EE 380 - H3.2 - Theme homework problem on application of E-mag to power systems.

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.

Note - This problem requires only two basic E-mag concepts:

Induced force calculations as learned in EE 280:

\[ F_{IND} = i(\vec{\ell} \times \vec{B}) \text{ Newtons} \]

Where \( i \) is the current flowing in a conductor, \( \ell \) is the length of the conductor in the direction of current flow, and \( B \) is the magnetic flux density surround the conductor, caused by current flowing through the adjacent conductor.

and the calculation of magnetic flux density \( B \) at a distance \( r \) from a current-carrying wire:

\[ H = \frac{I}{2\pi r} \quad \text{and} \quad B = \mu_0 H = \frac{\mu_0 I}{2\pi r} \]

H3.2) A Line-to-Line short circuit causes 40,000 A RMS to flow in opposing directions thru 2 adjacent bus conductors (a bus conductor is just a heavy pipe or bar made from copper or aluminum. These are the main current-carrying conductors inside high-voltage equipment, like "switch gear," or out in the open in substation "bus bar." Typical full-load ratings might be 1200 A RMS, for example).

The bus conductor is supported by insulators at 10-ft spacings, and the conductors are themselves 18" apart. You are an engineer who is worried about whether the insulators are strong enough to withstand the high induced force created by the short circuit current.

a) Make a sketch of what the bus bars and support insulators might look like.
b) Calculate the peak (maximum) amplitude of the current.
c) Using this worst-case peak current, calculate the magnitude and direction of the magnetic flux density \( B \) at one conductor due to the current in the other conductor.
d) Next, calculate the magnitude and direction of the peak induced force. Express this force both in Newtons and in lbf.
e) You've calculated the peak force. Consider that both the current and the flux density \( B \) are 60-Hz sinusoidal functions. The induced force will thus be a sinusoidally oscillating force. At what frequency does it oscillate? Sketch out the induced force as a function of time.
f) The insulators are rated to withstand a "cantelever force" of 1000 pounds without breaking. Will they handle it or will they break?
c) \[ B = \frac{M_0 \times 56,570}{27 \times 0.457} = 0.0246 \, T \] (upward)

d) \[ F = (56,570 \times 3.04 \times 0.0246) = 4258 \, N \]
\[ \times \frac{2.2 \, lb}{Kg} \times \frac{Kg}{9.8 \, N} \approx 960 \, lbf \]
\( e \) \( f = 120 \text{ Hz} \)

Consider trig identity: \( \sin^2 \alpha = \frac{1-\cos 2\alpha}{2} \)

\[ \therefore \sin^2 (\omega t) = \frac{1-\cos (2\omega t)}{2} \sin^2 (\omega t) \]

Induced force: 960 lb.

This is the oscillating force (vibration) the insulators are subjected to.

\( f \) It appears that the insulators are just strong enough, as they are rated at 1000 lbf.