**Advance Power Electronics and Control**
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**Lecture - 33**
**Cycloconverters and Matrix Converter**

Welcome to our courses of advance power electronics and control. We are discussing about the cycloconverter. Today, we will continue to discuss cycloconverter and thereafter matrix converter will be discussed.

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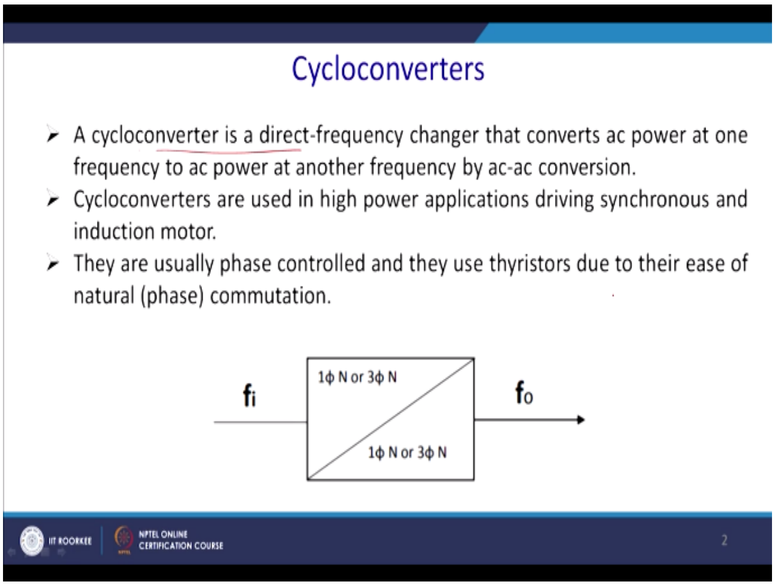


So as we have discussed in previous class, cycloconverter is direct frequency as well as the voltage conversion. So cycloconverter is essentially a direct frequency changer to convert AC power to another frequency and cycloconverter is used for the high power applications in driving synchronous machines or induction machine this kind of where it is actually. It runs in a constant speed at a constant frequency.

They are usually phase controlled; they use thyristors because of the high power rating with the invent of the IGCTs. Gradually, this technology will evolve and we may see that actually phase out of this technology.

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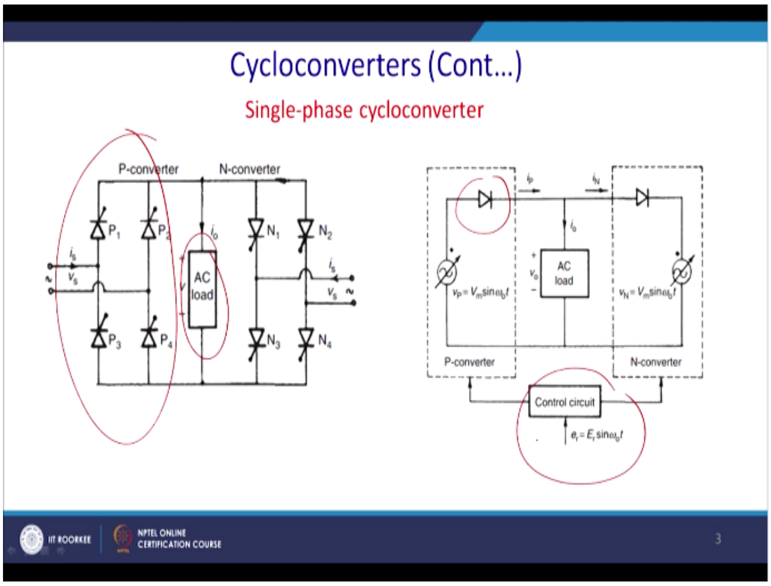


So we have discussed in previous class also, this is little recap. So what is the difference between this dual converter and this? Binary dual converter what is to happen you know essentially is that we had our DC load here but you will have AC load but otherwise it will act on a same manner. So this converter will be said to be the converter P once it will be switched off the positive cycle will be generated and once it will be switched on the negative cycle will be generated.

And so that you can have a variable frequency as well as variable analyzed value, so this is the configurations of it, so if you want AC load and you can think about power can sink this way and it can go out this way and the control will ensure that a different kind of switching pattern.

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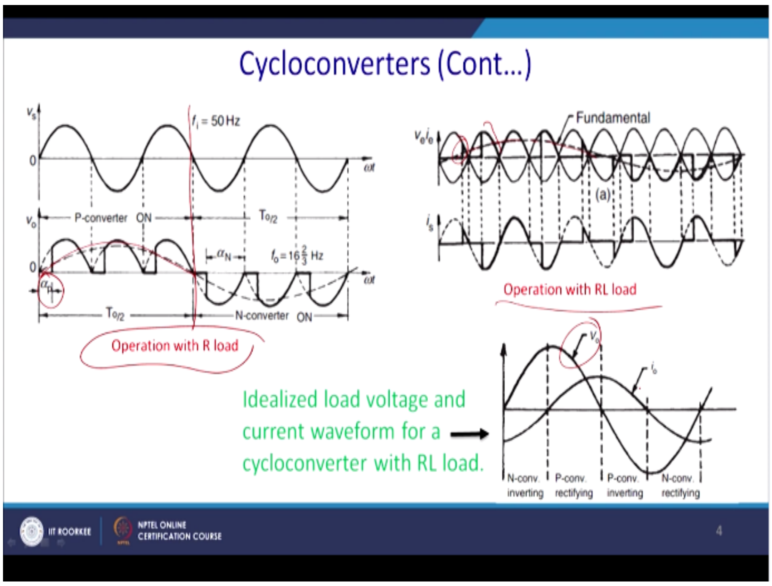

So if you wish to step down the frequency, you can also step it up but mostly these are step down for the way up control and other issues so what happen you know till this time, your switching continuously the converter one and thus you get and you can control the magnitude by controlling alpha and thus you get basically consecutive positive cycles and fundamental will be this.

Similarly, it will be a consecutive negative cycle fundamental will be this but mind it this simplicity arises due to the RL load as for only the normal resistive load but if you have a RL load and if you assume that actually high current flows then switching will be little difficult because you have to turn it on when the current through the thyristor is going to be low or zero. So for this reason, you can see that you want to generate this profile.

You will be actually switching on this portion of the voltage alpha should be changes. Thereafter, you will increase actually decrease the alpha so you have a more conduction angle gradually condition angle will increase and thereafter again it will reduce the conduction angle and thus it will track this envelope. Similarly, it is repeated in negative half cycle and thus what you will get this is the output voltage, across this AC load and this is output current across this is AC load for RL or inductive loading.

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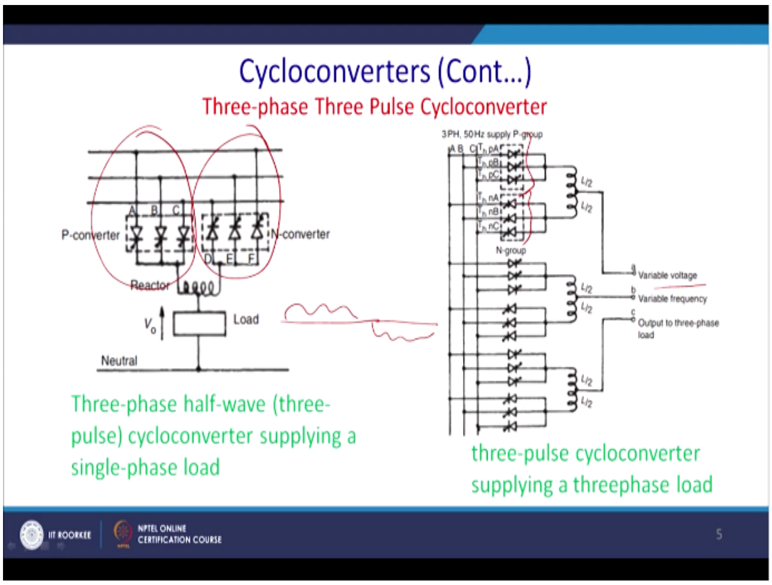


Now same concept can be actually used for the three-level half-bridge converter. So you have basically, you have discussed about we have already discussed basically half-bridge converter. Two half-bridge converter will be actually connected and thus what will happen so if consecutively positive half cycle is triggered, node will get this kind of positive half cycle. Then, if it is negative half cycle is triggered node will get a negative half cycle.

And all the free phase can be constituted, here only single line diagram has been showed. So proper diagram three-phase three-pulse cycloconverter of the three-phase load should be like this. So this is for the phase A, phase B, phase C and this is the thyristors and this is for the positive part of the voltage of phase A and this will be the negative part of the voltage for phase A. Similarly, this will be for phase B and phase C and so on.

And thus you get a variable voltage and frequency at the three-phase output, so you can see that you know this is for the half-bridge configuration or half-wave configuration. So in this case also, you require for each phase you require 6 thyristors and thus total 8 thyristors is required but if you wish to have a full bridge so number of thyristors will be 36.

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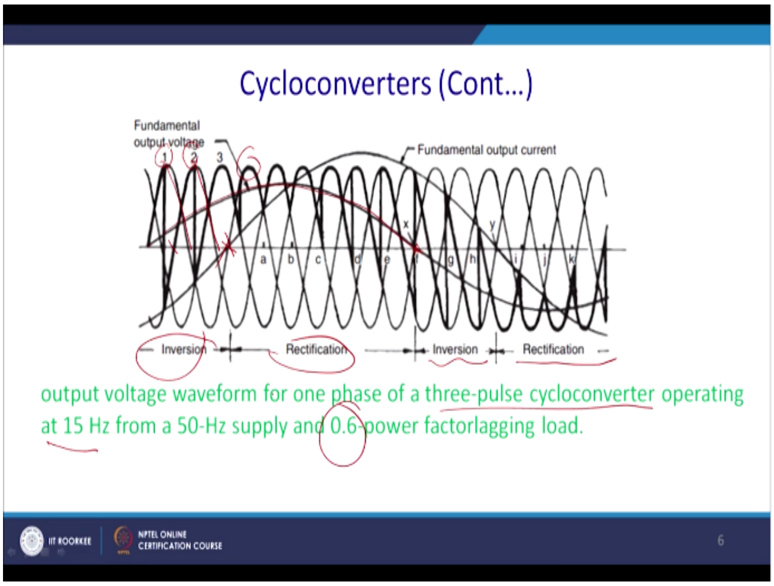


Thus, what will happen you know, this is the way you will generate? How you will generate? First, you will trigger actually the phase A of this voltage and this portion of the voltage you will get. Thereafter, again you know depending on the positive sequence, you will get this kind of voltage and gradually you will trigger on. This is corresponding to the 1, 2, 3 and thus from positive because till this point phase A have a maximum voltage.

After this basically after 120 degree phase B will have a positive sequence so then voltage will come from the phase B and that has been marked as 2. Similarly, you know it will be from phase 3. Similarly, again after 360 degree apart this phase A will be positive that is marked as 1 and again it will be triggered and there alpha will be changed to actually increase the magnitude.

So fundamental will be actually having this kind of pattern. Same thing is repeated but this is for the inversion operation and this is for the rectification operations. Please understand that here it is considering that RL load till this point, voltage is positive, current is negative. So amount of the energy spent here is essentially negative. Here basically the rectification operation again at this point voltage become negative and current become positive so it will be again inversion operation.

Similarly, when voltage and current both are negative you have a rectification operation. So in that way, you have to actually generate this. This is an example of the output voltage waveform of a single phase of the three-phase of three-pulse cycloconverter operating at 15 hertz from the 50 hertz supply at power factor 0.6 lagging.

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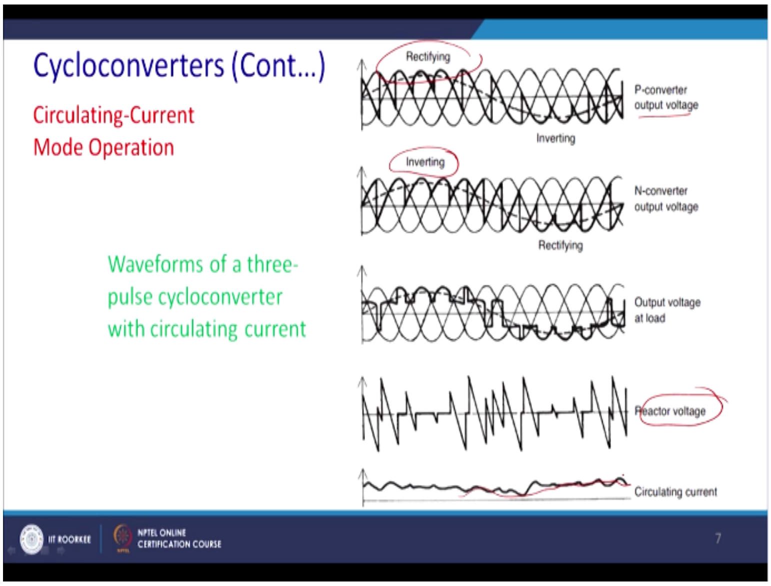


Of course, you can have a circulating current mode operation. This is something it is interesting to note. So we have seen that once voltage is positive and current is negative that is it is inversion mode when both voltage and current are positive it is in a rectifying mode. Now let us see that it is a P-type output converter and it is operating in such a way this is a rectifying mode and when N-type is operating, so this is the inverting mode for it.

When P-type converter is generating a positive voltage, we will say that it is a rectified operation and P-type converter is generating a negative voltage then we will say that it is a inverting operation. Similarly, a N-type converter is generating a positive voltage will say that there is inverting operation and wants the N-type converting generating the negative voltage we say that it is the rectification.

So output voltage of the load if you combine these two process, you will get essentially this and this is the reactor voltage that appear across these inductors because there will be an instantaneous voltage difference between this actually positive and the negative converter and this will have a (()) (09:35) and thus this will be smoothened by this actually the inductor and you will have these value of the circulating current.

And you have to allow the path to flow this circulating current. That is the one of the greatest challenge of the cycloconverter.

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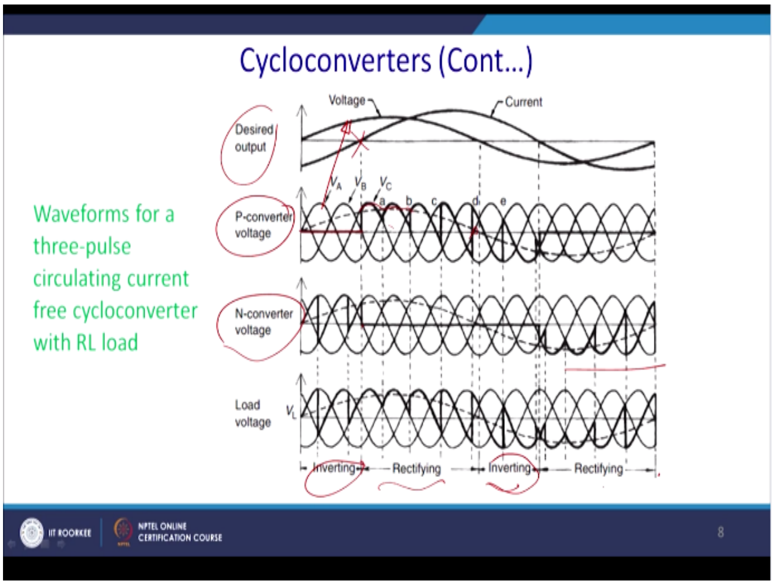


So see that we wanted to basically a stepping down of the frequency and thus from the 50 hertz you try to get this maybe 15 hertz or something and desired output is this this is the voltage and this is the current and it is lagging by something. So what happen initially, since the inversion operation? You have a choice, you may use actually the negative converter and you can generate the negative part of it.

So for this reason at this time you know P-type converter has been switched off and whole contribution is coming from the N-type converter. So it has been switched till this point where voltage and current actually current is crossing 0 and this becomes positive and till this from this point onward P-type converter will take the lead and ultimately it will conduct till the voltage becomes zero that means at this point.

So till this point, then also what you generally do, we do not generally switch it off and generally it will continue to work in an inverting mode. Thereafter, once current also become negative, you switch it on the N-type voltage and effectively you will get this load voltage across this actually the reactor. So this portion is inverting, thereafter rectifying, thereafter inverting, thereafter rectifying.

Mind it, after rectification again inversion operation starts and thus actually it will continue with the N-type converter. So now you have understood the logic why we are starting with the N-type converter because at this point N-type converter was functional.

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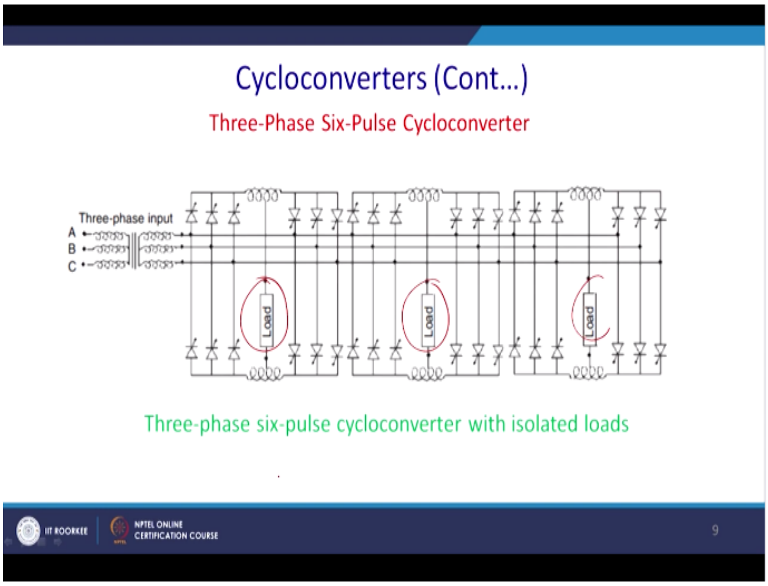


So this is the realization you know that require 36 switches so of the three-phase six-pulse cycloconverter. Ultimately, voltage becomes half in case of the half wave so that much of rectification cannot be done and so this is the individual load of three-phase load and this is the supply and you can generate this actually different kind of frequency and the voltage depending on the requirement.

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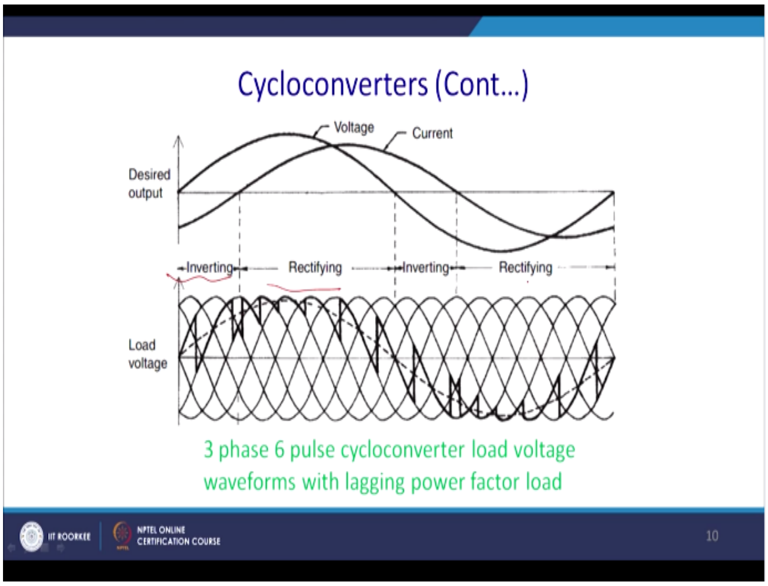


So same thing this is a desired voltage and this is the output voltage, this operation is inverting operation and for this reason generally it is followed by the negative half cycle so you will be switching on this load voltage in such a manner you will get it. From there, there will be a transition of rectification mode and similarly it will be converted into the it is inverting more thereafter again it is a rectification.

So this is the way we actually operate cycloconverter but one of the challenge is that it require huge number of switches that is one of the biggest challenge of it. Now another problem is that current has to be have given a path one challenge because all thyristors of the current controlling device, so controlling is very difficult and commutation failure anytime may occur. Apart from that, your this reactor voltage is basically a spike in nature.

And that cause lot of stress on the inductor and also actually causes the EMI, EMCs. Now can we have another type of AC to AC conversion? Another challenge it should have you know basically we try to mimic the characteristics of the transformer. So essentially what you want to do? You require to step up and step down. Here you can play with the frequencies, you can increase the frequency, decrease the frequency but generally voltage have been bucked or reduced.

But we can have another type of converter that we will be discussing right now. That is also an AC to AC conversion and there that is one of the modern actually area of research and also will see that its efficiency and applications.

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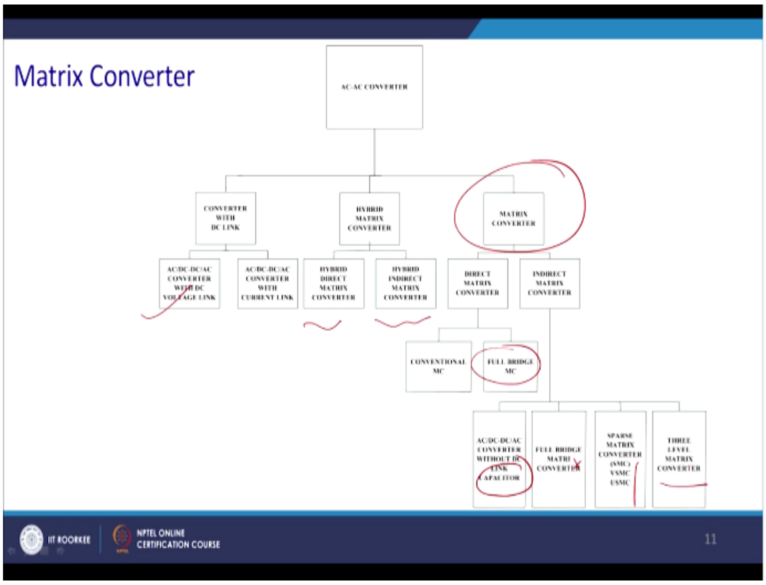


So AC to AC conversion, this is the overall actually the positions of pictorial representation. We can have a converter with the DC link that means first you convert AC to DC followed by DC to AC conversion. So we require DC link and thereafter we may have and thus we require a bulky capacitor and in between you may actually have an AC to DC or DC to AC followed by a current link, then we require a bulky inductor.

And we may have a hybrid matrix converter, hybrid direct matrix converter and hybrid indirect matrix conversion. So there will be some portion of the DC link and now we are interested in this part like we have studied cycloconverter. We like to remove the DC link and thus we have matrix converter. We can have a direct matrix converter, we can have a indirect matrix converter and direct matrix converter will have a conventional matrix converter as well as there will be a full bridge matrix converter.

Similarly, indirect matrix converter will be there, AC to DC and DC to AC converter with link capacitor, full bridge matrix converter and sparse matrix converter or it is called SMC or VMC or UMC will see that and three-level matrix converter. So cater the need of the higher voltage rating or level is required to increase so there we have a chance to actually increase the level by multilevel instead of the three-level we construct multi-level matric converter.

Now what is the utility of the matrix converter? So these are few things since it is a modern topic it is not available on the many of the books. So for this reason, I tried to actually simplify this content by saying some introduction.

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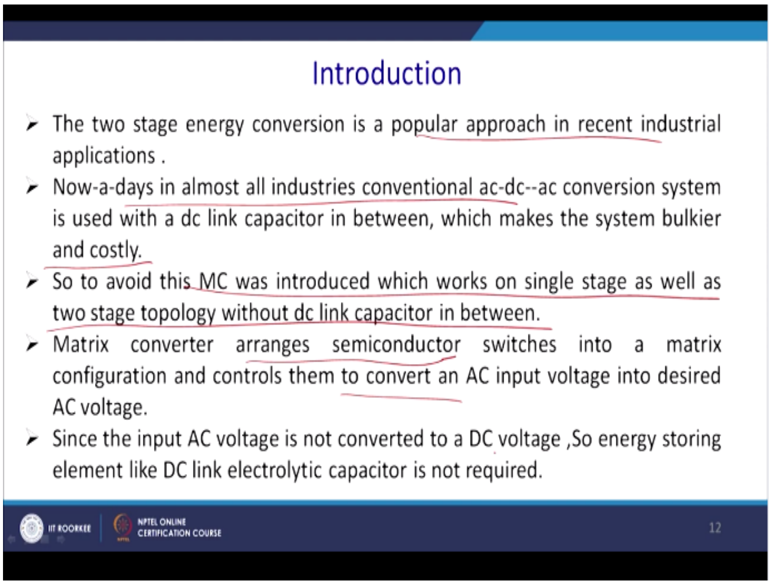


These two stages of energy conversion is a popular approach in recent industrial applications. So we try to remove the bulky DC link with the capacitor or inductor. Nowadays, in almost all industries, conventional AC-DC-AC conversion system is used like DC link capacitor in between which makes the system bulkier and the costly. To avoid this, MC was introduced which works on the single stage as well as two stage topology without DC link capacitor in between.

Matrix converter arranges semiconductor switches into a matrix configuration and control them to convert an AC input voltage to the desired AC voltage. So let us say you have V/f control, so we require precisions of V/f that can be done by the matrix converter. Since the input AC voltage is not converted into the DC voltage, so energy storing element like DC link electrolytic capacitor or if it is a current source, then we require high inductor, it is no longer required in this case and system become compact.

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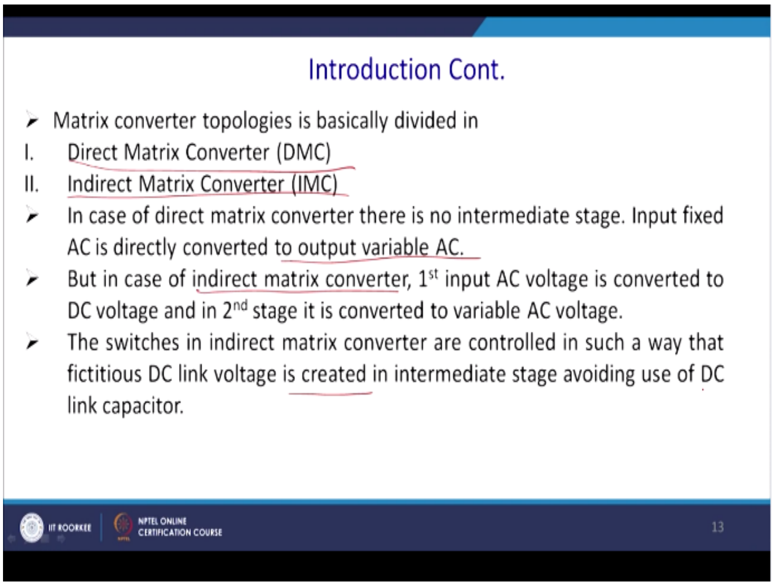


So matrix converter topologies are basically divided into the direct matrix converter and the indirect matrix converter. In case of the direct matrix converter, there is no intermediate stage, so it will be direct conversion. The input fixed AC is directly converted into output with output variable AC but in case of the indirect matrix converter, first input AC voltage is converted to the DC voltage.

And in next stage, it is converted to the variable AC voltage. The switches in the indirect matrix converter are controlled in such a way that fictitious DC link is created we shall discuss in detail how it has been done which is quite interesting phenomena intermediate stage avoiding use of the DC link capacitor.

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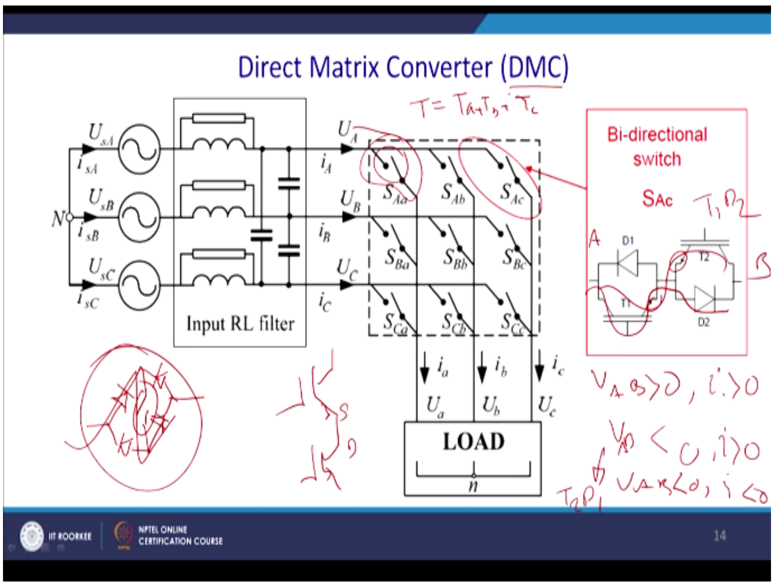

Now this is the example of a direct matrix converter and it is abbreviated as DMC. So you have three-phase matrix converter and mind you that there is also a problem of the circulating current here. So you want a bidirectional switch, so because current and voltage can have different kind of phase lag and phase lead and thus it will conduct. So for this example if you consider that between A and B, if B is>0 and you have given pulses to both T1 and T2.

Then, path of the current will be this. If VAB is<0 then path of the current will be through this. Then, what will happen then you know if voltage or current has a phase lag, if voltage is positive, current is still negative, then also you know since pulse has been actually continuously given to turn it on, so it will continue to flow in that mode. Then, only when current goes to 0, then only it changes the tracks of these two points.

Essentially, if AB is 0 and current is>0, then definitely path is through T1 and T2 but again if it is still >0, path is still T1 and T2. Once actually VAB is<0 and iA is<0, then you will find that path is to basically through will be this and ultimately in this corresponding figuration path will be through you know T2 and T1. So this is the way it will work. So we require but mind it we have studied inverter and generally we have required an inverter leg.

Mostly, this has been constituted by IGBT. It has you know the source generally what happen in IGBT in normal configuration, source and drain are connected together. This is the source of the upper thyristors and this is the drain of the lower thyristors. This is the configurations of the inverter legs but here you will have a difference. You will find that actually both the sources are being shorted together.

So to make it bidirectional switch, we have many ways to constitutive a bidirectional switch, it is not the single way, we can take an example of this example and this switch can be IGBT or MOSFET. So one of the advantages of this device is that so you have only one controlling device but disadvantage is that you know you require actually while current flowing actually it counts that drop across the four devices.

So that is something, this device, this device, this device, 3 devices and also while coming it will have a three devices but here it will account two devices but both required to be a control device. So you have a choice, if current rating is small then we sometime go for this kind of configurations and let us draw in a little manner.

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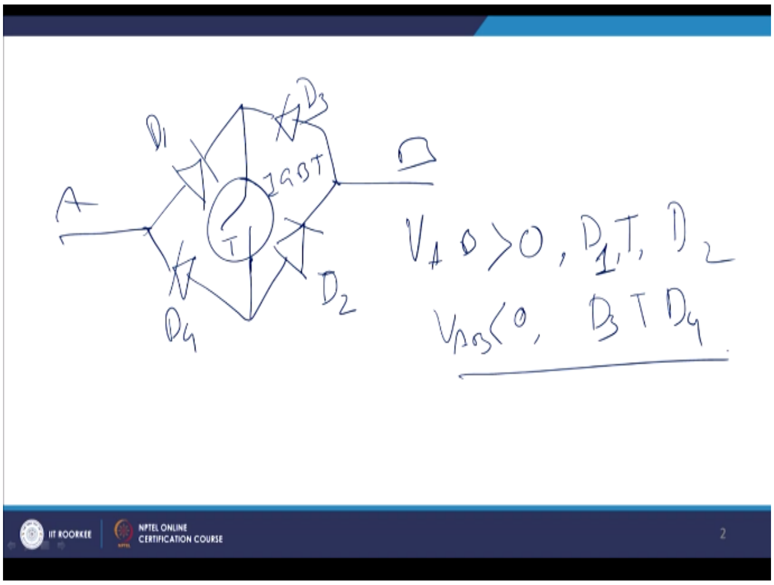


So if you wish to actually bidirectional switch with one controlling device so that can be this is IGBT or MOSFET then and this is the path let us say A and B. So this is the path and if you wish current to flow or the voltage to flow, so let us name it D1, let us say T because there is only one controlling devices and this one is D2 let us say D3 and D4. So if VAB is positive then through D1, T, D2 and if VAB is negative it is D3, T, D4.

This is the way basically current will flow and we can realize bidirectional switch. We require a bidirectional switch to work with the matrix converter. Now this is the configuration. Now accordingly you will generate. So ultimately you require 9 such switches and look there is a distinct advantage of this matrix converter over the cycloconverter, full bridge cycloconverter require 36 switches.

And here to constitute these switches, you can have one switch which we have shown but you will have a two diode and one switching switched off. So conduction losses will be more. Otherwise, you can realize with the two switches, so one switch and one drop will be there, one diode will be there, then number of switches required to be 18. So you have a choice. So for this reason, by considering the component count, matrix converter has been (()) (27:23) on the cycloconverter.

So now see that if you wish to generate, if you wish that actually it should be connected so that you get high voltage, so that you want that A phase to be connected, you will short it, similarly you can have a short but there is an issue like total time if it is T so Ta+Tb+Tc should be same will be equal to basically the switching time. So we shall see that what is how we can control the switching logic of the matrix converter in our next class.

And matrix converter is quite important in the sense that because we can eliminate the DC link and you no longer require a bulky thyristors with the commutation circuit to achieve the direct AC to AC conversion. So this is actually quite a modern concept and it is evolving and with the SIC devices like modern devices like silicon carbide devices, we can definitely have a higher rating matrix converter. Thank you for your attention. We shall continue with the matrix converter in our next classes.