Design of Power Electronic Converters

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Module: Analysis of Power Electronic Converters

Lecture 8

Bipolar vs Unipolar PWM

Welcome to the course in Design of Power Electronic Converters. So, prior to this lecture, we had discussed H bridge converter and then we saw two different modulation strategies your bipolar PWM and Unipolar PWM. Now, when you design a converter, then you have to choose the modulation strategy which suits your application and there may be many modulation strategies which may be available for that converter. So, you need to compare them to choose the right one. Now, here we are going to compare bipolar PWM and Unipolar PWM as we have discussed only these two in the course.

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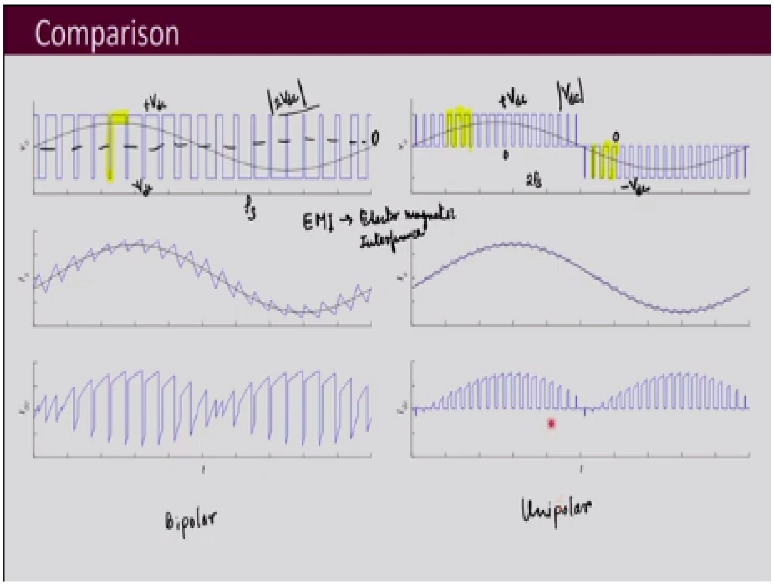

So, these two waveforms we have already seen. So, this is your output voltage waveform for bipolar PWM and this is for these are all the waveforms that we had obtained for Unipolar PWM. So, this is for your bipolar PWM and this is for your Unipolar PWM waveforms. Now, here what you see is that this output voltage over here is varying between minus V dc to plus V dc. So, this was your 0 and it varies from minus V dc to plus V dc.

And whenever you switch it in every switching this is happening it goes from plus V dc to minus V dc directly it is not hitting 0 anywhere, but if you see Unipolar PWM waveforms, you see that it goes from 0 to V dc and it keeps on following that for some time for half the cycle of the reference waveform and then for other half cycle it goes from 0 to minus V dc.

So, what we get from it here it switches from 0 to plus V dc for some time and here it switches from 0 to minus V dc. So, then the transition that is taking place in case of bipolar PWM is 2 V dc every time whereas, in case of Unipolar PWM the transition that is taking place every time that is equal to your mod of V dc.

So, with that what you see is that, when you have a converter, your output is going to be connected to an inductive load. So, it may be let us say a motor also or some other kind of inductive load may be there. So, then the insulation has to withstand these 2 V dc in case of bipolar PWM and for Unipolar PWM it has to withstand V dc.

So, we say that Unipolar PWM is advantages in terms of the insulation requirement of your whatever output to which we are connecting. And also later on in the course, we will discuss it there is a term which is called as electromagnetic interference you might have heard it before.

So, that is basically it interferes with your other surrounding electronic devices your power electronic converter may interfere with that and is dependent on the switchings that are happening and the greater the voltage switchings are, the more interference is likely to be. So, here in this case what we see is that since this switches by your 2 V dc, it is likely to have higher EMI electromagnetic interference as compared to Unipolar PWM where it may have lower EMI.

Now, EMI depends on many others things, so, do not make it a general statement that this is bound to be having less than EMI than this one, but looking at the amount of voltage transition, it is likely. Then, what another thing that we can observe if we compare these two waveforms, what we can see here is that, that this seems to be switching at a frequency of your what is the career frequency the output voltage waveforms frequency that we obtain.

But here although this waveforms were obtained by using the same carrier, the output voltage waveform, the number of switchings that are taking place are much more, it is double than what it is here. So, what we see is that for the same career frequency, the effective switching frequency that you get in the output is doubled in Unipolar PWM.

So, although you are not switching the devices at twice the switching frequency, you are still switching at Fs the switching frequency, but the output voltage has double of it in the waveform. So, here you get the effect of switching frequency 2 Fs but here it is Fs, although the number of switchings in the devices are still corresponding to Fs as switching frequency. So, that is also one advantage you can say off Unipolar PWM.

Now, if we compare this load current waveforms, what we can see here is that the amount of ripple that you observe in bipolar PWM is greater than the amount of switching frequency ripple that you observe in Unipolar PWM. So, that means, the amount of filtering that will be required for bipolar PWM current will be higher than that for Unipolar PWM. So, that is another advantage if the designer chooses Unipolar PWM for the converter because then the filter that you need are lesser and so, correspondingly your filter design is going to also change.

So, that is what you have to observe the waveforms depending on your choice of your modulation method that is going to change the design. For different modulation strategies, the design of the converter is going to be different. Then if we see your IDC waveform, so, this is your you can see here the switching frequency component that is present in case of bipolar PWM is greater than that in case of Unipolar PWM.

Here you get the switching frequency component corresponding to Fs whereas, here the switching frequency component is going to be corresponding to 2 Fs. So, your capacitance that you may be needing may be slightly lesser in case of Unipolar PWM although in case of your H bridge converter when it is used as a single phase inverter, then it is the second harmonic component of the fundamental which is more, a factor in deciding the value of the capacitance rather than the switching frequency components. But still you can see here that these two current waveforms idc current waveforms are different for your bipolar PWM and Unipolar PWM.

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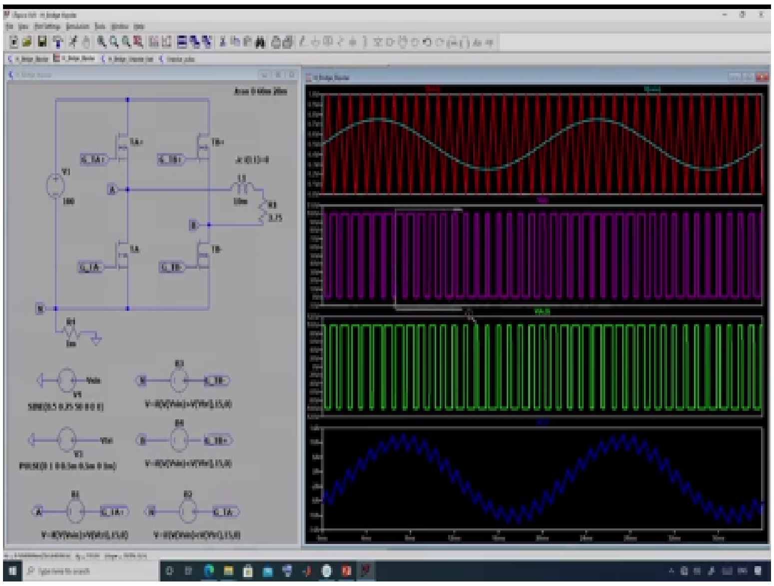

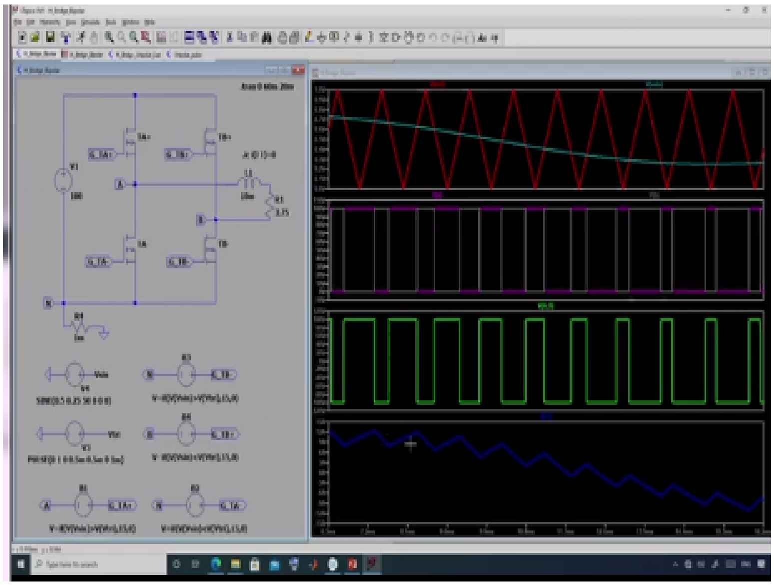

So, now, let us look into the simulation of these H bridge converter. I have simulated both the Unipolar PWM and bipolar PWM to show you whatever we have discussed till now in H bridge you can simulate it and you can see the waveforms and that will also help you in designing the converter.

So, this simulation is performed in LT spice, this is the H bridge converter with four MOSFETs they are being simulated and this is an inductive load of 10 Milli Henry and resistance 3.75 ohms which is used. Now, this is how your comparison is done this is the triangular carrier waveform. You can see here that this is 1 milli second that means it is 1 kilo hertz of switching frequency is used. And then this is that reference waveform that is obtained.

Now let us run the simulation, this is the carrier waveform, this carrier waveform that is shown here this red one we try and then this blue one is your modulating waveform or the reference waveform for the bipolar PWM. Then here this pink waveform that you see is the voltage over here Van so, that you can see that whenever this career is lesser than the reference waveform, then this leg voltage becomes equal to V dc.

You can zoom it and see it here that here whenever this reference is greater, then at that time it is the upper switch which is going to be on and so, the leg voltage will become equal to we V dc which is 100 volt here. Then, similarly, you can also observe this leg voltage b over here. So, if you want to see that you can see that it is just the complementary is what you observe here because that is how it is in your bipolar PWM, these two switches are turned on together and these two switches are turned on and off together.

And accordingly, this is your V AB voltage waveform that means your output voltage waveform between these two V AB is your this it goes from plus 100 to minus 100 all the time. And this is your this load current waveform I L L 1 and you see here that whenever your this voltage is positive the current is increasing and it is negative, then the current is decreasing.

So, we can see this whole waveform you can see that this is the current waveform which is following a sinusoid but it has got a switching frequency component in it. Now, you can change all these modulation your reference depending on how much is the output that you need, and you can also change the switching frequency and your load and the source voltage and you can play around with the simulations and you can observe different different things.

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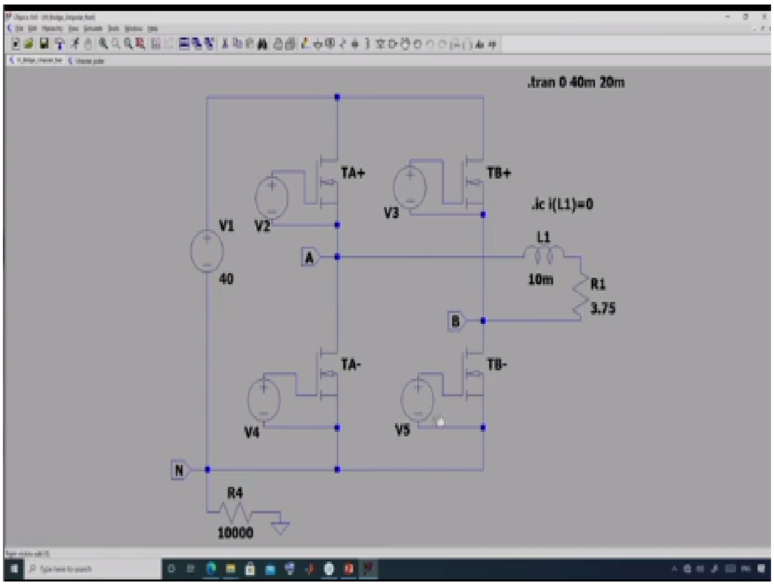

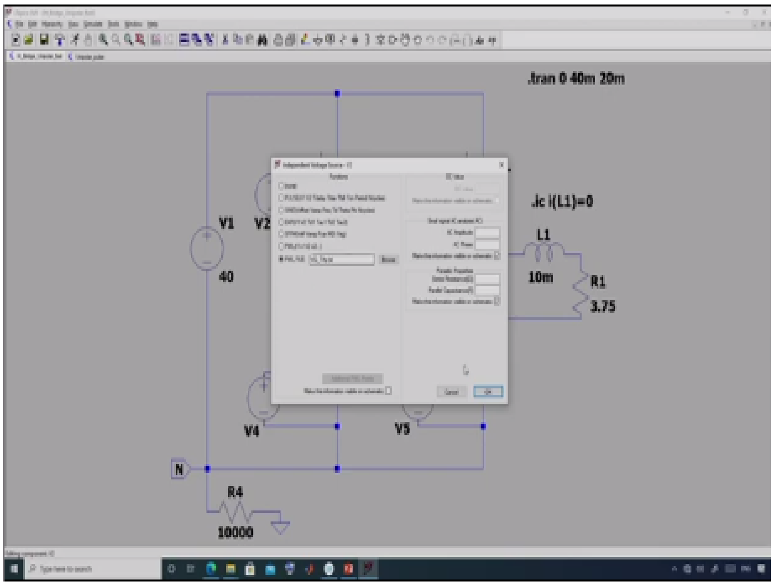

Then, next, let us look into your unipolar PWM. So, this is the simulation for unipolar PWM and here I have got these four switches again and the rest of it is actually this whole circuit is similar, but here this modulation waveforms, the comparisons are directly given using these four voltage sources. So, here if you will see that I have used this VPWL file where these pulses are directly given these pulses are recorded their values and then they are directly given using this file.

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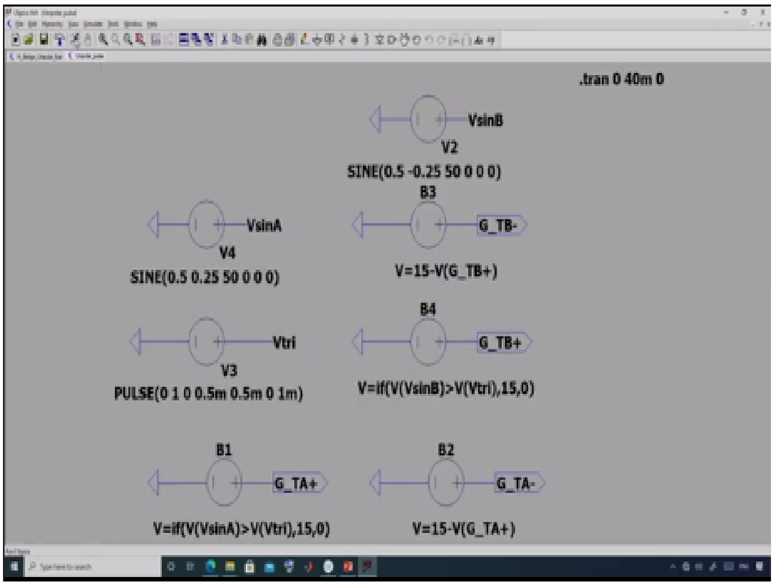

Now, how I have obtained this file that is using this simulation which generates the gate pulses. So, it has got these two references your V sin a for leg A and V sin B for leg B and this generates your triangular carrier and this is where the comparisons are taking place whether the reference is greater than the carrier or not and accordingly the pulses are generated.

Now, this is one very simple way of doing it. There are many other ways of doing it, I am just showing you a very very simple method for those who are just beginning with simulation. Now, why I have separated these two files I showed you the bipolar PWM simulation there it was not separated it was done all in the same simulation. Here also it is possible you can use all these in the same simulation of this edge bridge converter simulation.

But sometimes, if you separate out the two, they need help in speeding up the simulation it is basically saving time for the simulation otherwise, you can put these comparisons that I have done here and generated the file, those gate pulse files using this you can do directly over here as well then you do not have two different simulations.

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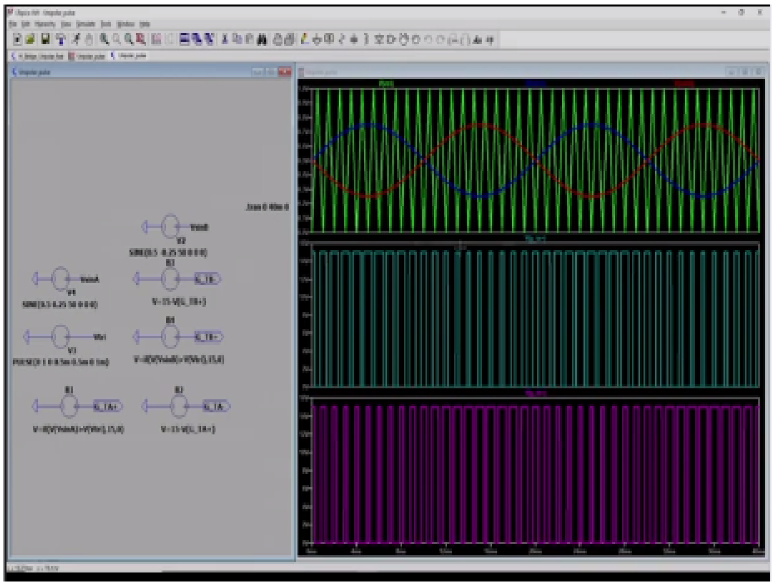

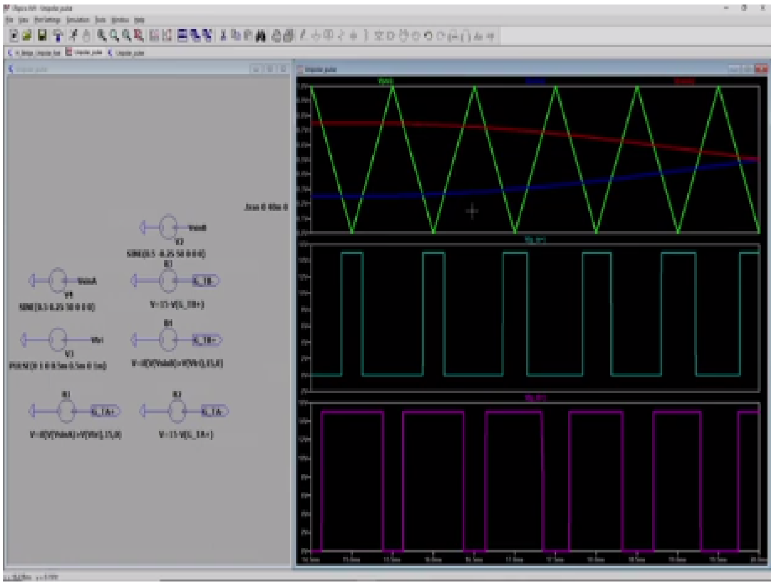

So, now, if I run this, I wanted to show you So, this is the simulation for generating the gate pulse and I have just run the simulation. So, this is your triangular career waveforms this is what is generated and then this is the reference for your leg A; the blue one and this red one is the difference for leg B. And then these two are the gate pulses which are generated for switch TA plus and for the switch TB plus.

Now, you can zoom it and you can see this comparison here. You can see over here that this one this over here this whenever the difference is greater, then your this switch is going to be turned on and so, to turn on the switch the voltage that is chosen is 15 volt and otherwise, it is off here and over here, this is where this is the red one.

And so, accordingly your this is for reference for leg B. So, for leg B you can see here that whenever this is greater, this gate pulse for TB plus is high just plus 15 volt and in this part it is equal to 0. So, over here you can change these frequency of your reference waveform you can also change the magnitude of it and the switching frequency of the carrier waveform also.

Now, let us look into the simulation for the Unipolar PWM using the gate pulses that we generated in the other simulation file. So, all of these if you will be seeing that it uses this PWM file, which contains the gate pulse which is generated using the other simulation.

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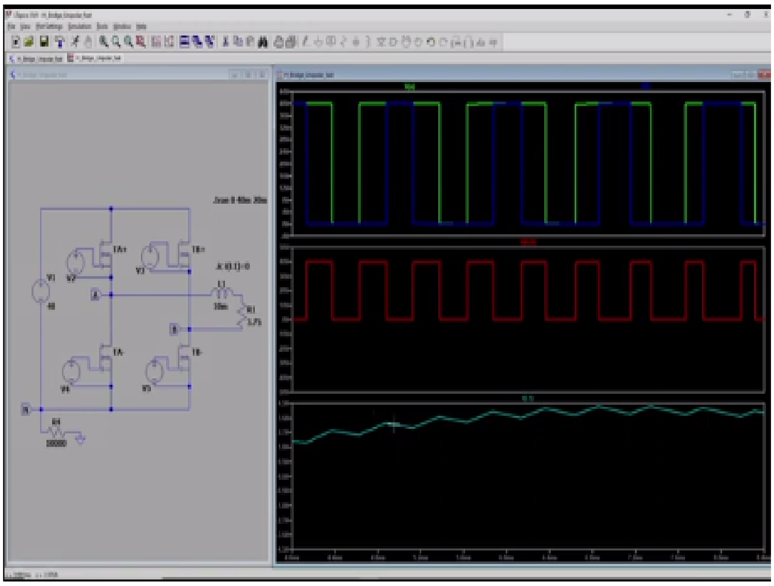

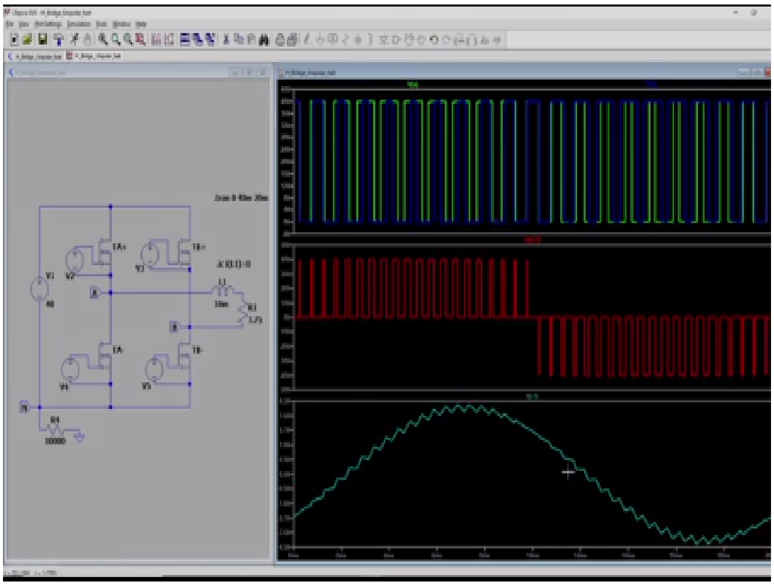

So, when we run this simulation, so, this is what you will obtain. So, what I have shown here is this leg voltage Va and then this leg voltage Vb. So, you can see here that whenever the voltage is positive means the reference voltage is positive your VA n pulse width of being positive is greater than that of VB n and so, your output voltage this red one is the output voltage it varies from 0 to V dc and here this V dc is taken as 40 volt. So, it goes from 0 to 40.

And whenever voltage is positive at that time here is this load current which is increasing and here it is becoming 0. So, the load current is decreasing at that time. And if we zoom this area where the voltage is reference voltage has become negative, you can see here the opposite has happened your VB n voltage its width is greater than VA n voltage and so, it varies from your 0 to minus Vdc it goes from 0 to minus 40.

And this is the current waveform you can see here again whenever it is negative the voltage then it is decreasing and whenever it actually becomes 0. So, with respect to it is becoming positive and so, the current is increasing. So, this is the load current waveform and what you see in this load current waveform.

So, what you see in this load current waveform is that it has got also a ripple and that ripple of course, we saw the bipolar PWM current waveform also the ripple is lesser than that. So, again with this simulation also you can play around and you can change different different values and see and rerun the simulation and see how the waveforms changes.

So, as I have told you before also simulation is one of the tools for power electronic engineer to design the converter before actually doing the hardware, beginning the hardware people like to simulate converters and observe different different waveforms.

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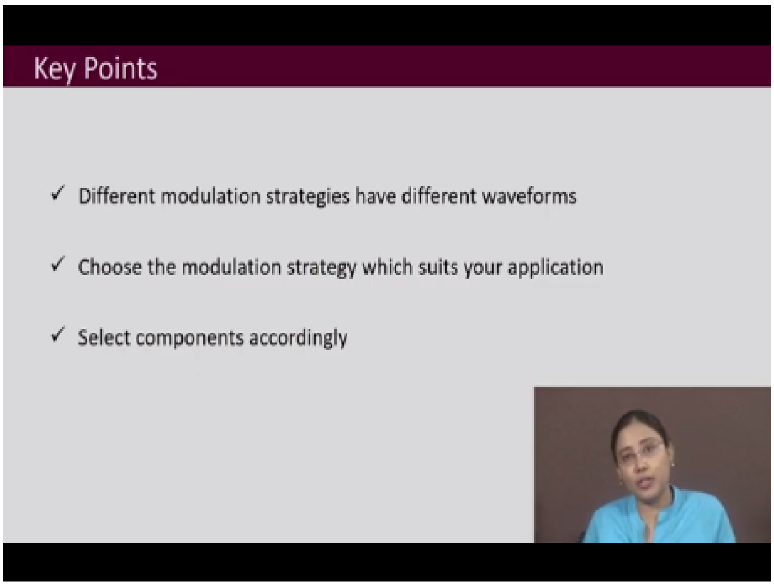

So, the key points of this lecture. A converter may have different modulation strategies. So, before choosing the modulation strategy you should study them and compare them and then choose the one which suits your application. And then, also know that the modulation strategy you choose that is going to change the design of the converter in different different modulation strategies the waveforms are different and accordingly the choice of components, the choice of inductor capacitors switches all of these may become different depending on the modulation strategy. So, before choosing your components you should fix your modulation strategy. Thank you.