5.9 Summary

The instantaneous ac power, p(t), oscillates at twice the line frequency and has a mean value, P, which determines the amount of work done in a specified time and is called the *Real Power*. This average value of power depends on the magnitudes of voltage and current and the cosine of the angle between them, so that $P = VI\cos\theta$, where V and I are rms values and P is in watts.

For an ideal inductor or an ideal capacitor the angle θ will be $\pm 90^0$ and its cosine will be zero, meaning that P will be zero if no resistance is present.

Complex power ***S*** is given by $\boldsymbol{S} = \boldsymbol{VI^*} = P + jQ$, where Q is the *Reactive Power*. The units of ***S*** are volt-amps (VA) and the units of Q are volt-amps-reactive (VAR). These quantities are represented in the *power triangle*, where P is the base, Q is the height, and ***S*** is the hypotenuse. The angle between P and ***S*** is θ, and its cosine is the *power factor*, (pf). Operational problems arise if the pf becomes too low; consequently, pf correction is important; when correcting pf, connect a capacitor in parallel with the load and keep the real power constant.

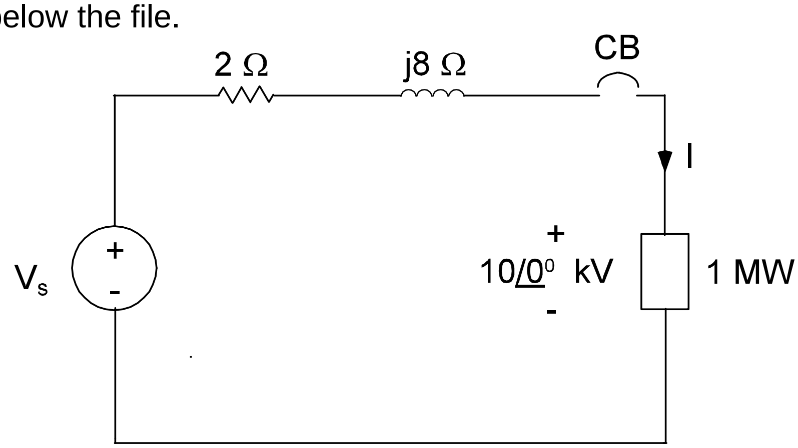
Virtually all electric power is generated and distributed as *three-phase* power. When three-phase systems are *balanced* they can be converted to a single-phase equivalent that makes analysis much simpler, the results are then converted back to three-phase quantities.

5.10 Computer Tools and Other Resources

Matlab is probably the most useful of the computer tools for performing power calculations. The following examples are files that show how voltage regulation is affected by:

- variations in load magnitude at a specified pf, and
- variations in pf at a specified load magnitude.

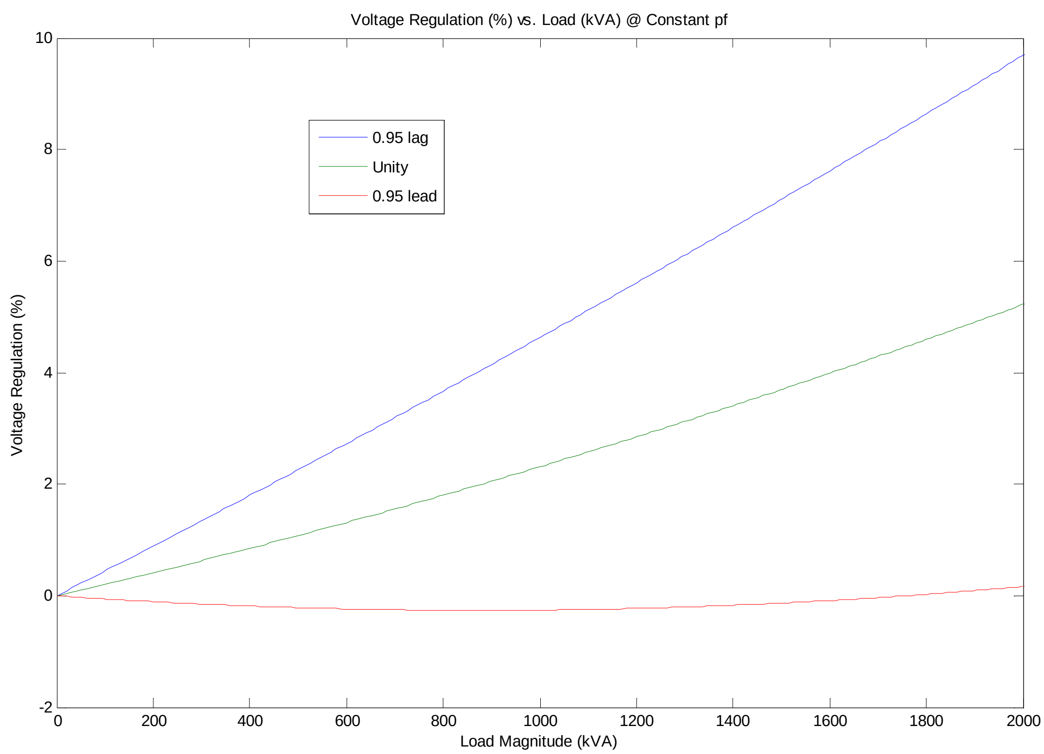
The Matlab commands that make up the files follow. When executed with the data for the single-phase system shown in figure 5.10 (reproduced below) they produce results shown below the file.



5.10.1 Voltage Regulation vs. Load Magnitude

The graphs are for unity pf and lagging and leading values of the specified pf of 0.95. The range is up to 200% of the stated load kVA.

```
% FEEDER REGULATION vs. MAGNITUDE of LOAD
%
% Input data
  Z = input('Zfeeder =');
VL = input('Vload =');
  S = input('Sload =');
pf = input('pf =');
%
% Define vector to vary load (load factor)
x = (0 : 0.01 : 2)';
%
% Establish rectangular components of load factor
theta = acos(pf);
rf = sin(theta);
%
% Determine current
Imag = S/VL;
I = Imag*[x'.*(pf+j*rf);  x'; x'.*(pf-j*rf)]';
%
% Calculate Supply Voltage and Voltage Regulation
Vs = VL + Z*I;
Vreg = 100*(abs(Vs)-VL)/VL;
%
% Plot Graphs
SL = S*x/1000;
plot(SL,Vreg)
title('Voltage Regulation (%) vs. Load (kVA) @ Constant pf')
```



5.10.2 Voltage Regulation vs. Power Factor Angle

The following file produces a graph of Voltage Regulation vs. power factor angle at the specified magnitude of load real power.

```
%    FEEDER REGULATION vs. POWER FACTOR ANGLE @ CONSTANT LOAD POWER
%
%    Input data
 Z = input('Zfeeder =');
VL = input('Vload =');
 P = input('Pload =');
%
%   Define vector to vary pf (angle factor)
 x = (-90 : 1 : 90);
%
%   Establish rectangular components of load factor
theta = pi*x/180;
pf = cos(theta);
 S = P./pf;
rf = sin(theta);
%
%   Determine current
Imag = S/VL;
   I = Imag.*(pf+j*rf);
%
%   Calculate Supply Voltage and Voltage Regulation
  Vs = VL + Z.*I;
Vreg = 100*(abs(Vs)-VL)/VL;
%
%   Plot Graphs
plot(x,Vreg)
title('Voltage Regulation (%) vs. pf angle (degrees) @ Constant P')
```