Fundamentals of Electrical Engineering
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Lecture - 37
Single Phase AC Circuits

So, I will still last video closer video classes, we have seen that we have done up to DC circuit, DC for DC for circuit. Now, we will start for your AC circuit. First what we will do, we will take the single phase AC circuit, then will go for your manual, your resonance and as well as that maximum power transfer theorem for AC circuit. And then, we will take that your three phase AC circuits and after that, we will consider single phase transformer and I and in the brief introduction, everything has been discussed.

It is only for the first year level whatever little bit is there. Then, 3 phase induction machine. There also, up to equivalent circuit and few examples and after that DC machine that is DC motor mainly, right. So, first we will now we will start with Single Phase AC Circuit, right. So, before starting with a Single Phase AC Circuit what we have to see is that, you we have to your what you call see that how EMF is generated, little some basic ideas.

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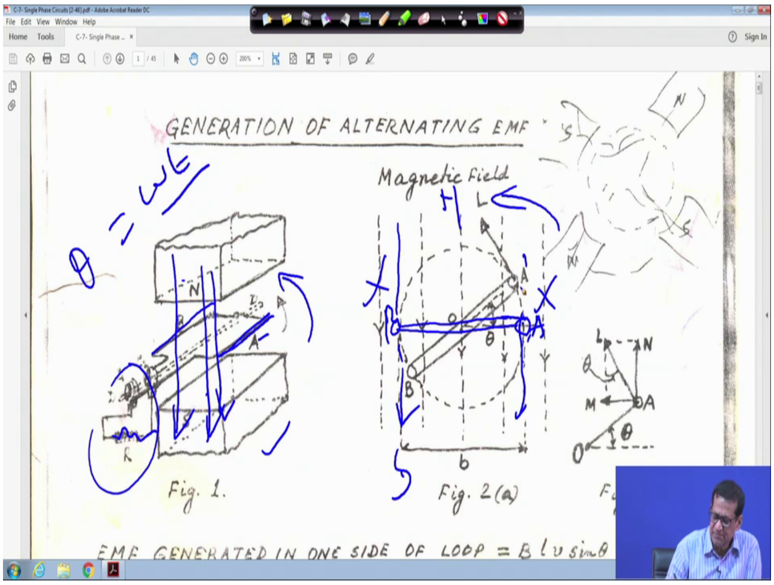

So, before giving mathematics and other thing, just for example suppose, you have two magnetic pole, this is your N pole and this is your S pole, right, s pole and one coil is there one coil there this is the one side of the coil. This is other side of the coil, this is side A and this is side B and by sub means, it is called prime number say this coil is revolving, it is rotating in the anticlockwise direction. It is shown here, it is rotating in the this sorry, this is rotating in the anticlockwise direction, right.

Now, when it is at in the diagram whatever it had been drawn; so, it is actually in the horizontal position, right. So, flux actually this is N pole and S pole. So, when flux actually going to the downwards from N to S pole, right, it is going to the downwards. Then, this coil this is one side of the coil, this is other side of the coil assuming it is a single turn, right and with that one there is one resistor is connected here such that proper whether voltage is generated. So, some resistance corrected resistance is connected such that your current will flow right, but we will we have our interest is not like that at the at this level. Only thing is that how EMF is generated right.

So, when it is a horizontal position, then this is this side of the coil and this side of the coil, this is actually will be outside of the your what you call that flux region right because this is a basically your in between N and S. It is a constant magnetic field, but when this coil is revolving it is cutting the flux, right. So, in this case, so this side and that side, this is your our reference position. So, there will be no flux linkage when it is at the horizontal position; that means, if you look into this diagram from here to here, this side is A and this side is B, right.

So, this is taking at when it is revolving in this way, this is shown. Suppose, it is moved your what you call in angle of theta right and theta is equal to omega t so, but when this is this side is a means just as this is a conductor, it is shows like this side is A and this side is B. So, this side suppose when the horizontal position, this side is A and when it is this side it is B say right and this position, when it is at this position, this flux are coming this is from N side and this is from S side forget about this drawing this we will give it up, right. So, flux actually this is coming like this.

So, when it is a horizontal position, this side and this side, there will be low flux or it will not leak the flux. So that means, at this position that EMF induced at this position will be 0, it is that is whatever in the diagram it is shown. Now, it is revolving. It is revolving in the anti your anticlockwise direction, this way it is revolving and suppose making an angle theta. So, it is angular speed is omega say, then theta is equal to omega t. This is from your physics you know right. So that means, so that means, so this is at the position; that means, this as suppose now, let me clear it let me clear it. Suppose, this is your what you call this side is A and this side is B.

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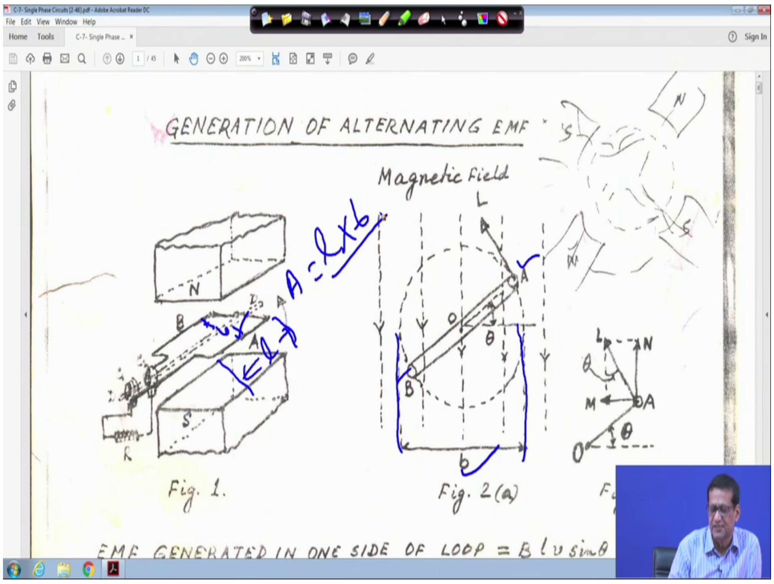

So, this breadth of this coil that means this distance is equal to B; that means, this A to B right. So, this is your what you call this is the breadth of the coil. So, this is B right and length of the coil, this is the length of the coil, this is your l, right. So, area of this one right if it is rectangular 1, it is l into b. This is the area of the coil right. If it is in centimeter, centimeter square; if it is in meter, you put in meter square, right. So, this is the area A is equal to l into b right.

So, now let me clear it. So, this is at some angle theta and this is your center, this is the center right and it is revolving. So, it is revolving this breadth actually; that means, it is making a circle with diameter b because this is this is the breadth, this is the breadth, this is that this is the breadth right. When it is revolving, it is making a diameter your B and this is a circle, circle is drawn, right.

So, at any point a some tangential velocity will be there. So, anywhere this point is A and this is L right and this is the vertical, your what you call vertical component say A N. Then, there should not be any mix up with that this is North Pole and this is simply A N, right. It is not North Pole or anything, it is simply your that capital later A N.

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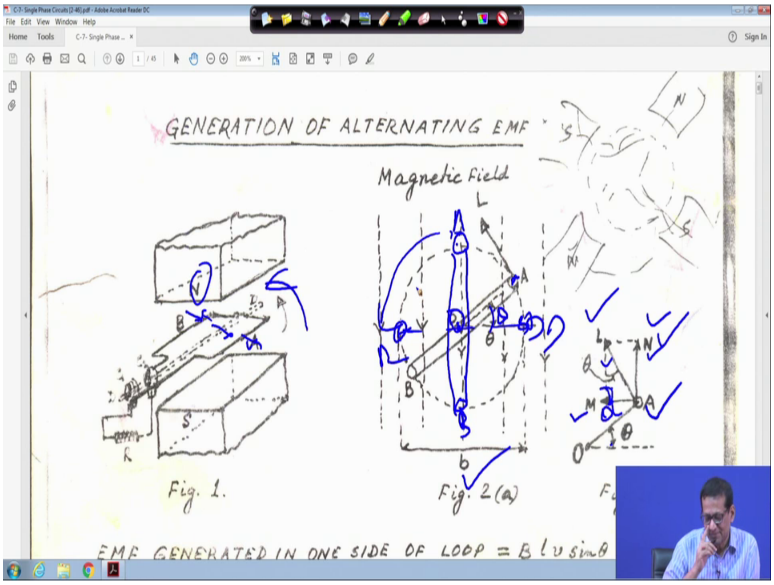

And this is your M and this is your O, the origin this is your O, the origin or center right and the this angle is theta, that is this angle is theta. Then, this angle is also theta and this is 90 degree. So, this angle is also theta right and this point is this point a right. This is the, your what you call basic understand that means. When the coil position when this position, it will rotate say 90 degree; that means, this position A will come here and this is your B and this point will come here. At that time, this if you if you imagine, you will find it is a single turn, you will find all the flux will link to this; that means, voltage generated will be maximum, right.

So, again it is moving, again will come when A will come to this and B will come to this. It is revolving this way, this is A and this is B again, it will horizontal position at that time voltage generation will be 0. So, it is a cyclic process, right. So, I hope you have understood because directly if I give you directly that your sinusoidal or current wave, then feelings will be slightly different. So, I started with this kind of thing first, right.

So, let me clear it. So, next is, so if you look at the voltage generated, so EMF generated at one side of the loop is B l v sin theta, that actually from your physics higher secondary physics, so when the coil is revolving in a constant magnetic field is EMF generated one side of the loop it is because it is a loop, it is a coil a B it is coil so, it is a loop. It will B l v sin theta, right. So, B actually flux density that is in Tesla or Weber per metre square and l, I told you this is the length of the your l is the your, this is the length of the coil, right. This is the length of the coil right.

And B is the tangential velocity because B is equal to omega t, we will see later and this is sin theta. This is B l v sin theta volts right and this side is the one side of the coil, this is another side of the coil. So, two sides therefore, total EMF generated will be 2 B l v sin theta volts, right. So, just hold on, so in this case, now v is the tangential velocity of the conductor, right. So, it will be b by 2 that is, it is b by 2 means the radius, right. So, this is your this is the diameter, b is the breadth basically when it is revolving, it is actually diameter right. So, b is equal to your what you call the diameter.

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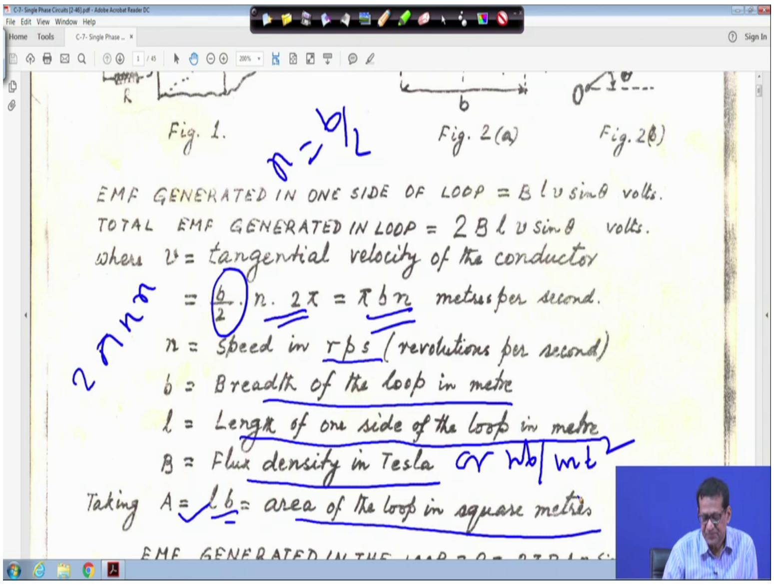

So, it is basically b by 2 is the radius. So, omega b is equal to, your b is equal to basically your 2 pi 2 pi n r, right. So, n r and r is equal to your b by 2. This is your b by 2. So, that is why 2 pi n r, right. So, that is B by 2.

So, that is equal to pi b n metre per second. This is your tangential velocity right, n is given speed in r p s revolution per second, b is the breadth of the loop in metre I told you, l is the length of the one side of the loop in metre and B is equal to flux density in Tesla or Weber per metre square right. And A is equal to I told you the l b, the area of the loop in your what you call in square metre square metre or so, in this in this mathematical expression that a is will be in the metre square metre, metre square, right.

So, this is from your higher secondary physics. Now, suppose let me clear it. Now, therefore, EMF generated in the loop will be e is equal to small e is equal to your this small e is equal to 2 pi B A n sin theta, right. So, what you do in this expression, let me just let me clear it what you do in this expression right, you know that B l v sin theta, you put in this expression b is equal to pi b n I mean I mean, if you put in this expression it is 2 B l into your pi B n, right.

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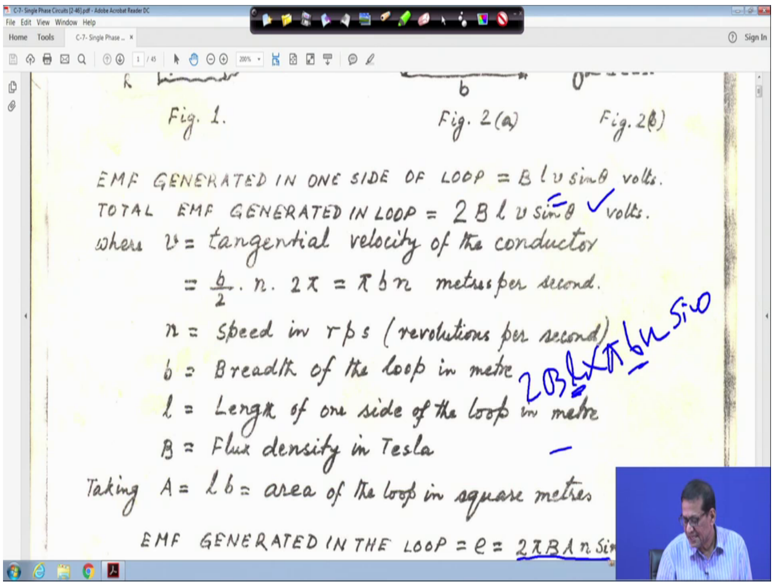

So, that is equal to B, then your sin theta. So, l into B, this l and B is equal to A and you put in put in this expression. Then, it will become put in this expression, then it will become 2 pi B a n sin theta volt, right.

So, let me clear it. So, in this case, this is your this is your 2 pi B A N sin theta volts. Now, if the loop is replaced suppose by a coil. So, you have n number of turns right you have n number of turns, then total your EMF generated will be that in the coil will be 2 pi B A you multiply you multiply this term, you multiply this term by capital N, it N is the total number of turns say. So, it will be 2 pi B A capital N into small n sin theta volts right. So, is equal to we can write that means, the maximum value of the EMF generated E m will be 2 pi B a small n into capital N right.

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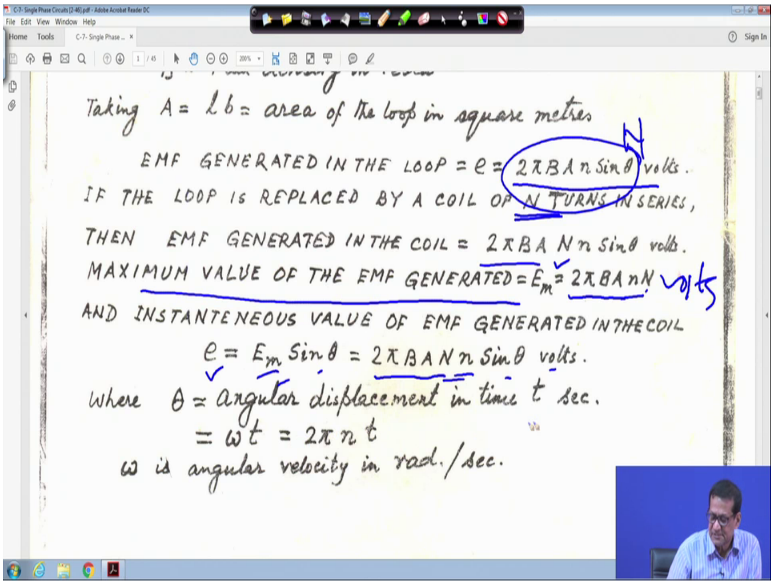

This is the maximum EMF generated, right. And if you want you can put this much of volts right. So, and instantaneous value of EMF generated in the coil will be then e is equal to E m sin theta right is equal to 2 pi B A capital N small n into sin theta volts, right. This is the thing. Now, theta is the angular displacement in time t second. So, let me clear it. So, in this case, so, when this coil is moving, this coil is moving right and it.

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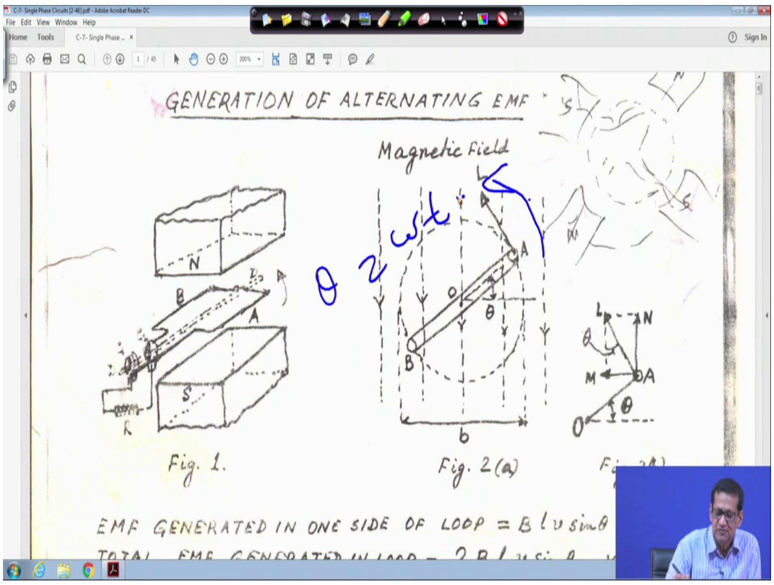

This is rotating, it is rotating. So, theta is rotating. So, theta actually is equal to omega t that is 2 pi n t because it is rotating. So, let me clear it. So, that means, if you put like this, your theta is equal to omega t that is 2 pi n t omega is angular velocity radian per second, then your what you call, then this equation that.

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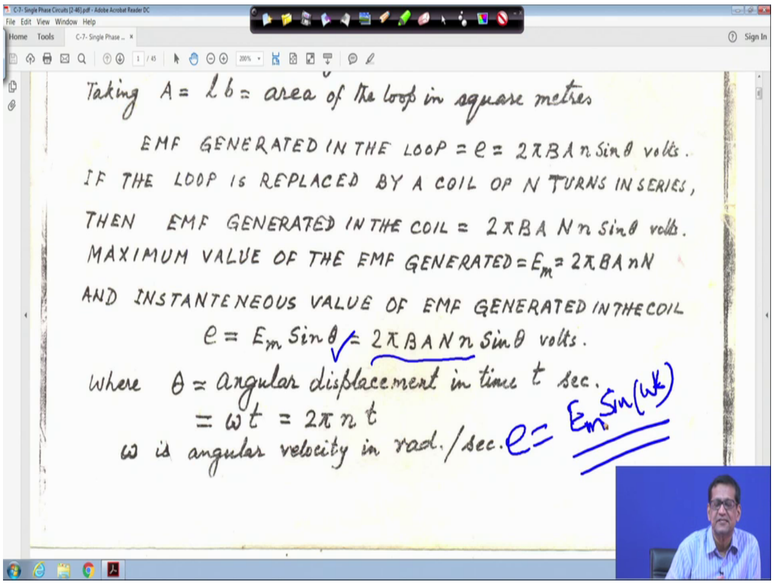

This equation e should be can be written as your E m right, then your sin omega t right because theta is equal to omega t. We are replacing theta by omega t and this is your E m. So, e is equal to E m sin omega t. So, this is the expression for the sinusoidal voltage, right. So, e is equal to E m sin omega t. E m is the maximum value of the voltage generated, right.

So, then this is the sinusoidal EMF that E is equal to your little bit here little bit, we have to we have to understand here right, right from the beginning that is why we have started from the scratch rather than going to the phase or another first we have to this because complex number will be involved again and again here, right. So, E is equal to now I told you that E is equal to your capital E m sin omega t right.

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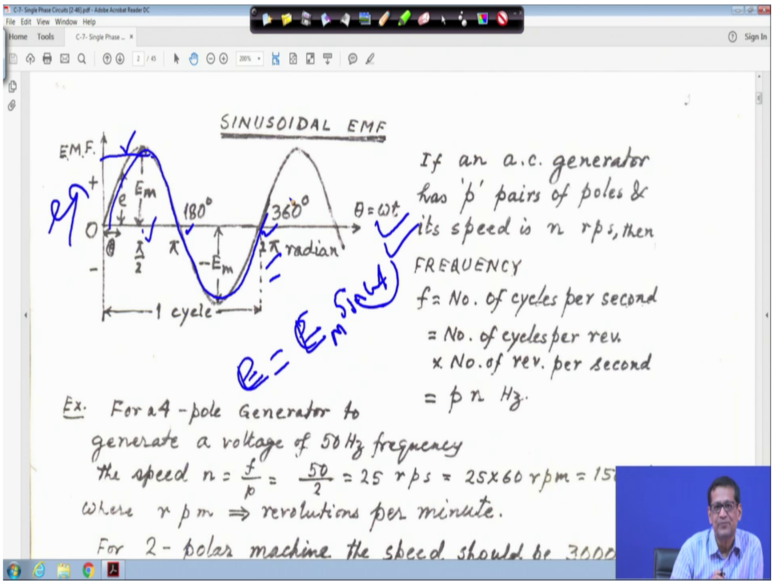

So, this is actually this your what you call. So, if you plot it so, this is from 0 to 2 pi, it is completing 1 cycle right because this is going like this and going like this and continuous it continuous and theta is equal to omega t right. So, this is your maximum value this is your maximum value E m and this side plot is actually E is equal to this thing the maximum value and this side is your what you call this is, it is cycling.

So, this side is a minus E m this side is a plus E m and this is 0, this is pi by 2, this is pi this is your 2 pi right. So, this is theta is equal to omega t. This is for your what you call for your single, if you look into that because N pole and S pole and single pair of poles right sorry, see your one pair of poles. Now, if an AC generator, so let me clear it. Now if an AC generator has p pairs of poles right when you have N pole and S pole, right.

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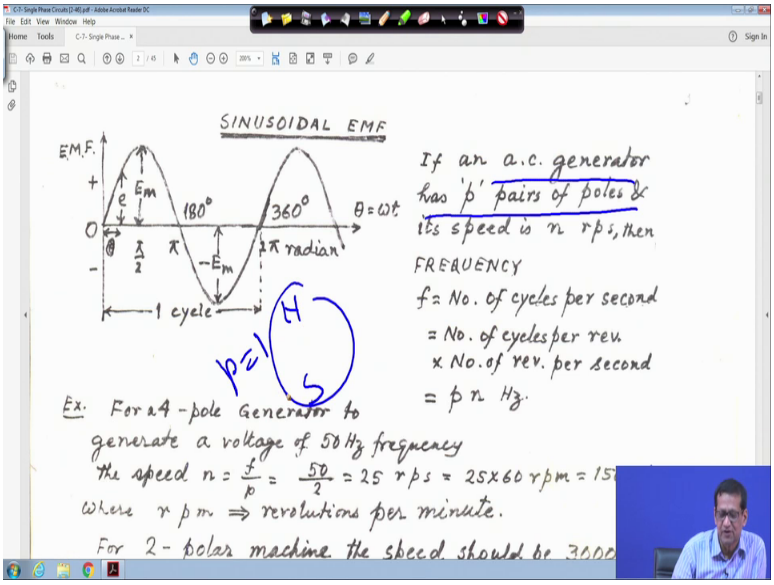

So, it is one pair of pole. So, it is p is equal to 1 because we are taking of a pair, not 2, 2 pole or 4 pole. We are taking pair of poles. Suppose, if you have let me delete, if you have look at this look at this your what you call just hold on, suppose if you have here I have made it initially here. Suppose, if you have here it is N pole here, it is S pole, N pole, S pole and it is revolving like this, it is revolving like this. So, here in this case you have p is equal to 2, that is two pairs of poles right.

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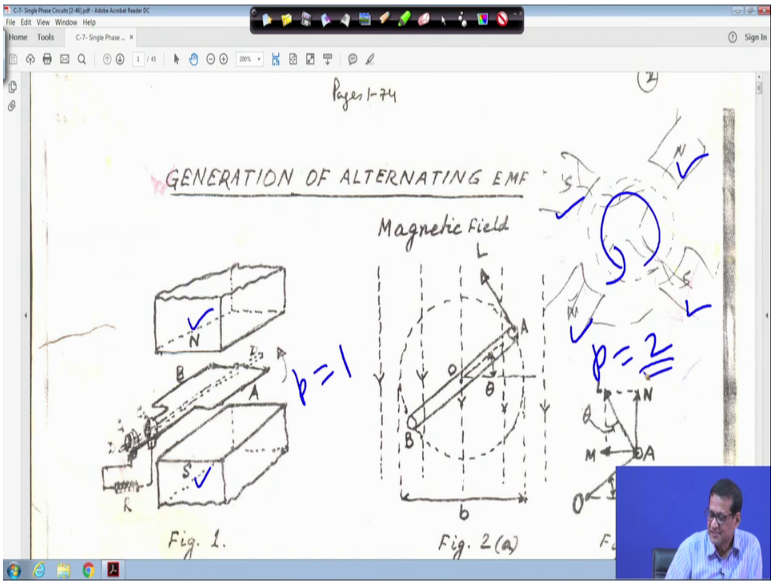

So, here it is N S, N S. So, 2 pair we have p is equal to 2 pairs of pole. So, it is, it may be more also, it does not matter, so when we are talking here, we talk pair of poles instead of number of pole, if you say number of pole then in this case, it is p is equal to 2 pole. But when you are talking about pair of poles, it is 1 and 1 together. So, it is 1 pair of pole that is N and S and here this p is equal to 2 because 2 pairs of poles right. So, if it is so, then therefore if an AC generator, if an AC generator has p pairs of poles, it is speed and n r p s, the frequency is equal to the frequency can be f this is small f can be given as number of cycles per second right, you have you have a Hertz, you have a Hertz that our frequency is 50 Hertz in a in Indian system.

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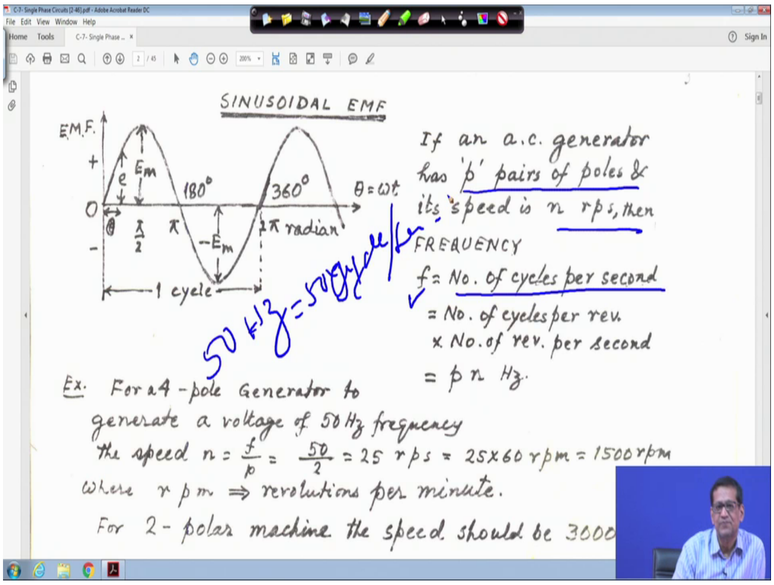

Our thing actually 50 Hertz is commonly practice in India your most of the countries. In USA, Canada, it is 60 Hertz and in Japan, I think it has 60 Hertz and 50 Hertz both are there right. But India is 50 Hertz, 50 Hertz means it is 50 cycles per second this is the frequency right. So, 50 cycles per second.

So that means, so in this case, the f is the number of cycles per second 50 hertz frequency means it is 50 cycles per second, right. Here, you show it is 1 cycle. So, if you have sinusoidal waveform, so it will complete 50 such cycles 50 such cycles in 1 second right. Then, you can find out 1 cycle will be computed by 1 upon 50 second that is 0.0, your what you call 0.02 second, right.

So, now question is that your this number of cycles per second that is f. So, this can be written as number of cycles per revolution into number of revolution per second. I mean if you write like this, it is number of cycles per revolution. So, you can write number of cycles per revolution into number of revolution per second.

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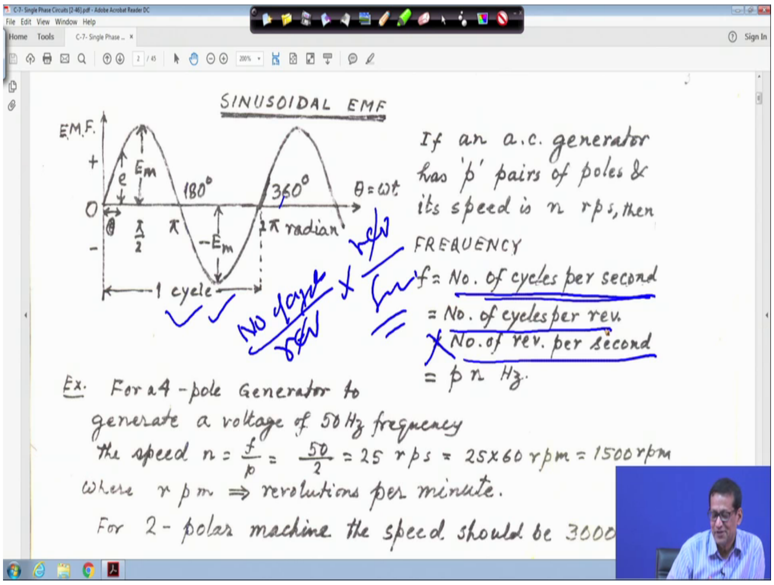

So, it is revolution per second right. So, number of revolution per second. So, in that case what will happen? So, it basically it will cancel it will become number of cycles per second. So, that is why number of cycles per second, we are writing number of cycles per revolution into this is into number of revolution per second, so right. So, number of cycles per second actually it will be number of pair of poles, right. So, if you have 1 pair of poles, it will may your what you call it is number of cycles per revolution, it will make 1 cycle per revolution, that is your it is you know it is electrical thing.

So, in this case, in this case that is why it is N pole and S pole that that here I have written N S, N S, right. So, it is electrical thing although if it will it will make your one rotation, if it is only N and S pole, then it is 1 cycles per second right. But if it is may pair your if you have 2 pairs of pole, although it will make your what you call that your 360 degree rotation, but electrically it is not, electrically it is not right. So, electrically, it will be 2 cycles right.

So, that means here, that means, here if you look into that it is p is the number of cycles per revolution, right. So, if you have 1 pair of poles, that it will make 1 cycle per revolution because it is electrical quantity it is, you are not looking at the mechanical thing, we are looking at the electrical thing N S, N S. Suppose, suppose that means, in that in that diagram your what you call in that your what you call that this diagram, here you have 2 pairs of poles. Although, it will rotate electrically or mechanically 360 degree, but it will basically complete 2 cycle because it will swap swipe N S and N S, this swipe has to link.

So, that is why this your what you call, that is why number of cycles per second is the number of cycles per revolution into number of revolution per second. So, this will be p into n; that means, p is equal to this p is number of pole pair. If you have 4 pole pair sorry, if you have 4 poles; that means, you have 2 poles pairs, this is pole pairs right. So, 2 pole pairs. So, in this case, your number of cycles per revolution means it will make 2 cycles per revolution. Although mechanical, it will rotate 360 degree, but electrically it will make 2 cycles per second right because you have four pole that mean 2 pole pair.

So, later when we learn your much more thing in the if you are an electrical engineering student, when you will go for your second year when you will study electrical machines, at that time you will learn much in detail right, but this course just to give you some basic ideas. This is the idea that if you have number of pole pairs is equal to number of cycles per revolution. This you have to keep it in your mind, right. So, for example, one small example I have taken for a 4 pole generator right. So, and frequency is 50 hertz say f is equal to 50 hertz right, then n is equal to f by p because f is equal to this is the formula f is equal to n p, this is the formula this is f is equal to p n right.

So, n is equal to then f by p and if f is equal to 50 Hertz and p is your what to call it is a 4 pole generator; that means, p is equal to 2 because it is four pole means 2 pairs. N and S it has to be there. So, basically two pairs so; that means, 50 by 2 it will be 50, 25 r p s right revolution per second and if you ones minute is equal to 60 second. So, multiply by this 60. So, it will be 1500 r p m, right revolution per minute. So, that will be your n I hope you have understood this right because before going to AC circuits or average value mean value and other thing, I hope you have understood this that how EMF is generated instead of directly starting by taking e is equal to E m sin omega t or i is equal to i M sin omega t.

I thought that I will start little bit with this kind of concept such that your our understanding will be will be little bit you known better right. So, that is why I have started with this one first, then we will come to the mean value and average value. So, this is an idea to give you how EMF is generated and how the your load and other thing is connected that is beyond the scope at the first year level.

So, that is why just let me clear it, that is why your in this diagram in this diagram; that in this diagram that is this part that this is the load right and this is connected, I did not mention anything because at this stage load not required right. So, only when you will study DC machine or DC motor little bit at that I told you similar philosophy I tell you how it is converted to DC because is a AC quantity is generated right. So, to start with AC single phase circuit, I thought this will be the base to depth this side is upper side is N and this side is S right. It is the flux moving from N to S while coming from N to S right. So, this way this is the sinusoidal EMF generated. Instead of taking e is equal to E M sin omega t, I have taken this one just for your understanding only right.

Now, we will come to mean value that is average or mean average value or mean value we call and RMS value or we call effective value of an alternating current because it is alternating because it is moving plus minus plus minus. So, alternating current right, so and it is symmetrical sin omega t is a symmetrical right symmetrical waveform right, it plus and minus side both are same. Area if you look, the plus side and minus side it is same with the same your what you call the time interval right.

So, this is average mean and this RMS for sometimes average value is equal to mean value RMS value that is root mean square value will see what is this is called effective value of an alternating current. Now, here for your for our understanding what we have done is, here we have not taken it your what you call a sinusoidal waveform like that. We have taken some wave form, but symmetrical. If you look into this side and this side, it is symmetrical, this side is symmetrical.

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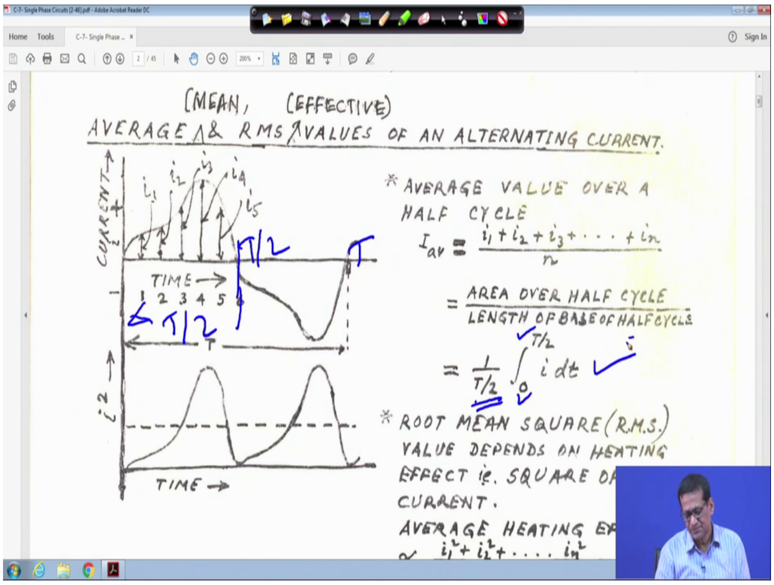

And this is this time period is T say 0 to T and this is your this time is T by 2 right. This is T by 2 and this is the this is 1, 2, 3, 4, 5, 6 if you take in second and second. Now, suppose that every at this that is the sampling instant also now you now you tell, right. So, at this point it is i 1 and this is i 2, this is i 3, i 4, i 5 and so on. Every, size or sampling instant or every time whatever you take the way you take right suppose this is i 1, i 2, i 3 up to this will come up to T by 2 right, up to T by 2 will come.

Now, this is the current this is the say current waveform will come to this later. So, this is the current waveform. So, average value over a half cycle that is I average I capital we have taken I average is equal to i 1 plus i 2 plus i 3 up to i n. I mean, you take all the value i 1, i 2, i 3 up to i n and i n divided by your n you have to consider up to this time interval up to n.

So, this is actually the average value or you can do like this or average value will be, you find out the area under the curve, this is the and we will make it only over the half cycle is because this is positive side, this is negative side. So, it is symmetrical. If you take average value from for the full cycle complete cycle from here to here, it will be 0 because this is positive area and this is negative area it will become 0. We will not do that. For symmetrical waveform, we will just go up to your half cycle. So, only up to this, so up to T by 2 not as a whole because from this one, it will be 0 right. So, that is not interested or even a half cycle.

So, average value over a half cycle that is why it is written over a half cycle it is i 1 plus i 2 plus i 3 up to this one by n. This is the average value or this one you make area over half cycle. So, this is the area this is the area over the half cycle divided by the length of the base of half cycle and this length of the base of half is T by 2, up to this right. So, let me clear it. So, that mean this is my T by 2 and this is T and this is your this is the base, T by 2.

So; that means, that is divided by the length of the base of the half cycle. So, area of the the suppose this I expression is known to you. So, you can integrate 0 to T by 2, then i into d t because this is a this is the expression for i, this is a some instead of taking sinusoidal some symmetrical waveform I have taken and this divided by your length of the base of the half cycle. So, this is T by 2. So, 1 upon T by 2, so this is your average value right, later we will see the expression, this is the average value.

Now, next is that your we have to come to the root mean square value root mean square value r m s value or effective value right. Let me clear it. So, in this case, in this case what has been done that suppose this plot is i square plot, this is the i and if you plot i square. So, it is coming like this, it is your T by 2 and this is T and this is the origin. This i, this is i and this is i square, this is i square plot right. If you plot the i square from it is this your what you call that when you try to find out the root mean square value, this area this is positive side.

Now, because it is square this was negative, but if you square it, is it is going like this. So, if for making your RMS value, half cycle or full cycle it will give the same result because area of this one and area of this one is same. So anyway, will consider this half cycle only because these are same, same area; if you consider 0, if you if you consider 0 to T by 2 right, if divided by T by 2 or 0 to T divided by 2, in that both will be covered. So, ultimate meaning is same. So, we will consider only your what you call only the half cycle right. Even you take the full cycle for r m s value, it will give the same result.

So, let me clear it. So, in this case what is happening? Similarly like here i 1 at if suppose 1, 2, 3, 4, you can calculate your this is i 1 square. This is i, this is i 2 square, this is your i 3 square like this. Here it is i 1, i 2, i 3 for this is square because this is a square right. So, whatever value you will get, this is i 1 square, this is i 2, this is 1, this is 2, this is 3 like this up to T by 2 and this is T, right. So, if you have some n such value before going to the in terms of T.

If you have some n such values right, then it will be your average area or what you call depends on the heating effect that is the square of the current because in DC circuit, we have studied the power loss is equal to i square r right. So, root mean square value depends on the heating effect that is square of the current as soon as we are taking in terms of square of the current basically, it depends on the heating effect because i square r we have seen, i square r is lost in the DC circuit. Same will be applicable to your AC circuit also. We will come to that. So, therefore, the average heating effect is proportional to i 1 square plus i 2 square up to i n square divided by n right.

You have you have such n such i 1, i 2, i n square value and divide by n right. This is the average heating effect which is proportional to this is proportional to right i 1 square plus i 2 square up to i n square divided by n right so, let me clear it. So, in this case, suppose now how we will get the r m s value. Suppose, i, i be the value of the direct current to produce the same heating in the same resistor as produced by a your by alternating current, right. So, we have to assume something that I be the value of the direct current to produce a same heating in the same resistor at produced by the alternating current, right.

So, then what we can do is, we can write I square is equal to I square is equal to i 1 square plus i 2 square up to i n square divided by n right or I is equal to square root of i 1 square plus i 2 square up to i n square sum it up, divided by your n, right.

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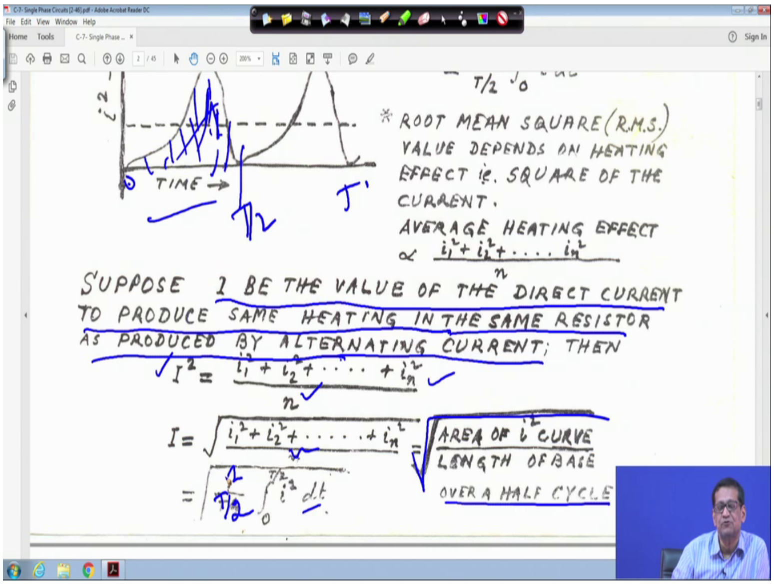

This is total square root or this one basically this one this area of this curve, I square curve, this curve only and this is your time T by 2, this is T, we will take half cycle.

So, this is your T by 2 therefore, this is area of I square curve divided by the length of base under root, this is under root, area of the I square curve. So, this is area of the I square curve divided by the length of the base that is your T by 2, 0 to T by 2. So, it is T by 2 minus 0. So, length of the base that is over a half cycle. Even in full cycle also, it will give the same result because this area and this it is a symmetrical. So, it has a same area right.

So, over a half cycle; so that means, this can be written as your 0 to T by 2 i square d t and this is your little bit this is your T by 2, 1 upon T by 2 right, 0 to T by 2 i square d t right. So, this way you can find out that what is the value of your what you call I value and this is called your r m s value, root mean square value or effective value and average value sometimes we call mean value right. So that means, let me clear it; that means, that means, for average directly, we are taking half cycle. For root mean square value, first we are squaring it square.

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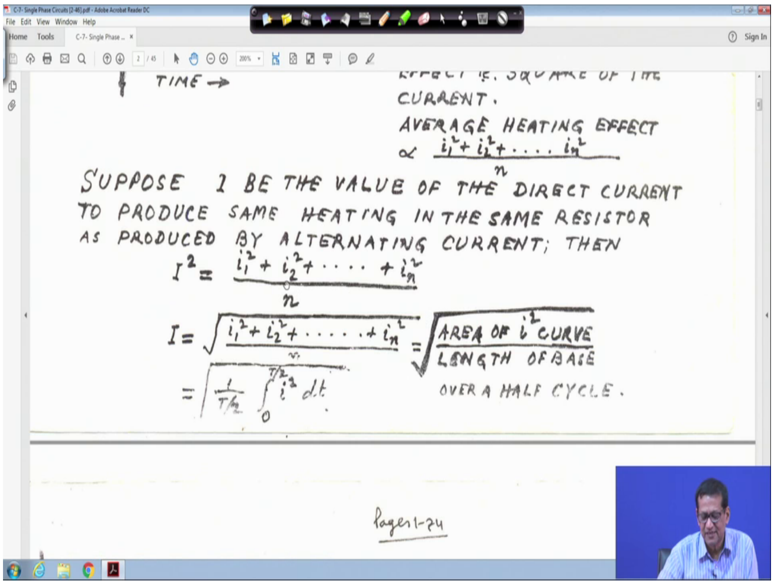

that your i square right and accordingly, that heating effect that will proportional to the your square of the current.

So, it is average heating effect is proportional to this right this and therefore, I square we write like this, i 1 square plus i 2 square plus i n square upon n and therefore, your I is equal to square root of i 1 square plus i 2 square up to i n square by n right. This is n right and is equal to square root of area of i square curve by length of base over a half cycle everything I have written. So, this is basically this square root of 1 upon T by 2, then 0 to T by 2, i square d t right. So, now if you come to this average and RMS values of a sinusoidal voltage or a current.

Thank you very much. We will be back again.