Power Quality
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Lecture - 16
Loads which Cause Power Quality Problems (contd.)

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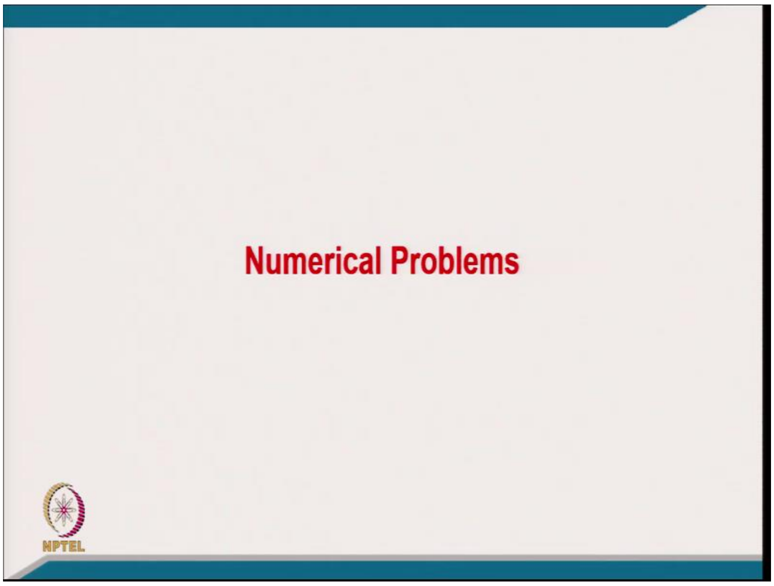

Welcome to this course on Power Quality. We will discuss the numerical problem of on non-linear load which cause the power quality problem.

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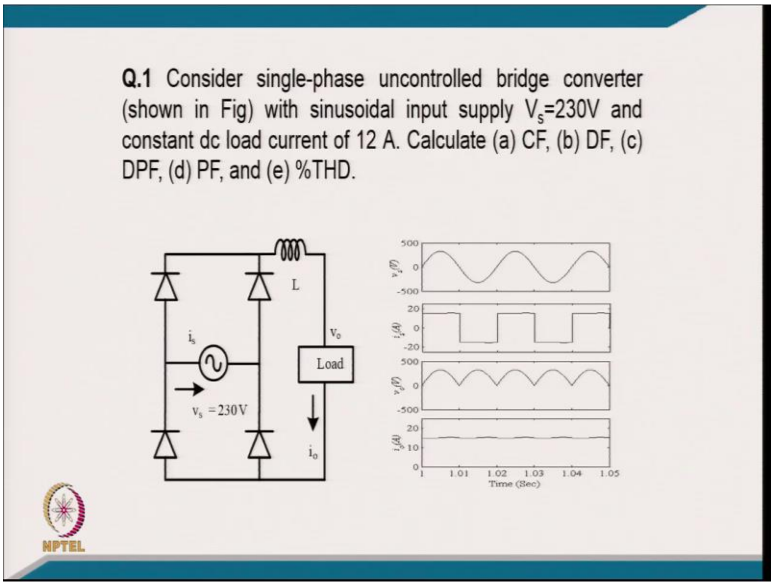

The, consider the single-phase uncontrolled bridge converter, shown here in figure below with the sinusoidal input supply voltage of 230 Volt and constant dc load current of 12 Ampere. Calculate the CF means crest factor, DF distortion factor, DPF displacement factor, d power factor, and e percentage THD.

And you can see, I mean this is typically diode rectifier with the RL load with a highly inductive circuit. Supply current will be square wave.

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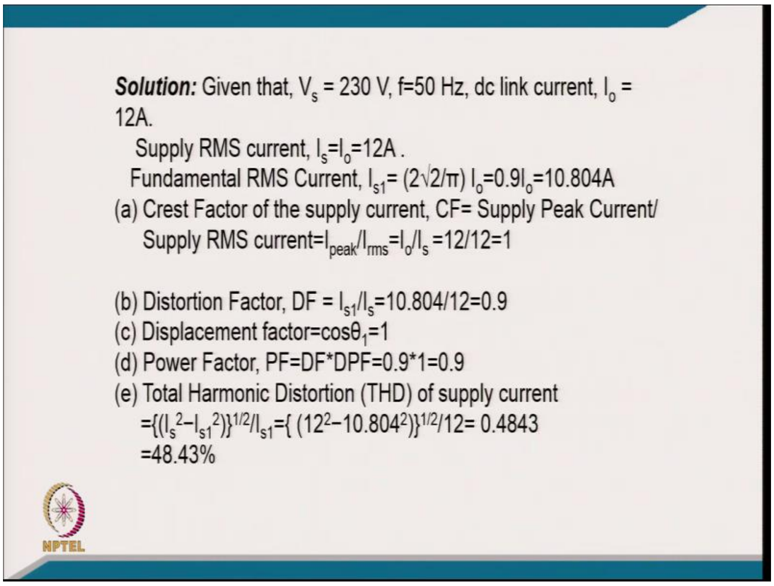

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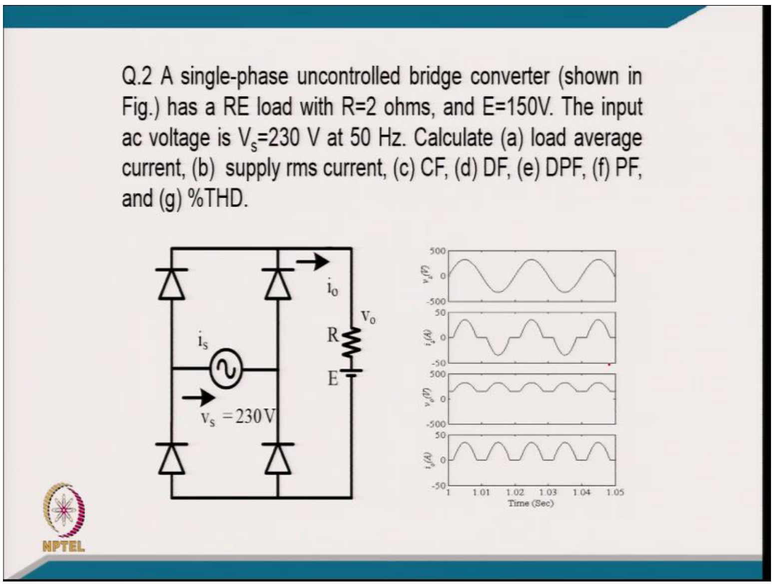

Coming to the a second example. A single-phase uncontrolled bridge converter shown in figure has a RE load with the resistance of 2 ohm and the battery voltage of your 150 Volt. The input ac voltage is 230 Volt at 50 Hertz and calculate the load average current, supply RMS current, crest factor, distortion factor, displacement factor, power factor, and percentage THD.

The waveform of supply voltage we take a sine wave. The current will be drawn only when supply voltage greater than the value of E. You will find supply current is peaky current.

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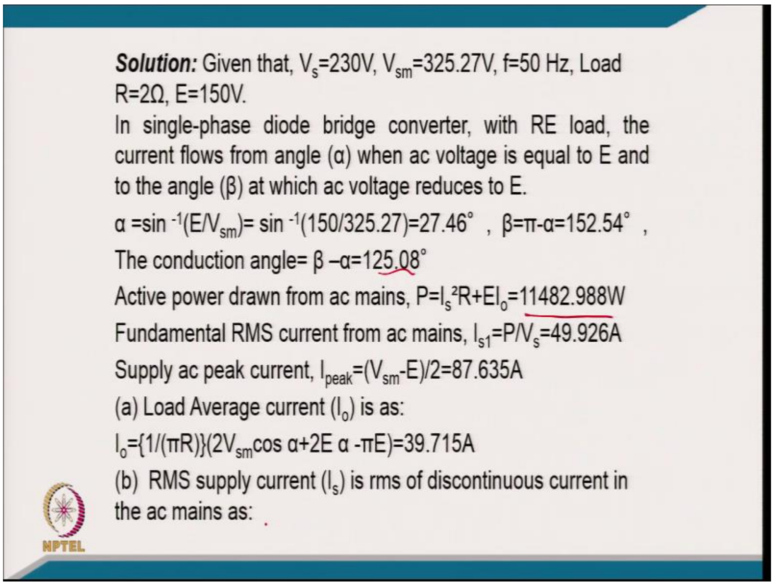

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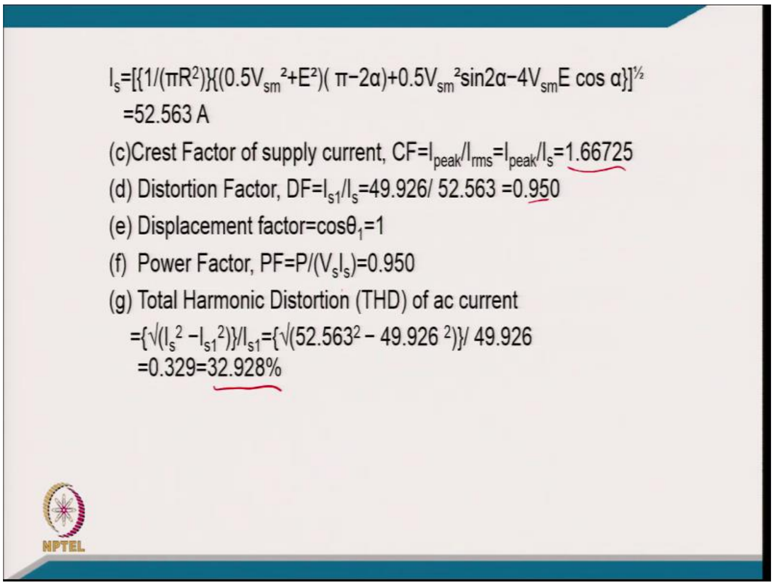

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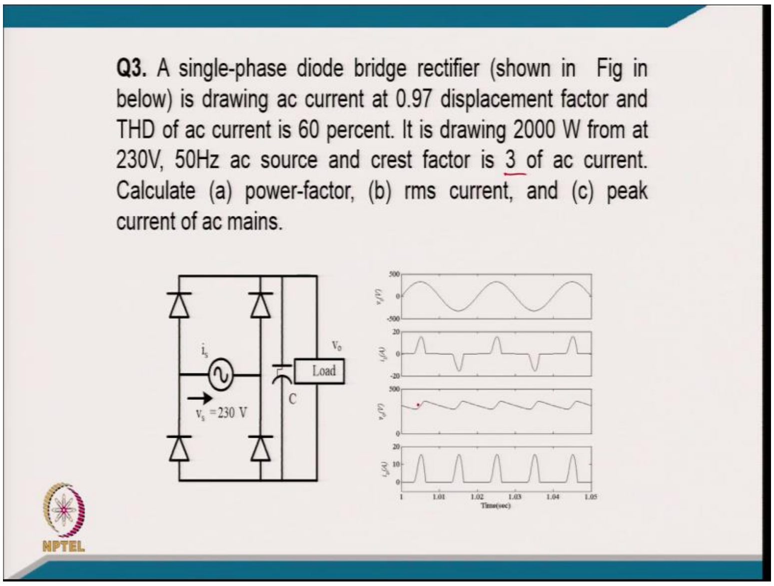

Coming to numerical example 3: A single-phase diode bridge rectifier, shown in the figure is drawing the ac current at 0.97 displacement factor and THD of the ac current is 60 percent. Drawing 2000 Watt from the 230 Volt, 50 Hertz ac source and crest factor is 3 of ac current. Calculate the power factor, RMS current, and peak current.

Only for the duration when ac supply voltage is more than the capacitor voltage, you will be drawing the current.

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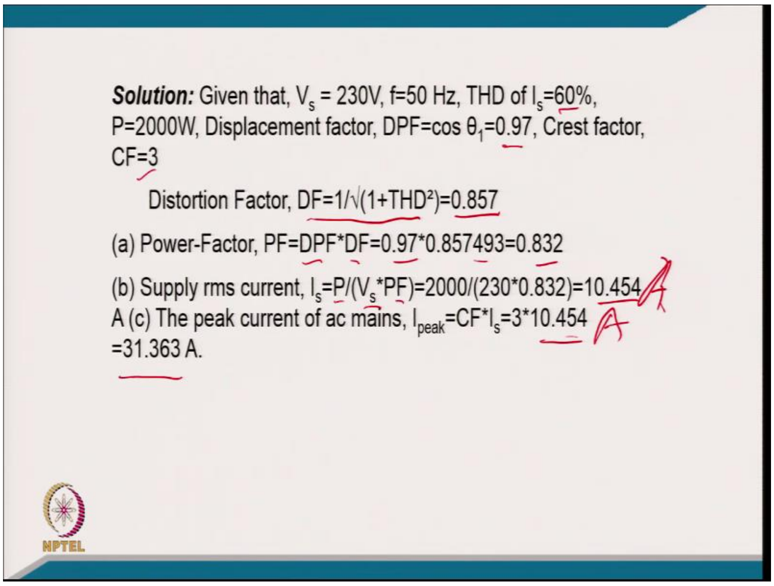

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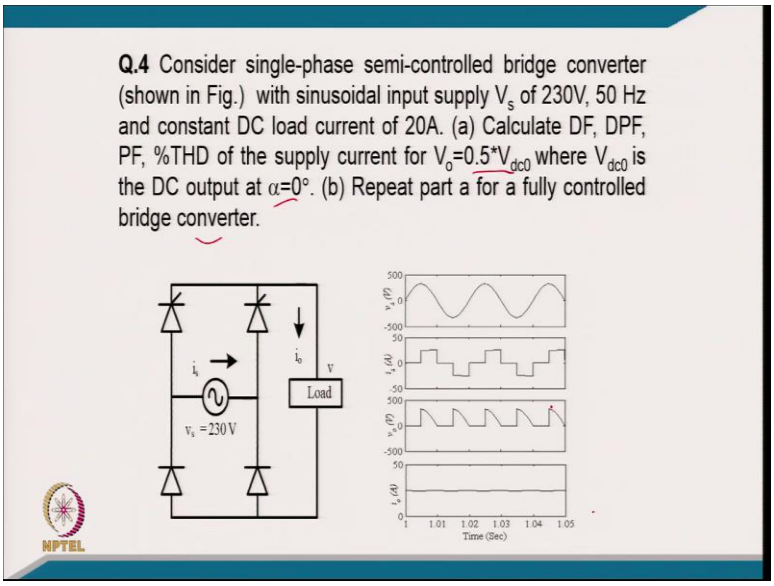

Coming to another example. Consider single-phase semi-controlled bridge converter with a sinusoidal supply voltage of 230 Volts, 50 Hertz and constant DC load current of 20 Ampere. Calculate the distortion factor, displacement factor, power factor. Repeat this part for fully controlled bridge converter where typically all 4 are the thyristor like.

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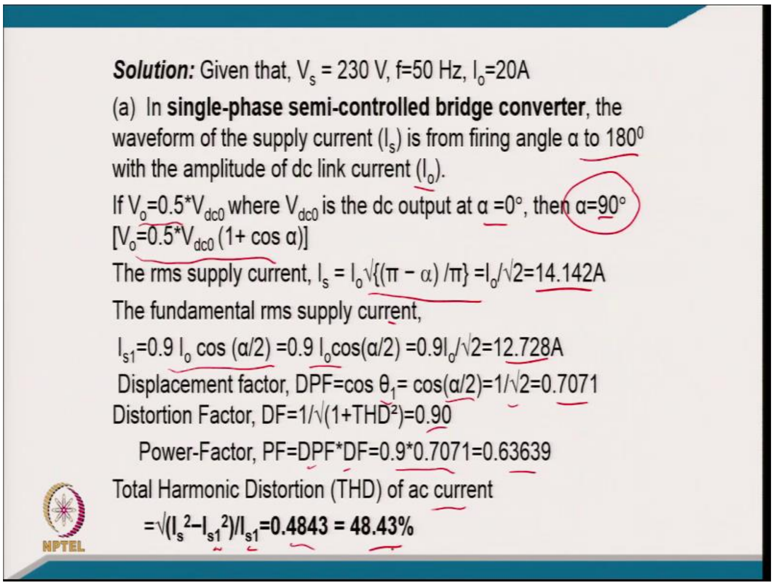

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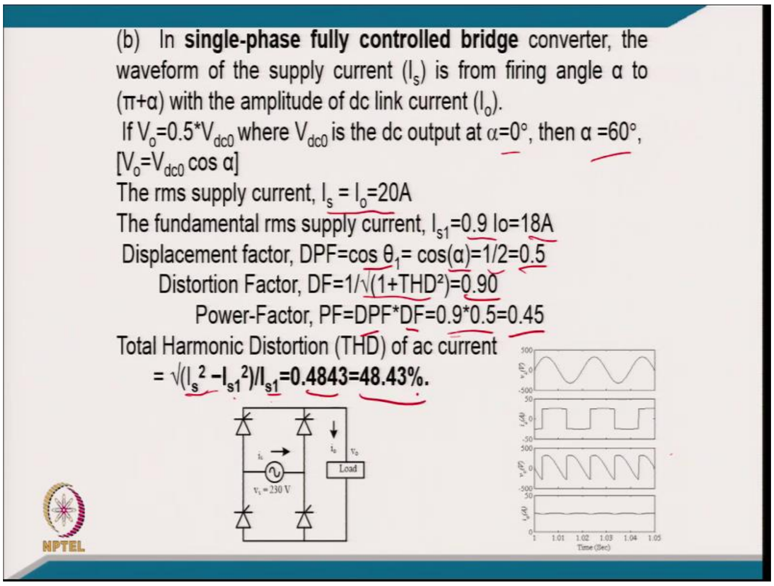

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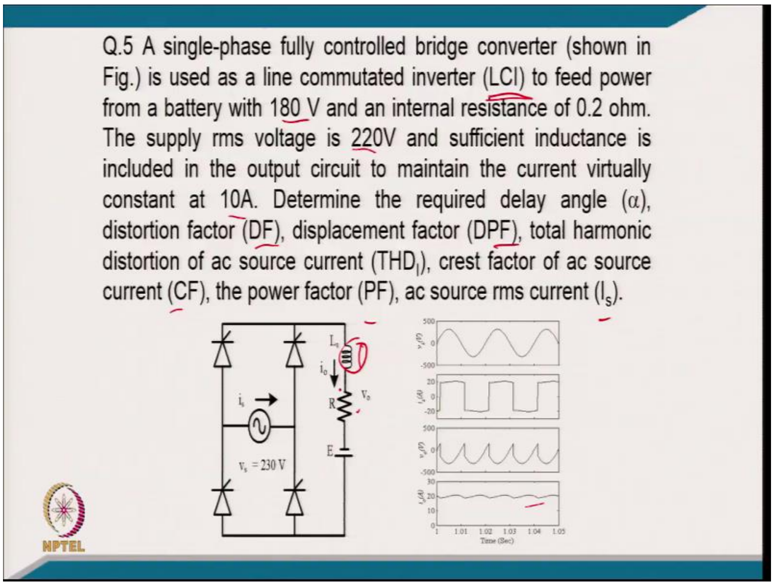

Coming to another example. A single-phase fully controlled bridge converter shown in this figure is used as a line commuted inverter to feed the power from battery with a 180 Volt and a internal resistance of 0.2 ohm and supply RMS voltage is 220 volt, so and a sufficient inductance is included typically in the output current to maintain virtually constant 10 Ampere. Determine the required delay angle of the thyristor, distortion factor, displacement factor, total harmonic distortion current, crest factor of current, power factor and ac rms current.

The current is a square wave where the load current is constant.

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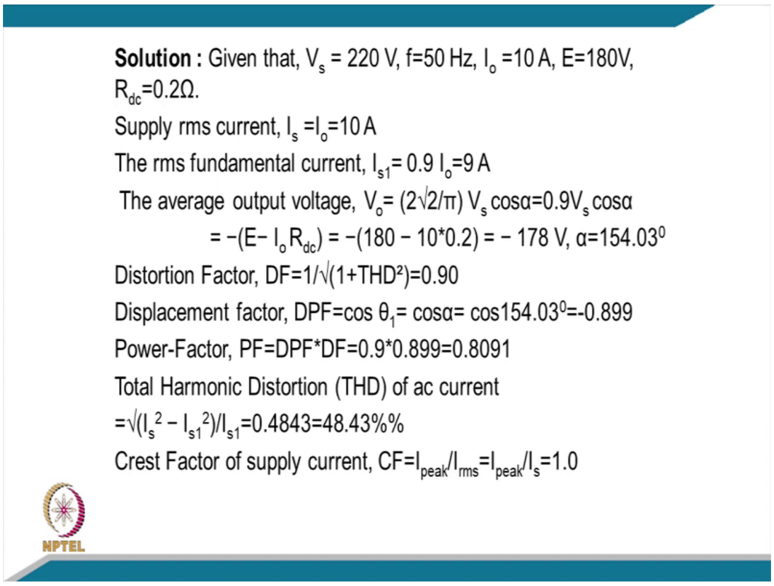

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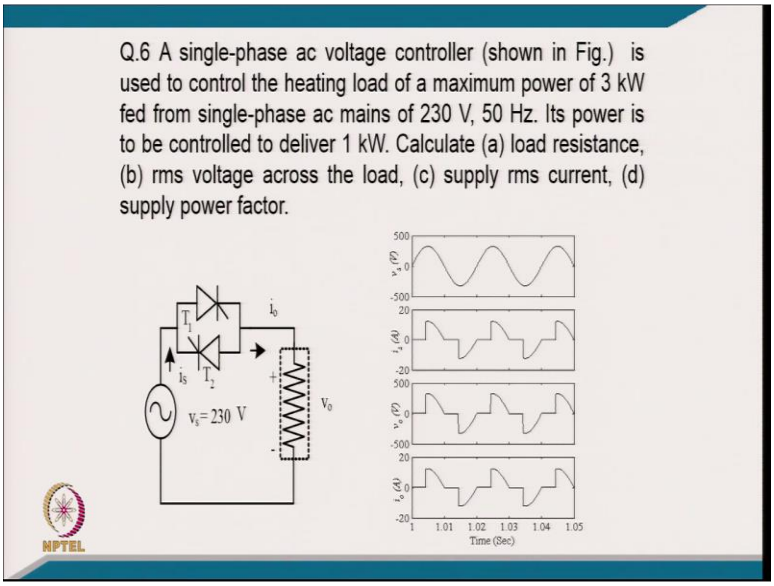

Coming to another example. A single-phase ac voltage controller on here in figure, is used to control the heating element of maximum power of 3 kilowatt from the single-phase ac mains of 230 Volt 50 Hertz. Its power is to be controlled to deliver 1 kilowatt. Calculate the load resistance, rms voltage across the load, supply current RMS, and power factor.

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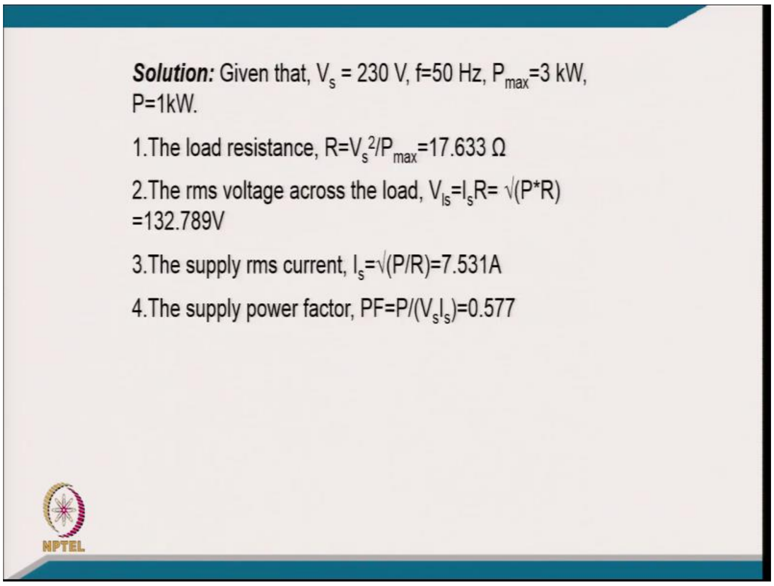

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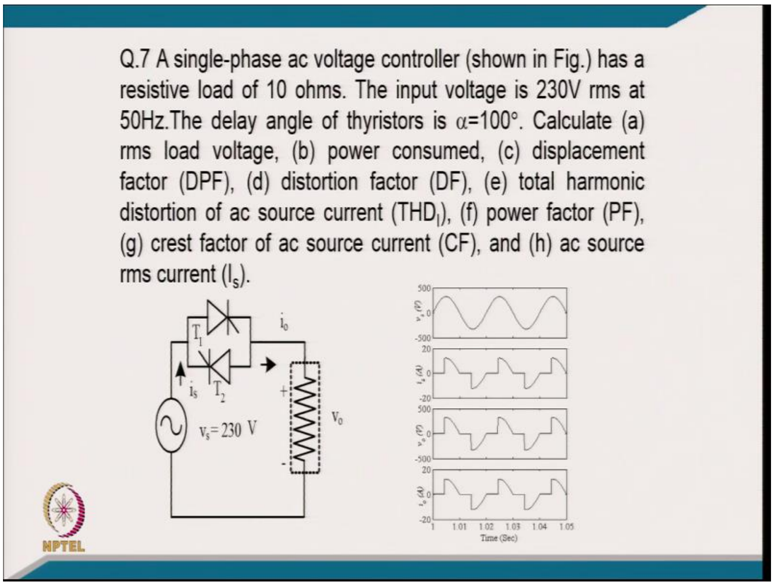

Coming to another example, this is single-phase ac voltage controller, shown has a resistive load of 10 ohm. The input voltage 230 Volt and delay angle is of thyristor is 100 degree. Calculate the load rms, rms load voltage power consumed, displacement factor, distortion factor, total harmonic distortion of ac mains current, power factor, crest factor of ac source current and ac source rms current.

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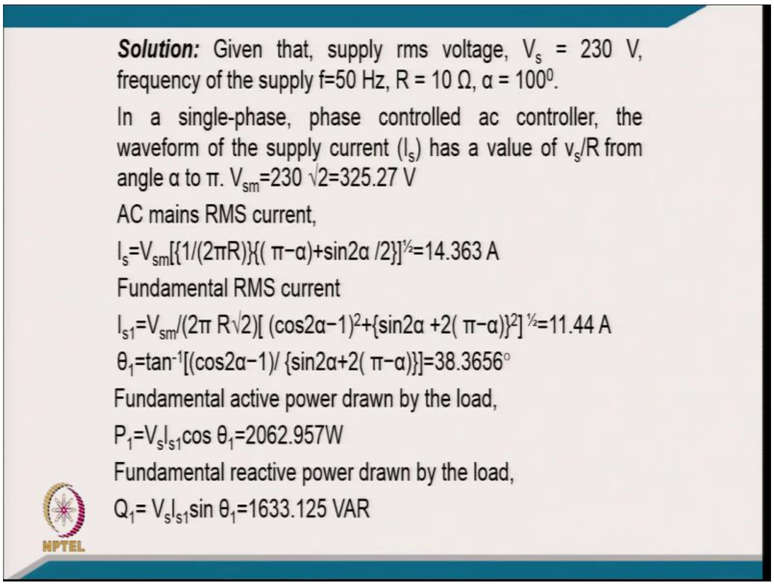

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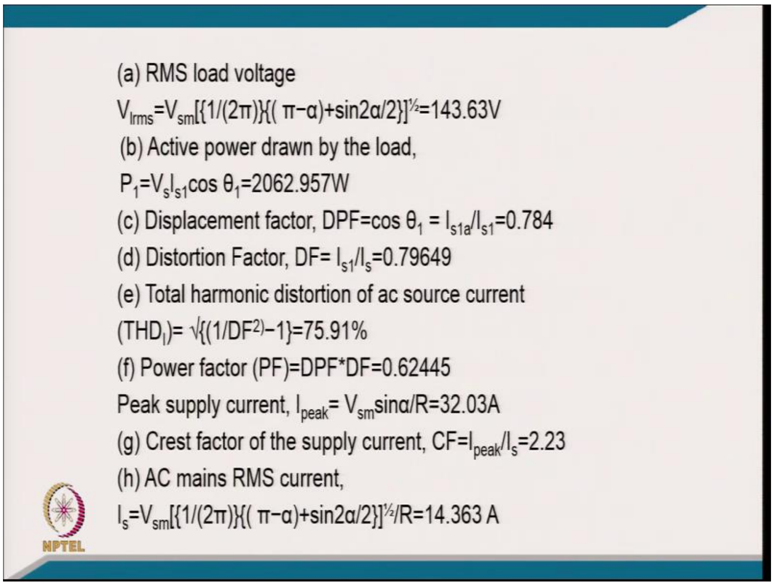

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Q.8 A single-phase, 230V, 50 Hz supply system is feeding a set of nonlinear loads, which consists of a semi-controlled bridge and a diode bridge rectifier connected in parallel (shown in Fig.). The diode bridge converter is drawing 10 A constant dc current. The semi-controlled bridge AC-DC converter is drawing 15 A constant DC current at 60° firing angle of its thyristors. For this composite nonlinear load, calculate (a) active power consumed, (b) reactive power drawn, (c) displacement factor (DPF), (d) distortion factor (DF), (e) total harmonic distortion of ac source current (THD_I), (f) power factor (PF), (g) crest factor of ac source current (CF), (h) ac source rms current (I_s).

Coming to another example. A single-phase 230 Volt, 50 Hertz supply system is feeding a set of non-linear load, which consists of semi-controlled bridge and the diode rectifier connected in parallel. The diode bridge converter drawing 10 Ampere constant DC current and semi-converter drawing 15 Ampere constant DC current at 60 degree firing angle of thyristors. And for this composite non-linear load calculate the active power consume, reactive power consume, displacement factor, distortion factor, total harmonic distortion of ac mains current, and power factor, crest factor of ac mains current, and ac source rms current.

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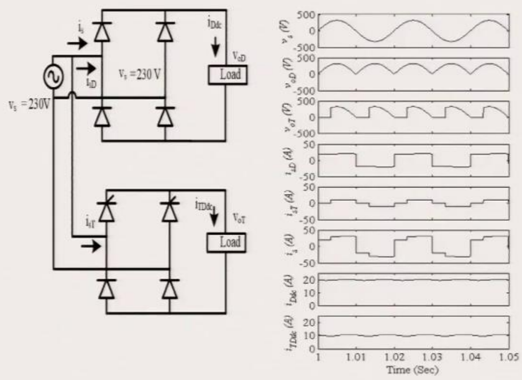

Single-Phase Converter Based Current Fed Type of Nonlinear Load.

This kind of load, one is the diode rectifier with a constant current, another is thyristor converter with constant current.

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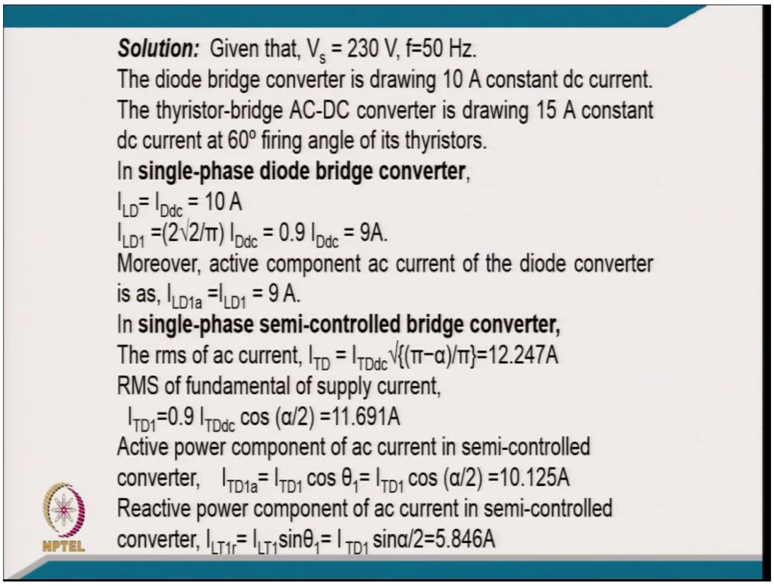

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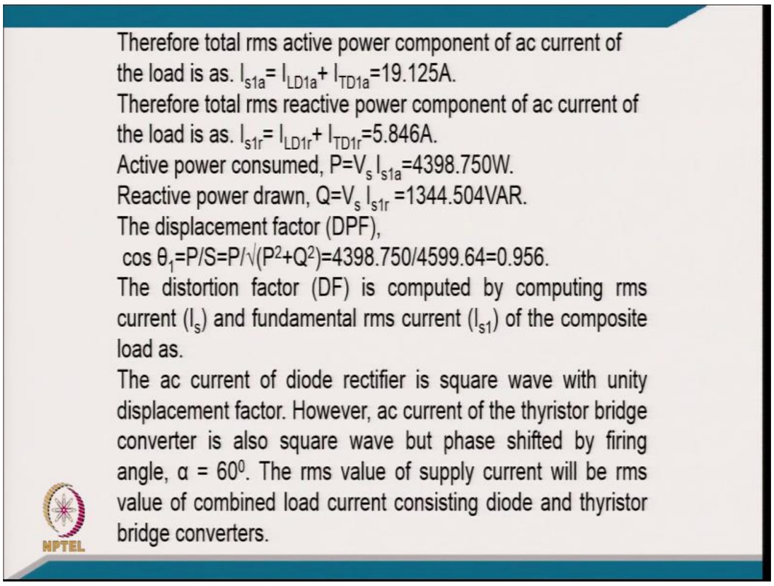

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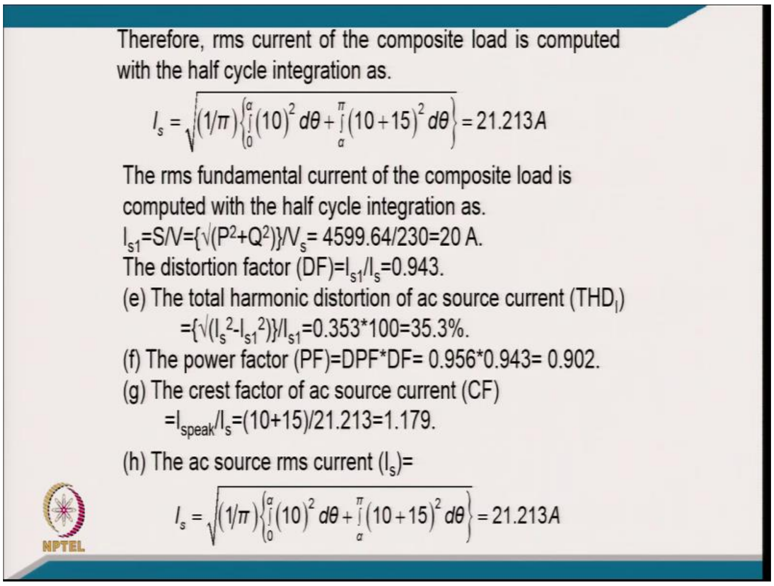

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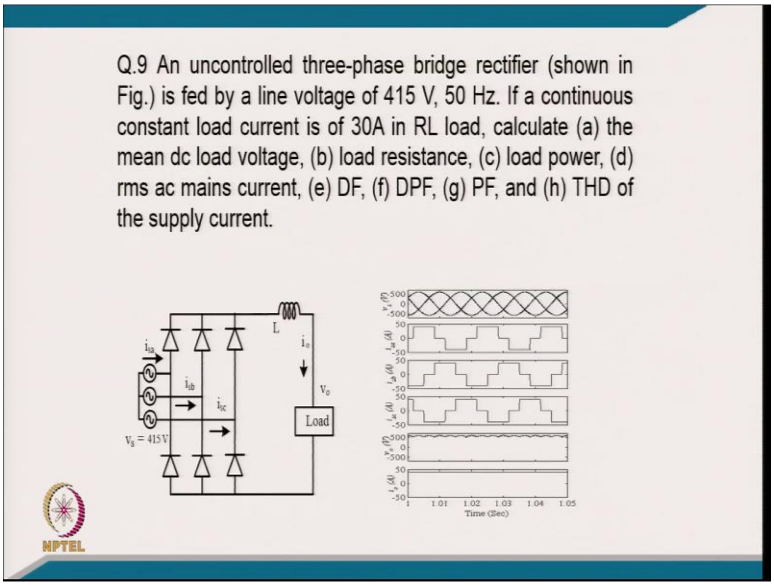

Now, let us go to another example with the three-phase. An uncontrolled three-phase bridge rectifier, shown in the figure, is fed by line voltage of 415 Volt, 50 Hertz. If a continuous constant current of 30 Ampere is in RL load, calculate the mean dc voltage, load resistance, load power, rms ac mains current, distortion factor, displacement factor, power factor and THD of supply current.

The three-phase supply current is quasi-square wave which are of 120 degree duration. And they will be in phase with the phase supply voltage.

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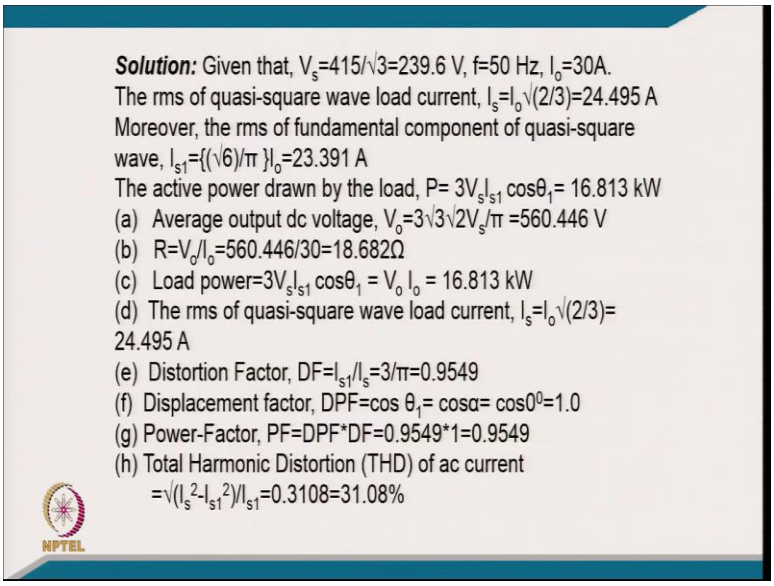

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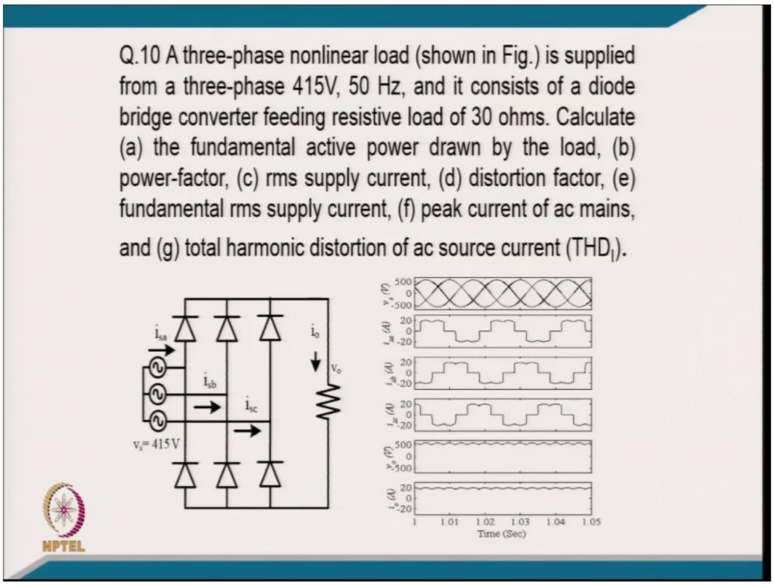

Coming to another example, a three-phase non-linear load is supplied from three-phase 415 Volt, 50 Hertz and it consist of a diode bridge converter feeding resistive load of 30 ohm. Calculate the fundamental active power drawn by the load, power factor, RMS supply current, distortion current, fundamental RMS current, peak current of main, and the total harmonic distortion of ac mains current.

We will find again the quasi-square wave.

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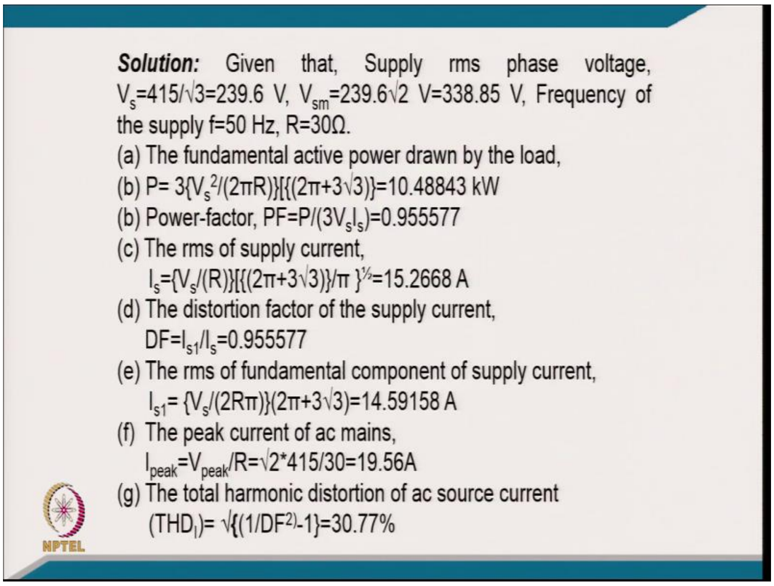

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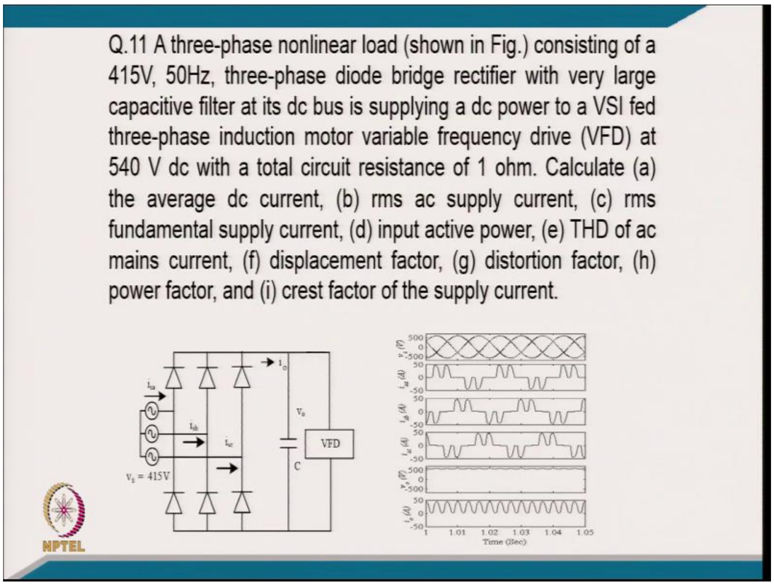

Coming to another example. A three-phase non-linear load, shown in figure consisting of a 415 Volt, 50 Hertz, three-phase diode rectifier with very large capacitive filter as dc bus is supplying a dc power of to a V voltage source inverter fed three-phase induction motor variable frequency drive at 540 Volt dc with a total circuit resistance of 1 ohm. Calculate the average dc current, rms ac supply current, rms fundamental supply current, input active power, THD of ac mains current, displacement factor, distortion factor, power factor, and crest factor of the supply current.

With this large capacitor value, you will get two notches in each half.

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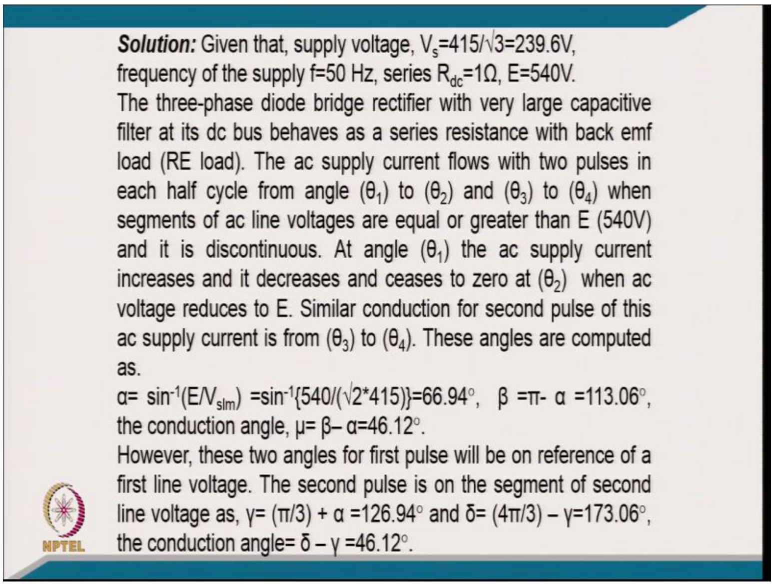

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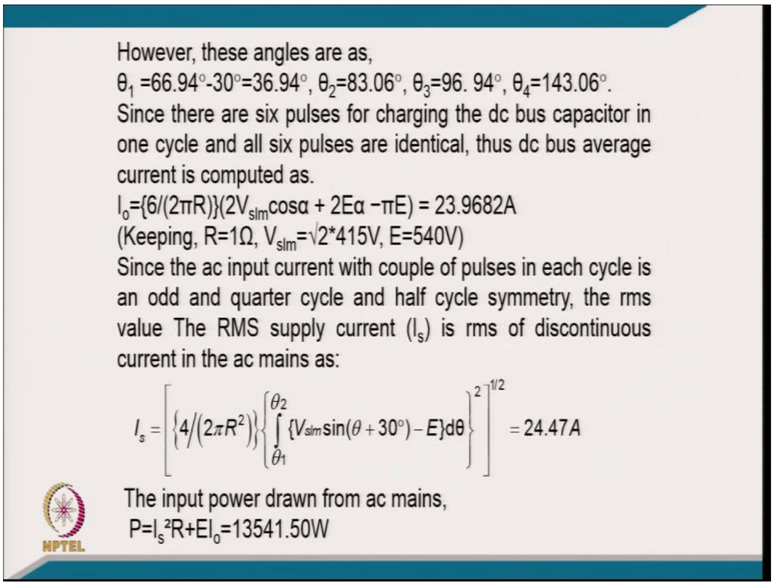

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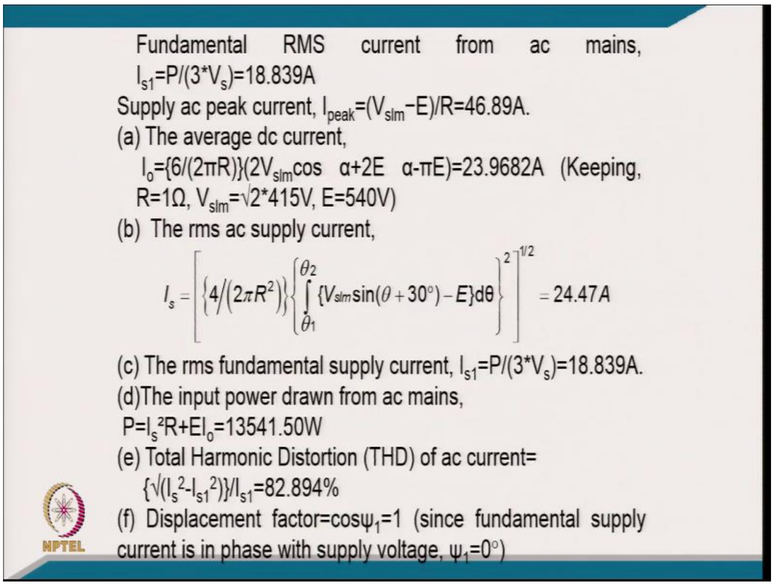

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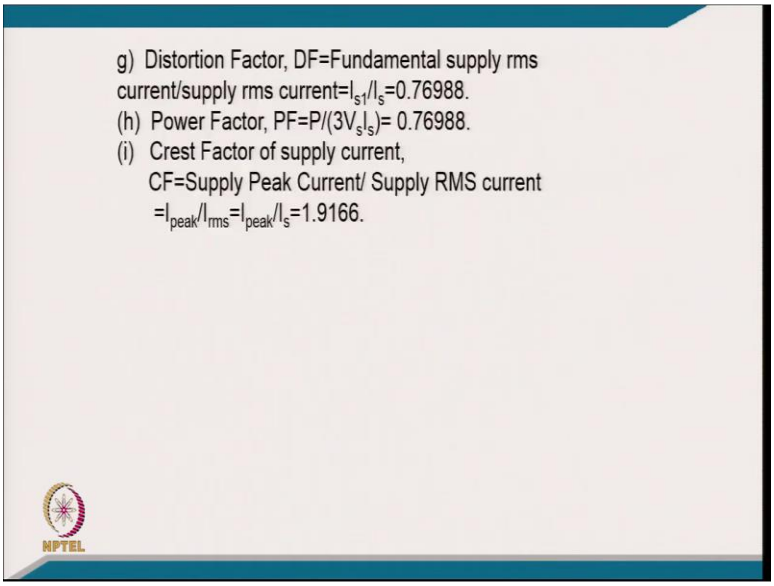

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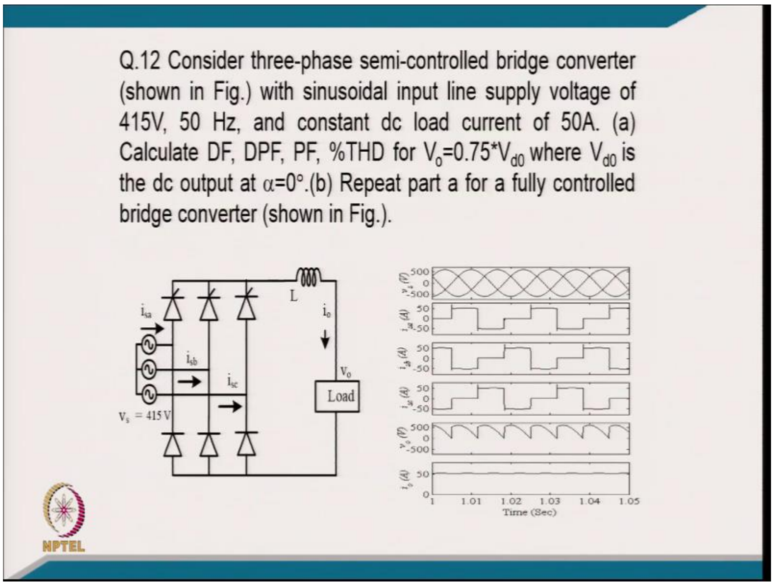

Consider the three-phase semi-controlled bridge converter, shown in this, sinusoidal input supply line voltage of 415 Volt, 50 Hertz and constant dc current of 50 Ampere here. Calculate the distortion factor, displacement factor, power factor, total harmonic distortion for V output equal to 0.75 V d 0, where V d 0 is the output voltage at alpha equal to 0 repeat part for part a for fully controlled converter.

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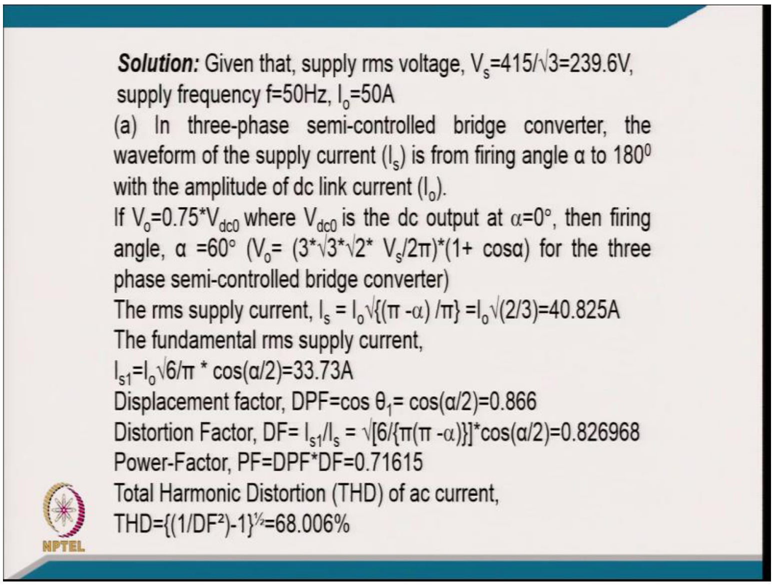

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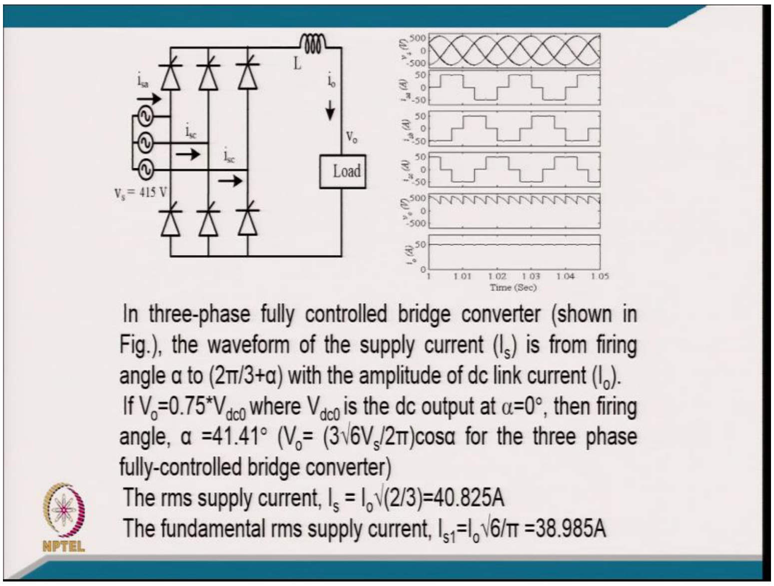

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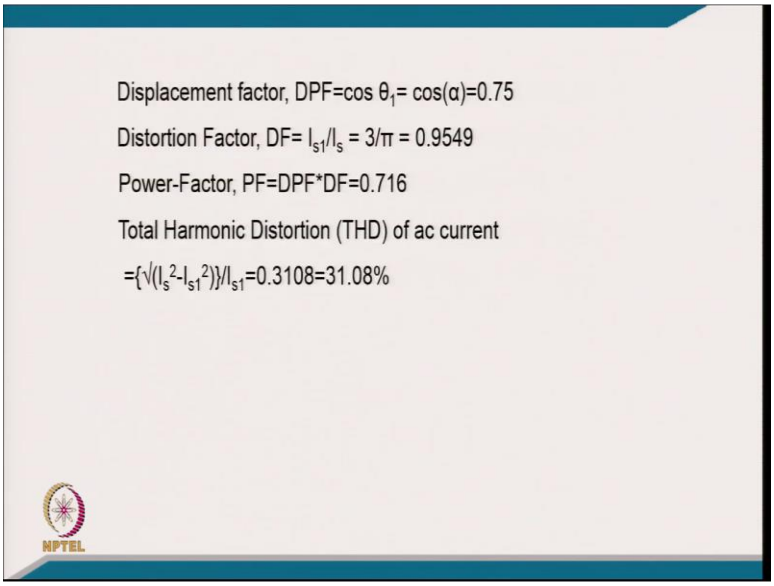

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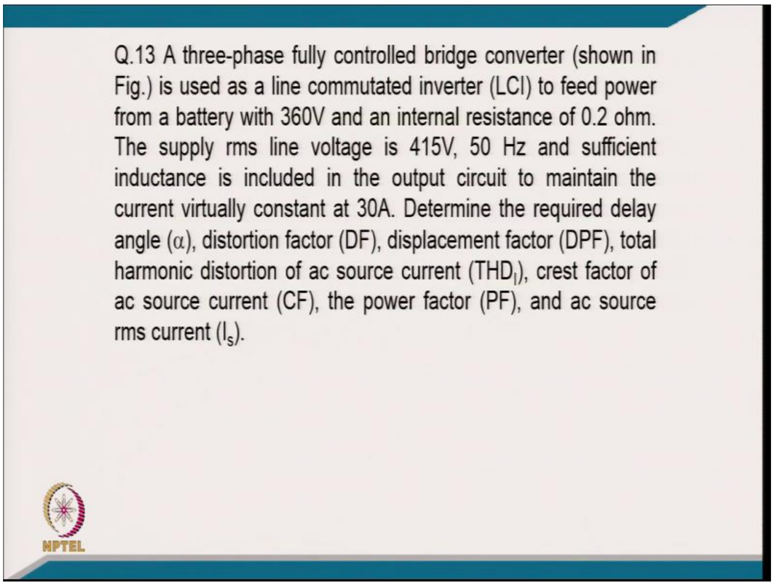

Coming to another numerical example. A three-phase fully controlled bridge converter shown here is used as a line committed inverter to feed the power from battery with 360 Volt, an internal resistance of 0.2 ohm. The supply RMS line voltage 415, 50 Hertz, and sufficient inductance is included in the output circuit to maintain the current virtually constant at 30 Ampere. Determine the required delay angle alpha, distortion factor, displacement factor, harmonic distortion of ac mains current, crest factor, and power factor, and ac rms current.

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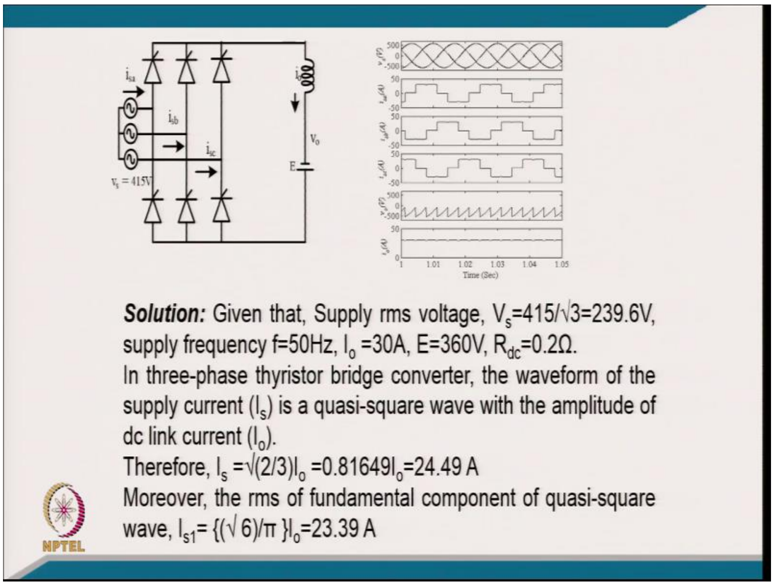

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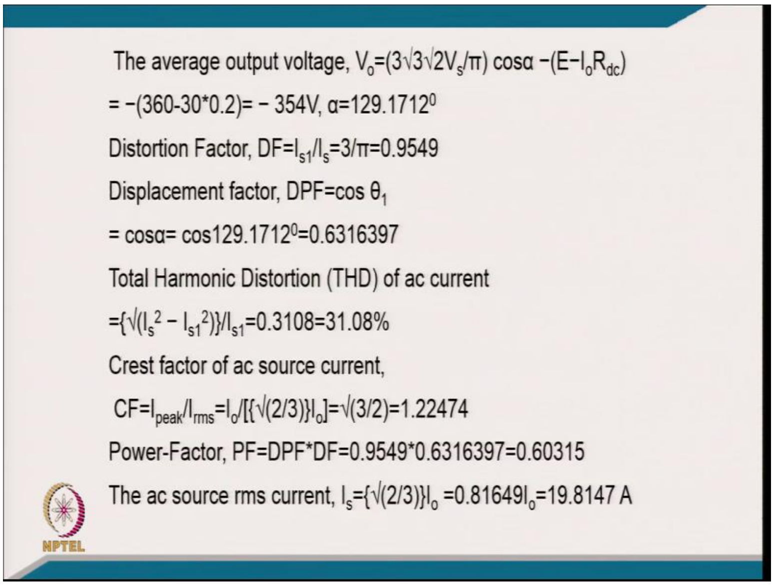

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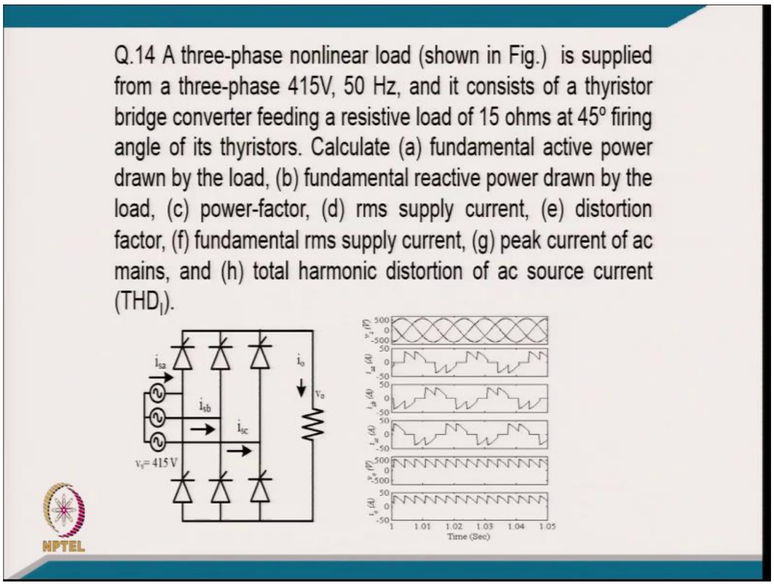

A three-phase, a non-linear load is supplied from a three-phase 415 Volt and it consist of thyristor bridge converter feeding a resistive load of 15 ohm at a 45 degree of firing angle. Calculate the fundamental active power drawn by load fundamental reactive power drawn by load, power factor, rms current, supply current, distortion factor, and fundamental RMS current, peak current of main and total harmonic distortion of the ac mains current.

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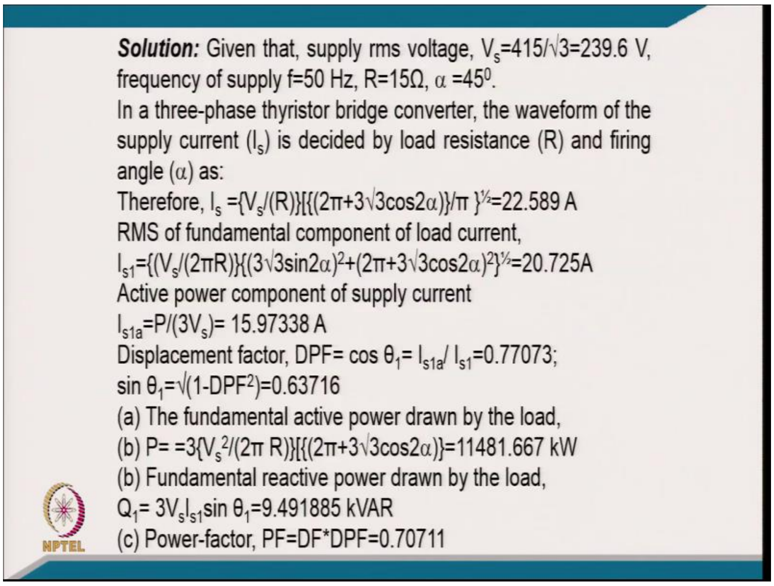

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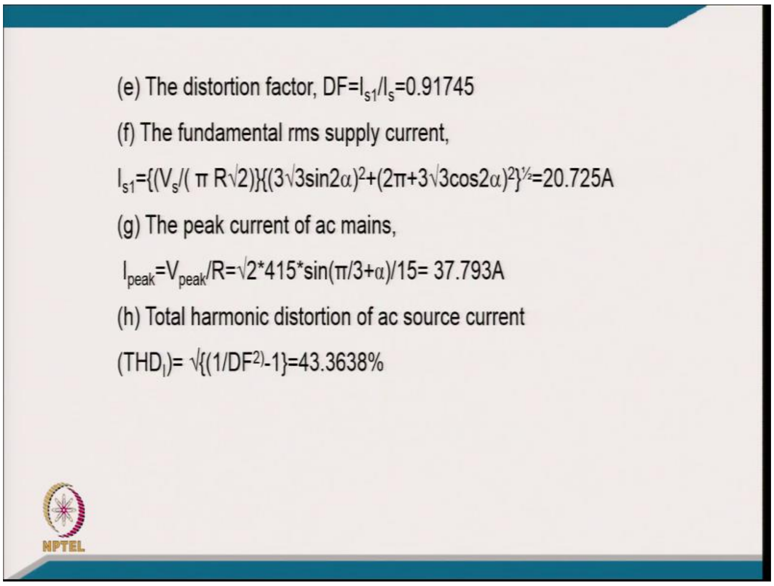

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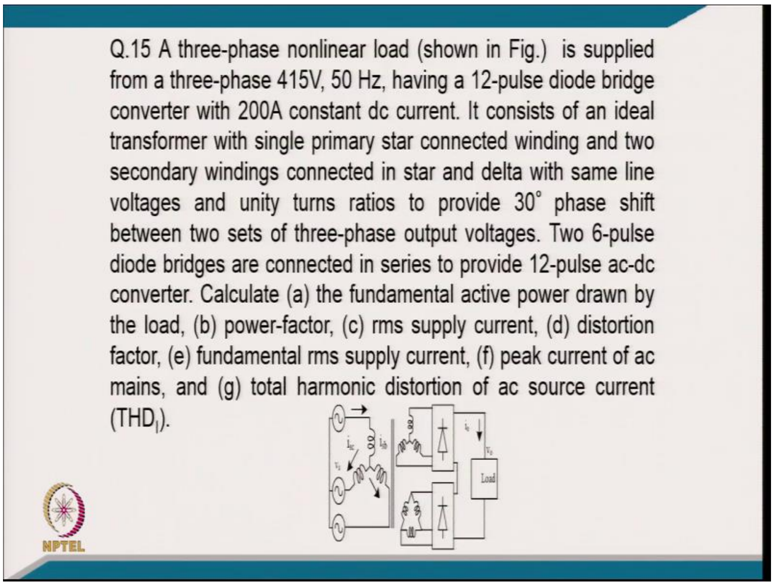

Coming to another numerical example, a three-phase non-linear load is supplied from three-phase 415 Volt, having a 12-pulse diode bridge converter with 200 Ampere dc current. It consists of ideal transformer with a single-phase primary star connected winding and two secondary winding connected in star delta with the same voltage and unity turns ratio to provide 30 degree phase shift between two sets of three-phase output voltage. Two 6-pulse thyristor bridge are connected in series to provide 12-pulse ac-dc converter. Calculate the fundamental active power drawn, power factor, RMS supply current, distortion factor, fundamental rms current, peak current of rms and total harmonic distortion.

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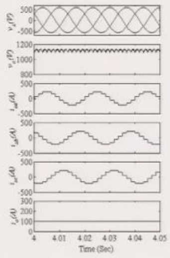
Solution: Given that, $V_s=415/\sqrt{3}=239.6$ V, f=50 Hz, $I_o=200$A.

In three-phase 12-pulse diode bridge converter, the waveform of the input ac current (I_s) is a stepped waveforms as (i) first step of π/6 angle (from 0° to π/6) and input current magnitude of $(I_o/\sqrt{3})$, (ii) second step of π/6 angle (from π/6 to π/3) and input current magnitude of $\{I_o(1+1/\sqrt{3})\}$, (iii) third step of π/6 angle (from π/3 to π/2) and input current magnitude of $\{I_o(1+2/\sqrt{3})\}$ and it has all four symmetric segments of such steps.



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Therefore, RMS of 12-pulse converter input current,

$I_s=I_o[(1/3)+(1+1/\sqrt{3})^2+(1+2/\sqrt{3})^2]^{½}=1.57735I_o=315.47$A

RMS of fundamental component of 12-pulse converter input current,

$I_{s1}=\{(2\sqrt{6})/\pi\}I_o=1.559393I_o=311.879$ A

(a) The active power drawn by the load, $P= 3V_sI_{s1}\cos\theta_1=224.179$ kW

(b) The Power factor, $PF=P/(3V_sI_s)=0.9886138$

(c) RMS of 12-pulse converter input current,

$I_s=I_o[(1/3) + (1+1/\sqrt{3})^2 + (1+2/\sqrt{3})^2]^{½}=1.57735I_o=315.47$ A

(d) The distortion factor, $DF=I_{s1}/I_s=0.9886138$

(e) RMS of fundamental component of input ac mains current,

$I_{s1}=\{(2\sqrt{6})/\pi\}I_o=1.559393I_o= 311.879$ A

(f) The peak current of ac mains,

$I_{peak}=\{I_o(1+2/\sqrt{3})\}=2.1547I_o=430.94$ A

(g) The total harmonic distortion of ac source current

$(THDI)= \sqrt{\{(1/DF^2)-1\}}=15.22\%$

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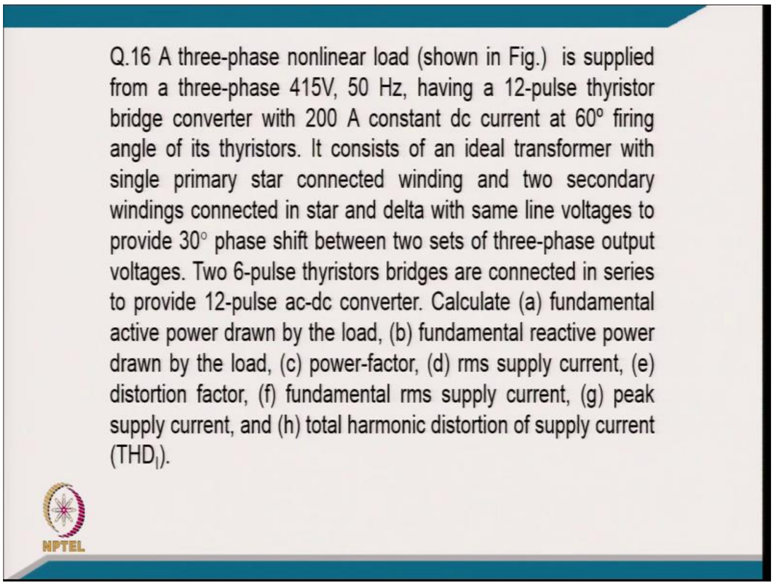

Coming to another example, three-phase non-linear load is supplied from three-phase 15 Volt having 12-pulse thyristor converter with the 200 Ampere, constant current at 60 degree firing angle thyristor. It consists of ideal transformer with single primary star connected and winding the two secondary connected in star and delta with the same line voltage of 30 degree phase shift between two sets of three-phase output. Two 6-pulse thyristor bridges are connected in series two 12-pulses ac-dc. Converter calculate the fundamental active power drawn, fundamental reactive power drawn for a power factor, rms supply current, distortion factor, fundamental rms current, peak supply current, and total harmonic distortion of supply current.

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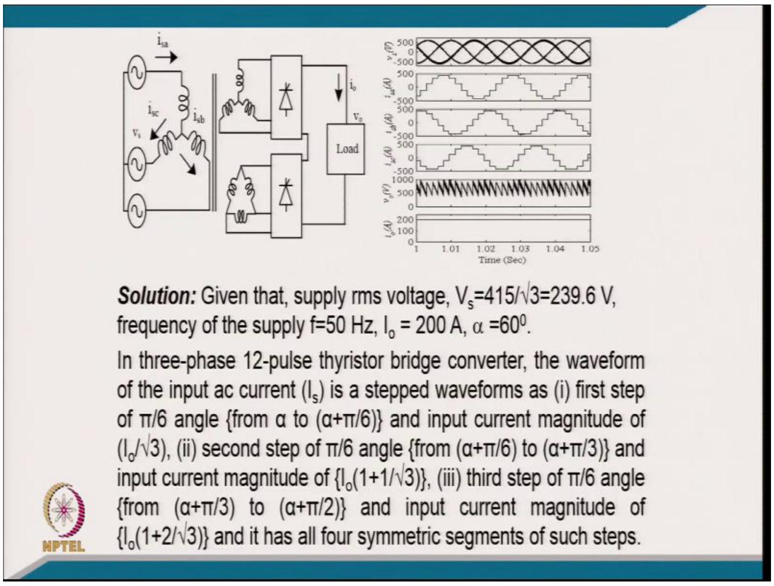

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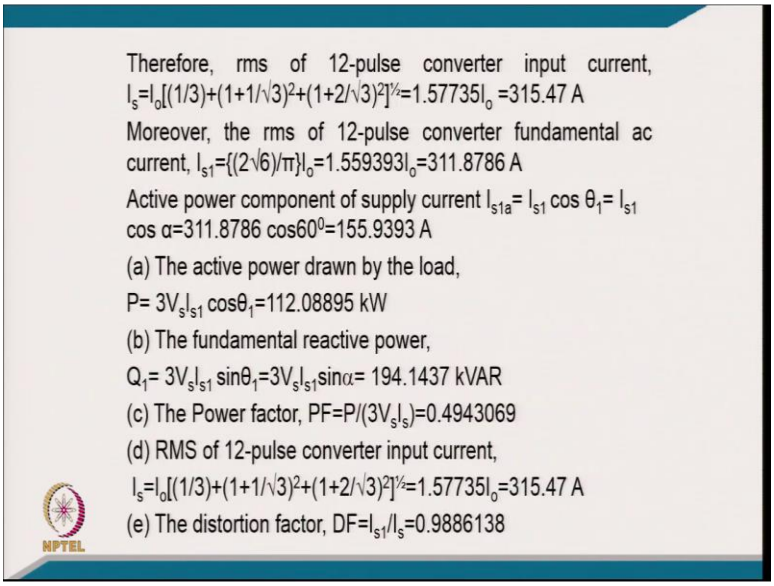

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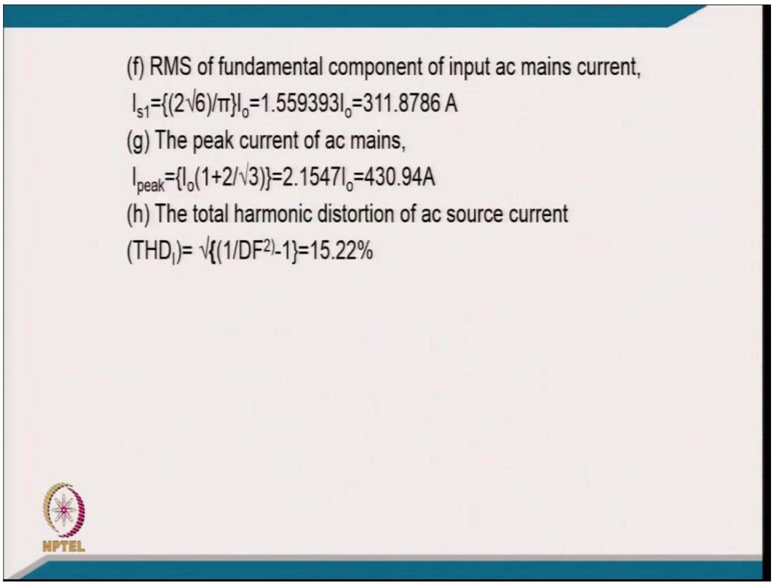

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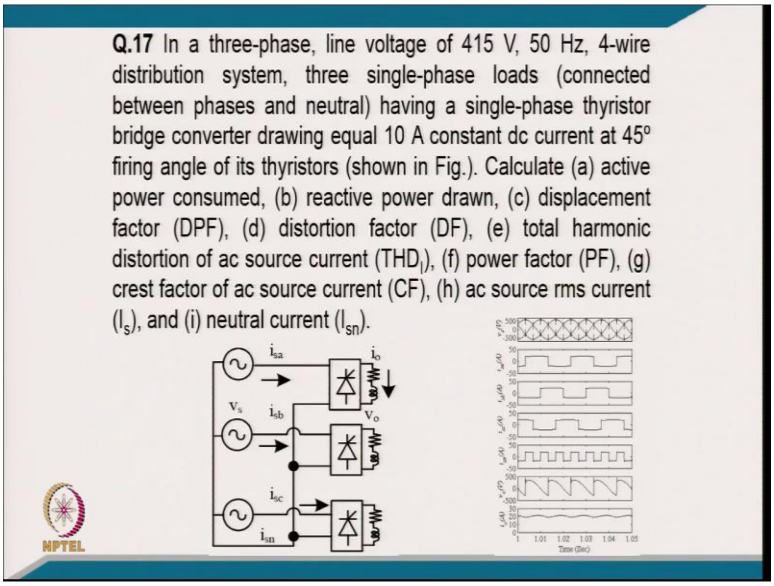

In the three-phase line voltage of 415 Volt, 4 wire distribution system, 3 single-phase load connected between line and it will having a single-phase thyristor converter. Drawing the 10 Ampere, here constant current at 45 degree angle calculate the active power consume, reactive power consume, displacement factor, distortion factor, total harmonic distortion, power factor, crest factor of ac mains and ac mains RMS current.

Three-phase square wave current is there and neutral current will be again a square wave, but 3 times the frequency.

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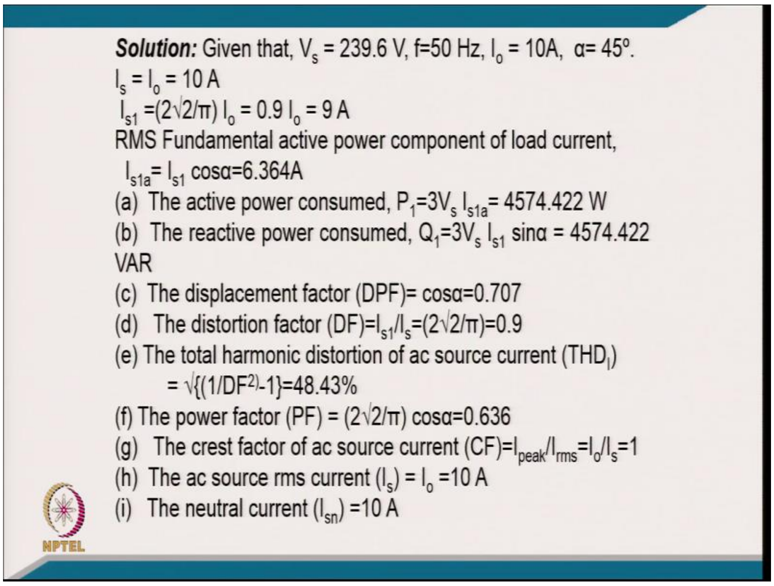

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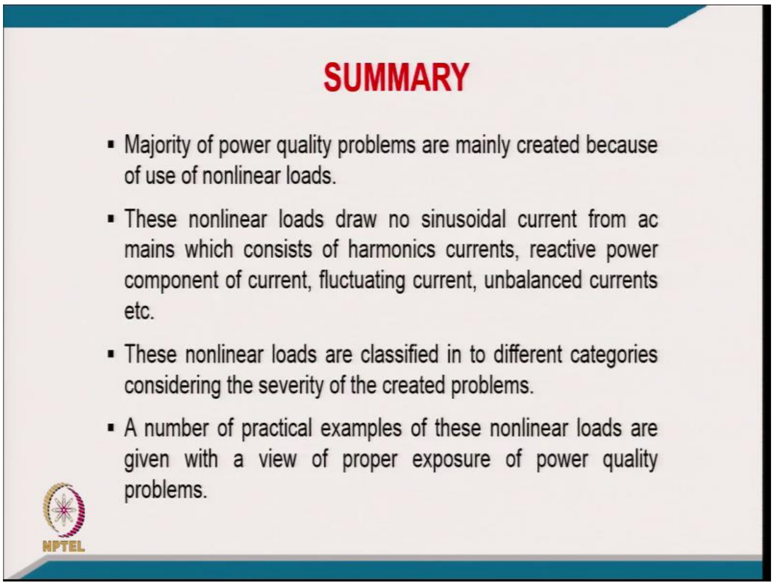

Well, to summarise majority of the power quality problems are mainly created because of the use of non-linear load.

These non-linear loads drawn non sinusoidal current form the ac mains which consists of harmonics current, reactive power component of current, fluctuating current, unbalanced current.

These non-linear loads are classified into different category considering the severity of created power quality problems. And number of practical examples of these non-linear loads are given with a view of proper exposure of power quality problems.

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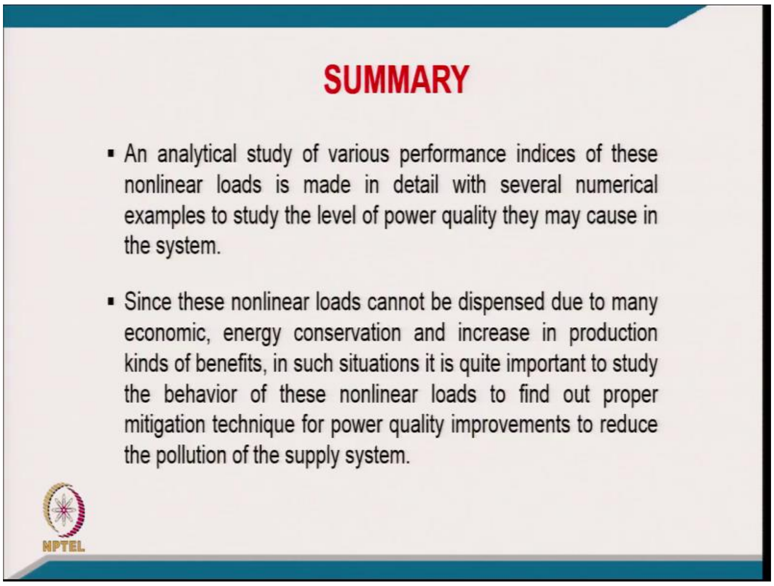

An analytical study of various performance indices of these non-linear loads is made in detail with several numerical examples to study the level of power quality they may cause in system. And since, these non-linear load cannot be dispensed due to many economy, energy conservation and increase in production kind of benefit, in such situation it is quite important to study the behaviour of this non-linear load find out our proper mitigation technique for power quality improvement to reduce the pollution on the supply system.

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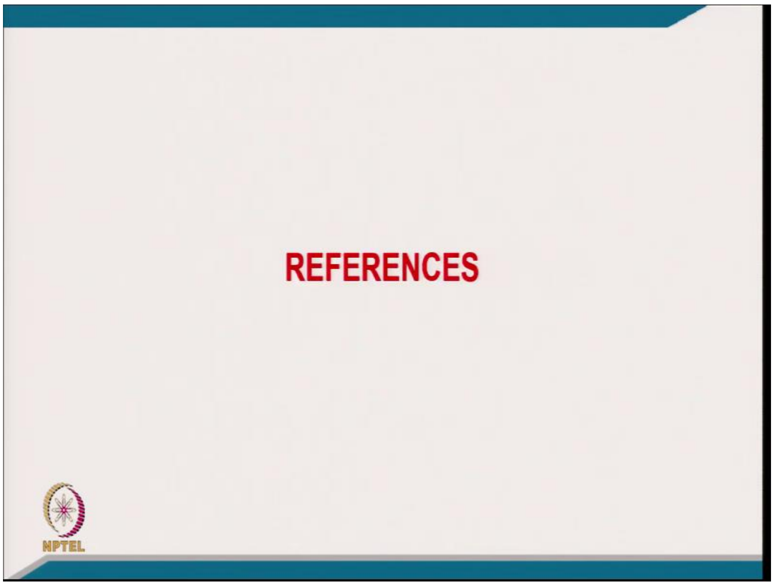

Thank you. And these are the some of the references.