Electrical Measurement And Electronic Instruments
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Lecture - 15
Voltmeter

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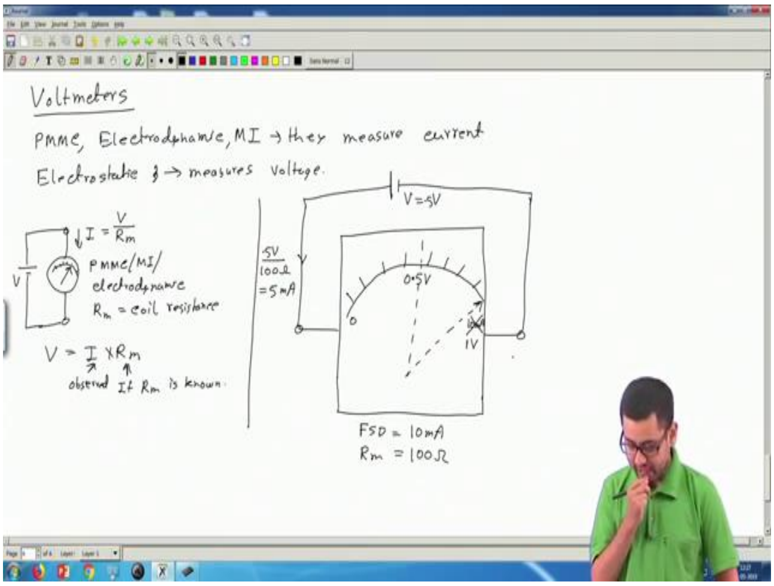

Welcome. So, in this video, we will talk about Voltmeters ok. Now, we have seen previously that PMMC, electrodynamic and MI - moving ion, they measure currents; they measure current directly. In a sense that if we apply a current across the coils of these meters the pointer is deflected and electrostatic instrument this measures voltage ok.

So, particularly electrostatic instruments cannot be used for a say DC current measurement directly as it is, because it is made up of ups set of two parallel plate plates. So, it is a parallel plate capacitor. And if we apply voltage between these two DC voltage between these two across these two plates, no current flows at all. So, it is sensitive to voltage, but a no current can flow through this meter. So, we cannot measure current directly, we can measure it indirectly, but not directly.

But electrostatic instruments are not generally used much this is used only for some high voltage applications mainly. And PMMC, electrodynamic, MI these are the most common type of instruments which are used most frequently, but they are current sensitive instruments. But can we not measure voltage with them? Yes, we can using Ohm's law.

How? Because say if I have this meter which is so which is say PMMC or electrodynamic or MI, if I apply a voltage V across this ok, so what will be the current through this meter, this current I will be V divided by R m. What is R m? R m is the coil resistance or metal resistance or internal resistance.

Now, if we know the value of R m, the pointer will of course, indicate the value of I, because this type of instruments in their pointer always indicate the value of the current. And if I know the value of this resistance R m, then I can always find V is equal to from this I times R m, if R m is known and I is observed. So, this is indicated by the position of the pointer, then V can be found ok. If I know the value of R m then I can compute the value of V. So, I can mark the scale of the instrument in terms of the voltage and instead of the value of the current ok. So, using Ohm's law we can measure any voltage using this type of instrument that is, so that is very easy.

Now, the question is what should be the or how should I mark this scale ok? So, if I have a PMMC meter say if I have a PMMC meter with full scale deflection current say equal to 10 milliampere and say the coil resistance is say 100 ohm ok, so that means, the pointer goes to extreme right when the current is 10 milliampere. So, this position indicates 10 milliampere, this is 0 ampere ok.

Now, if I apply a voltage across this meter which is say V equals say this V is equal to 1 volt ok. So, if I apply 1 volt across this meter, then how much current will flow? Then the current that will flow with 1 volt divided by the meter resistance which is 100 ohm. So, this will be equal to 10 milliampere, so that means, the pointer will go to the extreme right. And so this position I can mark as 1 volt instead of 10 milliampere because when I apply 1 volt across this meter then the pointer goes to the extreme right. So, instead of writing it as in terms of current, I can also write this position as 1 volt.

Now, similarly if I apply say 0.5 volt ok, so if I apply 0.5 volt, then the current that will flow here is this will be 0.5 volt divided by 100 ohm. So, this will come out to be 5 milliampere. So, the pointer will be here at this center ok. So, the central centre point, I can therefore, mark it as sub 0.5 volt. Instead of writing it in terms of current like 5 milliampere, I can write it as 0.5 volt. So, this way I can get a voltmeter.

Now, the next question is if I want to change the range of the measurement, how can I do that? Basically I have to change the resistance of the meter ok.

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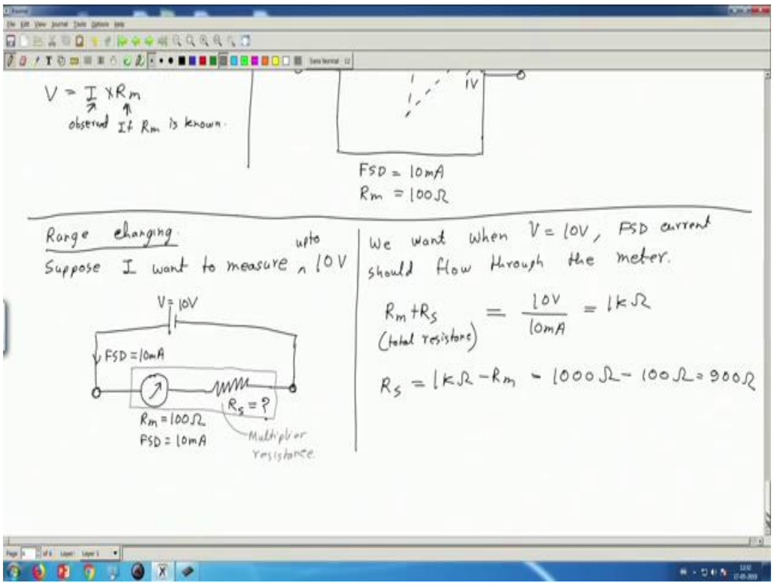

So, suppose so now range changing, suppose I want to measure up to 10 volt; up to 10 volt voltage ok. So, then what can I do, what I will do is this. So, I, either, so this is my meter it has an resistance of 100 ohm. I will connect some series resistance we call it R s, and I will apply the voltage the 10 volt voltage which I want to measure across this two terminals. So, here I will apply 10 volt. Now, what I want, when this voltage is 10 volt, I want the pointer to go to the extreme right position, that means, full scale deflection current should flow through the meter.

So, we want when V is equal to 10 volt, FSD current should flow through the meter ok. So, to achieve this what should be the value of R s ok. So, now, we know voltage is 10 volts. So, this is 10 volt and we want this current to be FSD current full scale deflection current which is given as. So, FSD for this meter is. So, let us take the previous example only 10 milliampere ok. So, this current is 10 milliampere ok.

So, the resistance total resistance of this circuit should be so which is

Rm+ Rs (total resistance) $=\frac{10\,V}{100mA}=$ 1k ohm

Rs=1k ohm – Rm=1000 ohm- 100 ohm=900 ohm

So, if we connect a 900 ohm resistance, then this meet this arrangement, then this arrangement, this meter together with this resistance will become a 10 volt meter ok.

So, this is how you can alter the range or choose the range of a volt meter that you want to make. Now, this resistance is sometimes called the multiplier resistance, the series resistance is called multiplier resistance ok. So, let me just write the name, this is multiplier resistance ok.

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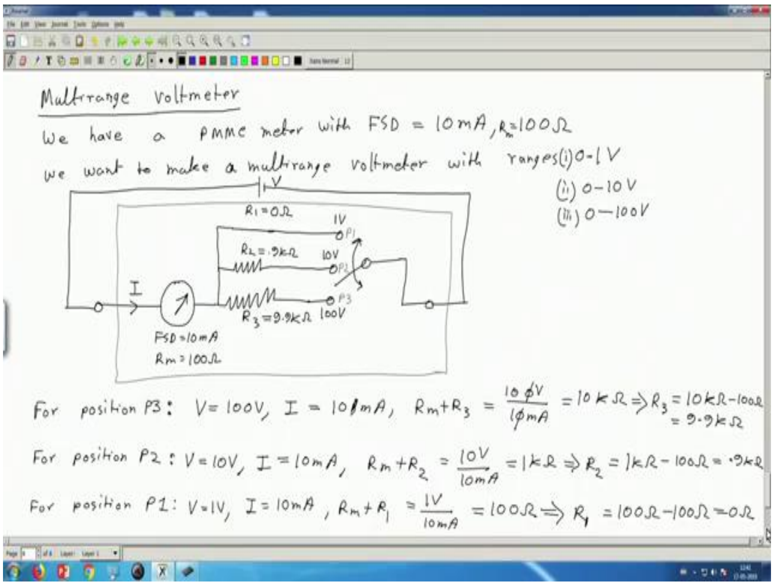

Now, let us ask ok, let us now let us make say multi range let us make multi range voltmeters ok. So, we have PMMC meter with FSD equals 10 milliampere, this is my favorite number 10 milliampere and say 100 ohm R m equals 100 ohm ok. And we want to make a multi range voltmeter with ranges say 1 volt, that means, 0 to 1 volt, then 0 to 10 volt and then say 0 to 100 volt. So, this is what you want to make.

How can we do that? So, basically we need three different values of the multiplier or series resistance. So, this is my meter and I will connect say a multiplier resistance. So, this is the meter with FSD, 10 milli ampere meter resistance 100 ohm and we will connect some resistance to get the desired range ok.

But now to get three different ranges, we need the provision to connect different multiplier resistances like this, so 1, 2 and 3, because we have three resistances. And then let me take a switch the switch can connect to either these or this or this. And this is the final two input terminals where we apply the voltage ok.

So, this is this entire thing is inside the multi range meter ok. Now, let us find out what should be the values of these three resistances ok. Say, we want the ranges to the say this is one this 1 volt range, this is 10 volt range and this is 100 volt range ok. So, let us compute the values of these resistances call this R 1, R 2, R 3. So, what say what will be the value of R 3 ok? So, let us calculate.

So, now, R 3 and R 3 plus R m this is the so let me first write for so, let me call this as position P 1, P 2 and P 3 ok. So, let me write for position say 3 or P 3 ok. So, we when we have 100 volt applied across these two terminals we want the pointer to go to the extreme right; that means, FSD current should flow through this centimeter ok.

So, for position 3, voltage will be V will be equal to. So, the voltage that we will apply across these two terminals will be equal to 100 volt and the current I will of course, be at that instant 10 milliampere . So, therefore, the total resistance R m plus R 3, this should be this $\frac{V}{I}$, 100 volt by 10 milliampere and this will come out to be 10 kilo ohm ok. And therefore, now R m is 100 ohm ok. So, therefore, R 3 will be 10 kilo ohm minus 100 ohm. So, this will be this is like 0.1, so, this will be 9.9 kilo ohm ok.

Now, similarly for position P 2, we want when this voltage applied is 10 volt full scale current full scale deflection current should flow. So, here V will be 10 volt and at that moment the current that should flow, so this current is I. And let me call this voltage, so I am calling this voltage as V this is V ok. So, then now V 10 volt I should be 10 milliampere, so that means, R m plus R 3 this should be 10 volt divided by 10 milliampere which means 1 kilo ohm. This will imply R 3 equals 1 kilo ohm minus R m which is 100 ohm. So, this will be 0.1 kilo ohm.

And similarly for position P 1 V applied voltage should be 1 volt current is once again 10 milliampere. So, R m plus R 3, this will be 1 volt divided by 10 milli ampere. So, this is a 0.1 k or 100 ohm ok. So, now, this will imply R 3 is equal to 100 ohm minus 100 ohm R m; R m its will be 100 ohm. So, R 3 should be 0 see if R 3 sorry this is not R 3, this is R 1, this is R 1. Here also it is r ok, here it is 2. So, this is 2, this is 2, this is 1, this is 1 right yes ok. So, then R 1 should be 0.

So, let us put the value R 3 should be point 9.9 kilo ohm, R 2 is 0.9 kilo ohm, R 1 is equal to 0 ohm, 0 ohm means we actually need a short circuit like this. So, no extra resistance is required meter resistant itself is enough ok. So, this how we can change the range of voltmeter and we can also make multi range volt meters. Now, the important thing that we should talk about volt meters is this ok.

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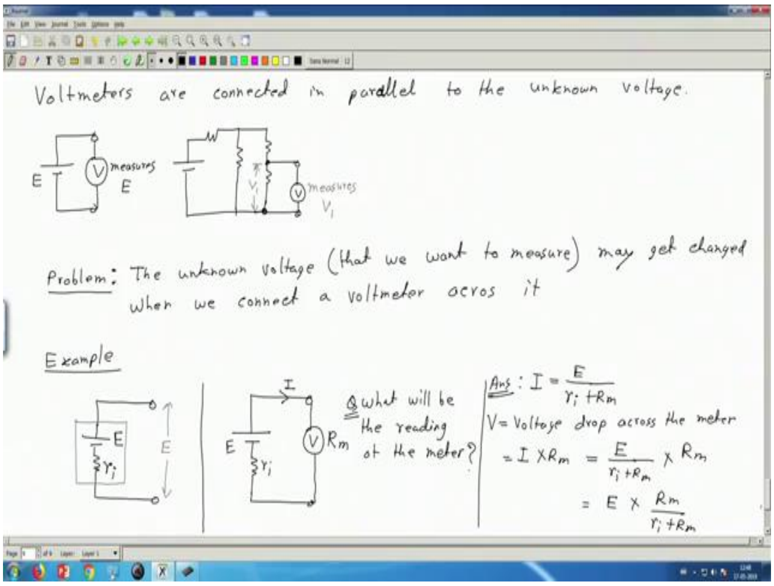

So, volt meters firstly, this is a trivial fact voltmeters are connected in parallel to the unknown voltage ok. So, if I have a unknown voltage source and I want to measure the voltage of this, I have to connect the voltmeter V across this like this. So, this is the symbol of a voltmeter a V inside a circle. If I have a complicated network maybe like this, and say I want to measure the voltage across this resistance ok, I want to measure the voltage between these two terminals then I have to connect the voltmeter V in parallel to this resistance ok. This is always connected in parallel ok.

So, then ok, so here this V if this I if I call this E, then this voltmeter V measures E in this circuit. If I call this potential drop as call this as V 1 between here between these two terminals, then this voltmeter is measuring voltage V 1 ok. So, voltmeters are always connected in parallel to the unknown voltage that we want to measure.

Now, there is a problem what is that problem? The problem is that ok, so the voltage the unknown voltage that we want to measure may get changed when we connect a voltmeter across it. So, if be why that is so, because the voltmeter has some internal resistance.

Therefore, in this circuit some current will flow. Now, through the voltmeter as well which was not flowing previously through these previously when the voltmeter was not there. Now, some extra current is flowing through this. So, the circuit is changed because of this voltmeter and therefore, this voltage may change when you connect a voltmeter.

So, let us take some small example ok, so example ok. So, let us take a simple battery just like this with some internal resistance r i ok. So, this is a battery with emf E and r i is the internal resistance of this battery. So, this is a battery or cell a voltage source ok. So, now, what is the EMF between these two these two terminals? This should also be equal to E.

So, the potential difference between these two terminals is E. But now if we want to measure the value of this potential difference using a voltmeter, so we have to connect a voltmeter between these two terminals like this. So, this is a voltmeter and say the internal resistance of this voltmeter is R m; R m for meter resistance.

Now, the question is what will be the reading of the meter? So, what will be the reading of this meter. So, we know in the absence of this voltmeter, this potential difference was E, but will this voltmeter indicate that value E or will it indicate some other value? So let us compute that. So, the answer is very simple ok. So, if I connect this voltmeter, then the current that flows in this circuit I, this is given by this is E,

$$I = \frac{E}{r_{i+R_m}}$$

$$I \times R_m = \frac{E}{r_{i+R_m}} \times R_m \neq E$$

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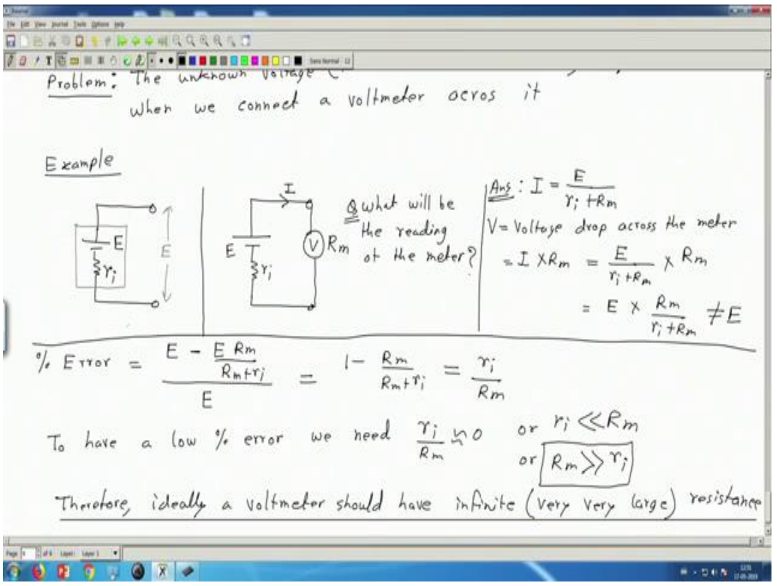

So, the volt meter reading will not be same as the voltage that was they are before the connection of the voltmeter ok. So, we can have some error. Now, the now will ok, so now, how much is the error? So, the error we can write say the percentage error or relative error, so this we can write as say the true value which is

$$\%Error = \frac{E - \frac{E\,R_m}{R_m + r_i}}{E} = 1 - \frac{R_m}{R_m + r_i} = \frac{r_i}{R_m}$$

Now, to have low error, low percentage error ok, we need r i by R m close to 0 or r i much much less than R m ok or R m much much greater than r i . So, this is the requirement. What is the requirement? The voltmeter resistance the meter resistance R m should be very large compared to the resistance of the internal resistance of the source, then only our reading will be correct ok.

So, therefore, ideally a voltmeter should have infinite theoretical infinite practically very very large resistance ok. So, this is one important fact about the volt meters that you should know. And now in this example, we have taken a very simple circuit ok, just a battery with an internal resistance. What will be the case if we use a complicated circuit, where we want to measure a voltage.

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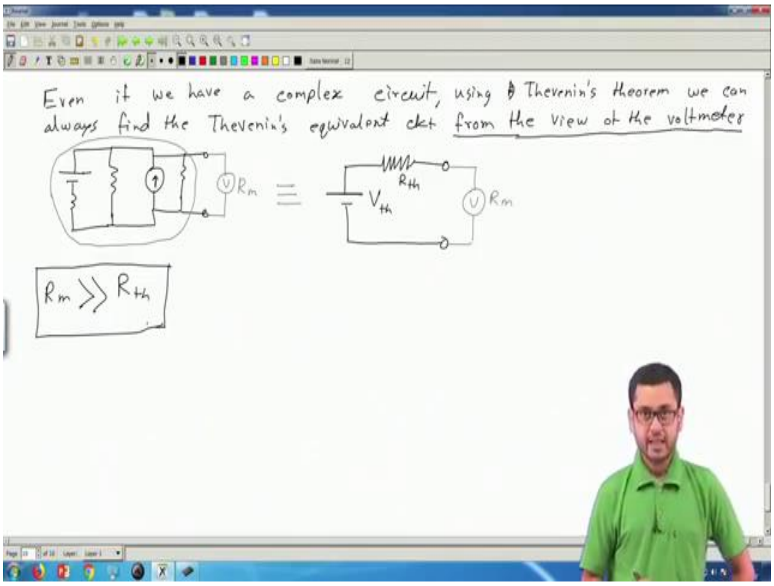

So, if even if take a complicated circuit, even if we have a complicated circuit complex circuit say like this let us take a complex circuit and say we want to measure the voltage across this terminal. So, we have to then connect the voltmeter here ok. Now, what should be the value of the R m, it should be high, but how high?

Once again even if we have a come so complicated circuit like this by virtue of Thevenin's theorem, we can always simplify this circuit into us into a Thevenin's equivalent. So, we can always find the Thevenin equivalent as long as the circuit is linear. So, Thevenin equivalent circuit from the view of the voltmeter; so, this is important from the view of the voltmeter that means.

From the view of the terminals, where this is this voltmeter is connected, that means if we look into this circuit from this two terminals from the perspective of these two terminals, so we can always get equivalent voltage source call it V th Thevenin voltage in series with R th Thevenin resistance this is same as the Norton's resistance the and the voltmeter is here with internal resistance R m now we can say R m should be much much higher than R th Thevenin resistance that is the resistance of the circuit as seen by the voltmeter . So, this is what we want.

Thank you.