Flexible AC Transmission Systems (FACTS) Devices

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Lecture – 31
UPQC Introduction and Classification

Welcome to our FACTS Devices lectures. We shall discuss today new topic that is Flexible AC Transmission System, for the sub topic will be essentially the UPQC and its introduction and classification.

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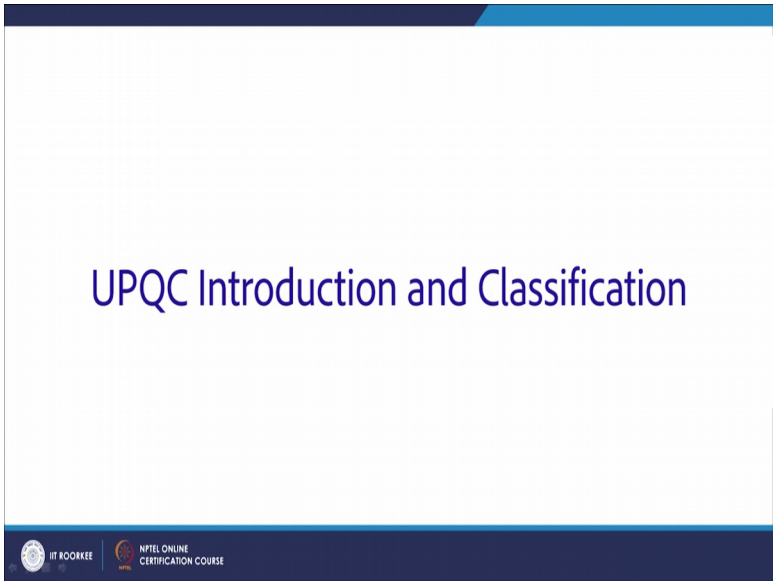

Abbreviations of the UPQC, stands Unified Power Quality Conditional. There will be another term will also discuss that is UPFC. So, let us see that what are the features of the UPQC?

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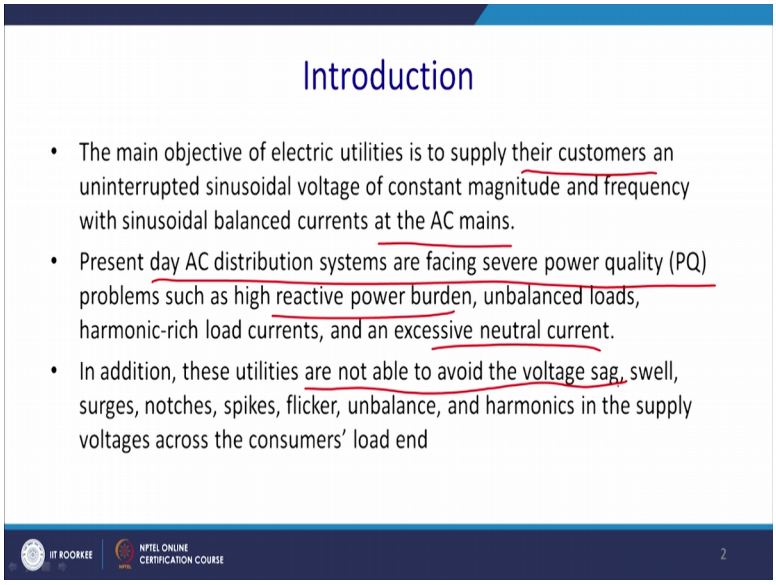

So, main objective of this electric utilities is to supply their customer an uninterrupted sinusoidal voltage at constant magnitude and the frequency with sinusoidal balanced current at the AC mains. So, we require the quality power to be available to the customer. So, that is the responsibility of the power utility companies. Unfortunately the due to this disturbance in the transmission line the sag swell and the harmonic contaminations due to the fact devices you do not get the customer does not get the desire power quality.

So, one of the solution to this actually give you given to this customer by this UPQC. At present the AC distribution system are facing several power quality or PQ problems such as high reactive burden, unbalanced loads, harmonic-rich load currents, and an excessive neutral currents; all are the actually dominating features that decreases the power quality to the customers.

In addition, this utilities are not able to avoid voltage sag, swell, surges, notches, flickers, spikes, unbalanced and harmonic in the supply of the voltage across the consumer to the load end. And what happens you know, this kind of phenomena or occurrence will may destroy our sensitive devices.

I am a customer. So, I am a talking in a customer point of view. It may destroy the household utilities like you know there will be a flash furnace in the campus and thus will get a poor power factor and thus, my utility get damaged and destroyed. So, it is not acceptable for the customer and for the session now days actually it is a responsibility of

this of this power quality people to deliver a clean power to me and also finalize for whom that power quality get distorted.

So, for the session, I this power utility company either finalizes the people who actually pollutes this power quality and fix it up with the method which will be discussing in future or they will ask that power quality that the pollutant consumer to actually clean up the mess; either operator is possible and both the cases ultimately we have a 1 pantia that is the UPQC.

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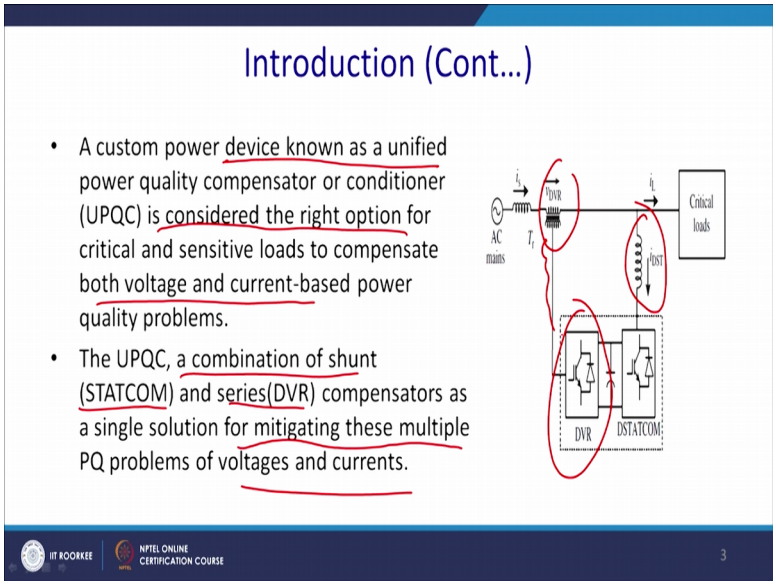

The customer power device is known as the customer power device known as unified power quality compensator or condenser; we shall use synonymously is considered as a right option for critical and the sensitive loads to compensate both voltage current based power quality problem.

See that you know ultimately this is basically a series DVR which is essentially series compensator and we also have a DSTATCOM that will basically compensate the current that is the shunt compensation. So, it is a combinations of the series and shunt. So, advantage of it. So, thus it in here it is the advantage of citizens and both.

The UPQC is a combination of the shunt STATCOM and the series DVR compensator as a single solution for mitigation of this multiple power quality problems in voltage and current.

Generally, you have a critical node that require to be supply and the clean power; you always supply the clean power irrespective of the load and the source disturbance.

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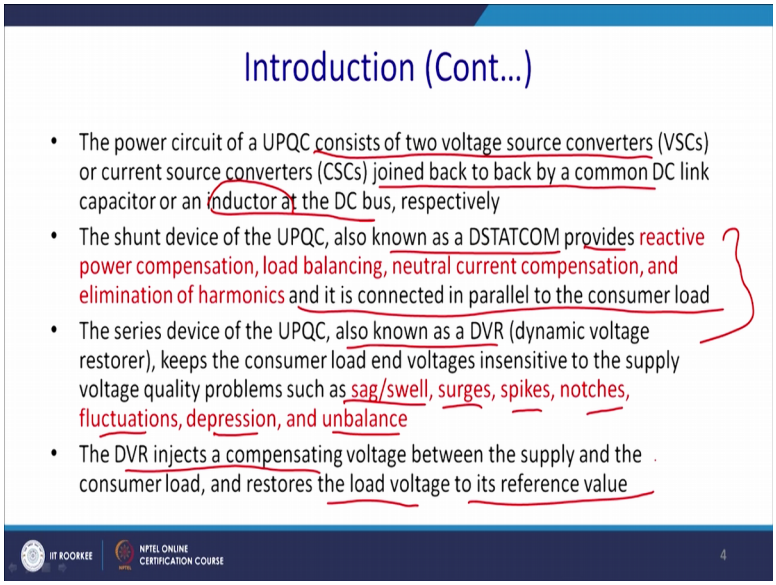

The power circuits of the UPQC, what we have discussed earlier; let us formally describe it. Consists of the two voltage source converter or a current source converter, but nowadays voltage source converter is preferred. Because size of the DC link will be lower we require a huge size of inductor, joined back to back by a common DC link capacitor or an inductor at the DC bus respectively.

We generally, do not connect inductor; the size of the inductor will be very high , but it is a possible solution. Shunt device of the UPQC is known as the DSTATCOM which we have discussed in while discussing the STATCOM total design and procedure has been discussed; provides reactive compensation, load balancing, neutral composition for three-phase 4-wire system and elimination of organics that is we shall that the shunt active power filter.

And it is connected in parallel to the consumer load. So, it is the shunt composition; shunt composition will do this job and series compensation with essentially DVR; series devices of UPQC also known as DVR, Dynamic Voltage Restorer keeps the consumer load and the voltages insensitive to the supply voltage quality problem such as sag, surges, spikes, notches, flocculation, depressions and unbalance.

So, these are the problem that will be mitigated by the series component of the UPQC. DVR injects a compensating voltage between the supply and the consumer load and restores the load voltage to it is inter phase level.

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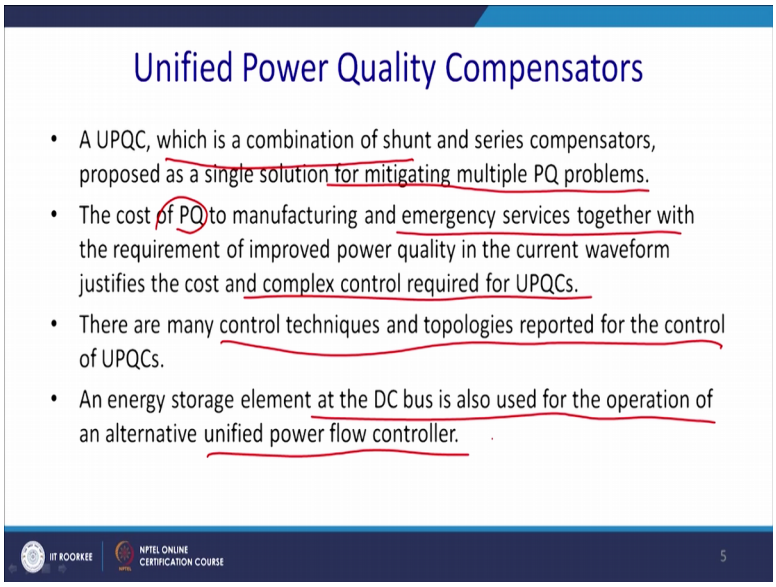

A UPQC essentially which is a combination of the shunt and the series compensator proposed a single solution for mitigating the multiple PQ problems. We have seen the problem arises from the current part. We have seal the current problem arises from the voltage part, both of it can mitigate.

The cost of power quality to manufacturing and the emergency services together with requirement of improved power quality in the current waveform justifies the cost and the complex control require for UPQC's. And however, day by day cost of this devices coming down and for the session UPQC is has got huge potential in present as well as the future; not only the cost of the devices.

But also the we have a very fast processes and these two combinations enables us to effective UPQC solutions. There are many control technique and the topology reported to the control the UPQC's; we shall take few important UPQC's. The energy storage element at the DC bus also used for the operations of the operation is an alternate of the unified power flow condition and then real power exchange is also possible and that can be used to reduce the pig demand capacity which is also a huge scope of research as well as utilization.

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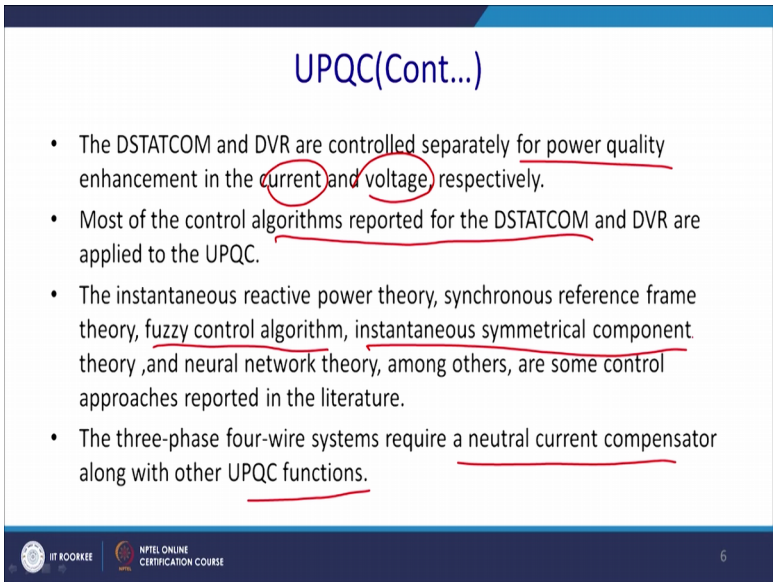

DSTATCOM and DVR are controlled separately for power quality enhancement for current and voltage respectively. DSTATCOM is for current harmonic mitigations and other current dated issues and voltage slickers, voltage harmonics are or voltage sags or swell other power of the DVR.

Most of the control algorithm reported for a DSTATCOM and DVR are applied for the UPQC. Essentially you put separate processing unit for as well as DSTATCOM and DVR; it should work, but there is a little change of the control circuit when you are using in a unified mode.

So, instantaneous reactive power theory propose by a Akagi Et Al and all those fellows in 1984. Synchronous reference frame proposed by Deepam Deepam Shivaji Bhatachrya et al and there after the many different kind of soft computing base reference generation technique like instantaneous algorithm, instant fuzzy logic control algorithm, instantaneous symmetric algorithm component theory.

It is Akagi and Nabae both were proposed that and the neutral network theory are an there is a wave plate base theory there is so many there is also time domain as well as the frequency domain. These all are discussed; please refer to our discursion in DVR orx some control approaches reporting in the literatures.

The three-phase four-wire systems require a neutral current compensator along with the other UPQC functions. So, if it is a three-phase three-wire system you have only possible sequence in the negative sequence, zero sequence is absent. .

So, in case of three-phase four-wire system, then zero sequence or the natural current has to be also compensated. So, further session algorithm readily changes for the session you got instantaneous symmetrical component theory is one at fits well in case of three-phase four-wire systems.

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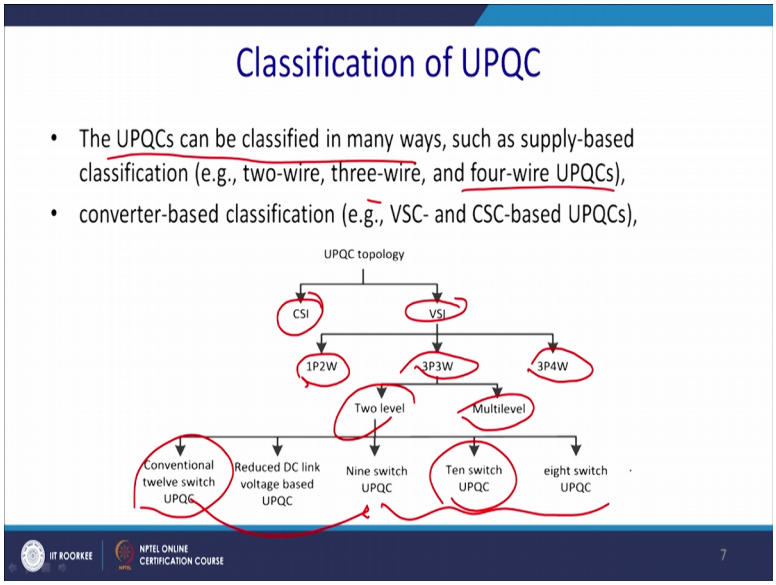

So, let us classify the UPQC. Please note that UPQC actually put into the distribution level. Transmission level discursions will be done after few classes, once we discuss UPQC thoroughly. The UPQC can classified in many based on the supply. For example, two-wire, it was single phase. It may be three-phase three-wire.

It may be four-wire kind of the UPQC and also converted base UPQC that is voltage control or the current control most of them are voltage control because of the size of the inductor. So, topology wise UPQC may be two types; current control Current Source Inverter and the Voltage Source Inverter and mostly we have a voltage source inverter.

It maybe actually one-phase two-wires system that is for single phase system; that is for the three-phase three-wire system for the interconnected line; this is mostly in a little higher distribution line and this is mainly the distribution line three-phase four-wire

system fitting single first and mostly in case of the three-phase three-wire system because voltage level has to be little higher. So, you will have two level as well as the multi level. In case of the two level, we can have a many combinations. Of course, it can be extended to multi level inverter it is not that is possible, but number of switch will be huge.

The Conventional twelve switch topology that is for the two level; so, reduce DC link voltage base UPQC, we shall see this topologies and there after instead of the twelve switch we can have a Nine switch topology that combinations of there is a some switch has been shared between series and shunt.

So, that is the reported topology and Ten switch topology also same thing these are the reduce switch topology. Ultimately it shares the power of the current as a voltage. So, it is a one leg or something is common for both. So, thus it reduces the number of switches. Now, let us put it in a formal way.

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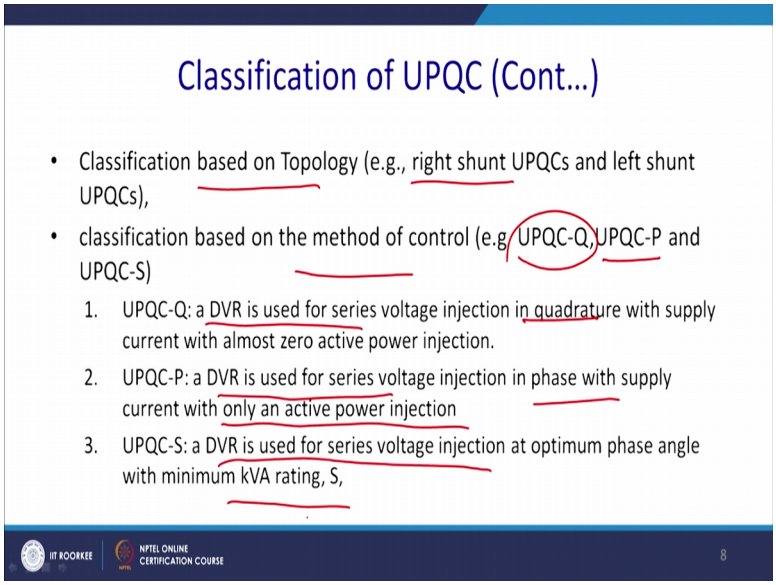

Classification based topology that is right shunt and the left is that is whether it is right shunt or the left shunt; please go back to the figure than only you will appreciate it. So, see that here it is a right shunt topology. We can put this, this side; then we say it the left shunt topology. So, we can have both. So, that is right shunt and the left shunt UPQC.

Classification based on method of control, you may have reactive power injection then we say that UPQC-Q; we may have UPQC-P that is in phase component and UPQC-S that is apparent power based UPQC. UPQC-Q a DVR is used in series voltage injection in quadrature with the supply current with almost zero active power injection. Then you said the say that it does not have any reactive power real power handling capability.

Same way, if it is UPQC-P a DVR used in series injection in phase injection in phase with supply current only the active power injection; it will inject only the active power and you may have a S that is the combination of it DVR is used for the series injection of the optimal phase angle to increase the effective power handling capability of the line.

And phase angle with maximum kVA of S. So, these are the 3 mode of operations of UPQC.

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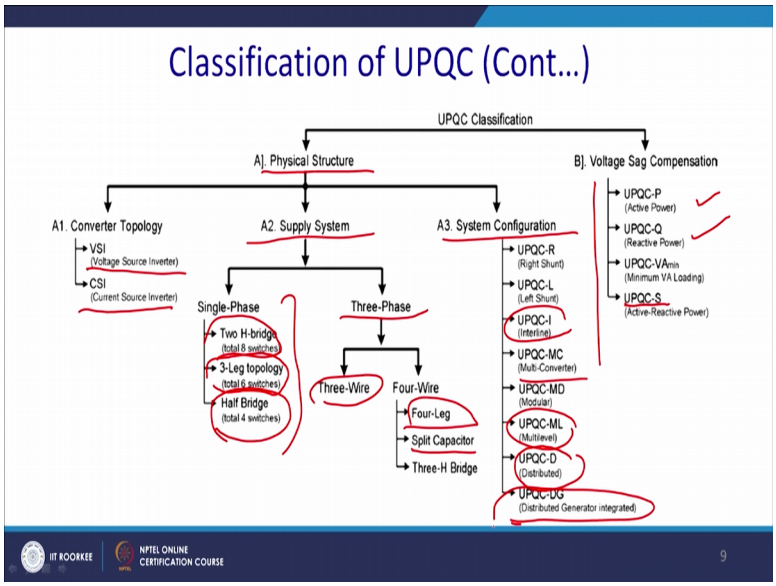

And this is the overall classification UPQC. Students are requested to actually keep this slide in their mind. So, one is Physical Structures; another is Voltage Sag Compensation. Based classification is based on the physical structure as well as the voltage sag combinations. If it is based on the physical voltage sag combinations that is UPQC-P, it will inject on a real power; UPQC-Q that only inject in a reactive power voltage inject in a quadrature to the quadrature to the supply voltage.

So, UPQC-VA minimum it stands for the minimum VA loading. So, rating of the switches will be reduced and UPQC-S, where actually apparent power to lags an apparent power. The apparent power rating is constant; it can compensate same amount of the it can go to the kVA rating; it is when fixed.

Similarly, based on the physical structure, we have a converted topology that is the first classification that is based on the voltage source inverter or current source inverter. We generally use voltage source inverter we have said repeatedly. Similarly, based on the supply system, we may have a single phase that is not terrifically use and we have three phase system and for the single phase, we try to reduce the cost and that is we have a reduced cost topology are very popular

So, further session and rating of thus obvious devices as also low compare to the three phase accurating and there for this session we have a total 8 switch normal topology and their might be a 3-Leg 6 switches topology where instead of the 4-Leg, 1-Leg is shared by shunt an series both and the half bridge topology that consist of the 4 switches. Each has its own advantage and disadvantages.

Generally, the conduction ratio of this reduce switches is more and there is no clear cut distinction between the shunt part in the series part and half switch actually switch rating is going to be double. But it is switch well in case of the single phase where rating of the supplied voltage rating is quite low.

Same way three-phase, you may have a three-wire or four-wire. Three-wire a again we may have a normal 6 normal (Refer Time: 19:16) topology or the reduced topology and in 4-leg we have few more option; that this 4-leg can be connected, we can put a 4-leg with the shunt part; we can put them middle point of the capacitor, that is the spilt capacitor.

Again, we can have a Three-H Bridge topology also. And based on the system configuration, UPQC-R that is right shunt; shunt is connected right shunt of a of the low, the closer to the load; left shunt, shunt is connected closer to the source. It can be interline that will discussed in future classes and UPQC-MC that stands for the multi converter it can cascaded 1 and it can be UPQC-MD that can be modular 1 to increase the rating of the devices and it can be ML that is stand for the multi level because to support the high voltage, the rating of this single switch may not be possible.

So, required to ever cascade switches and mostly we were discussing UPQC-D that is it used for the distributed generation. And for the distributed network or distribution network and UPQC-DG and that is very famous now a day's the distributed generated integrated.

So, that is actually may be the solar panel incorporated with it, that kind of thing.

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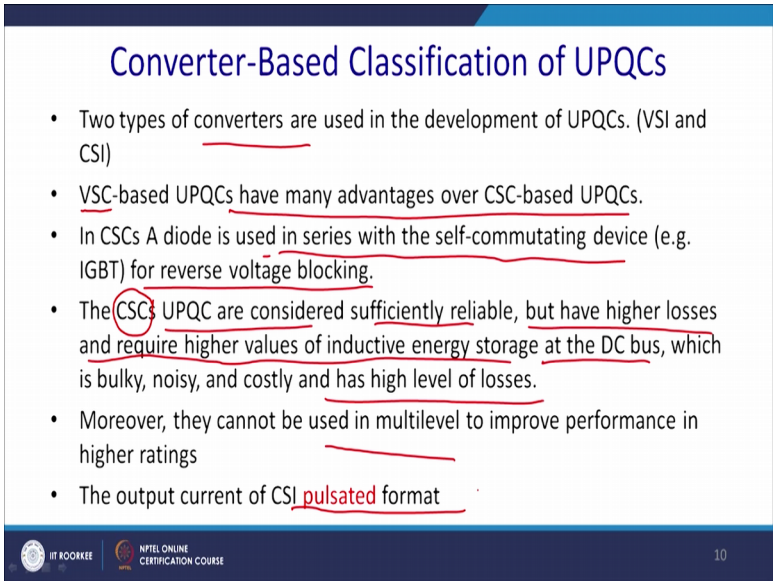

So, based on this classification, let us understand how UPQC works and which one you will choose and why those plus classifications has been put in. Two types of converter are used that I have told repeatedly used in development of UPQC. One is VSI; another is CSI.

But CSI is actually we do not use very much; VSI is preferred to. VSC, Volt Source Converter based on UPQC has many advantages over current source converter UPQC. In current source a diode is used in series with the self commutating commuting device IGBT for reverse blocking.

For this is what happened the current source converter UPQC has consider sufficiently reliable, but since these 2 switches comes into the parallel switching losses will be more. But have a higher losses and required higher values of the inductive energy storage. So, size of the inductive we will be very high since diode on the IGBT comes in series, their losses will add on and consider the rate is speeding a 1000 amperier of current. So, both

the top, we will add up and that gives you a basically lossy entity; storage at the DC bus which is bulky, noisy because of that you know switching may be actually below or audible range that is 20 to 20 kilo hertz. So, that is generally thousand hertz.

So, a cranky noisy sound will come out from this actually the inductor and has high level of losses. So, due to this disadvantages we generally do not use current source converter. Moreover, it cannot be used in the multi level to improve the performance of the higher rating and output current CSI is pulsated format.

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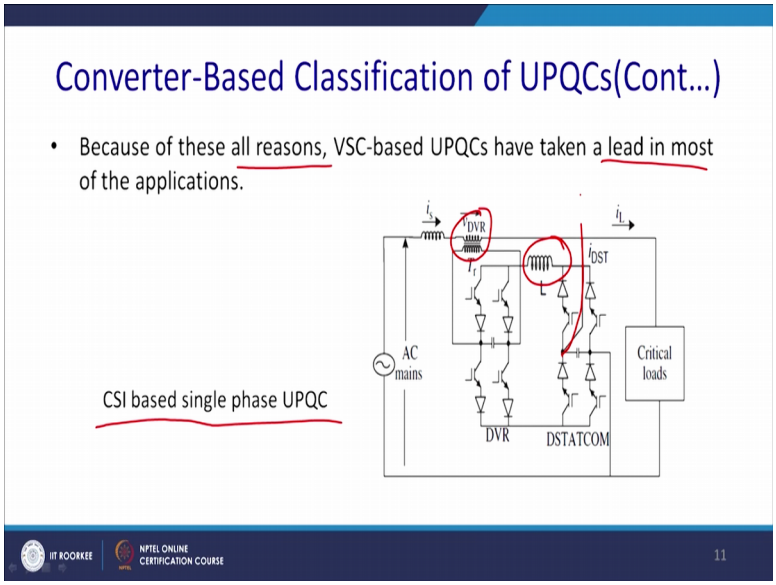

So, these are the actually disadvantage of this current source inverter. But anyway it is possible to work on it. So, this is a single phase CSI current source inverter base UPQC. Based on the all the results the VSC based UPQC have taken lead almost in all the applications.

But we have showing you an application. This is the inductor; size of the inductor is very high in the range of the hundreds of henry sometime and thus, you know this is the DVR and this is the portion actually, it compensate that is DSTATCOM and this is the critical note since wide of the inductor is quite heavy since comes with the copper and iron it also bulky. But this is may be the structures of the CS single phase CSI based UPQC. We shall continue with the topology base classification of UPQC.

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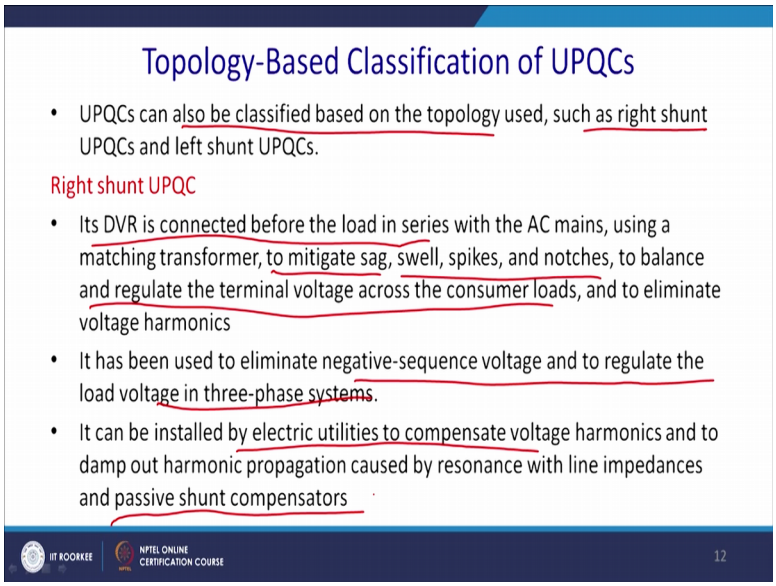

UPQC can also be classified based on the topology such as right shunt and the left shunt. The connective sources shunt is connected to a load or to also source. So, in case of the right shunt topology which is quite familiar. DVR is connected before the load in series with the AC mains using a matching transformer to mitigate sag, swell and the notches. .

So, that voltage part get cleared up by DVR. To balance that balance and regulate the terminal voltage across the consumer load and to eliminate voltage harmonics; so, whatever actually the power quality issue related to the voltage; that means, it clean out by the DVR. It has been used to eliminate the negative sequence voltage and to regulate the load voltage of the three-phase system. Moreover, it can be installed by the electric utilities to compensate the voltage harmonic to damp out the harmonic propagation caused by resonance with the line indeed, the resonance with the line impedances and the passive shunt compensator.

So, this is the advantage of the right shunt UPQC and this is quite preferred because voltage mess has been already cleanout and when damping also action can be done by the shunt active power filter. So, thus this solution is preferred. So, for this reason it can model it like this.

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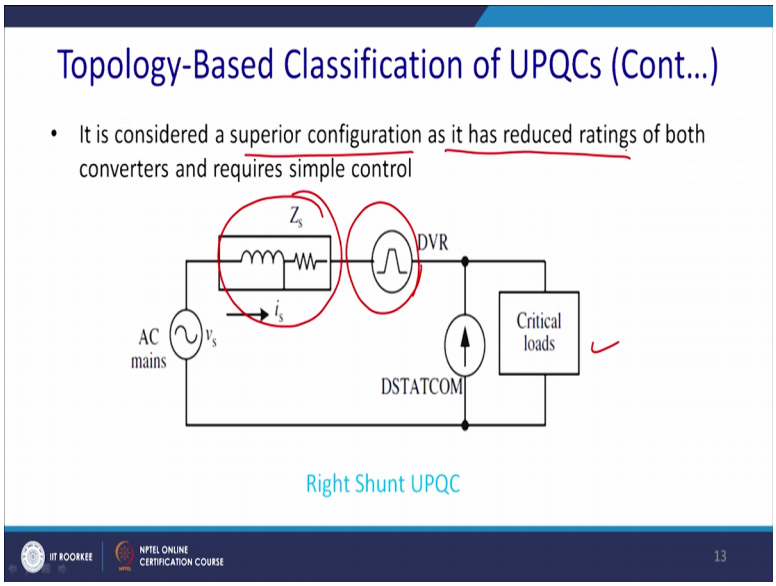

So, this is actually the source impedance and this is the DVR. Ultimately it will inject and cleanout and this is the DSTATCOM and critical load will always see that another very clean power is connected across it.

So, it is considered the superior configuration as it reduce the rating of both converter and the control is quite simple because you have already mitigated the voltage and thus, you are getting an clean voltage and DSTATCOM has to control only the issues related to the current.

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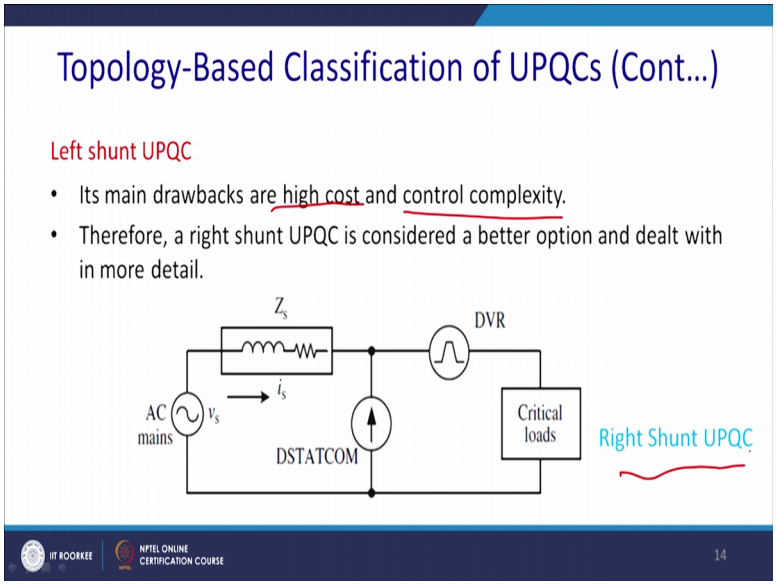

And same way we can have a left shunt. So, this is the combination the main drawback of this is actually high cost and the control complexity. Therefore, the right shunt UPQC is considered the better option to deal with. So, this is the actually the right shunt UPQC.

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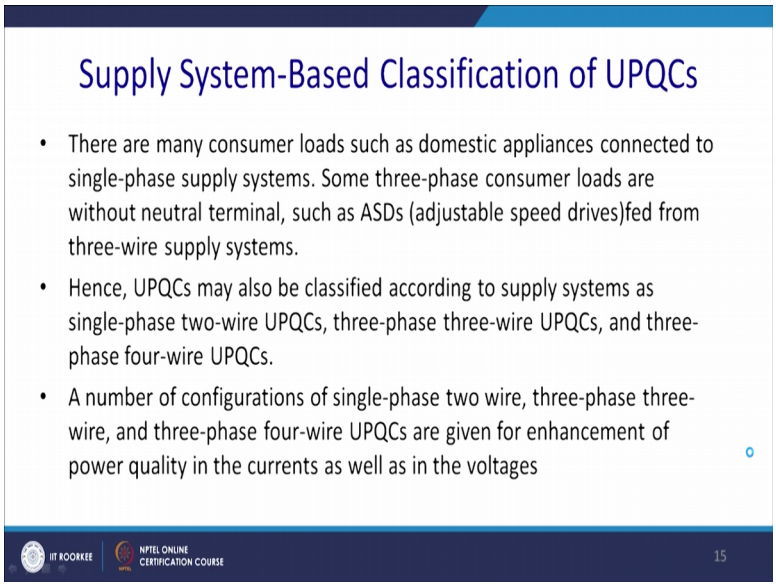

We shall continue our discussion that is on supply system base UPQC's in our next class. So, that is actually we shall see that what kind of supply is there and based on that the combination, we can classified UPQC.

Thank you for your kind attention. We shall start out a next class with Supply system based UPQC.

Thank you.