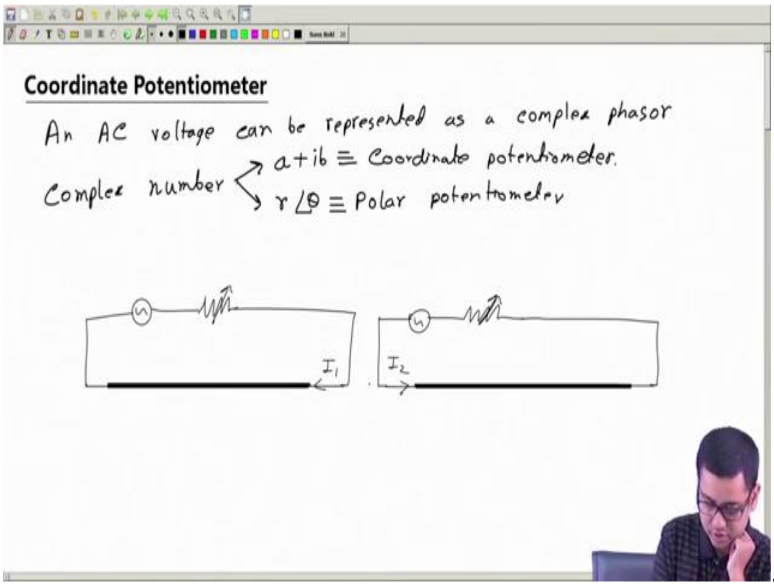
Electrical Measurement And Electronic Instruments
Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 36
Co-ordinate potentiometer

Welcome, we are studying potentiometers AC potentiometers particularly and the important issue about AC potentiometer is that, the phase angle of the unknown source matters ok. So, we have seen, how to take care of these phase angle using a polar potentiometer and we are going to see another type of potentiometer, which is coordinate potentiometer with which we can again measure unknown AC voltages with arbitrary phase angle.

(Refer Slide Time: 01:23)



Before we come to this let me motivate you by saying that an AC voltage can be represented as a complex phasor that you know, a complex number. Now, a complex number can be represented in two forms, one is

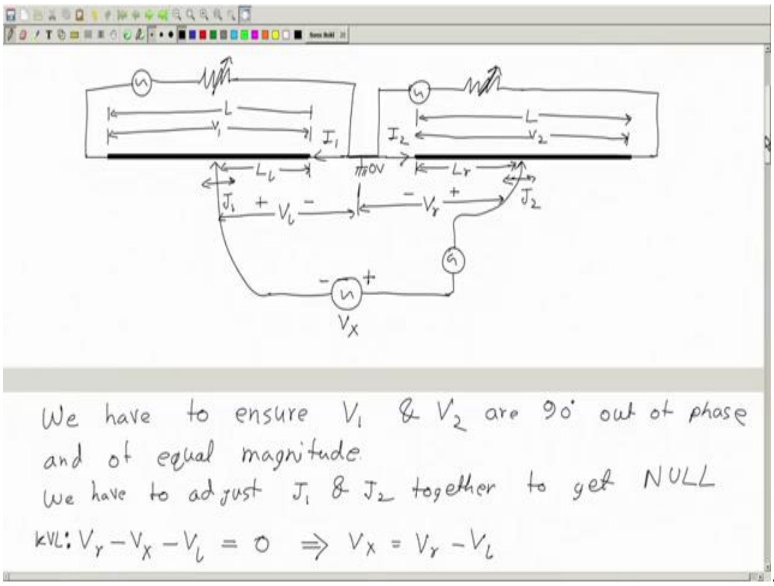
A+iB and r angle θ

So, we can represent a complex number in two forms. The polar potentiometer measures the unknown voltage in this form magnitude and phase angle. The phase angle is read from the dial of the phase shifter and the magnitude from the length at which the null point is obtained. So, this is the motivation or this representation is the motivation behind polar potentiometer because this is also called polar form of polar representation of a complex number and this is this is the motivation of today's topic coordinate potentiometer.

So, today the potentiometer that we will see, we will measure the unknown voltage in this form a plus i b. So, basically we need two potentiometers; one to measure the real part of a complex voltage another to measure the imaginary part so to say. So, we need two potentiometers. So, let me draw them like this, this is one potentiometer wire and this is another potentiometer wire. Now, the way we will do it is this. So, we will supply two I mean we will apply two voltages of course, two AC voltages in a one here another here in a way so that these two currents say this current and this current call it I_1 and I_2 they are at 90 degree phase angle.

So, I mean this is not what I am drawing now is not the complete picture, but just to motivate you for now. Let me have just two voltage sources such that the two currents are 90 degree out of phase. So, we have to somehow.

(Refer Slide Time: 05:55)



So, somehow, we have to ensure I_1 and I_2 are 90 degree out of phase and of equal magnitude. So, then it will actually mean that. So, this two are identical potentiometer wires.

So, the length of this and the length of this maybe are same. they are full their resistance per unit length may be same. So, if we can adjust I_1 and I_2 to have 90 degree phase angle then we can ensure that the voltage drop in this wire and this wire they are also 90 degree out of phase and the voltage drop per unit length will also be same. So, this will actually ensure ok, let me write it directly. So, we have to ensure that voltage call this voltage V 1 and this V 2, lengths are same the potentiometers have same length.

So, let us ensure that V 1 and V 2 are 90 degree out of phase and with equal magnitude, for that basically you have to adjust this I 1 and I 2 somehow you have to adjust this here and here to make I 1 and I 2 such that V 1 and V 2, 90 degree out of phase and of equal magnitude. Now, let me have the unknown source. So, the unknown source is here V x, x means unknown and what we will do is we will connect two jokeys like this one it through a galvanometer, one here another here and let me short these two terminals.

So, these two terminals are shorted, you can take this point as the reference for calculation; this is the reference point. So, now we have to adjust this and this during the measurement to get a null in this galvanometer. So, during measurement, we have to adjust both call this J 1 jokey one and J 2 we have to adjust J 1 and J 2 together to get null here in this galvanometer so; that means, no current should flow through this. When is that possible? That is possible only if this in this circuit, the voltage total voltage is 0.

Now, if this let me call this voltage from here to here, from this reference point up to this side call this V l and call this voltage as V r then what can we say and the reference direction so this is 0 side. So, V r is measured like this, V l is measured like this, V l is measured with respect to this point, V r is also measured with respect to this point. So, then we can say and V x let me take the reference of V x like this for example.

So, then we can write applying KVL starting from here. So, we have V r so this is

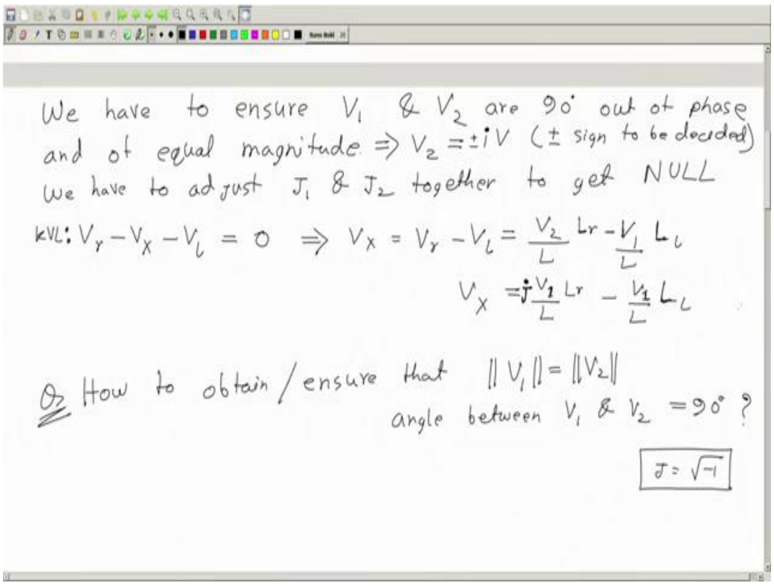
KVL: $V_r - V_x - V_L = 0$, right. V r rise, V x drop, V_L drop. So, So, then this implies

$$V_x = V_r - V_L = \frac{V2}{L}\,Lr - \frac{V1}{L}\,L_L = i\frac{V2}{L}\,Lr - \frac{V1}{L}\,L_L$$

Now, what is V_L? V l will be. So, if this length is capital L here also it is capital L and this length from. So, here to so, here to here.

This length, call it L l l for left and here length right left and right potentiometer.

(Refer Slide Time: 12:31)

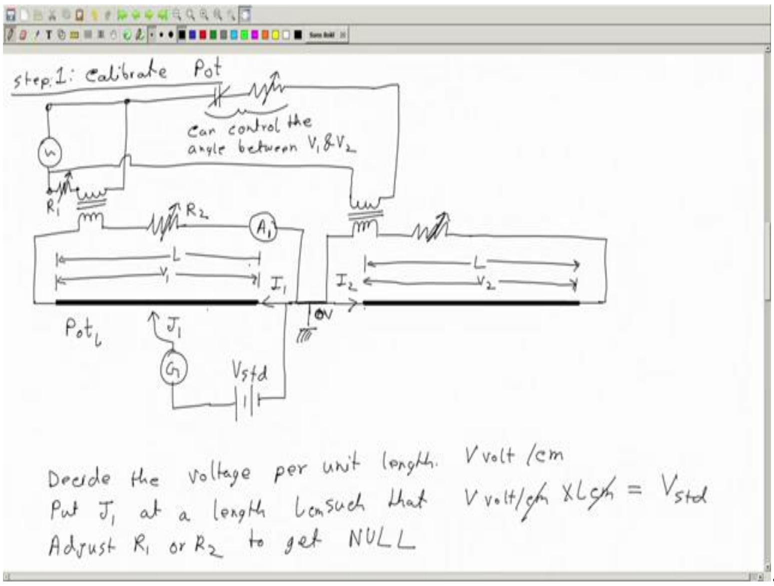


$V_2 = \pm i V$

So, you must understand this much before we proceed further and talk about more details like how to get these two currents these two voltages 90 degree out of phase, how to ensure that yes, they are exactly 90 degree out of phase, their magnitudes are same.

So, we will talk about this, but before that you may take a pause and make sure that you have understood up to this. If you have understood then let us proceed and ask, how to ensure or how to obtain or ensure that magnitude of V 1 is same as the magnitude of V 2 and the angle between V 1 and V 2 is 90 degree. So, this is the question of. So, what we will do is this.

(Refer Slide Time: 16:29)



Just like we did it for the polar potentiometer, we will take a source and supply this side and this side with one side through a capacitor, resister something to change the phase angle of the respective current between the respective currents. So, what we will do is this, let me first put say a transformer here.

So, this is a transformer and let me supply this transformer like this. If you want to control the current or the voltage of this and we finally, we have to control this voltage the magnitude of this voltage. So, we may need to put some resistance, you can put it here, you can also put it in the secondary side. So, by controlling this resistance also you can control this current and thereby this voltage; you can have a resistance here as well.

So, in principle both are ok and here this side we will again let me take a transformer, but let me feed this through variable capacitor, resister or some sort of impedance with which you can control the phase angle of this current and thereby the phase angle of the secondary voltage there by this current and so this voltage.

Now, so this is this can control the magnitude and phase angle between the V 1 and V 2 can control the angle between V 1 and V 2. So, you have to adjust this until and unless you get these two voltages V 1 and V 2 at 90 degree out of phase and same magnitude. So, this is the control how you can control, how you can change the angle, but the next question is more important question, how do we know that we are at the desired condition that we have obtained correct phase angle and correct magnitude? How do we test that? So, for that; so, the way we will do it like this.

So, let me tell you the entire procedure how to use it starting from the calibration. So, let me tell you the entire procedure in detail. So, first step is to calibrate steps. So, step 1, calibrate this potentiometer call this Pot L, Pot L left potentiometer calibrate Pot l, how? So, for that we need a standard cell DC standard cell. So, what we will do. So, let me make several copies of this.

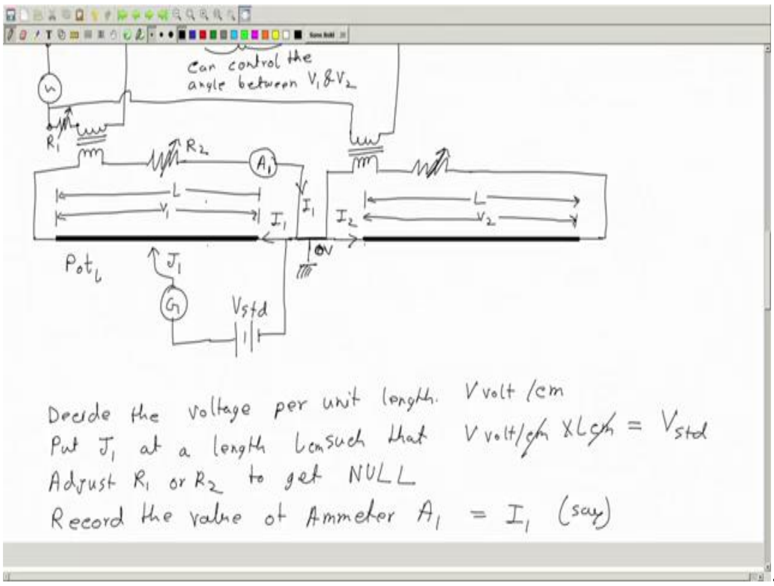
So, step 1 is calibration of potentiometer 1 for that let me. So, we do not need this unknown source right now. So, let me erase this unknown source. So, what we have to do? We have to connect the standard cell if we are taking this as the reference point.

So, let us connect this standard cell like this through a galvanometer and so, first decide the suitable length where you want to get the null. So, that is decided by the choice of voltage per unit length that you that and that in turn depends on the magnitude of the unknown voltage, you should have an idea of the magnitude of the unknown voltage. So, you decide. So, decide the voltage per unit length, accordingly put the jokey call this J 1 then put jokey J 1 at a length. So, from left, this is now from the right side ok. So, put jokey at a length call it l such that.

$$V_{volt/cm} \times Lcm = Vstd$$

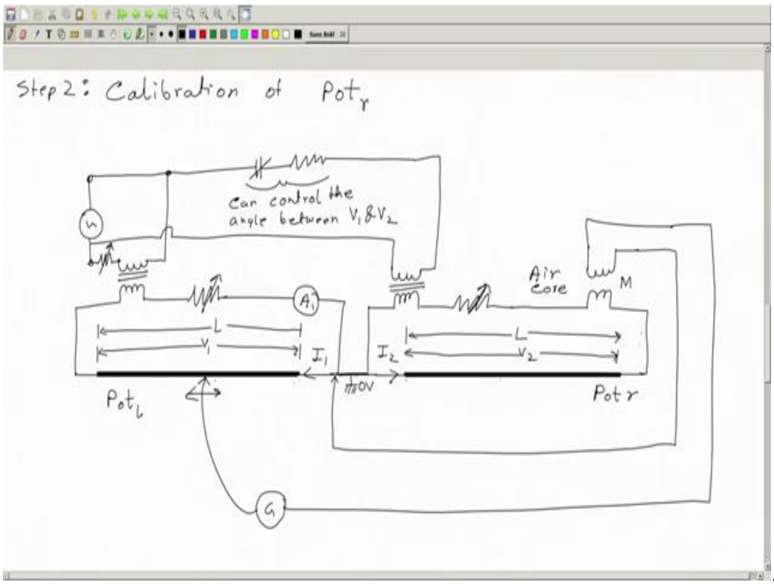
then adjust say this resistance or this resistance call this one R 1, R 2 adjust R 1 or R 2 or both to get null ok; that means, the potentiometer1 or potentiometer l is calibrated calibration is over, but of course, we need to record the value of this ammeter here.

(Refer Slide Time: 26:11)



So, record the value of ammeter A1 say this is equal to I 1. So, note this value and then the calibration of potentiometer1 is done.

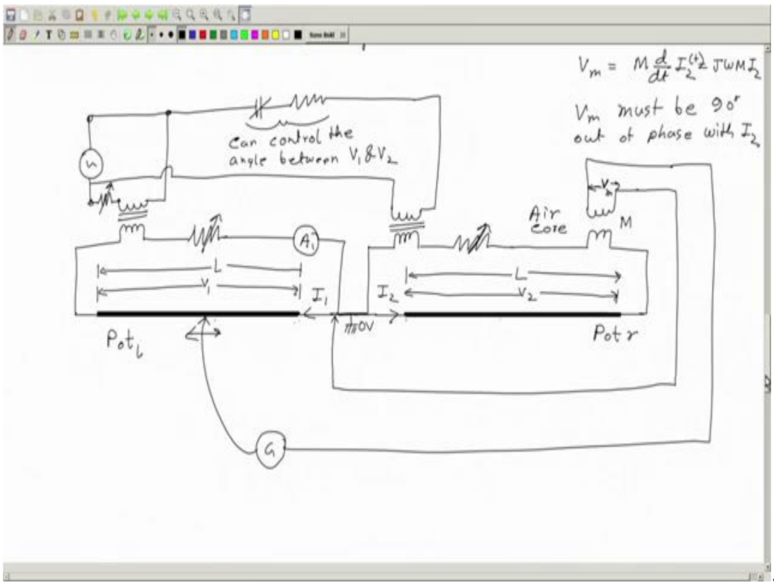
(Refer Slide Time: 26:43)



Now next step is calibration of potentiometer2. We call it Pot r. So, this is Pot r right Pot l, Pot r. Now, for that what we will do and then we have this ammeter A1 of course, and here we will put a new equipment, what is that? That is going to be air core transformer, important that this should be air core. So, I am not drawing any core. So, this is air core transformer and so, if any current is flowing here then we will have some voltage induced in the secondary, this voltage we will bring and connect one side here, another side through the galvanometer we will connect it here.

This is movable ok. Now, we need to know the mutual inductance of this transformer or; that means, between these (Refer Time: 29:14).

(Refer Slide Time: 29:35)

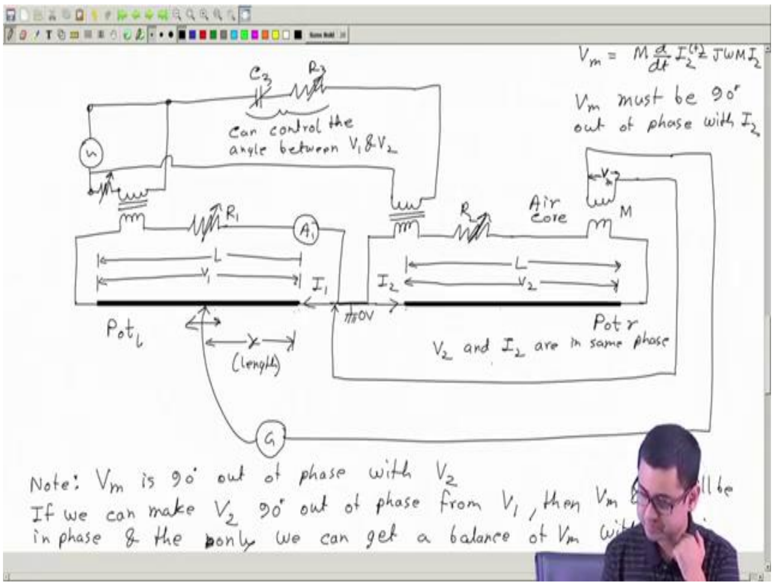


And now observe that this voltage in the secondary, call this V m. This voltage in the secondary is at 90 degree with the current which is flowing here or here I 2. V m must be 90 degree out of phase with I 2, why? Because, what is V m?

$$V_m = M \times \frac{dI2}{dt} = J\omega MI2$$

So, V m is 90 degree out of phase from this current.

(Refer Slide Time: 31:03)



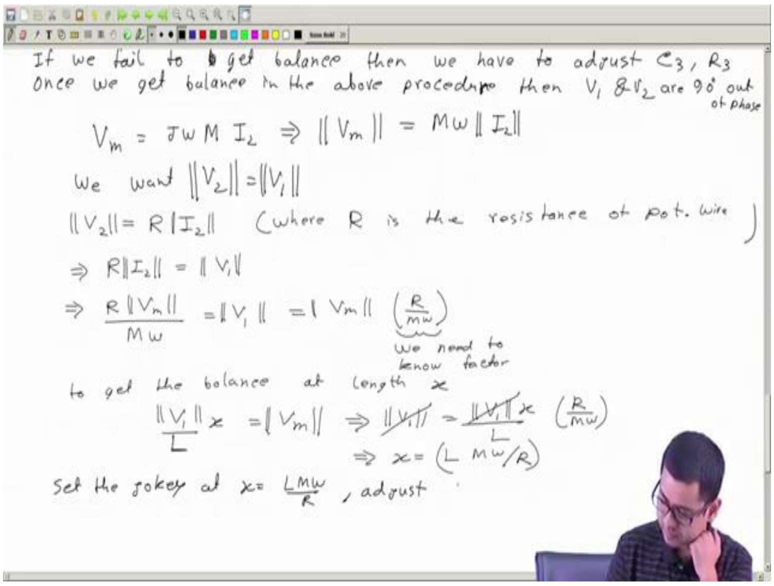
Now, this voltage V 2, V 2 is in phase with I 2. V 2 and I 2 are in same phase, why? Because this wire is resistive since the circuit is resistive. So, V 2 is nothing but I 2 multiplied by some resistance. So, V 2 and I2 are in same phase and V m and I 2 are 90 degree out of phase. Now, these two facts together, what does it imply? V m and V 2 they will be 90 degree out of phase.

So, this fact that V m is 90 degree out of phase from I 2, but I 2 is in same phase with V 2 this implies that V m is 90 degree out of phase with V 2. Now, if we can make V 2 90 degree out of phase from V 1, if we can make V 2 90 degree out of phase from V 1 then V m and V 1 will be in same phase same or 180 degree out of phase.

So, will be in phase ok. Because, if we can make V 2 90 degree from V 1, V 2 is 90 degree from V 1 and V m is 90 degree from V 2; that means, V 1 and V m will be either in 0 degree or 180 degree and then only we can get a balance here by moving this jokey. So, here actually we are bringing this V m to potentiometer1 and measuring this V m using potentiometer1 or potentiometer l and we can get a balance or null only if we can make V 2 90 degree out of phase of V m. And then only we can get a balance of V m with potentiometer L.

So, if we do not get any balance, if we fail to get any balance for any position of this jokey; that means, V m is that means, V m is not in phase with V 1 which in turn will mean V 2 is not at 90 degree with V 1 and then we have to adjust these things this capacitance, this resistance so that V 2 is 90 degree out of phase from V 1.

(Refer Slide Time: 35:19)



So, let me write. So, if we fail to get balance then we have to adjust this capacitor call that C 3 R 3, C 3 and R 3 and once we adjust it so that we get a balance, that ensures V 2 and V 1 are 90 degree out of phase.

Once we get balance above in the above procedure then V 1 and V 2 are 90 degree out of phase as desired ok. And also, also if we know the value of M if we know the; so, if we know the value of M then from V m we can estimate this current I 2. If we know the value of V m then we can estimate the value of this current I2 from V m and then from that we can estimate the value of V 2, if we know the resistance of this wire ok. So, now say if this is M then from the value of V m, how can we get the value of I 2?

I 2 is so let us write

Vm = J ω M $I2$

ll Vm ll = ω M || $I2$ ||

.|| V2|| = R ||I2||

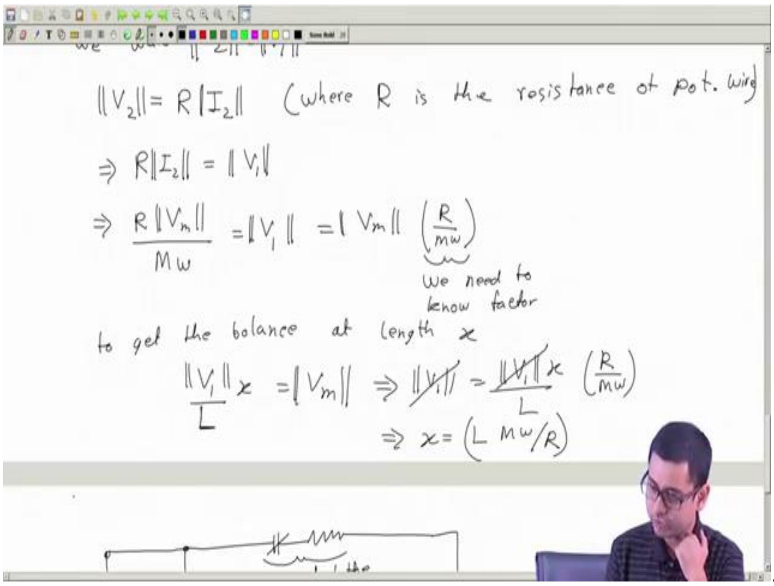
R ||I2|| = ||V1||

$$\frac{R||Vm||}{M\omega} = ||V1||$$

So, if we know this factor; so, we need to know this factor or maybe the potentiometer manufacturer or the seller will give us this factor for a particular value of omega. Then, we know that for which length here; so, for what value of this length call this l what call this x; I might have used l many a times, call this x this length.

So, what will be the value of this x? So, we can write that; so, this since we are getting V m, V m here and we want to get a balance.

(Refer Slide Time: 42:19)



$$\frac{||V1||}{L}\, x = ||Vm||$$

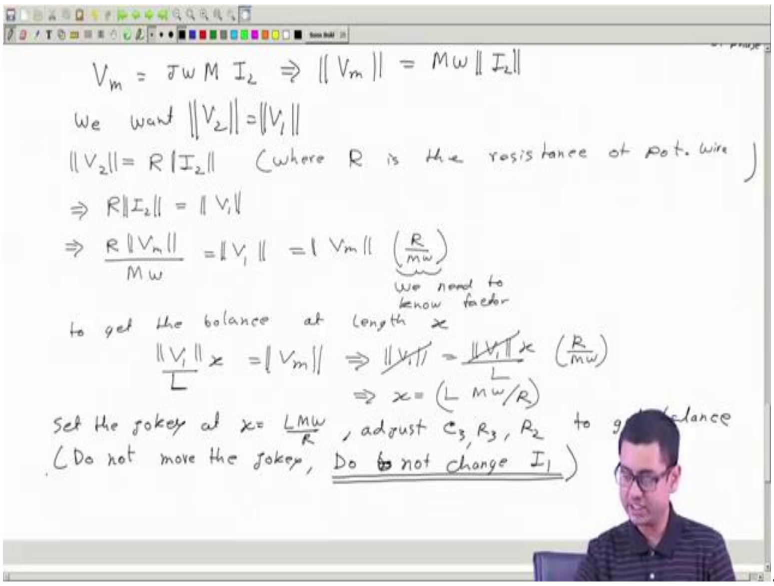
$$||V1|| = \frac{||V1||}{L}\, x \left(\frac{R}{M\omega}\right)$$

$$X = L\,\frac{M\omega}{R}$$

So, what we have to do is; we have to put the jokey at this particular length x and adjust these values these two values or you can also adjust this resistance to control the total current ok, call this R 1 R 2. So, x is obtained like this. Now; so, what we have to do is; set the jokey at $X = L\,\frac{M\omega}{R}$

ok, this factor M omega by R should be known. So, set the jokey there and adjust, what we can adjust? We can adjust C 3, R 3, R 2.

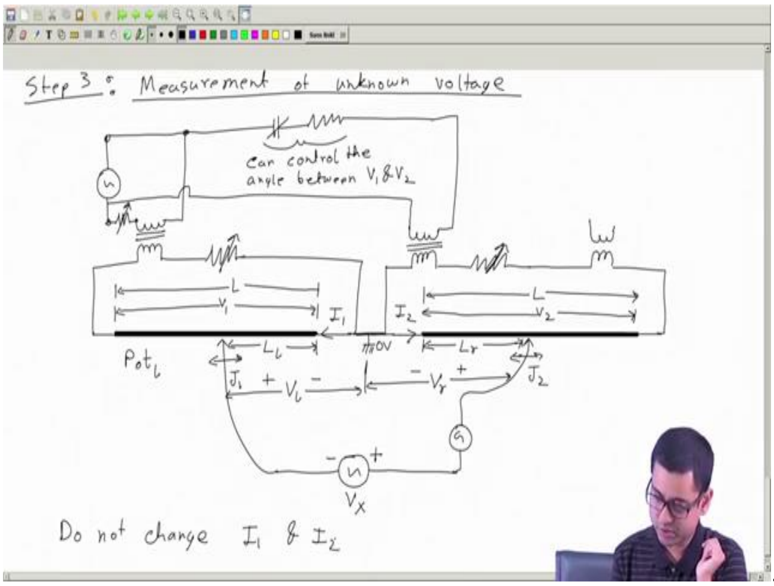
(Refer Slide Time: 45:05)



Adjust C 3, R 3, R 2 to get balance. Do not move the jokey at this point, do not change anything in the first potentiometer, do not change R 1 or this resistance. Do not change anything or in one words do not change this current I 1 which is fixed in the first step. Do not change I 1, this is most important.

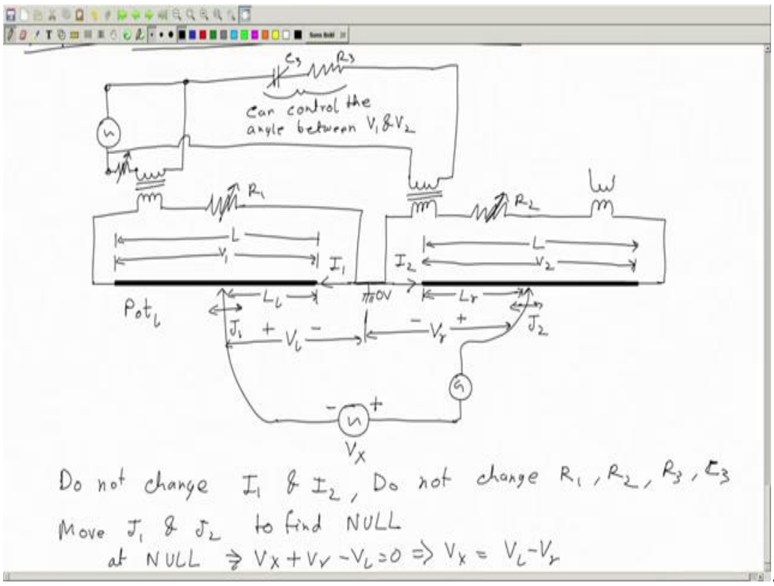
Once we get the balance, the calibration of the second potentiometer is over; that means we have made sure the voltage V 2 is in same phase out of phase from V 1 and same magnitude like V 1. So, this is step 2, over.

(Refer Slide Time: 46:22)



Now, final step step 3. This is the measurement of unknown voltage. So, in this phase we will still have this of course, this is always there. Here also we will have this, although we are not using it. So, you can keep it open. Here also you are not going to in this measurement phase, we are not going to use it you can keep it open, but and now we will connect the V x and we will have two jokeys.

(Refer Slide Time: 47:41)



So, do not change I 1 and I 2; that means do not change anything. So, this is R 1, this is R 2, C 3, R 3 ok. So, do not change any of these; R 1, R 2, R 3 or C 3 do not change any of these. Move the position of J 1 and J 2 to find null and once we have the null then we can write that. So, at null, we can write that V x is equal to V x is how much this is. So, we can write once again the KVL; $V_x + V_r - V_L = 0$,

$$V_x = V_L - V_r$$

So, that is the process that is the total entire process. So, maybe I recap a bit V 1 from here sorry V x from here is this. So, let me write j to be consistent j means root over minus 1. So, now you can put this value here for V l and V r. So, you will get V x and we are done.

So, let me just conclude this video by summarizing it in brief. So, what we have to do is first decide the per unit length voltage that we want to have then we have to set the standard, connect the standard cell to the potentiometer keeping in mind the chosen value of voltage per unit length, find the null that is calibration of potentiometer1.

Then using the air core transformer, we have to calibrate the second potentiometer. Once again, we have to first decide at which point the null should be obtained, put the jokey at that position, adjust the capacitance and resisters to change the phase angle and magnitude of the second potentiometer, once we get the null we are done. Phase 3 last phase, connect the unknown voltage across the two potentiometers together, adjust the two jokeys, do not change anything that can change the current in either potentiometer1 or potentiomete2. Change only the two jokeys, find the null and from the lengths get the voltage.

So, one small but important thing which I forgot to mention before is why we use air core transformer here? Why not iron core transformer? Ok. This is because in case of iron core transformer, the flux is not exactly in the same phase with the primary current, there is a small delay which we call the hysteresis lag due to which the flux generated by this primary coil which is this I 2 and the; so, I 2 and flux they will have a small lag between them.

Therefore, this volt secondary voltage V m will also not will not be exactly at 90 degree from the current I 2 ok, but in case of air core there is no hysteresis lag and that is why, this transformer must be air core that is important. Another small thing you observe that the, that the voltage induced in the secondary is the voltage here is V m and at the null condition when there is no current in the secondary circuit then there is no voltage drop also in the secondary.

So, therefore, the voltage that we are getting here is strictly V m, there is no voltage drop at all in the secondary this is also a nice thing; nice and obvious thing. So, the voltage that we are measuring that or that is coming here is exactly 90 degree out of phase from the from the; this current I 2. So, this is also important. So, since we are dealing with the subject of measurement where accuracy is very crucial important, these minute things must be remembered that we should not use a iron core transformer here.

Thank you.