

Flexible AC Transmission Systems (FACTS) Devices
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Lecture - 34
Operation and Control of UPQC – III

Welcome to our lectures on the FACTS devices. We shall continue with our UPQC. This is our third lecture on UPQC specially. We left it actually when from the previous class. So, we shall again start from UPQC-Q. Actually please recall our discussion in previous class.

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Rating and Control of UPQC (Cont...)

- These three-phase reference supply currents and sensed supply currents are used in PWM current controllers for generating gating signals of IGBTs of the DSTATCOM
- For the control of the DVR, reference injected voltages are computed from the difference of reference load voltages and sensed PCC voltages.
- Three-phase reference load voltages are computed from a desired/reference amplitude of load voltages and the transformation angle obtained from PLL over sensed DVR/supply currents.
- These three-phase reference injected voltages are given to a PWM voltage controller for generating gating signals of IGBTs of the DVR

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The a three phase a reference supply and the current in the in case of the UPQC-Q are been sensed and the supply current is used in PWM controller for generation of the getting signal of the IGBT of DSTATCOM that is the shunt point of this compensation and for the composition of the DVR that is a series part, the reference injected voltage and computed from the difference of the load voltage and the voltage senses PCC.

So, that will check that whether there is a sag or not apart from actually the control of the harmonics; but UPQC-Q mainly actually compensate sag. The three-phase reference load voltages are computed from the desired and the reference amplitude of the load voltage and the transformation angle obtained from PLL over the sensed DVR supply.

So, this is the way it will proceed while working and these are the three reference voltages are injected to the PWM voltage controller to generate signals for the IGBT for the DVR part. So now, we shall discuss about the control of UPQC-P.

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Rating and Control of UPQC (Cont...)

Control of UPQC as UPQC(P)

- This control algorithm of UPQCs has been conceptualized for the minimum voltage injection by the DVR.
- As evident from phasor diagrams the DVR injects minimum voltages for both conditions of voltage sag and swell.
- In this mode, the DVR needs totally active power for voltage injection of series compensation.
- In this case, the series voltage is injected in phase with the AC mains current or PCC voltages,
- Thus requiring only active power that has to be fed or received by the DSTATCOM through the DC bus

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So, it will inject the voltage in phase. So, this is the DVR voltage and this is the actually the DVR previously is it is injecting 180 degree out of phase and it is a 180 in phase you can say something like a step changing transformer; MS control algorithm, but there are there is a problem of the harmonics.

But here, change is quite smooth. The control algorithm of UPQC has been conceptualize for the minimum voltage injection by the DVR. So, it will inject voltage in phase. So, minimum injection is required and the rating can be lowered is a evident for the phasor diagram that that DVR injects the minimum voltage for both the condition of the voltage sag as well as swell. So, this is basically for the voltage sag.

So, it will inject actually in phase and this is for the voltage swell this will inject 180 degree out of phase. In this mode, DVR needs to totally the active power for the voltage injection for series compensation. So, what will happen? It will actually take active power from the system. In this case the series voltage is injected in phase with the ac mains current or the PCC.

Generally, actually current flows to the shunt path and it is being and it is being supply to the supply to this actually compensating the voltage in case of the sag operation and reverse happened in case of the swell operation. Thus, the requiring only the active power and that has to be fed or received by the statcom through the DC bus.

So, ultimately DC bus will ensure the supply and this DC bus is maintained mainly by the shunt path. It increases the current and thus the kVA rating of the STATCOM; however, the kVA rating of the DVR is minimal in this operating mode of UPQC as UPQC-P.

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Rating and Control of UPQC (Cont...)

- It increases the current and thus the kVA rating of the DSTATCOM.
- However, the kVA rating of the DVR is minimal in this operating mode of UPQC as a UPQC-P.
- In this case also, the DSTATCOM compensates the reactive power of the consumer load and all current related harmonic problems
- The voltage sag can be expressed as

$$X = |V_{Lc} - V_s| / V_{Lc} + V_{DVR} / V_{Lc}$$
- Therefore, the voltage rating of the compensator may be achieved from the required maximum value of sag or swell compensation



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Since, it is only inject the in phase component of the voltage. But series rating increases because it has to fed the V_L power through it. In this all in this case also the DSTATCOM compensate the reactive power of the consumer load and all the current related to the harmonic problem.

So, since just acts as a shunt active power filter and the voltage sag can be represented by as we have represented in case of the UPQC-Q, voltage at the load minus supply voltage by voltage after compensation V_{Lc} and supply voltage V_s by V_L ; ultimately this difference is supplied by DVR.

So, it is DVR by voltage after composition. Therefore, the voltage rating of the compensator may be achieved from the required maximum value of the sag and swell compensation. Thus, what will be the rating then incase of the UPQC-P?

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Rating and Control of UPQC (Cont...)

- The UPQC-P mode of operation requires minimum injection voltage and thus minimum VA rating of the DVR but at the expense of the DSTATCOM rating, which increases due to large active power flow through the DSTATCOM
- Therefore, this type of UPQC does not have minimum overall VA rating consisting of both elements of the UPQC.

The rating calculations of both DVR and DSTATCOM

- The injected voltage by the DVR is

$$V_{DVR} = V_{Lc} - V_s = V_{Lc} X$$



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UPQC-P mode of operation requires minimum injections of the voltage and thus minimum VA rating for DVR, but DSTATCOM will actually pay the cost for it. But at the expense of the DSTATCOM rating which increases due to the large flow of the active power large active power flow through the DSTATCOM. Therefore, this type of UPQC does not have a minimum value of VA rating and it consists of both the element of the UPQC.

The rating calculations of the DSTATCOM and DVR is done below as done in case of the UPQC-Q. So, it is basically DVR rating will be actually $V_{Lc} - V_s$ that is you know you can write V_{Lc} into the fraction of the sag or swell. So, thus overall VA rating of the DVR will be given by $V_{DVR} \times I_s$.

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Rating and Control of UPQC (Cont...)

- The VA rating of the DVR is totally an active power and is expressed as
$$S_{DVR} = V_{DVR} I_s = V_{Lc} I_L \cos(\phi)$$
- Where I_s and I_L are supply and load currents, respectively, and $\cos(\phi)$ is the load power factor.
- The current rating of the DSTATCOM is
$$I_{DST} = \sqrt{[I_L^2 - I_s^2] + (X/L) \cos(\phi)^2}$$
- The VA rating of the DSTATCOM is
$$S_{DST} = V_{Lc} I_{DST}$$
- Therefore, total VA rating of the UPQC is
$$S_{UPQC} = S_{DVR} + S_{DST}$$

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That is V_{Lc} into I_L into $\cos \phi$ and where, I_s and I_L are the supply and the load current respectively and $\cos \phi$ is a load power factor. So, it will depend on the load power factor.

So, current rating of the DSTATCOM is essentially I_{DST} should be I_L^2 minus I_s^2 plus X that is a fraction of the sag $X I_L \cos \phi$ square. So, please note that there is a $2X$; one X for actually impedance; another X for here actually X stands for the impedance not for the voltage sag. The VA rating of the DSTATCOM is S_{DST} equal to V_{Lc} by V_{Lc} into I_{DST} . Similarly, you can find it out the rating of the total that is S_{DVR} plus S_{DST} .

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Rating and Control of UPQC (Cont...)

- For real-time control, implementation of this mode of UPQC is also straightforward similarly to the DSTATCOM controlled in the UPQC-Q mode of operation.
- For the control of the DVR, reference injected voltages are computed from the difference of reference load voltages and sensed PCC voltages.
- Three-phase reference load voltages are computed from a desired/ reference amplitude of load voltages and the transformation angle obtained from PLL over sensed PCC voltages as these three-phase reference load voltages are to be in phase with PCC voltages.
- These three phase reference injected voltages are given to a PWM voltage controller

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So, the total rating you will find it is not at all optimal. The real time control and implementation of this UPQC is straightforward, similar to the what we have seen the in case of the UPQC-Q that is the DSTATCOM control in the case of the UPQC mode of operation. For the control of the DVR, the reference injected voltage are computed from the reference load voltages, sense at the point of common coupling is same here.

The phase reference voltage, the three-phase reference load voltage are computed form a desired reference amplitude of the load voltages and transformation angle obtained from PLL over the sense PCC voltage as there is a three-phase reference load voltage are to be in phase with the PCC. This three-phase references injected voltages are given to the PWM voltage controller to generate the reference voltage and this will be injected with the series compensator.

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Rating and Control of UPQC (Cont...)

Control of UPQC as UPQC-S

- This control approach of UPQCs has been featured as the most generalized one
- full utilization of DVR rating with reduced burden on the DSTATCOM or optimum sharing of rating between the DVR and DSTATCOM
- from the phasor diagrams the DVR may inject voltages for both conditions of voltage sag and swell compensation.
- In the UPQC-S mode of operation, the DSTATCOM is normally used for all current-based compensation other than full reactive power of the System

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So, control of the UPQC as S; where we try to optimize essentially the rating of actually UPQC-P as well as UPQC-Q; in this control approach the UPQC has been featured as most general one. So, we tried to compensate we actually or apparent power of the UPQC is fixed that is VA rating of the system is fixed. So, full utilization of the DVR rating with the reduced burden on the DSTATCOM or optimum sharing of the rating between DVR and the DSTATCOM. So, here it is possible. Thus, overall actually rating of the system out the system is minimized.

So, let us understand the phasor. Here, in this case DVR not necessary will inject the voltage in phase or quadrature. It can inject any optimal angle. So, for the session, this was a this was a voltage before compensations and DVR inject some volt voltage between angle.

So, this angle you know actually will make this voltage V_s and thus with a new voltage this become a new angle the V_L prime and it was actually the angle between the load and the mode voltage was V_L and this will actually in will be injected by the DSTATCOM that is the value of the I_{DSTAT} ultimately the current will become in phase with the voltage.

Similarly, for sag compensation you know this was uncompensated V_s prime ultimately V_r will inject this voltage and ultimately for this session actually new V_s will be this

and V_L was this and definitely this is the I_{DST} , the $DSTATCOM$ current that will making phase with this actually the compensated voltage.

From this phasor diagram, the DVR may inject voltage for both condition of the voltage sag as well as voltage swell compensation. So, this one for voltage sag and this one is for voltage swell, the UPQC-S mode of operation of the $DSTATCOM$ is normally used for current base compensation other than full reactive power of the system.

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Rating and Control of UPQC (Cont...)

- In this case, the DVR injects a voltage in series between the AC mains and the load end at a predetermined phase angle with the PCC voltage
- It needs both active power and reactive power through the DVR.
- This concept of UPQC-S with the phase angle control of the series voltage injection of the DVR has been perceived very recently for different objectives.

Some of the objectives of UPQC-S

- The first objective of this mode of control of UPQCs is based on the full utilization of DVR rating.
- Usually, VSCs of same VA rating are used for both DVR and $DSTATCOM$ to reduce the inventory by the manufacturers and customers as identical VSCs are selected for both components of the UPQC.

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In this case DVR injects voltage in series with the AC mains and the load end actually at the predetermined phase angle with the PCC. So, ultimately task of task of DVR and the $DSTATCOM$ is been actually segregated and ultimately, they will decide the which angle and hook for the voltage and current to be injected and which ways.

Then it both active power as we have seen that it is not injecting in quadrature, it is not neither it is injecting in phase. So, some portion of the active power is also required and the reactive power both from the DVR. This concept of the UPQC with the phase angle control of the series voltage injection the DVR has been perceived recently for the different objectives.

So, let us see the objective of the UPQC-S the first objective of both is mode of UPQC is based on full utilization of the DVR rating. So, you can adjust in such a way the rating of the $DSTATCOM$ and rating of the DVR is fully utilized. It is not under utilize in case of

the UPQC-P or UPQC-Q. Usually, actually voltage source converters is of same rating are used for DVR and the DSTATCOM to reduce the inventory.

So, you have a actually same kind of thing to be purchased. So, you have a component count get reduced by manufacturer and the customers are identical voltage source converters are selected for both; both the component of the UPQC.

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Rating and Control of UPQC (Cont...)

- In general, the DVR is used with an injection transformer, but a transformer is not mandatory for the DSTATCOM unless the customer needs it.
- The control of this mode of UPQC is as follows.
- The voltage injected by the DVR is its rated voltage ($V_{DVR} = V_R$) and the angle ψ_{DVR} at which it is to be injected with respect to the PCC voltage is

$$\psi_{DVR} = \pi - \cos^{-1}((V_s^2 + V_{DVR}^2 - V_{Lc}^2)/2V_s V_{DVR})$$
- where V_s is the PCC voltage under voltage sag condition and V_{Lc} is the load voltage after compensation.



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In general, DVR is used with an injection transformer; but transformer is not mandatory unless customer needed because system will be bulky. Sometime we required the galvanic isolation that is prescribed by the green code or it can be a choice of the customer also, then will provide the actually transformer in case of the DSTATCOM.

The control of this mode of UPQC is as follows. The voltage injected by the DVR is rated voltage that is DVR r and the phase angle DVR psi; it is a psi DVR at which is to be injected with respect to the PCC voltages DVR psi is pi minus cos inverse of V square plus DVR square minus L c by 2 V S DVR.

So, from there you get the optimal angle actually psi DVR to be injected in which phase the DVR to be infected; where, V S is a supply voltage under sag or swell condition and L c is a load voltage after compensation.

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Rating and Control of UPQC (Cont...)

- The current rating of the DSTATCOM is
$$I_{DST} = \sqrt{(I_L \sin(\beta))^2 + (I_L ((\cos \beta) - \frac{\cos \phi}{1-X}))^2}$$
- The VA rating of the DSTATCOM is
$$S_{DST} V_s I_{DST}$$
- Therefore, total VA rating of the UPQC is
- UPQC-S = $S_{DVR} + S_{DST}$
- This condition of UPQC-S reduces the burden on the DSTATCOM rating as some part of reactive power of the load is supplied by the DVR.

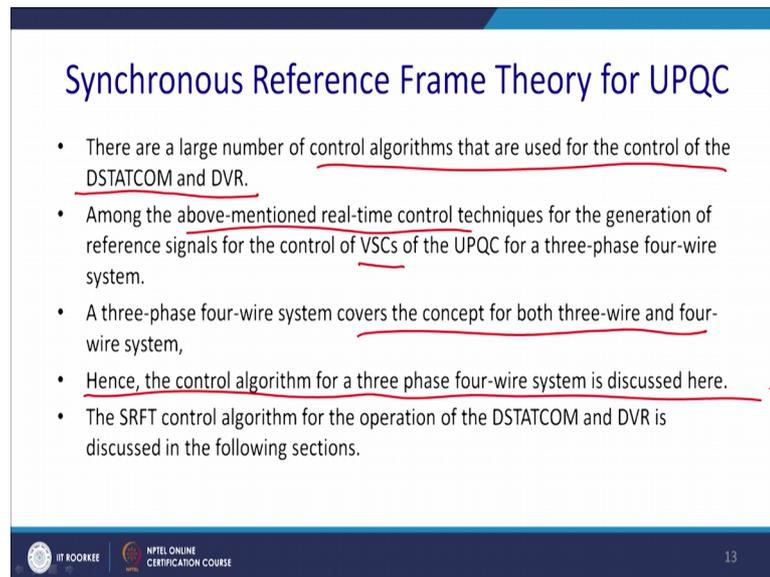
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Similarly, in case of the I DST, we can calculate from the phasor that is $I_L \sin \beta$ square plus $I_L \cos \beta$ square minus $\cos \phi$ by X 1 by X ; where X is a voltage sag and from there we can calculate the value of I_{DST} and since it is connected with the supply voltage. So, it will see the shunt voltage will see the V_s .

So, it will be V_s into I_{DST} will be the rating of the DSTATCOM and. So, therefore, the total rating of the DSTATCOM is actually $S_{DVR} + S_{DST}$. This condition of the UPQC actually what happen? It is reduce the burden of the individual voltage source converters.

What happens in UPQC-Q and P? One of this converter is burden more; here load is been shared by the both the converter equally. UPQC-S reduces the burden on the DSTATCOM rating as same part portion of the active power same portion of the some portion of the reactive power the load is supplied by the DVR.

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Synchronous Reference Frame Theory for UPQC

- There are a large number of control algorithms that are used for the control of the DSTATCOM and DVR.
- Among the above-mentioned real-time control techniques for the generation of reference signals for the control of VSCs of the UPQC for a three-phase four-wire system.
- A three-phase four-wire system covers the concept for both three-wire and four-wire system,
- Hence, the control algorithm for a three phase four-wire system is discussed here.
- The SRFT control algorithm for the operation of the DSTATCOM and DVR is discussed in the following sections.

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So, let us see the some reference generation technique that is required to control the UPQC, we shall discuss the very common theory of reference generation that is called Synchronous Reference Frame Theory. So, there are large number of control algorithm that are used to control the DSTATCOM and the DVR; we have discussed it in yesterdays day before yesterday class.

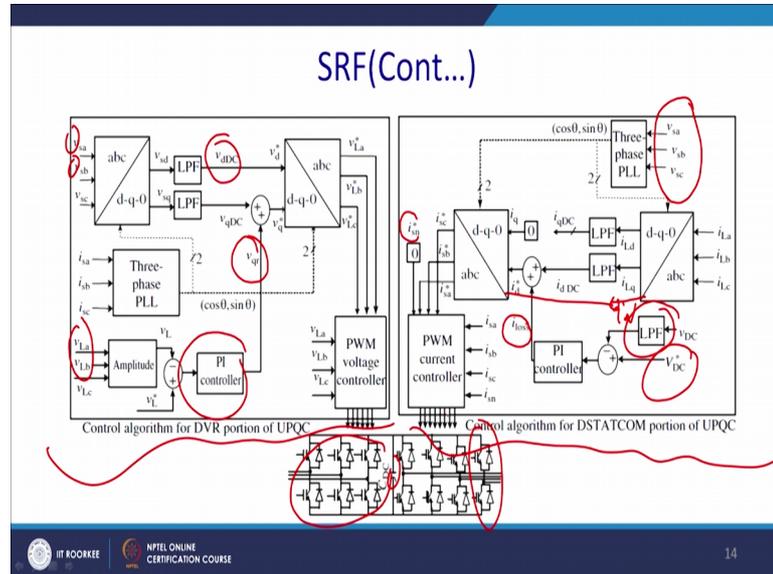
Among this above mentioned real time control technique for the generation of the reference signals for control of voltage source converter of the UPQC, three-phase four-wire system. So, we shall add some kind of new edition we shall consider the that it is in a distributed network for this is it is three-phase four-wire system.

So, for the session STATCOM will either have a four legs or midpoint of this midpoint of the capacitors can be connected with the neutral. The three-phase four-wire system covers concept of the both three-phase three-wire as well as the four-wire system.

So, if you do not consider the zero current, this essentially it leads to the three-wire system and if you consider the zero current to available here; then we can treat them as a three-phase four-system. Hence, the control algorithm for the three-phase four-wire system is discussed here and you just cut out the zero current zero makes zero current zero; then it is become a three-phase three-wire system

So, SRF theory that is actually transfer theory control algorithm for the operation of the DSTATCOM and the DVR is discussed now.

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So, this is the overall block diagram of it please try to understand this portion is for the DVR and this portion is for the DSTATCOM. Here in DSTATCOM portion we have a 4 leg; 1 leg is for composing the zero sequence current and another topology is possible, but there is there is a problem of we required a splitting of the capacitor and also balancing the capacitor voltage.

So, we will sense the 2 voltages; we did not have to sense the three voltages. So, we can generate another voltages for three-phase three-wire system then, for the for the three-phase four-wire system, we required to sense all the three voltages. From there we shall transfer to a b c the a b c to d q frame by parks transformations with the help of the PLL phase lock loop and that value will be fed that that is actually in a d-q frame; there will be actually V_s and V_q and we know that the harmonic content present can we actually $6n \pm 1$.

So, ultimately when you will pass through this actually low pass filter, then the actually the frequency that corresponds to 50 hertz will pass that will looks is DC in the d-q frame.

So, ultimately you will get V_{DC} reference that is the for the fundamental all the harmonics will be truncated by this actually low pass filter and similarly, with the q we will have this value. And again, we required to maintain the voltage sag and to maintain the voltage sag what happen?

You will also sense the load voltages at the point of common coupling and will actually see that what is the amplitude of the V_L . And accordingly, we will actually we will check with this actually the reference voltage sag and from there you will fit to the PI controller.

It is better because it is better to convert this quantity also in DC because PLL is available. So, ultimately we shall check the value of the V_q here with the reference V_q magnitude. So, we can fit to the PI controller and PI controller will add the some value of V_{qr} that is a component required to be injected for actually compositing the voltage sag and that will add up with the q component of the voltage.

And thus, you will again transferred to a d-q 0 to a b c frame and we shall generate actually V_{La} reference V_{Lb} reference and V_{Lc} reference and will fit to the PWM block or the space vector modulation block. So, then this portion of the system will work. Similarly we will actually generate PLL for current in case of the voltage and will generate PLL form voltage in case of the current or DVR portion. So, from $V_a V_b V_c$, we get the PLL and we get I_l, I_v, I_c .

So, ultimately you have actually $I_d I_q$ as well as I_{q0} in case of the zero component current and. So, zero component current is fed through as it is and it is pass through the low pass filter and you know that actually I_{DC} should be 0. So, for the session actually you fed I_q equal to 0 and here we required to maintain the DC bus voltage for the session, it will take little bit V_l power.

So, l p m you sense this actually the DC bus voltage and to wipe of the dipole, we have a low pass filter and you will compare with this actually reference DC bus voltage and you free to the PI controller. So, some amount of the real power is required to maintain the DC bus voltage that is the last component of it and that is fed to the I_d and it is add up and similarly this component I_0 will also come here and you will convert to d-q to a b c.

And that is basically you have shown here it is coming for as a neutral current that is $I_s n$ and it will be fed to this actually the PWM block, a b c and $I_s n$ will be corresponds to this block fourth leg only when the 0 sequence current is present and this will actually compensate the DVR since is the principle operation of the SRF mode.

So, quick take on from this.

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The slide is titled "SRF(Cont...)" and contains the following text:

Control of the DSTATCOM of the UPQC

- The control algorithm for the three-leg VSC-based DSTATCOM of the UPQC based on the synchronous reference frame theory is used for the control of the DSTATCOM.
- The objective of the DSTATCOM is to enhance the power quality of the supply current as well as to support the common DC bus of the DSTATCOM and the DVR by absorbing active power.
- In the control scheme of the DSTATCOM, the load currents (i_{La} , i_{Lb} , i_{Lc}), PCC voltages (v_{sa} , v_{sb} , v_{sc}), and DC bus voltage (v_{DC}) of the UPQC are sensed as feedback signals.

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The control algorithm of this three-leg voltage source DSTATCOM of the UPQC based on the synchronous reference frame is discussed for the control of the DSTATCOM.

The objective of the DSTATCOM is to enhance the power quality of the supply current as well as to support the common DC bus voltage of the DSTATCOM and DVR by absorbing the active power. The control schemes from the DSTATCOM the load current i_{La} , i_{Lb} and i_{Lc} PCC voltage V_a , V_s and V_c and the bus voltage V_{DC} of the UPQC are sensed as the feedback signal.

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SRF(Cont...)

- The load currents from the abc frame are first converted to the dq0 frame as follows:
$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \\ i_{L0} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\theta) & -\sin(\theta) & \frac{1}{2} \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & \frac{1}{2} \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) & \frac{1}{2} \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix}$$
- Where $\cos\theta$ and $\sin\theta$ are obtained using a three-phase PLL over PCC voltages.
- A PLL signal is obtained from PCC voltages for generating fundamental unit vectors for the conversion of sensed currents to the dq0 reference frame.
- The SRF controller extracts DC quantities by low-pass filters (LPFs) and hence the non-DC quantities (ripple) are separated from the reference signal.

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So, from there we have actually reverse parks transformation the load current from the a b c frame to first converted to the d-q frame. So, this is a parks transformation; where $\cos\theta$ and $\sin\theta$ is obtained from the PLL over the voltages. PLL signal is obtained from the voltages for generation of the fundamental unit of the vector for the conversion of the sense current to a b c to the dq 0 fame when you have a zero sequence component of the current control.

The SRF control extract the DC quantities by low-pass filter and hence non-DC quantities that is a ripple are been separated from the reference signal as well as if it is a noise contaminated with that also get eliminated.

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The slide is titled "SRF(Cont...)" and contains the following content:

- The d-axis and q-axis currents consist of DC (fundamental) and ripple (negative sequence and harmonics) components:
$$i_{Ld} = i_{dDC} + i_{dAC}$$
$$i_{Lq} = i_{qDC} + i_{qAC}$$
- SRF can be operated in UPF(unity power factor) and ZVR(zero voltage regulation) modes
- This control strategy considers that the AC mains must deliver the active power for maintaining the DC bus voltage and meeting the losses (i_{loss}) in the UPQC.

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So, ultimately you have d-axis and the q-axis component current consisting of the DC that will look as a fundamental component (Refer Time: 29:14) look as a DC in dq frame and the ripple a negative sequence as well as a harmonics because if it is a negative sequence, it will appear as actually second order because it is rotating at plus beta omega.

So, negative sequence you like a 2 omega. So, it will come as a double frequency oscillation and same way 5th and 7th will come as a 11 and the actually you will come as a this kind of reference.

So, SRF can be operated at the power factor or ZVR; that means, zero voltage regulation modes. We can compare we are discuss both the modes. So, it can be actually used either of it. This control strategy considered as AC mains must deliver the active power to maintaining the DC bus voltage meeting the losses of the UPQC.

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SRF(Cont...)

- The output of the PI controller at the DC bus voltage of the UPQC is considered as the current (i_{loss}) for meeting its losses.
- Therefore, the amplitude of reference supply current is
$$i_d^* = i_{dDC} + i_{loss}$$
- The reference supply current must be in phase with the voltage at PCC but with no zero-sequence component.
- It is therefore obtained by the following reverse Park's transformation with i_0^* as zero.
- The resultant dq0 currents are again converted into the reference supply currents using the reverse Park's transformation.
- The reference supply neutral current i_{sn}^* is set to zero for neutral current compensation.

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Now, output of the PI controller at the DC bus voltage of the UPQC is considered to the current i_{loss} to feed the losses of the different part of the component of the UPQC switching loss all the losses should be fit that component is i_{loss} . Therefore, the amplitude of the reference should be added. So, i_d^* become i_{dDC} plus i_{loss} the reference supply current must be in phase with the voltage and the PCC with no zero sequence component.

Therefore, they to obtain the zero sequence component, we do the reverse parks transformations and with i_q^* as $i_q^* = 0$. This resultant i_d^* i_q^* reference are again converted into reference supply current using the parks transformation. The reference supply of the neutral current i_{sn} is said to 0 for the neutral current compensation.

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SRF(Cont...)

Control of the DVR of the UPQC

- The control block of the DVR of the UPQC, in which the synchronous reference frame theory is used for reference signal generation consists of .
- The PCC voltages (v_s), supply currents (i_s), and load terminal voltages (v_l) are sensed for deriving the gate signals of IGBTs.
- The PCC voltages are converted to the rotating reference frame using the abc-dq0 conversion using the Park's transformation.
- Then, d-axis and q-axis voltages consist of DC (fundamental) and ripple (harmonic) components

$$\begin{aligned} V_{sd} &= V_{dDC} + V_{dAC} \\ V_{sq} &= V_{qDC} + V_{qAC} \end{aligned}$$

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So, same for the DVR; what you do for DVR? The control block DVR of the UPQC in which the synchronous reference frame theory is used for the reference signal of the generation consisting of the voltage at the common point the common coupling PCC, the supply current load terminal voltage V_l are sensed and for the actually getting the a get signals. This is a voltage convert it into the rotating reference frame a b c to dq and the by the park transformations.

Similarly, you have a DC component at the load component for the s d and the s q frame.

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SRF(Cont...)

- The amplitude of AC load terminal voltage (V_l) is controlled to its reference voltage (V_l^*) using a PI controller
- The output of the PI controller is considered as the voltage (v_{qr}) to be injected by the DVR.
- The amplitude of AC load terminal voltage (V_l) is calculated from the load terminal voltages (v_{La}, v_{Lb}, v_{Lc})

$$V_L = \sqrt{\frac{2}{3}(v_{La}^2 + v_{Lb}^2 + v_{Lc}^2)}$$

- Then, a PI controller is used to regulate this voltage to a reference value

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And from there AC amplitude of their from their amplitude of the AC load terminal voltage V_L is controlled and if compute is actually the V_L star. Output of the PI controller is considered as a voltage V_q to be injected by the DVR to compensate the voltage sag. So, amplitude of the AC voltage terminal V_L is calculated from the load terminal that is given by this equation. Then, PI controller is used to regulate the reference voltage value.

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SRF(Cont...)

- The reference quadrature-axis load voltage is

$$V_{Lq}^* = V_{qDC} + V_{qr}$$
- The reference direct-axis load voltage is

$$V_{Ld}^* = V_{dDC}$$
- The reference load voltage in the abc frame is obtained by reverse Park's transformation with V_{Ld}^* , V_{Lq}^* and V_{L0}^* as zero
- The reference load voltages (V_{La}^* , V_{Lb}^* , V_{Lc}^*) and the sensed load voltages (V_{La} , V_{Lb} , V_{Lc}) are used in a PWM controller to generate gating pulses to the VSC of the DVR.


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So, the SRF will have quadrature and the this component this is a quadrature component and this is a direct axis component. The reference load voltage in a b c frame is obtained reverse park transformation with $V_L d$ star V_q star and this actually the zero sequence component it is said to 0.

The reference load voltage $V_L a$, $V_L b$ and $V_L c$ and the sensed load voltage $V_L a$, $V_L b$ are used in a PWM control to generate the pulses both actually both the converter of the DVR as well as DSTATCOM.

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SRF(Cont...)

- The amplitude of AC load terminal voltage (V_L) is controlled to its reference voltage (V_L^*) using a PI controller
- The output of the PI controller is considered as the voltage (v_{qr}) to be injected by the DVR.
- The amplitude of AC load terminal voltage (V_L) is calculated from the load terminal voltages (v_{La} , v_{Lb} , v_{Lc})

$$V_L = \sqrt{\frac{2}{3}(v_{La}^2 + v_{Lb}^2 + v_{Lc}^2)}$$

- Then, a PI controller is used to regulate this voltage to a reference value

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So, similarly we shall have the PI controller. We should make this regulations and the output of the PI controller considering that we have a q r to be infected by a DVR and we can calculate what should be the amount of the q r present. And thus, we conclude to know our discussions on UPQC.

So, we have check the rating of the all the component and we have discussed how it can be designed by SRF technique; we have a different kind of control techniques same principle and theory will be followed and student are actually are actually considered that reference generation technique reference (Refer Time: 33:55) technique and compare them with any other control technique.

Thank you for attention; in next class we shall continue with the our UPFC operation.