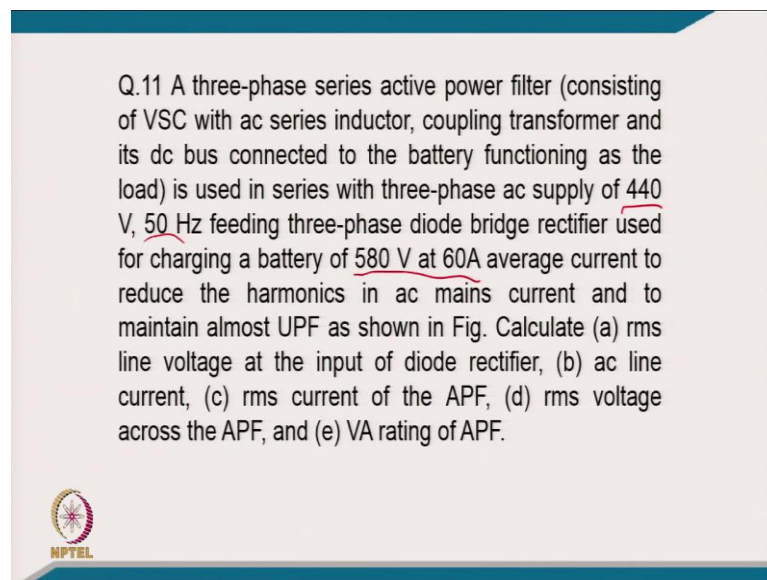


Power Quality
Prof. Bhim Singh
Department of Electrical Engineering
Indian Institute of Technology, Delhi


Module - 07
Lecture - 25
Active Series Power Filters (contd.)

Welcome to the course on Power Quality. We were discussing the numerical examples on series active filter.

(Refer Slide Time: 00:28)



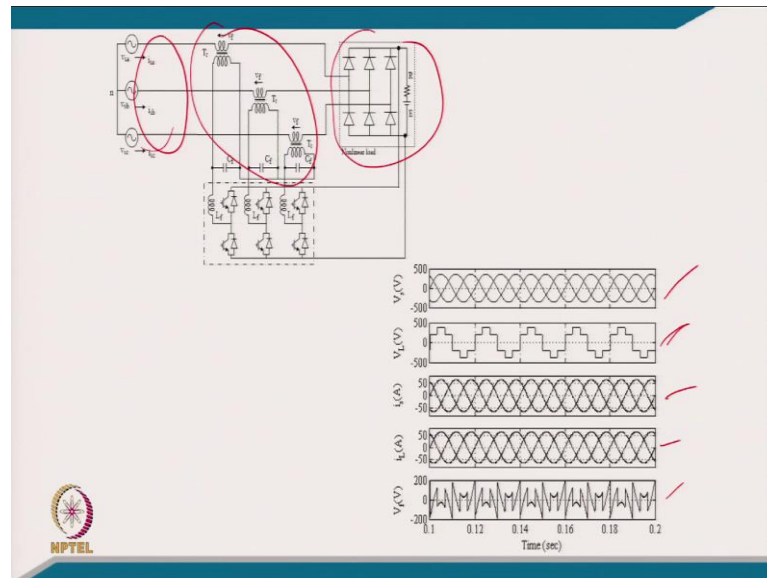
Q.11 A three-phase series active power filter (consisting of VSC with ac series inductor, coupling transformer and its dc bus connected to the battery functioning as the load) is used in series with three-phase ac supply of 440 V, 50 Hz feeding three-phase diode bridge rectifier used for charging a battery of 580 V at 60A average current to reduce the harmonics in ac mains current and to maintain almost UPF as shown in Fig. Calculate (a) rms line voltage at the input of diode rectifier, (b) ac line current, (c) rms current of the APF, (d) rms voltage across the APF, and (e) VA rating of APF.



Coming to example number 11, a three-phase series active filter of voltage source converter with ac series inductor, coupling transformer and its dc bus connected to the battery functioning as a load is used in series with the three-phase ac supply of 440 volt, 50 hertz feeding a three-phase diode bridge rectifier used for charging a battery of 580 volt at 60 ampere average current to reduce the harmonics in ac mains current and to maintain almost unity power factor as shown in figure.

Calculate a, the line voltage at the input of diode rectifier a, b, ac line current c, rms current of active power filter d, rms voltage across the active series active filter and the VA rating of series active filter like.

(Refer Slide Time: 01:19)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 03:47)

Solution: Given that, supply voltage, $V_s = 440/\sqrt{3}=254.03V$, frequency of the supply $f=50$ Hz, $V_{dload}=580V$, $I_{dc}=60A$.
 The active power is as, $P=V_{dc} I_{dc}=580*60 W=34800 W$.
 The supply current is as, $I_s=34800/(3*254.03)=45.664A$.

The sine wave supply current after the compensation results in continuous conduction of diodes of the three phase diode rectifier (each diode conducting for 180°) and it results in the waveform of the phase voltage at the input of diode (V_{pccph}) is a stepped waveforms as (i) first step of $\pi/3$ angle {from 0° to $(\pi/3)$ } and a magnitude of $(V_{dload}/3)$, (ii) second step of $\pi/3$ angle {from $(\pi/3)$ to $(2\pi/3)$ } and a magnitude of $\{2V_{dload}/3\}$, (iii) third step of $\pi/3$ angle {from $(2\pi/3)$ to (π) } and a magnitude of $\{V_{dload}/3\}$ and it has both half cycles of symmetric segments of such steps.

(Refer Slide Time: 05:38)


(a) The rms line voltage at the input of diode rectifier is computed as follows.

The sine wave supply current after compensation results in continuous conduction of diodes of the rectifier (180°) and it results in quasi square wave ac voltage at PCC with an amplitude of dc bus voltage, $V_{pcc} = V_{dcload} * (\sqrt{2}/\sqrt{3}) = 473.57 \text{ V}$.

Therefore, $V_{pcc} = 473.57 \text{ V}$.

(b) The supply line current at unity power is as, $I_s = 34800 / (3 * 254.03) = 45.664 \text{ A}$

(c) The current rating of series APF is as, $I_f = I_s = 45.664 \text{ A}$
(Since APF is connected in series with supply)




(Refer Slide Time: 06:48)

(d) The rms voltage rating of series APF, V_f is computed by taking the difference of the supply phase voltage and phase voltage at the input of diode rectifier as follows.


$$V_f = \sqrt{\frac{1}{\pi} \left\{ \int_0^{\pi/3} (254\sqrt{2}\sin\theta - 193.33)^2 d\theta + \int_{\pi/3}^{2\pi/3} (254\sqrt{2}\sin\theta - 386.67)^2 d\theta + \int_{2\pi/3}^{\pi} (254\sqrt{2}\sin\theta - 193.33)^2 d\theta \right\}} = 81.4622 \text{ V}$$

(e) The kVA rating of VSC of APF is as, $S = 3 * V_f * I_s = 3 * 81.4622 * 45.664 \text{ VA} = 11.16 \text{ kVA}$.



(Refer Slide Time: 08:13)

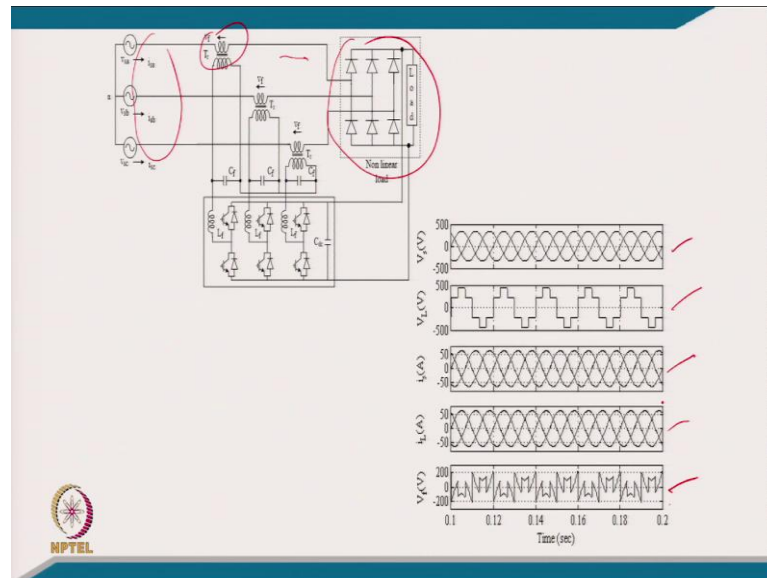
Q.12 A three-phase series active power filter (consisting of VSC with ac series inductor, coupling transformer and its dc bus connected to the dc bus of the load) is used in series with the three-phase ac supply of 415 V, 50 Hz feeding three phase diode rectifier with a parallel dc capacitor at a load of 60A average current to reduce the harmonics in ac mains current, to maintain UPF of supply current and to regulate the dc bus voltage of the load at almost constant 650V as shown in Fig. Calculate (a) rms line voltage at the input of diode rectifier, (b) ac line current, (c) rms current of the APF, (d) rms voltage across the APF, (e) VA rating of APF, and (f) turns ratio of the coupling transformer.



Coming to the numerical problem 12, a three-phase series active power filter consisting of voltage source converter with ac series inductor, coupling transformer and its dc bus connected to the dc bus of the load is used in series with the three-phase supply of 415 volt, 50 hertz feeding a three-phase diode bridge rectifier with a parallel dc capacitor at a load of 60 ampere average current to reduce the harmonics in ac mains current to maintain unity power factor of supply current and to regulate the dc link voltage of the load almost constant at 650 volt as shown in the figure.

Calculate a, rms line voltage at the input of diode bridge rectifier b, the ac line current c, rms current of the active series filter d, the rms voltage across the series active filter e, VA rating of the series active filter and f, the turns ratio of the coupling transformer is used in series active filter.

(Refer Slide Time: 09:13)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 11:30)

Solution: Given that, supply voltage, $V_s = 415/\sqrt{3} = 239.6V$, frequency of supply $f = 50$ Hz, $V_{dc} = 650V$, $I_{dc} = 60A$.

The active power, $P = V_{dc} I_{dc} = 650 * 60 \text{ W} = 39000 \text{ W}$.

The supply current is as, $I_s = 39000 / (3 * 239.6) = 54.257A$.

The sine wave supply current after the compensation results in continuous conduction of diodes of the three phase diode rectifier (each diode conducting for 180°) and it results in the waveform of the phase voltage at the input of diode (V_{pccph}) is a stepped waveforms as (i) first step of $\pi/3$ angle {from 0° to $(\pi/3)$ } and a magnitude of $(V_{dc}/3)$, (ii) second step of $\pi/3$ angle {from $(\pi/3)$ to $(2\pi/3)$ } and a magnitude of $\{2V_{dc}/3\}$, (iii) third step of $\pi/3$ angle {from $(2\pi/3)$ to (π) } and a magnitude of $\{V_{dc}/3\}$ and it has both half cycles of symmetric segments of such steps.

(Refer Slide Time: 13:11)

(a) The rms line voltage at the input of diode rectifier is computed as follows.

The sine wave supply current after compensation results in continuous conduction of diodes of the rectifier (180°) and it results in quasi square wave ac voltage at PCC with an amplitude of dc bus voltage, $V_{pcc} = V_{dc} * (\sqrt{2/\sqrt{3}}) = 530.72V$. Therefore, $V_{pcc} = 530.72V$.


(b) The supply line current at unity power is as,

$$I_s = 39000 / (3 * 239.6) = 54.257A$$

(c) The current rating of series APF is as,

$$I_f = I_s = 54.257A$$

(Since APF is connected in series with supply)




(Refer Slide Time: 13:14)

(d) The rms voltage rating of series APF, V_f is computed by taking the difference of the supply phase voltage and phase voltage at the input of diode rectifier as follows.

$$V_f = \sqrt{\frac{1}{\pi} \left\{ \int_0^{\pi/3} (239.6\sqrt{2}\sin\theta - 216.67)^2 d\theta + \int_{\pi/3}^{2\pi/3} (239.6\sqrt{2}\sin\theta - 433.33)^2 d\theta + \int_{2\pi/3}^{\pi} (239.6\sqrt{2}\sin\theta - 216.67)^2 d\theta \right\}} = 105.27 V$$

(e) The kVA rating of VSC of APF is as,

$$S = 3 * V_f * I_s = 3 * 105.27 * 54.257 VA = 17.135 kVA.$$


(Refer Slide Time: 15:31)


(e) The turn's ratio of the coupling transformer is computed as follows.

The maximum ac voltage on ac side of VSC of APF may be $m_a V_{dc} / (2\sqrt{2}) = 0.8 * 650 / (2\sqrt{2}) = 183.85 \text{ V}$

and on the supply side, it must be $V_{supply} = V_f$.


The turn's ratio of the coupling transformer is as.

$N_{vsi} / N_{supply} = 183.85 / 105.27 = 1.746$.



(Refer Slide Time: 16:14)

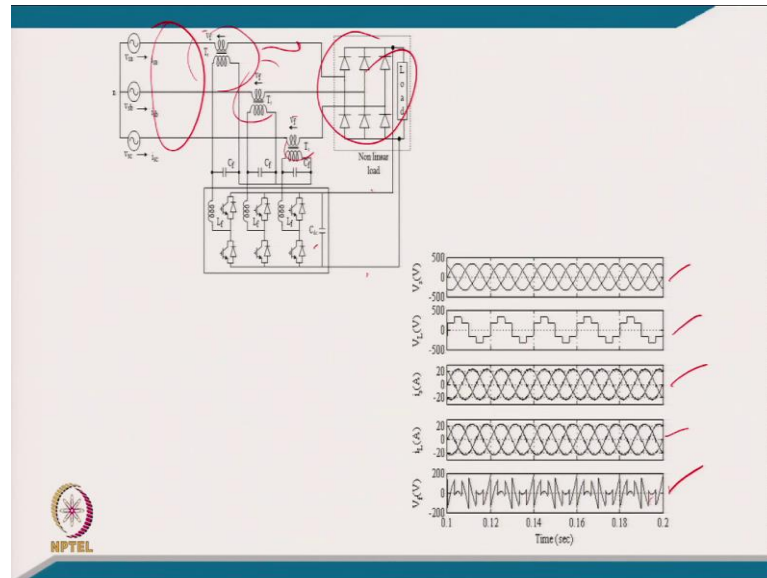
Q.13 A series active power filter (consisting of VSC with ac series inductor, coupling transformer and its dc bus connected to dc bus of the load) is used to reduce the harmonics in ac mains current and to maintain almost UPF connected in the series of three-phase ac supply of 415 V, 50 Hz feeding a three-phase diode rectifier with a capacitive filter of 10000 μF and resistive load of 20 ohms as shown in Fig. The dc bus voltage of the load is decided to result in minimum injected voltage of the APF. Calculate (a) rms voltage at the input of diode rectifier, (b) line current, (c) VA rating of APF, (d) dc bus voltage of the load, and (e) turns ratio of the coupling transformer.



Coming to the 13th example, a series active power filter consisting of voltage source converter with ac series network coupling transformer and its dc bus connected to dc bus of the load is used to reduce the harmonics in ac mains current and to maintain almost unity power factor connected in the series of the three-phase ac supply or 415 volt, 50 hertz feeding a three-phase diode rectifier with the capacitive filter of 10000 microfarad and the resistive load of 20 ohm as shown in the figure.

DCc bus voltage of the load is decided to result in a minimum injected voltage of series active filter. Calculate a, rms voltage at the input of diode rectifier b, the line current c, the volt VA rating of the series active filter d, the dc link voltage of the load and e, the turns ratio of coupling transformer.

(Refer Slide Time: 17:05)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 19:03)

Solution: Given that, supply voltage, $V_s = 415/\sqrt{3}=239.6V$, frequency of the supply $f=50$ Hz, $R_{dc}=20\Omega$.

If x volts is the dc bus voltage of the rectifier load, then the injected voltage of the APF is as.

$$V_f = \sqrt{\left(\frac{1}{\pi}\right)\left\{\int_0^{\pi/3} (V_s\sqrt{2}\sin\theta - x/3)^2 d\theta + \int_{\pi/3}^{2\pi/3} (V_s\sqrt{2}\sin\theta - 2x/3)^2 d\theta + \int_{2\pi/3}^{\pi} (V_s\sqrt{2}\sin\theta - x/3)^2 d\theta\right\}}$$

After integrating and taking derivative with respect to x , it gives

$$x = (\sqrt{2}/\pi) * (27/6) V_s = V_{dc} = 485.36 V.$$

The dc load current is as,

$$I_{dc} = V_{dc} / R_{dc} = 485.36 / 20 = 24.268 A.$$

(Refer Slide Time: 20:42)


The active power is as,

$$P = V_{dc} I_{dc} = 485.36 \times 24.268 \text{ W} = 11778.747 \text{ W.}$$

The supply current is as,

$$I_s = 11778.747 / (3 \times 239.6) = 16.39 \text{ A}$$

The sine wave supply current after the compensation results in continuous conduction of diodes of the three phase diode rectifier (each diode conducting for 180°) and it results in the waveform of the phase voltage at the input of diode (V_{pccph}) is a stepped waveforms as (i) first step of $\pi/3$ angle {from 0° to $(\pi/3)$ } and a magnitude of $(V_{dc}/3)$, (ii) second step of $\pi/3$ angle {from $(\pi/3)$ to $(2\pi/3)$ } and a magnitude of $\{2V_{dc}/3\}$, (iii) third step of $\pi/3$ angle {from $(2\pi/3)$ to (π) } and a magnitude of $\{V_{dc}/3\}$ and it has both half cycles of symmetric segments of such steps.



(Refer Slide Time: 22:03)


(a) The rms line voltage at the input of diode rectifier is computed as follows.

The sine wave supply current after compensation results in continuous conduction of diodes of the rectifier (180°) and it results in quasi square wave ac voltage at PCC with an amplitude of dc bus voltage, $V_{pcc} = V_{dc} \times (\sqrt{2}/\sqrt{3}) = 396.29 \text{ V}$. Therefore, $V_{pcc} = 396.29 \text{ V}$.

(b) The supply line current at unity power is as,

$$I_s = 16.39 \text{ A.}$$

(c) The current rating of series APF is as,


$$I_f = I_s = 16.39 \text{ A (Since APF is connected in series with supply)}$$


(Refer Slide Time: 22:52)

(d) The rms voltage rating of series APF, V_f is computed by taking the difference of the supply phase voltage and phase voltage at the input of diode rectifier as follows.

$$V_f = \sqrt{\frac{(1/\pi) \int_0^{\pi/3} (239.6\sqrt{2}\sin\theta - 161.79)^2 d\theta + \int_{\pi/3}^{2\pi/3} (239.6\sqrt{2}\sin\theta - 323.57)^2 d\theta + \int_{2\pi/3}^{\pi} (239.6\sqrt{2}\sin\theta - 161.79)^2 d\theta}{\pi}} = 71.12 \text{ V}$$

(e) The kVA rating of VSC of APF is as,


$$S = 3 \cdot V_f \cdot I_s = 3 \cdot 71.12 \cdot 16.39 \text{ VA} = 3.497 \text{ kVA.}$$


(Refer Slide Time: 24:14)

(e) The turn's ratio of the coupling transformer is computed as follows.


The maximum ac voltage on ac side of VSC of APF may be $m_a V_{dc} / (2\sqrt{2}) = 0.8 \cdot 485.36 / (2\sqrt{2}) = 137.28 \text{ V}$ and on the supply side, it must be $V_{\text{supply}} = V_f$.

The turn's ratio of the coupling transformer is as.

$$N_{\text{vsf}} / N_{\text{supply}} = 137.28 / 71.12 = 1.93.$$


(Refer Slide Time: 24:51)

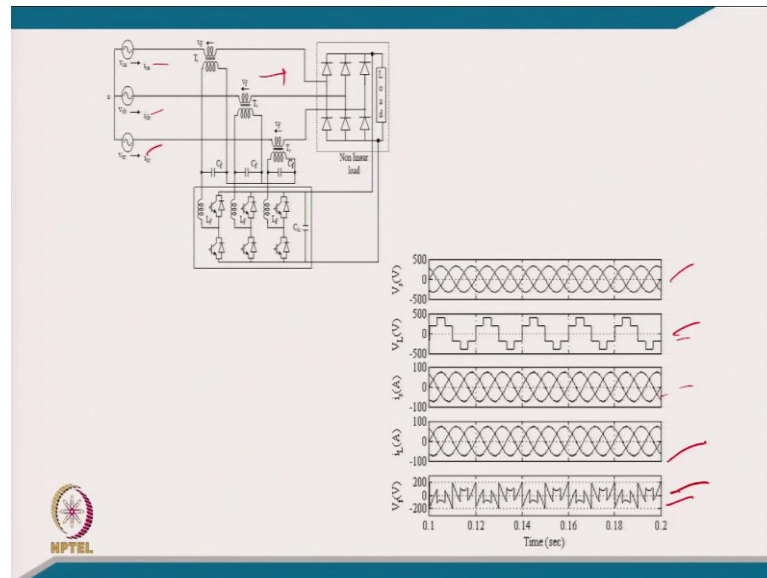
Q.14 A series active power filter (consisting of VSC with ac series inductor, coupling transformer and its dc bus connected to dc bus of the load) is used to reduce the harmonics in ac mains current and to maintain almost UPF in the series of three-phase ac supply of 400 V, 50 Hz feeding a three-phase diode rectifier with a capacitive filter of 40000 μ F and resistive load of 10 ohms as shown in Fig. If dc bus voltage of the load is to be maintained to constant ripple free 600V, then calculate (a) rms line voltage at the input of diode rectifier, (b) ac line current, (c) rms current of the APF, (d) rms voltage across the APF, (e) VA rating of APF, and (f) turns ratio of the coupling transformer.



Coming to the problem number 14, a series active power filter consisting of voltage source converter with ac series inductor, coupling transformer and its dc connected to the dc bus of the load is used to reduce the harmonics in ac mains current and to maintain the almost unity power factor in series with the three-phases ac supply of 400 volt, 50 hertz feeding a three-phase diode rectifier with the capacity filter of 40000 microfarad and resistive load of 10 ampere as shown in the figure.

If the dc bus voltage of the load is to be maintained constant ripple free of 600 volt, then calculate the rms line voltage at the input of diode rectifier, ac line current, rms current of the series active filter, rms voltage across the series active filter, VA volt ampere rating of the series active filter and the turns ratio of coupling transformer.

(Refer Slide Time: 25:45)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 27:06)

Solution: Given that, supply voltage, $V_s = 400/\sqrt{3} = 230.94\text{V}$, frequency of the supply $f = 50\text{ Hz}$, $V_{dc} = 600\text{V}$, $R_{dc} = 10\Omega$.
The dc load current is as, $I_{dc} = V_{dc}/R_{dc} = 600/10 = 60\text{A}$.
The active power is as, $P = V_{dc} I_{dc} = 600 * 60\text{ W} = 36000\text{ W}$.
The supply current is as, $I_s = 36000 / (3 * 230.94) = 51.96\text{A}$.
The sine wave supply current after the compensation results in continuous conduction of diodes of the three phase diode rectifier (each diode conducting for 180°) and it results in the waveform of the phase voltage at the input of diode (V_{pccph}) is a stepped waveforms as (i) first step of $\pi/3$ angle {from 0° to $(\pi/3)$ } and a magnitude of $(V_{dc}/3)$, (ii) second step of $\pi/3$ angle {from $(\pi/3)$ to $(2\pi/3)$ } and a magnitude of $\{2V_{dc}/3\}$, (iii) third step of $\pi/3$ angle {from $(2\pi/3)$ to (π) } and a magnitude of $\{V_{dc}/3\}$ and it has both half cycles of symmetric segments of such steps.

The NPTEL logo is visible in the bottom left corner.

(Refer Slide Time: 28:36)

(a) The rms line voltage at the input of diode rectifier is computed as follows.

The sine wave supply current after compensation results in continuous conduction of diodes of the rectifier (180°) and it results in quasi square wave ac voltage at PCC with an amplitude of dc bus voltage,


$$V_{pcc} = V_{dcload} * (\sqrt{2}/\sqrt{3}) = 489.89V.$$

Therefore $V_{pcc} = 489.89V$.

(b) The supply line current at unity power is as,

$$I_s = I_s = 36000 / (3 * 230.94) = 51.96A$$

(c) The current rating of series APF is as,


$$I_f = I_s = 51.96A \text{ (Since APF is connected in series with supply)}$$


(Refer Slide Time: 29:36)

(d) The rms voltage rating of series APF, V_f is computed by taking the difference of the supply phase voltage and phase voltage at the input of diode rectifier as follows.

$$V_f = \sqrt{\frac{1}{\pi} \left\{ \int_0^{\pi/3} (230.94\sqrt{2}\sin\theta - 200)^2 d\theta + \int_{\pi/3}^{2\pi/3} (230.94\sqrt{2}\sin\theta - 400)^2 d\theta + \int_{2\pi/3}^{\pi} (230.94\sqrt{2}\sin\theta - 200)^2 d\theta \right\}} = 92.6382 V$$

(e) The kVA rating of VSC of APF is as,

$$S = 3 * V_f * I_s = 3 * 92.6382 * 51.96 VA = 14.44 kVA.$$


(Refer Slide Time: 30:54)


The turn's ratio of the coupling transformer is computed as following.

The maximum ac voltage on ac side of VSC of APF may be $m_a V_{dc} / (2\sqrt{2}) = 0.8 * 600 / (2\sqrt{2}) = 169.7 \text{ V}$

and on the supply side, it must be $V_{supply} = V_f$.


The turn's ratio of the coupling transformer is as.

$N_{vsr} / N_{supply} = 169.7 / 92.6382 = 1.83$.



(Refer Slide Time: 31:37)

Q15. A three-phase series active power filter (consisting of VSC with ac series inductors, coupling transformers and dc bus capacitor) is used in series with the three-phase ac supply of 415 V, 50 Hz feeding a three phase 12-pulse diode rectifier (consisting of two parallel connected 6-pulse diode bridge rectifiers with star/delta and delta/delta transformers to output equal line voltages of 415 V) having a parallel dc capacitor filter with 400 V dc at a load of 60A average current to reduce the harmonics in ac mains current, and to maintain UPF of the supply current as shown in Fig. Calculate (a) the rms phase voltage at the input of 12-pulse diode rectifier, (b) the ac line current, (c) the rms current of the APF, (d) the rms voltage across the APF, (e) the VA rating of APF.

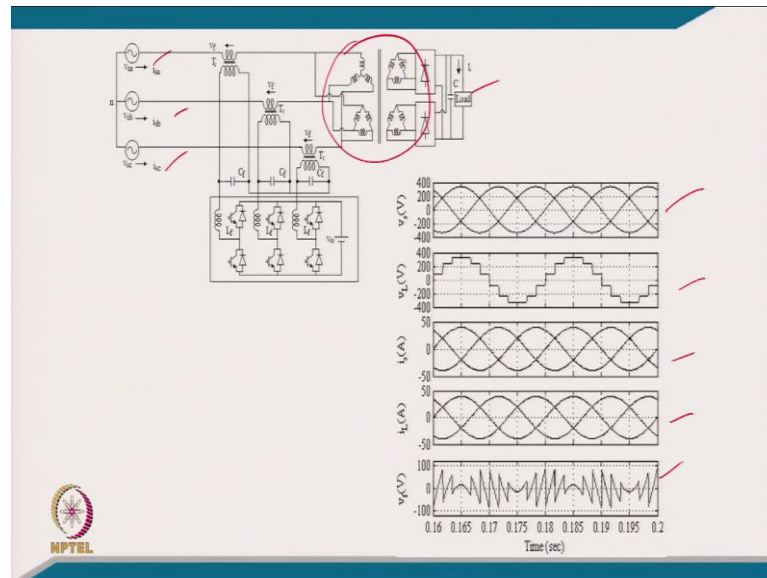


Coming to the numerical problem 15, a three-phase series active power filter consisting of voltage source converter with the ac series inductor, coupling transformer and dc bus capacitor is used to in series with the three-phase ac supply of 415 volt, 50 hertz feeding a three-phase 12 pulse diode rectifier consisting two parallel connected 6 pulse diode bridge rectifier with the star delta.

And star and delta, delta transformer to output equal to the line voltage of 415 volt having the parallel dc capacitors filter with 500 volt; 400 volt dc at the at a load of 60

volt average current sorry 60 ampere average current to reduce the harmonics in the ac mains current and to maintain the unity power factor of supply current as shown in the figure. Calculate a, the rms phase voltage at the input of 12 pulse diode rectifier b, the ac line current c, the rms current of the active series filter and d, the rms voltage across the active power filter, the VA rating of active power filter.

(Refer Slide Time: 32:41)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 34:12)

Solution: Given that, $V_s = 415/\sqrt{3}=239.6V$, $f=50$ Hz, $V_{dc}=400V$, $I_{dc}=60A$.

The active power is as, $P=V_{dc}I_{dc}=400*60$ W=24000 W.

The supply current is as, $I_s=24000/(3*239.6)=33.389A$.

The sine wave supply current after the compensation results in continuous conduction of diodes of the three phase diode rectifier (each diode conducting for 180°) and it results in the waveform of the phase voltage at the input of 12-pulse diode rectifier (V_{pccph}) is a stepped waveforms as (i) first step of $\pi/6$ angle (from 0° to $\pi/6$) and a magnitude of $\{V_{dc}(2/\sqrt{3}-1)\}$, (ii) second step of $\pi/6$ angle (from $\pi/6$ to $\pi/3$) and a magnitude of $\{V_{dc}(1-1/\sqrt{3})\}$, (iii) third step of $\pi/6$ angle (from $\pi/3$ to $\pi/2$) and a magnitude of $\{V_{dc}(1/\sqrt{3})\}$ and it has all four symmetric segments of such steps.

(Refer Slide Time: 35:37)

Turn ratio of the transformers is calculated as follows.

$$3\sqrt{2}V_{\text{line,sec}}/\pi = 400 \text{ V. } V_{\text{line,sec}} = 296.19 \text{ V.}$$

$$V_{\text{line,pri}} = 415 \text{ V.}$$


Primary to secondary turn ratio of star/delta transformer is as,

$$N_{ps}/N_{sd} = (415/\sqrt{3})/296.19 = 0.81.$$

Primary to secondary turn ratio of delta/delta transformer is as, $N_{pd}/N_{sd} = (415)/296.19 = 1.4.$

Hence the turn ratio 1.4 will be multiplied with each step.

(a) The rms phase voltage at the input of 12-pulse diode rectifier is computed as.



(Refer Slide Time: 36:15)

$$V_{\text{pcc,ph}} = 1.4V_{\text{dc}} \sqrt{\frac{1}{\pi} \left[\int_0^{\pi/6} \left(\frac{2}{\sqrt{3}} - 1 \right)^2 d\theta + \int_{\pi/6}^{\pi/3} \left(1 - \frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{\pi/3}^{2\pi/3} \left(\frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{2\pi/3}^{5\pi/6} \left(1 - \frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{5\pi/6}^{\pi} \left(\frac{2}{\sqrt{3}} - 1 \right)^2 d\theta \right]} = 236.8 \text{ V}$$


(b) The supply line current at unity power is as,

$$I_s = 24000/(3 \times 239.6) = 33.389 \text{ A.}$$

(c) The current rating of series APF is as,

$$I_f = I_s = 33.389 \text{ A.}$$


(d) The rms voltage rating of series APF



(Refer Slide Time: 37:12)


$$V_f = \frac{1}{\pi} \sqrt{\int_0^{\frac{\pi}{6}} (239.6\sqrt{2}\sin\theta - 86.7)^2 d\theta + \int_{\frac{\pi}{6}}^{\frac{\pi}{3}} (239.6\sqrt{2}\sin\theta - 236.8)^2 d\theta + \int_{\frac{\pi}{3}}^{\frac{2\pi}{3}} (239.6\sqrt{2}\sin\theta - 323.6)^2 d\theta + \int_{\frac{2\pi}{3}}^{\frac{5\pi}{6}} (239.6\sqrt{2}\sin\theta - 236.8)^2 d\theta + \int_{\frac{5\pi}{6}}^{\pi} (239.6\sqrt{2}\sin\theta - 86.7)^2 d\theta} = 36 \text{ V}$$

(e) The kVA rating of VSI of APF,
 $S = 3 * V_f * I_s = 3 * 36 * 33.389 = 3.606 \text{ kVA}$.



(Refer Slide Time: 38:11)

Q16. A three-phase series active power filter (consisting of VSC with ac series inductors, coupling transformers and dc bus connected to the dc bus of the load) is used in series with the three-phase ac supply of 440 V, 50 Hz feeding a three phase 12-pulse diode rectifier (consisting of two parallel connected 6-pulse diode bridge rectifiers with star/delta and delta/delta transformers to output equal line voltages of 440V) having a parallel dc capacitor filter of 10000µF with a 20 ohms resistive load dc to reduce the harmonics in ac mains current, and to maintain UPF of supply current as shown in Fig. If dc bus of the load is to be maintained to 650V, then calculate (a) the rms phase voltage at the input of 12-pulse diode rectifier, (b) the ac line current, (c) the rms current of the APF, (d) the rms voltage across the APF, (e) the VA rating of APF, and (f) turns ratio of the coupling transformer.



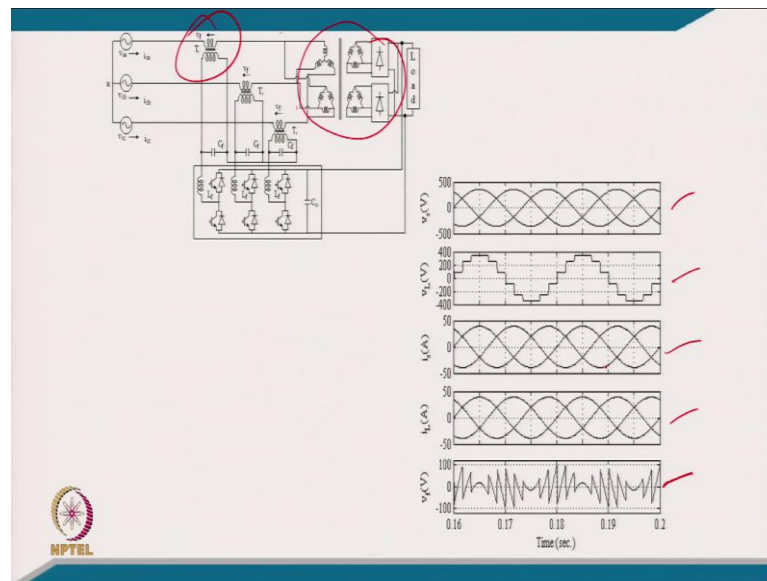
Coming to the 16 numerical problem, a three-phase series active power filter consisting of voltage source converter with the ac series inductor, coupling transformer.

And dc bus connected to the dc link of the load is used in series with the three-phase ac supply of 440 volt 50 hertz feeding a three-phase 12 pulse diode rectifier consisting of two parallel connected 6 pulse diode bridge rectifier with the star delta and delta delta transformer to the output to output equal to the line voltage of 440 volt having a parallel dc capacitor of 10000 microfarad with the 20 ohm resistive load dc to reduce the

harmonics in the ac mains current and to maintain the unity power factor of the supply current as shown in the figure.

If dc bus volt; dc bus of the load is to be regulated to 650 volt, then calculate the rms phase voltage of 12 pulse diode rectifier, the ac line current and c, the rms current rating of the series active filter d, the rms voltage rating of the series active filter and e, the VA rating of series active filter and f, the turns ratio of the coupling transformer.

(Refer Slide Time: 39:22)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 40:18)

Solution: Given that, supply voltage, $V_s = 440/\sqrt{3}=254V$, frequency of the supply $f=50$ Hz, $V_{dc}=650V$, $R_{dc}=20\Omega$.
 The dc load current is as, $I_{dc}=650/20=32.5$ A.
 The active power is as, $P=V_{dc}I_{dc}=650*32.5=21125$ W.
 The supply current is as, $I_s=21125/(3*254)=27.72$ A.
 The sine wave supply current after the compensation results in continuous conduction of diodes of the three phase diode rectifier (each diode conducting for 180°) and it results in the waveform of the phase voltage at the input of 12-pulse diode rectifier (V_{pccph}) is a stepped waveforms as (i) first step of $\pi/6$ angle (from 0° to $\pi/6$) and a magnitude of $\{V_{dc}(2/\sqrt{3}-1)\}$, (ii) second step of $\pi/6$ -angle (from $\pi/6$ to $\pi/3$) and a magnitude of $\{V_{dc}(1-1/\sqrt{3})\}$, (iii) third step of $\pi/6$ angle (from $\pi/3$ to $\pi/2$) and a magnitude of $\{V_{dc}(1/\sqrt{3})\}$ and it has all four symmetric segments of such steps.

(Refer Slide Time: 42:01)

Turn ratio of the transformers is calculated as:

$$3\sqrt{2}V_{\text{line,sec}}/\pi = 650 \text{ V}, V_{\text{line,sec}} = 481.312 \text{ V},$$

$$V_{\text{line,pri}} = 440 \text{ V}.$$

Primary to secondary turn ratio of star/delta transformer is as,


$$N_{ps}/N_{sd} = (440/\sqrt{3})/481.312 = 0.528.$$

Primary to secondary turn ratio of delta/delta transformer is as,

$$N_{pd}/N_{sd} = (440)/481.312 = 0.914.$$

Hence the turn ratio 0.914 will be multiplied with each step.

(a) The rms phase voltage at the input of 12-pulse diode rectifier is computed as.




(Refer Slide Time: 42:42)

$$V_{pcc,ph} = 0.914V_{dc} \left[\frac{1}{\pi} \left[\int_0^{\pi/6} \left(\frac{2}{\sqrt{3}} - 1 \right)^2 d\theta + \int_{\pi/6}^{\pi/3} \left(1 - \frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{\pi/3}^{2\pi/3} \left(\frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{2\pi/3}^{5\pi/6} \left(1 - \frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{5\pi/6}^{\pi} \left(\frac{2}{\sqrt{3}} - 1 \right)^2 d\theta \right] \right] = 251.1 \text{ V}$$

(b) The supply line current at unity power is as,

$$I_s = 21125/(3 \cdot 254) = 27.72 \text{ A}.$$

(c) The current rating of series APF is as,


$$I_f = I_s = 27.72 \text{ A. (Since APF is connected in series with supply.)}$$


(Refer Slide Time: 43:30)

$$V_f = \frac{1}{\pi} \left[\int_0^{\pi/6} (254\sqrt{2}\sin\theta - 91.91)^2 d\theta + \int_{\pi/6}^{\pi/3} (254\sqrt{2}\sin\theta - 251.1)^2 d\theta + \int_{\pi/3}^{2\pi/3} (254\sqrt{2}\sin\theta - 343)^2 d\theta + \int_{2\pi/3}^{5\pi/6} (254\sqrt{2}\sin\theta - 251.1)^2 d\theta + \int_{5\pi/6}^{\pi} (254\sqrt{2}\sin\theta - 91.91)^2 d\theta \right] = 38.22 \text{ V}$$


(e) The kVA rating of VSC of APF is as,
 $S = 3 * V_f * I_s = 3 * 38.22 * 27.72 \text{ VA} = 3.18 \text{ kVA}$.

(f) The turn's ratio of the coupling transformer is computed as follows.
 The maximum ac voltage on ac side of VSC of APF may be $m_a V_{dc} / \sqrt{2} = 0.8 * 650 / (2 * \sqrt{2}) = 183.85 \text{ V}$ and on the supply side, it must be $V_{\text{supply}} = V_f$. The turn's ratio of the coupling transformer is as.
 $N_{\text{vsf}} / N_{\text{supply}} = 183.85 / 38.22 = 4.81$.



(Refer Slide Time: 44:45)

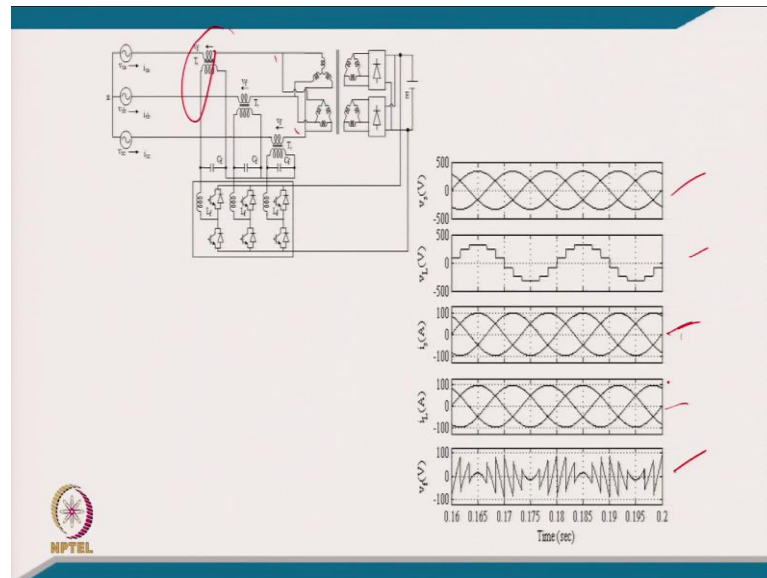
Q17. A three-phase series active power filter (consisting of VSC with ac series inductors, and its dc bus connected to the battery behaving as a load) is connected in series with the three-phase ac supply of 415 V, 50 Hz feeding three phase 12-pulse diode rectifier (consisting two parallel connected 6-pulse diode bridge rectifiers with star/delta and delta/delta transformer to output equal line voltages of 415 V) charging a battery of 500 V at 100A average current as shown in Fig. The series APF is employed to reduce the harmonics in ac mains current and to maintain almost UPF of the supply current. Calculate (a) the rms phase voltage at the input of 12-pulse diode rectifier, (b) the ac line current, (c) the rms current of the APF, (d) the rms voltage across the APF, (e) the VA rating of APF (f) turns ratio of the coupling transformer.



Coming to the numerical problem 17, a three-phase series active power filter consisting of voltage source converter with ac series inductor and its dc bus connected to the battery behaving as a load is connected in series with the three-phase ac supply of 415 volt, 50 hertz feeding a three-phase 12 pulse diode rectifier consisting of two parallel connected 6 pulse diode rectifier with star delta and its delta delta transformer to output equal line voltage of 415 volt charging a battery of 500 volt at a 100 ampere average current dc current as is shown in the figure.

Series active filter is employed to reduce the harmonics in ac mains current and to maintain the almost unity power factor of the supply current. Calculate a, the rms phase voltage at the input of 12 pulse diode rectifier b, the ac line current c, the ac the rms current of a series active filter the d, rms voltage across the active filter e, the VA rating of the active series active filter f, the turns ratio of the coupling transformer.

(Refer Slide Time: 45:50)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 46:53)

Solution: Given that, supply voltage, $V_s = 415/\sqrt{3}=239.6V$, frequency of the supply $f=50$ Hz, $V_{dc}=500V$, $I_{dc}=100A$.
 The active power is as, $P=V_{dc}I_{dc}=500*100 W=50000 W$.
 The supply current is as, $I_s=50000/(3*239.6)=69.56A$
 The sine wave supply current after the compensation results in continuous conduction of diodes of the three phase diode rectifier (each diode conducting for 180°) and it results in the waveform of the phase voltage at the input of 12-pulse diode rectifier (V_{pccph}) is a stepped waveforms as (i) first step of $\pi/6$ angle (from 0° to $\pi/6$) and a magnitude of $\{V_{dc}(2/\sqrt{3}-1)\}$, (ii) second step of $\pi/6$ angle (from $\pi/6$ to $\pi/3$) and a magnitude of $\{V_{dc}(1-1/\sqrt{3})\}$, (iii) third step of $\pi/6$ angle (from $\pi/3$ to $\pi/2$) and a magnitude of $\{V_{dc}(1/\sqrt{3})\}$ and it has all four symmetric segments of such steps.

The NPTEL logo is visible in the bottom left corner.

(Refer Slide Time: 48:17)

Turn ratio of the transformers is calculated as follows.

$$3\sqrt{2}V_{\text{line,sec}}/\pi = 500 \text{ V}, V_{\text{line,sec}} = 370.24 \text{ V},$$

$$V_{\text{line,pri}} = 415 \text{ V}.$$

Primary to secondary turn ratio of star/delta transformer is as,


$$N_{ps}/N_{sd} = (415/\sqrt{3})/370.24 = 0.647.$$

Primary to secondary turn ratio of delta/delta transformer is as,

$$N_{pd}/N_{sd} = (415)/370.24 = 1.121.$$

Hence the turn ratio 1.121 will be multiplied with each step.

(a) The rms phase voltage at the input of 12-pulse diode rectifier is computed as.



(Refer Slide Time: 48:57)

$$V_{pcc,ph} = 1.121V_{dc} \left[\frac{1}{\pi} \left[\int_0^{\pi/6} \left(\frac{2}{\sqrt{3}} - 1 \right)^2 d\theta + \int_{\pi/6}^{\pi/3} \left(1 - \frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{\pi/3}^{2\pi/3} \left(\frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{2\pi/3}^{5\pi/6} \left(1 - \frac{1}{\sqrt{3}} \right)^2 d\theta + \int_{5\pi/6}^{\pi} \left(\frac{2}{\sqrt{3}} - 1 \right)^2 d\theta \right] \right] = 236.87 \text{ V}$$


(b) The supply line current at unity power is as,

$$I_s = 50000/(3 \cdot 239.6) = 69.56 \text{ A}.$$

(c) The current rating of series APF is as,

$$I_f = I_s = 69.56 \text{ A. (Since APF is connected in series with supply.)}$$

(d) The rms voltage rating of series APF




(Refer Slide Time: 49:44)

$$V_f = \frac{1}{\pi} \left[\int_0^{\frac{\pi}{6}} (239.6\sqrt{2}\sin\theta - 86.7)^2 d\theta + \int_{\frac{\pi}{6}}^{\frac{\pi}{3}} (239.6\sqrt{2}\sin\theta - 236.8)^2 d\theta + \int_{\frac{\pi}{3}}^{\frac{2\pi}{3}} (239.6\sqrt{2}\sin\theta - 323.6)^2 d\theta + \int_{\frac{2\pi}{3}}^{\frac{5\pi}{6}} (239.6\sqrt{2}\sin\theta - 236.8)^2 d\theta + \int_{\frac{5\pi}{6}}^{\pi} (239.6\sqrt{2}\sin\theta - 86.7)^2 d\theta \right] = 36 \text{ V}$$


(e) The kVA rating of VSC of APF is as,
 $S = 3 * V_f * I_s = 3 * 36 * 69.56 \text{ VA} = 7.5 \text{ kVA}.$

(f) The turn's ratio of the coupling transformer is computed as follows.
 The maximum ac voltage on ac side of VSC of APF may be $m_a V_{dc} / (2 * \sqrt{2}) = 0.8 * 500 / (2 * \sqrt{2}) = 141.42 \text{ V}$ and on the supply side, it must be $V_{\text{supply}} = V_f$. The turn's ratio of the coupling transformer is as.
 $N_{\text{vsr}} / N_{\text{supply}} = 141.42 / 36 = 3.92.$



(Refer Slide Time: 50:37)

Q18. In a three-phase, line voltage of 380 V, 50 Hz, 4-wire distribution system, three single-phase loads (connected between phases and neutral) having a set of single-phase uncontrolled diode bridge converter, which has a RE load with $R=10$ ohms, and $E=220\text{V}$ as shown in Fig. It is desired to charge the battery E with an average current of 15A. Calculate (a) the supply phase current. If a three-phase series active power filter (consisting of VSC with ac series inductors, coupling transformers and its dc bus connected to the dc bus capacitor) is connected in series with the three-phase supply lines to maintain UPF at the ac mains, calculate (a) supply current, (b) the rms current of the APF, (c) the rms voltage at the input of the rectifier, (d) the rms voltage across the APF, (e) the VA rating of APF and (f) neutral current.

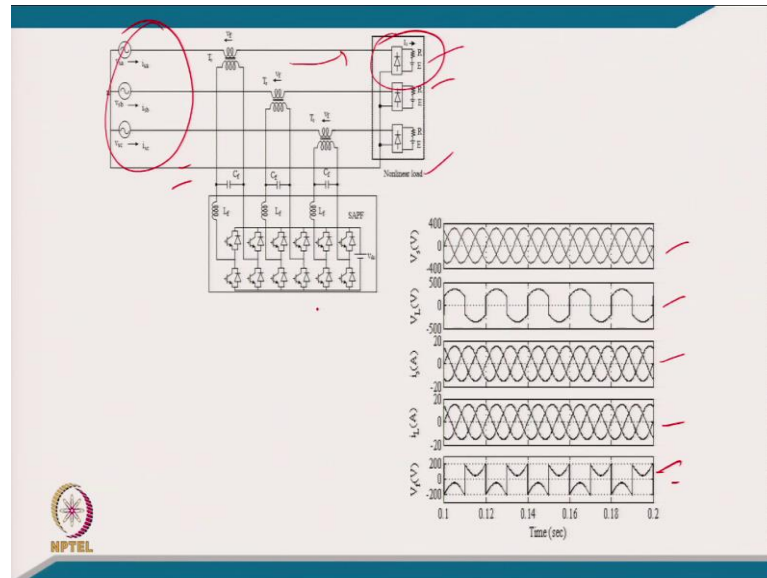


Coming to the problem number 18. In a three-phase line voltage of 380-volt, 50 hertz, 4 wire distribution system, three single phase loads connected between phase and neutral having a set of single-phase uncontrolled diode bridge converter which have a RE load of R equal to 10 ohm and E equal to 220 volt as shown in the figure. It is desired to charge the battery E with the average current of 15 ampere.

Calculate the supply phase current if three-phase series active filter consisting of VSC with series active inductor coupling transformer and dc bus connected dc bus capacitor is

connected in series with the three-phase supply lines to maintain unity power factor at ac main. Calculate the a, supply current b, rms current of the act series active filter c, the rms voltage of the input of rectifier and d, the rms voltage of the voltage across the series active filter and e, the VA rating of the series again d, the neutral current.

(Refer Slide Time: 51:36)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 53:06)

Solution: Given that, $V_s = 380/\sqrt{3} = 219.39V$, $f = 50$ Hz, a load of $R = 10\Omega$, $E = 220V$ and $I_{dc} = 15A$.

Since a series active filter is used to make the supply current sinusoidal. The rms supply current corresponding to average current of I_{dc} is as,

$$I_s = \pi I_{dc} / (2 \cdot \sqrt{2}) = 16.661A.$$

The active power is as,

$$P = 3(I_s^2 R + E I_{dc}) = 3(16.661^2 \cdot 10 + 15 \cdot 220) = 3 \cdot 6075.83$$

$$P = 18227.479 \text{ W.}$$

The supply current is as, $I_s = 16.661A$.

(a) The supply line current at unity power is as,

$$I_s = 16.661A.$$

(b) The current rating of series APF is as,

$$I_f = I_s = 16.661A.$$

(Refer Slide Time: 54:10)

(c) The rms voltage at the input of diode rectifier is computed as.

$$V_{pcc} = \sqrt{E^2 + (I_s R)^2} = 275.969 \text{ V.}$$

(d) The voltage rating of series APF, V_f , is as.


$$V_f = V_{rms} = \sqrt{\frac{1}{\pi} \int_0^{\pi} (219.39 \sqrt{2} \sin \theta - 220 - 166.610 \sqrt{2} \sin \theta)^2 d\theta}$$
$$V_f = \sqrt{\frac{1}{\pi} \int_0^{\pi} (52.78 \sqrt{2} \sin \theta - 220)^2 d\theta} = 174.004 \text{ V}$$

(e) The VA rating of VSC of APF is as,

$$S = 3 \cdot V_f \cdot I_s = 3 \cdot 174.004 \cdot 16.661 \text{ VA} = 8.697 \text{ kVA.}$$


(f) Since all three-phase currents are sinusoidal and balanced,

the neutral current of the supply is zero.



(Refer Slide Time: 54:57)

Q19. In a three-phase, line voltage of 415 V, 50 Hz, 4-wire distribution system, three single-phase loads (connected between phases and neutral) having a set of single-phase uncontrolled diode bridge converter, which have a RE load with $R=2$ ohms, and a battery voltage $E=264$ V as shown in Fig. It is desired to charge the battery with average current of 15A. If a three-phase series active power filter (three single phase VSC with ac series inductors, coupling transformers and its dc bus connected to the battery) is connected in series with the three-phase supply lines to maintain UPF at the ac mains, calculate (a) the ac line current, (b) the rms current of the APF, (c) the rms phase voltage at the input of a diode rectifier, (d) the rms voltage across the APF, (e) the VA rating of APF, and (f) turns ratio of the coupling transformer.

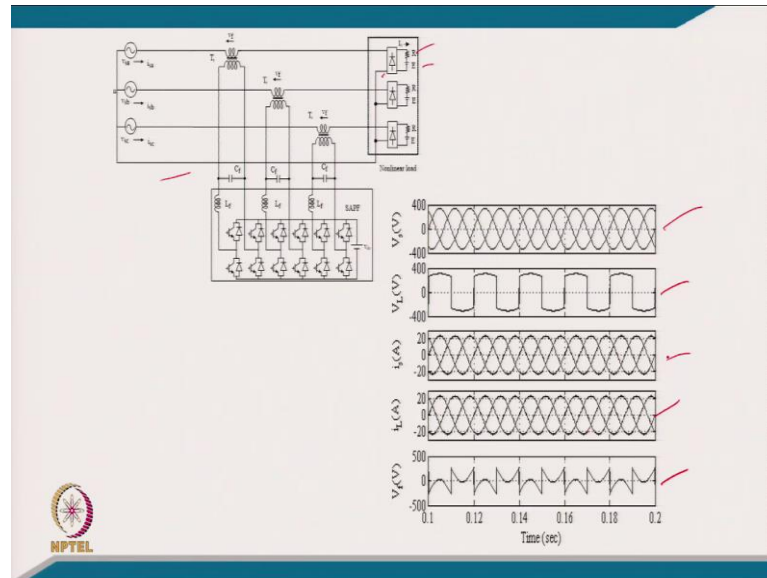


Coming to the 19 problem, in a three-phase line voltage of 415 volt, 50 hertz, 4-wire distribution system, three single-phase load connected between the phase and neutral having a set of single phase uncontrolled diode bridge converter which have a RE load equal to R equal to 2 ohm and battery voltage 264 as shown in the figure.

It is desired to charge the battery with the average current of 15 ampere. If the three-phase series active power filter single phase voltage source converter with the ac series inductor, coupling transformer and dc bus is connected to the battery is connected in

series with the three-phase supply line to maintain the unity power factor at ac mains. Calculate a, ac line current b, the rms current of the APF c, the rms phase voltage at the input of diode rectifier d, the rms voltage across the APF and the VA rating of APF and f is the turns ratio of coupling transformer.

(Refer Slide Time: 55:48)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 56:50)

Solution: Given that, supply phase voltage, $V_s = 415/\sqrt{3} = 239.6V$, frequency of the supply, $f = 50$ Hz, a load of $R = 2\Omega$, $E = 264V$ and $I_{dc} = 15A$.

Since a series active filter is used to make the supply current sinusoidal in each phase. The rms supply current corresponding to average current of I_{dc} is as,

$$I_s = \pi I_{dc} / (2 * \sqrt{2}) = 16.66A.$$

The active power is as, $P = 3(I_s^2 R + E I_{dc})$

$$P = 3(16.66^2 * 2 + 15 * 264) = 3 * 4515 = 13545W.$$

(a) The rms supply line current at unity power is as,

$$I_s = 16.66A.$$

(b) The rms current rating of series APF is as,

$$I_f = I_s = 16.66A.$$

(Refer Slide Time: 57:53)

(c) The rms voltage at the input of diode rectifier is computed as.

$$V_{pcc} = \sqrt{\{E^2 + (I_s R)^2\}} = 266.09 \text{ V.}$$

(d) The voltage rating of series APF, V_f is as.

$$V_f = V_{rms} = \sqrt{\frac{1}{\pi} \int_0^{\pi} (239.6 \sqrt{2} \sin \theta - 264 - 33.32 \sqrt{2} \sin \theta)^2 d\theta}$$

$$V_f = \sqrt{\frac{1}{\pi} \int_0^{\pi} (206.28 \sqrt{2} \sin \theta - 220)^2 d\theta} = 119.1164 \text{ V}$$

(e) The VA rating of VSC of APF is as,

$$S = 3 \cdot V_f \cdot I_s = 3 \cdot 119.1164 \cdot 16.66 \text{ VA} = 5953.4 \text{ VA.}$$



(Refer Slide Time: 58:32)

The turn's ratio of the coupling transformer is computed as follows.

The maximum ac voltage on ac side of VSC of APF may be

$$m_a E / \sqrt{2} = 0.8 \cdot 264 / (2 \cdot \sqrt{2}) = 74.67 \text{ V}$$

and on the supply side, it must be $V_{supply} = V_f$.


The turn's ratio of the coupling transformer is as.

$$N_{vsr} / N_{supply} = 74.67 / 119.1164 = 0.6268.$$



(Refer Slide Time: 58:57)

Q20. In a three-phase, line voltage of 380 V, 50 Hz, 4-wire distribution system, three single-phase loads (connected between phases and neutral) having a set of single-phase uncontrolled diode bridge converter, which has a resistive load with $R=10$ ohms, and parallel capacitive filter of 1000 μF as shown in Fig. It is desired to maintain the dc bus voltage at 200V. If a three-phase series active power filter (three single-phase VSC with ac series inductors, coupling transformers and its dc bus connected to a dc capacitor) is connected in series with the three-phase supply lines to eliminate neutral current, and to maintain UPF at the ac mains, calculate (a) the ac line current, (b) the rms current of the APF, (c) the rms phase voltage at the input of a diode rectifier, (d) the rms voltage across the APF, (e) the VA rating of APF, and (f) turns ratio of the coupling transformer.

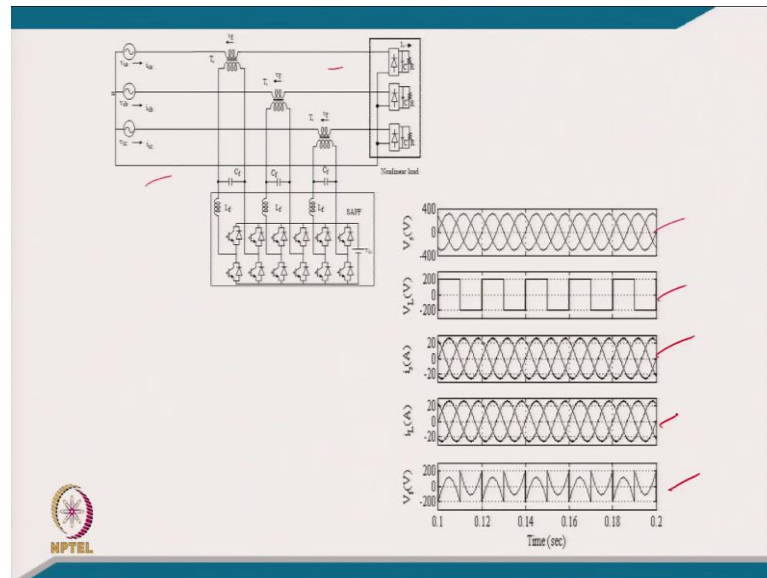


Coming to the solved example of 20. In the three-phase line voltage of 380 volt, 50 hertz, 4-wire distribution system, three single-phase load connected between phase and neutral having a set of single phase uncontrolled diode bridge converter which has a resistive load R to 10 ohm and parallel capacitive filter of 1000 micro farad it is desired to maintain dc bus voltage of 200 volt.

If the three-phase series active filter three single phase VSC with the ac series inductor, coupling transformer and its dc bus connected to a capacitor is connected in series with the three-phase supply line to eliminate neutral current and to maintain unity power factor of the ac main.

Calculate a, the ac mains line current b, the rms current of the active filter c, is the rms phase voltage at the input of diode rectifier and d, the rms voltage across the active power filter and the VA rating of active filter, e and f is the turns ratio of coupling transformer.

(Refer Slide Time: 59:54)



The explanation of the numerical problem is described in the screenshots herein.

(Refer Slide Time: 60:37)

Solution: Given that, supply phase voltage, $V_s = 380/\sqrt{3} = 219.39\text{V}$, frequency of the supply, $f = 50\text{ Hz}$, a load of $R = 10\Omega$, $V_{dc} = 200\text{V}$.

The dc load current is as, $I_{dc} = 200/10 = 20\text{A}$.

Since a series active filter is used to make the supply current sinusoidal in each phase. The rms supply current corresponding to it is as,

$$I_s = 200 \cdot 20 / 219.39 = 18.23\text{A}$$

The active power is as, $P = 3(V_{dc} I_{dc}) = 3(200 \cdot 20)$
 $P = 3 \cdot 4000 = 12000\text{W}$.

(a) The rms supply line current at unity power is as,
 $I_s = 18.23\text{A}$.

(b) The rms current rating of series AF is as,
 $I_f = I_s = 18.23\text{A}$.


(Refer Slide Time: 61:37)

(c) The sine wave supply current after compensation results in continuous conduction of diodes of the rectifier (180°) and it results in square wave ac voltage at PCC with an amplitude of dc bus voltage, $V_{pcc}=200$ V.
Therefore, $V_{pcc}=200$ V.

(d) The voltage rating of series APF, V_f is as follows.

$$V_f = \sqrt{\frac{1}{\pi} \int_0^{\pi} (219.39 \cdot \sqrt{2} \sin \theta - 200)^2 d\theta} = 95.52 \text{ V}$$

(e) The VA rating of VSC of APF is as,

$$S = 3 \cdot V_f \cdot I_s = 3 \cdot 95.52 \cdot 1740.14 = 5.22 \text{ kVA.}$$


(Refer Slide Time: 62:20)


The turn's ratio of the coupling transformer is computed as follows.

The maximum ac voltage on ac side of VSC of APF may be


$$m_a V_{dc} / \sqrt{2} = 0.8 \cdot 200 / (2 \cdot \sqrt{2}) = 56.568 \text{ V}$$

and on the supply side, it must be $V_{supply} = V_f$.

The turn's ratio of the coupling transformer is as.

$$N_{vsr} / N_{supply} = 56.568 / 95.52 = 0.592.$$


(Refer Slide Time: 62:40)




SUMMARY

- Series active power filters (APFs) are used to compensate the voltage quality problems of the supply system.
- They protect sensitive loads from interruptions, which cause loss of production and mal-operation of other critical equipment such as medical and healthcare systems.
- The series active power filters (APFs) are also used to compensate the power quality problems of harmonics currents of voltage fed types of nonlinear loads by injecting the appropriate voltage to block the harmonics currents.

Well, we will like to summarize. Now, the series active filter are used to compensate the voltage quality problems of the supply system. They protect sensitive load from interruption which causes loss of production and mal operation of the other critical equipment such as medical and healthcare instrument, healthcare system and the series active power filter also use to compensate the power quality problems of harmonic currents of voltage fed kind of load of non-linear load by injecting the appropriate voltage to block the harmonics current like which we have given many example.

(Refer Slide Time: 63:13)



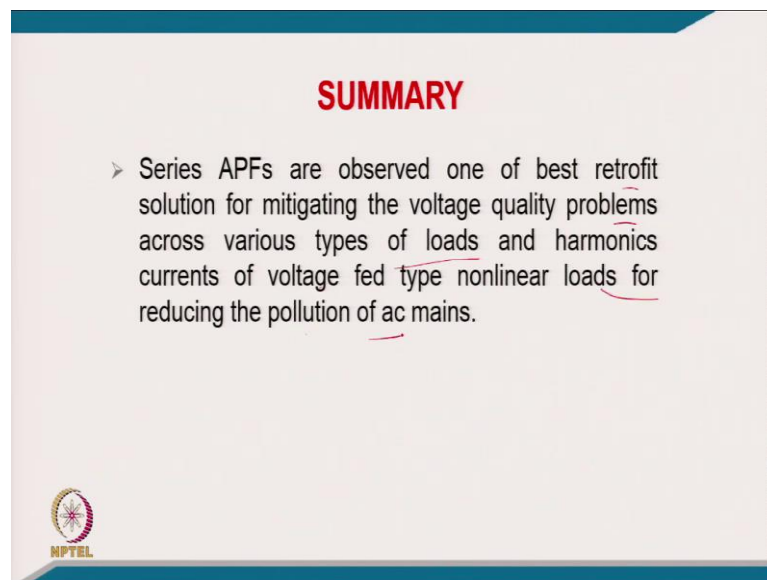
SUMMARY

- These series APFs offer best solution for voltage fed nonlinear loads with moderate rating.
- The PWM based voltage source converters (VSCs) are preferred to realize series APFs because of low cost, reduced size, light in weight and reduced losses.
- An analytical study of various performance indices of series APFs for the compensation of voltage based power quality problems of different types of loads and harmonics currents compensation of voltage fed types of nonlinear loads is made in detail with several numerical examples to study the rating of power filters and how it is affected with nature of various kinds of nonlinear loads.

And this series active filter offered the best solution for voltage fed non-linear load with moderate rating. The PWM based voltage source inverters converters are used are preferred to realize the series active power filter because of low cost, reduce size, light in weight and reduce losses.

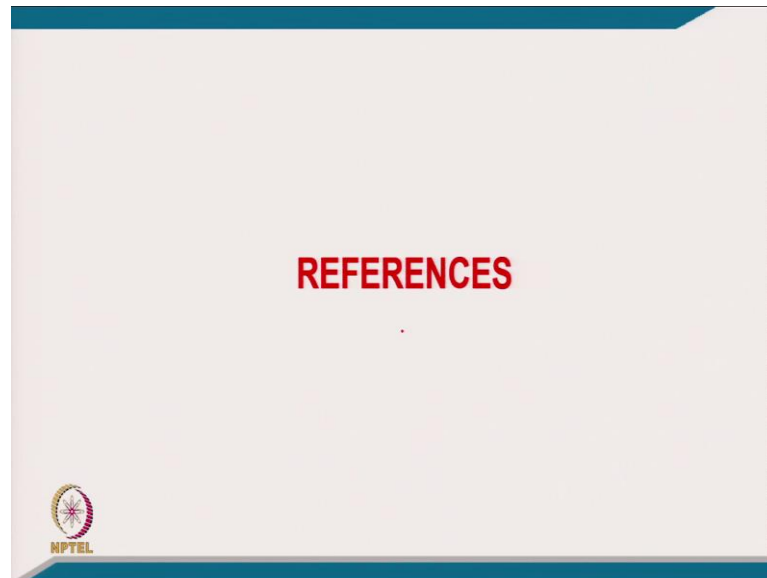
An analytical study of various performance indices of series active filters for compensation of voltage based power quality problem of different types of load and the harmonic current compensation of voltage fed kind of load is made in detail with the several numerical examples to study the rating of power filters and how it is affect the nature of various kind of non-linear load.

(Refer Slide Time: 63:51)

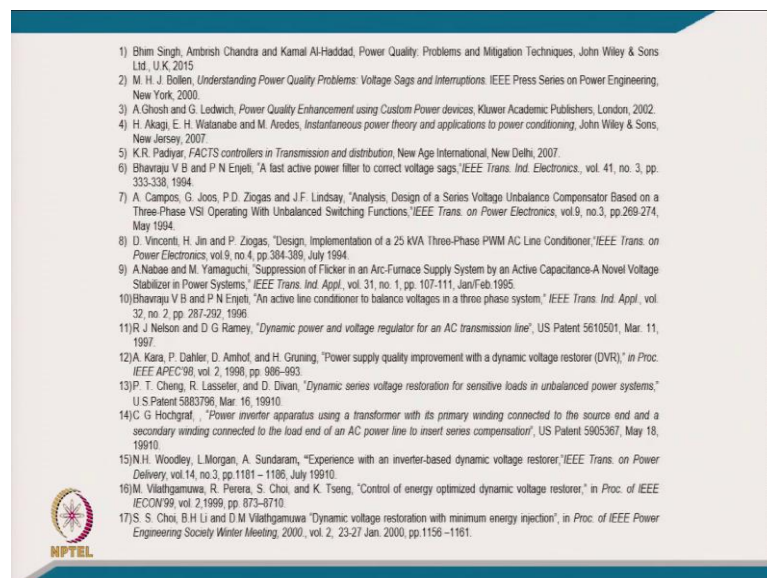


And series active filters are observed one of the best rate of it solution for mitigating voltage power quality problem across various type of load and harmonic currents of voltage fed kind of non-linear load for reducing the pollution of ac mains current.


(Refer Slide Time: 64:05)



(Refer Slide Time: 64:06)



(Refer Slide Time: 64:07)



18) P. Daehler and R. Affolter, "Requirements and solutions for dynamic voltage restorer, a case study," in *Proc. of IEEE-PES Winter Meeting*, vol. 4, 2000, pp. 2881-2885.

19) W. E. Brumsickle, R. S. Schneider, G. A. Luckjiff, D. M. Divan, and M. F. McGranaghan, "Dynamic sag correctors: Cost-effective industrial power line conditioning," *IEEE Trans. Ind. Appl.*, vol. 37, pp. 212-217, Jan./Feb. 2001.

20) J. G. Nielsen, F. Blaabjerg, and N. Mohan, "Control strategies for dynamic voltage restorer compensating voltage sags with phase jump," in *Proc. of IEEE APEC'01*, vol. 2, 2001, pp. 1267-1273.

21) L. Xu, E. Acha and V.G. Agelidis, "A new synchronous frame based control strategy for a series voltage and harmonic compensator," in *Proc. of 2001 IEEE Applied Power Electronics Conf.*, vol. 2, 2001, pp. 1274-1280.

22) A. Ghosh and Joshi A, "A new algorithm for the generation of reference voltages of a DVR using the method of instantaneous symmetrical components," *IEEE Power Engineering Review*, vol. 22, no. 1, pp. 63-65, Jan. 2002.

23) Hong-Ju Jung, In-Young Suh, Byung-Seob Kim, Hae-Young Kim, Sae-Young Choi, Jong-Hwan Song, "A Study on DVR Control for Unbalanced Voltage Compensation," in *Proc. of Seventeenth Annual IEEE Applied Power Electronics Conference and Exposition, 2002. APEC 2002. vol. 2*, pp. 1068-1073.

24) A. Ghosh and G. Ledwich, "Compensation of distribution system voltage using DVR," *IEEE Trans. on Power Delivery*, vol. 17, no. 4, pp. 1030-1036, Oct. 2002.

25) Hongfa Ding, Shu Shuangyan, Duan Xianzhong and Gao Jun, "A novel dynamic voltage restorer and its unbalanced control strategy based on space vector PWM," *International Journal of Electrical Power & Energy Systems*, vol. 24, no. 9, pp. 693-699, Nov. 2002.

26) H. Awad, Svensson J and Bollen, M.H.J., "Static series compensator for voltage dips mitigation," in *Proc. of IEEE Power Tech Conference*, Bologna, vol. 3, June 2003, pp. 23-26.

27) Edy C. Aeloiza, Prasad N. Enjeti, Luis A. Moran, Oscar C. Montero-Hernandez, and Sangsun Kim, "Analysis and Design of a New Voltage Sag Compensator for Critical Loads in Electrical Power Distribution Systems," *IEEE Trans on Ind. Appl.*, vol. 39, no. 4, pp. 1143-1150, July/Aug. 2003.

28) R. Affolter and B. Cornelli, "Experience with a dynamic voltage restorer for a critical manufacturing facility," in *Proc. of IEEE Transmission and Distribution Conference and Exposition*, vol. 3, Sept. 2003, pp. 937-9310.

29) Il-Yop Chung, Dong-Jun Won, Sang-Young Park, Seung-Il Moon and Jong-Kaun Park, "The DC link energy control method in dynamic voltage restorer system," *International Journal of Electrical Power & Energy Systems*, vol. 25, no. 7, pp. 525-531, Sept. 2003.


30) J. W. Liu, Choi S.S. and Chen S., "Design of step dynamic voltage regulator for power quality enhancement," *IEEE Trans. on Power Delivery*, vol. 18, no. 4, pp. 1403-1409, Oct. 2003.

31) Peter Dahler and Knap G, "Protection of a dynamic voltage restorer", US Patent 6633092, Oct. 14, 2003.

32) A. Ghosh, A.K. Jindal and A. Joshi, "Design of a capacitor-supported dynamic voltage restorer (DVR) for unbalanced and distorted loads," *IEEE Trans. on Power Delivery*, vol. 19, no. 1, pp. 405-413, Jan. 2004.

33) B. N. Singh and M. Simina, "Intelligent solid-state voltage restorer for voltage swell/sag and harmonics", *IEE Proc. on Electric Power Applications*, vol. 151, no. 1, pp. 98-106, Jan. 2004.

(Refer Slide Time: 64:07)



34) Hyosung Kim, Jang-Hwan Kim and Seung-Ki Sul, "A Design Consideration of Output Filters for Dynamic Voltage Restorers," in *Proc. of 35th Annual IEEE Power Electronics Specialists Conference Aachen, Germany, 2004*, pp. 4268-4272.

35) Sang-Joon Lee, Hyosung Kim, Seung-Ki Sul and Frede Blaabjerg, "A Novel Control Algorithm for State-Series Compensators by Use of PQR Instantaneous Power Theory," *IEEE Transactions on Power Electronics*, vol. 19, no. 3, pp. 814-827, May 2004.

36) Sang-Joon Lee, Hyosung Kim and Seung-Ki Sul, "A Novel Control Method for the Compensation Voltages in Dynamic Voltage Restorers," in *Proc. of Nineteenth Annual IEEE Applied Power Electronics Conference and Exposition, 2004. APEC '04*, vol. 1, pp. 614-620.

37) John Godsk Nielsen and Frede Blaabjerg, "A detailed comparison of system topologies for dynamic voltage restorers," *IEEE Trans. on Ind. Appl.*, vol. 41, no. 5, pp. 1272-1280, Sept/Oct 2005.

38) M.J. Newman, D.G. Holmes, J.G. Nielsen, and F. Blaabjerg, "A dynamic voltage restorer (DVR) with selective harmonic compensation at medium voltage level," *IEEE Trans. on Industrial Electronics*, vol. 51, no. 6, pp. 1744-1753, Dec. 2005.

39) M.R. Banaei, S.H. Hosseini, S. Khanmohamadi and G.B. Gharehpetian, "Verification of a new energy control strategy for dynamic voltage restorer by simulation," in *Proc. of Simulation Modelling Practice and Theory*, vol. 14, no. 2, Feb. 2006, pp. 112-125.

40) Fausto Bastos Libano, Sergio Lodeiro Muller, Rodrigo Antonio Marques Braga, Joao Verissimo Rossoni Nunes, Otavio Simoes Mano, Igor Abraham Paranhos, "Simplified Control of the Series Active Power Filter for Voltage Conditioning," in *Proc. of IEEE ISIE 2006*, July 9-12, 2006, pp. 1706-1712.

41) M.R. Banaei, S.H. Hosseini and G.B. Gharehpetian, "Inter-line dynamic voltage restorer control using a novel optimum energy consumption strategy," in *Proc. of Simulation Modelling Practice and Theory*, vol. 14, no. 7, Oct. 2006, pp. 989-9910.

42) D. Mahinda Vilathgamuwa, H. M. Wijekoon, and S. S. Choi, "A Novel Technique to Compensate Voltage Sags in Multiline Distribution System—The Interline Dynamic Voltage Restorer," *IEEE Transactions on Industrial Electronics*, vol. 53, no. 5, pp. 1603-1611, October 2006.

43) D. Mahinda Vilathgamuwa, H. M. Wijekoon and S. S. Choi, "A Novel Technique to Compensate Voltage Sags in Multiline Distribution System—The Interline dynamic Voltage Restorer," *IEEE Trans. on Industrial Electronics*, vol. 54, no. 4, pp. 1603-1611, Aug. 2007.

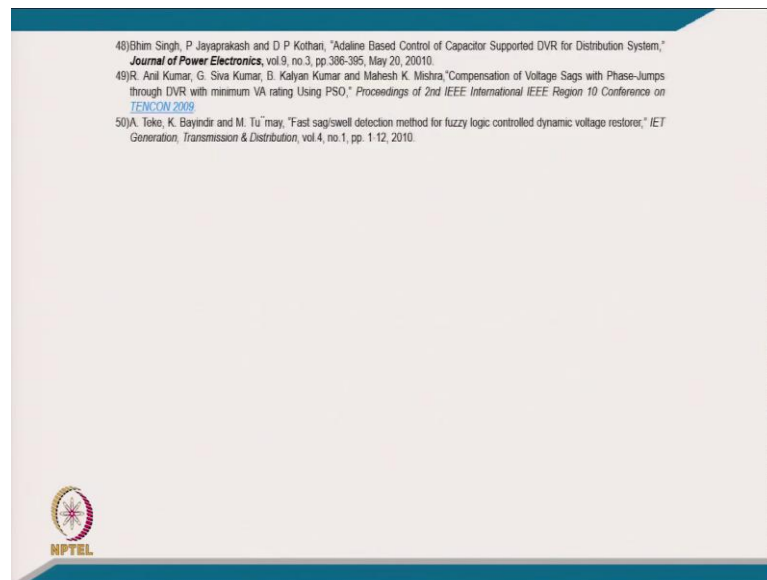
44) Amit Kumar Jindal, Arindam Ghosh and Avinash Joshi, "Critical load bus voltage control using DVR under system frequency variation," *Electric Power Systems Research*, vol. 78, no. 2, pp. 255-263, Feb. 2010.

45) Bhim Singh, P. Jayaprakash, D. P. Kothari, Ambrish Chandra and Kamal-Al-Haddad, "Indirect Control of Capacitor Supported DVR for Power Quality Improvement in Distribution System," *Proceedings of the 2008 PES General Meeting held 20-24 July, 2008 in Pittsburgh, PA USA*.

46) Jayaprakash P., Bhim Singh and Kothari D. P., "Control of Reduced Rating Dynamic Voltage Restorer with Battery Energy Storage System," *Proceedings of IEEE POWERCON 2008 & 2008 IEEE Power India Conference held in New Delhi (India) from 12th June to 15th October 2008*.

47) Bhim Singh, P. Jayaprakash, and D.P. Kothari, "Current Mode Control of Dynamic Voltage Restorer (DVR) for Power Quality Improvement in Distribution System," *Proceedings of 2nd IEEE International Conference on Power and Energy PECon 2008 in Johor Bahru, Malaysia on 1-3 December 2008*.

(Refer Slide Time: 64:08)



And these are the references for this topic.