Power Electronics

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Lecture - 28

So far we have studied 4 different DC to DC converters. They are; first one is buck buck converter, the output voltage V_0 is D into V_{DC}. Second one is boost, the output voltage is V_{DC} divided by 1 minus D and this expression is not valid for high values of D. So, in a non ideal boost, you need to take into the resistance of the inductor into account while deriving the transfer function and we found that this volt output voltage reaches a peak and it comes down and becomes 0 when D is equal to 1. Same thing is true for buck boost as well as the chuck converter. Ideal converters say that V_0 tends to infinity, wherein, non ideal converter, the output voltage is in all 3 – buck, buck - boost and chuck, they become 0.

These expressions are valid only if the inductor current is continuous, remember. These expressions are valid only if the inductor current is continuous and these expressions are independent of the inductor current, the magnitude of inductor current. They do not mention or there is no term containing i_L in the input output relations. So, if the current is discontinuous, we found that the output voltage is higher than these expressions, whatever is given by these, the transfer functions. We found in buck - boost as well as chuck, the output voltage is negative with the respect to the DC bus. Since, there is no isolation there is no isolation between input and output. In other words, I can have only 1 common reference in these circuits, in all the 4, I can have only 1 common reference.

Generally, we will take negative DC bus as the reference point. So, in other words, input and output are non isolated, they are not isolated. Now, so far we have studied AC to DC conversion. We have seen almost all the possible class of converter circuits and we have studied 4 numbers of DC to DC conversion. So, after doing that if I ask you to design a power supply; a design a 5 volt regulated power supply, the DC is derived from AC and then at the input, I give I consider ... power factor should be unity.

Now, what sort of a circuit you will suggest? Condition is AC to DC conversion, input is 230 volts, power factor should be unity, at the output I want to have 5 volt regulated DC power supply and it should efficiency should be reasonably high and you need not or you should not use a linear regulator. Your solution could be of this type.

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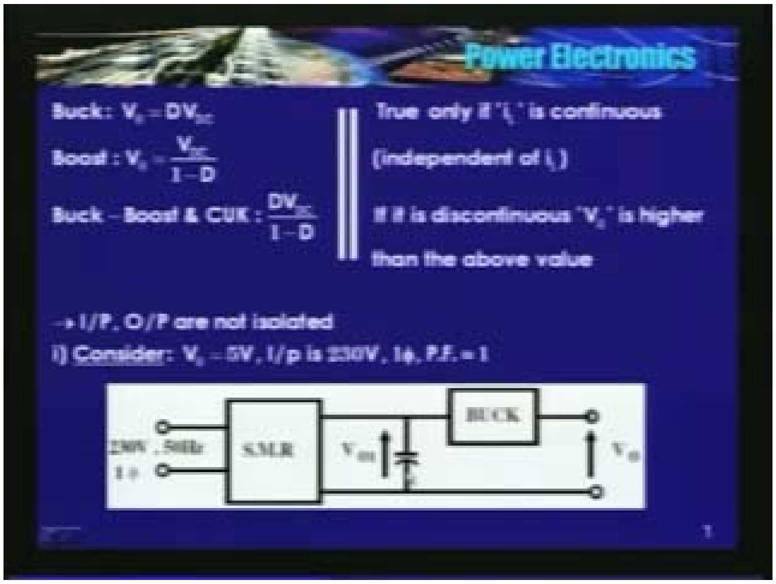

See, 230 volts, 50 hertz supply, I use or you may use switch, switch mode rectification, power factor is unity here. So, you have an output voltage V_{O1} and a buck regulator, wherein, you will get 5 volts power supply. You may suggest this sort of a configuration. Let me tell you one thing, there are far superior configurations available for this power supply. This is not the one. There are far more superior configurations than the this. So having studied so far, if you come out with this sort of a suggestion, I would I would suggest that this is some sort of an excellent suggestion for you.

Now, we will see the problems here. 230 is the input, you have used a switch mode rectification. So, V_{O1} will be definitely higher than 230 into root 2 because SMR can work satisfactorily only if V_{O1} is higher than the peak of the input. So, V_{O1} could be of the order of 350 to 400 volts. So, 350 to 400 volts is the input of buck converter and output is 5.

So, if I assume a continuous conduction or inductor current, output voltage is proportional to the input voltage and it is equal to D into V_{DC}. So, what is a value of D?

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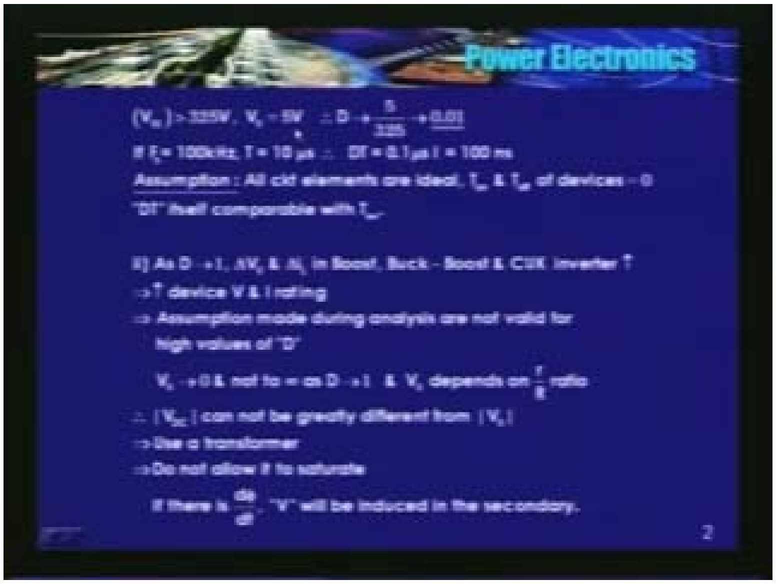

So, it comes up to be, see, V_0 is higher than 325 because V_0 is 5 volts. So, D is of the order of 0.1, 5 divided by 325, minimum I am considering. See, the, this should be higher than 230 into root 2, 230 into root 2. Minimum value here could be of the order of 350 to 400 volts or so if I use an SMR and you may have to use an SMR because I said that input input is an, input power factor should be unity.

Now, if you switch that DC to DC converter at 100 kilo hertz, so T becomes 10 micro seconds. So, DT is of the order of 100 nanoseconds or the device is off for approximately 100 nanoseconds. So, DT is 0.01, duty cycle is 0.01. So definitely, the inductor current is going to be discontinuous because I am storing energy for a very small fraction of the cycle. D is 0.01, duty cycle. So, I am storing for a very small duration and most of the times, stored energy is being dumped to the output. So definitely, inductor current is going to be discontinuous.

So, if the inductor current is going to be discontinuous, output voltage is no longer equal to D into V_{DC}. It is going to be higher than D into V_{DC}, we have seen this. What is the other problem? We found that the on time is of the order of 100 nanoseconds. While assuming the transfer function or in the or in analysis, we considered devices to be ideal. In other words, the on time of the device and off time of the device, we have neglected.

Now, the device is is on for 100 nanoseconds. Definitely, this figure is going to be comparable with the on time and off time of the device. So, D is very small, switch is switched at a fairly high frequency. I you cannot neglect the device non linearity, apart from the other passive elements, the non linearity of the passive elements. So, that is the problem 1.

So, what is the second problem? The second problem is in in buck, in buck – boost, boost and chuck converter, buck – boost, boost and chuck converter, as D tends to 1, the ripple in the output voltage as well as the output current increases. So, as D tends 1, most of the time, inductor is connected across this supply, output volt output capacitor is supplying power to the load. So, ripple in the inductor current as well as the capacitor voltage increases and the assumption that we made are no longer valid. Thus, decide the point.

So, if the ripple is going to increase, definitely, I need to choose a device of higher current rating and voltage rating because at the input, source is short circuited. So, source is source may get short circuited because inductor is being connected across a DC power supply and is all almost permanent because D tends to 1. So, in these non ideal converters, output voltage tends to 0 and not to infinity as D tends to 1. And this V_0, the peak value of V_0 depends on R by r ratio where small the r is the inductor resistance divided by the load resistance ratio. So, what do I can conclude?

Now, I can conclude that V_{DC} and V_O cannot be greatly different. In other words, magnitude of V_{DC} cannot be greatly different from the magnitude of V_0. We found input voltage is of the order of 400 volts if I use an SMR from a single from a single phase supply. Output voltage is of the order of 5 volts, D is going to be very small. Then, we have a problem. Now, if I want to boost a low voltage DC to a very high voltage DC, the transfer function says that D should tend towards 1. Then, again we have a problem. So therefore, these converters, you cannot have the magnitude of the input voltage greatly different from the magnitude of the output voltage. What next?

The situation demands, input is 230, 50 volts, power factor should be unity and I want a 5 volts regulatory power supply or input could be a 12 volt battery, battery DC and I want to boost a DC voltage to higher value. What should I do? In all these 3 circuits, sorry in all these 4 circuits, we have used an inductor. Input is DC, output is DC and we did not allow the inductor to saturate. So, in other words, you can use an inductor in a DC circuit, provided, you do not allow it to saturate. If I can use an inductor in the DC circuit, I can also use a transformer in a DC circuit, provided, I do not allow the transformer to saturate.

Our machine teacher might have told us that if you connect a transformer to the DC supply, there is going to be short circuit and transformer, it gets damaged. I am not saying that it is wrong but here I am telling you that you connect the transformer to the DC supply but then do not allow it to saturate. If there is a d phi by dt in the primary because if I connect a DC supply to an inductor or a primary of the transformer, current will increase linearly.

So, if the current increases or if the magnetizing current increases linearly, flux will also increase linearly. So, there is going to be a d phi by dt till the inductor saturates and I told you that I am not allowing the inductor to saturate. So, there is d phi by dt in the primary. So, if there is d phi by dt in the primary, there will be a voltage induced in the secondary. So therefore, you can use a transformer in a DC to DC converter but then do not allow the the transformer to saturate.

Now, before using a transformer in a DC to DC conversion, let us see how to recover the energy that is stored in an inductor? See, recovery of trapped energy or stored energy in the inductor.

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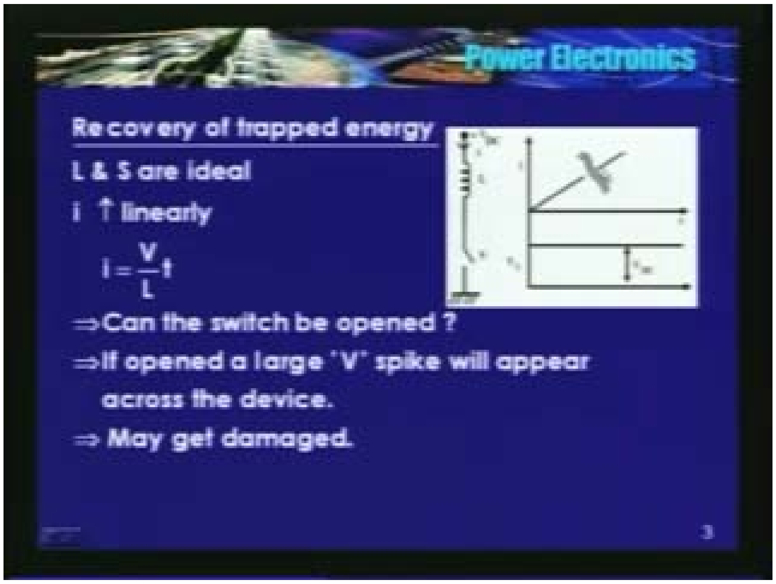

Consider this circuit; L is ideal, switch is also ideal. Close the switch or DC supply is applied to an inductor. So therefore, current will increase linearly. Inductor is not saturated, so current increases linearly. After some time, I want to open the switch. Can I open the switch now? Answer is no.

If I open the switch, I am breaking an inductive circuit. So, if if I break an inductor circuit, di by dt is going to be very large. A large voltage spike will appear across the switch and it will get damaged. So, in this circuit if you see, DC constant DC is applied to inductor. Current increases linearly, as long as till it saturates, current goes on increasing. You cannot open it, if you open it, a voltage spike will appear and device may get saturated. What next?

I have closed the switch. Now, after some time I have to open. If I do not open, inductor will saturate and switch will get damaged. You should not break the inductive circuit. In other words, current through the inductor should be continuous. Therefore, or in order to achieve this, I will connect a diode across the inductor. See, in this fashion.

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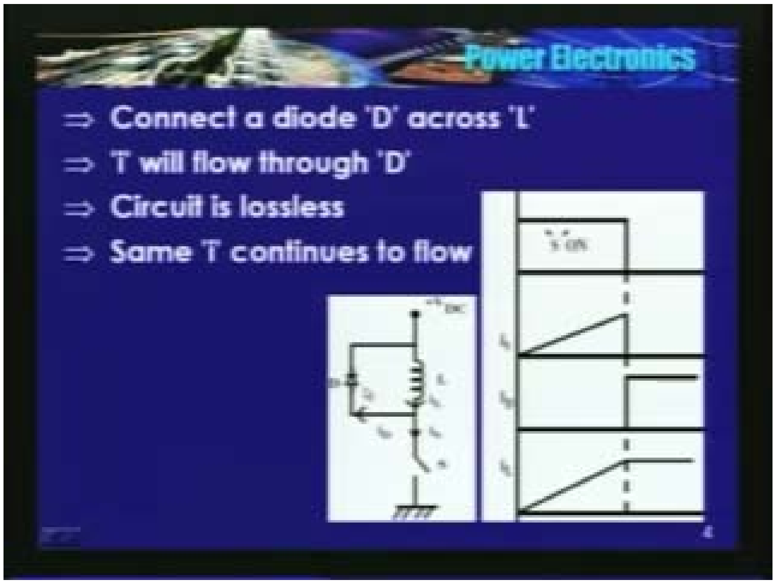

I connect a diode across the inductor. This diode is also known as freewheeling diode and sometimes we can call it as fly wheel diode, remember. Why fly wheel? You know that fly wheel stores the energy when it is accelerated and when it is decelerated, what happens? It is it can supply the energy back to the load, fly wheel concept.

Same thing is happening here also. I have stored the energy in the inductor and when I am opening a switch, that inductor current will flow through the diode. Ideally, there is no resistance or the internal resistance of the diode is very small. So, the inductor current starts flowing through this, very small resistive circuit. The value of the resistance in the circuit is very small. So, current slowly slowly decays, almost similar to a fly wheel.

So, you can call it as a freewheeling diode or a fly wheel diode. So, if I assume that diode is ideal, so what happens when I open the switch? Whatever the current that was going through the inductor starts flowing through the diode. So, at this point you have opened the switch, the switch current becomes 0, instantaneously. Immediately, the current starts flowing through the diode and this is the inductor current. I am assuming inductor and diode are ideal. In other words, circuit is loss less. So, current will remain constant.

But then in a non ideal circuit, there is going to be very small resistance in an inductor as well as a small resistance in the diode. So, if I use a high quality inductor, resistance may be very small but a finite resistance is present. Similarly, diode also has the small finite resistance. So, when I open the switch, the stored energy in the inductor is dissipated as heat in the internal resistance of the diode as well as the inductor.

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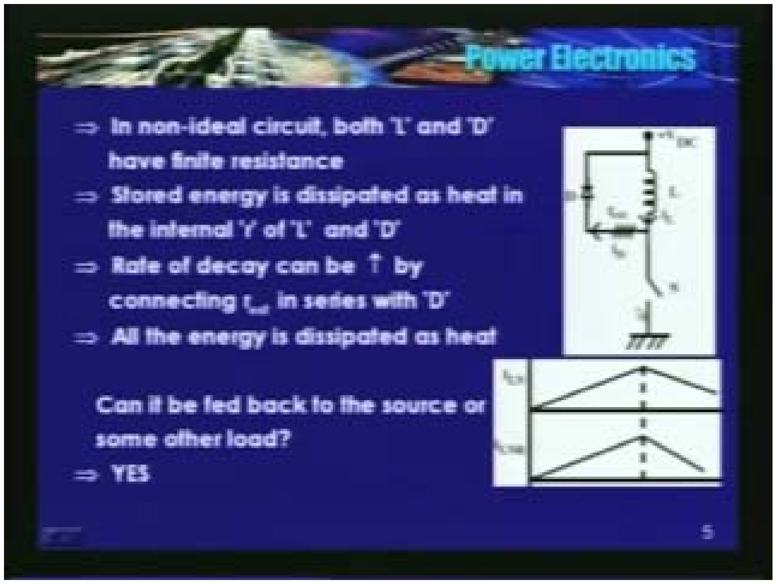

Since this resistance is small, the decay of current is also very small. The current decays very slowly. See in this fashion, decays very slowly. So, you may close the switch next time. At that time, immediately, whatever the current that is flowing through the diode starts flowing through the switch. So, if I close the switch somewhere at this point, this current, the magnitude of this current or the magnitude of current that was flowing through the diode starts flowing through this switch.

Now, by connecting an external resistance, small external resistance in series with the diode, I can increase this rate of decay. So, by connecting an external resistance, rate of decay can be increased. So, in the first case, ideal inductor and ideal diode; stored energy remains constant. Then I just considered the non idealities of inductor as well as the diode, stored energy is dissipated as heat, rate of decay is very small, in the sense, current decays very slowly. To increase this rate of decay, I connected an external resistance in series with the diode. So, decay rate increases. In all 2 cases, stored energy in the inductor is dissipated as heat. I will repeat; in these cases, stored energy is dissipated as heat.

Now, instead of dissipating, can you transfer it to a load or to a source? Answer is yes. How is that possible? Let us see. Now, before addressing this issue, let me discuss briefly about the principle of operation of a transformer. I am sure you all know this but I will just repeat it for a minute or 2.

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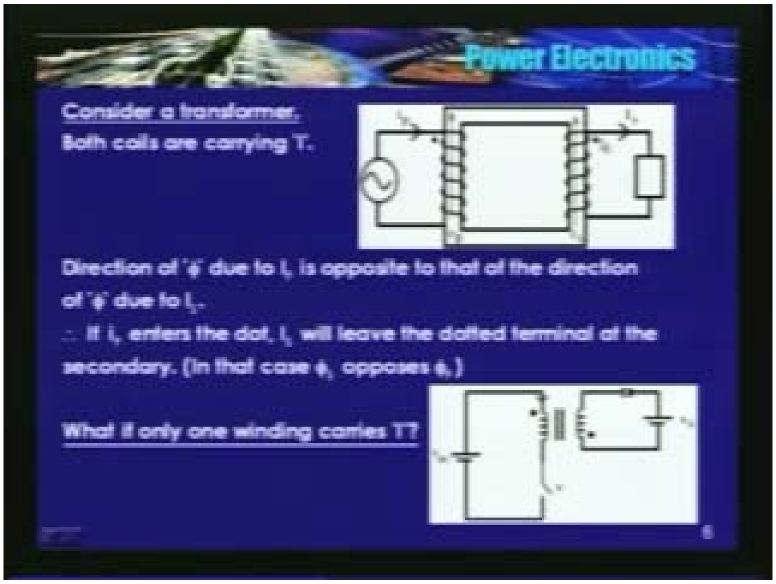

A simple 2 winding transformer; primary is connected to the source, secondary is connected to the load and we place a dot at both the windings. What this dot indicates? At any given time, these 2 dotted terminals have the same polarity. If this is plus, this is also plus. So, in the primary if the current enters the dot, in the secondary current should leave the dot. Why? Only then the flux produced by the primary opposes the flux produced by the secondary that is the principle of operation of transformer. So, dotted terminals are of the same polarity. So, at the primary side if the current enters the dot, current should leave the dot in the secondary. So, only under this condition, flux produced by primary opposes the flux produced by the secondary.

So therefore, if both the coils are carrying currents simultaneously which is the case here, transformer supplying power to the load, if the secondary is complete, secondary circuit is complete, i_S will flow. So, equivalent current will be there in the primary. So, current enters the dot, current leaves the dot. Both of them are carrying current simultaneously. So, direction of flux is opposite. That is about the transformer theory which has been taught to us by our teacher. Now, the question is what if only 1 coil is carrying current at a time? In other words, the primary is carrying current, at that time the secondary does not carry the current and vice versa. Can I have the same principle of operation? Answer is no. Why? We will see.

Take this circuit, transformer or 2 circuits are coupled. I close the switch here in the primary, voltage is applied to the primary winding, circuit is complete, current will flow, may be, DC supply, does not matter. So, if since it is a DC supply, current increases linearly because I can represent the primary winding by a coil having inductance L. Fixed inductance, fixed DC supply, primary current will increase linearly and when I close the switch, current should flow in this direction. That is the convention that we are following because if I close the switch, current has to flow in this direction in this direction.

In other words, current enters the dot currents enters the dot, listen to me carefully. What is the correct direction of the secondary current, if it has to carry the current simultaneously or at the same time? If current enters the dot in the primary, current should leave the dot in the secondary. That is the principle of operation of a transformer. But then there is a diode in the secondary. So, if the current has to leave the dot, it flows in this direction and we know that reverse conduction in diode is not possible. So therefore, current cannot leave the dot current cannot leave the dot. But then current can enter the dot current can enter the dot, current can enter the dot.

Therefore, when I close the switch in the primary, current is entering the dot. The correct direction of i_2 is to leave the dot because of the diode it is not possible. Therefore, when the primary is carrying current, there is no current in the secondary. In other words, I have a transformer and only 1 coil is carrying current. In other words, when I close the switch S, only primary is carrying current. There is no current in the secondary. So, if I use a transformer theory i_2 is 0. In other words, i_2 prime is 0. Therefore, source supplies only the magnetizing current and that magnetizing current is the one which is flowing through the magnetizing inductor. In the beginning I told that you can use a transformer in the DC circuit but I should not allow it to saturate.

So, in other words, I should not allow the magnetizing inductor to saturate. After some time I will open the switch. What happens when I open the switch? Current that is flowing through the magnetizing inductor should be continuous. You cannot break an inductive circuit. In other words, flux in the curve must be continuous. I cannot allow the flux to collapse. In other words, if flux collapses that is d phi by dt is infinity, a large voltage will appear across the switch and it will get damaged.

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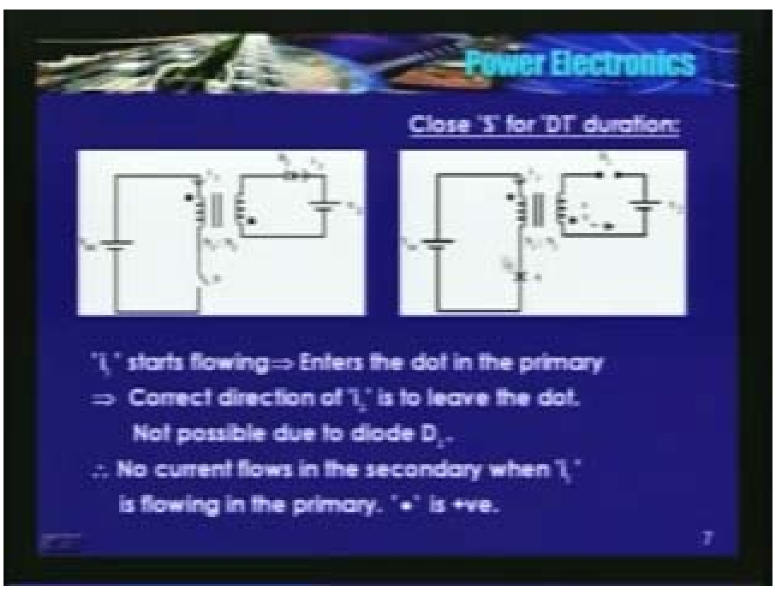

So, what next? What will happen? Inductive current or flux in the core must be continuous when the primary current was carrying the current voltage applied to the primary is V_{DC} with dot as positive. What is the equivalent or what is the voltage induced in the secondary? It depends on the turns ratio. It depends on the turns ratio with dot as positive with respect to this terminal.

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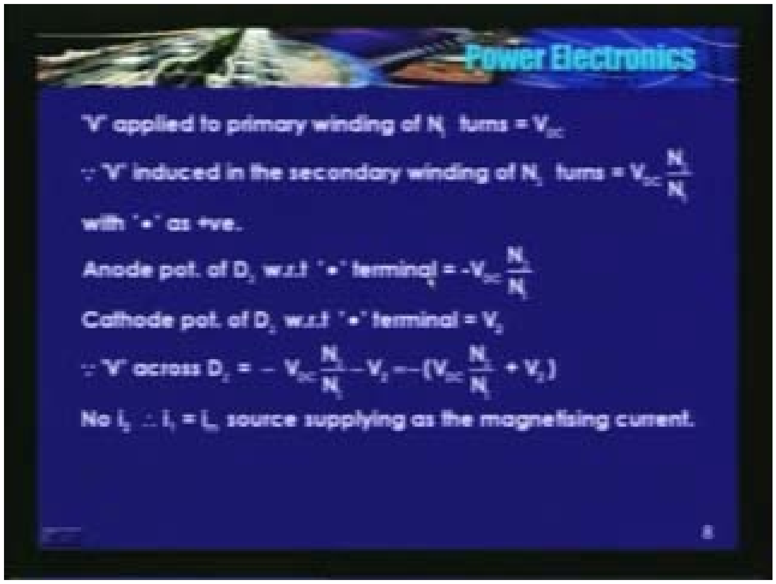

So, what is the voltage that is coming across the diode when the switch is carrying current in the primary? It is given by V_{DC} into N_2 by N_1 because V_{DC} is the voltage that is applied to N_1. So, volt per turn, it is V_{DC} divided by N_1 multiplied by N_2 is a voltage induced in the secondary with the dot as positive. Anode potential of D_2 with respect to the dotted terminal is now minus V_{DC} divided by N_2 by N_1. So, if you see in this circuit, this is positive. So, there will be definitely this will be negative. This magnitude of voltage induced in the secondary is V_{DC} into N_2 divided by N_1. Cathode potential is V_2 with respect to the dotted terminal. If I take this as the reference, thus or that is the reference point, cathode potential is V_2.

So, what is the voltage that is coming across the diode? It is sum of this voltage plus this voltage, isn't it? plus, minus, plus, minus. So, what is the voltage that is coming across the diode? It is sum of these 2 voltages, plus minus plus minus. So, voltage across the diode that is coming is V_{DC} into N_2 divided by N_1 plus V_2. In other words, diode should block this voltage when the switch is closed. So, this is the voltage that is coming across the diode. It should block when the switch is closed.

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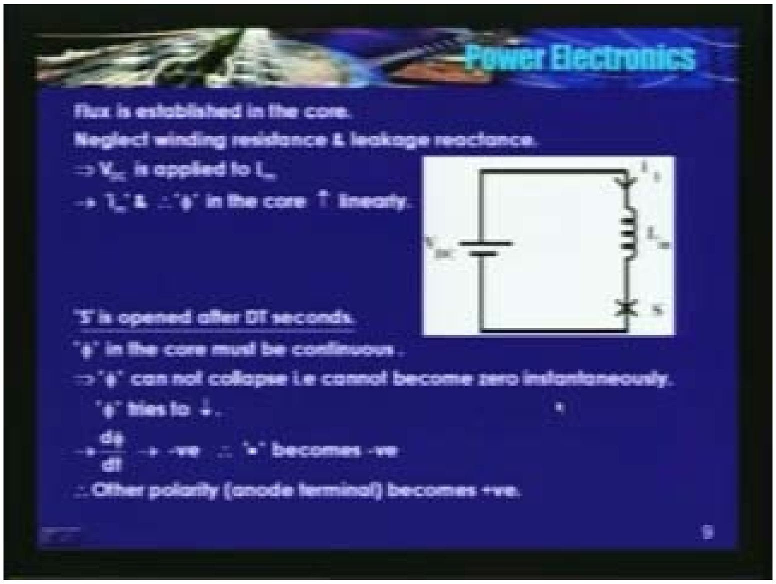

I told you, when I open the switch, flux has to be continuous. But then when I open the switch flux was increasing linearly. When I open the switch, flux starts decreasing. It tends to decrease. In other words, d phi by dt is going to be negative. If d phi by dt is going to be negative, the dotted terminals are going to be negative. I will repeat here, see, when I open the switch, flux trying to reduce, d phi by dt is going to be negative. Now, this is going to be negative. Therefore, this terminal is going to be negative. If this is negative, this will be positive.

Therefore, now diode can conduct diode can conduct and diode starts conducting and whatever that energy, that is stored in the magnetizing inductor is transferred to the load to the load. See in this equivalent circuit, diode starts conducting.

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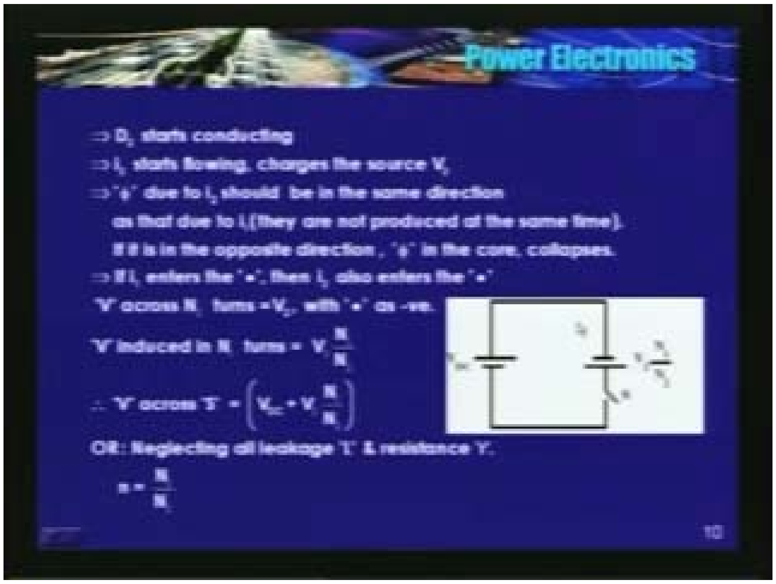

So, what should be the direction of flux produced by i_2? If both the coils are carrying current simultaneously, remember, if primary as well as the secondary coils are carrying current at the same time, flux produced by these 2 coils should oppose. We found in this circuit that only 1 coil is carrying current at a time. When I close S, no current is flowing in the secondary because of the diode. So therefore, the flux produced by the secondary when I open the switch should be in the same direction as that of the flux produced by the primary. Mind you, they are not being produce at the same time.

Now, if is going to be opposite like the same transformer theory, what is going to happen? Flux in the core is going to collapse because primary has produced some flux, immediately secondary current starts flowing. So, it will produce its own flux and even if this flux, secondary flux is going to oppose the primary, there is going to be a flux collapse, a step fall in the flux. You cannot have that sort of a situation. If you allow that sort of a situation to occur, a large voltage will be induced because d phi by dt is large. A large voltage will be induced across the switch or the diode and they will get damaged.

So therefore, the direction of flux when 1 coil is carrying current at a time in a transformer should be the same or or flux produced by the primary current, the direction of flux, I am sorry, the direction of flux produced by the primary current should be the same as that of the flux produced by the secondary current. Direction of the flux produced by primary should be same as the direction of flux produced by the secondary. Therefore, if i_1 enters the dot i_2 also will enter the dot in the secondary because these 2 currents do not flow at the same time, remember. They are not flowing at the same time. Therefore if i_1 leaves the dot, it should leave the dot in the secondary in the secondary.

Now, you may say that why not allow the diode to conduct when the switch is carrying current in this cycle? See in this circuit, you may say that allow the reverse the diode connection.

Therefore, if I reverse a diode connection, current enters the dot. Now, the current direction is in the secondary is to leave the dot. So, current current leaves the dot and current can leave because now I have reversed the diode connections. So, what is the primary current now? It is a magnetizing current plus the equivalent secondary current.

Now, when I opening the switch what will happen? I said magnetizing current has to be continuous. There is no path here, there is no path here, there is no path. Magnetizing current has to be continuous. Now, I said, when I open the switch d phi by dt is going to be negative, dot is going to be negative, dot is going to be negative, this is positive. I have interchanged the diode connections, I reversed. So, there is no path for the flux or the magnetizing current is going to be discontinues. A large voltage spike will appear and will damage the circuit.

So therefore, diode connections in the secondary are very important. So, you need to ensure that only 1 winding carries current at a time. You should ensure. This is the if, when the diode is conducting current, what is the voltage that is appearing across the switch? When the switch is carrying current, the some other voltage is appearing across diode. That we found. Now, when the diode is conducting, what is the voltage that is appearing across the switch?

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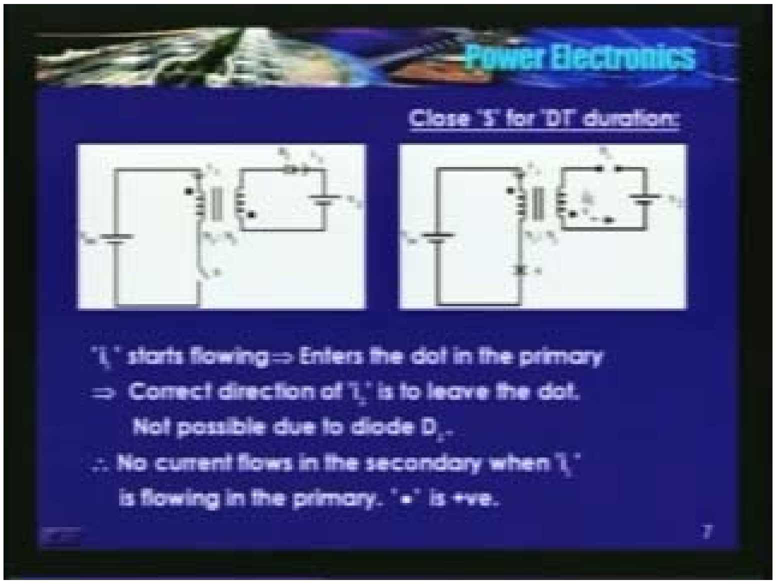

When the diode is carrying current, voltage appearing across the secondary winding is when I close this, when the diode is conducting, this is closed. Voltage that is appearing across the secondary is V_2, V_2 with dot as negative. So, what is the equivalent voltage or reflected voltage in the primary? V_2 here, with dot as the dot as negative, therefore dot is negative. V_2 into N_1 divided by N_2 is the voltage in the primary, induced in the primary.

So, voltage induced in the primary when the current that is flowing in the secondary, when the current flowing in the secondary, only then this circuit is closed and voltage applied to the secondary winding is V_2 with dot as negative. So, with dot as negative here, voltage induced in the primary is V_2 multiplied by N_1 divided by N_2.

So, the equivalent circuit is looks something like this. I have a V_{DC} source, an induced voltage with dot as negative, the voltage magnitude is V_2 multiplied by N_1 divided by N_2 and switch is here that is open. So, voltage across the switch is V_{DC} plus this volt. In other words, S should block some of these 2 voltages when the diode is conducting. So, I tried to explain the recovery of trapped energy using the first principle. The principle is that flux in the core should be continuous, only 1 coil is carrying current. So, direction of flux produced by the primary winding should be the same as the direction of flux produced by the secondary current because these 2 coils carrying current at 2 different times. They do not carry the current simultaneously. This is using the first principle.

Now, if you are not convinced, I will try to explain using a transformer equivalent circuit. Now, to explain this I will neglect the leakage inductance or leakage flux and the winding resistances. So therefore, now in the equivalent circuit only LM is left.

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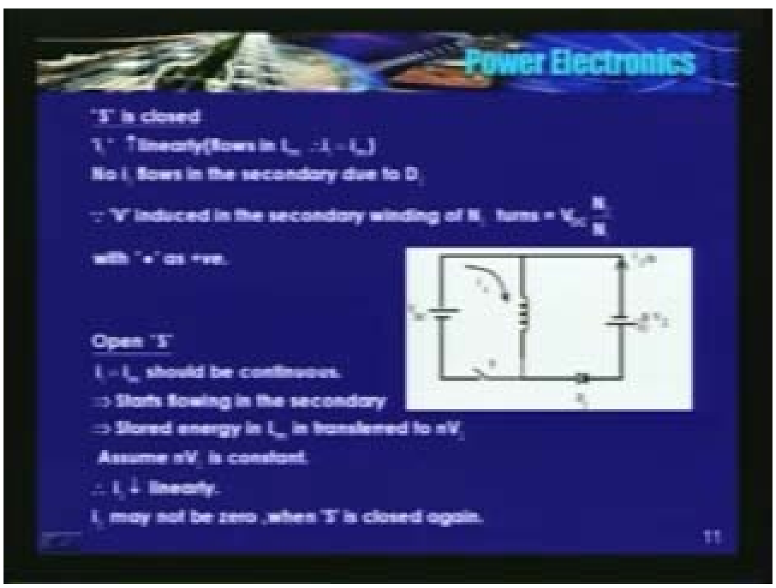

So, this is the equivalent circuit. Transformer is only represented by LM. Winding resistance is in the both primary as well as secondary and the leakage flux or leakage reactance is 0. So, I have only LM. This is V_{DC} and the switch here. I need to transfer whatever that is connected in the secondary to the primary.

Now, what is there in the primary? Primary I have to represent as it is, V_{DC} as well as the source. In the secondary, there is a battery of V_2 and the diode. Now, how do I connect this diode? We found that when switch is closed or when the current is flowing in the primary, no current will flow in the secondary. I will repeat; we found that when I close the switch S, primary current which is equal to the magnetizing current starts flowing. Secondary current is 0, no current flows because of the diode connection. So, how do I connect the diode in the secondary is, it is like this. Diode and the battery; cathode is connected to the positive here and V_2 is the voltage at the secondary, I will transfer it to the primary. So, this is what it is; V_2 divided by N_2 into N_1 is the voltage here.

Now, you may say that why did I connect this diode in this fashion? Now, assume that if I reverse the direction? Now, what will happen? When I close S, some current is flowing in the primary. Now, if I reverse this, some current can flow in this fashion, V_{DC} plus N_2V_2 diode this way. Current can flow in the secondary when the switch is closed. But then we found in the circuit, original circuit that when the primary is carrying current, there cannot be a current in the secondary. That is because of the diode connections.

So, this is the correct direction of or this is the right correction connections of the diode. So, when I close S, i_1 flows in the primary, no current can flow in the secondary. After sometime, I will open S, what will happen? This current should be continuous, i_1 which is nothing but the magnetizing current because no secondary current, i_2 prime is 0. So therefore, i_1 is only IM. So, a fixed voltage is applied to LM, i_1 increases linearly, therefore flux in the core also increases linearly.
So, when I open S, direction of i_1 or flux in the core or the current that is flowing through the inductor should be continuous. It starts flowing in this manner, in this way. So, stored energy here is transferred to a voltage source V_2, is supplied to V_2. Now, it may so happen that i_2 prime, the current that is flowing in the secondary may become 0 or may not become 0 when you close S for the second time.

Now, what happens if the current is finite or the current that is flowing in the secondary winding or i_2 prime is finite? We found that when i_1 is is increasing linearly flux in the core also increases linearly. When I open S, that i_1 starts flowing in the secondary. The magnetizing current starts flowing in the secondary and it starts decaying. In other words, flux in the core decreases when D_2 is carrying current. If the secondary current becomes 0, flux in the core also becomes 0. So, if the secondary current is 0, before the switch is closed again, the flux in the core has become 0. So, i_1 starts from 0 when I close the switch for the second time. Mind you, I am applying just the DC voltage to a core: the primary of the winding, either a positive voltage or no voltage. So, flux increases and decreases.

So, if I plot the BH curve, operation is going to be only in the first quadrant, remember because when I close the switch; i increases, therefore H increases, flux also increases in the core. Therefore, B also increases. When I open S, flux decreases. In other words, H decreases, flux also decreases. So, I am not applying a negative H. So, applied H is only positive and always in the first quadrant. It is a DC flux and the operation in the first quadrant only.

So therefore, if the secondary current is 0 for a finite time or it becomes just 0 prior to closing the switch S, flux in the core has become 0, so what I say is flux resetting has taken place or I have completely reset the DC flux that was there in the core. I will repeat; if the secondary current is 0 for a finite time or it becomes just 0 to prior to closing the switch S, we have rested the flux in the core. There is no flux or finite flux when I close the switch S for the second time. So, if there is a finite current present when I close the switch just prior to closing the switch in the secondary, immediately that current transfers to the switch or to the primary winding.

So, i_1 is going to be a finite value, immediately when I close the switch. So, if i_1 is finite, flux is also finite. So therefore, flux in the core is always positive always positive always positive. Now, whether to reset the core or not to reset the core; we will see sometime later. So, we found that if I use a transformer, you can transfer the energy from one source to another source. So, if I can transfer to another source, I can connect a capacitor and I can charge that capacitor. Now, what sort of a power supply we are talking about if I connect a capacitor at the output of the secondary of the winding? Before doing that we will plot the various waveforms of the circuit which we have discussed just now.

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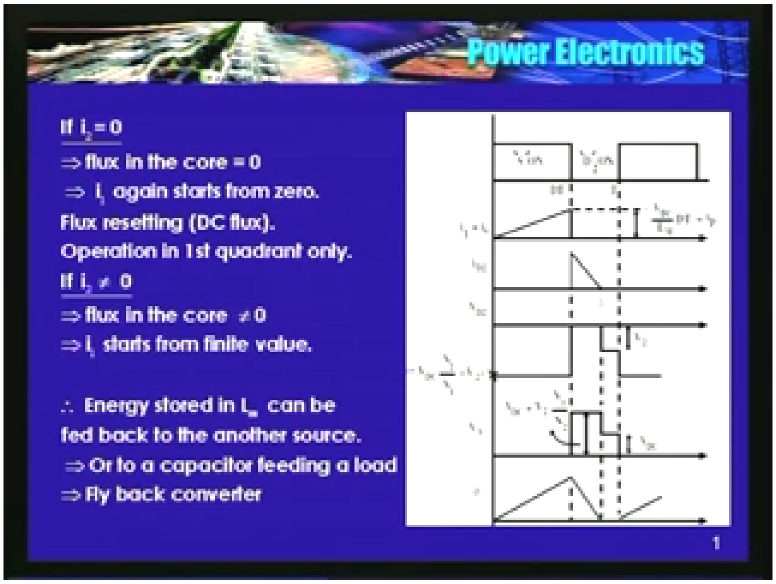

See here, S is on, D_2 is on. When I open when I close S or during 0 to DT primary current which is also the source current which is nothing but the magnetizing current increases linearly. Now, why is it starting from 0? It starts from 0 because in the previous cycle, just prior to closing S, i_2 is 0. I will repeat; it starts from 0 because just prior to closing S or much before closing the switch S, current in the secondary has become 0.

If there is a finite current in the secondary just prior to closing the switch S, the primary current would have started from a finite value. It starts from a finite value and increases linearly. So, I have assumed that secondary current is 0 for a finite time or it becomes 0 just prior to closing the switch S. So, it starts from 0. So, this is the peak value which is equal to V_{DC} divided by LM into D into T. So, this is nothing but applied voltage divided by the inductance into D into T. This is the peak value.

At DT, switch is opened, whatever the current that was flowing through the magnetizing inductance starts flowing to the secondary. So, this is the diode current or the secondary current.

What is the equivalent current? This is i_P is the peak current flowing in the primary. Now, this i_P starts flowing in the secondary. So, this magnitude depends on the turns ratio. i_P is the current that was flowing in the primary. Now, it is starts flowing in the secondary. So, I need to take the turns ratio into account. So, this peak and this peak they are not the same. It depends on the turns ratio turns ratio and it starts decreasing and it becomes 0, at somewhere beta. Therefore, flux in the core also becomes 0.

If you see here, flux in the core becomes 0 at this point because i_2 has become 0. i_1 has started increasing linearly from 0, flux also started increasing linearly from 0. It has become, at attained a peak and become 0 here. This is the voltage across the diode when the switch is on because this turn is a voltage induced in the secondary because we are applying V_{DC} to N_1. So, equivalent voltage that is induced in the secondary with the dot as positive is this. So, and the cathode potential is V_2 with respect to dot is this.
Same thing is true here. Now, the secondary voltage when the diode is conducting, see, when the diode is conducting, secondary voltage is V_2 is applied to N_2. So, this voltage is V_{DC} plus V_2 into N_1 divided by N_2. Now, what happens when the current has become 0 in the secondary? What happens when the current has become in the secondary?

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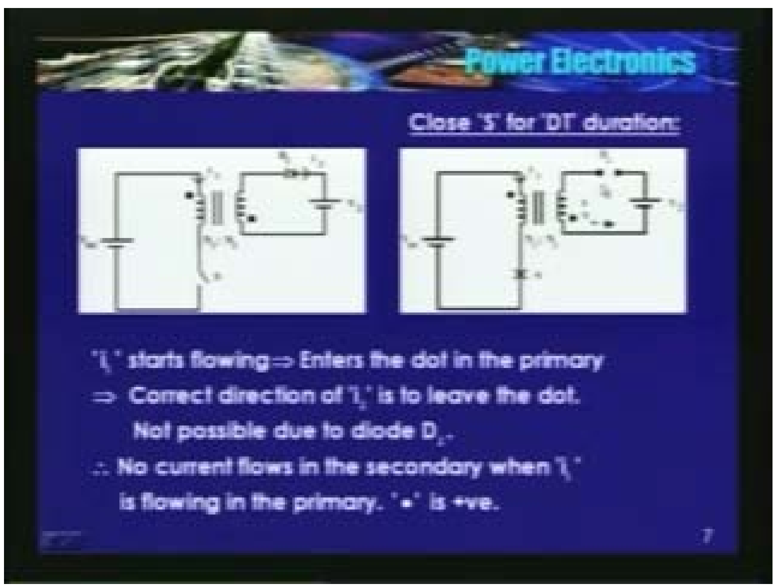

See in this circuit, no current is flowing in the secondary no current is flowing in the secondary. So, entire V_2 appears across the diode or diode is blocking the secondary voltage or V_2, diode is off. Similarly, no current is flowing in the primary because no current is flowing in the D_2, no voltage is induced here. So, when the diode has become current has become 0, voltage across the diode is V_2 itself. No current, no current is flowing, no current is flowing here. So, voltage across the diode is V_2.

Similarly, no current here, so no equivalent voltage reflected here. So, voltage across the switch is V_{DC} itself, V_{DC} itself. See here that I have seen, shown here, voltage across the switch is V_{DC}

here when the or during no current period and voltage across the diode is V_2 itself, V_2 itself. If if the if you know that continuous conduction or current current when just become 0, at this point you would had 0 voltage across the diode in the entire period.

Similarly, you would have had the same voltage in the entire period. So, when the current becomes 0, voltage appearing across the diode is the secondary voltage itself and in the primary, it is the source voltage. More about it, we will see in the next class.

Thank you.