Power Quality
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Module - 07
Numerical Examples
Lecture - 24
Active Series Power Filters (contd.)

Welcome to the course on Power Quality. We will discuss today the example on Series Active Filters.

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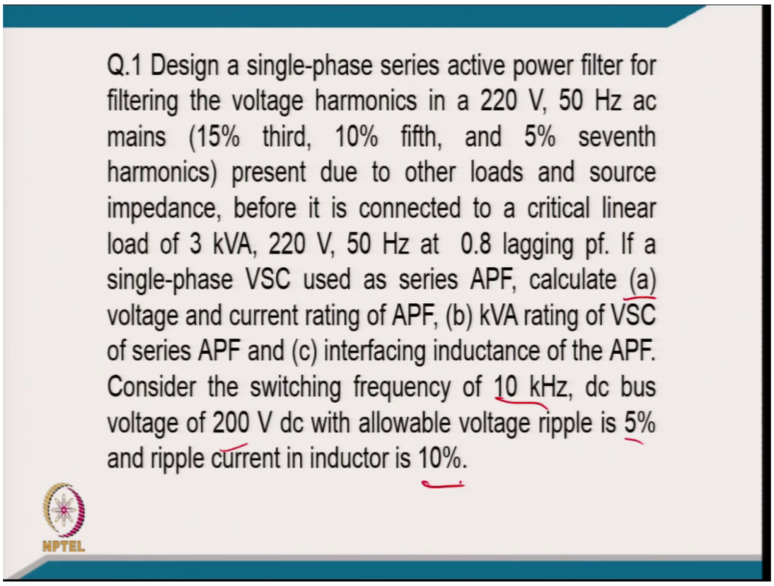

Starting with the first example. Design a single-phase series active filter for filtering the voltage harmonics in 220 volt, 50 hertz ac mains, which consist of 15 percent third, 10 percent fifth and 5 percent 7th harmonics present due to the other loads and source impedance before it is connected to a critical linear load of 3 kVA two it at 220 volt, 50 hertz at 0.8 lagging power factor.

If the single-phase voltage source converter is used as a series active filter calculate a voltage and current rating of series active filter kVA rating of voltage source series active filter and the interfacing inductance of series active filter. Consider the switching frequency of 10 kilo volt and dc bus voltage of 200 volt with the allowable voltage ripple of 5 percent and ripple current in the inductor is 10 percent.

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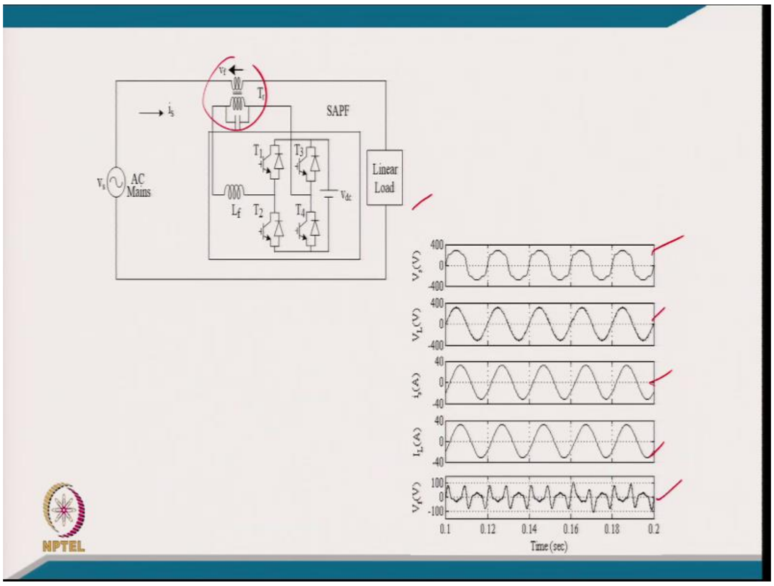

The explanation of the numerical problem is described in the screenshots herein.

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Solution: Given that, supply voltage, V_s = 220 V, frequency of the supply f=50 Hz, V_{s3}=15%, V_{s5}=10%, V_{s7}=5%, a critical load of 3kVA at 0.8 lagging PF, V_{dc}=200V, f_s=10 kHz, ΔI_f =10%, ΔV_{dc}=5%.

The load current is as, I_s=3000/220=13.636A.

ΔI_f =10% of I_s=1.364A,

ΔV_{dc}=5% of V_{dc}=10V,

V_{dcmin}=200- ΔV_{dc}=190V.

V_{s3}=15% of V_s=33 V,

V_{s5}=10% of V_s= 22 V,

V_{s7}=5% of V_s= 11 V.

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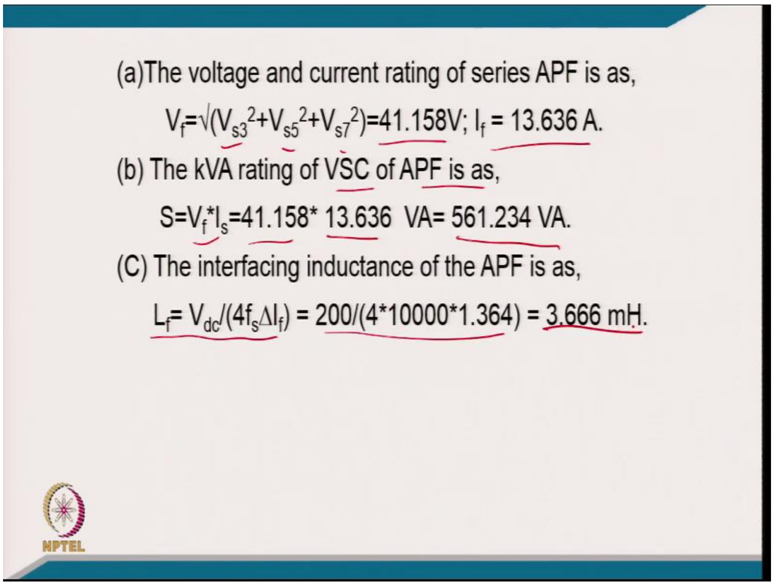

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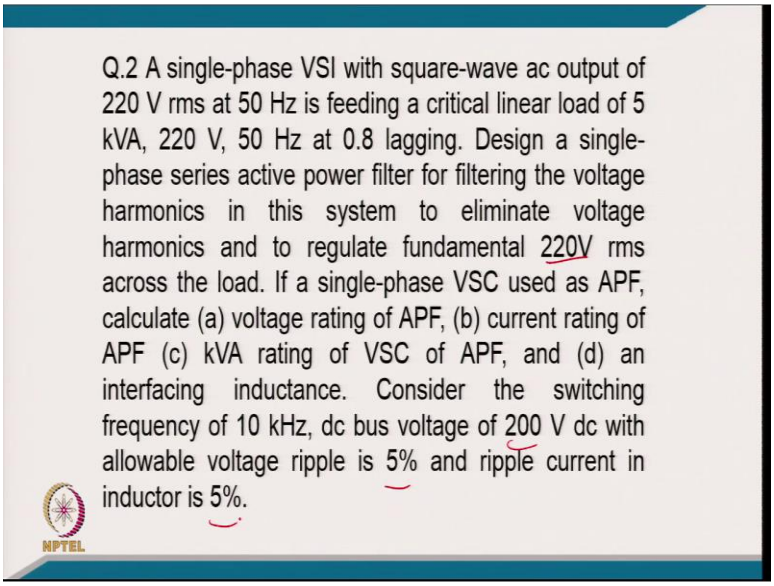

Coming to the next example number 2. A single-phase voltage source inverter with a square-wave ac output of a 220 volt, rms at 50 hertz is feeding a critical linear load of 5 Kva, 220 volt, 50 hertz at 0.8 lagging power factor and design a single-phase series active filter for filtering the voltage harmonics in this system to eliminate the voltage harmonics and to regulate the voltage fundamental voltage at 220 volt rms across the load.

If single-phase voltage source converter is used as a active power filter, calculate the voltage rating of active power filter, current rating of active power filter, kVA rating of the voltage source converter of active filter and design a interfacing inductance and consider the switching frequency of 10 kilohertz, dc bus voltage of 2 200 volt dc and with allowable voltage ripple of 5 percent ripple current of inductor is 5 percent like.

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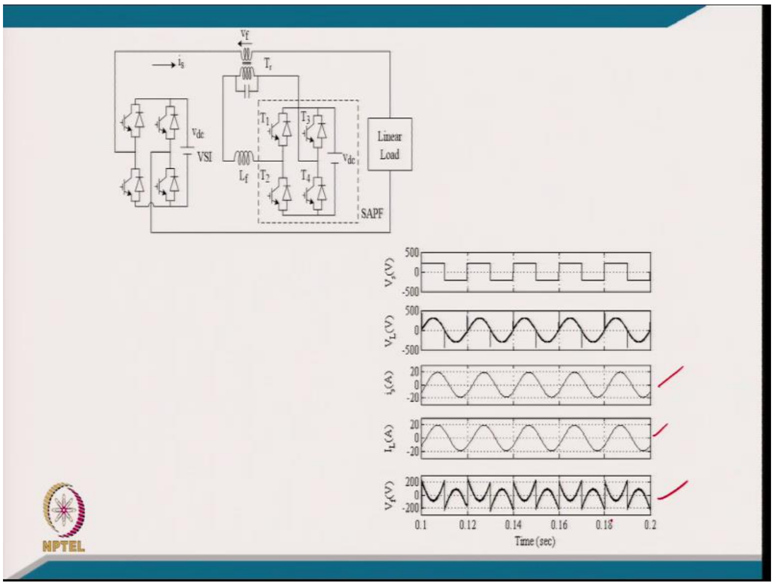

The explanation of the numerical problem is described in the screenshots herein.

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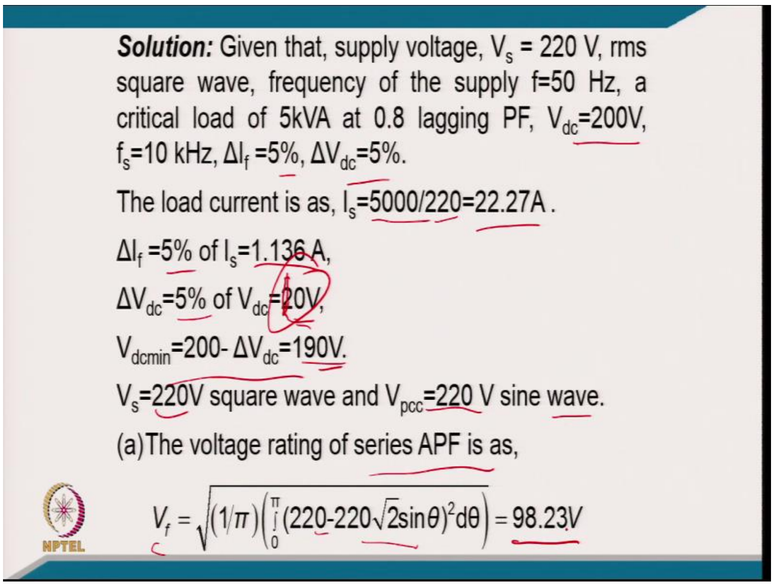

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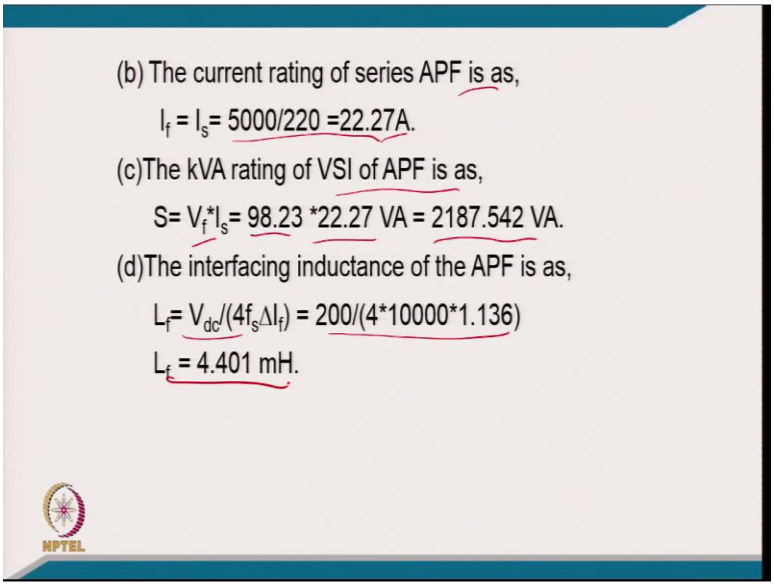

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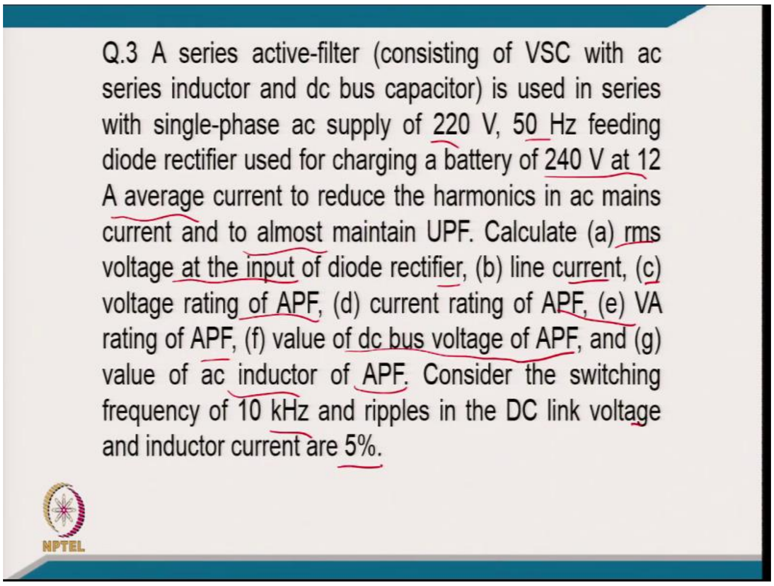

Coming to the numerical example 3. A series active filter constraints consisting of voltage source converter with ac series inductor and dc bus capacitor is used in series with the single-phase ac supply of 220 volt, 50 hertz feeding a diode rectifier used for charging a battery of 240 volt at 12 amp ampere average current to reduce the harmonics in ac mains current and to almost maintain unity power factor.

Calculate rms voltage at the input of diode rectifier, line current, then the voltage rating of active filter, current rating of active filter, VA rating of active series active filter and value of the dc link voltage of active filter and the value of ac inductor of series active filter. Consider the switching frequency of 10 kilohertz and ripple in the dc link voltage and inductor current are 5 percent.

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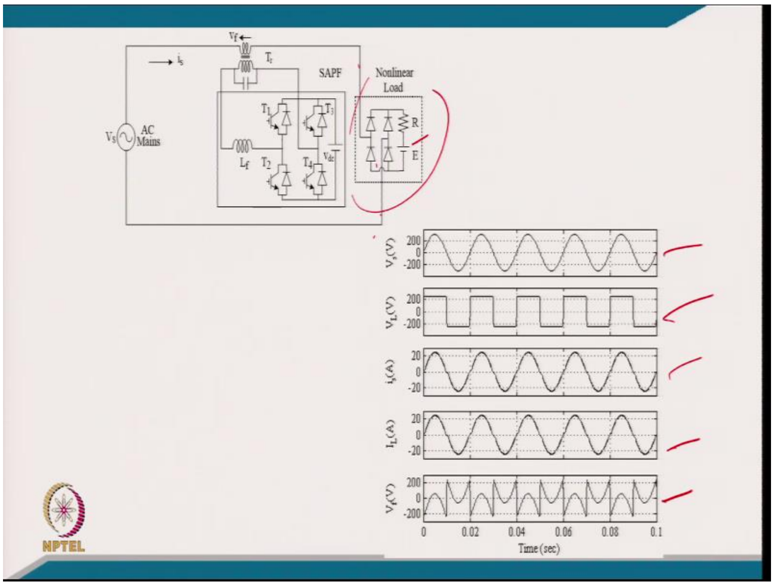

The explanation of the numerical problem is described in the screenshots herein.

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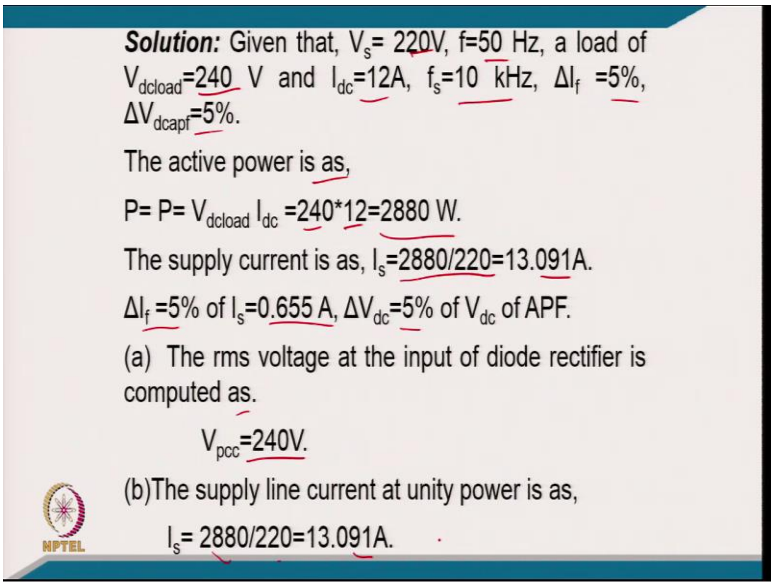

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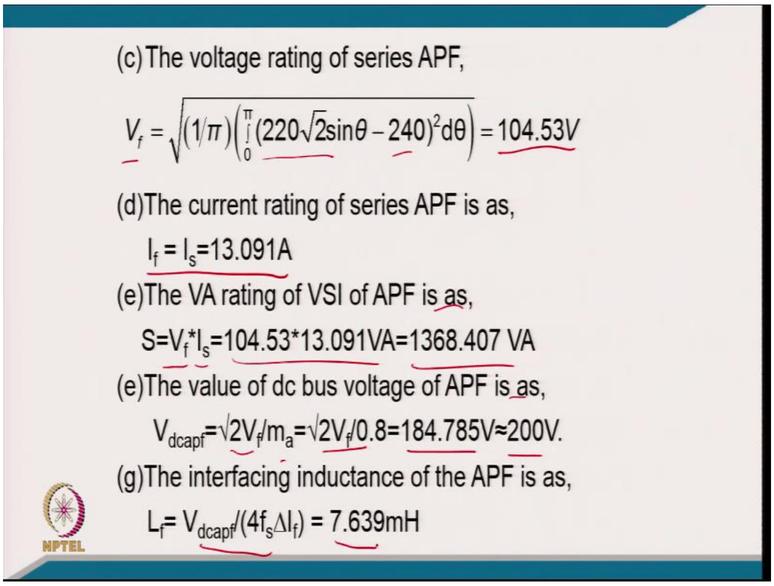

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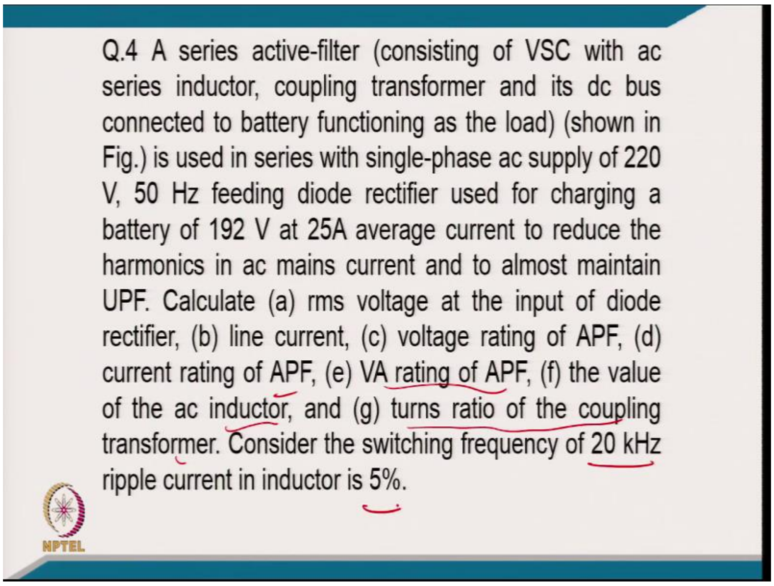

Coming to the 4th example. A series active filter consisting of voltage source converter with the ac inductor, coupling transformer and its dc bus connected to the battery functioning as a load shown in figure is used in series with the single-phase ac supply of 220 volt, 50 hertz feeding diode rectifier used for charging a battery of 192 volt at 25 a ampere average current to reduce the harmonics in ac mains current and to almost to maintain unity power factor.

Calculate the rms voltage at the input of diode rectifier, line current, voltage rating of series active filter, current rating of series active filter, VA rating of series active filter, the value of ac inductor, interfacing a dc inductor, the turn's ratio of the coupling transformer. Consider the switching frequency of 20 kilo hertz and ripple current inductor is 5 percent like.

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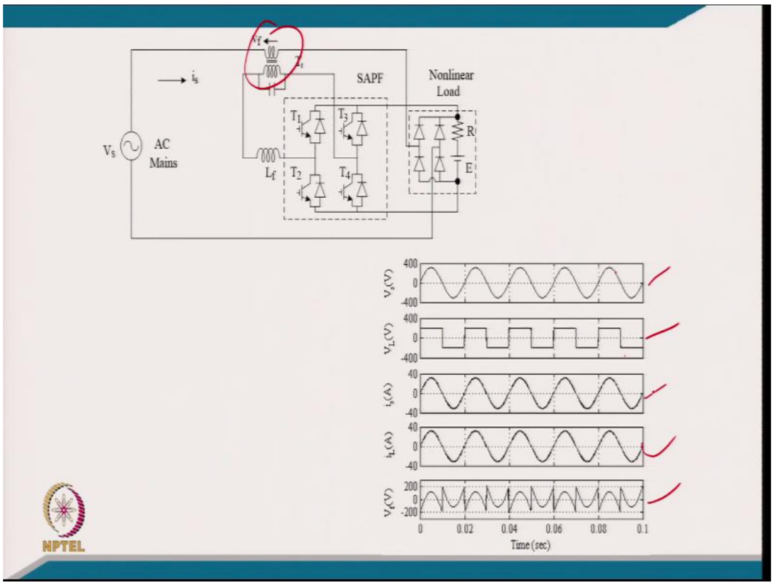

The explanation of the numerical problem is described in the screenshots herein.

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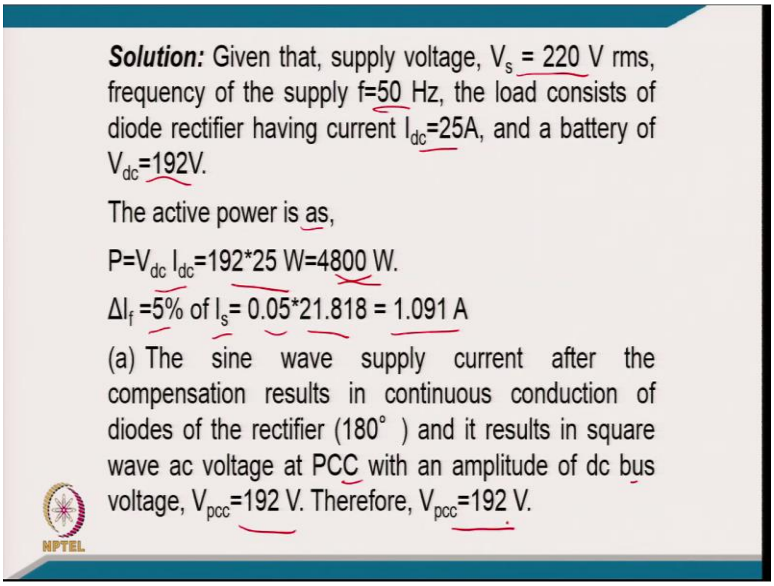

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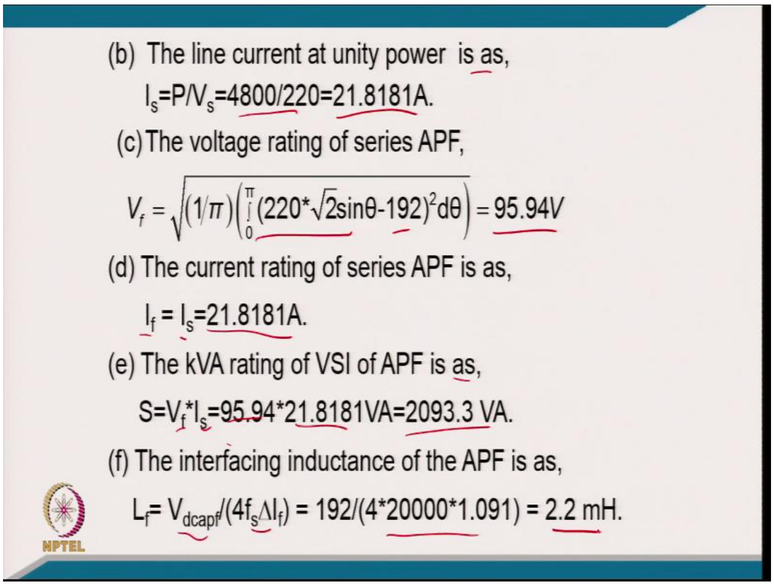

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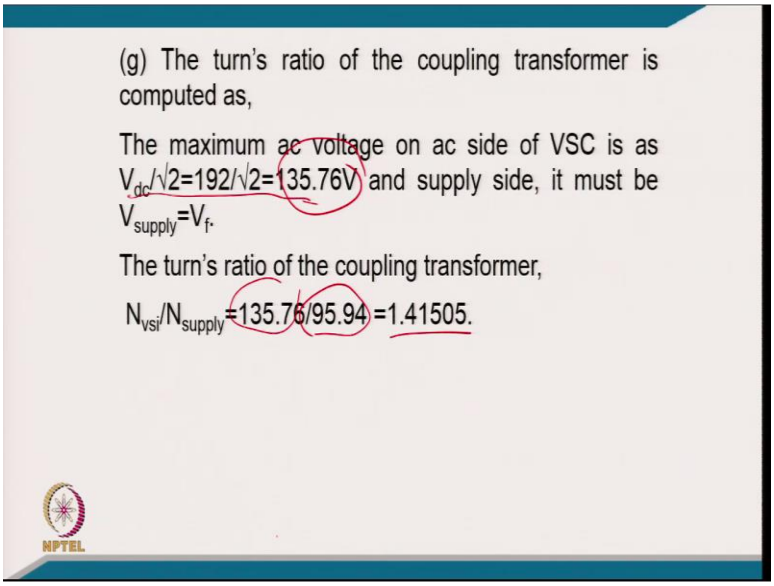

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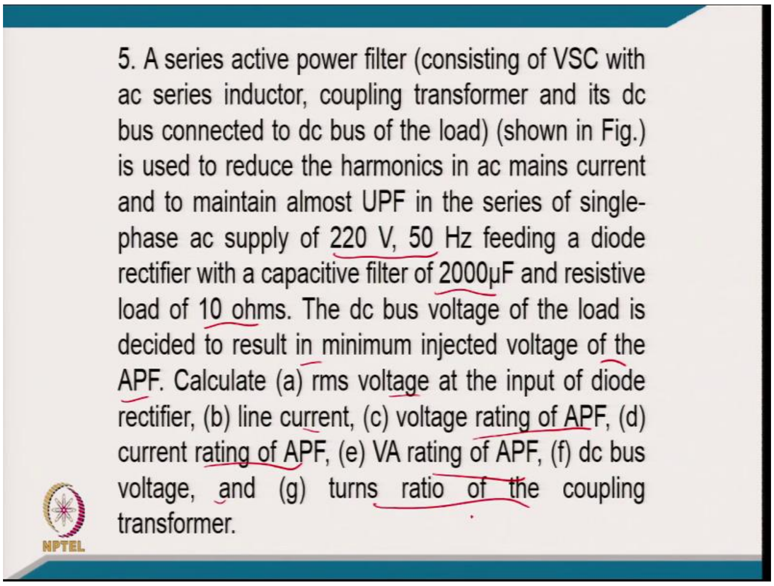

Coming to numerical example 5. A series active power filter consisting of voltage source converter with ac series inductor and coupling transformer and its dc bus connected to dc bus of the load is used to reduce the harmonics in ac mains current and to maintain almost a unity power factor in series supply of 220 volt, 50 hertz feeding a diode rectifier load with a capacitive filter of 2000 microfarad and a resistive load of 10 ohm in parallel.

And dc link voltage of the load is decided to result in a minimum injected voltage of the APF calculate the rms voltage at the input of diode rectifier line current, voltage rating of series active filter, current rating of series active filter, VA rating of series active filter, dc bus voltage of series active filter and turn’s ratio of the coupling transformer used in series active power filter.

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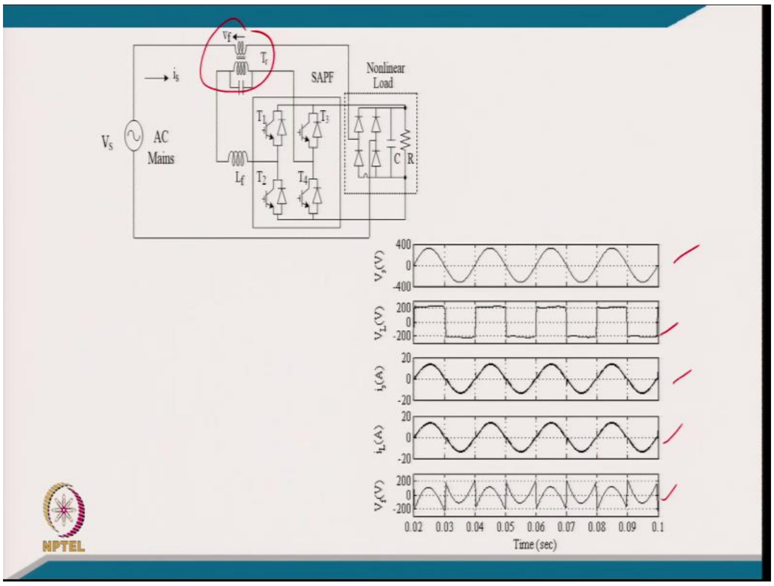

The explanation of the numerical problem is described in the screenshots herein.

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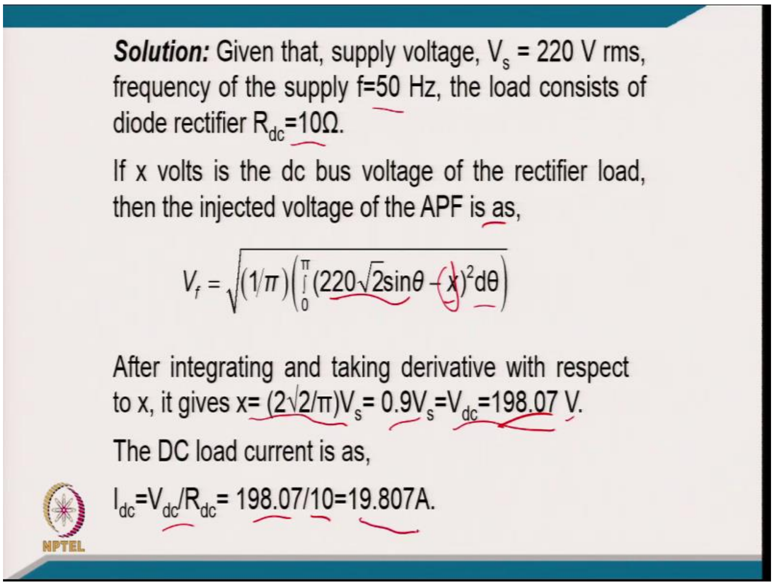

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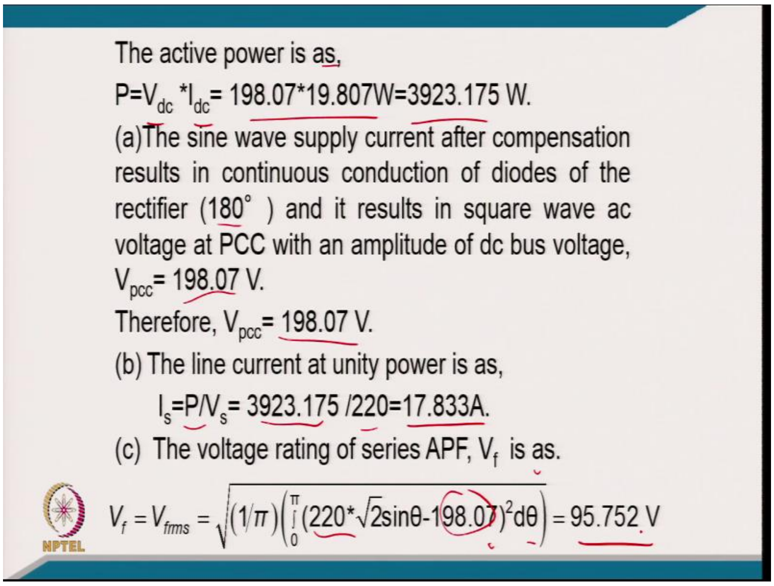

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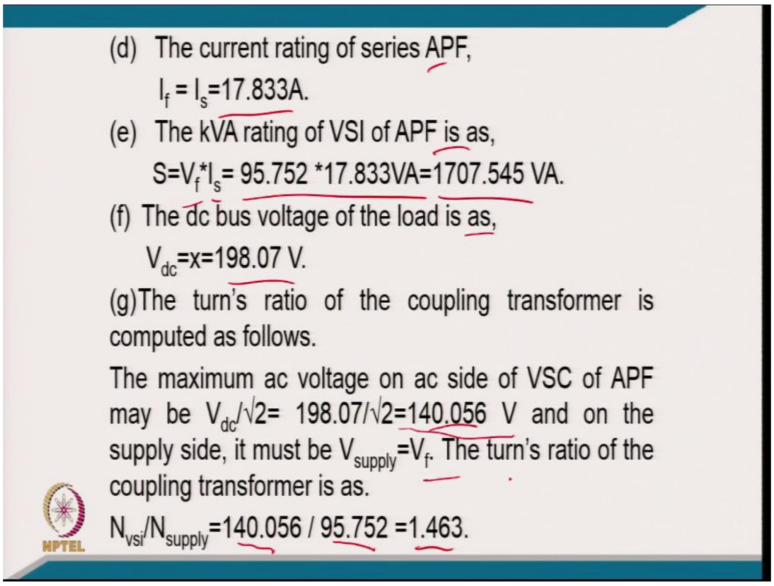

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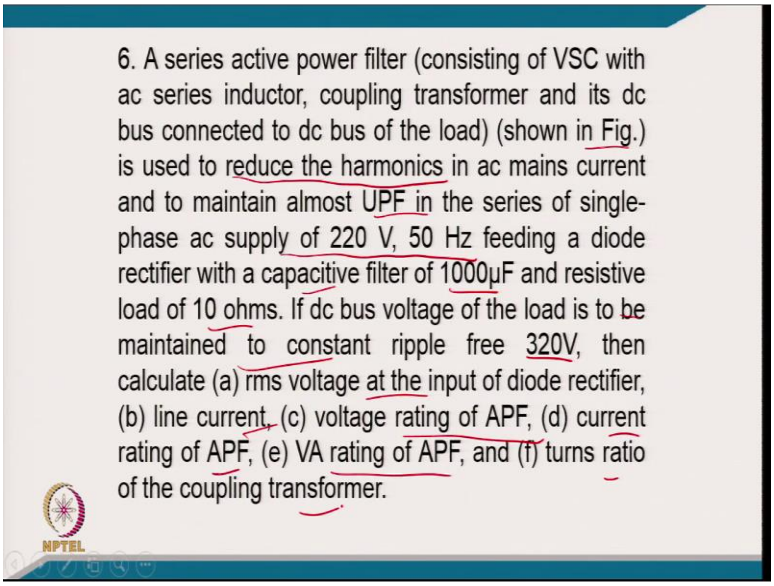

Coming to the 6 numerical example. A series active power filter consisting of voltage source converter with ac series inductor coupling transformer and it is a dc bus connected to the dc bus of the load shown on in the figure is used to reduce the harmonics in ac mains current and to maintain almost unity power factor in series of the single-phase ac supply of 220 volt, 50 hertz feeding a diode rectifier with a capacitive filter of 1000 micro farad and resistive load of 10.

If dc bus voltage of load is to be maintained constant ripple free of 320 volt then calculate the rms voltage at the input of diode rectifier, line current, voltage rating of series active filter, current rating of series active filter, VA rating of series active filter and turn’s ratio of coupling transformer.

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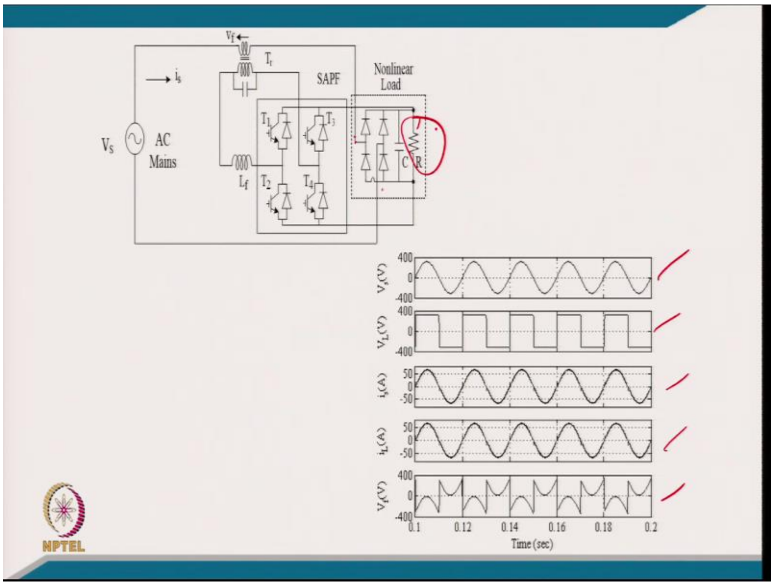

The explanation of the numerical problem is described in the screenshots herein.

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Solution: Given that, supply voltage, V_s = 220 V rms, frequency of the supply f=50 Hz, the load consists of diode rectifier R_{dc}=10Ω, V_{dc}=320V.

The load current is as, I_{dc}=320/10=32A.

The active power is as,

$P=V_{dc}\, I_{dc}$=320*32 W=10240 W.

(a) 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}=320 V. Therefore, V_{pcc}=320 V.

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

$I_s=P/V_s$=10240/220=46.545 A.

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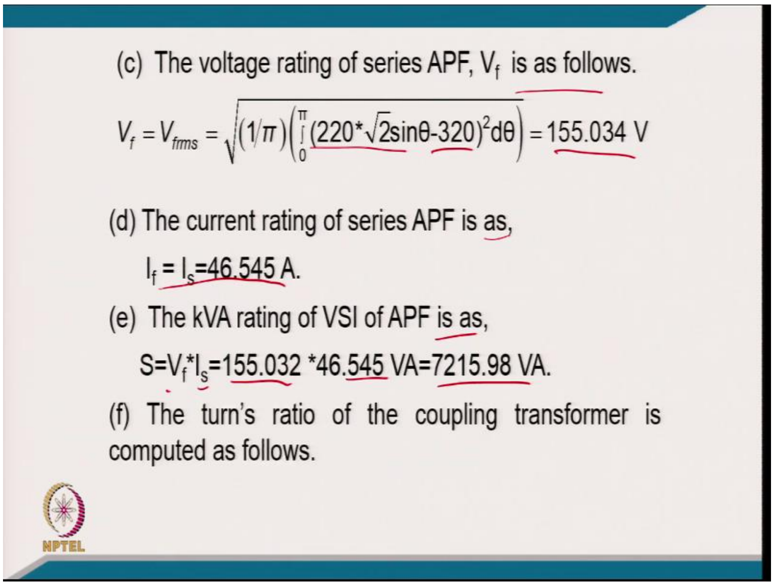

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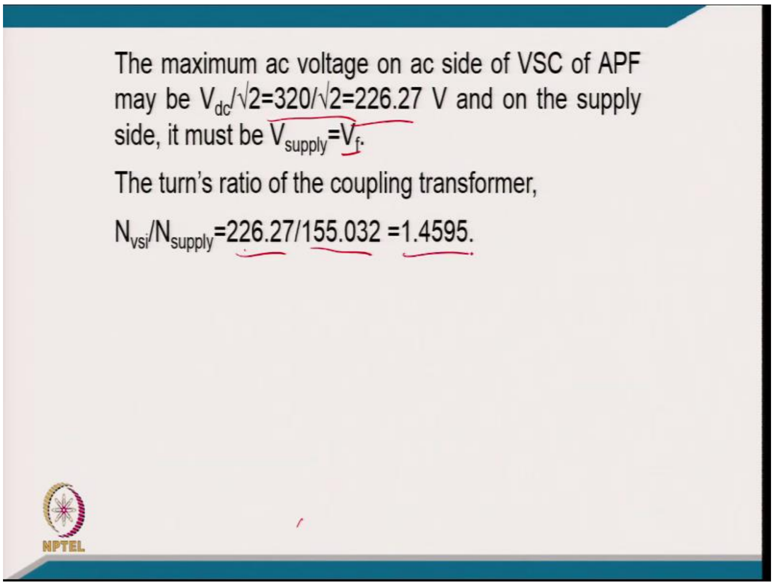

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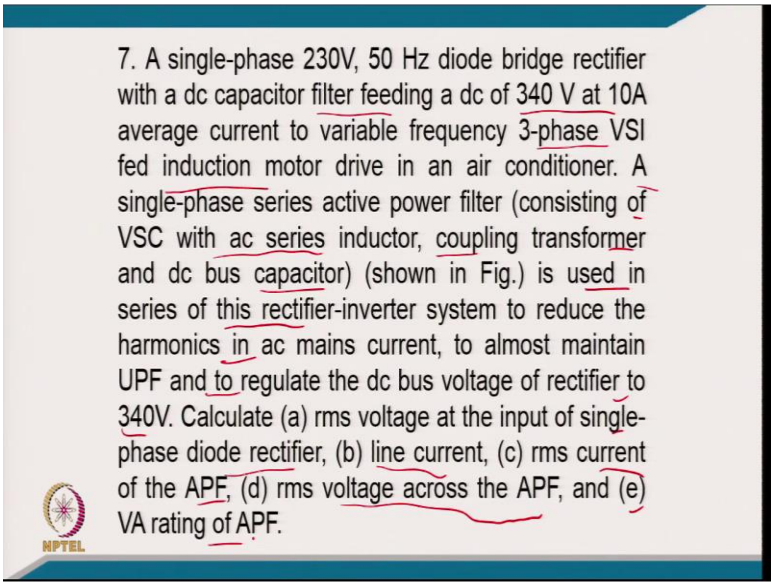

Coming to the numerical example 7. A single-phase 230 volt, 50 hertz diode bridge rectifier with the dc bus capacitive filter feeding a dc of two 340 volt and 10 ampere average current to a variable frequency 3-phase voltage source fed induction motor drive in an air conditioner.

A single-phase series active filter consisting of voltage source converter with series inductor coupling transformer and dc bus capacitor is used in series with the rectifier inverter system to reduce the harmonics in ac mains current and to almost maintain a unity power factor and to regulate the dc bus voltage of rectifier to 340 volt.

Calculate the a, rms voltage at the input of single-phase diode rectifier; b, line current; c, rms current of a series active filter; rms voltage across the series active filter and the VA rating of your series active filter.

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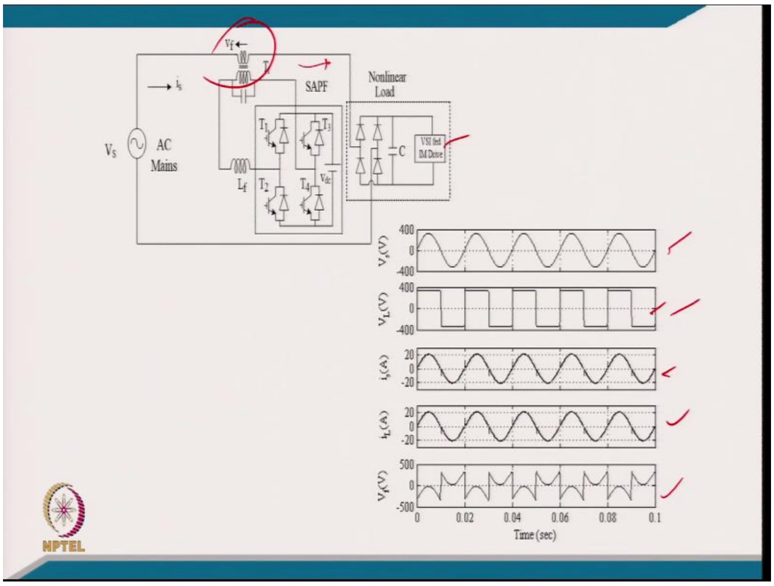

The explanation of the numerical problem is described in the screenshots herein.

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Solution: Given that, supply voltage, V_s = 230 V rms, frequency of the supply f=50 Hz, the load consists of diode rectifier having I_{dc}=10A, V_{dc}=340V.

The active power is as, $P=V_{dc}\ I_{dc}$=340*10 W=3400 W.

(a) 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}=340 V. Therefore, V_{pcc}=340 V.

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

$I_s=P/V_s$=3400/230=14.783A.

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

$I_f = I_s$=14.783 A.

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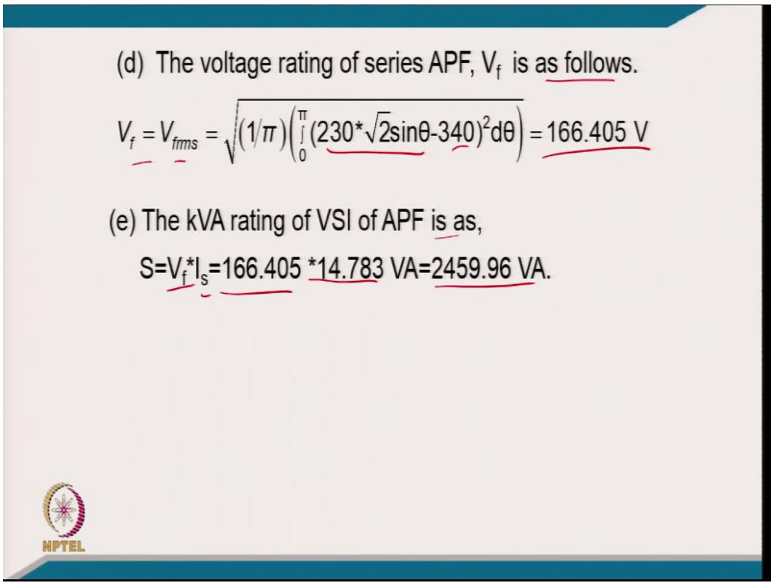

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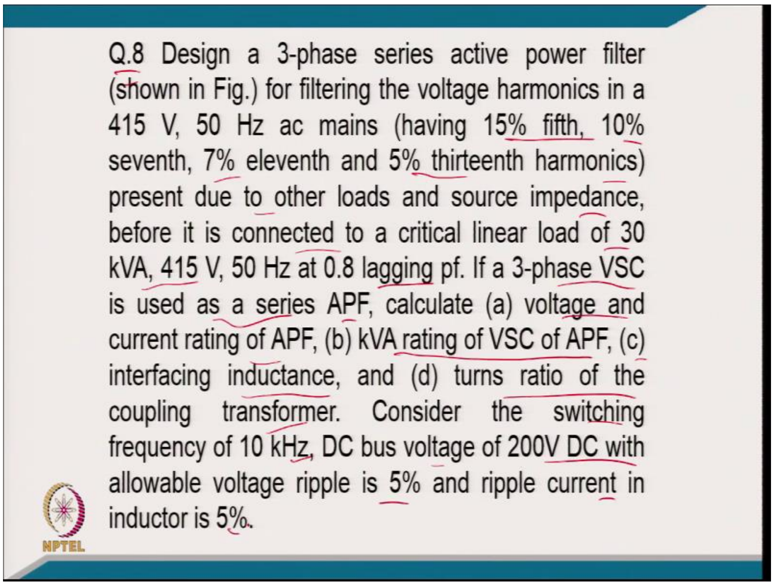

Coming to the numerical problems; design a numerical problem 8. Design a 3-phase series active filter for filtering the voltage harmonics of 415 volt 50 hertz ac mains having 15 percent fifth, thermal 10 per seventh and 7 percents eleventh and 5 percent thirteenth harmonic present due to the other loads and source impedance before it is connected to critical load of 30 kVA, 415 volt, 50 hertz at 0.8 lagging power factor.

If 3-phase VSC is used as a series active power filter, calculate the voltage and current rating of series active filter, kVA rating of series active filter, interfacing inductance and the turn's ratio of the coupling transformer. Consider the switching frequency of 10 kilohertz, DC link voltage of 200 volt DC and allowing voltage ripple of 5 percent and ripple current of inductor of is 5 percent.

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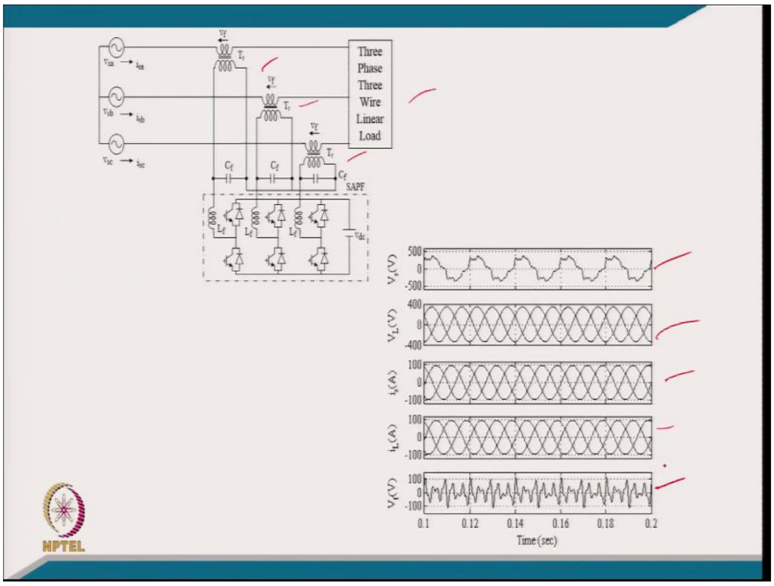

The explanation of the numerical problem is described in the screenshots herein.

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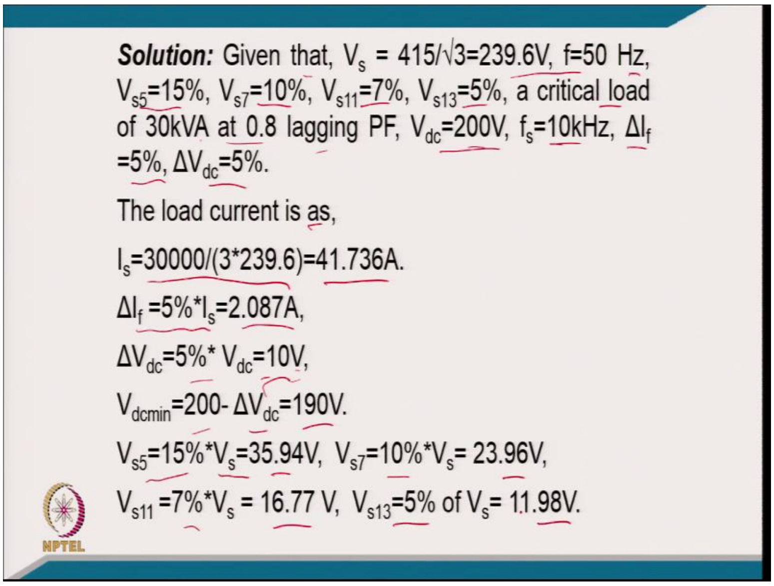

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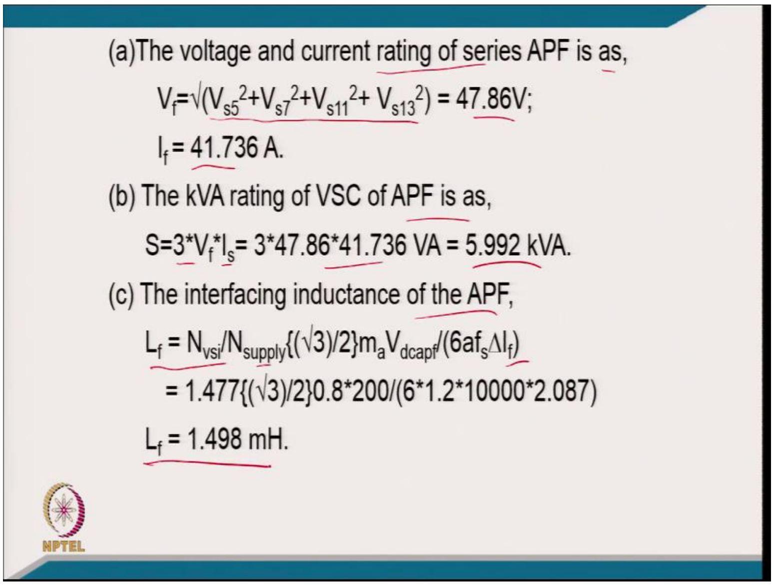

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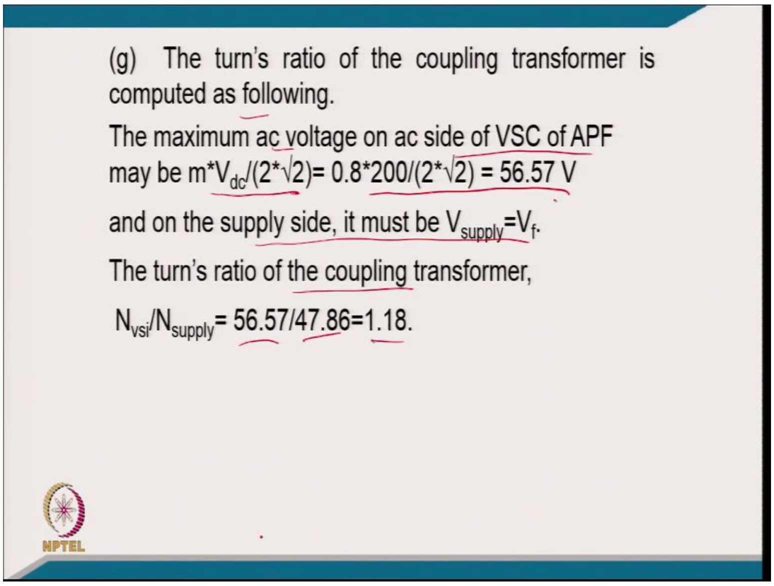

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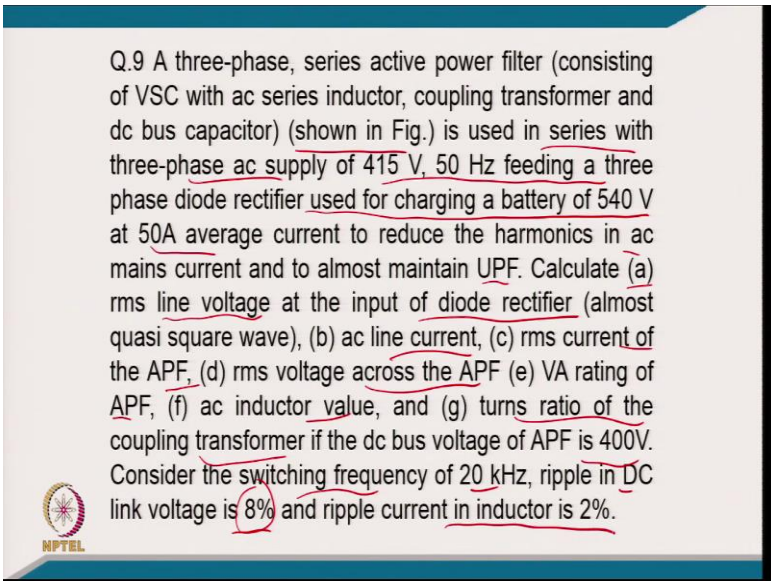

Coming to the 9 numerical problem. A 3-phase series active power filter consisting of voltage source converter with ac series inductor coupling transformer and dc bus capacitor shown in figure is used as a series in series with the 3-phase supply of 4 15 volt, 50 hertz feeding a 3-phase diode rectifier load for charging a battery of 540 volt at 50 ampere average current to reduce the harmonic currents in ac mains current and almost maintain unity power factor.

Calculate a, rms line voltage at the input of diode rectifier which will be almost quasi square because we will be forcing all 3-phase current to be sinusoidal, ac line current, rms current of the series active filter, rms voltage across the active filter, VA rating of a series active filter, ac inductor value, turn's ratio of series active filter sorry coupling transformer using series active filter if the dc link voltage of APF is 400 volt.

Consider the switching frequency of 20 kilo hertz and ripple in the dc link voltage deviation dc link voltage is 8 percent of its I mean reference value or nominal value and ripple current in the inductor is 2 percent.

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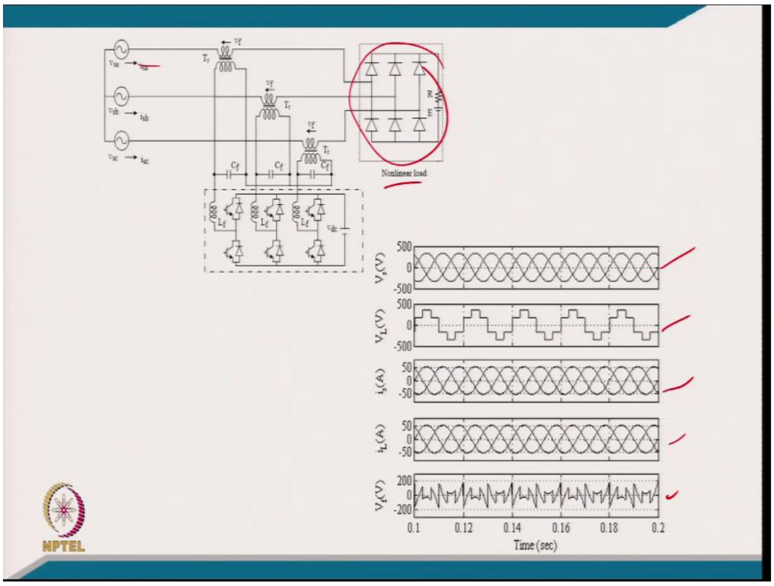

The explanation of the numerical problem is described in the screenshots herein.

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Solution: Given that, supply voltage, $V_s = 415/\sqrt{3}=239.6V$, frequency of the supply $f=50$ Hz, $V_{dcload}=540V$, $I_{dc}=50A$, $f_s=20$ kHz, $\Delta I_f=2\%$, $\Delta V_{dc}=8\%$, $V_{dcapf}=400V$.

The active power is as,

$P=V_{dc} I_{dc}=540*50$ W$=27000$ W.

The supply current is as,

$I_s=27000/(3*239.6)=37.563A$.

$\Delta I_f=2\%$ of $I_s=0.75125A$,

$\Delta V_{dc}=8\%$ of $V_{dc}=32V$,

$V_{dcmin}=400-\Delta V_{dc}=368V$.

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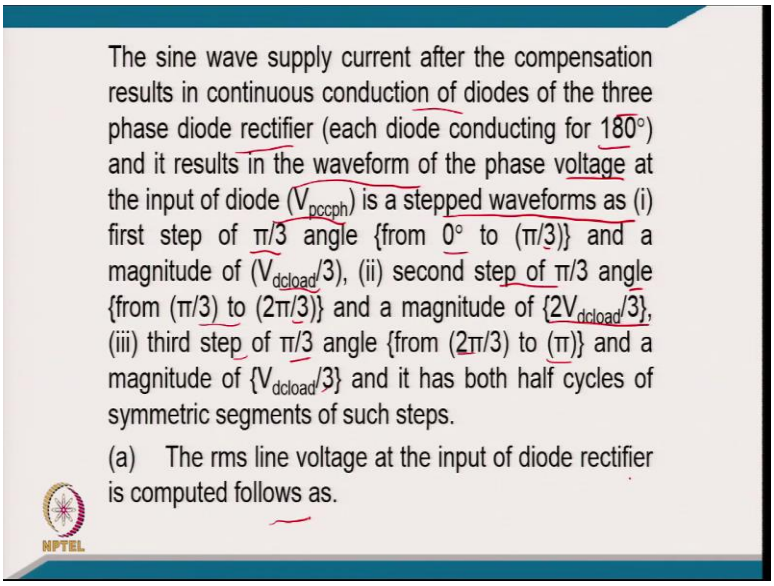

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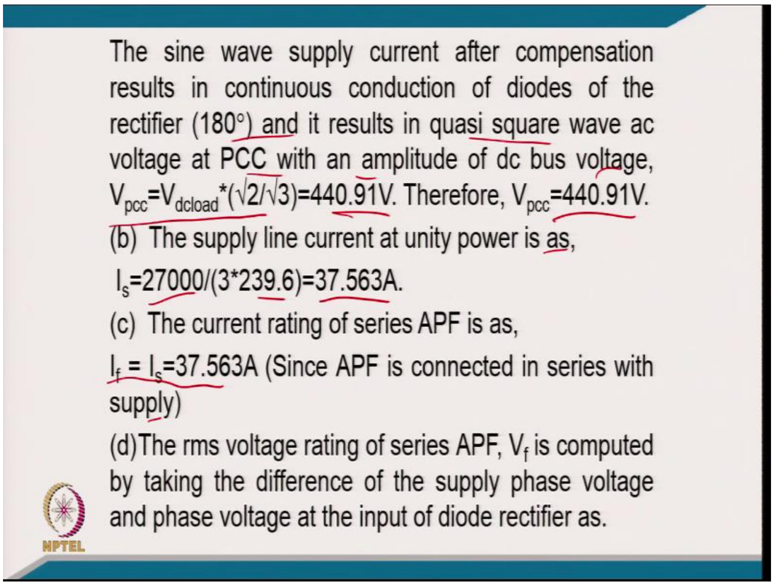

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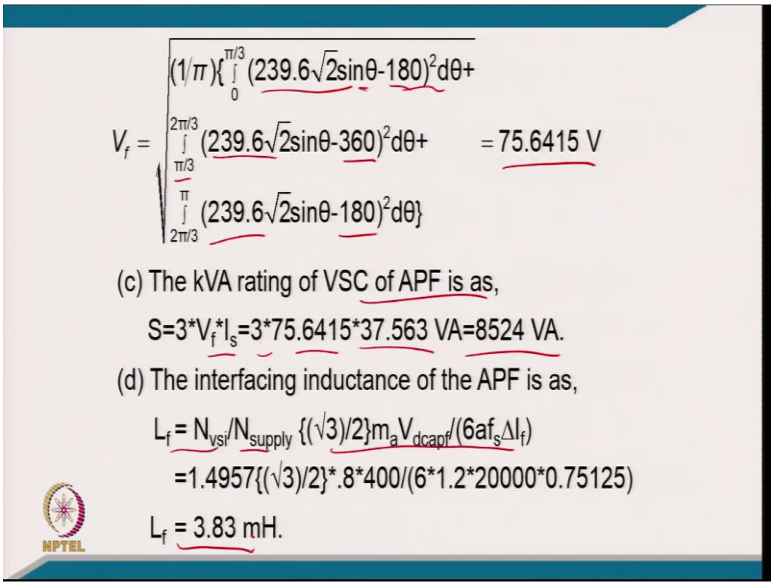

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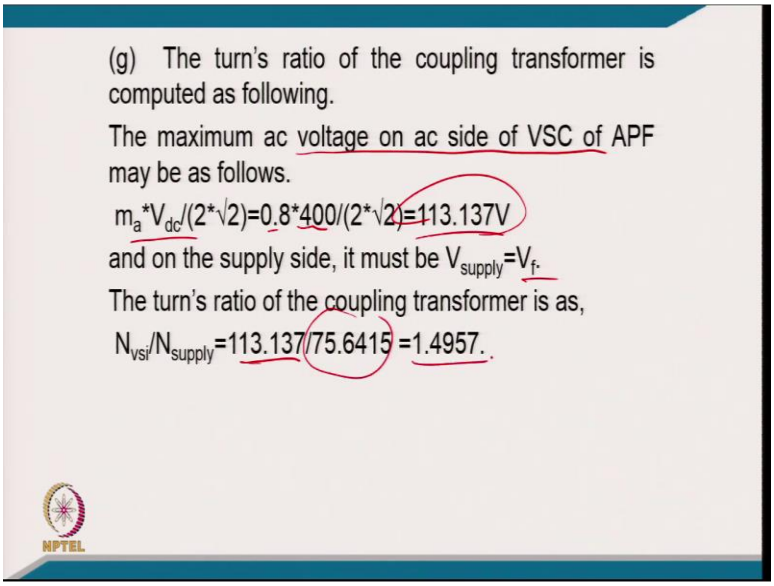

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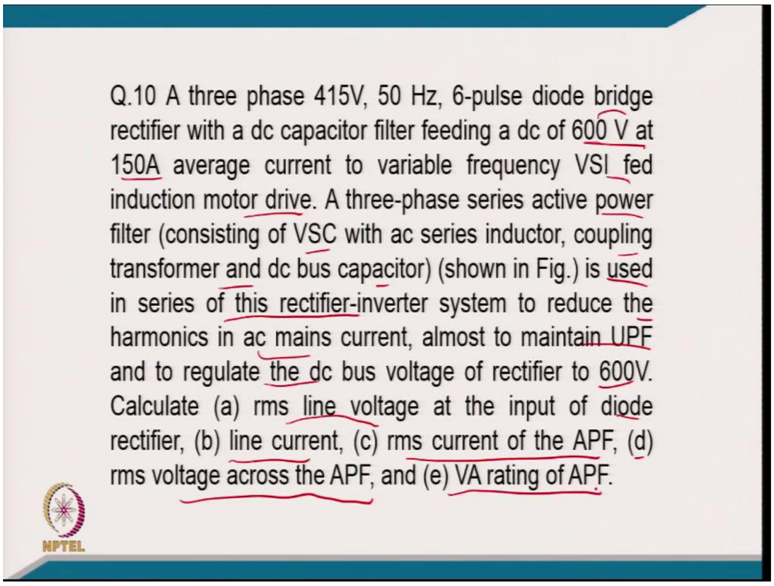

Coming to the 10th numerical problem. A three phase 4 15 volt, 50 hertz, 6-pulse diode bridge rectifier with the dc capacitor filter feeding a 600 volt at 150 ampere average current to variable frequency voltage source inverter fed index motor drive. A three phase series active filter consisting of voltage source converter with ac series inductor coupling transformer.

And dc capacitor is used in series with the rectifier inverter system to reduce the harmonics in ac mains current almost to maintain unity power factor and to regulate the dc bus voltage of the rectifier to 600 volt. [FL] calculate the rms line voltage at the input of diode rectifier; b, line current; c, the rms current of series active filter; d, is the rms voltage across the active filter and e, the VA rating of series active power filter.

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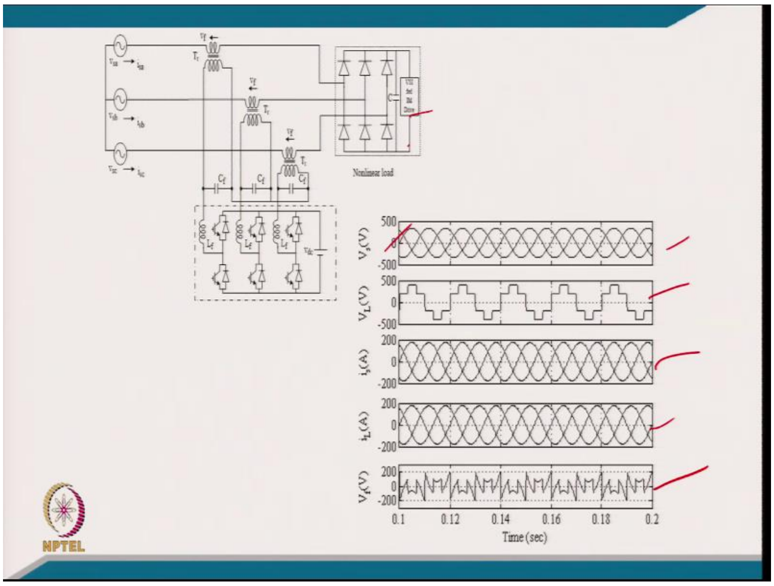

The explanation of the numerical problem is described in the screenshots herein.

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Solution: Given that, supply voltage, $V_s = 415/\sqrt{3} = 239.6V$, frequency of the supply f=50 Hz, V_{dcload}=600V, I_{dc}=150A.

The active power is as, $P = V_{dc} I_{dc} = 600*150$ W=90000 W.

The supply current, $I_s = 90000/(3*239.6) = 125.21A$.

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 π/3 angle {from 0° to (π/3)} and a magnitude of ($V_{dcload}/3$), (ii) second step of π/3 angle {from (π/3) to (2π/3)} and a magnitude of {$2V_{dcload}/3$}, (iii) third step of π/3 angle {from (2π/3) to (π)} and a magnitude of {$V_{dcload}/3$} and it has both half cycles of symmetric segments of such steps.

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(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,

$I_s=90000/(3*239.6)=125.21A.$

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

$I_f = I_s=125.21A.$ (Since APF is connected in series with supply.)

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(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.

$$V_f = \sqrt{(1/\pi)\{\int_0^{\pi/3}(239.6\sqrt{2}\sin\theta-200)^2 d\theta + \int_{\pi/3}^{2\pi/3}(239.6\sqrt{2}\sin\theta-400)^2 d\theta + \int_{2\pi/3}^{\pi}(239.6\sqrt{2}\sin\theta-200)^2 d\theta\}} = 89.323\ V$$

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

$S=3*V_f*I_s=3*89.323*125.21\ VA = 33.552\ kVA.$