Electrical Measurement and Electronic Instruments
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Lecture - 35
Polar potentiometer

Welcome all of you. We are studying about phase shifter and how to use it with a potentiometer to measure AC voltages with arbitrary phase arbitrary phase angle.

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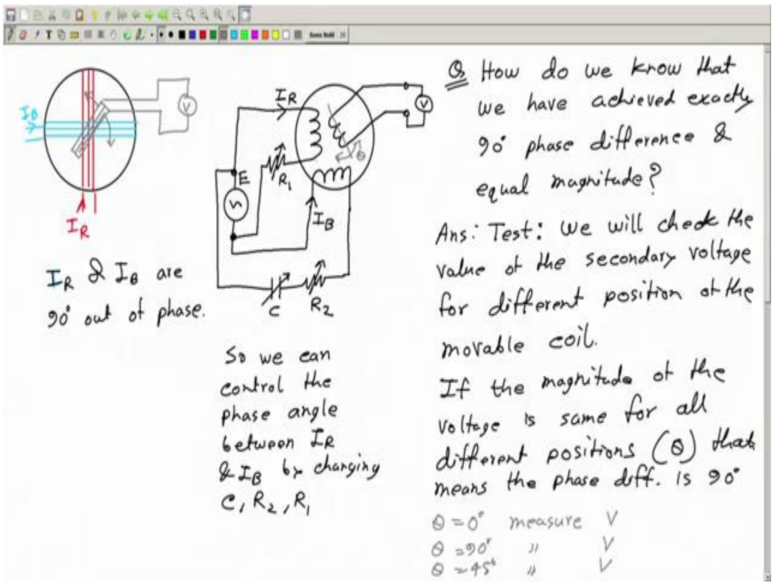

So, we have seen so far that a phase shifter you can think, it like a pair of coils. So, this is one coil and this is another coil and these two coils carry current which are 90 degree out of phase. So, this I am calling it as I_R and this current I am calling as I_B.

So, we need the angle between I_R and I_B to be 90 degree. So, I_R and I_B are 90 degree out of phase. Then if we have a third coil like this, then if we measure the potential across the two terminals of this third coil, then we will see there is some induced EMF. Because the red and the blue coil they create a rotating magnetic field and that rotating magnetic field intersects or cuts through this third coil or this secondary coil. Therefore, some EMF is induced and the phase angle of that EMF can be changed by changing the position of this third coil.

So, you can rotate this coil in either direction and by changing its angular position, we can change the phase angle of the generated EMF. Now the question is how to create, how to get I_R and I_B 90 degree out of phase. And we also; that means, need two sources of current, but what we can do say we will connect. So, let me draw the symbolic notation of this phase shifter ok. Symbolically we draw them; so, like a circle and then it has two coils.

So, say this is this horizontal coil and this is the vertical coil, the red one and this movable coil we draw it like this ok. So, we have to supply two currents ok. You can call them as so, one has I_R, one other as I_B and this are these two are to be 90 degree out of phase. How to get that? What we will do is as follows. So, we will connect AC source say here.

So, let me also put a rheostat so that we can control the amount of current and so, and this coil we will also connect to the same source. But this time we will connect it say through a variable capacitor and a variable resistance. So, the function of this capacitor or this capacitor resistance pair is to control the angle of this current. So, I_R is like this EMF divided by the impedance of this circuit which is this resistance plus this coil will have some inductance also some resistance.

So, you divide this resistance and this, you divide this EMF with this resistance and this inductance so, we will get I_R. Similarly, I_B can be obtained by dividing this EMF. If this EMF is E so, divide this EMF with the impedance of this circuit which is C plus these resistances are call it R1 and R2 C plus or J omega C plus actually 1 over J omega C plus R2 plus its inductance. So, you divide by that it total impedance, you get this current.

Now you can change this capacitor, you can change this resistance; thereby you can control both the magnitude of this current as well as the phase angle of this current compared to the phase angle of IR.

So, we can control the phase angle between the two currents I_R and I_B by changing this capacitance C ok. See as I mean you also may need to change R2 and you also have to ensure that the magnitude of these two currents are same provided that the number of turns of these two coils and the reluctance of the two paths are same, you also need to ensure that then this two currents have same magnitude. So, you may also need to vary R_1 R_2 to ensure that the two currents have same magnitude, but phase angle 90 degree ok. So, you change these impedances and its possible by changing it appropriately, you can make sure that these two currents are 90 degree out of phase, but with same magnitude.

But now I can ask a question. So, the question is how do we know that we have achieved exactly 90-degree phase difference and equal magnitude ok. So, we are changing this capacitance, these resistances, but how do we know that for what value of these impedances these two currents are at 90-degree angle? So, the answer is we have to do a test.What is that test. So, we will measure this voltage ok.

So, we will measure this voltage somehow maybe with a voltmeter or maybe with something else, but we will measure this voltage for different position of this third coil. So, this third coil can rotate, you know. So, it has an angular position which we can denote with theta with respect to some position. So, what we will do? We will check we will check the value of the secondary voltage; secondary means this voltage secondary voltage for different position of the this movable or turn able coil or secondary coil. If the magnitude of the voltage is same for all different positions; different positions means theta, the angular position of this coil. Then so; that means, the desired magnitude of these two coils and the desired phase angle between them is achieved ok.

So; that means, the phase angle bit or phase difference is 90 degree and they have of course, required equality of magnitudes ok. So, we may need equal magnitude of current or maybe some I mean; if this say for example, is turn ratio is not 1 is to 1, then we may need some other ratio of the magnitude of these two currents ok. But whatever is the requirement if we find that the secondary voltage is same the magnitude of the secondary voltage is same irrespective of the position of this coil; that means, the desired condition is achieved.

To say it in a in another word, we can say it like this ok. So, this thing I will say very briefly ok.

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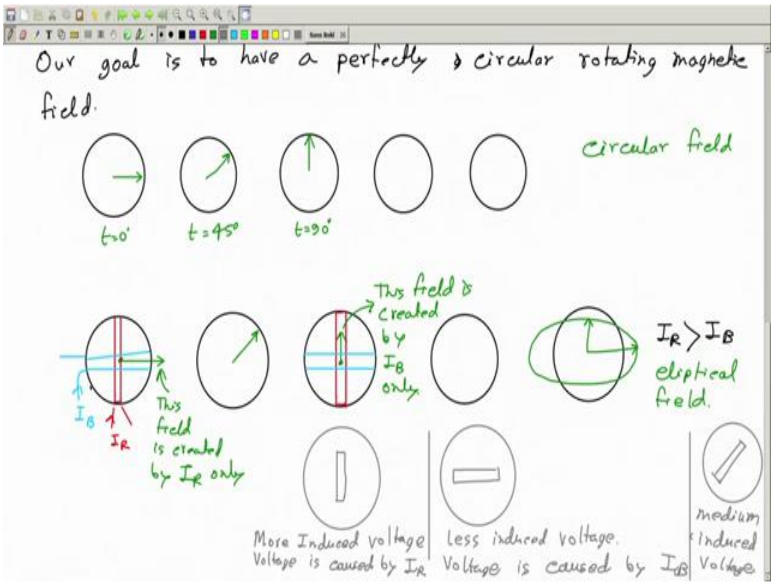

So, our goal is to have a rotating magnetic field; perfectly circular rotating magnetic. So, let us write it loosely perfectly root circular rotating magnetic field. So, what do I mean by that? So, I mean that so, if I draw the magnetic field as a vector at different time then so, this is the magnetic field at some time say t equal to 0. Then at so, they in at say t equal to 45 degree, the magnetic field should be like this.

So, it the length of this which denotes the strength or how strong the magnetic field is should be same, but the direction should be at a 45 degree angle. Then at t equal to 90 degree ok. So, t equal time 90 degree means actually when the phase angle of the reference current is 90 degree ok. Then again this should have same magnitude, but a different angle. So, this is a perfectly circular; circularly rotating magnetic field. So, this is what you want, but it may happen that ok.

So, let me draw the phase shifter again. So, this is this is the body of the phase shifter. So, this is the frame of phase shifter, I mean I did not write it. We may find that say at t equal to 0, the flux is like this; its magnitude is proportional to this length and it is at this angle at t equal to 45 degree. We find this say at say here and then at t equal to 90 degree, we find it here. Now it is magnitude is smaller than the magnitude of at the time t equal to 0 degree. When can this happen?

This is only possible if so, I have actually two coils. So, one coil like this; this is one coil which is creating the magnetic field in the horizontal direction ok. So, I have this if all always. This is one coil and another coil which is like this. So, this coil is horizontal; that means it is creating the field in the vertical direction. Now if the case is that this current call it I_B and this current is I_R. If I_R is greater than I_B or stronger than I_B so, then of course, this field ok; so, at this instant red current is maximum, blue current is 90 degree out of phase so, it is 0. So, there is no vertical component of the field and the field is only created by the rate current ok. So, this field is created by I_R only.

So, this field is created by I_R only. Similarly, at this moment red current will be 0, blue current will have its peak. So, this field so, this field is created by I_B only. So, the value of this field will depend only on the magnitude of I_B and the value of this field will depend on the magnitude of I_R. If I_R is stronger than I_B, we will have this field smaller than this field. Therefore, you see that the magnetic field it is rotating of course, it is rotating, but it is not rotating like a circle. So, to say because it is stronger here when it is here and it is weaker here.

So, this motion possibly, we can I mean to understand; we can possibly draw a ellipse like this and this means when the field is here, it is stronger and when the field is here, it is weaker. So, then the field is elliptically rotating. So, here so in this case, we have circular field; circular field. Here we have elliptical field ok. And what happens if the field is like this? Then the induced EMF in the secondary will depend on the position of the secondary.

If for example, if the secondary coil is so, say the secondary coil is like this or this is the third coil where we measured EMF, then the EMF will be induced EMF will be smaller l induced voltage will be less; so, lesser induced voltage ok. Why because sorry this will be more and if and if we have the coil here, then we will have less induced voltage, why? So, so you can see that for, this position for this position the induced EMF in this coil is actually created only by this red coil. The flux of the blue coil is vertical so, it does not go through this secondary coil at all ok.

So, for this position, the field is created mainly by the rate coil. So, voltage is created, voltage is caused by I_R mainly only and here voltage will be is generated or induced or caused by I_B only an I_B is weaker. So, we will have less induced voltage than this position. Here we will have less induced voltage, here we will have more induced voltage and if we put the coil like this say, at an angle, then we will have intermediate value of induced voltage or let us call it medium in medium induced voltage.

So, what happens? If we look at the voltage for different position of this coil; if the field is not circular, then we will have different values. So, let me just summarize this fact. What we want is a circularly moving field and a circularly moving field is possible only for equal magnitude of I_R and I_B. So, if I_R and I_B are equal, field will be circular and the induced EMF in the secondary will be of same magnitude; no matter the position of the secondary. But if I_R and I_B are not equal, field will be elliptical and the induce EMF will depend on the position of the secondary.

So, we can check whether the induced EMF depends on the position of the secondary. If it does not depend, then we are happy because; that means, the field is circular. The two currents are 90 degree out of phase and also equal in magnitude. So, this is the test we have to do. We have to move this coil. So, you have to move this coil at different positions and check the induce voltage and make sure the induced voltage is same. If it is not same, then we have to adjust this C R2 R1.

So, we will change this angle theta, we will measure this voltage say so, that maybe we will do the test like this say set theta equal to 0-degree measure voltage V, then said theta equal to 90-degree measure voltage V. If this two are equal; if this two are not equal, then adjust C R2 R1 to make this equal. If this is equal ok, then we are happy; then we may do some more tests to be more satisfied like will make theta equal to 45-degree measure V. If once again we get the same value of V, we are happy we are done; that means, these two currents are 90 degree out of phase and are at different magnitude ok.

So, now last thing is how to use this phase shifter in a potentiometer?

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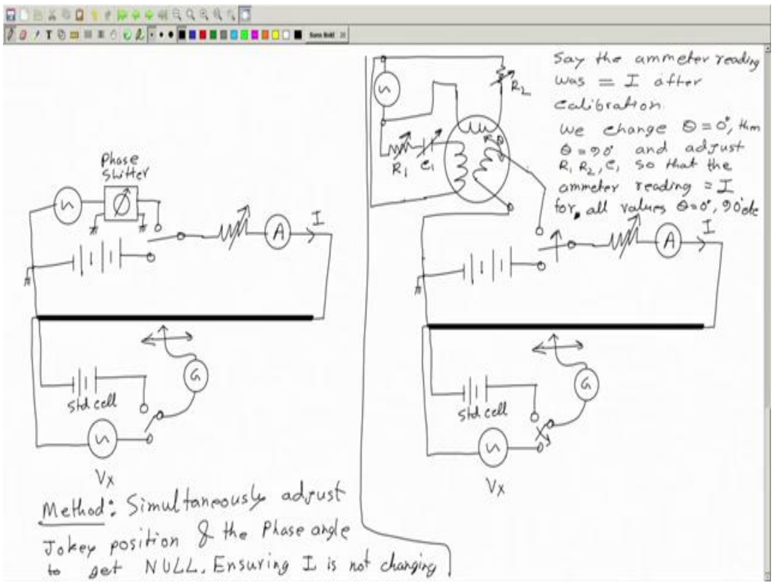

So, let me draw the AC potentiometer circuit that we had. So, this is the potentiometer wire and we have to measure a unknown voltage. So, let me have this unknown voltage VX AC. So, we connect it like this through a galvanometer, this jokey can move along the wire ok. So, we can connect it here and so, you also possibly recall that we also need a standard cell for the calibration.

So, this is standard cell and then we need the power sub voltage supply for this wire. So, of course, we will again need two voltage supplies; one for standardization which will be a DC. This ammeter is to is mainly for the calibration of standardization and this is to ensure that the RMS value of DC current during the standardization is same as the RMS value of the AC current when we connect this to the ac source ok. So, this is what we have seen yesterday, but now the problem is that if the phase angle of this source and this source unknown; if these two are not equal, then we can never get a balance.

So, what we will do? We will actually connect this source via our phase shifter. So, instead of connecting it like this, we will connect schematically; let me first draw this is the source, then we will have a phase shifter. So, this is a phase shifter and ok. So, it can think the schematic of this like this ok. So, this is a phase shifter and the task of this phase shifter is to change the angle of this supply voltage.

So, we can change the angle and we can move this jokey together until and unless we get a null ok. So, during the measure measurement phase, so, what we have to do? So, the method is simultaneously adjust the jokey position and the phase angle this to up to get null. So, it is like a trial and error method, you have to simultaneously move this jokey and change this phase angle ok. It is bit practically difficult two things; you have to change together, but that is the process that is what you have to do ok.

So, you have to change these two things and practically it is not that difficult. So, you have to change this to until and unless you get the balance. And one more thing you have to ensure that this current or this reading is not changing ok. So, ensuring this current I so, this is this should not change I is not changing. Its value should be same as the value which we have got during the standardization or calibration phase when we use this standard cell ok. Now this is the schematic ok.

Actually, that is mainly all maybe for a better understanding, I will just repeat this by actually drawing the schematic of a better schematic of a phase shifter. So, this schematic ok; so, let me put this diagram in this part of the diagram here ok. So, this schematic; if we want to make it more practical more realistic so, let us then do it like this. So, let me first draw the phase shifter which has two coils. These two are to be supplied with to 90 degree out of phase currents.

So, to control it control save these two currents, I am putting capacitor and a register in one circuit and then let this be the AC source which drives both this current ok. So, this circuit is complete; now complete this circuit ok. So, then it is getting the two currents required, you can control these resistances and capacitance to change the angle and then this will supply here. So, from the secondary, there is connect one side here and the other side here ok. So; that means, this is the source which is which will be driving the current through the main wire of this potentiometer.

Now what we can do is so, what we do. After calibration so, after standardization say, this current the reading of this current say, the ammeter reading was equal to I during standardization or after standardization or calibration whatever you call ok. Now we have to make sure that the same current flows when we have switch to the AC supply ok; here also we have switched to the unknown source ok.

But, before we actually connect this unknown source, we have to ensure that this has a perfectly rotating magnetic field and the magnitude of the EMF voltage is same for different position different theta. So, for that what we do we move? The or we change theta we move the dial; we change theta to say equal to first 0 degree and then theta equals 90 degree and adjust this resistance and capacitances call them R1 R2 C1 and adjust R1 R2 C1.

So, that this current ammeter reading is again I for all values of theta. So, that the ammeter reading is equal to I for all values of theta like theta equal to 0-degree, 90 degree etcetera. And once that is done, then we can move; then we can first connect this key to this switch to this unknown source and adjust this jokey and adjusts this angle get to get the null.

So, this is important. Before we connect the unknown source, we have to ensure that this current is same as I which was the current, we fixed or we got after the calibration after the standardization; whatever that current was, we have to maintain that current for all values of theta. So, we will check for different values of theta whether this current is constant; if not, we will adjust these values and when we get this current to be constant for different values of theta, then we can connect the unknown source.

So, this is how to use the polar potentiometer that is it. So, if you have any query, you may post in the forum, you can email us. In the next video, we will talk about another potentiometer; coordinate potentiometer which also measures AC voltage with unknown arbitrary phase angle.

Thank you.