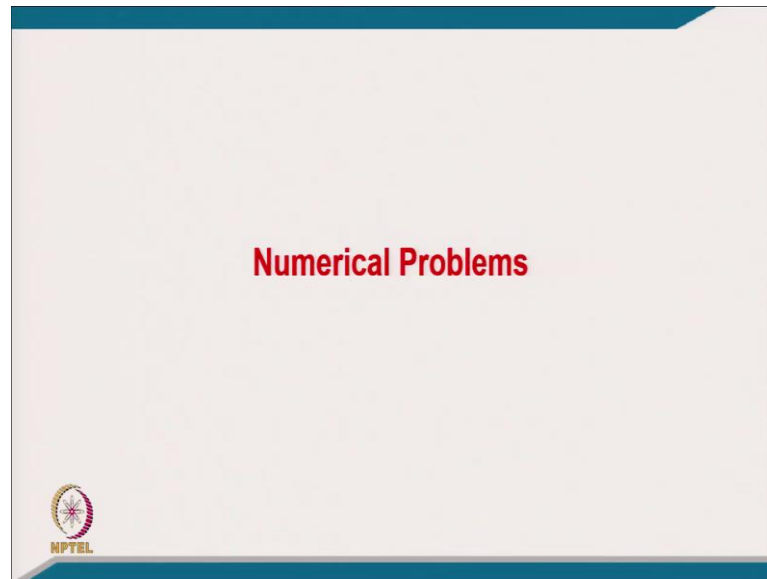


**Power Quality**  
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**Lecture - 16**  
**Loads which Cause Power Quality Problems (contd.)**

(Refer Slide Time: 00:17)



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

(Refer Slide Time: 00:29)

**Q.1** Consider single-phase uncontrolled bridge converter (shown in Fig) with sinusoidal input supply  $V_s=230V$  and constant dc load current of 12 A. Calculate (a) CF, (b) DF, (c) DPF, (d) PF, and (e) %THD.

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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.

(Refer Slide Time: 01:13)

**Solution:** Given that,  $V_s = 230$  V,  $f=50$  Hz, dc link current,  $I_o = 12$  A.

Supply RMS current,  $I_s = I_o = 12$  A .

Fundamental RMS Current,  $I_{s1} = (2\sqrt{2}/\pi) I_o = 0.9 I_o = 10.804$  A


(a) Crest Factor of the supply current,  $CF = \text{Supply Peak Current} / \text{Supply RMS current} = I_{\text{peak}} / I_{\text{rms}} = I_o / I_s = 12 / 12 = 1$

(b) Distortion Factor,  $DF = I_{s1} / I_s = 10.804 / 12 = 0.9$

(c) Displacement factor =  $\cos\theta_1 = 1$

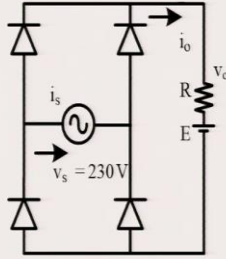
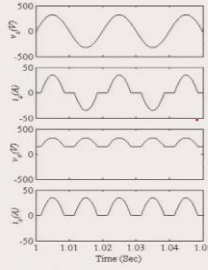

(d) Power Factor,  $PF = DF * DPF = 0.9 * 1 = 0.9$

(e) Total Harmonic Distortion (THD) of supply current  
 $= \{(I_s^2 - I_{s1}^2)\}^{1/2} / I_{s1} = \{(12^2 - 10.804^2)\}^{1/2} / 10.804 = 0.4843$   
 $= 48.43\%$



(Refer Slide Time: 03:11)

Q.2 A single-phase uncontrolled bridge converter (shown in Fig.) has a RE load with  $R=2$  ohms, and  $E=150$  V. The input ac voltage is  $V_s=230$  V at 50 Hz. Calculate (a) load average current, (b) supply rms current, (c) CF, (d) DF, (e) DPF, (f) PF, and (g) %THD.

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.

(Refer Slide Time: 04:21)

**Solution:** Given that,  $V_s=230V$ ,  $V_{sm}=325.27V$ ,  $f=50$  Hz, Load  $R=2\Omega$ ,  $E=150V$ .

In single-phase diode bridge converter, with RE load, the current flows from angle ( $\alpha$ ) when ac voltage is equal to E and to the angle ( $\beta$ ) at which ac voltage reduces to E.

$\alpha = \sin^{-1}(E/V_{sm}) = \sin^{-1}(150/325.27) = 27.46^\circ$  ,  $\beta = \pi - \alpha = 152.54^\circ$  ,

The conduction angle =  $\beta - \alpha = 125.08^\circ$

Active power drawn from ac mains,  $P = I_s^2 R + EI_o = 11482.988W$


Fundamental RMS current from ac mains,  $I_{s1} = P/V_s = 49.926A$

Supply ac peak current,  $I_{peak} = (V_{sm} - E)/2 = 87.635A$

(a) Load Average current ( $I_o$ ) is as:

$I_o = \{1/(\pi R)\} (2V_{sm} \cos \alpha + 2E \alpha - \pi E) = 39.715A$

(b) RMS supply current ( $I_s$ ) is rms of discontinuous current in the ac mains as:



(Refer Slide Time: 06:21)

$$I_s = \left[ \frac{1}{\pi R^2} \left\{ (0.5V_{sm}^2 + E^2)(\pi - 2\alpha) + 0.5V_{sm}^2 \sin 2\alpha - 4V_{sm}E \cos \alpha \right\} \right]^{1/2}$$

$$= 52.563 \text{ A}$$

(c) Crest Factor of supply current,  $CF = I_{\text{peak}}/I_{\text{rms}} = I_{\text{peak}}/I_s = 1.66725$


(d) Distortion Factor,  $DF = I_{s1}/I_s = 49.926/52.563 = 0.950$

(e) Displacement factor =  $\cos \theta_1 = 1$

(f) Power Factor,  $PF = P/(V_s I_s) = 0.950$

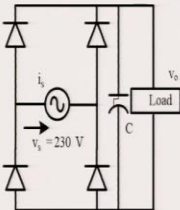
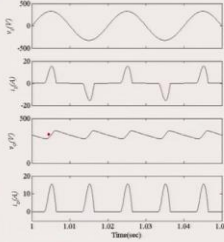

(g) Total Harmonic Distortion (THD) of ac current

$$= \frac{\sqrt{I_s^2 - I_{s1}^2}}{I_{s1}} = \frac{\sqrt{52.563^2 - 49.926^2}}{49.926}$$

$$= 0.329 = 32.928\%$$


(Refer Slide Time: 07:50)

**Q3.** A single-phase diode bridge rectifier (shown in Fig in below) is drawing ac current at 0.97 displacement factor and THD of ac current is 60 percent. It is drawing 2000 W from at 230V, 50Hz ac source and crest factor is 3 of ac current. Calculate (a) power-factor, (b) rms current, and (c) peak current of ac mains.

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.

(Refer Slide Time: 08:59)


**Solution:** Given that,  $V_s = 230\text{V}$ ,  $f=50\text{ Hz}$ , THD of  $i_s=60\%$ ,  $P=2000\text{W}$ , Displacement factor,  $\text{DPF}=\cos \theta_1=0.97$ , Crest factor,  $\text{CF}=3$

Distortion Factor,  $\text{DF}=\frac{1}{\sqrt{1+\text{THD}^2}}=0.857$

(a) Power-Factor,  $\text{PF}=\text{DPF}*\text{DF}=0.97*0.857493=0.832$

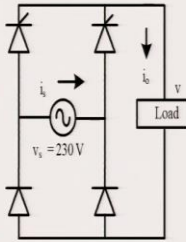
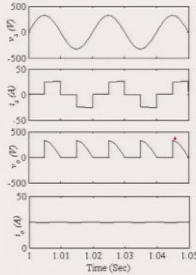

(b) Supply rms current,  $I_s=\frac{P}{(V_s*\text{PF})}=\frac{2000}{(230*0.832)}=10.454\text{ A}$

(c) The peak current of ac mains,  $I_{\text{peak}}=\text{CF}*I_s=3*10.454=31.363\text{ A}$



(Refer Slide Time: 10:29)

**Q.4** Consider single-phase semi-controlled bridge converter (shown in Fig.) with sinusoidal input supply  $V_s$  of 230V, 50 Hz and constant DC load current of 20A. (a) Calculate DF, DPF, PF, %THD of the supply current for  $V_o=0.5*V_{\text{dc0}}$  where  $V_{\text{dc0}}$  is the DC output at  $\alpha=0^\circ$ . (b) Repeat part a for a fully controlled bridge converter.

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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**Solution:** Given that,  $V_s = 230\text{ V}$ ,  $f = 50\text{ Hz}$ ,  $I_o = 20\text{ A}$

(a) In **single-phase semi-controlled bridge converter**, the waveform of the supply current ( $I_s$ ) is from firing angle  $\alpha$  to  $180^\circ$  with the amplitude of dc link current ( $I_o$ ).

If  $V_o = 0.5 V_{dc0}$  where  $V_{dc0}$  is the dc output at  $\alpha = 0^\circ$ , then  $\alpha = 90^\circ$   
 $[V_o = 0.5 V_{dc0} (1 + \cos \alpha)]$

The rms supply current,  $I_s = I_o \sqrt{(\pi - \alpha) / \pi} = I_o / \sqrt{2} = 14.142\text{ A}$


The fundamental rms supply current,  
 $I_{s1} = 0.9 I_o \cos(\alpha/2) = 0.9 I_o \cos(\alpha/2) = 0.9 I_o / \sqrt{2} = 12.728\text{ A}$

Displacement factor,  $\text{DPF} = \cos \theta_1 = \cos(\alpha/2) = 1/\sqrt{2} = 0.7071$

Distortion Factor,  $\text{DF} = 1/\sqrt{(1 + \text{THD}^2)} = 0.90$

Power-Factor,  $\text{PF} = \text{DPF} * \text{DF} = 0.9 * 0.7071 = 0.63639$

Total Harmonic Distortion (THD) of ac current  
 $= \sqrt{(I_s^2 - I_{s1}^2)} / I_{s1} = 0.4843 = 48.43\%$



(Refer Slide Time: 12:57)

(b) In **single-phase fully controlled bridge converter**, the waveform of the supply current ( $I_s$ ) is from firing angle  $\alpha$  to  $(\pi + \alpha)$  with the amplitude of dc link current ( $I_o$ ).

If  $V_o = 0.5 V_{dc0}$  where  $V_{dc0}$  is the dc output at  $\alpha = 0^\circ$ , then  $\alpha = 60^\circ$ ,  
 $[V_o = V_{dc0} \cos \alpha]$

The rms supply current,  $I_s = I_o = 20\text{ A}$

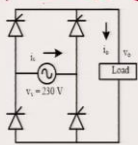
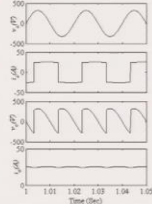

The fundamental rms supply current,  $I_{s1} = 0.9 I_o = 18\text{ A}$

Displacement factor,  $\text{DPF} = \cos \theta_1 = \cos(\alpha) = 1/2 = 0.5$

Distortion Factor,  $\text{DF} = 1/\sqrt{(1 + \text{THD}^2)} = 0.90$

Power-Factor,  $\text{PF} = \text{DPF} * \text{DF} = 0.9 * 0.5 = 0.45$

Total Harmonic Distortion (THD) of ac current  
 $= \sqrt{(I_s^2 - I_{s1}^2)} / I_{s1} = 0.4843 = 48.43\%$

(Refer Slide Time: 14:25)

Q.5 A single-phase fully controlled bridge converter (shown in Fig.) is used as a line commutated inverter (LCI) to feed power from a battery with 180 V and an internal resistance of 0.2 ohm. The supply rms voltage is 220V and sufficient inductance is included in the output circuit to maintain the current virtually constant at 10A. Determine the required delay angle ( $\alpha$ ), distortion factor (DF), displacement factor (DPF), total harmonic distortion of ac source current (THD<sub>i</sub>), crest factor of ac source current (CF), the power factor (PF), ac source rms current ( $I_s$ ).

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Coming to another example. A single-phase fully controlled bridge converter shown in this figure is used as a line commutated 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.

(Refer Slide Time: 15:42)

**Solution :** Given that,  $V_s = 220 \text{ V}$ ,  $f = 50 \text{ Hz}$ ,  $I_o = 10 \text{ A}$ ,  $E = 180 \text{ V}$ ,  $R_{dc} = 0.2 \Omega$ .

Supply rms current,  $I_s = I_o = 10 \text{ A}$

The rms fundamental current,  $I_{s1} = 0.9 I_o = 9 \text{ A}$

The average output voltage,  $V_o = (2\sqrt{2}/\pi) V_s \cos \alpha = 0.9 V_s \cos \alpha$   
 $= -(E - I_o R_{dc}) = -(180 - 10 * 0.2) = -178 \text{ V}$ ,  $\alpha = 154.03^\circ$


Distortion Factor,  $DF = 1/\sqrt{(1+THD^2)} = 0.90$

Displacement factor,  $DPF = \cos \theta_1 = \cos \alpha = \cos 154.03^\circ = -0.899$

Power-Factor,  $PF = DPF * DF = 0.9 * 0.899 = 0.8091$

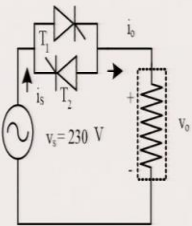
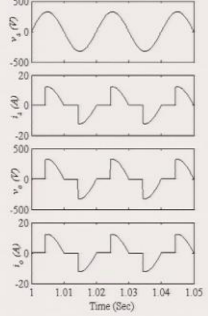

Total Harmonic Distortion (THD) of ac current  
 $= \sqrt{(I_s^2 - I_{s1}^2)}/I_{s1} = 0.4843 = 48.43\%$

Crest Factor of supply current,  $CF = I_{peak}/I_{rms} = I_{peak}/I_s = 1.0$



(Refer Slide Time: 17:13)

Q.6 A single-phase ac voltage controller (shown in Fig.) is used to control the heating load of a maximum power of 3 kW fed from single-phase ac mains of 230 V, 50 Hz. Its power is to be controlled to deliver 1 kW. Calculate (a) load resistance, (b) rms voltage across the load, (c) supply rms current, (d) supply power factor.


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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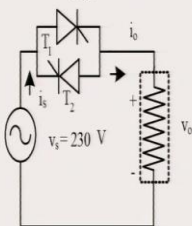
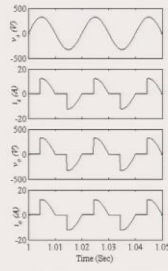

**Solution:** Given that,  $V_s = 230$  V,  $f=50$  Hz,  $P_{\max}=3$  kW,  $P=1$  kW.

1. The load resistance,  $R=V_s^2/P_{\max}=17.633 \Omega$
2. The rms voltage across the load,  $V_{ls}=I_s R= \sqrt{(P \cdot R)}$   
 $=132.789$  V
3. The supply rms current,  $I_s=\sqrt{(P/R)}=7.531$  A
4. The supply power factor,  $PF=P/(V_s I_s)=0.577$



(Refer Slide Time: 18:42)

Q.7 A single-phase ac voltage controller (shown in Fig.) has a resistive load of 10 ohms. The input voltage is 230V rms at 50Hz. The delay angle of thyristors is  $\alpha=100^\circ$ . Calculate (a) rms load voltage, (b) power consumed, (c) displacement factor (DPF), (d) distortion factor (DF), (e) total harmonic distortion of ac source current (THD<sub>i</sub>), (f) power factor (PF), (g) crest factor of ac source current (CF), and (h) ac source rms current ( $I_s$ ).

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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**Solution:** Given that, supply rms voltage,  $V_s = 230$  V, frequency of the supply  $f=50$  Hz,  $R = 10 \Omega$ ,  $\alpha = 100^\circ$ .

In a single-phase, phase controlled ac controller, the waveform of the supply current ( $I_s$ ) has a value of  $v_s/R$  from angle  $\alpha$  to  $\pi$ .  $V_{sm}=230 \sqrt{2}=325.27$  V


AC mains RMS current,  
 $I_s = V_{sm} \left[ \frac{1}{2\pi R} \right] \left\{ (\pi - \alpha) + \sin 2\alpha / 2 \right\}^{1/2} = 14.363$  A

Fundamental RMS current  
 $I_{s1} = V_{sm} / (2\pi R \sqrt{2}) \left[ (\cos 2\alpha - 1)^2 + \{\sin 2\alpha + 2(\pi - \alpha)\}^2 \right]^{1/2} = 11.44$  A

$\theta_1 = \tan^{-1} \left[ (\cos 2\alpha - 1) / \{\sin 2\alpha + 2(\pi - \alpha)\} \right] = 38.3656^\circ$

Fundamental active power drawn by the load,  
 $P_1 = V_s I_{s1} \cos \theta_1 = 2062.957$  W

Fundamental reactive power drawn by the load,  
 $Q_1 = V_s I_{s1} \sin \theta_1 = 1633.125$  VAR



(Refer Slide Time: 20:31)

(a) RMS load voltage  
 $V_{rms} = V_{sm} \left[ \frac{1}{2\pi} \right] \left\{ (\pi - \alpha) + \sin 2\alpha / 2 \right\}^{1/2} = 143.63$  V

(b) Active power drawn by the load,  
 $P_1 = V_s I_{s1} \cos \theta_1 = 2062.957$  W

(c) Displacement factor,  $DPF = \cos \theta_1 = I_{s1a} / I_{s1} = 0.784$

(d) Distortion Factor,  $DF = I_{s1} / I_s = 0.79649$


(e) Total harmonic distortion of ac source current  
 $(THD)_i = \sqrt{\left\{ \frac{1}{DF^2} - 1 \right\}} = 75.91\%$

(f) Power factor (PF) =  $DPF * DF = 0.62445$

Peak supply current,  $I_{peak} = V_{sm} \sin \alpha / R = 32.03$  A


(g) Crest factor of the supply current,  $CF = I_{peak} / I_s = 2.23$

(h) AC mains RMS current,  
 $I_s = V_{sm} \left[ \frac{1}{2\pi} \right] \left\{ (\pi - \alpha) + \sin 2\alpha / 2 \right\}^{1/2} / R = 14.363$  A



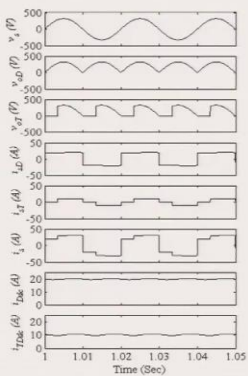
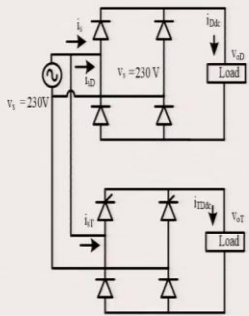
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Q.8 A single-phase, 230V, 50 Hz supply system is feeding a set of nonlinear loads, which consists of a semi-controlled bridge and a diode bridge rectifier connected in parallel (shown in Fig.). The diode bridge converter is drawing 10 A constant dc 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), (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.

(Refer Slide Time: 23:09)

**Solution:** Given that,  $V_s = 230$  V,  $f=50$  Hz.  
 The diode bridge converter is drawing 10 A constant dc current.  
 The thyristor-bridge AC-DC converter is drawing 15 A constant dc current at  $60^\circ$  firing angle of its thyristors.


**In single-phase diode bridge converter,**  
 $I_{LD} = I_{Ddc} = 10$  A  
 $I_{LD1} = (2\sqrt{2}/\pi) I_{Ddc} = 0.9 I_{Ddc} = 9$  A.  
 Moreover, active component ac current of the diode converter is as,  $I_{LD1a} = I_{LD1} = 9$  A.

**In single-phase semi-controlled bridge converter,**  
 The rms of ac current,  $I_{TD} = I_{TDc} \sqrt{((\pi-\alpha)/\pi)} = 12.247$  A  
 RMS of fundamental of supply current,  
 $I_{TD1} = 0.9 I_{TDc} \cos(\alpha/2) = 11.691$  A  
 Active power component of ac current in semi-controlled converter,  $I_{TD1a} = I_{TD1} \cos \theta_1 = I_{TD1} \cos(\alpha/2) = 10.125$  A  
 Reactive power component of ac current in semi-controlled converter,  $I_{TD1r} = I_{TD1} \sin \theta_1 = I_{TD1} \sin \alpha/2 = 5.846$  A



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Therefore total rms active power component of ac current of the load is as,  $I_{s1a} = I_{LD1a} + I_{TD1a} = 19.125$  A.  
 Therefore total rms reactive power component of ac current of the load is as,  $I_{s1r} = I_{LD1r} + I_{TD1r} = 5.846$  A.  
 Active power consumed,  $P = V_s I_{s1a} = 4398.750$  W.  
 Reactive power drawn,  $Q = V_s I_{s1r} = 1344.504$  VAR.  
 The displacement factor (DPF),  
 $\cos \theta_1 = P/S = P/\sqrt{(P^2+Q^2)} = 4398.750/4599.64 = 0.956$ .  
 The distortion factor (DF) is computed by computing rms current ( $I_s$ ) and fundamental rms current ( $I_{s1}$ ) of the composite load as.  
 The ac current of diode rectifier is square wave with unity displacement factor. However, ac current of the thyristor bridge converter is also square wave but phase shifted by firing angle,  $\alpha = 60^\circ$ . The rms value of supply current will be rms value of combined load current consisting diode and thyristor bridge converters.



(Refer Slide Time: 25:04)

Therefore, rms current of the composite load is computed with the half cycle integration as.

$$I_s = \sqrt{\left(\frac{1}{\pi}\right) \left\{ \int_0^{\pi} (10)^2 d\theta + \int_{\pi}^{2\pi} (10+15)^2 d\theta \right\}} = 21.213A$$

The rms fundamental current of the composite load is computed with the half cycle integration as.

$$I_{s1} = S/V = \{\sqrt{P^2 + Q^2}\} / V_s = 4599.64 / 230 = 20 A.$$


The distortion factor (DF) =  $I_{s1} / I_s = 0.943$ .

(e) The total harmonic distortion of ac source current (THD)  
 $= \sqrt{(I_s^2 - I_{s1}^2)} / I_{s1} = 0.353 * 100 = 35.3\%$

(f) The power factor (PF) = DPF \* DF =  $0.956 * 0.943 = 0.902$ .

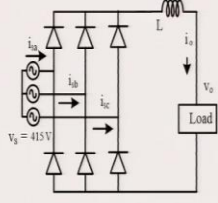
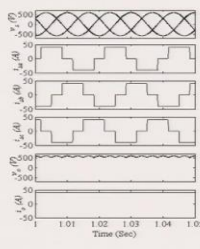

(g) The crest factor of ac source current (CF)  
 $= I_{speak} / I_s = (10+15) / 21.213 = 1.179$ .

(h) The ac source rms current ( $I_s$ ) =

$$I_s = \sqrt{\left(\frac{1}{\pi}\right) \left\{ \int_0^{\pi} (10)^2 d\theta + \int_{\pi}^{2\pi} (10+15)^2 d\theta \right\}} = 21.213A$$


(Refer Slide Time: 26:01)

Q.9 An uncontrolled three-phase bridge rectifier (shown in Fig.) is fed by a line voltage of 415 V, 50 Hz. If a continuous constant load current is of 30A in RL load, calculate (a) the mean dc load voltage, (b) load resistance, (c) load power, (d) rms ac mains current, (e) DF, (f) DPF, (g) PF, and (h) THD of the supply current.






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.

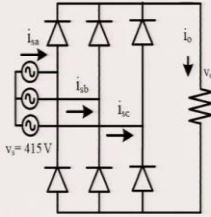
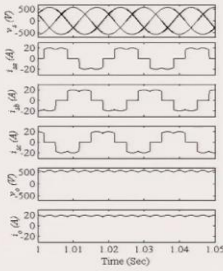

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**Solution:** Given that,  $V_s=415/\sqrt{3}=239.6$  V,  $f=50$  Hz,  $I_o=30$ A.  
 The rms of quasi-square wave load current,  $I_s=I_o\sqrt{(2/3)}=24.495$  A  
 Moreover, the rms of fundamental component of quasi-square wave,  $I_{s1}=\{(\sqrt{6})/\pi\}I_o=23.391$  A  
 The active power drawn by the load,  $P=3V_sI_{s1}\cos\theta_1=16.813$  kW  
 (a) Average output dc voltage,  $V_o=3\sqrt{3}\sqrt{2}V_s/\pi=560.446$  V  
 (b)  $R=V_o/I_o=560.446/30=18.682\Omega$   
 (c) Load power= $3V_sI_{s1}\cos\theta_1=V_oI_o=16.813$  kW  
 (d) The rms of quasi-square wave load current,  $I_s=I_o\sqrt{(2/3)}=24.495$  A  
 (e) Distortion Factor,  $DF=I_{s1}/I_s=3/\pi=0.9549$   
 (f) Displacement factor,  $DPF=\cos\theta_1=\cos\alpha=\cos0^\circ=1.0$   
 (g) Power-Factor,  $PF=DPF*DF=0.9549*1=0.9549$   
 (h) Total Harmonic Distortion (THD) of ac current  
 $=\sqrt{(I_s^2-I_{s1}^2)}/I_{s1}=0.3108=31.08\%$



(Refer Slide Time: 28:18)

Q.10 A three-phase nonlinear load (shown in Fig.) is supplied from a three-phase 415V, 50 Hz, and it consists of a diode bridge converter feeding resistive load of 30 ohms. Calculate (a) the fundamental active power drawn by the load, (b) power-factor, (c) rms supply current, (d) distortion factor, (e) fundamental rms supply current, (f) peak current of ac mains, and (g) total harmonic distortion of ac source current (THD<sub>I</sub>).


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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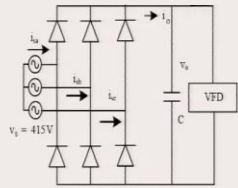
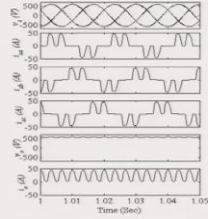

**Solution:** Given that, Supply rms phase voltage,  $V_s=415/\sqrt{3}=239.6$  V,  $V_{sm}=239.6\sqrt{2}$  V=338.85 V, Frequency of the supply  $f=50$  Hz,  $R=30\Omega$ .

(a) The fundamental active power drawn by the load,  
 (b)  $P=3\{V_s^2/(2\pi R)\}[(2\pi+3\sqrt{3})]=10.48843$  kW  
 (b) Power-factor,  $PF=P/(3V_s I_s)=0.955577$   
 (c) The rms of supply current,  
 $I_s=\{V_s/(R)\}[(2\pi+3\sqrt{3})/\pi]^{1/2}=15.2668$  A  
 (d) The distortion factor of the supply current,  
 $DF=I_{s1}/I_s=0.955577$   
 (e) The rms of fundamental component of supply current,  
 $I_{s1}=\{V_s/(2R\pi)\}(2\pi+3\sqrt{3})=14.59158$  A  
 (f) The peak current of ac mains,  
 $I_{peak}=V_{peak}/R=\sqrt{2}\cdot 415/30=19.56$  A  
 (g) The total harmonic distortion of ac source current  
 $(THD)_I=\sqrt{\{(1/DF)^2-1\}}=30.77\%$



(Refer Slide Time: 29:50)

Q.11 A three-phase nonlinear load (shown in Fig.) consisting of a 415V, 50Hz, three-phase diode bridge rectifier with very large capacitive filter at its dc bus is supplying a dc power to a VSI fed three-phase induction motor variable frequency drive (VFD) at 540 V dc with a total circuit resistance of 1 ohm. Calculate (a) the average dc current, (b) rms ac supply current, (c) rms fundamental supply current, (d) input active power, (e) THD of ac mains current, (f) displacement factor, (g) distortion factor, (h) power factor, and (i) crest factor of the supply current.

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.


(Refer Slide Time: 30:44)

**Solution:** Given that, supply voltage,  $V_s = 415/\sqrt{3} = 239.6V$ , frequency of the supply  $f = 50$  Hz, series  $R_{dc} = 1\Omega$ ,  $E = 540V$ .

The three-phase diode bridge rectifier with very large capacitive filter at its dc bus behaves as a series resistance with back emf load (RE load). The ac supply current flows with two pulses in each half cycle from angle  $(\theta_1)$  to  $(\theta_2)$  and  $(\theta_3)$  to  $(\theta_4)$  when segments of ac line voltages are equal or greater than  $E$  (540V) and it is discontinuous. At angle  $(\theta_1)$  the ac supply current increases and it decreases and ceases to zero at  $(\theta_2)$  when ac voltage reduces to  $E$ . Similar conduction for second pulse of this ac supply current is from  $(\theta_3)$  to  $(\theta_4)$ . These angles are computed as.

$\alpha = \sin^{-1}(E/V_{s_{lm}}) = \sin^{-1}\{540/(\sqrt{2} \cdot 415)\} = 66.94^\circ$ ,  $\beta = \pi - \alpha = 113.06^\circ$ ,  
the conduction angle,  $\mu = \beta - \alpha = 46.12^\circ$ .

However, these two angles for first pulse will be on reference of a first line voltage. The second pulse is on the segment of second line voltage as,  $\gamma = (\pi/3) + \alpha = 126.94^\circ$  and  $\delta = (4\pi/3) - \gamma = 173.06^\circ$ ,  
the conduction angle  $= \delta - \gamma = 46.12^\circ$ .



(Refer Slide Time: 32:30)

However, these angles are as,  
 $\theta_1 = 66.94^\circ - 30^\circ = 36.94^\circ$ ,  $\theta_2 = 83.06^\circ$ ,  $\theta_3 = 96.94^\circ$ ,  $\theta_4 = 143.06^\circ$ .


Since there are six pulses for charging the dc bus capacitor in one cycle and all six pulses are identical, thus dc bus average current is computed as.

$I_o = \{6/(2\pi R)\}(2V_{s_{lm}} \cos \alpha + 2E\alpha - \pi E) = 23.9682A$   
(Keeping,  $R = 1\Omega$ ,  $V_{s_{lm}} = \sqrt{2} \cdot 415V$ ,  $E = 540V$ )

Since the ac input current with couple of pulses in each cycle is an odd and quarter cycle and half cycle symmetry, the rms value The RMS supply current ( $I_s$ ) is rms of discontinuous current in the ac mains as:

$$I_s = \left[ \frac{4}{2\pi R^2} \int_{\theta_1}^{\theta_2} \{V_{s_{lm}} \sin(\theta + 30^\circ) - E\} d\theta \right]^{1/2} = 24.47A$$

The input power drawn from ac mains,  
 $P = I_s^2 R + E I_o = 13541.50W$





(Refer Slide Time: 33:22)

Fundamental RMS current from ac mains,  
 $I_{s1} = P / (3 \cdot V_s) = 18.839A$   
 Supply ac peak current,  $I_{peak} = (V_{s1m} - E) / R = 46.89A$ .

(a) The average dc current,  
 $I_o = \{6 / (2\pi R)\} (2V_{s1m} \cos \alpha + 2E - \alpha - \pi E) = 23.9682A$  (Keeping,  
 $R = 1\Omega, V_{s1m} = \sqrt{2} \cdot 415V, E = 540V$ )

(b) The rms ac supply current,  


$$I_s = \left[ \frac{4}{2\pi R^2} \int_{\theta_1}^{\theta_2} \{V_{s1m} \sin(\theta + 30^\circ) - E\} d\theta \right]^{1/2} = 24.47A$$

(c) The rms fundamental supply current,  $I_{s1} = P / (3 \cdot V_s) = 18.839A$ .

(d) The input power drawn from ac mains,  
 $P = I_s^2 R + E I_o = 13541.50W$

(e) Total Harmonic Distortion (THD) of ac current=  
 $\sqrt{(I_s^2 - I_{s1}^2)} / I_{s1} = 82.894\%$

(f) Displacement factor =  $\cos \psi_1 = 1$  (since fundamental supply current is in phase with supply voltage,  $\psi_1 = 0^\circ$ )




(Refer Slide Time: 34:11)

g) Distortion Factor,  $DF = \text{Fundamental supply rms current} / \text{supply rms current} = I_{s1} / I_s = 0.76988$ .

(h) Power Factor,  $PF = P / (3V_s I_s) = 0.76988$ .

(i) Crest Factor of supply current,  
 $CF = \text{Supply Peak Current} / \text{Supply RMS current}$   
 $= I_{peak} / I_{rms} = I_{peak} / I_s = 1.9166$ .



(Refer Slide Time: 34:41)

Q.12 Consider three-phase semi-controlled bridge converter (shown in Fig.) with sinusoidal input line supply voltage of 415V, 50 Hz, and constant dc load current of 50A. (a) Calculate DF, DPF, PF, %THD for  $V_o=0.75*V_{d0}$  where  $V_{d0}$  is the dc output at  $\alpha=0^\circ$ . (b) Repeat part a for a fully controlled bridge converter (shown in Fig.).

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.

(Refer Slide Time: 35:19)

**Solution:** Given that, supply rms voltage,  $V_s=415/\sqrt{3}=239.6V$ , supply frequency  $f=50Hz$ ,  $I_o=50A$

(a) In three-phase semi-controlled bridge converter, the waveform of the supply current ( $I_s$ ) is from firing angle  $\alpha$  to  $180^\circ$  with the amplitude of dc link current ( $I_o$ ).

If  $V_o=0.75*V_{d0}$  where  $V_{d0}$  is the dc output at  $\alpha=0^\circ$ , then firing angle,  $\alpha =60^\circ$  ( $V_o = (3*\sqrt{3}*2* V_s/2\pi)*(1+ \cos\alpha)$  for the three phase semi-controlled bridge converter)

The rms supply current,  $I_s = I_o\sqrt{\{(\pi -\alpha) / \pi\}} = I_o\sqrt{2/3}=40.825A$

The fundamental rms supply current,  $I_{s1}=I_o\sqrt{6/\pi} * \cos(\alpha/2)=33.73A$

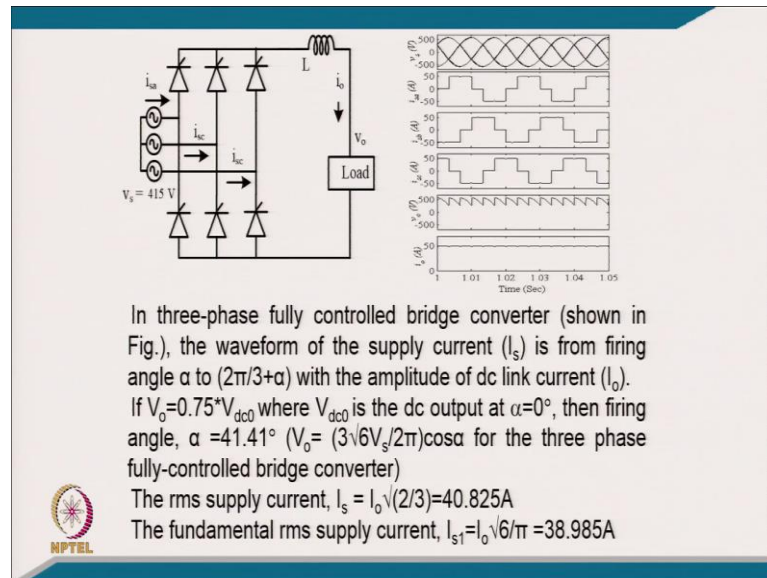
Displacement factor,  $DPF=\cos \theta_1= \cos(\alpha/2)=0.866$

Distortion Factor,  $DF= I_{s1}/I_s = \sqrt{6/\{\pi(\pi -\alpha)\}}*\cos(\alpha/2)=0.826968$

Power-Factor,  $PF=DPF*DF=0.71615$

Total Harmonic Distortion (THD) of ac current,  $THD=\{(1/DF^2)-1\}^{1/2}=68.006\%$

(Refer Slide Time: 36:26)



(Refer Slide Time: 37:14)

Displacement factor,  $DPF=\cos \theta_1 = \cos(\alpha)=0.75$

Distortion Factor,  $DF= I_{s1}/I_s = 3/\pi = 0.9549$


Power-Factor,  $PF=DPF \cdot DF=0.716$

Total Harmonic Distortion (THD) of ac current

$$=\sqrt{(I_s^2 - I_{s1}^2)}/I_{s1}=0.3108=31.08\%$$

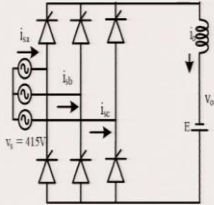
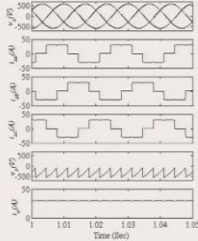
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Q.13 A three-phase fully controlled bridge converter (shown in Fig.) is used as a line commutated inverter (LCI) to feed power from a battery with 360V and an internal resistance of 0.2 ohm. The supply rms line voltage is 415V, 50 Hz and sufficient inductance is included in the output circuit to maintain the current virtually constant at 30A. Determine the required delay angle ( $\alpha$ ), distortion factor (DF), displacement factor (DPF), total harmonic distortion of ac source current (THD<sub>i</sub>), crest factor of ac source current (CF), the power factor (PF), and ac source rms current ( $I_s$ ).




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.

(Refer Slide Time: 38:15)

**Solution:** Given that, Supply rms voltage,  $V_s = 415/\sqrt{3} = 239.6V$ , supply frequency  $f = 50\text{Hz}$ ,  $I_o = 30A$ ,  $E = 360V$ ,  $R_{dc} = 0.2\Omega$ .  
 In three-phase thyristor bridge converter, the waveform of the supply current ( $I_s$ ) is a quasi-square wave with the amplitude of dc link current ( $I_o$ ).  
 Therefore,  $I_s = \sqrt{(2/3)} I_o = 0.81649 I_o = 24.49 A$   
 Moreover, the rms of fundamental component of quasi-square wave,  $I_{s1} = \{(\sqrt{6})/\pi\} I_o = 23.39 A$



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The average output voltage,  $V_o = (3\sqrt{3}\sqrt{2}V_s/\pi) \cos\alpha - (E - I_o R_{dc})$   
 $= -(360 - 30 \times 0.2) = -354V, \alpha = 129.1712^\circ$

Distortion Factor,  $DF = I_{s1}/I_s = 3/\pi = 0.9549$


Displacement factor,  $DPF = \cos\theta_1$   
 $= \cos\alpha = \cos 129.1712^\circ = 0.6316397$

Total Harmonic Distortion (THD) of ac current  
 $= \sqrt{(I_s^2 - I_{s1}^2)}/I_{s1} = 0.3108 = 31.08\%$

Crest factor of ac source current,  
 $CF = I_{peak}/I_{rms} = I_o / \{[\sqrt{(2/3)}]I_o\} = \sqrt{(3/2)} = 1.22474$

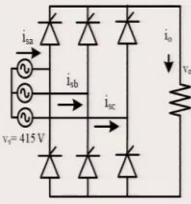
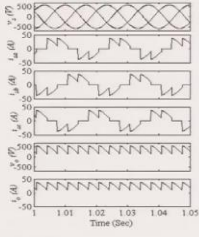

Power-Factor,  $PF = DPF \times DF = 0.9549 \times 0.6316397 = 0.60315$

The ac source rms current,  $I_s = \{[\sqrt{(2/3)}]I_o\} = 0.81649I_o = 19.8147 A$



(Refer Slide Time: 40:01)

Q.14 A three-phase nonlinear load (shown in Fig.) is supplied from a three-phase 415V, 50 Hz, and it consists of a thyristor bridge converter feeding a resistive load of 15 ohms at  $45^\circ$  firing angle of its thyristors. Calculate (a) fundamental active power drawn by the load, (b) fundamental reactive power drawn by the load, (c) power-factor, (d) rms supply current, (e) distortion factor, (f) fundamental rms supply current, (g) peak current of ac mains, and (h) total harmonic distortion of ac source current (THD<sub>i</sub>).

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.

(Refer Slide Time: 40:37)

**Solution:** Given that, supply rms voltage,  $V_s = 415/\sqrt{3} = 239.6$  V, frequency of supply  $f = 50$  Hz,  $R = 15\Omega$ ,  $\alpha = 45^\circ$ .

In a three-phase thyristor bridge converter, the waveform of the supply current ( $I_s$ ) is decided by load resistance ( $R$ ) and firing angle ( $\alpha$ ) as:


Therefore,  $I_s = \{V_s/(R)\} \{[(2\pi + 3\sqrt{3}\cos 2\alpha)]/\pi\}^{1/2} = 22.589$  A

RMS of fundamental component of load current,  
 $I_{s1} = \{(V_s/(2\pi R)) \{[(3\sqrt{3}\sin 2\alpha)^2 + (2\pi + 3\sqrt{3}\cos 2\alpha)^2]\}^{1/2}\} = 20.725$  A

Active power component of supply current  
 $I_{s1a} = P/(3V_s) = 15.97338$  A

Displacement factor,  $DPF = \cos \theta_1 = I_{s1a}/I_{s1} = 0.77073$ ;  
 $\sin \theta_1 = \sqrt{(1 - DPF^2)} = 0.63716$

(a) The fundamental active power drawn by the load,  
 (b)  $P = 3(V_s^2/(2\pi R)) \{[(2\pi + 3\sqrt{3}\cos 2\alpha)]\} = 11481.667$  kW  
 (b) Fundamental reactive power drawn by the load,  
 $Q_1 = 3V_s I_{s1} \sin \theta_1 = 9.491885$  kVAR  
 (c) Power-factor,  $PF = DF * DPF = 0.70711$




(Refer Slide Time: 41:48)

(e) The distortion factor,  $DF = I_{s1}/I_s = 0.91745$

(f) The fundamental rms supply current,  
 $I_{s1} = \{(V_s/(\pi R\sqrt{2})) \{[(3\sqrt{3}\sin 2\alpha)^2 + (2\pi + 3\sqrt{3}\cos 2\alpha)^2]\}^{1/2}\} = 20.725$  A


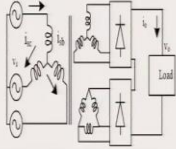
(g) The peak current of ac mains,  
 $I_{peak} = V_{peak}/R = \sqrt{2} * 415 * \sin(\pi/3 + \alpha)/15 = 37.793$  A

(h) Total harmonic distortion of ac source current  
 $(THD)_1 = \sqrt{\{(1/DF^2) - 1\}} = 43.3638\%$



(Refer Slide Time: 42:10)

Q.15 A three-phase nonlinear load (shown in Fig.) is supplied from a three-phase 415V, 50 Hz, having a 12-pulse diode bridge converter with 200A constant dc current. It consists of an ideal transformer with single primary star connected winding and two secondary windings connected in star and delta with same line voltages and unity turns ratios to provide  $30^\circ$  phase shift between two sets of three-phase output voltages. Two 6-pulse diode bridges are connected in series to provide 12-pulse ac-dc converter. Calculate (a) the fundamental active power drawn by the load, (b) power-factor, (c) rms supply current, (d) distortion factor, (e) fundamental rms supply current, (f) peak current of ac mains, and (g) total harmonic distortion of ac source current (THD).



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.

(Refer Slide Time: 42:55)

**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  $\pi/6$  angle (from  $0^\circ$  to  $\pi/6$ ) and input current magnitude of  $(I_o/\sqrt{3})$ , (ii) second step of  $\pi/6$  angle (from  $\pi/6$  to  $\pi/3$ ) and input current magnitude of  $\{I_o(1+1/\sqrt{3})\}$ , (iii) third step of  $\pi/6$  angle (from  $\pi/3$  to  $\pi/2$ ) and input current magnitude of  $\{I_o(1+2/\sqrt{3})\}$  and it has all four symmetric segments of such steps.

**NPTEL**

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Therefore, RMS of 12-pulse converter input current,  
 $I_s = I_o \left[ \left( \frac{1}{3} \right) + \left( 1 + \frac{1}{\sqrt{3}} \right)^2 + \left( 1 + \frac{2}{\sqrt{3}} \right)^2 \right]^{1/2} = 1.57735 I_o = 315.47$  A  
 RMS of fundamental component of 12-pulse converter input current,  
 $I_{s1} = \left\{ \frac{2\sqrt{6}}{\pi} \right\} I_o = 1.559393 I_o = 311.879$  A

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

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

(c) RMS of 12-pulse converter input current,  
 $I_s = I_o \left[ \left( \frac{1}{3} \right) + \left( 1 + \frac{1}{\sqrt{3}} \right)^2 + \left( 1 + \frac{2}{\sqrt{3}} \right)^2 \right]^{1/2} = 1.57735 I_o = 315.47$  A

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

(e) RMS of fundamental component of input ac mains current,  
 $I_{s1} = \left\{ \frac{2\sqrt{6}}{\pi} \right\} I_o = 1.559393 I_o = 311.879$  A

(f) The peak current of ac mains,  
 $I_{peak} = \{ I_o (1 + 2/\sqrt{3}) \} = 2.1547 I_o = 430.94$  A


(g) The total harmonic distortion of ac source current  
 $(THDI) = \sqrt{\left\{ \frac{1}{DF^2} - 1 \right\}} = 15.22\%$

**NPTEL**



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Q.16 A three-phase nonlinear load (shown in Fig.) is supplied from a three-phase 415V, 50 Hz, having a 12-pulse thyristor bridge converter with 200 A constant dc current at  $60^\circ$  firing angle of its thyristors. It consists of an ideal transformer with single primary star connected winding and two secondary windings connected in star and delta with same line voltages to provide  $30^\circ$  phase shift between two sets of three-phase output voltages. Two 6-pulse thyristors bridges are connected in series to provide 12-pulse ac-dc converter. Calculate (a) fundamental active power drawn by the load, (b) fundamental reactive power drawn by the load, (c) power-factor, (d) rms supply current, (e) distortion factor, (f) fundamental rms supply current, (g) peak supply current, and (h) total harmonic distortion of supply current (THD).



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

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  $\alpha$  to  $(\alpha + \pi/6)$ } and input current magnitude of  $(I_o/\sqrt{3})$ , (ii) second step of  $\pi/6$  angle {from  $(\alpha + \pi/6)$  to  $(\alpha + \pi/3)$ } and input current magnitude of  $\{I_o(1 + 1/\sqrt{3})\}$ , (iii) third step of  $\pi/6$  angle {from  $(\alpha + \pi/3)$  to  $(\alpha + \pi/2)$ } and input current magnitude of  $\{I_o(1 + 2/\sqrt{3})\}$  and it has all four symmetric segments of such steps.

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Therefore, rms of 12-pulse converter input current,  
 $I_s = I_o [(1/3) + (1 + 1/\sqrt{3})^2 + (1 + 2/\sqrt{3})^2]^{1/2} = 1.57735 I_o = 315.47$  A

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

Active power component of supply current  $I_{s1a} = I_{s1} \cos \theta_1 = I_{s1} \cos \alpha = 311.8786 \cos 60^\circ = 155.9393$  A

(a) The active power drawn by the load,  
 $P = 3V_s I_{s1} \cos \theta_1 = 112.08895$  kW

(b) The fundamental reactive power,  
 $Q_1 = 3V_s I_{s1} \sin \theta_1 = 3V_s I_{s1} \sin \alpha = 194.1437$  kVAR

(c) The Power factor,  $PF = P/(3V_s I_s) = 0.4943069$

(d) RMS of 12-pulse converter input current,  
 $I_s = I_o [(1/3) + (1 + 1/\sqrt{3})^2 + (1 + 2/\sqrt{3})^2]^{1/2} = 1.57735 I_o = 315.47$  A


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

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(f) RMS of fundamental component of input ac mains current,  
 $I_{s1} = \left(\frac{2\sqrt{6}}{\pi}\right) I_o = 1.559393 I_o = 311.8786 \text{ A}$

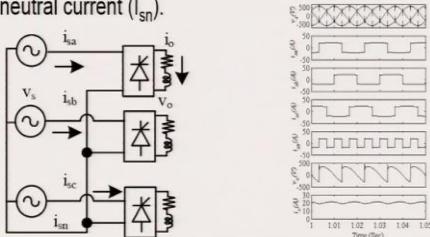

(g) The peak current of ac mains,  
 $I_{\text{peak}} = \left\{ I_o (1 + 2/\sqrt{3}) \right\} = 2.1547 I_o = 430.94 \text{ A}$

(h) The total harmonic distortion of ac source current  
 $(\text{THD}_i) = \sqrt{\left\{ \frac{1}{\text{DF}^2} - 1 \right\}} = 15.22\%$



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**Q.17** In a three-phase, line voltage of 415 V, 50 Hz, 4-wire distribution system, three single-phase loads (connected between phases and neutral) having a single-phase thyristor bridge converter drawing equal 10 A constant dc current at  $45^\circ$  firing angle of its thyristors (shown in Fig.). 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<sub>i</sub>), (f) power factor (PF), (g) crest factor of ac source current (CF), (h) ac source rms current ( $I_s$ ), and (i) neutral current ( $I_{sn}$ ).

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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**Solution:** Given that,  $V_s = 239.6$  V,  $f=50$  Hz,  $I_o = 10$ A,  $\alpha= 45^\circ$ .

$I_s = I_o = 10$  A  
 $I_{s1} = (2\sqrt{2}/\pi) I_o = 0.9 I_o = 9$  A  
RMS Fundamental active power component of load current,  
 $I_{s1a} = I_{s1} \cos\alpha = 6.364$ A


(a) The active power consumed,  $P_1 = 3V_s I_{s1a} = 4574.422$  W  
(b) The reactive power consumed,  $Q_1 = 3V_s I_{s1} \sin\alpha = 4574.422$  VAR  
(c) The displacement factor (DPF) =  $\cos\alpha = 0.707$   
(d) The distortion factor (DF) =  $I_{s1}/I_s = (2\sqrt{2}/\pi) = 0.9$   
(e) The total harmonic distortion of ac source current (THD<sub>i</sub>)  
=  $\sqrt{\{(1/DF^2) - 1\}} = 48.43\%$   
(f) The power factor (PF) =  $(2\sqrt{2}/\pi) \cos\alpha = 0.636$   
(g) The crest factor of ac source current (CF) =  $I_{peak}/I_{rms} = I_o/I_s = 1$   
(h) The ac source rms current ( $I_s$ ) =  $I_o = 10$  A  
(i) The neutral current ( $I_{sn}$ ) =  $10$  A



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### SUMMARY

- Majority of power quality problems are mainly created because of use of nonlinear loads.
- These nonlinear loads draw no sinusoidal current from ac mains which consists of harmonics currents, reactive power component of current, fluctuating current, unbalanced currents etc.
- These nonlinear loads are classified in to different categories considering the severity of the created problems.
- A number of practical examples of these nonlinear loads are given with a view of proper exposure of power quality problems.

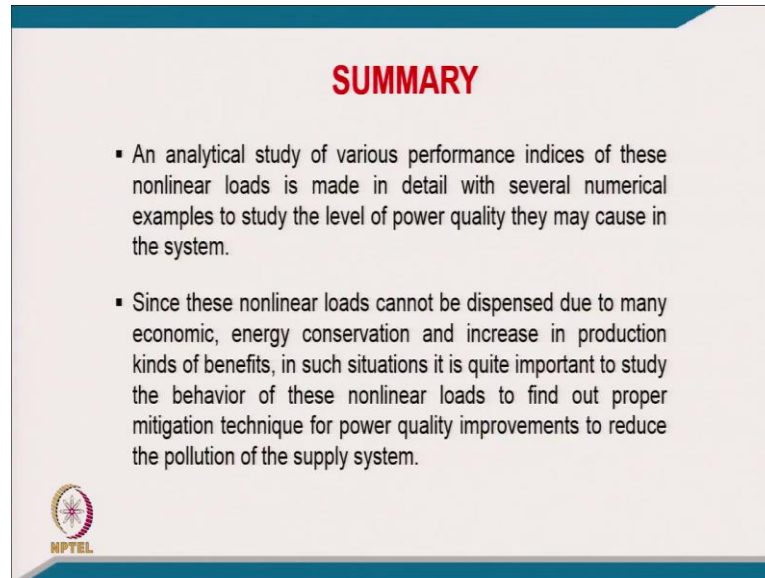


Well, to summarise majority of the power quality problems are mainly created because of the use of non-linear load.

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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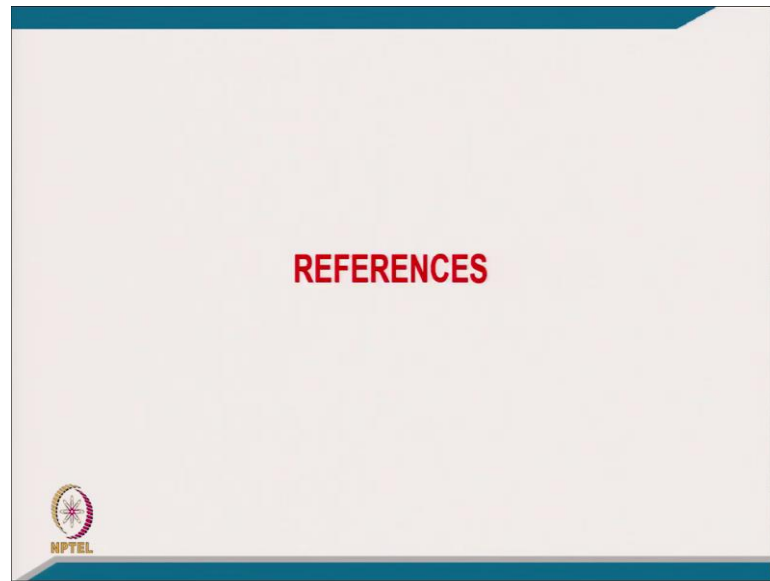
**SUMMARY**

- An analytical study of various performance indices of these nonlinear loads is made in detail with several numerical examples to study the level of power quality they may cause in the system.
- Since these nonlinear loads cannot be dispensed due to many economic, energy conservation and increase in production kinds of benefits, in such situations it is quite important to study the behavior of these nonlinear loads to find out proper mitigation technique for power quality improvements to reduce the pollution of the supply system.

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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.