1. A 125 hp motor is used to cut lumber in a sawmill. The motor is loaded only 60% of the time and at this condition the output shaft delivers only 120 hp. The rest of the time the motor is relatively unloaded and the output shaft delivers only 50 hp. The motor turns at 1780 RPM and is powered by three-phase 480 V.
   a. Compute the electric (real) power input for both conditions.
   b. Compute the reactive power for both conditions.
   c. Compute the amperage draw for the motor under both conditions.
   d. What is the effective (average) real power used by the motor?

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>motor_hp</td>
<td>125 hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded</td>
<td>60%</td>
<td>time the motor is loaded</td>
<td></td>
</tr>
<tr>
<td>Max_shaft</td>
<td>120 hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>min_shaft</td>
<td>50 hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPM</td>
<td>1780 rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volts</td>
<td>480 V</td>
<td>three phase power</td>
<td></td>
</tr>
</tbody>
</table>

At the "loaded" condition, the motor is loaded
Max_load 96%  = Max_shaft/motor_hp

At the "idle" condition, the motor is only loaded
Min_load 40%  = min_shaft/motor_hp

Estimate the full load motor efficiency
eta_FL 94.30%

Note the part load efficiency is about
f_PL 100%

Table 11.3 Motor Efficiency Multipliers for Part-Load Operation (f_PL = f_PL × η_FL)

<table>
<thead>
<tr>
<th>Power (hp)</th>
<th>0.4-1</th>
<th>1.5-5</th>
<th>7.5-10</th>
<th>15-25</th>
<th>30-60</th>
<th>75-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4-1</td>
<td>0.82</td>
<td>0.95</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1.5-5</td>
<td>0.90</td>
<td>0.96</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>7.5-10</td>
<td>0.96</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>15-25</td>
<td>0.98</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>30-60</td>
<td>0.99</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>75-100</td>
<td>0.99</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

(estimate 125hp motor f_PL based on trend of data for smaller motors)
\[
\begin{align*}
\text{power\_max} & = 94.9 \text{ kW} = \frac{\text{Max\_shaft}}{\eta_{FL}/f_{PL}} \times 0.746 \\
\text{power\_min} & = 39.6 \text{ kW} = \frac{\text{min\_shaft}}{\eta_{FL}/f_{PL}} \times 0.746 \\
\text{Note: } 0.746 \text{ kW} &= 1 \text{ hp}
\end{align*}
\]

Need the power factor for the two conditions:

- max\_PF: 85%
- min\_PF: 48%

\textbf{Figure 14: Motor Power Factor}

Reactive power is the kVAR. First find the total power (kVA):

- tot\_pow\_max: 111.7 kVA = \frac{\text{power\_max}}{\text{max\_PF}}
- tot\_pow\_min: 82.4 kVA = \frac{\text{power\_min}}{\text{min\_PF}}
react_max 58.8 kVAR = tot_pow_max * SIN(ACOS(max_PF))
react_min 72.3 kVAR = tot_pow_min * SIN(ACOS(min_PF))

amperage draw based on real power and three-phase
amps_max 134.3 amps = \frac{power\_max}{Volts/max\_PF/\sqrt{3}} \times 1000
134.3 = \frac{tot\_pow\_max}{Volts/\sqrt{3}} \times 1000
amps_min 99.1 amps = \frac{power\_min}{Volts/min\_PF/\sqrt{3}} \times 1000

since motor is 60% loaded and 40% idle, average power draw is
pow_avg 72.8 kW = Loaded \times power\_max + (1 - Loaded) \times power\_min
2. A company has twenty 10 hp TEFC motors that fail each year. The motors operate continuously at an average loading of 70%. Generally the motors are rewound. The motors operate at 1780 RPM and 230V.
   a. Use MotorMaster to determine the payback period if the motors are replaced with premium efficiency motors.

   using the default cost basis ($0.06/kWh and $3.47/kW demand)

   simple payback is 1.40 yrs
3. The electrical power used by a three-phase motor is measured by the volts and amps it uses. The three RMS voltages recorded are 478V, 479V, and 482V, and the three currents measured are 121 amps, 120.5 amps, and 119 amps.
   a. calculate the power use if the motor is 40% loaded.
   b. calculate the power use if the motor is 100% loaded.

\[
\begin{align*}
V_{\text{avg}} &= 479.7 \text{ V} = \text{AVERAGE(B6:B8)} \\
A_{\text{avg}} &= 120.2 \text{ amps} = \text{AVERAGE(B12:B14)} \\
kW_{\text{app}} &= 99.8 \text{ kW} = V_{\text{avg}} \times A_{\text{avg}} \times \sqrt{3} / 1000 \\
hp_{\text{app}} &= 133.8 \text{ hp} = kW_{\text{app}} / 0.746 \\
}\end{align*}
\]

ignores the power factor

**Motor Power Factor vs. % Full Load Amperage**

\[
\begin{align*}
\text{PF}_{40} &= 45\% \\
\text{PF}_{100} &= 84\% \\
kW_{40} &= 44.9 \text{ kW} = kW_{\text{app}} \times \text{PF}_{40} \\
hp_{40} &= 60.2 \text{ hp} \\
kW_{100} &= 83.9 \text{ kW} = kW_{\text{app}} \times \text{PF}_{100} \\
hp_{100} &= 112.4 \text{ hp}
\end{align*}
\]