**Power Quality**
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**Indian Institute of Technology, Delhi**

**Lecture - 27**
**Hybrid Power Filters (contd.)**

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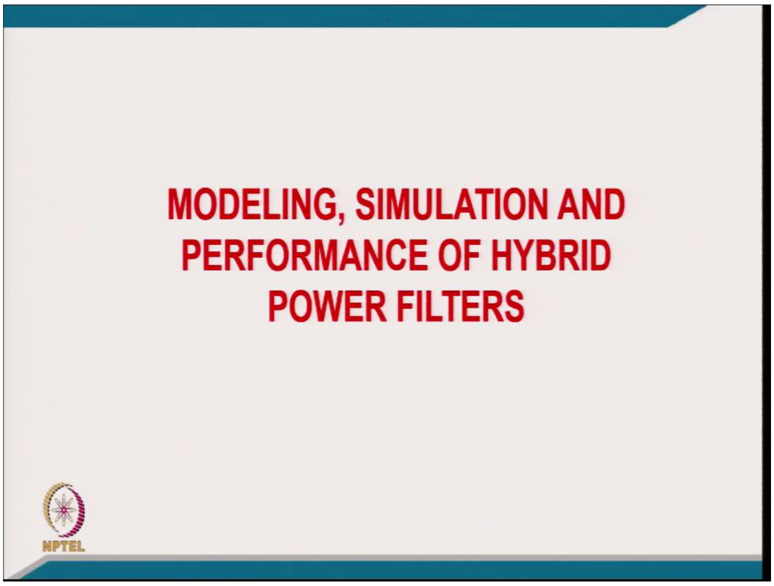


Welcome to the course on Power Quality. We were discussing about the Hybrid Power Filter.

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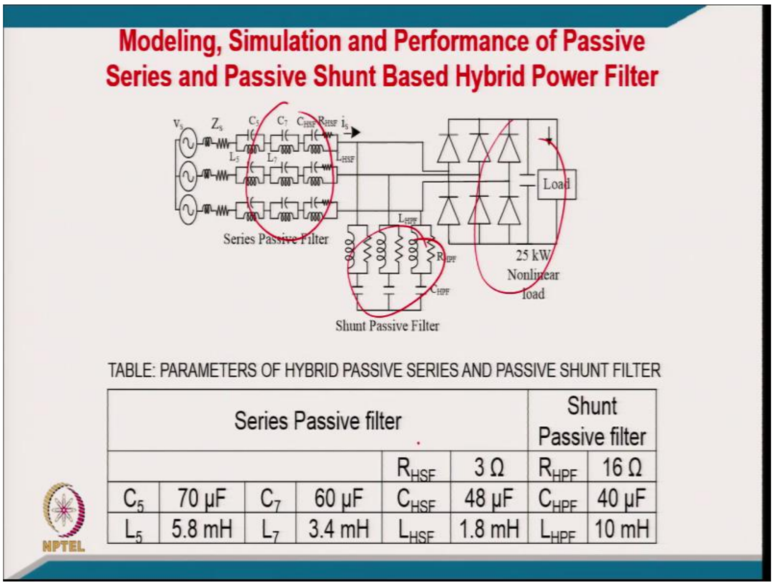

The simulation performance of the hybrid power filter are detailed in the following screenshots.

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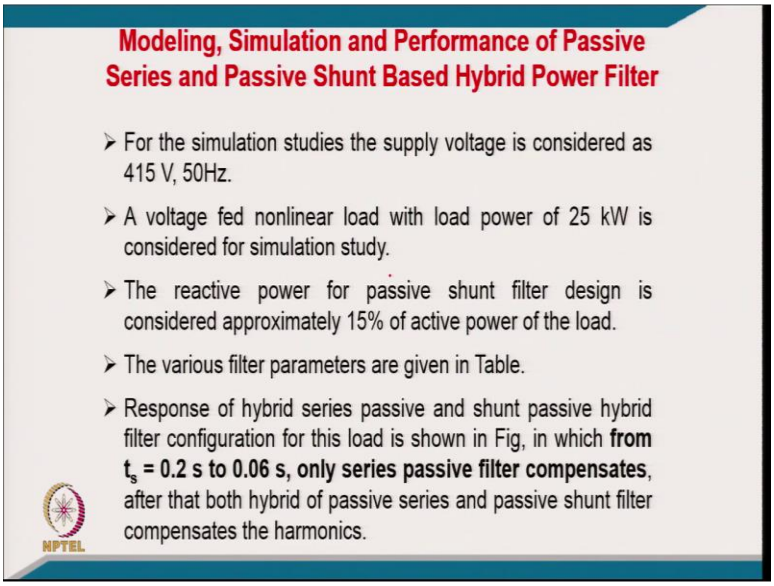


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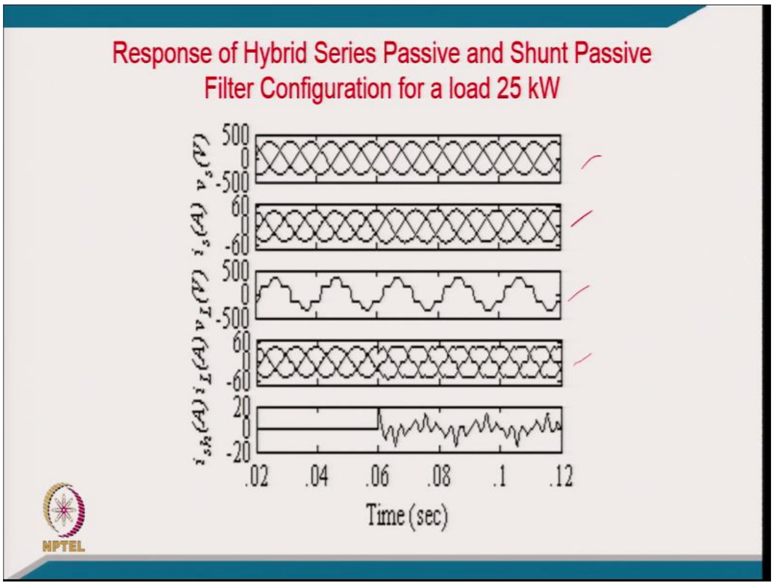

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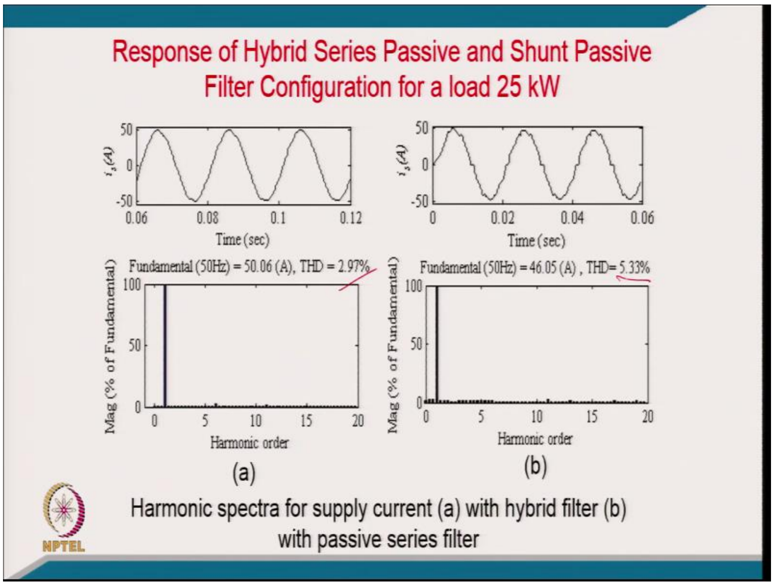


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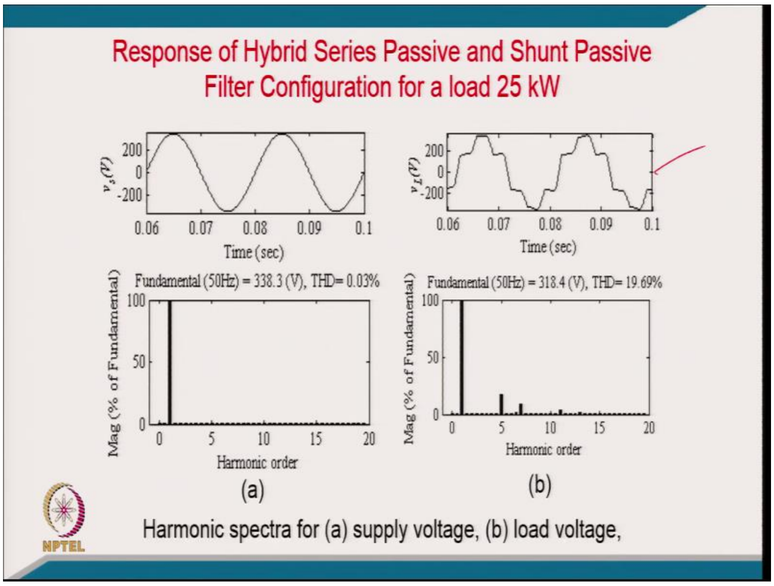

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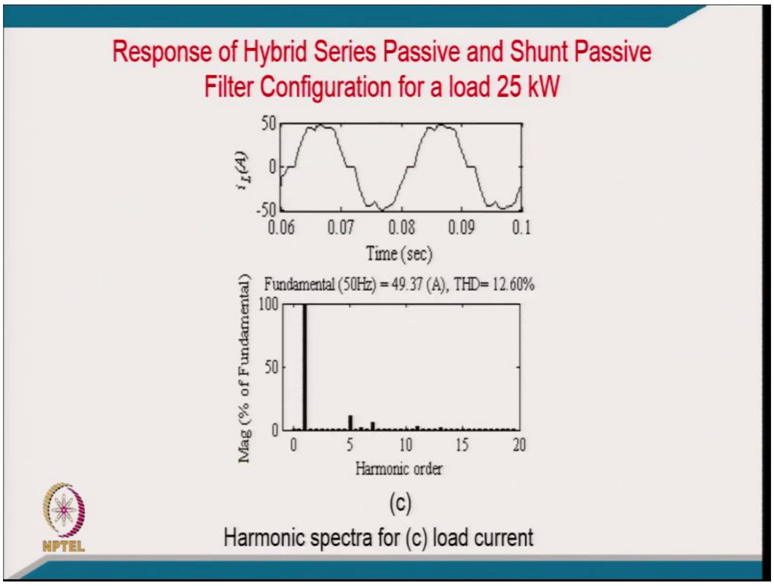


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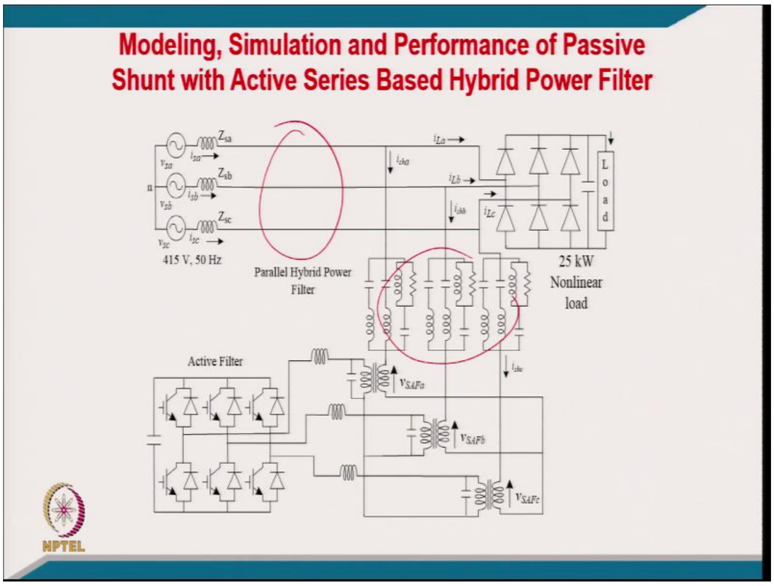

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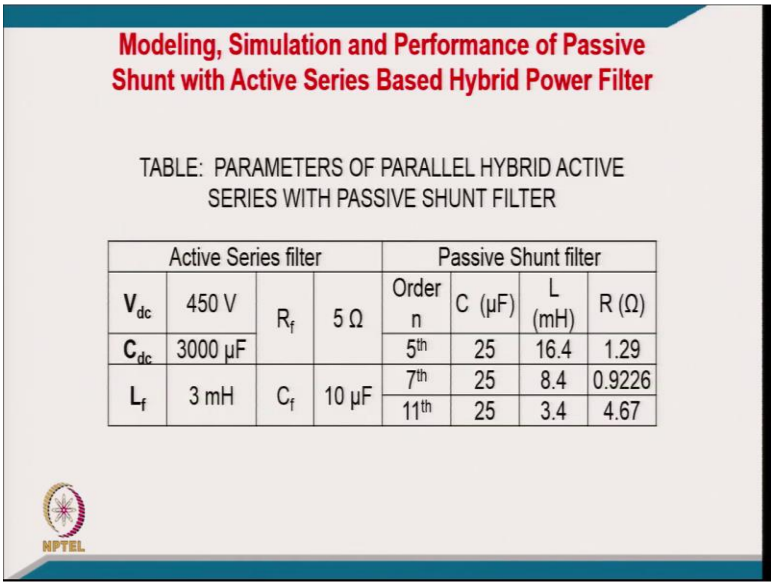


| Active Series filter | | | | Passive Shunt filter | | | |
|---|---|---|---|---|---|---|---|
| $V_{dc}$ | 450 V | $R_f$ | 5 Ω | Order n | C (μF) | L (mH) | R (Ω) |
| $C_{dc}$ | 3000 μF | | | 5th | 25 | 16.4 | 1.29 |
| $L_f$ | 3 mH | $C_f$ | 10 μF | 7th | 25 | 8.4 | 0.9226 |
| | | | | 11th | 25 | 3.4 | 4.67 |

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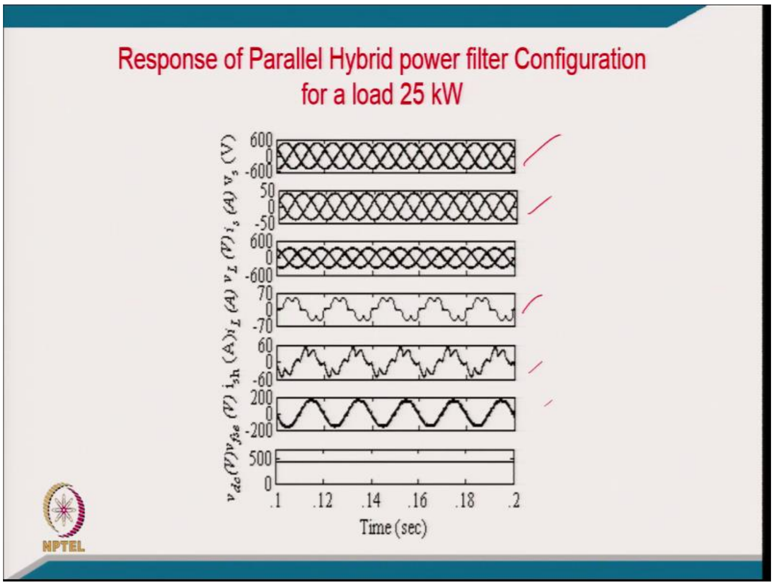

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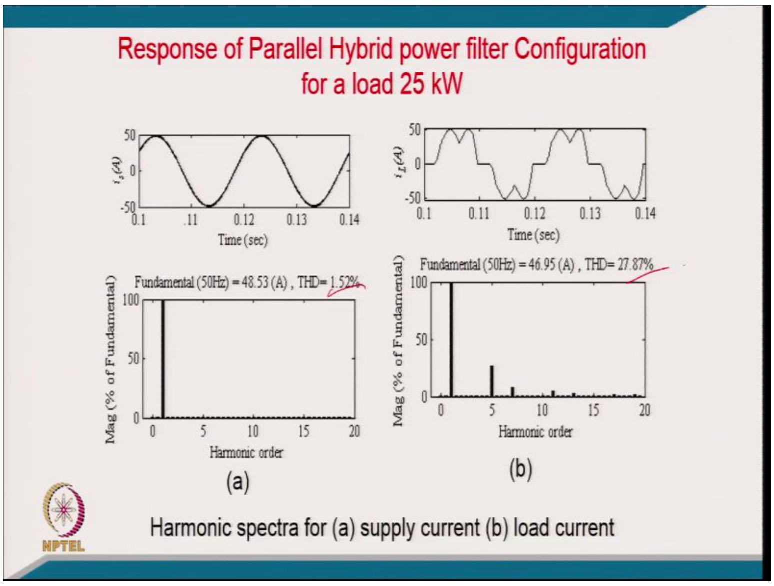


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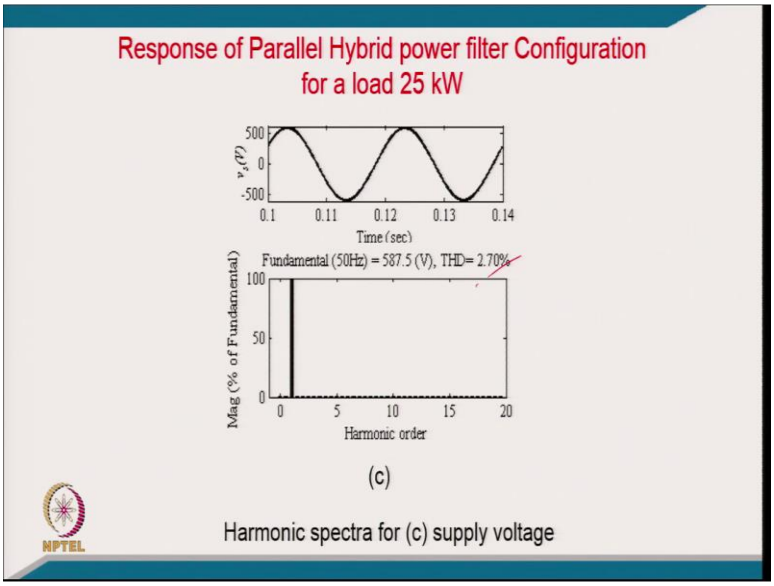

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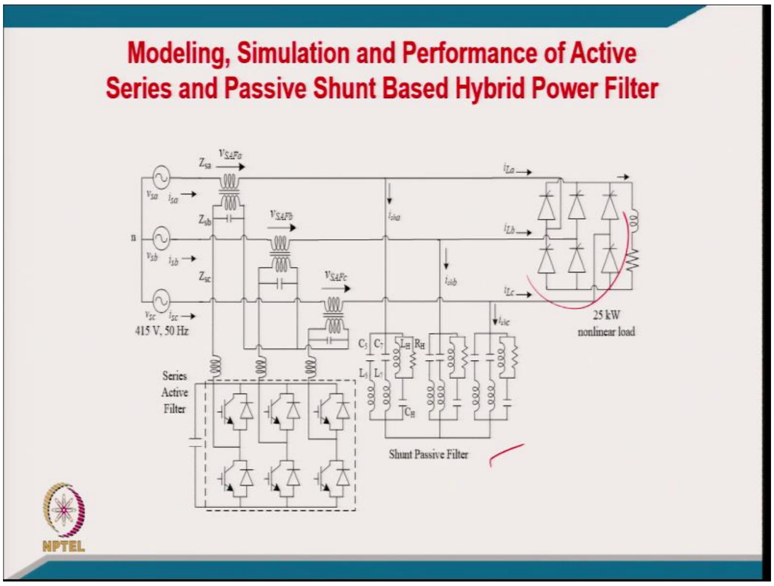


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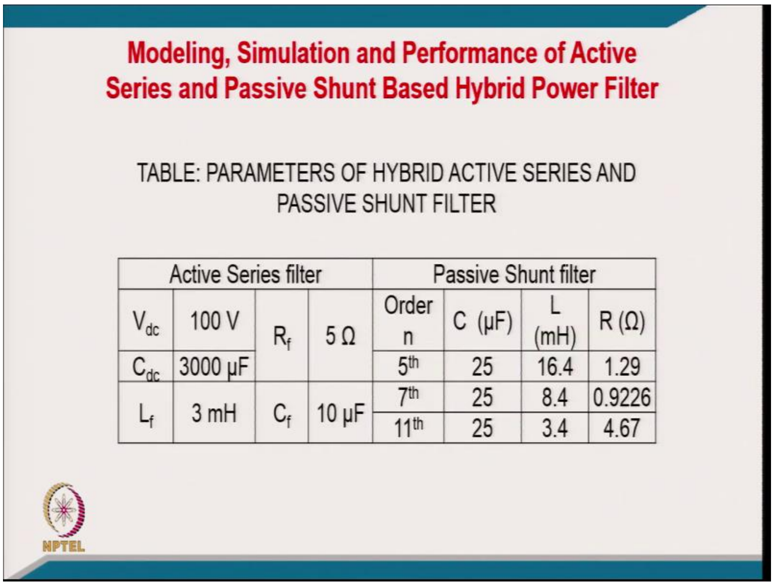


| Active Series filter | | | | Passive Shunt filter | | | |
|---|---|---|---|---|---|---|---|
| $V_{dc}$ | 100 V | $R_f$ | 5 Ω | Order n | C (μF) | L (mH) | R (Ω) |
| $C_{dc}$ | 3000 μF | | | $5^{th}$ | 25 | 16.4 | 1.29 |
| $L_f$ | 3 mH | $C_f$ | 10 μF | $7^{th}$ | 25 | 8.4 | 0.9226 |
| | | | | $11^{th}$ | 25 | 3.4 | 4.67 |

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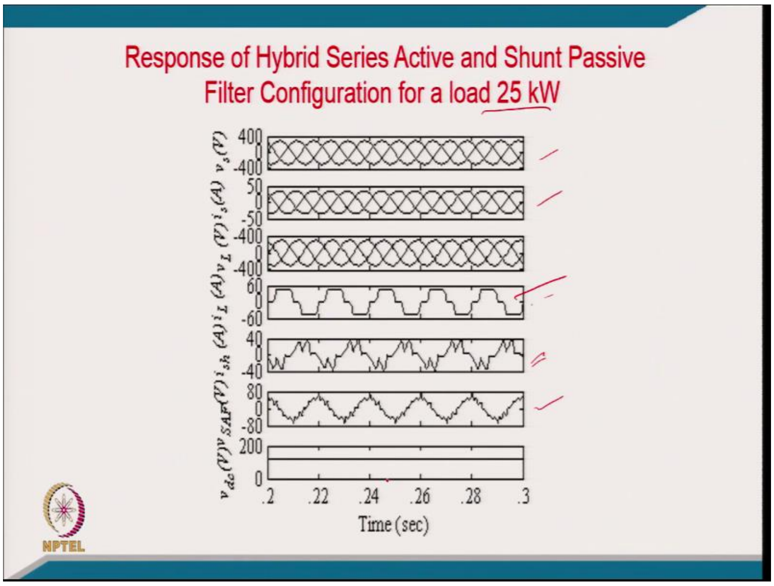


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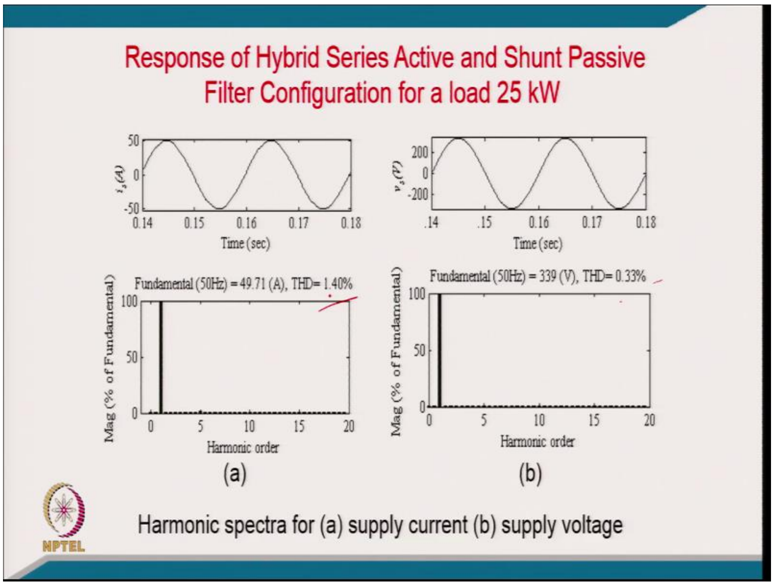

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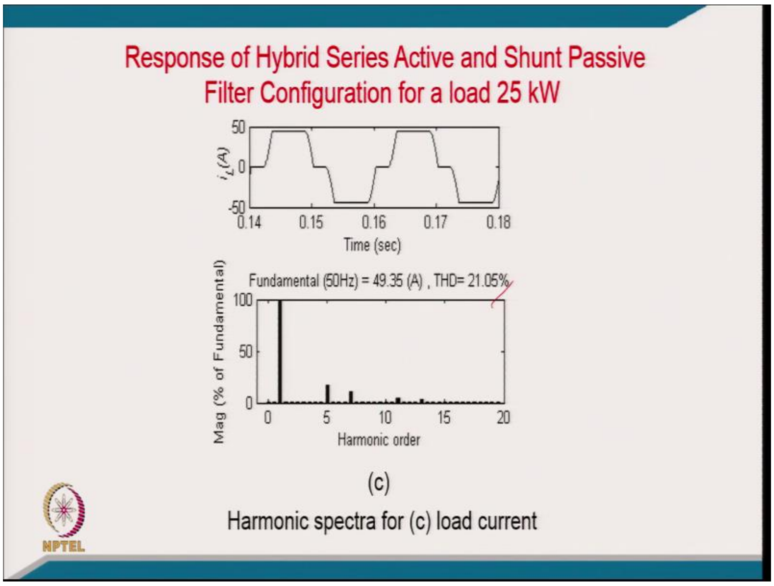


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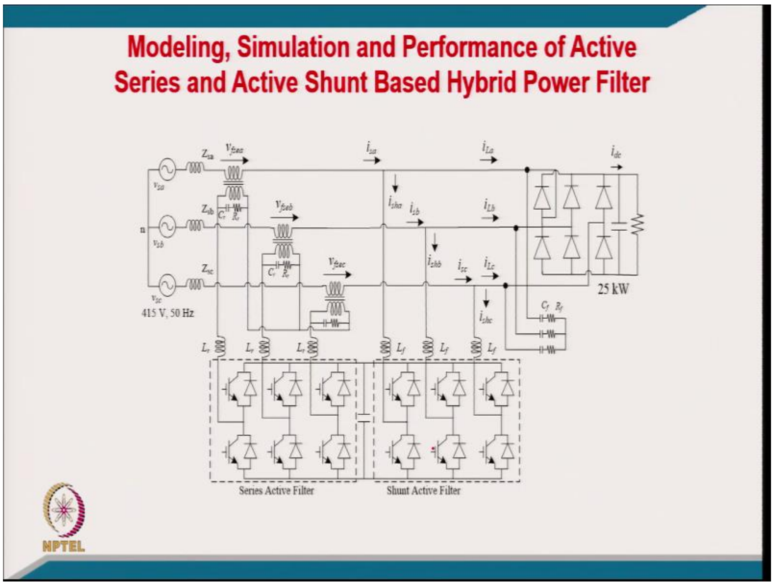

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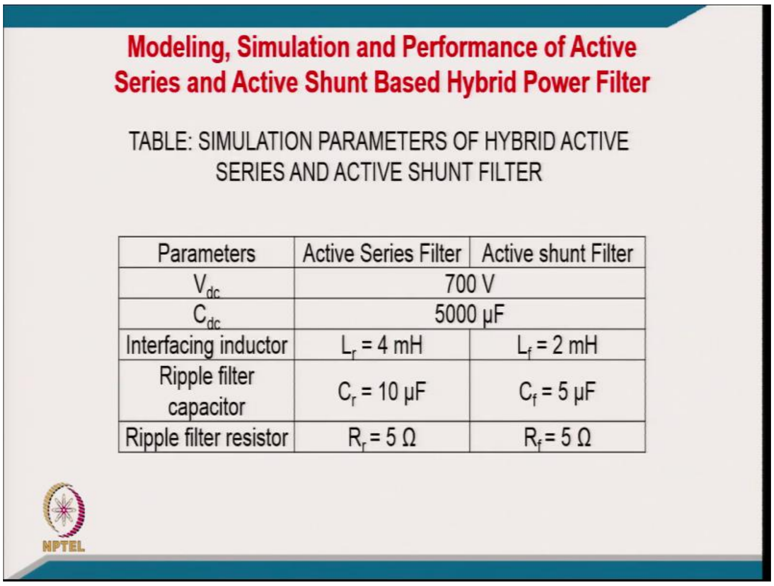


| Parameters | Active Series Filter | Active shunt Filter |
|---|---|---|
| $V_{dc}$ | 700 V | |
| $C_{dc}$ | 5000 μF | |
| Interfacing inductor | $L_r$ = 4 mH | $L_f$ = 2 mH |
| Ripple filter capacitor | $C_r$ = 10 μF | $C_f$ = 5 μF |
| Ripple filter resistor | $R_r$ = 5 Ω | $R_f$ = 5 Ω |

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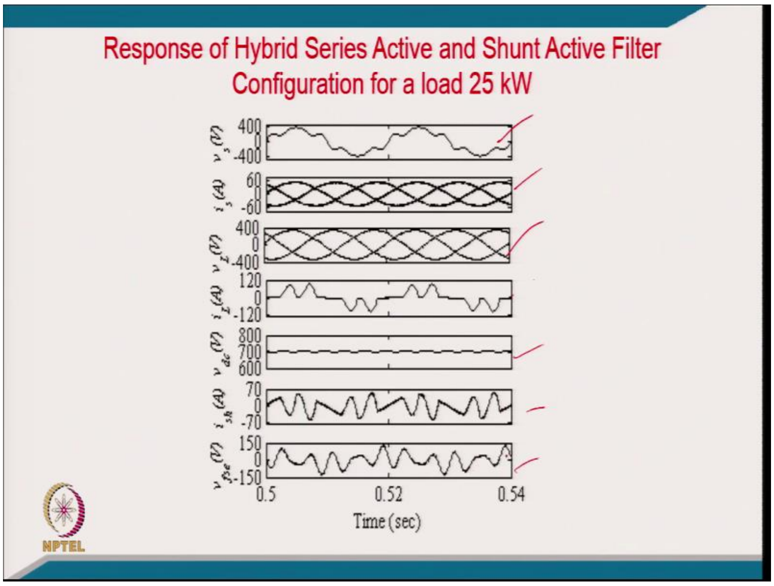

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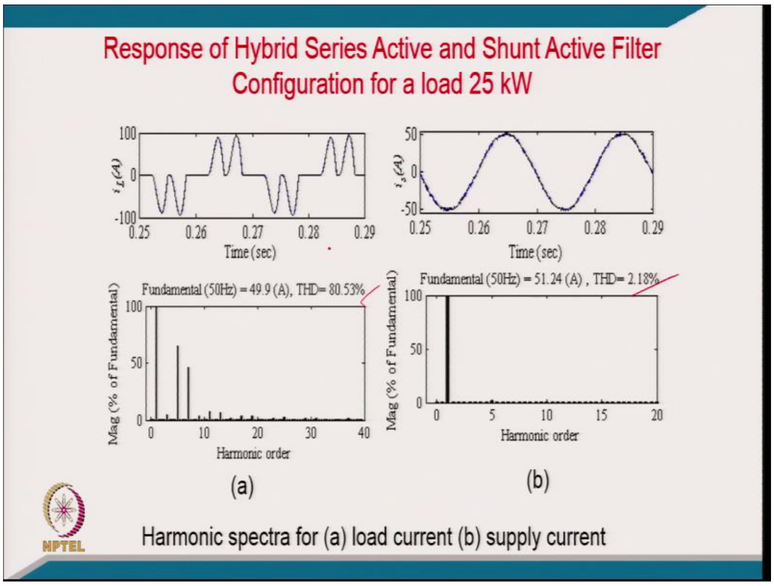


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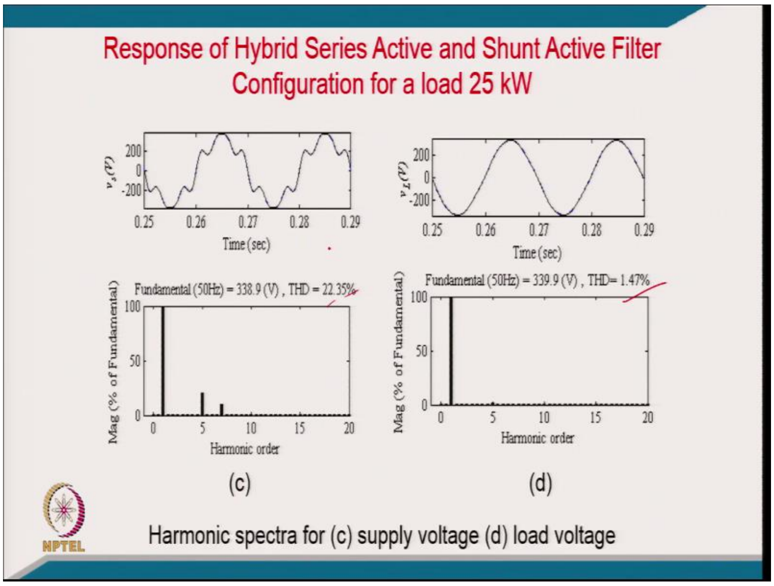

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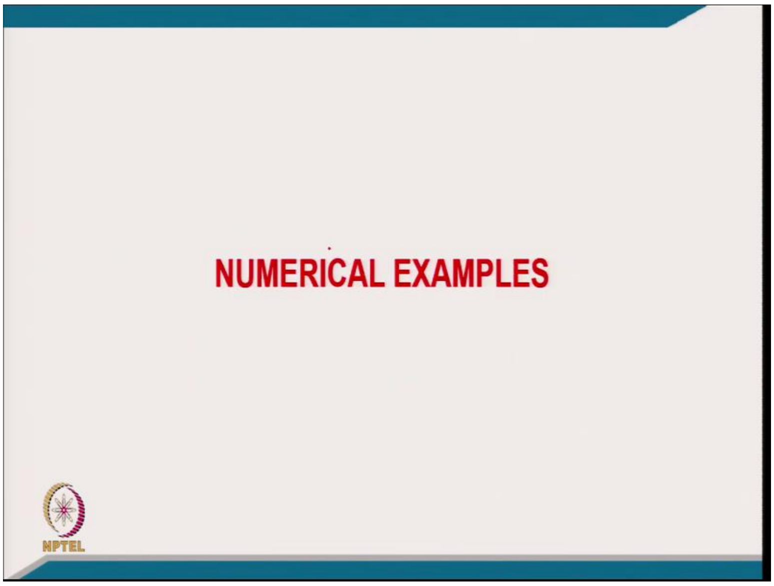


Now, we will discuss some of the numerical examples.

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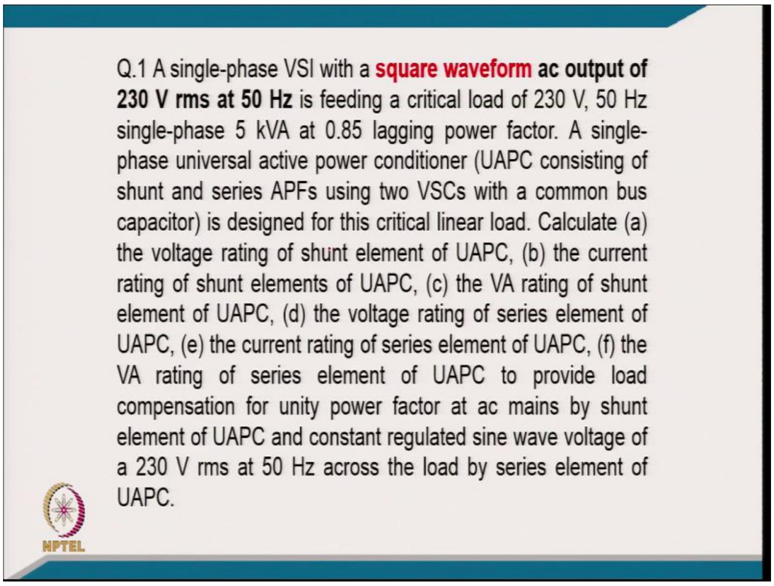


Coming to the first numerical example, a single phase voltage source inverter with a square wave ac output of 230 volt, 50 hertz is feeding the critical load of 230 volt, 50 hertz single-phase 5 kVA at 0.8 lagging, 0.85 lagging power factor and single-phase universal active power conditioner UAPC consisting of shunt and series active power filter using two VSC with common dc bus capacitor is design for this critical linear load.

Calculate the voltage rating of shunt element of UPAC, Universal Active Power Filter; current rating of the shunt element of u Universal Active Power Filter; voltage rating of the VA rating of the shunt element and voltage rating of series element and current rating of series element and the VA rating of series element of u Universal Active Power Filter to provide the load compensation for unity power factor at ac mains and by shunt element and constant regulated sine voltage of a 230 volt rms 50 hertz across the load by series element of UPAC.

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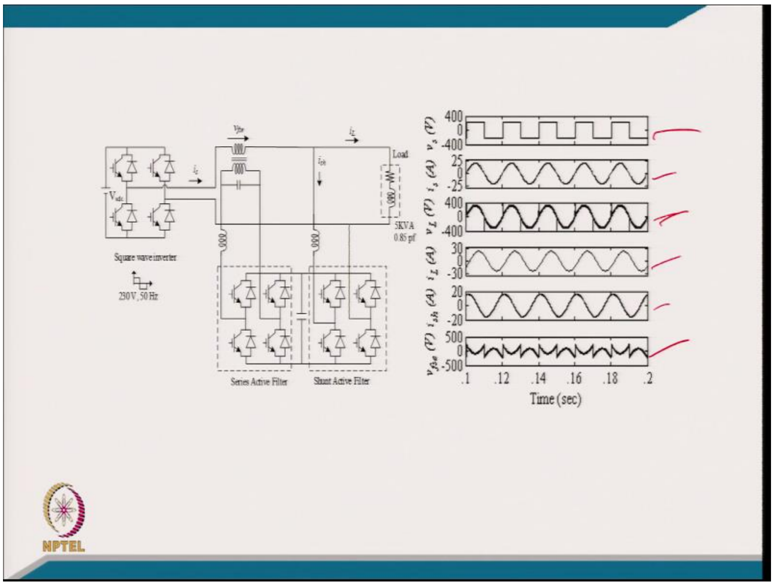


The explanation of the numerical problem is described in the screenshots herein.

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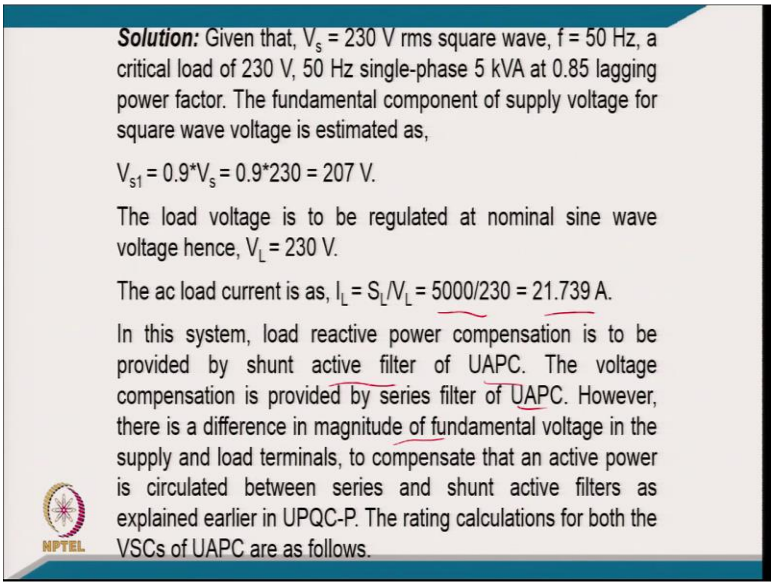


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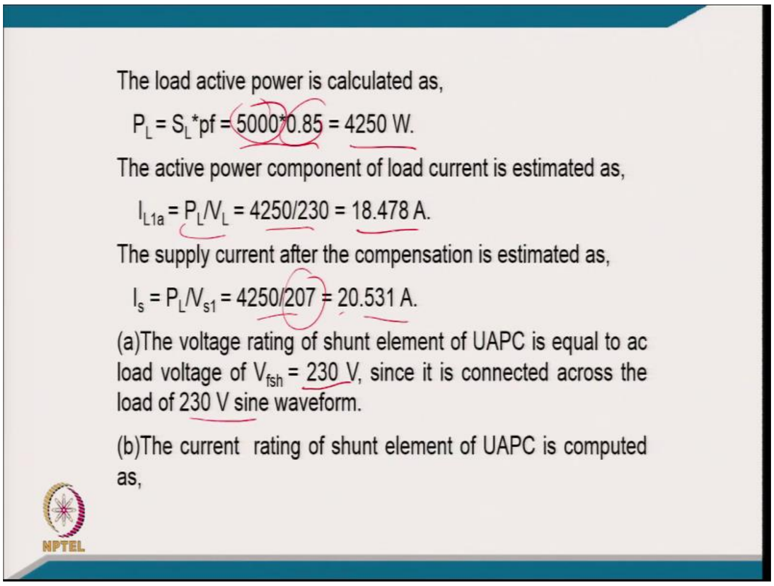

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The shunt element of UAPC is to correct the power factor of the load to unity, hence it supplies the reactive power required for the load, therefore reactive power component of the shunt APF current is estimated as,

$I_{shr}$=Reactive power component of current of the load

$=I_L\sqrt{(1-PF^2)} = 21.739*0.527 = 11.452$ A.

The supply fundamental voltage is lower as compared to the required load voltage. Hence, shunt APF absorbs active power and that active power is delivered back into the system via series APF. The active power component of the shunt APF current is estimated as,

$I_{sha} = I_s - I_{L1a} = (20.531 - 18.478)\ A = 2.053$ A.

The net current rating of shunt APF is estimated as,

$I_{sh}=\sqrt{(I_{sha}^2+I_{shr}^2)}=\sqrt{(2.053^2+ 11.452^2)} = 11.635$ A.

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(c) The VA rating of VSC of shunt APF is as,

$S_{sh} = V_{fsh}*I_{sh} = 230*11.635 = 2675.956$ VA.

(d) The voltage rating of series active filter of UAPC is computed as,

The supply voltage is square wave of $V_s$= 230 V rms and the load voltage at PCC must be sine wave of $V_L$ = 230 V. Therefore the series APF must inject the difference of these two voltages to provide the required voltage at the load end.

The voltage rating of series APF,

$$V_{fse} = \sqrt{(1/\pi)\left(\int_0^{\pi}(230-230\sqrt{2}\sin\theta)^2 d\theta\right)} = 102.696V$$

(e) The current rating of series active filter of UAPC is same as supply current,

$I_{se} = I_s = 20.531$ A.

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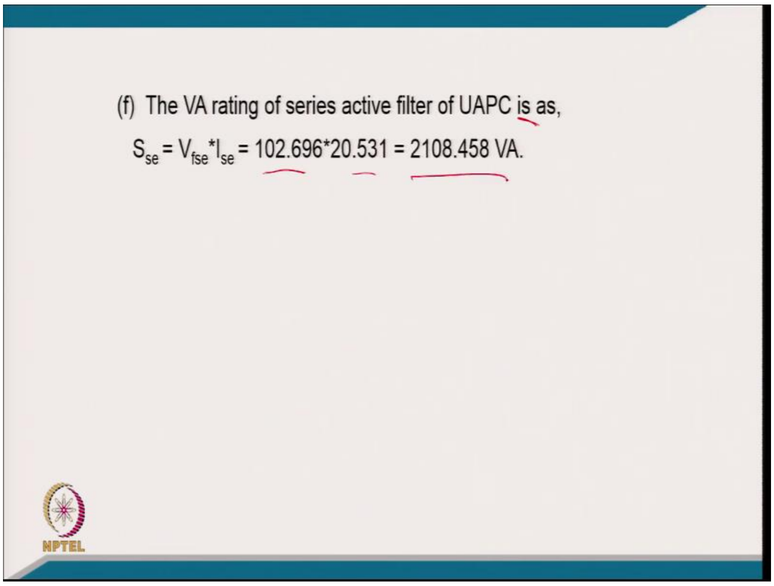


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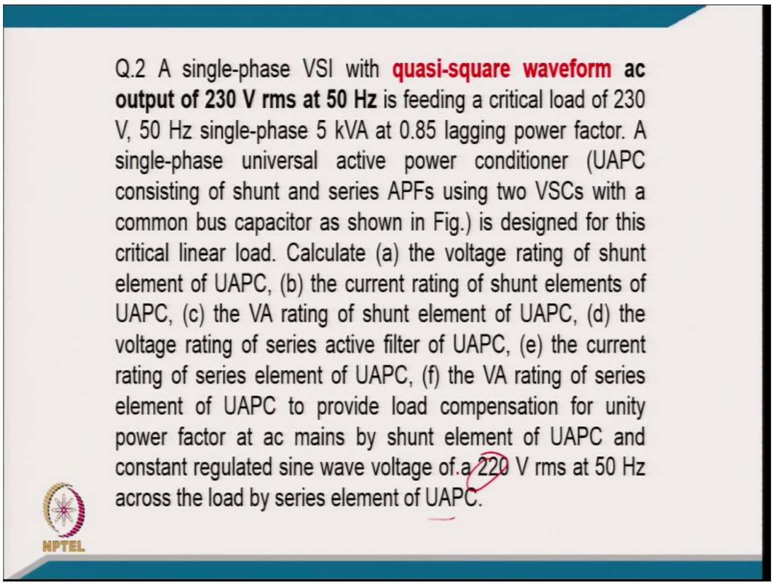


Coming to another example. A single-phase voltage source inverter with the quasi-square waveform ac output of 230 volt rms at 50 hertz is feeding a critical load of 230 volt 50 hertz single-phase 5 kVA at 0.85 lagging power factor. A single-phase universal active power condition conditioner or consisting of shunt and series active power filter using two voltage source converter with common bus capacitor shown in the figure is design for critical linear load.

Calculate the volt a, voltage rating of shunt element of universal active power filter; b, the current rating of shunt element of the universal active power filter; c, the VA rating of the shunt element of universal active power filter and d, the voltage rating of the series active power filter of universal active power filter.

And e, the current rating of series element of series universal active power filter; f, is the VA rating of the series active filter to provide the load compensation of for unity power factor that ac mains and by shunt element of universal active power filter and constant regulator voltage sine wave volt 220 volt rms at the across the load by series element of typically of universal active power filter.

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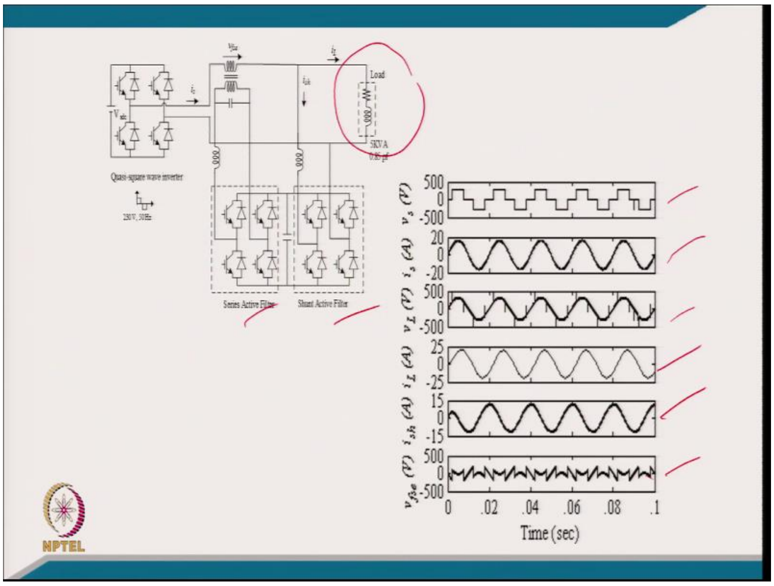


The explanation of the numerical problem is described in the screenshots herein.

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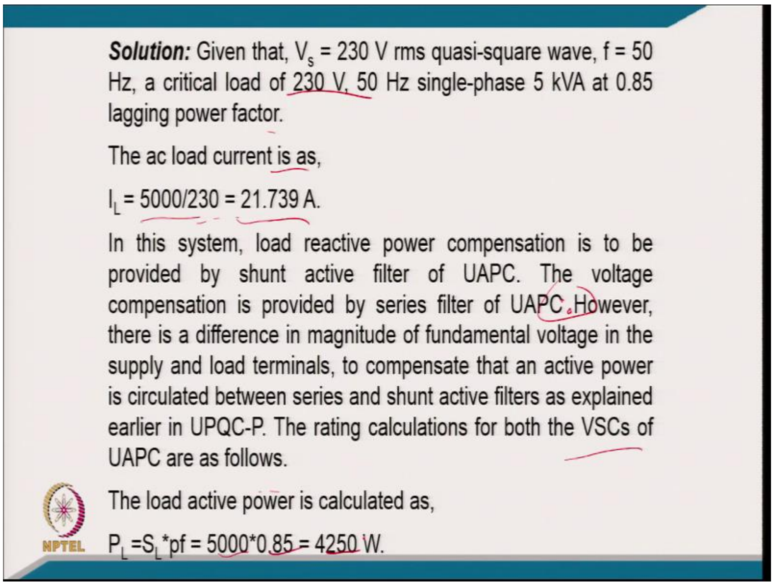


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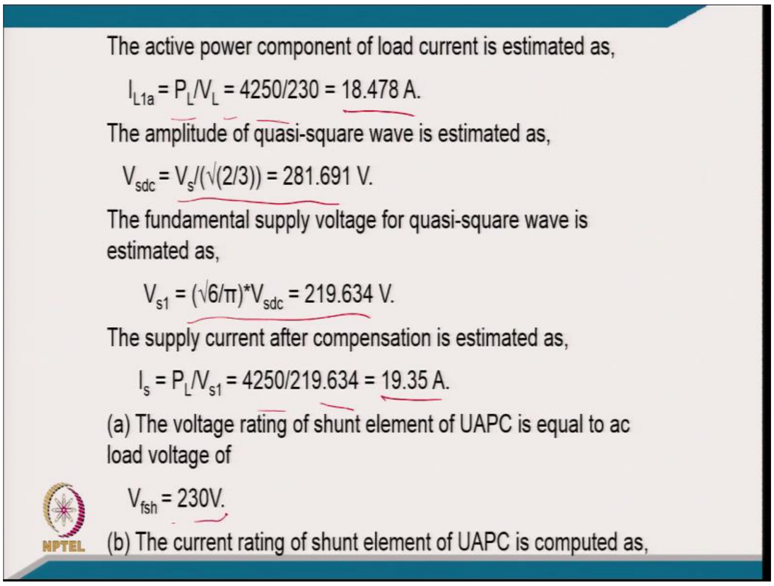

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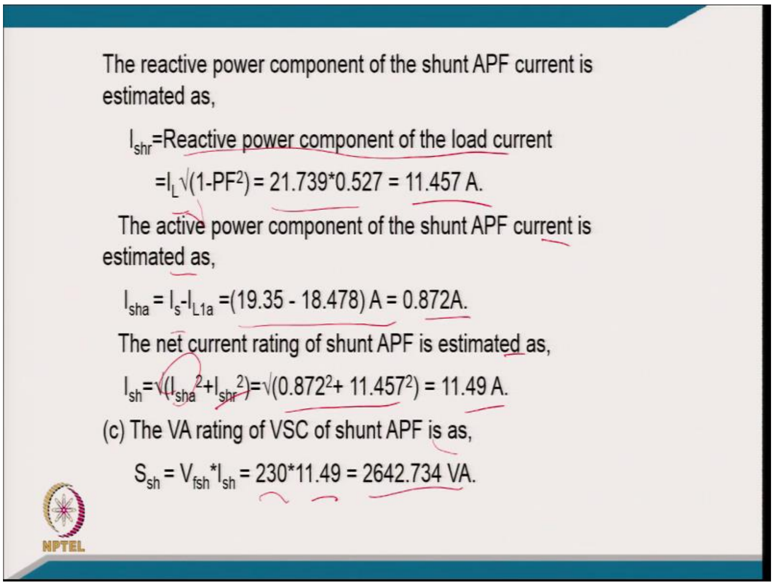


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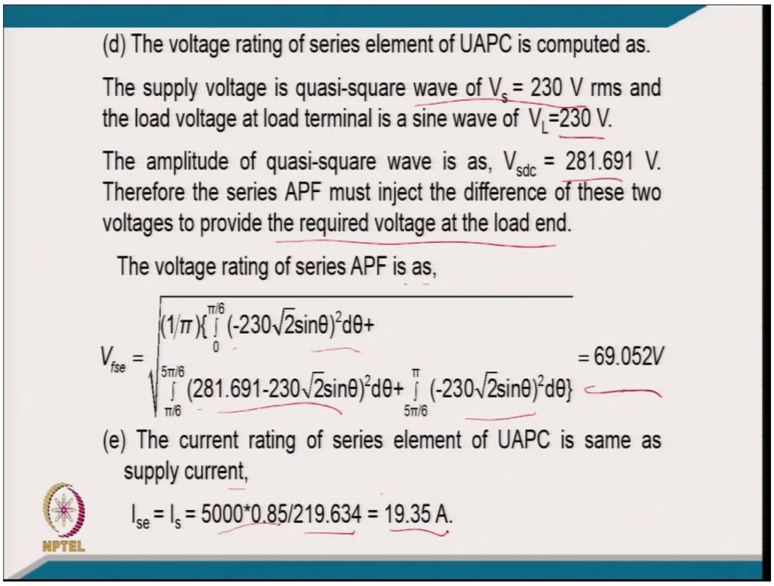

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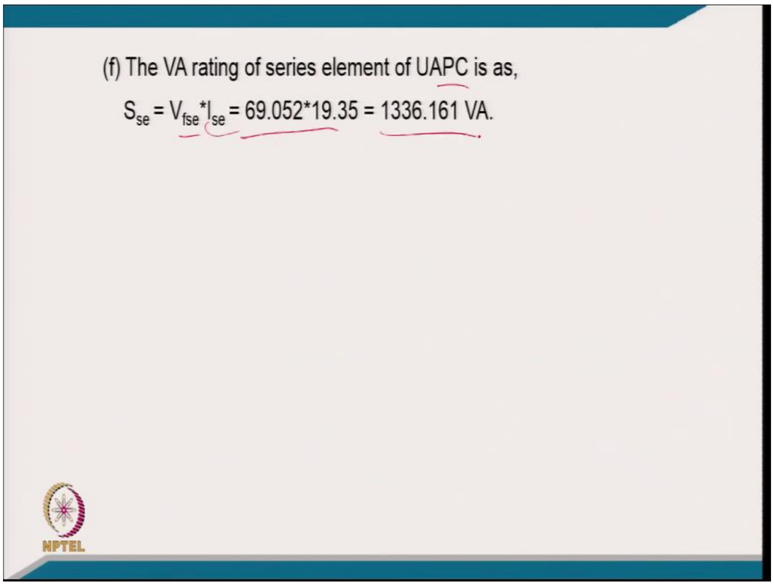


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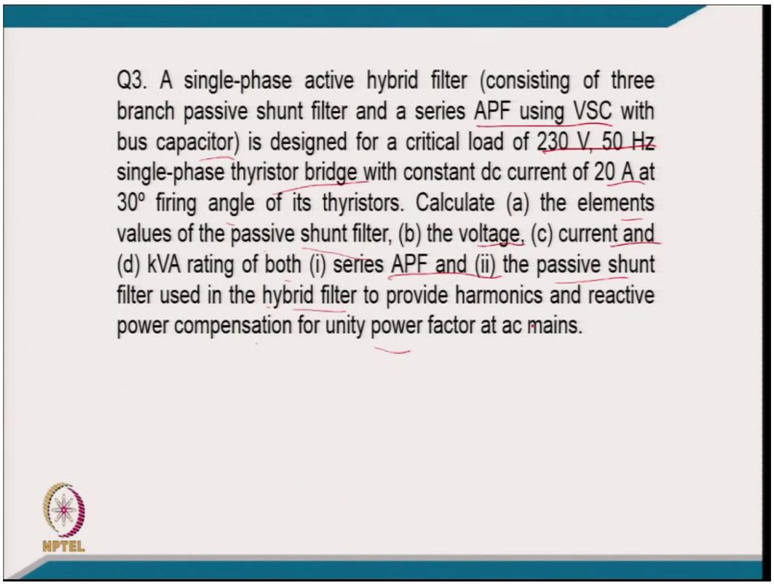


Coming to example 3, a single-phase active hybrid filter consisting of three branch passive shunt filter and a series active filter using a voltage source converter with the dc bus, designed for a critical load of 230 volt 50 hertz. Single-phase thyristor bridge with constant dc current of twenty ampere with 30 degree fire angle of its thyristor.

Calculate the element value of the passive shunt filter; the voltage rating; current and current rating and the kVA rating of both series active filter and passive shunt filter used in hybrid filter to provide the harmonics and reactive power compensation for unity power factor at a t mains; at a c mains like.

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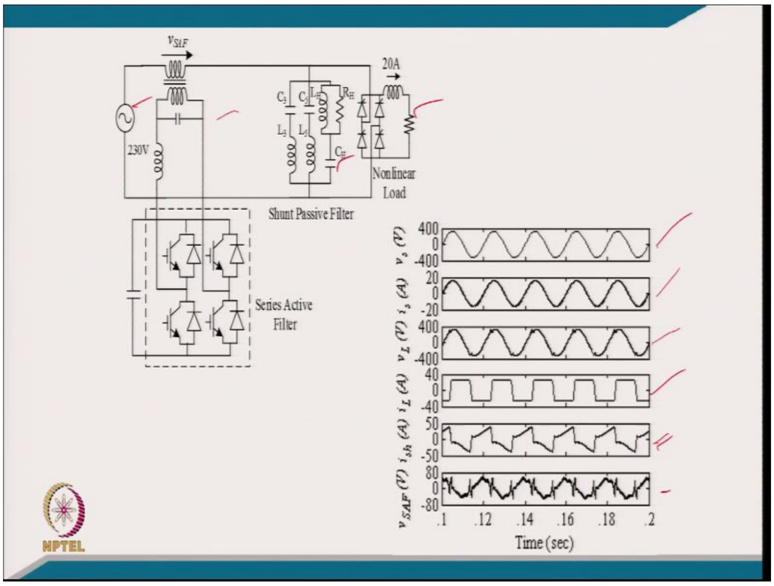


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***Solution:*** Given that, $V_s$ =230 V rms, f = 50 Hz, a nonlinear load of 230 V, 50 Hz single-phase thyristor bridge converter with constant dc current of 20 A at 30° firing angle of its thyristors.

The ac load rms current is as, $I_L = I_{dc} = 20$ A.

The fundamental rms input current of the thyristor bridge converter ,

$I_{1T} = (2\sqrt{2}/\pi)I_L = 0.9*20 = 18$ A.

The fundamental active power component of load current,

$I_{L1a} = I_{L1}\cos\alpha = 0.9I_{dc}\cos 30° = 15.588$ A.

The fundamental active power of the load,

$P_1 = V_{s1}I_{L1}\cos\theta_1 = V_{s1}I_{L1a} = 230*15.588 = 3585.315$ W.

The fundamental reactive power of the load,

$Q_1 = V_{s1}I_{L1}\sin\theta_1 = V_{s1}I_{L1}\sin\alpha = 230*18*0.5 = 2070$ VAR.

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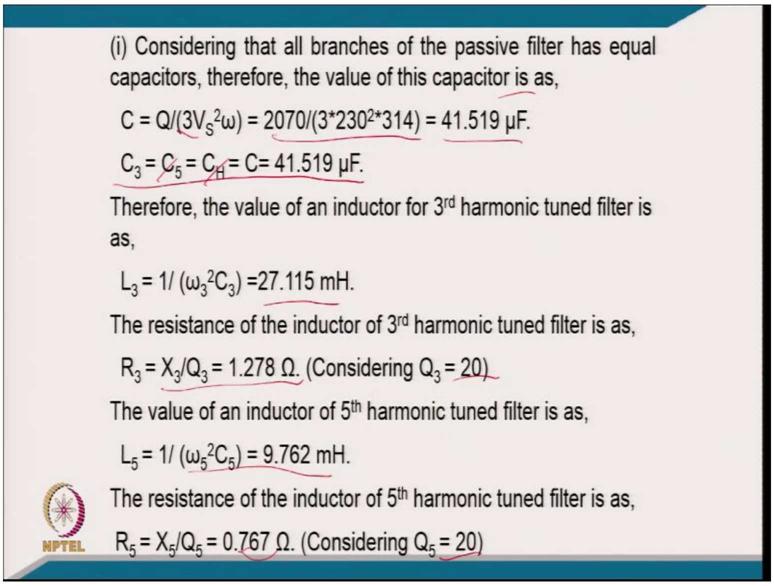


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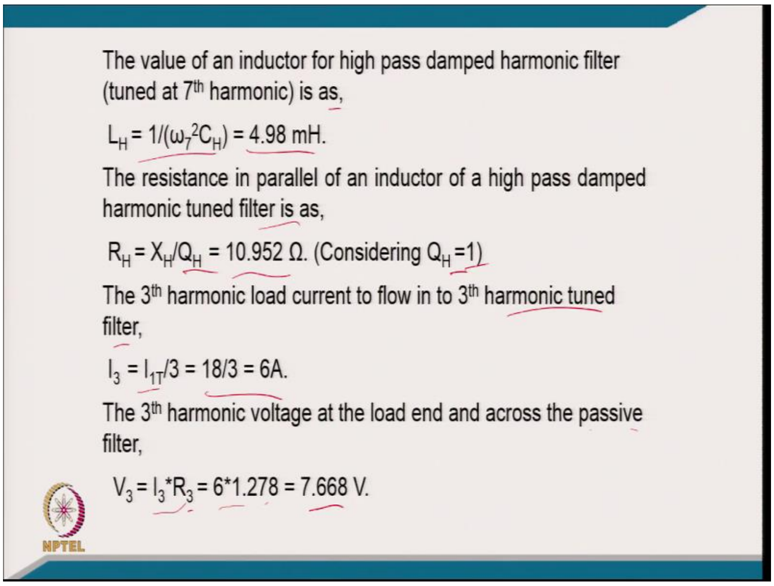

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The 5th harmonic load current to flow in to 5th harmonic tuned filter,

$I_5 = I_{1T}/5 = 18/5 = 3.6$ A.

The 5th harmonic voltage at the load end and across the passive filter,

$V_5 = I_5 * R_5 = 3.6 * 0.767 = 2.76$ V.

All other harmonics load currents to flow in to high pass damped harmonic filter is as,

$I_H = \sqrt{[I_L^2 - I_{1T}^2 - I_3^2 - I_5^2]} = \sqrt{[20^2 - 18^2 - 6^2 - 3.6^2]} = 5.2$ A.

All higher order harmonics voltage at the load end and across the passive filter is as,

$V_H = I_H * R_H = 5.2 * 10.952 = 56.950$ V.

All harmonics voltages other than the fundamental voltage at the load end and across the passive filter is as,

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$V_{LH} = \sqrt{(V_3^2 + V_5^2 + V_H^2)} = 57.531$ V.

(a) The voltage rating of the series active filter is as,

$V_{SAF} = V_{LH} = \sqrt{(V_3^2 + V_5^2 + V_H^2)} = 57.531$ V.

(b) The current rating of the series active filter is as,

$I_{SAF} = I_s$ = The fundamental active power component of load current,

$I_{L1a} = I_{L1} \cos\alpha = 0.9 I_{dc} \cos 60^\circ = 15.588$ A.

(c) The VA rating of the series APF is as,

$S_{APF} = V_{SAF} * I_{SAF} = 57.531 * 15.588 = 896.812$ VA.

The pu rating of the series APF is as,

$S_{APFpu} = S_{APF}/S_L = 896.812/(230*20) = 0.195 = 19.5\%$ of the load rating.

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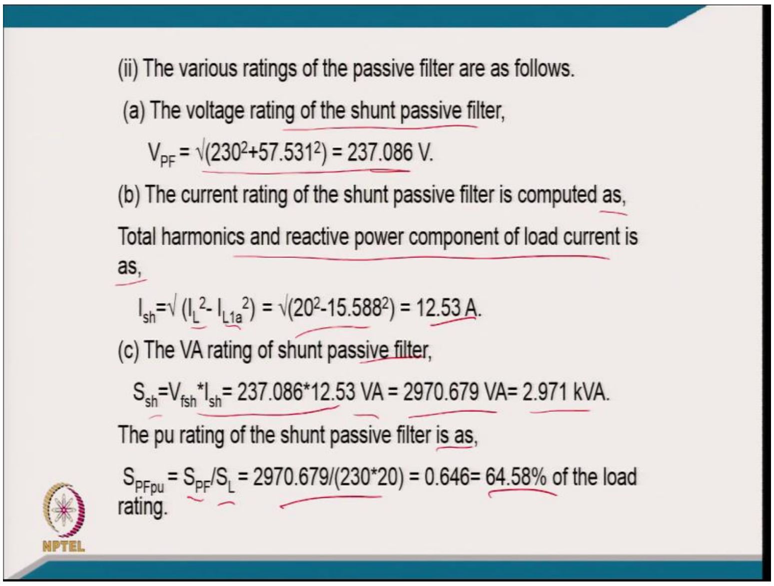


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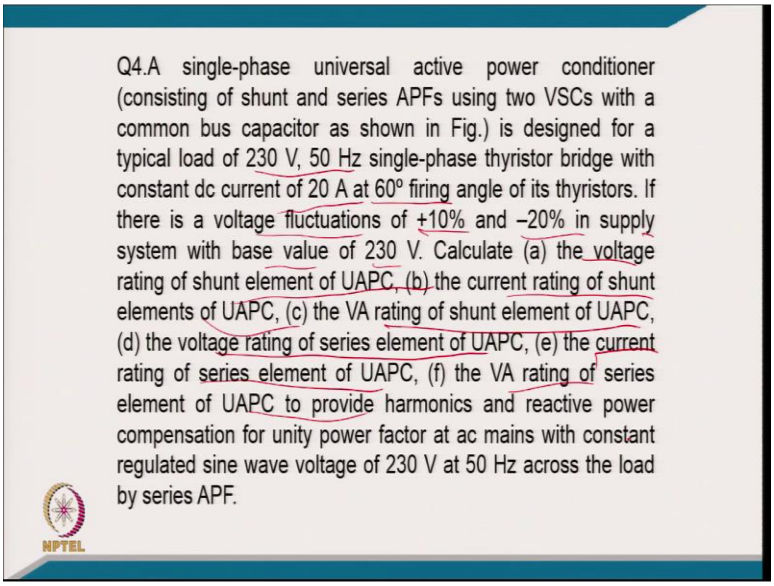


Coming to like a fourth numerical problem, a single-phase universal active power conditioner consisting of series and shunt active filters using two voltage source converter with common dc bus capacitor is designed for a typical load of 230 volt, 50 hertz single-phase thyristor bridge with the constant current of 20 ampere at 60 degree fire angle of its thyristor and if there is a voltage fluctuation of 10 percent plus and 20 percent minus in supply voltage with the base value of 230 volt.

Calculate the voltage rating of the shunt element; current rating of shunt element; VA rating of the shunt element series voltage rating of series element and current rating of series element and the VA rating of series element to provide the harmonic and reactive power compensation for unity power factor at ac main and constant regulated sine wave voltage of 230 volt 50 hertz across the load by series active filter.

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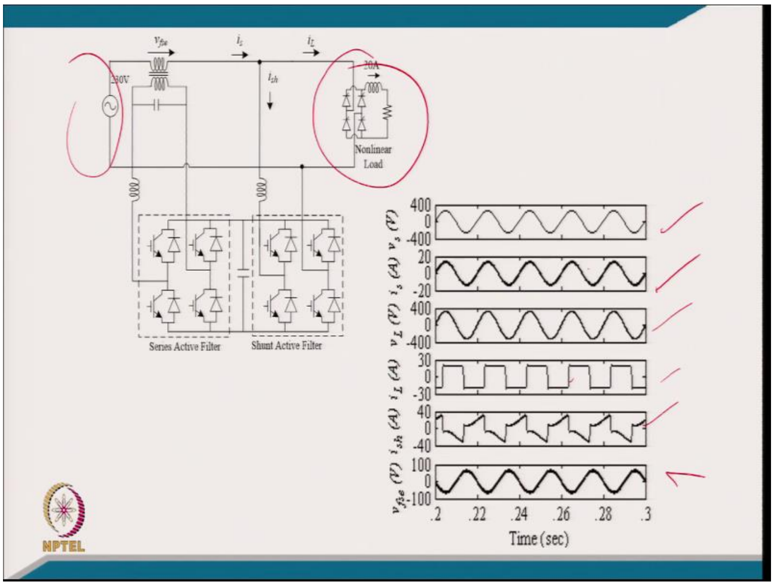


The explanation of the numerical problem is described in the screenshots herein.

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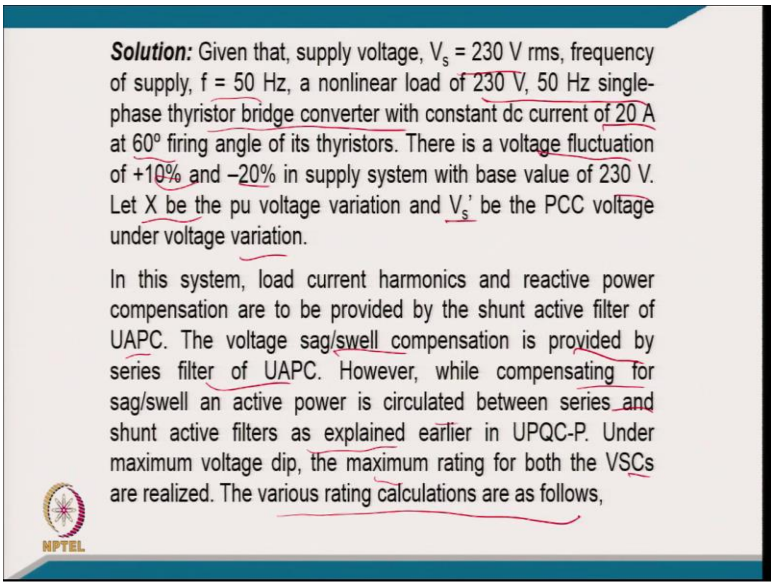

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The ac load rms current is as, $I_L = 20$ A.

The fundamental active power component of load current,

$I_{L1a} = I_{L1} \cos\alpha = 0.9*20*\cos 60^o = 9$ A.

The active power consumed by the load is as,

$P_L = V_s*I_{L1a} = 230*9 = 2070$ W.

The supply voltage under maximum voltage sag is as,

$V_s' = V_s(1-X) = 230*(1-0.2) = 184$ V.

The supply current under maximum voltage variation (-20% sag) is as,

$I_s' = P_L/V_s' = 2070/184 = 11.25$ A.

(a) The voltage rating of shunt element of UAPC is equal to ac load voltage of $V_{fsh}$=230V, since it is connected across the load of 230 V sine waveform.

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(b) The current rating of shunt element of UAPC is computed as,

The shunt element of UAPC is to provide load current harmonics and reactive power compensation, hence the required harmonics current and reactive power of the load it has to supply. Therefore, total harmonics and reactive power component of current of shunt filter is as,

$I_{shr} = \sqrt{(I_L^2 - I_{L1a}^2)} = \sqrt{(20^2-9^2)} = 17.86$ A.

The supply fundamental voltage is lower as compared to the required load voltage. Hence, shunt APF absorbs active power and that active power is delivered back into the system via series APF. Under voltage sag the active power component of shunt APF current is calculated as,

$I_{sha} = I_s' - I_{L1a} = (11.25-9)$ A $= 2.25$ A.

The net current rating of shunt active filter is calculated as,

$I_{sh} = \sqrt{(I_{sha}^2 + I_{shr}^2)} = \sqrt{(2.25^2+17.86^2)} = 18.00$ A.

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