Power Electronics

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Lecture - 24

In my last lecture we discussed the limitations of a linear regulated power supply. I told you that linear regulated power supplies are bit heavy and bulky because they use a 50 hertz step down transformer. Second is source current is peaky, has a predominant third harmonic component because source supplies power only for a very short duration. When the output voltage or unregulated voltage is becomes equal to the input voltage, diodes gets forward biased. So, very, for a very short duration source supplies power and at that time when the instant diode turns on, a large current flows. Basically, source current is peaky, power factor is poor.

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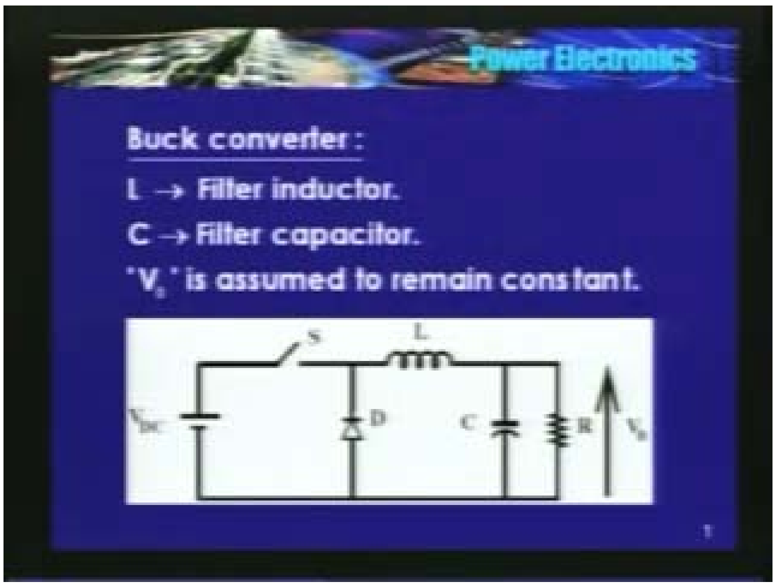

Third is efficiency is low because the series element or the regulating element comes in, is connected in series, series with the load or it is in the main path of the power flow and it is always acts in or is operated in linear or active mode. The difference between unregulated and regulated is dropped across the series element. So, it is invariably, it is operated in linear region, losses are high, temperature, temperature rise then, therefore, you require a larger heat sink, whereas, a switched mode power supply, they are operated in very high frequency. The magnetics which are used in SMPS or switched mode power supplies, they are operated in very high frequency. Then I told you that as the frequency of operation increases, size of a transformer or an inductor or for that matter the capacitor, filter requirement comes down.

So, first one in the series is the buck convertor. I had explained you the principle operation. When I close S, inductor current builds up, diode is reverse biased and when I open S, the inductor current freewheels through the diode. So, while deriving the transfer function, we made assumptions. The assumption that we made are V_0 is constant and ripple free, all the circuit elements are ideal, switches are also ideal and these are the equivalent circuits. Inductor current builds up here, inductor currents freewheels through diode and it falls.

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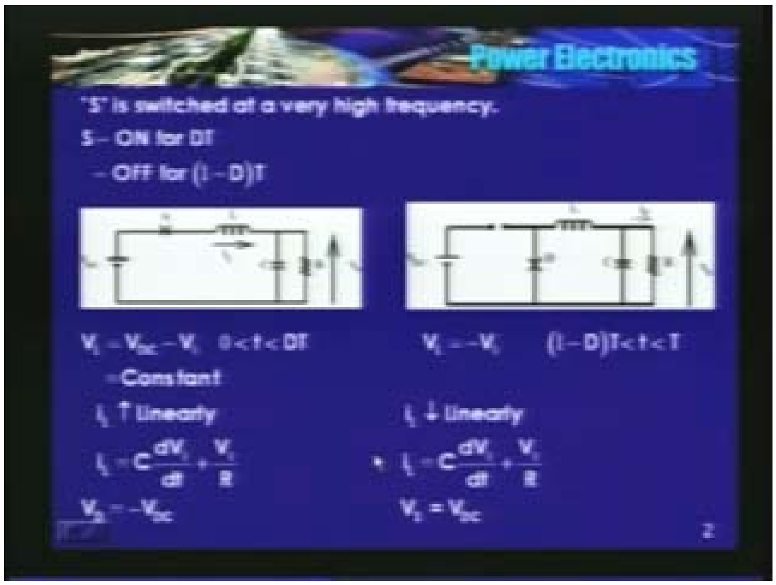

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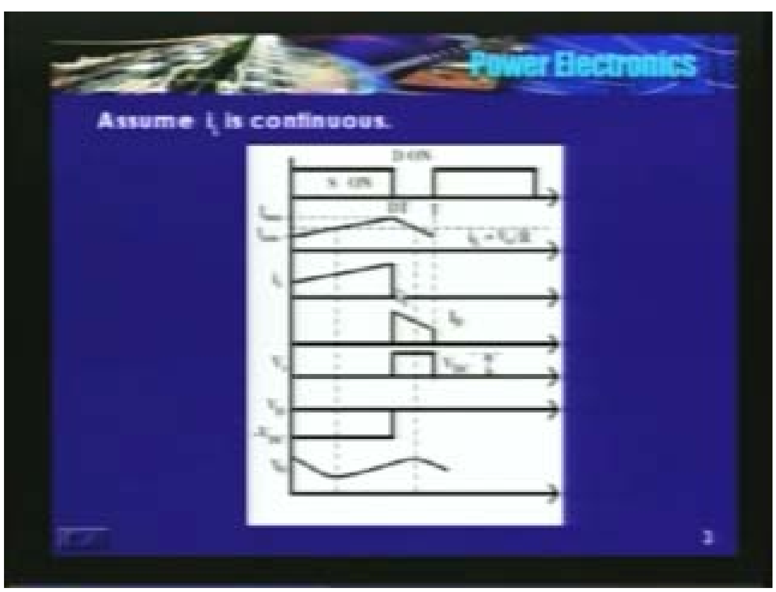

And, I did discuss the various waveforms here. Switch is on, inductor current increases: diode is on, inductor current falls. At steady state, I_{min} at T is equal to 0 is equal to T is equal to T or beginning of the next cycle. See the switch current, the moment I turn on the switch, the current that is flowing through the diode at this point, at this point the current starts flowing through the switch or the source.

So, source current jumps here, increases and when the switch is off, source current becomes instantaneously 0. So, source supplies power only for a short duration here or only for the duration when the switch is on. Same thing, when the diode current of the instantaneously rises to I peak, reduces and at this instant it falls abruptly. When the switch is on, voltage across the switch is 0 and when it is off when it is off see here, voltage across this switch is V_{DC} itself because diode is conducting. This point gets connected to this point. So, voltage across the switch is V_{DC} itself and when switch is on, V_{DC} appears across the diode. So, in both the cases: or the voltage rating of S as well as D is V_{DC} itself and this is the variation in the capacitor voltage.

Over here, we assume that or in analysis we assume that voltage output voltage remains constant but then this does vary but over a very narrow range. Generally, output voltage ripple is specified, it is very small. So, when that is when does it starts charging and when does it start discharging? At any given point, KCL has to hold good. i_L is equal to i_C plus I_0, ripple in V_0 is very small. So therefore, V_0 by R is a ripple in I_0. That can be really neglected. So, I am assuming that load current remains constant at I_0 which is equal to V_0 by R.

This is the positive direction of current. If the current flows in this direction, capacitor charges and if the current reverses, capacitor discharges. So, out here, current starts from a minimum value, increases, reaches a peak and this is the average value of the load current, I_0. This is I_0, is equal to V_0 by R. From T is equal to 0 to till this point, you find that inductor current is less than inductor current is less than the load current, I_0. So therefore, the remaining current has to come from the capacitor, remaining current has to come from the capacitor. So, capacitor is discharging, capacitor V_0 is changing.

From this point to till here, we will find that inductor current is higher than the load current, mind you. See the load, switch is opened here, S is open, diode starts conducting. Since, the current is higher than I_0 capacitor continues to charge till here. So, from here capacitor starts charging till here and beyond this point again it starts discharging. So, do not think that the moment you turn on S, output capacitor starts charging, no; it all depends on the inductor current and the average load current.

We have assumed that inductor is ideal, switch is also ideal, therefore the losses that are taking place in the convertor is approximately 0. So, under that condition, input power should be equal to the output power. What is the input power? Input power is the battery voltage, source voltage into source current, V_{DC} into i_S, V_{DC} into i_S should be equal to V_0 into I_0. This is the output power, i_S is the source current, average.

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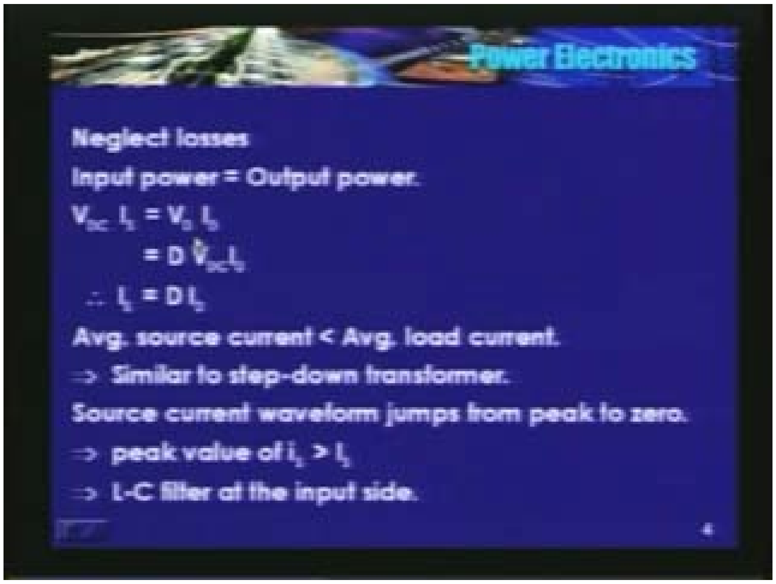

We have derived an expression, output voltage V_0 is equal to D into V_{DC}. So therefore, i_S source current is equal to D into I_0. So therefore, average value of the source current is less than the average value of the load current. See here, if you see in the in the waveform also, source current supply source supplies power for only till DT or when the switch is on, source supplies power and but then the moment the switch is turned on, instantaneous value of current is high. This is the, I minimum is the current value the current that starts flowing through the source and is abruptly starts falling.

What is desirable? Desirable is source also supplies the constant value of current. The moment, see, it has to supply abrupt value of current. There are stresses, stress on the on the source increases. Take for example, you are just sitting, all of a sudden I will come and put 10 kgs on your head, immediately, instantaneously. So, there is going to be a heavy load coming on you. Instead, if I gradually increase or gradually increase the load, it is better or I can I will not get exhausted. All of a sudden, I am instantaneously, I will come and put a heavy load on you, definitely, I do not think you can sustain, you may you may collapse.

Though at steady state you may be able to carry that much of load. Same thing happens to in the any any physical device, wherein, if you instantaneously load it, it may not be able to supply that much of current or the stress on the on the equipment increases. So it is always is better to have a constant value of current. But in this case it is just not possible. So definitely, in order to reduce the stress on the on the source, we need to have some sort of a LC filter at the input. You need to have some sort of a LC filter at the input. A source, a small LC filter and a switch, just to reduce the current stresses that on the source.

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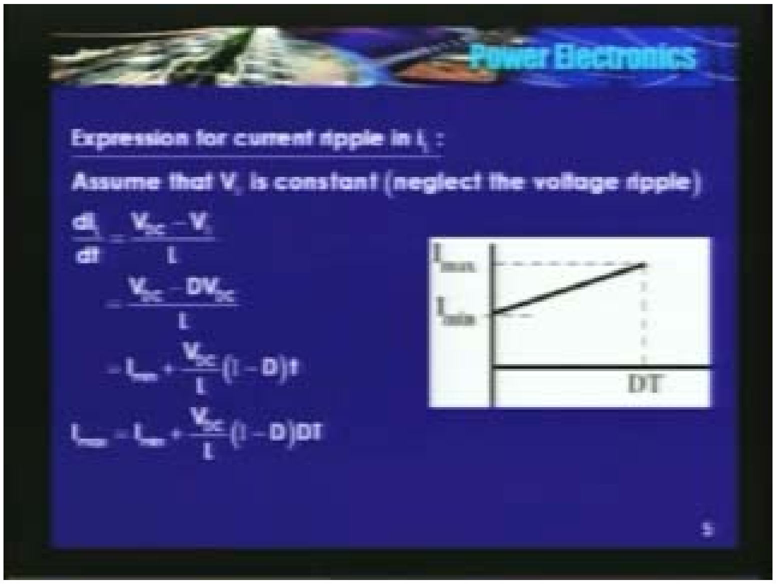

Now, what is the expression for the ripple, that is the ripple ah ripple in the current that is flowing through the inductor or current in i_L? After all, how do I choose the value of inductor and how do I choose the value of C, output capacitor? Definitely, I need to specify the ripple in the current as well as the ripple in the output voltage. So, we will make 1 assumption. That is while deriving an expression for the ripple in the current that is flowing through i_L, I will neglect the ripple in the voltage, output voltage V_0 or can be vice versa.

If that is the case, rate of change of current d i_L by dt dt is given by V_{DC} minus V_0 divided by L, when the switch is on. So, V_0 is nothing but D into V_{DC}. So, the equation to this line is I_{min} plus the slope of the line into 1 minus D into t. So, I is equal to I_{max} at this point, at that time T is equal to DT. So, this is the expression for I_{max}.

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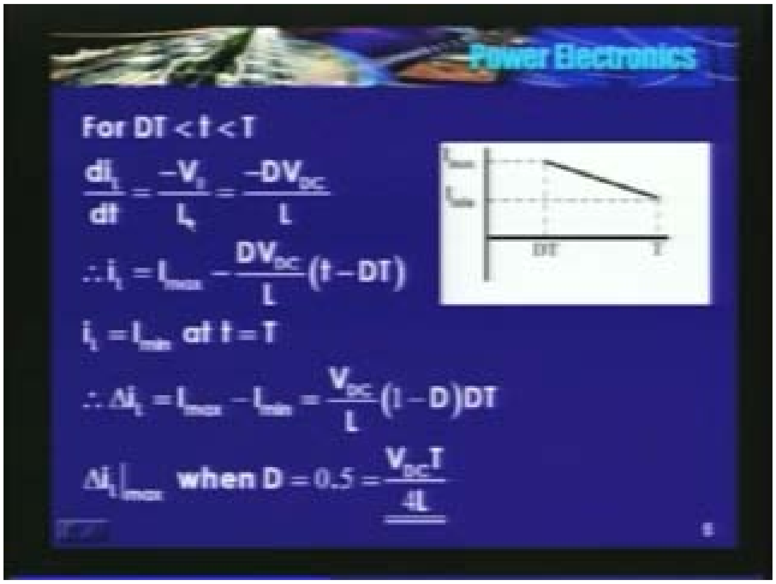

For during this duration from when the switch is open, current falls. Current falls from I_{max} to I_{min}. The slope of this line is now minus V_0 by L, remember, because voltage across the inductor is minus V_0. So, substitute for V_0, we will get D into V_{DC} divided by L. So, equation for i_L is given by this, i_L is equal to I_{max} into this. That is nothing but very simple, if I know the the coordinates, coordinates at this 2 point, I can write the equation of a line.

Again, i is equal to I_{min} at T is equal to T. Substitute at this point, so you will get I_{min} is equal to t, time period t minus DT. What is the ripple in the current? This is the ripple in the current, I_{max} minus I_{min} is given by this term, this is the ripple in the current. So, when it is maximum? Of course, you differentiate it with respect to D and equate it to D, equate it to 0, you will find that ripple is maximum when D is equal to 0.5 and it is given by V_{DC} by T into 4 by L.

So, L can be selected or L is selected in such a way that having specified the maximum ripple, the input voltage and T, L can be determined. Switching frequency is decided, input is the source voltage, current ripple is specified, that is the desired value, so you choose the value of L. Now, how do I determine the ripple in the output voltage, V_0?

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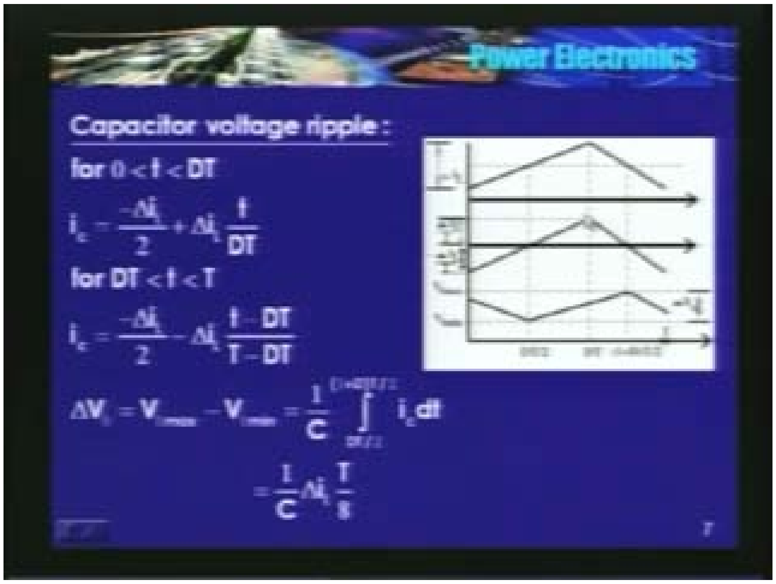

This is the expression for or this is the variation in the inductor current, I_{max} I_{min} to I_{max}. When the inductor current is less than I_0 less than I_0 capacitor is supplying that current, capacitor discharges and at this point, both are same. Inductor current as well as the load current is the same and beyond this point, inductor current increases, capacitor starts charging till here. So, in this region capacitor is charging. Capacitor discharging, charging, discharging so this is the change in or ripple in the output voltage. Ripple in the output voltage.

From 0 to T, what is the equation for the capacitor current i_C? It is given by this. This is delta i_L by 2, varies linearly, linearly with the time. So, this is the expression for i_C, this is the expression for i_C and again from DT to T variation is linear and expression for current is given by this. So, variation in the output voltage that is delta V_0 is equal to 1 by C, integral of i_C dt in this region. In this region, there is a change in the voltage. So that is a capacitor current, iC dt. So, integrate it, you will find that expression for V_0 is given by this. In both cases, I have written the expression there.

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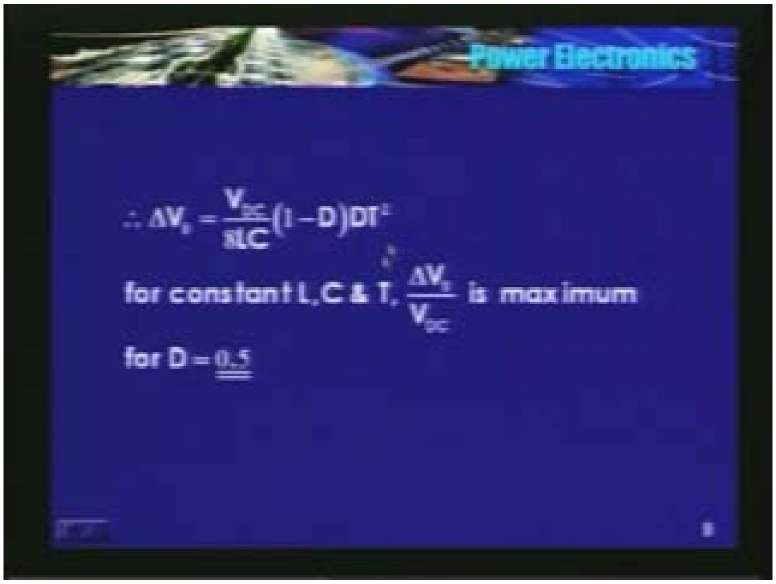

Now, substitute for i_L from the previous value. You will get delta V_0 is given by this equation. So, if I again, delta V_0 is maximum for D is equal to 0.5 both cases; delta, ripple in the current as well as ripple in the output voltage is maximum for D is equal to 0.5. So if I mention, if I specify value of V_0, I can choose the value of C because all other values are fixed. T is fixed, V_{DC} is fixed, L is fixed from the previous value. So, that is about the buck convertor operating in continuous zone.

In other words, inductor current varies from I_{min} which is non 0 to I_{max}. It may so happen that the inductor current may become 0 and remain 0 for a finite time. So, what are that conditions or in what way the inductor current is related to I_0 or what is the relationship or what is the critical value of R above which the the inductor current is going to be a discontinuous?

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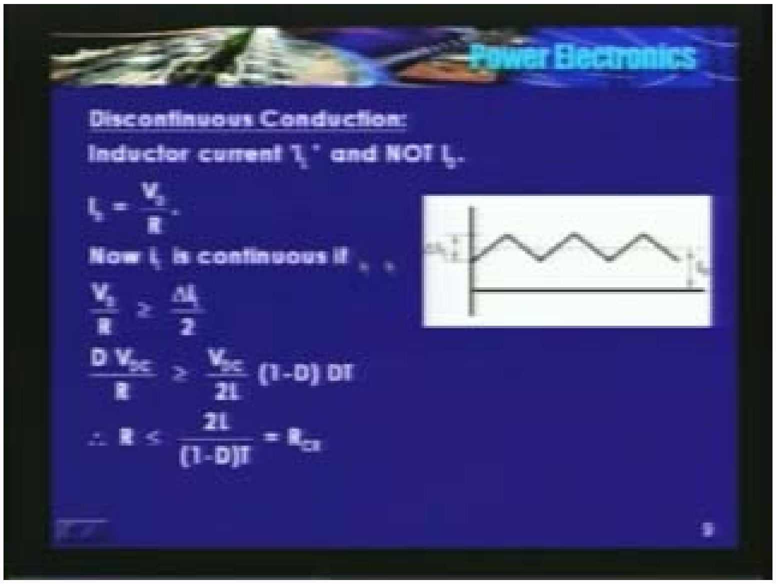

This is the variation in I_L; increases, decreases. This is the constant value of I_0. Now, inductor current is continuous or it is positive if I_0 I_0 is higher than higher than delta i by 2 ripple, this ripple. Definitely, if this value is higher than delta i by 2, inductor current is always positive always positive. If I_0 is less than delta i by 2 then the inductor current is going to be discontinuous, discontinuous.

Now, in in AC to DC conversion, especially in a line commutated converters, when it is discontinuous, it implied that what does it imply? The load current will going to be discontinuous, whereas, in DC to DC conversion or in power supplies, the discontinuous current implies that implies that current in the inductor is discontinuous. Please, do not say that load current is discontinuous. How can you have a load current discontinuous?

We have assumed that assumed that output voltage remains approximately constant, V_0 supposed to be constant and ripple free. So therefore, if I connect a load and the circuit is complete, current has to flow. Therefore, invariably we assume that I_0, I_0 the load current is constant and ripple free. The question of discontinuity does not arise unless until load circuit is open. So, in buck converter or a few more power supplies that we will be seeing, when I am saying discontinuous current it implies that the inductor current.

So, this is the relationship, V_0 by R is average value of current, should be greater than or equal to delta i_L by 2, this value. So, if I substitute for i_L from the previous value, you will get this equation. Critical value of critical value of R should be this. If the load resistance is less than this value, you have always continuous conduction. So, if the load resistance is higher than this value, you will go in for a discontinuous. What is the concept of this, what will happen?

We have derived a transfer function - V_0 is equal to D into V_{DC}. We derived it assuming that inductor current is continuous. When the diode is continuously conducting, when diode conducts from DT to T, only then voltage across it becomes minus V_0 and we equated this voltage is …

when the switch is on, voltage across inductor is positive; when diode is conducting, voltage across inductor is negative. When we equated it, since average voltage across inductor should be 0 and we got V_{DC} is equal to or V_0 is equal D into V_{DC}. And, it is independent of the inductor current i_L. V_0 is equal to D into V_{DC} and i_L does not appear there. Only, only condition is i_L should be continuous. What happens if i_L is discontinuous?

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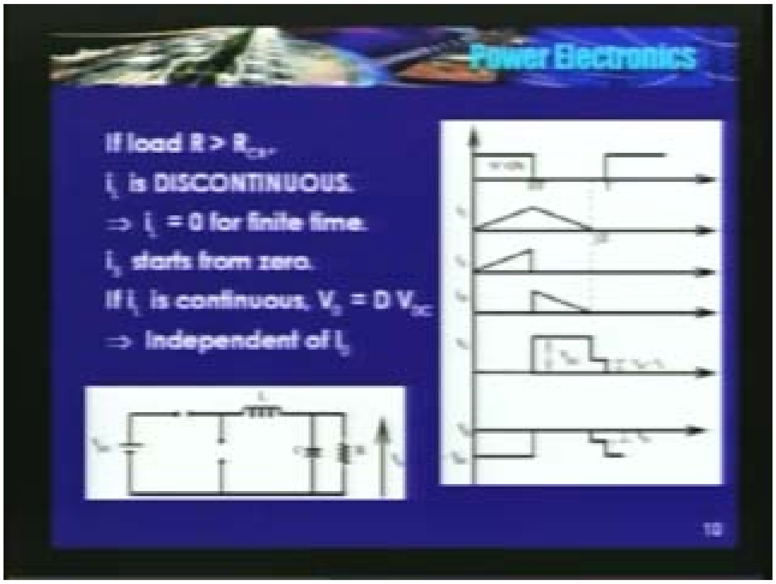

So, when the diode has stopped conducting, what happens to the voltage across the inductor now? So, current has become 0 much before the beginning of the next cycle. So, when you when I turn on the switch S, current starts from 0 and starts increasing or varies linearly, may be, for the source is better now, it starts from 0. And, when the current has become 0 or when the diode has turned off, what is the voltage that is appearing across the switch? No current is flowing through the inductor. So, potential at this point, potential at this point is same as the potential at this point. So, this potential is V_0, this potential is V_0 this potential is V_0, plus V_0. This potential is V_{DC}. So, voltage across the switch is V_{DC} minus V_0, V_{DC} minus V_0.

If the current is continues, voltage across the switch is V_{DC} itself. For the entire region we would have add V_{DC}. Now, current has become 0, voltage at this point is V_0, no current is flowing through the inductor. So definitely, voltage at this point is equal to voltage at this point. Both points are at the same potential. Therefore, no current, so this potential is V_0, this is V_{DC}. Difference is appearing across this switch, so, V_{DC} minus V_0.What happens?

The voltage across the diode, voltage across the diode is same as V_0 because what is the potential that is appearing at this point, it is V_0. So therefore, when the diode is on, voltage across it is 0. When it turns off, voltage that is appearing across the diode is V_0 and when I turn on the switch again, current starts increasing now.

So, voltage across the switch is V_{DC} itself because this point closes. So, entire source voltage appears across the diode. So, it is V_0 from beta T to T. So, this during this period, voltage across the diode is V_0, voltage across the switch is V_{DC} minus V_0 and beyond T when it turn on S, it jumps to minus V_0.

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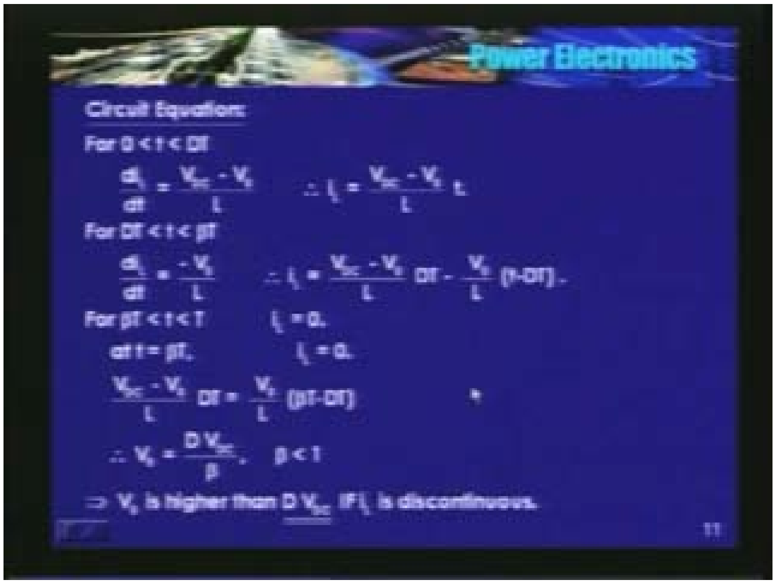

So, what are the circuit equations? Circuit equations are same; d i_L by dt is equal to V_{DC} minus V_0 divided by T. But only thing is if the current is continuous, circuit equation when the switch is open is d i_L by dt is equal to minus V_0 by L and it is true for, true from DT to T, whereas, now this equation is true from dt to beta T. When beta is inserted the current becomes 0. So, this is the expression for current, V_{DC} minus V_0 into T and i_L was the current.

This is the peak value of current or the current that is attained just prior to opening the switch that V_{DC} minus V_0 by L into D into t when D into t. This is I_{max}, this is I_{max} minus the reduction in the current from beta T to t. i_L is 0 and current become 0 at t is equal to beta T. So, i_L is equal to 0. You equate it, so you will find that V_{DC} minus V_0 divided by L into D into T, this term should be equal to this term. So, expression for V_0 is now D into V_{DC} divided by beta and beta is less than 1, beta is less than 1, beta is less than 1.

So, what is the result if the current is discontinuous? Output voltage V_0 is D into V_{DC}, independent of the inductor current. If the current is discontinuous for a given value of D, output voltage is higher than D into V_{DC}. Output voltage in the discontinuous case is higher than D into V_{DC}. It is given by d V_{DC} divided by beta where beta is the instant where the current becomes 0 and is always less than 1.That is about the buck converter, wherein, the output voltage V_0 is always less than or equal to V_{DC}, depends on D.

The duty cycle is almost the same as a step down transformer in AC. Output voltage is less, depends on number of turns n, whereas, the source current or the in primary, current again is higher than. That is about the buck converter, wherein, the output voltage is always less than the input voltage. It is almost the same as a step down transformer in AC. Whatever that happens in a step down transformer, it happens in a buck converter. Therefore, we can call it as a step down DC transformer. We can call buck converter as a step down DC transformer.

In AC, we had a step up transformer. So definitely, we will have or we should have a step of DC transformer also. So that is nothing but a boost converter. We have already studied this and switch mode rectification. I will repeat it here and we will derive the other expressions.

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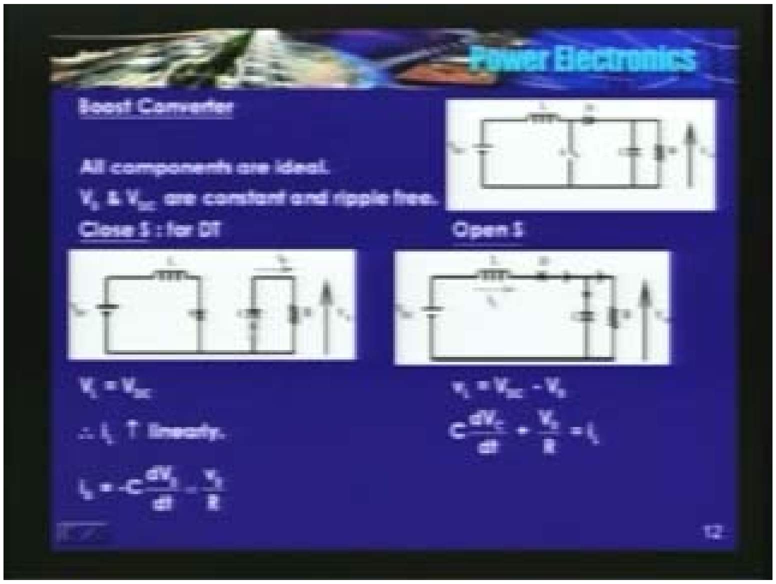

Shown here; switch, inductor, diode and the output stage. Switch is close for D into T, diode is off, capacitor supplies power. Open S, stored energy in the inductor is transferred to the output. Out here, I am making an assumption saying that remember, again I will emphasize V_0 is constant and ripple free, constant and ripple free.

So, what is the circuit equation here? V_L is equal to V_{DC}. Therefore, i_L increases linearly, capacitor is supplying power, i_0 is equal to minus C d V_0 dt that is V_0 by R. Here, V_L, a voltage across the inductor is V_{DC} minus V_0 and this should be negative only then current decreases. Here V_{DC}, voltage across the inductor is positive, i_L increases. So, at steady state, current should increase here and current should decrease in this case. So, i_L should fall when I open the switch or when the switch is opened, i_L should decrease. So, V_{DC} minus V_0 is negative. In other words, V_0 should be higher than V_{DC}. Hence the name, boost converter and KCL at this point is capacitor current, C d Vc by dt or d V_0 by dt, d V_0 by dt, capacitor voltage is same as V_0 here plus V_0 by R should be equal to i_L.

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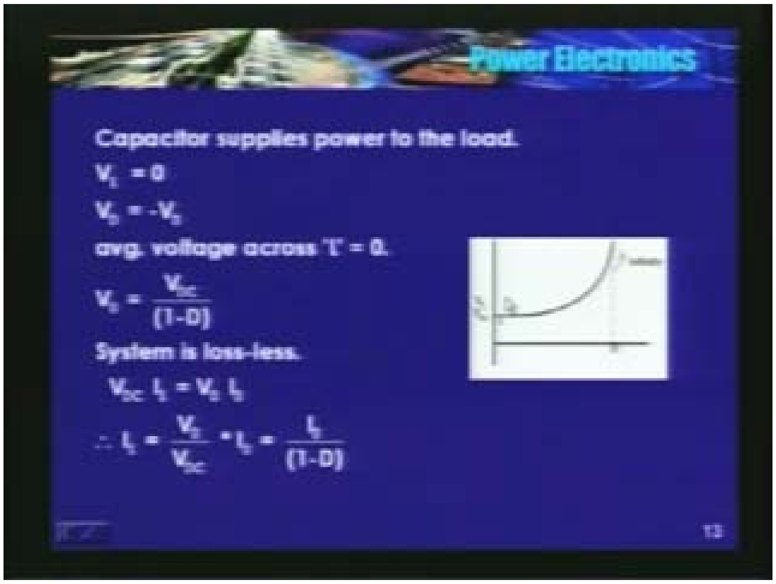

So, when the switch is closed, voltage across it is 0, voltage across the diode is minus V_0, voltage across the diode is minus V_0 here. Entire V_0 appears across the diode, this point gets connected at this point and when the diode is conducting, the switch is on. Again, V_0 appears across it. So, in both the cases, voltage rating of switch as well as the diode is V_0. I will assume I had assumed that V_0 and V_{DC} are constant and ripple free. I will equate it and I will find that V_0 is V_{DC} divided by 1 minus D, this is the transfer function.

So, if I plot, I will get this sort of a variation, V_0 by V_{DC} is equal to 1 when D is equal to 0. That means switch is opened, switch is opened, average voltage at inductor is 0. So therefore, average value of the input is same as the average value of the output and increases and goes towards infinity for D is equal to 1, provided, system is ideal. I have assumed that all the circuit elements are ideal, all the circuit elements are ideal, inductor is lossless, both voltage sources are constant and ripple free. So, there is a flow in our assumptions, will we will find out what are their flows.

Now, I assumed the system to be lossless. So, input power should be equal to output power. So, V_{DC} into i_S where i_S is the source current, should be equal to V_0 into I_0. We substitute for V_0, we will get the relationship between the source current and the output current. So therefore, i_S is equal to I_0 divided by 1 minus D. So, i_S is given by i_S is given by I_0 divided by 1 minus D, simple.

Now, we will derive our transfer function taking into account the non idealities or taking into account the internal resistance of the inductor. I have not derived it for the buck converter. Now, what may happen in buck converter when D is equal to 1? When D is equal to 1, source continuously supplies power to the load. So, D is equal to 1. So, average value of V_0 is equal to average value of the input voltage, V_0 is D into V_{DC}, whereas, if I approach or if make D is equal to 1here, output voltage, you know ideal converter, that is what the expression says that output voltage stands to infinity, looks like there is a problem. Looks like there is a problem, if I take into account or if I take, consider the converter to be an ideal one. So therefore, we will take the non idealities into account and we will find that what are the flows or what in our assumptions that we made?

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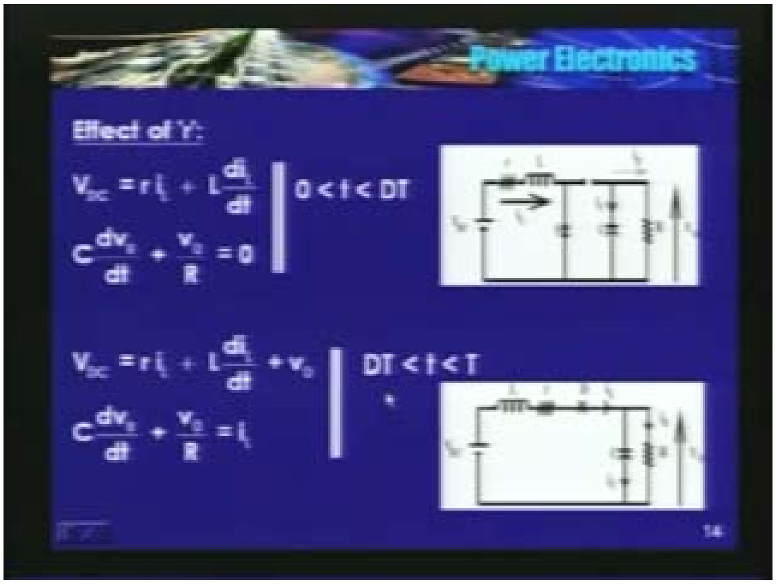

So, we will consider a small r, resistance of the inductor. Now, Circuit equation is the same, KVL is r into i_L plus L di by dt, the secondary correction is the same and when the switch is opened, it is V_{DC} is equal to r into i_L plus L di by dt plus V_0. There is a KVL here, KVL here.

Now, I will find out the average values, this is true for 0 to DT and this is from DT to T. I will take the average values and I will add them. So, V_{DC} is here, V_{DC} is here, r into i_L, r into i_L, L di by dt, L di by dt and V_0 is here only from DT to T.

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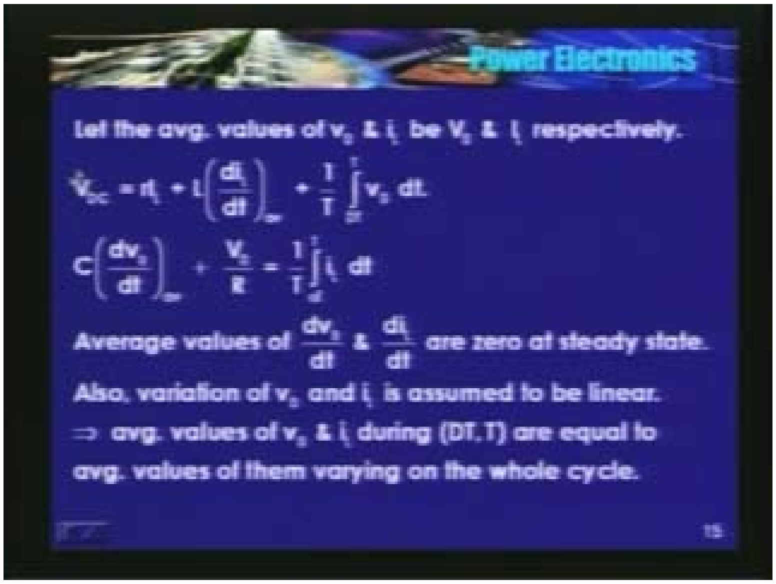

So, what do I get? V_{DC}, average value is the same, r into i_L. L di by dt is the average value plus 1 over T, DT to T into T into V_0 into dt because this V_0 is there only from DT to T. Similarly, the current equation if you see, dV_0 CdV_0 V_0 by R, V_0 by R and is equal i_L here from DT to T is 0 here.

So, if I have to find out the average value or integrate and you do it and you will get this value, C dV_0 by dt average, V_0 by R. So, 1over T, DT to T to T, i_L dt. So, at steady state, the variation in inductor current, average value should be 0 at steady state. Current increases and decreases, it has attained the same value at T is equal to 0 is equal to T is equal to beginning of the next period. Similarly, the output voltage. Of course, capacitor would have does changed but then average value should be remain constant or in other words, average current flowing through the capacitor should be 0 at steady state. Average value of the current that is flowing through capacitor should be 0 at steady state. So, I will get 2 equations because this is 0, this is 0.

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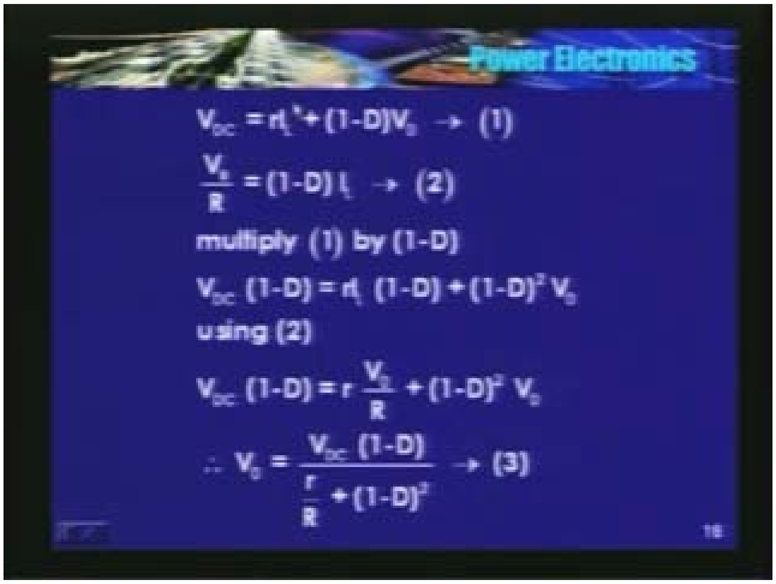

So, the 2 resulting equations are RDC is equal to r into i_L plus 1 minus D into V_0. See, if r tends to 0, you have the same equation; V_{DC} is equal to 1 minus D into V_0. The difference between an ideal and non ideal is only this, r into i_L but looks like it effects significantly. We will see some time later. Similarly, I_0 is equal to 1 minus D into i_L. Now, I will do sum jugglery, I will multiply this equation 1 by 1 minus D and I will get this equation. Multiply this equation by 1 minus D, I will get this. Now, I have here, 1 minus D into i_L, I have 1 minus D into i i_L. So, I will substitute, so I will get this equation, very simple maths.

So, now I will write an expression for V_0 in terms of V_{DC}. So, I will get this. Again, if you substitute here r is equal to 0, r is equal to 0, so you will get same as V_0 is equal to V_{DC} divided by 1 minus D. So, this term remains 0, this gets cancelled on this, so same equation. But then what will happen for finite values of r, small r?

If D is equal to 0, if D is equal to 0, what is the average value of the output voltage? It is no longer is equal to V_{DC}. Now, I have a potential divider, small r here. See here, a small r here and a R here. Input is V_{DC}, so output voltage V_0 is V_{DC} divided by r plus R that is the current that is flowing multiplied by this R is the output voltage. It is not equal to V_{DC} itself.

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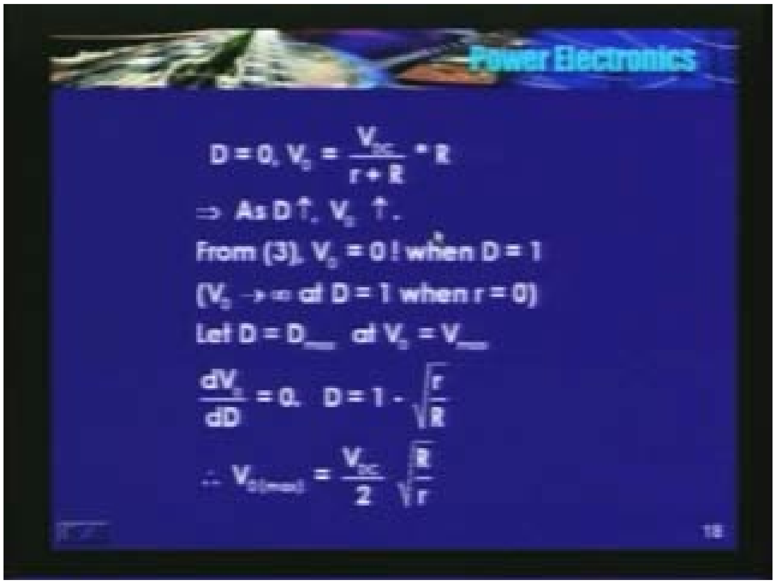

So, as D increases, V_0 also increases. If you see in this equation, see in this equation, when D is equals to 1, D is equals to 1, output voltage is 0, output voltage is 0. See, we have a very interesting equation here, if I neglect r, if I neglect r here and D is equal to 1, D is equal to 1, V_0 becomes infinity and if I consider r at D is equal to 1, V_0 becomes 0, V_0 becomes 0. If I neglect r, D is equal to 0, output voltage is same as input voltage. If I take r into account, output voltage is V_0 divided by r plus r into R, small r plus r multiplied by the load resistance, capital R which is less than V_{DC} itself. Fine, there is no much difference because the winding internal resistance is very small compared to the load resistance.

What happens when D is equal to 1? If I neglect the winding resistance R or the internal resistance of the inductor, D is equal to 1, V_0 is equal to infinity. Now, if I take r into account, V_0 becomes 0, V_0 becomes 0. Why such a large difference, ideal case infinity, non ideal case 0? Such a large difference; ideal transformer, no load current is very small sorry ideal transformer no load current is 0, non ideal transformer, no load current is of the order of 5, 2 to 5%, a good transformer.

Here, ideal boost converter, V_0 is infinity; non ideal boost converter, V_0 is 0. Poles apart, why so? I will address, I will come to that point. But then, as D increases, in both cases, V_0 starts increasing initially and D is equal to 1 and in the second case, it becomes 0. So definitely, for 1 value of D, V_0 approach V_0 becomes maximum and becomes and from there onwards, it starts decreasing.

How do I find? I will differentiate that equation and equate it to 0, differentiate it with respect to D and equate to 0, you will find that you find that this value of D is equal to 1 minus r divided by R, square root of this equation. You need to differentiate this equation; V_0 is equal to V_{DC} 1 minus D into this. Differentiate it with respect to D, equate it to D, you will find the value of D. At that instant, V_0 is maximum. So, that value of D is found to be this.

So, if you substitute r is equal to 0, D is equal to 1. Same, it is ideal case, infinity and if you put this value, you substitute this value in this equation; substitute for D, you will get V is equal to V_{max} and that is equal to V_{DC} divided by R divided by r, R is the load resistance, this small r. Therefore, V_0, maximum voltage that you can get at the output is the strong function of the internal resistance of the inductor.

It depends on the ratio of load resistance to the internal resistance of the boost converter. As this ratio increases, as the internal resistance becomes 0, in other words, I am going towards the ideal case voltage, I can get a higher, maximum voltage V_0 in V_0 max increases.

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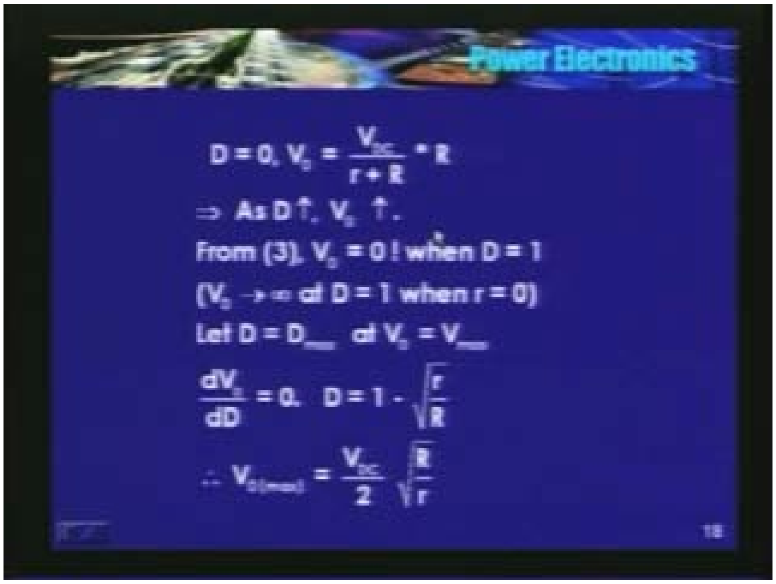

See here, R is equal to sorry it does not decrease, it increase, goes on increasing, please at 1 and goes on increasing, does not decrease. It attains the peak and comes down, it attains the peak and comes down. Please, it starts from 1, increases, attains the peak and comes down. If R is equal to 0, it becomes infinity. So, R by r for this curve is higher compared to this.

Now, what is the difference, 0 and infinity? Before answering this question, I want to ask; what are the assumptions that we made? We said that V_{DC} is V_{DC} and V_0 are constant and ripple free, V_{DC} and V_0 are constant and ripple free. D is equal to 1 or D approaches 1, what does it imply? Most of the time switch is closed and what is the equivalent circuit when the switch is closed? See, here is equivalent of the circuit if the switch is closed.

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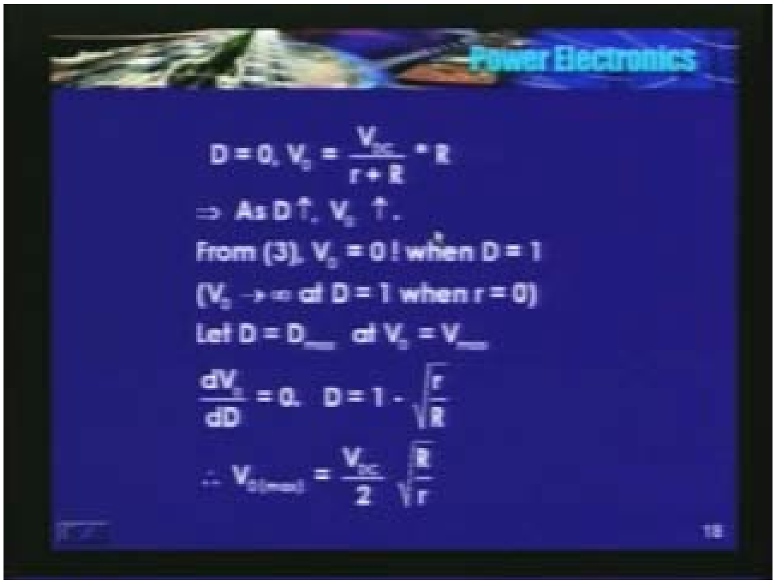

Capacitor continuously supplying power to the load and switch is inductor current increases linearly and when S is equal to 1, what does it imply? S is equal to 1 implies that switch is permanently closed, switch is permanently closed, capacitor is permanently supplying power to the load. What is this situation? This situation results into a case where output voltage becomes 0, capacitor has to discharge and capacitor will discharge, it is continuously supplying power, it does not receive power at all when D is equal to 1. So, capacitor voltage gradually decreases and becomes 0.

What happens at the input stage? A V_{DC} is permanently applied across an inductor. A constant voltage is permanently applied across the inductor. So, L di by dt is V_{DC} that is positive. In other words, di by dt goes on increasing. The device, the inductor or the source have their own current rating capacity. Beyond a point, V_{DC} will fail or inductor will fail or switch will fail.

At steady state, if the switch is permanently closed, current is steady state current is V_{DC} divided by small r. Inductor is saturated, inductor is saturated, V_{DC} divided by small r, r is very small, so L, large current in flow and it will definitely damage all 3 or one of them and at the output, V_0 becomes 0, V_0 becomes …

So, there is a flow in our assumption or in other words, assumptions are valid only if the value of D is low. As D approaches 1, our assumptions are not valid. What are they? V_0 is constant and ripple free, no, V_0 will decrease, V_0 will decrease. Here, current increases and it may saturate the inductor and may damage the source or inductor or the switch. So, our assumptions are not valid for high values of D. They are valid only for low values of D. For low values of D implies I close the switch, dumping the energy, closing the switch, dumping an energy. So, I can safely assume that output voltage will remain approximately constant and here inductor does not saturate, that is.

So, remember, our analysis is everything correct, only the problem with our assumptions. So, what is the average value of the current? See, V_{DC} divided by R by r. It is true, voltage input voltage is V_{DC} for D is equal to 0. In other words, switch is permanently open. The current that is flowing is the total resistance of the circuit, V_{DC} divided by total resistance is R divided by r. Average value of this current is goes on increasing with the D and at D is equal to 1, it is V_{DC} divided by R. D is equal to 1, switch is permanently closed. Current that is flowing is V_{DC} divided by small r. It will be very high. I do not think you can achieve that value.