Advance Power Electronics and Control
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Lecture – 29
MLI –II &ZSI

Welcome to our lecture on the advance power electronics and control. Today, we are going to discuss the MLI another multi-level inverter. And there after we shall discuss another important typology of the inverter that is called Z source inverter. Now in previous class I was actually discussing the diode clamped multi-level inverter please recall the circuit now actually we already have discussed this.

Disadvantage and advantage of the diode clamped multi-level inverter but just it is a small recap of the previous class that is advantages are actually the simplicity of the circuit and it can be actually write it down in this 3 or 4 advantages the large number of levels yields a small harmonic distortion and it is very common for all the multilevel inverter now it is not specific to the only this diode clamped multi-level inverter

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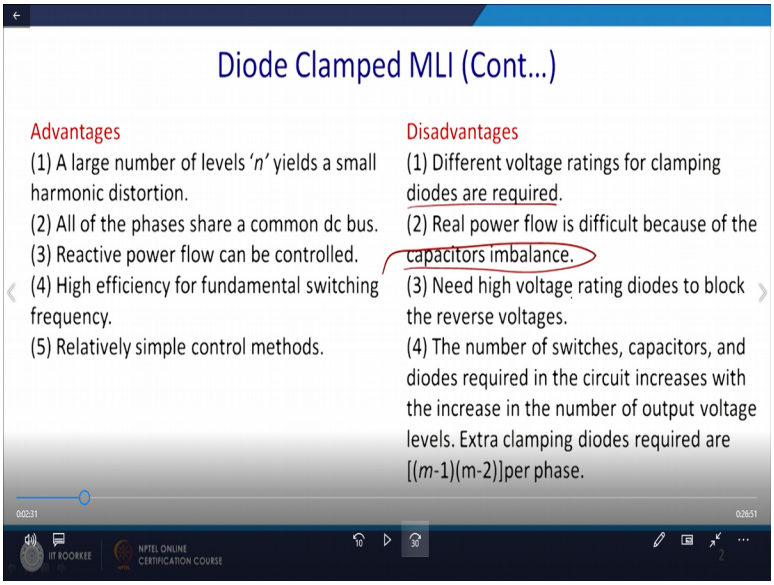

All the phases share that common dc bus. So this is a common for diode clamped multi-level inverter as we will as the capacitor clamped level inverter. Reactive power flow can be controlled high efficiency for the fundamental switching frequency and relative simple control methods.

Because you did not have to balance we will see the next topology there we required to actively balance the chargers across the capacitor.

Or you are required to maintain the deceivers voltage so these are the control complex controlled application will be there and it is absent and thus it is quite simple in operation. Disadvantages different voltage rating for clamping diodes are required. So different diode and block a different kind of voltages so for this reason we required to have a different rating of the diodes. The real power flow is difficult because of the capacitor unbalanced or imbalanced.

Need high voltage rating diodes to block the reverse voltages number of switches capacitor and the diode required in the circuit increases with the increase in the number of output voltages and levels. Extra clamping diodes are required and we have discussed actually that in the previous class also that is if m is the level and you require m-1=m-2 this will be the number of the diode required to construct that m level multi-level inverter.

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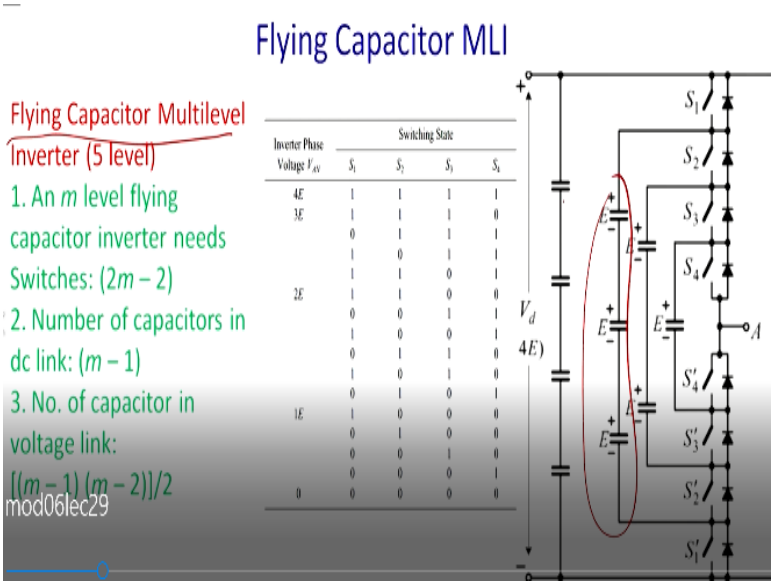

Now let us talk about another important topology that is called flying capacitor multilevel inverter. Here you know actually you will have a diode we have discussed a 5 level multilevel inverter for the diode clamp same it will be discussed here. So we have 4 level there after we got this there after we got this capacitor and gradually it will be actually increased like that and if you have a 6 level then there will be a 8 capacitor.

So then we actually it would be 2 to 3 power there after 2 to 3 power 1 thereafter it will be basically 3 thereafter 4 and 5 and so on. Depending on the level will have a number of capacitors and M level flying multilevel inverter needs switches that is all same that have this actually the diode clamp that is 2m-2 and number of capacitor is required is basically m-1 so this is actually the level so you required the 4 such capacitor.

And number of capacitor links in case of it will be required with basically m-1 *m-2 /2 . But there actually if you recall there is a capacitor that is m-1*m-2 so component count it will be less and the principle operation is quite simple we know that actually we please recall that we have a same switches S1 S2 S3 S4 but your logic will change a little bit and thereafter please recall in your diode clamped circuit it was basically S1 prime S2 prime S3 prime and so on.

But the sequence will be changing so if this S1 the top switch is S1 the bottom switch will be S1 prime then we are complementary logic so what happened accordingly you will generate a different name of voltage to this output voltage output terminal of the inverter if you wish that all let us assume that all the cells are basically holding the voltage E then you one that actually 4E voltage will appear across this terminal A.

Then all the upper switch is required to be on so S1 S2 S3 S4 should be on and all the lower switch will be OFF and you will get the voltage that is =4E and if you wish to have a 3E then S4 is going to be off . If S4 is going to be off then automatically you can understand that S4 prime is going to be on and thus what will happen you know this 3 voltages thereafter this capacitor will come into the picture and this switch be on.

And ultimately this voltage will be subtracted and you will get 3E. So if it is on at this point 4E will come you subtract -E you will get 3E. Similarly there will be another combinations you have a multiple combination to produce essentially this 3E voltage you can also OFF S1 so you can also OFF S1 and you can directly short these 3 switches this this this then also you have you can have the same voltage 3E.

So thus you can see that you know actually you can witch it off 0 0 0 S1 S3 S4 still you manage to get the 3E voltages. So you have a more possibility and thus you can reduce the switching losses and these are that quite remarkable advantages of it. But one of the disadvantage of it will come a little later that actually all the voltages which you assumed to be E it does not withstand because the charging either current is going from this point.

Or getting in depending on the actually the sequence volt current is lagging then it is a different issue with leading there will be a different issue if it was a co phrase then it is quite easy to operate it. Then similarly this 2E voltage also can be made with that various combination of 1 1 upper 2 switches it on and this load to switches can be actually on you can make this to lower switches on.

So that actually the from this 2 voltage switches you get 2E and all lots of combinations are there. Similarly 1E you can make any of the switches on and generate other switches=off and you generate the voltage of E and similarly you can make actually all the lower switches off and thus all the upper switch is on and the lower switch is off you will get a 0 voltage. So basic advantage of this plank capacitor is that.

Its in variant capability to generate state in various compositions. So you can generate these different voltages with a different switching frequency based on which actually switches was conducting and thus you can reduce the switching losses across the devices.

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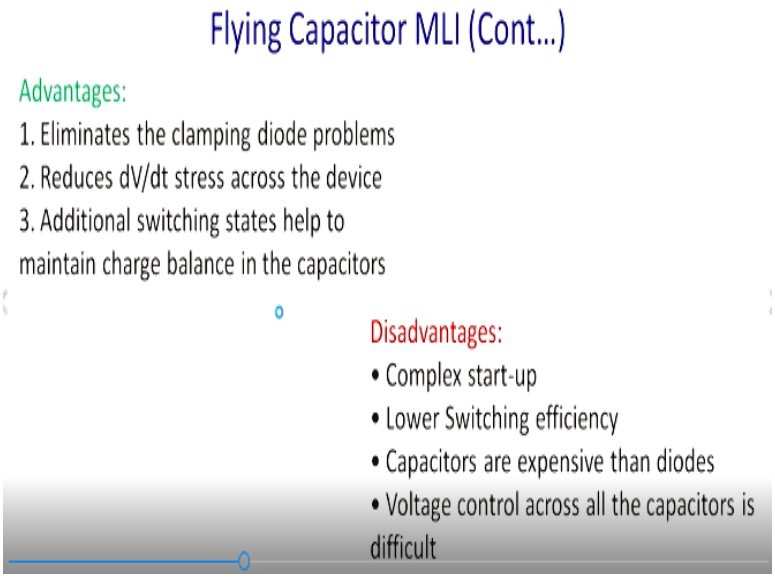

Now what are the advantage of it since already actually capacitor has been put in parallel to the system so it eliminates the clamping diodes and thus and also it added advantage of lower dV/dT stress across the switches. So dV/ dT stress across the devices will reduce and so we can choose a lower dV/dT devices. Additional switching states also help to maintain charge balance of the capacitor.

That is very important of what we have assumed that in all the capacitor being an equal voltage and not necessarily any moment at the point A either current is actually getting in to the system thus it is going to the capacitor the moment actually current pulling in to the charge and voltage will swell off and reverse will happen eventually when current is leaving point A.So, current will also what will happen.

Then voltage will swell up in opposite direction so for this to balance it we have a different kind of switching sequence so that you can maintain the voltage E as required but it require a complex control the close to operation. Disadvantage is that for this reason we require a complex start up and we have to ensure that all the capacitors has maintained the value E then only you can start with competition.

That is the first thing you will do while actually operating this flying capacitor multilevel inverter is that you ensure that all the capacitor has been charged to its desire value lowest

switching efficiency. So, because you know you have a multiple switching is require to ensure that to maintain the capacitor voltage reportage and the switching efficiency will be poured. Most of the cases you know capacitors are expensive and bulky and then the direct.

Are where you have a space constraints and you have a wet constraint like every annex and other applications we generally cannot and this is actually quite disadvantageous to use this capacitor flying capacitor multi level inverter voltage control across all the capacitor is difficult and you know at some point we are require to have a state space analysis of it and we have to find it out that whether all the capacitor voltage are observable of not.

That is one of the biggest challenge from the control point of view we have to make all the capacitor observable as well as the control level to control the voltage of the each of the capacitor then only function appropriately. Now let us switch over to another important multi level inverter till now what you have discussed we had only one bolt source but in this consider upgradation the cascaded h bridge multi level inverter require.

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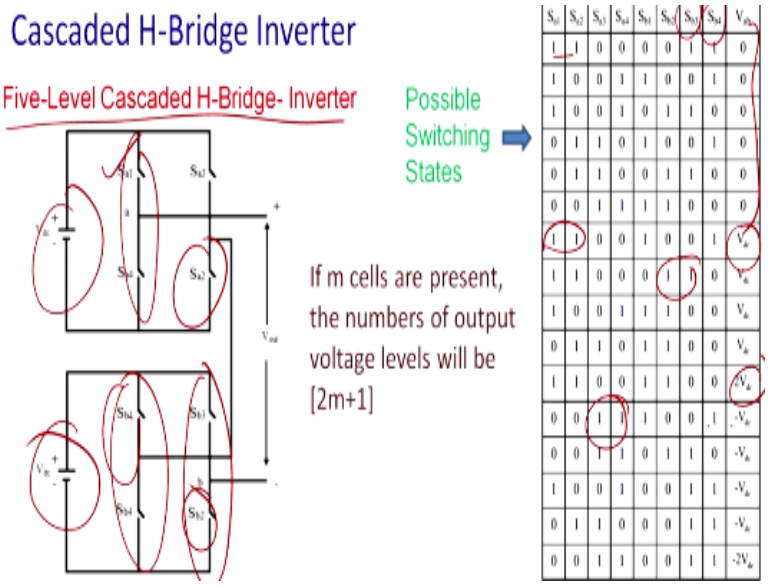

Basically a two independent voltage source if you do not choose the same source an independent voltage source then the residing voltage will shot and you will get 0 voltage and for this reason we have to ensure that these are different. Now these are getting applications for green field solar

power plant because you know this voltage sources can be actually the solar panel and they can be independent voltage source confirm there you can generate multi level inverter.

It will give you a better THD and size of the filter will be drastically reduced this is one of the reasons the advantages of this actually this multilevel inverter finds its pre- dominance application in solar inverter topologies so this is a 5 level cascade and H bridge inverter so this is basically BDC and you can see that how will generate 5 level multilevel cascade H bridge inverter is that.

Let us say that everything associated with this bridge is a and everything associated with bridge B is too. So S1 S2 are the switches when it is closed or on. And let us consider that also this SBS3 and SBS4 are closed. Then you will get a voltage actually 0 so you can actually make this voltage 0 with various combinations. That is a one of the biggest advantage of it so you can do so again you can reduce the switching losses.

So, a lot of permutation combinations are possible and as you can reduce that switching losses and ensure the more conduction same way if you wish that actually voltage V out required to be the VDC then also you can combination this one to be 1 1 and you can make SB1 and SB4 are short so you can get basically VDC. So, one voltage will come across it and similarly you can also shot any of the switch you can shot SB1 and SB4.

That mean this switch you can short also SB3 and SB4 you can short this switch also any of the switch you get short you get this voltage only so it is VDC same way you can short this voltages and let it operate. So, you get also VDC and if you wish to get 2VDC if there is only one way for E voltage so you have to operate this switch and this switch similarly from the lower half you have to operate this switch and this switch.

Thus you get total 2VDC similarly the reciprocal has to be done you have to operate actually this 2 switches shot there after this switches will give you minus vacancy in that way. Actually you can do this sequencing and generate different kind of voltage level as required for the cascade H bridge multi level inverter.

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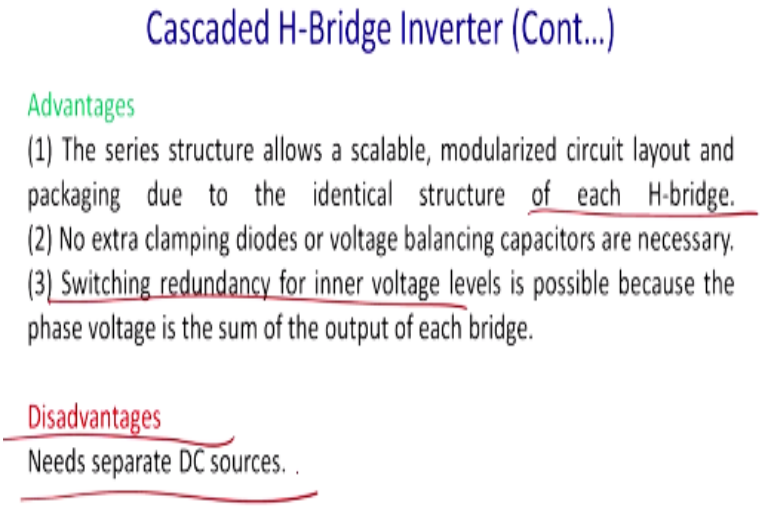

So, what are the advantage of it quite simple circuit you know and it is a modular in there is an then it has got least component count and these are modular in nature and you can add up to several level where any level it has to add the number of the h bridge and you get a huge number of multilevel inward. So, one aspect is a modular in nature second is a simplified operation there is no charge balancing component count in this list there is no diode.

And nowadays since you use the high efficiency all our control switch whoever pretty high efficiency the series structures allows us scalable modular modularized circuit layout and packing due to the identical structure of the eighth of each H bridge no extra clamping diode no voltage capacitors are necessarily. These are the main drawbacks of this multi level due to multilevel inverter.

We have discussed earlier that clamp at the flying capacitor switching redundancy for inner voltage level s is possible because of that phase voltage is the sum of the output voltage of each of the bridge so you can have multiple redundancies and you can generate and volt it is thus if there is any particular switch is damaged somehow so you can still generate a different voltage level as dessert main disadvantage is only one that is needs a separate DC voltage source.

That is the main disadvantage of this cascade multilevel inverter now let us compare these 3 topologies are multilevel inhibitor compare the study of the among these different multi level inverters topology.

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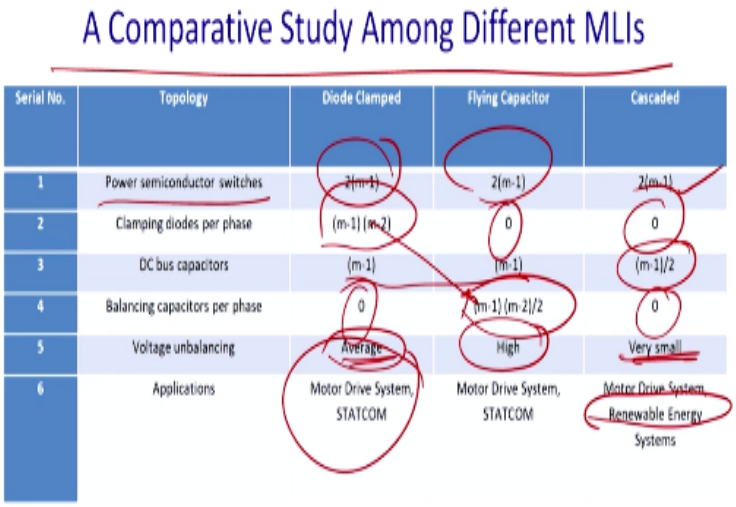

Power semiconductor switches that clamp that is you require a 2m - 1 number of switches. Flying capacitor also require a same kind of switches there is no more not much advantages on the basis of the switches and here also require the same number of switches. Clamping diode that you require huge clamping diode in case of that clamped multilevel inverter that is m-1 m-2 here you require a 0 flying capacitor and also in cascade multilevel inverter it is 0.

Bus capacitor it is same for both and m-1 and m-1 and here it is basically half of it balancing capacity at each phase. It does not have a balancing capacitor in the diode clamped multilevel inverter it has actually m-1* m-2/2 half of the diode will be the balancing So, this and this can compare and there is no balancing diode voltage and balance. There will be a voltage and balance because of the capacitor may actually changes voltages because of the current sink.

And the current discharge from the capacitor and thus you will have a little voltage and balance between those capacitors. Here it can be high if it is not actively maintained and for this reason we have to actively maintain the capacitor voltages and here it is very small and because it is

associated with a voltage source. We assume that the voltage source actually has a constant voltage and thus you do not have any almost no changes in the capacitor voltage.

And thus unbalance of the voltages courtiers applications. Application you find it is a motor drive system STATCOM many applications in the same thing motor drive STATCOM and apart from this motor drive and STATCOM we also find lots of applications for the cascade H bridge multilevel inverter in renewable energy mostly in solar because of that availability the DC sources.

Now let us come to another new typology it is invented FZ Peng and it has had a huge advantages let us little bit brief state that the background of it most of the inverter we have a delink voltage and we actually operate this inverter in to this mostly this a predominant inverters and there operate it in many regions of the PWM inverter.

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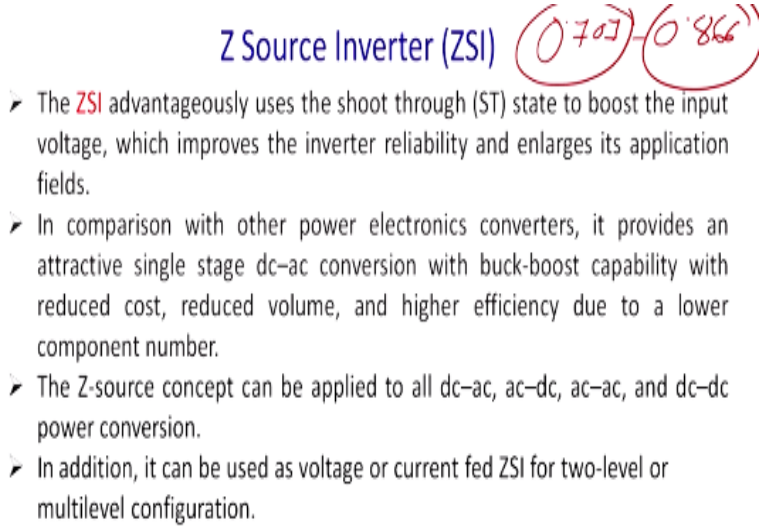

And thus linear region of the PWM inverter is actually 0.707 thereafter drooping characteristic starts and most of the cases if you have a state perspective modulation and all those things you can get maximum modulation indexes in an amount of 0.866 but what does happen to know is let us say most of their drives what does it do actually it will rectify the voltages and since these are part of that and that will give you at least to hold drop.

Because to that at least comes into the picture and depending on the mode of operation to folder hold on and thereafter and that is a dizzy link voltage you will be getting the average value and once this average value you will get it and then again you multiply with 0.66 you will see that 60 will they will be a 60% amplitude of the voltage. If your line voltage which you are feeding to the input of the inverter for followed by a for 10 converter or rectifier is a 400 volt.

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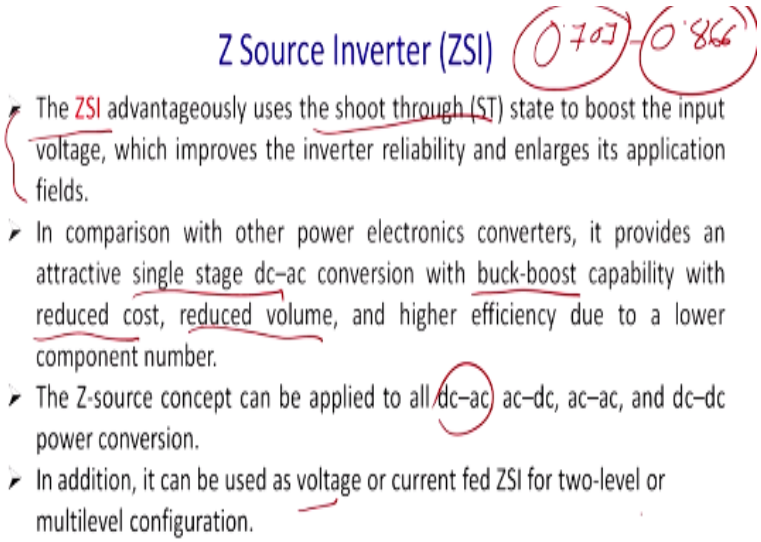

Then by this process actually you have 3 levels the three power supply you have a diode rectifier and assume and you will get an average voltage here. This average voltage you know that actually root 3/Pi and basically thereafter you have an inverter and its modulation index you will sacrifice basically because it is a sity circuit and efficiency of the converter very simple when we look at it.

It is around 80% or 0.8 if so happens since the series circuit so current will prevail what happen there will be average voltage and you have a calculation voltage for ideal cases and since if current is very high drop across this devices will be more and then you will find that loss also will be more and thus this voltage will be actually rectifier to around 600 volt. And if you same voltage if you generate and you will get you will see that.

If you are 400 volt line to line voltages here you will get actually little about 300 volt yes because your drizzling voltage is around 600 volt root 3 root 3 VM/Pi. You can calculate and you

will get the results so but your motor rating is actually your motor rating is 400 volt and then again you have to boost this voltages are some intermediate states has to be employed or if you are managing with a device control.

So, actually you have to reduce to the 40 hertz operation instead of the 50 hertz operation you cannot go to that maximum power rating of the machine. So, to overcome this problem precise objecting discovered new topology which gives you the desire of the booster claim voltages so let us switch over to the other slides. Now let us take to understand the advantages of that set source inverter.So, the advantage of the Z source inverter uses the shoot through state.

To boost that input voltages which improves the inverter reliability and enlarges applications and fields us shall see in subsequent stages in comparison with other power electronics converter. It provides an attractive single stage DC to AC conversion with boost buck capability of the buck boost capabilities with reduced cost reduced volume and higher efficiency due to the lower component our numbers.

Z source in water z course in concept can be applied to various kind of topologies that is dc to ac to dc and ac to ac and dc to dc power conversion. So, it is that versatile phenomena this is their source in addition is Z source. Can be used as a voltage or current to fed ZSI 2 level are the multilevel configuration. So, there are many advantages of the Z source multilevel inverter so first of all we will see that by how it will introduce to suit to stage.

And boost up the voltage and if you want to buck up the bug the voltage you can play an around the PWM.PWM will reduce the line voltage available from Z source inverter since we are talking about the inverter we will restrict our discussion to dc to ac applications with a short of time. Also, we will be restricting our discussions mainly in DC to AC inverter applications so apart from that it can be applied in our various configurations.

And in later we shall discuss with the matrix converter and we have briefly discussed the initial stages and matrix converter also actually is Z source inverter can be incorporated and while incorporating the z source inverter what you will find that actually also possible to boost that

drizzling voltage at the output stage. Essentially actually a matrix converter is more fundamental transformer but not only the voltages.

But also the frequency can be varied with the input and the output so thus we conclude today discussions based on the Z source inverter. We shall continue our discussions with Z source inverter in our next class and we shall see that different advantage of this typology. And there is a different variant of the Z source. There is a new topic has been popped in after inventories a invention of this Z source inverter process check in.

Thank you for your attention and I am looking forward to this discussion of the Z source inverter in our next class. Thank you.