Engr228 Lab #7

Power Factor Correction

Name ____________________________

Partner(s) ____________________________ Grade _____/10

Note to lab instructor: Refer to the picture taken of the hardware setup. Make sure the little switch on the motor is in the up position to start the motor. The proper sequence of the two main switches (run, start) is: 01, 11, 10.

Introduction
Voltage and current waveforms as applied to motors tell us a great deal about the power environment surrounding the motor. This lab will guide you through the calculation of various power quantities as applied to an induction motor. Calculations will be done to verify the advantages from improving power factor.

Lab Objectives
- Apply classroom principles and theory to physical devices;
- Understand complex power issues using a real motor;
- Understand the benefits of power factor correction.

Equipment
- Induction motor;
- Benchtop DMM’s;
- Handheld DMM’s;
- Wattmeter (new);
- Capacitor decade box (new).

References
- Pre-lab #7 assignment;
- Circuits text book;
- Descriptions of instruments handout.
**Procedure**

The data for this last lab of the quarter will be gathered from one setup so everyone will use the same data in their calculations. Note that the lab instructor will operate the motor and explain the procedure. The table below will be filled out in steps 1-3.

<table>
<thead>
<tr>
<th></th>
<th>$V_L$ (V)</th>
<th>$P$ (W)</th>
<th>$I_L$ (A)</th>
<th>$I_M$ (A)</th>
<th>$I_C$ (A)</th>
<th>$C_{\text{calc}}$ ($\mu$F)</th>
<th>$C_{\text{exp}}$ ($\mu$F)</th>
<th>pf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Step 2</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Step 3</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1.00</td>
<td>---</td>
</tr>
</tbody>
</table>

1. The induction motor is connected as shown in the figure above. Initially, there is no capacitor in the circuit so $I_C = 0$ amps. Once the motor has been started and thermally stabilized, measure the line voltage $V_L$, the power $P$ (using the Watt-meter), the line current $I_L$, and the motor current $I_M$. Record this data in the row labelled **Step 1** in the table above.

2. From the measurements in step 1, calculate the power factor of the motor and the parallel capacitance required to correct the power factor to unity. Enter these numbers in the row labelled **Step 2**.

3. Tell the lab instructor what value of capacitance you have calculated from step 2. After the instructor has placed your calculated value of capacitance in parallel with the motor, measure and record the voltage, power, and currents asked for in **Step 3** above. Also, have the lab instructor experimentally find the value of capacitance that minimizes the line current and enter this value into the table.
4. Calculate the percent reduction in line current by correcting the power factor to unity:

\[
\%\text{reduction} = \left[ \frac{\text{original} - \text{new}}{\text{original}} \right] \times 100\% 
\]

% reduction: __________

5. Calculate the percent reduction in apparent power required when the power factor is corrected to unity.

% reduction: __________

6. Estimate the impedance of the motor and express it in rectangular form.

7. State your observations and conclusions regarding this lab.
Figure 1 - Example Power Factor Correction Graph.

- Motor Power Factor = 0.83 lag
- Desired Power Factor = 0.95 lag
- Motor Power = 30000 W
- Line Impedance = 0.2x+0.1-j1Ω
- Old Line Loss = 5398 W
- New Line Loss = 4121 W
- Power Saved = 1278 W 4.26 %

Waveforms and Power-Factor
Matlab Code for the Graph in Figure 1

% Power Factor Correction (lag only, with power waves)
% Carlton Cross 28 May 10  Rev 1 Dec 11

clear all
close all

Vline = 220; % line voltage, Vrms
P = 30000; % Machine power, W
Pphase = P/3; % Machine power per phase, W
pfxtxt = ['lag']; % annotation text (only lag is possible)
pf = 0.83; % motor power factor (lag)
pfd = 0.95; % desired power factor (lag)
Zline = 0.2 + 0.1j; % line impedance (series)

w = 2*pi*60; % line frequency (60 Hz)
Vp = Vline/sqrt(3); % line voltage
Sm = Pphase*(1 + j*tan(acos(pf))); % motor power
Sd = Pphase*(1 + j*tan(acos(pfd))); % corrected motor power
Sc = Sd - Sm; % capacitor reactive power

C = Sc/(-j*w*Vp^2); % capacitor reactive power
Im = conj(Sm/Vp); % motor current
Ic = j*w*C*Vp; % capacitor current
Iline = Im + Ic; % line current

Plossold = 3*real(Zline)*abs(Im)^2; % total power loss
Plossnew = 3*real(Zline)*abs(Iline)^2; % total power loss with power factor correction
Psave = Plossold - Plossnew; % power savings
Psavepercent = 100*Psave/P; % percent power savings

T = 2*pi/w;
npts = 500;
t = linspace(-0.2*T, 1.2*T, npts);

vp = sqrt(2)*Vp*sin(w*t); % motor voltage
im = sqrt(2)*abs(Im)*sin(w*t + angle(Im)); % motor current
ic = sqrt(2)*abs(Ic)*sin(w*t + angle(Ic)); % capacitor current
iline = sqrt(2)*abs(Iline)*sin(w*t + angle(Iline)); % line current
Pmt = vp.*im; % instantaneous power

% Set up figure positions.
scrnz = get(0,'ScreenSize');
scale = scrnz(3)/scrnz(4);
figure('Position', [0.02*scrnz(3) 0.1*scrnz(4) 0.8*scrnz(3) 0.8*scrnz(4)])
figure(1)
plot(t,vp,'k', t,im,'b--', t,ic,'r-.', t,iline,'m', 'linewidth',1.5)
v = axis; % get the graph edges
xmin = v(1); xmax = v(2); ymin = v(3); ymax = v(4);
hold on

% Note: The code is designed to be executed in an environment where
% the variables are pre-defined or where the code is adapted to
% the specific environment where it is to be run.
plot(t,Pmt/500,'c','linewidth',1.5)
plot([xmin xmax],[0 0],'k','linewidth',1.5)  % horizontal axis
plot([0 0],[ymin ymax],'k','linewidth',1.5)  % vertical axis
hold off
grid
set(gca,'xtick',[0 T/4 T/2 3*T/4 T])
set(gca,'ytick',[])% vertical axis
legend('Line Voltage, V','Motor Current, A',...'
'Capacitor Current, A','Line Current, A',...'
'Instantaneous Power, VA')
title('\textfont{14}Waveforms and Power-Factor')
ylabel('Magnitude, V, A, VA')
xlabel('Time, s')
vx = axis;   % axis gets the graph end points
xmin = vx(1); xmax = vx(2); ymin = vx(3); ymax = vx(4);

xrel = 0.31;  % establish a relative position for text
yrel = 0.3;
vspace = (ymax-ymin)/25;  % spacing for 25 lines in the box
px = xrel*(xmax-xmin) + xmin;  % x coordinate for text
py = yrel*(ymax-ymin) + ymin;  % y coordinate for text

% coordinates for text

% Motor Power Factor = ' num2str(pf) ' pftxt]
'backgroundcolor',[1 1 1])
text(px,(py-1*vspace), [Desired Power Factor = ' num2str(pfd) ' pftxt],...
'backgroundcolor',[1 1 1])
text(px,(py-2*vspace),  [Motor Power = ' num2str(round(3*Phase)) ' W'],...
'backgroundcolor',[1 1 1])
text(px,(py-3*vspace),  [Line Impedance = ' num2str(Zline) ' \Omega'],...
'backgroundcolor', [1 1 1])
text(px,(py-4*vspace), ['Old Line Loss = ' num2str(round(Plossold)) ' W'],...
'backgroundcolor', [1 1 1])
text(px,(py-5*vspace), ['New Line Loss = ' num2str(round(Plossnew)) ' W'],...
'backgroundcolor', [1 1 1])
text(px,(py-6*vspace),  ['Power Saved = ' num2str(round(Psave)) ' W', ' '] num2str(round(100*Psaveparcent)/100) ' %'],  'backgroundcolor',[1 1 1])
text(xmin,(ymin-2.5*vspace),... ['Carlton Cross From file p:\matlab\e228\exmpl\powerfactordemo.m ' ...'
' plotted ' date);