Switched Mode Power Conversion
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Lecture - 17
Problem set – I

Good day to all of you. In today's lecture we will look at the selected problems in power conversion circuits. In the past 3 or 4 lectures we had been looking at the study state analysis of power conversion circuits by making certain assumptions of ideal operation of the switches ideal performance of all the energy storage elements. With these ideal conditions, we develop the principle of volt second balance on inductors and charged balance on capacitors. Using these basic principles under ideal operating conditions we found out how this power conversion circuits where performing.

We found out what is the voltage conversion ratio of different power converters. If certain input voltage Vg is given to a power conversion circuit, which is operating with switches operating with certain duty ratios. Then how this input voltage V g got converted to some other voltage and delivered to the load as we out output voltage. The ratio of output voltage to input voltage is one of the important parameters in the power conversion circuits. Similarly, if certain current is drawn from a power converter at the output, how does it reflect on the input source of the power converter circuit? I g the source current divided by I naught or the output current.

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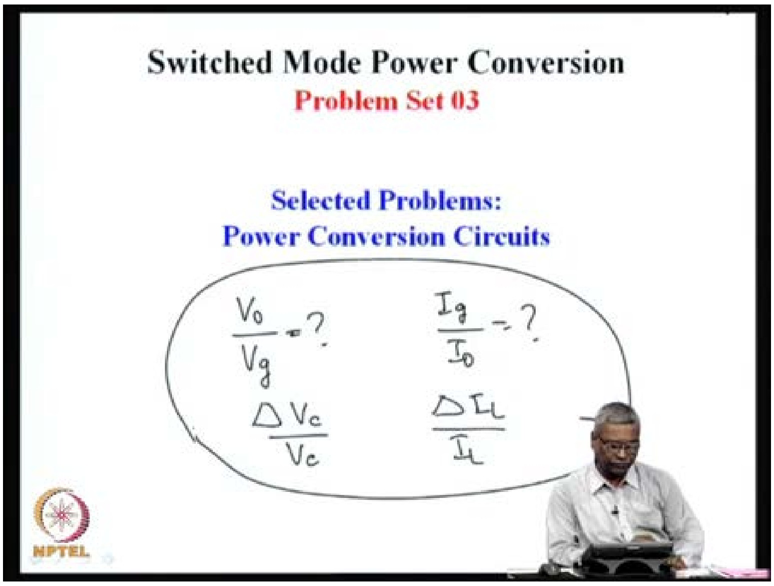

We said V naught by Vg is one of the important conversion factors in the power converter, it is called the forward voltage conversion ratio. Similarly, Ig by I naught, which is called the inverse current conversion ratio, we saw how these quantities can be evaluated based on the idealized operating conditions. We invoke the principle of volt second balance and charged balance on the electromagnetic energy storage element inductors on electrostatic energy storage elements capacitors. So, in this section today we will practice, how we will apply these principles to find out the different conversion ratios of power converters.

We also saw that under study state this converters also were not converting the voltage perfectly to DC, but there was some over ripple voltage an AC ripple present on the capacitor voltages. Similarly, AC ripple present on the inductor currents and this ripple calculation also is a one of the important performance index of the power converters. So, in today's session we will we will try to take several power converter circuits and try to apply the principle of volt second balance and charged balance and evaluate under ideal conditions. What is the voltage conversion ratio? What is the current conversion ratio? Similarly, what are these voltage ripple quantities? Current ripple quantities are alternately if these ripple quantities are specified what is the value of inductors, and capacitors to be used in a circuit and so on.

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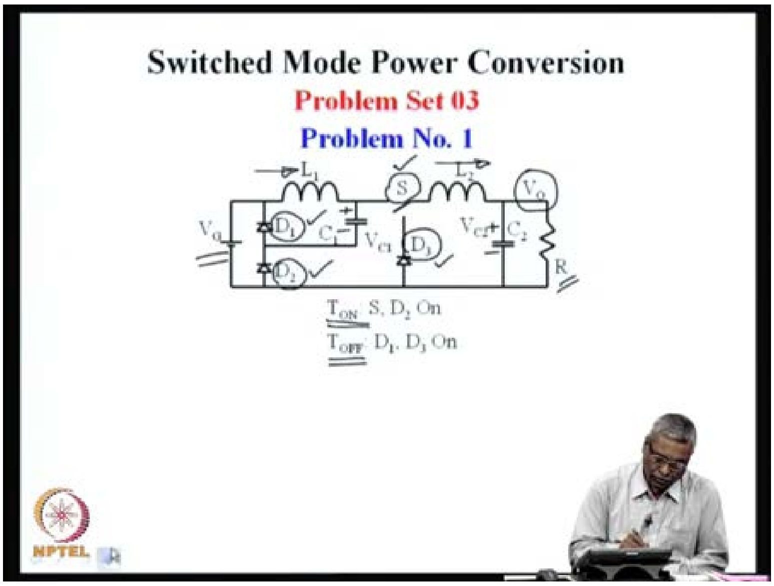

This is the problem set which would like to see first you will notice that there is a source which is V G and to the load resistive load a voltage of V naught is delivered by this power conversion circuit. The power conversion circuit has an active switch and several passive switches D1, D2 and D3. During the on time of a switching cycle which is T ON the switch S and the switch D2 are on and during the off time of a switching cycle the diode D1 and the diode D3 are on.

So, this is the operating condition and it has two energy storage inductors L1 and L2 and two energy storage capacitors C1 and C2. The inductor currents may be called I L 1 and I L 2 under steady state. The capacitor voltages may be V C 1 and V C 2 under steady state. So, our concern, now is to analyze this circuit using the volt second balance principle and the charged balance principle and evaluate the power conversion ratio and so on.

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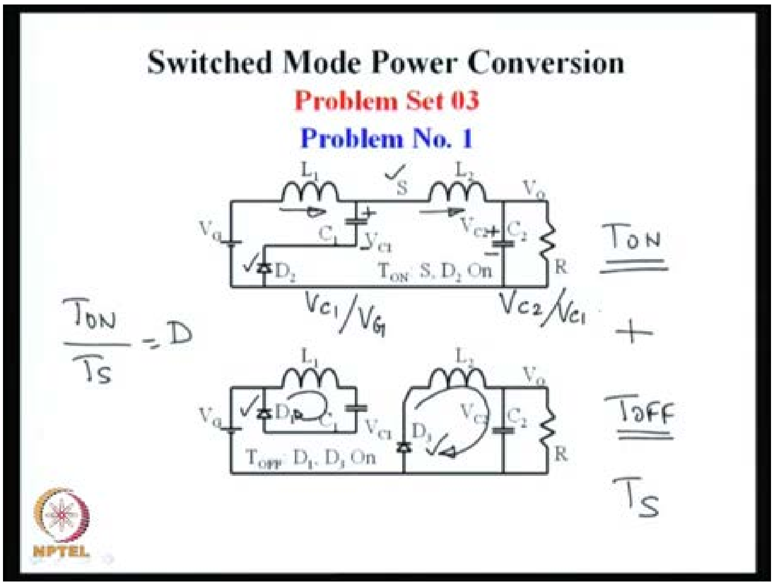

So, we can see that this circuit operates in two different sub cycles. We will call this as T ON and T OFF in every cycle there is one interval know as T ON and one interval know as T OFF and the total cycle T ON plus T OFF is equal to T S, which is one cycle time. This ratio of T ON by T S is normally defined as the duty ratio of the convertor D. So, during the on time D 2 is on and S is on power now is flowing from the source to the load inductor is L 1 having a current of I 1 and L 2 having a current of I 2. This capacitor V C 1 as a voltage of V C capacitor C 1 as a voltage of V C 1 and capacitor C 2 has the voltage of V C 2 under steady state condition.

Now, during the of time the switch S is off and the D 2 is off and instead D 1 and D 3 are on the circuit conditions, now are L 1 C 1 D 1 form the closed path for the current, D 3 L 2 V C 2 form a closed path for the current. Now, in this particular situation we are interested in finding out what is the relationship between V C 1 and V G that is what is the conversion ratio V C 1 to V G under steady state? On the output side what is the conversion ratio V C 2 by V C 1 under steady state. Now, these quantities can be evaluated by applying the principle of volt second balance on each of the inductors L 1 and L 2 one by one.

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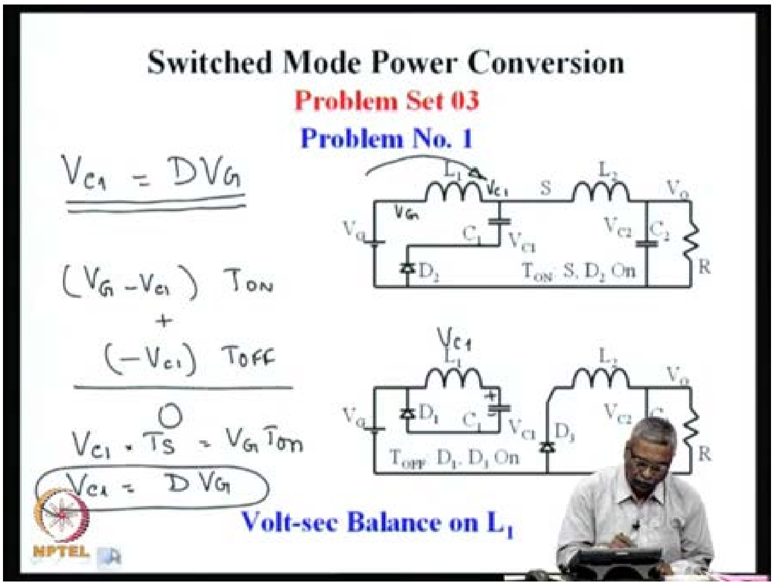

So, you might see that on L 1 on the inductor L 1. It is possible to apply the volt second balance for example, the L 1 as a voltage of V G on this side and V C 1 on this side during the on time and during the off time the voltage is simply plus minus V C 1. So, we might say volt second balance on L 1 as V G minus V C 1 multiplied by T ON plus in the OFF time it as only V C 1. But with minus on this side and plus on that side into T OFF this sum is equal to 0. So, from this it is possible to find out the condition that V C 1 into T ON plus T OFF is T S is equal to V G into T ON or we say that V C 1 is D times V G.

So, this is the first relationship, when we apply volt second balance on L 1 we find the condition that the capacitor voltage V C 1 is, now D times V G. Under steady state this should be the relationship of voltage conversion that takes place in the first stage of the power conversion V G to V C 1 and that is what we see here. Now, we can find out again if we apply volt second balance on L 2, we will be able to find out the relationship from V C 1 to from V C 1 to V C 2 for example, during the T ON time the voltage on L 1 is V C 1 on the left hand side and V C 2 on right hand side multiplied by T ON.

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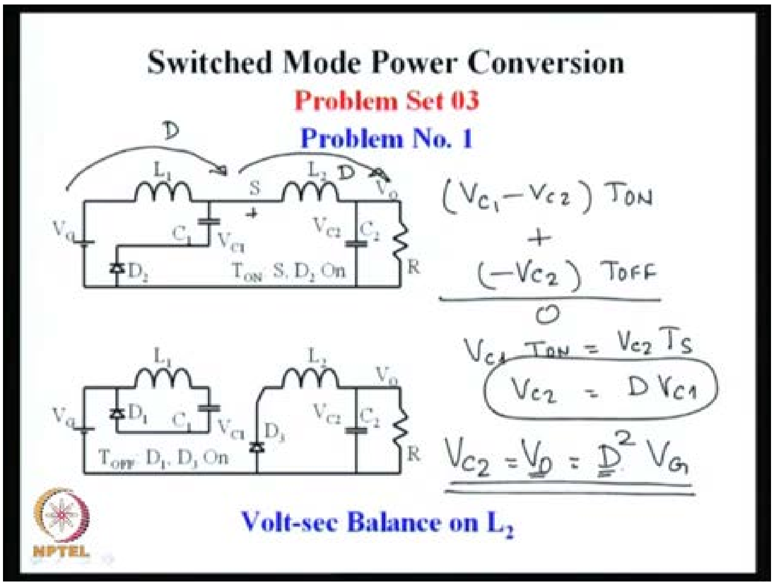

So, that is the volt second during the on time plus during the off time this end is 0 this end is V C 2 you might say that minus V C 2 into T OFF. If both these are over one cycle if this is added and equated to 0 then we find that V C 1 into T ON is equal to V C 2 into T S or V C 2 is equal to D times V C 1. So, this is the second relationship by applying the volt second balance on L 2, now we find that the voltage conversion ratio from V C 1 to V C 2 is D and from V G to V C 1 is D or we can say that V C 2, which is the output voltage, which is same has V naught is D square times V G.

So, this is really a two stage buck converter there is one stage of D times V G in the first L and C and there is another stage of D times V C 1 between L 2 and C 2 and effectively the output voltage is D square times V G. This particular converter is also called quadratic converter because the output voltage is square times, square of the duty ratio times the input voltage. This is a quadratic converter because output voltage is a square function of the duty ratio and like this simple buck converter.

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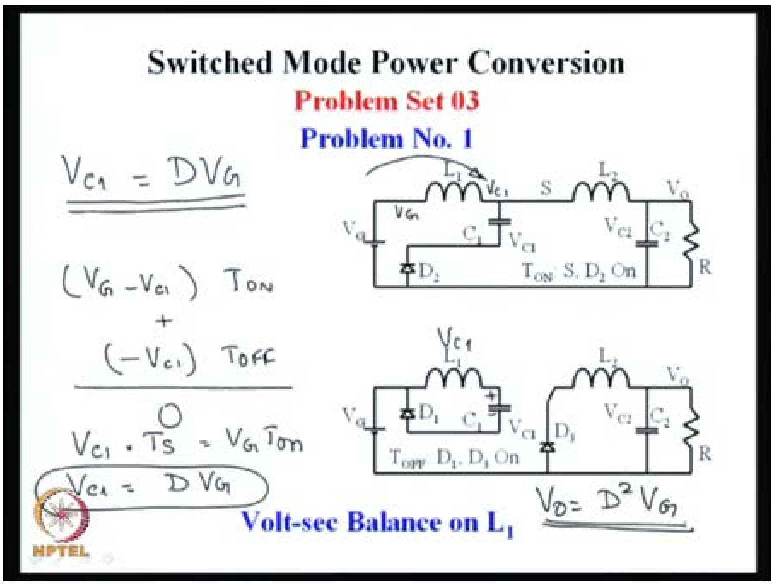

So, we might say that in this converter our V naught is D square times V G. So, this is the first operating condition on the power converter.

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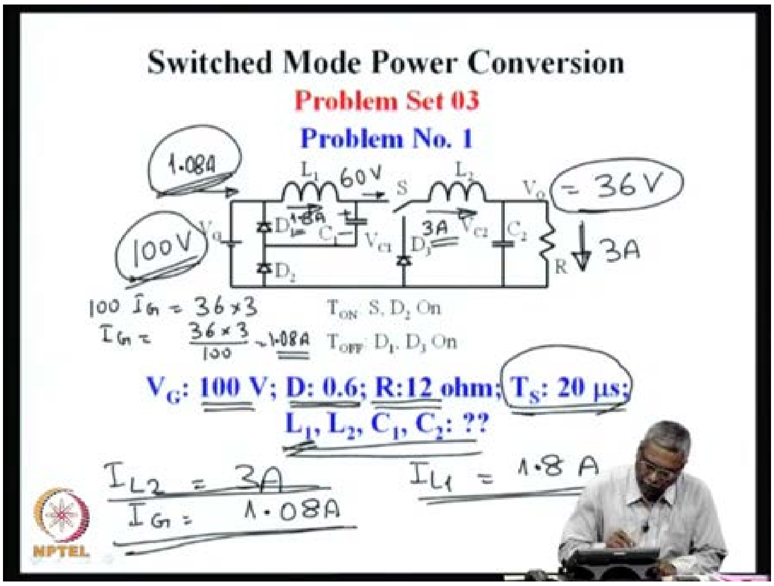

What is the forward power conversion ratio? Now, in this supposing if V G is 100 volts and duty ratio is 0.6. We can say that the output V naught will be D square times input D square is 0.6 into 0.6, which is 0.36. 0.36 into 100 is 36 volts, so in this particular example when the input voltage is 100 volts duty ratio is 0.6 the output voltage ideally will be 36 and with the resistance of 12 ohms the output current will be 3 amperes. So, we have a power converter, now which takes in 100 volts at the input operates certain duty ratio of 0.6 produces 36 volts ideally at the output and delivers on a 12 ohms resistor 3 amperes of current.

If we further specify that this converter operates with the duty ratio with a switching period of 20 micro second it is possible for us to calculate what will be the required value of L 1 L 2 C 1 C 2 and so on. Isolate with this specified period of switching at 20 micro second, let us find out what will be the required value of L 1 what will be the required value of L 2 and so on. We have assumed that all the switches are ideal, it means there are no loses in the converter. If that is, so then we might also say that the input power is the same as the output power.

So, we might say that 100 times I G is equal to 36 times 3 amperes the output power is V into I that is 6 into 3 input power is V G into I G. So, from this we can say that the input current I G average current will be 36 into 3 divided by 100 there is 1.08 amperes. So, what we might say is that the average current drawn from the this convertor is 1.08 amperes. Here one can see at the inductor the output current 3 amperes, also as to come from the inductor L 2 because C t2wo does not supply any DC current. So, the DC current on L 2 will be the same as the output current. So, this will be 3 amperes.

Then these 3 amperes is coming out from this branch for duration of duty ratio 0.6. So, might say that the average current of L 1 will be this 3 multiplied by this 0.6, which is 1.8 amperes. So, we might say that I L 2 is 3 amperes same as I naught and I L 1 is 3 amperes into 0.6, which is 0.8 amperes and I G is 0.6 into 1.8, which is 1.08 amperes. 0.6 multiplied by 1.8 is 1.08 amperes, which the same as this current. So, by the assumption of volt second balance and ampere second balance on the capacitors, we have now managed to find out all the average currents in the inductors and the voltage ratios.

For a 100 volt input we get a 36 volts, at this point and this capacitor will be 60 volts 0.6 into 100 is the first stage conversation. So, V C 1 has a voltage of 60 volts V C 2 has a voltage of 36 volts input voltage is 100 output current is 3 amperes the inductor first inductor current is 3 amperes the input inductor current is 1.8 amperes and input average current is 1.08 amperes. all this we are able to do by applying by invoking the condition of volt second balance on the inductor and the ampere seconds balance on the capacitor.

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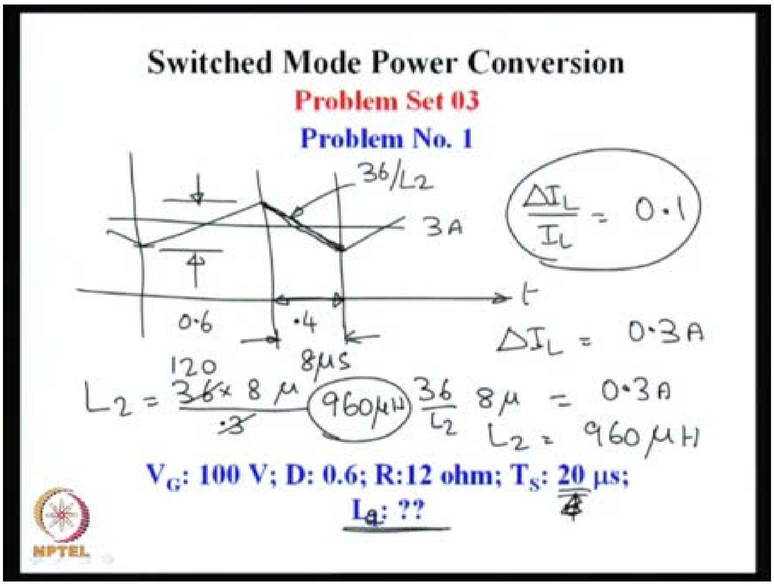

Now let us look at the conditions to find out what will be L 1 for example, we had seen that I L 1 in any cycle where duty ratio is 0.6 times T S half times is 0.4 times T S and the inductor as a average current of 3 amperes. So, we know that during the on time the inductor current increases and during the off time inductor current decreases. So, this is a our steady state inductor current and inductor has a repeal current of certain value. So, if we assume this delta L by I L as 10 percent 0.1 then we can say that delta I l is 0.3 amperes.

Because I L is 3 amperes delta I L will be 0.3 amperes and this half period is when the inductor as a D I by D T of output voltage V naught divided by L 2 36 by L 2 and this half duration is 20 micro second multiplied by 0.4 which is 8 micro second. So, in this triangle the slope is 36 by L 2 duration is 8 micro second and this D I by D T into time is delta I, which is 0.3 amperes. So, from this one can say L 2 will be 36 into 8 micro divided by 0.3, so this would be 120, 36 by 0.3 is 120.

So, this would be 960 microhenry our L 2 that is the secondary the output side inductor current L 2 will have a value of 960 microhenry. This is obtained by finding out what is the D I by D T during the off time what is the duration of the off time and we assumed repeal current which is 10 percent of the total current. In the same way it is possible for us to find out the repeal current on the input side inductor.

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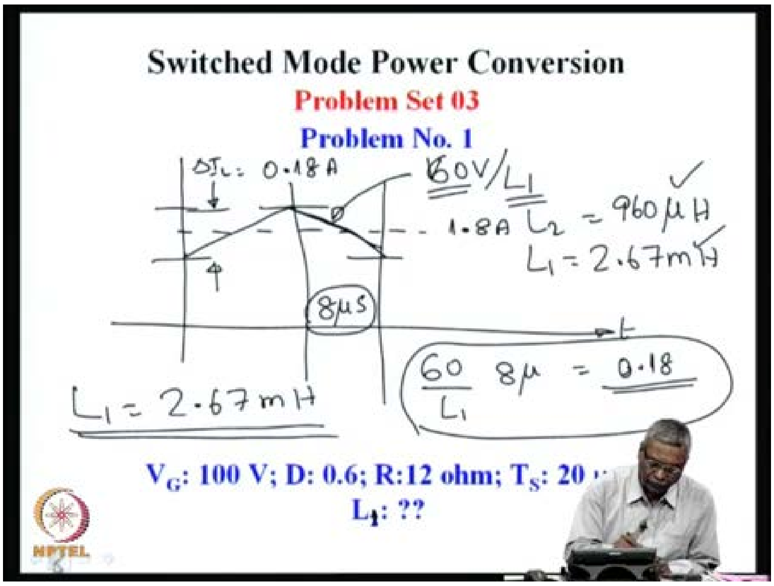

We know that the input side inductor also follows the similar kind of on time, off time current is increasing, decreasing and this current on the input side inductor is 1.8 amperes. So, we might put a condition that this delta I L is 10 percent of that, which is 0.18 amperes, if delta I L is 0.18 amperes then during the off time the inductor faces voltage of 60 volts in inductor value is L 160 volts divided by L 1 and duration is 8 micro second. So, we might say that 60 by L 1 into 8 micro is equal to 0.18, so from this L 1 can be calculated to be 60 into 0.8, 60 into 8 divided by 0.18, 60 which is 2.67 millehenry.

Now, the same principle was applied, we found out want is the D I by D T during the off time. What is the voltage across the inductor? The D I by D T is V by L and during the off period is inductor is losing that voltage, so the total current repel is taken to be 10 percent of the average current and by finding out the relationship between these two V by L into T is equal to delta I.

We are able to find out what is L 1 in this particular example we find that L 1 is 2.67 millehenry and L 2 second inductance is 960 microhenry. The same principles of the circuit equation L D I by D T equal to V is what is used and during off time the L D I by D T is the same as the output voltage. From that equation we are able to find out what is the relationship between the L and delta I and by forcing delta I to be 10 percent of the total current the inductor average current we are able evaluate the value of inductor. By applying these principles we have found out what is a value of N, and what is a value of L 2.

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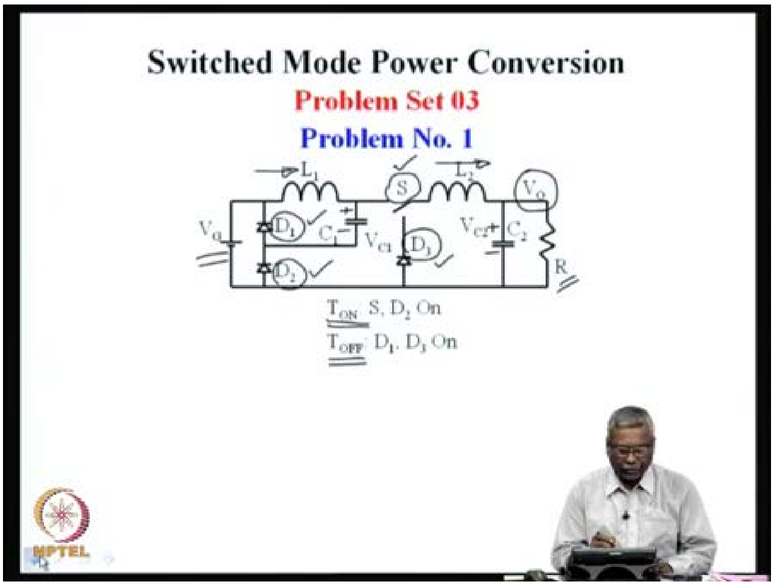

So, if we go back again to the problem set as we had given, we are able to find out what is the voltage conversation ratio. From the input to the output what are in the currents in the various inductors? What are voltages in the various capacitors? Then by forcing the condition of current repel to be 10 percent. We are able to also find out what could be the value of the required conductors in the inductors has a next measure, what we will do is by forcing the voltage on the capacitor to be certain percentage. We can find out what is the value of the capacitor C 2? And what is the value of the capacitor C 1.

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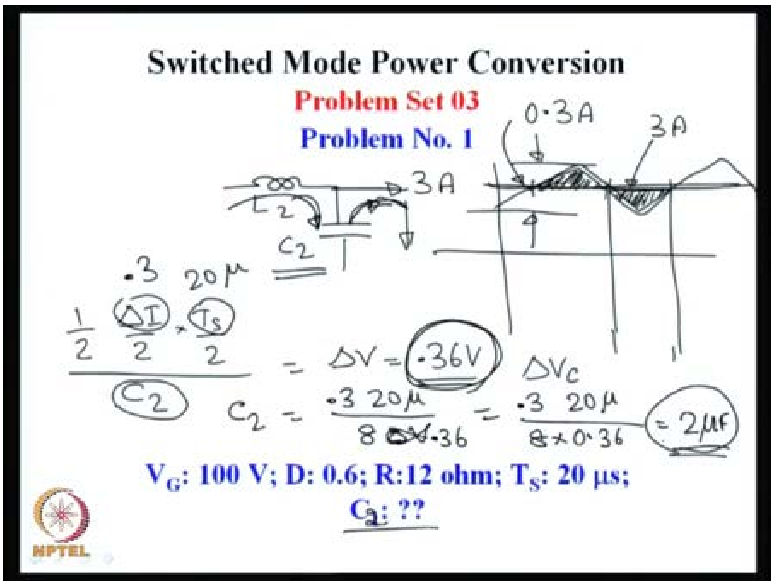

Let us come back again to the circuit condition we have the inductor L 2 capacitor C 2 and here we drawing a current of 3 amperes. So, we see that the inductor current is varying between minimum and maximum and this repel current is 0.3 amperes and the average current is 3 amperes. So, in this particular example if the output current is exactly 3 amperes then what we see here the current above the DC current is the current going into the capacitor. What we see here the current below the DC current output current is the current coming out of the capacitor.

So, if we know what is a current going into the capacitor or what is the current coming out of the capacitor, it is possible to find out we will be delta V C. Because this is the current which is discharging from the capacitor and this is the current which is charging from the capacitor. And if we find out the charge into the capacitor which is nothing but delta I by 2, which is the height of this rectangle into T S by 2 which is the base of this triangle into 1 by 2 this is the total quantity of the charge that divided by C 2 is delta V.

So, I might put a condition that delta V is 1 percent of the output voltage, which is 0.36 volts output volt is 36 volts 1 percent of that 36 volts is 0.36 volts. Now, this equation all the quantities are known except C 2. We know that delta I is 0.3 T S is 20 micro. So, it is possible, now to write C 2 as 8 into delta V in the denominator and delta I is 0.3 and T S is 20 micro. So, if this simplified and delta V is 0.36, so this simplified 0.3, 20 micro divided by 8 into 0.36, which is 0.3 into 20 micro divided by 8 divided by 0.36 so that is 2 micro per head.

So, what I need at the output of the convertor is a capacitor C 2 which has a value of 2 micro per head, so that the output repel voltage is fine 36 volts. So, what we have used in this relationship, in this particular evaluation we have found out C 2 in this evaluation is the amount of charge coming into the capacitor during the on time and the amount of charge going out of the capacitor during the off time. We take anyone of them the charging current is the top triangle or the discharging current, which is the bottom triangle. Find out the total charge that is either going into the capacitor or coming out of the capacitor, use the relationship that Q by C is V for this application

From that if we know what is delta V the charge that is going into the capacitor. We are able to evaluate the value of the output capacitance C 2. So, in this particular example we need a capacitance C 2 of 2 micro per head if further go in, it is possible to find out next c one capacitance, also this is a little more different in the sense if you see the equivalent circuit this is C 1 which has a voltage of 60 volts.

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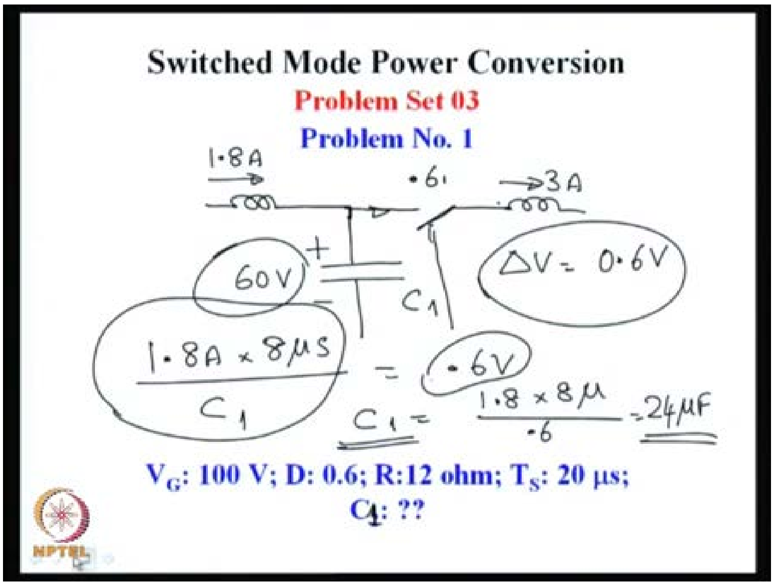

So, we might say that we would tolerate a voltage ripple of 1 percent which is 0.6 volts. Now, in this circuit we know that this capacitor has on this side an inductor, which is giving a continuous current of 1.8 amperes. The continuous current coming on the input side inductor is 1.8 amperes, but on this side we know that there is a switch which turns on with the duty ratio of 0.6 amp 0.6 and the current of 3 amperes this is equivalent circuit seen from the node of that capacitor.

So, what we see, now is that this 0.6 into 3 is the average current going out here that average current is the same as the average inductor current. So, that there is no net average current in C 1, but during the time this inductor is this switch is open where the inductor current is free willing this entire 1.8 amperes is flowing into the capacitors C 1. So, you might say that the charge going into C 1 is 1.8 amperes multiplied by the off time.

Off time is 0.4 into 20 micro second which is 8 micro second on time of this is 0.6 into 10 micro second 20 micro second off time is this amount of charge is going into the capacitor is 1.8 into 8 micro second this divided by C 1 is the ripple voltage and ripple voltage is 0.6 volts. Now, from this C 1 can be calculated to be 1.8 into 8 micro divided by 0.6 that is 3 into 824 micro per head. So, you can see that this is 1.8 into 8 divided by 0.6, which is 24 micro per head.

So, in this particular example, if we wish to keep the voltage ripple at 0.6 volts for an average voltage of 60 volts on the capacitor C 1 the charging current into the capacitor is 1.8 amperes into 8 micro second. The capacitance value is C 1 and the ripple voltage is 0.6 volts, which is 1 percent of 60 volts by equating this relationship I can find out the value of C 1 that is 24 micro per head. So, in this particular example, now we can put all these things together and say that.

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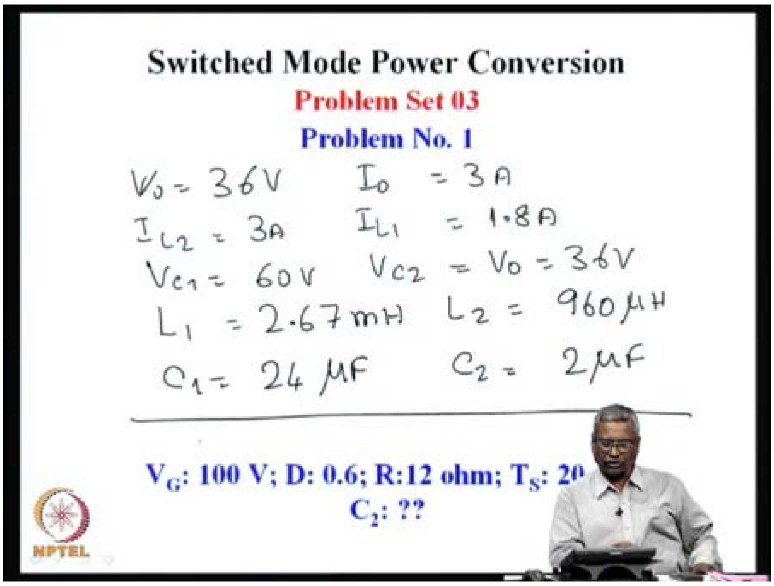

Our V naught is 36 volts I naught is 3 amperes I L 2 is 3 amperes I L 1 is 1.8 amperes V C 1 is 60 volts V C 2 is same as V naught, which is 36 volts. Then L 1 is, how much did we find L 1 is 2.67 millehenry and L 2 is 960 microhenry then C 2 is 2 micro per head and C 1 is 24 micro per head. This is with the condition that the current ripples are 10 percent and voltage ripples are 1 percent. So, all the principles at we have studied in the DC to DC converters study state analysis have been used in this particular example, but we have done all the calculations based on the idealized analysis.

We have considered all the switches to be ideal, we have considered the inductors not have any resistor, you consider that the capacitors are ideal and so on. The non ideality of the switches will certainly affect this, but we will see in some subsequent problems how those are to be handled. The key to analysis to any DC to DC converter for steady state operation is just old second balance on the inductors to find the voltage conversion ratio. Old second balance on the or ampere charge balance on the capacitors to find out the different current conversion ratios. Then the inductor voltages can be studied for the dynamic property of L D I by D T is the voltage across the inductor from that it is possible to find out what will be the current ripple and if current ripple is known then we can find out what is the inductor to be used.

In the same way from the capacitors if we know what is a voltage ripple that is allowed it is possible to evaluate the required capacitance. See in these particular examples under idealized modeling we have done all the analysis to find out the voltage conversion ratio, current conversion ratio, the value of inductors and value of capacitors for 10 percent current ripple in the inductors and 1 percent voltage ripple on the capacitors.

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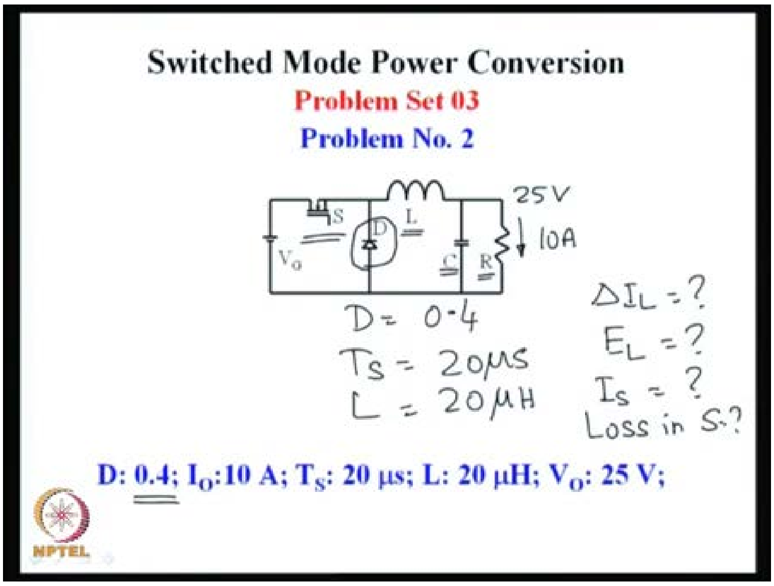

So, let us look at certain other problems, now this is a problem which is a non isolated converter. In this particular converter we will see how the non idealities or been take into account. Now, in this converter I have a source of V G and a switch of S this switch is S and there is a free wiling diode which is D what you see here. And there is an inductor and a capacitor forming the filter for the converter and power is delivered to the load which is a resistive load in this particular example this duty ratio is taken as 0.4 and V naught is taken to be 25 volts.

The resistance is such that the output current is 10 amperes and the duty ratio D is 0.4 and the switching period is 20 micro second and the inductor used in the circuit is 20 microhenry this is a non isolated converter. We wish to find out several quantities relating to the operating performance of this converter. So, we would like to find out in this particular converter what is ripple current on the inductor we would like to find out what is a peak stored energy in the inductor.

We will find out let us see delta E L this is required to be formed out then we would like to find out what is the peak energy stored in the inductor as the second quantity and then we would like to find out what is the current through the switch? What kind of current will be flowing through the switch. Then finally, we would like to find out the loss in the switch, let say these are the quantities we wish to find out here. We would also like to take it account the non idealities in the converter, so that we will be able to find out what is the loss that is taking place in the switch.

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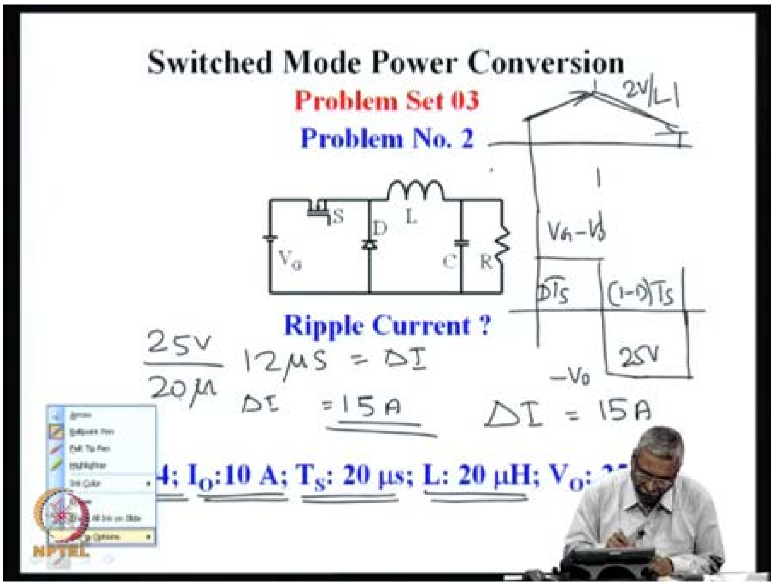

So, what is the first thing that we wish to calculate is the ripple current ripple current is always to found out by finding out the what is the voltage across the inductor. For example, the inductor has a voltage which is V G minus V naught when the switch is on and when the switch is off it has a voltage of minus V naught. Because when the switch is off this diode is conducting and the inductor has a voltage of minus V naught during 1 minus D T S and then V G minus V naught during D times T S. So, this is a kind of voltage and that is on the inductor and you can see that during the on time inductor voltage will increase because of the positive voltage. And during the off time inductor voltage will decrease.

So, we can use either the on time voltage to find out the ripple or the off time voltage in this case we know only the off time voltage which is 25 volts. So, this slope is 25 divided by l and l is given to us as 20 microhenry. So, you find that 25 volt divided by 20 microhenry is the slope of the current during the fall time during the off time and off time is existing for a duration of 0.6 times T S. So, off time is 0.6 into 20, which is 12 micro second. So, this has to be equal to delta I, so this two units are micro, so this will be 25 into 12 25 into 12 divided by 20. So, that is 15 amperes delta I is equal to 15 amperes. So, this is the first relationship that we find out that the current ripple in the inductor is 15 amperes and the actual current through the inductor DC current through the inductor is 10 amperes.

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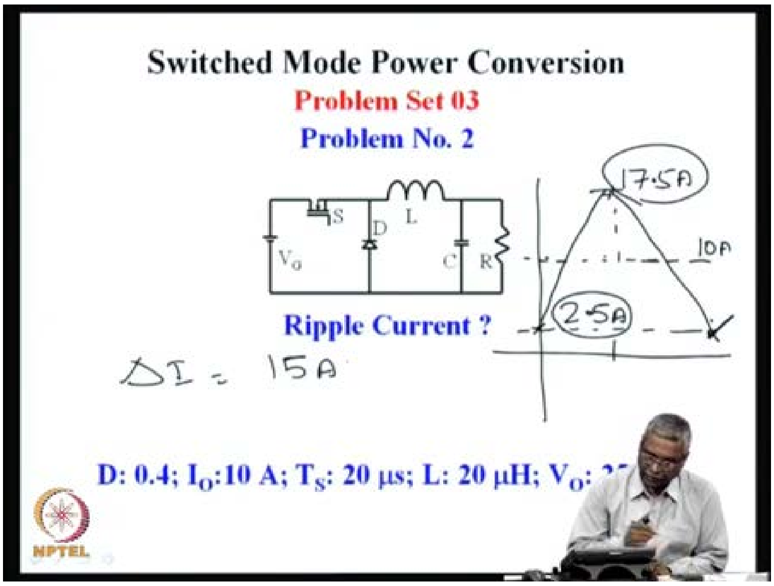

So, we might now say that the DC current in the inductor is 10 amperes and the ripple current is 15. So, from 10 minus 7.5 and from 10 plus e, so this 2.5 amperes and 17.5 amperes the maximum current on the inductor is 17.5 amperes minimum current on the inductors is 2.5 amperes, average current on the inductor is 10 amperes. The ripple current is 15 amperes, so this is what we have found out in the, for the first part of the question, which is the ripple current in the inductor.

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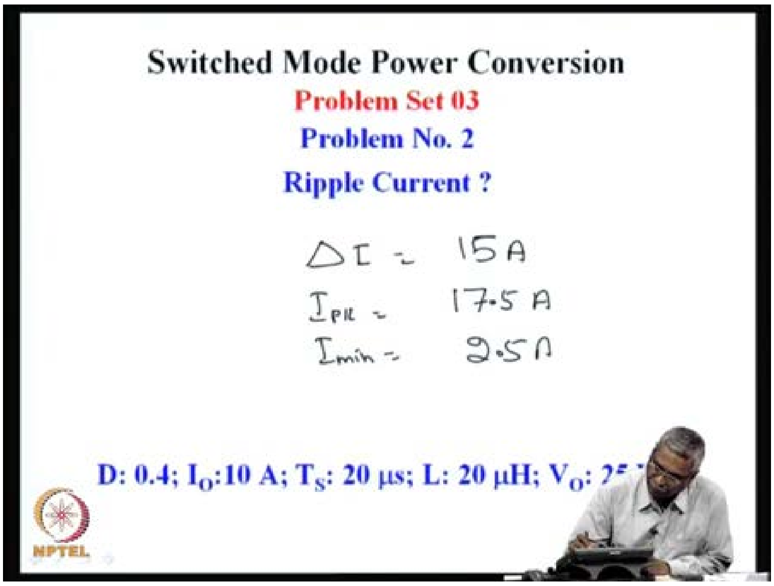

The next measure is delta I is 15 amperes I peak is 17.5 amperes and I minimum is 2.5 amperes this is what we have found out.

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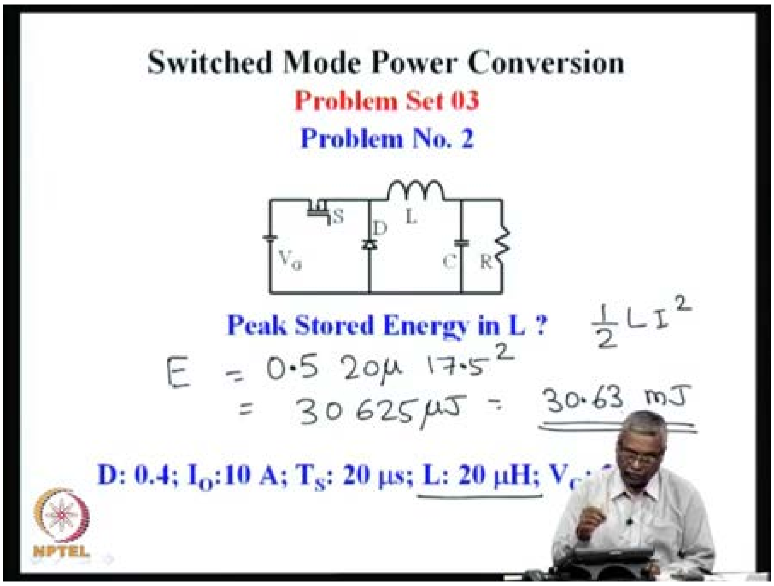

Now, what is the peak stored energy in the inductor we know that the inductor stored energy is 1 half of l into I square. In this example is energy peak is 0.5 and L is 20 microhenry and the peak current is 17.5 amperes, 17.5 square and that would be in joules the unit for energy is joules. So, because of this micro it will be micro joules 0.5 into 20 into 17.5 whole square, that is 30625 micro joule and that is equal to 30.63 mille joule.

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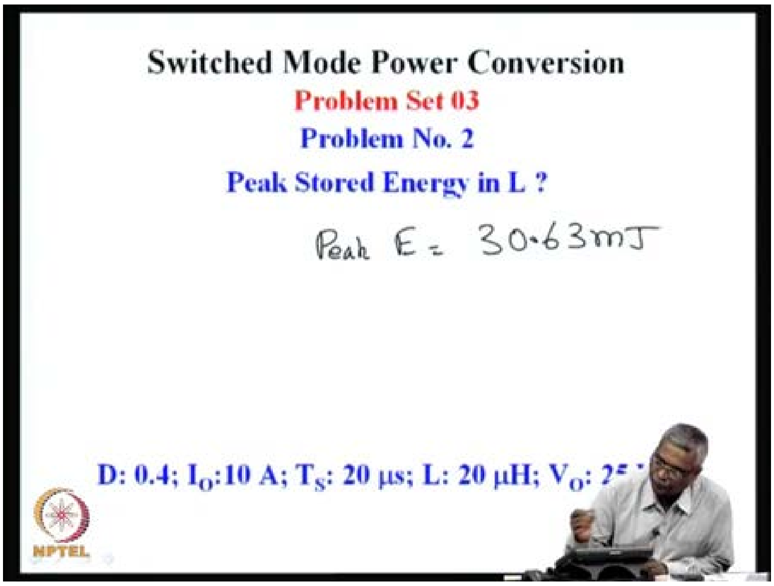

So, the peak energy that is stored in the inductor is half L I square and that is 30.63 mille joule. The next measure we would like to know is this, we have already found out peak energy is 30.63 mille joule.

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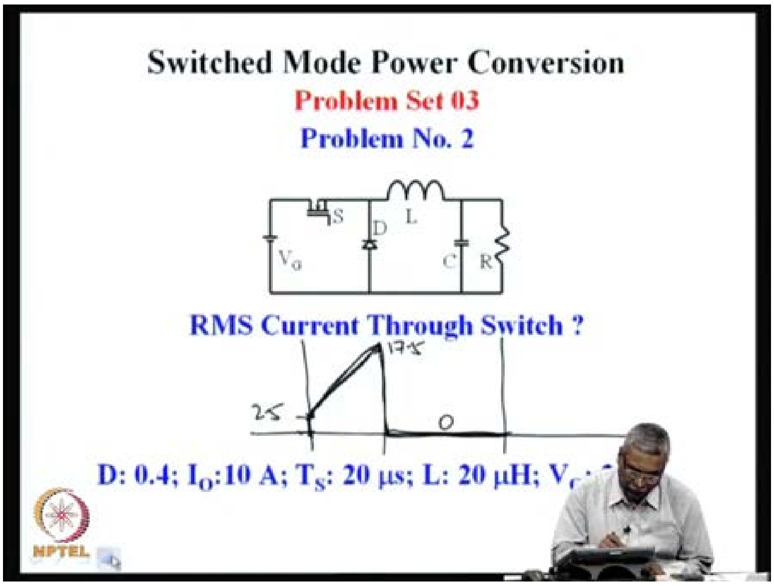

The next thing we would like to know is what is the R M S current through the switch, we know that the current through the switch is only during the only during the on time current is flowing it is 2.52 17.5. So, this is the current that is flowing through the switch 0 during the off time during the on time it first jumps to 2.5 then it linearly increases all the way to 17.5 and drops to 0 during the entire off time. So, we are now interested in finding out the R M S current of this particular current rating current through the switch. Now, this is not a constant current this is a variable current it varies with respect to time. So, it is possible to evaluate the R M S current, but let us see if we can do it in a simpler way.

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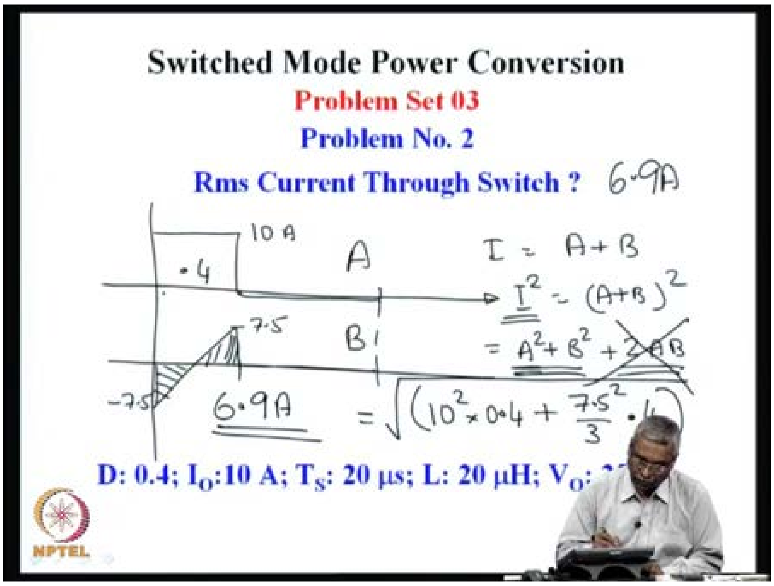

So, this current can be considered to have two components; one is a current of 10 amperes during one time and on top of that a current of a ramp current of plus minus 7.5. So, the sum of these two current is what is the actual current, so if you call this as current A this as current B actual current I is equal to A plus B and one can write what we are interested in finding out I square that is a plus B whole square. This can be written as a square plus B square plus 2 A B, now if you want to find out R M S, you have to find I square and take average that is what root mean square square it mean it and take square root of that.

So, when I square it A square will give you the R M S of the first wave form 10 amperes R M S square B square will give the R M S square of the second this is the product of these two currents if you notice this product. So, this has negative area same as the positive area. So, when you multiply A and B this 2 A B's average will become 0. Say if we break up the current in this way, this term goes to 0 because this goes to 0 my R M S consists of only the R M S of the square wave. R M S of the triangular wave R M S of the square wave is quite easy to find out that is simply 10 square into 0.4 because it is existing only for a duty ratio 4 and the R M S of triangle is nothing but 7.5 square by 3 and then it also exist for only a duration of 0.4, so this is a simple way of evaluating the R M S and this current you calculate that, so it turns out to be 10 square into 0.4 plus 7.5 square by 3 into 0.4 take square root of all that it is 6.9 amperes. The R M S current of the switch R M S current through the switch is 6.9 amperes.

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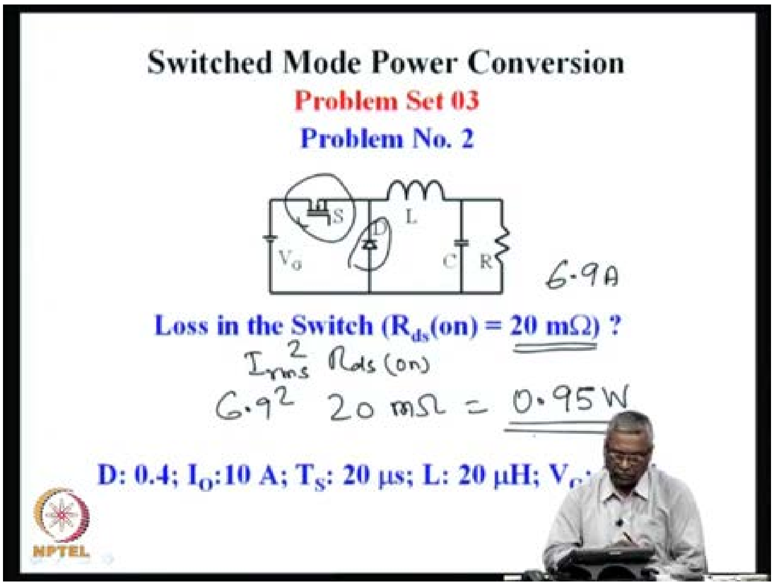

The switch itself has a non state resistance of 20 mille ohms and it has an R M S current of 6.9 amperes. So, then what will be the loss in the switch loss in the switch is I R M S square multiplied by R D S on the on straight resistance of the switch, that is 6.9 square into 20 mille ohm in that quantity is 0.95 watts.

So, this is the power loss in the switch, so in the switch if we know the parasitic resistance of the switch, it is possible to find out how much is the power loss. Ideally the switches do not have voltage drop and in account of that the switch loss will be 0. But in this particular example if we know what is the current? That is flowing through the switch evaluating the R M S current, then multiplying with the on straight resistance will give us the loss in the switch. Similarly, it is possible to find out the loss in the diode and these two losses together will make up the total loss in the converter. The output power plus the loss will be the input power to the converter see in the first example we had assumed everything to be ideal.

Under that circumstance we found out applying volt second balance and ampere second balance voltage ripple current ripple and so on. Using that we evaluated what is the voltage conversion ratio, current conversion ratio, the value of the conductors, value of the inductors, value of the capacitors and so on. All under the assumption that everything is ideal in this example considering everything to be ideal, we find out the ripple current.

Then we find out what is the current through the switch and switch has a non ideality which is on straight resistance by knowing the R M S current of the switch in this particular example we have found out what is the total loss, total power loss in the switch on an average. In this example we have also found out what is the peak current in the inductor, what is the energy storage requirement in the inductor and so on the loss we have found out.

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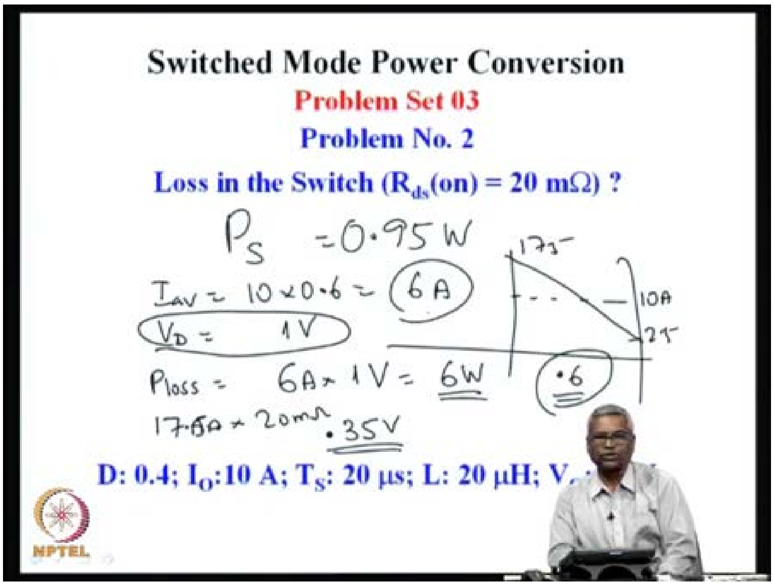

To be equal to 0.95 watts, this is the power loss in the switch the diode also carries the current during the off time. If you see the off time same 17.5 to 2.5 the average of this is 10 amperes during this time, but this is only a duty ratio of 0.6. So, you can say that I average in the diode will be 10 into 0.6 which is 6 amperes. If the diode drop if the voltage drop in the diode is about 1 volt then the power loss in the diode will be power loss in the diode will be 6 amperes is the average current into 1 volt it will be 6 watts.

So, we have seen that in this particular example the diode loss is 6 times more than the switch loss, it will be so because the diode drop is about 1 volt and the device drop with a current of about 17.5 amperes and with on straight resistance of only 20 mille ohm. You can see that it has voltage drop of only 0.35 volts, so because the on straight voltage of the switch is 0.35 in comparison with the on straight voltage of the diode, which is three times less. Similarly, off time is 0.6 on time is 0.4 there also diode carries current for a longer time, so the diode loss tends out to be almost 6 times in comparison with the switch loss.

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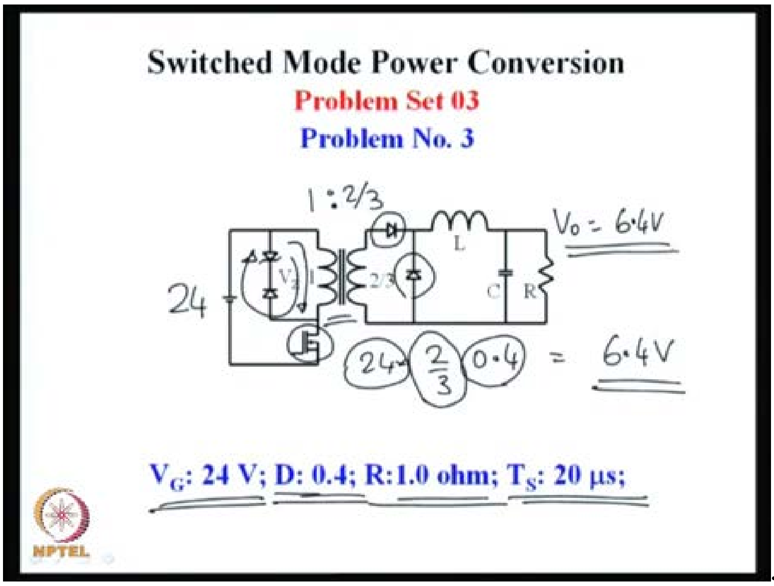

Now, we will start with another problem, which is an isolated converter. Now, in this particular converter apart from the voltage conversion ratio inductor capacitor voltage ripple current ripple and so on. We have an additional loss in the converter, which is because of the magnetizing current in the inductor this is a forward converter. We had seen that how this forward converter has magnetizing current, which is built up during every on time and then it is lost in the Zener diode during every off time. So, the magnetizing energy is lost in the in the diodes and Zener diode which is in the primary side of the forward converter. In this example the source voltage is 24 volts duty ratio has before is 0.4 and the load resistance is 1 ohm.

Switching period is 20 micro second, let us see what are all the quantities we are interested in finding out in this particular converter ideally this 24 volts and a duty ratio

0.4 and the turns ratio 1 is to 2 by 3 will produce an output voltage of 24 into 2 by 3 into duty ratios. 0.4 will be the ideal voltage conversion ratio and this is 6.4 volts our V naught ideally is 6.4 volts. Because we do not assume that there are any losses in this switch losses in the diode losses in the diode we consider everything to be ideal. In such a situation we will find that the output voltage will be 24, which is a source voltage multiplied by 2 by 3 by 1, which is the turns ratio of the transformer and multiplied by the duty ratio of the main switch, which is 0.4. The output voltage ideally is 6.4 volts and that is what we will see at the output as the average output voltage.

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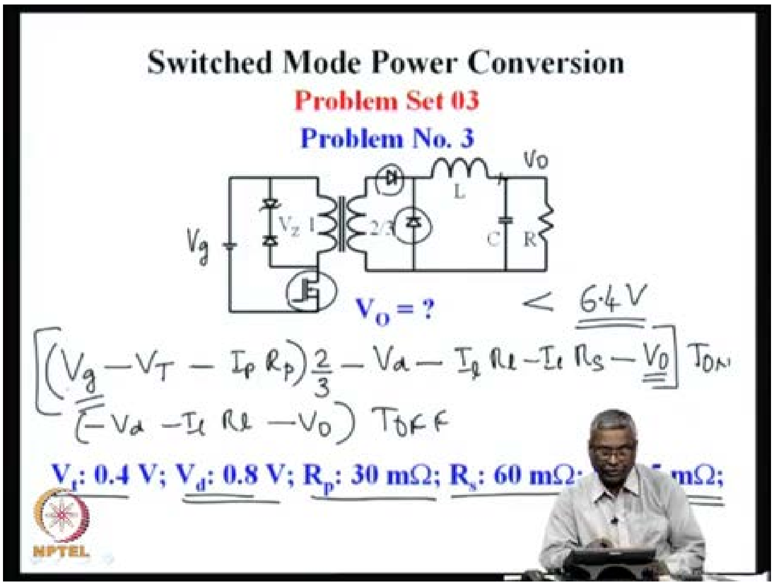

In a real converter because of the several voltage drops in the converter this V naught will not be the same as 6.4 volts. It will be drop because of the switch drop because of the diode and so on. For example, now we are given several information about the various drops the parasitic resister in the winding parasitic resister in the secondary winding. Then the diodes, which are on the secondary side 0.8 volts in each of the diodes and then the main active switch which is the transistor has a drop of 0.4 volts.

Then this inductor, output inductor has a parasitic resistance of 15 ohms, so all these will contribute to losses at every stage on account of all these losses this V naught will be less than the ideal voltage that we found out. See ideally, we found this voltage is equal to 6.4 volts if the switch drop is 0 diode drop is 0 and then the inductor has no resistance and so on. If that is the case output voltage will be 6.4 volts, but because of this losses, which are at different stages in the power converter.

Our output voltage will be less than 6.4 volts how much it will be less depends on these parasitic losses, so it is possible to evaluate all this quantities following the same principle of volt second balance. So, what we will do is, we will write the volt second balance for the entire circuit and from that we will apply all these numbers and we would like we will find out eventually how much this voltage is different from 6.4 volts. For example, if you call this as V G V G is the input voltage from that there is a voltage drop V T, which is the switch drop.

This drop minus whatever is the primary current that is flowing in the inductor into R primary is the voltage drop in the primary voltage of this, so this entire thing gets multiplied by 2 by 3, which is our N 2 by N 1. Now, after this voltage, after this there is 1 diode drop, which is this first diode drop then we see that, after that there is a secondary current I L into R L, which is a drop in this inductor. Similarly, this I L into R S is a voltage drop in the secondary, right all these drops are contributing to that minus V naught, which is the voltage at this point so this is really the voltage across the inductor during T on.

So, what we notice is that, now the vole second balance during time is not simply V G into 2 by 3 minus V naught V G into 2 by 3 minus V naught. Only these terms where in the ideal model, but there are several non idealities, which are now included in the same way. If we write during the off time you will find that 0 minus V D which is this drop minus I L into R L is the drop across this and minus V naught is the voltage at the output. If I, now multiplied this by T off this is the volt second balance during the off period. Now, the whole cycle volt cycle balance is that the sum of these 2 quantities is equal to 0 from that we should be able to find out what is the relationship between V naught and V G. So, we will stop here and in the next lecture we will continue from here and then evaluate the volt second balance and find out by what amount this voltage has dropped and efficiency of the converter is effected and so on.