Fundamental of Power Electronics
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Lecture – 26
Power factor – discussion

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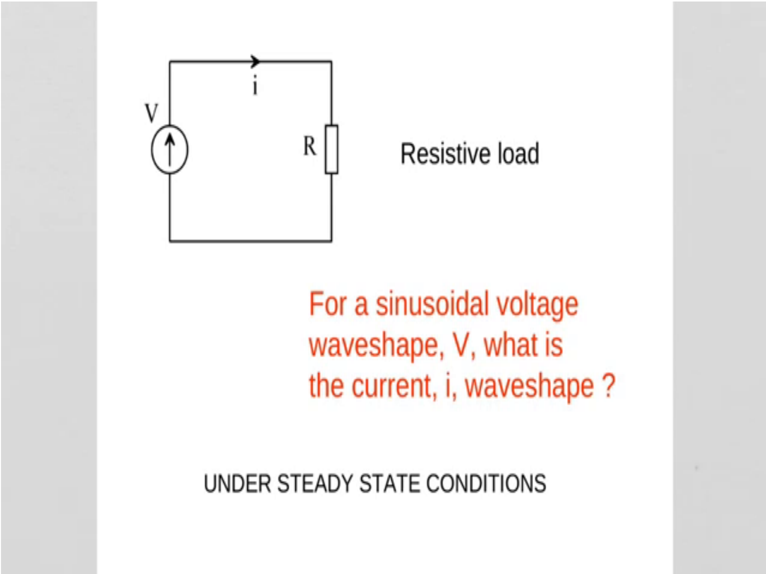

Now, consider this simple circuit. You have a voltage source, and the voltage source is connected across a resistance R and a current i flows through it. So, this is a resistive load. Now, for a sinusoidal voltage waveshape V what is the current i waveshape under steady state conditions?

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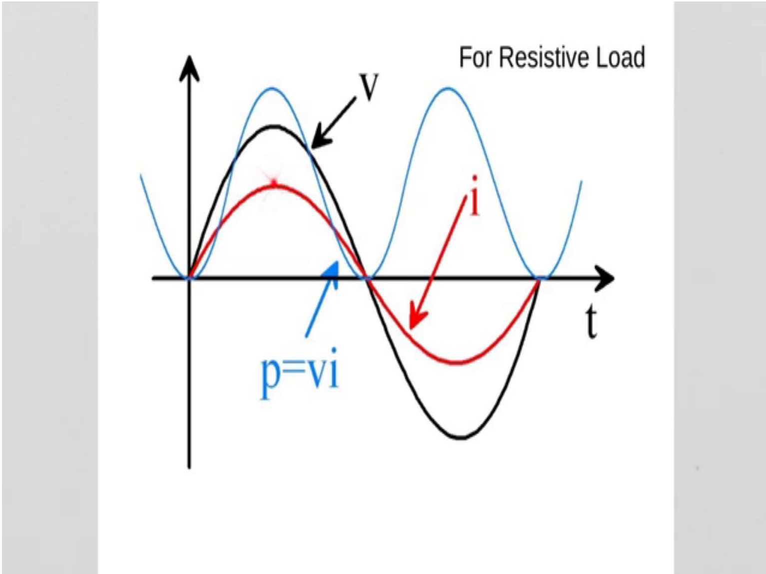

So, you see that the voltage waveshape is like this sinusoidal and importantly the current waveshape is in phase with the voltage waveshape as seen here.

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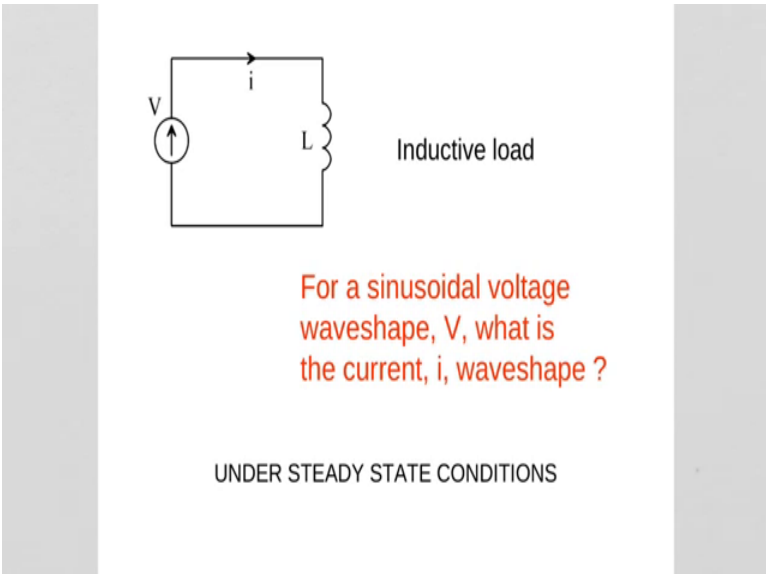

Now, consider a pure inductance connected across the same voltage source. Now, for this pure inductive load and also for a sinusoidal voltage waveshape V m sin omega t what is the current waveshape extracted under steady state conditions.

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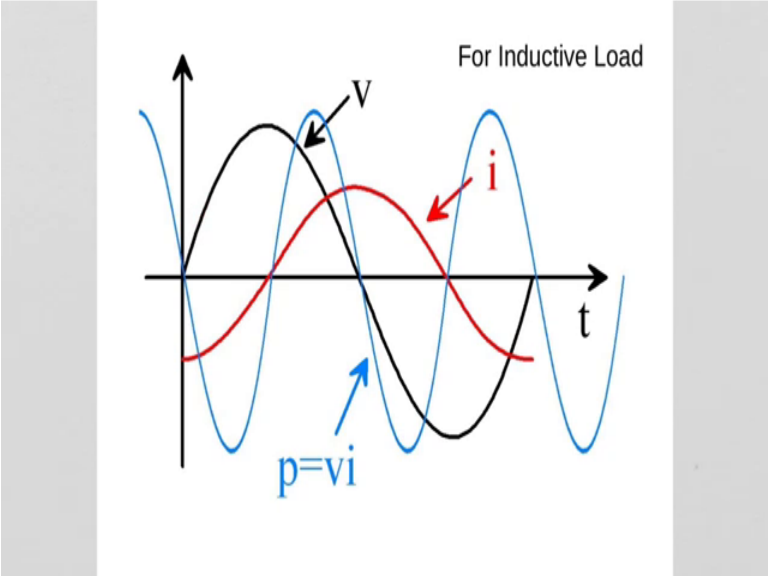

So, you will see that the current i in this case is delayed by pi by 2 or 90 degrees with respect to the voltage waveshape.

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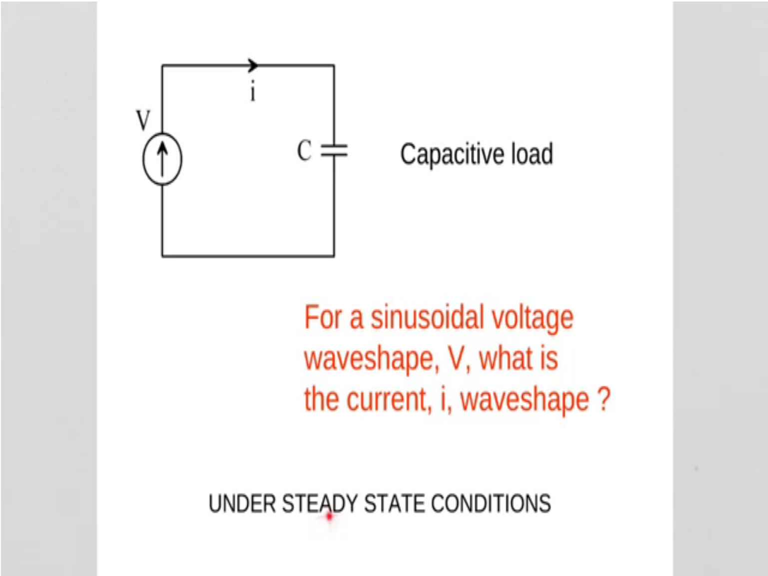

Likewise, if you consider a pure capacitive load connected across a sinusoidal voltage wave shape and then for a sinusoidal voltage waveshape V m sin omega t what is the current that you will expect under steady state conditions?

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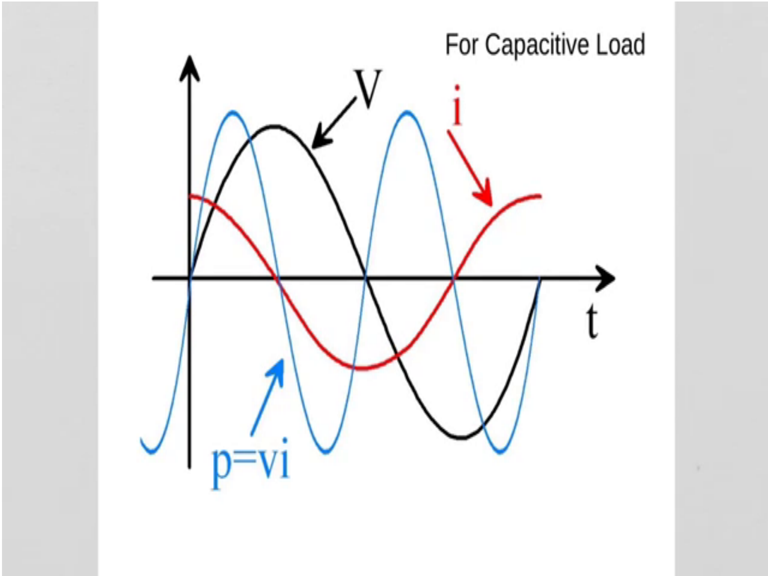

Here in this case you will see that the current is leading the voltage waveshape as against inductive load where the current was lagging by 90 degrees. So, the current here is leading by 90 degrees.

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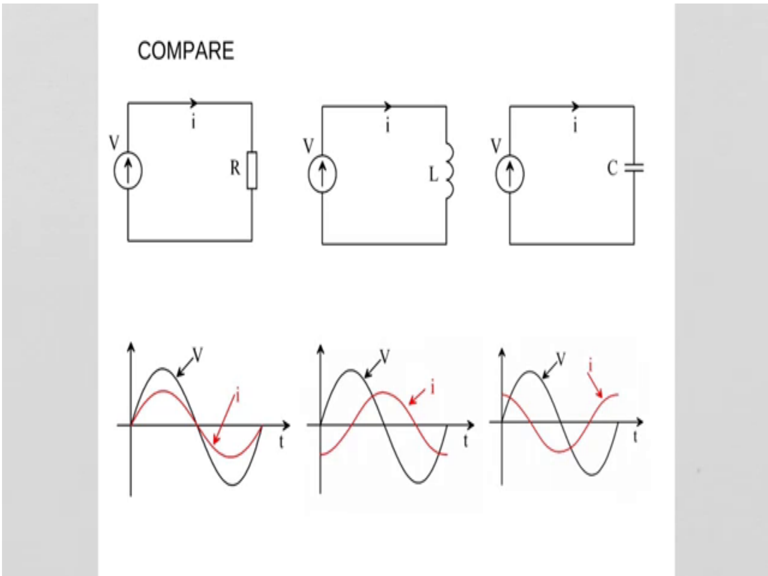

Putting them all together comparatively you will expect visually on the oscilloscope for a resistive load V and i like this for a resistive load, V and i like this for an inductive load, and this is for a capacitive load.

Now, take the case of the resistive load waveshape. You have voltage and current in this fashion. Now, let us say you would like to plot the instantaneous power. So, when you plot the instantaneous power which is instantaneous value of V into instantaneous value of i, instantaneous value of V into instantaneous value of i, instantaneous value of V into instantaneous value of i, at same time locations you will get this power curve as shown here.

Observe that at this point here power is 0 instantaneous value of power is 0 because V 0 i 0, and here too power is 0 because V 0 i 0 and at around this region power peaks because its V m and i m both are at max value. And observe that the power curve is having double the frequency of the voltage or current frequency. And another thing is that the power curve is having an average value is shifted up. So, if you now, only consider as this power curve and remove all the other waveforms.

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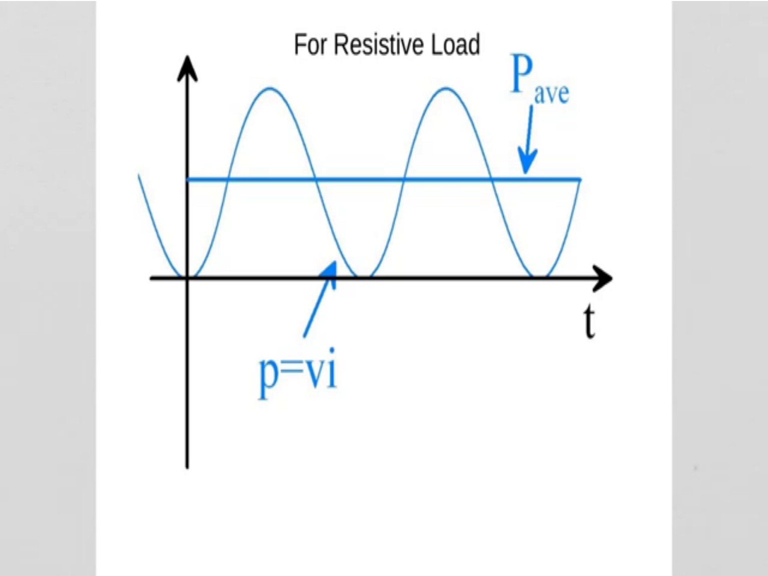

You will see it something like this, this is the power curve and there is an average value P average. So, this is a visualization that you should expect for any resistive load where in the source is a sinusoidal source.

For an inductive load where the waveshapes are like this, voltage waveshape, and current waveshape, multiply instantaneous values of the current and instantaneous value of the voltage at the same time points you will get the instantaneous power curve like this, w waveform. Observe that this is having a 0 average, if you remove out the voltage and the current waveshapes you will get only the power waveshape for the inductive load which is like this, the average value is 0 whereas, the instantaneous value is double the sin frequency as the fundamental.

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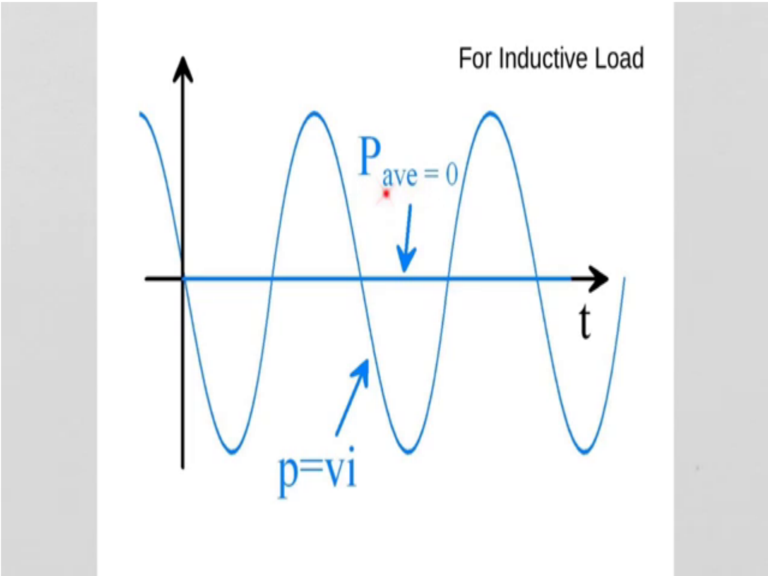

In a similar manner if you look at the capacitive load reaction wavesha[pe]- waveforms voltage a leading current waveform like this. If you multiply the instantaneous values of the current and the voltages you will get the power curve in this fashion. This is the p is equal vi instantaneous power curve. Here again if you remove the voltage and the current waveforms becomes clear that the average power is 0.

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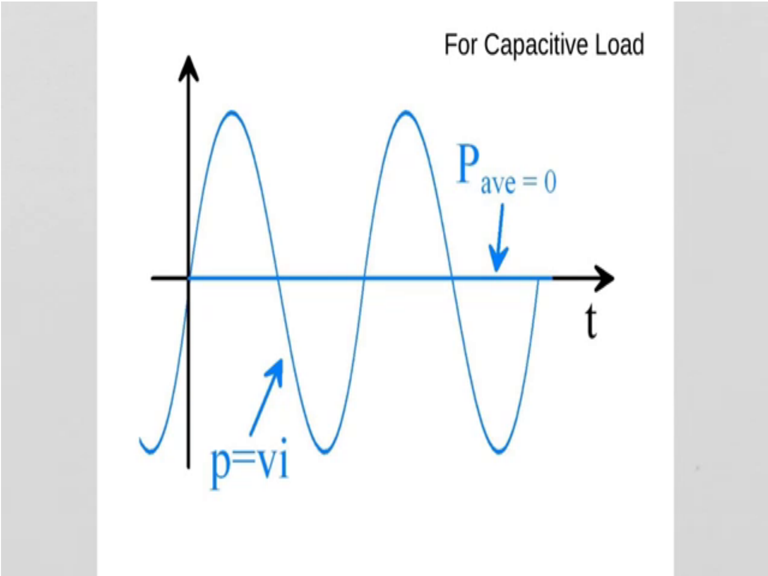

Comparing all the three cases, you should visualize that on an any oscillogram for a few resistive load this will be your power curve and the average power.

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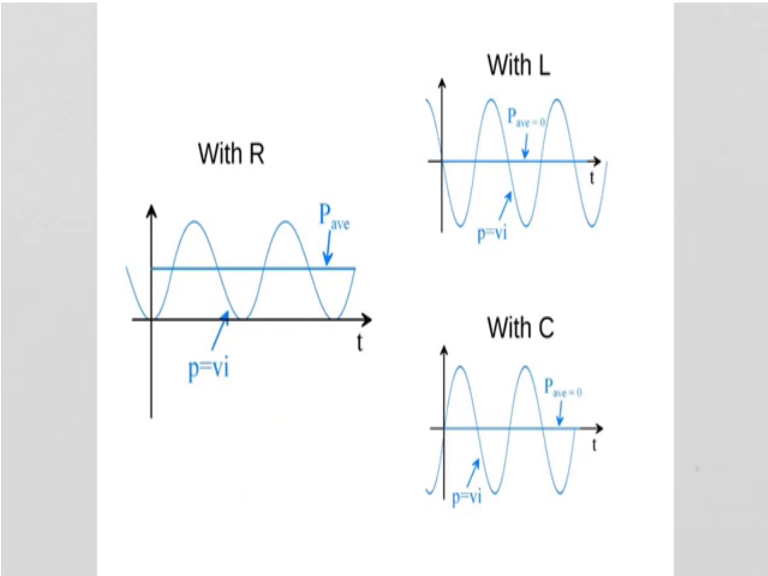

This would be the power curve for an inductive averrage power is equal to 0, average power is equal to 0 for the capacitive pure capacitive load also.

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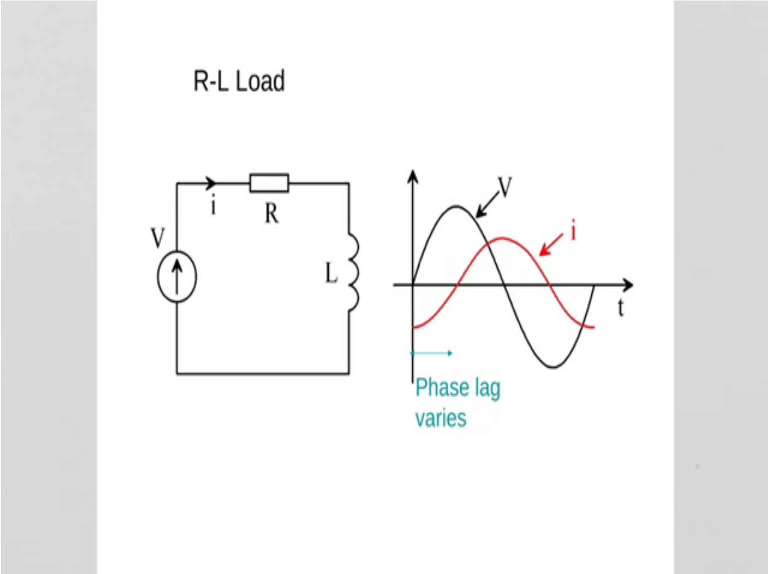

Now, consider the same voltage source V m sin omega t applied across R and L, hybrid impedance consisting of resistance and inductance. Now, the voltage waveshape is shown like this. The current waveshape can vary with different lags. It can be 0 when it is purely resistive and as the value of resistance keeps decreasing and inductance increases you will see the phase shift starts moving like as towards when purely inductive.

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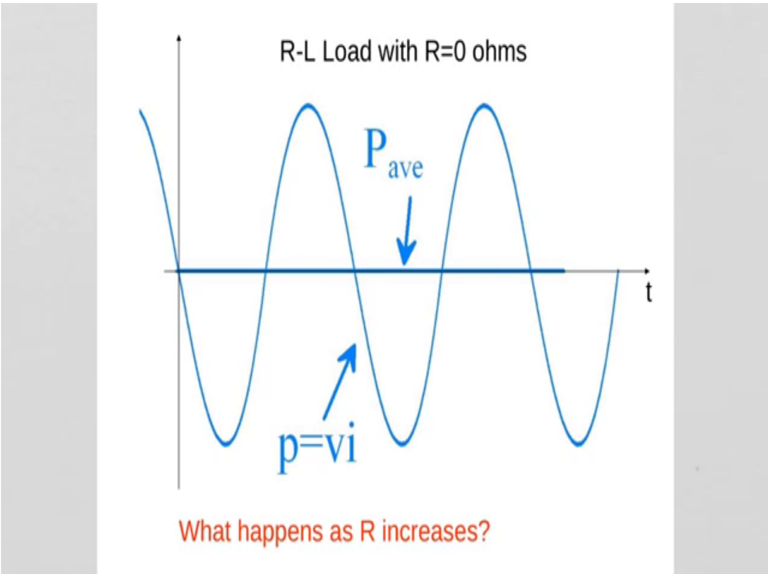

So, if you look at the power curve for the case when R is equal to 0 ohms it will look like an inductive visualization, average power is 0 and this is the instantaneous power curve. Now, keep increasing the value of R then it becomes an R L load.

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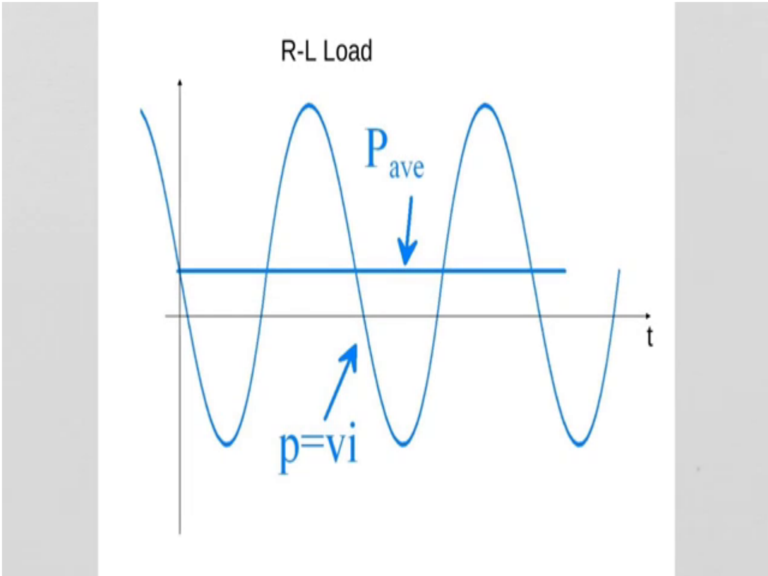

So, as you start increasing the value of R you will see that the entire power waveshape shifts up and there is an average power available and that is active power or the real power that gets dissipated because of the resistor R.

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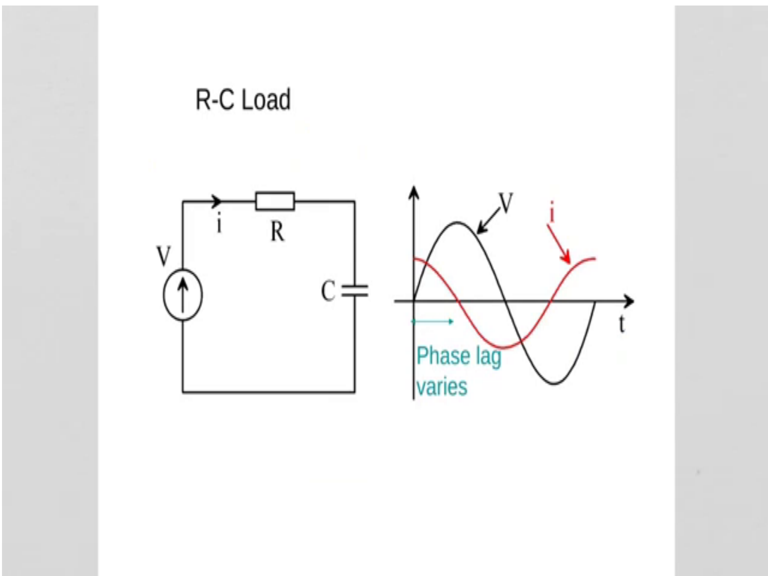

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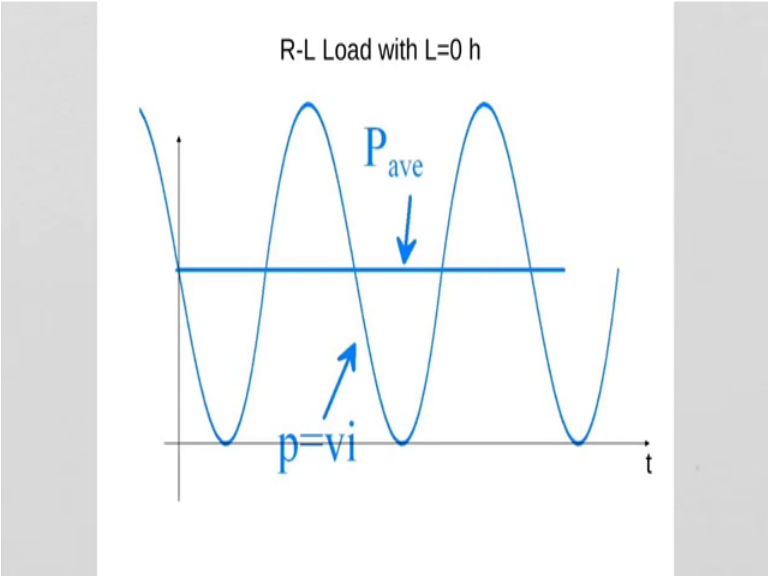

So, as it starts moving up at a point you will see that as their value of inductance becomes 0 the R L load tend towards the resistive load and you will see a waveshape like this, where the average is given by V m i m by 2.

Likewise, for the R C load also where you are having R and C connected except for the phase shift which changes from lag to lead.

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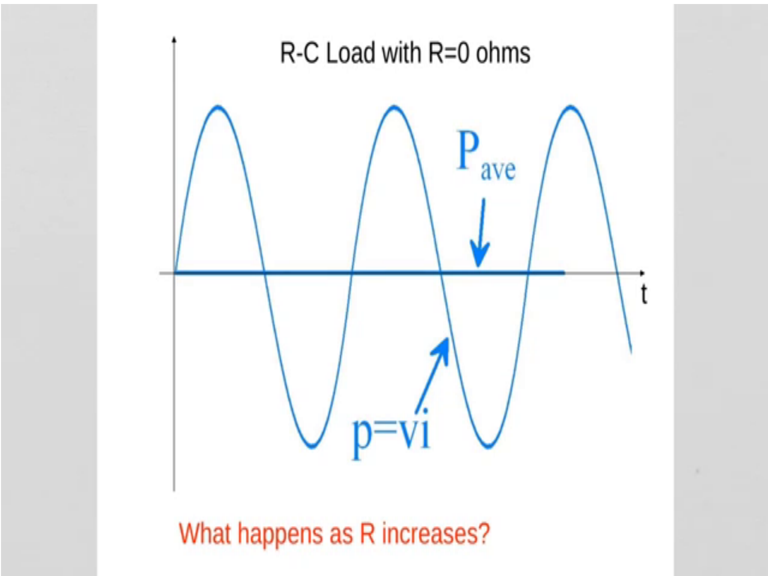

You will see that the as the value of R increases the value of C decreases, you will see that it starts moving in this fashion going more towards the pure resistive type of load.

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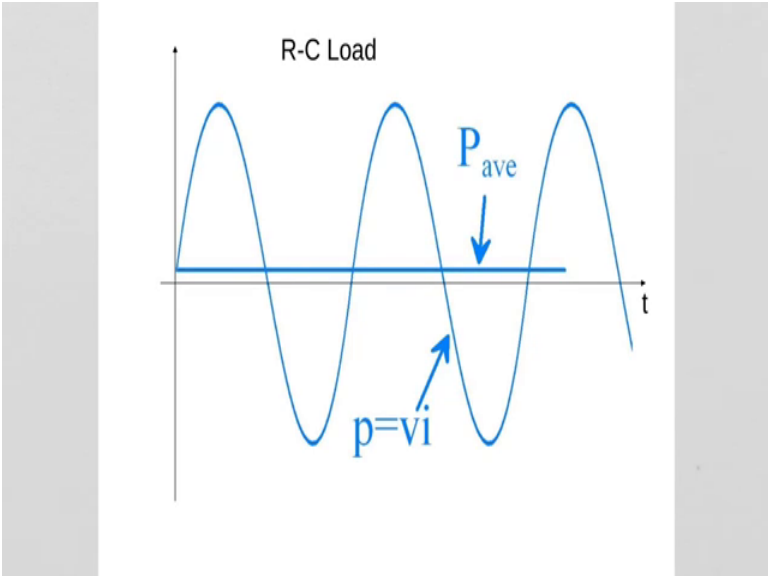

Some remarks that we can make at this point in our discussion, is that the average power is maximum only for pure resistive load. For any other type of load any other combination of the loads the maximum power is less than V m i m by 2.

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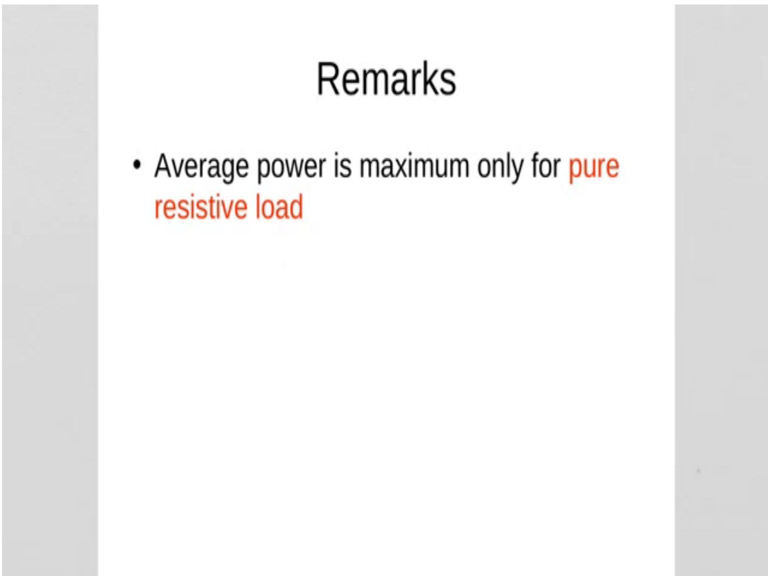

Let us now discuss how to measure power factor. We would like to measure power factor only using the waveshapes as seen on the oscilloscope, the voltage and current waveshapes.

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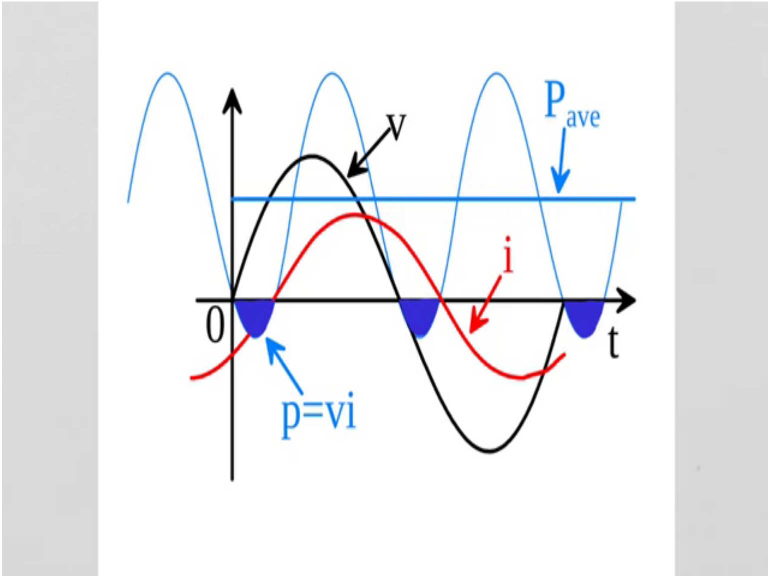

Let us begin with sinusoidal waveshapes, sinusoidal voltage and current and then move on to the non-linear waveshapes of rectifier capacitor filter circuit. Now, on this graph let us put in the voltage sinusoidal voltage waveshape and let us take an arbitrary delayed current waveshape. So, there is an arbitrary phase delay of phi which means it is an R L load

Now, this when you multiply the instantaneous values of the voltages and the currents you would get the instantaneous power curve and this would look like this. Observe that the power goes negative here. This is because the voltage is positive in this region current is negative in this region the power is v into i and therefore, it has to go a negative. At this point voltage is 0 current is negative at this point current is 0 voltage is positive. So, therefore, the power crosses the 0 point at this point.

Likewise, here also voltage is 0 at this point power is 0 then voltage goes negative here, current is positive and therefore, the power negative in this region till this point when both current and voltage goes negative and from here onwards power becomes positive. So, this is the power curve having double the frequency the voltage or the current. So, this power curve will have an average value like this as shown. Now, this negative part which I have showing shaded here this is the negative power which means that it is put back into the source. It is taken from the source and then put back into the source and the positive part is pushed into the output. So, the positive parts of this would be the active power pushed into the output and this negative part is the part the reactive part which is put back.

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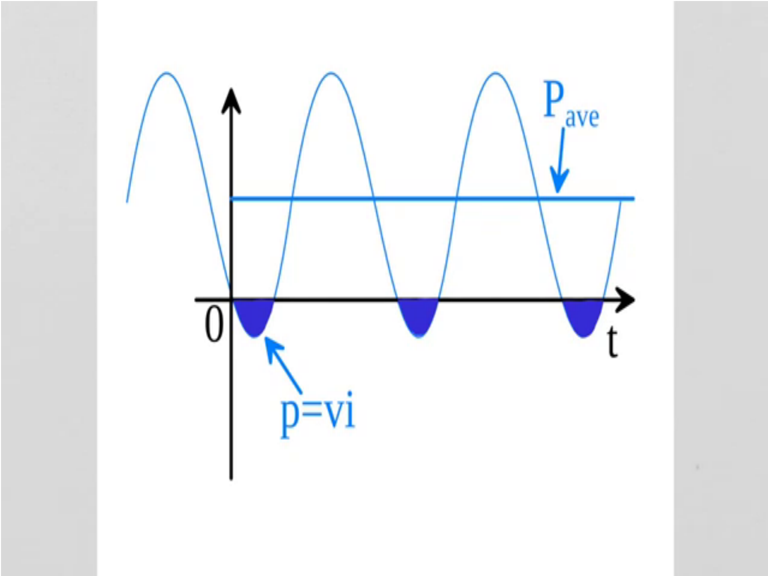

So, this is the power curve showing the positive and negative aspects, the active and the reactive part.

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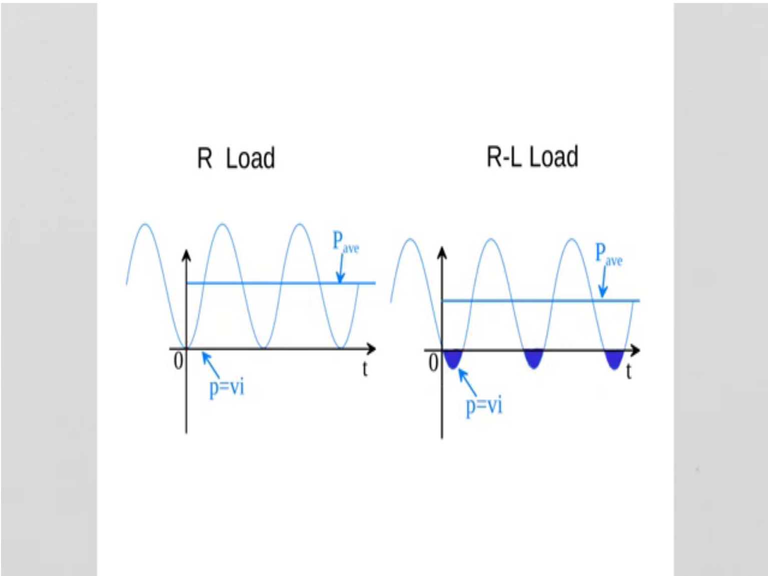

Now, if you compare with an R-L load, R and an R-L load you will see that the current waveform here is in phase and that is having a phase shift of phi, and the power instantaneous power curve here and the instantaneous power curve for the R-L load is like this.

Now, the averages. Look at the average the average for the R load is much higher than the average for the R-L load because of this negative portion which get subtracted from the area when you are integrating.

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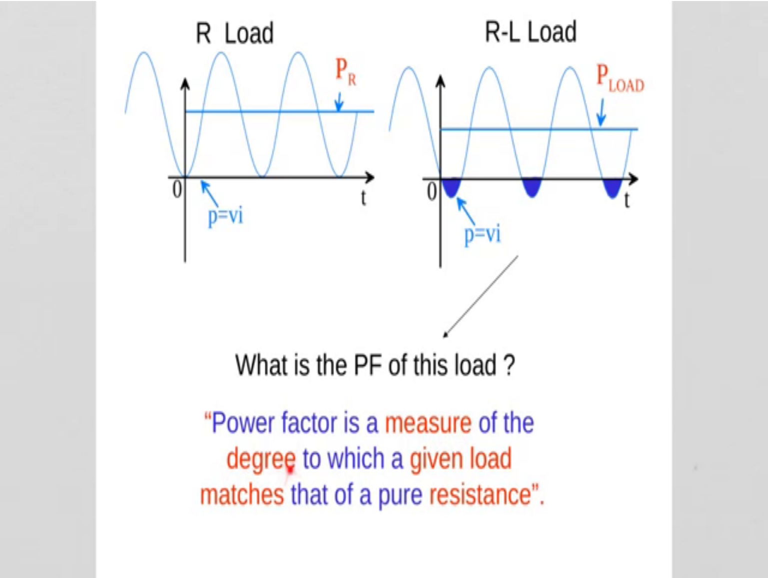

Let us remove the voltage and current waveforms (Refer Time: 12:33) becomes clear. Let us move this waveform arc. I am going to compare this R-L load with respect to a pure resistor which implies that by comparison I am going to get the power factor which is basically telling which is giving me a measure of this R-L load how close it is to a pure resistance

So, let me call this as P R the average of a resistive load pure resistive load and this we can call it as P load this is the R-L load. So, now, what is power factor for this load? We define that power factor is a measure of the degree to which this R-L load matches to that of the pure resistance.

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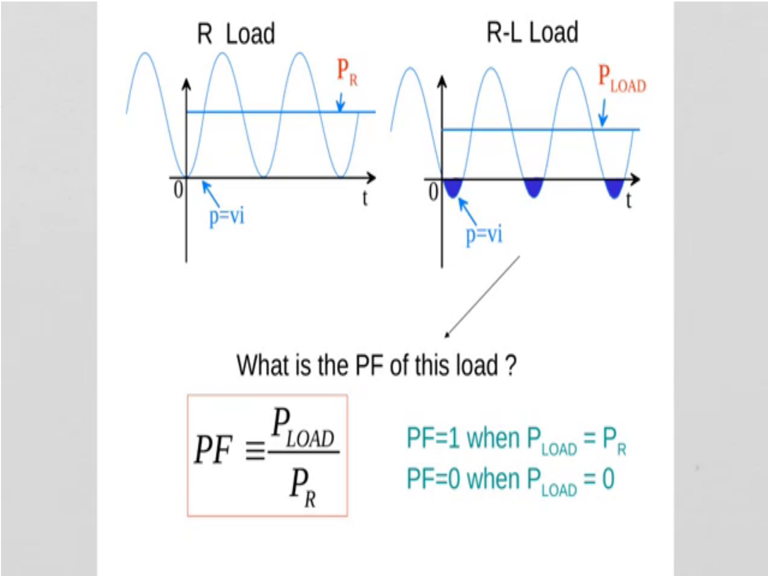

Power factor let us say we define it as P load divided by the reference pure resistive load power which is P R, all else being same the amplitude of the current and amplitude of the voltage.

So, this is the definition that we will be using and which will give you the measure of the closeness of any given load to that of a pure resistance. When PF is 1 that is P load and P R are same, means these two values are same. Then we say, it is a resistive load or the the load is equivalently same as that of the resistive load when PF is 0 that is when P load is 0 then the load is farthest away from being a resistor it is a reactive load.

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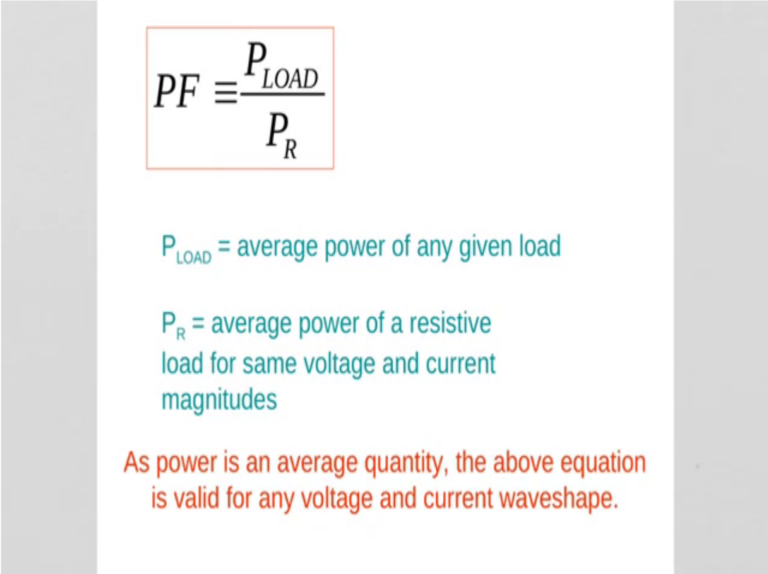

So, now this definition PF which is P load by P R. P load is the average power any given load and this can be measured from the voltage and current waveforms of the oscilloscopic cell. P R is the average power of a resistive load for the same voltage and current magnitudes this is the important clause there. So, as power is an average quantity, so this measure definition should be valid for any voltage and current wave shape.