High Voltage DC Transmission

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Module No # 02
Lecture No # 01

Analysis of Simple Rectifier Circuits

Welcome to module two, lecture one, in this module I will discussed about the analysis of convertor circuit and in this convertor circuit, then we will go for the modeling of equivalent electrical circuit, so that we can analyze the complete HVDC link. So, before go for this analysis of convertor circuit it is important, let us see the simple analysis of rectifier circuit, and then we will see what are the desired features or requirement for the convertor circuits that can be used for HVDC application.

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So, in this convertor circuit rectifier circuit, let us see the various assumptions and there justification that which I am going to make. So, first assumption is this AC source has no impedance, it is believe that AC source, which we are using it is a perfect sinusoidal and also the frequency is constant. Normally, you know the generation is a balance circuit and it is perfectly giving sinusoidal and also the frequency is constant. So, for all our analysis we will take the voltage of the source is a constant voltage as well as the constant frequency. If you are taking the poly phase circuit source means, we will go for three phase circuit analysis for the convertors then we will assume that it is a balance voltage means, all three phase are balanced and you know the balance means you all the three phases magnitudes are equal and they are displaced by one twenty degree and it is in clockwise, if they are displaced by 120 degree means here.

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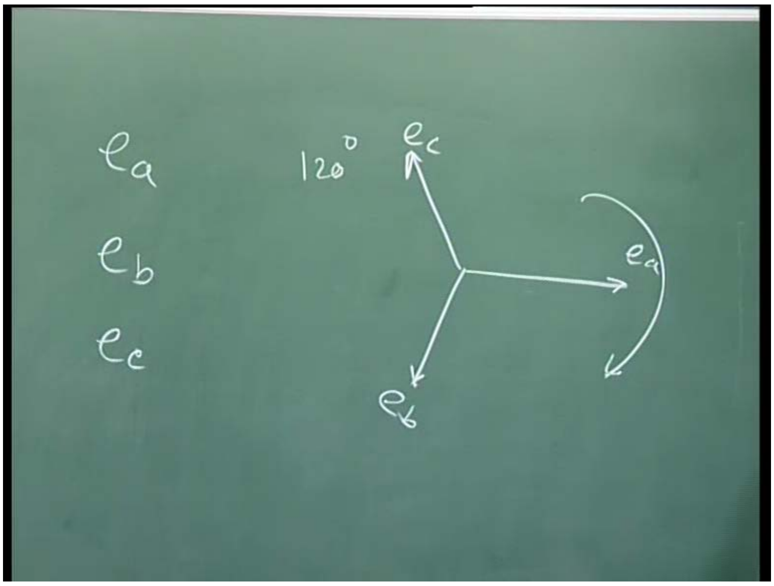

If I want to balance circuit means, we are having e a phase a phase, here it is e b, here it is e c. So, they are displaced by one twenty degree and it is your, if the draw the phasor diagram it is your e a here, it is e b and here it is e c means, it is in clockwise reaction. Another assumption regarding the transformer it is believe that it is a ideal transformer means, it has a no leakage impedance means there is no drop across the transformer and its exciting admittance is also negligible or 0 means, it is just like a ideal transformer and even they will also not considered the resistance of the transformer which will assume this is the ideal transformer; however, if I going to take the your practical transformer it will simple drop some impedance means, it will due to the current flow there will be some loss as well as some drop in the inductance will be there, but for our analysis purpose we will take this transformer is ideal one.

The third assumption is the your DC load has the infinite inductance means, you are the DC current is constant means, it is a ripple free. But the voltage will have pluses, it is not ripple free.

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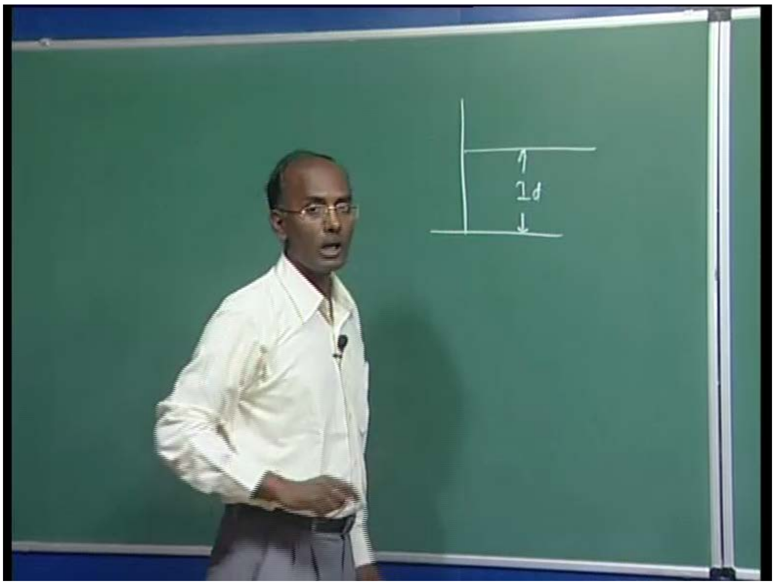

Means, if I want to say that here if your current is perfect DC in the output, here the this is your DC current the DC or I d, it is a constant, it is a ripple free; however, your output voltage it is not ripple free and we will see later on. The last assumption that is I am going to make, we are assuming the valve is ideal means, it will offer the 0 resistance during the conduction phase, once it is conducting it will offer the 0 resistance and once it is in off condition, then it will offer the infinite resistance. 0 resistance means, it is also loss less means, there is no loss in the valve as well.

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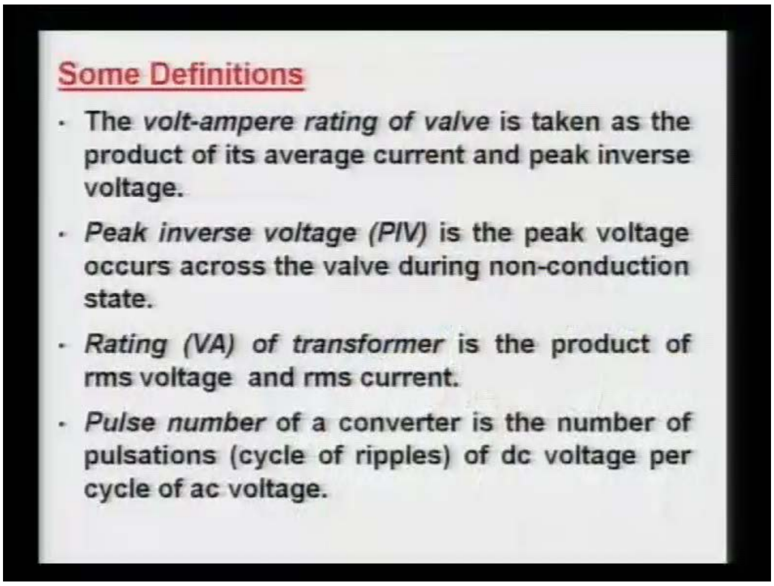

Let us see some definitions, which will be use even though for the further analysis; first one is the rating of valve, the valve rating you know at the valve here I mean it may be a simple thyristor, it may be or it may be combination of thyristor or so it is a complete valve and normal rating here.

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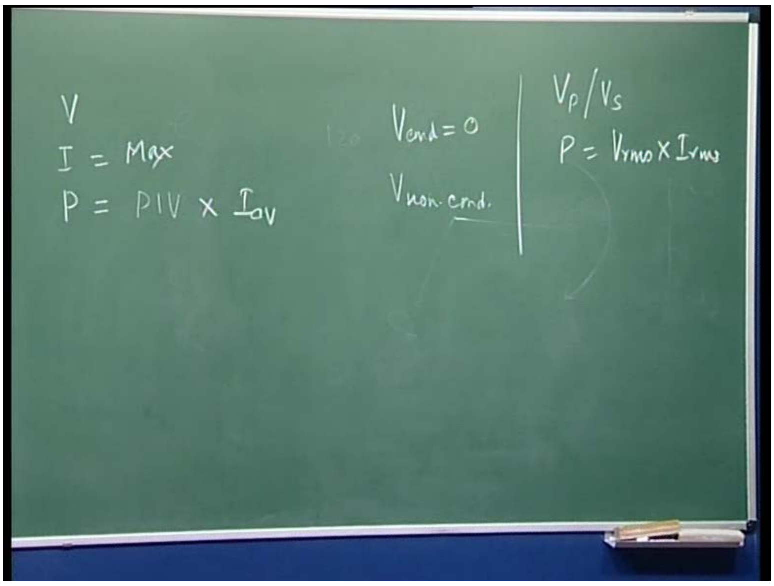

Normally, we say that the thyristor or valve rating if your voltage current and it is a power rating here this voltage rating is nothing but it is the peak inverse rating, peak inverse voltage that is appearing across the valve this power is nothing but it is your the peak inverse voltage we will discuss what is the peak inverse voltage across this valve and then multiplied by the I Everest, it is not I DC it is the Everest voltage which is appearing across the valve, this is the this is a Everest current multiplied by peak inverse voltage and peak inverse the negative side what is the maximum voltage appearing you know the forward voltage is always 0 once it is conducting so it will be zero. So, we go for the peak inverse voltage and the current here, the current rating it is a maximum the current which is flowing through this valve. So, the volt ampere rating here is the Everest current multiplied by the peak inverse voltage, how about the voltage rating is your peak inverse voltage rating your current rating is maximum current which is flowing through the valve it is the rating.

So, the peak inverse voltage PIV which I will be using continuously is the peak voltage occurs across the valve during the non conduction state or phase, you know once it is conducting as a said here once in the conduction V conduction the valve will be 0 and then we have say non conduction state and it will be the varying instantaneously, but we are going to see what is the maximum voltage in the non conduction phase. Another we will also see the rating of the transformer, we use the transformer from primary to secondary and then convertor is connected. So, the VA rating of the transformer is the product of rms voltage multiplied by the rms current. Now, you know in the transformer the primary rms voltage multiplied by the primary your rms current will be equal to your secondary rms voltage and rms current, because the transformer the primary VA rating will be the same as the secondary VA rating. So, it any side if you going to calculate what will be the rating of the transformer it will be your rms voltage simple, I can say multiplied by your rms current.

So, the transformer rating here again we go for its V that is the maximum voltage it can sustain, again it is going to be primary side or secondary side. So, I can say it is V p over V s then we go for the power rating here and this power rating is nothing, but your V rms multiplied by your rms if you are considering the primary side then it is a primary rms voltage multiplied by primary rms current or if you considering secondary, because this primary side power will be the same as your secondary side. And we have assumed it is a ideal transformer. So, that is no losses the both will be reject. And an another term which will be continuously use is a pulse number, normally it will be denoted by small p and the pulse number of a convertor is the number of pulsation or pulse cycle ripples of the

DC voltage per cycle of AC voltage means per cycle of AC voltage, how many the pulses or ripples are pulsation that is going to occur in the DC side voltage and that is called the pulse number we will again with the examples we will see all the terminology again.

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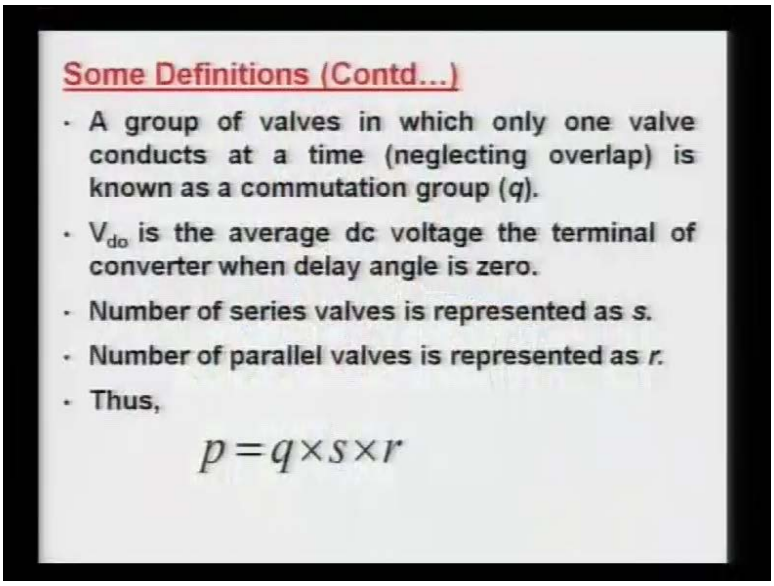

Now, another term which is slightly tricky and why this is used and this is called the commutation group and normally it is denoted by q and it is defined as a group of valves in which only one valve conducts at a time neglecting the overlap is known as a commutation group, this will be more clear when I will be discussing about the three phase convertors and this q is used to generalized our topology, what will be the best suitable your convertor configuration this q will be used. To realize it, you can see the equation which is written the p there is a pulse number it is equal to your q multiplied by s is equal multiplied by r, here the q is nothing but is a same commutation group and then your s is defined as number of series valve and your r is number of parallel valve in a convertor bridge. So, this pulse number is basically multiplication of the three quantities and we will see what should be the optimal value of q s and r that will give the better performance of a convertor circuit and we will analyze later on.

Another term will be also used that is a V d o and that is nothing but it is the average DC voltage of the convertor terminal, when the delay angle is 0 delay angle if you are using thyristor V d o arrive as it is you can delay in your firing and that is normally it is called delay angle alpha, alpha will be used very commonly here in our analysis as well. So, V d is the d is denotes your DC and o denotes you are the delay angle which zero. So, V d o is the DC output of your rectifier or convertor circuit when there is no delay means we are firing at the 0 instant.

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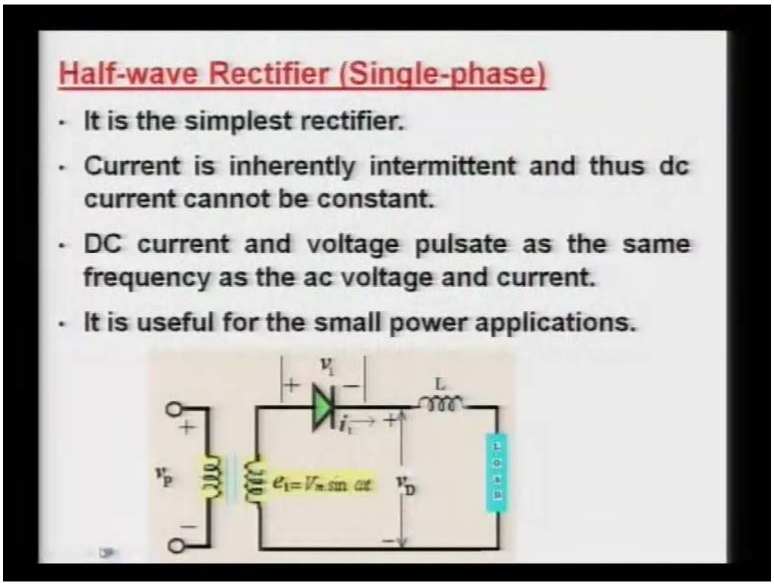

Now, let us see a simple already you know it half wave rectifier circuit and we are considering single phase, of course here and it is very simple circuit and it is call half wave because half of the wave we are getting the output voltage in same average contains voltage, whatever we are here that will be appearing here and the remaining half of the cycle it will be 0, because this will be in the reverse biased. In this case only problem that we cannot get even though you are putting here inductor circuit to make the DC current ripple free, but it is not possible in this case because half of the cycle it will be zero. So, this that is why here written the current is inherently intermittent which is varying and thus DC current cannot be the constant in this case. So, we will see if you are going for this full wave of rectifier that is full that we can have the constant DC current, but in this case we cannot attach and again we will see its all put another things; so, DC current and your voltage pulsate at the same frequency at the AC voltage and the current; and if you will see, its output here.

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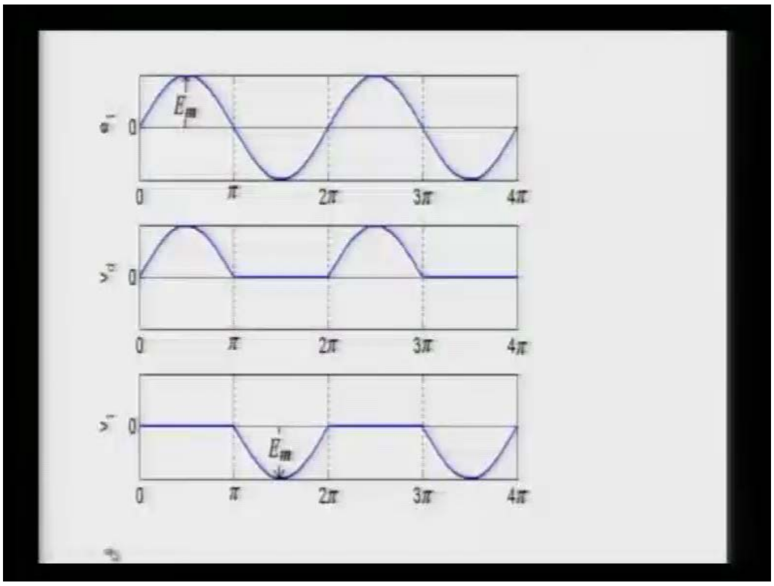

You see, this is your applied secondary side voltage, where it is E m signed sine omega T, and what is your output voltage instantaneous output voltage here that is varying a first up cycle when you are diode or thyristor becomes positive and then we are getting here if the delay angle is zero. So, then we are getting here the complete cycle and other cycle it is 0, because it is in reverse wires and no similarly here. So, this is the instantaneous voltage, which is appearing the output of this rectifier circuit. And if you are going to take calculate, what will be the Everest voltage that we have to just integrate over complete cycle. Here you can see the pulsation number the pulse number is unity because it is a in one cycle here we are getting only one pulse of the DC output. So, the number of p in this case is unity one, another very important factor here I have written the voltage across your valve or your diode or thyristor whatever you can call. So, here it is a valve voltage. This is very important when we will go for this analyzing the convertor circuit, because this decides the rating of your valve or you can say that individual valve here.

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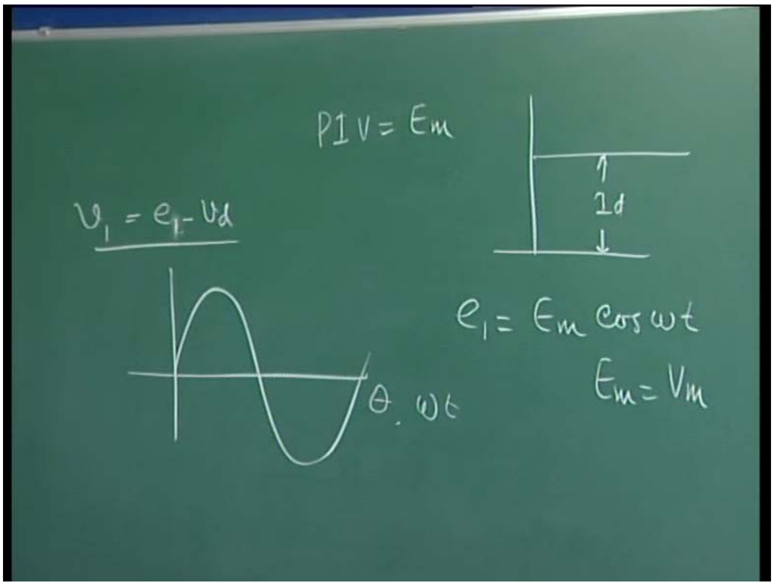

So, this is your is call the peak inverse voltage and this V here it is nothing but V 1, here I am writing this one denote this is the voltage across the first valve in this case only one valve is there. So, it is V 1 is denoted later on we will see when we are going to use the two valve then V 1 V 2 will be use if you are using 6, then it will V 1 to V 6 valve voltage this is nothing, but it is your e 1 which is just applied here minus you are the instantaneous voltage V d. So, this is the valve voltage and the peak value of this is known as peak inverse voltage means it is your peak inverse voltage, in this case will be nothing but you E m if you are supplied voltage of secondary side that is e 1, it is I am writing here E m cause omega T or you can take sine omega T in this representation I have taken it is sine t. So, this is your V one that is the voltage appearing across the valve during the complete your conduction as well as non conduction state once as you can see here, once it is a conducting here this voltage is 0 because we have assume it is a ideal valve. Only during the non conduction phase here, this minus this you can see we are appearing here across the valve.

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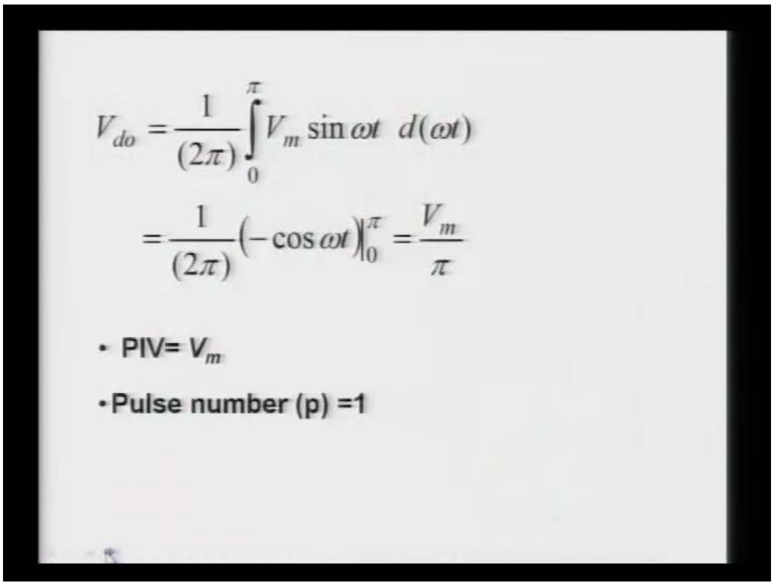

Now, this basically circuit again I want to say that this is the very simple means a simplest rectifier circuit and especially used for the very small power applications it is not use for the large power applications the DC output voltage, here kindly calculate it you can see here as I said only you have to take the Everest voltage across what is this in this upper pi k. So, here in this portion you are getting this some voltage here is the voltage 0 and this is the complete cycle. So, we have to take the Everest or we can just take this is zero.

So, we can go to take this Everest, but we are integrating over the complete cycle and with this expression, we can calculate what will be this the DC voltage you can say it is divided by 2 pi because we are talking about the it is again regular and the pulsating output voltage. So, the 2 pi here, but from here 0 to pi, I have to consider because you know is positive of cycle only appearing remaining is zero. So, it is a V n sine omega T differentiate with the d omega T one of the major, what people get confuse here normally while integrating they go for the d T whether the d omega T because once you are your waves it is here either you are writing in theta or you are writing in omega T because this is we are writing in the radiant's or in the degree. So, your differentiation will be also is d omega T you have omega T is theta simple.

So, it is nothing but if V m sine theta d theta it is not d T, because later on we will see if you are doing some mistake then it will giving different result. So, here we have integrating and finally, we are getting output voltage or Everest output voltage is V m that is the peak voltage divided by pi. I think here in our sinusoidal repentant in the figure it is E m in this case E m and V m is same means here your E m is nothing but V r. So, we can see here the peak inverse voltage already in the figure just we have seen here the peak inverse voltage is your E m and the pulse is unity and you are the DC output voltage here DC output voltage is your V m upon pi.

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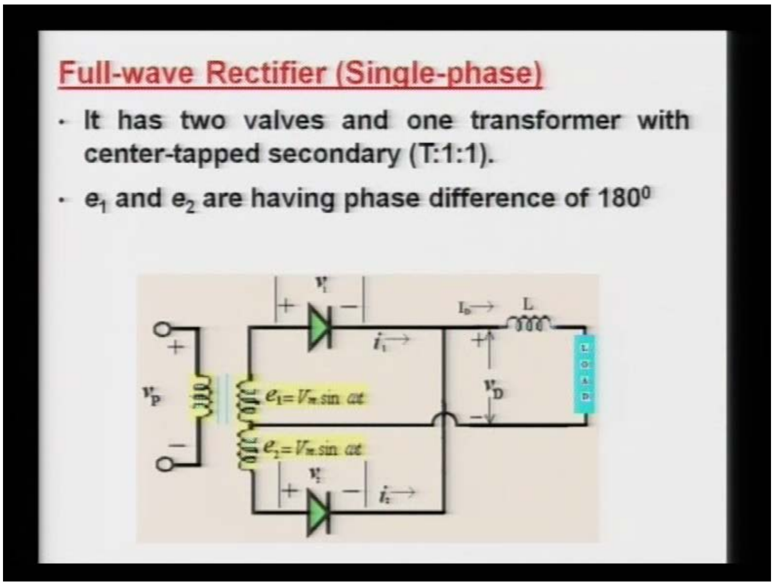

Now, another circuit that is call full wave of rectifier circuit, again we are considering for the single phase; it have the two valves because we have the two here you can see the first and second that is the denoted by V 1 and the V 2 means it is a voltage across this is V 1 means this we are taking the positive side. So, this is your V 1 this is your V 2 means bar one valve two and it had the two valve the circuit, but this the transformer we are having it is a just a center tapped secondary transformer having the term ratio T this side is one is to one here. Now in this case here, we are using the a large inductance to make our DC current constant ripple free and we are having some loads here and again if we see the difference here this e 1 and e 2 are in the phase difference of 180 degree. Here if it is a positive E is appearing. So, here it is a positive here it is going to be 0 here going to be negative. So, both e 1 and e 2 in the phase opposition and from this voltage we have say you can again see it.

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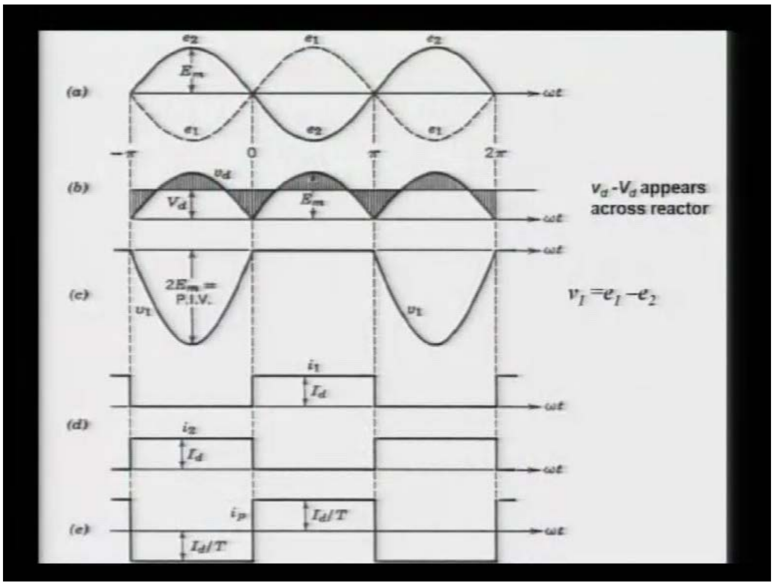

Now, you can see in this diagram your e 1 here it is it is going to be positive here we have taken the 0 axis here or you can take anywhere here. So, here is e 1 is positive, but e 2 is here is phase one eighty degree. So, this is e 1 is varying here your e 2 is varying. So, the output voltage you will see in the circuit this is where this your e 1 is positive means your first valve we conducting and in the second here will e 2 is going to with positive your second valve is conducting and e 1; that means, valve one will be half line. So, here you are you can see here in one of the cycle here we are getting two pulses. So, number of pulse is to and only here we have assume is I DC is the constant.

Now, in the second figure this V d is the voltage that is appearing across the load this after inductor. So, your inductor this sided portion is the basically the voltage that appears across the inductor means, in the circuit again you can see here you V d is here this V capital V that is the DC voltage here was appearing here. So, the difference voltage appearing here this is the instantaneous voltage which is coming just output of your rectifier circuit and this voltage again will be the e 1 minus your V d will be appearing across this and this voltage here you are e 2 minus V d will be appearing across the V 2 that is the valve voltage.

Now, here only the difference here you can see the major difference from the previous case, the valve you can see the peak inverse voltage in this case is coming the twice of it is the voltage of the secondary side. In earlier case it is a half wave it was the peak inverse voltage was only E e m and now this twice of V m why it is happening again is as per definition you can see from this circuit here what is this your voltage this is your V d this is curve of your V d. So, the voltage the peak inverse voltage let suppose you want to see across the V 1 when this here e 2 is conducting means V 2 a e 1 is half. So, this is the voltage this minus this. So, now it is minus of the two e 2 because this e 1 we are talking once here e 2 is conducting means voltage again we have to see here the V 1 is your now in this case it is your which e 2 minus V d this no e 1 minus V d with always it will be e 1 minus V d. So, here this is e 1 minus E m sine omega T means at this it is E m and now going to be difference of this. So, this is going to be minus. So, it is a twice of this similarly we can calculate for your another circuit means another valve.

So, it you can see here the ripple is two and your peak inverse voltage going to be twice of your peak voltage that is of secondary side, in the current if we will see the current which is said now the current it is once it is your in this case is a positive voltage you are this valve one is conducting. Once valve one is conducting it will carry complete the DC current I d, you can see during this period valve one is conducting. So, we are getting the DC voltage at DC voltage is coming and this I one here the current is complete varying; however, this if you will see the I two it is half condition it will be zero. Similarly, when your e 2 is becoming positive valve two is conducting and valve one is half. So, this is your current is coming here. So, this is the current which is coming in this you are the secondary that is the I 1 and I 2, but you see the primary current it will be here this I d by T because we are taking this in this case it is by T means it is the term arise we are considered. So, in this case we can see the voltage which a current which is appearing across the primary banding it is not a sinusoidal; it is a just like a pulse here I think here it is not seen, but the current in the primary side it is going to be this it is going to be here and like this it is a just like a pulsate it is not a sinusoidal, that is why in the DC circuit here analysis in the convertor circuit always we are not getting the positive sinusoidal we are having a lot of harmonics.

But the fundamental having the highest magnitude and another harmonics will have the minimum, but and that is why our transformer are design a special way. So, that there should not be any situation and losses should be minimum because there are so many in harmonics are entering the transformer. Similarly, it will be go for large and larger phases we will see this with almost perfect sinusoidal and we will analyze several three phase circuits.

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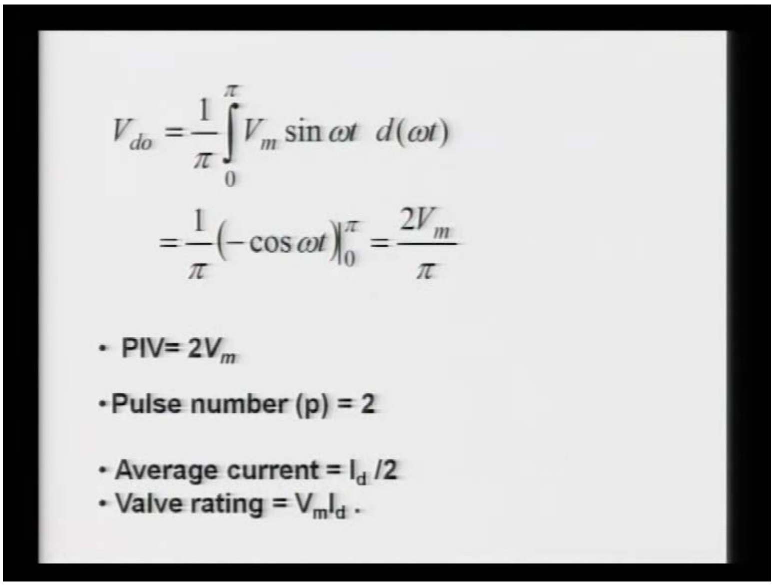

To see this average voltage, which is going to appear across this output of the your rectifier circuit here since it was pulsating twice in a cycle we can take the average half one pulse only and then it means it is a cyclic. So, here that is why it is average over pi and we are also integrating some 0 to pi and here is a V m, V m I think we have taken in the figure it is E m both are V m and E m is same here sine omega T V omega t. So, if you are going to integrate now you are saying this output DC voltage becomes twice of the half wave rectifier that is two V m upon pi and but problem here, if the peak inverse voltage of the valve become twice of V m means you are going for the double of rating of a single valve. Now, you can imagine here noted out the pulse number is two, but we are going for the two valves and but the peak inverse means rating is going to be double, but if you will see the Everest current, Everest current is going to be reduced and it is I d by two and if you are going to multiplied the rating we will see the V m over I d.

So, the rating of the valve becomes V m that is peak voltage multiplied by here, but the voltage rating you should go for the twice there is a consideration that the power rating is same, but the peak inverse voltage are different for example, same you can see here let suppose here the voltage rating is your E m the current rating is your I d, because the maximum current which is showing and your this value the peak inverse in one case it is your E m into I d by 2. In another case, may be its I d the power rating of a of a rectifier valve may be same, but this rating can change. So, the cost of that valve will be more its twice up this because the voltage rating is very very important. So, if you will see if you will go far another configuration then people say it is better to go far another configuration also in this case the transformer is not utilized properly.

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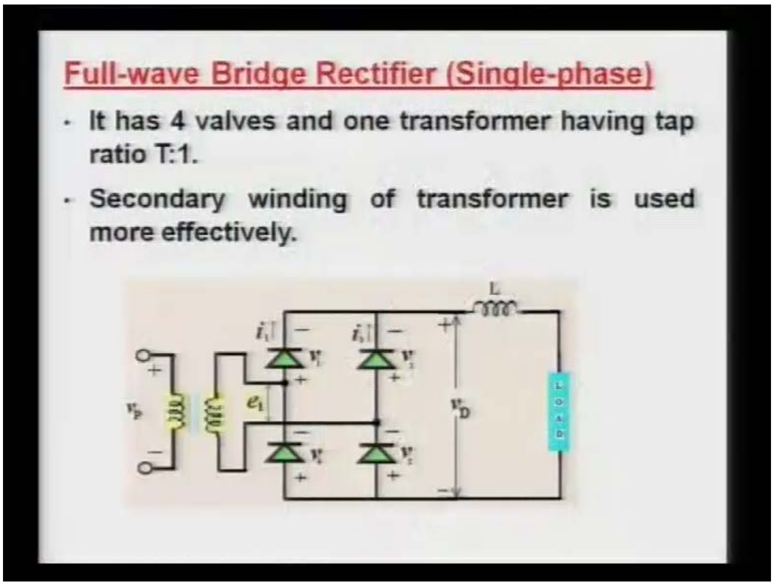

So, it was suggested that we can go for your bridge rectifier circuit in this bridge rectifier circuit is almost same, only you will see here in one phase here that two valves are there in another if I reversing here the two valves are conducting means it is the your transformer is the basically used twice in the same cycle and that is why the utilization of this transformer is better, but we are going to have the four valve, in this it is for single phase again we are going to use four valve and one transformer having that tap ratio here T is to 1 because T, I am denoting because in the website we are using the T. So, in this case the major advantage is that we are having the better utilization of your transformer, but the number of valves are increasing to see here again this we have said here now, this is your secondary voltage that is appearing this I am assuming as a 0 axis because it is a cannot initially changing you can have your axis anywhere in this. So, you are just taking here the sinusoidal voltage of one cycle now taking as a 0 axis here you are getting lets go E m sine omega T your this values your that is appearing in the secondary of this your bridge rectifier.

Now here, you see that they as a two valves are conducting in the pair and especially as for numbering which we have denoted here you are in the first way it is your valve one and the valve two are conducting means its normally in such way that in the positive half here this is going to be positive this is conducting and your current is flowing here and it is going back. So, your valve one and two are conducting during the positive half once this is going to reverse here now this voltage here, your this is going to be conducting means your three and four are conducting and we are getting the output voltage means in one it is the two also conducting at the time and you can see here means, again in one cycle once in a positive cycle we are getting this is output voltage means, here your one and your two are conducting and in the another cycle here your three and four are conducting and this is your V d is showing your instantaneous output voltage.

Now, if you see this the valve voltage which is going to appear across the various valves let us goes valve one in this case, your valve one and two are conducting if the voltage across the valve one is 0. Now here, the valve one and two is r half and the voltage here we have to now see it is not directly from this minus this minus this you are doing we will see it is twice of this, but here V 1 and that can be again analyze by this circuit in the basic circuit you can see why it is your now you can see here this is your half during the half cycle means you are this is conducting and it is going to be this. So, the voltage across this is the voltage means voltage across this is this voltage minus this voltage, no doubt and here you will find this voltage across this is only E m means just your to this voltage V DC V d minus you are the reverse of this your substituting this voltage is going to appear and this voltage is in, but your simple E m if my peak inverse voltage. So, compare to the previous circuit the peak inverse voltage in this case is reduced by half, but numbers of valves are increased by twice.

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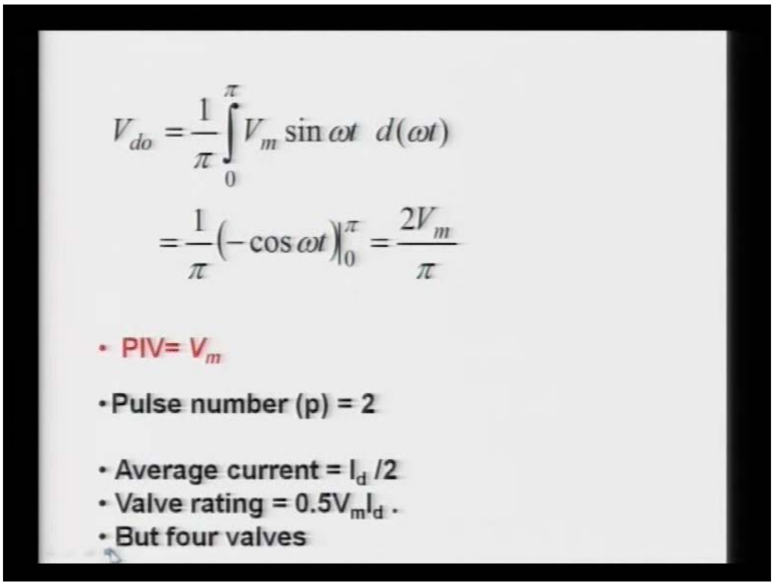

So, what happens here you can see the number of pulses are again same, but only the peak inverse voltage here which is going to appear it is your E m are this I am writing here V m and if you see the rating of the valve rating here is reduced by your point five here this. Now, if you see the cost wise compression this is no doubt it is reduced by half, but we are going to use four, but this value is reduced by half. So, in this total circuit configuration of fine this is the cheaper option compare to the pervious, because in that case it was twice V m and this was the point double or this now you are going to use four. So, it is the same multiplied by two, it is V m I d because the Everest power here again I d by 2 and you are going to be your peak inverse voltage is this. So, the rating half your thyristors are you are valve is reduced by half in the voltage sense power rating if you going for four it will be half. Now, Everest voltage I just said it is again the two pulse full wave rectifier. So, the Everest voltage will be also two V m upon pi, you can just calculate because we have taken for one cycle only not one cycle even half of the cycle of AC and it is since pulse setting twice.

So, we have just average over to pi and we can get it here, we will see in later state taking the where is output DC voltage taking sine omega T is not convenient you know it is any signal here, you are taking Everest let far this signal you want to take the Everest half of this one option that you can integrate this from here 0 two let goes pi and then you are taking sine up this signal Everest can have whatever the value here you are having here we have taken the V m here it is V m. So, I can say it is a 0 to pi V m sine omega T and I am going to take one over pi another half option is that we can set our axis and we can take from here the same E equal to this 1 over pi minus pi by 2 2 pi by 2 and here it is your V m cosine omega T d omega T both are same, what happen here our axis is shifted here and we are integrating from here to here means same wave said we are doing in this another way and we realize later on this option is better for calculating that is the output because you know the cosine integration that will become sine and once you know sine value 0 to pi very clear otherwise cosine value it is going the second quadrant it going to negative 1. So, this option will be very frequently used when we will go for the three phase circuit in the single phase you can either use this or use it this is both complication complicity is almost same, but in the three phase very life this is the very convenient option compare to it single this is sine wave.

So, here as I am using here, but we will see later on we will use the cosine and again our only we have to change our integration levels and other thing will be same. So, in this circuit we can see I can say here in the peak inverse voltage is halved and this circuit is basically very widely use for high voltage application, you know why it is high voltage application because your peak inverse voltage becomes only E m if you are going for this your another circuit full wave rectifier it was a 2 E m and there is a possibility that you cannot get the your valve of this such a high rating.

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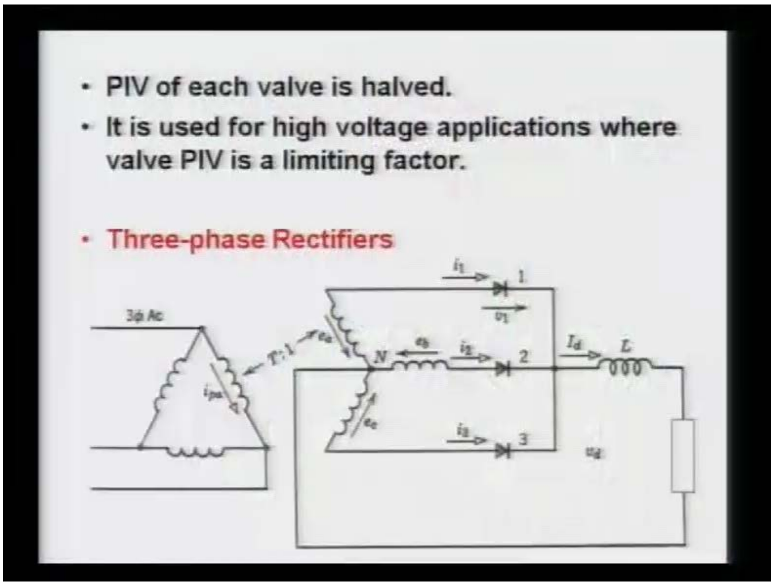

So, bridge rectifier single phase is used for high voltage application where the peak inverse voltage is a one of limiting factors, but if you are going for high power application even though you are the pervious full wave rectifier is also sufficient. Another here advantage, as I said in this circuit in the signal phase your bridge circuit here this your transformer here means going to be properly utilize. So, this is also a ration while if you are going to analyze any circuit what is the utilization factor of the transformer. So, in the later phase when we will go for the our analyzing of the DC rectifier what should be the optimal configuration this is the our main consideration that, we should have the maximum output voltage here for the same given here the your sinusoidal emf and your transformer must be utilize properly and the peak inverse voltage of the valve should be the minimum.

So, these three criteria for any convertor circuit is normally used means we should get the maximum output we should have the minimum peak inverse voltage and the transformer should be the properly utilized with this conditions, we will see when we will go for the actual 6 pulse or 12 pulse rectifier circuits are convertor circuit will see with these consideration and then we will see what should be the configuration and finally, we will find the bridge convertor is the best option with the simplified modification. So, in this if you see the current as I said the current through the valve here valve one and your valve three is the same once your this is valve one and two is conducting and it is across your three and four it is this when your seconds half it is means when one and two are half means it is a going to be a three and four valves are conducting the primary side the current, you can see here this is the primary side current in this case it is a pulse another difference with a half wave circuit rectifier circuit you can see this secondary side as well as the primary side is same means, you can see here I s is equal to the T multiplied by I p means T is the term ratio if the T is unity means I p is equal to I s means primary and secondary I am talking.

So, this configuration here you can see it is a complete square wave in the primary as well as the secondary of this transformer; however, if we will see in your previous circuit it was here you can see in this circuit this circuit only it was primary was this; however, the secondary was either this one because we are having the two transformer center trapped one was here another was here. So, it was not a perfect it was having some DC current as well in the secondary of the transformer; however, in that case we have the DC is 0 and we are having no doubt harmonics also here we are having, but the primary current is complete square wave means DC value is zero, but the secondary currents having some DC values and that is why it is more loss. So, there so many if you compare your bridge, your bridge rectifier circuit and your full wave rectifier circuit, this is the better I have this is the good question, here I am assuming the transformer as no leakage impedance and it as a very minimum exciting admittance the no leakage, here I am considering only for analysis purpose, but let pose if you are having the highest means more leakage impedance what does it happen, it only reduce the voltage of your secondary side nothing else, because there will be drop in the leakage and that leakage drop will reduce your this value this instantaneous voltage will be reduced by certain factor nothing else, but for analysis purpose because we are talking very easily what is the your primary side and secondary side. So, we are not going to consider the leakage impedance of the transformer, but no doubt here the actual transformer is designing in such way that you should have the larger leakage reactants, because when there is any short circuit in the convertor circuit or may be in the DC side if the current will flow through the transformer and it should limited.

Especially during the convertor fall this transformer is only the safety measure or safety valve for protecting the your valves. So, in practically we should go for the last leakage impedance, but analysis I am taking as a 0 because we are assuming. So, only the secondary side voltage is transform by the term ratio and that is appearing across your valve, nothing it is no difference. Now, we are let us go for this three phase, because single phase, this I analyze here is your three phase rectifier and this three phase rectifier it is a very simple one wave rectifier here having you are the three valves means this is your delta E star connected transformer here it is delta term ratio in the phases per phase transformer it is the T is to 1 it is from this phase to the phase and here it is a neutral is available and this it is connected to the neutral. So, we are having the valve one two and three they are connecting in phase a b and phase c. So, here this is the continuous firing of the valves, when valve one is going to conduct means your valve three was conducting and then valve three will come into the picture then valve two then valve three and so on this will be is a complete cycle, it will be keep on conducting in this case also, here we are assuming the DC current is constant that is we thought and the voltage across this the DC output voltage it is a instantaneous voltage a small quantities are representing by instantaneous value instantaneous quantities and the capital it is showing over the Everest or DC values.

So, this I d is shown as the DC current which is the constant which is instantaneous as well as the constant value, but the output voltage here we are measuring that is the V d which I am calculating here this is your Everest value and that is integration of this V d nothing else. to see it again let us see the wave same of this it will be slightly complex as that is why I start with the single circuits.

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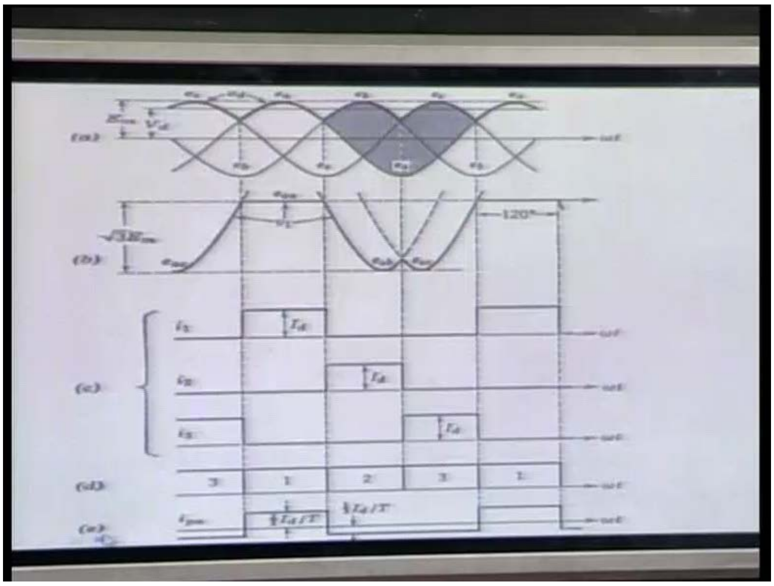

So, that the single circuit looks very simple, now we are jumping into three phase that is why it was my motive to start with the single circuit it directly if I am coming here will say what I am doing here. So, it is better to now analyze what happens, we are taking at here at the 0 axis. Now, in the circuit here you are this E a is going to be positive because your E c is going to be here negative at this point your E c and E a is 0 is equal means now once your E a is going to phase and means your valve one can be fired, because the condition of any valve that can be ignite can be go in the conduction mode if it its having forward biased. So, at this point you can say E a is more than your E c at this point it is equal mean this even though you are having a gate pulse to your valve one it will not conduct. we are assuming your valve three was conducting valve three means E c voltage was appearing across your output and at this point we can if you are giving the positive pulse to your valve this will conduct because the voltage across this is going to be positive and valve three it is going to be negative. So, what happens here we have set here we are assuming there is no delay right now we assuming it is a perfect diode. So, here it can ignite your one can be conducting and once one is conducting your output voltage is beginning E a. I think this previous slide showing you the circuit, but once you are going to analyze this wave say it will give important that we should again see here what happens as I said this your E c is here this is the conducting means your the value is coming to be your E c.

Now, this voltage across this is your E a minus E c and once it is going to be e a c means always if you writing this E a minus E c is basically voltage which is appearing across your valve one all the time here during that conduction phase here it is going to be your this, but it is every time wants this is the conducting the voltage across this is going to be change because at that time this is your E a minus E b. So, there is a three phases in complete one cycle once it is conducting then voltage will be 0 one this is conducting then this voltage is appearing here means this voltage is same. So, this minus means E a minus E c will be appearing once this is conducting then this E b is coming here and E b means E a minus E b. So, the voltage across valve one at certain period it is your 0 once it is conducting and if it is in half condition it is nothing, but your e a minus e b other than terminology is used that is call commutation voltage the commutation voltage is a voltage at which the valve is going to fired you known as I said the valve three is conducting because we are talking in the sequence of the conduction means before one three was conducting. So, it is three one two three one two three and so on.

So, for it is sequence of conduction means, once here we will see the three was conducting the voltage across this will be positive then this can be fired and it can be fired when this is going to be equal e a is equal to your e c. So, in that wave I say that is here it is going to be here this is the conducting. So, this is called a e a c is called its commutation voltage because it is going to fired means the voltage which is going to just here going to be positive. So, that I can be fired means once you are e a c become positive, if you see from this graph again because these things we will be using when we will go for the bridge convertor now, here as I said we are taking as here 0 axis means e c is coming output voltage means your this valve three is conducting. So, your current was showing from e a c to neutral in that previous diagram, here now at this point this e a between positive compare the e c means e a minus e c here is 0 and this e a c is called the commutation voltage of valve one similarly, if you will see the commutation voltage of valve two it is you will see here means it is your e b minus e a means this it is going to be positive this commutation voltage is very very important when we will go for the bridge circuit analysis and the commutation voltage is a voltage when it is going to be positive that valve can be fired this can ignite can be earn and as I said the V one can be worn when your E AC is going to be positive.

So, at g stand it can be fired and then it will be the that is why the commutation voltage in this case for valve one it is this minus this that is E a c similarly for valve two it is your E b a for this valve three it is E c minus E b that is E c b. So, these are the commutation voltages and you know you see in one of the cycle here this is there is three pulses. So, we are getting the three pulse cycle now your pulse is now it is your p is equal to three in this in one cycle. So, it is a three pulse three phase rectifier circuit and the simple it is call one wave circuit three phase one wave, because always is one way it is current is not showing through the two now, if you will see the voltage across the peak inverse voltage here once it is going to be E a E a c is going to positive here means it is conducting during this phases your one is half during this and this conduction phase because only it is during this phase it is a one is conducting means one is it is here e this is your e a c up to this period now here once two is going to be earn.

Now, the voltage which is appearing in the circuit again you can see how much voltage we are going to get now once this was conducting it was 0, now the next turn of this valve we are assuming the we are giving the pulsate at the regular interval it is not that you are just half we assuming this a continuous pulsation this is every this three valve. So, there means every it is a in the 1 pi 60 a 360 degree it is 120 120 it is conducting. So, it is 120 its conducting after that this is tern and it is going to be fire once it is going to conduct you can see the E b is appearing here this is again half. So, the voltage here it will not come this side because this is half. So, the voltage across this will be your E b and this is E a minus E b will be appearing across this. Similarly, the voltage across the valve three will be this b here and this is the E c. So, this minus this means E c minus E b will be appearing across the valve three now next turn is this. So, there will be sudden change because some here to here we are going to conduct this third is going to be fired because the positive voltage arise after one twenty degree regain. So, that three will come here the voltage across this becomes E a minus E c now if it is conducting the voltage across this becomes E b minus E c.

So, if you see in your website the voltage that you can see here as I said here once you are two is conducting the voltage across valve one here at this point itself it was conducting here it was 0 voltage across the valve one suddenly this valve two is going to conduct here, now it is solving this circuit here E a b because E a is the positive side and b is coming your cathode side. So, this voltage is going to follow here up to this point when third is going to be fired because this E c is going to be positive then your E b. So, E can this your valve will conduct now at this point it is going to be E a minus E c because E a was appearing at the anode side and cathodes c is going to be third valve is conducting now it is going to here and again we have following this. So, the peak inverse voltage in this case it is a E a b it is not E a means your E a in this case I can say here this E m cross omega T are fine omega T here lets go take. So, this is your line to line voltage, if your fine voltage here is your E m then this voltage will be your line to line in three phase circuit it will be under three multiplied by E m. So, the peak inverse voltage in this case it is your under root three E m.

So, this is your and you will find this is valve one voltage we are drawn similarly, you can draw the voltage fire valve two valve three it will be nothing, but it will slightly shifted one twenty degree because one this is the conducting. So, this will be here it will be conducting and for the remaining period it will be similar same. The current you can see if for the valve one it is one once it is conducting only for 120 degree for here 260 120 and 120 it is half. So, this your getting this current in the phase wave phase one similarly we are getting here for valve two conduction it is this and it is valve three if you add here all together this is basically shows three one two three one it is nothing, but it is the sequence of conduction means you can see one is conducting the current here is a DC cross this the voltage across this is a valve is 0 and output voltage will be E a because we are taking neutral as the written path and if you see the primary current here it is a just like a pulses here that is appearing across the delta winding.

But in this case, you will find the this is the Everest value is not is Everest value is zero, but the it is not perfect sinusoidal in the phase, but you will convert into the delta pi to the transformer of the is the line side just I want to explain that here this is the your this phase current we are talking now if you go for this current here it will be this current minus this current will this current and then will have the square wave or the output and that we can see on the next term as well. So, here I in this analysis you will see what we are getting now here the each valve is conducting for 120 degree the peak inverse voltage becomes it is under three times of the phase voltage magnitude and again it is a always negative because peak inverse voltage inverse side of the voltage and the current this valve is carrying the currents are only 120 degree and the remaining 240 degree it is half condition the phase here, the current are this delta winding here we are getting this one you can see you are getting here if you are transformer is E star E star then what we are going to get whatever the current here it is showing that will be your primary side because E star E star this is valve is one phase current it will be just transform to the primary.

But in the due to the delta here we are getting the difference shape current you can say this current is no doubt the magnitude is less, but it is for wider 240 degree and here it is for lesser degree and due to this again we are having our transformer is not utilize properly in this case, you can say the transformer is only in the primary side it is only conducting the primary binding it is 120 degree remaining time this one phase is ideal and this only this here you can see one twenty degree this and one twenty degree this. So, the utilization of transformer if you analysis it is not proper and also here it is giving some DC current that is appearing in your you know your secondary side and that is not true because the DC current which is if you say take the Everest of the any of the phases in this secondary side it is DC and due to the again the DC current is not is our own in the transformer.

So, here I want to tell that this is a one very rough analysis of the three phase one wave circuit, but it is not use because it as a. So, many limitations limitation as I said the DC current is appearing the your secondary and also it is the not properly utilize, but here the peak inverse voltage is not double even compare to other it is still less and the power we can also calculate what will be the power of the valve it will be the Everest of this current multiplied the peak inverse voltage. So, you can calculate what will be the valve rating valve rating in terms of volt f it will be is a under root three m the Everest current here it will be how much I d by 3 because the remaining period it is I by I d by three and if you multiplying here you are going to get you see is a one by root three E m by I d by under root three and, but this case you will take the Everest here the DC here Everest zero, but this is phase is a for this period it is a less magnitude, but for constant mode distance hence more distance means 240 area 120 120 degree here we are taking more current for this. So, your transformer is not symmetrically loaded I can say and that is why it is a proper care should be taken for this.

So, I can just conclude the end of this lecture one that, we analyze very simple circuit is starting from the half wave single phase rectifier circuit and we saw about the rating of valves we also saw what will be the valve voltages, we also saw what will be the DC instantaneous output voltage and we calculated to the Everest DC output as well then we saw a three phase three phase a one wave circuit where it was a star delta E star transformer and the three valves where there and then we saw the peak inverse voltage is under root three times of p sinusoidal magnitude voltage magnitude and then it is we also saw the DC current are available in your secondary side and the transformer is not properly utilize. Now, we will see some more some more three phase circuits then we will go for the actual requirement what should be the desired features for our HVDC link convertors and then we will analyze in terms of general derivation here we they write for individual cases now we have to derive a general expression and then based on that we have derive what should be the real configuration is required and that will be discuss in your next lecture. Thank You.