

Power Quality
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Lecture - 14
Unified Power Quality Compensators (contd.)

Welcome to this course of Power Quality. [FL] We are discussing the numerical problem on UPQC.

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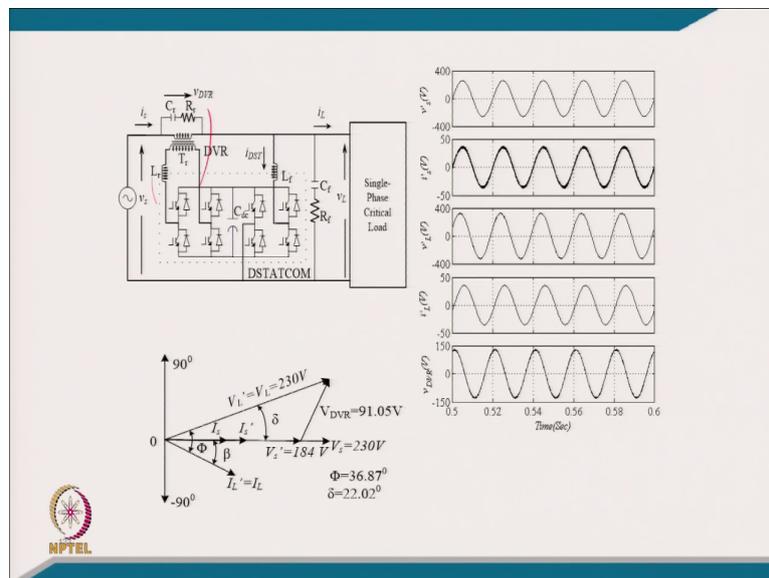


Q.9 A single-phase unified power quality compensator (UPQC consisting of DSTATCOM and DVR using two VSCs with common DC bus capacitor) is to be designed for a load compensation of 230 V, 50 Hz, 25A, 0.8 lagging power factor as a **Right Hand UPQC-S** (shown in Fig.). There is a **voltage sag of -20%** in supply system with base value of 230 V. Calculate (a) the voltage rating of DVR of UPQC-S, (b) the current rating DVR of UPQC-S, (c) the VA rating of DVR of UPQC-S, (d) the voltage rating of DSTATCOM of UPQC-S, (e) the current rating of DSTATCOM of UPQC-S, (f) the VA rating of DSTATCOM of UPQC-S, (g) total VA rating of UPQC-S to provide reactive power compensation for unity power factor at PCC with constant regulated voltage of 230 V at 50 Hz across the load. **Consider same power angle for equal reactive power sharing in both VSCs in steady state condition for unity power factor at AC mains without voltage sag condition.**

[FL] Coming to 9th numerical problem is single-phase UPQC consisting of DSTATCOM and DVR using two VSC with common DC bus capacitor is to be designed for load compensation of 230 volt, 50 hertz, 25 ampere, lagging power factor at a Right Hand UPQC-S. And there is a voltage sag of minus 20 percent in supply voltage with base value of 230 volt.

Calculate the voltage rating of DVR, current rating of DVR, VA rating of DVR, voltage rating of DSTATCOM, current rating of DSTATCOM, VA rating of DSTATCOM, to provide the reactive power compensation for unity power factor at PCC voltage with a constant voltage regulate across the load. Consider the same power angle for both reactive power sharing in both VSC in a steady state condition for unity power factor at AC mains without voltage sag condition.

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[FL] This is typically the Right Hand you [FL] we have a DSTATCOM on Right Hand side, and we have a DVR on Left Hand side. This is typically the phasor diagram for the condition which are given that we are putting a, this typically the angle same in both condition without sag and with sag. And these are the voltage wave form after making the model of this like.

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Solution: Given that, $V_s = 230$ V, $f = 50$ Hz, a load of 230 V, 50 Hz, 25 A, 0.8 lagging power factor. There is a voltage sag -20% in the supply system with base value of 230 V.

Under Steady State Condition for Unity Power Factor at ac Mains without Voltage Sag

The active power of the load is, $P_L = V_L \cdot I_L \cdot \text{pf} = 230 \cdot 25 \cdot 0.8 = 4600$ W.

The reactive power of the load is,
 $Q_L = V_L \cdot I_L \cdot \sqrt{1 - \text{pf}^2} = 230 \cdot 25 \cdot 0.6 = 3450$ VAR.

The supply current is as, $I_s = P_L / V_s = 4600 / 230 = 20$ A.

The power factor angle can be calculated as
 $\cos^{-1}(\text{pf}) = \cos^{-1}(0.8) = 36.86^\circ$.

In Right Hand UPQC-S, each VSC has reactive power rating equal to half of the reactive power of the load, which is equal to
 $Q_{\text{DST}} = Q_{\text{DVR}} = Q_L / 2 = 3450 / 2 = 1725$ VAR.

From the following relation of reactive power of DVR, the power angle is computed as.
 $Q_{\text{DVR}} = V_L I_s \sin \delta = 1725$, therefore, $\delta = 22.02^\circ$.



[FL] Coming to numerical part of this given that voltage 230 volt, 50 hertz at a load of 230 volt, 50 hertz, 25 ampere, 0.8 lagging power factor, there is a voltage sag of minus 20 percent in the supply system base value of 230 volt. [FL] Under a steady state condition for unity power factor AC mains without voltage sag the active power of load is typically of your $V I$, pf [FL] it comes 4600 watt.

And reactive power of the load is like your 230 into 25 into 0.6 – 3450 VAR. And the supply current is typically of typically power divide by the voltage 20 ampere. And power factor angle is 36.86. [FL] In the Right Hand UPQC-S each VSC have a reactive power rating equal to half of the reactive power of load which is equal to your reactive power, 340, 3450 by 2, [FL] it becomes like 1725 VAR. And from the following relation of reactive power of DVR,

the power angle computed is typically your from the VAR that comes delta equal to 22.02 degree.

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$$P_{DVR} = -V_L I_s (1 - \cos \delta) = -339.69 \text{ W.}$$

$$S_{DVR} = \sqrt{(Q_{DVR}^2 + P_{DVR}^2)} = 1758.12 \text{ VA,}$$

$$I_{DVRN} = I_s = 20 \text{ A, } V_{DVRN} = S_{DVR} / I_{DVRN} = 87.90 \text{ V.}$$

This -sign denotes that DVR absorbing this active power which is fed to dc bus and therefore, active power of DSTATCOM is as,

$P_{DST} = -P_{DVR} = 339.69 \text{ W.}$

The voltage rating of DSTATCOM of UPQC is equal to ac load voltage of $V_{DSTN} = 230 \text{ V,}$

The current rating of DSTATCOM of UPQC is computed as.

Therefore, angle between supply voltage and load current is as,

$\beta = \phi - \delta = 36.87^\circ - 22.02^\circ = 14.85^\circ$

Therefore, DSTATCOM current is as,

$$I_{DSTN} = I_L \sqrt{(1 + \cos^2 \phi - 2 \cos \beta \cos \phi)}$$

$$= 25 \sqrt{(1 + 0.8^2 - 2 * 0.8 * 0.967)} = 7.64 \text{ A}$$

[FL] P DVR from this angle calculation come 339.69; and S DVR is a Q DVR plus P DVR [FL] it comes 1758.12 angle. And I DVR equal to I s that is 20 ampere; and voltage DVR is typically S DVR divide by as we know calculated [FL] I DVR [FL] it is a comes 87.90. [FL] This minus sign denotes the DVR absorbing this active power which is fed to DC bus.

And therefore, active power of DSTATCOM is equal to p DSTATCOM P DVR equal 339.69. And the voltage rating of DSTATCOM, equal to the load voltage that is 230 volt and current rating of DSTATCOM, can be calculated from angle beta equal to phi minus delta, [FL] it comes like 14.85. [FL] DSTATCOM current can be calculated I L in terms of load current and power factor angle and beta angle, it comes 7.644 ampere like.

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The phase angle between DSTATCOM voltage and current can be calculated as,

$$P_{DST} = 339.69 \text{ W} = V_L I_{DSTN} \cos \phi_{DST}, \phi_{DST} = 79.02^\circ \text{ and}$$

$$Q_{DST} = V_L I_{DSTN} \sin \phi_{DST} = 1725 \text{ VAR}$$

$$S_{DST} = \sqrt{P_{DST}^2 + Q_{DST}^2} = 1758.12 \text{ VA.}$$

Voltage Sag Compensation by Right Hand UPQC-S

It means after the voltage supply voltage reduces to $V_s' = V_s (1 - X) = 230 \times (1 - 0.20) = 184 \text{ V}$. and $X = 0.2$, $K_0 = V_s / V_s' = 1.25$, $n_0 = 1 / K_0 = 0.8$.

The supply current is after the sag compensation is as,

$$I_s' = P_L / V_s' = 4600 / 184 = 25 \text{ A.}$$

In Right Hand UPQC-S, for same power angle $\delta = 22.02^\circ$, as above, the reactive power can be computed as,

$$Q_{DVR} = K_0 V_s' I_s' \sin \delta = (V_s / V_s') V_s' I_s' \sin \delta = 2155.85 \text{ VAR, for same power angle of } \delta = 22.02^\circ.$$

$$P_{DVR} = -K_0 V_s' I_s' (n_0 - \cos \delta)$$

$$= -(V_s / V_s') V_s' I_s' \{(V_s / V_s) - \cos \delta\} = 730.55 \text{ W.}$$


[FL] Phase angle between the DSTATCOM voltage and current can be calculated 339. P equal to 339.69 watt. And from this phi DST will be your phase angle will be 79.02 degree. And Q DST will be 1725 VAR, and S DST will be 1758.12. And voltage sag compensation of Right Hand UPQC will be equal to the V s dash equal to typically the sag it is a point typically 8, [FL] supply current after the sag compensation is your typically by active power 4600 divide by 184 because it is a unity power factor it comes like a 25 ampere.

And in Right Hand UPQC, the same power angle Q equal to 20 22.02 degree. And from the above relation the power can be calculated of Q DVR equal to from this relation [FL] putting the value it comes 2155.85 VAR. The angle power angle is of 22.22. [FL] We can calculate the power DVR equal to from this relation, [FL] it comes 730.55 watt.

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(a) The voltage rating of the DVR is as,
 $V_{DVR} = V_L \sqrt{\{1+n_0^2 - 2n_0 \cos \delta\}} = 230 \sqrt{\{1+0.8^2 - 2*0.8*\cos 22.02^\circ\}}$
 $= 91.05 \text{ V.}$

(b) The current rating of the DVR is as,
The supply current is after the sag compensation is as,
 $I_{DVR} = I_s = P_L / V_s = 4600 / 184 = 25 \text{ A.}$

(c) The VA rating of the DVR is as,
 $S_{DVR} = V_{DVR} * I_{DVR} = 91.05 * 25 = 2276.27 \text{ VA.}$
Active power of DSTATCOM is as, $P_{DST} = - P_{DVR} = - 730.55 \text{ W.}$

(d) The voltage rating of DSTATCOM of UPQC is equal to ac load voltage of $V_{DST} = 230 \text{ V,}$

(e) The current rating of DSTATCOM of UPQC is computed as.
Therefore, angle between supply voltage and load current is as,
 $\beta = \phi - \delta = 36.87^\circ - 22.02^\circ = 14.85^\circ.$
Therefore, DSTATCOM current is as,
 $I_{DST} = I_L \sqrt{\{(1+K_0^2 \cos^2 \phi) - 2K_0 \cos \beta \cos \phi\}}$
 $= 25 \sqrt{\{1+1.25^2*0.8^2 - 2*1.25*0.8*0.967\}} = 6.46 \text{ A}$



The voltage rating of the DVR is equal to typically from the load voltage and from these factors [FL], it comes 91.05 volt. And current rating of DVR from this voltage sag compensation will be your power divide by your voltage, [FL] it comes 25 ampere. And VA rating of DVR is your voltage multiply current [FL] it comes 2276.27 VA, and active power DSTATCOM is equal to 730.55 watt.

And the voltage rating of DSTATCOM, equal to the typically is a 230 volt. And the current rating of DSTATCOM is computed equal to beta equal to phi minus delta that is 14.85. [FL] DSTATCOM current rating comes from this relation, it comes typically putting a value 6.46 ampere.

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The phase angle between DSTATCOM voltage and current can be calculated as,
 $P_{DST} = -730.55 \text{ W} = V_L I_{DST} \cos \theta_{DST}$, $\theta_{DST} = 119.5^\circ$ and
 $Q_{DST} = V_L I_{DST} \sin \theta_{DST} = 1293.88 \text{ VA}$.

(f) The VA rating of VSC of DSTATCOM of UPQC,
 $S_{DST} = V_{DST} I_{DST} = 230 \times 6.46 \text{ VA} = 1485.88 \text{ VA}$.
The VA rating of UPQCS during voltage sag is as,
 $S_{UPQCS(\text{under sag})} = S_{DST} + S_{DVR} = 1485.88 + 2276.27 = 3762.15 \text{ VA}$.
Hence considering an overall rating (both normal and under voltage sag), ratings of both compensators are as,
 $V_{DVR} = 91.05 \text{ V}$, $I_{DVR} = 25 \text{ A}$,
 $S_{DVR} = V_{DVR} I_{DVR} = 91.05 \times 25 = 2276 \text{ VA}$.
 $V_{DST} = 230 \text{ V}$, $I_{DST} = 7.64 \text{ A}$,
 $S_{DST} = V_{DST} I_{DST} = 230 \times 7.64 = 1757.2 \text{ VA}$.

(g) The overall VA rating of UPQC-S is as,
 $S_{UPQCS} = S_{DST} + S_{DVR} = 1757.2 + 2276.27 = 4033.47 \text{ VA}$.



[FL] Phase angle between DSTATCOM voltage and current can be calculated from the active power. And from reactive power that comes from active power phi DST equal to eleven point 119.5 degree. And from which we can calculate now Q DST 1293.88 from putting this relation here.

And VA rating of VSC of DSTATCOM is equal to VST DST [FL] 230 into 6.46, [FL] it comes 1485.88 VA. And voltage VA rating of the UPQC during voltage sag composition is the your S UPQC equal to S DST plus S DVR, [FL] it is virtually 1485.88 plus 2276.27, [FL] it come 3762.15VA. [FL]

Hence considering the overall rating both normal and under voltage sag, the rating of both compensator are V DVR equal to 91.05, I DVR equal 25 ampere. And S DVR, V DVR, I DVR [FL] putting the value voltage and current, it comes to 2276 VA. And V DSTATCOM

is 230 volt, and current is 7.6, [FL] S DST will be your 1757.22. And overall VA rating of the UPQC-S will be your DSTATCOM rating plus DVR rating that is 1757.2 plus 2276.27, [FL] it comes 4033.47 VA.

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Q.10 A single-phase unified power quality compensator (UPQC consisting of DSTATCOM and DVR using two VSCs with common dc bus capacitor) is to be designed for a load compensation of 230 V, 50 Hz, 25A, 0.8 lagging power factor as a **Left Hand UPQC-S** (shown in Fig.). There is a **voltage sag of -20%** in supply system with base value of 230 V. Calculate (a) the voltage rating of DVR of UPQC-S, (b) the current rating DVR of UPQC-S, (c) the VA rating of DVR of UPQC-S, (d) the voltage rating of DSTATCOM of UPQC-S, (e) the current rating of DSTATCOM of UPQC-S, (f) the VA rating of DSTATCOM of UPQC-S, (g) total VA rating of UPQC-S to provide reactive power compensation for unity power factor at PCC with constant regulated voltage of 230 V at 50 Hz across the load. Consider same power angle for equal reactive power sharing in both VSCs in steady state condition for unity power factor at ac mains without voltage sag condition.

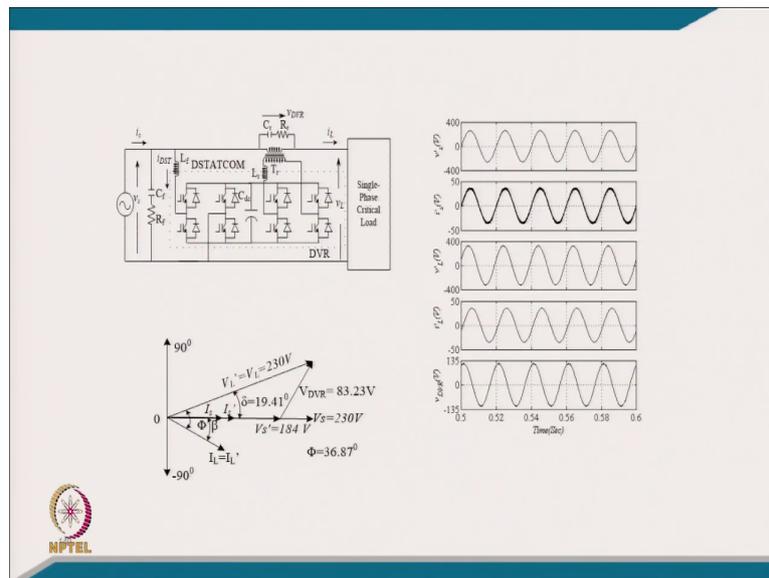
Coming to the 10th numerical problem, a single-phase UPQC consisting of your DSTATCOM and DVR using two VSC with common DC bus capacitor is designed for a load compensation of 230 volt, 50 hertz, 25 ampere, 0.8 lagging power factor as a Left Hand UPQC-S. There is a voltage sag of minus 20 percent in the supply system with the base value of 230 volt.

Calculate the voltage rating of DVR, the current rating of DVR, VA rating of DVR, voltage rating of DSTATCOM, current rating of DSTATCOM, and VA rating of DSTATCOM, [FL]

total VA rating of UPQC-S to provide reactive power compensation for unity power factor at PCC with constant voltage regulate at 230 volt, 50 hertz across the load.

Consider the same power angle for equal reactive power sharing in both VSC in a steady state condition at for unity power factor AC mains without voltage without voltage sag condition.

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[FL] This is typically we can call it is a Left Hand UPQC. [FL] This is the circuit of Left Hand UPQC where DVR is on the right side. This is a phase diagram for a given condition. And these are the typical waveform.

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Solution: Given that, $V_s = 230$ V, $f=50$ Hz, a load of 230 V, 50 Hz, 25A, 0.8 lagging power factor. There is a voltage sag -20% in the supply system with base value of 230 V. Both VSCs are of same ratings.

It means after the voltage supply reduces to $V_s=230*(1 - 0.20) = 184$ V, and $X=0.2$.

Under Steady State Condition for Unity Power Factor at ac Mains without Voltage Sag Compensation

The active power of the load is,
 $P_L = V_L * I_L * pf = 230 * 25 * 0.8 = 4600$ W.

The reactive power of the load is,
 $Q_L = V_L * I_L * \sqrt{1 - pf^2} = 230 * 25 * 0.6 = 3450$ VAR.

The supply current is as, $I_s = P_L / V_s = 4600 / 230 = 20$ A.

In Left Hand UPQC-S, each VSC has reactive power rating equal to half of the reactive power of the load, which is equal to
 $Q_{DST} = Q_{DVR} = Q_L / 2 = 3450 / 2 = 1725$ VAR.



Then coming to the numerical solution. Given that is the V equal 230 volt, 50 hertz, load of 230 volt, 50 hertz to 25 ampere, point lagging power factor load. There is a voltage sag of 20 degree, 20 percent in the supply system with base voltage of 230 volt. Both VSC have a same rating.

[FL] It means that after the after the voltage supply reduces to 230 with a sag of 20 percent 184, and X is 0.2 that is the typically the level of sag compensation. [FL] Under a steady state condition for unity power factor AC mains without voltage Sag compensation with the active power V I I L [FL] that is virtually putting a value, it comes 4600 watt.

And the reactive power of the load comes from this 3450 VAR, and supply current from power and voltage because power factor unity on supply side after compensation, [FL] it comes 20 ampere. And in the Left Hand UPQC each VSC have a reactive power rating equal

to half of the reactive power of the load which is equal to your Q_L upon by 2, [FL] it comes a 1725 VAR.

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From the following relation of reactive power of DSTATCOM, the power angle can be computed as.
 The reactive power DSTATCOM is as,
 $Q_{DST} = V_s I_L \sin \beta = 1725 \text{ VAR}$,
 $\beta = 17.46^\circ$, $\delta = \phi - \beta = 36.87^\circ - 17.46^\circ = 19.41^\circ$.
 The active power DSTATCOM is as,
 $P_{DST} = V_s I_s - V_s I_L \cos \beta = 4600 - 5485.15 = -885.15 \text{ W}$.
 The current of DSTATCOM is as,
 $I_{DSTN} = S_{DST} / V_{DSTN} = (\sqrt{P_{DST}^2 + Q_{DST}^2}) / V_{DSTN} = 8.43 \text{ A}$.
 $\phi_{DST} = \cos^{-1}(P_{DST} / (V_{DSTN} * I_{DSTN})) = 117.22^\circ$.
 $S_{DST} = V_{DSTN} * I_{DSTN} = V_s * I_{DSTN} = 230 * 8.43 = 1938.90 \text{ VA}$.
 This -sign denotes that Dstatcom absorbing this active power which is fed to dc bus and therefore, active power of DVR is as,
 $P_{DVR} = - P_{DST} = 885.15 \text{ W}$.
 The current rating of DVR of UPQC-S is equal to ac load current of $I_{DVR} = I_L = 25 \text{ A}$,



[FL] From the following relation of the reactive power of DSTATCOM, the power angle can be computed. [FL] Reactive power of DSTATCOM is Q_{DST} equal to $V_L \sin \beta$, [FL] it comes one point 1725, now where beta can be calculated 17.46 degree. And from which once you know already phi power factor angle and beta angle there, [FL] delta can be calculated, [FL] it comes 19.41 degree.

The active power DSTATCOM from this now can be calculated from this relation it comes 885.15 watt. And current rating of DSTATCOM, can be calculated from VA rating of DSTATCOM divide by voltage rating [FL] this will be $P^2 + Q^2$ [FL] divided

by it come 8.43 ampere. And typically the angle of DSTATCOM I mean becomes 117.22 from this relation from power and VA rating.

And the DSTATCOM VA rating comes like your current multiplied the voltage, it comes 1938.9 VA. And minus sign denotes that the DSTATCOM absorbing this active power which fed to the DC bus. Therefore, active power of this your DVR is as P DST equal to 885.15 watt. And current rating of DVR of UPQC equal to the AC load current of 25 ampere.

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The voltage rating DVR of UPQC is computed as.

$$V_{DVRN} = S_{DVR} / I_{DVRN} = 1938.90 / 25 = 77.56 \text{ V.}$$

$$Q_{DVR} = V_{DVRN} \cdot I_{DVRN} \cdot \sin \phi_{DVR} = 1725 \text{ VAR, } \phi_{DVR} = 62.79^\circ.$$

$$P_{DVR} = -P_{DST} = 885.15 \text{ W.}$$

$$S_{DVR} = \sqrt{(P_{DVR}^2 + Q_{DVR}^2)} = 1938.95 \text{ VA.}$$

Voltage Sag Compensation by Left Hand UPQC-S

It means after the voltage supply voltage reduces to $V_s' = V_s \cdot (1-X) = 230 \cdot (1 - 0.20) = 184 \text{ V.}$ and $X = 0.2,$

$$K_0 = V_s / V_s' = 1.25, n_0 = 1 / K_0 = 0.8.$$

The supply current after the sag compensation is as,

$$I_s' = P_L / V_s' = 4600 / 184 = 25 \text{ A.}$$

(a) $V_{DST} = V_s' = 230 \cdot (1 - 0.2) = 184 \text{ V.}$

Under the voltage sag, the same power angle, $19.41^\circ,$ from following relation of reactive power of DSTATCOM can be computed as. $\delta = \phi - \beta = 36.87^\circ - 17.46^\circ = 19.41^\circ.$

$$Q_{DST} = V_s' \cdot I_s' \cdot \sin \beta = n_0 V_s I_s \sin \beta = 1380 \text{ VAR, for same power angle of } \delta = 19.41^\circ \text{ and } \beta = 17.46^\circ.$$

$$P_{DST} = V_s' I_s' - V_s' I_s' \cos \beta = 4600 - 4388.06 = 211.94 \text{ W.}$$


The voltage rating of DVR of UPQC is computed as your VA rating of DVR divide by current. [FL] This is the VA rating divide by current is 77.56 volt. And Q DVR will be equal to from this relation, it comes like a 1725 VAR with the angle of 62.79. And P from which you can calculate the power is same [FL] 885.15.

And S DVR will be under root $P^2 + Q^2$, they will become 1938.95. And voltage, voltage sag compensation by Left Hand QC, after the voltage sag it means after the voltage sag supply voltage reduces by 20 percent, [FL] it becomes like 184 with X equal 0.2. And K is calculated for the depth is the $1 / (0.8 + 1.25K)$, and edge equal to $1 / (K + 0.8)$.

[FL] Supply current after the sag compensation is your I s equal to P / V , [FL] it comes 25 ampere. And V DSTATCOM again comes because its Left Hand and it is a 184. [FL] Under the voltage sag condition, the same power angle from 91.41 from the following relation of reactive power DSTATCOM can be computed. [FL] Delta equal to phi [FL] that comes 19.41.

And from this Q, I mean Q DST can be calculated from this angle, [FL] it comes 1380. [FL] You can calculate the delta as well as beta comes 17.46 like. And power for DSTATCOM from this relation equal to 211.94.

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$\theta_{DST} = \cos^{-1}(P_{DST}/(V_{DST} \cdot I_{DST})) = 81.31^\circ$
(b) The current of DSTATCOM is computed as,
 $I_{DST} = P_{DST}/(V_{DST} \cdot \cos \theta_{DST}) = 7.59 \text{ A}$
(c) The VA rating of the DSTATCOM is computed as,
 $S_{DST} = V_{DST} \cdot I_{DST} = V_S \cdot I_{DST} = 184 \cdot 7.59 = 1396.37 \text{ VA}$
The rating of DVR is computed from the common relations of DSTATCOM and DVR as.
Active power of DVR is as, $P_{DVR} = -P_{DST} = -211.94 \text{ W}$
(d) The current rating of DVR of UPQC-S is equal to ac load current of $I_{DVR} = I_L = 25 \text{ A}$.
(e) The voltage rating DVR of UPQC is computed as.
The remaining reactive power of the load (which not supplied by DSTATCOM) has to be supplied by DVR, which is computed as,
 $Q_{DVR} = 3450 - 1380 = 2070 \text{ VAR}$
 $S_{DVR} = \sqrt{(P_{DVR})^2 + (Q_{DVR})^2} = 2080.64 \text{ VA}$
 $V_{DVR} = S_{DVR}/I_{DVR} = 2080.64/25 = 83.23 \text{ V}$

And your phi DST will be comes from power divide by V I [FL] that is cos inverse of this [FL] 81.31 degree. And the current rating of DSTATCOM can be computed from power V and typically this relation from active power [FL] 7.59 ampere; and VA rating of DSTATCOM computed from V DST, I DST, [FL] it comes like typically from 1396.37 volt ampere.

[FL] rating of the DVR is computed from the common relation of DSTATCOM and DVR. And active power of DVR is your DSTATCOM equal to DVR equal to 211.94 watt. And current rating of DVR, UPQC equal to the AC load current of 25 ampere. And the voltage rating of DVR is computed as typically the remaining reactive power of the load not supplied by the DSTATCOM has to be supplied by DVR will be computed here typically from this 3450 that it total load reactive power.

And this is by DSTATCOM [FL] it the D VAR have to supply the 2070 VAR. And you can find out the DVR VA rating under root P square Q square, [FL] it comes 2080 VA. And V DVR from this form S and current can be calculated, [FL] it comes 83.23 volt.

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(f) The VA rating of DVR is computed as.
 $S_{DVR} = \sqrt{(P_{DVR}^2 + Q_{DVR}^2)} = 2080.64 \text{ VA}$.
 The VA rating of UPQCS during voltage sag is as,
 $S_{UPQCS(\text{under sag})} = S_{DST} + S_{DVR} = 1396.37 + 2080.64 = 3477.01 \text{ VA}$.
 Hence considering overall ratings (both normal and under voltage sag), ratings of both compensators are as,
 $V_{DVR} = 83.23 \text{ V}$, $I_{DVR} = 25 \text{ A}$,
 $S_{DVR} = V_{DVR} * I_{DVR} = 83.23 * 25 = 2080.75 \text{ VA}$.
 $V_{DST} = 230 \text{ V}$, $I_{DST} = 8.43 \text{ A}$, $S_{DST} = V_{DST} * I_{DST} = 230 * 8.49 = 1938.9 \text{ VA}$.
 (g) The VA rating of UPQC-S,
 $S_{UPQC-S} = S_{DST} + S_{DVR} = 1938.9 + 2080.75 = 4019.55 \text{ VA}$
 However in case of same inventory for both the inverters the VA rating of both the power converters is as,
 $S_{DST} = S_{DVR} = 2080.75 \text{ VA}$.
 Hence overall rating under same inventory for inverters is given as,
 $S_{UPQC-S} = S_{DST} + S_{DVR} = 2080.75 + 2080.75 = 4161.5 \text{ VA}$.



And the VA rating of DVR comes from typically P square plus Q square under root, [FL] it is 2080.64. And VA rating of UPQC will be this during the sag will be your DSTATCOM VA rating and VAR voltage rating, it comes totally 3477.01 VA. Hence considering overall rating both under this the rating of both compensator are V DVR equal to 83.23, and I DVR 25 ampere, and S DVR equal to giving the value it comes to 2080.75 VA.

And voltage of DSTATCOM current of DSTATCOM [FL] it comes like a typically 1938.9 VA. And the overall VA rating of UPQC come sum of the both, [FL] it is 4019.55 VA. However, in case of the same inventory for both the inverter same, [FL] power converter can

be of the same rating of S DST equal to as we have 2080.75. Hence overall rating of this equal to the sum of both, [FL] it become 4161.5.

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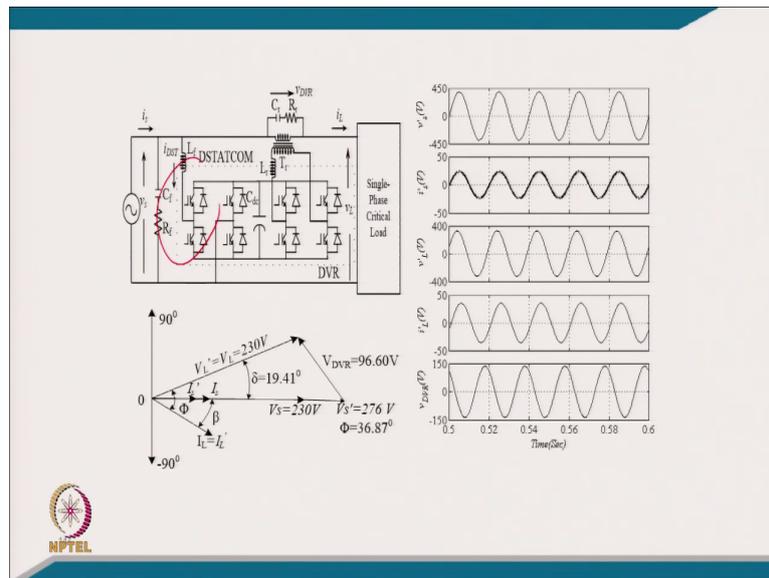
Q.11 A single-phase unified power quality compensator (UPQC consisting of DSTATCOM and DVR using two VSCs with common dc bus capacitor) is to be designed for a load compensation of 230 V, 50 Hz, 25A, 0.8 lagging power factor as a **Left Hand UPQC-S** (shown in Fig.). There is a **voltage swell of +20%** in supply system with base value of 230 V. Calculate (a) the voltage rating of DVR of UPQC-S, (b) the current rating DVR of UPQC-S, (c) the VA rating of DVR of UPQC-S, (d) the voltage rating of DSTATCOM of UPQC-S, (e) the current rating of DSTATCOM of UPQC-S, (f) the VA rating of DSTATCOM of UPQC-S, (g) total VA rating of UPQC-S to provide reactive power compensation for unity power factor at PCC with constant regulated voltage of 230 V at 50 Hz across the load. **Consider same power angle for equal reactive power sharing in both VSCs in steady state condition for unity power factor at ac mains without voltage swell condition.**

Coming to the numerical example 11, a single-phase UPQC consisting of DSTATCOM DVR in two VSCs with common DC bus capacitor is to be designed for a load compensation of 230 volt, 50 hertz, the as a Left Hand UPQC. [FL] There is voltage sag swell of 20 percent in the supply system with the base value of 230 volt.

Calculate the voltage rating of DVR of UPQC, current rating of UPQC, VA rating of DVR, voltage rating of the DSTATCOM, current rating of DSTATCOM, and VA rating of DSTATCOM, and VA rating of UPQC to provide the reactive power compensation for unity power factor at PCC and constant voltage regulated of 230 50 hertz across the load.

Consider the same power angle for equal reactive power sharing in both VSC in a steady state condition for unity power factor AC mains without voltage swell condition like.

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[FL] that is typically Left Hand UPQC because DSTATCOM on left side and VAR on right side. And this is the phase diagram corresponding to this for this swell typically condition. And this is typically the waveform corresponding to that.

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Solution: Given that, $V_s = 230$ V, $f=50$ Hz, a load of 230 V, 50 Hz, 25A, 0.8 lagging power factor. There is a voltage swell +20% in the supply system with base value of 230 V.

Under Steady State Condition without Voltage Swell

The active power of the load is, $P_L = V_L \cdot I_L \cdot \text{pf} = 230 \cdot 25 \cdot 0.8 = 4600$ W.

The reactive power of the load is,
 $Q_L = V_L \cdot I_L \cdot \sqrt{1 - \text{pf}^2} = 230 \cdot 25 \cdot 0.6 = 3450$ VAR.

The supply current is as, $I_s = P_L / V_s = 4600 / 230 = 20$ A.

In Left Hand UPQC-S, each VSC has reactive power rating equal to half of the reactive power of the load, which is equal to $Q_{\text{DST}} = Q_{\text{DVR}} = Q_L / 2 = 3450 / 2 = 1725$ VAR.

From the following relation of reactive power of DSTATCOM, the power angle can be computed as.

The reactive power DSTATCOM is as, $Q_{\text{DST}} = V_s I_s \sin \beta = 1725$ VAR,
 $\beta = 17.46^\circ$, $\delta = \theta - \beta = 36.87^\circ - 17.46^\circ = 19.41^\circ$.

The active power DSTATCOM is as, $P_{\text{DST}} = V_s I_s - V_s I_L \cos \beta$
 $= 4600 - 5485.15 = -885.15$ W.



[FL] coming to the numerical portion given that 230 volt, 50 hertz, a load of 20 volt, 50 hertz, 25 ampere, 0.8 lagging power factor. There is a voltage swell of 20 percent in the supply system this with the base value of 230 volt. [FL] Under coming to steady state condition without voltage swell, the active power of load is $V_L I_L$ into computing a value, it come 4600 watt. And reactive power of the load will be like corresponding to $V_L I_L$ under root 1 minus power factor square [FL] it putting the value, it come 3450 VAR. And supply current equal to I_s equal to P_L upon V_s that is 4600 power 230 that is 20 ampere.

In the Left Hand UPQCs, each VSC have a reactive power rating equal to half of the reactive which is equal to the Q_L upon 2 equal to 3450 divide by 2, it comes like a 1725 VAR. And from the following relation of the phase angle can be calculated, [FL] reactive power of this equal to the from this [FL] we can calculate the value of beta equal to 17.46, phi equal to 7,

19.41. The active power of DSTATCOM equal to from this calculation, we get the 885.15 watt

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The current of DSTATCOM is as, $I_{DSTN} = \frac{S_{DST}}{V_{DSTN}} = \frac{\sqrt{P_{DST}^2 + Q_{DST}^2}}{V_{DSTN}} = 8.43 \text{ A}$.
 $\phi_{DST} = \cos^{-1} \left(\frac{P_{DST}}{V_{DSTN} * I_{DSTN}} \right) = 117.22^\circ$ and
 $S_{DST} = V_{DSTN} * I_{DSTN} = V_S * I_{DSTN} = 230 * 8.43 = 1938.90 \text{ VA}$.
 This -sign denotes that DSTATCOM absorbing this active power which is fed to dc bus and therefore, active power of DVR is as, $P_{DVR} = - P_{DST} = 885.15 \text{ W}$.
 The current rating of DVR of UPQC-S is equal to ac load current of $I_{DVR} = I_L = 25 \text{ A}$.
 The voltage rating DVR of UPQC is computed as,
 $V_{DVRN} = \frac{S_{DVR}}{I_{DVRN}} = \frac{1938.90}{25} = 77.56 \text{ V}$.
 $Q_{DVR} = V_{DVRN} * I_{DVRN} * \sin \phi_{DVR} = 1725 \text{ VAR}$, $\phi_{DVR} = 62.79^\circ$ and
 $P_{DVR} = - P_{DST} = 885.15 \text{ W}$.
 $S_{DVR} = \sqrt{P_{DVR}^2 + Q_{DVR}^2} = 1938.95 \text{ VA}$, which is same as DSTATCOM rating.

[FL] current rating of the DSTATCOM from this relation by putting the value, it comes like 8.43 ampere. And the angle of DSTATCOM virtually comes 117.22 degree, and the VA rating of DSTATCOM from one this relation 1938.9VA. And minus sign denotes that the DSTATCOM absorbing this active power which is fed by DC. Therefore, active power of DVR is same as the DSTATCOM that is 885.15.

And current rating of DVR, is equal to 25 ampere. And the voltage rating of DVR is computed from here, it comes like a VA rating divided by current, [FL] it is a 77.56. And the Q I mean reactive power rating of DVR as 1725 [FL] phi DVR equal to 6.79, and P DVR

from 885 [FL] S DVR comes from this [FL] it comes 1938 which is same as the DSTATCOM rating.

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Voltage Swell Compensation by Left Hand UPQC-S
 It means after swell the supply voltage increases to
 $V_s' = V_s(1+X) = 230*(1+0.20) = 276 \text{ V}$. and $X = 0.2$,
 $K_0 = V_s/V_s' = 1/(1+X) = 1/1.2 = 0.8333$,
 $n_0 = 1/K_0 = 1+X = 1+0.2 = 1.2$.
 The supply current after the swell compensation is as,
 $I_s = P_L/V_s' = 4600/276 = 16.67 \text{ A}$.
 (a) Since DSTATCOM is connected across ac mains so voltage rating of DSTATCOM is same as ac mains voltage as, $V_{DST} = V_s' = V_s(1+X) = 230*(1+0.2) = 276 \text{ V}$.
 Under the voltage swell, the same power angle of 19.41° , from following relation of reactive power of DSTATCOM, can be computed as.
 $Q_{DST} = V_s' I_s' \sin \beta = n_0 V_s' I_s' \sin \beta = 2070.27 \text{ VAR}$, $\beta = 17.46^\circ$, $\delta = 0^\circ$ -
 $\beta = 36.87^\circ - 17.46^\circ = 19.41^\circ$
 $P_{DST} = V_s' I_s' - V_s' I_s' \cos \beta = 4600 - 6582.09 = -1982.09 \text{ W}$ and
 $S_{DST} = \sqrt{(P_{DST}^2 + Q_{DST}^2)} = \sqrt{(1982.09^2 + 2070.27^2)} = 2866.13 \text{ VA}$.



[FL] volt coming to voltage sag compensation by now typically of Left Hand UPQC-S means after voltage or supply voltage increases to like 230 into point 1.2, [FL] it is 176, 276 volt. With this and the you can calculate the K 0 that is comes typically 0.833 and it comes 1.2. [FL] supply current after the swell compensation is typically 4600 divide by 276, [FL] it is a 16.67 on supply side. And since the DSTATCOM is connected AC mains so the voltage of DSTATCOM is same as the AC voltage [FL] that is typically 276 volt.

Under the voltage swell condition, the same power angle of 19.41 from following relation of the reactive power of DSTATCOM can be computed. [FL] Q DST equal to Q DST equal to DSTATCOM rating I mean from this relation, it comes typically like a 2070, and from which

beta it calculates 17.46, and delta say 30 typically 19.41. And the power of DSTATCOM from this relation 1982.09 watt, and SD S DST under it becomes a P DST plus Q DST under root of that putting a value it comes 2866.13 VA.

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(b) The current of DSATCOM is computed as,
 $I_{DST} = S_{DST} / V_{DST} = 10.384 \text{ A}$.
 $\theta_{DST} = \cos^{-1}(P_{DST} / (V_{DST} * I_{DST})) = 133.75^\circ$.

(c) The VA rating of the DSATCOM is computed as,
 $S_{DST} = V_{DST} * I_{DST} = V_S * I_{DST} = 276 * 10.384 = 2866.13 \text{ VA}$.
 The rating of DVR is computed from the common relations of DSATCOM and DVR as.
 Active power of DVR is as, $P_{DVR} = - P_{DST} = 1982.09 \text{ W}$.

(d) The current rating of DVR of UPQC-S is equal to ac load current of $I_{DVR} = I_L = 25 \text{ A}$,

(e) The voltage rating DVR of UPQC is computed as.
 The remaining reactive power (not supplied by DSTATCOM) of load must be supplied by DVR is computed as,
 $Q_{DVR} = 3450 - 2070.27 = 1379.72 \text{ VAR}$,
 $P_{DVR} = - P_{DST} = 1982.09 \text{ W}$ and
 $S_{DVR} = \sqrt{(P_{DVR}^2 + Q_{DVR}^2)} = 2415 \text{ VA}$.
 $V_{DVR} = S_{DVR} / I_{DVR} = 2415.02 / 25 = 96.60 \text{ V}$.

[FL] coming to current rating of the VA, [FL] we now VA rating divide by voltage [FL] it come 10.384. And the angle of DSTATCOM comes from this relation 133.75, and VA rating of DSTATCOM is your DST it comes like typically 288, 2866.13. And the rating of DVR is computed from common relation of DSTATCOM DVR, [FL] it is a power is active power both because whatever power DVR taking DSTATCOM have to be [FL], it comes 1982.08.

And the current rating of DVR for equal is to AC load, it is a 25 ampere. And the voltage rating of DVR of UPQC computed as the remaining reactive power not supplied by this term supply from DVR [FL] Q DVR equal to the difference of it. It comes 1379.2. And P

DSTATCOM, this is same that is 1982.09. [FL] S DVR will be equal to square root of both 25, 2415 VA. And V DVR from S DVR by I DVR, it comes like nine six 96.06, 90 point, 96.6 volt. [FL]

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(f) The VA rating of DVR is computed as,
 $Q_{DVR} = 3450 - 2070.27 = 1379.72 \text{ VAR.}$
 $P_{DVR} = -P_{DST} = 1982.09 \text{ W and}$
 $S_{DVR} = \sqrt{(P_{DVR}^2 + Q_{DVR}^2)} = 2415 \text{ VA.}$
 The VA rating of UPQC-S during voltage swell is as,
 $S_{UPQCS(\text{under swell})} = S_{DST} + S_{DVR} = 2866.13 + 2415 = 5281.18 \text{ VA.}$
 Hence considering overall rating (both normal and under voltage swell), ratings of both compensators are as,
 $V_{DVR} = 96.60 \text{ V, } I_{DVR} = 25 \text{ A,}$
 $S_{DVR} = V_{DVR} * I_{DVR} = 96.6 * 25 = 2415 \text{ VA.}$
 $V_{DST} = 276 \text{ V, } I_{DST} = 10.38 \text{ A,}$
 $S_{DST} = V_{DST} * I_{DST} = 276 * 10.38 = 2866.13 \text{ VA.}$
 (g) The VA rating of LH-UPQC-S is as,
 $S_{UPQC-S} = S_{DST} + S_{DVR} = 2866.13 + 2415 = 5281.18 \text{ VA.}$



VA rating of the DVR comes like a VAR of the load minus the DSTATCOM reactive power that come 1379 VAR. And P DVR DVR both are same as 1882.09. And S DVR is a now from this relation comes 2415. And VA rating of UP as per voltage swell condition comes sum of the both VA, [FL] adding this [FL] it comes 5281.18.

Hence considering overall rating both normal and rating of both compensator typically are [FL] V DVR 96.6, I DVR 25 ampere, [FL] S DVR will be your 2415. And V DST is 276, I DST is 10.36. Putting the value, it comes 2686.13. [FL] Total rating is the sum of both VA rating, it comes 5281.18 VA.

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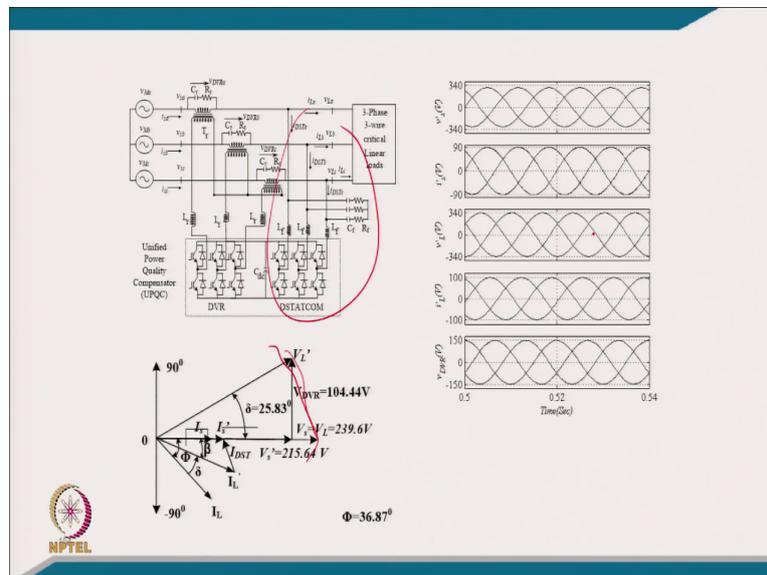
Q.12 A three-phase supply with ac line voltage output of 415 V rms at 50 Hz is feeding a critical linear load of 50 kVA, 415 V, 50 Hz at 0.8 lagging pf. A voltage sag of -10% occurs in the supply voltage at PCC. Design a three-phase unified power quality compensator (UPQC consisting of DSTATCOM and DVR using two VSCs with common dc bus capacitor) in this system to compensate the pf of the load to unity at ac mains and mitigation of the voltage sag to avoid the interruption to the load. If two three-phase VSCs are used as a **Right Hand UPQC-Q** (shown in Fig.), calculate (a) the voltage rating of DVR of UPQC-Q, (b) the current rating DVR of UPQC-Q, (c) the VA rating of DVR of UPQC-Q, (d) the voltage rating of DSTATCOM of UPQC-Q, (e) the current rating of DSTATCOM of UPQC-Q, (f) the VA rating of DSTATCOM of UPQC-Q, (g) total VA rating of UPQC-Q to provide reactive power compensation for unity power factor at ac mains with constant regulated voltage of 415 V at 50 Hz.



Coming to numerical problems 12, a three-phase supply with AC line voltage of 415 rms 50 hertz is feeding the critical load of 50 k VA, 415 volt, 50 hertz at 0.8 lagging power factor. The voltage sag of 10 percent occurs in the supply voltage at PCC. Design a three-phase UPQC consisting of DSTATCOM and DVR with the common DC bus capacitor in the system to compensate the power factor of the load to unity and at AC mains and mitigation of the voltage sag to avoid the interruption of the load.

[FL] if two three-phase VSCs are used as a Right Hand UPQC, calculate the voltage rating of the DVR, current rating of the DVR, VA rating of the DVR, voltage rating of the DSTATCOM, current rating of DSTATCOM, and VA rating of DSTATCOM, in VA rating of total UPQC Q to provide the reactive power compensation for unity power factor AC main with constant voltage of 415 volt, 50 hertz in three-phase.

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So, this is you can call it the Right Hand UPQC. [FL] DSTATCOM on right side DVR on left side. And this is typical because its UPQC [FL] we have to add per phase these are per phase phasor diagram [FL] we have to add the voltage to bring this both voltage equal I mean, [FL] so that both voltage are equal. And this is typically you can call it source voltage I mean because sag, but grid current and the typically the low voltage load current and the DVR voltage to be injected.

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Solution: Given that, $V_{sl} = 415$ V, $f=50$ Hz, a load of 415 V, 50 Hz, 50 kVA, 0.8 lagging power factor. There is voltage sag of -10% in supply system with base value of 415 V.

Operation of UPQC-Q under Nominal Grid Condition

Under nominal grid condition, the DVR of UPQC-Q injects zero voltage same as single-phase case. However the DSTATCOM injects current in the quadrature to the load voltage for compensation of reactive power of the load.

$V_{sp} = V_{sl}/\sqrt{3} = 415/\sqrt{3} = 239.6$ V, $V_{Lp} = V_L/\sqrt{3} = 415/\sqrt{3} = 239.6$ V.

The active power of the load is,
 $P_L = 3 * V_{Lp} * I_{Lp} * pf = 50000 * 0.8 = 40$ kW.

The reactive power of the load is,
 $Q_L = 3 * V_{Lp} * I_{Lp} * \sqrt{1 - pf^2} = 50000 * 0.6 = 30$ kVAR.

The supply current before any voltage sag is as,
 $I_s = I_{DVRN} = P_L / (3 * V_{sp}) = 40000 / (3 * 239.6) = 55.64$ A.

The current supplied by DSTATCOM can be calculated as
 $I_{DSTN} = Q_L / (3 * V_{Lp}) = 41.73$ A.



[FL] Given the condition that supply voltage is 415 volt, 50 hertz, and load of 415, 50 hertz 50 k VA lagging power factor load. [FL] There is a voltage sag of 10 percent supply system with a 415 volt. And operation of UPQC under normal condition; [FL] under normal condition the DVR of QC inject zero voltage because there is the same single.

However, the DSTATCOM inject the current in the quadrature to the load voltage for compensation of reactive power. [FL] You can calculate the per phase voltage. Then the typical here the an active power of the load and from this you can calculate the reactive power and this reactive power have to be supply virtually from typically from [FL] you can calculate the supply current. And then you can calculate the typically a DSTATCOM current from reactive power.

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Reactive power rating of DSTATCOM is $Q_{DSTATCOM} = Q_L = 30 \text{ kVAR}$.

Voltage Sag Compensation by Right Hand UPQC-Q

(a) The voltage rating of DVR of UPQC-Q is computed as.

There is voltage sag of -10% in the supply system with base value of 239.59 V .

It means after the supply voltage reduces to

$$V_{sl} = 415 \times (1 - 0.10) = 373.5 \text{ V}, V_{sp} = V_{sl} / \sqrt{3} = 215.64 \text{ V}.$$

The phase load voltage is, $V_{Lp} = 415 / \sqrt{3} = 239.59 \text{ V}$.

The phase load current is, $I_{Lp} = 50000 / (3 \times 239.59) = 69.56 \text{ A}$.

The supply current during the voltage sag compensation is as,

$$I_s = P_L / (3 \times V_{sp}) = 40000 / (3 \times 215.64) = 61.83 \text{ A}.$$

The voltage rating of DVR,

$$V_{DVR} = \sqrt{V_L^2 - V_s^2} = 239.59 \sqrt{(1^2 - 0.9^2)} = 0.4359 \times 239.59 = 104.44 \text{ V}.$$

(b) The current rating DVR of UPQC must be same as supply current after shunt compensation as.

I_{DVR} = The fundamental active component of load current,

$$I_s = I_{DVR} = P_L / (3 \times V_{sp}) = 40000 / (3 \times 215.64) = 61.83 \text{ A}.$$


And [FL] DSTATCOM rating is corresponding to load reactive power that is 30 k VAR. Now, coming to the case of voltage sag compensation by Right Hand u this is Right Hand UPQC, [FL] voltage rating of the DVR of UPQC is 10 percent sag. [FL] It becomes with the base voltage of 239 [FL] after the sag even call it line voltage become 373.5 volt, and the phase voltage becomes 215.64 in place of your 239.59.

And phase load current from active power and from this relation you can find out under normal typically you have 69.59 this much current, and the supply current for the voltage sag compensation certainly is the active power divide by your voltage and three [FL] it become 61.81.

And the voltage rating of the DVR from this relation because it is a $Q [FL] V L \text{ square minus } V s \text{ square } V \text{ DVR}$. [FL] Putting the value, it becomes 104.44 volt. And the current rating of

DVR of UPQC must be the same as the supply current after the, [FL] I DVR equal to the fundamental active power of the load current that is from this [FL] we can calculate 61.83.

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(c) The VA rating of series element of UPQC-Q is as,
 $Q_{DVR} = 3 \cdot V_{DVR} \cdot I_{DVR} = 3 \cdot 104.44 \cdot 61.83 \text{ VA} = 19,373 \text{ VAR.}$
 $P_{DVR} = 0.0$
 $S_{DVR} = \sqrt{(P_{DVR}^2 + Q_{DVR}^2)} = Q_{DVR}$
 $= 3 \cdot 104.44 \cdot 61.83 \text{ VA} = 19373 \text{ VA} = 19.373 \text{ kVA.}$

(d) The voltage rating of DSTATCOM of UPQC is equal to ac load voltage of $V_{DST} = 239.59 \text{ V.}$

(e) The current rating of DSTATCOM of UPQC-Q is computed as,
 The DSTATCOM of UPQC-Q is to correct the power factor of the source to unity, hence the required reactive power by DSTATCOM is now lower than the load reactive power as the angle between supply voltage and load current is reduced to $\beta = \phi - \delta$.
 where $\cos \phi$ is load power factor and δ is the angle between the load voltage and PCC voltage after the compensation. This angle δ is computed as follows.
 $\tan \delta = V_{DVR} / V_s = 104.44 / 215.64 = 0.4842$, $\delta = 25.83^\circ$, and power factor angle is as. $\phi = \cos^{-1}(0.8) = 36.87^\circ$.

And thus the VA rating of the series element will be your VAR, [FL] we have no injected voltage current multiplied the three four three-phase, [FL] it become typically 19373 VAR and power is 0. [FL] S DVR because UPQC Q [FL] the VAR rating becomes like a simply 19.373 k VA. And voltage rating of the DSTATCOM is equal to the same as load voltage rating because coming connected across the load. The voltage compensated there, [FL] 239.59.

The current rating of DSTATCOM is computed as the DSTATCOM UPQC is correct to power factor of unity, hence the required reactive power by the DSTATCOM is now lower than the reactive power of the angle between supply voltage and current is reduced to beta

equal to phi minus delta, where cos phi is the load power factor and delta is the angle between the load voltage and PCC voltage after compensation.

And this angle computed as your v DVR from this. [FL] It come delta equal to 25.83, and the power where the power factor angle 30 is corresponding cos inverse 0.8 that is 36.86.

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The DSTATCOM current rating is as,

$$I_{DST} = I_L \left[\sqrt{\frac{(1-X)^2 + \cos^2 \theta - 2 \cos \theta \cos(\theta - \delta)(1-X)}{(1-X)}} \right]$$

$$= 69.56 \left[\sqrt{\frac{0.9^2 + 0.8^2 - 2 * 0.8 * \cos(36.87^\circ - 25.83^\circ) * 0.9}{0.9}} \right]$$

$$= 14.796 \text{ A.}$$

(f) The VA rating of DSTATCOM is as,

$$Q_{DST} = 3 * V_{DST} * I_{DST} = 3 * 239.59 * 14.79 \text{ VA} = 10630 \text{ VAR.}$$

$$P_{DST} = 0.0$$

(g) $S_{DST} = \sqrt{P_{DST}^2 + Q_{DST}^2} = Q_{DVR} = 10630 \text{ VA.}$
 The VA rating of UPQC-Q during voltage sag is as,

$$S_{UPQCQ(\text{under sag})} = S_{DST} + S_{DVR} = 10630 + 19373 = 30003 = 30.003 \text{ kVA.}$$

Hence considering the overall rating (both normal and under sag), ratings of both compensators are as,

$$V_{DST} = 239.6 \text{ V, } I_{DST} = I_{DSTN} = 41.73 \text{ A.}$$

$$S_{DST} = 3 * V_{DST} * I_{DSTN} = 3 * 239.6 * 41.73 = 30000 \text{ VA.}$$

$$V_{DVR} = 104.44 \text{ V, } I_{DVR} = 61.83 \text{ A.}$$

$$S_{DVR} = 3 * V_{DVR} * I_{DVR} = 19370 \text{ VA.}$$

(h) The VA rating of UPQC is as,

$$S_{UPQC-Q} = S_{DST} + S_{DVR} = 30000 + 19370 = 49370 \text{ VA} = 49.370 \text{ kVA.}$$


[FL] Then we can find out the from this relation the DSTATCOM current rating on per phase basis. [FL] It comes like a 14.796 ampere. And VA rating of DSTATCOM from this relation comes to be your 10.63 k VA, and active power is 0, because this DVR is not asking any power because just say UPQC Q. And the VA rating of the DSTATCOM is same as the is Q rating, [FL] it is a like you can call it 10.63 k VA.

And voltage rating of UPQC during the voltage sag condition [FL] sum of the both, it comes 10630 plus 19373, [FL] it becomes your 30 k VA. And hence considering the overall rating of both under this, [FL] we have voltage rating of DSTATCOM, 239.6 current rating 41.73 [FL] DSTATCOM rating comes 30 k VA. And DVR voltage rating which comes 104.44 and current rating 61 [FL] VA rating comes nineteen point, and total rating is the sum of both it comes like 49.37 k VA.

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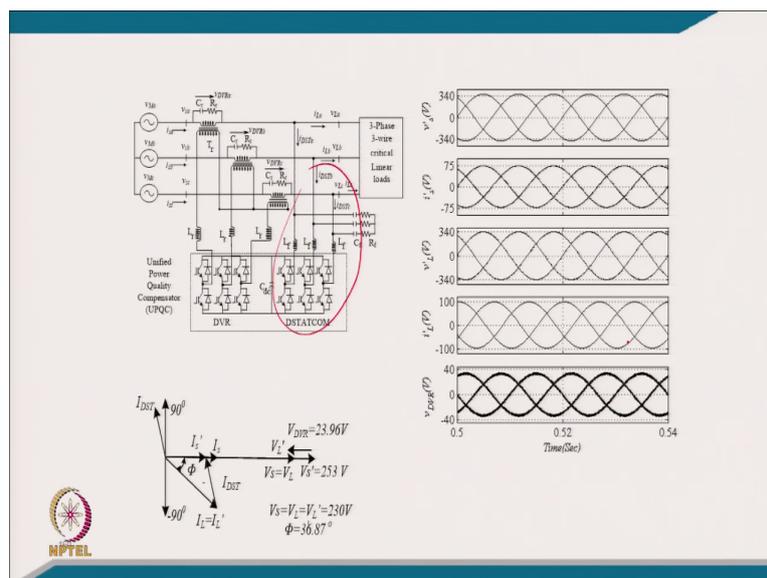
Q.13 A three-phase supply with ac line voltage of 415 V rms at 50 Hz is feeding a critical linear load of 50 kVA, 415 V, 50 Hz at 0.8 lagging pf. A voltage swell of +10% occurs in the supply at PCC. Design a three-phase UPQC-P (UPQC consisting of DSTATCOM and DVR using two VSCs with common dc bus capacitor) in this system to compensate the pf of the load to unity at ac mains and mitigation of the voltage swell to avoid the interruption to the load. If two three-phase VSCs are used as a Right Hand UPQC-P (shown in Fig.), calculate (a) the voltage rating of DVR of UPQC-P, (b) the current rating DVR of UPQC-P, (c) the VA rating of DVR of UPQC-P, (d) the voltage rating of DSTATCOM of UPQC-P, (e) the current rating of DSTATCOM of UPQC-P, (f) the VA rating of DSTATCOM of UPQC-P, (g) total VA rating of UPQC-P, (h) interfacing inductance, (i) dc bus capacitance of VSCs, (j) dc bus voltage, and (k) turns ratio of the injection transformer for DVR. Consider the switching frequency of 20 kHz and dc bus voltage has to be controlled within 8% range of nominal value and the ripple current in the interfacing inductor is 5%.

Coming to the numerical 13, [FL] a three-phase supply with AC voltage of 415 volt rms at a 50 hertz is feeding critical linear load of 50 k VA, 415 volt of at 0.8 lagging power factor. A voltage swell of 10 percent is occurs in the supply. Design a three-phase UPQC consisting of DVR and DSTATCOM. The common DC capacitor in this system to compensate the power

factor load to unity at the AC mains mitigation of voltage swell to avoid the interruption of the to the load.

And if the three-phase VSCs are used as a Right Hand UPQC-P ok, calculate the voltage rating of the DVR, current rating of the DVR, voltage rating of DVR, current voltage rating of DSTATCOM, current rating of DSTATCOM, VA rating of DSTATCOM, and total VA rating of the UPQC, interfacing inductance, DC bus capacitance, DC bus voltage, turns ratio of injection transformer; I mean consider the switching frequency of 20 kilo hertz, DC voltage have to be controlled within 8 percent of the range value, and ripple current in the interfacing inductor is 5 percent. [FL]

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This is again you can call it Right Hand UPQC means and which is connected across the load, and series is in series with the line. And these are typically phasor diagram corresponding to

this typically the swell compensation. These are the I mean supply voltage, supply current load voltage and load current, and the DVR voltage to be injected.

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Solution: Given that, $V_{sl} = 415$ V, $f=50$ Hz, a load of 415 V, 50 Hz, 50 kVA, 0.8 lagging power factor. There is a voltage swell of +10% in supply system with base value of 415 V.

The phase load voltage is as, $V_{lp} = 415/\sqrt{3} = 239.59$ V.

The phase load current is as, $I_{lp} = I_s = 50000/(3 \times 239.59) = 69.56$ A.

The active power of the load is,

$$P_L = 3 \times V_{lp} \times I_{lp} \times \text{pf} = 50000 \times 0.8 = 40 \text{ kW.}$$

The supply current before the voltage swell is as,

$$I_s = P_L / (3 \times V_{sp}) = 40000 / (3 \times 239.6) = 55.64 \text{ A.}$$

Voltage Swell Compensation by Right Hand UPQC-P

After the voltage swell, the supply voltage increases to $V_{sl}' = 415 \times (1 + 0.10) = 456.50$ V, $V_{sp}' = V_{sl}' / \sqrt{3} = 263.56$ V.

(a) The voltage rating of DVR of UPQC-P is computed as.

For UPQC-P the injected voltage is in phase with source voltage hence the value of injected voltage is algebraic difference between load and source voltage.

$$V_{DVR} = V_{sp}' - V_{sp} = 263.56 - 239.6 = 23.96 \text{ V.}$$


[FL] Coming to the solution. Given that the supply voltage 415 volt at 50 hertz, and load voltage is 50 hertz for 15 50 hertz 50 k VA 0.8 lagging power factor. There is a voltage swell of 10 percent, and supply voltage 415. [FL] The phase voltage comes like typically 415 by root 3, 239.59. And the typically the phase load current is your active power divide by your 3 times voltage, [FL] it is 69.56. And active power comes typically of your from this relation 40 kilowatt.

And the current of a grid is typically in the normal condition comes 55.64 ampere. The voltage swell compensation by Right Hand UPQC. The after voltage swell the supply voltage

increases to 10 percent voltage swell, [FL] it comes 456.54 or phase voltage is typically 263.56 in place of 239.39.

[FL] The voltage rating of the DVR of UPQC is computed as for UPQC-P the injected voltage in phase with the source voltage. And the value of injected voltage is algebraic sum of the difference of the two, [FL] you can find out DSTATCOM DVR voltage equal to directly 23.96 volt.

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(b) The current rating DVR of UPQC must be same as supply current during voltage swell compensation.
 $I_s' = P_L / (3 * V_{sp}') = 40000 / (3 * 263.56) = 50.589 \text{ A.}$

For Voltage Swell Compensation

(c) The VA rating of series element of UPQC-P is as,
 $P_{DVR} = 3 * V_{DVR} * I_{DVR} = 3 * 23.96 * 50.58 \text{ W} = 3636.4 \text{ W} = 3.6364 \text{ kW.}$
 $Q_{DVR} = 0.0$
 $S_{DVR} = \sqrt{(P_{DVR}^2 + Q_{DVR}^2)} = P_{DVR} = 3636.4 \text{ VA.}$

(d) The voltage rating of DSTATCOM of UPQC is equal to ac load voltage of $V_{DSTP} = 239.59 \text{ V.}$

(e) The current rating of DSTATCOM of UPQC-P is as follows.
 $Q_{DST} = Q_L = 3 * V_L * I_L * \sin\phi = 50000 * 0.6 = 30000 \text{ VAR,}$
 $P_{DST} = P_{DVR} = 3636.4 \text{ W.}$
 $S_{DST} = \sqrt{(P_{DST}^2 + Q_{DST}^2)} = 30220 \text{ VA.}$
 The DSTATCOM current rating is as,
 $I_{DST} = S_{DST} / (3 * V_{DST}) = 42.04 \text{ A}$



And the current rating of DVR of UPQC might be the same as the current rating of the swell condition [FL] from this we can find out the current from typically on the grid side, [FL] it 50.5. And [FL] for the voltage swell compensation the VA rating of series element of UPQC is P DVR equal to 3V DVR I DVR [FL] it becomes like a typically your 3.6364 kilo watt.

And Q equal to 0 and S DVR equal to P Q under root, [FL] it becomes 3636.4 VA. And the voltage rating of the DSTATCOM same as equal to the AC load voltage because its connected across the load [FL] its come 239 point 239.59. And current rating of DSTATCOM as the UPQC P is the same VA rating is the same reactive power of the load, and active power is the same as your DVR 3636.4.

And S DVR under root of Q P square plus Q square, [FL] it comes 30.22 k VA. And from this way, we can calculate the current rating of typically of DSTATCOM, it come forty 42.04 ampere.

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(f) The VA rating of DSTATCOM is as,
 $S_{DST} = \sqrt{(P_{DST}^2 + Q_{DST}^2)} = 30220 \text{ VA}$.
 The VA rating of UPQC-P during voltage swell is as,
 $S_{UPQC-P} = S_{DST} + S_{DVR} = 30220 + 3636.4 = 33856.4 \text{ VA}$.
 Considering an overall rating (both normal and under voltage swell), ratings of both compensators are as,
 $V_{DST} = 239.6 \text{ V}$, $I_{DST} = 42.04 \text{ A}$, $S_{DST} = 3 * V_{DST} * I_{DST} = 30220 \text{ VA}$.
 $V_{DVR} = 23.96 \text{ V}$, $I_{DVR} = 55.64 \text{ A}$, $S_{DVR} = 3 * V_{DVR} * I_{DVR} = 3999.4 \text{ VA}$.
 The VA rating of UPQC,
 $S_{UPQC-P} = S_{DST} + S_{DVR} = 30220 + 3999.4 = 34219 \text{ VA}$.
 (g) The turn's ratio of the injection transformer for DVR is as.
 The dc bus voltage of 750 V (decided for 415 V for DSTATCOM), can be used to obtain a 415 V across the line at the output of VSC using PWM controller. However, DVR requires only 23.96 V/phase. Therefore, the turns ratio of the injection transformer is as,
 $K_{DVR} = N_{VSC} / N_{DVR} = 415 / (\sqrt{3} * 23.96) = 10$.



[FL] VA rating of DSTATCOM, comes under root P square plus Q square [FL] it is a 30.22 VA k VA. And the VA rating of the UPQC during voltage swell comes sum of both, [FL] it comes 33.856 k VA. Considering the overall rating of both typically under normal and swell

condition, [FL] it comes DSTATCOM voltage rating of 239 with a current rating of 42, [FL] S VA rating on 30.22 k VA.

And DVR current voltage rating two 23.96, current rating 50.64, [FL] VA rating comes 39.99 k VA. And overall rating is a sum of both, it come 34.22 VA, k VA. The turns ratio of the injection transformer is now correspond to DC bus capacitor of 750 volt, 415. And DSTATCOM can be obtained 415 across the line of this PWM. However, the DVR require this much. [FL] Therefore, the turns ratio of this can be calculated from here around 10.

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(i) The dc bus voltage is decided based on the ac voltages impressed across the VSCs.
 $V_{dc} = 2\sqrt{2} (V_L/\sqrt{3})/m_a = 2\sqrt{2} * 415/\sqrt{3}/0.9 = 752.99 \approx 750V.$

(j) The interfacing inductances are required in VSCs, which are working as DSTATCOM and DVR.
 The interfacing inductance of the DSTATCOM,
 $L_{DST} = \frac{\{(\sqrt{3}/2)m_a V_{dc}\}}{(6af_s \Delta I_{DST})}$
 $= \frac{\{(\sqrt{3}/2)\} * 9 * 750}{(6 * 1.2 * 20000 * 2.1002)} = 1.93 \text{ mH}.$

The interfacing inductance of the DVR,
 $L_{DVR} = \frac{\{(\sqrt{3}/2)m_a V_{dc} * K_{DVR}\}}{(6af_s \Delta I_{DVR})} =$
 $= \frac{\{(\sqrt{3}/2)\} * 9 * 750 * 10}{(6 * 1.2 * 20000 * 2.53)} = 16 \text{ mH}.$

(k) The dc bus capacitance of VSCs is computed as,
 The change in stored energy during dynamics,
 $\Delta E = \frac{1}{2} C_{dc} (V_{dc\text{capf}}^2 - V_{dc\text{minapf}}^2) = 3 * V_{DST} * I_{DST} * \Delta t$
 $\Delta E = \frac{1}{2} C_{dc} (750^2 - 690^2) = 3 * 239.6 * 42.04 * 10/1000$ (Considering $\Delta t = 10\text{ms}$)
 $C_{dc} = 7018.28 \mu\text{F}.$



And the dc bus capacitor decided according to this value [FL] it comes 752, we can select 750. The interfacing inductance required for which is this, [FL] we can calculate DSTATCOM rating from this relation, [FL] it comes 1.93. And DVR current rating from this

relation comes to 1, 16 milli Henry. And the dc bus capacitance of this from this dynamics of this which we calculated for other compensators also it comes like a 7018.28 micro Farad.

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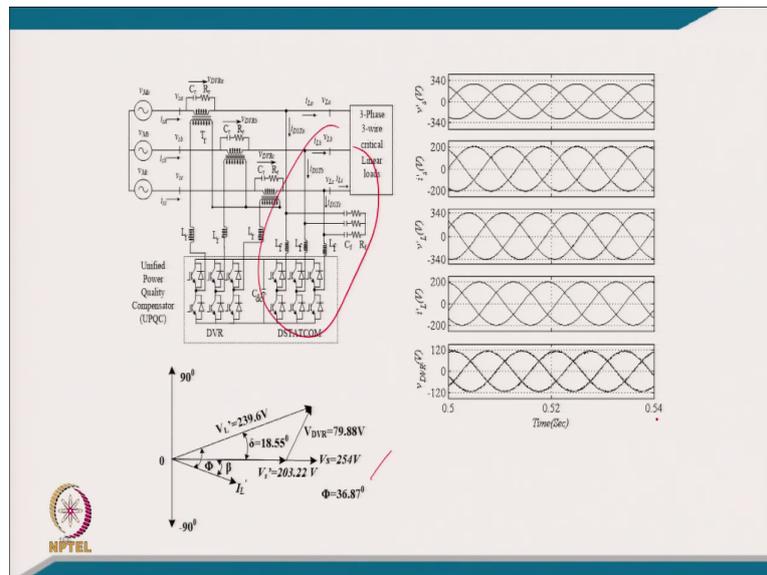
Q.14 A three-phase supply with ac mains voltage of 440 V, 50 Hz has **voltage sag of -20%** due to a rural feeder and a nearby factory. A hospital needs a three-phase 415 V, 100 kVA, at 0.8 lagging PF, 50 Hz linear load in critical equipment. If a **Right hand-UPQC-S** (consisting of DSTATCOM and DVR using two VSCs with common dc bus capacitor) is used as a unified power quality compensators (shown in Fig.), then calculate (a) the rating of the shunt and series components of UPQC to provide rated voltage across the load and to realize a unity power factor at ac mains, if an injecting transformer is used to inject the voltage in DVR, calculate (b) turns ratio of injecting transformer, (c) values of interfacing inductors, and (d) the value of dc bus capacitor. Consider the switching frequency of 10 kHz and dc bus voltage has to be controlled within 8% range and ripple current in inductor is 10%. Consider same rating of the both VSCs.

[FL] Coming to the numerical number 14, a three-phase supply with a ac mains voltage of 440 volt, 50 hertz has a voltage sag of 20 percent due to rural feeder and nearby factory. A hospital needs a three-phase 415 volt, 100 k VA, 0.8 lagging power factor linear load in critical equipment.

If the Right Hand UPQC considering the DSTATCOM DVR using two UPQC with common capacitor is used as a UPQC, then the calculate the rating of the shunt and series component, UPQC to provide the rated voltage across the load and to realize the unity power factor ac mains if the an injecting transformer is used to inject the voltage here. Calculate the turns ratio of the injecting transformer, interfacing inductors, and the value of dc link.

Consider the switching frequency of 10 kilohertz, and dc link voltage have to controlled within 8 percent of range and ripple 10 percent consider the same rating of both VSC.

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[FL] It is we have a again Left Hand sorry Right Hand UPQC and injection transformer with DVR is on the left side. And this is the typical phasor diagram corresponding to that. These are the typical waveform for.

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Solution: Given that, $V_{sl} = 440$ V, $f=50$ Hz, a load of 415 V, 50 Hz, 100 kVA, 0.8 lagging power factor. There is voltage sag of -20% due to a rural feeder and a nearby factory.

It means after the supply voltage reduces to
 $V_{sl}=440*(1 - 0.20) =352$ V, $V_{sp}=V_{sl}/\sqrt{3}=203.22$ V.

The phase load voltage is, $V_{Lp}=415/\sqrt{3}=239.59$ V.

The phase load current is, $I_{Lp}=100000/(3*239.59)=139.12$ A.

The active power of the load is,
 $P_L=3*V_{Lp}*I_{Lp}*pf=100000*0.8=80$ kW.

The supply current during the voltage sag compensation is as,
 $I_s=P_L/(3*V_{sp})=80000/(3*203.22)=131.22$ A.

Under Steady State Condition for Unity Power Factor at ac Mains and Voltage Compensation across the Load

The active power of the load is,
 $P_L=3*V_{Lp}*I_{Lp}*pf=100000*0.8=80$ kW.

The reactive power of the load is,
 $Q_L=P_L=3*V_{Lp}*I_{Lp}*\sqrt{(1-pf^2)}= 100000*0.6=60$ kVAR.



[FL] Coming to the numerical portion given that the voltage is 440 volt, 50 hertz, a load 415, 100 k VA, 0.8 lagging power factor. [FL] There is voltage sag of 20 percent due to rural feeder. And the it means the voltage supply reduces to your 440 into 0.8 [FL] it becomes 352, and phase voltage become 203. However, load voltage is your 239.59, [FL] your phase current becomes from the typically I mean your 100 k VA divide by this value, it is become one-third 139.12 ampere.

And power active power becomes like a 100 k VA into 0.8, 80 kilowatt. And supply current after the volt compensation from this kilowatt divide by the voltage into, [FL] it become 131.22. [FL] Under the steady state condition for unity power factor ac mains and the voltage compensation the active power of the load is 80 kilowatt. And the reactive power is typically 60 k VAR.

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Voltage Rise Compensation by Right Hand UPQC-S under Nominal Operating Condition

even under nominal grid conditions $V_{sp} = 440/\sqrt{3} \text{ V} = 254 \text{ V/phase}$.
 The per unit extra voltage is estimated as,
 $X = \{(V_{sp}/V_{Lp}) - V_{Lp}/V_{Lp}\} = \{(254/239.6) - 239.6/239.6\} = 0.06 \text{ pu}$,
 $K_0 = V_{Lp}/V_{sp} = 239.6/254 = 0.943$, $n_0 = 1/K_0 = 1 + X = 1 + 0.06 = 1.06$,
 The supply current during-voltage swell compensation is as,
 $I_s = P_L/(3V_{sp}) = 80000/(3 \times 254) = 104.99 \text{ A}$.
 In Right Hand UPQC-S, each VSC has reactive power rating equal to half of the reactive power of the load, which is equal to $Q_{DST} = Q_{DVR} = Q_L/2 = 60/2 = 30 \text{ kVAR}$.
 Under the voltage rise condition, from the following relation of reactive power of DVR, the power angle is computed as.
 $Q_{DVR} = 3K_0V_s I_s \sin \delta = 3(V_L/V_s) V_s I_s \sin \delta = 30000 \text{ VAR}$, therefore,
 $\delta = 23.42^\circ$.

$P_{DVR} = -3K_0V_s I_s (n_0 - \cos \delta)$
 $= -3(V_L/V_s) V_s I_s \{(V_s/V_L) - \cos \delta\} = -10766.15 \text{ W}$.



And voltage rise for the compensation for Right Hand UPQC. [FL] Even under normal grid condition [FL] voltage is 254. And the per unit extra voltage is typically you can call it an under normal condition 6 percent higher, and you can calculate all the constant. [FL] You can calculate current on this on supply side, [FL] it comes like a from this voltage it comes 104.99 ampere.

In the Right Hand each UPQC has a reactive power of half of the this equal to, [FL] it is a 60 by 230 k VAR. [FL] Under normal voltage rise condition from the following relation, we can find out the Q DVR. [FL] From this, we can calculate the delta equal to 23.43; and P DVR from this relation we get 107.66, 110.77 kilowatt.

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The voltage rating of the DVR is as,
 $V_{DVR} = V_L \sqrt{\{1+n_0^2 - 2n_0 \cos \delta\}} = 239.6 \sqrt{\{1+1.06^2 - 2*1.06*\cos 23.42^\circ\}}$
 $= 101.12 \text{ V.}$

The current rating of the DVR is as,
 $I_{DVR} = I_s = P_L / (3V_{sp}) = 80000 / (3*254) = 104.99 \text{ A.}$

The VA rating of the DVR is as,
 $S_{DVR} = 3 * V_{DVR} * I_{DVR} = 3 * 101.2 * 104.98 = 31873.37 \text{ VA.}$

Active power of DSTATCOM is as,
 $P_{DST} = - P_{DVR} = 10747.15 \text{ W.}$

The voltage rating of DSTATCOM of UPQC is equal to ac load voltage of $V_{DST} = 239.6 \text{ V.}$

The current rating of DSTATCOM of UPQC is computed as.
Therefore, angle between supply voltage and load current is as,
 $\beta = \phi - \delta = 36.87^\circ - 23.42^\circ = 13.45^\circ.$

Therefore, DSTATCOM current is as,
 $I_{DST} = I_L \sqrt{\{1+K_0^2 \cos^2 \phi - 2K_0 \cos \beta \cos \phi\}}$
 $= 139.12 \sqrt{\{1+0.943^2 * 0.8^2 - 2*0.943*0.8*0.973\}} = 44.34 \text{ A.}$



[FL] Voltage rating of the DVR from this relation, we can calculate [FL] it comes 101.12. And current rating of DVR, from this relation from power and voltage, we can calculate the 104.99, and VA rating of the DVR comes from typically voltage and current [FL] it comes 31.87 k VA.

And active power of DSTATCOM virtually the same active power of the DVR that is 10.75 kilowatt. And voltage rating of DSTATCOM, is same as the load 239.6. [FL] current rating of DSTATCOM is computed that is corresponding to this angle beta equal to phi minus, [FL] it comes 13.45. Therefore, DSTATCOM current rating from this relation giving the value which comes 44.34.

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The phase angle between DSTATCOM voltage and current can be calculated as,
 $P_{DST} = 10747.15 \text{ W} = 3V_L I_{DST} \cos\theta_{DST}$, $\theta_{DST} = 70.29^\circ$.
 $Q_{DST} = V_L I_{DST} \sin\theta_{DST} = 30000 \text{ VA}$.
The VA rating of VSC of DSTATCOM of UPQC,
 $S_{DST} = 3 \times V_{DST} \times I_{DST} = 3 \times 239.6 \times 44.34 \text{ VA} = 31873.16 \text{ VA}$.
The VA rating of UPQC-S,
 $S_{UPQC-S} = S_{DST} + S_{DVR} = 31873.16 + 31873.37 = 63746.53 \text{ VA}$.
Voltage Sag Compensation by Right Hand UPQC-S
After the voltage sag, the supply voltage reduces to
 $V_{sl} = 440 \times (1 - 0.20) = 352 \text{ V}$, $V_{sp} = V_{sl} / \sqrt{3} = 203.22 \text{ V}$.
The phase load voltage is, $V_{Lp} = 415 / \sqrt{3} = 239.59 \text{ V}$.
It means after the voltage supply voltage reduces to
 $V_{sp} = 203.22 \text{ V}$, and $X = 0.152$, $K0 = 1.179$, $no = 0.848$.
The supply current is after the voltage sag compensation is as,
 $I_s = P_L / (3 \times V_s) = 80000 / (3 \times 203.22) = 131.212 \text{ A}$.



And phase angle between the DSTATCOM voltage and current I mean from typically the power here is [FL] form active power we can calculate the angle of the DSTATCOM 70.29. And the reactive power corresponds to 30 k VA, and voltage rating of DSTATCOM is typically of 239. [FL] We can find out VA rating voltage and current [FL] that comes 31.87 k VA.

And VA rating of the UPQC the sum of the both DSTATCOM and DVR, [FL] it comes 63.75 k VA. And voltage sag compensation by Right Hand after the voltage sag, [FL] it will be reduces to typically like your 8352 volt. And phase voltage becomes 2 by root 3 203.22. And phase load, however, load voltage supply regulated to 239.59. It means after the voltage supply reduces to with this [FL] we have a sag of 15.2. And performing this, [FL] we can find out the typical say supply current for performing this voltage, [FL] it comes to 139.212.

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In Right Hand UPQC-S, each VSC has reactive power rating equal to half of the reactive power of the load, which is equal to $Q_{DST}=Q_{DVR}=Q_L/2=60000/2=30000$ VAR.

Under the sag, from the following relation of reactive power of DVR, the power angle can be computed as.

$$Q_{DVR}=3K_0V_s I_s \sin \delta=3(V_L/V_s) V_s I_s \sin \delta =30000 \text{ VAR, therefore, } \delta=18.55^\circ.$$
$$P_{DVR}=-3K_0V_s I_s (n_0-\cos \delta)$$
$$=-3(V_L/V_s) V_s I_s \{(V_s/V_L)-\cos \delta\} = 9419.9 \text{ W.}$$

The voltage rating of the DVR is as,

$$V_{DVR}=V_L \sqrt{1+n_0^2-2n_0 \cos \delta}=239.6 \sqrt{1+0.848^2-2*0.848*\cos 17.46^\circ}$$
$$=79.88 \text{ V.}$$

The current rating of the DVR is as,

The supply current is after the sag compensation is as,

$$I_{DVR}=I_s=P_L/(3*V_s)=80000/(3*203.22)=131.212 \text{ A.}$$

The VA rating of the DVR is as,

$$S_{DVR}=3*V_{DVR}*I_{DVR}=3*79.88*131.212=31444.33 \text{ VA.}$$


And in the Right Hand UPQC each VSC have a reactive power rating equal to half of the reactive power [FL] that is 60 by 230 k VAR. Under the voltage sag, the following relation of reactive power angle to be computed, [FL] it comes delta equal to 0.85 from this relation. And P DVR from giving the value, it comes 9.42 kilowatt.

And voltage rating of DVR comes from this relation 79.88, I mean putting the value, [FL] current rating of DVR comes from this active power on the grid side [FL] it comes like a 131.21. [FL] VA rating of the DVR comes 3 times voltage current, it comes 31.44 k VA.

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Active power of DSTATCOM is as, $P_{DST} = -P_{DVR} = -9419.9 \text{ W}$.
 The voltage rating of DSTATCOM of UPQC is equal to ac load voltage of $V_{DST} = 239.6 \text{ V}$, since it is connected across the load of 239.6V sine waveform.
 The current rating of DSTATCOM of UPQC is computed as.
 Therefore, angle between supply voltage and load current is as,
 $\beta - \theta = 36.87^\circ - 18.55^\circ = 18.32^\circ$
 Therefore, DSTATCOM current is as,
 $I_{DST} = I_L \sqrt{(1 + K_0^2 \cos^2 \theta - 2K_0 \cos \beta \cos \theta)}$
 $= 139.12 \sqrt{(1 + 1.179^2 * 0.8^2 - 2 * 1.179 * 0.8 * 0.949)} = 43.74 \text{ A}$.
 The phase angle between DSTATCOM voltage and current is calculated as,
 $P_{DST} = -9438.71 \text{ W} = 3V_L I_{DST} \cos \theta_{DST}$, $\theta_{DST} = 107.47^\circ$.
 $Q_{DST} = 3V_L I_{DST} \sin \theta_{DST} = 29990 = 30000 \text{ VA}$.
 The VA rating of VSC of DSTATCOM of UPQC,
 $S_{DST} = 3 * V_{DST} * I_{DST} = 3 * 239.6 * 43.74 \text{ VA} = 31444 \text{ VA}$.



[FL] Active power DSTATCOM equal to same as DVR because DVR taking same DST [FL] 9.42 kilowatt. And the voltage rating of DSTATCOM of UPQC equal to the AC load voltage that is 239 point, [FL] since it is connected across the load. And current rating of DSTATCOM UPQC computed from the angle between the supply voltage that is beta equal to phi, [FL] 18.32.

Current from this relation can be is calculated 40 to 43.74. And phase angle between DSTATCOM voltage and current is calculated from the active power, [FL] it comes from 107.47. And the reactive power from putting this value it come 30 k VA. And VA rating of DSTATCOM is 3 times voltage current, [FL] it comes 31.44 k VA.

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The VA rating of UPQC-S during voltage sag is as,
 $S_{UPQCS(\text{under sag})} = S_{DST} + S_{DVR} = 31444 + 31444 = 62888 \text{ VA}$.
Hence considering an overall rating (both normal and under voltage sag), ratings of both compensators are as,
 $V_{DST} = 239.6 \text{ V}$, $I_{DST} = 44.34 \text{ A}$, $S_{DST} = 3 * V_{DST} * I_{DST} = 31871.59 \text{ VA}$.
 $V_{DVR} = 101.12 \text{ V}$, $I_{DVR} = 131.21 \text{ A}$,
 $S_{DVR} = 3 * V_{DVR} * I_{DVR} = 39803.86 \text{ VA}$.
(a) The total VA rating of UPQC-S considering both VSC share equal VA rating all the time,
 $S_{UPQCS} = S_{DST} + S_{DVR} = 31871.59 + 39803.86 = 71674.86 \text{ VA}$.
The total VA rating considering same inventory for VSCs is as,
 $S_{DST} = S_{DVR} = 39803.86 \text{ VA}$.
The VA rating of the UPQC-S is as,
 $S_{UPQC-S} = S_{DST} + S_{DVR} = 39803.86 + 39803.86 = 79607.72 \text{ VA}$.
(b) The turn's ratio of the injection transformer for DVR is
 $K_{DVR} = N_{VSC} / N_{DVR} = 415 / (\sqrt{3} * 101.12) = 2.37 \approx 2.0$.



[FL] VA rating of UPQC-S is sum of the both k VA, [FL] it comes typically double of this [FL] say 62.88 VA k VA. Hence considering the overall both normal this rating [FL] DSTACOM voltage rating current rating, and the total rating is the 31.1 0.87 k VA. And the DVR voltage and current and it comes the typically the KV rating of DSTATCOM, 39.80 k VA.

The total VA rating of considering the both share equally [FL] sum of both, it comes typically 70, 71.67 k VA. And total VA rating considering the inventory same, [FL] it is a 39.98. [FL] Overall VA rating comes sum of both, [FL] it is a 79.61 k VA. [FL] Turns ratio of the injection transformer of this, I mean from correspond to the voltage 415 we have to generate to 101, this [FL] turns ratio comes around 2.

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The dc bus voltage across the VSCs is
 $V_{dc} = 2\sqrt{2} (V_s / \sqrt{3}) / m_a = 2\sqrt{2} * 415 / \sqrt{3} / 0.9 = 752.99 \approx 750V$.

(c) The interfacing inductances are required in VSCs, which are working as DSTATCOM and DVR.

The interfacing inductance of the DSTATCOM, $L_{DST} =$
 $\{(\sqrt{3}/2) m_a V_{dc} / (6\omega_s \Delta I)\}$
 $= \{(\sqrt{3}/2) * 0.9 * 750 / (6 * 1.2 * 10000 * 4.374)\} = 1.86 \text{ mH}$.

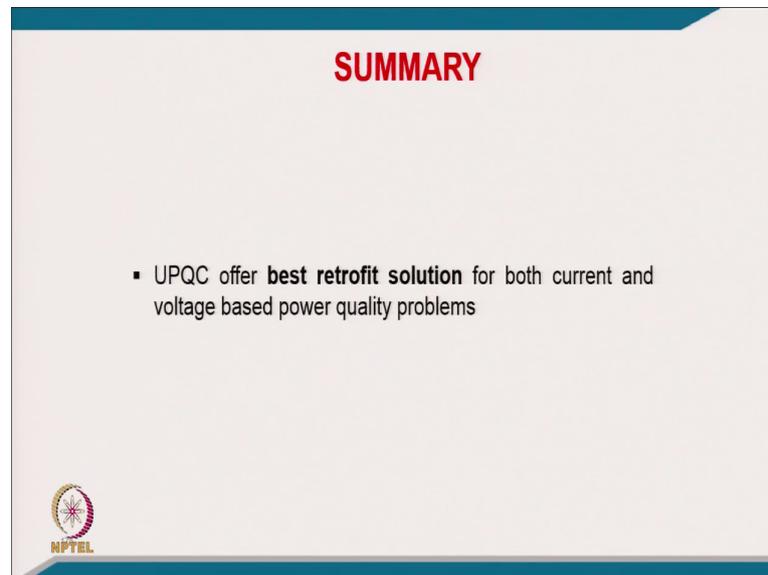
The interfacing inductance of the VSC of DVR is as, $L_{DVR} =$
 $\{(\sqrt{3}/2) m_a V_{dc} / (6\omega_s \Delta I_{DVR} / K_{DVR})\} =$
 $= \{(\sqrt{3}/2) * 0.9 * 750 / (6 * 1.2 * 10000 * 13.112/2)\} = 1.238 \text{ mH}$.

(d) The dc bus capacitance of VSCs is computed as,
 The change in stored energy during dynamics,
 $\Delta E = \frac{1}{2} C_{dc} (V_{dc\text{capf}}^2 - V_{dc\text{minapf}}^2) = 3 * V_{DST} * I_{DST} * \Delta t$
 $\Delta E = \frac{1}{2} C_{dc} (750^2 - 690^2) = 3 * 239.6 * 43.74 * 10 / 1000$
 (Considering $\Delta t = 10\text{ms}$)
 $C_{dc} = 7227.85 \mu\text{F}$.



And the DC link voltage from the basic relation can be calculated, it comes 750 volt. And interfacing inductance required for typically from this relation putting the value, it come from 1.86. Interfacing inductance for VSC of DVR, it comes from 1.238; and DC bus capacitance for dynamics of energy storage, it comes 7227.85.

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[FL] With this we like to summarize that UPQC is offers best retrofit solution for both current and voting based power quality problem. It is able to compensate voltage sag swell especially the voltage based compensation as well as current base compensation. And we have seen the variety of the numerical problems, the rating differs with the configuration of the placing of your whether you are putting DSTATCOM on the load side or on the grid side. But preferred configuration is certainly putting the DSTATCOM on load side, I mean that we have concluded.

And it is able to compensate and with we have to give the right control with the typically I mean with this with the maybe with the UPQC-S like I mean or so. [FL] It is capable of supplying the regulated voltage across the load and maintaining the unity power factor on the grid side in spite the voltage may be unbalance or the typically current maybe also unbalance.

Well, with this now we like to summarize this lecture on unified power quality compensators. The UPQC offers the best retrofit solution for current and voltage based quality problem. We have discussed the configuration of UPQC, the best configuration among the various configuration is that we put the DSTATCOM version compensated on the load side that is on right side, and the DVR on left side.

And the as far as the typically the control power is typically from UPQC-S that is correspond to control with the angle control I mean like. And with typically I mean it can provide you very clean voltage across the load with a you can call it balance and a unity power factor current on the supply side like. [FL]

Thank you very much.