Power Quality
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Lecture - 22
Shunt Active Power Filters (contd.)

Welcome to the course on Power Quality, ~~[FL]~~ we are discussing the examples on Shunt Active Power Filter [FL].

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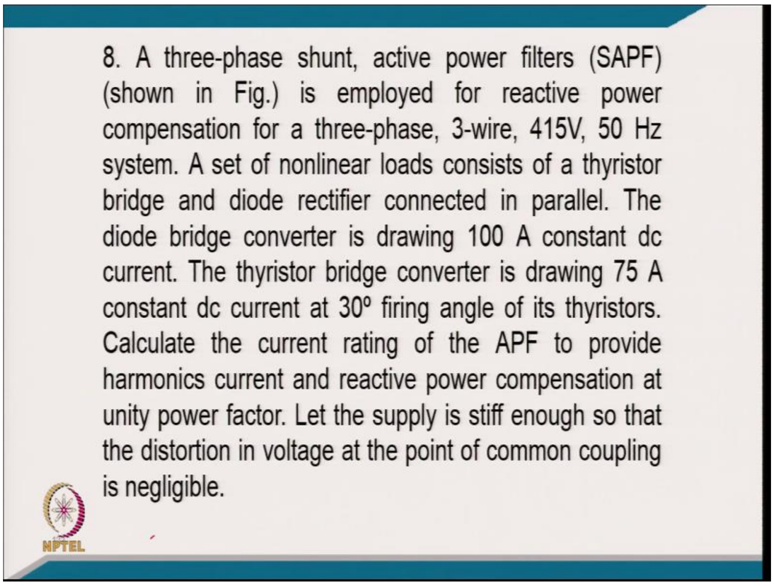

This is the 8th example, a three phase shunt, active power filter is employed with a reactive power compensation for three phase, 3 wire, 415 Volt, 50 Hertz system. A set of non-linear load consist of thyristor bridge and diode rectifier connected in parallel. And the diode bridge converter is drawing 100 Ampere constant dc current.

Thyristor bridge converter is drawing 75 Ampere constant dc current at 30 degree firing angle of its thyristor. Calculate the current rating of the active power filter to provide harmonic current and reactive power compensation at unity power factor. Let the supply is stiff enough, so that the distortion in the voltage at the point of common coupling is negligible.

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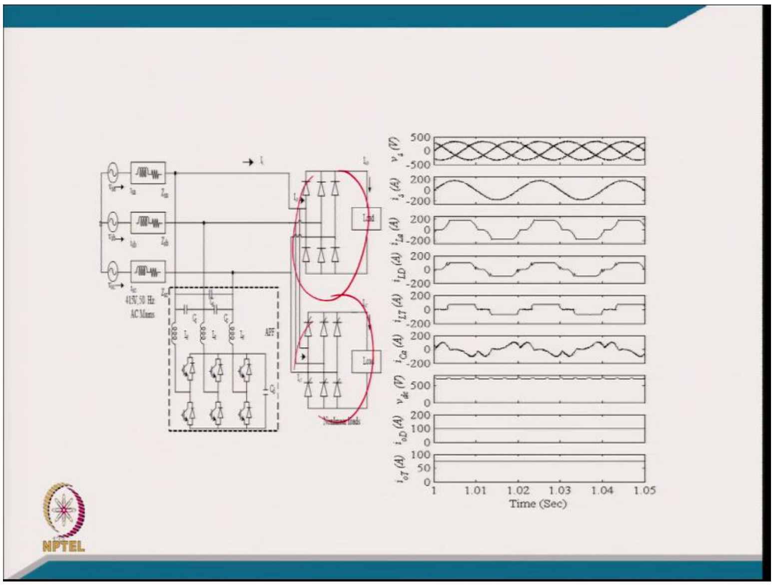

The solution to the numerical is detailed in the following screenshots.

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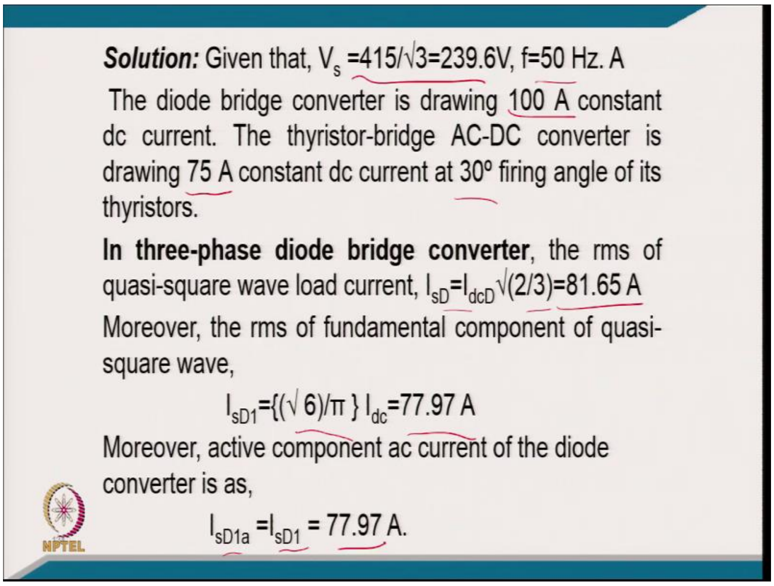

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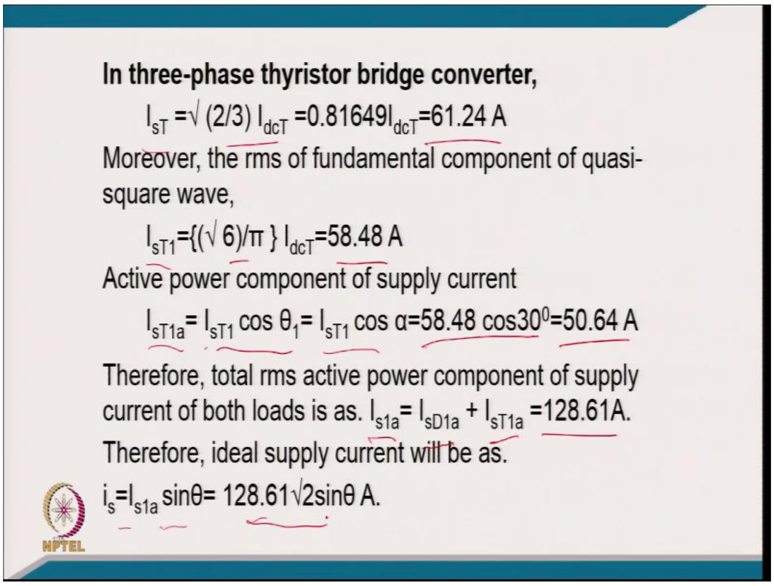

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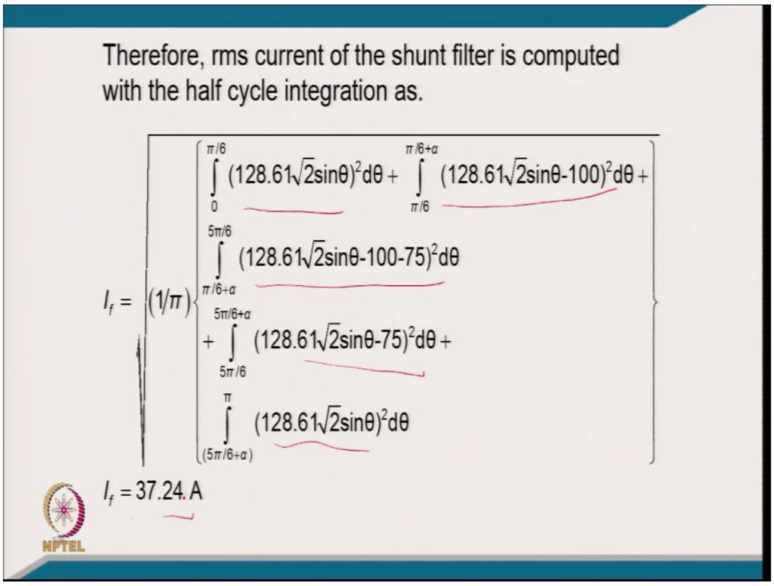

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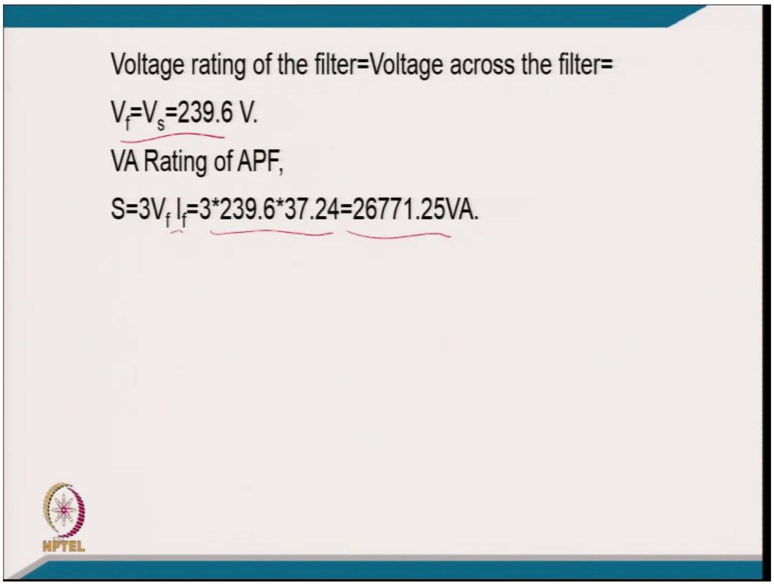

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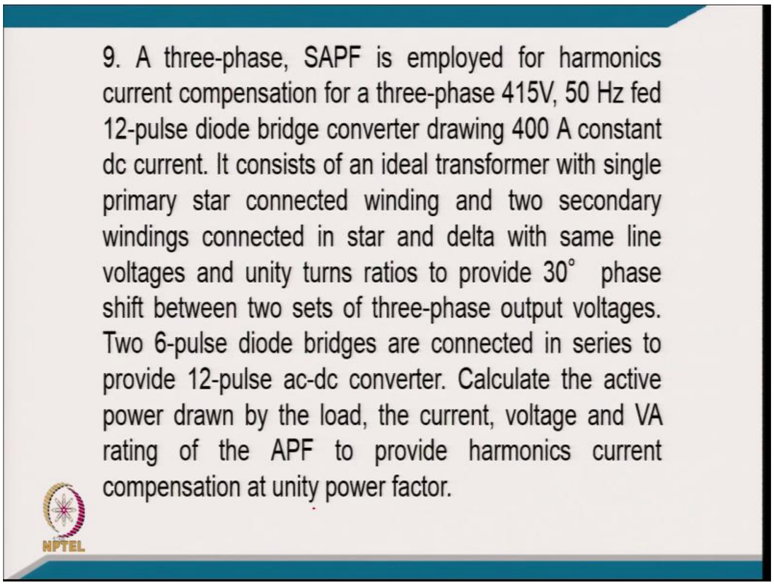

Coming to another example, example number 9, a three phase shunt active power filter is employed to for current harmonic current compensation of with three phase 415 Volt, 50 Hertz fed 12 pulse diode bridge converter drawing 400 Ampere dc current. It consist of an ideal transformer with single primary star connected winding and two secondary winding conducted in star and delta with the same phase voltage.

And unity turns ratios to provide 30 degree phase shift between two sets of three phase output voltage. And two 6 pulse diode bridges are connected in series to provide 12 pulse ac dc converter. Calculate the active power drawn by the load, current, voltage and VA rating of the active power filter to provide harmonic current compensation at unity power factor.

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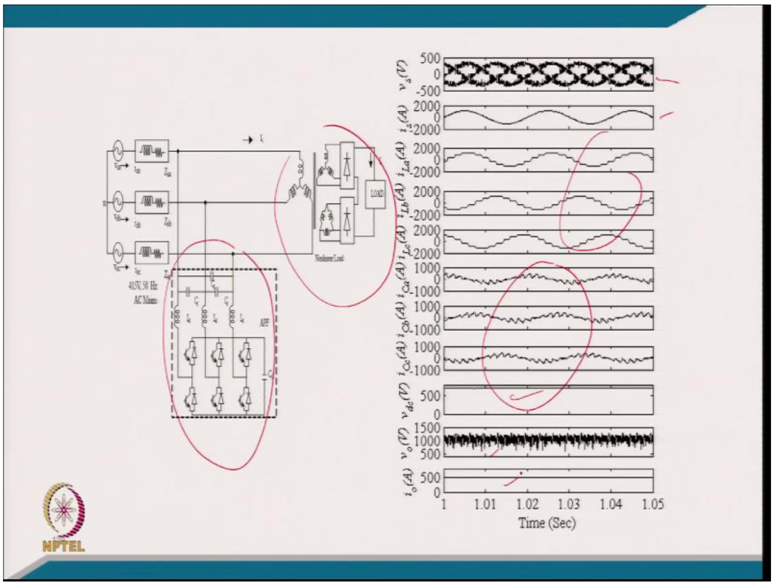

The solution to the numerical is detailed in the following screenshots.

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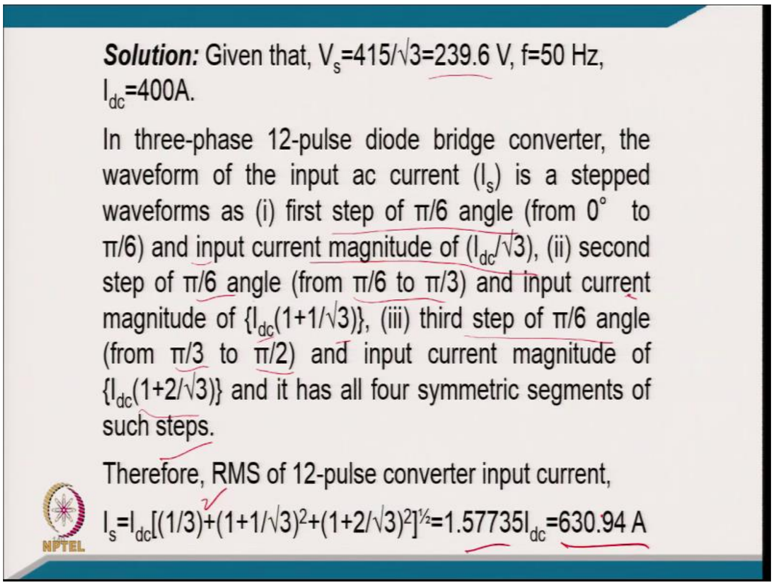

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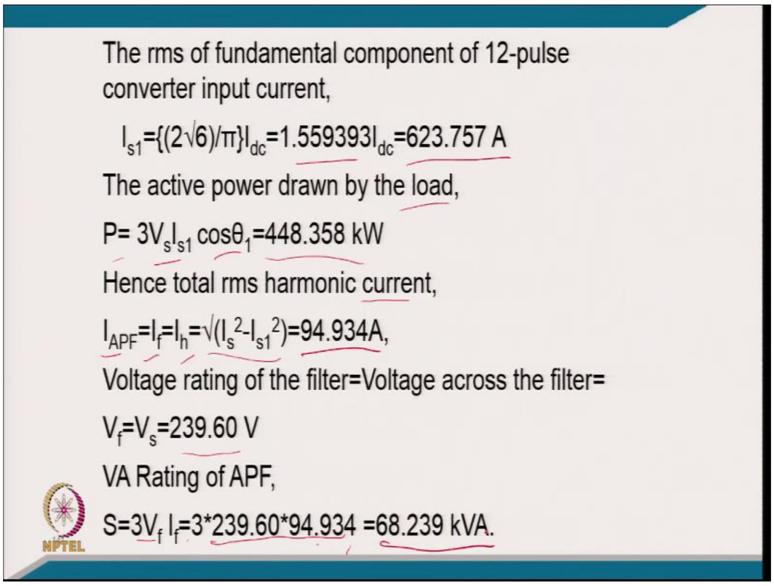

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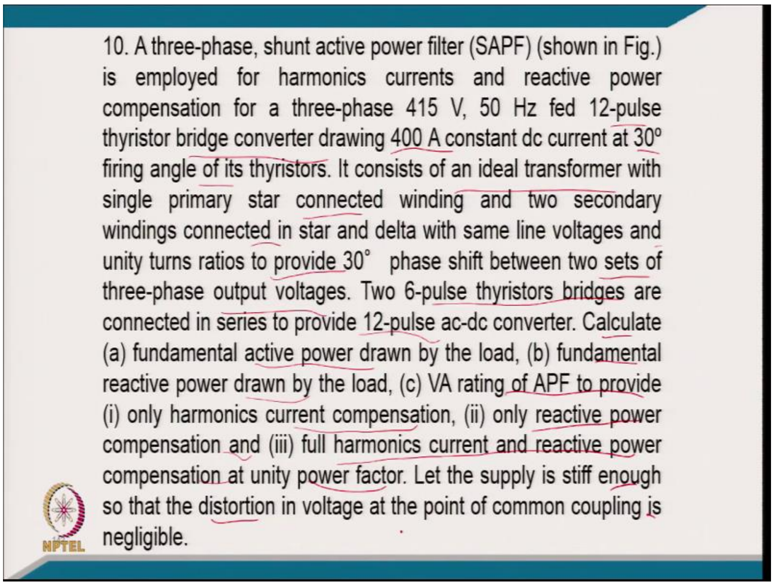

Now, coming to 10th example, a three phase shunt active power filter is employed for harmonic current and reactive power compensation for three phase 415 Volt, 50 Hertz, 12 pulse thyristor bridge converter drawing a 400 ampere constant dc current at 30 degree firing angle of its thyristor.

It consists of an ideal transformer with single primary star connected winding and two secondary winding connected in star and delta with the same line voltage and unity turns ratios to provide 30 degree phase shift between the two sets of three phase output voltage.

And two 6 pulse thyristor bridges are connected in series to provide 12 pulse ac dc converter. Calculate the fundamental active power drawn by the load, fundamental reactive power drawn by the load, VA rating of active power filter to provide, only harmonic current compensation, only reactive power compensation, full harmonics current and reactive power compensation at unity power factor. Let the supply is stiff enough, so that the distortion in voltage at the point of common coupling is negligible.

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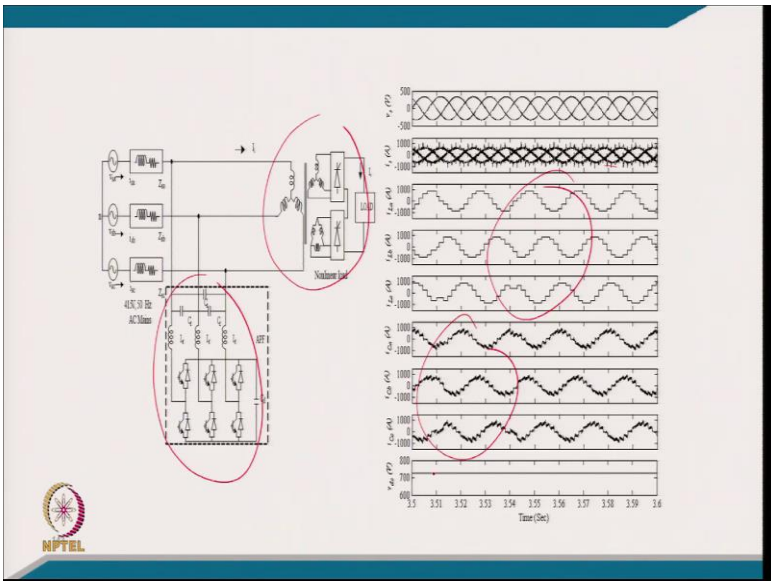

The solution to the numerical is detailed in the following screenshots.

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Solution: Given that, supply rms voltage, $V_s=415/\sqrt{3}=239.6$ V, frequency of supply f=50 Hz, I_{dc} = 400 A, $\alpha = 30^0$

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 $\pi/6$ angle {from α to $(\alpha+\pi/6)$} and input current magnitude of $(I_{dc}/\sqrt{3})$, (ii) second step of $\pi/6$ angle {from $(\alpha+\pi/6)$ to $(\alpha+\pi/3)$} and input current magnitude of $\{I_{dc}(1+1/\sqrt{3})\}$, (iii) third step of $\pi/6$ angle {from $(\alpha+\pi/3)$ to $(\alpha+\pi/2)$} 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,

$I_s=I_{dc}[(1/3)+(1+1/\sqrt{3})^2+(1+2/\sqrt{3})^2]^{½}=1.57735I_{dc}$ =630.94 A

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Moreover, the rms of 12-pulse converter fundamental ac current, $I_{s1}=\{(2\sqrt{6})/\pi\}I_{dc}=1.559393I_{dc}$ 623.757 A

Hence total rms harmonic current,

$I_h = \sqrt{(I_s^2-I_{s1}^2)} = \sqrt{(630.94^2- 623.757^2)}$ =94.934 A

Active power component of supply current

$I_{s1a}= I_{s1} \cos \theta_1= I_{s1} \cos \alpha=623.757\cos 30^0=540.19$ A

Total harmonics and reactive current $I_f = \sqrt{(I_s^2-I_{s1a}^2)}$ $=\sqrt{(630.94^2-540.19^2)} = 326.01$ A

(a) Fundamental active power drawn by the load,

$P_1=3V_sI_{s1}\cos \theta_1=3V_sI_{s1}\cos \alpha=388.289$ kW

(b) Fundamental reactive power drawn by the load,

$Q_1= 3V_sI_{s1}\sin \theta_1=224.172$ kVAR

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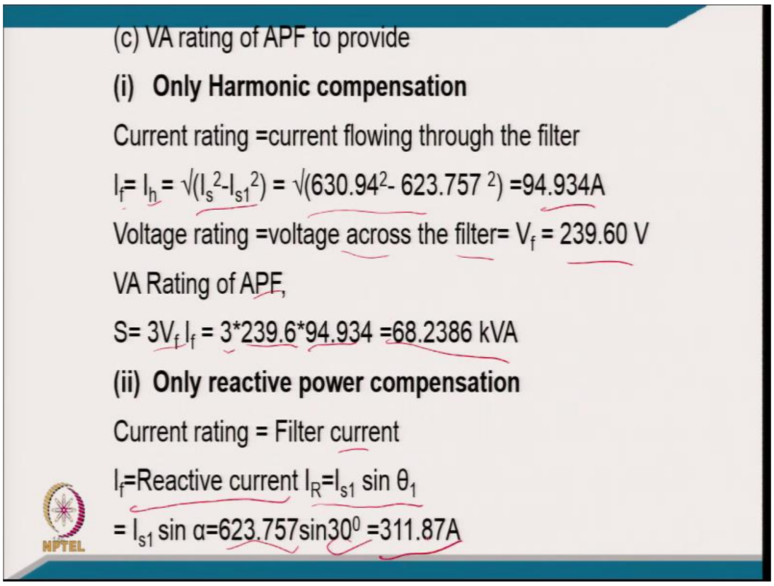

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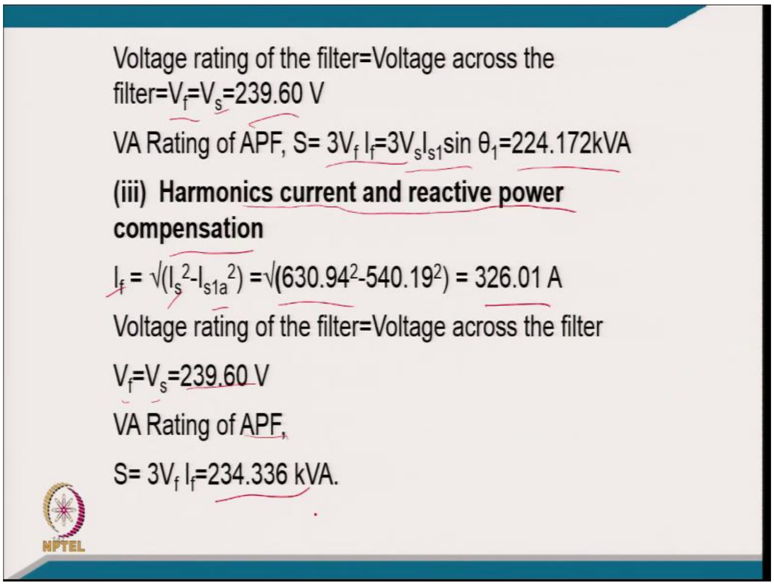

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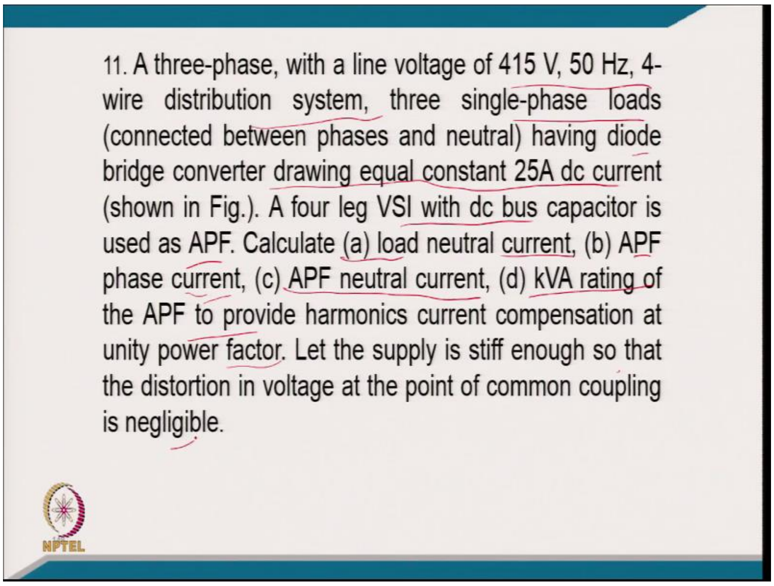

Coming to numerical number are 11, a three phase with a line voltage of 415 Volt, 50 Hertz, 4 wire distribution system, three single phase loads connected between phase and neutral having a diode bridge converter drawing a equal constant 25 Ampere dc current.

A four leg VSI with the dc bus capacitor is used as an active power filter. Calculate a load neutral current; b active power filter phase current; then the c active power filter neutral current; d k VA rating of the active power filter to provide harmonic current compensation at unity power factor. Let the supply is stiff enough, so that the distortion in voltage at the point of common coupling is negligible.

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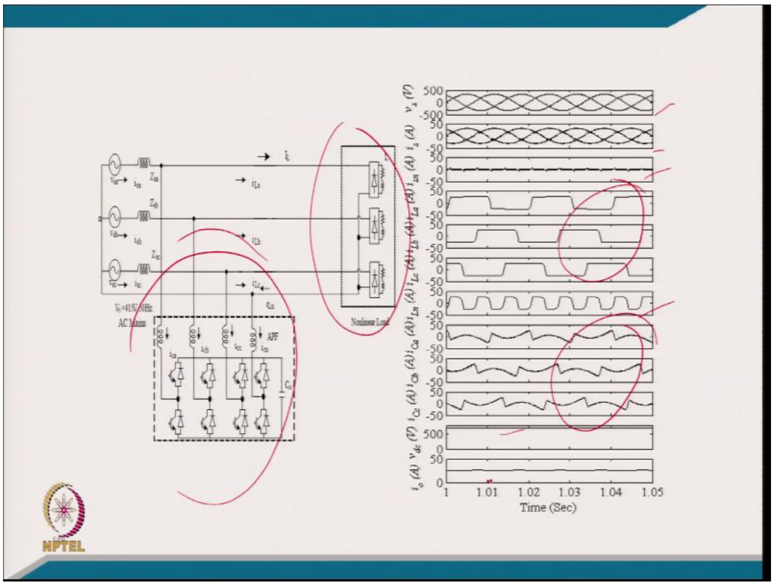

The solution to the numerical is detailed in the following screenshots.

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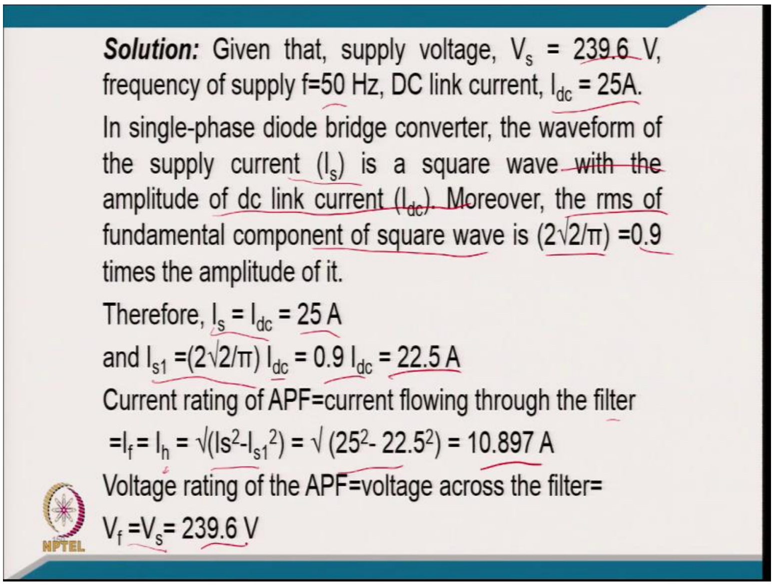

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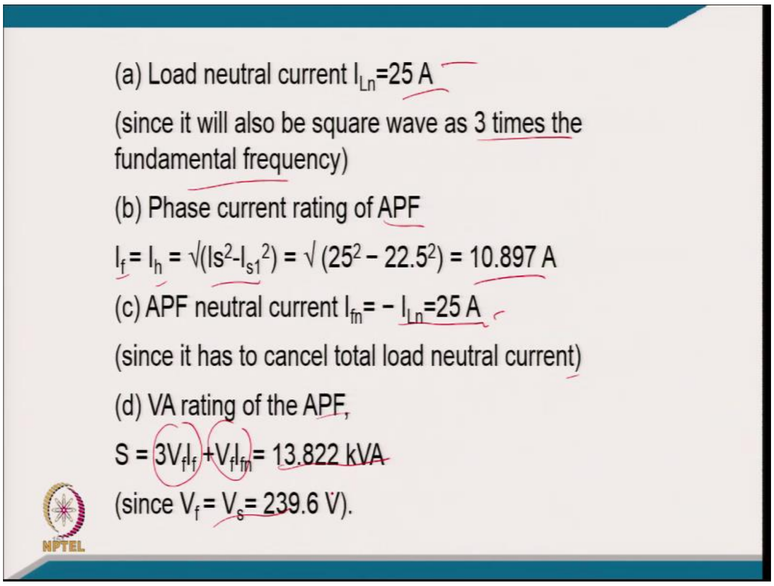

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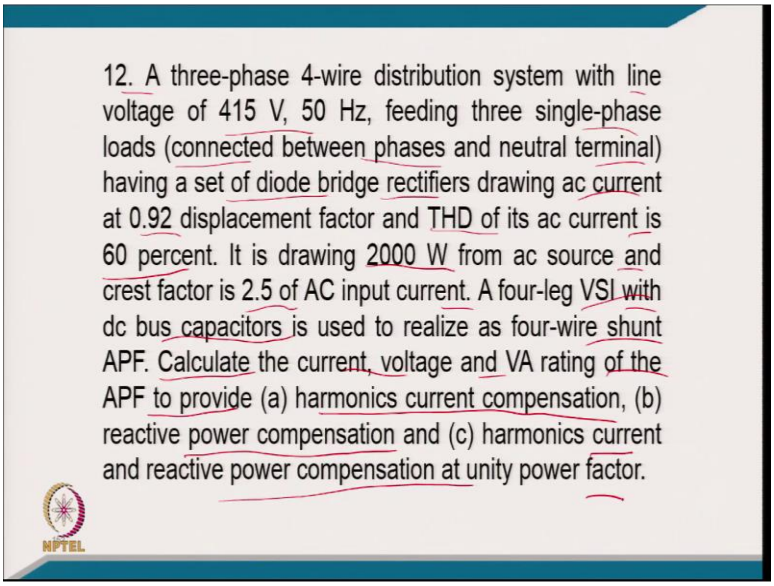

Coming to the 12th numerical problem, a three phase 4 wire distribution system with line voltage of 415 Volt, 50 Hertz, feeding the three single phase loads connected between phase and neutral having a set of diode bridge rectifier drawing ac current at 0.92 displacement factor and THD of the ac current is 60 percent.

It is drawing 2000 Watt from the ac source and crest factor is 2.5 ac of input current. A four leg voltage source in inverter with the dc bus capacitor is used to realize the four wire shunt active filter. Calculate the current voltage and VA rating of the active power filter to provide; harmonic current compensation, reactive power compensation, harmonic current and reactive power compensation at unity power factor.

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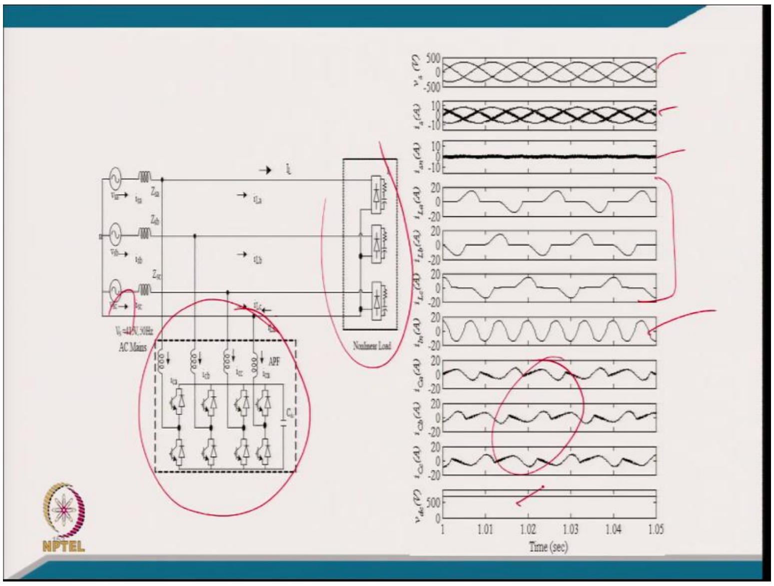

The solution to the numerical is detailed in the following screenshots.

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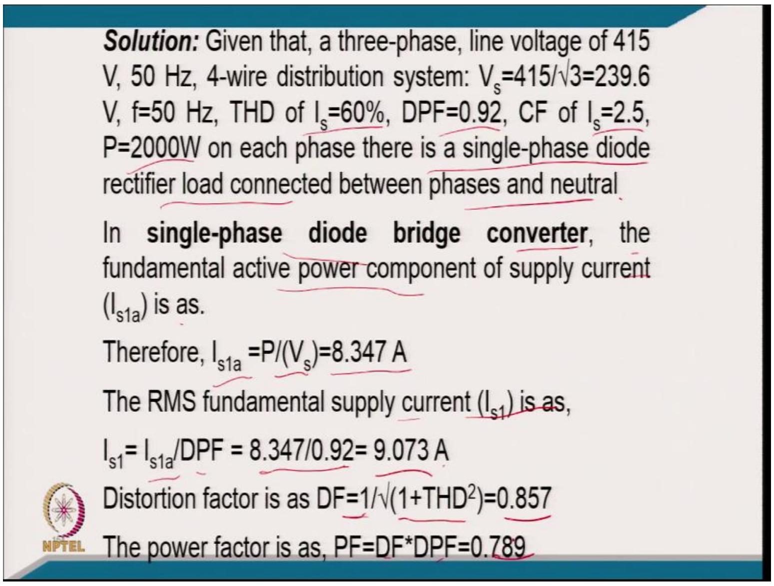

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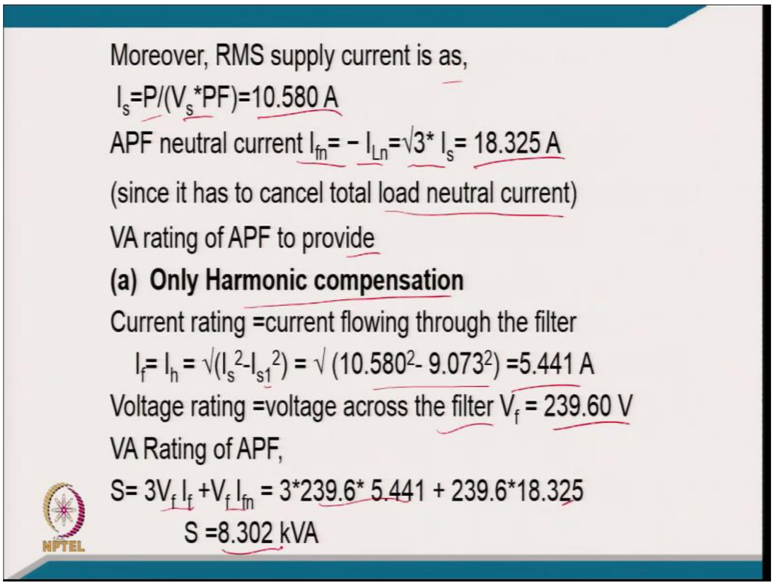

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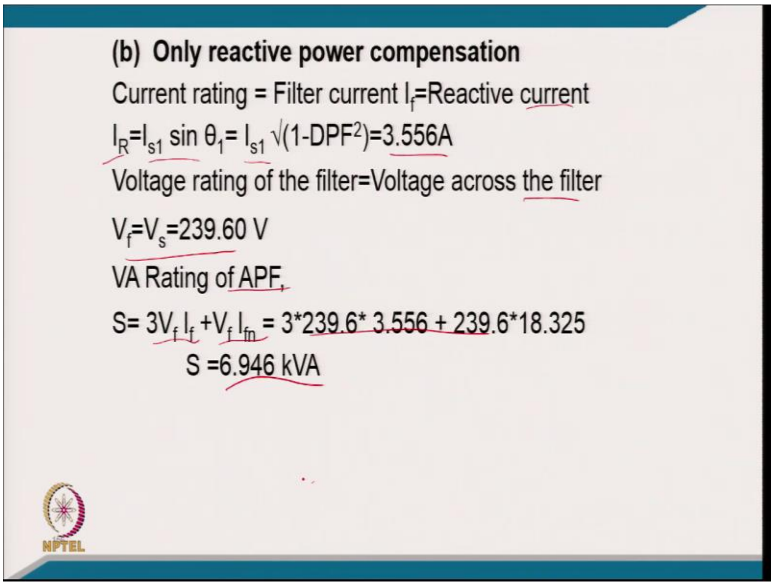

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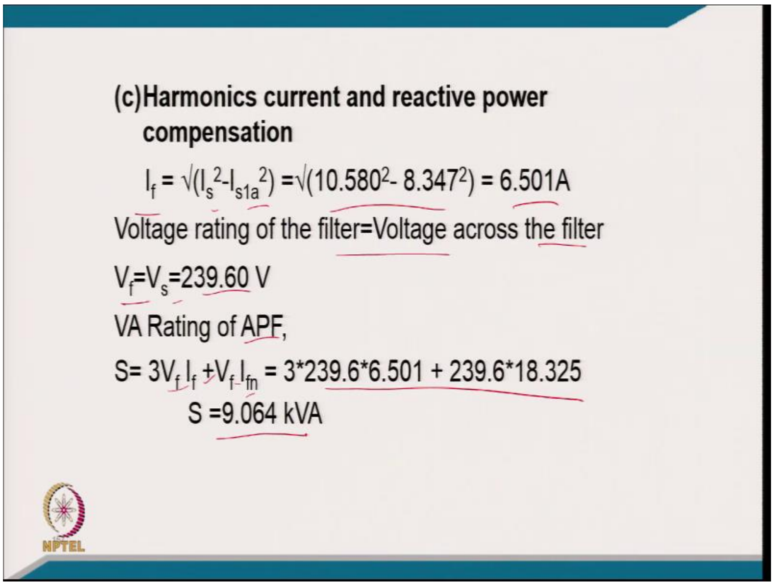

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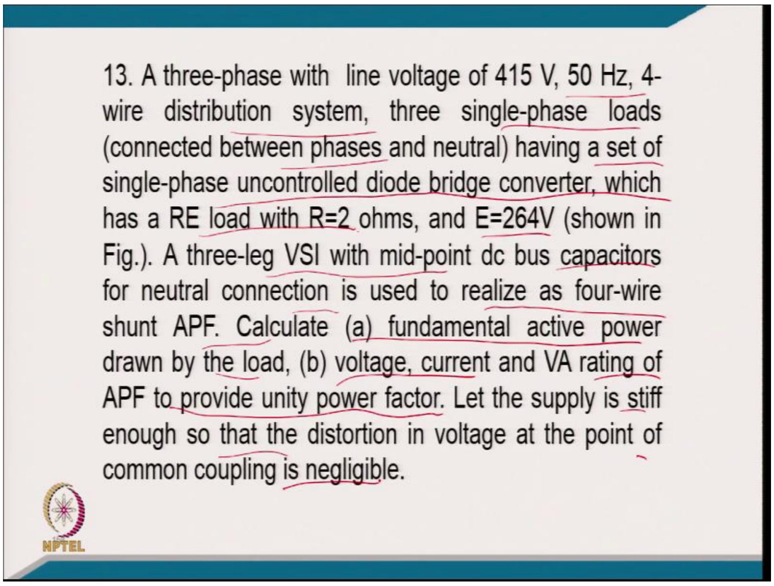

Now, coming to the numerical problem 13, a three phase with line voltage of 415 Volt, 50 Hertz, 4 wire distribution system, three single phases loads connected between the phases and neutral having a set of single phase uncontrolled bridge reactive wire, which have a RE load with resistance of 2 Ohm and the voltage of batteries 264 Volt.

A three leg VSI with the midpoint dc bus capacitor is used for neutral current compensation to realize as a four wire shunt active filter. Calculate a fundamental active power; b voltage, current and VA rating of active power filter to provide unity power factor. Let the supply is stiff enough, so that the distortion in voltage at the point of common coupling is negligible like.

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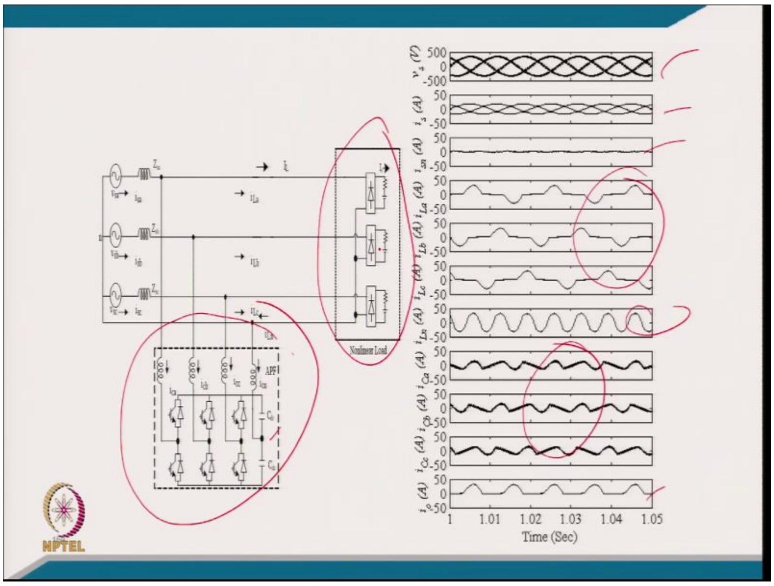

The solution to the numerical is detailed in the following screenshots.

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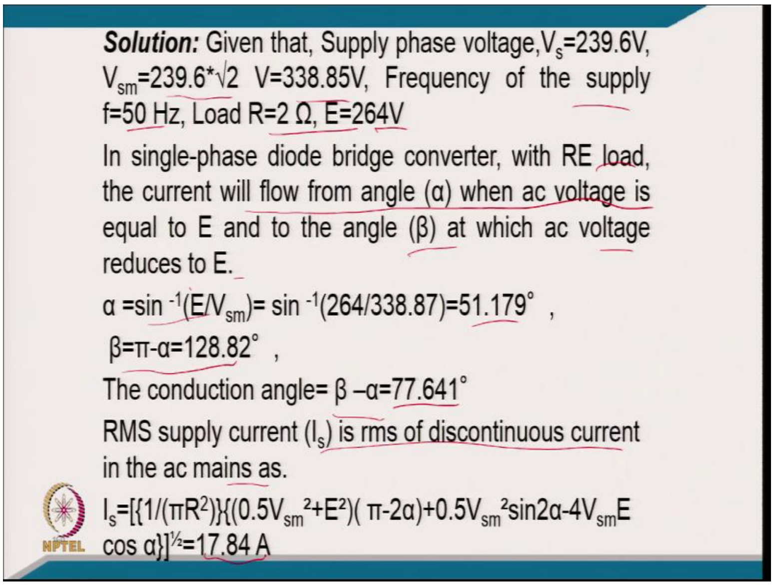

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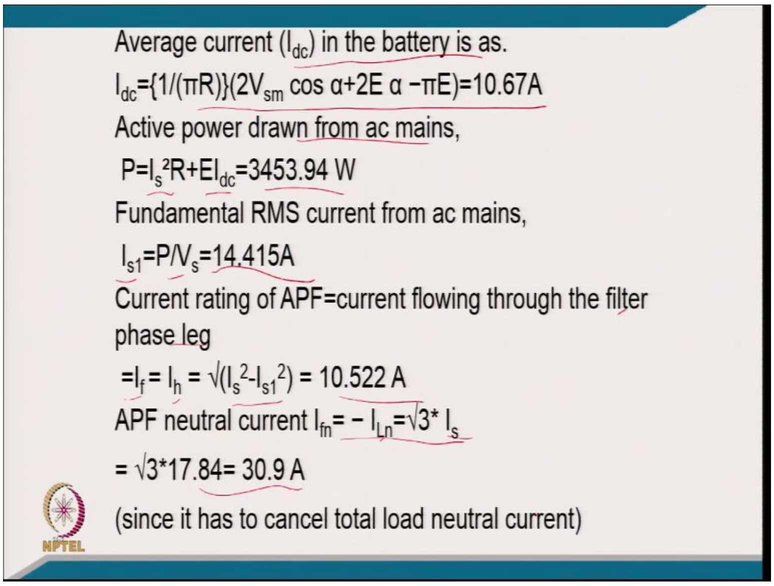

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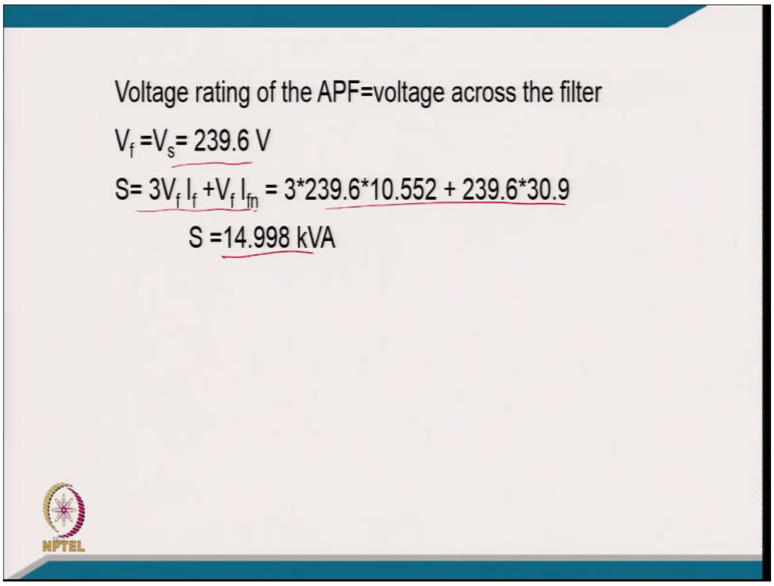

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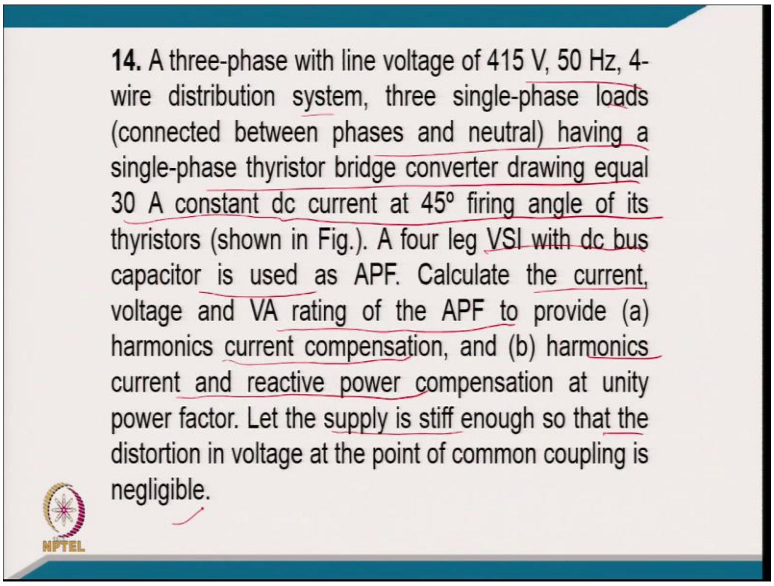

Coming to 14th numerical problem, a three phase line voltage of 415 Volt, 50 Hertz, 4 wire distribution system, three single phase loads connected between phases and neutral having a single phase thyristor bridge converter with the equal current of 30 Ampere constant dc current at a 45 degree angle of the thyristor.

And four leg VSI with the dc bus capacitor is used as active power filter. Calculate the current, voltage and VA rating of active power filter to provide; a harmonic current compensation, harmonics current and reactive power compensation and unity power factor. Let the supply is stiff enough, so that the distortion in the voltage at the point of common coupling is negligible.

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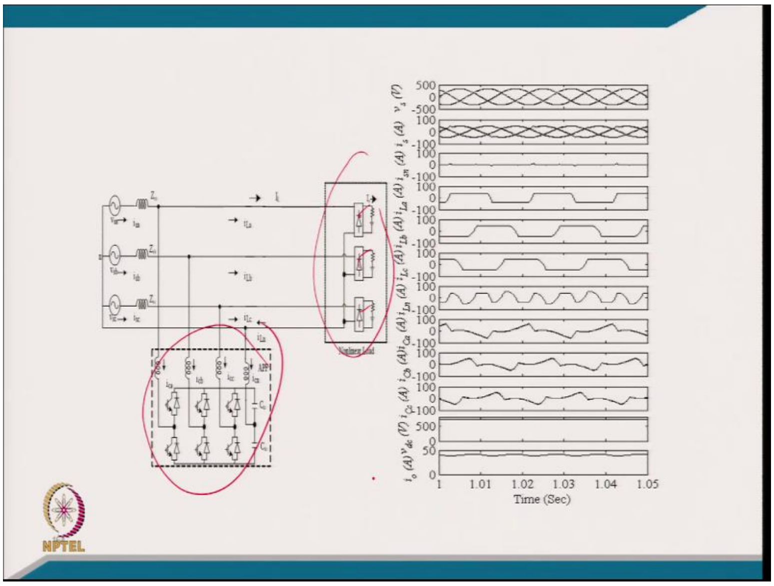

The solution to the numerical is detailed in the following screenshots.

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Solution: Given that, Supply voltage, V_s = 239.6 V, Frequency of the supply f=50 Hz, DC link current, I_{dc} = 30A, Firing angle, α= 45°

In single-phase thyristor bridge converter, the waveform of the supply current (I_s) is a square wave with the amplitude of dc link current (I_{dc}). Moreover, the rms of fundamental component of square wave is $(2\sqrt{2}/\pi)$ =0.9 times the amplitude of it.

Therefore, $I_s = I_{dc}$ = 30 A and

$I_{s1} = (2\sqrt{2}/\pi)\, I_{dc} = 0.9\, I_{dc}$ = 27A

RMS Fundamental active power component of load current, $I_{s1a} = I_{s1} \cos\alpha$=19.092A

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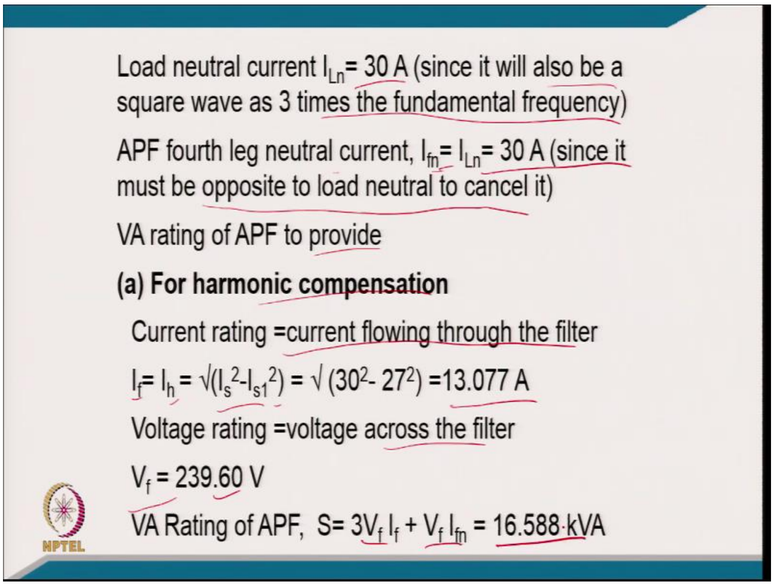

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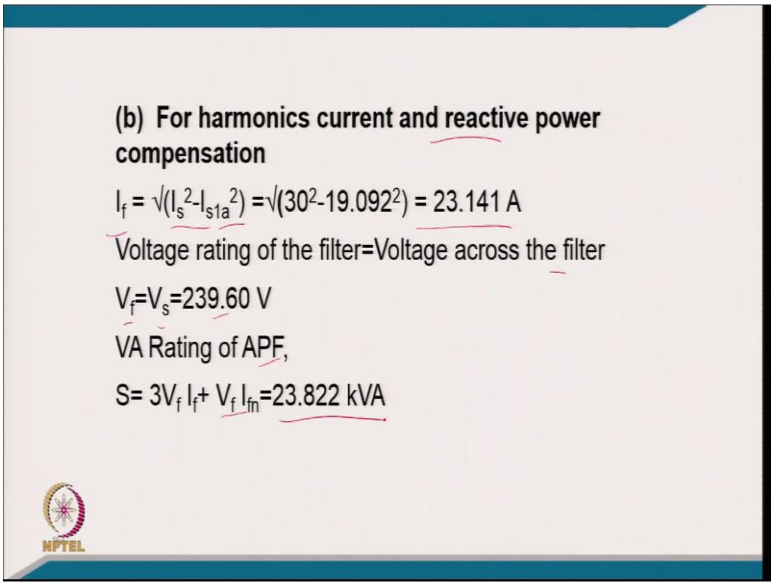

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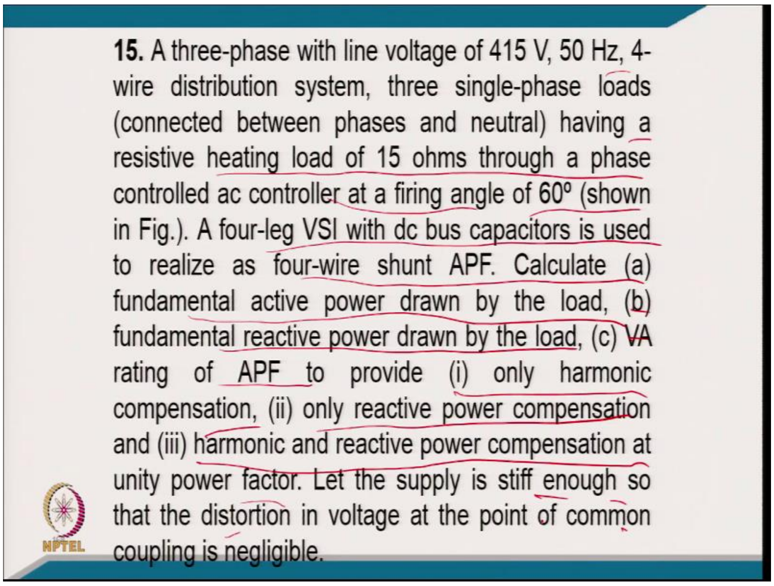

Coming to the numerical problem 15, a three phase with line voltage of 415 Volt, 50 Hertz, 4 wire distribution system, three single phase load connected between phase and neutral having a resistive heating element of 15 Ohm through a phase control ac controller with the firing angle of 60 degree. And a four leg VSI with the dc bus capacitor is used to realize as a four wire shunt active filter.

Calculate a fundamental active power drawn by the load, fundamentally b fundamental reactive power drawn by the load, and c the VA rating of active power filter to first to provide, only harmonic compensation second, only reactive power compensation, and third harmonics and reactive power compensation at unity power factor. Let the supply is stiff enough, so that the distortion in the voltage at the point of common coupling is negligible.

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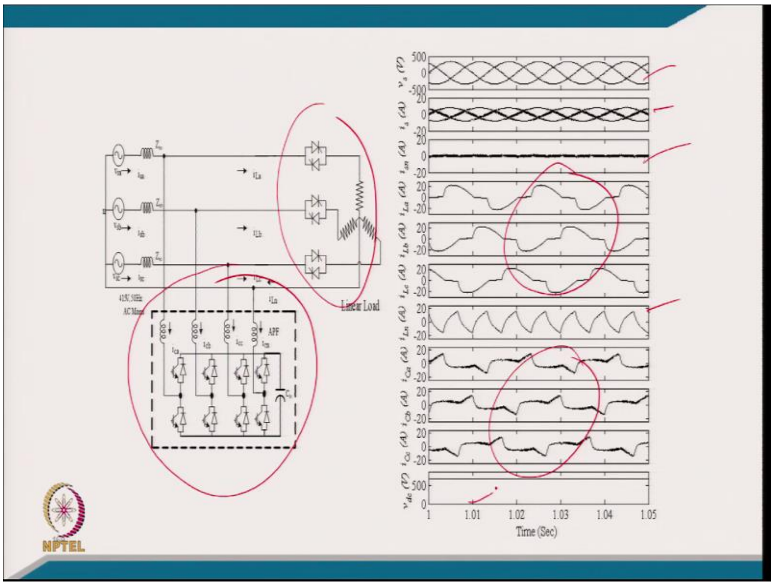

The solution to the numerical is detailed in the following screenshots.

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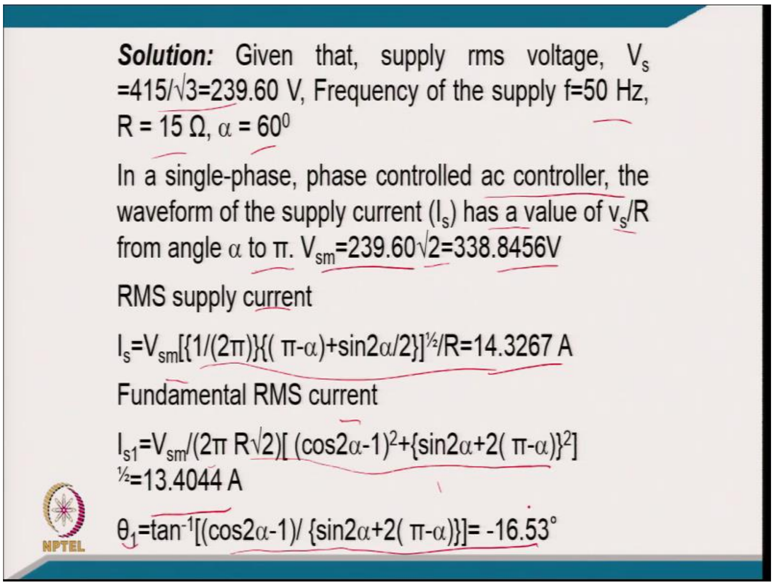

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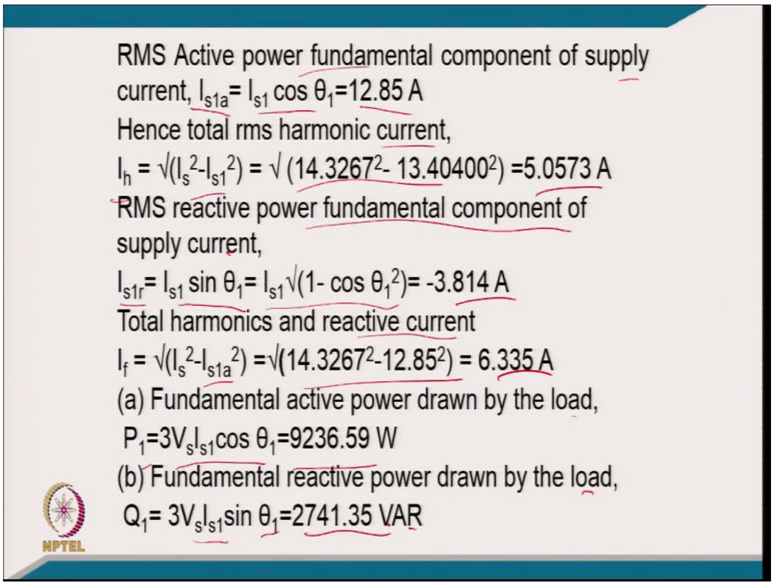

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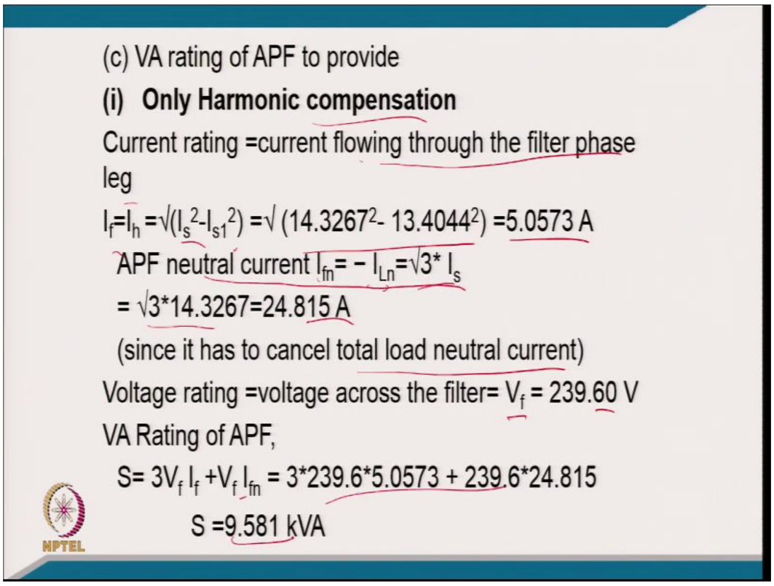

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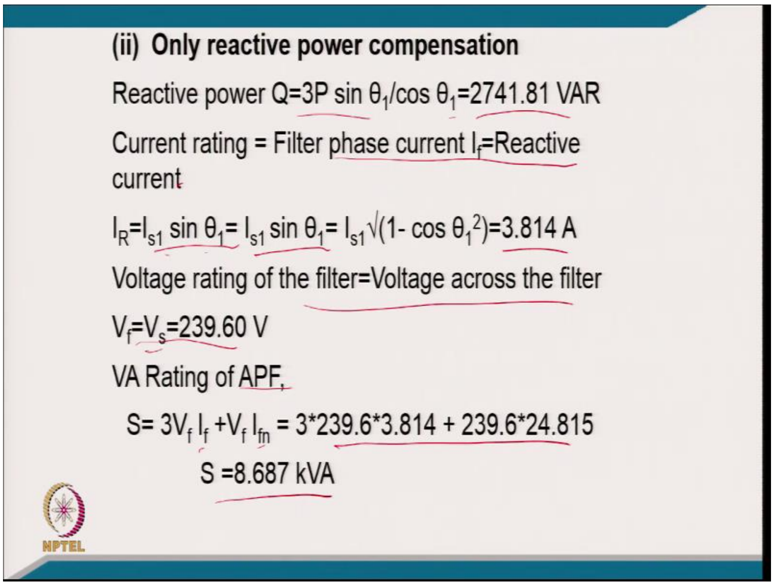

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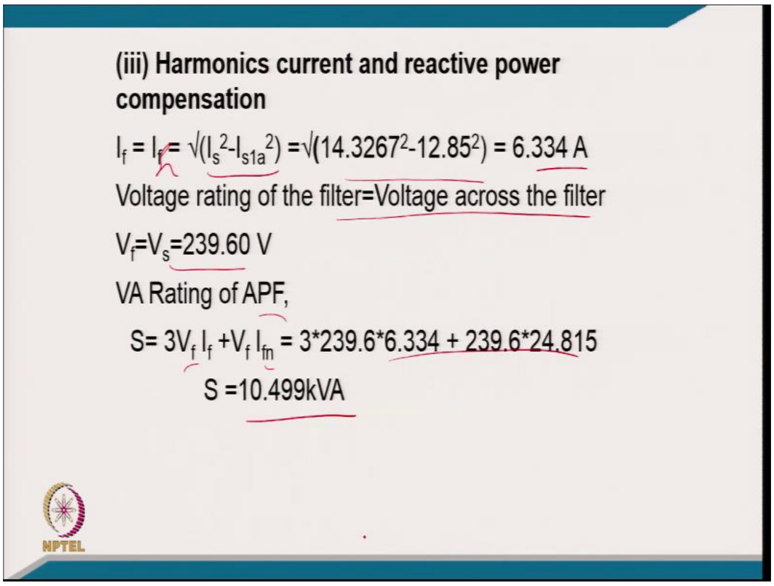

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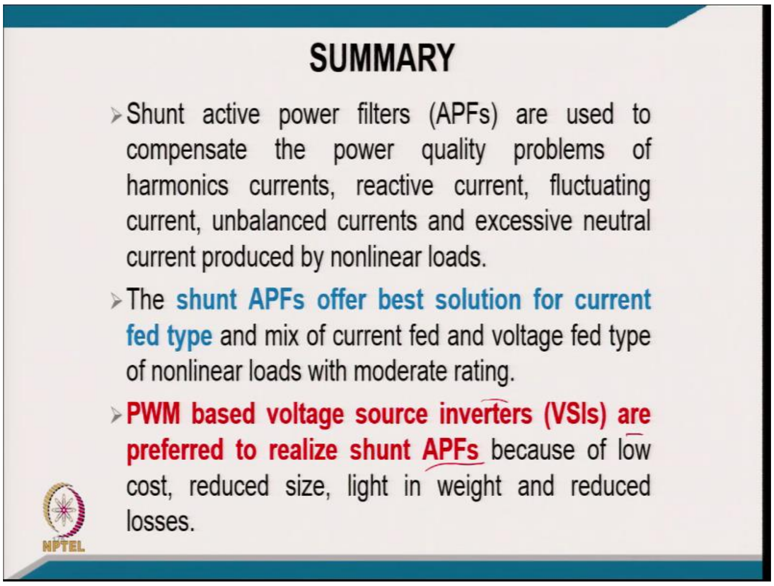

With this we would like to summarize the shunt active power filter. Shunt active power filter are used for to compensate the power quality problem of harmonic currents, reactive current, fluctuating current, unbalanced current and excessive neutral current produced by the non-linear load.

Shunt active filter offer the best solution for current fed type and mix type of load, current fed and voltage fed kind of non-linear load with moderate rating.

PWM based voltage source inverters are used preferred to realize the shunt active power filter, because of low cost, reduce size, light in weight and reduced losses.

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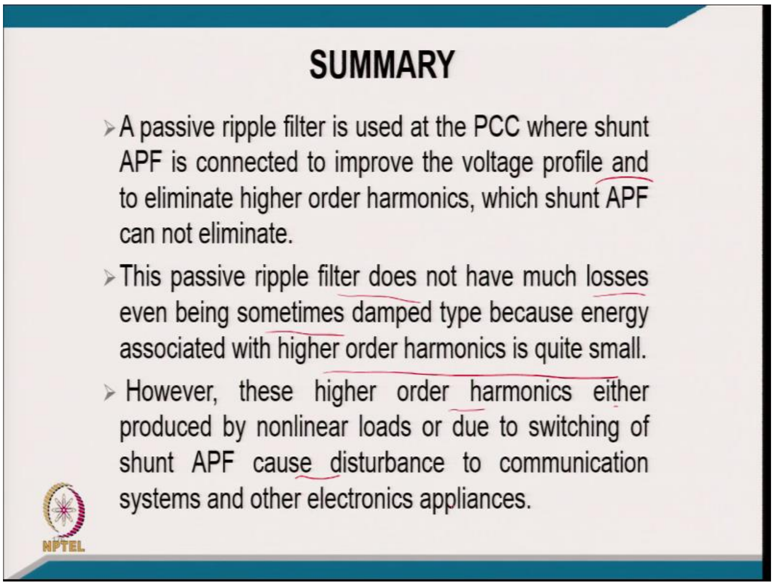

A passive ripple filter is used at the point of common coupling, where the shunt active filter is connected to improve the voltage profile and to eliminate the higher order harmonics, which shunt active power filter cannot eliminate.

This passive shunt, a small passive ripple filter does not have much losses even being sometimes damp type because of energy associated with the higher order harmonics is a quite small. However, these higher order harmonics either produced by non-linear load or due to switching of shunt active power filter cause disturbance to communication system and other electronics appliances like.

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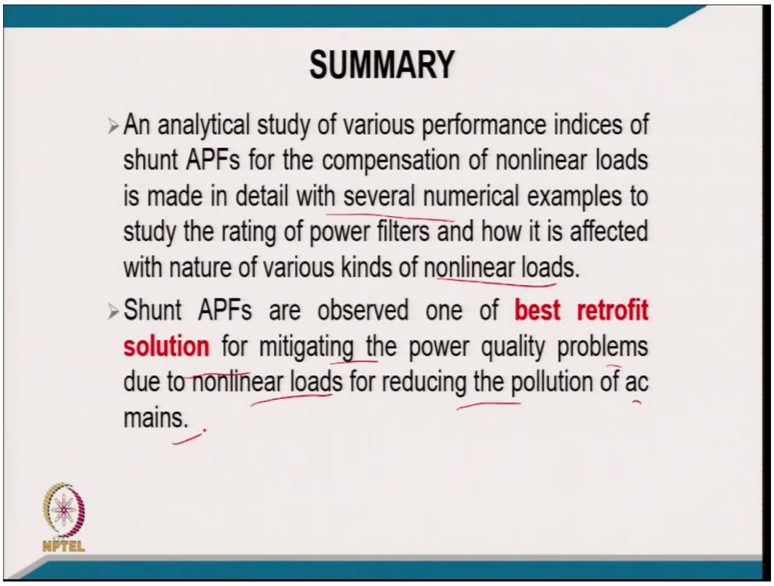

An analytical study of various performance indices of shunt active power filter for compensation of non-linear load, it made it in detail with several numerical example to study the rating of power filter and how it is affected with the nature of the various kind of non-linear load. Shunt active power filter are observed one of the best retrofit solution for mitigating power quality problem due to non-linear load for reducing the pollution ac mains.

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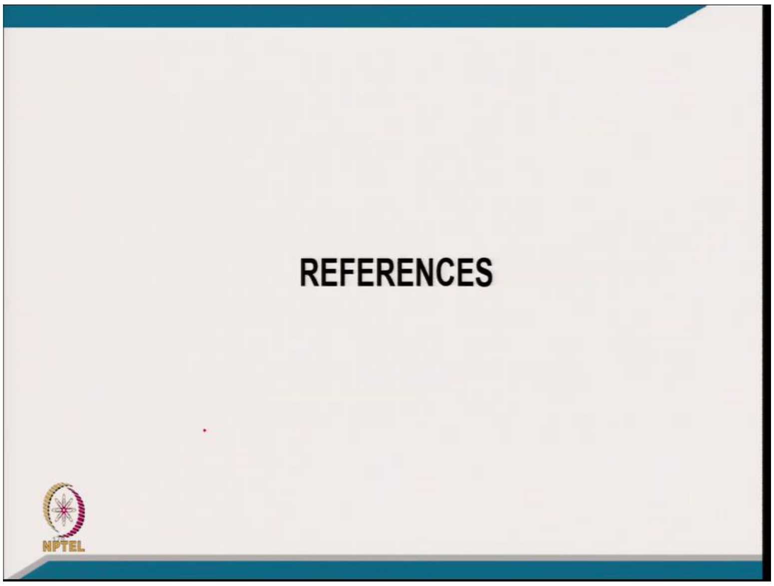

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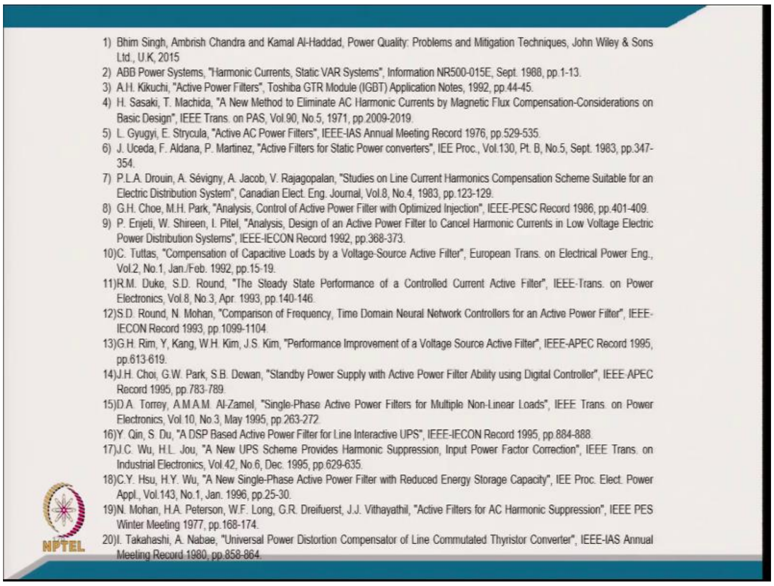

1) Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, Power Quality: Problems and Mitigation Techniques, John Wiley & Sons Ltd., U.K, 2015
2) ABB Power Systems, "Harmonic Currents, Static VAR Systems", Information NR500-015E, Sept. 1988, pp.1-13.
3) A.H. Kikuchi, "Active Power Filters", Toshiba GTR Module (IGBT) Application Notes, 1992, pp.44-45.
4) H. Sasaki, T. Machida, "A New Method to Eliminate AC Harmonic Currents by Magnetic Flux Compensation-Considerations on Basic Design", IEEE Trans. on PAS, Vol.90, No.5, 1971, pp.2009-2019.
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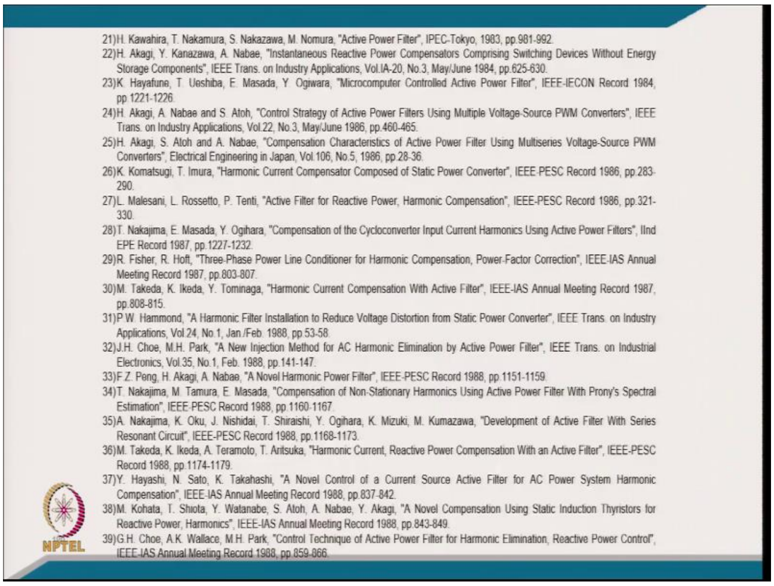

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