Electrical Machines - I
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Lecture – 58
Introduction to Rotating D.C Machines

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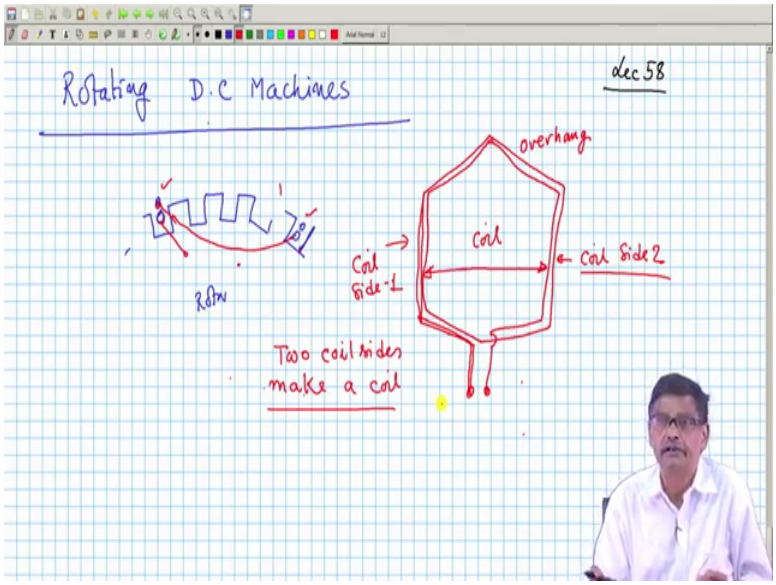

Welcome to lecture number 58 and we have been discussing about rotating DC machines formal type of DC machines as we understand and used in practice.

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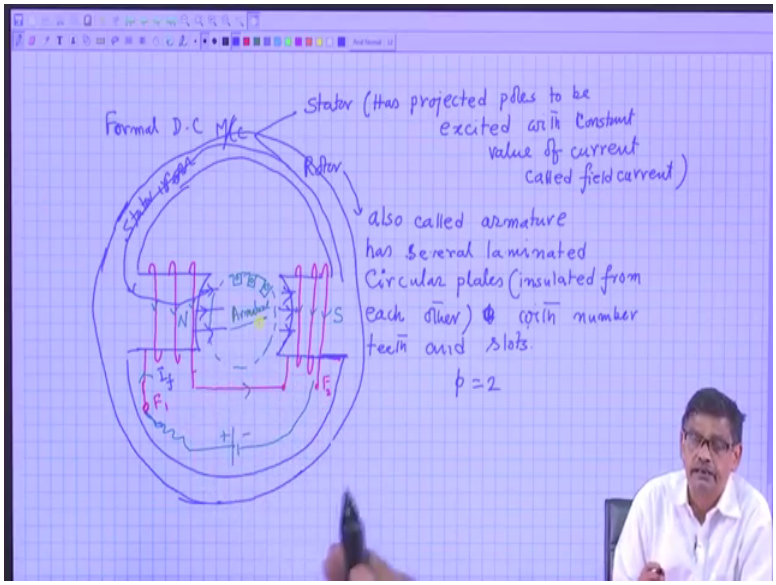

And, in my last lecture, I just told you what are the basic structure in a very rough sketch, but it brings about all the important structural features of a DC machine. For example, this stator will have two projected poles, if it is a two pole machines p equal to 2. There may be multiple number of projected poles, if the number of poles of the machine is higher and, this part is almost a solid piece of iron, over which there will be coils with red colors this is these are called field coils.

One of the simplest stator coils are no complications, yes take wires and make this coil over the projected poles. And, these two can be suitably connected; so, that when you pass DC current in it. This produces North Pole, South Pole, because this is the direction of the current so, lines of force will come out from this, like this. And, it will enter here creating the South Pole.

And, these lines of force will complete their path through the stator iron like this a sample lines of force will be. And, the armature is a number of circular thin plates made or soft iron and they are staged together. So, that you get the length of the machine, which in this case will be perpendicular to the paper.

Similarly, this projected pole is also having a length perpendicular to the paper. Anyway so, this is the basic structure, but the armature is slightly complicated. And, why it will be complicated that we will discuss in detail do not worry about that, but essentially armature has got slot and teeth, where there will be conductors placed, ok.

And, so; and this field will be excited by some DC source and this field current is often denoted by I f, constant value DC current, and depending upon the strength of this field current these are essentially electromagnetic. So, the strength of the value of flux density in the air gap will be decided. So, lines of force will be completing their paths through the stator iron, cross the air gap, armature iron, cross the air gap and back to square 1. So, this is how the field is created.

Now, our concentration would be about the armature coil. Now, armature coil is you know in my electrical machines 2 lecture, I have discussed in the winding portion of the course the basic terminologies used in making a winding, ok. And, I will go rather quickly here to tell you about that ok, but you can if you like please see those videos, whose links will be given in your website for this course.

Now, we must understand that the rotor being a structure rotor will be like this, there will be slot and teeth, slot and teeth, all along the rotor this is the rotor, only a portion I am drawing. And, I will place a conductor here, which will be take a piece of wire put in one slot at the end you turn around and through another suitable slot you bring out this end.

So, at the end you will have two terminals for this coil, ok. And, you can of course, have a multi turn coil, that is you take this wire single wire come here, then once again repeat these. So, a multi turn coil we will look like this one take a piece of wire, this is one slot it goes it at the end it will be like this. And, then make several turns like this, another turn it is a two turn coil, and two terminals would be there. And, this is a coil ok; and, this coil has got two sides, this is coil side 1 and this is coil side 2. And, this coil physically will be placed in the two slots I am sorry I have put it in the teeth, it will be actually in slots.

So, it goes comes back like that and comes back. So, in these two slots suppose this coil is placed it can be placed around that. And, this can be understood in this way, that suppose these are the slots here.

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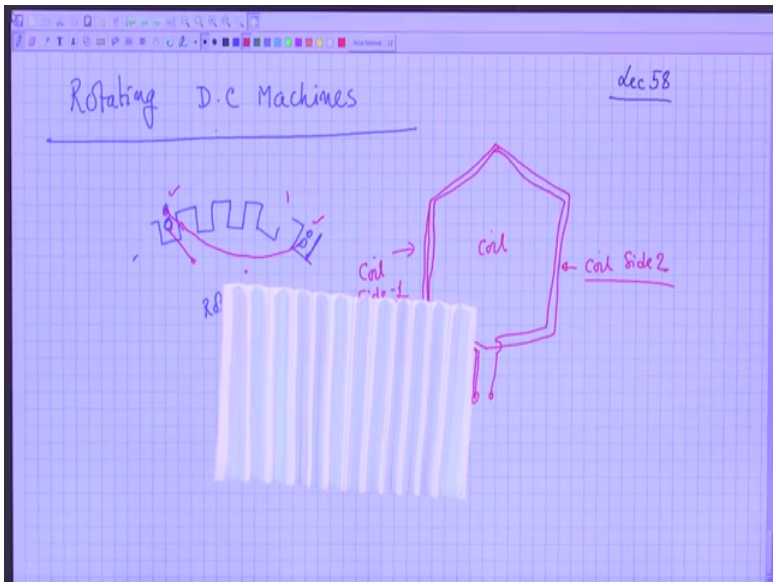

Suppose this is the slots and these are the suppose slot and teeth, I just a this simple thing and then you have a coil (Refer Time: 07:28) [FL].

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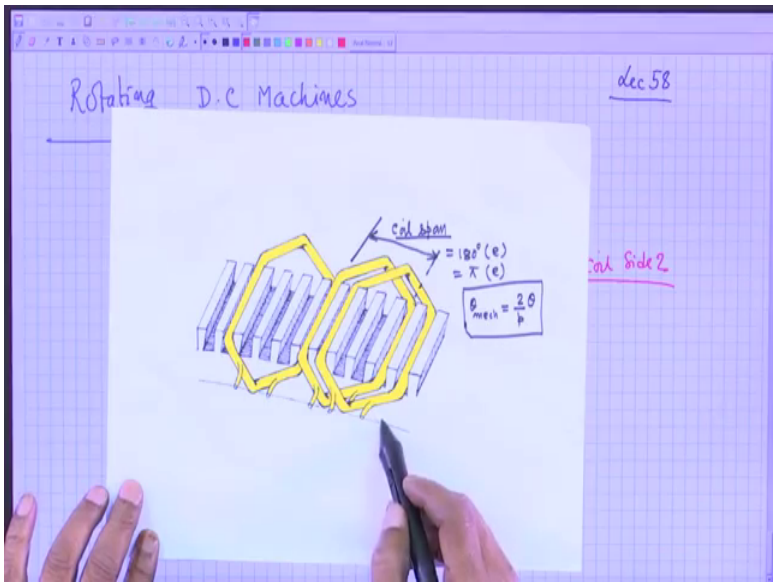

Anyway, this you see just this is the teeth, this is the teeth, these are the slots and, therefore, you this is one coil; this is one coil side it goes along the length then it comes back and it has got two terminals. Similarly, another coil, it has got this coil side it goes around and returns and two terminals for the second coil and so on, is that clear.

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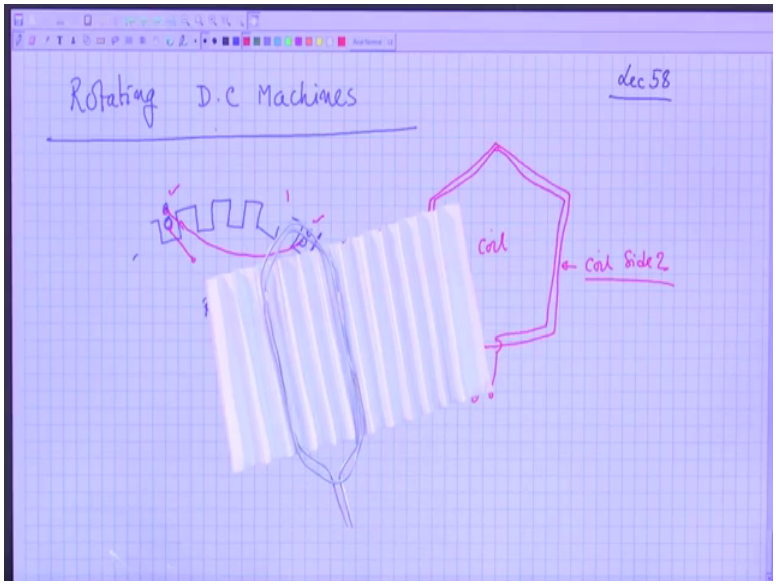

Physically a coil will look like this a practical coil, it is just made two turns coil, you take a piece of wire on a format you make this two times you go around and these are the two terminals of the coil, these two clear. And this, what I will do, I will place it in one slot,

this coil side and the other coil side at some appropriate slot, arbitrarily it cannot be placed ok. This is how the coils will be placed;

One good information is all coils are identical ok, this is one coil, another coil will be also placed in these slots, only displaced from the first coil by some space angle that is all. But the idea is very clear so, each coil will look like this and it will be in this fashion.

Now, the question is so, each coil has got two coil side, coil side 1, coil side 2, that is what I have written here, coil side 1 and coil side 2. This is how I have tried to and it is almost like a diamond shaped. The effective length of the machine is this one, which will be the under the influence of the North and South Pole and, these portions that is this portion and this portions are called overhang of the coil, overhang. There no voltages will be used, because it will be under the purview of the magnetic field produced by the stator when it will be running.

Now, the big question is where this, what should be the difference in number of slots between these coil sides. So, two coil sides make a coil remember, this two coil sides make a coil with two very distinct terminals that is all and all coils are identical.

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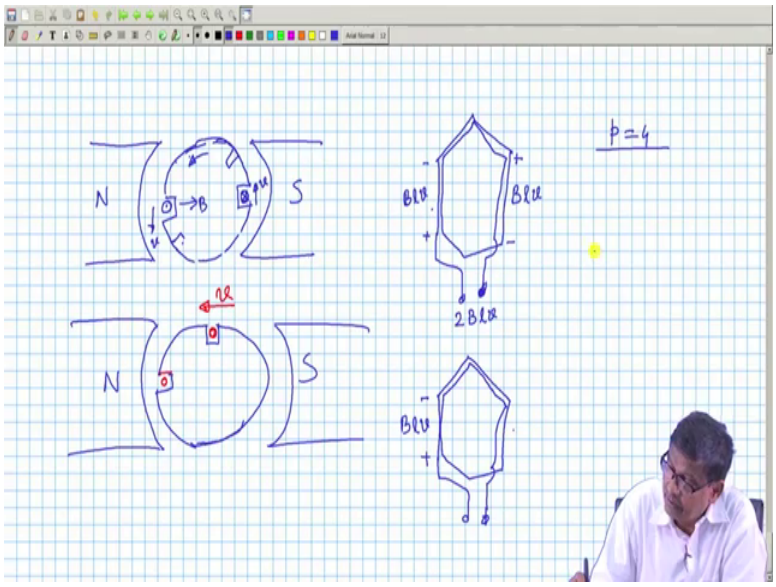

Now, if I ask you this question that, consider a simple two fold DC machine that is here, this can be easily understood. Suppose field coils I am not drawing it has created North Pole and South Pole and here you have the armature. And, there are one slot here and

you have a coil side here, which is perpendicular and by coil side I know where it is part of a coil one coil side. Suppose this is coil side one, what will be the induced voltage in it.

Suppose this armature is moving in this direction it is like this. So, induced voltage will be you apply you have to apply right hand rule B v and l; so, this will be cross will be the induced voltage or if you change the direction of rotation. Suppose, it is moving in this direction, then the induced voltage will be like this B and v is this way this is the direction of B North to South lines of forces are. And, your ah this coil side I will show a dot to indicate the induced voltage polarity, is it not B l v.

Now, this is a single conductor, but to make it a coil side I must; it must have a another coil side like this here. Therefore, what you do is this you suppose there are two slots, which are diametrically opposite. And, this is one coil side and this is the another coil side ok, that is coil side I was telling nha where the coil side should be placed, suppose it is a two turn coil.

So, one coil side is there and the other coil side in which slot should I place there will be number of slots, I will place it so, that induced voltage in the coil becomes maximum across between these two terminals. Suppose, it is in generator mode, if it is running there will be induced voltage in this conductor cross and in this conductor it would be cross, because velocity is this way B is this way you can once again apply right hand rule.

So, what happens is this the polarity of the induced voltage, this will be plus, this will be minus for this coil side coil side 1, and it will be minus, it will be plus if it is coil side 2 like this, because it is on the South Pole having same velocity. Therefore, across this coil this is the induced voltage in coil side 1 with this polarity this is the induced voltage in coil side 2 with this polarity. So, you will get 2 B l v as the induced voltage between these two wires, clear.

Therefore, you must place the coil sides of a coil intelligently. So, that across the coil, if you allow that coil to move related to a magnetic field, the induced voltage in the coil becomes maximum, which ultimately told in a different language I will always say that if one coil side at a given instant of time. If it is under the center of the North Pole, the other coil side must be under the center of the South Pole at the same time.

It will rotate after some time if it is rotating it will come here this will go there, but it is still under South Pole may be at reduced strength, but once again the voltage will be 2 B l v with the magnitude will not remain same, is it not. Therefore, the essential consideration is that, if this coil side to check you have properly placed it or not imagine that one coil side, if at a given instant of time is under the center of the North Pole, the other coil side of the same coil must be under the center of the South Pole, this is how we tell that. If, that is the case then you check the maximum induced voltage here.

For example, if somebody says he has put the two coils he has made a coil and he has put it like this. This is there was a slot available here and there was a slot also available there, he; and the it is a two Pole configuration like this North and this is South and he places one coil side, he make a coil, he makes a coil such that one coil side is here and it is return coil side is here, when the center; when this coil side is under the center of the North Pole the other coil side is in the magnetic neutral zone B is 0 here, or tangential to the velocity if velocity is this way. Can this conductor produce voltage? No, because B and v are along the same lines B is from left to right.

Therefore, in this case of course, at this instant there will be induced voltage under this condition, what will be the nature of the voltage, nature of the voltage will be like this. This will have induced voltage like this B l v and this will have 0 voltage this coil side. So, you will get voltage across the coil, but only B l v.

So, that is why you always insist upon that for a given coil, if one coil side is under the center of the North Pole, then other coil side must be under the center of the South Pole that will tell you in which slots the coil should be placed. And, as I told you that will be number of coils number of slots, but all coils are identical ok, in different slots you go on putting the coils in a particular fashion that is the, that is all.

So, this is like this if you have understood me, then you should tell what happens, if it is suppose the machine is 4 pole. What do I mean by 4 pole? 4 pole means on the, I will go to next page.

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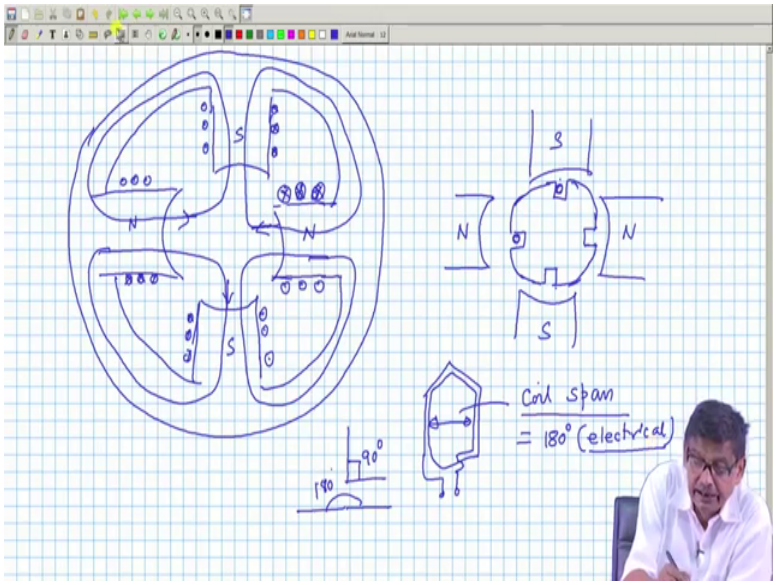

4 pole means, suppose on the stator there will be 4 projections, this is your stator. I (Refer Time: 20:09) not very nicely drawn, but it will give you the idea and this is the stator iron. So, if you and suppose this is the sectional view of those coils. So, there will be now 4 field coils, got the point. So, I want to make this is not, so the currents are like this cross dot here, then the next poles will be a South Pole. So, lines of force will go in therefore, it must have cross here and dot there. So, that it will become South Pole. And, this one once again cross and dot so, lines of force will enter; oh, no this I have to make this cross and this will be dots.

So, that once again it will become a South Pole, North Pole, that is here lines of force were coming out, here also lines of force will here. So, alternately you have to create the poles, north-south here it is north there I want to make it south. So, it must be cross and this should be dot and lines of force within go in. So, lines of force will complete their path like this, north south, north south and this is north this is also create a lines of force like this and this will also create a lines of force like this. So, north-south, north-south this is the thing.

So, and this field coil should be connected in series in such a fashion the current distribution in this conductor is like this, then only this pattern will be created ok. If, that be the case then a in this simplified diagram, now I will not show the coils, I can create a 4 pole stator as simply as this with 4 projections with conductors around it. And so,

suppose you have created this poles, north, south, north, south, then it is called a 4 pole decimation, full stator I am not drawing.

Now, on the let us come back to the armature, which is a circle with lot of slots and teeth. For example, here is a slot; here is also a slot, ok. And, there is also a slot like that it is available and there are many other slots here there, many slots are there, ok.

Now, I say that I will make a coil like this as usual, if this is coil side one of a coil where do you like to have your other coil side should it be here diametrically opposite. If, you place, if you make a coil whose span is this much that is this coil side, this coil side, then across the conductor there will be induced voltage, but the polarity of the induced voltage will be subtracted. And, across the coil you will get 0 voltage, that is why the rule is that is you must ensure, if one coil side is under the center of the North Pole, the other coil side must be under the center of the South Pole to ensure that maximum voltage is induced.

So this is how the coil span, this is called coil span ok. So, this is the thing ok, then a coil span I will always say it should be equal to 180 degree electrical. Now, the question is what is 180 degree electrical? 180 degree, whenever we say angle we say in mechanical terms we understand. For example, 90 degree is this, is it not and 180 degree is this, these are all mechanical angles. Now, what do I mean by 180 degree electrical, the idea is simple, it is like this.

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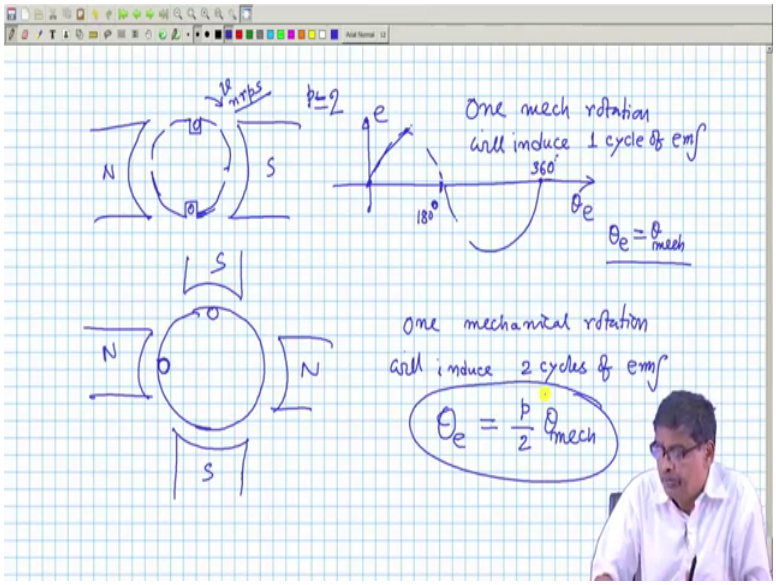

That is if you imagine, you have a two pole structure like this and you have a single conductor. Suppose a single conductor and you allow it to move with certain velocity or n r p s equivalent to that. If, it moves the voltage across this conductor, in this position it will be 0 is not, because B and v are among the same line. It will be having some maximum value when it comes under South Pole, then once again it will be 0, then once again it will be maximum, but polarity will reverse, because it is now under North Pole and once again back to 0.

Now, listen to me carefully. If, this conductor makes a complete 360 degree rotation, your output voltage across this conductor; across this conductor means across this coil side, other coil side I have not drawn I could also draw that ok, or if you fill put another coil here other coil side. So, voltage across the coil is 2 B l v at any time and it will be 0 here, then either positive maximum or negative maximum.

So, with respect to time if you sketch it is 0 here, then it attain some positive value is it not when this fellow comes here it will have some positive value say, then when this fellow comes here it will have once again 0 voltage. So, like that it will grow by some rule, but anyway it will have a peak back to 0 here, then when this conductor makes a complete rotation of 360 degree mechanical you will get one cycle of emf generated across the coil, AC voltage will be generated B l v. But if you have a 4 pole structure, if you have a 4 pole structure like this north, south, then once again north, once again south. And, I have learned what, where this coil should be placed here one conductor slots I am not drawing it will have two coil sides and you allow it to rotate.

So, if this arrangement rotates by 360 degree mechanical 1 rpm, 1 rotation mechanical rotation we will ensue what 1, 2 cycles of emf. Because, it will undergo north then south, then once again north and then once again south back to north. So, one complete rotation of the rotor will induce two cycles of emf, here that is one rotation one mechanical rotation will induce two cycles of emf.

Here in two Pole configuration one rotation; one mechanical rotation will induce one cycle of emf, got the point. So, here the conductors or the coil undergoes sees only two poles, north-south one cycle of emf. In this case coil will see north south once again north south till it makes a complete mechanical rotation.

Therefore, this angle for electrical induced voltage is the theta electrical, that is 360 degree electrical, is it not and this is 180 degree electrical. In case of mechanical two polar machine we will see that theta electrical is equal to theta mechanical no difference angle in theta electrical and theta mechanical, when you plot these sketch the voltage in terms of theta, theta is omega t it will become eventually. So, it will be like this.

So, in this case I will say theta electrical must be equal to how much p by 2 into theta mechanical, that is you move by 90 degree means you have moved by 180 degree electrical. So, think about this, this is very basic concepts that I will use while discussing about the armature winding of DC machine and understanding of this is essential, you cannot avoid. And, better look at the detail introductory part on the winding lectures of my electrical machine two course. I am briefly telling, but rather quickly because no point in repeating the same stuff once again which is already available.

So, see that ideas are simple; so, I must distinguish between electrical and mechanical angle. Number of poles of a machine will be always even, it cannot be odd, because you cannot have a monopole. If, there is a North Pole accompanied South Pole must be there. So, I have indicated the basic idea of this and next time we will continue from here.

Thank you [FL].