Department of Electrical Engineering
Indian Institute of Technology Bombay, Powai
EE111 : Introduction to Electrical Engineering
Solution to Assignment 4

1. $V_{ph} = 400/\sqrt{3} = 231$ V
   Load impedance per phase $= 231/30\angle{-30^\circ} = 7.7\angle 30^\circ \Omega$
   Total real power $= \sqrt{3} \times 400 \times 30 \times \cos 30^\circ = 18$ kW
   Total reactive power $= \sqrt{3} \times 400 \times 30 \times \sin 30^\circ = 10.392$ kVAR
   $W_A = V_{AB} I_A \cos(30^\circ + \theta) = 6$ kW
   $W_B = V_{AB} I_A \cos(30^\circ - \theta) = 12$ kW
   Delta Connected Load
   $V_{AB} = 400\angle 0^\circ$, $V_{BC} = 400\angle{-120^\circ}$, $V_{CA} = 400\angle{-240^\circ}$
   $I_{AB} = 400/7.7\angle 30^\circ = 52\angle{-30^\circ} A$, $I_{BC} = 52\angle{-150^\circ} A$, $I_{CA} = 52\angle{-270^\circ} A$
   $I_A = I_{AB} - I_{CA} = 90\angle{-60^\circ}$ A, $I_B = 90\angle{-180^\circ}$ A, $I_C = 90\angle{-300^\circ}$ A
   $W_A = V_{AB} I_A \cos(30^\circ + \theta) = 18$ kW, $W_C = 36$ kW

2. $V_{phase} = V_{L-L} = 400$V.
   Phase current = 20A. Therefore, Line current=$20\sqrt{3}$A.
   Total active power, $P = 3 \times 400 \times 20 \times \cos 40^\circ = 18385.06$ W
   Total reactive power, $Q = 3 \times 400 \times 20 \times \sin 40^\circ = 15426.9$ VAR
   Total VA $= \sqrt{P^2 + Q^2} = 24000$. Source capacity = 24000 VA.
   Wattmeter 1, $W_1 = V_{AC} I_A \cos \angle V_{AC}, I_A$
   Wattmeter 1, $W_2 = V_{BC} I_B \cos \angle V_{BC}, I_B$
   $\angle V_{AC}, I_A = 70^\circ$

$\angle V_{BC}, I_B = 10°$

Therefore, $W_1 = 4739.17$ W and $W_2 = 13645.89$ W.

3. $V_{RY} = 400\angle 0°$, $V_{YB} = 400\angle -120°$, $V_{BR} = 400\angle -240°$

   $I_{RY} = 20000/400 = 50 + j0$ A, $I_{YB} = 30000\angle -120 - 36.86° = 75\angle -156.86°$ A, $I_{BR} = 20000\angle -240 - 53.13° = 50\angle -187°$ A

   $I_R = I_{RY} - I_{BR} = 99.82\angle -3.4°$ A, $I_Y = I_{YB} - I_{RY} = 122.56\angle -166°$ A, $I_B = I_{BR} - I_{YB} = 40.37\angle 61.4°$ A

   $W_1 = V_{RY} I_R \cos\angle(V_{RY}, I_R) = 39857.7$ W

   $W_2 = V_{BY} I_B \cos\angle(V_{BY}, I_B) = 16.14$ kW

   $W_1 + W_2 = 56$ kW

4. Converting delta to star

   $Z_{Yeq} = Z_{delta}/3 = 10 - j53.1\Omega$

   $Z_{eq} = (20 + j37.7)//(10 - j53.1)\Omega = 68.39\angle 9.98°\Omega$

   Line current = phase current = $398/(\sqrt(3) * 68.39) = 3.36$ A

   Power factor = 0.985 lag

   Real Power = $\sqrt{3} * V_L * I_L * \cos\theta = 2.28$ kW

   Reactive Power = $\sqrt{3} * V_L * I_L * \sin\theta = 397.83$ VAR

5. $3V_{ph}I_{ph}\cos\theta = 5000$ kW

   $I_{ph} = 360.8$ A

   Active component = $I\cos\theta = 288.7$ A

   Reactive component = $I\sin\theta = 216.5$ A

   At 0.9 power factor, new output = $5000 * 0.9/0.8 = 5625$ kW

6. $\tan\theta = \sqrt{3}(W_B - W_C)/(W_B + W_C) = 1$, therefore $\theta = 45°$

   $P = \sqrt{3} * V_L * I_L * \cos\theta$

   $I_L = I_{ph} = (836 + 224)/(\sqrt{3} * 400 * \cos 45° = 2.16$ A

   $I_{AN} = V_{AN}/Z$, therefore $Z = 106.95\angle 43°\Omega$

7. Phase voltage $= 208/\sqrt{3} = 120$ V

   $I_A = V_{AN}/Z_A = 12$ A, $I_B = 8\angle{-150°}$ A, $I_B = 12\angle{-210°}$ A

   $I_N = -(I_A + I_B + I_C) = 5.67\angle 159°$ A

   Power input to phase A $= I_A^2 Z_A \cos\theta = 1440$ W

   Power input to phase B $= I_B^2 Z_B \cos\theta = 832$ W

   Power input to phase C $= I_C^2 Z_C \cos\theta = 1247$ W

   Total power $= 3579$ W

8. $Q = P \tan\phi$

   Total P $= 3450$ kW, Total Q$=1137.5$ kW

   $\cos\phi = 0.95$

   $S = \sqrt{P^2 + Q^2} = 3633$ kVA

   Load that the cable can carry at UPF $= 3633$ kW

9. Active power $= 440 \times 40 \times 0.7 = 12320$ W

   Q $= 440 \times 40 \times \sin(\arccos 0.7) = 12569$ VAR

   At 0.9 p.f lag, P remains the same.

   Q supplied by capacitor $=$ 12569 - 12320 $\tan(\arccos 0.7) = 6602$ VAR

   $X_C = V^2/6602$, $C = 108\mu$F

10. Voltage across the lamp at u.p.f $= 500/4 = 125$ V

    Voltage across the choke $= \sqrt{250^2 - 125^2} = 216.5$ V

    $2\pi f L = 216.5/4$; $L = 0.1723$ H

    $S = 250 \times 4 = 1000$ VA; $Q = \sqrt{1000^2 - 500^2} = 866$ VAR

    Q supplied by C $= 866$ VAR; $C = 44\mu$F