Flexible AC Transmission Systems (FACTS) Devices
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Lecture – 32
UPQC Classification - 1

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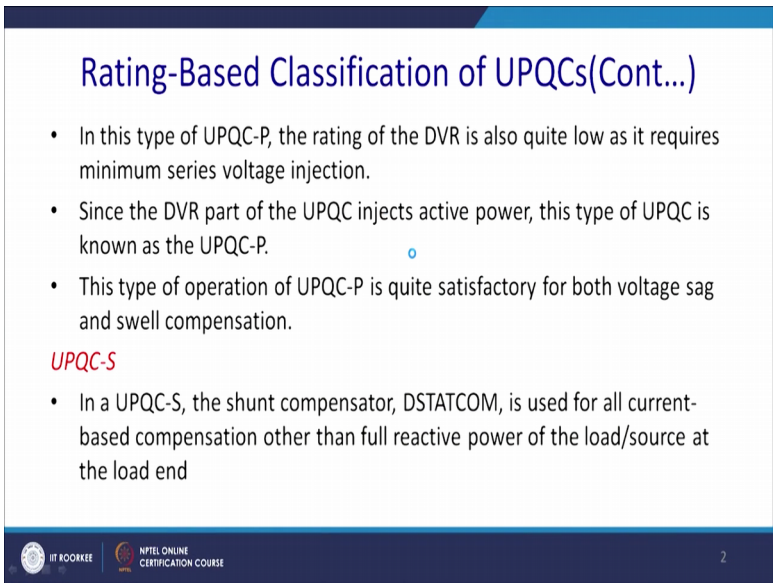

Welcome to our NPTEL lectures on Flexible AC Transmission Systems FACTS Devices. Today we are will continue to our discussions with UPQC, this will be our second lecture on the UPQC based on the UPQC classification. So where we have left, let us continue with that so, we our discussing a different kind of topology, different kind of CSI or VSI.

Now, and also the shunt type compensation is connected in the right hand on the left hand. Then you can also considered the a classification on the UPQC, based on the rating that is rating base classification of the UPQC. The in this type the UPQC-P that is actually, which injects the voltage in phase. The rating of the DVR is quite low, because you know actually it does not if it does not have a power story's element, generally the element will be this rating will be quiet low. And it requires the minimums series injection, so only it required to compensate the sags.

Since DVR part of the UPQC active power, this topic of UPQC-S known as that UPQC-P that is relate to the real power, and mostly it will mitigate the sag. The this type of operation of the UPQC-P is quite satisfactorily operation what does it do you know, both

sags and swell compensation. In case of the swell, it will take out extra, it will inject the voltage 180 degree phase opposition, thus voltage swelling will come down.

And another is UPQC-S that is on the apparent power. UPQC-S, the shunt compensator, STATCOM or DSTATCOM is used for current based compensations, other then the full reactive power of the load, or the source end. So, what it will do you know, it is used for the current base compensation. It will try to actually mitigate mostly the different kind of harmonics, if it is present that also, and the reactive power, as well as a negative sequence component of the current. So, the full reactive power, both load and the source end.

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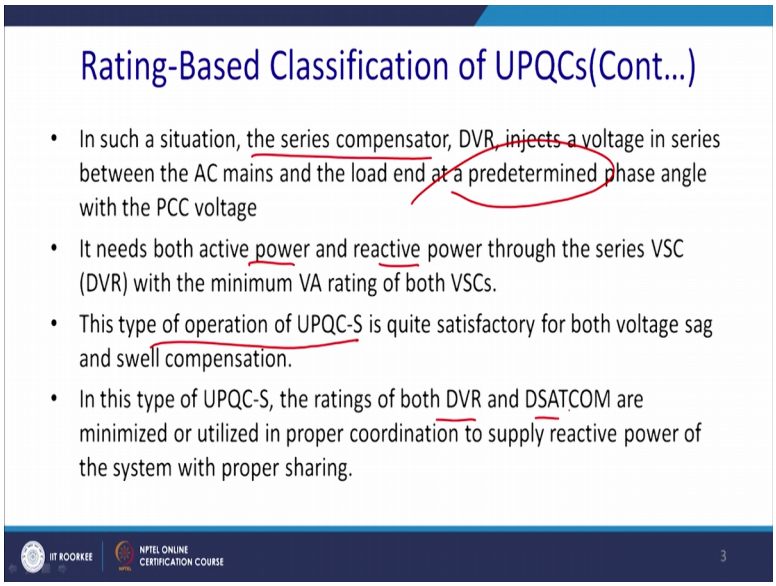

Then what happened, in such situation, the series compensator, DVR, inject voltage in series between the AC mains and the load end that is predetermined by the phase angle of the PCC. And made may not be actually the quadrature, or the phase injection, it may be a different angle to meet that demand.

It need both active and the reactive power, though the voltage source converter of the DVR with a minimum rating both minimum VA ratting and the VSCs. So, for this session, what does it do, it will be basically optimize the rating of the actually series compensator. And this type of operation of the Q s is quite satisfactory for both sag and swell elimination, it can also do the both, apart from that it can also DSTATCOM will eliminate the current part of it.

In this type of QS, the rating of both DVR and DSTATCOM are minimized, or utilized in a proper condition to supply the reactive power of the system for the purpose sharing. What does it actually we can understand it, it is basically the optimal solution Q s. What happened you got a DSTATCOM, ultimately the delta angle changes, because of the injection, because you have a shunt injection thus you are injecting IC. So, thus a since your injecting IC, so angle between the voltage and current also get changed.

So, for the session, you know when the sags and swell occurs, instead of actually injecting in phase of quadrature, it will actually calculate the angle, it required to inject, an injecting that angle. In the tutorial classes all assignment, we shall consider this actually this kind of ASTATCOM, and we can have to find it out that their angle, so that we can inject that voltage by the DVR.

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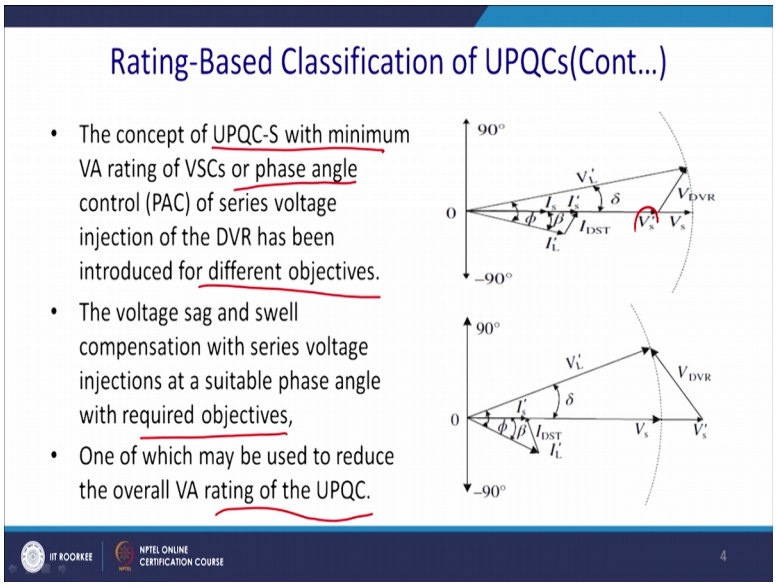

Please try to understand for this phasor diagram with this concept; the concept of UPQS with the minimum VA rating. It is very much required, because it will reduce the power rating of the switches of the voltage source converter, or the phase angle control PAC of the series voltage injection of the DVR has been introduced for the different objectives.

What happen you know, let us read out the nomenclature of fit. The voltage sag and swell compensation in series voltage injection at a suitable phase angle with required objectives, this is the objective. One of which may be used to reduce the VA rating of the UPQC, let us understand it.

So, what happen, you know actually this was uncompensated V s, and this was the actual load current. And you inject this voltage in phase that is not in not in phase of quadrature in an optimal angle, so that you know actually V L become this. And ultimately, the new highest become this, and you have a optimal connection. Same way here, you have this V S. Now, what you do basically you inject this DVR, and thus you know your V L become this load voltage. And ultimately, you can make this current sinusoidally.

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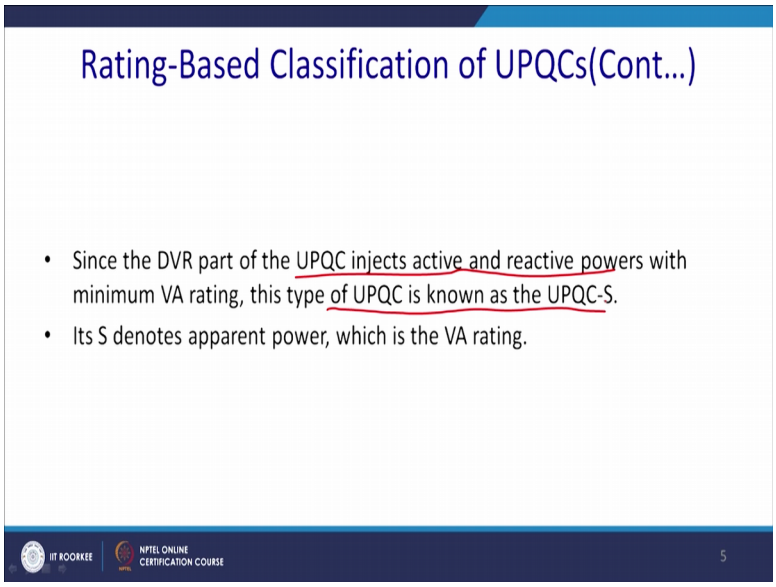

So, let us understand it. Since DVR part of the UPQC inject active and the reactive power with minimum VA rating, for this is in this type of UPQC is known as the UPQC-S and where S denotes the apparent power, which is its VA rating.

Why it is optimal, because you understand it, you know actually you can inject in phase, or the quadrature, but then also is optimal correction of the delta was not possible. You want that angle between them required to be delta, and ultimately, in this case you know in this case what happened, this was a V S, and this was I L, and this is coming from the DSTATCOM, and that will make this actually current in phase with the V S.

And so, you required to compensate some portion of the sag, so that actually V L has to be reduced. So, you inject this voltage ultimately this and this, and ultimately new voltage become V S prime that is your rated voltage, and thus you get a compensation both line in phase, the new S, new I S, and V S are in at phase. So, this operation is optimal operation of the UPQC, and where rating of this actually the UPQC is list.

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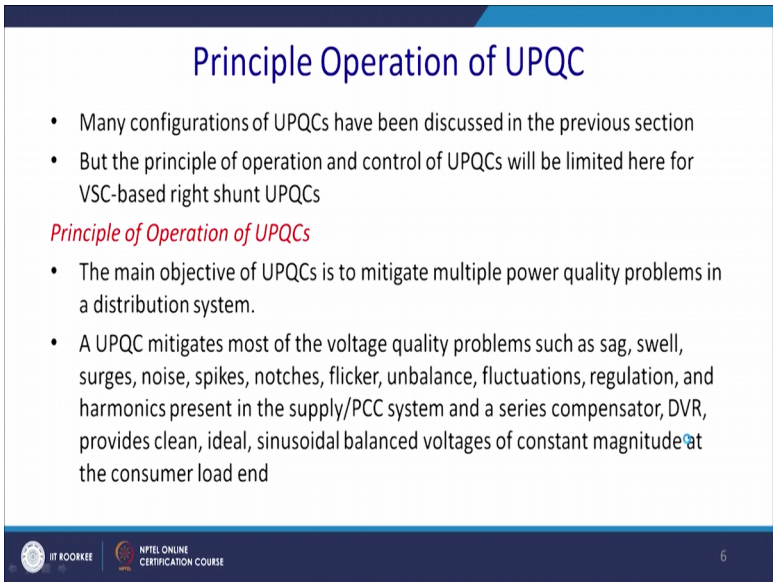

Now, let us now discuss about the principle of the operation of the UPQC. So, as we have seen that there is a many topologies, many way of classifying it, many configurations for the, so how can you generalize its operation, of course it is a power quality, it will mitigate the power quality problem, but how it can we generalized this actually principle operation. So, has told you that many configuration of the UPQC has been discussed in previous classes. But the principle operation in the control of the UPQC will be limited here for the voltage source based shunt UPQCs.

So, we shall actually restrict our discussion, most popular type of UPQC. The main objective of this UPQC is to mitigate multiple power quality problem, which has been discuss, there is a voltage, it is related to the voltage, it is related to the current. So, mitigate multiple power quality problem in a distribution system that is surges, spikes, so a voltage source, voltage sags there is (Refer Time: 10:47) actually voltage harmonics, and all those things. And also unbalanced, load unbalance, (Refer Time: 10:55) sequence component, all those and the reactive power from the current harmonics, all those are we will be actually the part of the current disturbance. So, we it will required to mitigate, both are actually problem arises from current, as well as the voltage.

UPQC mitigates most of the voltage quality problem such as the sags, swell, these are all voltage problem, surge, noise, spikes, notches, flickers, unbalanced voltage, unbalanced current in volts. Also there, fluctuations, regulations, and harmonic present in the supply,

slash point of common coupling PCC transfer, point of common coupling system, and a series compensator that is DVR, cleans this all this nasty things, and give us ideal, sinusoidal balance constant magnitude load, constant magnitude voltage source to the consumer and the load end.

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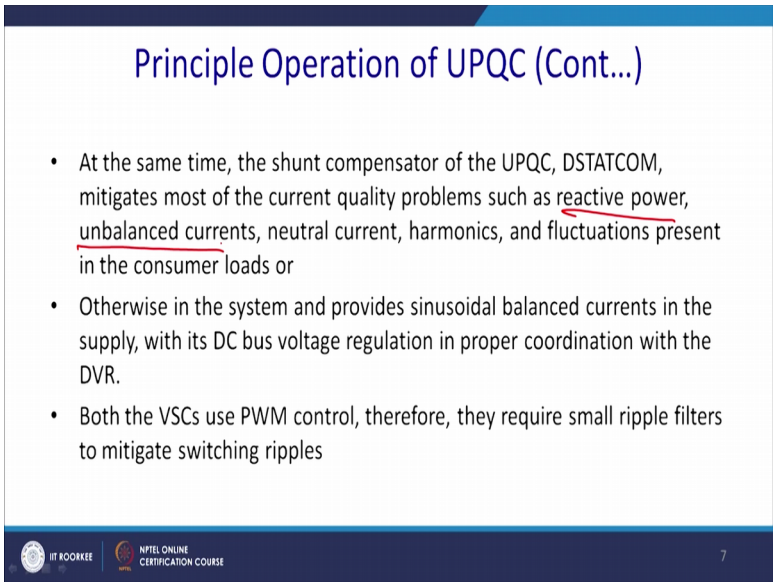

At the same time, the shunt compensator of UPQC that is essentially DSTATCOM, mitigates most of the current quality problem such as reactive power, unbalanced current, if it is three phase four wire, then neutral current, harmonics, fluctuation presents in the loads. And due to that load current fluctuations, all those entities required to be clean up by the DSTATCOM.

Otherwise, the system provide what does this DSTATCOM do, this DSTATCOM the system, otherwise in the system and it provides a sinusoidal balance current in the supply, with the DC bus voltage regulations in proper coordination with the DVR; And maintaining the DVR, also maintaining the actual the DC link voltage, which is shared by DVR as well as well as DSTATCOM. Also the task of this also this task of this actually the DSTATCOM, DSTATCOM generally maintains the DC bus voltage.

Both voltage source converter, uses PWM control, but in some cases you will find that actually the DSTATCOM may use a hysteresis controller, for sake of simplicity. But, there is a problem of hysteresis controller, which we have discussed in previous classes that it is a it is not a constant frequency operation, ultimately designing of the inductor,

and all those things are actually complex. But, advantage of this advantage of a hysteresis controller is simple, why simple, because you need not have tune the PI controller.

And therefore, they require small rip. And what happened, since it is if it is made by the PWM control, then it will require a small ripple filter to mitigate the switching ripple. It is applicable for both actually for hysteresis control, as well as the PWM control.

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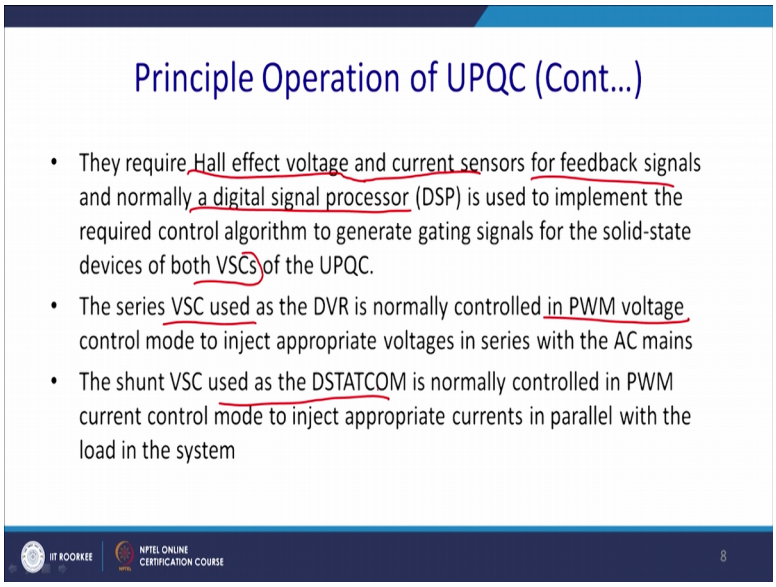

Generally what happened, how it will work? They require a Hall Effect voltage and the current sensor, for feedback signals. Since, this is a DSTATCOM level; it does not require (Refer Time: 14:43) in distribution level, for feedback signals. And normally a digital signal processor DSP or APJ, we can use programmable filter also, is used to implement the required control algorithm to generate the gating signals for the solid-state devices both this VSC of UPQC.

The series VSC used as DVR normally controlled in the PWM voltage control mode to inject the appropriate voltage in series with the AC mains. And generally, it will have a series transformer also, so ultimately that it will also a mitigate some amount of the switching harmonics.

The shunt voltage source converter uses DSTATCOM, and is normally controlled in current control PWM mode, it can be average current mode control or big current mode

control. Generally, we prefer average current mode control, and we required tune the PI control for the session; Mode current control mode to inject the appropriate current in parallel, or in shunt with the load of the system.

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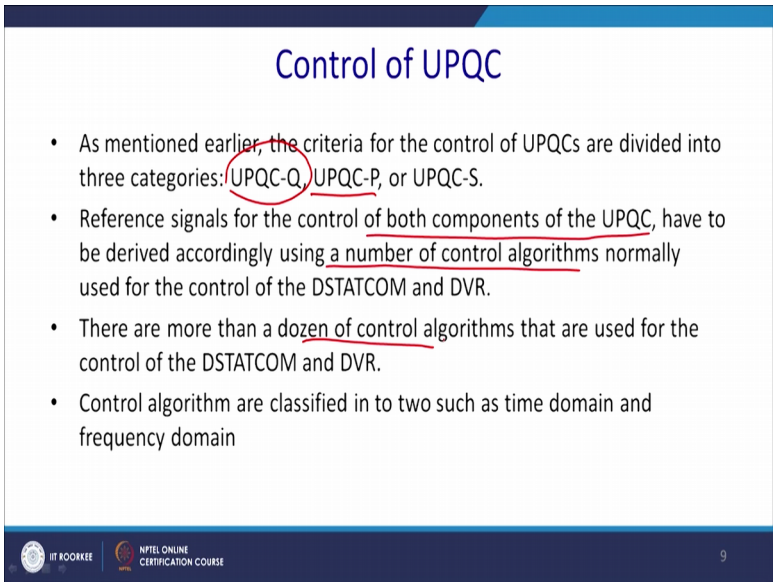

We have discussed earlier, so the slide says that is mentioned earlier, the criteria of the control of UPQC are divided into the all the three categories that is UPQC-Q that will inject voltage in quadrature with the V S, UPQC-P that will inject voltage in phase, and UPQC-S it will inject the voltage optimal angle, so that rating of the UPQC will be the list.

The reference signal for the control of both components of the UPQC, have to be derived accordingly using a number of the control algorithm normally used for controlling the DVR, and the DSTATCOM. So, whatever the we have a series of the actually reference generation technique, we have discussed in that case cover DSTATCOM, most of them can be applied. So, so it is just little extension, or what we have seen in the DSTATCOM.

There are more than dozens, rather it should be around 50 now. Control algorithms are used for the control of the DSTATCOM and a DVR. Few are popular, we shall discuss few, because you know that it shall can be a course, what are the reference generation technique will in practically finds application for UPQC.

Control algorithms are satisfied into two such categories, one is time domain, another is frequency domain. Another domain is nowadays actually emerging, these are the evolutionally computing like GA base, artificial neutral network based all those things. But, but process itself, you know it is basically a derived form only the time domain, and frequency domain.

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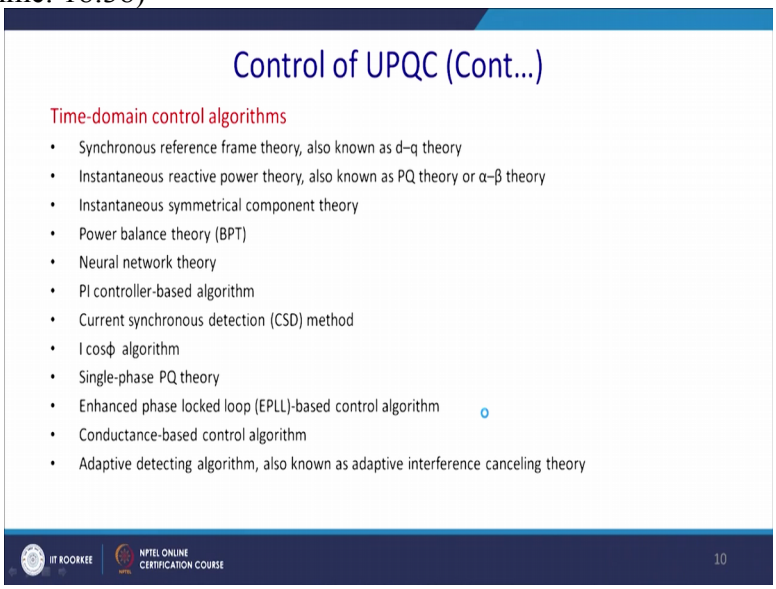

So, these are actually the list of list of the time-domain algorithm. So, I do not want to fill more slide on it, so I restricted. So, this number is quite huge, and we shall just take out one or two control algorithm for it.

So, one popular actually time-domain reference generation technique is actually SRF we in abbreviation we say synchronous reference frame theory known as d-q theory, Deepak Devan and Shivaji Bhattacharya et al actually, they came out this theory. When will cite the reference, there is a very good application note as well as, this thing in industrial electronics. So, you can refer that actually SRF note for the DSTATCOM, but you can extend it too definitely to the UPQC.

Instantaneous reactive power theory, this is a first want to see the light of it, Akagi et al is propose that or it is a alpha beta theory say that, it came in 1984, quite long ago, but it is quite popular also. Instantaneous symmetrical component theory, so this is this is actually find very much applicable, in case of the three phase four wire systems. An Akagi Nabae, proposed this theory, in 1991 I think. So, that power balance theory, so

instantaneous power consumption should be 0 accept losses from there, this comparer will come out. But, most of them actually uses a low pass filter, so that is there is a delay.

And now, you have a neural network, artificial neural network, and then you can change the weight with the adapted neural called Edline. So, this also has been used in practice processing things, have lot of papers on this category. And then PI controller based algorithm, we are all (Refer Time: 21:08) algorithm. So, it is actually some kind algorithm is there. There after another methods are current synchronous detection, all the CSD method, so that is call synchronous current method. So, it will find it out the unique template and all those things.

And thereafter I cos phi, because this is a real component of the power algorithm, you tried to optimize this value, this and these are almost similar. And if it is a single phase system then SRF can be modified and it set to be the actually the, single phase PQ theory, instead of a d-q theory. It is just very simple thing, you know it given 90 degree phase shift, and you say that actually it is v it is real power, and the apparent power. And also enhance phase loop based control algorithm, it is generate the unit template in a proper way, for the distorted voltage and current. So, this is also finding lot of applications.

Conductance base this control algorithm that is also find the application figure it sees that conductance has to be minimized, so in that way, we can optimize the actually the reference and track the reference generation. So, because you know when resistance is nil sorry in an when you are got a resistive load that impedance is minimum, so from them for this concept, you know actually try to minimize the value of the impedance, and thus conductor or increase the conductor. This is the method of conductive phase algorithm.

And there after you have adapted detection algorithm known as, the adaptive interference cancel theory. So, it will be mostly, it is used in air and base system. So, there it will automatically adopt the weight, and find it out actually what (Refer Time: 23:16) actual component of the voltage harmonics, in the current harmonics of the sag component of it. So, these are the few basic time-domain algorithm, which has been put into the practice for UPQC as well as the DVR, and DSTATCOM.

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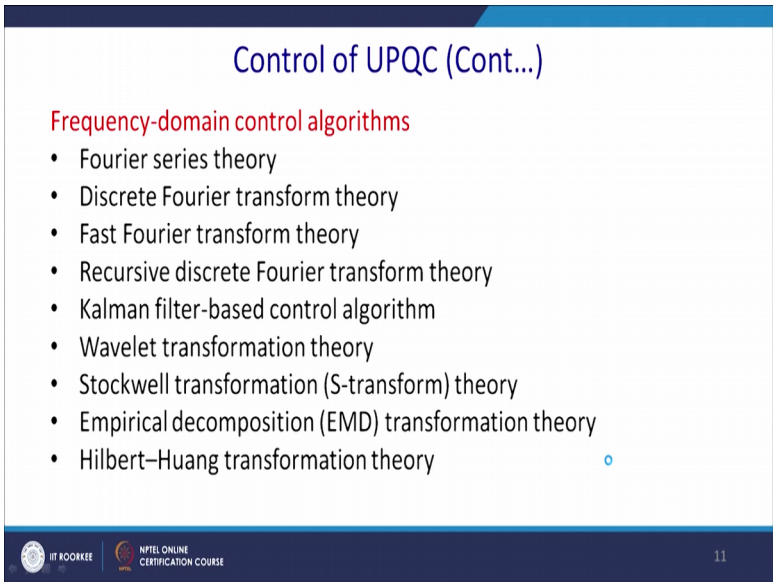

Same way, we will have a sum ah some technique on the frequency domain. These are Fourier series, so you take a sample, and do the FFT. From the FFT, you find it out the exact component of the harmonics, and that is quite trivial. And then it is basically then improvement on this actually FFT, Fourier base theory. So, these are discrete Fourier transform theory, and it is almost the same thing. So, here you can minimize the noise. And this actually from this actually you can have a first Fourier transformation, which I was telling FFT, this is quite popular entity here, for generating the reference.

And thereafter, recursive discrete Fourier transformation, it is discrete, because it is a digital domain. You take the samples of one of the period, and find it out its component. And generally what happen, recursive one actually has a advantage, that it does not have the property of changing actually you did not have to compute. Computational benefit is there in recursive discrete, because you know you did not have to do the matrix inversion. So, computation will be fast for the recursive discrete. Same way, Kalman filter-based algorithm is also popular in digital domain, you can find it out actually the harmonic content in present in to the current as well as a voltage by the Kalman filter.

And there is a wavelet transformation theory, you have to design the mother wavelet that is a challenge, otherwise it is a very good technique. And it can detect that time of the change anything has been occurred also the blot, or the voltage, or this thing, then only it will take a corrective actions. And it can detect a basically phase and frequency both.

And the from thus phase, we can compute there basically time that changes occurred. And then you can take, when it is wavelet based design, also can compute the harmonic required to be injected or suppress.

Same way, the new emerging few techniques, this is coming in a research job that is Stockwell transformations theory. So, this kind of techniques are now emerging, for computations of the computation of this actually the current content in a load, as well as the voltage. Empirical decompositions and transformation theory, this is also coming from the evolutionary computing, this also one of the very important thing; Nowadays, many researchers working on it.

Another is Hilbert-Huang transformation theory, this is quite also important. So, this is actually Hilbert transformations also used to compute the harmonic components. These are basically the major way of actually computing the harmonic. So, we can go back in SRF method, how we have done it. So, same kind of mostly you know actually for the power electronic domain, we generally work into the time domain. And these see actually the control techniques are popular and useful.

We have discussed this little, in case of the in case of the DSTATCOM, so we are not going to that detail now. And you are actually requested to revisit our actually DSTATCOM lecture, where all those actually theory has been discussed in actually briefly, so that will be helpful to understand our next lectures that is based on this actually application of this application of this. And you know, this DSTATCOM, and this DVR this combination is one of the major success to mitigate the power quality.

And for this session, mostly this actually this three methods, basically you know, this method basically it employees, all employee basically a PI controller an a low pass filter. So, how well you tune the low pass filter, and how well you actually set the how well you set the cutoff frequency of the low pass filter, and how well you actually tune the PI controller based on this, this actually this operation demands. So, it requires a expertise to actually implement this controllers. And however, in control domain, this in frequency base control domain, this expertise can be nullified. So, you have to write a very good program, and you can extract the harmonic content operate.

So, for this session, this methods are gaining popularity, but those who are in work in a power electronic domain, they are very much familiar with actually the actual the correct

statics are the features, and their comfortable in time domain. So, and those who basically now emerging, and they have a very good knowledge on DSP Digital Signal Processing.

And this methods, they are basically now actually and I am good in mathematics basically, they can they actually go for this methods. And now this is gaining popularity. So, both of them claim their superiority, but actually you can choose either of it. But, you find you your comfortable in that particular way of actually generating signals.

Thank you for your kind attention. We shall continue to all lecture on classifications and different kind of control technique of the UPQC, in our next class.