Power Quality
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Lecture - 19
Passive Power Filters (contd.)

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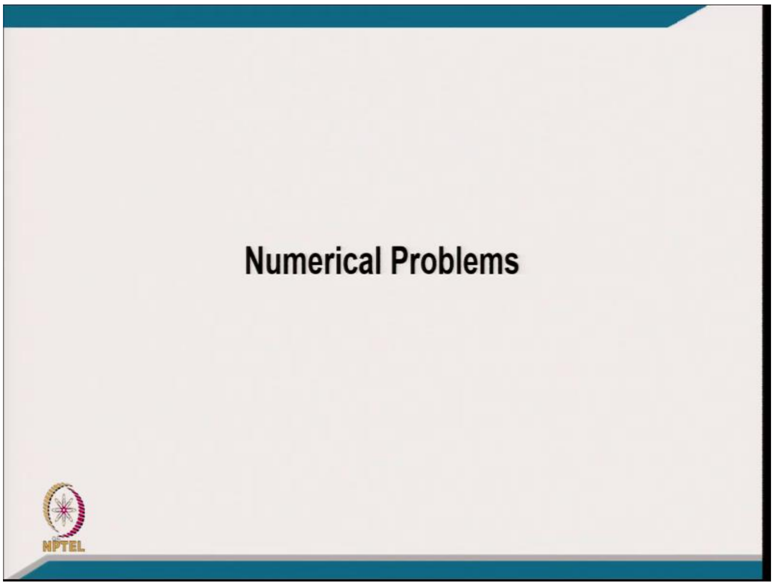

Welcome to the course on Power Quality and we were Passive Power Filter. We have discussed the configuration design and limitations; we will now discuss the numerical problems on passive filters.

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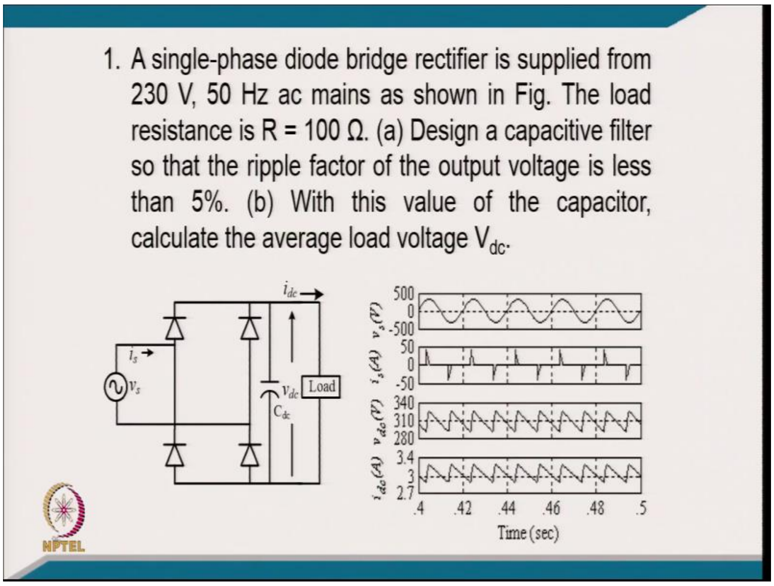

Starting from first problem, a single phase diode bridge rectifier is supplied from 230 Volt, 50 Hertz ac mains as shown in the figure. The load resistance is of 100 Ohm. Design a capacitive filter, so that ripple factor of output voltage is less than 5 percent. With this value of the capacitor, calculate the average load voltage.

You have a circuit here which consist typically of diode rectifier and a capacitive filter followed by the load.

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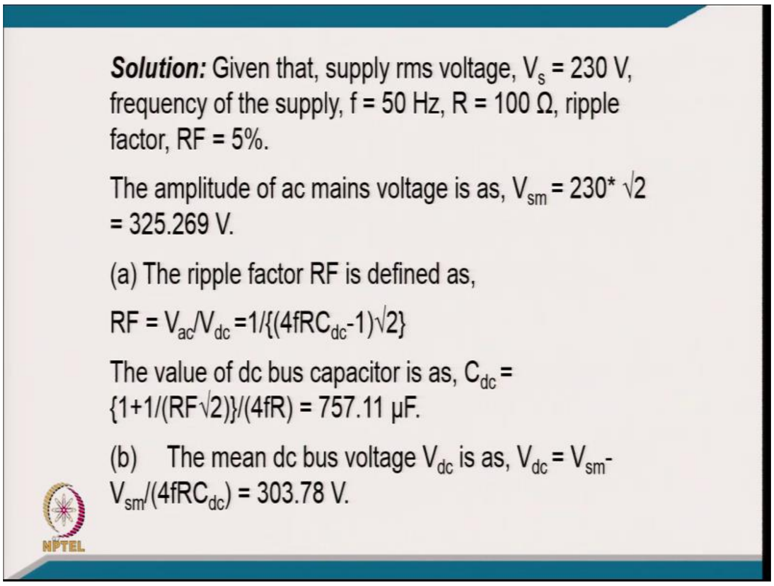

The solution to the numerical is detailed in the screenshot.

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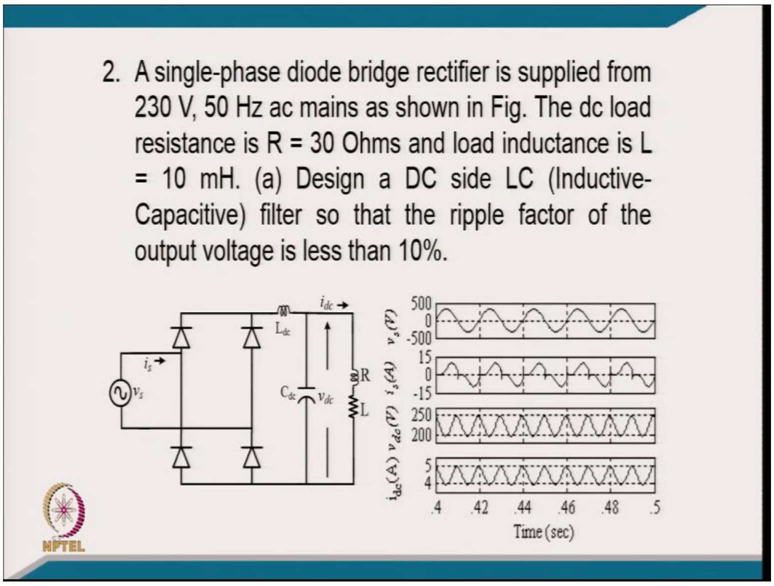

Coming to an example 2, a single phase diode bridge rectifier is supplied from 230 Volts, 50 Hertz, ac mains as shown in the figure here. The dc load resistance is of 30 Ohm and the load inductance is your 10 milli Henry. Design a DC side LC field capacitive filter, so that the ripple factor of the output voltage is less than 10 percent.

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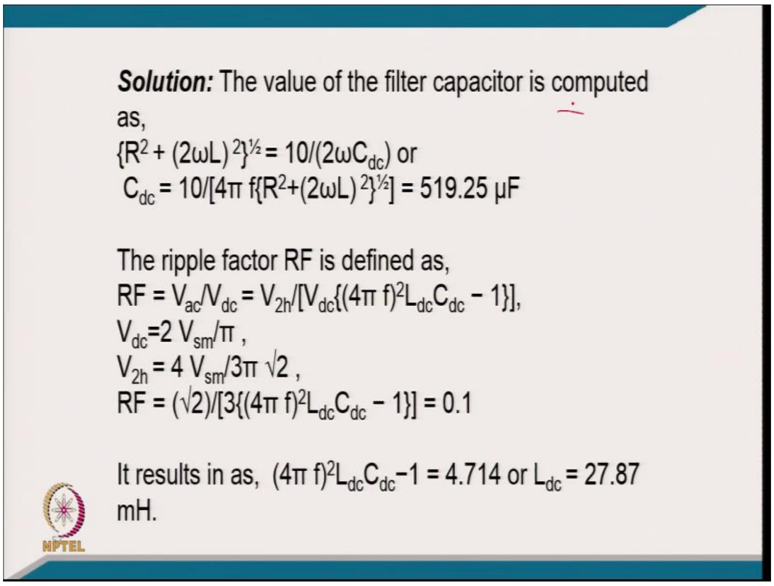

The solution to the numerical is detailed in the screenshot.

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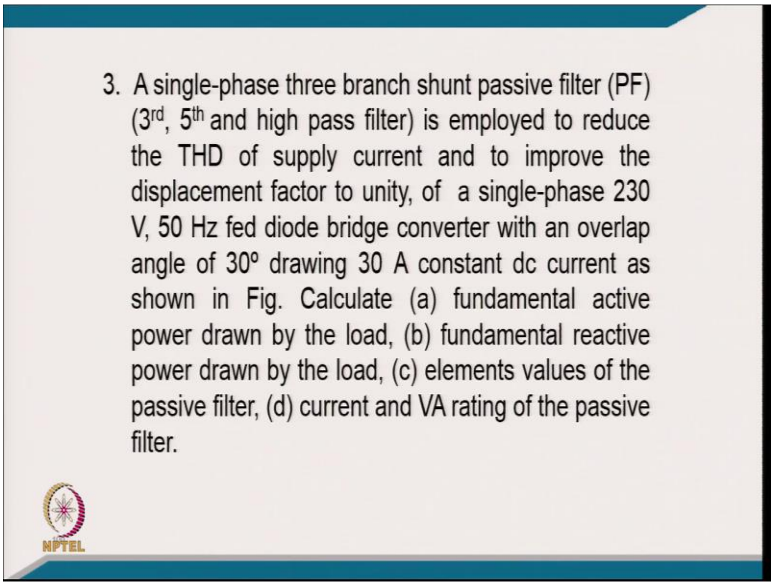

Now, coming to the 3rd numerical problem, in which we have designed the ac side filter. A single phase three branch shunt passive filter consisting of 3rd, 5th and high pass filter is used to reduce the total harmonic distortion of supply current and to improve the displacement factor to unity of single phase 230 Volt, 50 Hertz fed diode bridge rectifier with an overlap angle of 30 degree drawing 30 Ampere constant dc current as shown in the figure. And calculate the fundamental active power drawn by the load, fundamental reactive power drawn by the load, elements value of the passive filter, and current and VA rating of the passive filter like.

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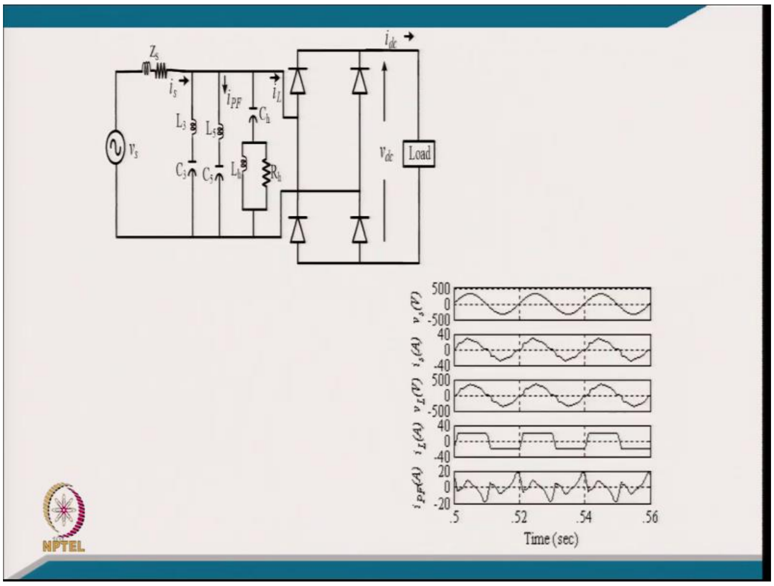

Here we have the circuit of total system; we have a diode rectifier with the load and we have a typically the filter component.

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Solution: Given that, V_s = 230 V, f = 50 Hz, 230 V, 50Hz ac supply with an overlap angle, μ = 30°, dc link current, I_{dc} = 30 A.

In single-phase uncontrolled bridge converter with an overlap angle, the waveform of the supply current (I_s) is a trapezoidal wave with the amplitude of dc link current (I_{dc}). Since this trapezoidal wave of input current is an odd and quarter cycle and half cycle symmetry, the supply rms value of it is computed as.

$I_s = I_L = \sqrt{[\{1/(2\pi)\}\ (\text{Area of the total waveform})]}$

$$= \sqrt{(1/2\pi)\left(4\int_0^{\mu/2}(2I_{dc}\theta/\mu)^2 d\theta + 2\int_{\mu/2}^{\pi-\mu/2} I_{dc}^2 d\theta\right)}$$

The solution to the numerical is detailed in the screenshots.

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$= I_{dc}\sqrt{[\{1/(2\pi)\}\{(2\mu/3)+2(\pi-\mu)\}]} = 0.94281*30$

$= 28.284\text{A}.$

The trapezoidal wave of input current is an odd and quarter cycle and half cycle symmetry, the rms value of n^{th} harmonic RMS Current, I_{snrms} is computed as.

$$I_{snrms} = B_n/\sqrt{2} = \left[(8/2\pi)\int_0^{\pi/2} f(\theta)\sin n\theta d\theta\right]$$

$$I_{snrms} = \left[(8/2\pi)\left(\int_0^{\mu/2}(2I_{dc}\theta/\mu)\sin n\theta d\theta + \int_{\mu/2}^{\pi-\mu/2} I_{dc}\sin n\theta d\theta\right)\right]$$

$$I_{snrms} = I_{dc}\left[(8/\pi\mu n^2)\sin(n\mu/2)\right]/\sqrt{2}$$

(Since the trapezoidal wave will not have A_n)

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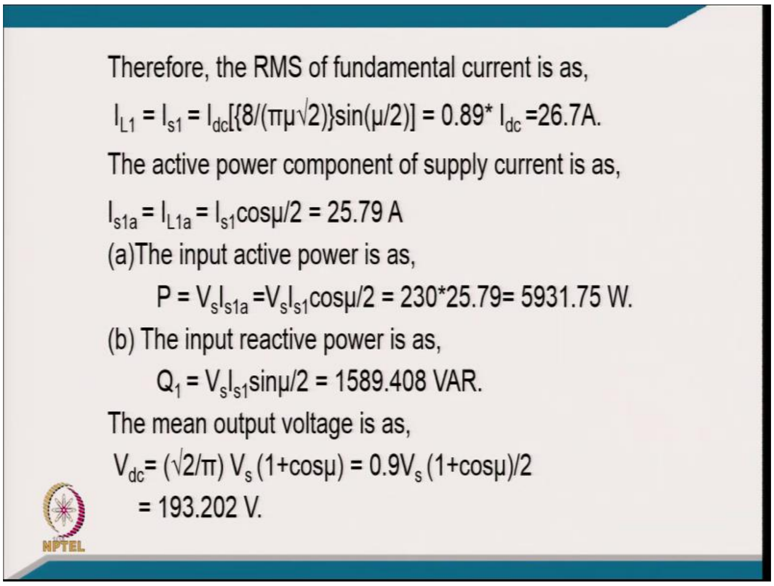

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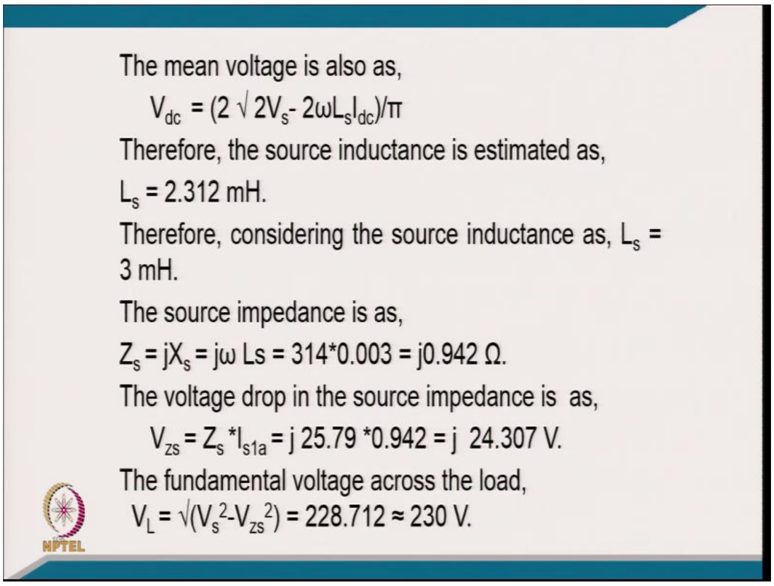

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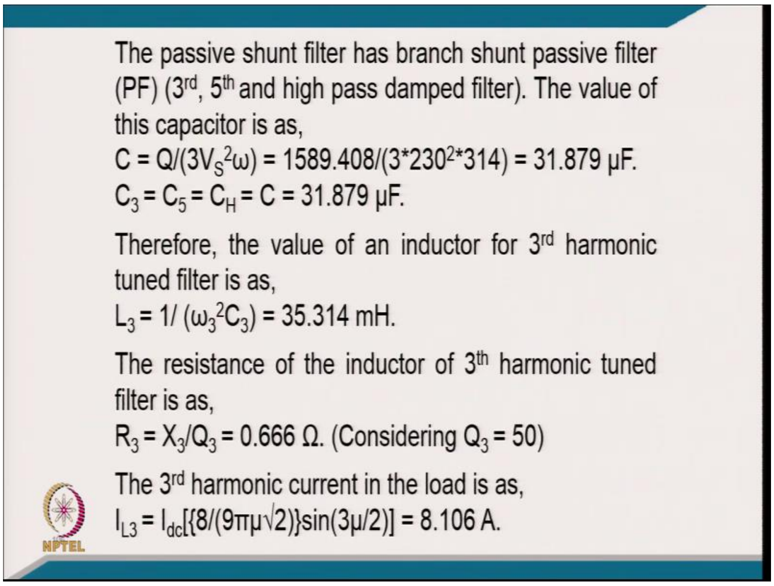

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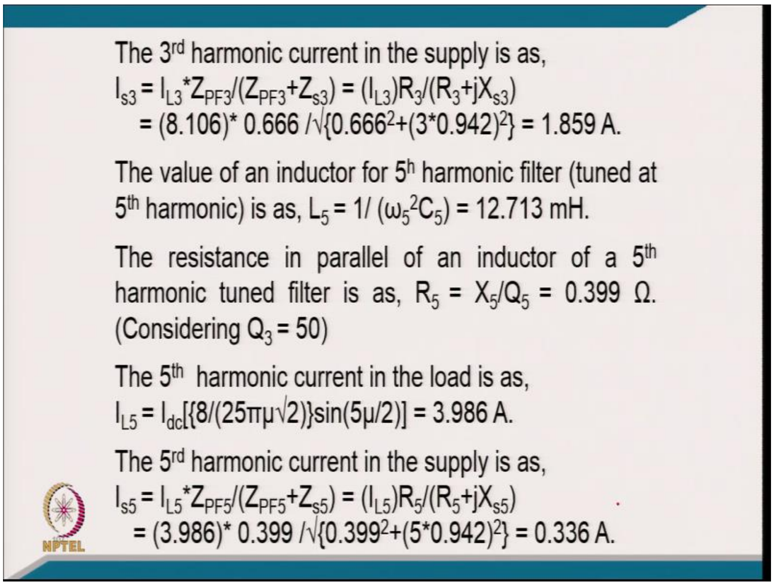

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The value of an inductor for high pass damped harmonic filter (tuned at 7th harmonic) is as,

$L_H = 1/(\omega_7^2 C_H) = 6.486$ mH.

The resistance in parallel of an inductor of a high pass damped harmonic tuned filter is as,

$R_H = X_H/Q_H = 14.264\ \Omega$. (Considering $Q_H = 1$)

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

$I_{LH} = \sqrt{[I_L^2 - I_{L1}^2 - I_{L3}^2 - I_{L5}^2]} = \sqrt{[28.284^2 - 26.7^2 - (8.106)^2 - (3.986)^2]} = 2.345$ A.

$I_{SH} = I_{LH} * Z_{PFH}/(Z_{PFH} + Z_{sH}) = (I_{LH}) R_H/(R_H + jX_{sH})$

$= (2.345) * 14.264/\sqrt{\{14.264^2 + (7*0.942^2\}} = 2.129$ A.

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$THD_{Is} = \{\sqrt{(I_{s3}^2 + I_{s5}^2 + I_{SH}^2)}/I_{s1a}\} = 0.11 = 11.04\%$.

$THD_{VL} = [\sqrt{\{(X_{s3} I_{s3}^2) + (X_{s5} I_{s5})^2 + (X_{sH} I_{SH})^2\}}/V_{s1}] = 0.066 = 6.553\%$.

$I_{PF} = \sqrt{[I_s^2 - I_{s1a}^2 - I_{s3}^2 - I_{s5}^2 - I_{sH}^2]} = 11.259$A.

The VA rating of the passive shunt filter is as,

$VA_{PF} = V_s * I_{PF} = 230*11.259 = 2589.509$ VA.

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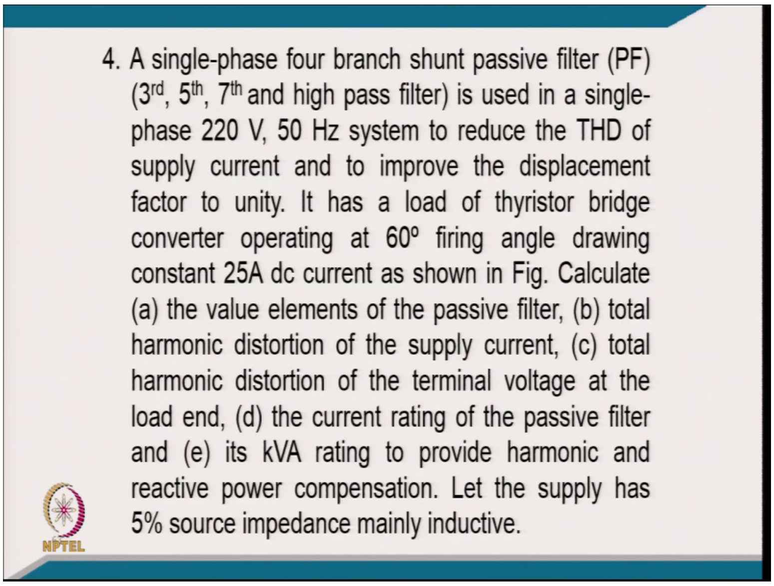

Coming to example 4, a single phase four branch passive filter 3rd, 5th and 7th and high pass filter is used to single phase 220 Volt, 50 Hertz system to reduce the THD of supply current and to improve the displacement factor to unity. It has a load of thyristor bridge converter operating at 60 degree firing angle drawing constant 25 Ampere dc current as shown here. Calculate the value of elements of passive filter, the total harmonic distortion of supply current, the total harmonic distortion of thermal voltage, load end, and the current rating of the passive filter and e the kVA rating of kVA rating to provide harmonics and reactive power compensation. Let the supply has a 5 percent source impedance mainly inductive.

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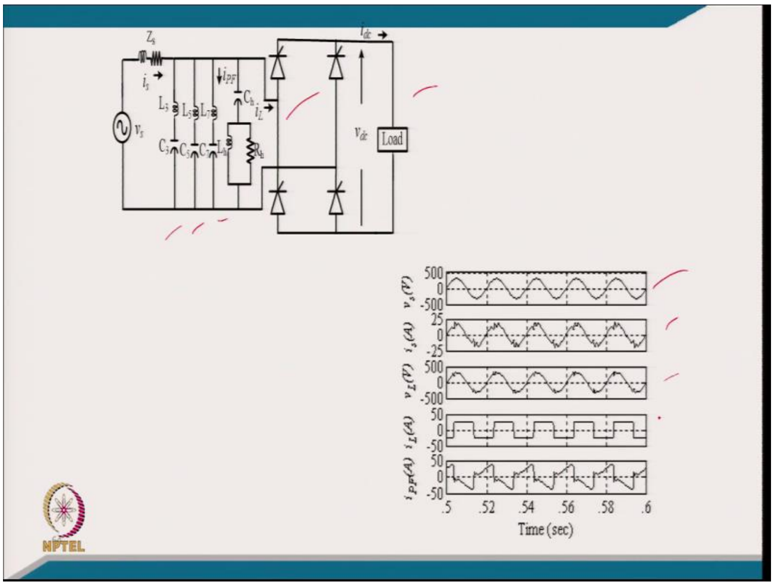

The solution to the numerical is detailed in the screenshots.

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Solution: Given that, supply voltage, V_s = 220 V rms, frequency of supply, f = 50 Hz, with a source impedance of 5% mainly inductive feeding a nonlinear load of 220 V, 50 Hz single-phase thyristor bridge converter with constant dc current of 25 A at 60° firing angle of its thyristors.

In this system, the load current harmonics and reactive power compensation is provided by a single-phase four branch shunt passive filter (PF) (3rd, 5th, 7th and high pass damped filter) to reduce the THD of the supply current and to improve the displacement factor close to unity.

The ac load rms current is as, $I_L = I_{dc}$ = 25 A.

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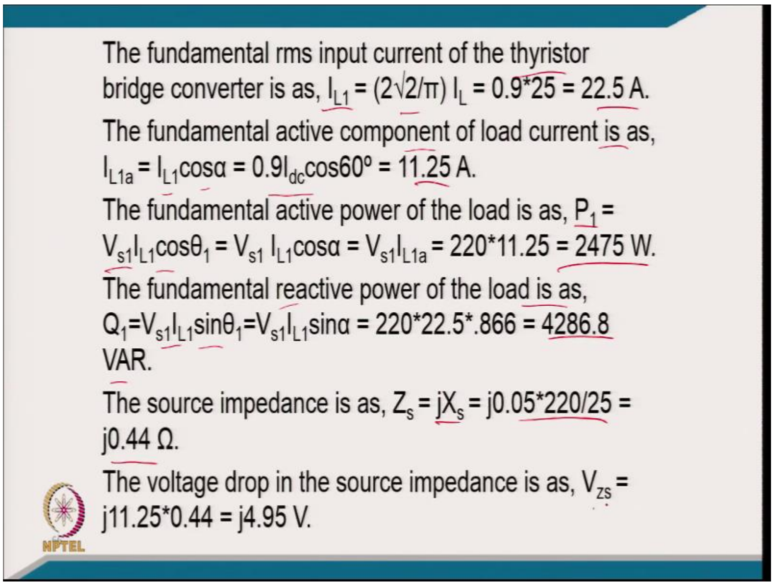

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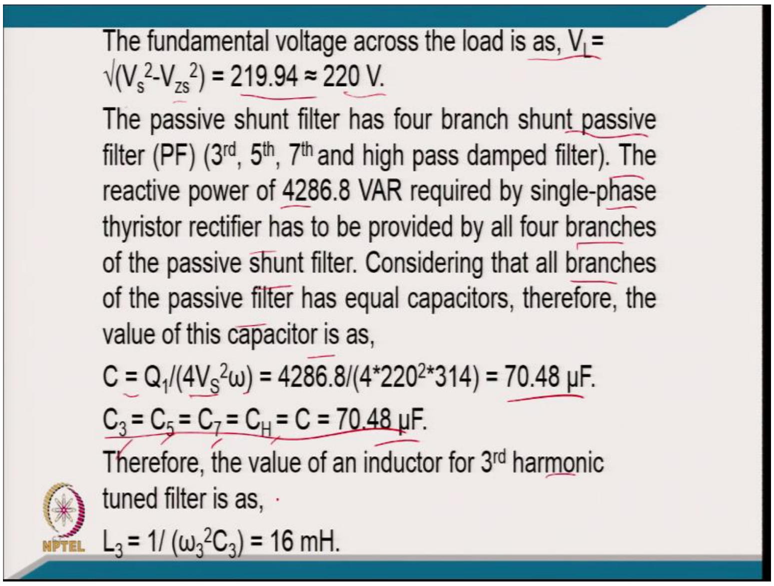

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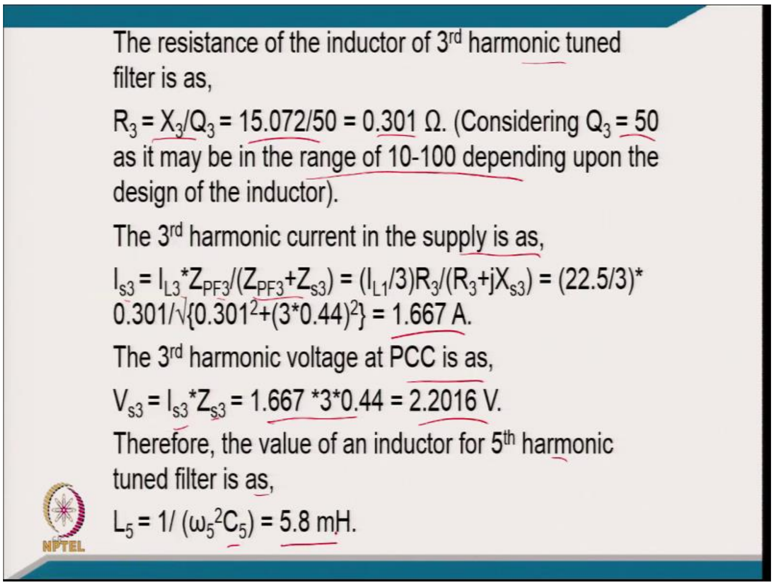

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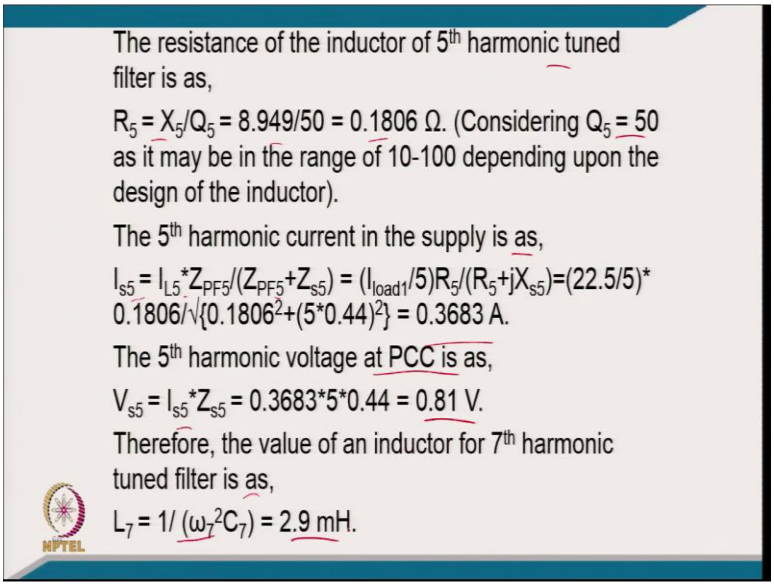

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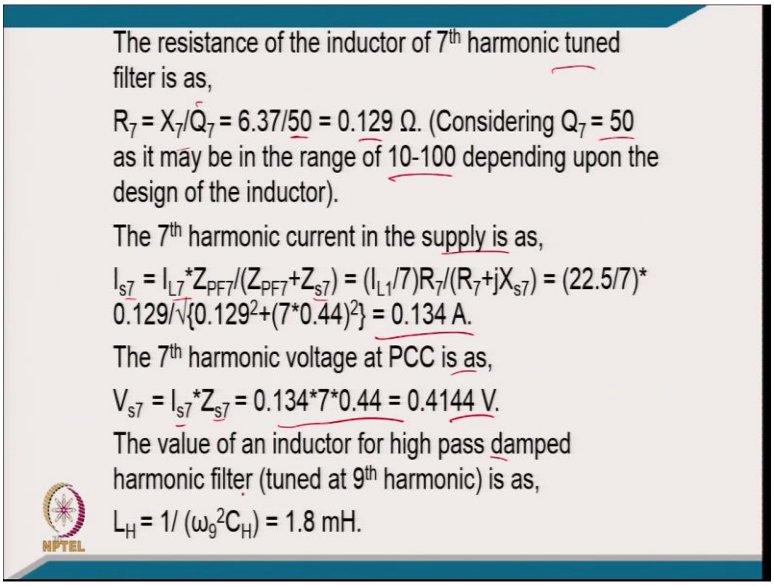

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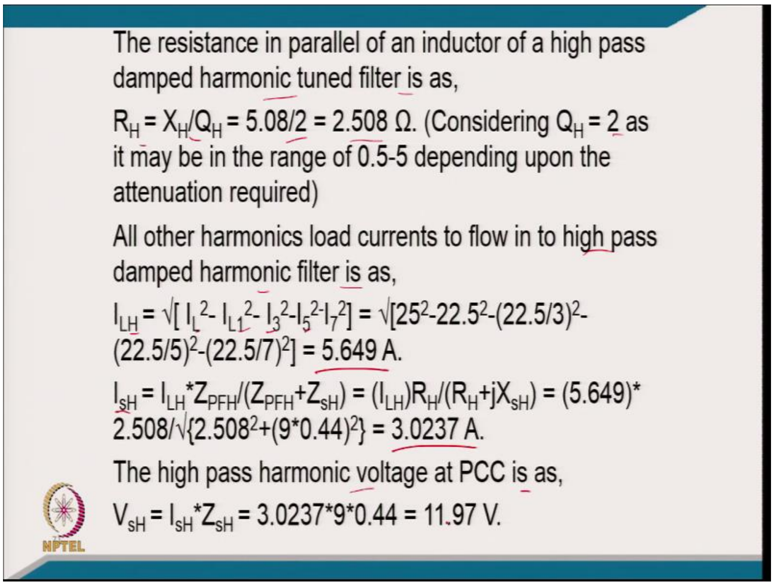

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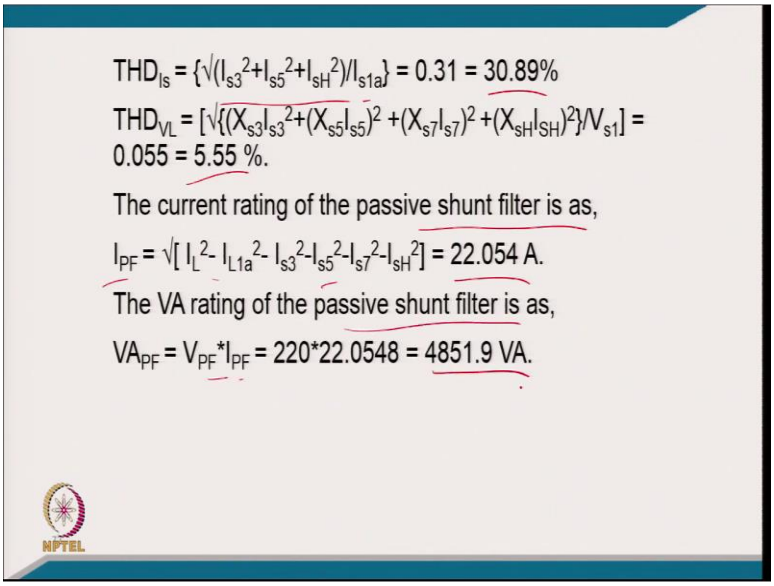

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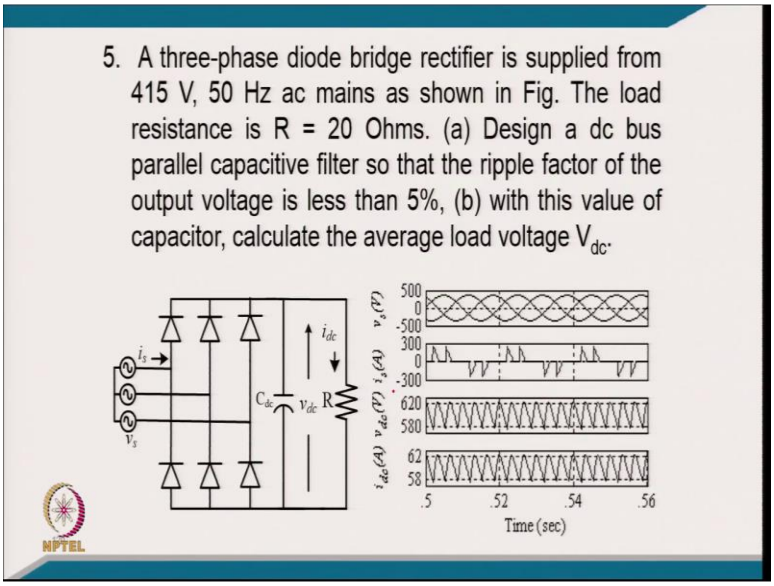

Coming to the fifth example, a three phase diode bridge rectifier is supplied from 415 Volt, 50 hertz ac mains as shown in the figure below and load resistance is R equal to 20 Ohm. Designed a dc bus parallel capacitive filter, so that the ripple filter of the output voltage is less than 5 percent And with this value capacitor, calculate the average voltage dc.

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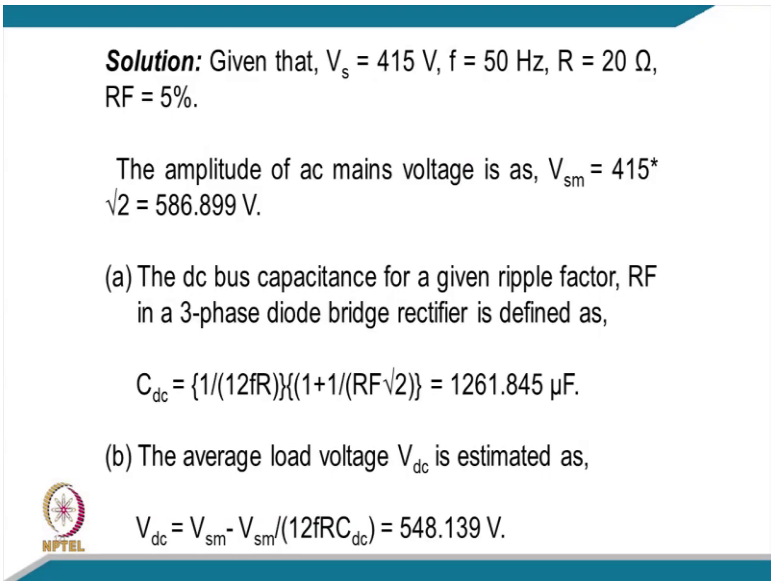

The solution to the numerical is detailed in the screenshots.

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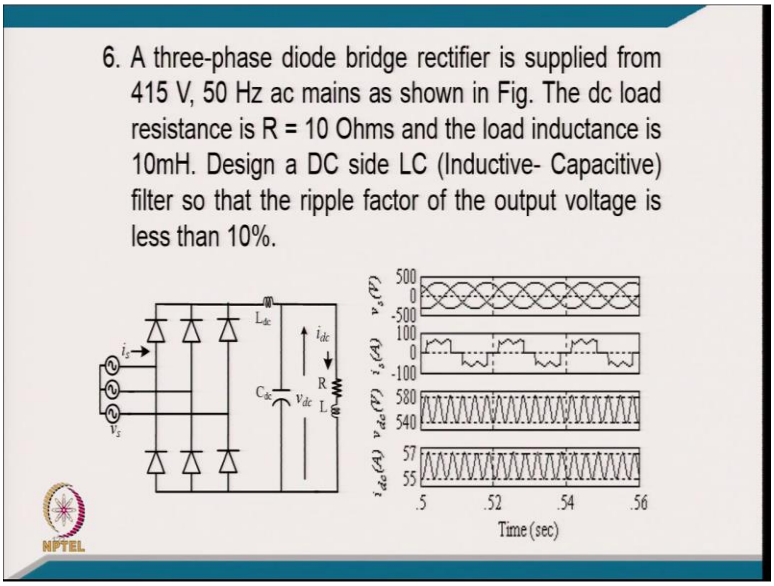

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Solution: Given that, supply rms voltage, V_s = 415 V, frequency of supply, f = 50 Hz, R = 10 Ω, L = 10 mH, Ripple Factor, RF = 10%.

The value of the filter capacitor is computed as,

$\{R^2+(6\omega L)^2\}^{½} = 10/(6\omega C_{dc})$ or $C_{dc} = 10/[12\pi f\{R^2+(6\omega L)^2\}^{½}]$ = 248.63 μF.

The ripple factor RF is estimated as,

$RF = V_{ac}/V_{dc} = V_{6h}/[V_{dc}\{(12\pi f)^2L_{dc}C_{dc}-1\}]$

$RF = 2/[35\{(12\pi f)^2L_{dc}C_{dc}-1\}] = 0.1$

It results in as,

$(12\pi f)^2L_{dc}C_{dc}-1= 0.57$ or L_{dc} = 1.8 mH.

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7. A three-phase three branch shunt passive filter (tuned 5^{th}, 7^{th} and high pass) is employed to reduce the THD of supply current and to improve the displacement factor to unity for a three-phase 415 V, 50 Hz fed 6-pulse thyristor bridge converter drawing 100 A constant dc current at 30° firing angle of its thyristors as shown in Fig. Calculate (a) fundamental active power drawn by the load, (b) fundamental reactive power drawn by the load, (c) values of filter elements, (d) THD of supply current, and (e) THD of load voltage, (f) the voltage, current and VA rating of the passive filter. Let the supply has 5% source impedance mainly inductive.

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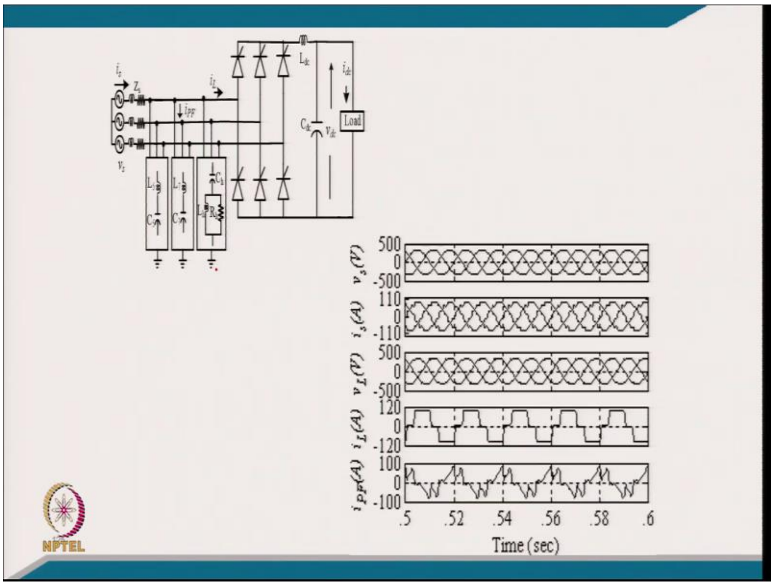

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Solution: Given that, supply voltage, V_s = 415/√3 = 239.6 V rms, frequency of supply, f = 50 Hz, with a source impedance of 5% mainly inductive feeding a nonlinear load of 415 V, 50 Hz three-phase thyristor bridge converter with constant dc current of 100 A at 30° firing angle of its thyristors.

In this system, the load current harmonics and reactive power compensation is provided by a three-phase three branch shunt passive filter (PF) (5th, 7th and high pass damped filter) to reduce the THD of the supply current and to improve the displacement factor close to unity.

The ac load rms current is as, $I_L = I_{dc}\sqrt{2}/\sqrt{3}$ = 81.65 A.

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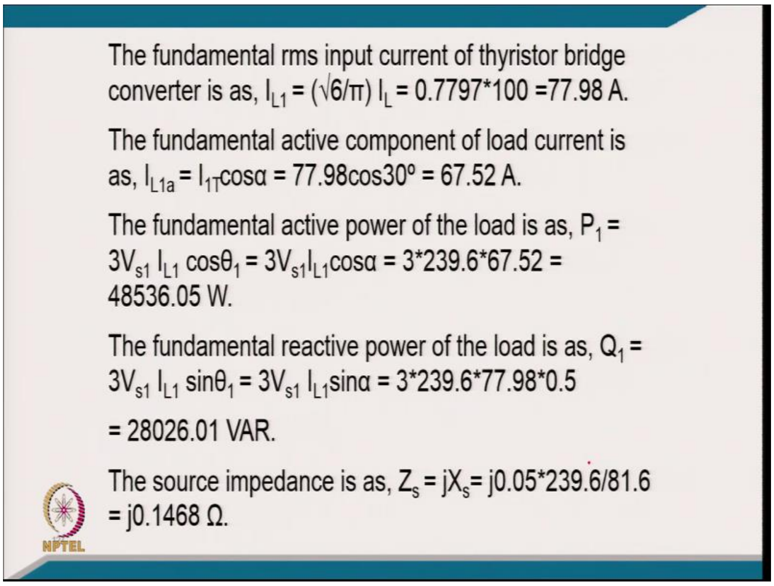

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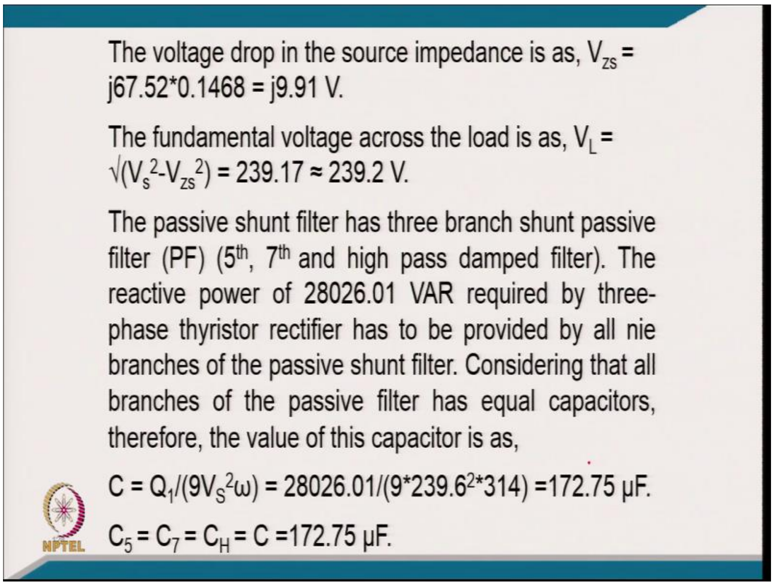

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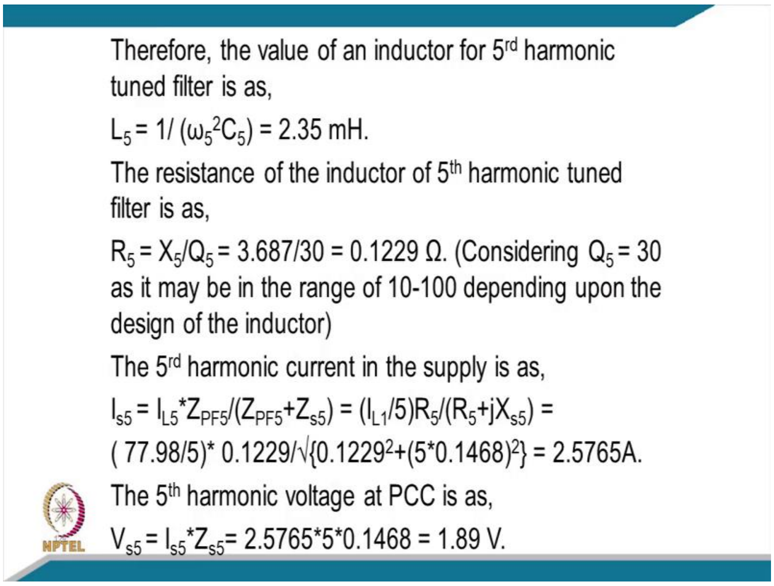

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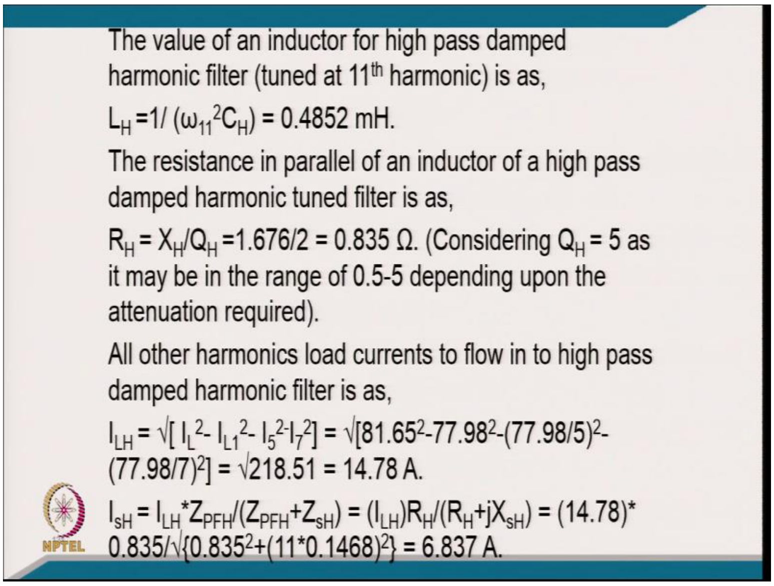

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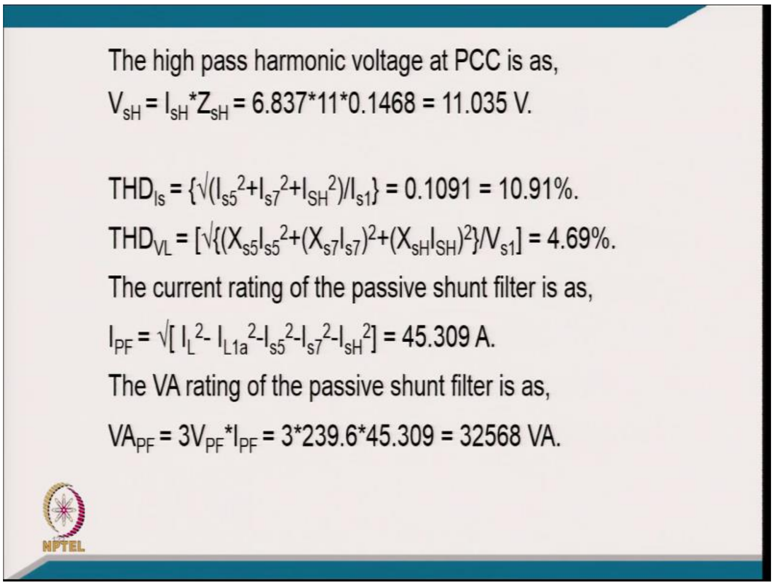

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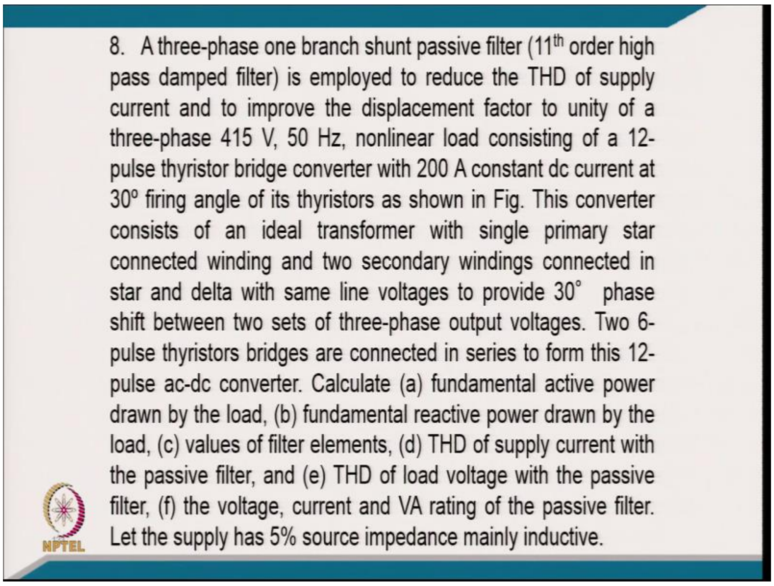

Now, coming to the 8th numerical problem, a three phase one branch shunt passive filter 11th order high pass damped filter is employed to reduce the THD of the supply current and to improve the displacement factor to unity of three phase 415 Volt, 50 Hertz, non-linear load consisting of 12 pulse thyristor converter the 200 Ampere constant dc current at 30 degree firing angle of its thyristor as shown in figure. And the converter consists of ideal transformer with single primary star connected winding and two secondary winding connected in star and delta with same line voltage to provide 30 degree phase shift between the two sets of three phase output voltage. The two 6 pulse thyristor bridges are connected in series to form this 12 pulse ac dc converter. Calculate a fundamental active power drawn by the load, fundamental reactive power drawn by the load, value of filter elements, total harmonic distortion of supply current with the passive filter, the total harmonic distortion of voltage with passive filter, voltage, current and VA rating of the passive filter.

Let the supply has a 5 percent source impedance mainly inductive.

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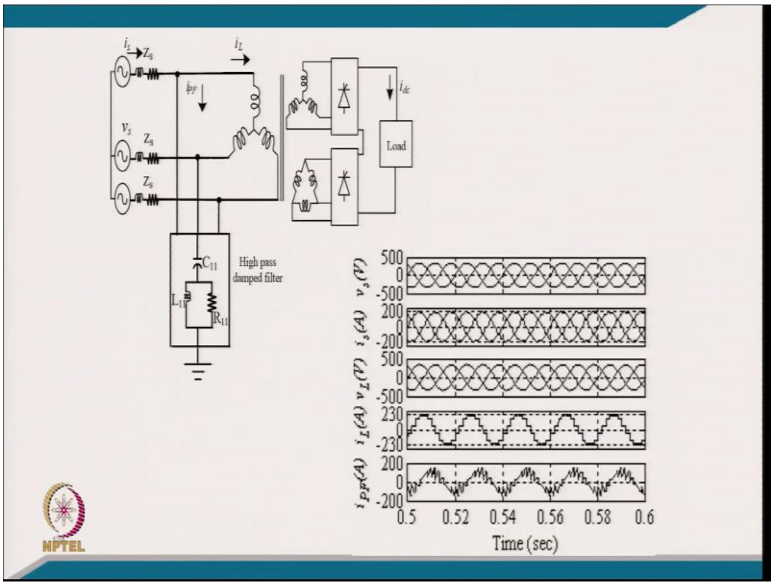

The solution to the numerical is detailed in the screenshots.

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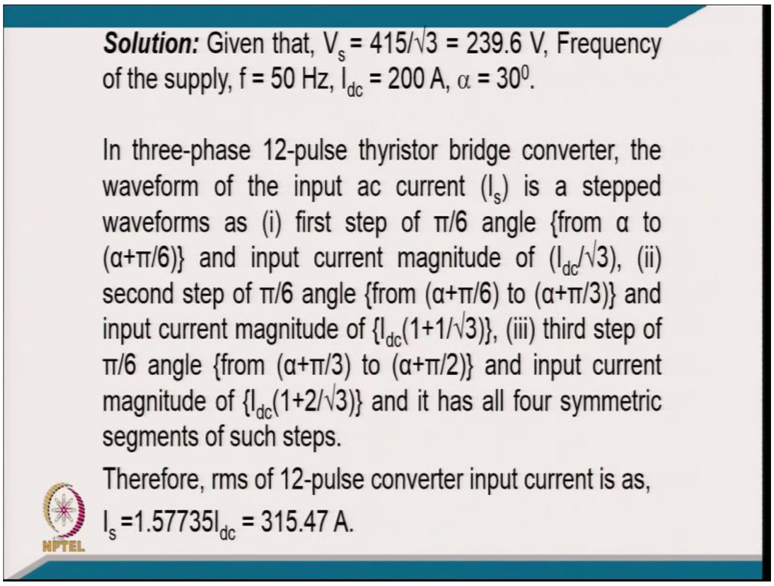

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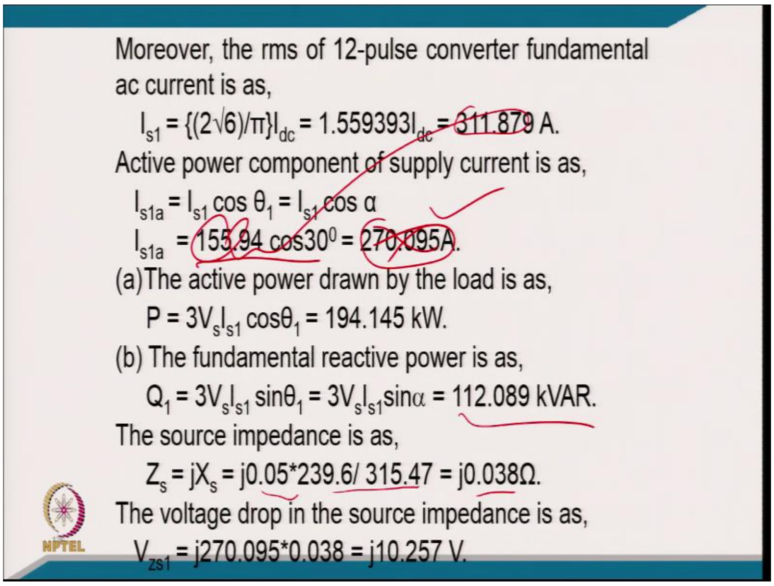

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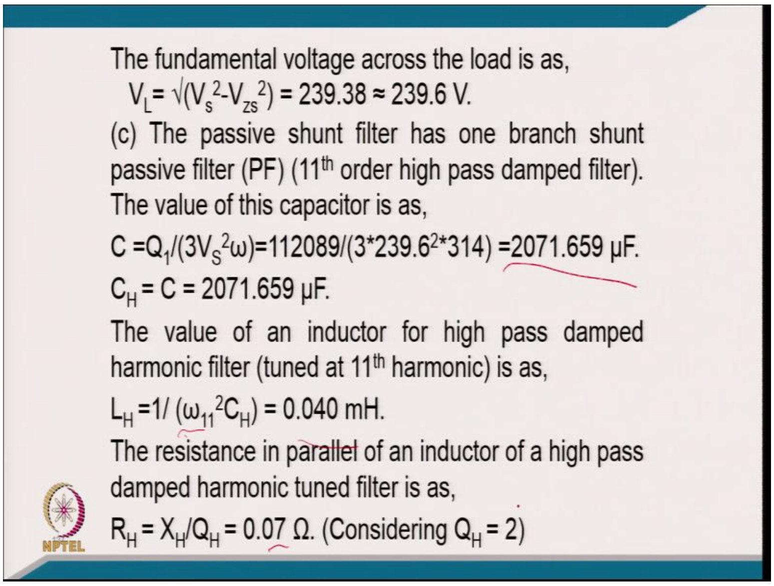

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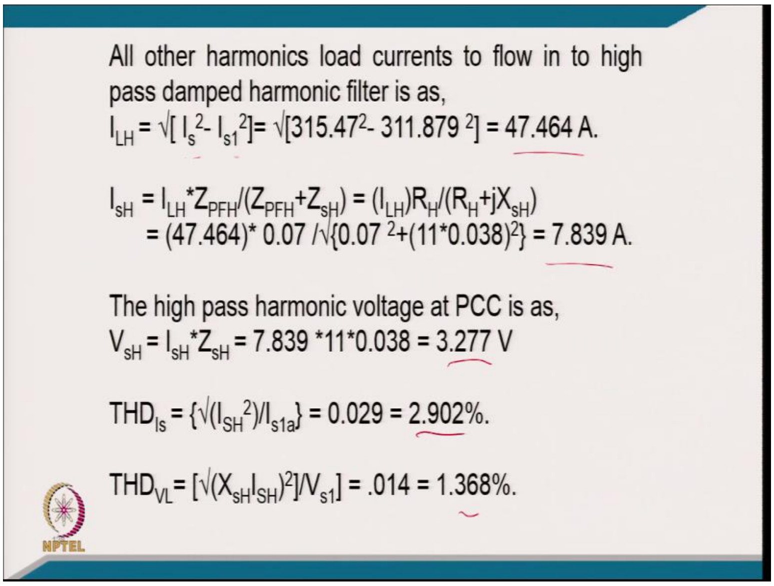

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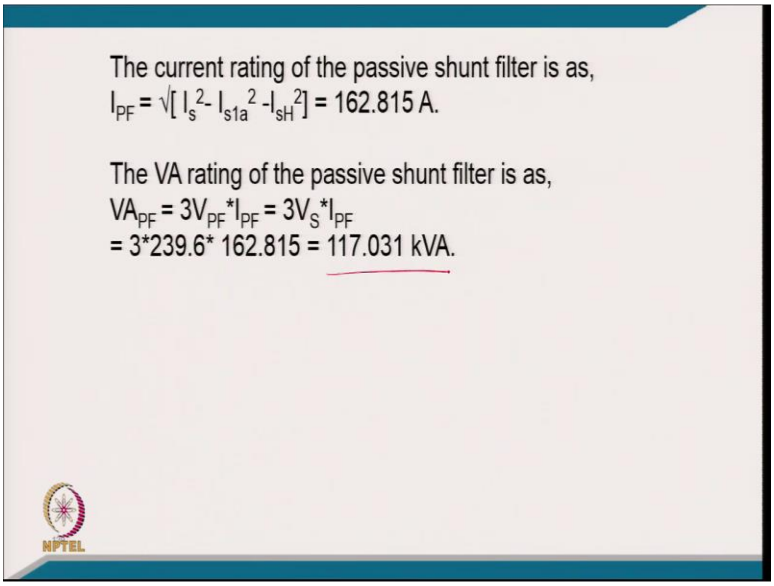

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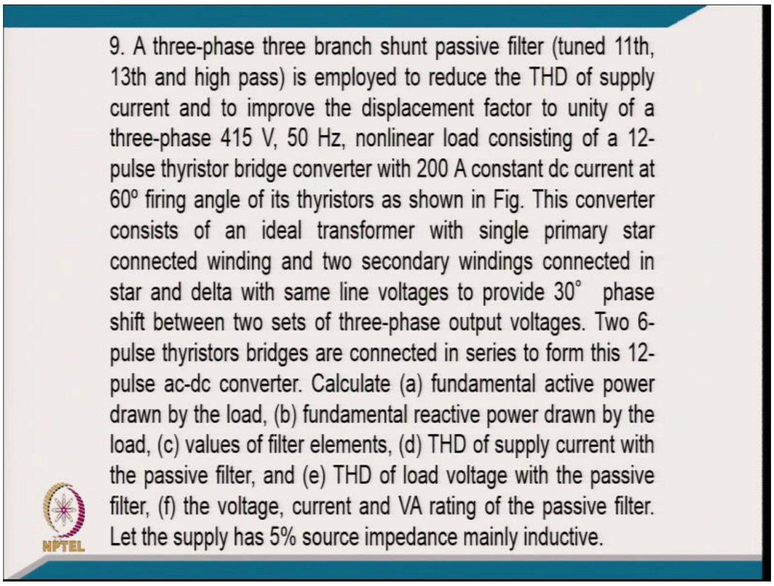

Coming to example 9, a three phase three branch shunt passive filter tuned for 11th and 13th and high pass is employed to reduce the THD of supply current and to improve the displacement factor to unity of three phase 415 Volt, 50 Hertz non-linear load consisting of 12 pulse thyristor bridge converter with 200 Ampere constant dc current at 60 degree firing angle of its thyristor as shown in figure. This converter consists of ideal transformer with single primary star connected winding and two secondary is connected in star and delta with the same line voltage to provide 30 degree phase shift between two sets of three phase output voltage. [FL] two single pulse two 6 pulse thyristor bridges are connected in series to form a 12 pulse ac dc converter. Calculate a fundamental active power drawn by the load; b fundamental reactive power drawn by the load; c the value of filter elements; d the THD of supply current with the passive filter; and e the THD of load voltage with the passive filter; f the voltage current and VA rating of the passive filter.

Let the supply has a 5 percent source impedance mainly inductive.

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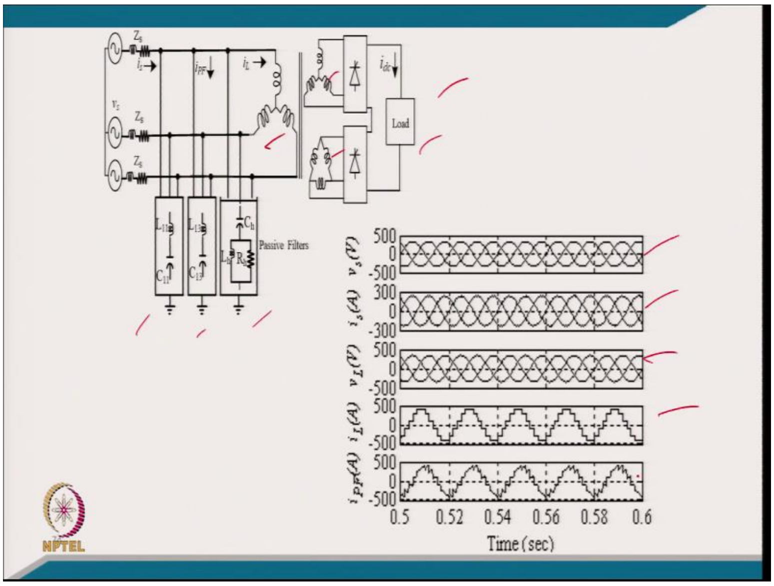

The solution to the numerical is detailed in the screenshots.

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Solution: Given that, supply rms voltage, $V_s = 415/\sqrt{3} = 239.6$ V, frequency of the supply, f = 50 Hz, I_{dc} = 200 A, $\alpha = 60^0$.

In three-phase 12-pulse thyristor bridge converter, the waveform of the input ac current (I_s) is a stepped waveforms as (i) first step of π/6 angle {from α to (α+π/6)} and input current magnitude of ($I_{dc}/\sqrt{3}$), (ii) second step of π/6 angle {from (α+π/6) to (α+π/3)} and input current magnitude of {$I_{dc}(1+1/\sqrt{3})$}, (iii) third step of π/6 angle {from (α+π/3) to (α+π/2)} and input current magnitude of {$I_{dc}(1+2/\sqrt{3})$} and it has all four symmetric segments of such steps.

Therefore, rms of 12-pulse converter input current is as, $I_s = I_L = 1.57735 I_{dc}$ = 315.47 A.

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Moreover, the rms of 12-pulse converter fundamental ac current is as, $I_{s1} = I_{L1} = \{(2\sqrt{6})/\pi\}I_{dc} = 1.559393I_{dc} = 311.8786$ A.

Active power component of supply current is as, $I_{s1a} = I_{s1} \cos\theta_1 = I_{s1} \cos\alpha = 311.8786 \cos 60^0 = 155.9393$ A.

(a) The active power drawn by the load is as, $P = 3V_sI_{s1} \cos\theta_1 = 112.08895$ kW.

(b) The fundamental reactive power is as, $Q_1 = 3V_sI_{s1} \sin\theta_1 = 3V_sI_{s1}\sin\alpha = 194.1437$ kVAR.

The source impedance is as, $Z_s = jX_s = j0.05*239.6/315.47 = j0.037975\ \Omega$.

The voltage drop in the source impedance is as, $V_{zs} = j155.9393 * 0.037975 = j5.922$ V.

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The fundamental voltage across the load is as, $V_L = \sqrt{(V_s^2 - V_{zs}^2)} = 239.53 \approx 239.6$ V.

(c) The passive shunt filter has three branch shunt passive filter (PF) (11th, 13th and high pass damped filter). The reactive power of 194143.7 VAR required by three-phase thyristor rectifier has to be provided by all nine branches of the passive shunt filter. Considering that all branches of the passive filter has equal capacitors, therefore, the value of this capacitor is as,

$C = Q_1/(9V_S^2\omega) = 194143.7/(9*239.6^2*314) = 1196.68$ μF.

$C_{11} = C_{13} = C_H = C = 1196.68$ μF.

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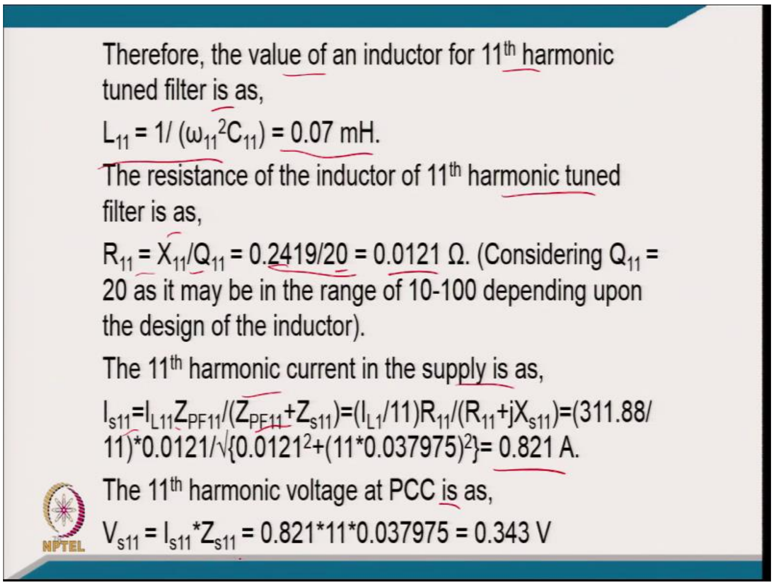

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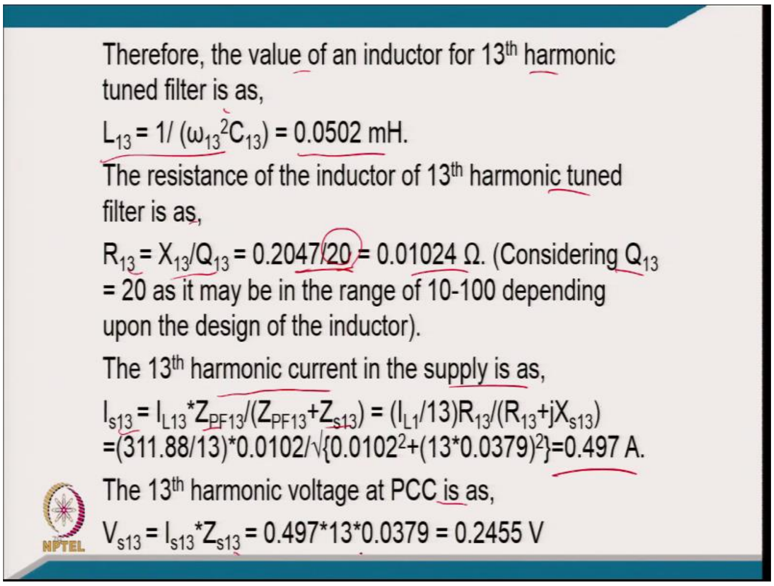

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The value of an inductor for high pass damped harmonic filter (tuned at 23rd harmonic) is as,

$L_H = 1/(\omega_{23}^2 C_H) = 0.016$ mH.

The resistance in parallel of an inductor of a high pass damped harmonic tuned filter is as,

$R_H = X_H/Q_H = 0.1157/2 = 0.0579\ \Omega$. (Considering $Q_H = 2$ as it may be in the range of 0.5-5 depending upon the attenuation required).

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

$I_{LH} = \sqrt{[I_L^2 - I_{L1}^2 - I_{11}^2 - I_{13}^2]} = \sqrt{[315.47^2 - 311.88^2 - (311.88/11)^2 - (311.88/13)^2]} = 29.54$ A.

$I_{sH} = I_{LH} * Z_{PFH}/(Z_{PFH} + Z_{sH}) = (I_{LH})R_H/(R_H + jX_{sH}) = (29.54)*0.0579/\sqrt{\{0.0579^2 + (23*0.0379)^2\}} = 1.958$ A.

(Refer Slide Time: 40:54)

The high pass harmonic voltage at PCC is as,

$V_{sH} = I_{sH} * Z_{sH} = 1.958*23*0.0379 = 1.71$ V

$THD_{Is} = \{\sqrt{(I_{s11}^2 + I_{s13}^2 + I_{SH}^2)}/I_{s1a}\} = 0.014 = 1.4\%$.

$THD_{VL} = [\sqrt{\{(X_{s11}I_{s11})^2 + (X_{s13}I_{s13})^2 + (X_{sH}I_{SH})^2\}}/V_{s1}]$

$= 0.0074 = 0.74\ \%$.

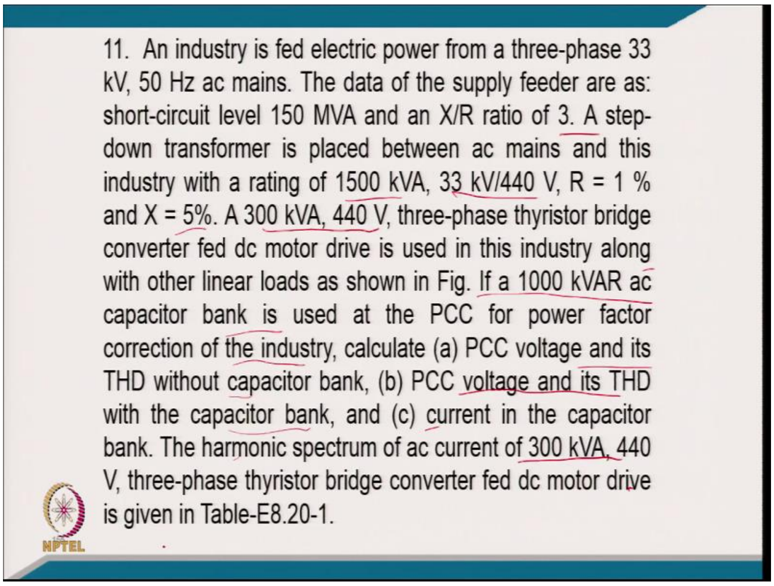
The current rating of the passive shunt filter is as,

$I_{PF} = \sqrt{[I_s^2 - I_{s1a}^2 - I_{s11}^2 - I_{s13}^2 - I_{sH}^2]} = 274.14$ A.

The VA rating of the passive shunt filter is as,

$VA_{PF} = 3V_{PF} * I_{PF} = 3*239.6*274.14 = 197060$ VA.

(Refer Slide Time: 46:10)



Coming to now another numerical problem, an industry is fed from electric power from a three phase 33, 50 Hertz ac mains the data of the supply feeder are as short circuit impedance level is 1 150 k 50 kVA, X R upon 3. And step down transformer is placed between the ac mains and the industry with a rating of 1500 kVA, 33 kV upon 440 with the resistance of 1 percent, X equal to 5 percent at 3 kVA, 440 Volt, three phase thyristor converter, where dc motor drive is used in this industry along with the other linear load as shown in the figure. If a 1000 kVAR capacitor is used at the point of common coupling for power factor correction of the industry. Calculate the PCC voltage and its total harmonic distortion without capacitor bank, PCC voltage and total harmonic distance of capacitor at its THD with the capacitor bank and current in the capacitor bank, harmonic spectrum of ac current of the 300 kVA, 50 Hertz, three phase thyristor converter for dc type is given in the table next table.

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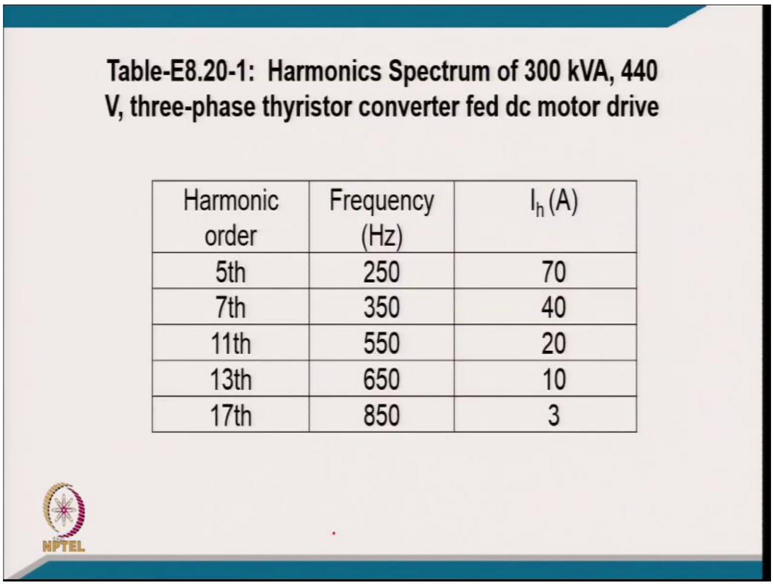

Table-E8.20-1: Harmonics Spectrum of 300 kVA, 440 V, three-phase thyristor converter fed dc motor drive

Harmonic order	Frequency (Hz)	I_h (A)
5th	250	70
7th	350	40
11th	550	20
13th	650	10
17th	850	3

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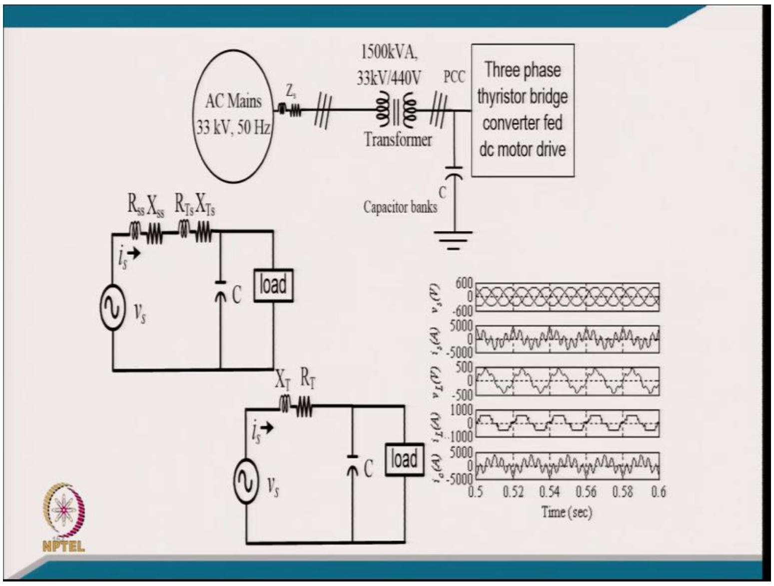

The solution to the numerical is detailed in the screenshots.

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Solution: Given that, a three-phase 33 kV, 50 Hz ac mains has a feeder with data as: short-circuit level 150 MVA and an X/R ratio of 3. A step-down transformer is placed between ac mains and this industry with a rating of 1500 kVA, 33 kV/440 V, R = 1% and X = 5%.

A 300 kVA, 440 V, three-phase thyristor bridge converter fed dc motor drive is used in this industry along with other linear loads. A 1000 kVAR ac capacitor bank is used at the PCC for power factor correction of the industry. The total system and its equivalent circuit are shown in Fig.

(Refer Slide Time: 48:41)

The total system and its equivalent circuit are shown in Fig.

Here feeder impedance is given in terms of short circuit MVA (MVA_{SC}) and X/R ratio and voltage level.

The values of the feeder resistance and reactance in ohms are calculated as,

$R_s = (kV_{LL}^2/MVA_{SC}) \cos\{\tan^{-1}(X_s/R_s)\}$

$= (33^2/150) \cos\{\tan^{-1}(3)\} = 2.2958\ \Omega.$

$X_s = (kV_{LL}^2/MVA_{SC}) \sin\{\tan^{-1}(X_s/R_s)\}$

$= (33^2/150) \sin\{\tan^{-1}(3)\} = 6.8874\ \Omega.$

These data of the feeder in ohms are referred to LV side of the transformer as follows,

$R_{ss} = R_s/n^2 = 2.2958/(33000/440)^2 = 0.00040814\ \Omega.$

$X_{ss} = X_s/n^2 = 6.8874/(33000/440)^2 = 0.0012244\ \Omega.$

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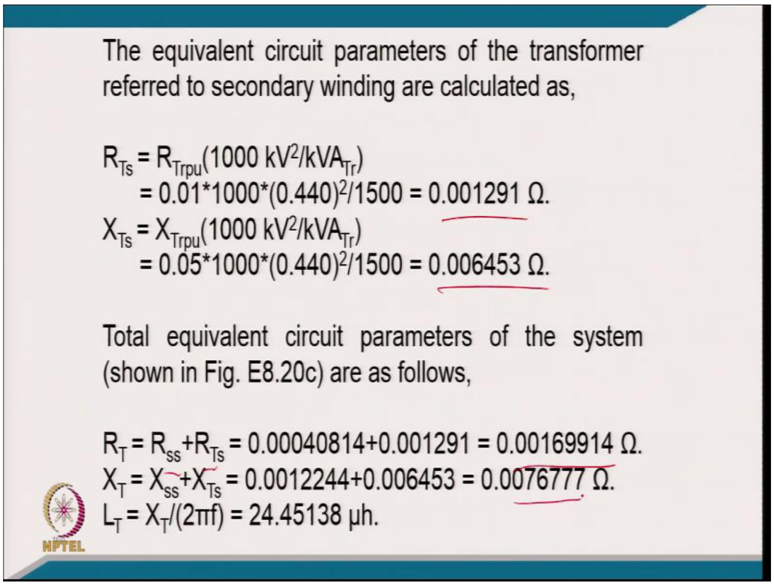

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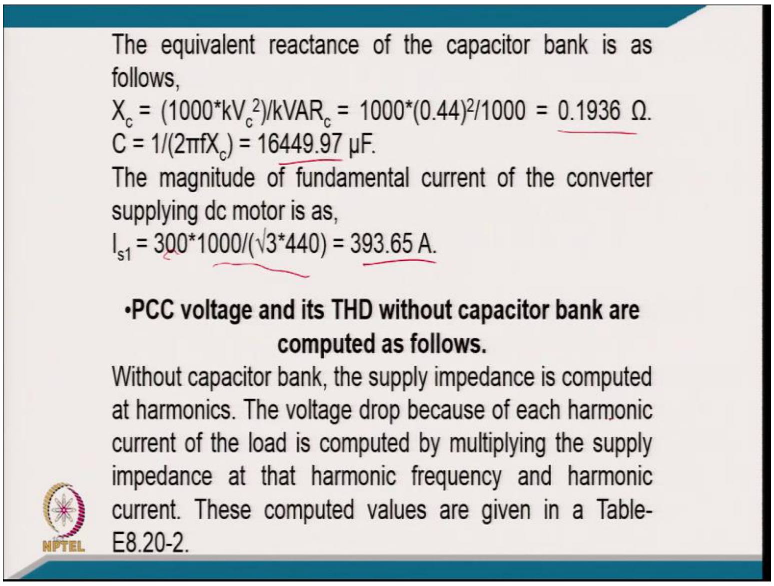

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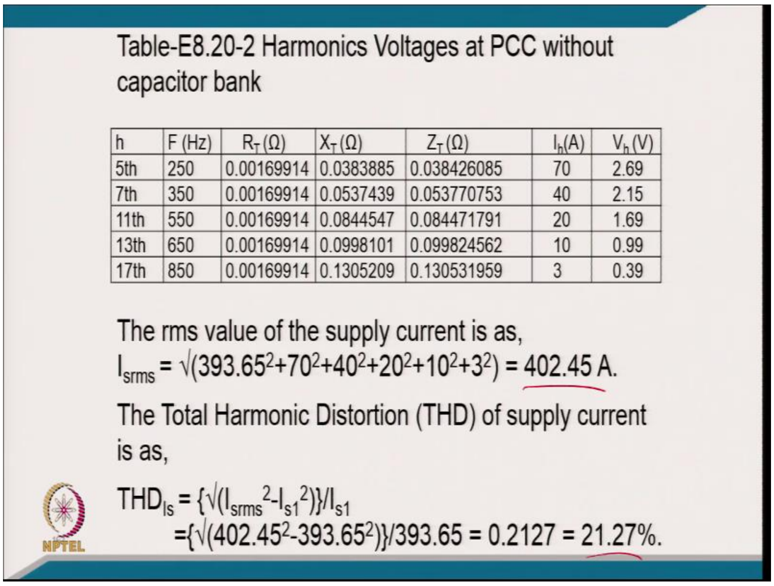

Table-E8.20-2 Harmonics Voltages at PCC without capacitor bank

h	F (Hz)	$R_T (\Omega)$	$X_T (\Omega)$	$Z_T (\Omega)$	I_h(A)	V_h (V)
5th	250	0.00169914	0.0383885	0.038426085	70	2.69
7th	350	0.00169914	0.0537439	0.053770753	40	2.15
11th	550	0.00169914	0.0844547	0.084471791	20	1.69
13th	650	0.00169914	0.0998101	0.099824562	10	0.99
17th	850	0.00169914	0.1305209	0.130531959	3	0.39

The rms value of the supply current is as,

$I_{srms} = \sqrt{(393.65^2+70^2+40^2+20^2+10^2+3^2)} = 402.45$ A.

The Total Harmonic Distortion (THD) of supply current is as,

$THD_{Is} = \{\sqrt{(I_{srms}^2 - I_{s1}^2)}\}/I_{s1}$

$= \{\sqrt{(402.45^2-393.65^2)}\}/393.65 = 0.2127 = 21.27\%$.

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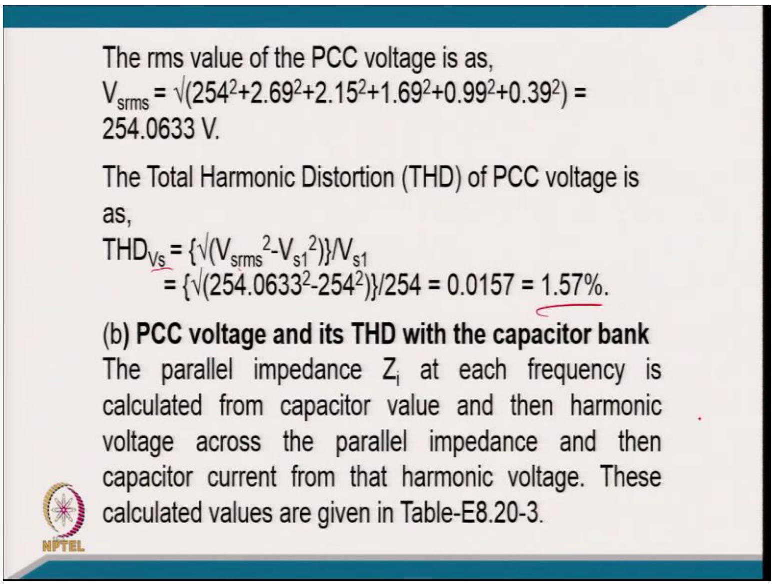

The rms value of the PCC voltage is as,

$V_{srms} = \sqrt{(254^2+2.69^2+2.15^2+1.69^2+0.99^2+0.39^2)} =$ 254.0633 V.

The Total Harmonic Distortion (THD) of PCC voltage is as,

$THD_{Vs} = \{\sqrt{(V_{srms}^2 - V_{s1}^2)}\}/V_{s1}$

$= \{\sqrt{(254.0633^2-254^2)}\}/254 = 0.0157 = 1.57\%$.

(b) **PCC voltage and its THD with the capacitor bank**

The parallel impedance Z_i at each frequency is calculated from capacitor value and then harmonic voltage across the parallel impedance and then capacitor current from that harmonic voltage. These calculated values are given in Table-E8.20-3.

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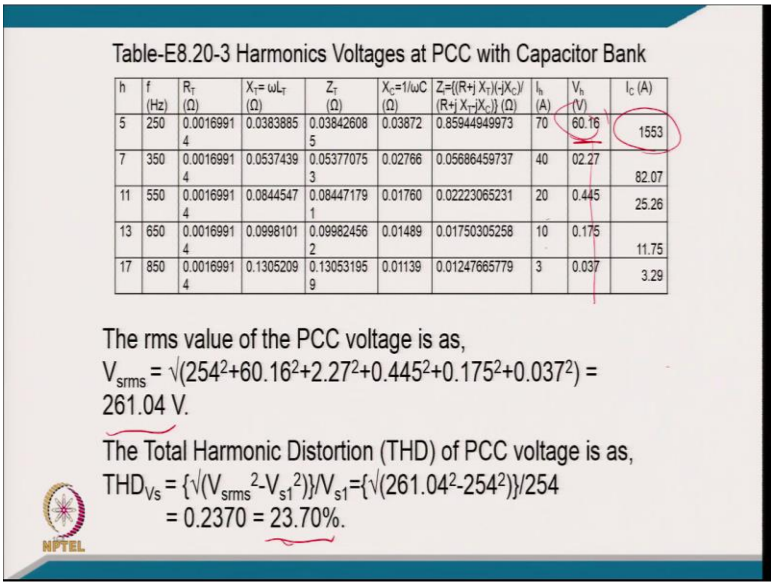

Table-E8.20-3 Harmonics Voltages at PCC with Capacitor Bank

h	f (Hz)	R_T (Ω)	$X_T = \omega L_T$ (Ω)	Z_T (Ω)	$X_C = 1/\omega C$ (Ω)	$Z_t = \{(R + jX_T)(-jX_C)/(R + jX_T - jX_C)\}$ (Ω)	I_h (A)	V_h (V)	I_C (A)
5	250	0.00169914	0.0383885	0.038426085	0.03872	0.85944949973	70	60.16	1553
7	350	0.00169914	0.0537439	0.053770753	0.02766	0.05686459737	40	02.27	82.07
11	550	0.00169914	0.0844547	0.084471791	0.01760	0.02223065231	20	0.445	25.26
13	650	0.00169914	0.0998101	0.099824562	0.01489	0.01750305258	10	0.175	11.75
17	850	0.00169914	0.1305209	0.130531959	0.01139	0.01247665779	3	0.037	3.29

The rms value of the PCC voltage is as,

$V_{srms} = \sqrt{(254^2+60.16^2+2.27^2+0.445^2+0.175^2+0.037^2)} = 261.04$ V.

The Total Harmonic Distortion (THD) of PCC voltage is as,

$THD_{Vs} = \{\sqrt{(V_{srms}^2 - V_{s1}^2)}\}/V_{s1} = \{\sqrt{(261.04^2-254^2)}\}/254$

$= 0.2370 = 23.70\%$.

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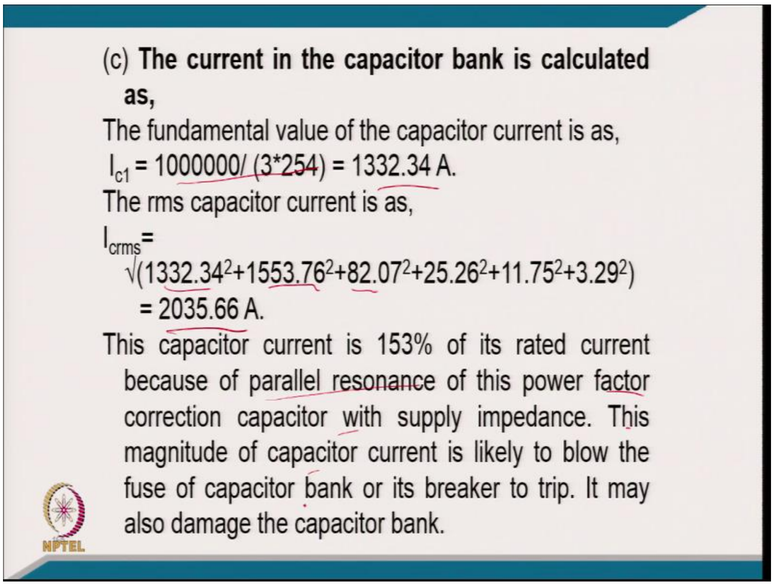

(c) **The current in the capacitor bank is calculated as,**

The fundamental value of the capacitor current is as,

$I_{c1} = 1000000/(3*254) = 1332.34$ A.

The rms capacitor current is as,

$I_{crms} = \sqrt{(1332.34^2+1553.76^2+82.07^2+25.26^2+11.75^2+3.29^2)}$

$= 2035.66$ A.

This capacitor current is 153% of its rated current because of parallel resonance of this power factor correction capacitor with supply impedance. This magnitude of capacitor current is likely to blow the fuse of capacitor bank or its breaker to trip. It may also damage the capacitor bank.

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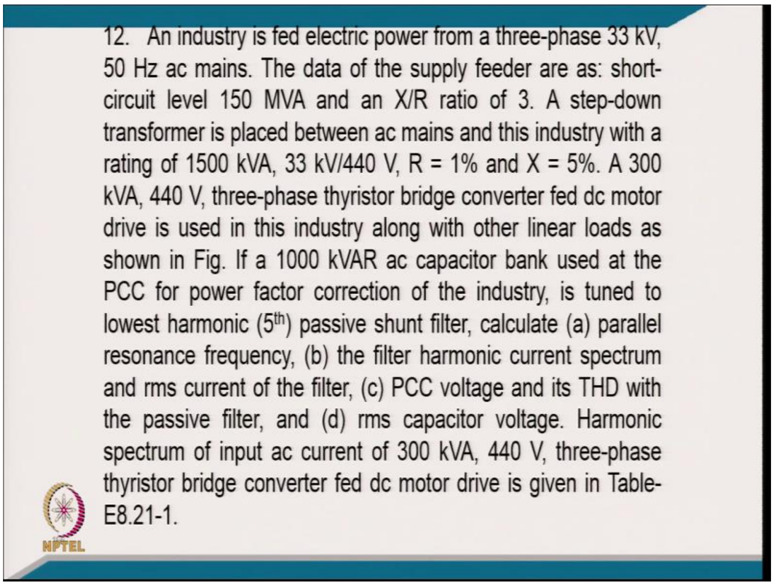

Now, coming to a 12th problem, an industry is fed from electric power from a three phase 33, 50 Hertz ac mains. The data of supply feeder are, as like a short circuit current level of 150 kVA, X upon R ratio of 3. A step down transformer is placed between the ac mains and this industry of 1500 kVA, 33 kV by 440 with the resistance of 1 percent and reactance of 5 percent.

A 300 kV, 440 Volt, three phase thyristor converter bridge dc drive is used in this industry with other linear load. And if 1000 kVAR capacitor bank is used at the PCC with the power factor correction, it tuned to lowest harmonic 5th harmonics passive shunt filter. Calculate the parallel resonance frequency, the filter harmonic spectrum, current top filter PCC voltage and THD of passive filter.

The rms capacitor voltage harmonic spectrum of ac mains current of 300 kVA of this is given in table 1.

(Refer Slide Time: 54:57)

Table-E8.21-1: Harmonics Spectrum of 300 kVA, 440 V, three-phase thyristor converter fed dc motor drive

Harmonic order	Frequency (Hz)	I_h (A)
5th	250	70
7th	350	40
11th	550	20
13th	650	10
17th	850	3

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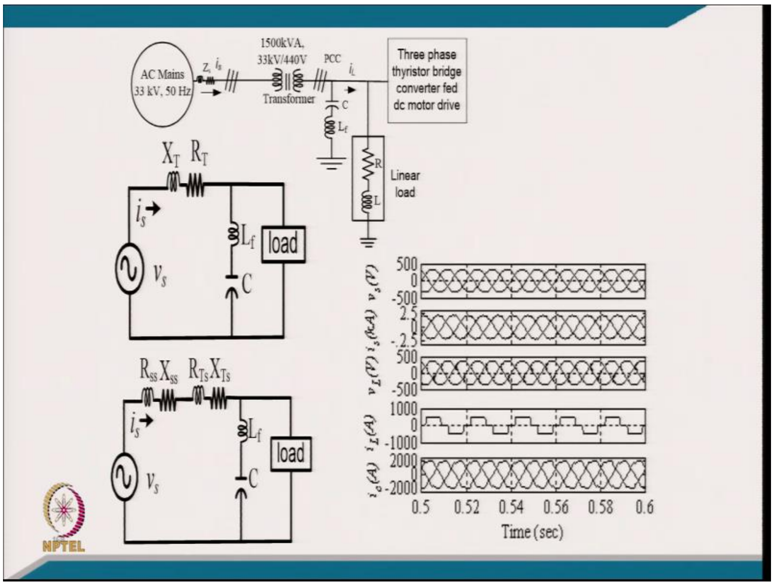

The solution to the numerical is detailed in the screenshots.

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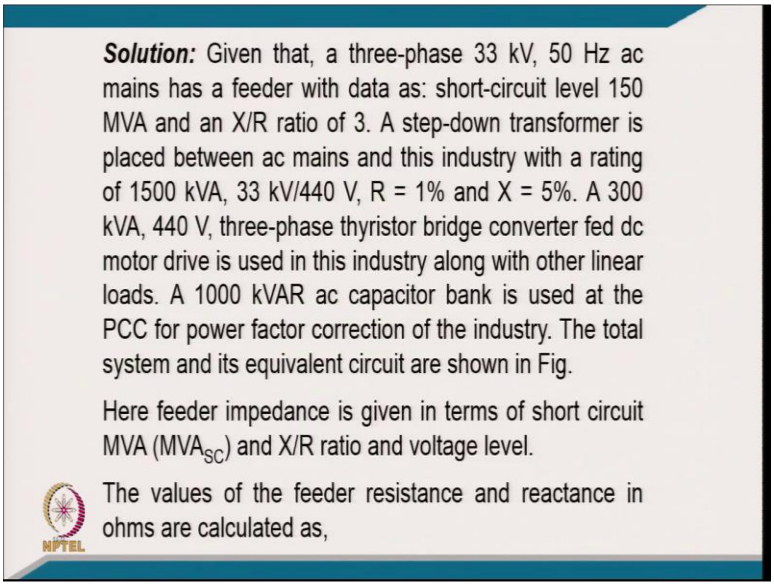

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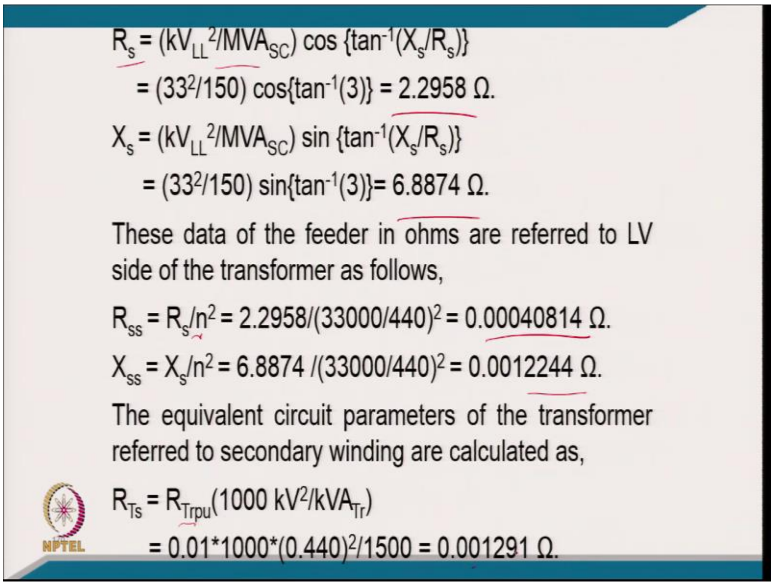

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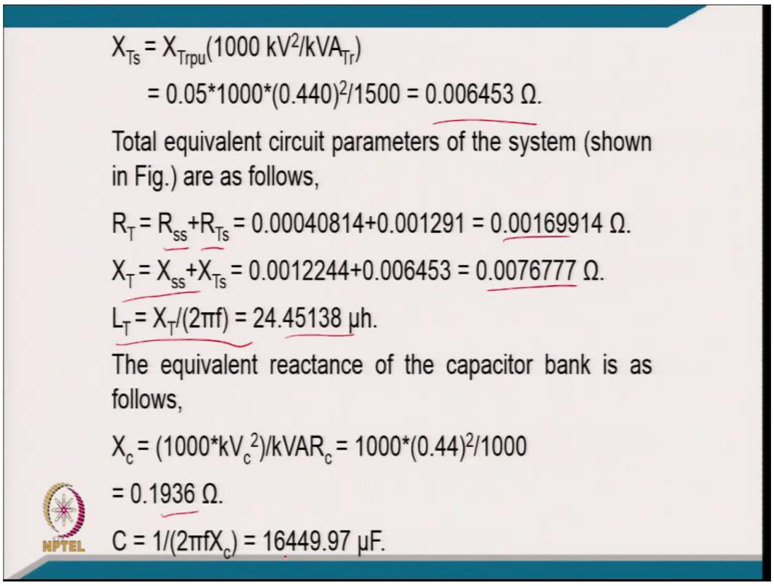

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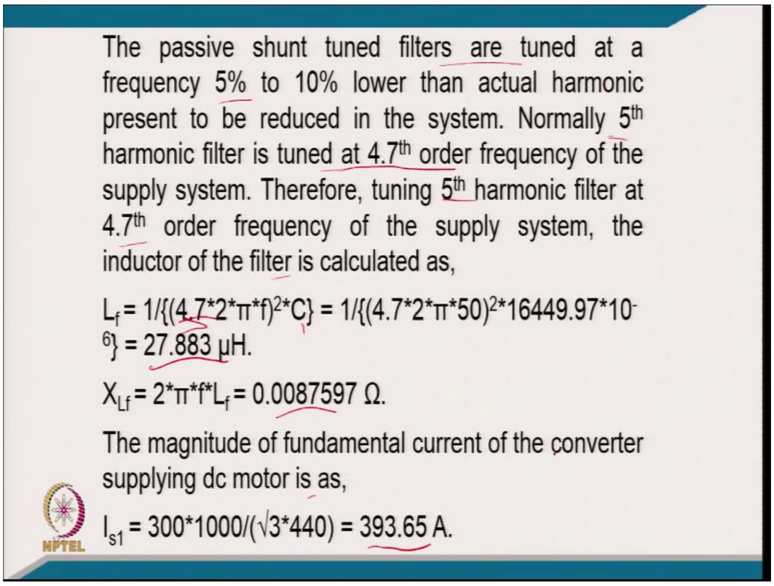

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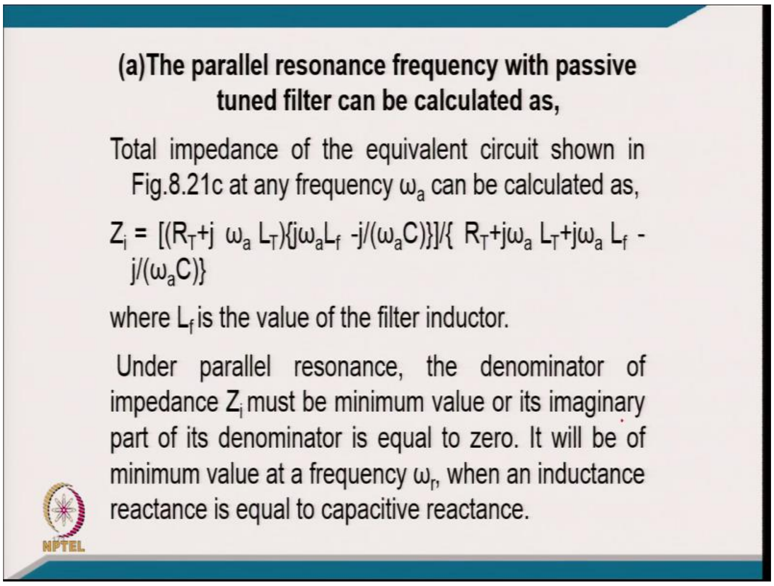

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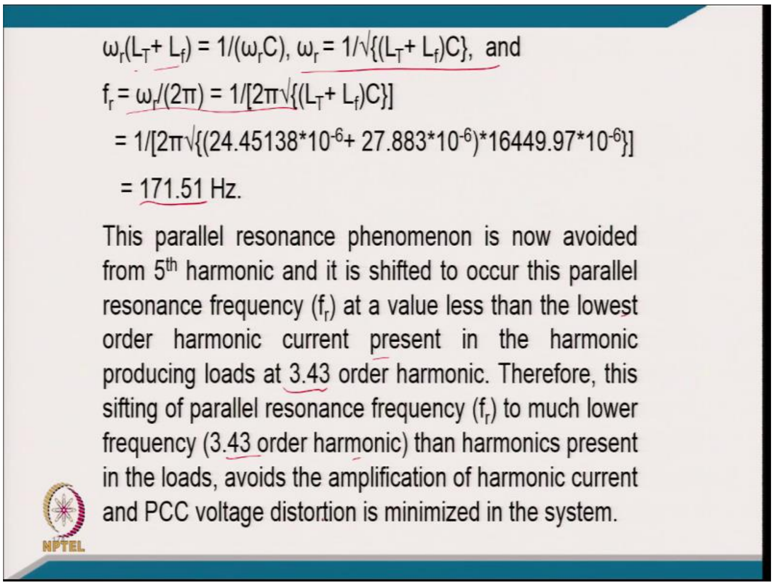

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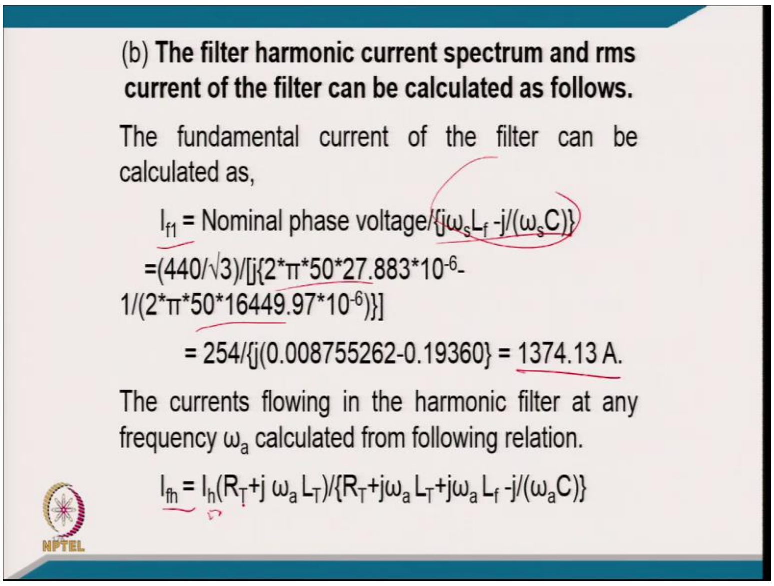

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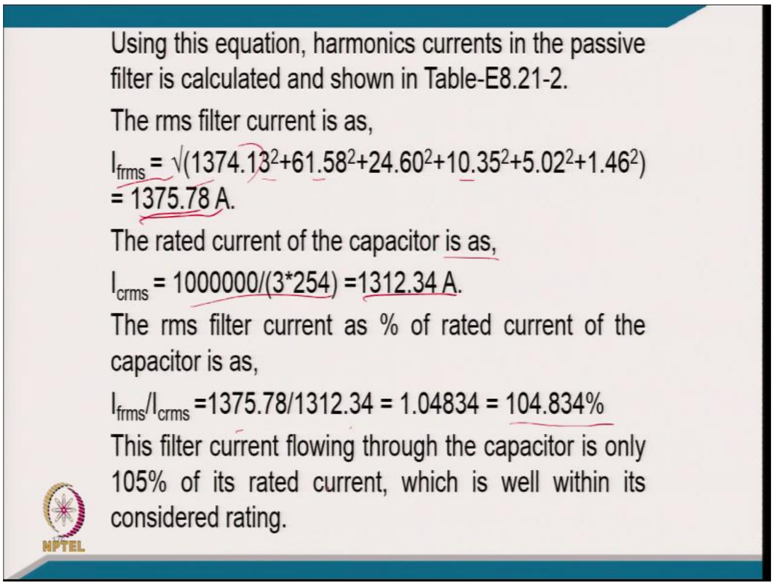

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Table-E8.21-2 Harmonics Voltages at PCC with Passive Filter

h	f (Hz)	R_T (Ω)	$X_T=\omega L_T$ (Ω)	Z_T (Ω)	$X_C=1/\omega C$ (Ω)	$X_f=\omega L_f$ (Ω)	I_h (A)	I_{fh} (A)	I_{sh} (A)	V_h (V)	V_{ch} (V)	V_{Lh} (V)
5	250	0.00169914	0.0383885	0.038426085	0.03872	0.0437985	70	61.58	08.14	0.313	2.384	2.697
7	350	0.00169914	0.0537439	0.053770753	0.02766	0.0613179	40	24.60	15.40	0.828	0.681	1.509
11	550	0.00169914	0.0844547	0.084471791	0.01760	0.0963567	20	10.35	09.65	0.815	0.182	0.997
13	650	0.00169914	0.0998101	0.099824562	0.01489	0.1138761	10	05.02	04.98	0.497	0.075	0.572
17	850	0.00169914	0.1305209	0.130531959	0.01139	0.1489149	3	01.46	01.54	0.201	0.017	0.217

(c) The PCC voltage and its THD with the passive filter

For calculation of the voltage distortion, harmonics currents flowing in to the supply system at a frequency ω_a are computed and shown in Table-E8.21-2 from these relations,

(Refer Slide Time: 62:36)

$I_{sh} = I_h(j\omega_a L_f - j/(\omega_a C)/\{R_T + j\omega_a L_T + j\omega_a L_f - j/(\omega_a C)\}$

The fundamental PCC voltage is as,

$V_{s1} = 440/\sqrt{3} = 254$ V.

The harmonic voltage at each harmonic present at PCC may be calculated as,

$$V_h = I_{sh}(R_T + j\omega_a L_T)$$

These equations are used to calculate all harmonic voltages to find THD of the PCC voltage and calculated values are given Table-E8.21-2.

The rms value of the supply current is from Table-E8.21-2 as,

$I_{srms} = \sqrt{(393.65^2+8.14^2+15.4^2+9.65^2+4.98^2+1.54^2)} = 394.187$ A.

The THD of the supply current is as,

$THD_{Is} = [\sqrt{(393.187^2-393.65^2)}]/393.65 = 0.0522 = 5.22\%$.

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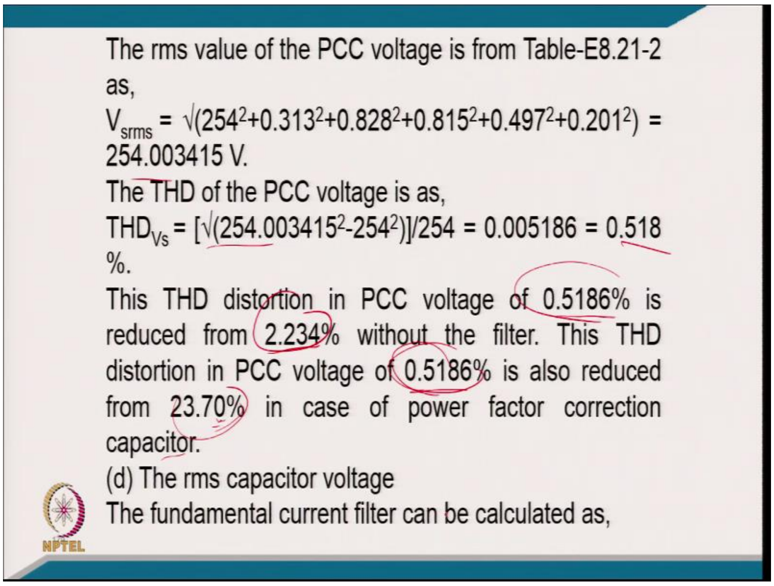

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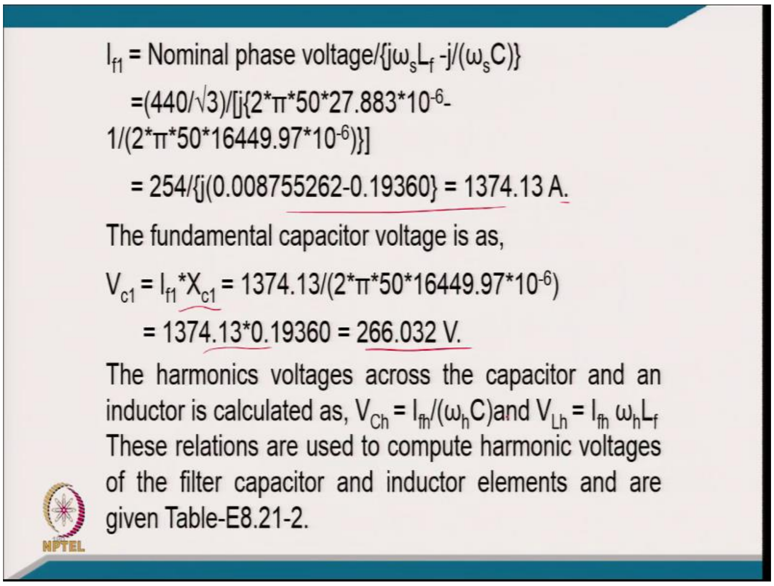

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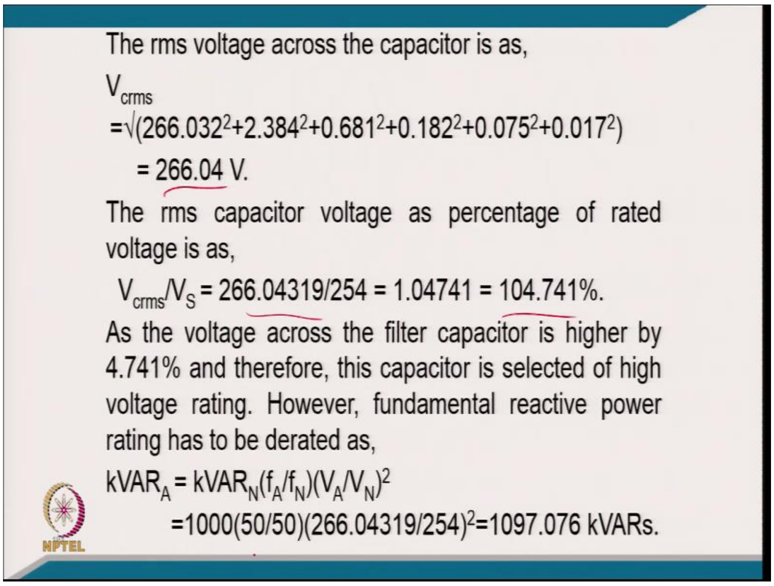

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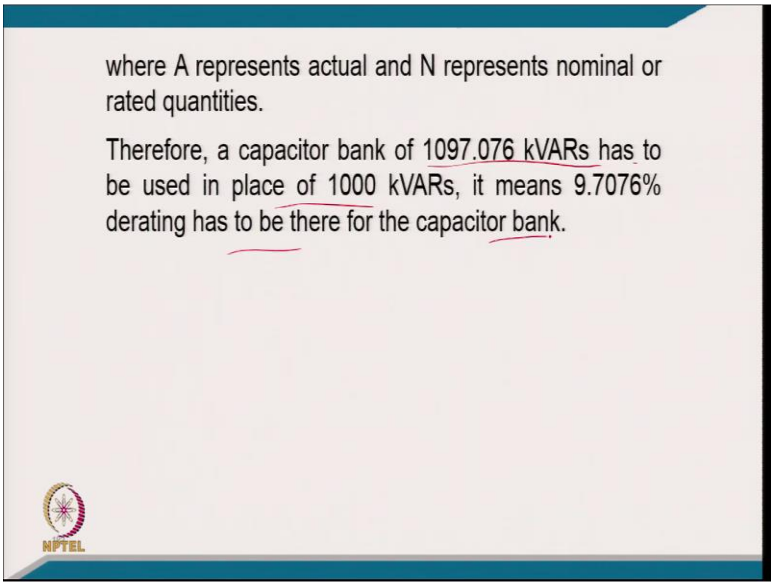

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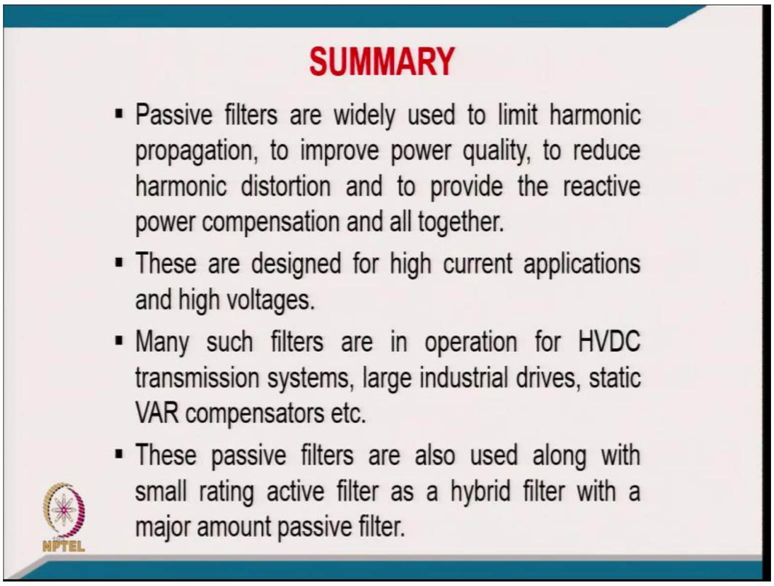

Passive filter are widely used to limit the harmonic propagation, to improve the power quality, and to reduce the harmonic distortion and to provide the reactive power compensation and all together. And there are these are designed for high current applications and high voltage like HVDC and high rating current source converter one.

And many such filters are in operation for HVDC transmission system, large industrial drive, static VAR compensator. And these passive filters are also used along with the small rating active filter as a hybrid filter with a major amount of passive filter.

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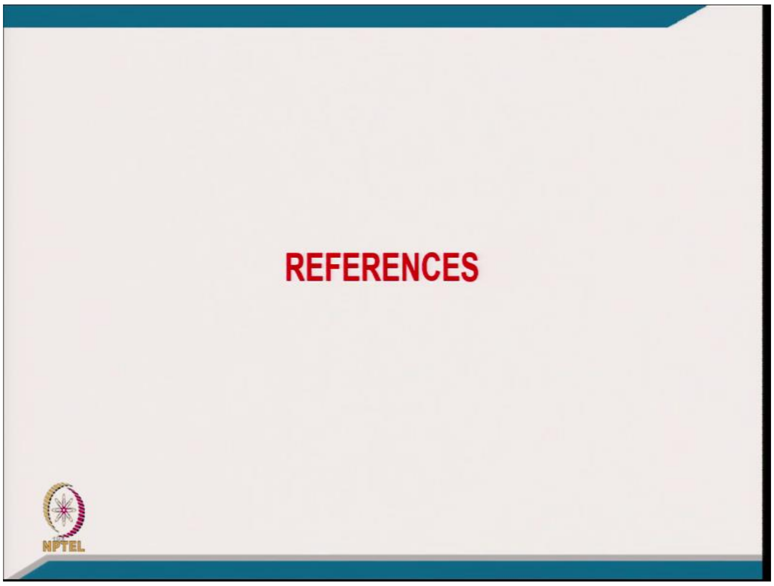

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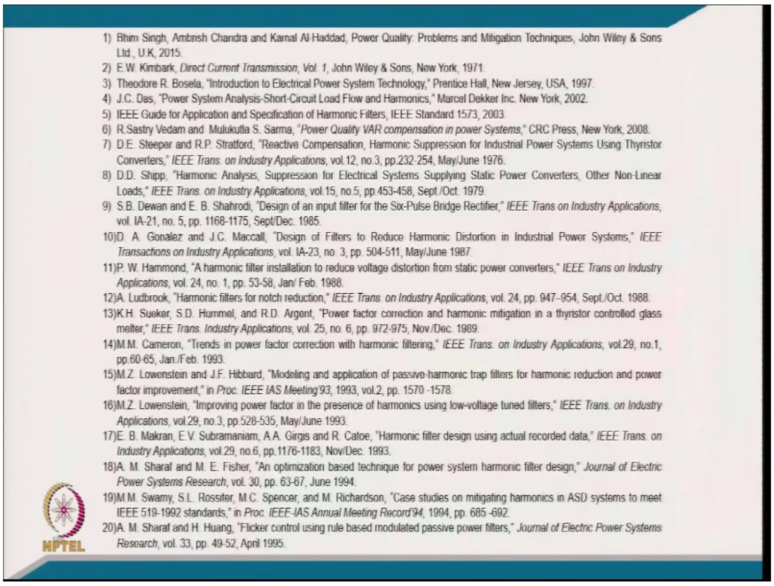

And these are the some of the references and.

Thank you.