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EE361 HW#3

NAME: *SOLUTION*

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Q.1.

The parameters that are used:

```
n = 10;
fs = 50;
R1 = 1.6;
R2 = 16e-3;
L1 = 7e-3;
X1 = L1*2*pi*fs;
L2 = 70e-6;
X2 = L2*2*pi*fs;
Rc = 32e3;
Lm = 14.6;
Xm = Lm*2*pi*fs;
```

Load current vector creation (magnitude)

```
%Insert your code here

Irated = 30e3/220;
Imax = Irated*1.1;
iload = linspace(0,Imax,100);
V2 = 220;
Sload = iload*V2;
V1rated = 2200;
```

At unity pf

```
pf = 1;
Pload1 = Sload*pf;
V2 = 220;
```

$$E_2 = V_2 + I_L(R_2 + jX_2)$$

$$E_1 = nE_2$$

$$Z_m = 1/((1/R_c) - j(1/X_m))$$

$$I_m = E_1/Z_m$$

$$I_m = E_1/Z_m$$

$$I_1 = I_m + I_L/n$$

$$V_1 = I_1(R_1 + jX_1) + E_1$$

$$reg = 100|V_{1mag} - V_{1rated}|/V_{1rated}$$

$$loss = I_{1mag}^2 R_1 + I_{Lmag}^2 R_2 + E_{1mag}^2/R_c$$

$$eff = 100P_{load}/(P_{load} + P_{loss})$$

```
E2 = V2+iload*(R2+j*X2);
E1 = E2*n;
Zm = 1/((1/Rc)-j*(1/Xm));
Im = E1/Zm;
I1 = Im+iload/n;
V1 = I1*(R1+j*X1)+E1;
V1m1 = abs(V1);
I1m1 = abs(I1);

reg1 = 100*abs(V1m1-V1rated)/V1rated;
loss1 = abs(I1).^2*R1+abs(iload).^2*R2+abs(E1).^2/Rc;
eff1 = 100*(Pload1)./(Pload1+loss1);
```

pf = 0.8 lagging

```
pf = 0.8;
Pload2 = Sload*pf;
i2 = iload*0.8-j*iload*0.6;
V2 = 220;
E2 = V2+i2*(R2+j*X2);
E1 = E2*n;
Zm = 1/((1/Rc)-j*(1/Xm));
Im = E1/Zm;
I1 = Im+i2/n;
V1 = I1*(R1+j*X1)+E1;
V1m2 = abs(V1);
I1m2 = abs(I1);

reg2 = 100*abs(V1m2-V1rated)/V1rated;
loss2 = abs(I1).^2*R1+abs(iload).^2*R2+abs(E1).^2/Rc;
eff2 = 100*(Pload2)./(Pload2+loss2);
```

pf = 0.8 lagging

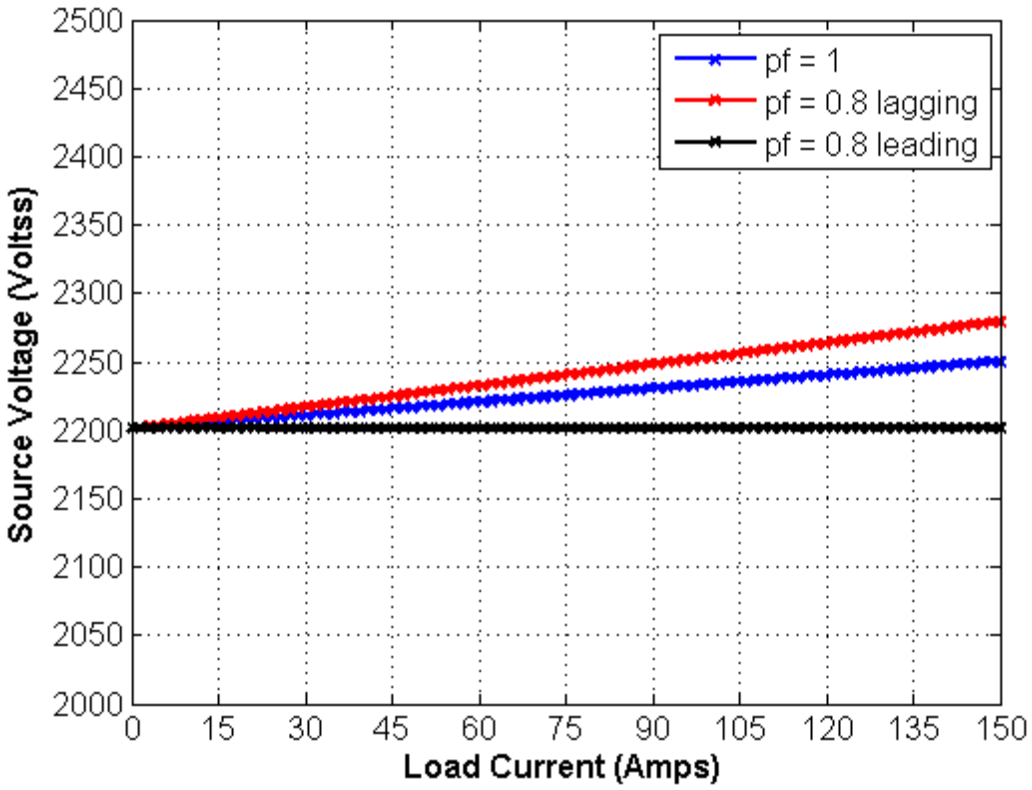
```
pf = 0.8;
Pload3 = Sload*pf;
i2 = iload*0.8+j*iload*0.6;
V2 = 220;
E2 = V2+i2*(R2+j*X2);
E1 = E2*n;
Zm = 1/((1/Rc)-j*(1/Xm));
Im = E1/Zm;
I1 = Im+i2/n;
V1 = I1*(R1+j*X1)+E1;
V1m3 = abs(V1);
I1m3 = abs(I1);

reg3 = 100*abs(V1m3-V1rated)/V1rated;
loss3 = abs(I1).^2*R1+abs(iload).^2*R2+abs(E1).^2/Rc;
eff3 = 100*(Pload3)./(Pload3+loss3);
```

PART (a)

source voltages

```
figure;
plot(iload,V1m1,'bx-','Linewidth',1.5);
hold on;
plot(iload,V1m2,'rx-','Linewidth',1.5);
hold on;
plot(iload,V1m3,'kx-','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlim([0 150]);
ylim([2000 2500]);
xlabel('Load Current (Amps)','FontSize',12,'FontWeight','Bold')
```

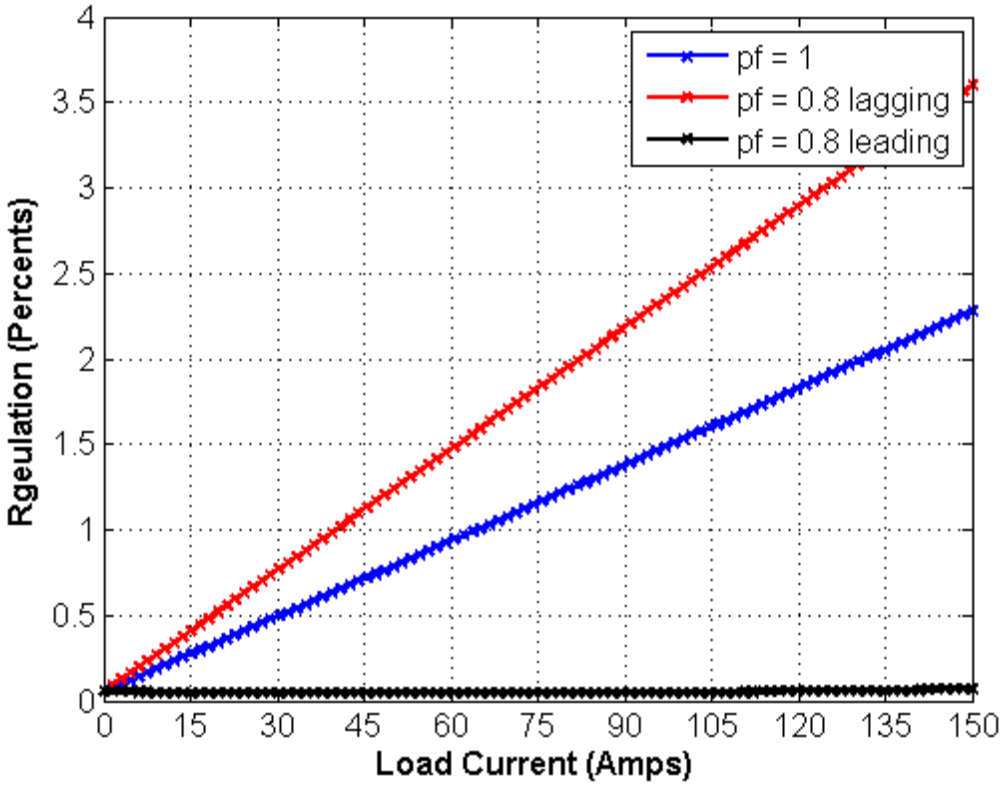
```
ylabel('Source Voltage (Voltss)','FontSize',12,'FontWeight','Bold')
set(gca,'xtick',[0:15:150]);
set(gca,'ytick',[2000:50:2500]);
legend('pf = 1','pf = 0.8 lagging','pf = 0.8 leading');
```



PART (b)

voltage regulations

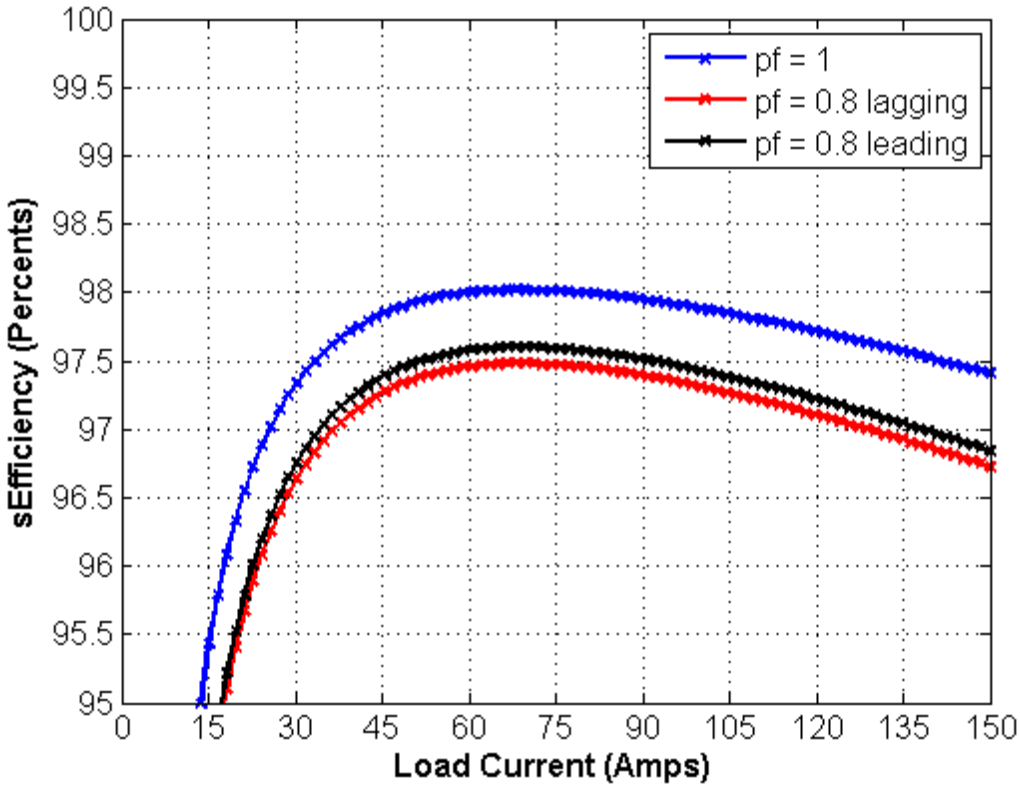
```
figure;
plot(iload,reg1,'bx-','Linewidth',1.5);
hold on;
plot(iload,reg2,'rx-','Linewidth',1.5);
hold on;
plot(iload,reg3,'kx-','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlim([0 150]);
%ylim([0 1]);
xlabel('Load Current (Amps)','FontSize',12,'FontWeight','Bold')
ylabel('Rgeulation (Percents)','FontSize',12,'FontWeight','Bold')
set(gca,'xtick',[0:15:150]);
%set(gca,'ytick',[0:1:5]);
legend('pf = 1','pf = 0.8 lagging','pf = 0.8 leading');
```



PART (c)

efficiency

```
figure;
plot(iload,eff1,'bx-','Linewidth',1.5);
hold on;
plot(iload,eff2,'rx-','Linewidth',1.5);
hold on;
plot(iload,eff3,'kx-','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlim([0 150]);
ylim([95 100]);
xlabel('Load Current (Amps)','FontSize',12,'FontWeight','Bold')
ylabel('sEfficiency (Percents)','FontSize',12,'FontWeight','Bold')
set(gca,'xtick',[0:15:150]);
%set(gca,'ytick',[0:1:5]);
legend('pf = 1','pf = 0.8 lagging','pf = 0.8 leading');
```



PART (d)

Since transformer is an inductive element, regulation is worst at inductive load. With capacitive load, power factor at the source terminal is corrected so that regulation is best. Note that, the load impedance at capacitive load is adjusted for almost perfect regulation in our case. At same load current, the loss on copper elements will be nearly same. On the other hand, unity power factor means more real power delivery to the load at the same current magnitude. Therefore, best efficiency is obtained with unity pf.

PART (e)

As loading increase, regulation increases (gets worsen) for all power factor conditions since the voltage drop on the series elements of the transformer gets higher. As loading increase, efficiency increases up to a point since low output power yields losses comparable to the delivered power. After a point, efficiency decreases with loading. This is because that the increasing current will yield mote power loss on the series resistive elements. Note that, the maximum efficiency point corresponds to the maximum power transfer point (where line impedance is equal to load impedance).

Q.2.

PART A

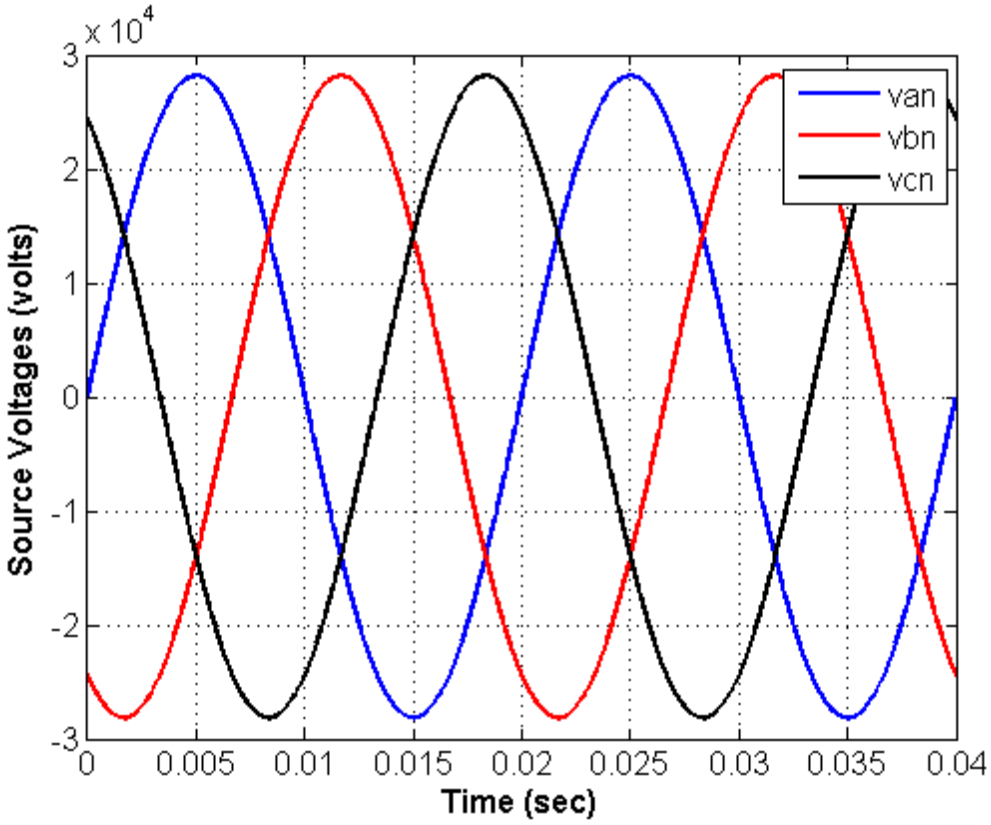
PART a

$$v_{an} = V_{peak}\, sin(2\pi ft)$$

$$v_{bn} = V_{peak}\, sin(2\pi ft - 2\pi/3)$$

$$v_{cn} = V_{peak}\, sin(2\pi ft + 2\pi/3)$$

```
Vpeak = sqrt(2)*34500/sqrt(3);
Fs = 1e5;
fs = 50;
t = 0:1/Fs:0.04;
van = Vpeak*sin(2*pi*fs*t);
vbn = Vpeak*sin(2*pi*fs*t-2*pi/3);
vcn = Vpeak*sin(2*pi*fs*t+2*pi/3);

%Insert your code here
figure;
plot(t,van,'b -','Linewidth',1.5);
hold on;
plot(t,vbn,'r -','Linewidth',1.5);
hold on;
plot(t,vcn,'k -','Linewidth',1.5);
hold on;
grid on;
set(gca,'FontSize',12);
xlabel('Time (sec)','FontSize',12,'FontWeight','Bold')
ylabel('Source Voltages (volts)','FontSize',12,'FontWeight','Bold')
legend('van','vbn','vcn');
```



PART b

```
%Define parameters
Zline1 = 12+102*j;
Zline2 = 0.6e-3+5e-3*j;
Ztrans = 27+403*j;
turns_ratio = 34500/(400/sqrt(3));
```

$$i_{source} = i_{load}(sqrt(3)/n)e^{(-j\pi/6)}$$

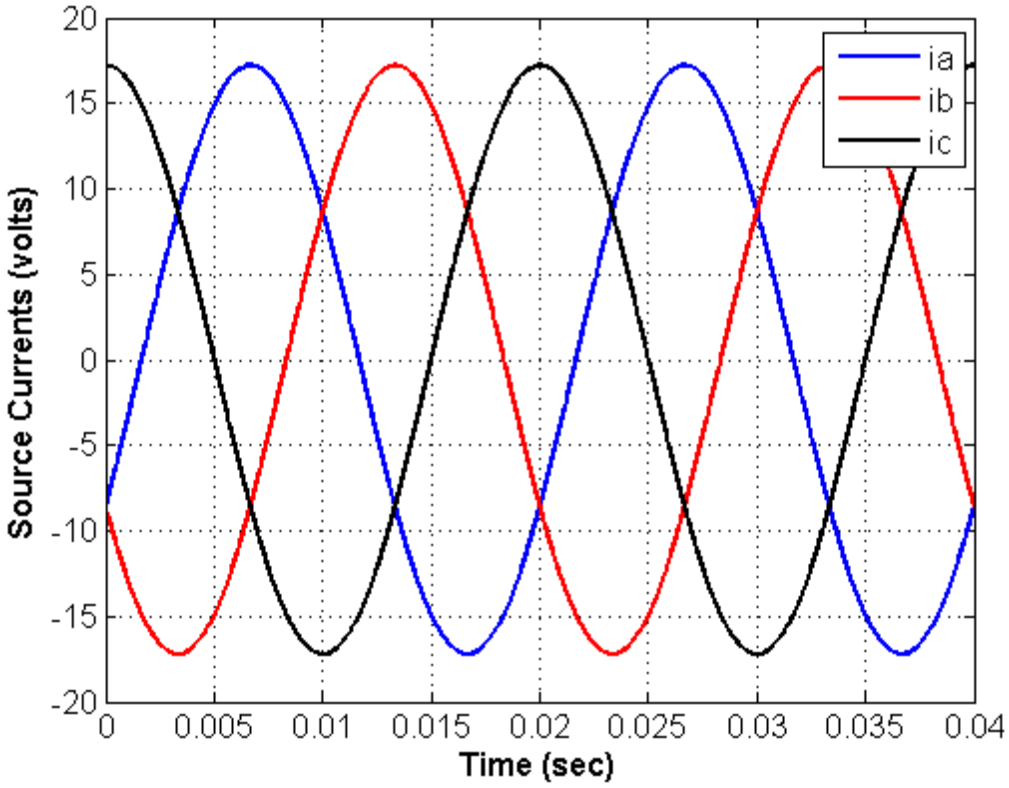
```
Iload_mag = 1050;
Iload_phase = 0;
[re1,im1] = pol2cart(Iload_phase,Iload_mag);
Iload = re1+j*im1;
Isource = (1/turns_ratio)*(cos(30*pi/180)-j*sin(30*pi/180))*Iload*sqrt(3);
Isource_mag = abs(Isource);
Isource_phaser = phase(Isource);
Isource_phase = phase(Isource)*180/pi;
```

$$i_a = I_{peak}\,sin(2\pi ft + \phi)$$

$$i_b = I_{peak}\,sin(2\pi ft + \phi - 2\pi/3)$$

$$i_c = I_{peak}\,sin(2\pi ft + \phi + 2\pi/3)$$

```
Isource_peak = Isource_mag*sqrt(2);

ia = Isource_peak*sin(2*pi*fs*t+Isource_phaser);
ib = Isource_peak*sin(2*pi*fs*t+Isource_phaser-2*pi/3);
ic = Isource_peak*sin(2*pi*fs*t+Isource_phaser+2*pi/3);

%Insert your code here (plot)
figure;
plot(t,ia,'b -','Linewidth',1.5);
hold on;
plot(t,ib,'r -','Linewidth',1.5);
hold on;
plot(t,ic,'k -','Linewidth',1.5);
hold on;
grid on;
set(gca,'FontSize',12);
xlabel('Time (sec)','FontSize',12,'FontWeight','Bold')
ylabel('Source Currents (volts)','FontSize',12,'FontWeight','Bold')
legend('ia','ib','ic');
```



PART c

$$Z_{total} = (Z_{line1}(sqrt(3)/n)^2) + (Z_{trans}(1/n)^2) + Z_{line2}$$

$$R_{total} = Re(Z_{total})$$

$$X_{total} = Im(Z_{total})$$

$$V_{load-mag} = sqrt(V_{source-mag}^2 - I_{load}^2 X_{line}^2) - I_{load} R_{line}$$

```
Vsource_mag = 34500/turns_ratio;
Ztotal = (Zline1/(turns_ratio/sqrt(3))^2)+(Ztrans/(turns_ratio^2))+Zline2;
Rline = real(Ztotal);
Xline = imag(Ztotal);
Vload_mag = sqrt(Vsource_mag^2-Iload^2*Xline^2)-Iload*Rline;

disp(Vload_mag);
```

```
   224.0960
```

PART d

$$V_{source_ref} = I_{load} Z_{total} + V_{load}$$

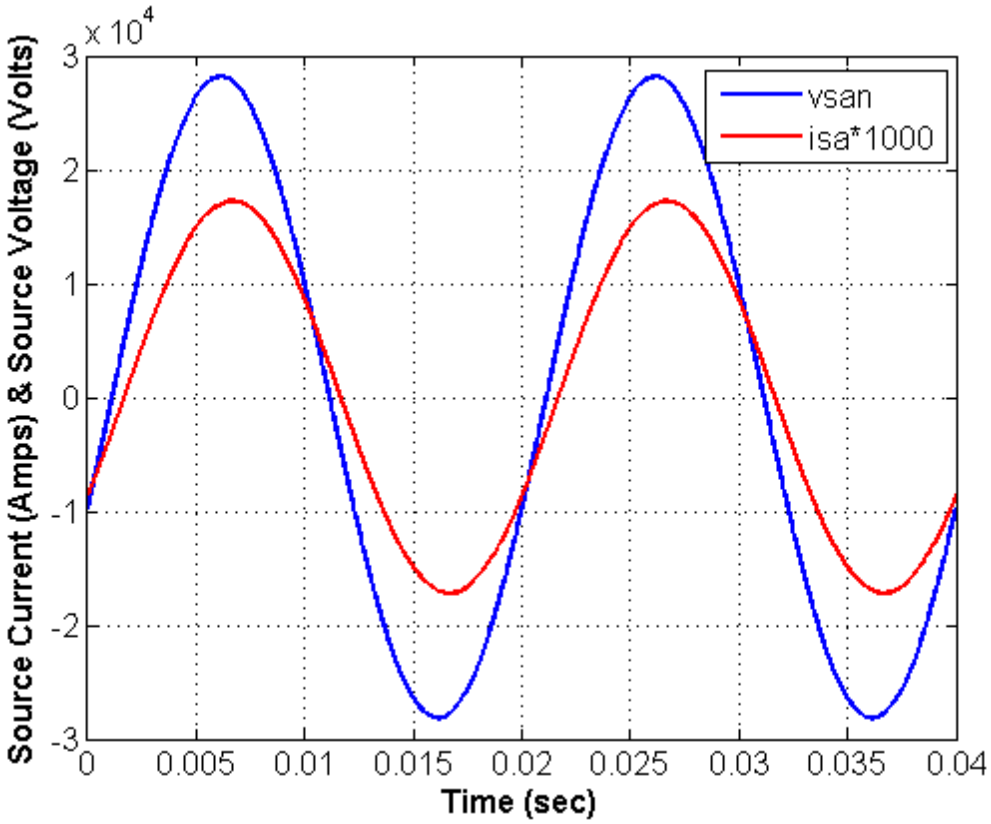
$$V_{source-ll} = V_{source-ref}\, n$$

$$V_{source-ln} = (V_{source-ll}/(sqrt(3)))e^{-j\pi/6}$$

```
Vload = Vload_mag;
Vsource_ref = Iload*Ztotal + Vload;
Vsource_ref_phase = phase(Vsource_ref)*180/pi;

% your result will be here
disp(Vsource_ref_phase);

%Insert your code here (plot)
% actual line-to-line source voltage
Vsource = Vsource_ref*turns_ratio;
% actual line-to-neutral source voltage
Vsource_ln = Vsource/sqrt(3)*exp(-j*(pi/6));
Vsource_ln_mag = abs(Vsource_ln);
Vsource_ln_phase = phase(Vsource_ln)*180/pi;
Vsource_ln_phaser = Vsource_ln_phase*pi/180;
Vsource_peak = Vsource_ln_mag*sqrt(2);

isa = Isource_peak*sin(2*pi*fs*t+Isource_phaser);
vsan = Vsource_peak*sin(2*pi*fs*t+Vsource_ln_phaser);

figure;
plot(t,vsan,'b -','Linewidth',1.5);
hold on;
plot(t,isa*1000,'r -','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlabel('Time (sec)','FontSize',12,'FontWeight','Bold')
ylabel('Source Current (Amps) & Source Voltage (Volts)','FontSize',12,'FontWeight'
```

```
legend('vsan','isa*1000');
```

```
    9.6237
```



PART e

```
phase_dif = Vsource_ln_phase-Isource_phase;
pf = cos(phase_dif*pi/180);

disp(pf);
```

```
    0.9859
```

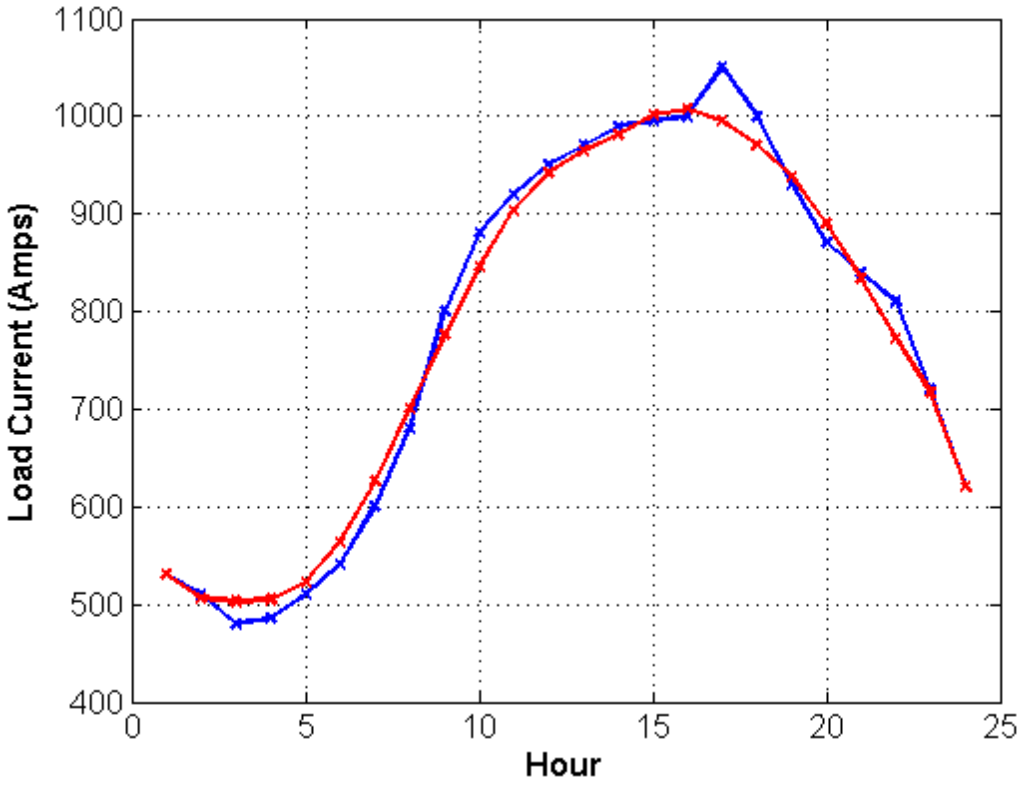
PART B

Part a

Data import

```
data = xlsread('load_profile_METU.xlsx');
iload = data(2:25,2);
hour = data(2:25,1);

%Insert your code here
iload2 = smooth(iload); %to smooth the curve
figure;
```

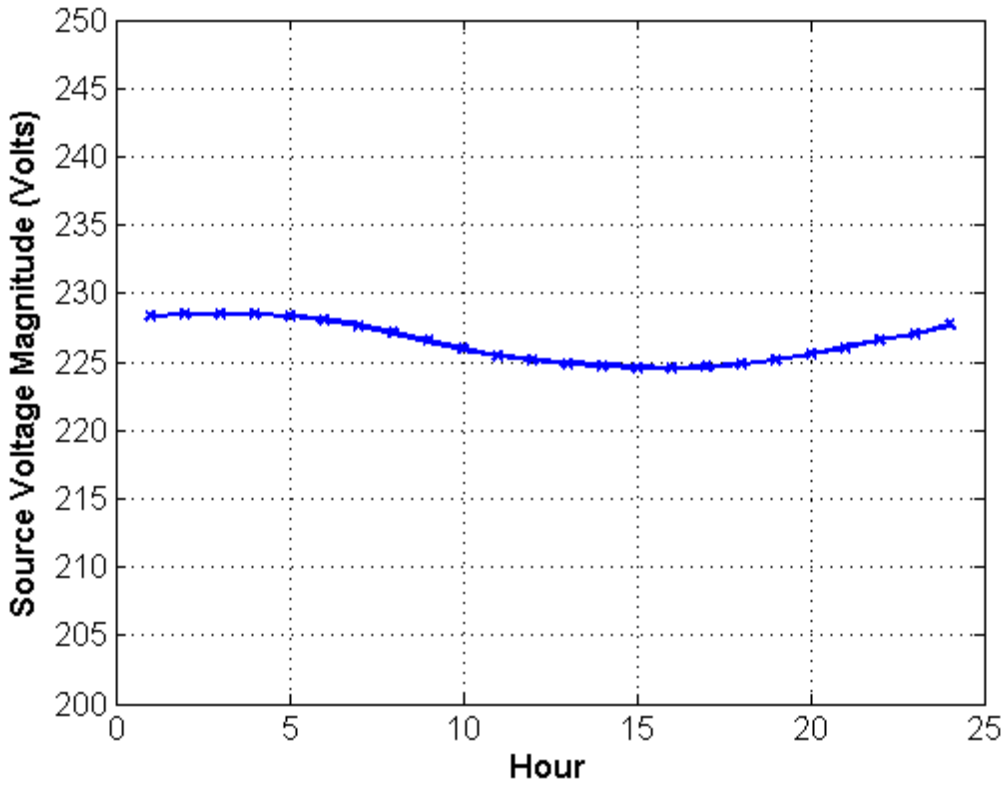
```
plot(hour,iload,'bx-','Linewidth',1.5);
hold on;
plot(hour,iload2,'rx-','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlabel('Hour','FontSize',12,'FontWeight','Bold')
ylabel('Load Current (Amps)','FontSize',12,'FontWeight','Bold')
```



Part b

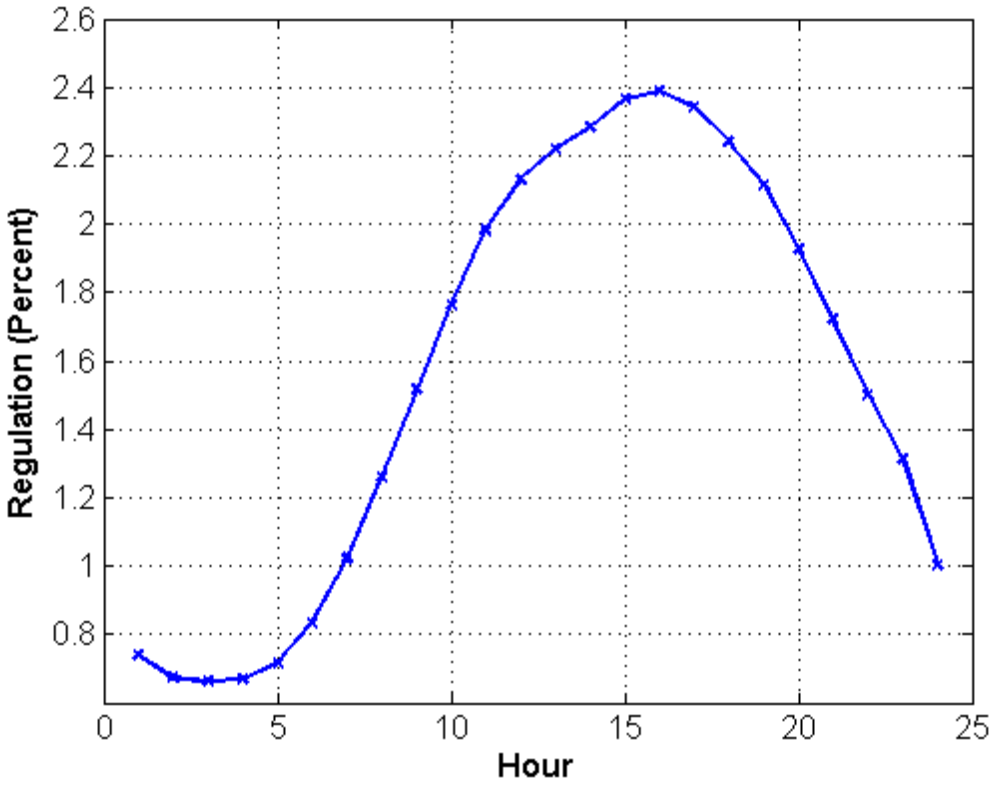
```
%load voltage vs hour

% use smoothed characteristics
clear Iload;
turns_ratio = 34500/(400/sqrt(3));
Iload = iload2';
n = numel(Iload);
Vsource_mag = ones(1,n)*34500/turns_ratio;
Zline1 = ones(1,n)*(12+102*j);
Zline2 = ones(1,n)*(0.6e-3+5e-3*j);
Ztrans = ones(1,n)*(27+403*j);
Ztotal = (Zline1/(turns_ratio/sqrt(3))^2)+(Ztrans/(turns_ratio^2))+Zline2;
Rline = real(Ztotal);
Xline = imag(Ztotal);
Vload_mag = sqrt(Vsource_mag.^2-Iload.^2.*Xline.^2)-Iload.*Rline;
```

```
%Insert your code here (plot)
figure;
plot(hour,Vload_mag,'bx-','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
ylim([200 250]);
xlabel('Hour','FontSize',12,'FontWeight','Bold')
ylabel('Source Voltage Magnitude (Volts)','FontSize',12,'FontWeight','Bold')
```



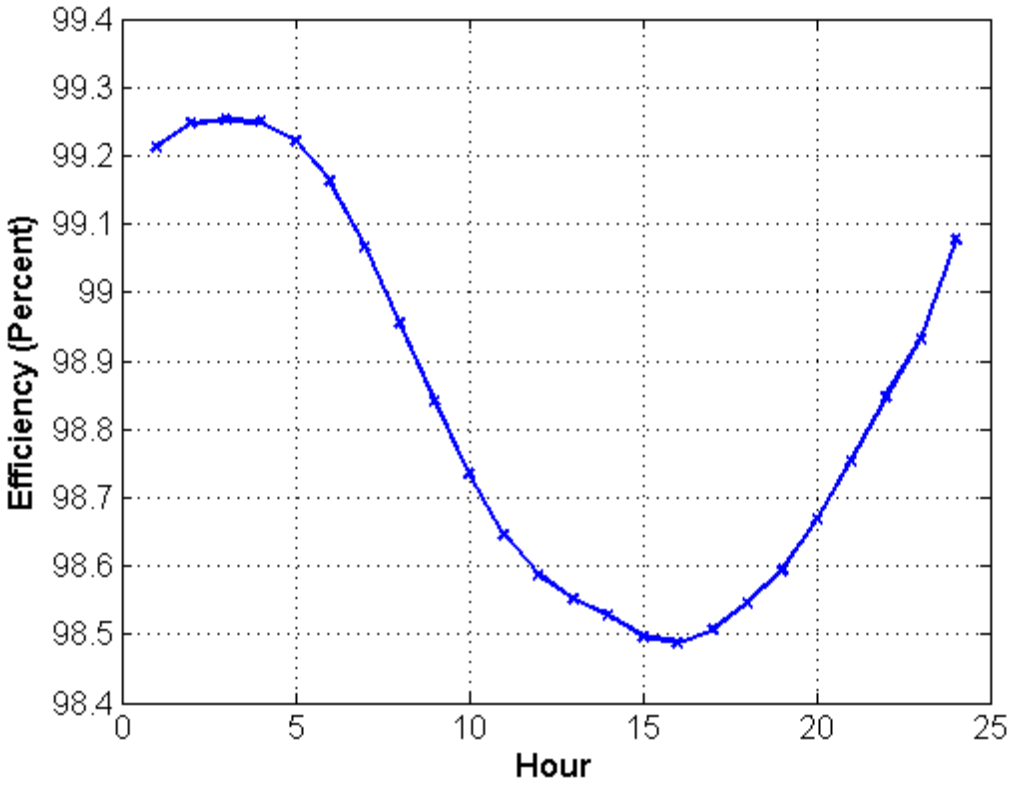
Part c

```
%regulation vs hour

Vload_rated = ones(1,n)*230;
V_loadr = 230;
reg = 100*(Vload_rated-Vload_mag)/V_loadr;

%Insert your code here (plot)
figure;
plot(hour,reg,'bx-','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Hour','FontSize',12,'FontWeight','Bold');
ylabel('Regulation (Percent)','FontSize',12,'FontWeight','Bold');
```



Part d

```
%efficiency vs hour

Rloss = Rline(1,1);
Ploss = 3*Iload.^2*Rloss;
% since the load is purely resistive
Pout = 3*Vload_mag.*Iload;
Pin = Pout+Ploss;
eff = 100*Pout./Pin;

figure;
plot(hour,eff,'bx-','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Hour','FontSize',12,'FontWeight','Bold');
ylabel('Efficiency (Percent)','FontSize',12,'FontWeight','Bold');


%publish('solution_hw3.m', 'pdf')
```



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