EE 380 - H3.3 - Voltage dip problems due to Induction motor starting.

Homework problem will be discussed briefly in class on Monday, Jan 31st. Set up the problem beforehand and be ready to take advantage of any pointers. It may be collected in class on Wed Feb 2nd.

H3.3) The A-N per-phase Thevenin equivalent of the source supplying your office building is given above. Your business depends on computers, photocopiers, and other sensitive electronic equipment (if the voltage drops below 90% rated voltage for even a fraction of a second, the equipment may shut down or be damaged). The total 3-phase load of this existing equipment is 50-kVA at a PF of 0.85 LAG.

A 20-HP 208-Volt 3-phase induction motor needs to be added to provide HVAC (heating, ventilating, and air-conditioning) for your networking/server facility. The proposed motor is Code H. At full load, it is 87% efficient and has PF = 0.85 LAG. Engineers need to investigate the effects of the motor's addition. They are worried about voltage regulation when the motor is added, and more importantly they are worried about voltage dip (sometimes called "flicker") problems that may occur each time the motor is started.

Assuming rated voltage at the loads,

a) Calculate the phasor value of the phase A line current of the existing load.
b) Calculate the phasor value of the phase A line current for the fully-loaded motor.
c) Calculate the phasor value of $V_s$ and the VR, both before and after adding the motor.
d) Using the NEC (National Electrical Code) method, calculate the motor's starting current.
e) Calculate the voltage dip that occurs when the motor starts.
f) Will this cause any problems with your computer equipment? If so, explain what you as an engineer can do to correct the problem. How can you change the motor's specification, change the way the motor is started or operated, change the design of your electrical system, etc?
INDUCTION MOTOR STARTING CURRENT

THREE METHODS:

1. EXACT MODEL - set \( S = 1 \) (locked rotor) and solve for \( I_{\text{START}} \)

2. RULE OF THUMB -

\[
I_{\text{START}} = I_{\text{RATED}} \times \text{P.F.} \times 6
\]

3. NEC Section 430-7(b) MOTOR CODE LETTERS

<table>
<thead>
<tr>
<th>Code Letter</th>
<th>Kilovolt-Ampere per Horsepower with Locked Rotor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>3.15</td>
</tr>
<tr>
<td>C</td>
<td>3.55</td>
</tr>
<tr>
<td>D</td>
<td>4.0</td>
</tr>
<tr>
<td>E</td>
<td>4.5</td>
</tr>
<tr>
<td>F</td>
<td>5.0</td>
</tr>
<tr>
<td>G</td>
<td>5.6</td>
</tr>
<tr>
<td>H</td>
<td>6.3</td>
</tr>
<tr>
<td>J</td>
<td>7.1</td>
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<tr>
<td>K</td>
<td>8.0</td>
</tr>
<tr>
<td>L</td>
<td>9.0</td>
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<tr>
<td>M</td>
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<tr>
<td>N</td>
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<tr>
<td>R</td>
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<tr>
<td>S</td>
<td>16.0</td>
</tr>
<tr>
<td>T</td>
<td>18.0</td>
</tr>
<tr>
<td>U</td>
<td>20.0</td>
</tr>
<tr>
<td>V</td>
<td>22.4 and up</td>
</tr>
</tbody>
</table>

EXAMPLE: 10 HP, 240V, 30 IND MOTOR, CODE D

\[
I_{\text{START}} = \frac{(4.49 \text{ kVA/HP}) \times (10 \text{ HP})}{\sqrt{3} \times 0.24 \text{ kV}}
\]

\[
= \boxed{108 \text{ AMPS}}
\]
H3.8

a) \( I_L = \frac{50,000}{\sqrt{3}(208)} \cos^{\circ} 85 = 138.8 \angle -31.8 \text{ A} \)

b) \( I_M = \frac{20(744)}{\sqrt{3}(208)(0.87)(0.85)} \cos^{\circ} 85 = 56.0 \angle -31.8 \text{ A} \)

c) \( V_S \) for only \( I_L \):
\[
V_S = 120 \angle 0^\circ + (138.8 \angle -31.8^\circ)(0.01 + j0.03)
\]
\[
= 123.4 \angle 1.3^\circ \text{ Volts RMS}
\]
\[
VR = \frac{123.4 - 120}{120} = 2.83\% \quad \text{OK}
\]

\( V_S \) for both \( I_L \) & \( I_M \):
\[
V_S = 120 \angle 0^\circ + (194.8 \angle -31.8^\circ)(0.01 + j0.03)
\]
\[
= 124.8 \angle 1.81^\circ \text{ Volts}
\]
\[
VR = \frac{124.8 - 120}{120} = 4\% \quad \text{(Still acceptable)}
\]
d) \[ |I_{\text{START}}| = \frac{(7.09)(7.09 \text{ kVA / HP})(20 \text{ HP})}{\sqrt{3}(0.208)} = 393.6 \text{ Amps RMS} \]

e) If we assume this is primarily a resistive current (\(s=1\), so main impedance in the induction motor is \(R_2 = R_1 = R_2\)), then

Before switch closes, \(V_{\text{LOAD}} = 120 \angle 0^\circ \text{ V}\).

After closing switch, \(I_{\text{TOTAL}} = I_L + I_{\text{START}}\)

\[ I_{\text{TOTAL}} = (138.8 \angle 31.8^\circ \text{ A}) + 393.6 \angle 0^\circ \]

\[ = 516.8 \angle -8.1^\circ \text{ Amps} \]

\[ V_L = V_3 - I_{\text{TOTAL}} (0.014 \angle 0.03) \]

\[ = 123.4 \angle 13^\circ - (516 \angle -8.1 \times 0.014 \angle 0.03) = 116.66 \angle 5.8^\circ \text{ V} \]

So, voltage dips to under 117 volts.
f) Luckily, the voltage dips only

\[
\frac{3.34}{120} = 2.78\% 
\]

Hopefully, the equipment can "ride out" such a momentary dip, as it's only a small drop from a nominal voltage. 120-V equipment is often rated for a range of 113-125 volts. Also, lights should not noticeably dim. If it was a more severe problem, we could as engineers recommend

- Larger wiring to reduce voltage drop.
- Get motor with lower Code letter.
- Provide motor with soft-starter (like in EE280 Lab).
- Get UPS for computer equipment.
- Other ideas?