Advance Power Electronics and Control
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Lecture - 19
Power Factor Improvement Techniques – III and Non-isolated DC-DC Converters

Welcome to our NPTEL lectures on Advanced Power Electronics and Control. Today, we shall continue the remaining portion of the Power Factor Improvement Techniques that was extinction angle control and all those issues related to the full control converter that and we shall start a new important topic that is Non-isolated DC to DC converter. So please recall actually we were actually discussing about extinction angle control.

To have a extinction angle control we assume that load current to be actually the constant. So this is the load current.

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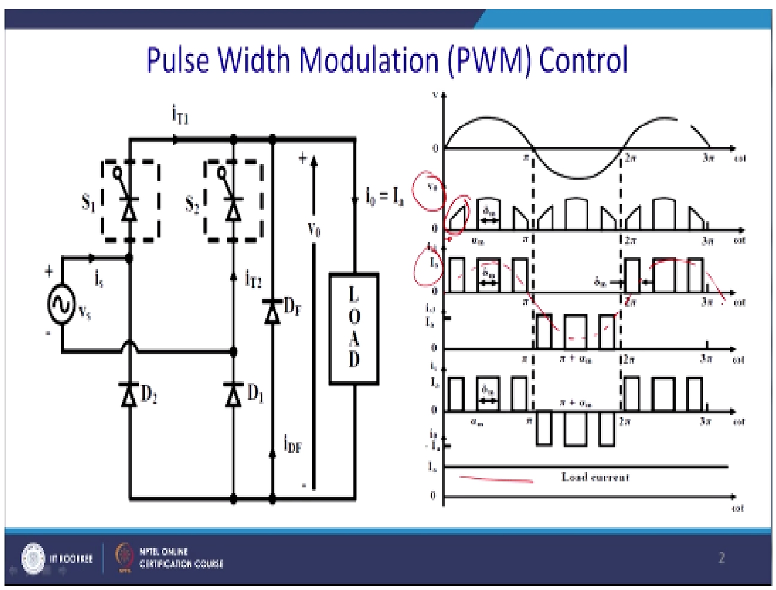

And you will trigger ON in some places, let us say it is alpha thereafter you will again actually a forced converter if in case of a Thyristors or you will have a GTO then you actually require to commuted by the negative get converter and so on. So current will be actually chock like this in input. So due to that you know when actually it is not getting a current definitely at that time actually free wheel diode comes into the picture and that makes the load current continuous.

And ultimately this will be the Is1 and this is the actually current through the actually the Thyristor. This is the actually the; upper one is the load voltage so you will have this kind of chopping profile and this one will be the actually will be the input current assuming you have got a constant load current and this will continue. So what will find to you know actually the fundamental of this current is will be again will have a unity power factor.

Moreover, you can go for we shall discuss in detail about the selective harmonic elimination. One of the problem is that you cannot have a dominating harmonics because it is a square root. And since it is a single phase so you have odd symmetry so you got a harmonics thought dominating harmonic. So by this you can eliminate the actually selective harmonics that will be actually causing problem to it. So these are the few discussions of the PWF converter.

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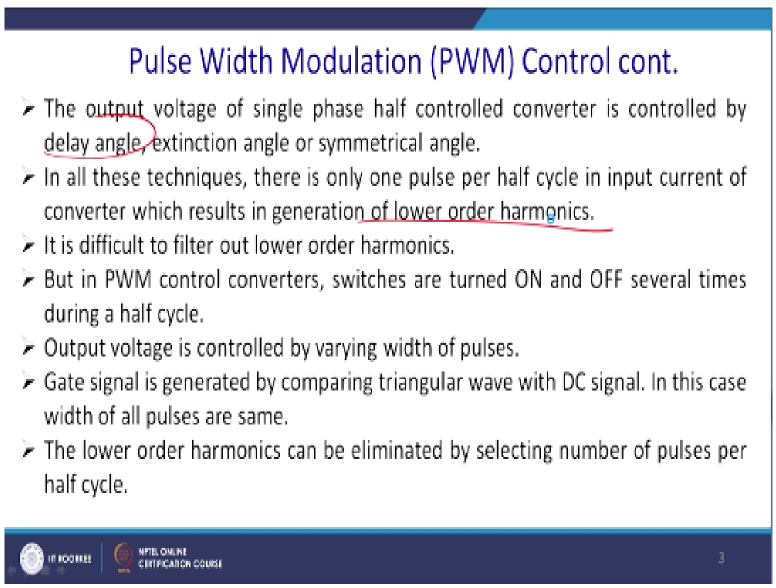

The output voltage of the single phase half controlled PWM converter is controlled by delay angle; this one is a delay angle and extinction angle or a symmetrical angle. All these techniques are only one pulse half cycle in the input current which we have shown in the previous class. Current of the converter which results in generation of the lower order harmonics, so this is one of the difficulty of it.

So if you have chopping on by extinction and the symmetrical control you will have a problem of high THD because of the presence of the lower order harmonic. It is difficult to filter out the lower order harmonic because size of the filter will be quite big and bulky. But PWF control converters, switches are turned ON and turned OFF in several times during the half cycle. And you can shift those frequencies to the higher order and thus size of the frequency becomes lower.

Output voltage is controlled by, we shall discuss about choosing a particular elimination or the particular selected harmonic that will be dominating in a particular case that is called Selective Harmonic Elimination SHE, so that will be taken up by the subsequent courses. So when we will actually talk about the PWF mean that is. But the PWF controlled converters, switches are turned ON and turned OFF several times during one half cycle and thus it can mitigate the lower order harmonics.

Output voltage is controlled by varying the pulse width. So if you vary the pulse width in output voltage can be controlled. So ultimately this width can be change to change the output voltage at a level to the lower. So because this duration is decreasing and thus overall output is increased. Output voltage is controlled by controlling the pulse width. Get signal is generated by comparing the triangular wave with the DC signals. In this case width of all pulses required to be the same. And a lower a harmonic can be eliminated by selecting the number of pulses per half cycle that is a part of Selecting Harmonic Elimination.

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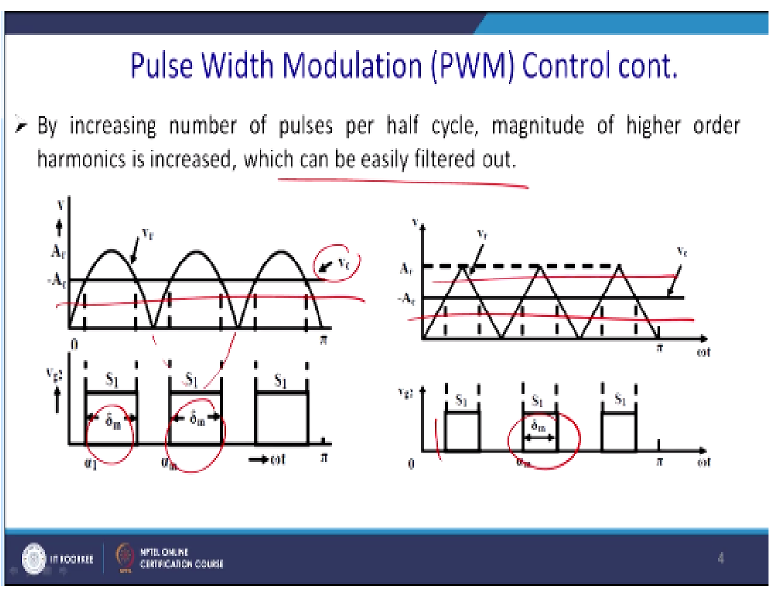

So just see that this is actually the sinusoidal wave form and its replica. So you can change this value Vc and thus you can change the value of Dm. So by increasing the number of pulse per half cycle, magnitude of the higher order harmonics is increasing, which can easily be filtered out.

Or you can have a triangular shape waveform and you can compare and you can actually get this if you take it this way then actually pulses is increase if you take it upper way pulses is decrease and average voltage come across the load will increase or decrease accordingly. Now let us see that what is the output voltage you will get here.

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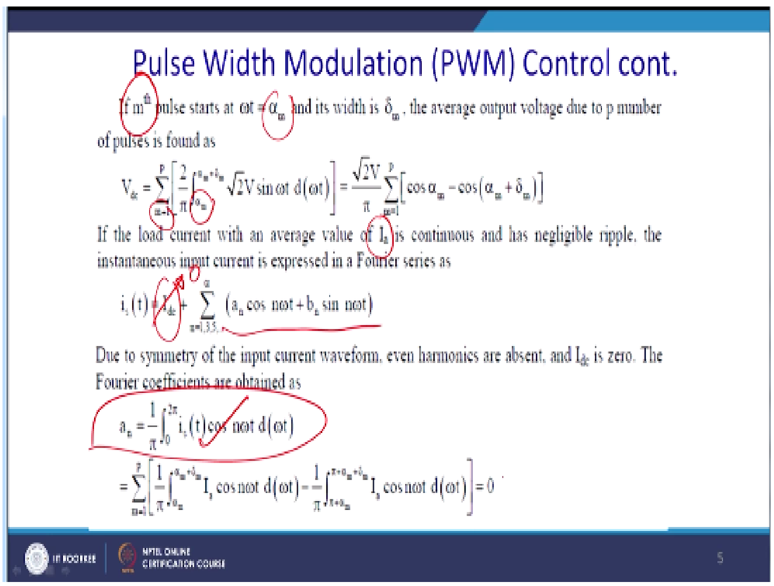

Let us see consider that Mth pulse starts alpha m and with the modulation index delta m with a average output voltage due to P number of pulses is required to be found out. So we can have the summation 1 to P 2/pi alpha m to alpha m+Dm Vm sin omega T you can actually integrate operate so you will root T/pi so you get a summation.

And if the load current with the average value of IA is continuous and have a negligible ripple that instantaneous then it will be square F so thus we can apply the instantaneous Vr transformation. So you will have Idc followed by actually the oscillating components superimpose on the DC.

So we can check it out what is actually the fundamental kind of thing. And now if you have a symmetry, if you have actually positive and the negative cycle symmetry that is average value; DC is basically the average value we have; since it is a symmetrical pulse so Ibe should be equal to 0. And also all the; we have since it is a sin wave we can choose voltage as a sin wave so we have a odd wave symmetry.

Since it is a odd wave symmetry so all the actually even harmonics will be vanished. And thus, you will left with basically this component and you can calculate and this value is for the odd, this value is for the even because you know that cos is a even function and ultimately all the coefficient of it will be 0 and will just left with the value of bm.

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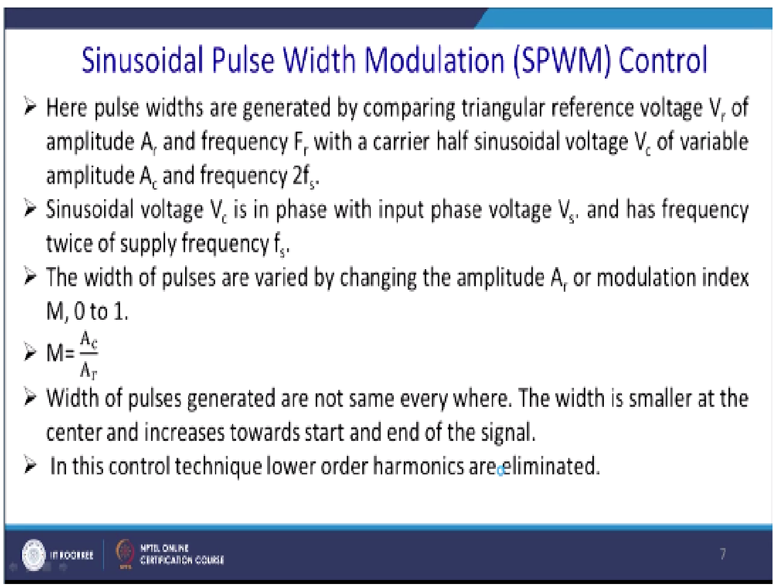

So you require to calculate the value of bm so it is 1/pi 0 to 2pi Is sin omega T so we have a P such pulses in a half cycle so it is 1 to P summation of that if you do that integration you will get basically 2iA where A is the constant output current by Mpi m=1 to P cos in alpha – bm square. So you know you see that you can choose this actually alpha in such a way that value of bm can be made 0, so if you trigger at ones you can actually eliminate only one alpha.

So in case that; since it is a actually all harmonic at present so 1st, 3rd, 5th and all those harmonics will be present. You can choose in such a way that actually b3 can be made 0 then it is set to be the selective harmonic elimination. And anyway let us comeback to the coefficients.

Since A part is 0 so Tan phi is basically 0 and you got the magnitude is basically Pn/100 root 2 that is the RMS value.

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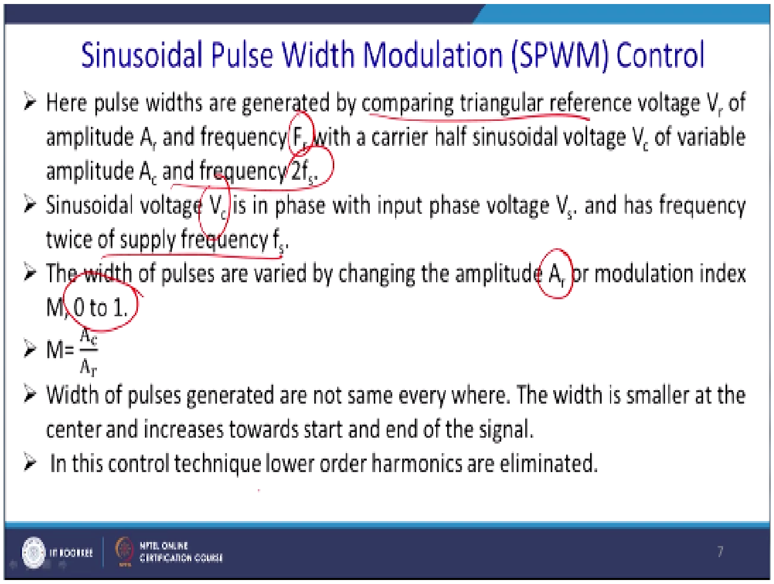

Now, here the pulse rate are generated by as we have discussed here comparing the triangular reference voltage Vr of the amplitude Ar and the frequency as of the supply frequency Fr with the carrier sinusoidal voltage Vc of the variable amplitude Ac of the frequency double frequency oscillation. So you have to rectify it and get it done. The sinusoidal voltage Vc is the phase with the input voltage Vs and has frequency twice of supply frequency Fs.

So width of the pulse are varied by changing the amplitude Ar you can refer back to this slides which has been shown you, so this is the discussions or modulation index M which can be varied 0 to 1 and the modulation index is given by the ratio Ac/Ar. The width of the pulse generated are not same everywhere. The width is smaller at the center and increases towards the start and end of the signal.

In this control technique what happen generally, the lower order harmonics are got eliminated and as I have discussed little bit briefly how it can be eliminated so we got a less bulky system. If higher order; lower order harmonic represent to filter it out and to have to have a desired power quality, you require to put the bulky inductor into the system bulky filters into the system that makes actually the system bulky as well as the cost increases. So this is basically as we have seen that if you have only one triggering then only one harmonic can be eliminated.

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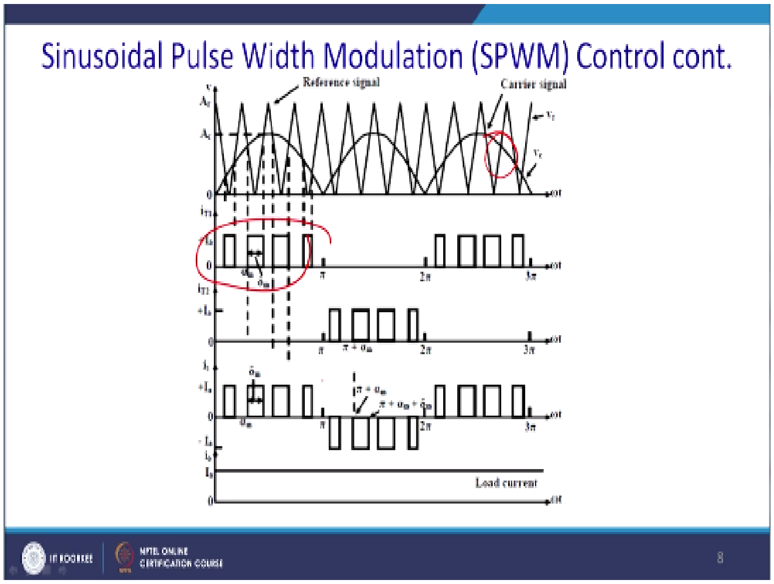

Now we can choose a triangular wave that is quite higher than this supply frequency mostly actually the Vc will be at the supply frequency. So accordingly you have a multiple pulses can be generated and for this reason you will find that actually the width since you are comparing width here it will be more and here width will be narrow. So in that way it will vary. So similarly you can have this kind of variations of the input current.

And this kind of variation if you take the harmonic analysis you will find that lower order harmonics are been eliminated. So this is the actually the consideration of sinusoidal pulse width modulation technique for the converters which is used for AC to DC rectifications without throwing much garbage to the system. Thank you for your attention and I continue to my in a same class that is the next part portion of it that is DC to DC converter.

So DC to DC converter is very important for our day to day applications. Because why I require a DC to DC converter is unfortunately unlike DC we do not have DC transformer. And most of the cases the supply which you read rectified voltage if you have 2Vm/pi it is the single phase value you would have read the diode which rectified and what you will be using there is a difference. So you may require to boost the voltage; you may require to buck the voltage, you may; you do not know when you sometime require to boost or buck the voltage.

And in those conditions you know, we require a different kind of converter that is basically a DC to DC converter. Till now we are discussing the conversion AC to DC. Assume that this is available to you constant DC or ripple DC and you want that a load will take a specific voltage of the DC. So there is a huge kind of application like water purification application. It requires a very high current and low voltage DC.

And your SMPS of mouse or all those things that actually require; your mobile charger, laptop charger or this actually a mobile, laptop all are essentially DC which you are charging use for utilities. So for this reason and we have actually.

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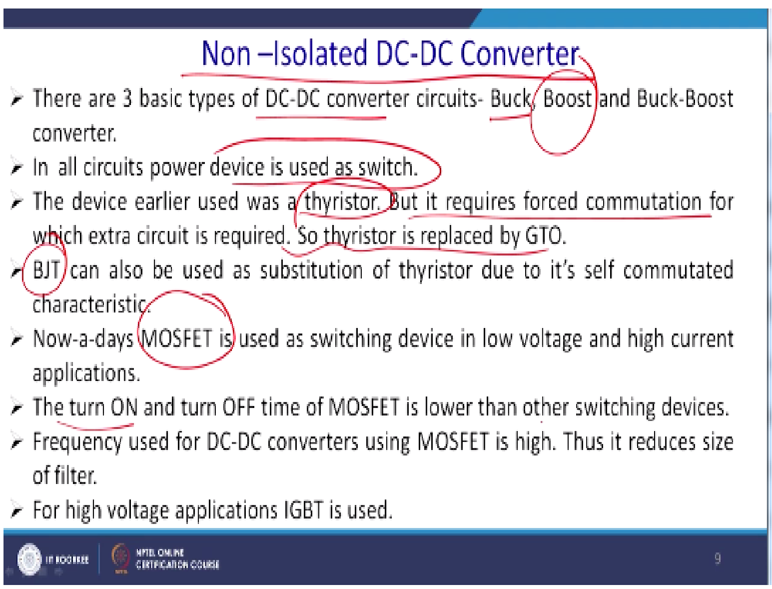

Today we will discuss about the Non-Isolated DC to DC converter. Definitely there is another part of it there is a isolated DC to DC converter. So input and the output stage has got the Galvanic isolation. But SMPS is definitely the DC to DC converter, non-isolated DC to DC converter. So of course depending upon the application.

We have three type of DC to DC converter circuits one is buck there is a that actually it is essentially the AC equivalent will be the step down transformer and then Boost as name suggested the AC equivalent will be a step up transformer and Buck-Boost converter it is something like track changing transformer or auto transformer or where you can boost up the voltage where you can actually buck the voltage.

And since you cannot use transformers, static device we require the power electronic circuit to do that. All the; in all circuits power devices are used as a switch and since it may have a higher rating and for this reason we require actually high power switches. Device earlier use was Thyristor that means basically the converter that is AC to DC converter.

And one of the advantage of using Thyristor, Thyristor no one can meets its power rating as we have discussed in our earlier classes. And Thyristors has a actually one of the advantage in case of the, in case of the actually AC to DC application is a line commutation. It is naturally commutated by line so you may not require a forced commutation. And as I saying it requires forced commutation which is extra circuit is required.

So here for actually you will find that for high power application this Thyristor will be replaced by the GTO where you can turn ON and turn OFF at your will but frequency should be below 1 kilohertz. And power rating can move up to the level of actually 100 of kilovolts. BJT can also use but BJT now has been faced out with the invert of the IGBT can also be used to substitute Thyristor due to its self commutated transformer, self commutated characteristic by the Ib.

But since it require a very high base current and so with the invent of the IGBT BJT actually we do not use nowadays power BJTs. And nowadays actually the MOSFET is used, MOSFET power MOSFET has a power handling capability in a range of the volts in a range of the actually sub kilo volt level, so and there switching frequency can be high. So if you wish to have a compact DC to DC supply of the power rating below 100 or below 1000 getting a 1000 kilo volt power rating will be difficult with the MOSFET.

And but you can; once can challenge it to do it so we can have that kind of devices and their switching frequency can be quite high as high as actually 100 kilo volts so there you can find that actually we can use a very compact solution for the DC to DC converter. Most of your laptop charges, mobile charges having a power devices are essentially MOSFET.

So the turn ON and turn OFF time of the MOSFET is lower than the other switching devices. Frequency of the DC to DC converters using MOSFET is quite high in a way it can be as high as actually 100 kilo volts. And due to reduced size and it reduces the size of the filters. And for the high voltage applications and there is a high power application we use IGBT.

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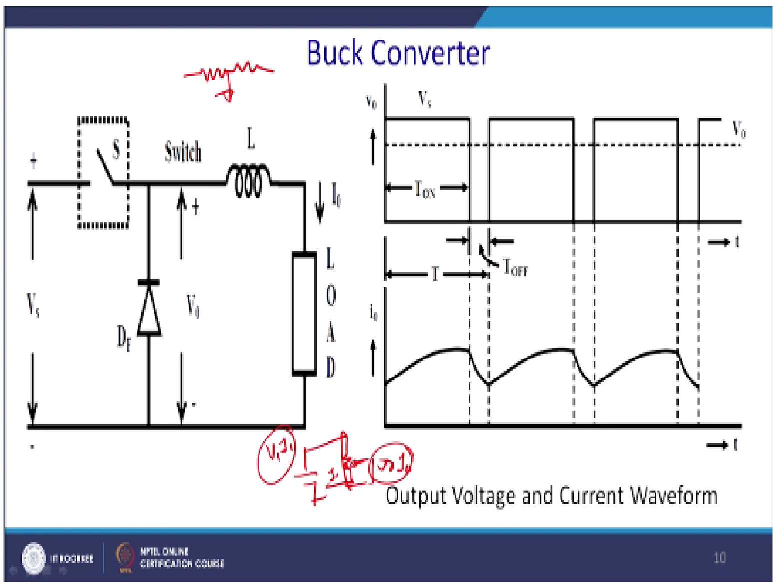

So why SMPS we are trying to discuss first essentially we think of pot kind of solution. But pot will give you a loss? So you can have a DC supply and you can have a pot. From the pot you can choose the output voltage. So what happen you know, if you actually your V1 I1 is a current and V0 I0 is a output you will find that efficiency is quite low. Why because, you know there is a constitute of current and some portion of the current actually is flowing to the actually this let us switch.

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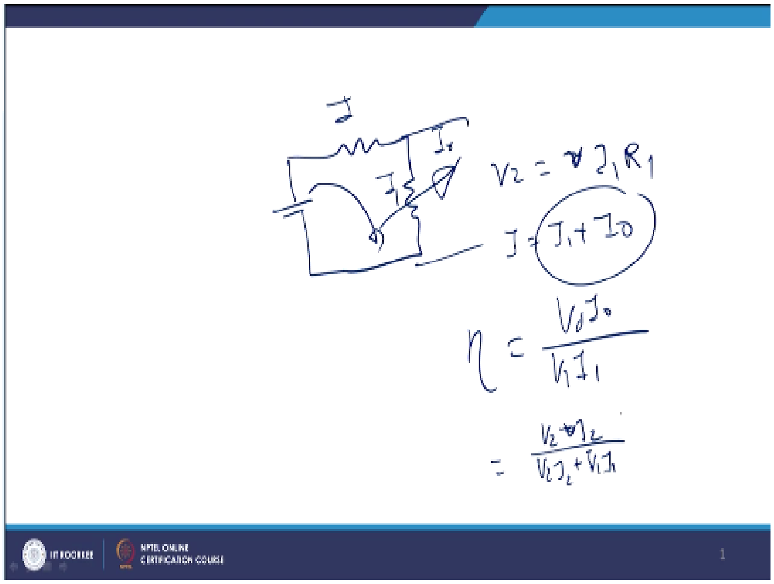

So you have this kind of thing essentially. So what happen you know current flowing through here it is I and here it is actually I1 and here it is I0. So you know V2= essentially you know, I1*I; V2=I1*R1 and similarly you can find it out actually an I=I1+I0. So you can find it out what is actually the efficiency, efficiency will be given by essentially V0*I0. By V1*I1 you can split this two voltages. And essentially you can write it in terms of V2*I2+V1*I1/V2*I2. So you can divide it can you can get this results ultimately it will depend on this ratio.

So you can find it out the efficiency of this actually converter will be quite low because of the constant dissipations of the current. So for this what we have you know, we have a switches, ideal switches we have discussed characteristics of it. Once this value is (()) (21:59) I impudence state that means it is OFF, no current flows so there is a no losses ideally across the switch.

And if there is a energy stored into the system that will be actually fitting the load. And when it is ON then power will be coming inductor will be storing the energy to dissipate it when the switch is OFF, and you will get a average power into the system. So what happen you know, this is the output voltage, average output voltage and when it is switched ON actually you will get the voltage equal to Vs and when it is OFF actually we will get the 0 voltage.

And since it will be fitting this thing fitting the load so inductor current will actually ramp on thereafter current will free wheel assuming that it is a continuous conduction mode, so you will get the average voltage which is equal to output voltage V0 and where your input voltage is Vs.

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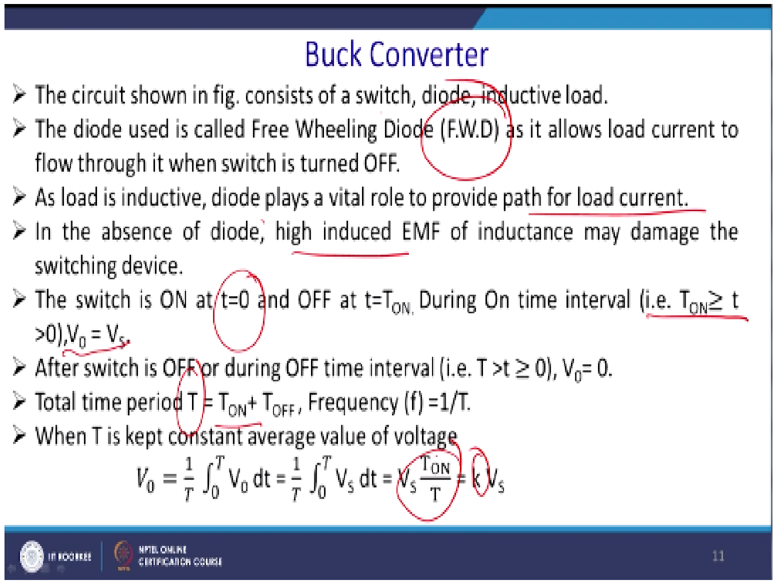

So we can have the actually voltage time average (()) (23:21) and find it out the actually the output/input characteristics as well as the expressions. The circuit shown in the figure consists of a one switch, a diode and the inductive load. The diode used is called we have discussed already this is called Free Wheel diode as it allows the load current to flow through when switch is turned ON.

Also, load is inductive, diode plays a vital role to provide the path for the load current otherwise high spikes will appear across a switch and which may damage the switch. So Free Wheel diode is actually given the purpose not only to fitting the load, when switch is OFF also to actually the mitigating stress across the switch. The absence of the diode in the absence of the diode high induced EMF of the inductance may damage the switching devices.

The switch is ON at t=0 and OFF at t=T ON during the interval of T ON that is greater than 0 and less than Ts then output will be equal to the Vs the supply voltage. After the switch is OFF during OFF time interval so output voltage required will be 0 because of the Free Wheel action because you will get the load will get the voltage from the; induct stored inductor NHA. So total time period t can be divided into the two part T ON and T OFF so frequency will be 1/T when T is constant so V0 will be 1/T, V0 T V0 DT 1/T V0 T Vs DT so you can get actually Vs T ON/T. And this is something like your transformer Trans ratio, so essentially you get k*Vs.

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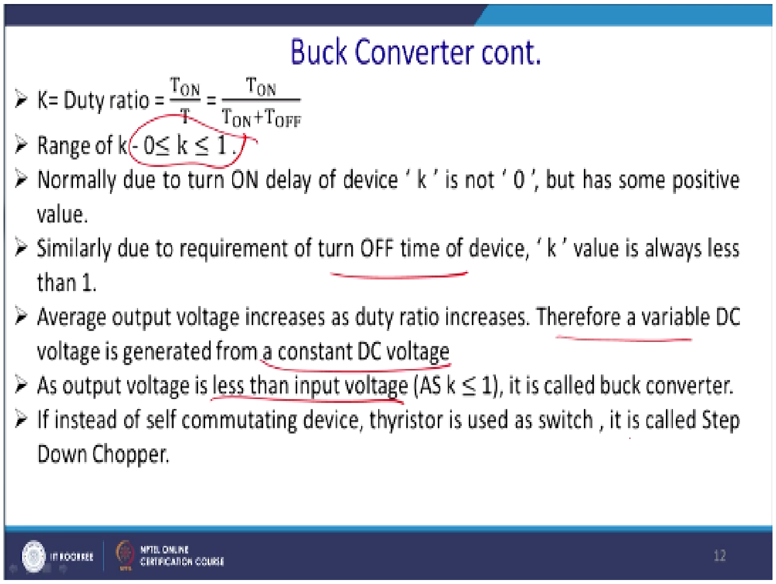

So while K is the Duty ratio that is T ON/T, so you can write in this format also. T ON T ON+ T OFF. So range of the k will vary from 0 to k, 0 to 1 so you can choose any duty cycle for the continuous conduction mode and you will get up actually direction relation between the input and the output voltage. Normally due to ON delay the device k is not equal to 0 and has some positive value because you cannot have 0 turn ON time as well as turn OFF time.

So similarly due to the requirement of the turn OFF time device is it will less than the value of 1; maximum value will be less than 1. The average output voltage increases as a duty ratio, increases. Therefore, a variable DC voltage is generated from a constant DC voltage. This is a purpose of it.

But not necessarily you know, you may have a reverse converter where the input voltage is varying and you require to actually get a constant DC voltage then also you can do that and duty cycle will change to actually give you the constant output voltage but input voltage itself is varying due to the irradiations or temperature like in case of the solar cell. Though, and output voltage is less than the input voltage, so k is < 1 it is called the buck converter.

Instead of the self commutating device, thyristor is used and then it is called the Chopper for high power application. But the chopper require to be, require to come with the commutation circuits.

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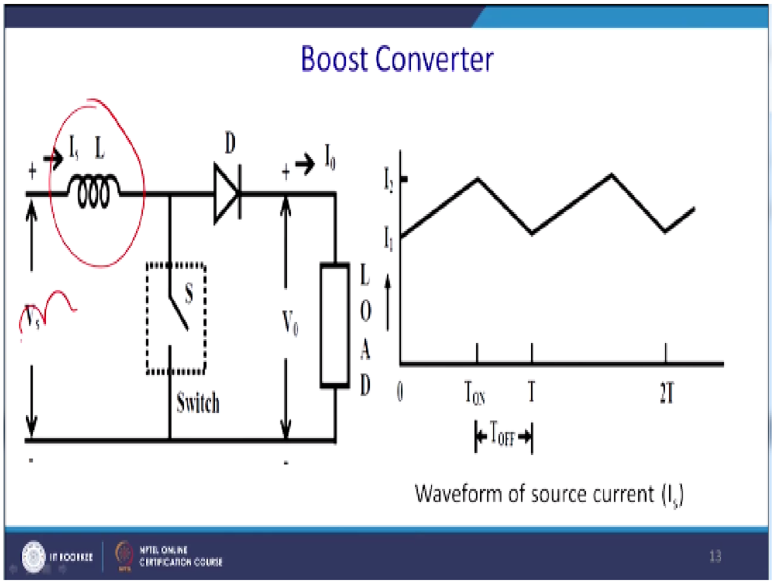

Now Is is the source current. Now let us come to the another converter that is the Boost Converter. So here actually you can boost the voltage. But there is a limit of it so practically, theoretically speaking you can boost it any voltage from Vin*infinity but there is a practical limitation due to the parasitics of the inductive capacitor as well as a switching.

And also this converter require actually mostly as a stable kind of system and since it is boosting a voltage and there is a possibility that this voltage can go up very high but parasitics will come into the picture and ultimately it will give you the 0 voltage after some duty cycle. So we require to operate in a different control loop. So controlling of this actually boost converter is little complicated than the buck converter.

So we will see that actually what is the application of it and most of the application we find that you know, we have discussed please recall we have discussed in detail with the PWM converter. So we have actually a boost PWM converter where actually we have boosted the voltage where input is a sinusoidal ripple DC with after rectifications and there we have used the boost converter. So and mostly it is used for that purpose, mostly it is used for that purpose. As well as its finds the application in case of the solar inverter.

What happen you know, solar inverter actually its DC output voltage we had to crack the maximum power point it varies with the; it varies with the irradiations. So only in evening maybe actually that it imperative voltage is matches with the desired dazzling voltage is required to inject the power to the great. But rest of the time or the day time it may not match.

So for this reason we require to boost this voltage and ultimately you can fit it that voltage of the output so that this kind of applications in this application boost controlled are been used as well as preferred. And of course we can use a buck-boost converter, we shall see that. So we shall continue to our discussions with the boost converter in our next class. Thank you for your attention. I will discuss in the next class Boost converter.