Switched Mode Power Conversion
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Lecture - 15
Isolated Converters – II

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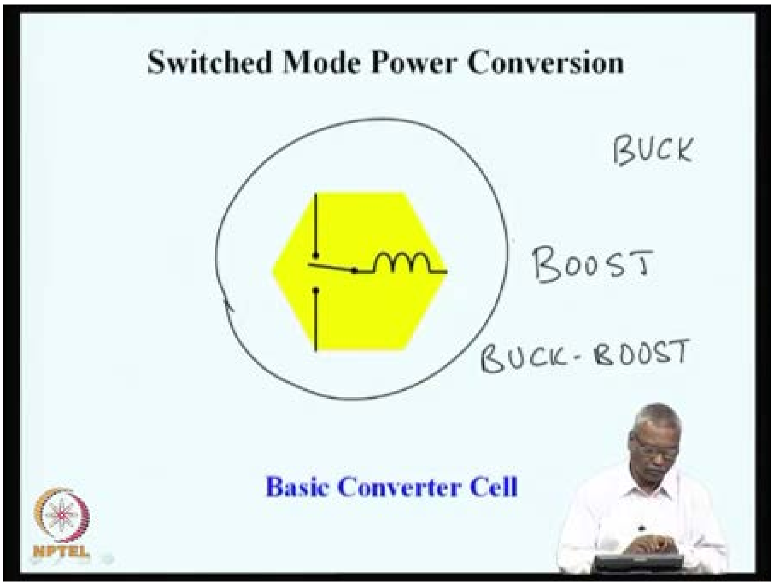

Good day to all of you. In today's lecture we will continue the same ideas that we had seen in the last lecture namely the isolated power converters. We had seen in the previous lectures that in switched mode power conversion. We defined, we defined a basic cell which consists of a single pole double cross switch and one energy storage element inductor. Then this was converted in several ways to identify different power conversion functions, namely buck power converter. Then we saw the boost power converter, then we saw the buck boost power converter. So, all this power converts, we are providing power from a source to a load with the ground potential which is common the 0 potential, which is common for the source as well as the load. So, such converters were called the non isolated power converters.

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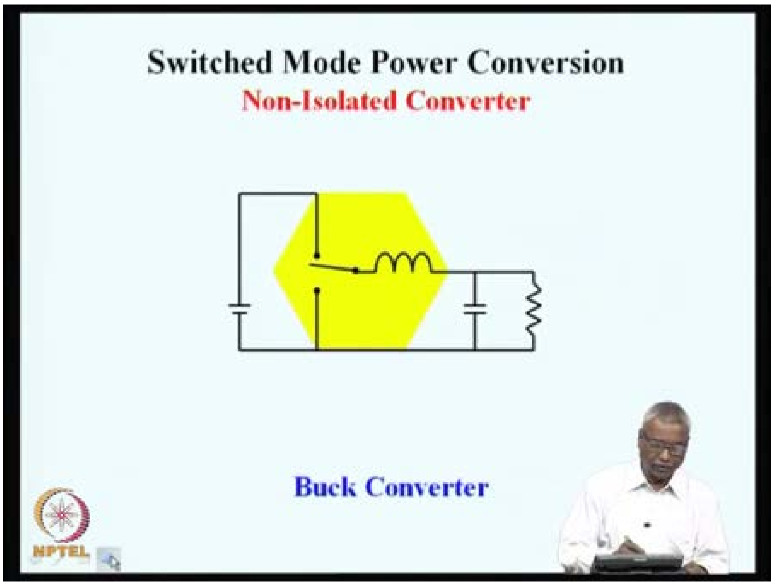

This is a non isolated buck converter, and we saw the variations of boost converters and fly back converters all belonging to the non isolated family of power converters.

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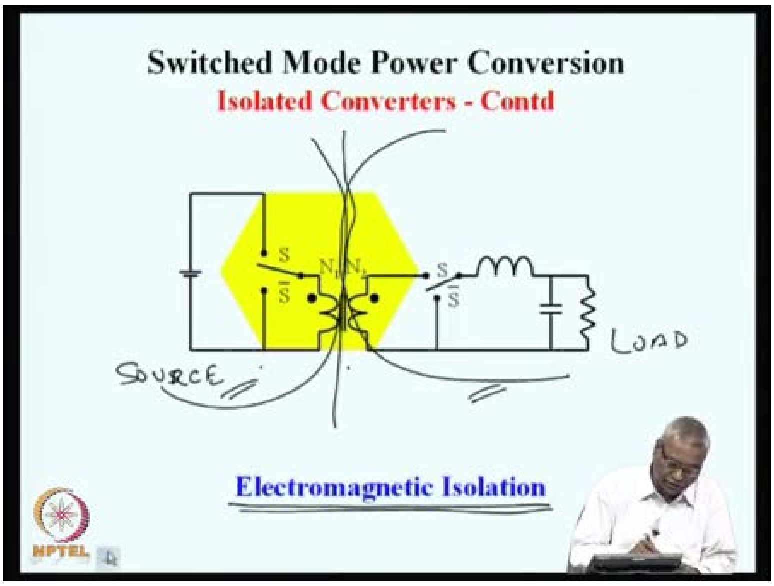

Then in the last lecture, we introduced the idea of isolated power conversion and we had seen that the isolation is obtained by an electromagnetic process of decoupling. The source side potential and the load side potential. If the source is at certain potential if the load has certain other potential. Both of them are electrically isolated at the transformer, which provides electromagnetic isolation power is converted energy is transferred from electrical to magnetic and then magnetic to electric, achieving electrical isolation between the source and the load. In the last lecture we saw the key idea of this isolation is through an electromagnetic process, which is through a transformer, which is connected to the source side on the primary.

This source side on the primary and load side on the secondary and in that the important point to notice is that the electromagnetic element should have the flux operating in stable condition, while this switched mode power converter works. So, for that we saw that the flux balancing required suitable resetting of the magnetic core. In the whole of last lecture, we went through the process of what is known as the forward converter where the losses reset the reset process of the magnetic circuit was been done with losses.

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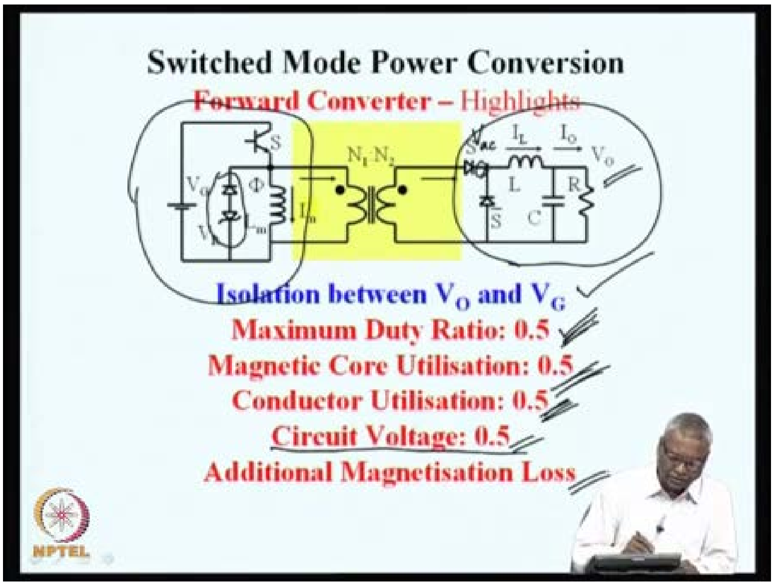

This was the forward converter that we had seen in the last lecture and it introduces. A passive method of resetting through a voltage source across the primary which ensures that the transformer core is subjected to a negative voltage during the off period and thus the process of resetting got established. The secondary side voltages which being noticed on this side, we AC switching voltage is then filtered through the inductor L and C. We provide V naught at the output the secondary part is identical to our standard non isolated buck converter. The primary switch ensures that energy is transferred to the transformer primary. Then from the secondary side this energy is transferred to the load and we saw that we achieved isolation between the source and the load.

The maximum duty ratio unlike the non isolated converter got limited to 0.5 because half the time we needed in order to reset the flux the during the on time when the flux in the magnetic circuit gets established. We needed a similar time in order to reset the flux on account of that the maximum duty ratio got limited to 0.5. The consequence of this is that the magnetic core is utilized only in one side the magnetization of the core is taking place on one side of the in one polarity on account of that. Even though we are using a material, which is capable of getting magnetized in both directions, we are using it in only one direction.

So, we say that the core was utilized only to 50 percent of its capacity. Because the duty ratio was limited to 0.5, the conductors on the primary end the secondary of the transformer carries current only for half the time. So, the utilization of the conductor was also limited to 0.5 and we also saw that during the reset process double the voltage is applied across the half switch S. So, we would say that the circuit voltage is also only half of what is the maximum voltage, which is which is seen by the switch so on account of all these terms.

We find that these forward converter, even though it achieves the isolation it loses capacity or for the same power conversion. We have to use a lot more material ion is more because magnet is underutilized copper is more, because copper is underutilized the switches have to be rated for more V a rating. Because the circuit voltage is only one half and further there is also an addition of magnetization loss all these points. We had seen in grid details and in today’s lecture, we will see some of these points and we will see also several other isolated converters.

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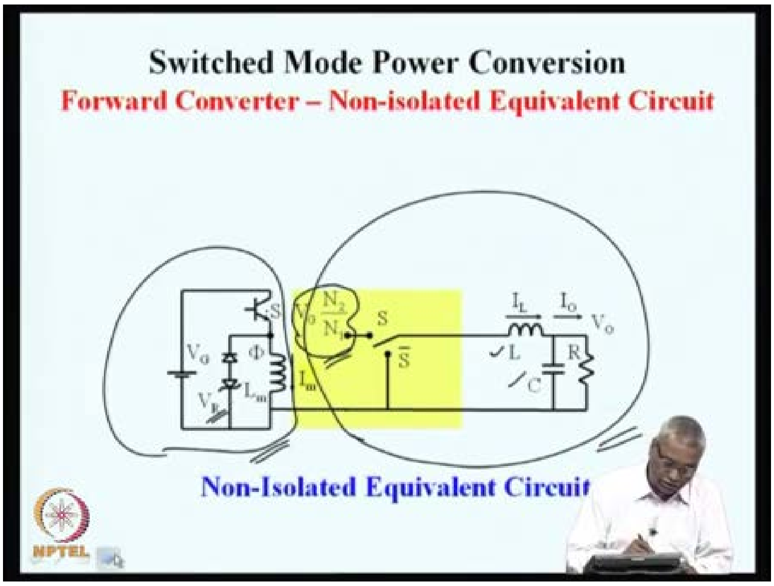

As for as the power conversion voltage conversion ratio current conversion ratio etcetera are concerned, we can draw an equivalent circuit where we have a non isolated equivalent circuit, which is subjected to a voltage of V G into N 2 by N 1 and rest of the circuit the L C and the output voltage all these things are as before. So, we might say that our forward converter consists of a switch plus the magnetization of the transformer. Then as far as the load is concerned we can treat it as if it is been subjected to a source voltage of V g into N 2 by N 1 and a non isolated converter. So, we will be able to do all the other analysis based on the circuit that is on the secondary side and the magnetization part alone can be carried out based on the primary side equivalent circuit. The primary equivalent circuit, when the switch is on the transformer is replaced by its magnetization equivalent L M and when the switch is off this L M is subjected to a voltage of V R which is a negative voltage.

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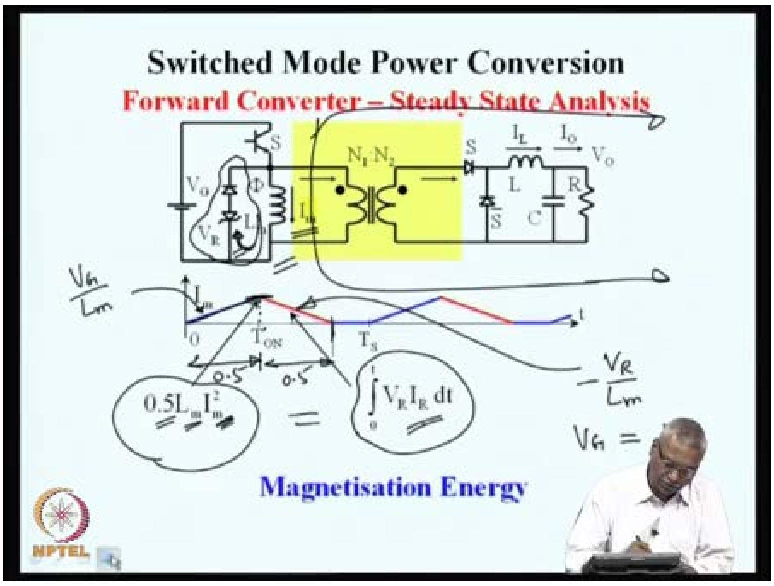

So, in this circuit we could look at the process of magnetization and also the energy associated with the magnetization and eventually the loses associated with the process of isolation. We can see that as far as the magnetization current I M is concerned, we have replaced the rest of the circuit as an equivalent ideal circuit, on the right hand side of this border. What we have here is a magnetization inductance and the magnetization voltage which normally is realized by a zener voltage and a diode. This part of the circuit can be separately seen, so during the on time the inductance magnetization inductance L M is subjected to a supplied voltage of V G.

So, the current magnetization current is a linear ramp increasing at the rate of V G divided by L M is d I by d t. The end of the on time there is a peak current reached here which is shown as I M. This peak current is I M peak and the total energy at that time in the core can be written as 1 half of L M into this. I M peak whole square, now this energy is trapped in the core and this energy is what we are trying to reset using the process of the reset circuit here, which is the V R plus the diode. So, during the second half or during the half period the inductance continues to pass this current, because the main switch has turned off this current continues to flow through the zener.

So, during this time we see that the d i by d t is V R divided by L M with the minus sign. So, if V R and V G are equal. If V G is equal to V R, then the magnetization time t on will be the same as demagnetization time. This is the reason why we are unable to use the forward converter for duty ratios beyond 0.5. So, if we magnetize the core for a duration t on we will require a similar time for demagnetizing the core. So, the maximum duty ratio at which this converter can be used is only 0.5 and the remaining 0.5 will be used for demagnetizing. So, this is the energy that is in the core and during the half time that energy is dissipated in V R with this total energy integral of the voltage across the reset circuit current in the reset circuit. d t integral 0 to t V R I R d t by consideration of the energy, we can also say that this energy is the same as the half L M I M peak square energy. So, this energy is what is last last in V R part resetting part of the circuit and to that extent.

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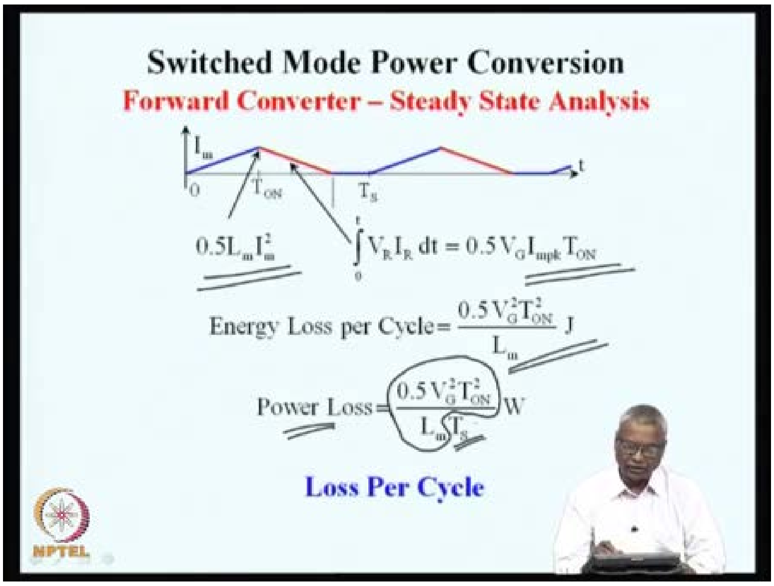

This converter will be less efficient compared to its non isolated counterpart the magnetization energy that you see here. This is the energy that is lost in V R and energy loss per cycle is this half L I square. This can be replaced by appropriate term substituted here and the power loss is energy loss in 1 second. If the switching frequency is f of s, then this whole quantity which is the energy loss per cycle multiplied by f of s or divided by t s is a power loss in 1 second energy loss in 1 second is the power loss.

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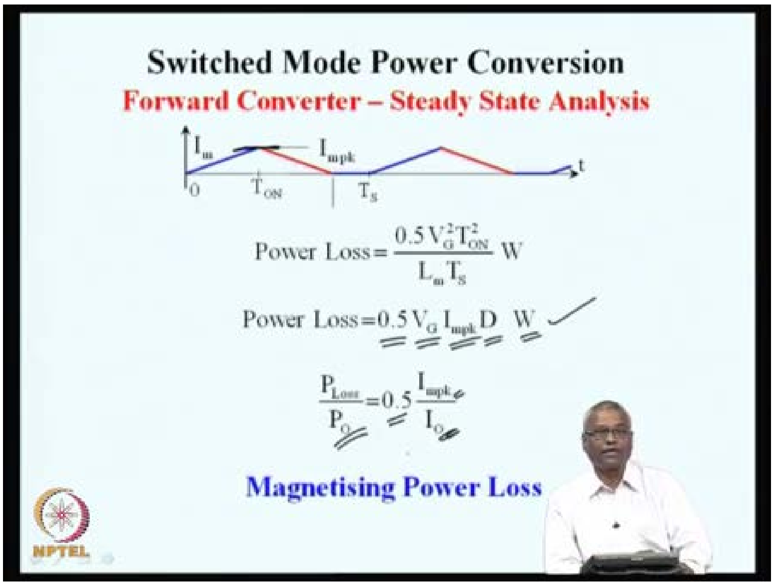

This is the loss per cycle and if we talked about the power loss that is takes place in the converter, this can be modified and put in this form where half of source voltage peak magnetizing current duty ratio and unities in watts. This is the power loss and if we take the ratio of magnetization loss compared to the output delivered this is more important because as a ratio this loss will tell us how much is the delivered power and what portion of that what fraction of that is lost in the magnetization circuit? So, this turns out to be one half of peak magnetization current divided by the load current. If we call this peak current here as peak magnetization current that divided by the load current is multiplied by 0.5 and that gives us the ratio of magnetizing power loss.

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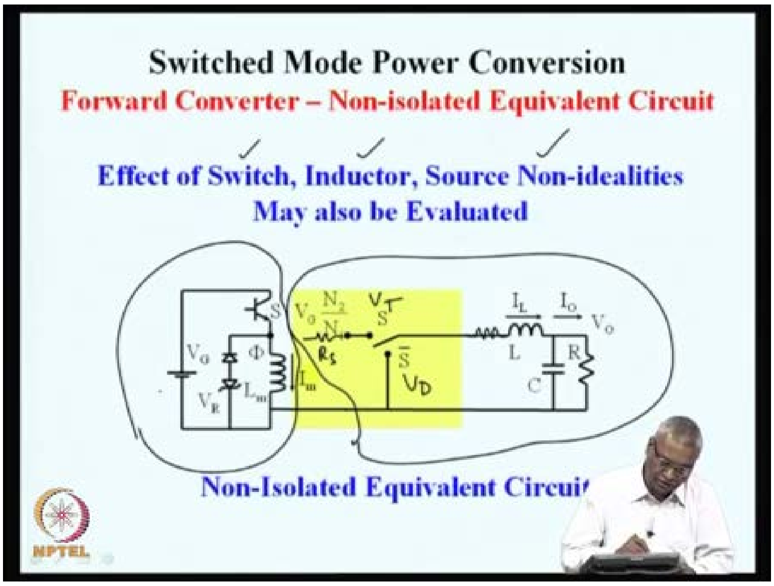

This loss has to be accounted for as for as the performance of voltage conversation ratio current conversion ratio etcetera. The what is shown here is our equivalent circuit as for as the secondary side is concerned the magnetic circuit part has been seen already by this section. The switch non ideality, what we see here the inductor non ideality which is the resistor of the inductor the switch non ideality is the drop in the voltage v t v d etcetera. The source non idealities, which are again resistance of the source etcetera all this may be evaluated by analyzing the non isolated equivalent circuit. Just as we did in the precious circuit and the loss in the magnetic circuit can be separately analyzed by this simple idealized circuit, where the magnetic magnetizing inductance is charged by V G and discharged by V R. This is a fairly simple method of doing the complete study state analyses.

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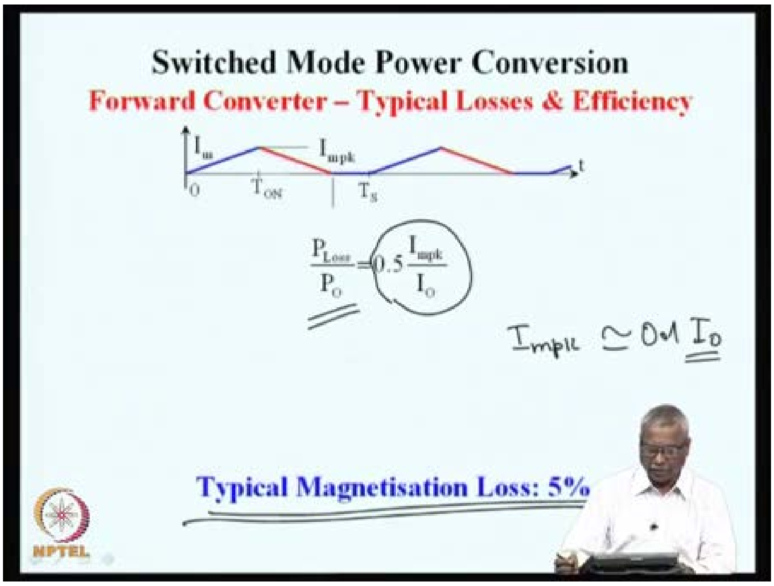

We saw that the loss on account of magnetization is 0.5 times peak magnetization current divided by load current. Normally, we would like to keep the peak magnetization current approximately 0,1 times i naught. We will keep the magnetizing current peak to be just about 10 percent of the load current and that will result in typical magnetization loss to be limited about 5 percent. So, if the convertor is ideal and if the magnetization path alone is a taken into account the loss could be 5 percent, you could have another 5 percent loss because of the switches. Another 1 or 2 percent loss because of the inductors drops and so on so typically efficiencies of the order of 85 to 90 percent it is common.

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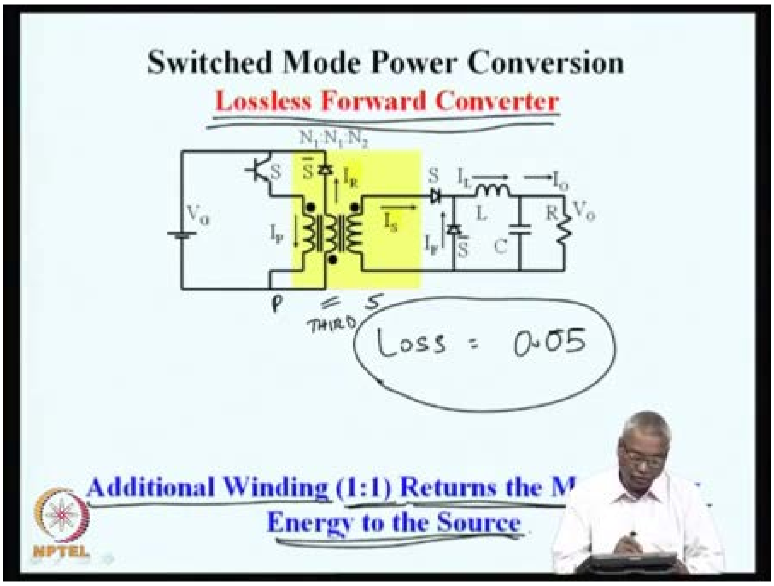

However, this big 0,05 loss on account of magnetization is not good news. So, the next evolution in the isolated convertor is what is known as the lossless forward convertor the same forward convertor is modified a little, so that the magnetization energy is not lost. But it is taken back into the source, so what we here is such a circuit which is called the lossless forward convertor, what this has in comparison with previous circuit, is that there is the third winding. The primary, the secondary and then a third winding is introduced in the middle of this which has the same number of turns as the primary N 1 is to N 1 is to N 2.

So, the second the middle winding which is used for resetting purpose has a same numbers of turns has the primary winding and the secondary has number of turns N 2, which is depending on what is the output voltage that is required. So, there is an a additional winding number 1 and it has A 1 is to 1 turns ratio number 2. The purpose of this winding is to return the magnetizing energy to the source, so these are three curishial points in this. Let see how this happens?

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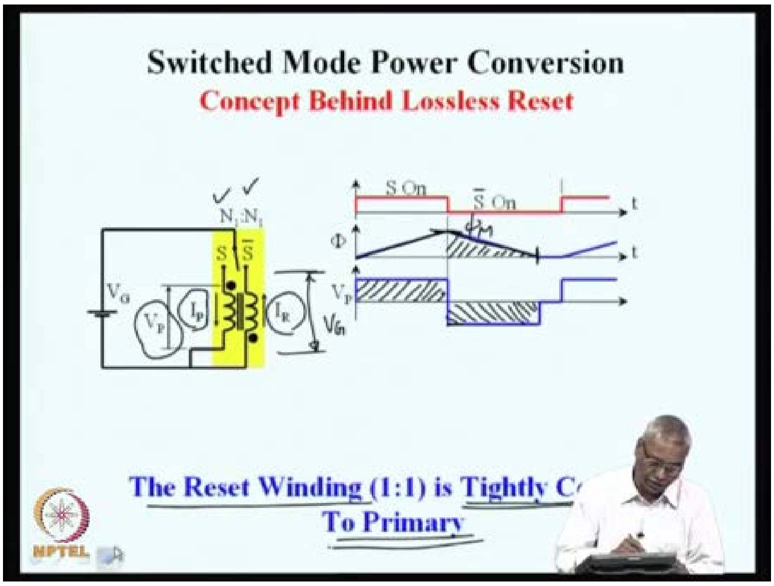

If we see the magnetization reset portion alone, we have two windings N 1 and N 1 winding 1 and winding 2 or having the same number of turn. They are tightly coupled the reset winding is tightly coupled to the primary this means that there are no, there is no energy leakage between the primary winding and the reset winding is I P is the primary current I R is the reset current and v p is the primary voltage. So, when the switch s is on the primary voltage is V G in the positive direction. Thus that is results in the flux increasing linearly to reach a maximum flux of 5 M.

You might call this as five m so as soon as s is switched off and it is move to s bar what we see is same V G is now applied across this winding across this winding same V G is applied. But with a sense which is totally opposite lot of the winding is now at the bottom in comparison with the top or effectively we are applying minus V G to the winding. So, we are applying a voltage which is exactly the opposite polarity of the source voltage. So, if we find that the flux during the on time was increasingly linearly in the positive direction during the off period. The winding is now subject to the voltage of V G, but with a negative polarity.

So, natural a flux starts dropping and in an equal time as the on time, the flux will reach at here value of 0 and the flux would have completely reset, we ensure that this s bar is made up for diode. So, that the current will not go in the opposite direction and flux also will not go in the opposite direction. So, the process of resetting is now being done with another winding and the reset energy is going back into the source V G during this period. This entire reset energy is going into the battery, which means that we have recovered completely the magnetic energy and there are no losses in the convertor.

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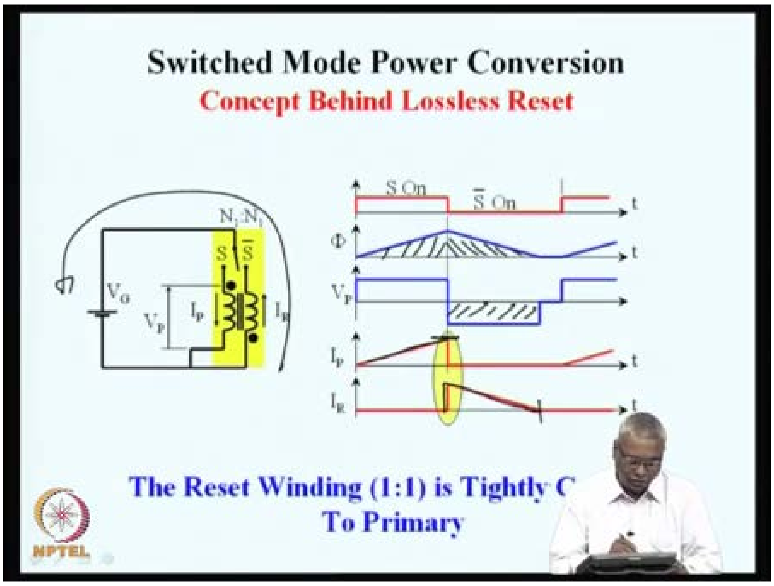

So, during the half period when the switch is connected to s bar, you can see that the magnetization current I P, which had reached a peak current just transfer to I R. Now, it flows through I R back into the source in the opposite direction. So, what we notice is that the flux is now being reset there is negative voltage across this winding. This negative voltage forces the current back into the source, so that this current falls all the way down to 0. This as I said the reset winding is tightly coupled to the primary winding.

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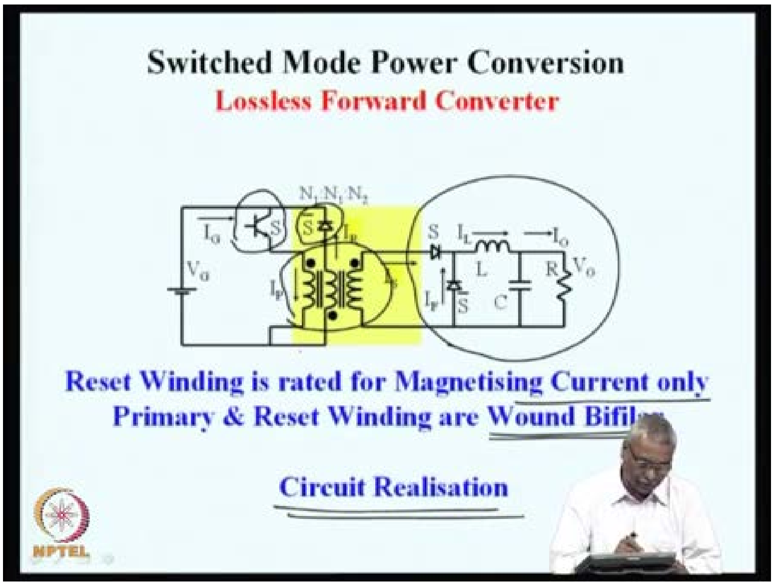

So, this winding is normally bifilar winding the two windings N 1 and N 1 the reset winding and the primary winding are bound together with turns ratio of 1 is to 1 the same number of turns, but only with the sense being different. The primary has dot on the top and the secondary has dot at the bottom, so the resetting reset winding carries only the in the previous one. We must have seen this reset winding carries only the reset current the magnetizing current. So, there is no need to make this winding capable of carrying the full load current, it will be wound only for carrying the magnetizing current, which means it will have a very cross section.

So, practically it will occupy very little space the transformer space copper space is decided mainly by the primary and the secondary. The reset winding will occupy very little space in the transformer, because it handles only the magnetization current and the magnetizing current is the small fraction of the load current. The circuit realization you can see of this s and s bar is done by transistor mass factor or a bipolar transistor s bar is realized simply by a diode, because this stored energy in the inductor will force the current through the reset winding. Through the diode and this current has to flow only till the current reaches 0, so a simple passive diode is used for this switch. The secondary path is as just before just like a non isolated convertor, so this type of forward convertors are called lossless forward convertor compare to the pervious one which was a lossy forward convertor.

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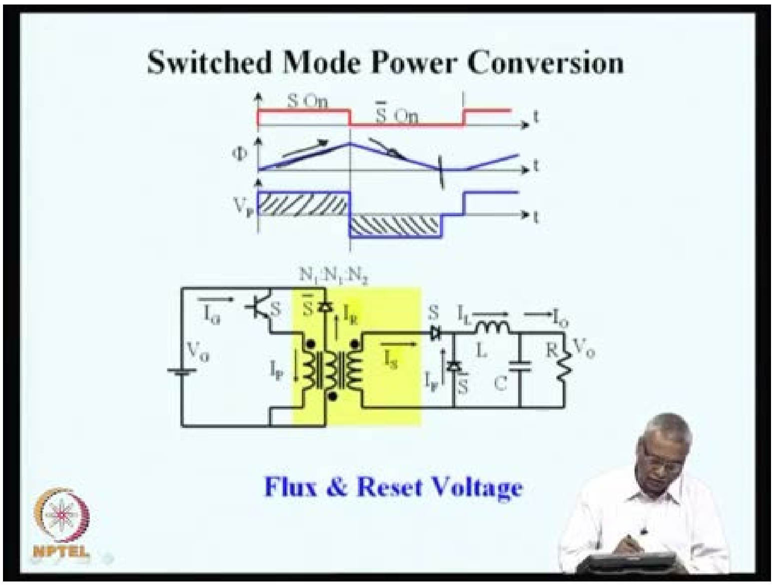

The flux reset voltage in this is because of the reverse of V G to this winding for the appropriate dot positions here. You can see during the positive half plus voltage applied to the winding and flux is increasing in the positive direction. Then during the negative half, during the reset interval, the voltage across the winding is negative. So, flux will start decreasing and because of the diode in the circuit the current does not reverse in the winding and flux also does not reverse in the winding.

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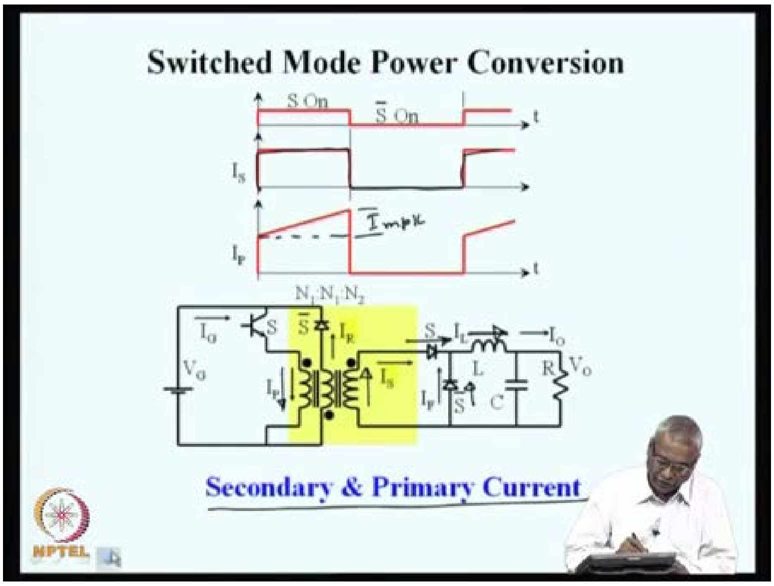

That is the process of reset the secondary and primary current can be separately treated by completely transferring the reset process to reset winding. Now, N 1 and N 2 are the primary and secondary windings. You can see if you are see on that I l constant. Then the secondary current is a square wave current during the off time it will freewill through the freewill diode. During the on time, it will flow through the mains diode here s, which also flow through the secondary winding and then a reflected current of this I s plus. The magnetizing current is what will be flowing on the primary this part is the peak magnetizing current the rest of 8 is the reflected primary current. This is how we will see the now primary and secondary current in the windings?

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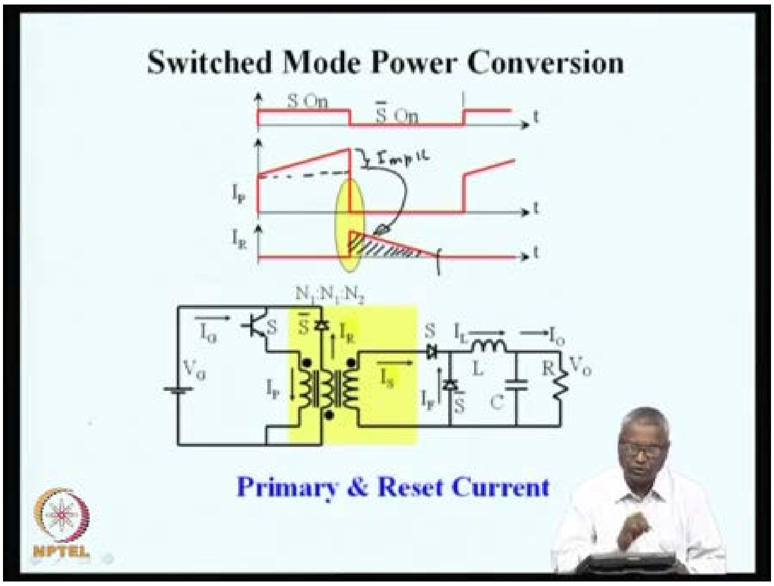

Now, if you see the reset winding just when the switch is turned off the magnetic magnetization part of the winding will get transferred to the reset winding. It will slowly die down in a time, which is same as the on time to 0 there, during this time. This reset current is completely being transfer to the source.

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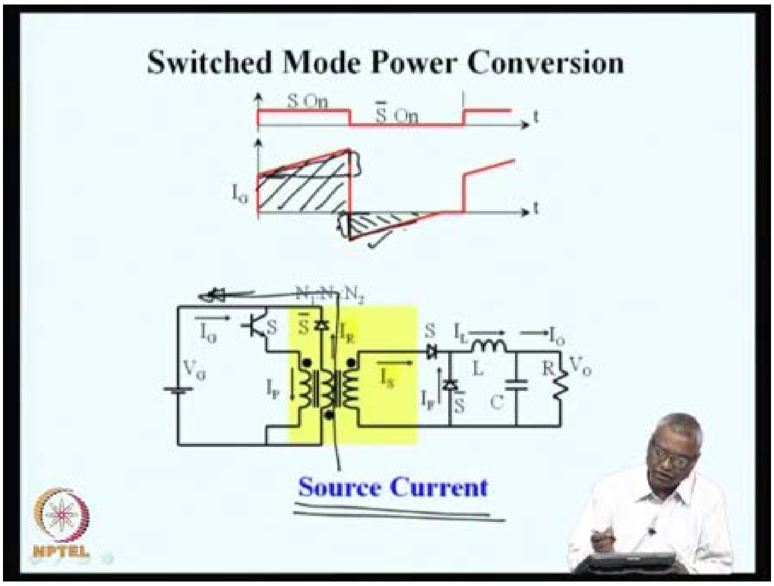

So, if you see the source current source current will show the secondary reflected current on the primary plus the magnetizing current, but during the reset period the magnetizing current reverses direction. It is flowing back with through the higher winding through the diode its flows back into the source and that is what you see here. So, practically the current that is feedback into the source is as the same as the current that was taken for magnetization. So, ideally the entire magnetizing energy is going back into the source and so the convertor does not incur any loss on account of the magnetization. The source current takes this magnetization current back and puts it into the source.

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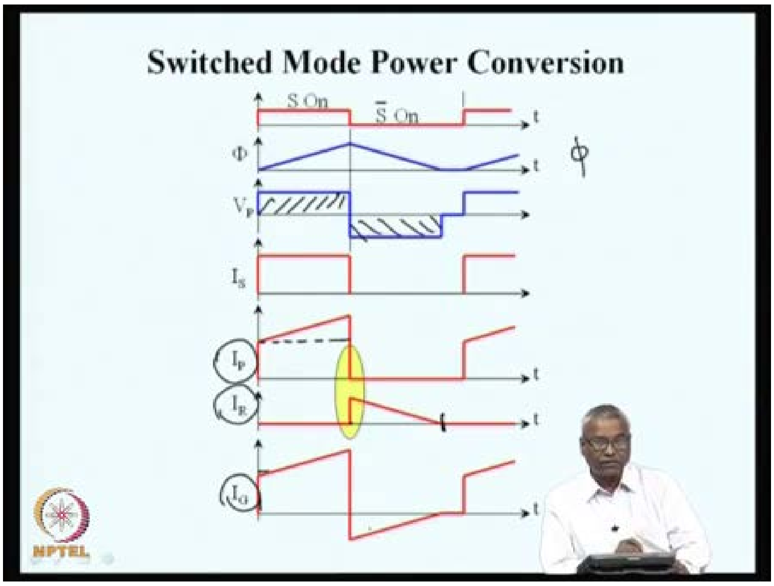

So, here is a picture of the complete set of wave forms you see that the flux in the core on this side and the primary voltage which is both positive and negative in the on period. The reset period the secondary current, which is on only during the on period and the primary current, which consensus of secondary reflected current plus the magnetization current. The reset current which is only in the off period also part of the off period and which is the same as the magnetizing current and the source current, which is the primary current. During the on period and the reverse of the recovery current the reset current during the off period this is the complete set of wave forms on that convertor.

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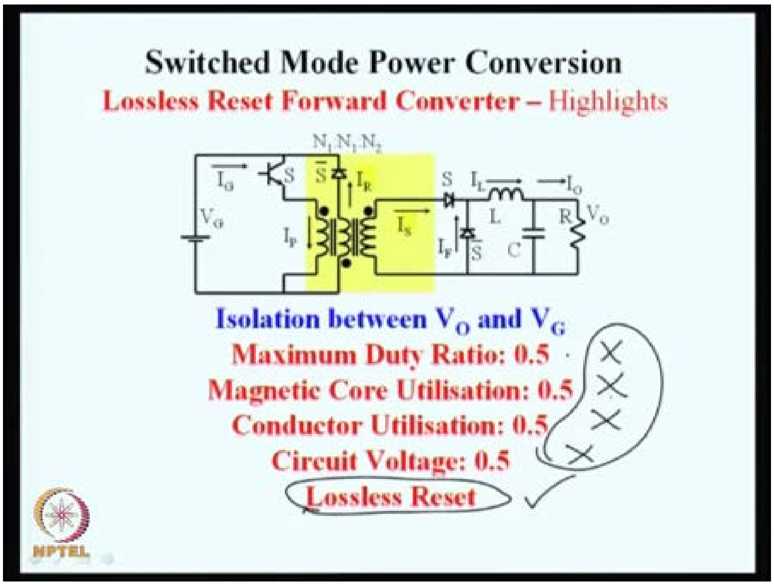

The highlights of this or that all other things being same reset is now lossless to that extend, we get better efficiency. However, a duty ratio is limited to 0.5. So, this negative feature remains as before core utilization is only 0.5. This negative features also remains as before conductor utilization is 0.5, because the winding carries current only for half the duration. Circuit voltage is also 0.5 because during the off period the switch experiences double. The resources voltage, so switch has to rated for double the voltage so all these negative features remain as it is. But we have now achieved lossless reset. This is our original purpose isolation between V naught and V G. Now, with lossless reset it is now being done efficiently, but there are number of limitations the core utilization is not perfect, conductor utilization is not perfect, circuit voltage is also double maximum duty ratio is only half and so on.

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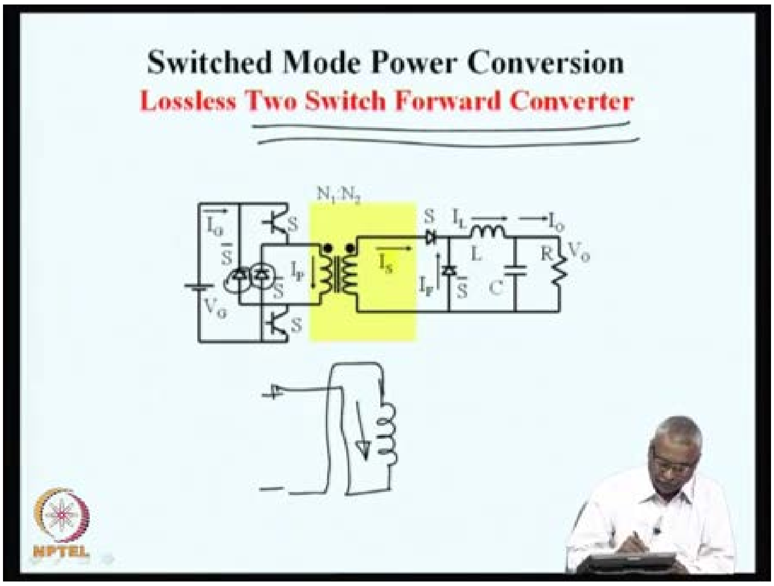

There are a number of other circuit configurations, which achieve the same lossless reset and also achieve isolation, but with reduced penalty in terms of material utilization. This is another variation, this called a lossless two switch forward convertor. What you notice here is that the winding has only the transformer has only two windings, but we have added two more diodes; 1 and 2. So, when the may and also put two switches s and s, so when the switches s is on initially the transformer is supplied power from plus and minus V G.

The magnetizing current is build up and building up on the primary secondary voltage is induced. Then secondary part works as before, but the moment we switch off s and s. What we notice is that through the diodes that are here negative is connected to this end and positive is connected to this end through the diodes. We apply minus V G to the winding during the off period. This entire reset process is now done by the same winding and sent to the same source. What we have saved is the additional winding that was added in the first converter that we had seen.

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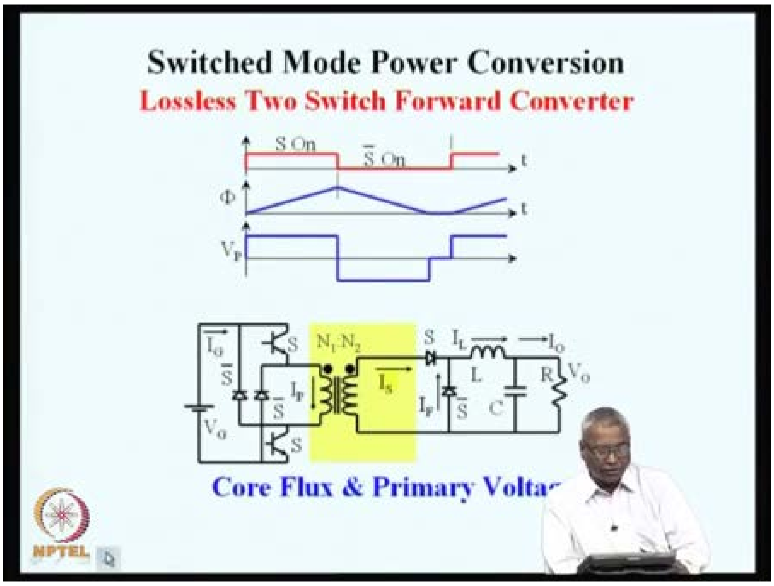

The process of core flux, increasing during the on time decreasing during the off time. The winding voltages, these are very similar to what we have seen before what is seen here is core flux and the primary voltage.

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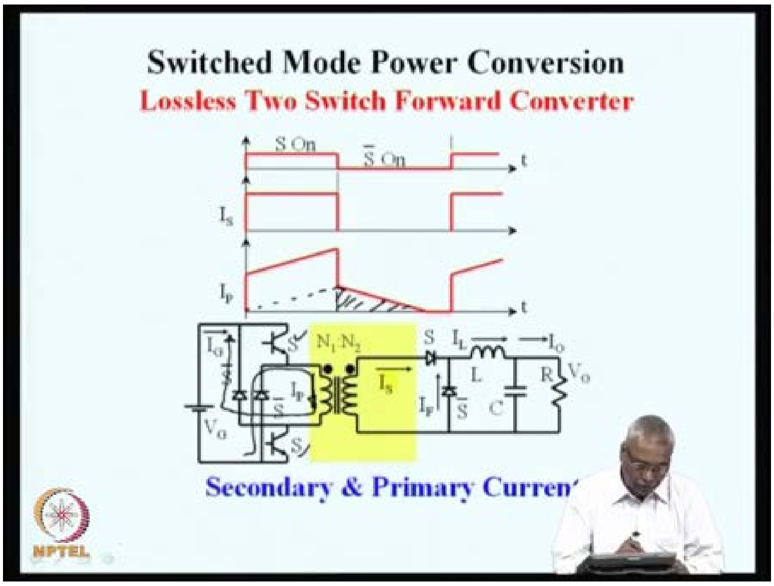

The secondary voltage and the reflected secondary voltage are also identical, but now the primary itself carries the reset winding reset current. You can see that the primary winding was carrying the magnetization current and when the switch s and s are switched off, the same current comes from the negative bus in the same direction here, through the positive direction diode. It goes back into the source, so primary current now resets through the same winding by applying an negative voltage.

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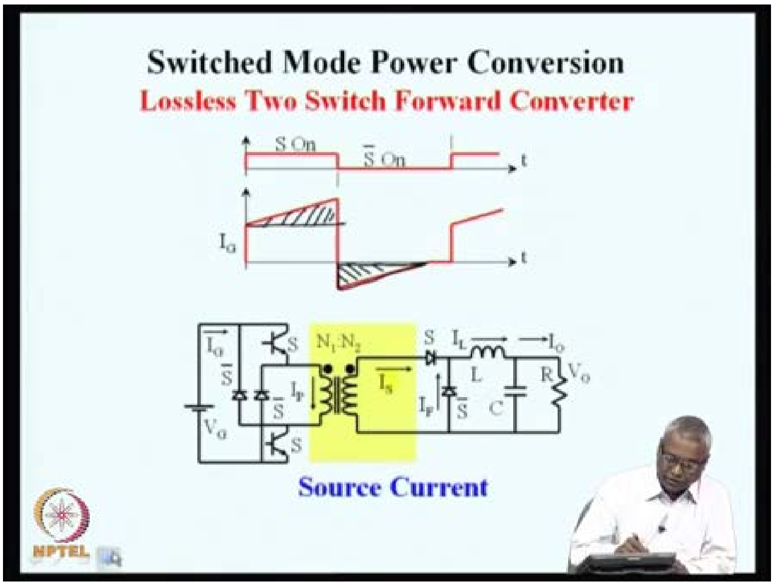

If you see the source voltage during the on time the primary current is the same as the source current. During the reset time primary current is the inverse of the reset current on account of that you see, you source current is in negative direction just as before we see that same amount of energy that was drawn during the magnetization part is been sent back to the source. During the demagnetization part, so we have sufficiently without loss we have recovered. The entire magnetization energy and so this isolation is now without any penalty non efficiency.

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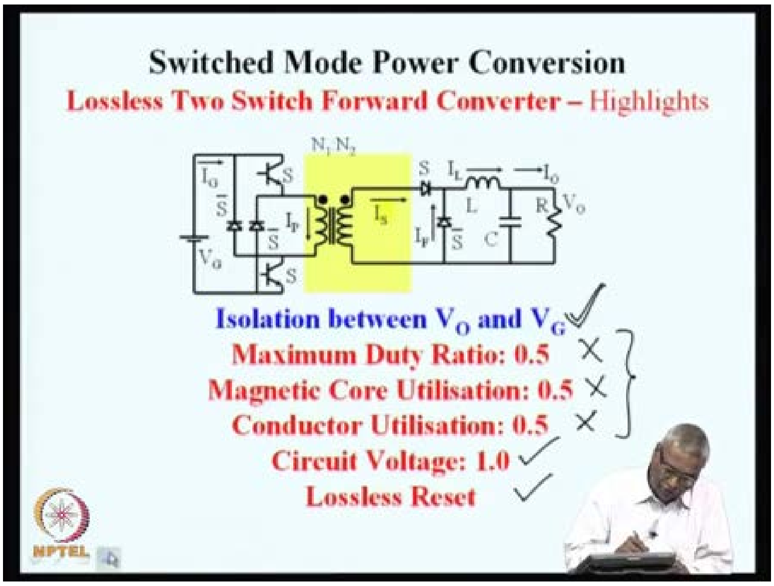

Now, the maximum duty ratio continues to remain at 0.5, the magnetic core utilization remains at 0.5, the conductor utilization also only at 0.5, but because of the diodes here. Now, we do not see double the voltage on the transformer or on the switch, but there are two switches. Now, instead of one switch, we have two switches. But the circuit voltage is now 1 and reset is lossless and isolation is achieved. So, what we have now we are trying to find out circuits, which 1 by 1 get better and better for the required performance.

Isolation is our main goal, initially we had lousy reset, now we have a lossless reset. Then we had a circuit voltage, which was double now. That also has come within normal utilization, now we have in this configuration. We have three other limitations due to ratio is not full magnetic core is not fully utilized, conductor is not fully utilized. You will see in the next few slides other circuits which are doing this better.

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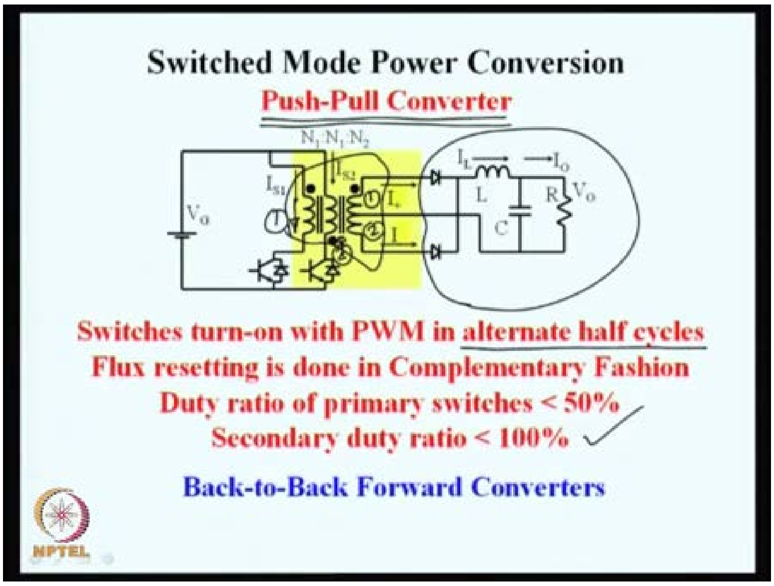

The next circuit that achieves this isolation is called push pull converter, you can see that this push pull converter is just two forward converters put back to back. For example, this winding one and this stop half forms one forward converter. Then winding two and the bottom half forms the second forward converter. Both these forward converters are interleaved in the same transformer by two switches here. So, we will see the wave forms, now so effectively push pull converter is really two forward converters connected back to back using the same magnetization circuits. The transformer is the same earlier we had a circuit where winding one. Winding one the positive part and winding one made the one forward converter. Here that is retained and we have put one more winding and then the negative part of this here with respective the centre tab.

So, effectively now two forward converters are integrated into single magnetic element switches turn on. Now, in alternate half cycles in one half cycle forward converter can work only for 50 percent of the duty ratio. So, in the first 50 percent, one forward converter is working and in the second 50 percent, the second forward converter is working. So, effectively the load will be receiving power in each of these half cycles. So, we find that the duty ratio on the secondary sides as far as what we see on the secondary side is really 100 percent, even though each half of the primary switches of rate at the most at 50 percent. So, we will see because of this the the duty.

Ratio can go to one, that one of the limitations of these isolations. Isolated circuit is overcome the primary switches continue to be at 50 percent and these two alternate half cycles make sure that the magnetized core is energized in direction; one in one half and I direction, two in the other half. That ensures that the magnetic core is magnetized in both positive and negative half on account of that.

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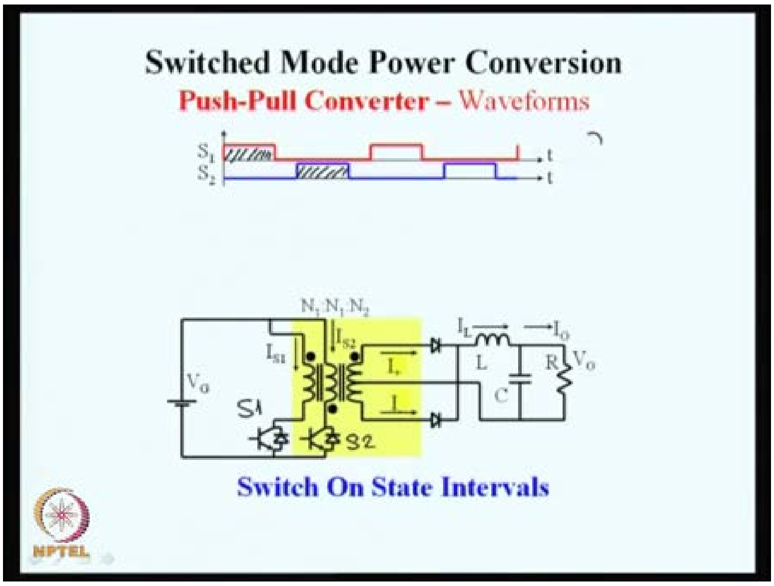

We will find that the core is also utilized fully in both directions, so the switch s 1 call this as s 1 and call this as s 2. s 1 and s 2 are turned on as per the duty ratio that are shown here. s 1 is turning on in alternate half cycles, s 2 is turning on in the other alternate half cycles. So, what we see here or the switch duty ratios.

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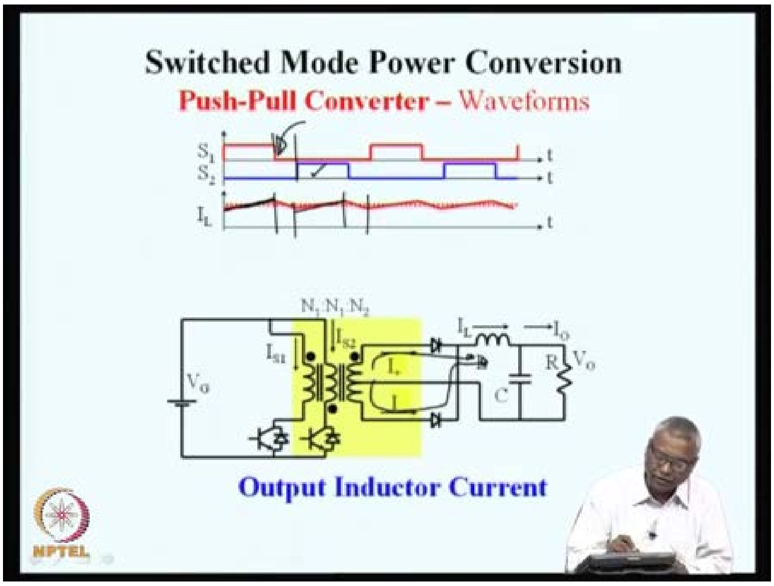

On account of this when s 1 is on through the positive half of the secondary voltage is applied to this inductor. You see that the current is raising is a first part current in the output inductor is raising. Then when the switch s 1 and s 2 both of them are off, so this is interval when both are off s 1 is also off s 2 is also off. So, during that time the output inductor current is just prevailing through these two diode, through the secondary winding, it prevails like this. Like this both diodes are on and if they are adding up to the inductor current I L. So, primary side none of the windings conducting both the secondary windings are carrying half of the load current. This would be the current during the period when both the switches are not conducting and in the next half cycle it is s 2, which is conducting s 2 which is conducting. Again on account of that through the bottom winding of the output transformer through the bottom diode inductor current is now increasing.

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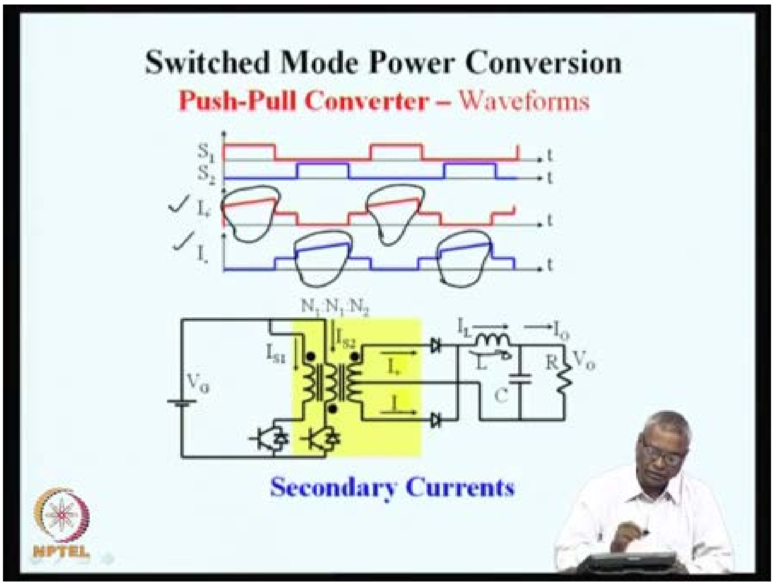

So, effectively if we find out what is the current in I plus and I minus, so during the active regions the current will be same as the output current what you see here in the circle. But during the time and both the switches are off. In fact I plus and I minus will be equal and opposite the entire load current will be shown by both of them. The prevailing will take place through the winding and through the diodes this will be the secondary current what you see here or the secondary currents.

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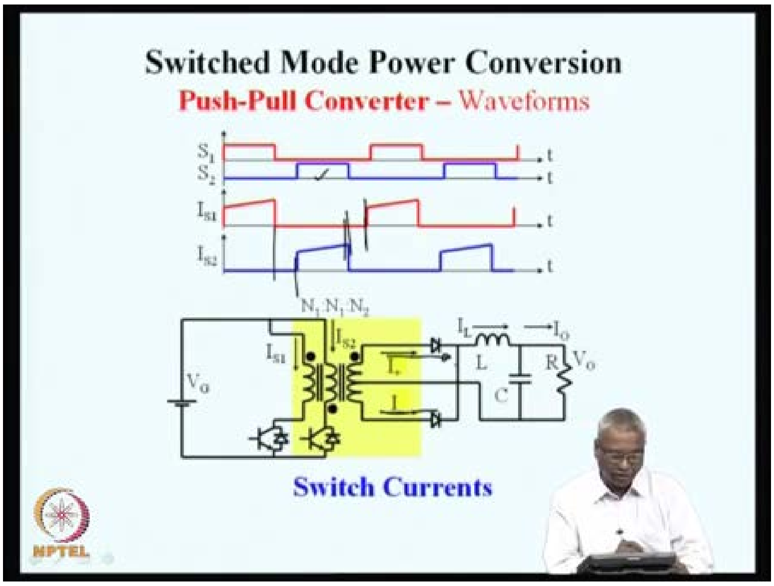

The switch currents or the secondary current reflected onto the primary side, so I s 1 carries current current in s 1 is whenever s 1 is on current in s 2. Whenever s 2 is on and in between during the time when both of them are off, there is no current in either s 1 or s 2, but the load current is supported by prevailing through both the diodes. The secondary winding and primary currents are totally 0.

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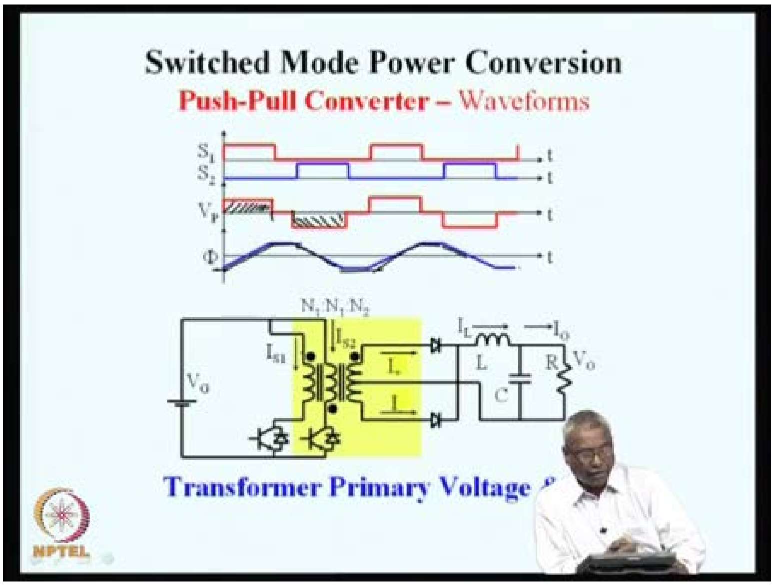

How about the transformer winding voltage and flux? So, during the time switch is on the transformer is subjected to voltage which is positive for that winding during the time when both switches are off the transformer has no voltage. During the time there s 2 is off the transformer because of the dot points are being different turns former is subjected to a negative voltage. So, you see that the voltage applied to the transformer is perfectly symmetrical be positive half and the negative half or equal. So, the flux will be now swinging both in positive direction and in negative direction equally. So, we will see that the core is utilized better in this.

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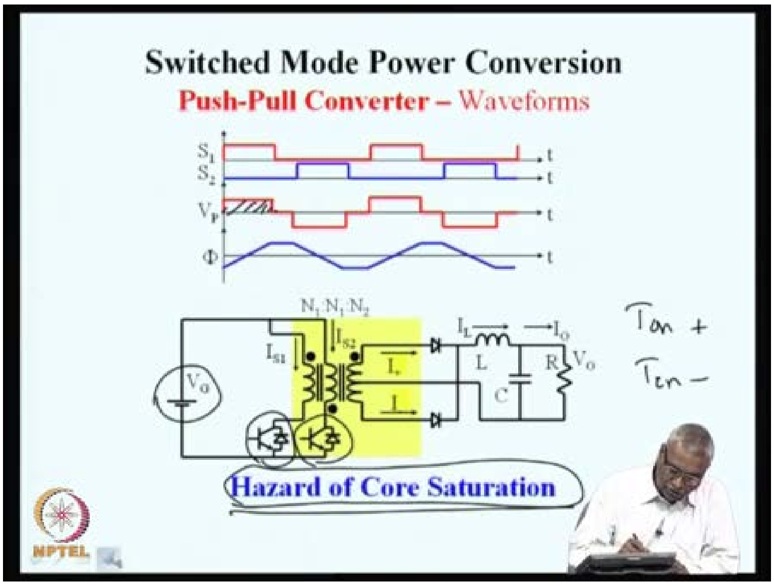

But there is one catch here. Supposing, if the voltage is perfect and the duration of positive t on positive and t on negative are also perfectly equal. But if the switch voltages switch drops V t 1 and V t 2 are not equal than… We will see that there is a net DC voltage applied to the winding of the transformer. This transformer core core can saturate this is something which requires suitable handling. We will not look at right now, but later on we will see this, when we try to do the current mode control. One of the negative point, so one of the dangerous of push pull converter is that it has the hazard of core saturation. So, at low powers it can be directly used at high powers you have to take additional precautions to make sure that the core does not saturate.

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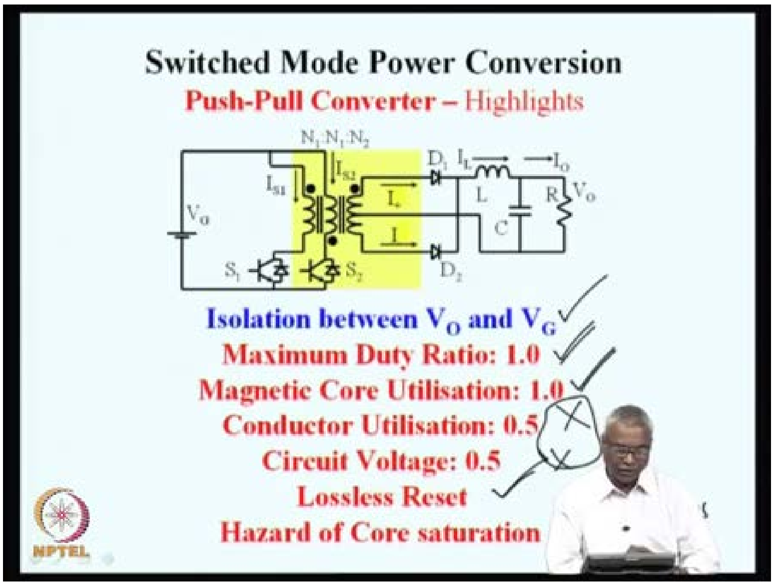

So, let us see how the isolation and all the penalties come over what we want is isolation and here also the reset is without loss duty ratio is now 1. Because as far as load is concerned we can pump our practical continuously at 100 percent duty ratio, the core utilization is (( )) full both positive and negative. The conductor utilization is only half because each winding carries current only for half of the time either winding primary one. This winding or the primary two and secondary the second half of the centre tab winding.

So, this continues to be a negative point and then the circuit voltage is still 0.5 because whenever one switch is on the other switch is subjected to double the source voltage. There is another negative aspect which is the hazard of core saturation at low power. This is not very significant when we are handling small powers this is not a significant point. So, we have practically now overcome full duty ratio problem full core utilization and lossless reset. But there are two other issues which are conductor utilization and circuit voltage.

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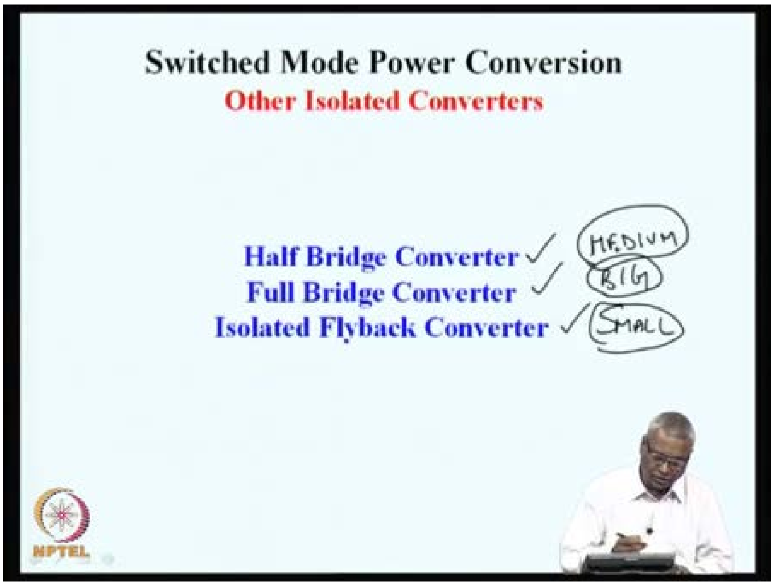

So, let us see what are the other circuits the the next the family of isolated converters has a few other circuit topologies out of them this half bridge. Full bridge are the important converters, which are used for large power ratings full bridge is practically the only circuit, which is used for very large power ratings isolated. Fly back power converter is used for very small power ratings, this is for small this is for big going even into omega watt of power. This is for medium hundreds of kilo watts or hundreds of watts few kilo watts tens of kilo watts and so on. But big power is handled by full bridge converter very small power less than hundred watts and that kind of power is handled by isolated fly back converter. Then the medium level of power is handled by half bridge converters, so let us see, how this circuit topology look like?

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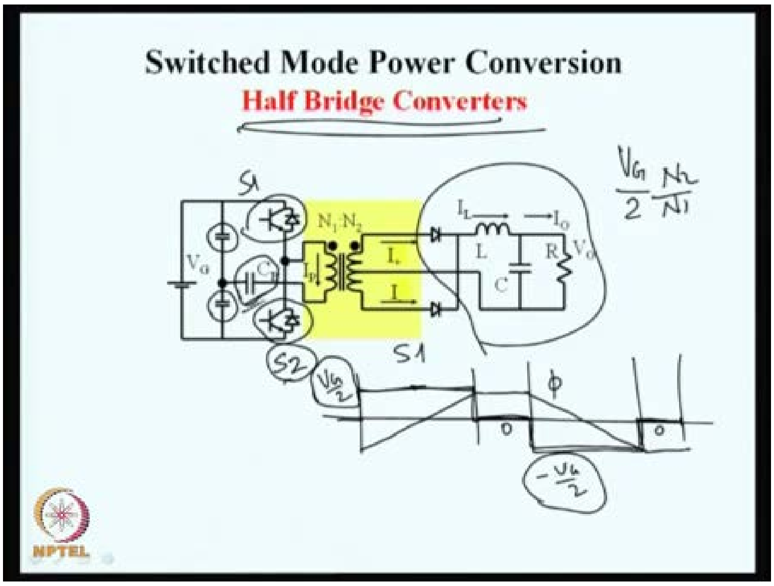

You can see that this half bridge converter utilizes two switches; but unlike the two switch forward converter, these two switches are operated in the push pull mode. That is for in one half cycle the top switches pulse width modulated in the other half cycle the bottom switches pulse width modulated, if I call this as s 2 and this as s 1 s 1 on time is controlled in one half cycle. s 2 is on time is controlled in the other half cycle and the isolation transformer is now connected between the switch and the midpoint of V G. This is obtained by splitting V G using two capacitors. So, that this midpoint will be V G by 2 and then it is we will just you know movement is what the C B is this is called C blocking capacitor.

We will see the function and value of that so this power is connected this midpoint is connected to the other end of the transformer for a movement. You assume that the C B is short circuit. Later we will see what are the design conditions required to satisfy that so in such a case the trans transformer primary is subjected to half the supply voltage when the top switch is on with positive polarity so we will say that in one cycle. when top switch is on the transformer is subjected to V G by 2 and when both the switches are off transformer has a voltage of 0 and when s 2 is on transformer is seeing a voltage of minus V G by 2.

Then during this time when both are of it is 0 again. So, you see that a perfectly symmetric square wave is applied to the transformer both in positive and negative. So, naturally the flux also will follow or ramping up constant flux ramping down then constant flux. So, this will be the flux, so what we notice is that the flux is now bipolar or the magnetic core is fully utilized the transformer voltage is only half the voltage supply voltage if it is. V g only half of that voltage is supplied to the primary, so what you will see on the secondary side will be V G by 2 into N 2 by N 1 will be the voltage that is supplied to the secondary side. Then you have a one standard non isolated buck converter on the other side the C B has a special function called D C blocking. We will see in the moment what that is the full bridge converter? He is using four switches; s 1 s 1, s 2 s 2.

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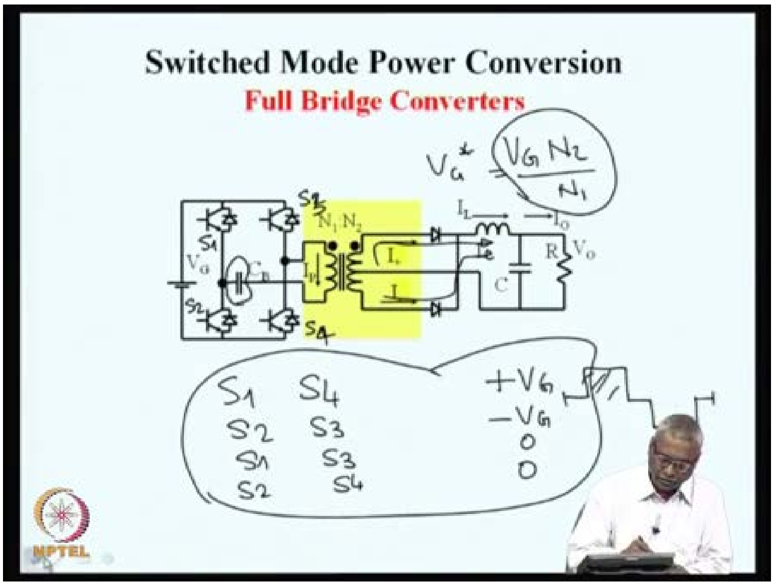

For example, s 1 s 1, we will call this as s 1, s 2, s 3, s 4. Totally four switches when s 1 and s 4, s 1 s 4 gives you output voltage of plus V G, then S 2 and s 3 gives enough output voltage of minus V G. s 1 and s 3 on nu 0 voltage s 2 and s 4 on nu 0 voltage. So, it is possible now by appropriately modulating to get a voltage across the primary which will be plus 0 and minus. Now, in a full bridge converter, this is how the pulse width modulation is done to get here square wave A C voltage, which is symmetric. Then during the positive half through the top diode. The load will be supplied during the negative half through the bottom diode will be supplied. During the time the voltage is 0.

There will be prevailing of the load current through the both the diodes. Now, I have to still explain about this blocking capacitor so as far as the secondary part is concerned. V

G into N 2 by N 1 is the equivalent equivalent buck converters source voltage V G star is V G into N 2 by N 1 in half bridge. We saw that it is V G by 2 into N 2 by N 1 in full bridge converter. It is the full voltage V G multiplied by N 2 by N 1. This is the reason for the name full bridge or half bridge. Half bridge has only V G by 2 half the voltage only is only applied and in full bridge. Full voltage is applied and this is V G into N 2 by N 1 and the full bridge has all the switches switch s 1 s 4 or defined at every point. At least two of them conduct at every instant where as in half bridge.

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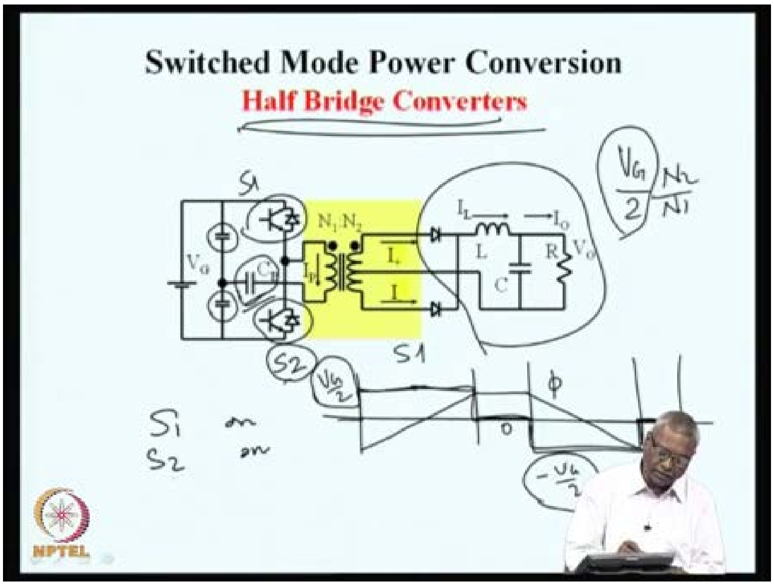

We have regions where both of them do not conduct either s 1 is on or s 2 is on. We do not have conditions where both s 1 and s 2 being on because that will give rise to short circuit of the source. So, there is a region where s 1 and s 2 both are off.

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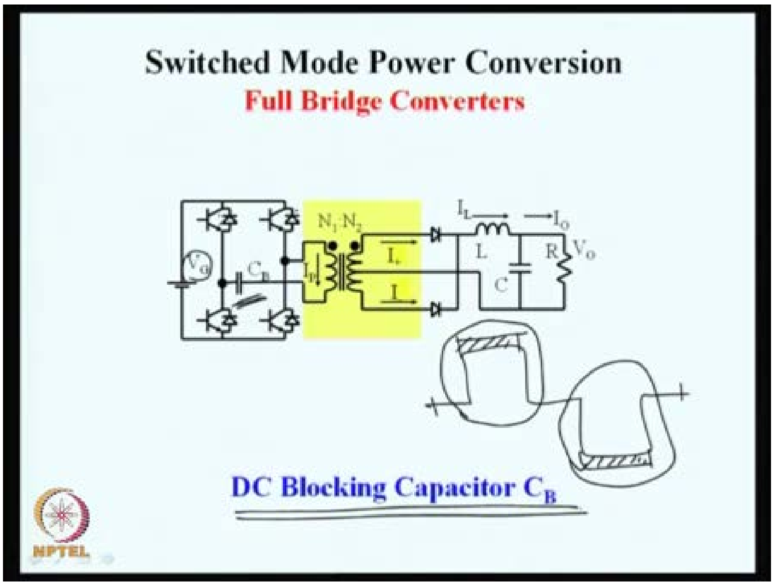

Now, the D C blocking capacitors C has a very special function. As I said if the if the on period of the switches are on or equal and source voltage is certain value the actual voltage applied to the transformer is supply voltage minus two device drops on the positive side. Similarly, supply voltage minus two device drops from the negative side. Even if supply voltage is very study these two voltage drops need not be what you drop here drops. Then similarly, this side the device drops need not be perfectly equal.

So, on account of that it so happens that the positive area of volt second and negative area of volt second will not be equal in any application. There will be a net D C voltage. The purpose of this C B is to block that DC voltage and it is called D C blocking capacitor C B. It blocks the D C voltage from reaching the transformer and saturating the core.

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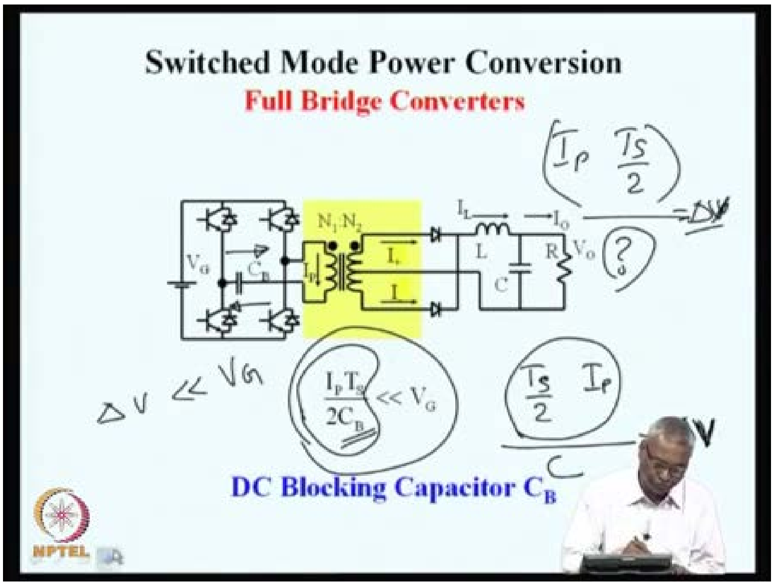

How do you size this capacitor? We have to make sure that the voltage across C Bis very small and it is only two block. The D C voltage that will be across the transformer and the voltage across the capacitor is very easy to find out because in every half cycle every half cycle of t s by 2. The primary current is flowing through the capacitor in 1 t s by 2. It flows in one direction in the other half it flows in the other direction. So, what we notice that in every cycle, this is the total charge that is going into the capacitor in the positive half. The same similar kind of charge t s by 2 into minus i p flows through the capacitor in the negative half cycle.

So, this divided by the capacitance the charge divided by the capacitance will be the voltage on the capacitor delta V. So, if this blocking capacitor should not have any consequence on the overall voltage applied to the transformer. Then this delta V has to be very much less small compared to supply voltage. That is what, this equation tells the ripple voltage on the capacitor I t by C I P multiplied by t S by 2 half the period. This is the coulomb charge into the capacitor this is the blocking capacitor value charge by the capacitance is the delta V or change in voltage in the capacitor. So, long as that is very, very small compared to V G. The blocking capacitor will do its function well and that is how this C B is selected in every application.

If I know what is a I P and if I know what is a switching frequency. This is and if I know how much voltage ripple, I can tolerate then from that we can find out what is the blocking capacitor to be used, okay?

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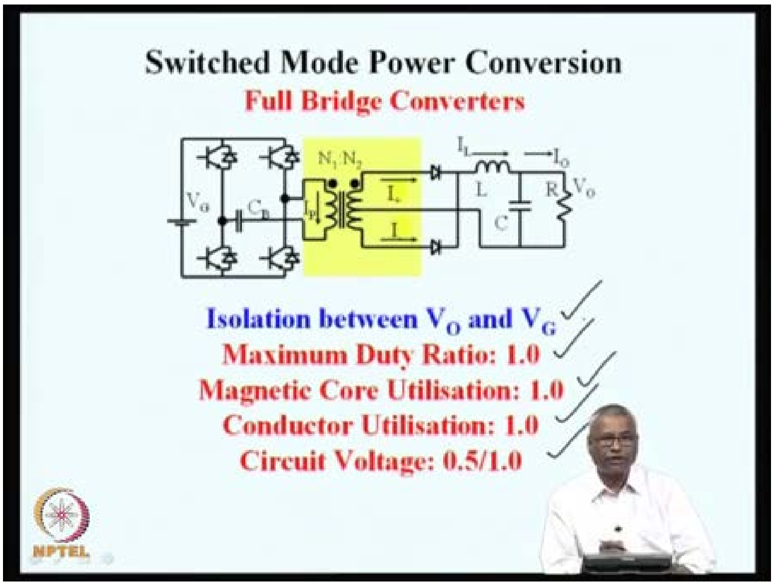

So, now if you see this half bridge or full bridge converter, we can see that isolation has been achieved duty ratio is one core is fully utilized conductor is also fully utilized. Because you see on the primary current is flowing both in positive half and negative half circuit voltage is also 1 in the full bridge and half in the half bridge. So, we can see that every one of those negative points, which we started with in isolation have been addressed by all this circuit topologies.

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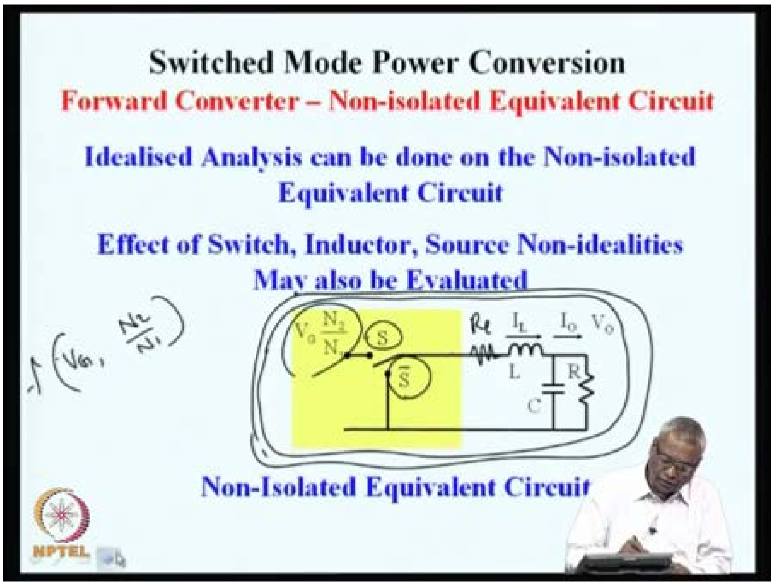

But the other performance figures like voltage conversion current conversion and the non idealities is contributing to efficiency loss and so on. As far as those quantities are concerned, we can replace that isolated converter by an equivalent non isolated converter in the equivalent non isolated converter. The source voltage will be now a function of V G and N 2 by N 1 in the case of forward converter. It is just simply V G into N 2 by y N 1. In the case of half bridge it will be V G by 2 into N 2 by N 1. In the case of full bridge it will be V G into N 2 by N 1 and so on. But the performance of the voltage conversion ratio current conversion ratio, the efficiency on account of the switch non ideality is s.

s bar efficiency loss on account of the inductor non idealities, which is R L and so on. All those analysis can be done in the same way as we had done for the other converters. It is a very, very similar exercise. Only this source voltage has now been replaced by the non isolated equivalent voltage. The circuit is identical to the buck converter the forward converter push pull converter two switch forward converter, half bridge converter, full bridge converter, all of them have an output L C filter and in the standard form, they all are similar to the buck converter.

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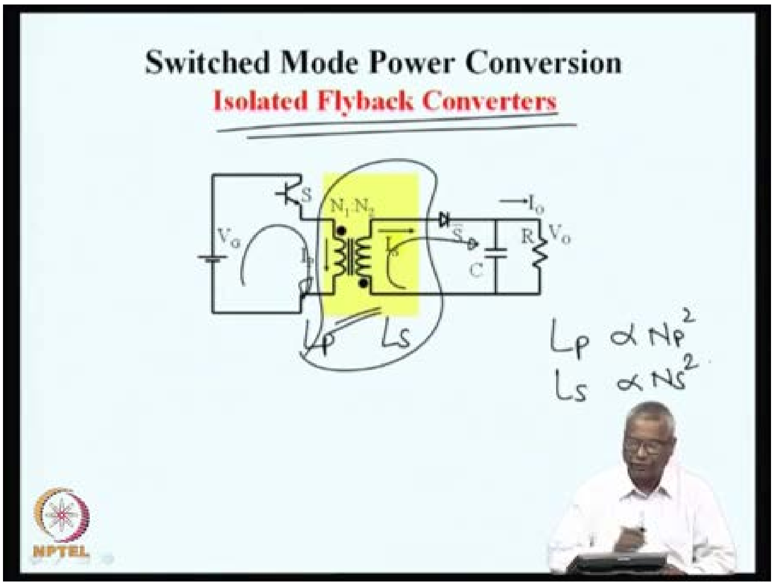

The analysis of many of these quantities can be done in the same way the smallest power levels. Normally, the converter circuit which is very popular is the isolated fly back converter all that is done is the fly back conductor is now split into a primary inductor. A secondary inductor on the magnetic circuit and while energizing the core through the primary energy comes into the core through I P and then when the switch is turned off the stored energy in the inductor goes through the diode to the load. So, this also is a fairly simple converter and the important point to be noticed is, it has only one magnetic element for both isolation and storage. In the earlier converters like the forward or any of them we had one inductor for smoothening.

The energy flow and another electromagnetic circuit for providing isolation so there are two electromagnetic elements, but in the fly back converter these have been combined into a single electromagnetic structure. This is working both as a transformer and also as an output filters. So, the inductance of the fly back non isolated fly back is seen from the secondary side inductance, but energy drawl is from the source from the primary the primary side inductance. You can say that this inductor has L P and L S L P will be proportional to N P square and L S will be proportional to N S square.

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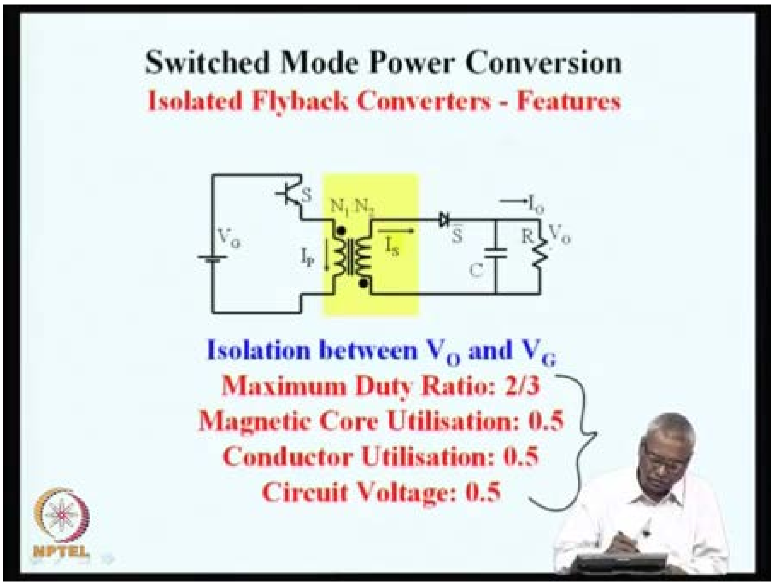

So, this circuit also can be found out yes in this again utilization is not as good magnetic core is utilized strongly in one direction, because it is not a transformer. It is inductor conductor is utilized only for half because winding carries current only for part of the cycle duty ratio probably can go a little beyond 0.5. Normally, typical up to 2 by 3 circuit voltage also, is only partly utilized. Because of these reasons because of these limitations the fly back isolated or isolated fly back converter is normally used at low power levels, at very low power levels. This is practically the de facto circuit topology, because this is the simplest one with only one electromagnetic element. Then a capacitor and the output resister at small power levels this is the most economical circuit design.

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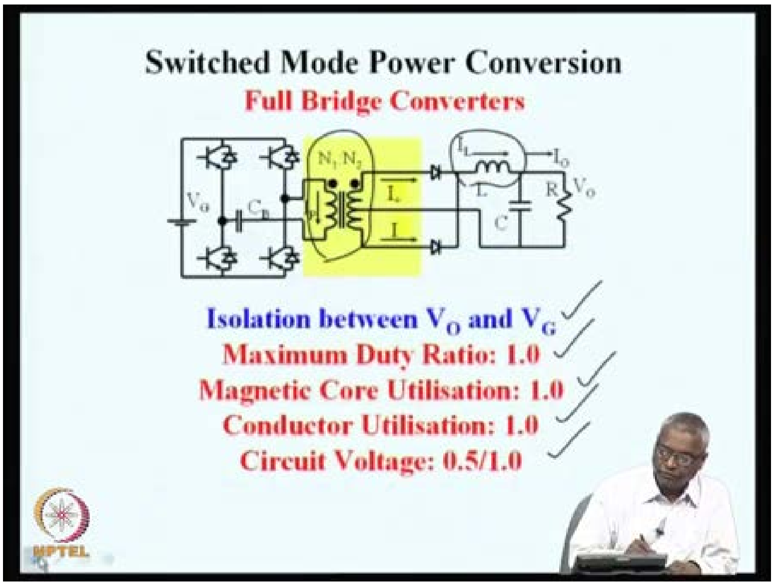

Now, let us see again the bridge converters at very high power levels. It is half or full bridge at medium power levels. It could be single switch forward converter or the isolated fly back converter at very low power levels. It could be isolated fly back converters or the lossy forward converter because at low power. You do not care very much about the losses another interesting thing is that in the half bridge circuit and the push pull circuit. The lossy reset or lossyless reset you find that there is energy trapped in the core in the form of magnetizing. The energy in the push pull circuit it is true because there are conditions in both the switches are off in the push pull circuit not push pull in a half bridge circuit.

You can see that there are in surges when both the switches s 1 and s 2 are off and at that time, if there is any trapped energy inside the core, it has no place to go. So, naturally it will create problems in terms of over voltages etcetera. Half bridge circuit has this kind of trapped energy the same is true in push pull circuit also when both the switches are off you have. No conducting, but there could be trapped energy in the core in the forward converter also. If the lossless reset or loss lossy reset or lossless reset, whichever is used there is a trapped energy in the core, we know that energy trapped in any circuit can give rise to problems.

If we do not have appropriate methods of absorbing that energy from that point of view the full bridge converter has no trapped energy, because any time at least two switches are on. So, here is always a path for the magnetic circuit to complete its current that is one reason why full bridge circuit can be scaled to any any power level. 2 megawatt power levels, the same is true with a two switch forward converter. There also, there is no trapped energy the same winding through diodes will completely transfer its energy to this source.

So, this two switch forward converter and the full bridge converter in a way or circuits, which can be used or scaled up to any power level. So, that brings us to practically the end of non isolated converters. The different circuit topologies, there are many other circuit topologies, but in principle this should give rise to most of what we want to do a little later. We will see later several circuit examples of the same type of converters

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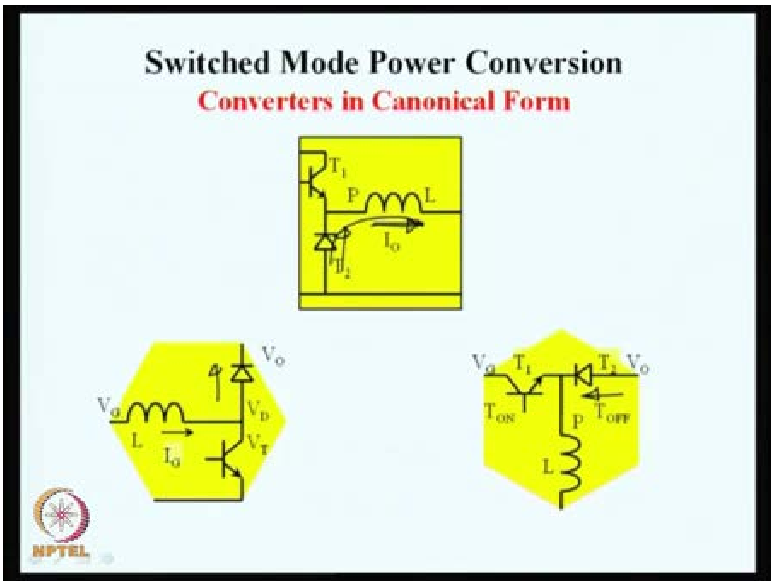

I just want to briefly indicate what is going to come next see in all this converters, what we see in a canonical form is a buck converter or a boost converter or fly back converter in these converters. There is a diode which is in the circuit and this diode does not allow the current in the inductor to be in both directions. For example, if the current in the inductor is like this diode, can support it, but if it reverses the diode cannot supports, so in all these converters, as we realize with the transistor. The diode there is a problem relating to the flow of the current in both directions. That gives rise to a new operating mode called discontinuous current mode of discontinuous conduction mode of operation.