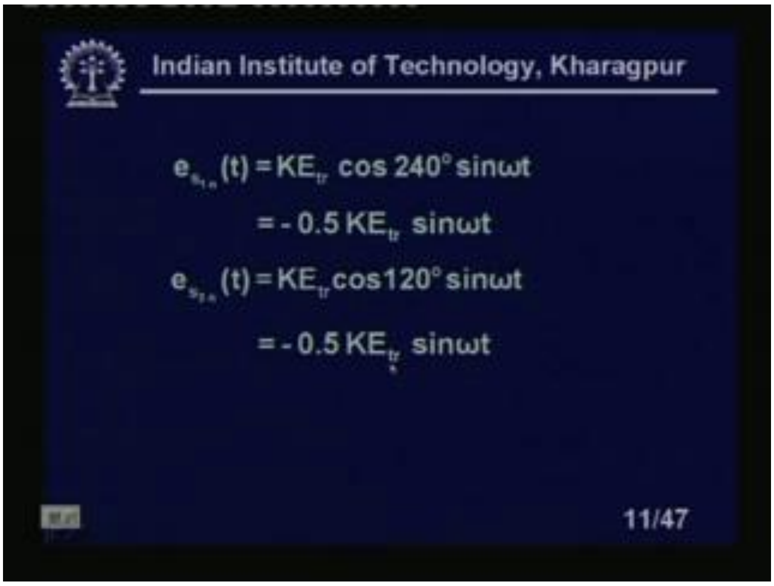

So, those voltages will look like you see e s 1 n KE tr cos 240 degree into sin omega t, and minus 0.5 into KE tr into sin omega t. This is our e s 3 n time domain t K into E tr cos 120 degree into sin omega t equal to minus 0.5 KE tr, because 120 degree will be KE tr Etr is there, because it is in transmitters we are giving it Etr subscript tr. So, I have abbreviated these transmitters by tr, right into sin omega t.

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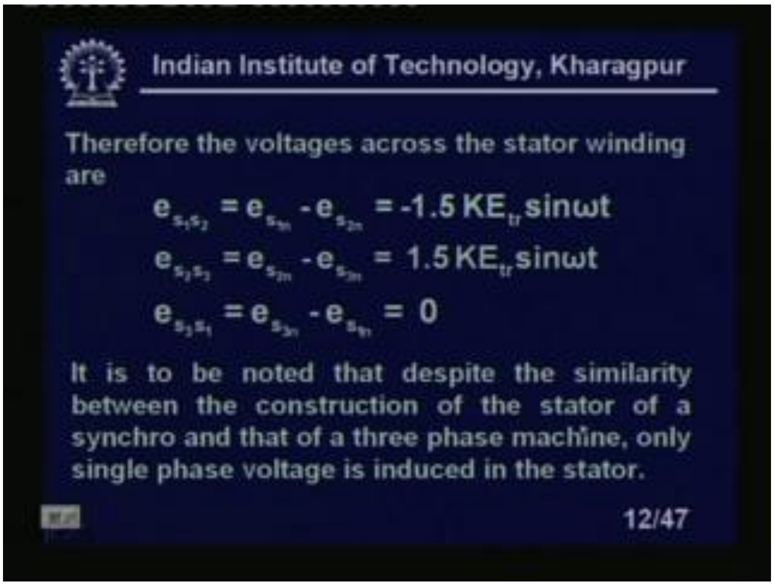

Therefore the voltage across the stator windings are e S 1 S 2; that means of instead of neutral if I measure the voltage across S 1 and S 2. I will simply subtract the voltage e S

1 n between winding 1 and neutral and winding 2 and neutral which is equal to minus 1.5 KE tr into sin omega t. E S 2 S 3 equal to e S 2 n minus e S 3 n equal to 1.5 KE tr into sin omega t. E S 3 S 1 equal to e S 3 n minus e S 1 n. So, these 2 will be in phase, so this should be equal to 0, clear?

So, these are the 2 different voltages we are getting. So, it will give the position of the synchro rotor right; that means, transmitter rotor position can be predicted from this voltage. Because we always we said that we within all synchros we are getting the 3 different stator voltages. That stator voltage will indicate the position of the rotor of the synchro. It is to be noted that despite the similarity between the construction of the stator of a synchro, and that that of a 3 phase machine only the single phase voltage is induced in the stator. As if we is the thing I mean three phase indication machine they are looking very similar to the 3 phase induction machine, but you will see that the a single phase voltage induced in the stator.

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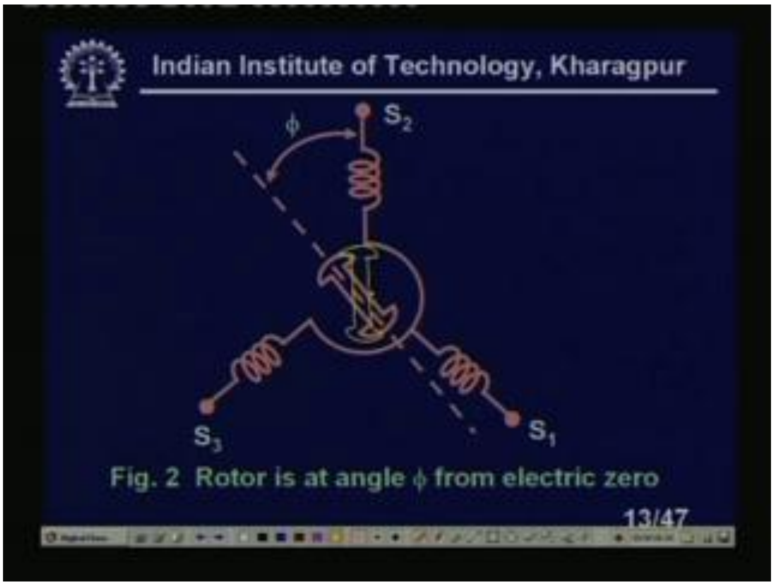

Now, what I did? I actually I rotate, the previously you see this stator is in this alignment is not it stator were like this 1 right. Previously what we had? I had the stator like this 1 like this 1 I had a stator like this 1, clear? Now, I have rotated by angle phi in anticlockwise directions. I have rotated the stator in anticlockwise direction by an angle phi with respect to S 2. In fact, the positions, which I have shown that is considered to be the electric 0 right, you see this is angle phi which is making with the stator winding S 2.

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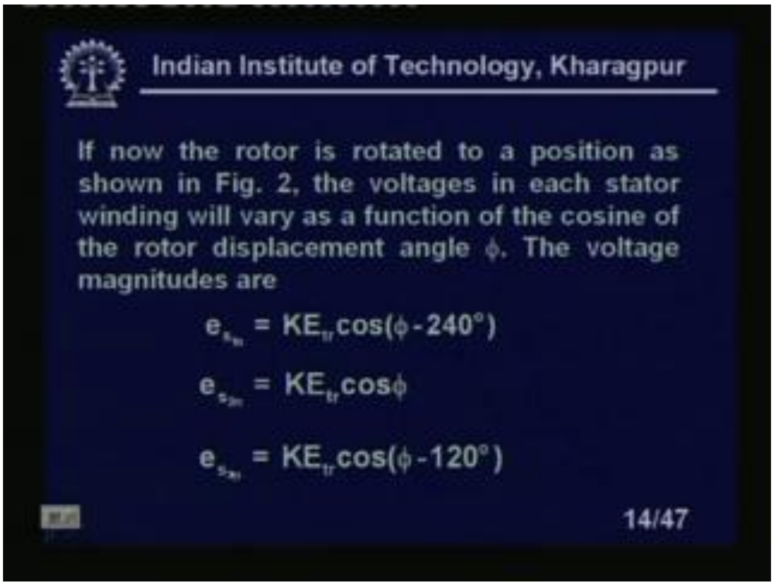

If now the rotator is rotated. To a position as shown it figure 2 that is figure 2. I think, yes. The voltage the voltages in each stator winding will vary as a function of the cosine of the rotor displacement angle phi. The voltage magnitudes are e S 1 in KE tr cos phi minus 240 degree. And this will be; obviously, multiplied by the sin omega t please note, because sin omega t will be there. So, I am not writing it everywhere sin omega t is there, because that is excitation, is not it? That single will be always there.

So, I am not writing into sin omega t E KE tr cos phi minus 240 degree e S 2 n equal to KE tr into cos phi and e S 3 n; that means, the between the winding 3 and neutral stator winding stator between 3 and neutral between 2 and neutral between 1 and neutral. So, it is 1 and neutral KE tr cos phi minus 240 degree e that between 2, and neutral when the rotor is shifted by the angle phi from the winding 2 in anticlockwise directions KE tr into cos phi, and e S 3 n equal to KE tr into cos sorry KE tn.

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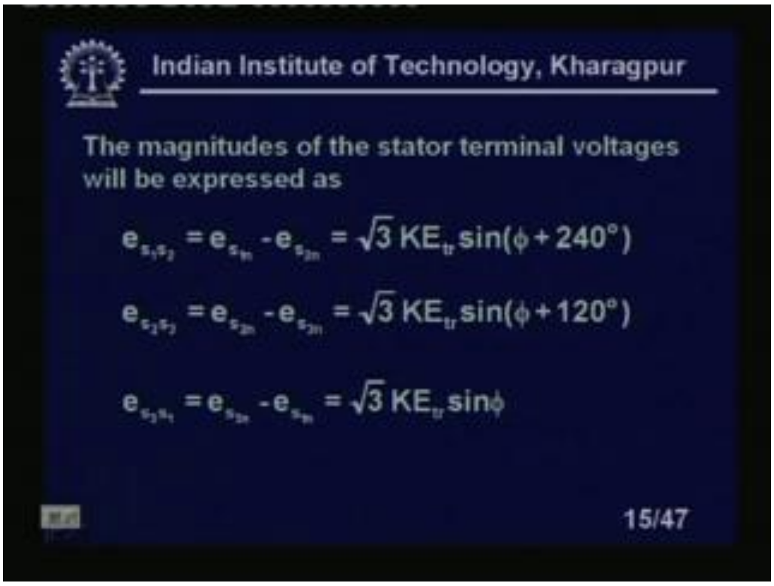

KE tr cos phi minus 120 degree clear, with sin omega t; obviously, with that will be there. The magnitudes of the stator terminal voltage will be expressed as e S 1 S 2. That means, that in this position thus voltages across the stators will be given by e S 1 n minus e S 2 n root 3 KE tr sin phi plus 240 degree e S 2 S 3. That means, between the stator of the winding 2 and 3 between that is can be given by the voltage, which will get at the stator 2 and neutral and the stator 3 and neutral root 3 KE tr sin phi plus 120 degree into sin omega t everywhere sin omega t is there. And e S 3 S 1 equal to e S 3 n minus e S 1 equal to root 3 KE tr into sin phi, clear?

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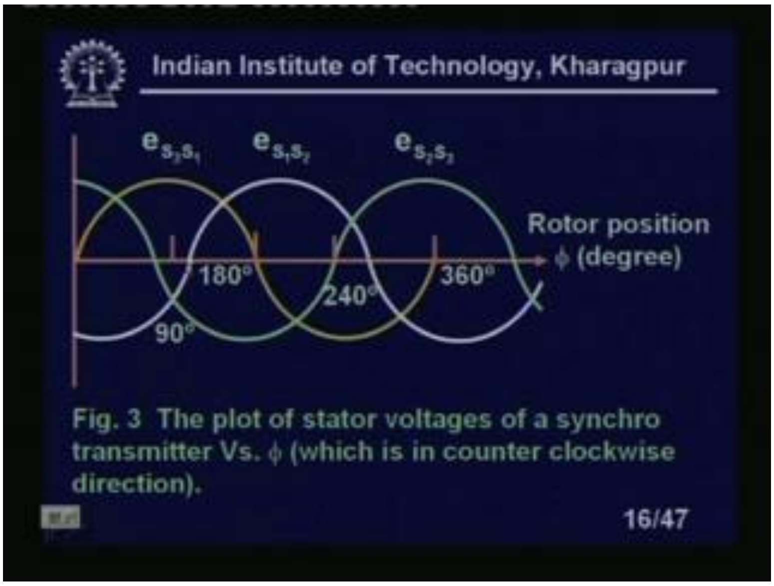

You see this is the plot of the stator voltages of a synchro transmitter versus phi. What is phi, which is in counter clockwise directions? Plot of the stator voltage of this you see here e S 3 S 1. So, you have plotted like this right is not e S 3 1. There is KE tr into sin phi sin omega is there forget about that, because we are drawing only with respect to phi. So, e S 3 1 like this 1 whereas, S 1 S 2 you see S 1 S 2 S 1 S 2 has a, I mean 240 degree. So, it is it looks like this you see at 240 degree it is becoming 0. Whereas, S 1 S 2 will like this 1 at 180 degree it should become 0, clear?

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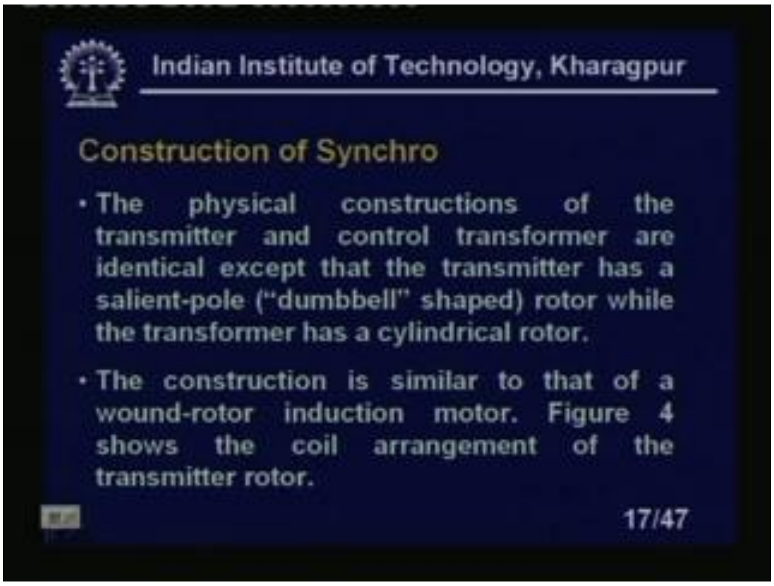

Construction of a synchro; The physical construction of the transmitter and the control transformer are identical, except that the transmitter has a salient pole dumbbell shaped rotor while the transmit transformer has a cylindrical rotor. This is the distinct difference or only difference between the rotors because stator in the 2 cases are same. Both in the case of transmitter and control transformers, only the difference is in the case of design of the stator. Because to reduce the weight we have made dumbbell shaped whereas, the control transformer rotor is the cylindrical shape. The construction is similar to that of a wound rotor induction motor and the figure 4 shows the coil arrangement of the transmitter rotor.

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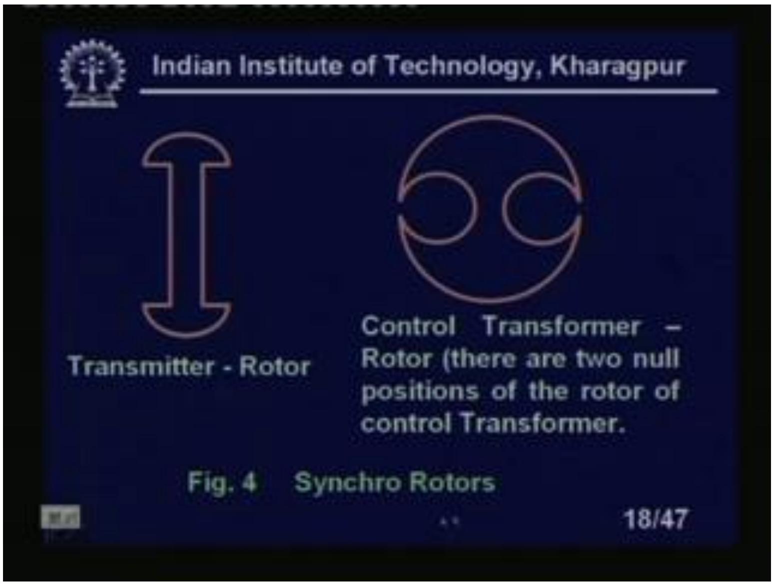

See this is the coil arrangement of the transmitter rotor, and this is the control transformer rotor. There are 2 null positions of the rotor of the control transformer. This is the synchro rotors constructions. You see this is dumbbell shaped whereas, this is cylindrical shape, why this is cylindrical shape? Dumbbell shapes already, I have defined. And why it is cylindrical shape? That we will define after few minutes.

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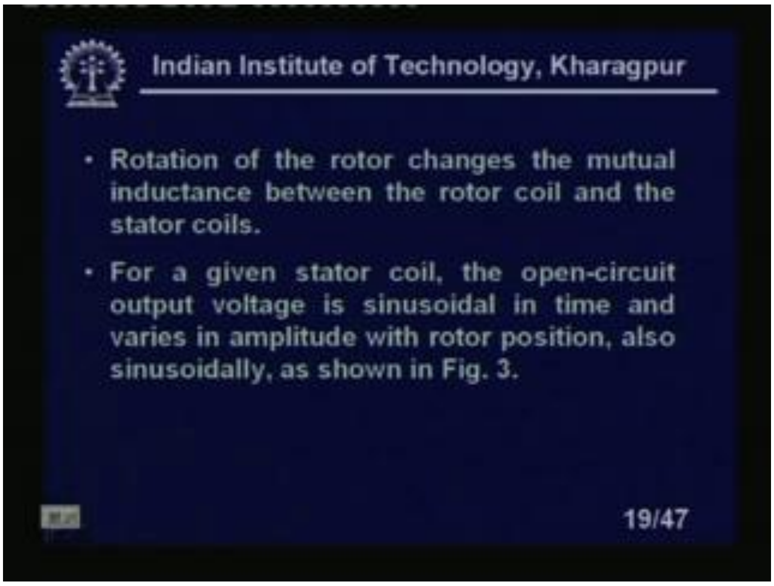

The rotation of the rotor changes the mutual inductance between the rotor coil and the stator coils. That is the reason I am getting different voltages is not it. You see write I will write it again rotation of the rotor changes the mutual inductance, between the rotor coil, and the stator coils. For a given stator coil, the open circuit output voltages is sinusoidal in time, and varies in amplitude with the rotor positions also sinusoidally as shown in the figure 3. Already we have shown that with the changes of rotor positions is not it we have seen in the figure.

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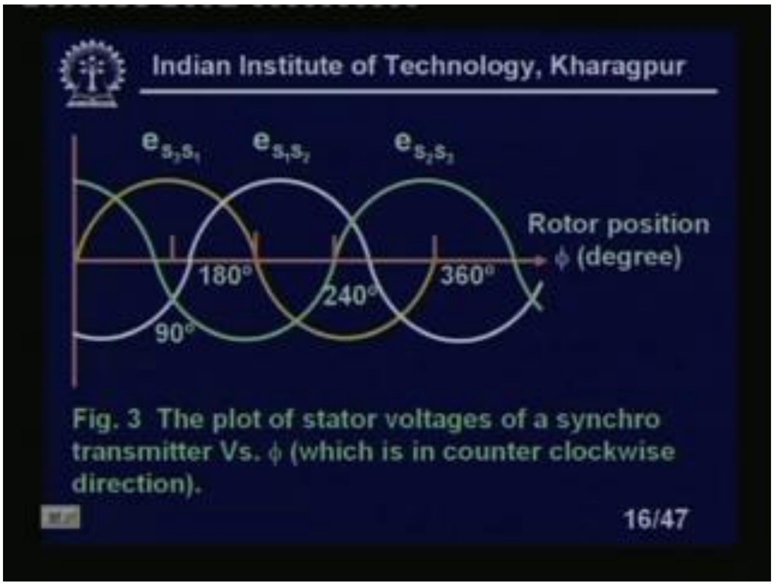

Where is that it figure. You see here, with the changes in rotor positions. This signals varies sinusoidal is not it. You see the signal varies sinusoidal, with the changes in the rotor position. Rotation of the rotor changes the mutual inductance between the rotor coil and the stator coils. For a given stator coil, the open circuit output voltage is sinusoidal in time, and varies in amplitude with the rotor position, also sinusoidally as shown in figure 3. This output voltage will be; obviously, sinusoidal is not it.

The 3 voltage signals from the stator coils uniquely define the angular position of the rotor. This will uniquely define the angular position of the rotor, in which position whether it is clockwise or anticlockwise everything will be known from this when these 3 voltages are applied to the stator coil. These 3 voltages will be applied to the stator coils of the control transformer. They produce a resultant magnetomotive force, aligned in the same direction as that of the transmitter rotor.

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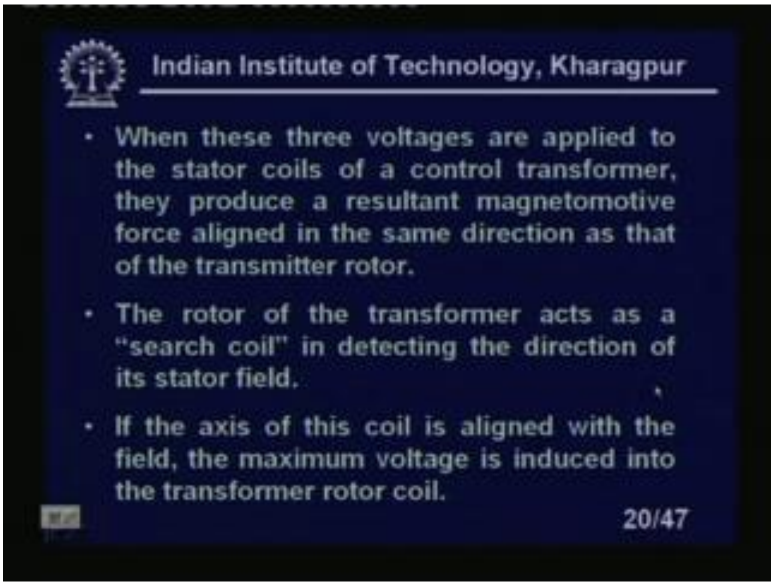

This will produce the magnetomotive force and which will be aligned in same position. That means, it will result in magnetomotive force aligned in the same direction as that of the transmitter rotor, the rotor of the transformer act as search coil in detecting the direction of the stator field. Rotor of the transformer acts as a search coil; that means, you see the rotor of the transformer can be act as a search coil. This will give you, because is there any mismatch between the rotor position of the 2. I mean of the rotor positions of the transmitter and the control transformers I will get some output if the axis of this coil is aligned with the field. The maximum voltage is induced into the transformer rotor coil.

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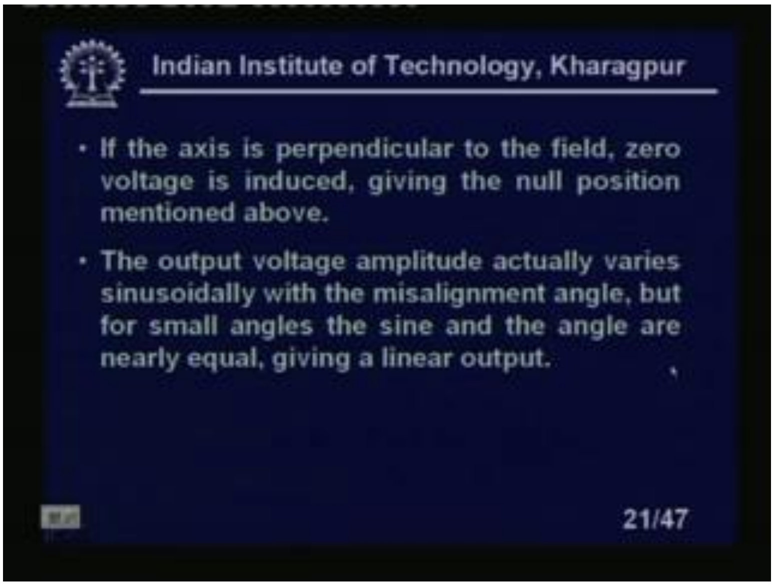

If the axis is perpendicular to the field 0 voltage is induced and giving the null position mentioned above. The output voltage amplitude actually varies sinusoidally with the misalignment angle, but for small angle the sine and the angle are nearly equal giving a linear output. How it is happened?

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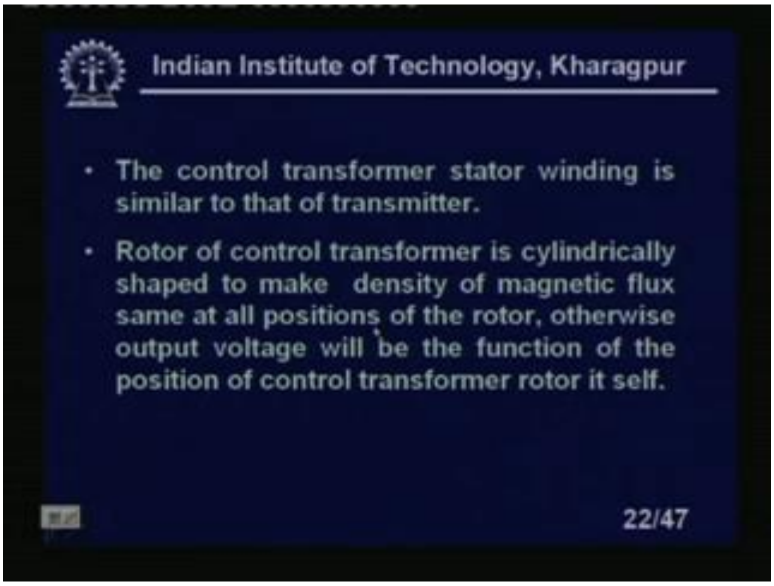

Let us see the control transformer stator winding is similar to that of the transmitter that is already we have discussed. The rotor of control transformer is cylindrically shaped to make the density of magnetic flux same, at all positions of the rotor. Otherwise the output voltage will be the function of the position of the control transformer rotor itself right. So, that is the undesirable characteristic previously nowadays you know that is almost all the I mean the output voltage should not be a function of that. So, you want to intimate the independent for that particular part. So, that is the reason the density of the magnetomotive magnetic flux is same at all positions of the rotor.

Otherwise the output voltage will be the function of the position of the control transformer rotor itself that I do not want is not it. I want that the rotor output will be the mismatch of the position of the transmitter rotor to the control transformer rotor. But if the control transformer position of the control transformer gives additional change of voltage that is undesirable. That I do not want, that is the reason the control transformer rotor is cylindrical shaped. So, that in all positions; the same density of magnetic flux will be available. That is distinct difference please note, why it is done like this? This is done purposefully, so that the output will be independent of the position. Out only, I mean if there is mismatch of the shaft positions of the rotor with that of the control transformer I will get the output.

But I do not want to get any change of output for the different positions of the control transformer rotor. That is the reason we made it it cylindrical shape. I will read it again rotor of the control transformer is cylindrically shaped to make the density of magnetic flux same at all position, if it is same at all positions what will happen in the case of rotor in the transmitter. In the case of transmitter, because it is dumbbell shaped. If I change the position there are different linkage mutual inductance are difference I am getting different sets of voltage. But here I will not get in the control transformer I will not get that thing right that is the reason it is cylindrical shaped. Now, the voltage only deferred only what were the output voltage I will get from stator of the control transformer. That which will depend on the position or the position mismatch of the transmitter and the control transformer, clear?

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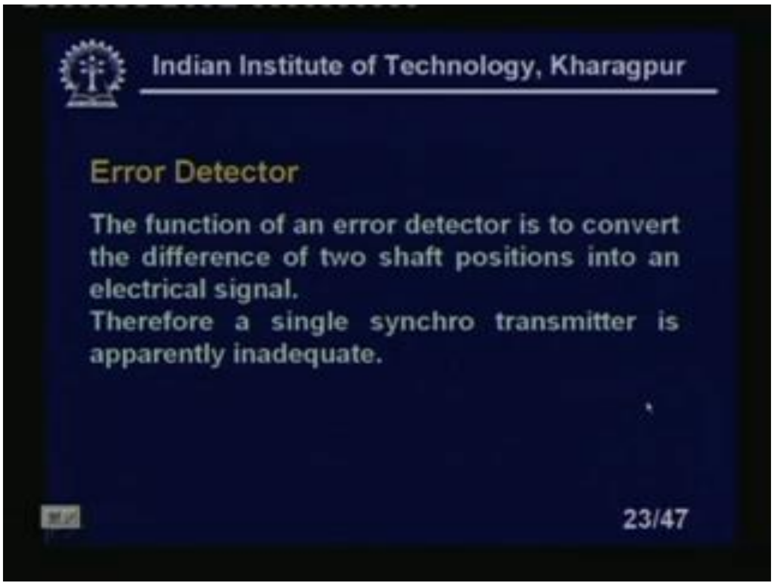

Error detectors, we will that we will more the function of an error detector is to convert the difference of 2 shaft positions into an electrical signals. That we want that the if there is any mismatch of the if the functional error if the mismatch of the difference of the shaft positions, I will get a electric signals. Therefore, a single synchro transmitter will not apparently inadequate as I told you single synchro transmitter will not occur. We will always need a single transmitter. I mean we need the transmitter along with the control transformer; that means, if we call it synchro pair.

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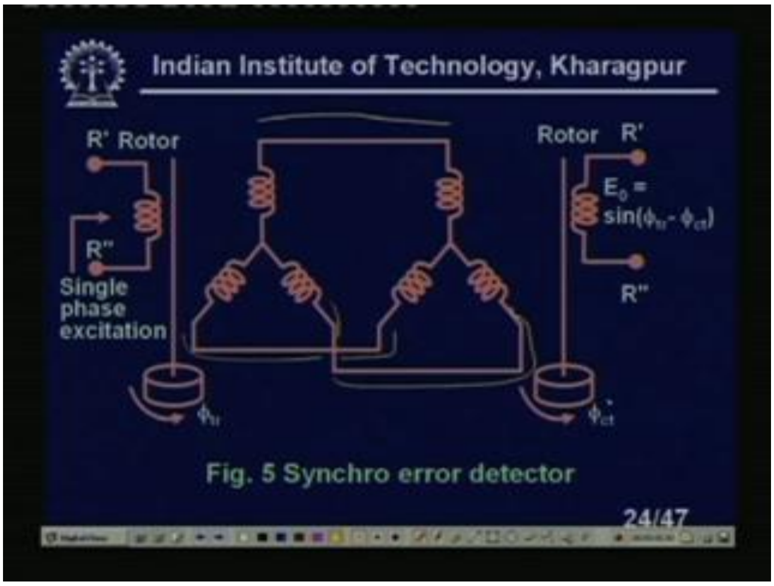

This is the, you see we have talked about; you see stators are look at it very carefully stators are connected. You see all the stators corresponding this stators is connected this stators is connected to this stator is connected to this I have a rotor and, I have a single phase excitation here. Now, if the, these 2 rotors as the same positions I will get the 0 output voltage if these rotor positions are different. This position and these positions are different. I will get output voltage which can be given by E naught equal to sin of phi tr into phi ct this phi ct is the position of the control transformer that is phi ct whereas, the phi tr is the position of the transmitter that is the reason. I will get you phi tr.

So, multiplying factor will be there KE that is not out routing this is the rotor output we will peak up the voltage at this point. R dash and R double dash whereas, I will take the voltage here, I will give the excitations R dash and R double dash are there. This is the shaft of the synchro transmitter and this is the shaft of the synchro control transformer. What I do not want that the, for the different positions of the control transformer I will get a different output voltage. This output voltage I will get that will be only the mismatch of the 2 rotor; that means, phi tr minus phi ct.

But if it is not cylindrically made this rotor of the control transformer is not cylindrically made then. What will happen? You will see for different positions I will get a different sets of voltage, even only for that. Now, if the, these 2 are same phi tr and phi ct same. I will get the 0 output. Because here at that position because these will this output voltage will not change due to the position of the phi ct only, position of the rotor of the control transformer. It is the difference of the 2 transformer will give you output volt. That is the reason this is dumbbell shaped and this is cylindrical shaped, clear?

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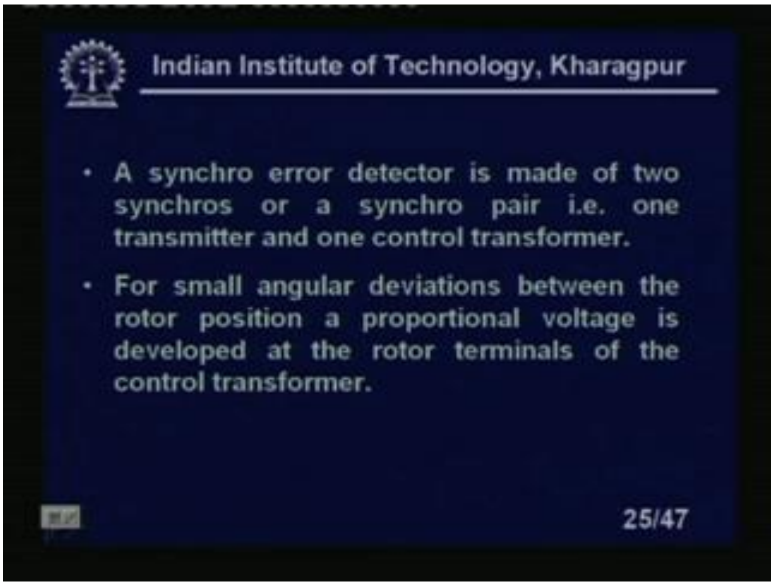

Now, synchro error detector is made of 2 synchros or a synchro pair or a synchro pair. that is 1 transmitter and 1 control transformer. For small angular deviations between the rotor position, a proportional voltage is developed at the rotor terminals of the control transformer right. That means, for small deviations it will find we have seen that it is the sinusoidal voltages. So, for small deviations near the vicinity of the null, we can use it as a linear sensor right.

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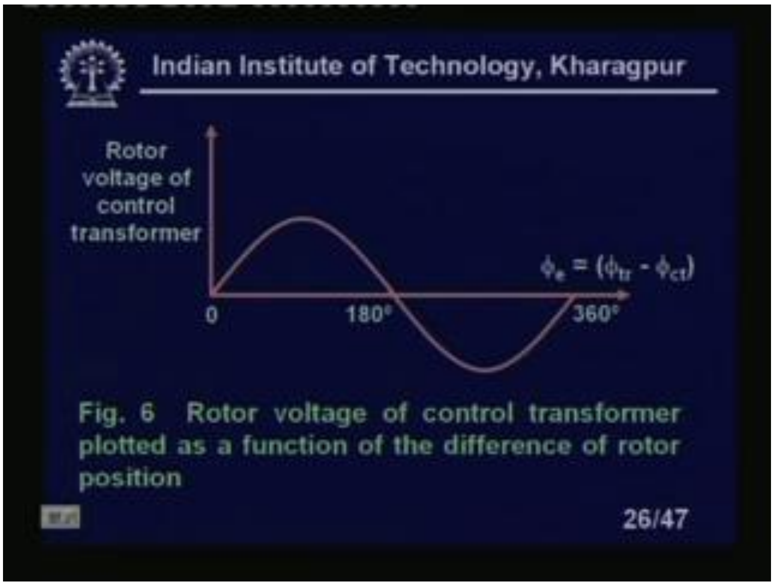

You see this is a you can see here. So, you can see for 15 degree almost you can see it is used as a linear sensor the rotor voltage of the control transformer along with the verses error of the; or mismatch or a misalignment of the transmitter and the control transformer rotor right. So, you see here it is voltage is increasing it is coming like this 1. So, near the vicinity of the null near the null I can say sorry. Say the near the vicinity of the null, I can say it is a linear senses. So, during these positions I can say it is the linear sensor. So, for these positions I can say it is a linear sensor. Otherwise, it is a non-linear device. Obviously, the sin is not linear function it is a non-linear function.

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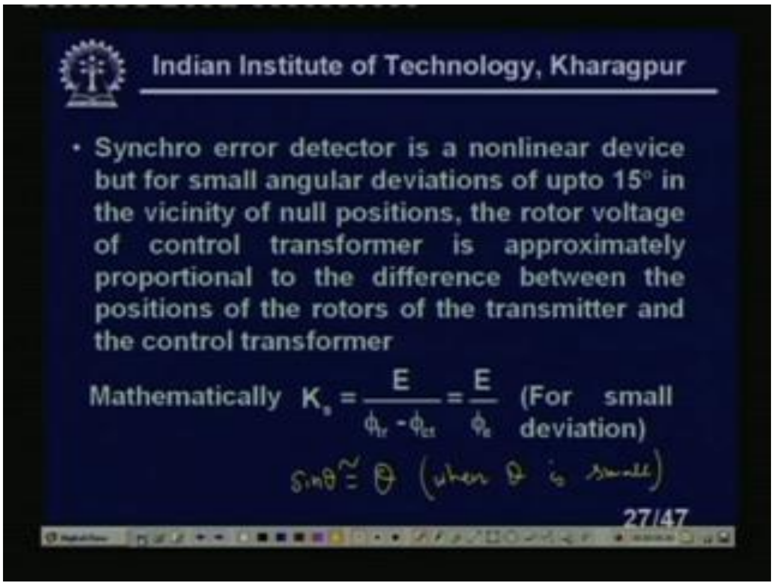

Synchro error detector is a non-linear devices, but for small angular deviations, up to 15 degree. In the vicinity of the null positions, the rotor voltages of control transformer is approximately proportional to the difference between the positions of the rotors of the transmitter and the control transformer. Synchro error detectors is a non-linear devices, but for a small angular deviations of up to 15 degree in the vicinity of the null position the rotor voltages of the control transformer is approximately proportional to the difference between the positions of the rotors of the transmitter and the control transformer. Mathematically K S equal to we can write, E equal to phi tr minus phi ct equal to E by I mean phi e for small deviations. We are writing it is, because sin theta or equal to sin theta for small e is not it? That is we all we know; that means, sin theta is almost equal to theta when theta is small right.

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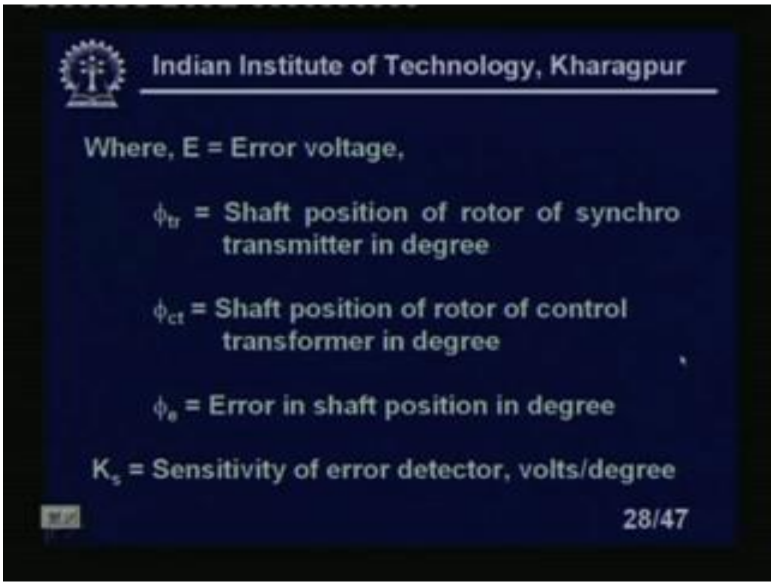

Where E is a error voltage phi tr is a shaft position of rotor, of synchro transmitter in degree, phi ct phi subscribes ct shaft position of the rotor of the control transformer in degree, phi e is the error in the shaft position in degree. And KS is the sensitivity of the error detector. It is in volts per degree.

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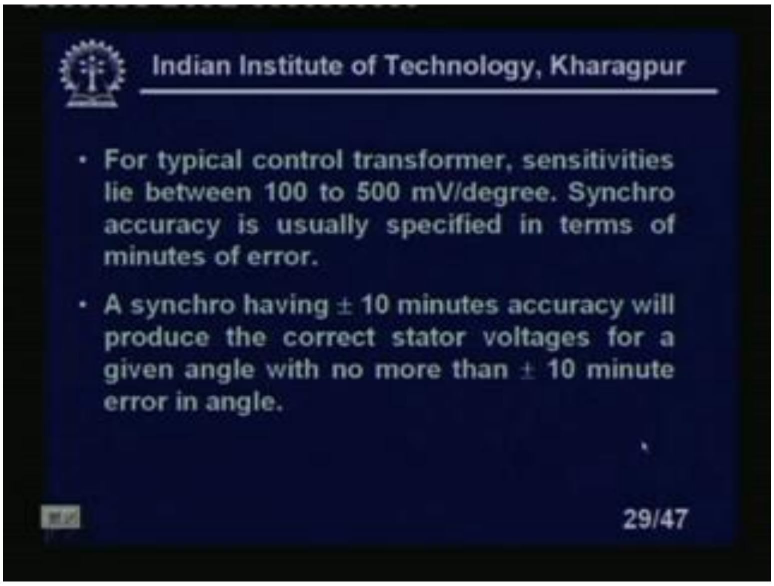

For typical control transformer, the sensitivities lies lie between 100 to 500 millivolt per degree. And synchro accuracy is usually specified in terms of the minutes of the error as you know 60 equal to 1 degree. A synchro having plus minus 10 of accuracy will produce the correct stator voltages for a given angle with no more than plus minus 10 of error signal.

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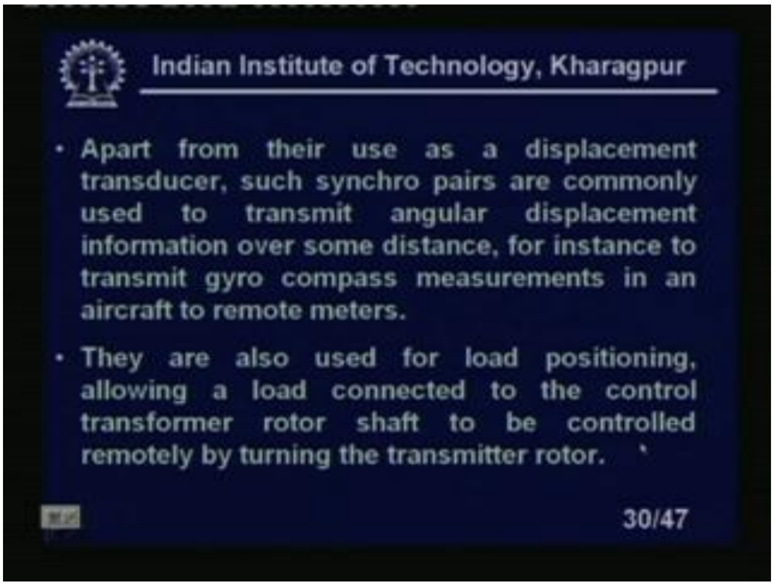

Apart from their use as a displacement transducer such synchro pairs are commonly used to transmit angular displacement information over some distances for instance to transmit gyro compass measurements in an aircraft to remote meters. That is also another use of the synchro transmitters. They are also used for load positioning allowing a load connected to the control transformer rotor shaft to be controlled remotely by turning the transmitter rotor. By transmitting rotor automatically what about that given signals I have given rotate rotary angles I have given to transmitter that will be followed in the control transformer.

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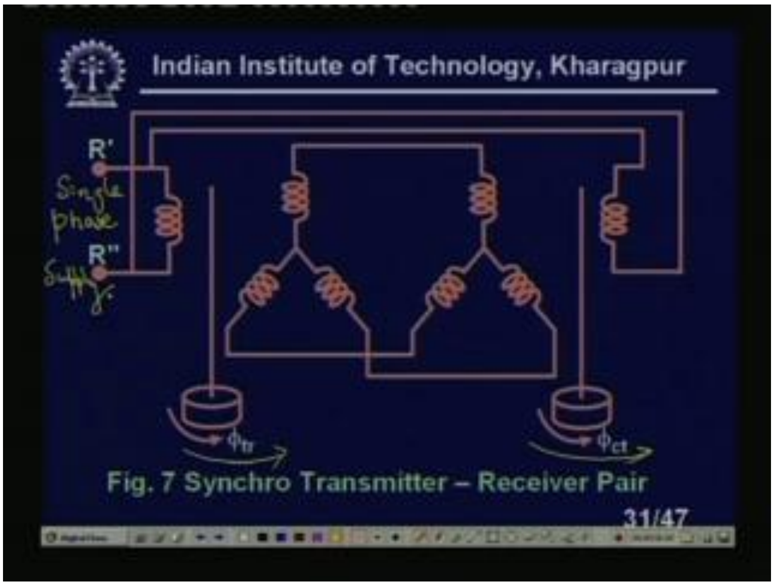

Fig. 7 Synchro Transmitter – Receiver Pair

You see this is a, I mean this is for low torque measurements for low torque applications, we can use a synchro transmitter receiver pair. This is especially for the low torque measurements you see the rotor is connected to rotor and stators are connected to stators. So, what will happen you see that whatever the rotations I will give to phi tr whatever, the rotations I will give to the phi tr same phi ct will rotate by the same angle. Whatever the rotations I will give in the phi tr that the same angle will given to the phi ct, right. So, there will be no error between phi tr and phi ct, because these 2 rotors are connected together.

I am giving a single phase supply here I am giving a single phase supply here, single phase supply, single phase supply. I am giving here. So, this is basically it is a I mean it can be previously you see this type of systems were used. Suppose in a I mean I am giving the digital clock was not that I mean commonly available. Some 30, 40 years back you can you can see that people are using this type of synchro, because in railway stations and all those places air I mean airport previously you know the all the watch should have the same time.

And that time what they do they have master clock, and they are connected through a synchro transmitter to a several slave clocks, and since all are connected together. It is because you know the rotations or the it is basically low torque devices. I mean rotating a, the arm of the second arms or the minutes arms or the hour arms does not need the large track. So, this is very well suited for this type of applications where a master clock whatever way it is rotating the slave will follow exactly the same. So, there will be no error or mismatch of timing between all the slave clocks right, but basically as I told you this is a low torque devices.

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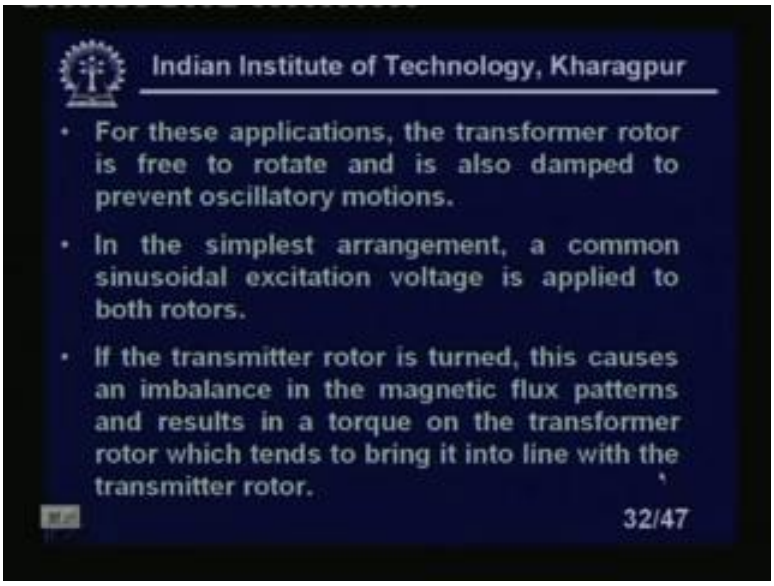

For these application the transformer rotor is free to rotate and is also damped by preventing oscillatory motion. The simplest arrangement the common sinusoidal excitation voltage is applied to the both rotors. If the transmitter rotor is turned this causes an imbalance in the magnetic flux patterns. If the transformer is the transmitter rotor turns these causes an imbalance in the magnetic flux patterns. And the results in a torque on the transformer rotor which tends to bring it into the line with the transmitter rotor.

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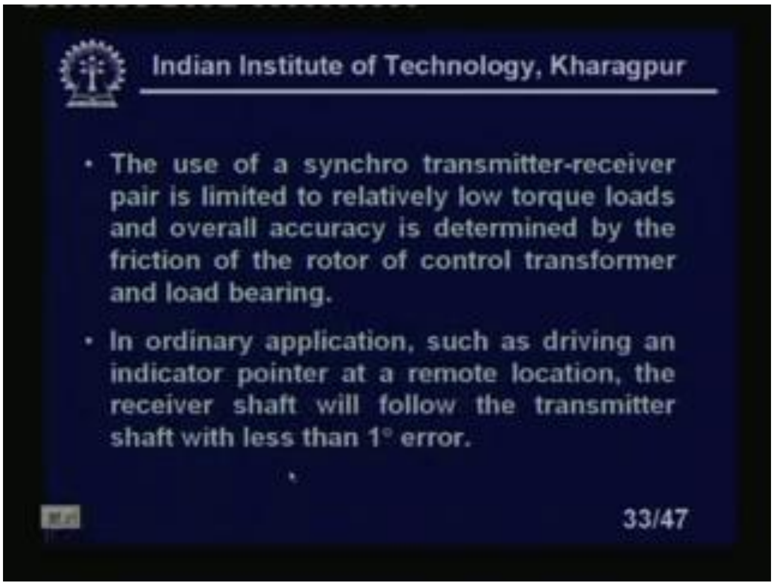

The use of a synchro transmitter receiver pair is limited to relatively low torque loads. And overall accuracy is determined by the friction of the rotor of the control transformer and load bearings if it is in large. So, it cannot be used, because that that we have to use some servo mechanism. Otherwise, for low torque divisions when bearing problem is not that much excuse me I mean we can use this type of device this type of I mean connecting 2 rotors shorting 2 rotors and shorting. I mean the 1 stators are connected together in all the pair I mean whenever you are using the synchro pairs all the stators will be connected on that.

Like that, but if you use a servo mechanisms we do not we will not connect 2 rotates together right. Excuse me in ordinary applications such as driving an indicator pointer as I told you, indicator pointer might be the, I mean clock also wall clock pointer at remote location. The receiver shaft will follow the transmitter shaft with less than 1 degree. This is the high accurate you can see the 1 degree is nothing right. So, is in ordinary applications such as driving an indicator pointer at a remote location. The receiver shaft will follow the transmitter shaft with less than 1 degree clearer.

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Now, this torque is typically small and for small displacements. So, that this technique is only useful if the load torque on the control transformer shaft is extremely small otherwise you cannot right.

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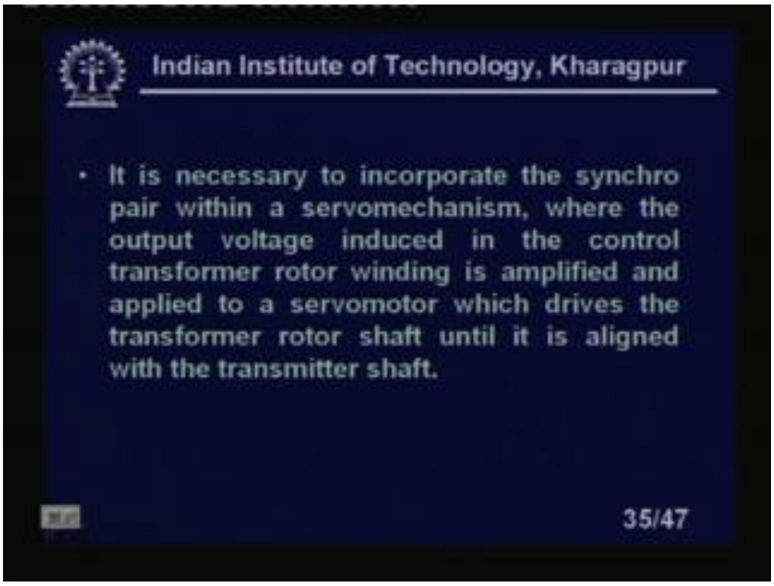

It is necessary to incorporate the synchro pair within a servomechanism, where the output voltage induced in the control transformer rotor winding is amplified and applied to the servomotor, which drives the transformer rotor shaft, until it is aligned with the transmitter shaft.

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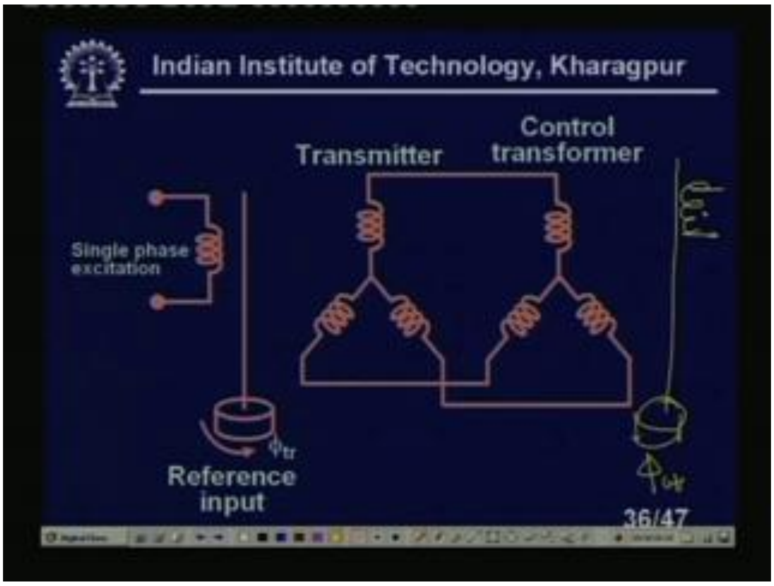

These we have shown, it is also spread up in the 2 this is a error synchro error detectors which I am going to show you, single phase excitations we have phi tr, we have phi ct. But it is spread over 2 slides, because this is a big diagram which cannot be accommodated on the single slide.

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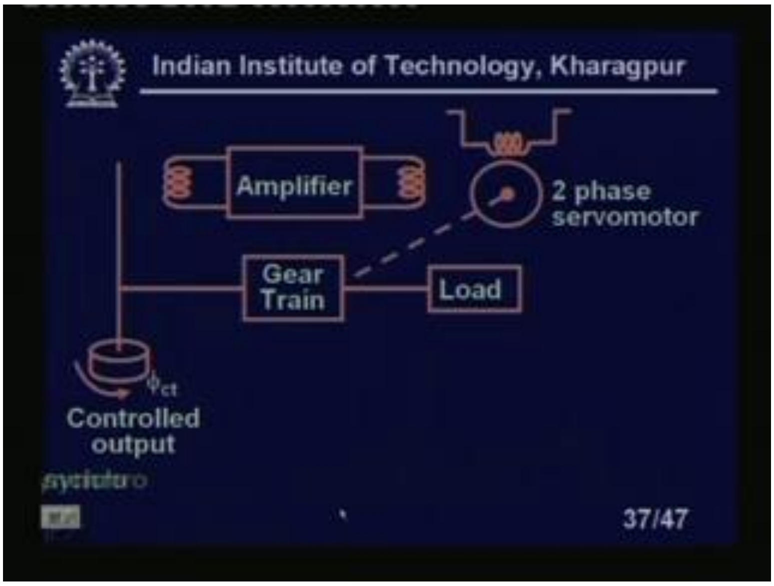

Let us look at the next line you see here, previous slide let us look at. This is now we have a another, what we have? We have one another. This goes to the next slide please note right. So, we have another right, this will work as an error in voltage. What is that?

This is phi ct. So, in any mismatch of phi tr and phi ct we will be get will be received as a error voltage here. You see here this is the things just I have drawn this is our synchro controlled transformer rotor output.

Because this error voltage we will available in the control transformer rotor out output. This rotor output is going to the amplifier, and this amplifier is fed to a 2 phase servomotor. And is to the servomotor is there. So, this is another phase and these 2 are in quadrator, right. So, the servomotors always will try to with proper sin to reduce this error voltage. So, it will it will rotor in a direction, if I have a large load in a gear train. So, that the phi ct will automatically follow the phi tr until or unless this error voltage becomes 0, right.

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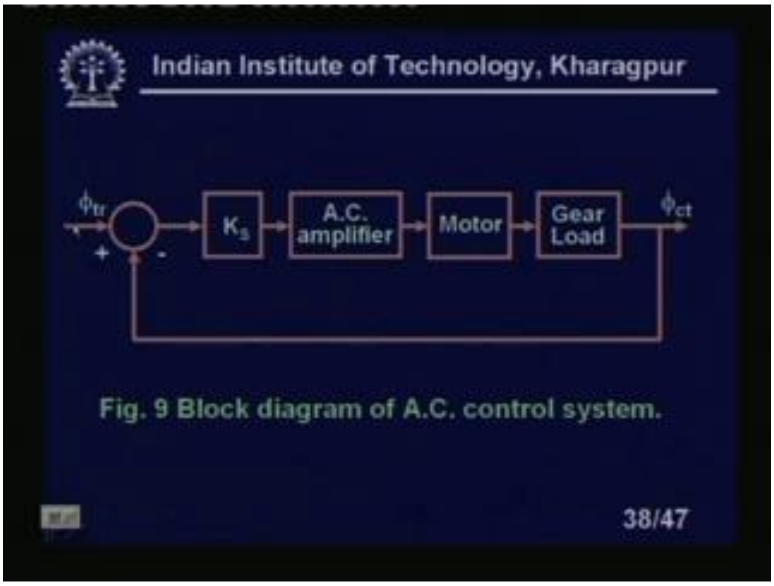

Fig. 9 Block diagram of A.C. control system.

We will see the details, this is our excuse me block diagram of AC control systems. We have phi tr, this is our command rights. I want this particular I mean position I am getting phi c our goal is phi ct should be exactly equal to phi tr. So, if there is mismatch this is coming as a error, if this is there is no error phi c phi tr minus phi ct will be 0. If there is an error there is an non 0 voltage will come down here. This will be amplified this will be go to the 2 phase servomotor. Servomotor will automatically make the correction until unless will rotate in a direction until and unless this error voltage becomes 0 and phi tr will be equal to phi ct. This is the block diagram of AC position control system, right.

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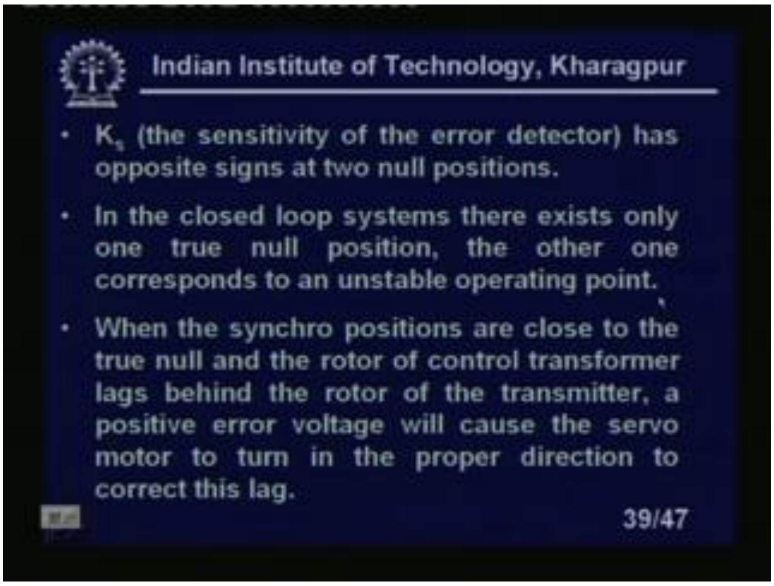

KS is the sensitivity of the error detector has an opposite signs at 2 null positions. It has opposite signs in 2 null position. In the closed loop systems there exists only 1 true null true position. And the other one corresponds to an unstable operating point on the system, right. Now, when the synchro positions are close to the true null and the rotor of the control transformer lags behind the rotor of the transmitter.

A positive error voltage will cause the servo motor to turn in the proper direction to correct this lag. If this is positive it will always correct the lag right. When the synchro positions are close to the null, true null, the rotor of the control transformer lags behind the rotor of the rotor of the transmitter and a positive error voltage will cause the servo motor to turn in the proper direction to correct this lag. But if the synchro rotor in not in the true null position, then what will happen? Let us look at…

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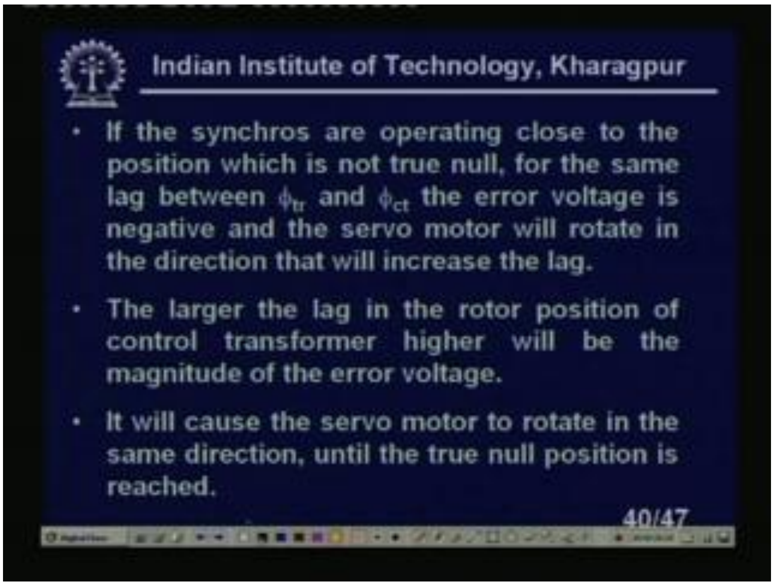

If the synchros are operating close to the position which is not true null, for the same lag between phi tr and phi ct the error voltage becomes negative. And the servo motor will rotor in the direction that will increase the lag. So, this will continue until unless we get the true null position. The larger the log in the rotor position of control transformer higher will be the magnitude of the error voltage. Larger the lag in the rotor position of control transformer higher will be the magnitude of the error voltage quite; obviously, right and it will cause the servo motor to rotate in the same direction. Until the true null position is reached, it will go is like this one. Now, the synchro error signal can be properly written like this.

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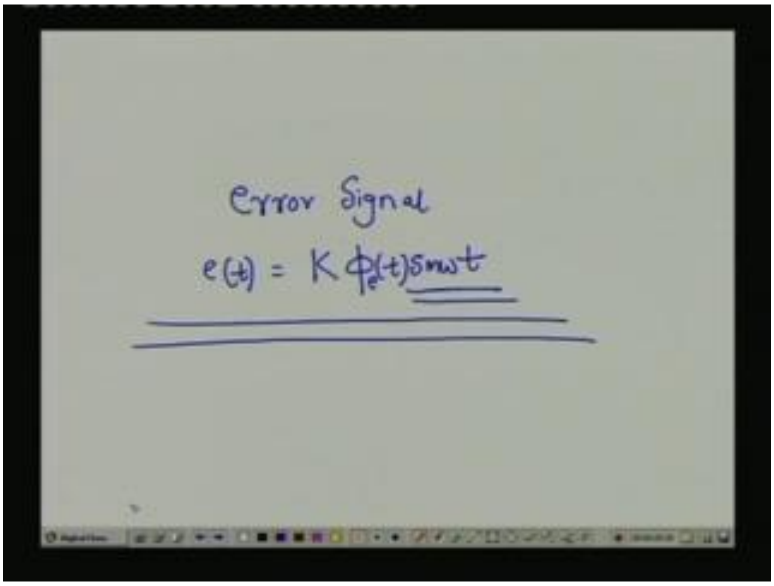

If I take a blank page and if I take a blue, so it will look like this, it will be error signal, et will be equal to you can write K phi et into sin omega t. And let me erase sin omega t you can see this is a this is a wave form of a modulated wave with the suppressed carrier right. So, it is very similar to the modulated wave with a suppressed carrier, because sin omega t will be there always. So, it is ((Refer Time: 41:46)) always will be there. So, error signal will be modulated wave with suppressed carrier, right.

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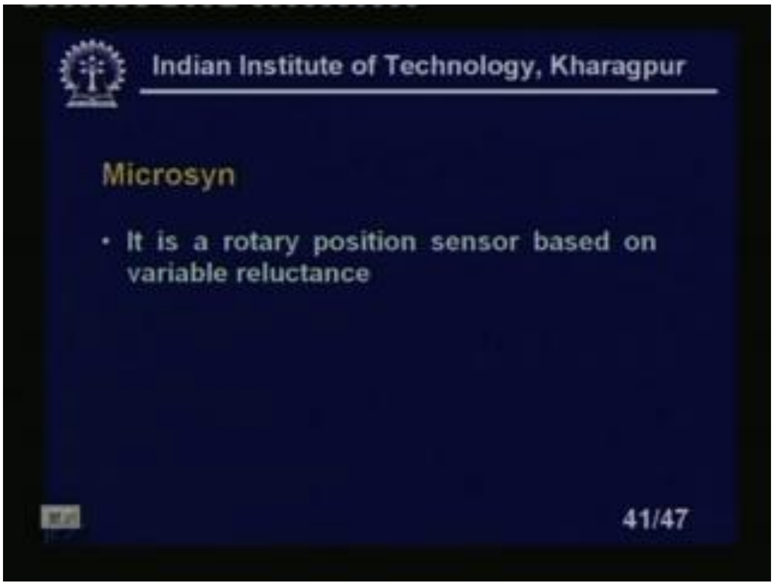

Now, we will discuss next our topic is a microsyn. Microsyn is nothing but micro synchro. So, it is a trade name as you would say some companies developed. And only features it has it has that it has no winding on the rotor. Since, it has no windings the tremendous advantage there is no question of slip rings right. So, obviously, there is a great advantage of the, this type of devises. This is also a position sensor that means, angle measurement is possible; obviously, the lode is less torque size is less. It can be used for the as a position sensors or for the angle measurements let us look at the details of this one. It is a rotary position sensor based on the variable reluctance, right. It is a variable reluctance sensor right, based on the reluctance as simplest that.

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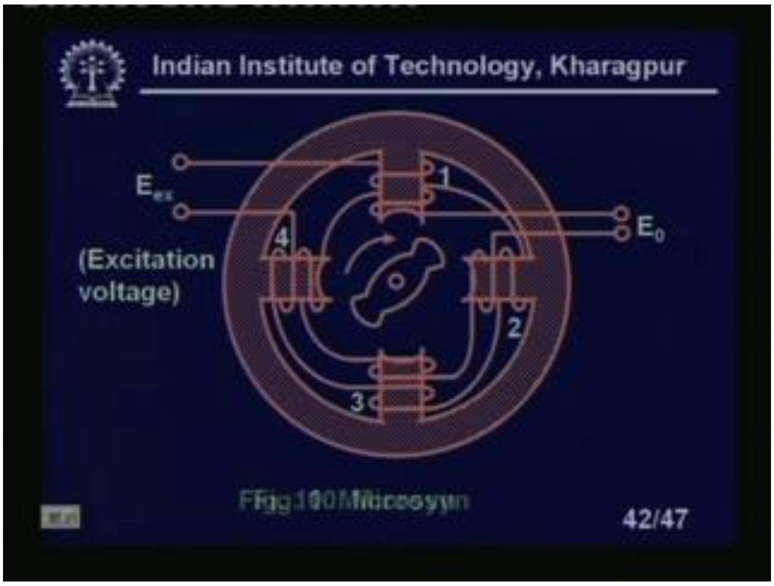

This is our microsyn you see this is a diagrams of the microsyn, which I have shown we have a excitation voltage excitation you see these 2 coils are different. If you look at very carefully you see this excitation is going through this 1 single winding it is coming like this 1 it is going like this it is going like this it is going like this. And in output voltage these are also separate there is no connection between the, this expatiation coil and the output which we are taping, right. You see this is going like this this is going like this going like this this is going like this going like this it is coming out, right.

So, this is our output and we are giving the input excitation single space excitation voltage clear. Now, see this windings 1 and 3 we have done in such a way that this will aid each other. Now, winding 2 and 4 we have made in such a way also that winding 2 and 4 open winding 1 and 3 1 and 3 will aid each other 2 and 4 will aid each other, but will oppose 1 and 3. Now, in this position in this particular position, so which I have shown this is the rotor this is basically made of iron this is the rotor this is the null position.

Why this is null position? You see in this particular position the reluctance of the coil between 1 and 3 or between this and this between the iron and the coil and between iron and the coil number 3, will exactly balanced by the reluctance. Because if the reluctance is large; obviously, the inductance will be small. What will happen you see here the reluctance of this between angle between soft iron is iron and the coil 2 and the iron and the coil 4 will cancel each other we will get 0 voltage. If it moves I will get a unbalanced voltage, right. That is a typical and beauty of the synhro the microsyn they say you can see here there is no winding on the rotor of the we had taken a section there is no winding on the rotor of the microsyn, right.

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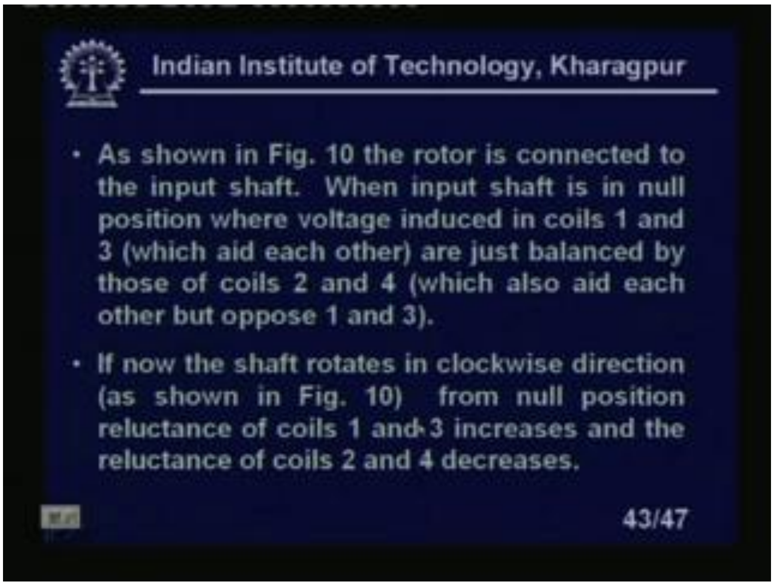

As shown in figure ten the rotor is connected to in the input shaft when the input shaft is in the null position, where the voltage induced in coils 1 and 3 which aid each other are just balanced by those of the coils 2 and 4 which also aid each other, but opposes 1 and 3 right. This is the balanced conditions; that means, the as I told you the voltage induced in the coils 1 and 3 which aid each other will exactly balanced by those of the coils 2 and 4 which aid reach other. But opposite to the coils 1 and 3 that I told at the beginning of this microsyn right.

Now, if now the shaft rotates in clockwise direction then what will happened if the shaft rotation in the clockwise direction from the null position? The reluctance of the coils 1 and 3 increases let us go back you see here if it rotation in this direction. Then what will happen reluctance between coil 1 and 3 will increase, because reluctance also depends on this co iron. So, reluctance between 1 and 3 will increase and reluctance between coil 2 and 4 will decrease are you get unbalanced voltage. That unbalance voltage will tell the position of this rotor or the angular measurements will be over. If now the shaft rotates in a clockwise direction as shown in figure 10 from the null position reluctance of the coils 1 and 3 increases and reluctance of coil 2 and 4 decreases, what will happen in that?

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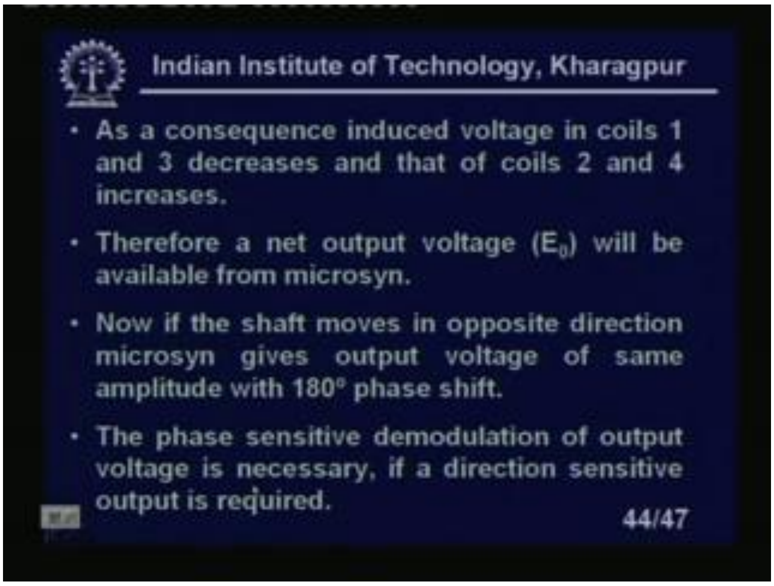

As a consequence induced voltage in coils 1 and 3 degreases, because we have a large reluctance if this voltage will degrees and that of the coils 2 and 4 increases because the reluctance has decreases. So, I will get a large voltage. Therefore, a net output voltage E naught will be available from the microsyn. So, I will get excitation. So, I will get output voltage the output voltage will tell you the position of the rotor. Now, if the shaft moves in opposite direction microsyn gives an output voltage, but with a 18 degree phase shift right. So, it is very difficulty in the in both direction whether it is clockwise direction and or anticlockwise directions I will get same unbalanced voltage.

But if I know want to since whether the rotor has moved in the clockwise directions or anticlockwise directions I have to make some phase shift demodulations. That is I am telling now if the shaft moves in opposite direction microsyn gives an output voltage of the same amplitude with 180 degree phase shift. That means if the position is same as in the clockwise direction if the anticlockwise direction, which is amplitude of the signal will remain same, but with an 180 degree phase shift right. The phase sensitive demodulations of the output voltages is necessary if a direction sensitive output is required in a phase sensitive demodulation will be necessary here right output is required.

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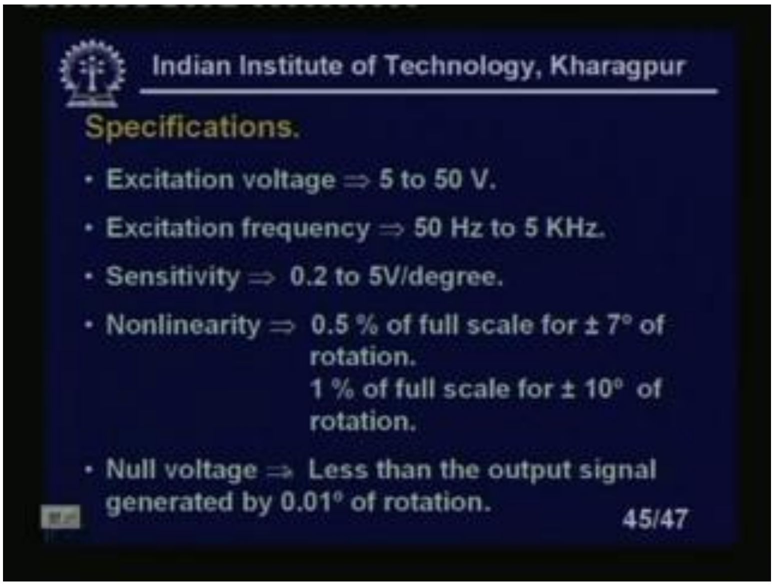

Now, specification let us look at excitation voltage is 5 to 50 volt. Then we have this typical excitation voltage that is we have excitation we have an output already we have discussed in excitation frequency its lies between 50 hertz 5 kilo hertz. Now, typical range depends on the size and all those things we can use this up to 50 hertz to 5 kilo hertz the sensitivity 0.2 to 5 volt per degree. You can see the sensitivity is enough to get the same number that is I do not meant the further amplifications whatever you get from the microsyn the signal is enough high and it is enough high. So, that I can use directly that signal to make my angle measurement for; obviously, it is and it is not very difficult I mean to amplify the signal if the signal is even small. Suppose you if it is 0.2 volt; that means, 200 milli voltage it is not very we can get an amplifier simple the single amplifier or devices cannot divided the signals.

And I can get a large resolutions of the I am mean I can measure a smaller angular I mean it is not that we measure a fraction of that I mean degree. But we can do it we can have a large output voltage. Obviously the sensitivity is quite high nonlinearity is 0.5 percent of full scale scale for plus minus 7 degree of rotation. So, plus minus 7 degree of rotation this is 0.5 percent of the full scale readings I will get and 1percent of full scale for ten degree of rotation, because it is a non-linear devices it is a relatively seen that the 2 coils will be there. So; obviously, we will get non-linear device, because the basically principle dip depends an as well same as synchro only difference is that there is no winding on the rotor otherwise it is same. So, I will get a sinusoidal signal again I am giving a sinusoidal signals; obviously, it will be a now null voltage, because I thought I am saying that the you will see that the voltage 1 and 3 will exactly cancels.

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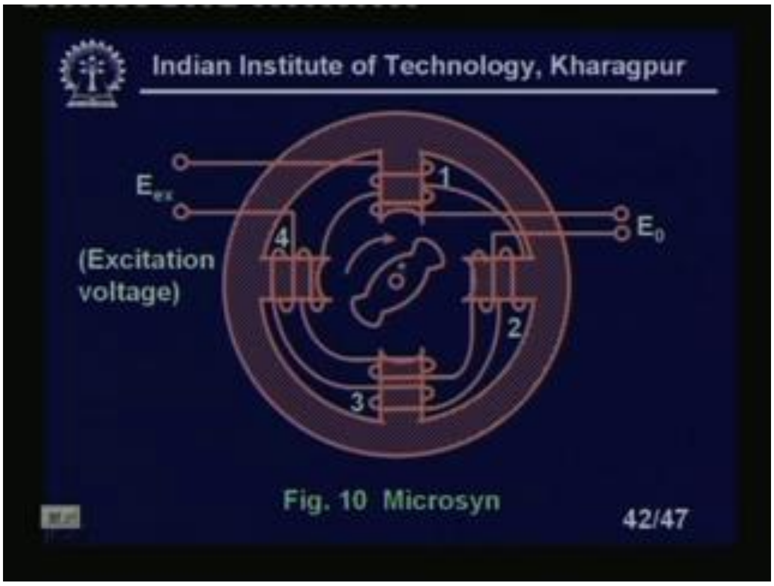

What is that and you have seen in the microsyn that is the soft iron code no winding nothing to the core. So, the reluctance we are very in this positions reluctance between these and this and reluctance between this and this will aid each other this will also aid each other, but it will opposes. So, it will exactly same, so I will get a 0 output voltage clear, but what will happen t moves then I will get a non-linear output voltage. So, non-linear output voltage why you simple that between 1 and 3, what will happen if it moves the reluctance between 1 and because this move is iron ore has moved this core has moved.

So, reluctance between 1 and 3 will increase and reluctance between this 2 and 4 will decrease. But though I am saying that at these positions we have exactly the these 2 voltages; that means, when it will in this position reluctance will between this. And this these 2 coils with this position of the coil reluctance between these 2 coils is exactly same. Though it is in the figure it will appears to be exactly same, but 2 windings you know that 2 magnetic surface is very extremely difficult to make exactly identical. So, there will be always some mismatch. So, though it is an our position; that means, this 2 voltages and this 2 voltage should nullify each other.

But you will get a non zero voltage why that is actually I want to that is to be specified that is called the null voltage of a microsyn right. Null voltage less than the output signal generated by, so it is 0.01 degree of rotation now; obviously, it is quite small as you can see that is actually we are not interested in measurement of such a small angle. But it is less than the output signal generated by the 0.01 degree of rotation this is extremely small this null volt. That means, this voltage will be equivalent to a voltage which is we will get from the microsyn when it is rotated by 0.01 degree clear.

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The advantages as a I told you earlier this microsyn has the advantage over the synchro permanent synchro. But the application areas is very narrow as I told you I mean compare to synchro it is nothing and very small angular displacement can be measured. Because there is no sleep dreams, because slip rings will make an missions it will always allow you to make the problem that is a it will a use additional I mean resistance to the rotary I mean systems. So that smaller angular measurement extremely difficult very small angular displacements can be measured with this type of system right. And no slip rings are required for the rotor excitation in contrast with synchro that is the great advantage of thesse particular devices.

But especially as I told you it is very slow I mean low torque devices compared to synchro it is not that popular just some manufacturer company we have used. Only advantage that I have prominent these are the 2 prominent advantage what we have in the microsyn micro synchro right. With this I come to the end of the lesson 30 of industrial instrumentation. Welcome to the lesson 31 of industrial instrumentation. In this lesson and the subsequent lesson; that means, lesson 31 and 32, we will discuss basically the dissolved oxygen sensors. So, was not that important I am some time bad, but due to the evolution of the biotechnology in a very big way.

So, this is to be considered very thoroughly and also I, its application, because the newer the bio deters are coming up in the markets. And lots of new product are coming like I mean medicines then antibody which is a basically the I mean the growth of sales. So, and in this particular I mean situations we must consider the dissolved oxygen sensors. That is one of the new sensors, which can which can measure the dissolved oxygen concentration as that the partial pressure of the oxygen in a liquid medium. And this will give you lot of other informations which is not exactly measurable which usually we have to estimate.

So, that is a reason this is also this I mean this dissolved oxygen sensors we brought under the industrial instrumentations. And it has also I mean I should say that the it is also used as a I mean measurements of the dissolved oxygen in environments likes the in the water treatment plans. And the water discharged where it is in the I mean, because there is some safety level of the water I mean dissolved oxygen concentration which is essential for the living animals like fish and others as we and all those things.

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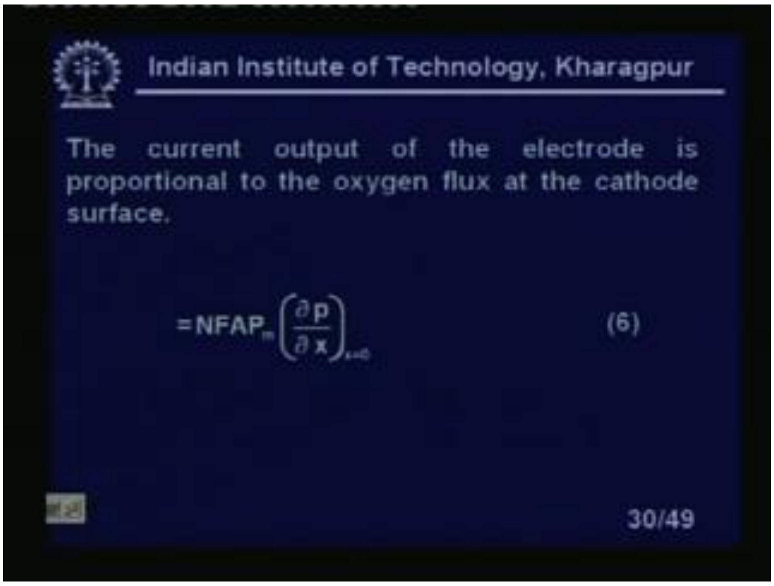

The current output of the electrode is propositional to the oxygen flux at the cathode surface. Now, NFA Pm will be equal to multiplied by partial derivative of P with respect to equal to 0; that means, at the cathode surface.

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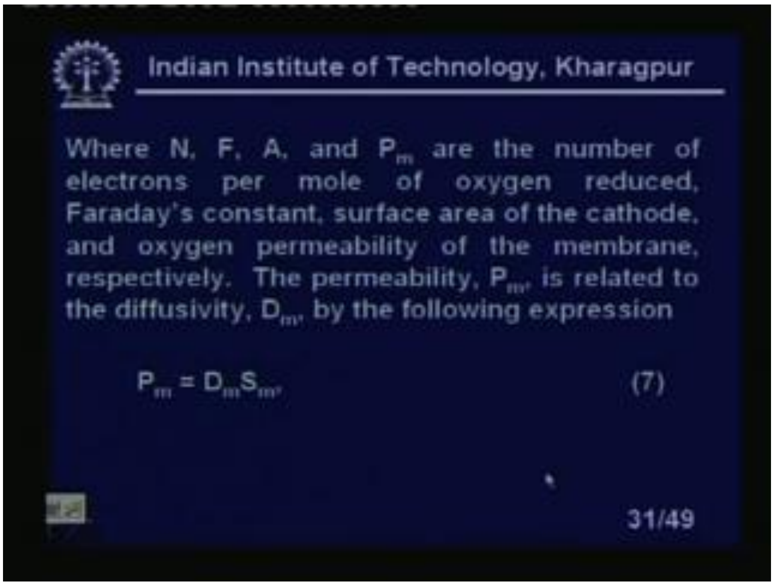

Where N, F, A and Pm are the number of electrons per mole of the oxygen reduced and Faraday's constant, it is FA is a Faraday's constant is a surface area of the cathode, which is very easy to calculate. Because it is a pi R square or pi D squire by 4 and the oxygen permeability Pm is the oxygen permeability of the membrane respectively right.

A is the number of electrons per mole of the oxygen reduced A is the Faraday’s constant A is a surface area of the electrode cathode and Pm is the oxygen permeability of the membrane respectively. The permeability Pm is related to the diffusivity of the oxygen by the following expression what is that expression Pm equal to Dm into Sm.

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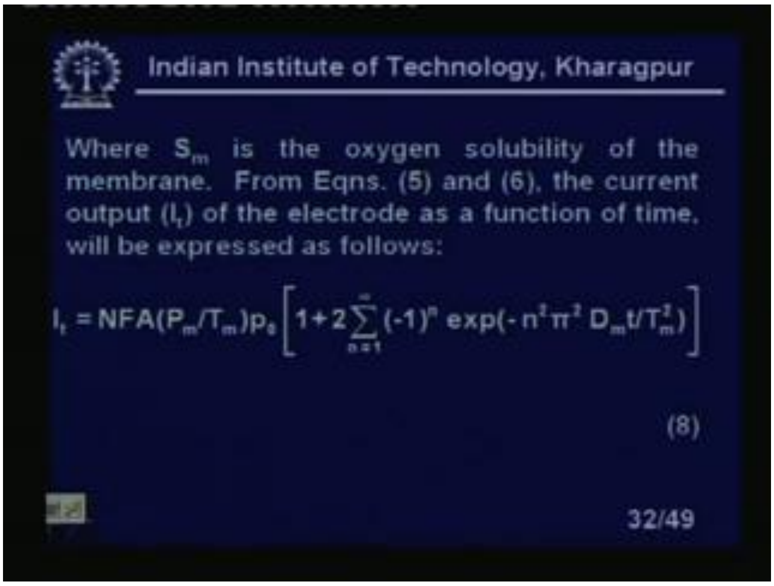

What is a Sm? Let us look at where Sm is the oxygen solubility of the membrane and from equation 5 and 6 the current output, it the current output. Because actually that is only measurement that is reason, we are going for the permanent membrane based electrode membrane covered electrode. Otherwise, we can make the chemical analysis we need this current output for continuous measurements or continuous control of the partial pressure of oxygen or dissolved oxygen concentration either in the bioreactors or in the waste water treatment plant. As function of time will be expressed as follows this is equal to you see the current output it equal to NFA Pm by Tm multiplied by Po 1 plus 2 summation n equal to 1 infinity minus 1 to the power n exponential minus n square pi square Dmt upon Tm square this is equation number 8.

In IIT Kharagpur say in the bioprocess institution lab and we found that we got a consistently good results though the result in consistent obviously, but when you measure with the other sensors. So, there is slight options that which is quite obvious. So, this galvanic electrode actually it worked very nice in our laboratory right. So, with this I come to the end of lesson 31 of industrial instrumentation. Basically, we have considered the dissolved oxygen sensing here and basic more details of the sensors 4 different will I will more details of this sensing will come in the lesson number 32.