Switched Mode Power Conversion

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Lecture - 18
Problem set - II

Good day to all of you. In today's lecture, we will continue with a few more problems relating to the study state solution of power convertors. We will look at a few power convertors, which are isolated power convertors as well as non isolated power convertors; continues conduction as well as in discontinues conduction. We will analyze the circuits to find out there study state operation just as we did in the last lecture. We will take a few more problems. We will take a 3 more problems and look at their study state voltage gain, the current wave shapes, the losses in the convertor efficiency, and so on.

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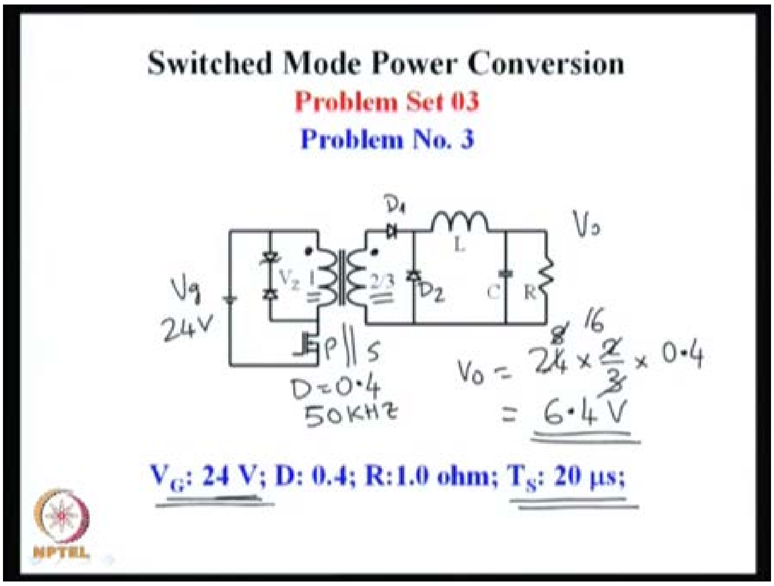

What you see in this circuit here is an isolated convertor. The power is transferred from the primary site to the secondary site, so that what is delivered? The V naught delivered from V g is electrically isolated, and the source voltage is 24 volts, this is 24 volts. The switch is operating with a duty ratio of 0.4 at switching period of 20 micro seconds, which corresponds to 50 kilohertz of switching. The switching is taking place at 50 kilohertz. The convertor that we see here is a forward convertor, isolated forward convertor. So, during the time the switch is on, power is transferred from the primary to the secondary, and through this diode D 1, it is delivered to the output inductor and to the output load.

And whenever the switch goes off the inductor current free wills through the diode D 2 and then feeds the output power v naught from the stored energy. So, in such a convertor with a turn's ratio 1 is to 2 by 3 between the primary and secondary. The ideal output voltage will be the input voltage 24 multiplied by the turns ratio, which is 2 by 3 and multiplied by duty ratio, which is 0.4. So, this number is 8. This is 16. 16 into 0.4 are 6.4 volts. So, ideally this power convertor will deliver an output voltage of 6.4 volts, if there are no losses in the convertor. In this particular example, we would like to known what are the consequences of the various losses in the convertor.

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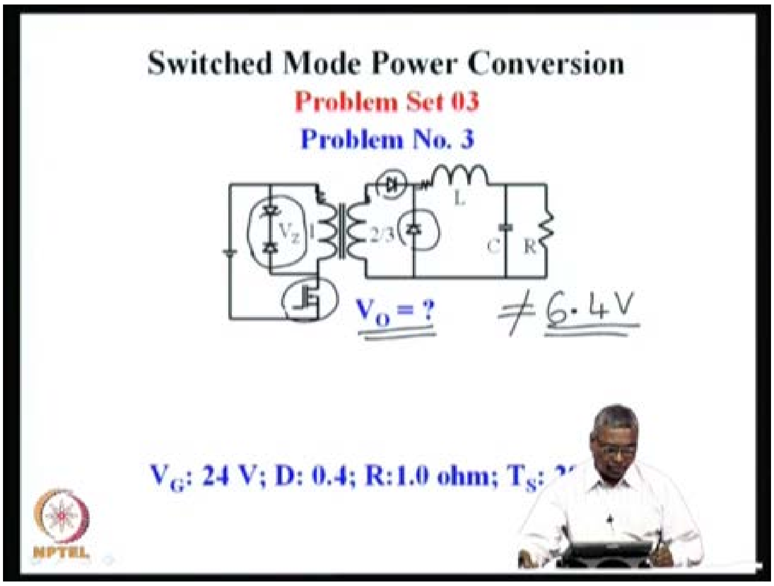

We wish to know the output voltage v naught, under the conditions that there are losses in the diodes, losses in the transistors and losses in the magnetizing circuit. So, there are losses in the inductors, losses in the primary winding and losses in the secondary winding. There are several losses in the convertor. When these losses are taken into account, what happens to the ideal output voltage 6.4? Is a true or not? Definitely it is not true. Where is going to be power loss in the convertor, voltage loss in various switches and so V naught will certainly not the equal to the ideal value of 6.4 volts. We would like to find out how this can be calculated.

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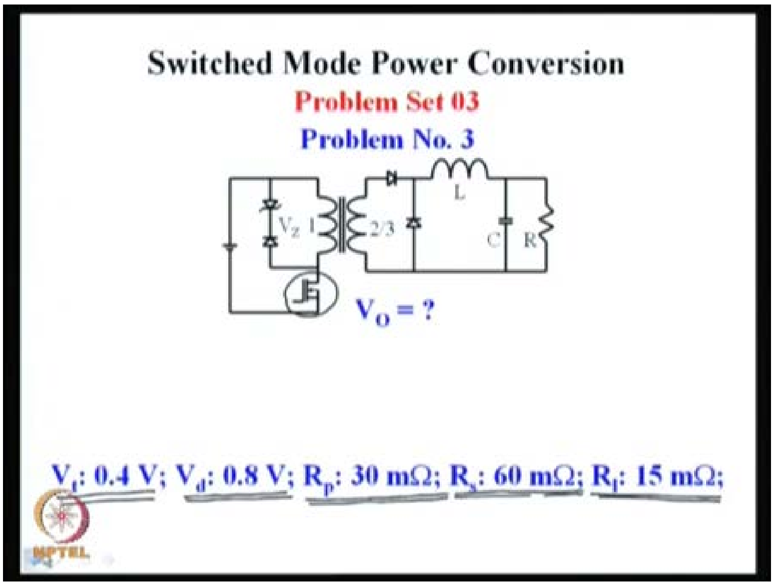

All the non idealities are indicated here. The transistor drop is 0.4 volts, what we see. We must write transistor has a voltage drop while it is conducting of 0.4 volts. The diodes which are on the secondary side of the transformer, they have a voltage drop of 0.8 volts during conduction. The primary winding of the transformer has a 30 milli ohm of resistance. The secondary winding of their transformer has 60 milli ohm of resistance. The inductor itself has a resistance of 15 milli ohm. All these are the non idealities associated with the convertor.

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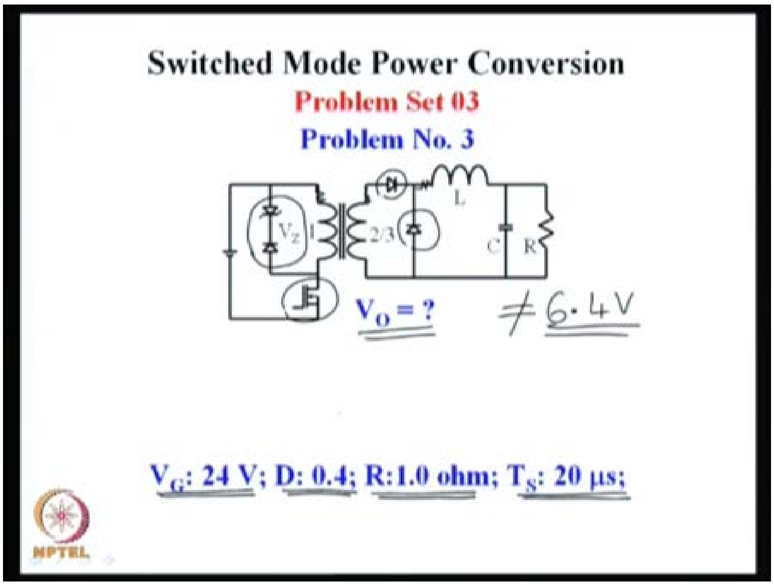

We had seen in the previous slight that the input voltage is 24 volts, the resistance is 1 ohm, switching period is 20 micro seconds and duty ratio is 0.4. So, if we come back again to our…

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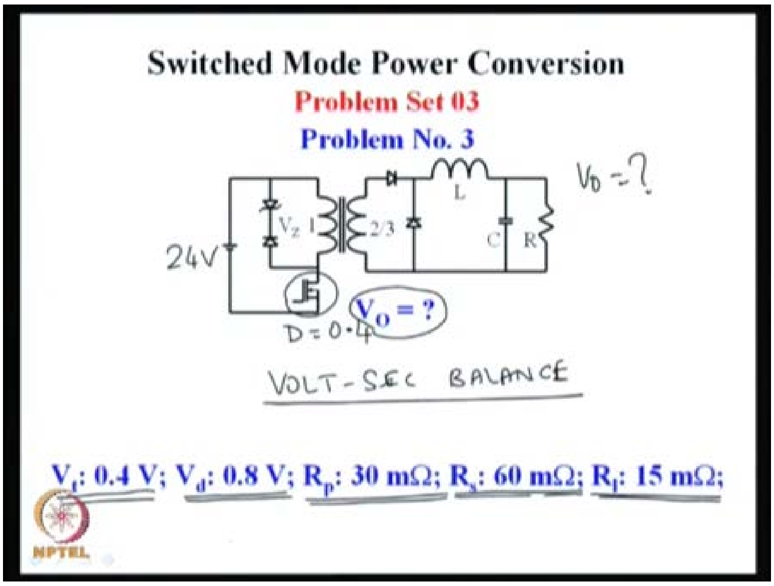

So, this is 24 volts and duty ratio is 0.4. Under this condition how are we going to find out what is V naught that is our current problem. In doing this we know that we v naught is found out by finding out the volt second balance on the inductor. So, we find out what is the voltage applied across the inductor over one cycle and equate it to the average value. We equate it to 0. That is how we have been finding out the voltage gain, what will be the output voltage. So, we follow the same method, we try to now write the volt second balance for this particular convertor.

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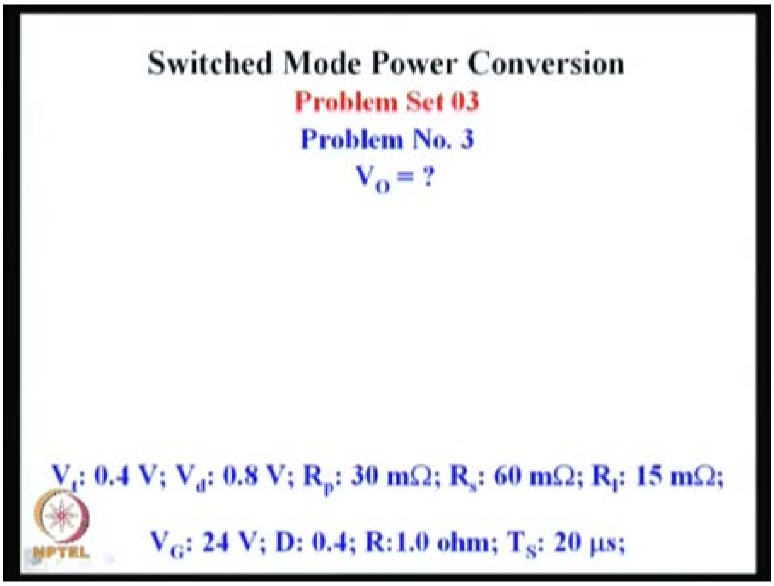

We can see that the inductor has a voltage of…

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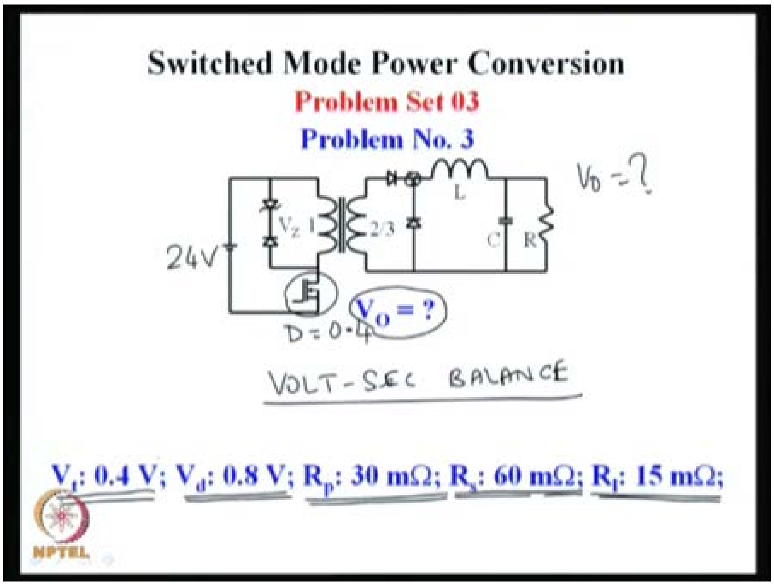

Go back to the previous slide. The inductor has on this site during the on time a voltage, is 24 minus the device drop multiplied by the turn's ratio minus the resistive drop on the primary minus the resistive drop on the secondary minus the diode drop on this side. Then on the output side we have V naught. So, if we write all this quantities it is possible to write this volt second…

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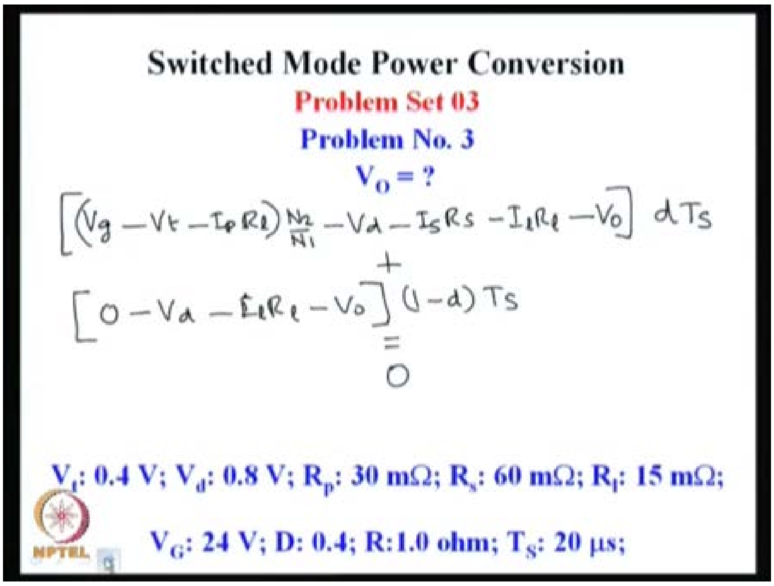

During the on time the voltage across the inductor can be written as V g minus the switch drop V t minus primary current multiplied by R l. This is the voltage applied to the primary, that multiplied by N 2 by N 1 is a voltage on the secondary. The secondary side we have a diode voltage drop minus secondary current drop I s into R s minus inductor resistance drop I l into R l on the left hand side of the inductor and minus V naught which is the right hand side of the inductor. This voltage is applied for duration of d T s. So, this is the voltage apply to the inductor, what you see on the square bracket multiplied by d T s. Then during the off period we have to add the voltage. So, that quantity is on the primary sides switch is off.

So, nothing is coming from the primary side. The free V link staring from 0 minus 1 diode drop, the free V link diode minus I l into R l minus V naught. So, this is the voltage across the inductor and this is for aduration of 1 minus d T s, so adding both of this equal to 0. This is what we... This is the volt second balance equation. From this we should identify, we should isolate all the known quantities on one side and the unknown quantities related to V naught on the other side. And find the relationship between V naught and V g, so this can be done by rewriting this equation.

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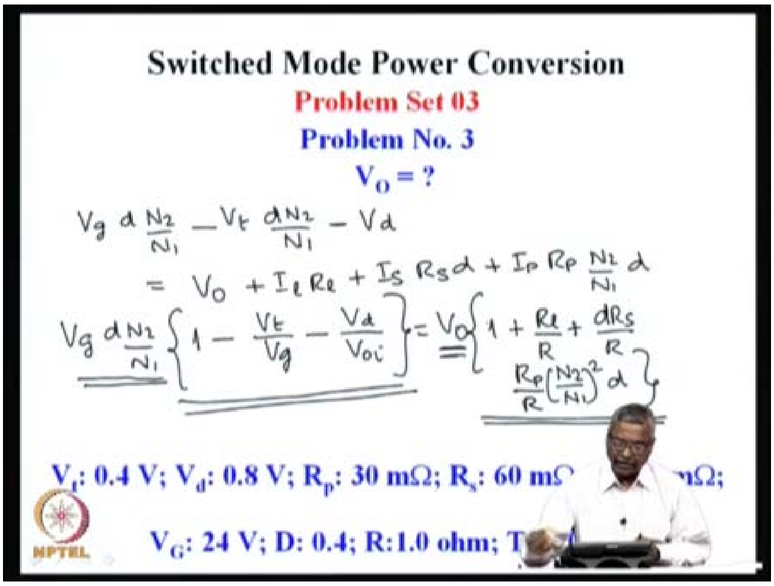

So, let me rewrite this equation as by expanding the terms V g d N 2 by n 1, this is the term on the first term. Then transistor drop V t d N 2 by N 1. So, we take all the other terms on to the right hand side and then minus V d. All other terms are taken to the right hand side, that turns to be v naught plus I l R l plus I s R s into d plus I p R p into N 2 by N 1 into d. So these are all our quantities. The equation all the quantities like quantities relating to V naught have all been taken to the output side. This can be written as V g d N 2 by N 1, this is the ideal gain.

You please note how these terms are separated. The first term is ideal gain. So, we write all the other quantities as a correction factor 1 minus V t by V g, is a second term minus V d divided by V naught i, whatever is taken out is the ideal V naught, so we will write it as ideal V naught. This is on one side. The other side will write this as again V naught multiplied by 1 plus R l. This I l inductor current is as same as the output current so this can be written has R l by R, the load resistance. Similarly, I s is the same as the inductor current, so this will also be d times R s by R, the second next term.

This last term I p and I s are not equal to each other, but the primary current is related to the secondary current through the turns ratio, so I p can be written as again R p N 2 by N 1 whole square divided by R multiplied by d and that is the right hand side. So, effectively now we see that V naught is the ideal quantity with all the correction factors.

The interesting. To see here is the way we have written it, then the non idealities are 0. Whatever is in this bracket will become 1.

Similarly, whatever is in this bracket will become 1. So, all the non idealities have written in such a way that they will be a correction factor, which will be 1 if the entire ideal condition true and it will be different from 1 if the non ideality exits. So, if you see this under ideal conditions, because these bracketed quantities are 1 each V naught is same as V g into d into N 2 by N 1. So, now we can write all these terms in terms of the ideal quantities

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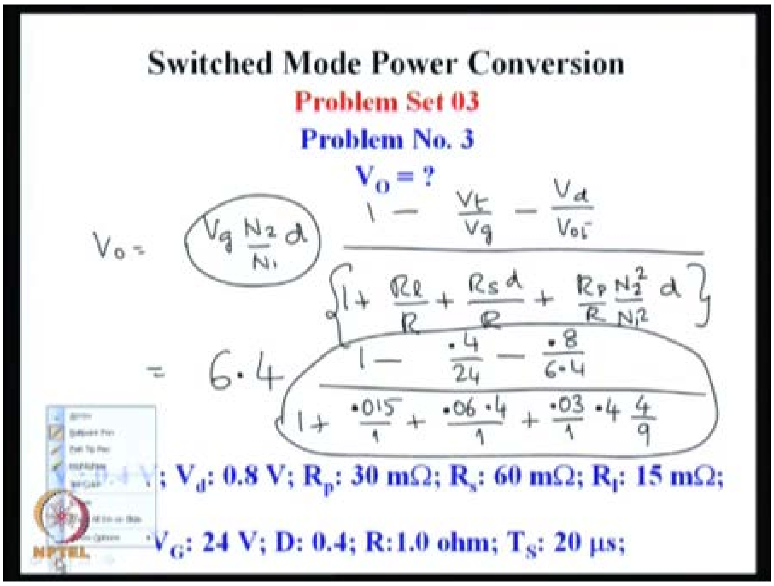

We can say that V naught is now V g N 2 by N 1 into d. This is our ideal. Then we have, because we take all the terms to the one side, V naught is now related to the ideal gain, then 1 minus V t by V g minus V d by V naught ideal. Denominator has these other entire terms 1 plus R l by R plus R s into d by R plus R p into N 2 square by N 1 square into d by R. So, you can see that all the numerator quantity of this correction factor has several minus terms and the denominator has several plus terms, which are contributing to the change in the output voltage. So, in our particular case this ideal gain is 6.4, 24volts multiplied by 2 by 3 into 0.4 duty ratio is 6.4.

All these other terms if I put in now 1 minus 0.4 by 24 V t by V g minus 0.8 by 6.4 ideal gain and divided by 1 plus 0.15 by 1, R l is given as 15 milli ohm plus R s into d, which is 0.06 into 0.4 divided by 1 plus primary is resistance is 0.03 divided by 1 d is 0.4 N 2 by N 1 whole square is 2 by 3 whole square which is 4 by 9. So, if all these numbers are put in, you can see that this is the correction factor. This correction factor can be evaluated now and once this numbers are evaluated let me clear up this.

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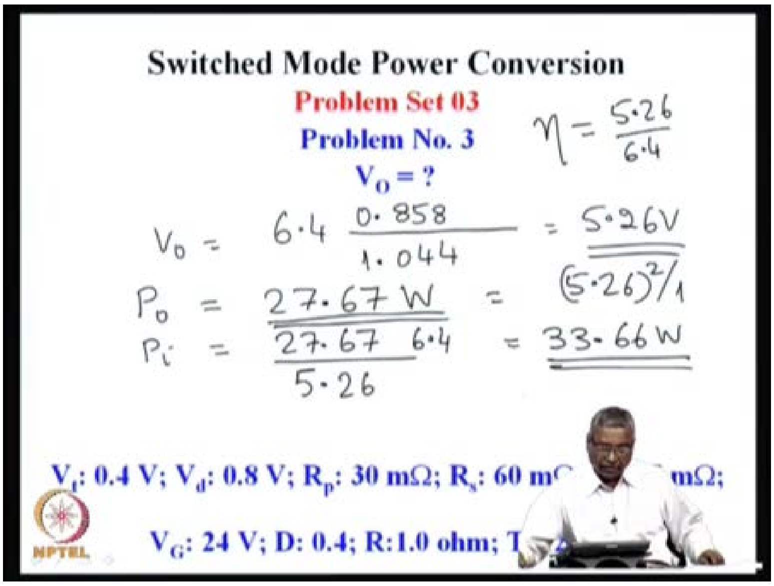

We will find that V naught is 6.4; in this correction factor V naught to be 0.858 divided by 1.044 and this is 5.26 volts. So, on account of various non idealities we find that the output voltage has reduced, has dropped by certain voltage. So, that this is 5.26 divided by 5.26 instead of 6.4. Now, from this it is possible for us to find out what is V naught and what is P i. So, P naught will be the output voltage is now related to 5.26 square divided by 1 ohm, because our load is 1 ohm 5.26 whole square.

So, this is 27.67. So, this is just 5.26 square divided by 1 ohm V square by R. We also know that the efficiency as far as this particular process is concerned is the ratio of 5.26 divided by 6.4. So if that is so the input power is nothing but 27.67, which is output power divided by efficiency. If I divide by efficiency this will be 5.26 and 6.4 and that will be 33.66. So, output power in this particular situation is 27.67 watts and input power taking into account losses what we have calculated is 33.66 watts. Then there is one particular loss which we have not accounted for...

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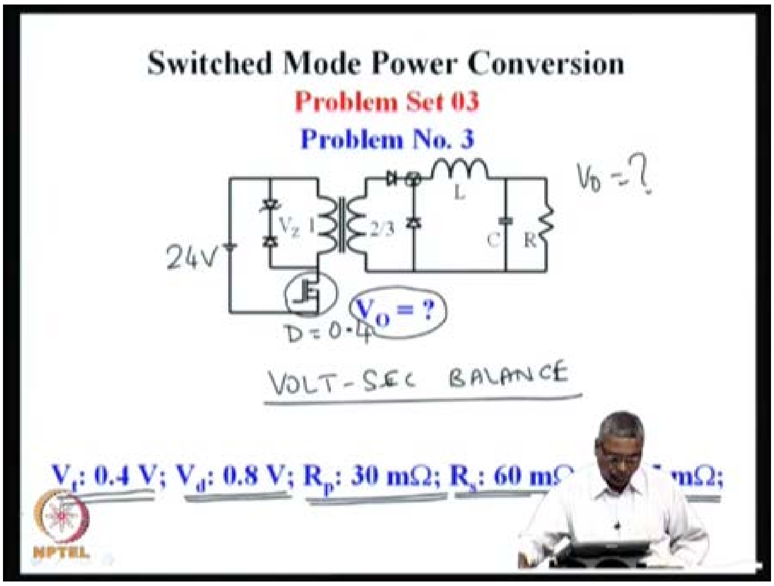

If we go back to the circuit; we have accounted for the losses in the switch, we have accounted for the losses in the diodes in the transformer primary and secondary as conduction loss and the inductor output l loss in the resistor of that. But we have not taken into account the loss that is taking place in the zener diode, it is magnetization loss. That is the separate loss which is taking place apart from these losses, so let us find out what those losses are.

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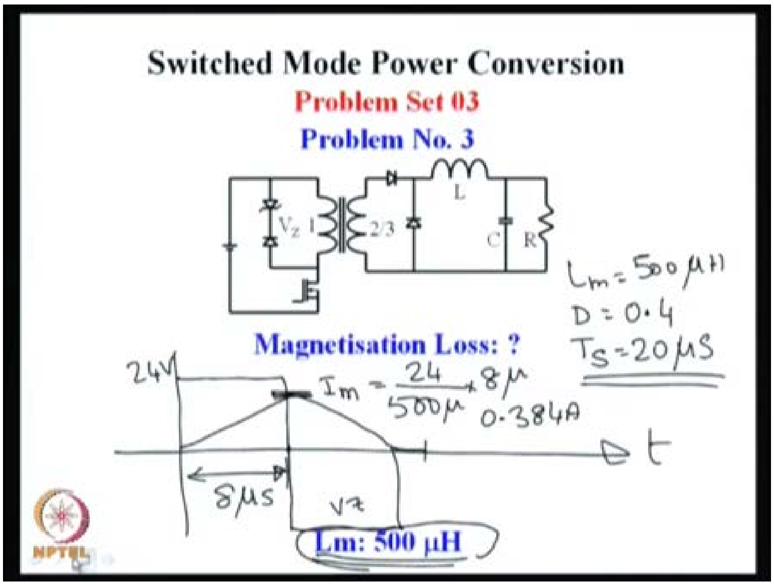

Magnetization loss is related to the magnetization inductance of the transformer. In this particular case that is given as L m is 500 micro hendry and we know that the on time is 0.4 and switching time is/ switching period is 20micro second. So, the transformer is fad during the on time transformer is supplied the voltage of 24volts, for duration of 0.4 into 20 is 8micro second. This is the magnetization voltage and during the off period this energy goes through the zener and the transformer gets reset.

So, we have seen that this is the V z. V z will be normally selected to with the same as the 24volts. So, with this magnetization voltage the transformer magnetization inductance L m will draw a current, which will be linearly rising and then it will be linearly dropping. So, the magnetization energy that is picked up in the inductor is related to this magnetization current peak.

This current is whatever is the voltage applied to the transformer and the transformer magnetization inductance and the on time 8micro. So, effectively the total magnetization current from this we can calculate it will be 24volt supplied to the winding. Winding has of 500micro hendry and it is on for 8micro second. The total current will be 24 multiplied by 8 divided by 500 which are 0.384. This is the magnetization current.

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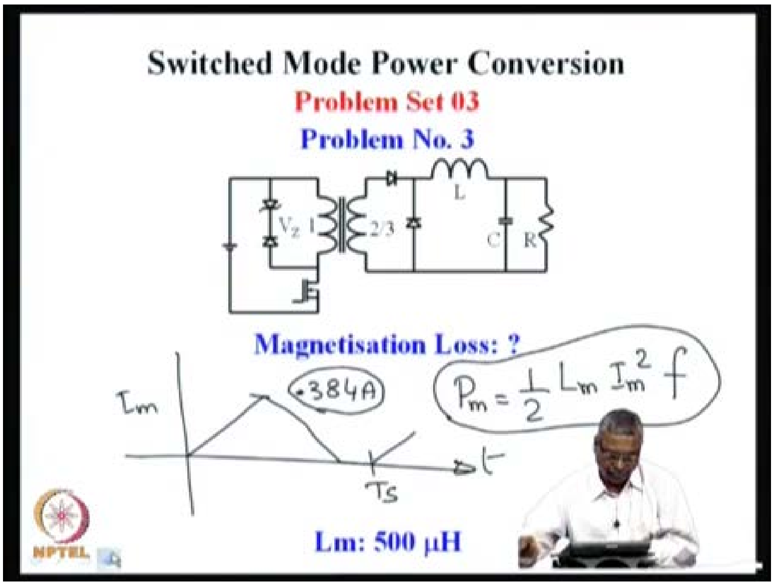

This is what is. We can probably draw it again; the transformer. This is T s. Next cycle stress like that. So, this energy 0.384 amperes in every cycle is last inside the zener. So, we can say that the magnetization loss P m can be written as whatever is the energy in this L m, 1 half of L m into I m square. This is the energy stored in the inductor. If we switch at 50kilo hertz every cycle so much of energy is lost. This would be the total magnetization loss and this can be calculate…

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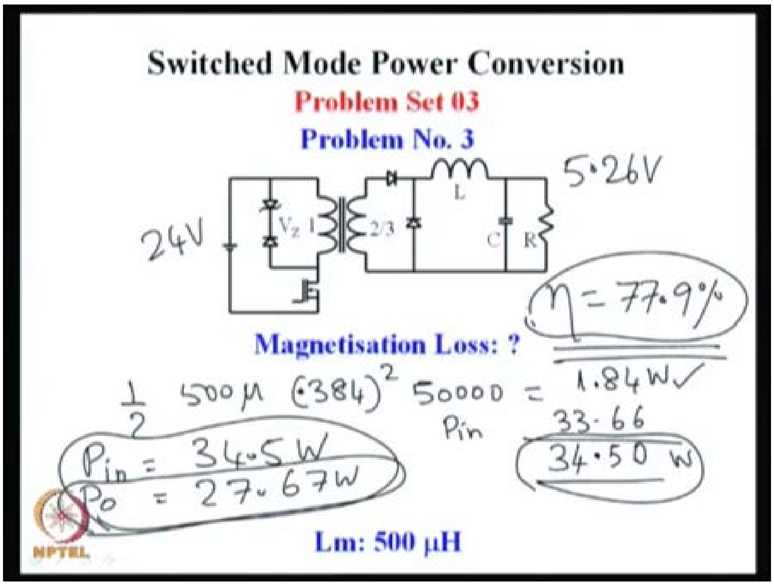

As one half L m is 500 micro and I m is 0.384 whole square and frequency is 50kilo hertz 50000L m square. So, this loss turns out to be; you calculate that it is 500 into 10 to the power minus 6 multiplied by 0.384 whole square multiplied by 50000 divided by 2 which is 1.84 watts. Now, this is the additional loss compared to what I had already calculated. The other P in without taking this into account was 33.66. So, I had all of them; 6 plus 14. So, our P in 34.5 watts and P naught is 27.67 watts. From this we can say efficiency is 77.9 percent.

So, what we had done is; first we did not worry about the magnetization loss. We wrote the volt second balance because this magnetization is a shunt non ideality that was separately calculated. Using the series non ideality, which is the switches diodes resistors etcetera we evaluate what is the output voltage. We saw that that was 5.26 volts starting from 24volt here. After that we found what the losses in the various quantities are. Then separately magnetization loss was taken into account. That was calculated from here. So, with that we calculated the total input power, compared it with total output power and wrote down what the overall efficiency is.

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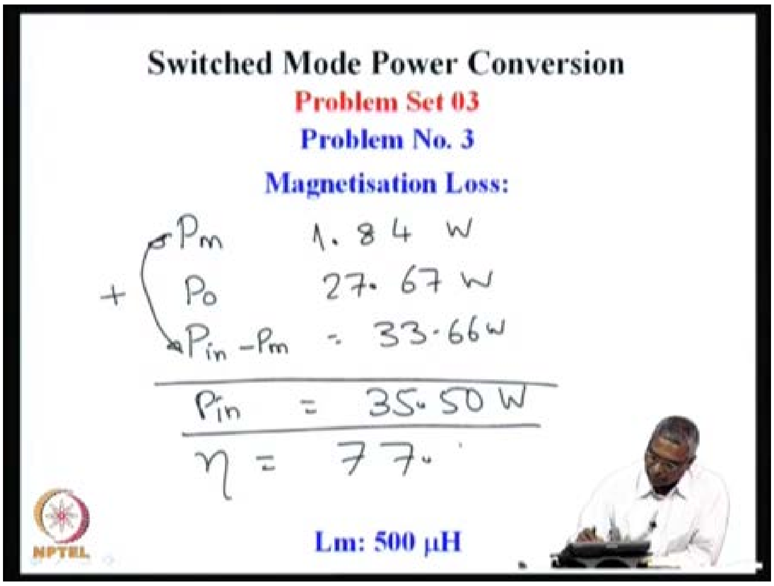

If you now go back we had seen that the magnetization loss itself is 1.84 watt. This is magnetization. P naught is 27.67 watts. Then P in minus magnetization loss is separately calculated, that was thirty 3.66 watts. Then taking/adding these two, we found out what is P in and that is 35.50watts. From this we calculated efficiency is 77.9 percent.

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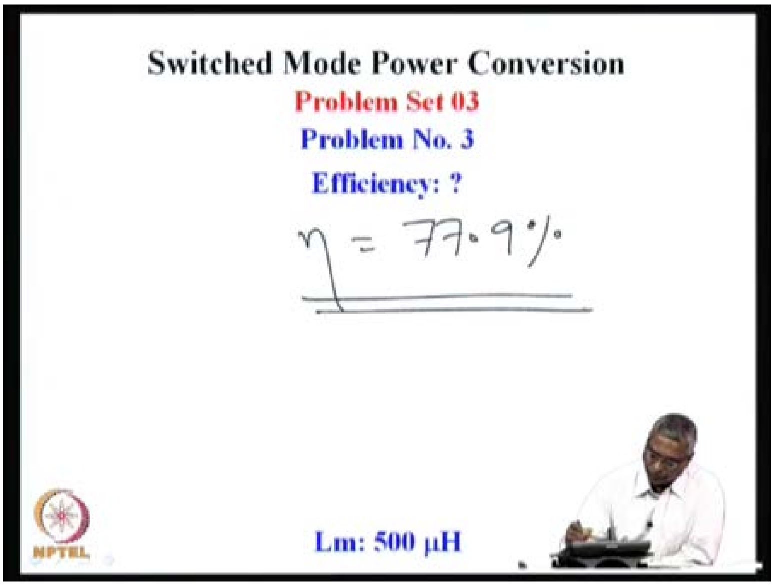

Efficiency calculated is 77.9 percent.

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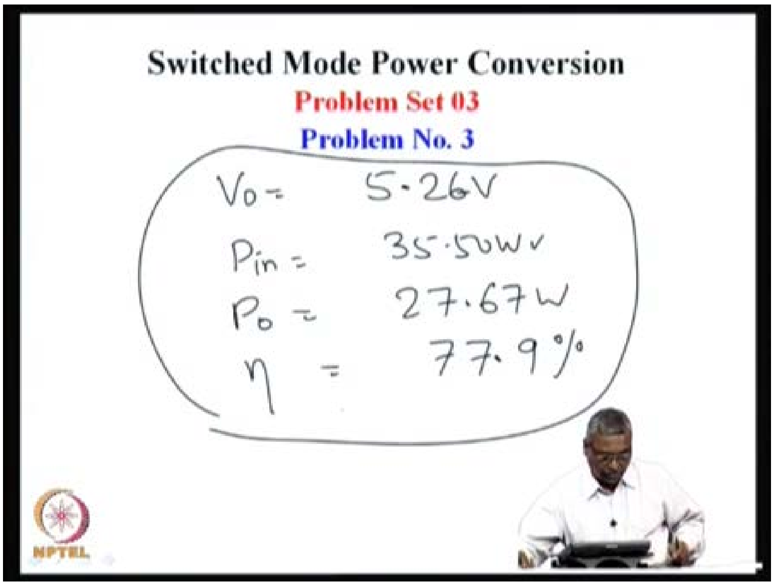

We saw all the quantities that we had solved; V naught was 5.26volts, P in is 35.50 watts, P naught is 27.67watts and efficiency is 77.9percent. So, this effectively is a our total solution. We are interested in the gain that has been calculated. We know; what is output power because we know the load, what the input power is, what are the losses, input power minus output power and what is the overall efficiency. Normally this efficiency this loss will appear as heat and which has to be handled in the converter.

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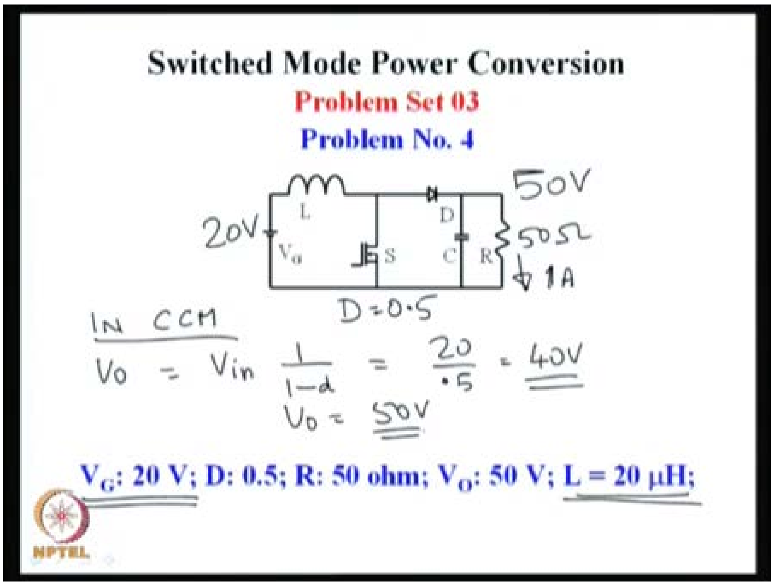

So let us look at another problem this is slightly different problem. It is shown as non isolated converter non isolated boost converter. It works from a source voltage of 20 volts, what you see here. It is delivering an output voltage of 50 volts, it operates with a duty ratio 0.5 and the resistance is 50 ohm load resistance is 50 ohm, so that the load current is 1 ampere. So, these are all known quantities and the inductor is given to be 20 micro Hendry. The first thing that we would like to know is, is this converter operating in CCM continuous current mode or discontinuous mode. This is a boost converter. It is operating with a duty ratio of 0.5. If the IN CCM continuous current mode output voltage is V in, input voltage multiplied by 1 by 1 minus d which is equal to 20 divided by .5 which is 40 volts. So, if the converter is operating in continuous current mode the output voltage should be 40volts.

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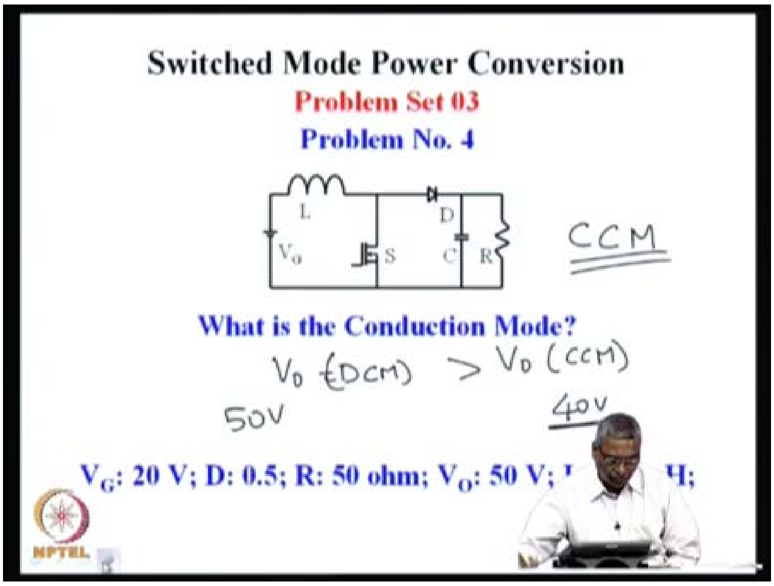

What we see here is an output voltage of 50 volts V naught is fifty volts, so it is possible now to evaluate whether the conduction mode is CCM or DCM. We know that V naught in DCM is always greater than V naught in CCM. So, clearly in this particular case the output voltage is 50 volts and the continuous mode output voltage is 40 volts. This being higher than the continuous mode voltage the converter is operating in CCM that is the first conclusion that we can make. The operating of the converter is such that the inductor current reaches 0 before the end of the cycle. The inductor current is not continuous, so let us see how the inductor current will look like.

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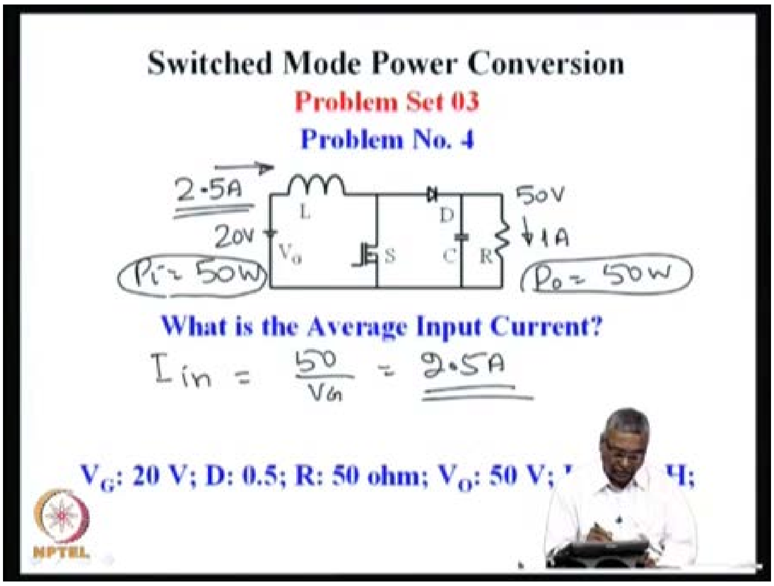

In this particular case we have output of 50 volts and 1 ampere and input is 20 volts. So, if we neglect all the losses P naught is 50 watts P i also will be 50 watts. If the input power is 50 watts then input voltage is 20 volts, we can say that the average input current will be 50 P naught divided by V g, which is 2.5 amperes. So, it is possible that we can calculate the average current here is 2.5 amperes and the output voltage is 50 volts. The input power, assuming that there are no losses in the converter all the components are ideal, the input power is same as output power. P i and P naught are equal and from that it is possible to find out what is the current drawn from the source. The average current is 2.5 amperes. The next thing that we would like to see is how the input current will look like.

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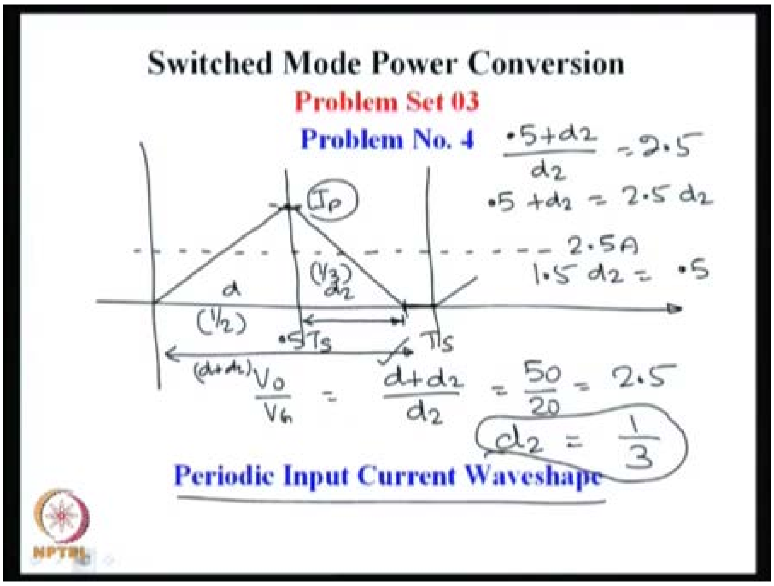

For example, the periodic input current wave shape is the next thing that we would like to see. You see that during the on time we have seen that our 0.5 into T s and this is T s during the on time the current increases and reaches peak value. Then because it is in discontinuous conduction it reaches 0 current even before the end of the cycle. Then current gain increases from this. So, the average current of this is 2.5amperes. The average current drawn from the source is 2.5 amperes.

It has a peak current here I peak and it has 0 at this. This duration is something what we can find out. For example, in the boost converter the ratio V naught by V g is also written, if this is d and if this is d 2 this ratio is given as d plus d 2 divided by d 2 and that is 50 by 20 which is 2.5. So, in this in this particular Equation d is known all other quantities are known. It is possible to find out d 2.

So, if we evaluate d 2 here we will find that 0.5 plus d 2 divided by d 2 is equal to 2.5. So, we can write this as 0.5 plus d 2 is equal to 2.5 d 2 or 1.5 d 2 is equal to 0.5 or we say d 2 is 1 by 3 so this is 1 by 2 and this is 1 by 3. So, for a fraction 1 by 2 of the cycle the inductor current keeps increasing. Following that for a fraction 1 by 3 of the cycle inductor current keeps falling and eventually it reaches 0 at the end of 1 half plus 1 by 3 of the duty ratio. So, this is the shape of the periodic current and we would like to know what this peak current is, I peak. So, we know that the average current is 2.5 the shape has a triangular shape and then followed by a zero region. So, this duration from here to here is d plus d 2 T s. If you take the average current it is…

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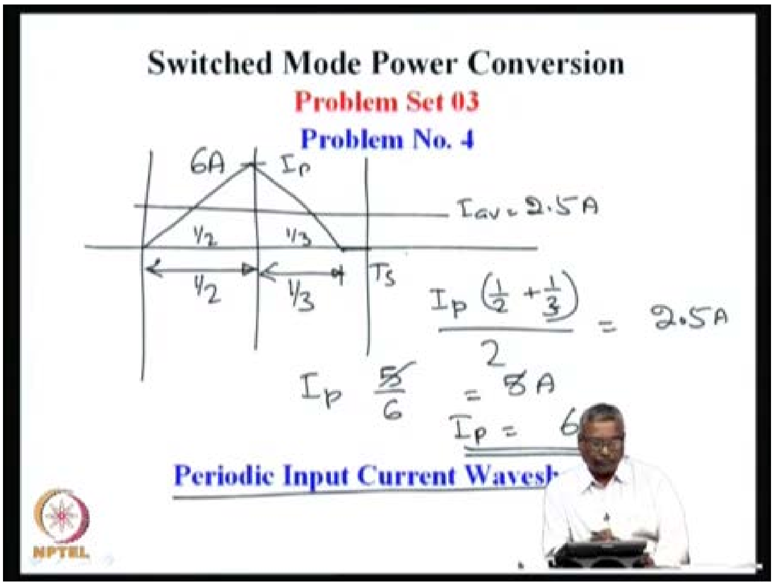

So, we will draw that again. This is I peak. This is I average, which is 2.5 amperes. This is 1 by 2. This is 1 by 3. So, if I take the average of the input current I p into 1 by 2 plus 1 by 3 and because it is a triangle current divided by 2 is the average and that is equal to 2.5 amperes. So, you can say that I p 1 by 2 plus 1 by 3 can be written as 5 by 6 is equal to 2 into 2.5 is 5 amperes or I p is equal to 6 amperes. So, the peak current here is 6 amperes. This duration is half the duty ratio and this duration is one third of the duty ratio. 1 cycle is T s. So, from applying these principles we also found out the periodic current shape and what the peak value is and so on.

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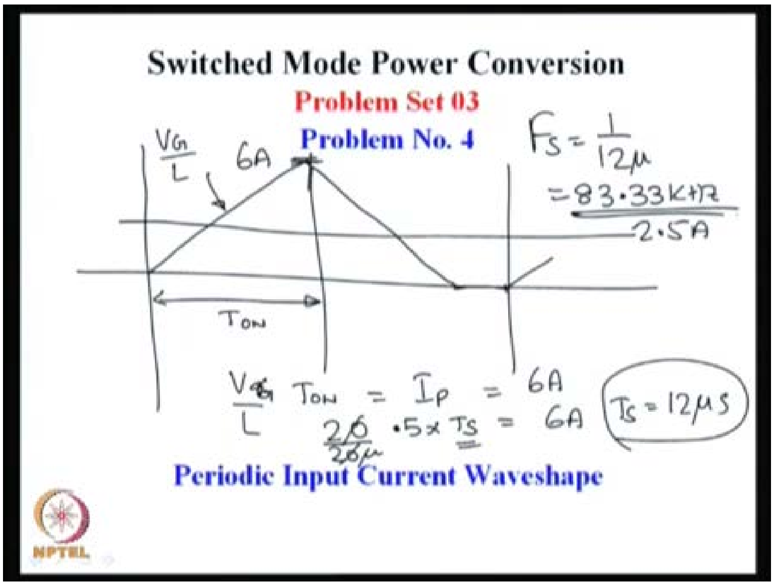

The next thing that we would like to know is at what frequency is this converter operating. Periodic current wave shape we had seen already. It has it goes up to 6. So, the average of that is 2.5 amperes. How is this 6 amperes obtained, it is the current reached during at the end of the on period. On period is T on and the slope of the current during that time is V g divided by l. So V g divided by l into T on.

This is the peak current and this is 6 amperes right. This can be written as 20 the voltage in this particular example is 20 volts divided by 20micro Hendry, inductor is 20 micro hendry into T on is 0.5 into T s this is equal to 6 amperes. So, here all quantities are known to us and the only unknown quantity is T s. So, we can write this as, take T s to the other side. 20 20, so T s is 6 by 0.5 12 micro second so from this equation we find out that the switching period is 12 micro second or the switching frequency is 1 by T s which will be 1 by 12 micro and that is 83, yeah 83.33 kilo hertz's. So, this is the switching period.

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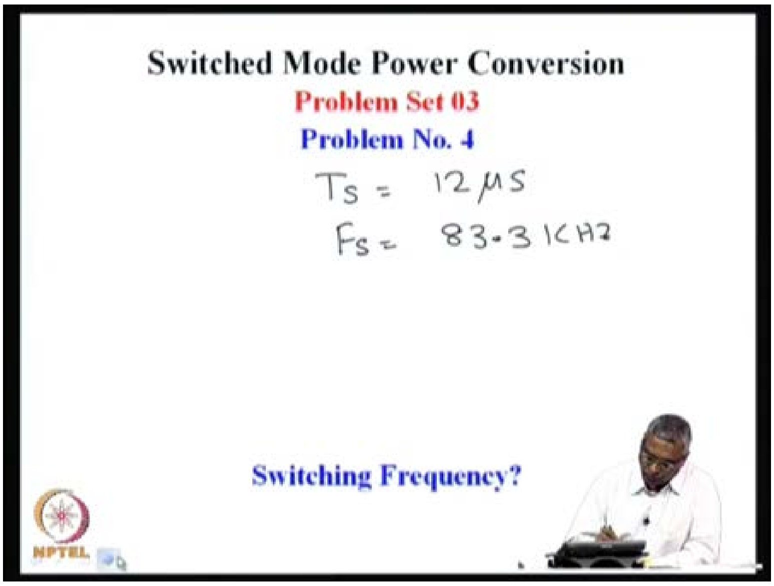

Another quantity that we would like to know, Switching frequency we have seen. Switching period is 12 micro second and switching frequencies is 83.3Kilo hertz's. So, the next thing…

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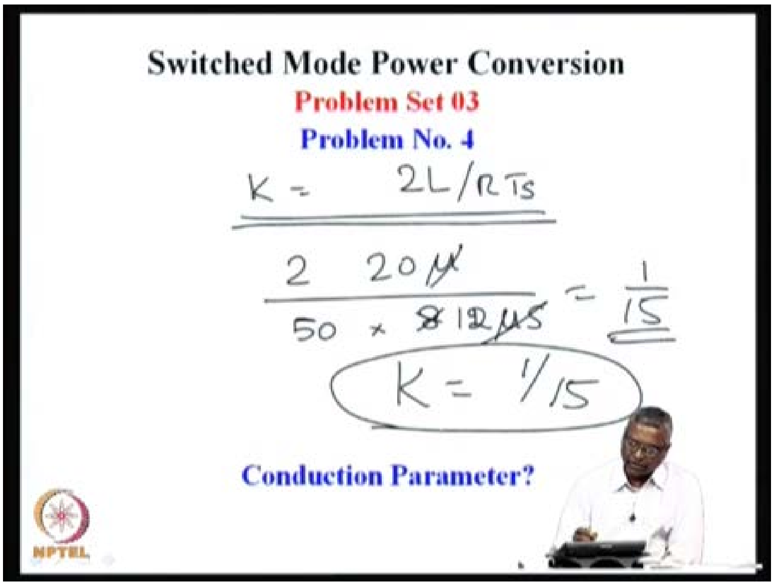

So the next thing that we would like to know is conduction parameter which is 2 L by R T s. So, this in all continuous conduction and discontinuous conduction analysis depends on the parameter conduction parameter of the converter. That quantity is given as the ratio of 2 L by R T s. In our case 2 inductor is 20 micro divided by R is 50 multiplied by

T s is 12 micro second and this quantity micro is gone, it is 40 by 40. 1 by 15. So, conduction parameter K is 1 by 15 and this is the reason why this converter is now right. Now in discontinuous conduction mode conduction parameters is very, very small. We have seen that if conduction parameter is more than this K critical in all these converters they will be operating always in continuous conduction, in this particular case…

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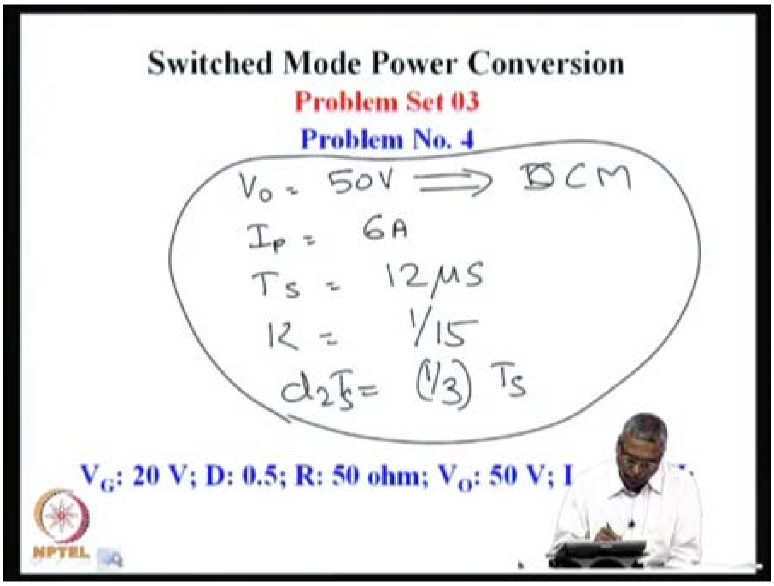

We have found that the output is 50 volts which was given so from that we said that operating condition is in DCM. Then we found that the peak current in the switch is 6 amperes. Then we were able to find out the switching period is 12micro second. Conduction parameter is 1 by 15. So, this and the d 2 which is the freewheeling diode on time is 1 by 3 times, is the ratio d 2 this is 1 by 3 times T s. So, by going through the principles of volt second balance and then the integration of the inductor voltage to find out the inductor current and then from the inductor current finding out the average current equating it for power balance using all the basic principles for this particular converter we were able to find out all the operating conditions. Let us see if we can move on to one more problem.

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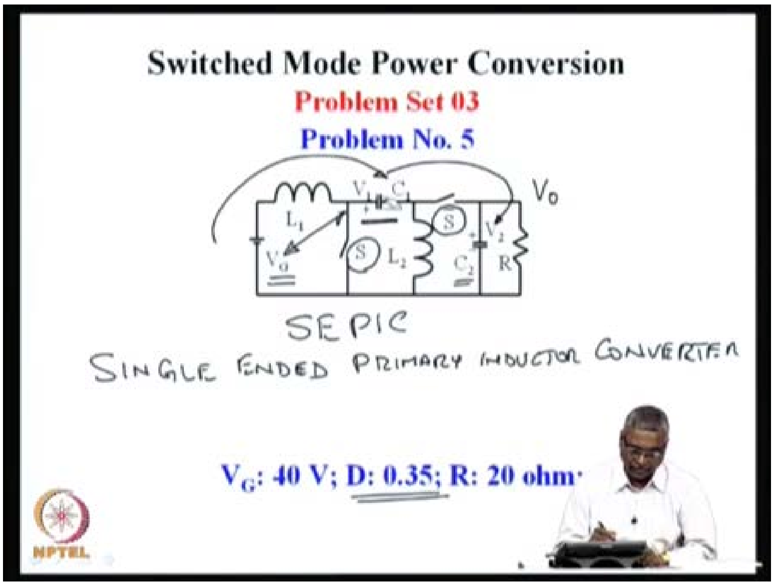

This is another simple problem. Here this is also a non isolated power converter the from the source voltage of V g we deliver our Output voltage of V naught. Now it consists of 2 switches S and S bar. S in on during the on time during this on time and S bar is on during the off time. It has totally 4 energy storage limits unlike the earlier ones that we had seen; it has L 1 L 2 C 1 C 2 and then finally, the load which is receiving the power. This particular converter has a special name called Sepic converter that is single ended. Single ended because one end is common, single ended primary inductor. So, this name Sepic converter has come from this long name single ended primary inductor. There is an inductor at the input side.

This has an advantage because of the presence of this inductor input current is continuous. So in such a converter again we might apply the same principles of volt second balance and find out the relationship between V 1 to V g and similarly, V 2 to V g and so on. We have 2 inductors and we can apply the volt second balance on each one of them. For example, if we apply the volt second balance on L 2 that will relate the V 1 to V 2. So, we can get the relationship between the voltage on capacitors C 1 and voltage on capacitor 2 by applying the volt second balance on L 2. Then if you apply the volt second balance in L 1 we can find out the relationship between V g and V 1, how the source voltage is related to the capacitor voltage V 1 capacitor 1.

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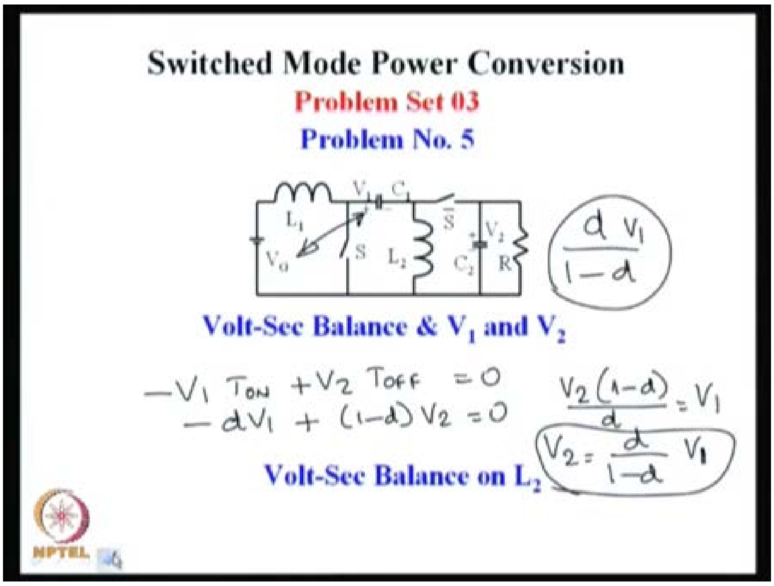

So, let us see if we can do these quantities volt second balance and V 1 and V 2. We will do all this. So, during the on time when this switch is on L 2 is facing the voltage V 1 with the minus sign. So, minus V 1 into T on is voltage across the inductor and when this switch is open and S bar is closed, V 2 is supplied across L 2 and that is plus V 2 into T off is equal to zero. We can write this as if you divide everywhere by T s it will be minus d times V 1 plus 1 minus d times V 2 is equal to zero or we can say that V 2 into 1 minus d divided by d is equal to V 1 or V 2 is equal to d by 1 minus d into V 1. So, the conversion factor, ideal conversion factor for this converter is d by 1 minus d V naught by V g is a sorry V 2. Now, we have to establish the relationship between V g and V 1, so this is volt second balance L 2.

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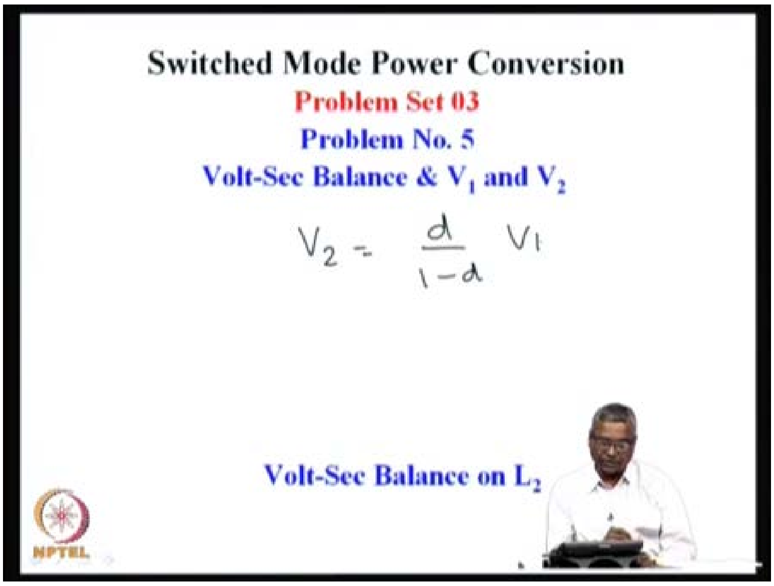

So, let us yes this is done and we know that V 2 is d by one minus d times V 1, this is the first relationship.

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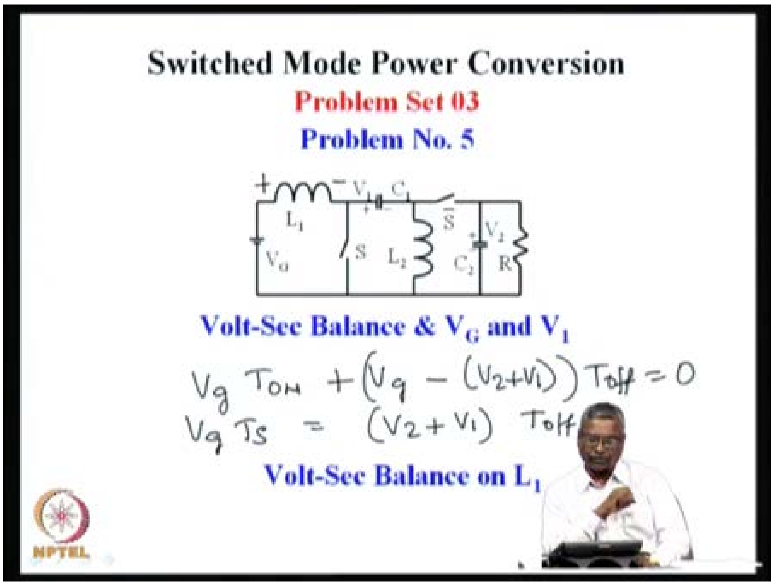

So we can now do the volt second balance on the L 1 and this is when the switch is on. V g is what is applied across L 1 with plus on this side and minus on this side. So V g into T on is the voltage across the inductor and then plus. When this switch is off the voltage across this inductor is V g on one side. On the other side because this is also close now it is V 2 plus V 1 V g minus V 2 plus V 1 into T off is equal to 0. So, you can say that V g into T s is this first term, is equal to V 2 plus V 1 into T off V 2 plus V 1 is taken out to that side.

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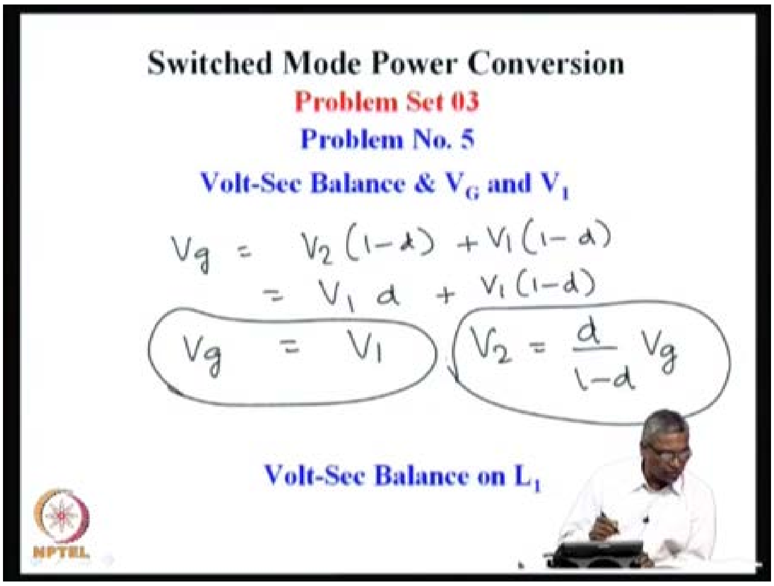

So that term you can write this as V g is equal to V 2 into 1 minus d plus V 1 into 1 minus d, so V 2 itself is V 1 times d by one minus d. So, this becomes V 1 into d plus V 1 into one minus d that is equal to V 1. So, what we find is the capacitor V 1 voltage is a same as V g and capacitor V 2 voltage is d by one minus d time V 1i which is the same as V g. So, this is our total volt second balance condition. So, if we wish to…

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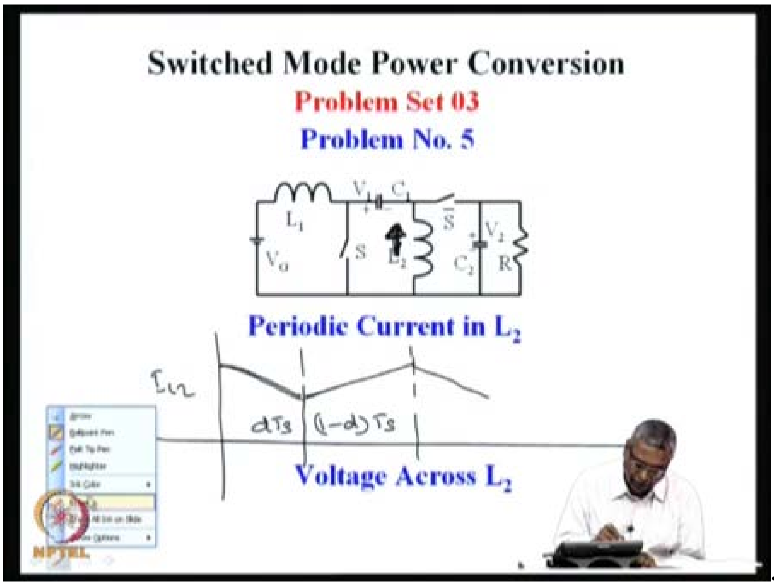

Now see how the periodic current in L 2 will be L 2 as a current because L 2 has the voltage V 1 with a negative as shown here. When this switch is closed minus V 1 is applied to inductor during the on time so you will find that the Inductor current will be falling down during that time. Then during the next time an S bar is no inductor voltage will be rising so inductor voltage will fall during the on time for L 2, this is L 2. This is d T s 1 minus d t.

So when the switch S is on the capacitor V 1 voltage which is same as V g is applied reverse to L 2, so L 2 current starts dropping. During the time S bar is on V 2 voltage, which is plus on the top is applied to the inductor. So, inductor current starts rising. Ok! In this way here inductor current is in this. So, when the switch is on inductor current is rising in there polarity shown here with arrow and when the switch is off it is going in the other, it is in this polarity it will be falling.

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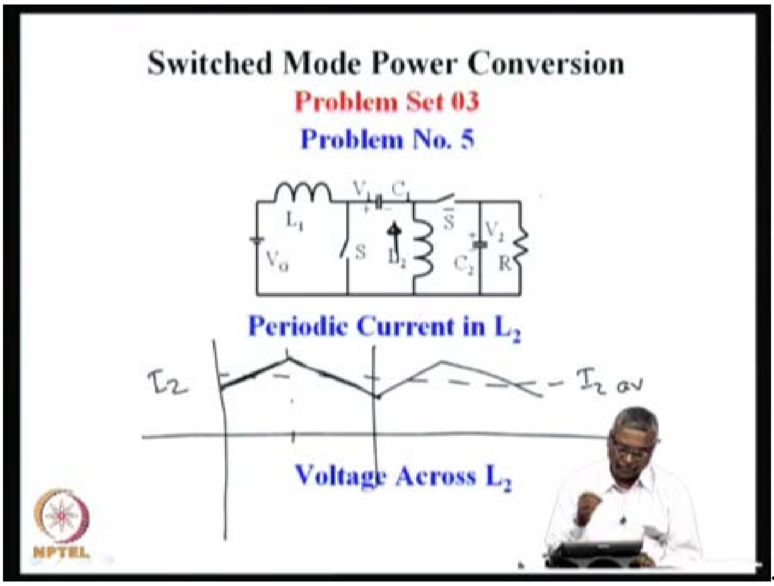

Let me draw that correctly these on this. So, the inductor current now I will show in this polarity in this direction. This is a direction of the current. It will go and charge this. So, in that direction negative voltage is supplied to L 2. L 2 current will be rising in the direction that is shown here will rising and during the next interval it will be falling during the time. It is the cycle goes on. So, this will be the I 2 current and this is I 2 average, average current in the inductor. So, the voltage across the inductor L 2 has V g on one side and V naught on the other side.

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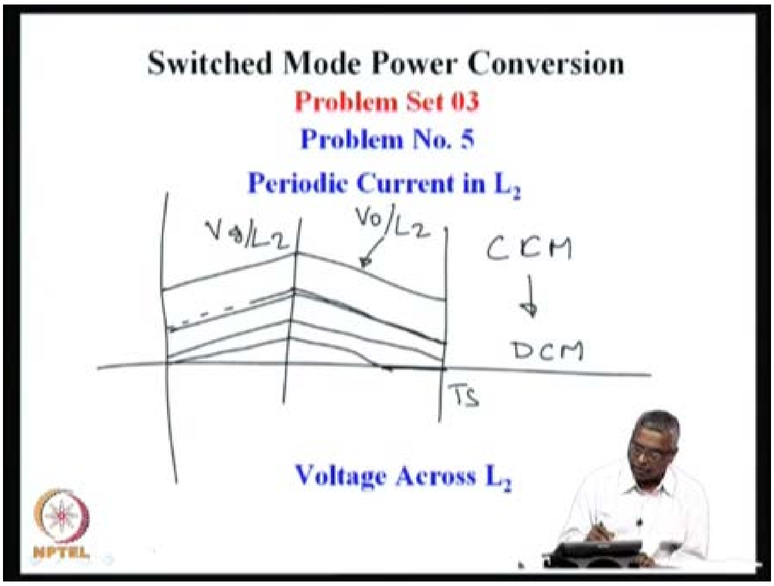

So, let us see the next periodic current in L 2, has rising time which is V g by L and a falling time which is V naught by L 2. Now, if the load is decreased in the convertor, this current will keep dropping and eventually it will reach discontinues conduction. As you move as the current keeps coming down eventually the convertor go into discontinues conduction mode.

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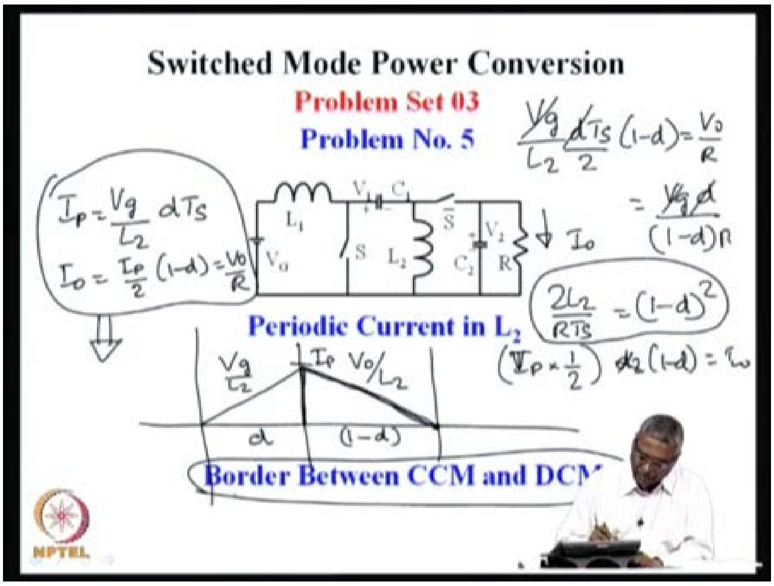

So, in discontinues conduction mod or in the border between continues conduction and discontinues conduction you will find that the rise in the inductor current and fall in the inductor current V g by L 2 and V naught by L 2. They both will be finally, it will reach zero condition and the output average current the inductor current during S bar is only contributing average current. If you call this as d and this as 1 minus d then the peak current I peak, I peak into 1 by 2 into d 2 or 1 minus d if it is in the border, this will be equal to the output current I naught. Output current this is going into these. So, from this it is possible to find out.

Let us see how this particular quantity is carried out the peak current. This I peak can be calculated to be V g by L 2 into d T s. So, this is I peak and I naught which is output current which is I peak by 2 into 1 minus d is equal to V naught by R. This is I naught which is V naught by R. So, from this quantities it is possible to say that on the border of continuous and discontinuous conduction the output current V naught by R equal to I p by 2 into 1 minus d. So, if I now substitute I p from here you will find that V g by L 2 d T s divided by 2 into 1 minus d is equal to V naught by R and V naught itself is V g into d by 1 minus d R. So, from this two by combining by substituting I p, we have put that d will cancel with that V g will cancel and we find that 2 L 2 by R T s is equal to 1 minus d whole square. So, this is the condition for the operation to be on the border between CCM and DCM.

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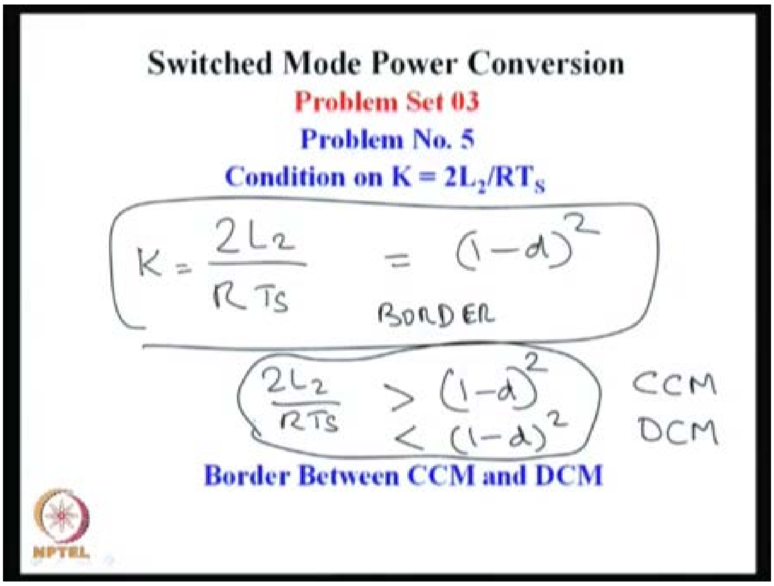

We can say that the condition 2 L 2 by R T s, this is called the conduction parameters in all these converters, this K is equal to 1 minus d whole square. So, if this is true, then we will find that the operation is on the border between continuous conduction and discontinuous conduction. If this 2 L 2 by R T s is greater than 1 minus d whole square then conduction is continuous and if it is less than 1 minus d whole square conduction is discontinuous. If it is equal to 1 minus d Whole Square, then that is the border case. So in peak converter also just like fly back converter this border between continuous and discontinuous conduction equation is identical.

This relationship between conduction parameter and duty ratio is identical say in peak converter plus the fly back converter. So, with this set of problems we have now demonstrated to ourselves that; using the old second balance, finding out the voltage across the inductors, current through the inductors, average currents, the ideal voltage to voltage gain and ideal current to current gain. We know that ideally when there are no losses forward voltage gain is same as reverse current gain.

We have also seen that it is possible; to incorporate the losses in the converter, find out how the voltage gain changes, how the converter losses can be represented through the efficiency of the converter and so on. So, in the following lectures we will get on to develop dynamic models for these converters. We will stop with this on the steady state performance on the converters. In the coming lectures, we will try to understand the dynamic operation of the converter, the mathematical model and to analyze the converter during the tarsiers.