Design of Power Electronics Converters
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Lecture 60
EMI Filters - II

Welcome to the course on design of power electronic converters. So, we were discussing electromagnetic interference and we had started discussing EMI filters. So, now, let us go further on that discussion.

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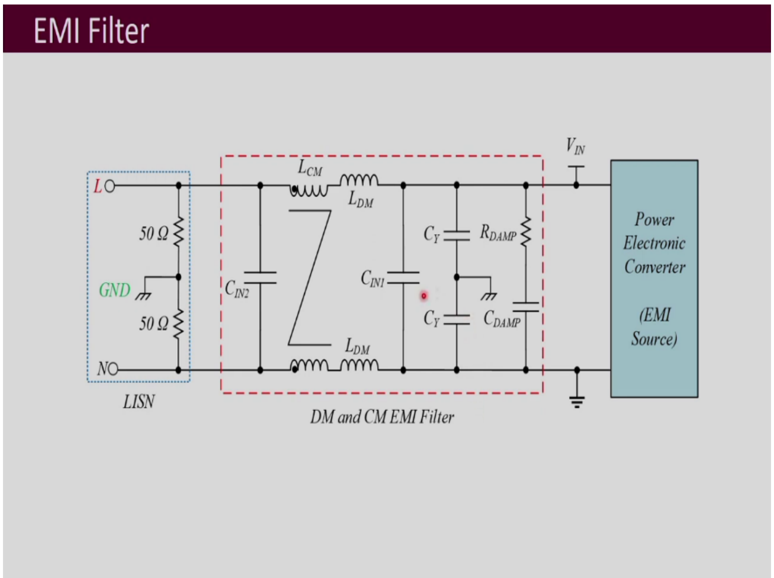

So, this is the example of EMI filter that I had shown you and I also showed you that this is meant to filter out both your differential mode and common mode noise and this is using our Pi structure of EMI filter that means, you have got C L and C. So, now, let us see if we have to understand the different terms of choosing an EMI filter, how do we look into it?

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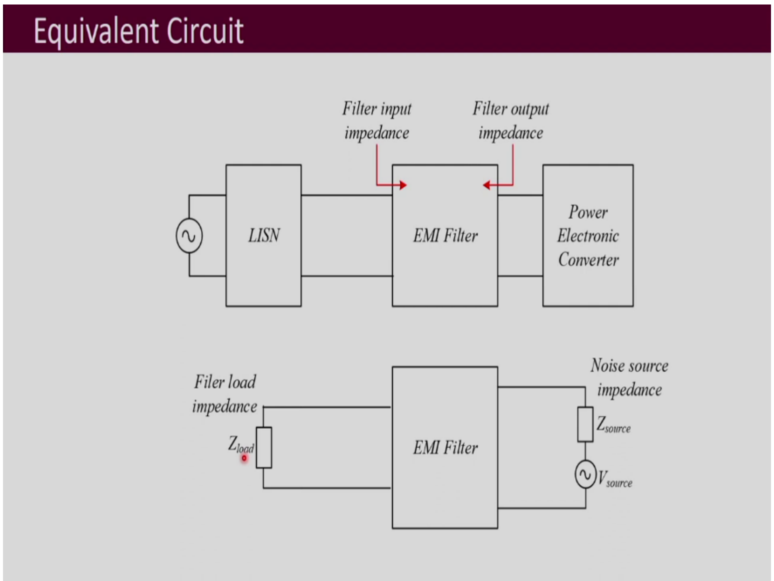

So, if we draw this block diagram where you have this EMI filter here in between and then on one side is the LISN which is your line impedance stabilization network used to measure your common mode emissions and on the other side we have the power electronic converter and on this side is the supply. The job of the LISN will be that it does not let any noise from the supply enter over here and also any noise from this side to go to the supply side and so, in between the measurement of the conducted emissions can be done.

So, now, if you see this filter, when you look at it as a two-port network, it will have an output impedance and an input impedance. The input and output impedances are marked on the block diagram of the EMI filter. Now, this converter is the source of the interference. Now, so, we can model this from the perspective of your source of EMI and analysis of EMI.

So, the power electronic converter can be replaced with a voltage source the impedance that the noise observes is your Z_{source}. So, now do not confuse it with your normal voltage supply that is placed here, we want to do the modelling or you can say that is we want to make an equivalence circuit where we want to analyze the filter, how effective it is going to be for the common mode and differential mode noise.

So, for that, we are modelling here this converter as a source of that common mode and differential mode noise. So, this V source is your common-mode voltage and differential-mode voltage, the noise voltages, and the impedance that they observe because of the converter is Z_{source}.

So, it is a noise source impedance and then in between, we have the filter which is supposed to attenuate this noise and then further on this side, this LISN can be looked upon like a load. So, it is like the filter load impedance Z_{load} and known because we know that these are terminated for 50 Ohm resistances.

So, based on it, if you want to choose the filter topology, in the last lecture I had shown you different types of filter topologies that can be used like a C, an L or a T network, Pi network or a Gamma network. Which is the filter network you should be choosing? So, based on this diagram, you can understand that.

So, what you can see from the block diagram is that there is a filter and we do not want the noise to travel from the source side to the load side. So, that means we want mismatching of the impedances between the source impedance, the filter impedance and the load impedance.

Now, when a LISN is used, the load impedance is 50 ohms but practically instead of LISN, the impedance of the connected source would be considered as the load impedance for our analysis. So, then again we want a mismatch between this load impedance and the EMI filters impedance. So, there is a mismatch that means, the noise will not be able to propagate from the converter to the supply side.

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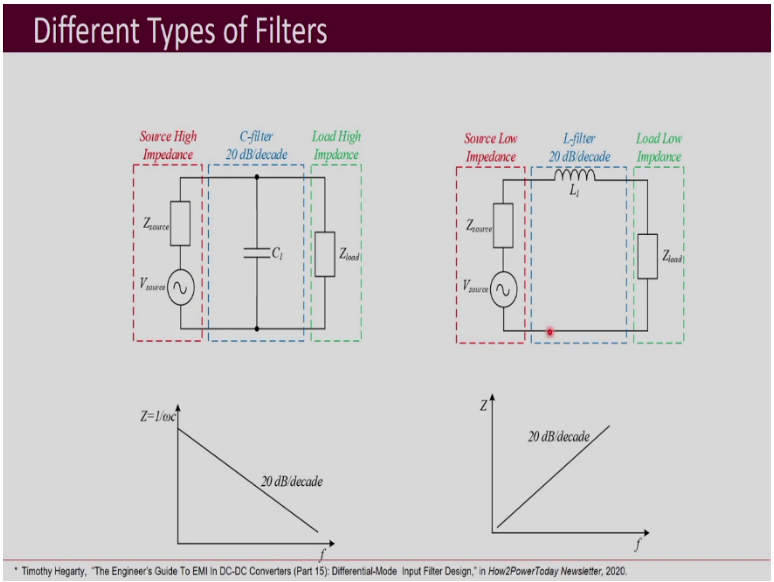

So, accordingly from that perspective, if we again look into the different types of filters, then what we see is that, let us say your converter which is the source of the noise presents itself as a high impedance source. Also, let's assume the Impedance of the load to the EMI filter is also high. So, then in between, we want something which at high frequencies provides low impedances.

And so, then we know that the capacitor can do that. Now if we have the reverse scenario, meaning the source side is low impedance and your load side is also low impedance, then we want something in between which gives high impedance for high frequencies and that will be an inductor. So, now just L and C cannot do efficient filtering of your common mode and differential mode noise, most of the time you will using a Pi Network or T network for your filter.

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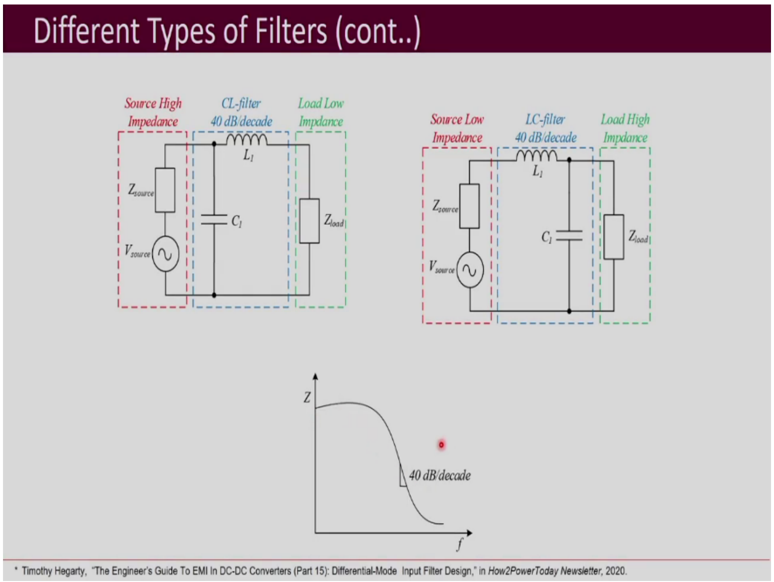

So, then here what we observe is that if we want to use the other ones like gamma type of filters in a case where we have high impedance on the source side and a low impedance on the load side. So, towards the load side, you can put the L inductor and towards the source side you can put the C, because C will provide the low impedance at high frequencies and L will provide high impedance at high frequencies.

So, then you will have the mismatch. And for the opposite case when you have low impedance on the source, so, you put a L towards the source and you have a high impedance in the load, so, put a C towards the load.

And you know that if you just have two elements L and C the impedance will decrease by 40 dB per decade and for just either L or C it will be your rising or falling by 20 db per decade. But for LC type, you will have 40 db per decade as this is the change in the impedance with respect to frequency.

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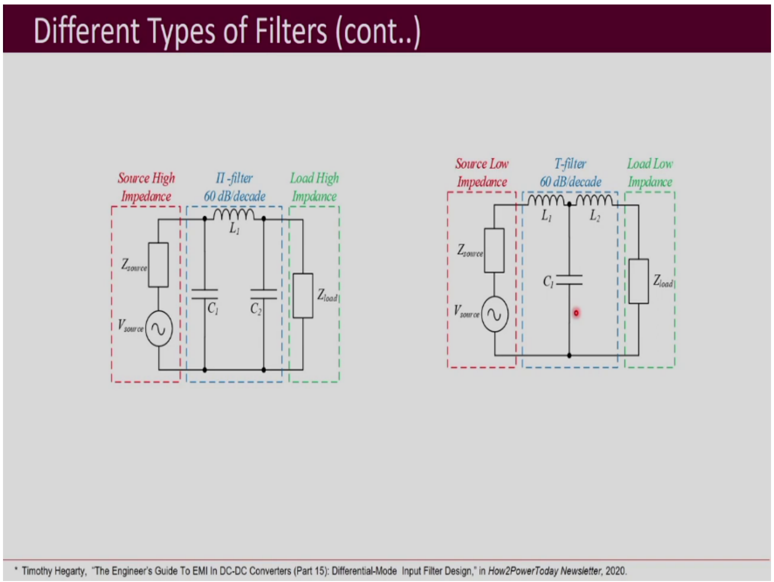

A pi filter can be used when we have high source and load impedance. As both the source and load have high impedance put C on both the source and the load side with an L in between. Here the impedance will be changing by 60 db per decade with respect to frequency.

A T filter can be used when both the source and the load present low impedances to the noise. The configuration would have inductors on the source and the load side with a capacitor in between as shown in the diagram. So, this gives you an idea on how you can choose the filter type: LC or a CL or a Pi or a T for your converter.

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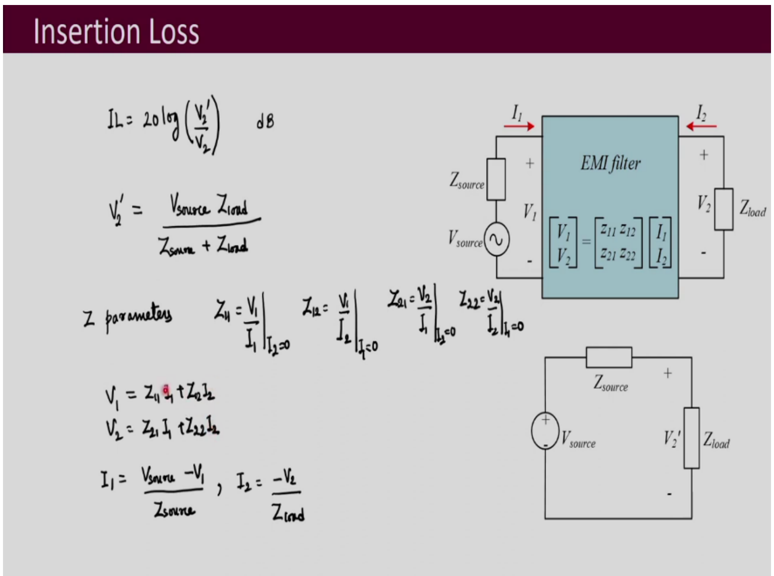

Now, there is another term which is very important with respect to EMI filters and that is insertion loss. So, here this EMI filter is going to be analyzed as a two-port network using the Z impedance. So, you have this V_1, V_2, which are your input voltage and output voltage and I_1 and I_2 are the input and output currents. So, the impedances will be Z_{11}, Z_{12}, Z_{21} and Z_{22}.

And in the second figure, the same thing is drawn without the EMI filter. Here, you have V_{source} and Z_{source} and the Z_{load}. The insertion loss is defined as:

Aswe see V_2' is the voltage across the load when there was no filter and V_2 is the voltage across the load when the filter is present.

So, now, let us try to find out this insertion loss in terms of impedances. V_2' can be written

as:

If we look into the two port network and since we're using Z parameter

So, therefore, we can write:

Now, let us substitute these two in this equation these two equations for I_1 and I_2.

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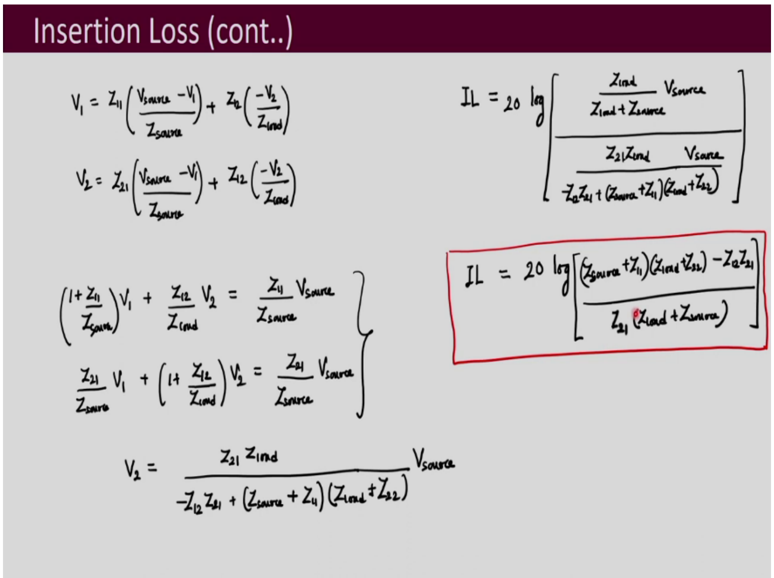

So, what you will be getting is :

These are the two equations that we will be obtaining if we rearrange it further. From here if you solve for V_2 what you will be getting is

So, therefore, from this the insertion loss terms of the impedances is obtained as:

So, now, what you see is that you should have an idea of the Z source and Z load when usually these keep on changing in power electronic converter it is not fixed and so, that is where the challenge comes up in the order of choosing EMI filters for power electronic converters. But this insertion loss is the term which is used for finding out whether a particular filter is going to be suitable for the converter that you are designing.

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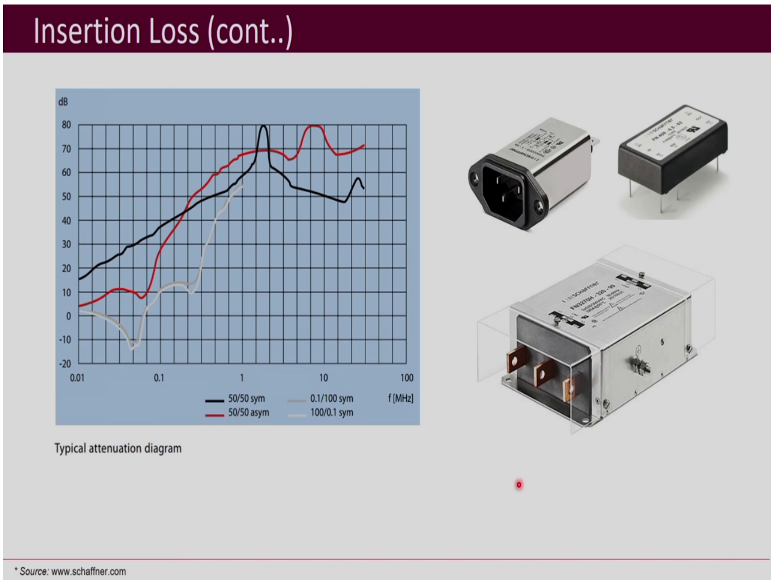

Now, there are different manufacturers of EMI filters. One is of course you can design it on your own, you can buy common mode chokes X and Y capacitors, you can decide their values and then you can put it on the board on the power electronic converter board that you are designing yourself. So, that is one way that also is done by many designers of power electronics converters and at the same time there are manufacturers of EMI filters also.

So, these types of off the shelf EMI filters that you can buy from the manufacturers and they make some standard values, I mean they design values which can be suited for many applications for or rather for a range of applications. On the slides are some examples of EMI filters.

So, these have all these LC common mode chokes and where your damping resistors, damping capacitors all that will be inside them you just have to get it and insert it with your converter to meet the EMC standards and then you can decide that if the particular EMI filter is not working for you, you can buy another one and you can check with that if that one works for your particular converter.

And those manufacturers also provide these kinds of graphs. So, these are attenuation diagrams of what you can call the insertion loss diagram. So, you can see that the decibels of the insertion loss of the attenuation are provided and the frequency is also provided. So, using it you can see what is the attenuation that will be provided. Attenuation and insertion loss are the main terms used interchangeably.

Insertion loss also means is that basically how much is the loss that is happening for that frequency? And the greater it is happening, so, that means the better way it will be filtering out those particular frequency components. So, an attenuation is also the same thing means how much you are attenuating a particular signal, so, the more the attenuation of a particular frequency means, the better the filtering for that frequency.

And so, these insertion loss graphs can be used and you can also the equations previously described to do some calculations and check which type of EMI filter is going to best suit your purpose.

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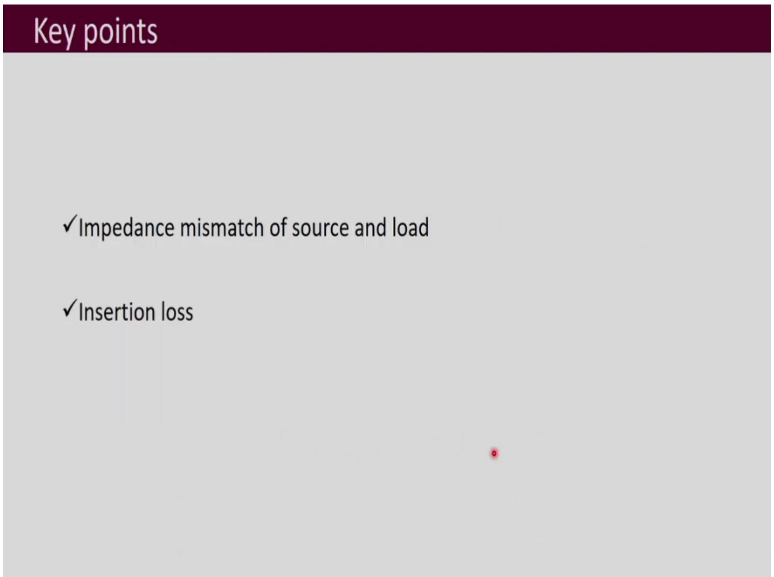

So, the key points of this lecture are that for filtering we have to do impedance mismatch between source and load there are various different types of filter topologies that are there and you can choose the one which is going to suit for you. And for filters there is a very important term which is your insertion loss we have to look into the insertion loss for choosing your filter. Thank you.