

Fig. 1 shows a simple, one-phase AC circuit consisting of an inductive load with a shunt-connected capacitor C . The load, modeled as a series L - R , might be the induction motor for a refrigerator or fan. This lab exercise demonstrates that, if properly sized, the capacitor has the beneficial effect of increasing the power factor and thus decreasing the net current.

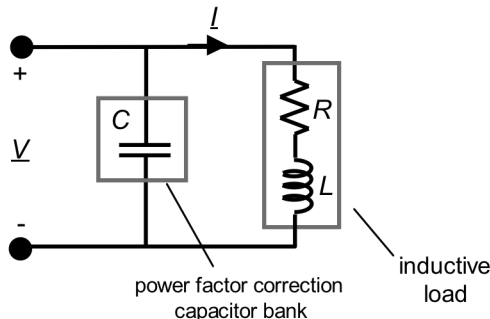


Fig. 1. Simple AC circuit model for an inductive load using a capacitor C to correct the power factor of an inductive load and thus minimize the current.

The power factor of the inductive load (without the capacitor) is $PF = \cos \theta$ (lagging), where $\theta = \tan^{-1}(X/R)$ and $X = \omega L$. In terms of rms current I , the real and reactive power quantities are, respectively, $P_R = RI^2$ and $Q_X = XI^2$. The reactive power does not contribute to the time-average real power consumed by the load, but does increase the required current from the source by the factor $1/PF$. Higher current means higher ohmic losses. The heavier wiring increases capital costs of the distribution system. To decrease reactive current, parallel capacitance is added to "correct" the power factor. Doing so does not affect delivery of time-average power to the load in any way. The capacitance is chosen so that its reactive power $Q_B = -BV^2$, where V is the rms voltage magnitude and $B = \omega C$ is capacitive susceptance, at least partially cancels the reactive power to the load. If $Q_B + Q_X = 0$, then $PF = 1$ and the required current is minimized.

Capacitive power factor correction works because the capacitive current is 180° out of phase with the reactive component of the inductive load current. Thus, the net current supplied to the combined network consisting of the load and the shunt-connected capacitor C are reduced if the capacitance is correctly specified.

Two alternative experimental setups for the exercise are shown in Fig. 2. A variable autotransformer (Variac[®]) provides adjustable 60 Hz AC voltage to a load consisting of a choke coil (inductor) and a series resistor. The shunt-connected capacitors can be switched into the network. The network is instrumented with either (i) an AC voltmeter, AC ammeter (both reading rms), and wattmeter (reading average real power) or (ii) an electronic power meter.

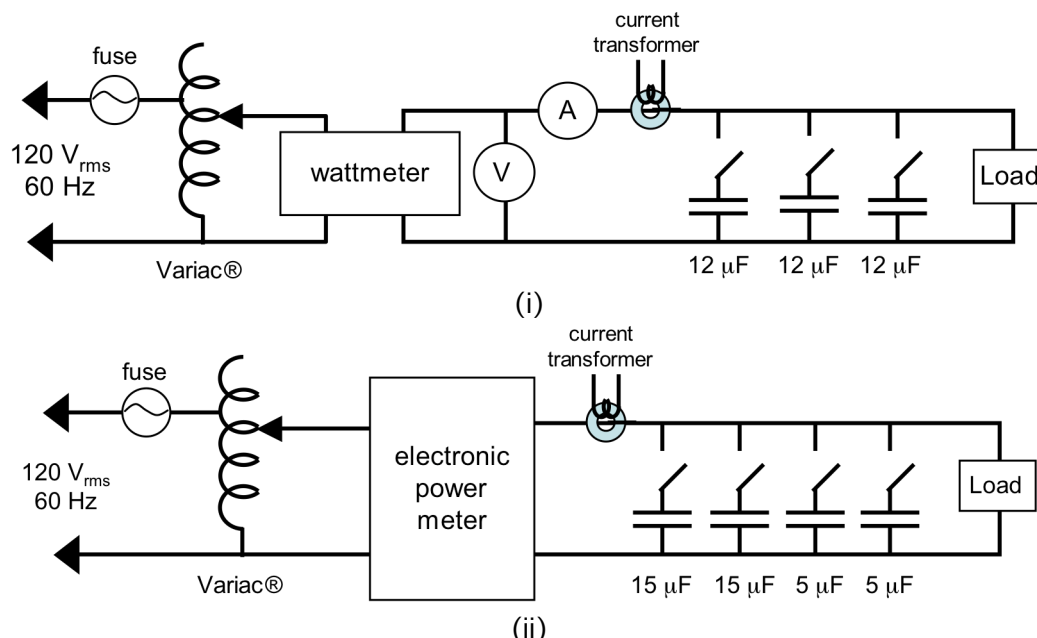


Fig. 2. Two alternative setups for measuring AC power factor using (i) an analog (electro-mechanical) wattmeter, a voltage meter, and an ammeter and (ii) an electronic power meter. The analog meters are generally more accurate. The electronic power meter, while more convenient seems to operate reliably only if the voltage is greater than ~ 90 V-rms and if harmonics are not significant. The current transformers (CT) permit display of the current waveform on an oscilloscope.

Warnings: *You will be working with line voltages and currents in this lab. Follow all procedures exactly and do not touch any circuit or re-wire anything unless the Variac supply is unplugged!*

The power resistors get very warm in just a few minutes of operation. If your apparatus has a fan, be sure to operate it continuously.

Never exceed 90 V-rms with the analog meter setup or 100 V-rms with the electronic power meter setup.

Assignment

You can perform the lab with either the analog system, which is clunky and old-fashioned but much more accurate and reliable, or the electronic power meter, which is convenient but sometimes inaccurate. Working with one (1) partner, perform all the measurements needed to complete the table on the next page. Hand it in with neat, well-organized page or two summarizing your calculations. The best plan is to do the calculations as you make the measurements rather than to wait until later when you may find errors in the measurements.

The current transformer allows you to observe the harmonic content of the current waveform simultaneously as you obtain the measurements. The influence of harmonics becomes more significant as more capacitors are added and the unity PF condition is approached. Be sure to record your observations, to capture some screen shots that reveal the harmonics, and include them in your report.

ECE227/427 Power Factor Lab

date

names

DATA SHEET TO BE HANDED IN

$C(\mu\text{F})$		V_{meas}	I_{meas}	P_{meas}	$(VA)_{\text{calc}}$	PF_{meas}^*	PF_{calc}	Q_{calc}	I_{calc}
0	0								
12	15								
24	30								
36	35								
--	40								

*... PF is not directly obtainable using the electromechanical instrument setup.

The following relationships will be useful in performing the calculations required to complete the table: $PF_{\text{calc}} = P_{\text{meas}} / (V_{\text{meas}} I_{\text{meas}})$, $Q_{\text{calc}} = \sqrt{(V_{\text{meas}} I_{\text{meas}})^2 - (P_{\text{meas}})^2}$, and $I_{\text{calc}} = \sqrt{(P_{\text{meas}})^2 + (Q_{\text{load}} + Q_{\text{C}})^2} / V_{\text{meas}}$, where $Q_{\text{load}} = Q_{\text{calc}}$ is the reactive power with no capacitance switched in and $Q_{\text{C}} = -\omega C V_{\text{meas}}^2$. The switchable values for C are found on Fig. 2. Note: $\omega = 2\pi(60) \approx 377$ rad/s.