EE361 HW#3 FALL 2016

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NAME: *SOLUTION*

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Q.1.

PART A

Given parameters

```
Vs = 15e3; % V
Iload = 836; % A
Zf1 = 1e-3*(5+1j*45); % Ohms
Zt1 = 1e-3*(20+1j*225); % Ohms
Ztline = 1+1j*9.5; % Ohms
Zt2 = 15+1j*60; % Ohms
Zf2 = 1e-3*(25+1j*240); % Ohms
turns1 = 15/154;
turns2 = 154/34.5;

Ztline_ref = turns1^2*Ztline; % Ohms
Zt2_ref = (turns1^2)*Zt2/3; % Ohms
Zf2_ref = (turns1*turns2)^2*Zf2; % Ohms

Ztotal = Zf1+Zt1+Ztline_ref+Zt2_ref+Zf2_ref; % Ohms

Vs_ln = Vs/sqrt(3);
Iload_ref = Iload/(turns1*turns2);

Xtotal = imag(Ztotal);
Rtotal = real(Ztotal);

delta = asin(Xtotal*Iload_ref/Vs_ln);
delta_deg = 180*delta/pi;

Vload_ln_ref = Vs_ln*cos(delta)-Iload_ref*Rtotal;
Vload_ref = Vload_ln_ref*sqrt(3);

Vload = Vload_ref/(turns1*turns2);
```

Part A-(a)

```
fprintf('Magnitude of the load voltage (line-to-line) is %g Volts.\n',Vload);
```

```
Magnitude of the load voltage (line-to-line) is 33533.7 Volts.
```

Part A-(b)

```
fprintf('Load angle between source and load voltage is %g deg.\n',delta_deg);
```

```
Load angle between source and load voltage is 7.59439 deg.
```

Part A-(c)

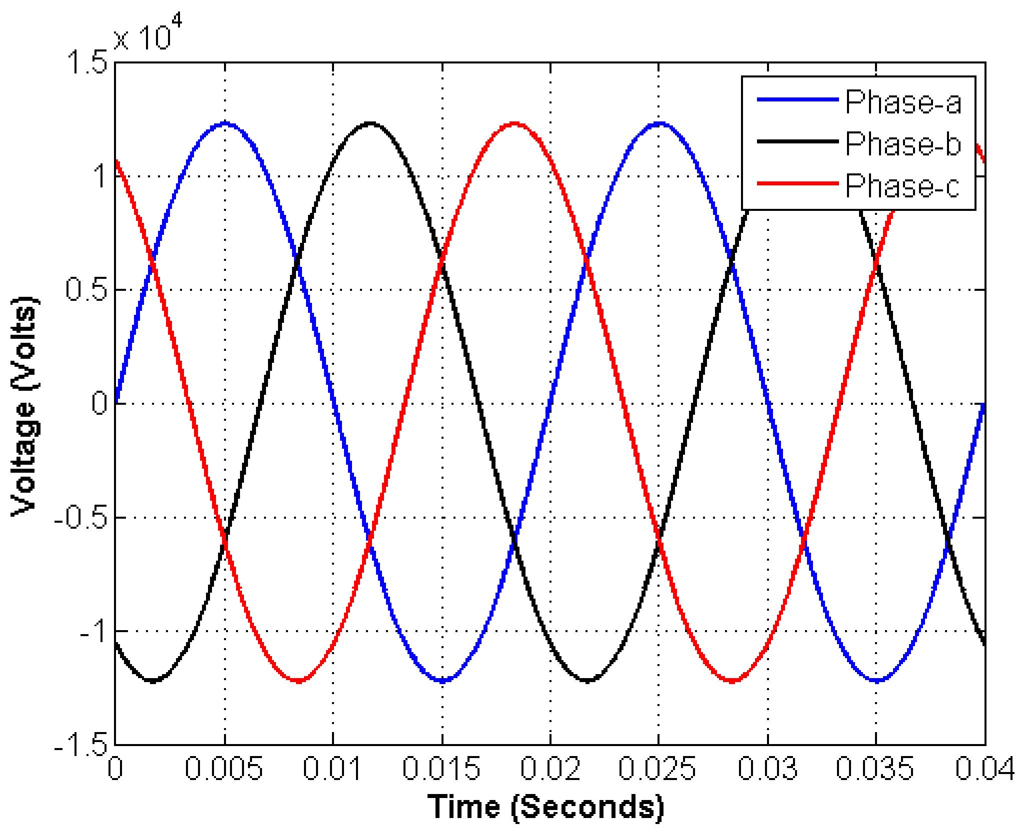
```
Is = Iload_ref;
fprintf('Line current in feeder-1 is %g Amps.\n',Is);
```

```
Line current in feeder-1 is 1922.8 Amps.
```

Part A-(d)

```
time = 0:20e-6:0.04;
Vs_peak = Vs_ln*sqrt(2);
```

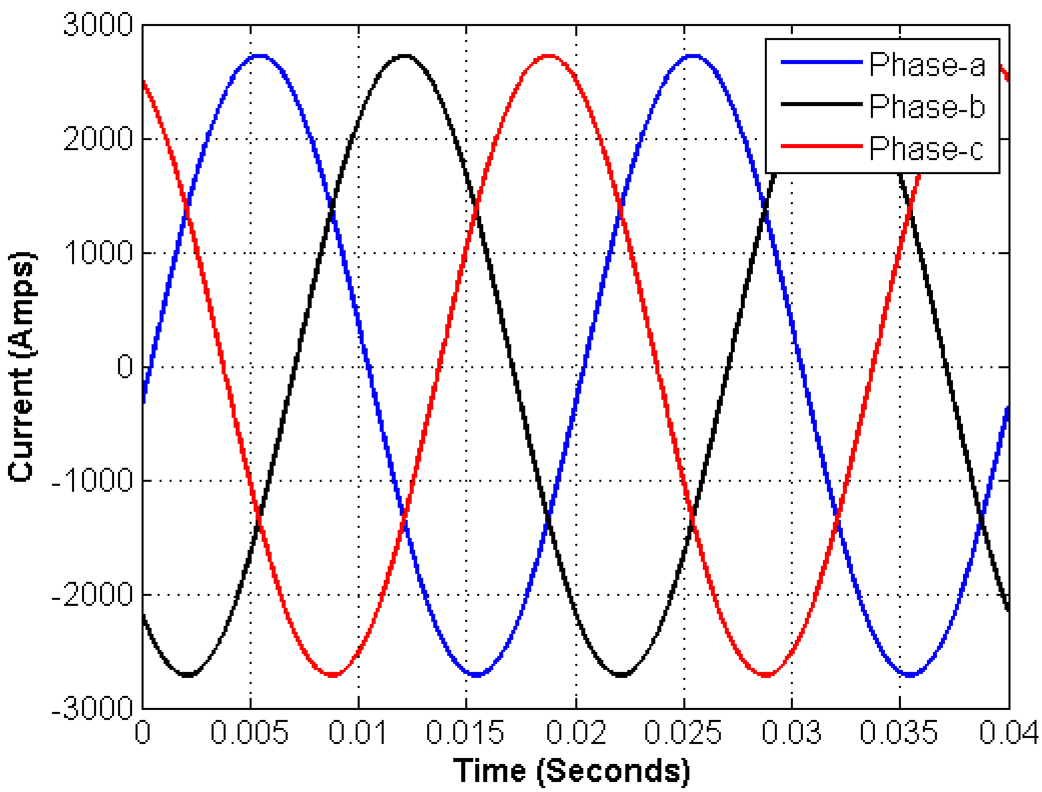
```
f = 50; % Hz
Vs_a = Vs_peak*sin(2*pi*f*time);
Vs_b = Vs_peak*sin(2*pi*f*time-2*pi/3);
Vs_c = Vs_peak*sin(2*pi*f*time-4*pi/3);

figure;
plot(time,Vs_a,'b -','Linewidth',1.5);
hold on;
plot(time,Vs_b,'k -','Linewidth',1.5);
hold on;
plot(time,Vs_c,'r -','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlabel('Time (Seconds)','FontSize',12,'FontWeight','Bold')
ylabel('Voltage (Volts)','FontSize',12,'FontWeight','Bold')
legend('Phase-a','Phase-b','Phase-c');
```



Part A-(e)

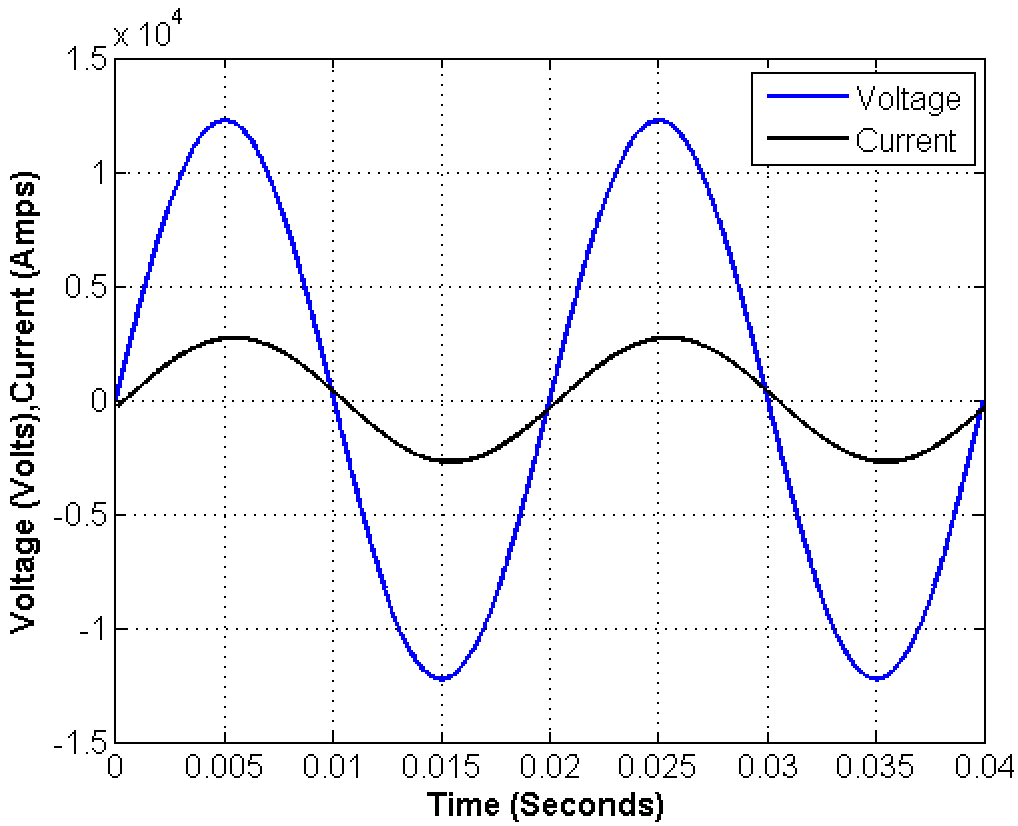
```
Is_peak = Is*sqrt(2);
phase = delta;
Is_a = Is_peak*sin(2*pi*f*time-phase);
Is_b = Is_peak*sin(2*pi*f*time-phase-2*pi/3);
Is_c = Is_peak*sin(2*pi*f*time-phase-4*pi/3);
```

```
figure;
plot(time,Is_a,'b -','Linewidth',1.5);
hold on;
plot(time,Is_b,'k -','Linewidth',1.5);
hold on;
plot(time,Is_c,'r -','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlabel('Time (Seconds)','FontSize',12,'FontWeight','Bold')
ylabel('Current (Amps)','FontSize',12,'FontWeight','Bold')
legend('Phase-a','Phase-b','Phase-c');
```



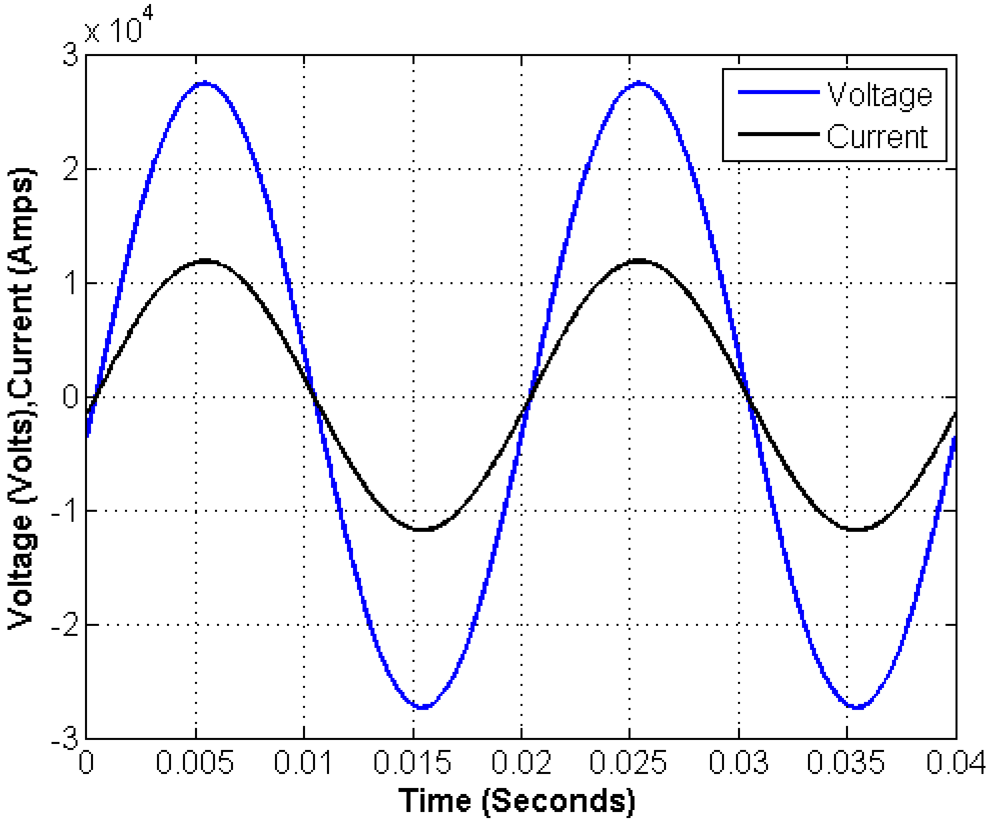
Part A-(f)

```
figure;
plot(time,Vs_a,'b -','Linewidth',1.5);
hold on;
plot(time,Is_a,'k -','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlabel('Time (Seconds)','FontSize',12,'FontWeight','Bold')
ylabel('Voltage (Volts),Current (Amps)','FontSize',12,'FontWeight','Bold')
legend('Voltage','Current');
```



Part A-(g)

```
Vload_ln = Vload/sqrt(3);
Vload_peak = Vload_ln*sqrt(2);
Vload_a = Vload_peak*sin(2*pi*f*time-phase);
Iload_peak = Iload*sqrt(2);
Iload_a = Iload_peak*sin(2*pi*f*time-phase);

figure;
plot(time,Vload_a,'b -','Linewidth',1.5);
hold on;
plot(time,10*Iload_a,'k -','Linewidth',1.5);
hold off;
grid on;
set(gca,'FontSize',12);
xlabel('Time (Seconds)','FontSize',12,'FontWeight','Bold')
ylabel('Voltage (Volts),Current (Amps)','FontSize',12,'FontWeight','Bold')
legend('Voltage','Current');
```



Part A-(h)

```
pf = cos(delta);
fprintf('Power factor at source terminals is %.3g.\n',pf);
```

```
Power factor at source terminals is 0.991.
```

Power factor is not unity as expected. The inductive lines and transformers form a load which is inductive at the source terminals.

Part A-(i)

One can employ several power factor correction techniques. One example is connecting a capacitor which will deliver the amount of reactive power that is drawn by the system (lines-transformers and load).

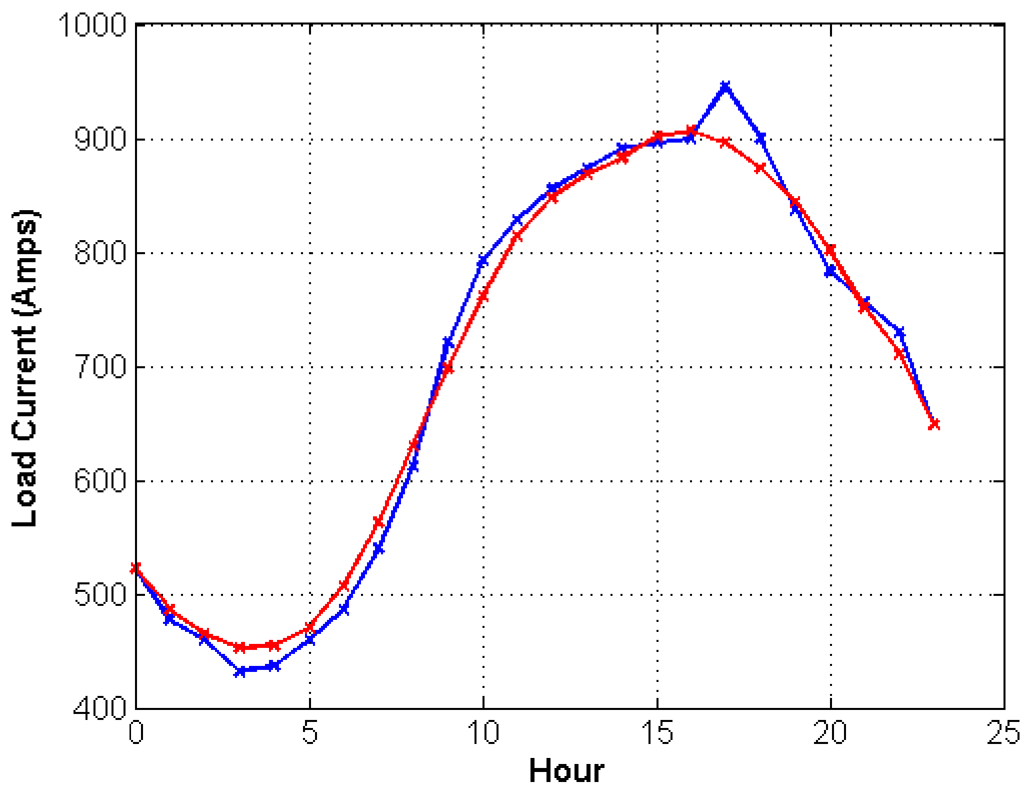
Part A-(j)

All the reactive components will have a greater impedance due to the equation: X = 2xpixfxL. This would mean: 1) Higher voltage drop, and hence worse regulation. 2) Worse power factor at the source terminals.

PArt B-(a)

```
data = xlsread('load_profile.xlsx');
```

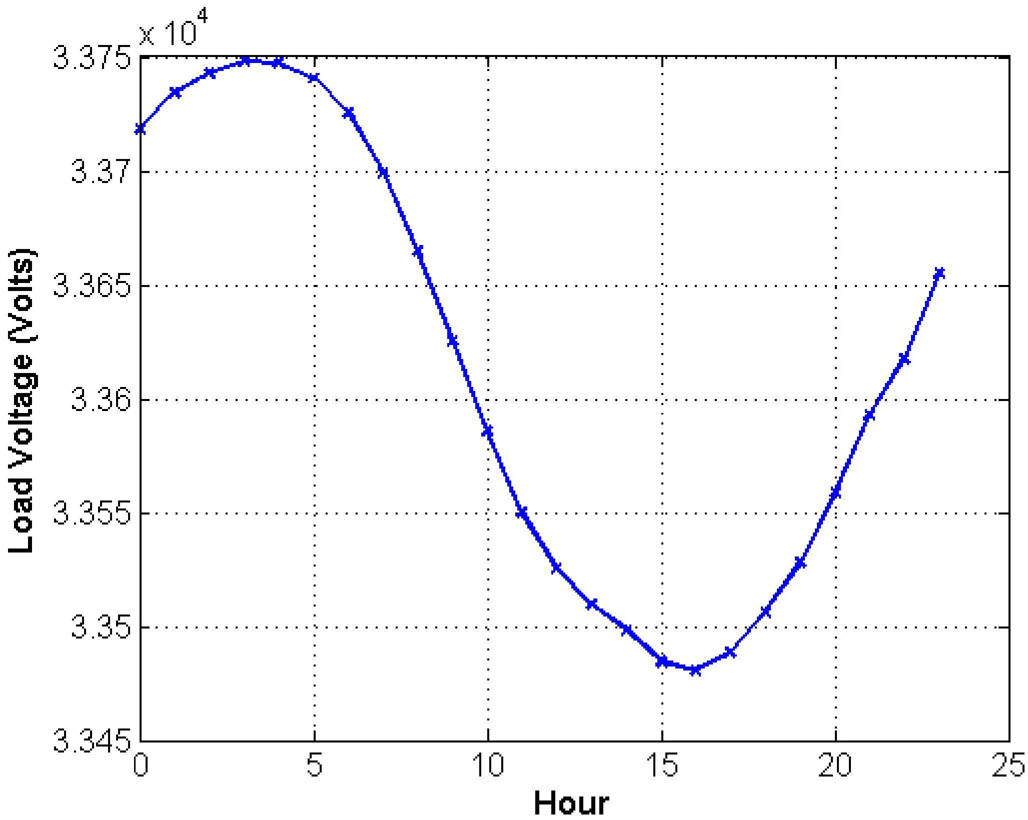
```
iload = data(:,2);
hour = data(:,1);
iload2 = smooth(iload); % to smooth the curve

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-(b)

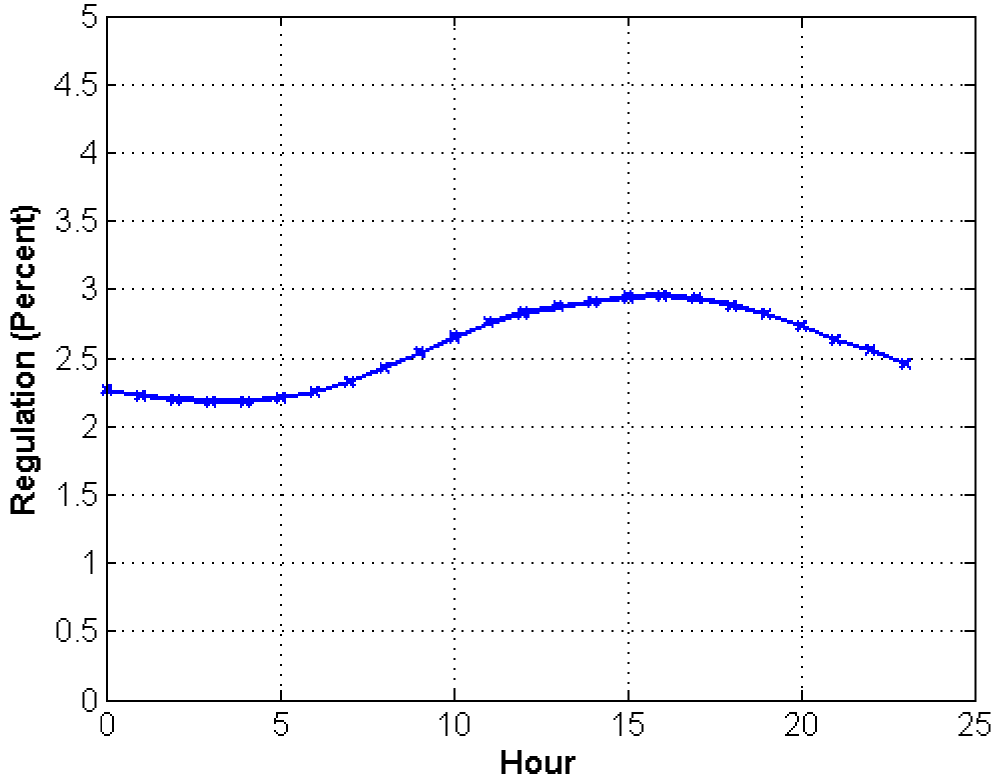
```
iload_ref = iload2/(turns1*turns2);

delta = asin(Xtotal*iload_ref/Vs_ln);
delta_deg = 180*delta/pi;

Vload_ln_ref = Vs_ln*cos(delta)-Iload_ref*Rtotal;
Vload_ref = Vload_ln_ref*sqrt(3);

Vload = Vload_ref/(turns1*turns2);
```

```
figure;
plot(hour,Vload,'bx-','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Hour','FontSize',12,'FontWeight','Bold')
ylabel('Load Voltage (Volts)','FontSize',12,'FontWeight','Bold')
```



Part B-(c)

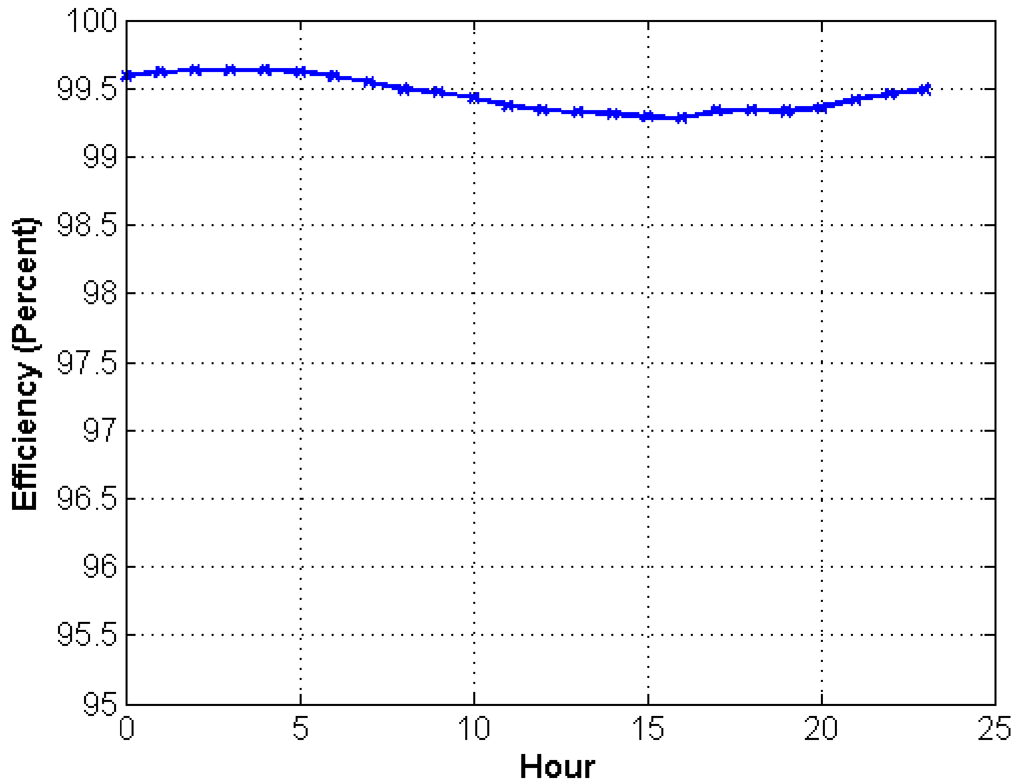
```
Vrated = 34.5e3;
Vnoload = Vrated*ones(24,1);
regulation = 100*(Vnoload-Vload)/Vrated;

figure;
plot(hour,regulation,'bx-','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Hour','FontSize',12,'FontWeight','Bold')
ylabel('Regulation (Percent)','FontSize',12,'FontWeight','Bold')
ylim([0 5]);
```



We want the regulation to be low. Regulation came out to be positive at all times and nonzero since the load is purely resistive and the lines are inductive. As expected, regulation is better during the hours where less current is drawn by the load. At ruch hours, the system has worse regulation as the voltage drop will be higher on the lines.

Part B-(d)

```
Pload = sqrt(3)*Vload.*iload;
is = iload_ref;
Ploss = is.^2*Rtotal;
efficiency = 100*Pload./(Pload+Ploss);

figure;
plot(hour,efficiency,'bx-','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Hour','FontSize',12,'FontWeight','Bold')
ylabel('Efficiency (Percent)','FontSize',12,'FontWeight','Bold')
ylim([95 100]);
```



Similar to the regulation, efficiency is better (higher) at the hours where less current is drawn. The reason is that, the losses on the line are proportional to the square of the current. At rush hours, efficiency gets worse due to higher current.

Part B-(e)

```
energy = 1e-6*sum(Pload); % MWh
fprintf('Total energy delivered to the load is %g MWh.\n', energy);
```

Total energy delivered to the load is 975.997 MWh.

Q.2.

Given parameters

```
I = 45; % Amps
Nturn = 50;
A = 10e-4; % m^2
m = 0.1; % kg
k = 100; % N/m
g = 9.8;
u0 = 4*pi*1e-7; % H/m

x = 0:0.0001:0.2;
```

Part a)

RELUCTANCE

$$R = x/(u_0 A)$$

```
R = x/(u0*A);
```

INDUCTANCE

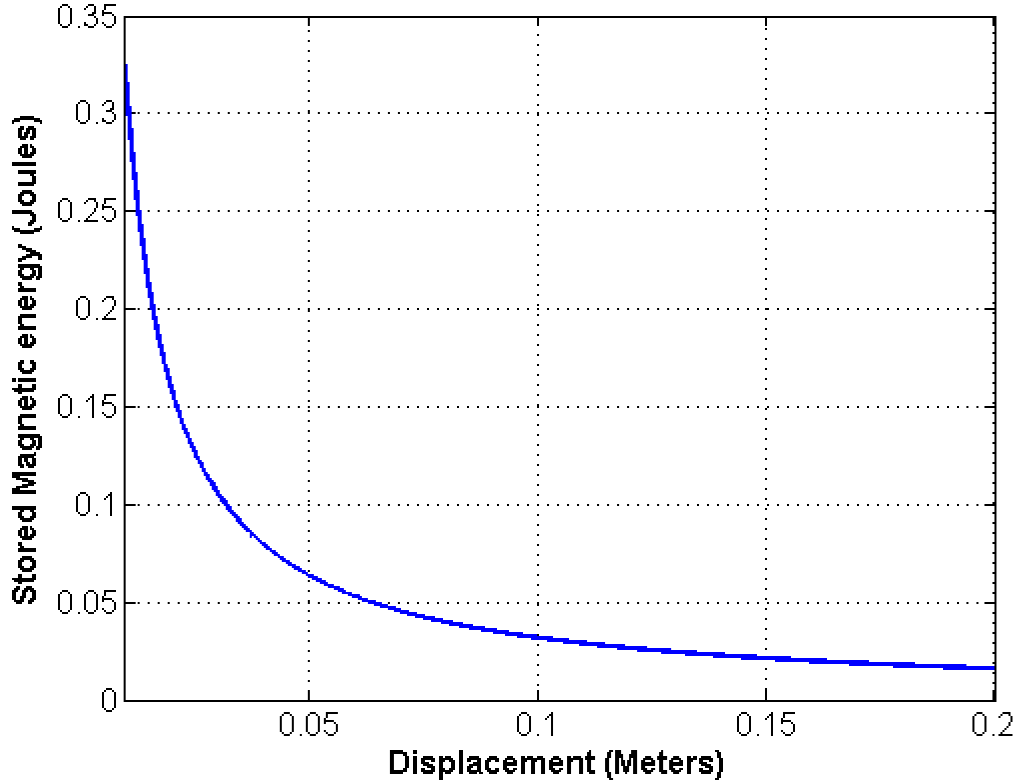
$$L = N^2/R$$

```
L = Nturn^2./R;
```

part b)

$$W = (1/2)LI^2$$

```
W = (1/2)*L*I^2;

figure;
plot(x,W,'b -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')
ylabel('Stored Magnetic energy (Joules)','FontSize',12,'FontWeight','Bold')
xlim([0.01 0.2]);
```



part c)

part c-i)

ELECTROMAGNETIC FORCE

$$W = (1/2)LI^2$$

$$W = (1/2)(N^2/R)I^2$$

$$W = (1/2)(N^2AI^2u_0)/(x)$$

$$Fem = dW/dx$$

$$Fem = (1/2)(N^2AI^2u_0)/x^2$$

```
Fem = 0.5*Nturn^2*I^2*u0*A./x.^2;
```

part c-ii)

MECHANICAL SPRING FORCE

$$Fms = kx$$

```
Fs = k*(x-0.1);
```

part c-iii)

GRAVITATIONAL FORCE

$$Fg = mg$$

```
Fg = m*g*ones(1,numel(x));
```

part c-iv)

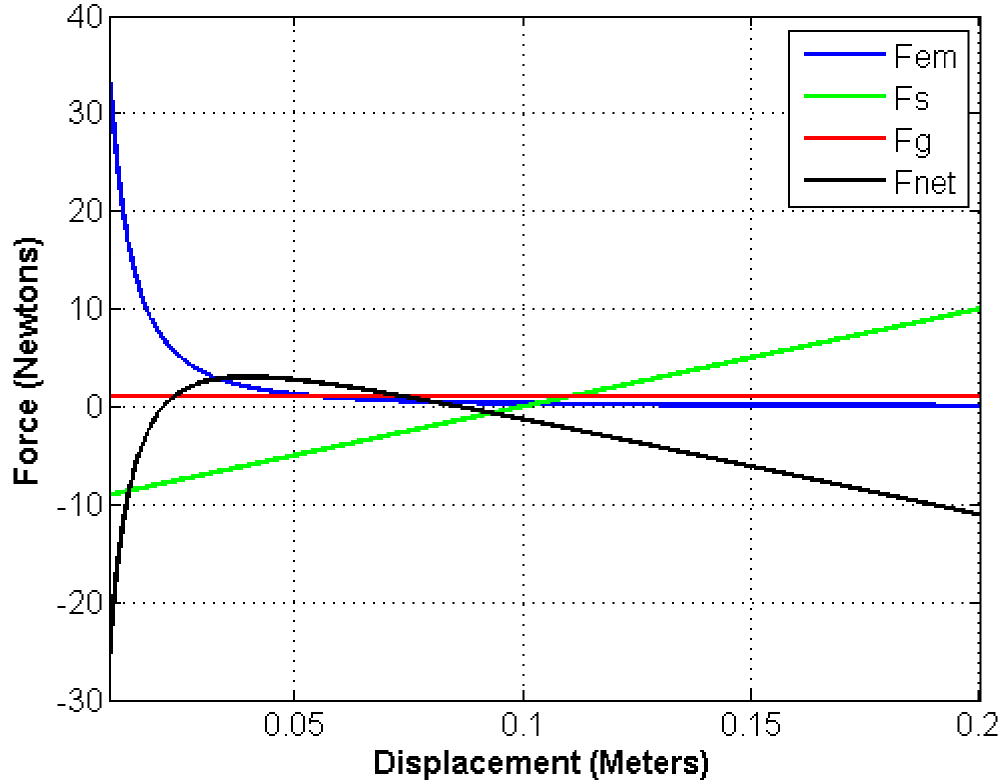
```
% NET FORCE
```

$$Fnet = -(Fem + Fms + Fg)$$

```
Fnet = -(Fem+Fg+Fs);
```

part c-v)

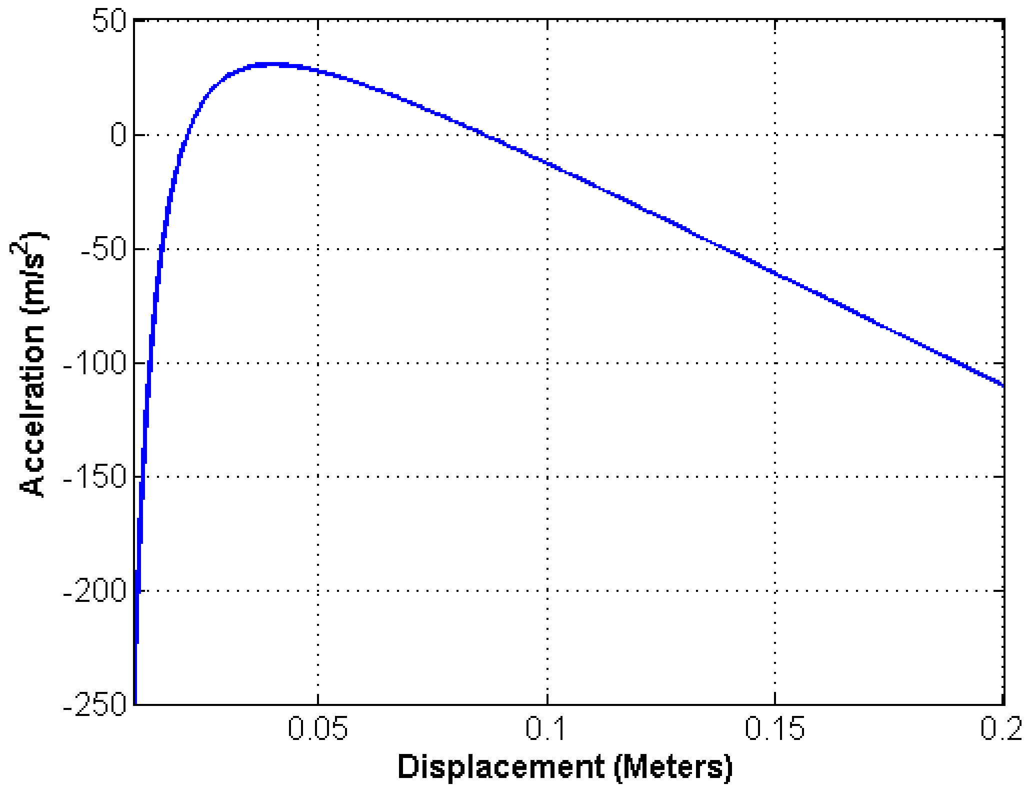
```
figure;
plot(x,Fem,'b -','Linewidth',1.5);
hold on;
plot(x,Fs,'g -','Linewidth',1.5);
hold on;
plot(x,Fg,'r -','Linewidth',1.5);
hold on;
plot(x,Fnet,'k -','Linewidth',1.5);
hold off;
grid on;
xlim([0.01,0.2]);
set(gca,'FontSize',12);
xlabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')
ylabel('Force (Newtons)','FontSize',12,'FontWeight','Bold')
legend('Fem','Fs','Fg','Fnet');
```



part d)

ACCELERATION

```
a = Fnet/m;

figure;
plot(x,a,'b -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')
ylabel('Accelration (m/s^2)','FontSize',12,'FontWeight','Bold')
xlim([0.01,0.2]);
```



part e)

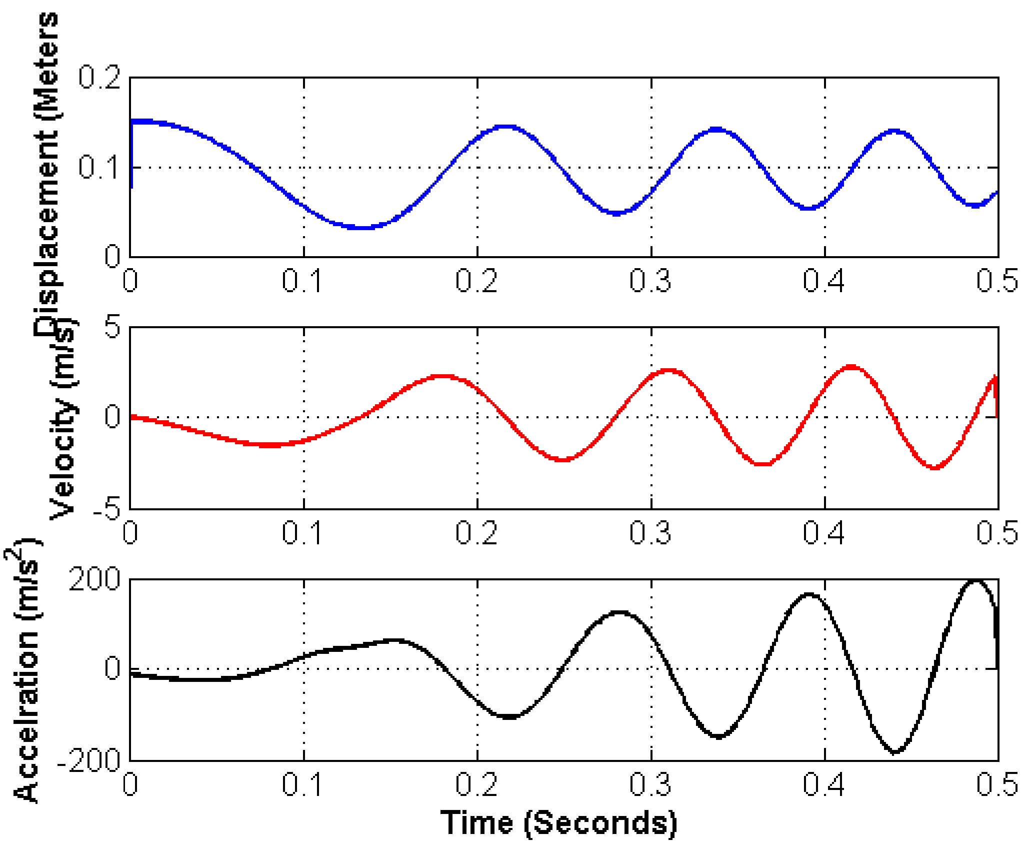
part e-i)

AGAINST TIME

```
Ts = 1e-3; % time step (seconds)
t = 0:Ts:0.5; % time vector
N = numel(t); % number of elements
position = zeros(1,N);
velocity = zeros(1,N);
acceleration = zeros(1,N);
position(2) = 0.15;

for k = 2:N-1
    Fem = 0.5*Nturn^2*I^2*u0*A/position(k)^2;
    Fg = m*g;
    Fs = k*(position(k)-0.1);
    Fnet1 = Fem+Fg+Fs;
    acceleration(k) = -Fnet1/m;
    velocity(k) = velocity(k-1)+acceleration(k)*Ts;
    position(k+1) = position(k)+velocity(k)*Ts;
end
```

part e-ii)

```
figure;

subplot(3,1,1);
plot(t,position,'b -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
ylabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')

subplot(3,1,2);
plot(t,velocity,'r -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
ylabel('Velocity (m/s)','FontSize',12,'FontWeight','Bold')

subplot(3,1,3);
plot(t,acceleration,'k -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Time (Seconds)','FontSize',12,'FontWeight','Bold')
ylabel('Accelration (m/s^2)','FontSize',12,'FontWeight','Bold')
```



part f)

The device has an oscillatory behaviour such that the mass moves from one equilibrium point to another periodically. The device operation is similar to an LC resonant tank which has a similar oscillatory behaviour. The energy is transferred from one form to the other form. In our case, it is stored on the spring and then stored on the electromechanical device periodically. The reson for the system to continue its oscillation is that there is no dissipative element. For example, it we had a resistor in the LC tank, the initial energy would eventually decrease to zero. In case of friction, the same is true. As the friction is some kind of dissipation, the oscillation will die out in time and the mass would stop eventually.

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