Bucking Coils produce Energy Gain

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1. Introduction

Osamu Ide has claimed overunity in a form of BEMF capture circuit that uses bucking coils. This paper considers such coils to show that a magnetic propagation delay from one coil to the other gives the connected pair of bucking coils a clockwise flux v. current loop, and such a clockwise loop is known to deliver energy. By considering a fast transient current supplied to the loops the presence of the magnetic delay is seen to produce an inductance that reduces with time from which the clockwise loop can be inferred. The resulting simplified waveform is seen to compare favourably with that shown by Ide. The analysis is then extended to a general case for sinusoidal current through the two coils to show that the propagation delay creates a negative series resistor in the equivalent circuit.

2. Fast Transient Analysis

Osamu Ide's OU converter uses short pulses, which suggests that magnetic propagation delay may have something to do with its performance. The claimed "forward EMF" being in the same direction as the current is simply another way of saying negative resistance, i.e. it represents an energy source. The diagrams show this "forward EMF" region being a narrow spike within the waveform. Now it is well known that for inductive systems an energy sink (energy loss) is represented by an anti-clockwise BH loop (which is really a material characteristic) where the area of the loop represents an energy density (Joules per cubic meter). At the system level an anti-clockwise flux (Φ) v. current (I) loop represents that same energy loss where the area of the loop now gives energy (Joules) directly. A clockwise BH loop or ΦI loop represents an energy source that supplies power to the electrical circuit. It is shown here that bucking coils as used by Ide can produce that CW ΦI loop.

When the two bucking coils are energised simultaneously there will be a short period of time where the magnetic wavefronts propagate along the ferrite core but have not yet reached the opposite coil. This has been illustrated here by simply taking a FEMM plot and truncating it to represent the moving wavefront from one coil.

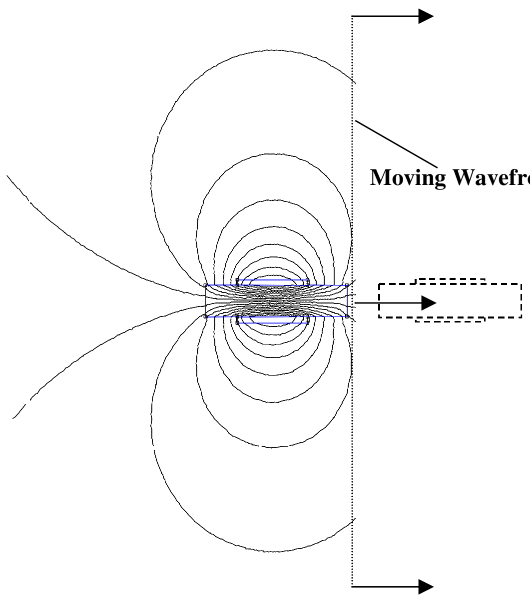

Figure 1. Magnetic Wavefront.

Of course the magnetic field from the RH coil also has a wavefront moving from R to L towards the first coil. The important thing to note is that during this time the drive source is seeing just two non-interacting coils. When the wavefronts finally reach the opposite coils then the combined inductance reduces because of their bucking interaction. This change of inductance during the applied pulse accounts for a CW loop as shown in the next figure. Here it is assumed that the coils are suddenly connected to a low impedance voltage source that enforces a constant dΦ/dt and dI/dt where the values are determined only by the voltage and the inductance. Thus when the inductance changes value then so does the slope of the flux and current waveforms. Initially these rates are low according to the initial high value of inductance, then the rates increase when the inductance becomes lower. Upon removal of the voltage the inductor discharges into the load resistor, again initially at high inductance then followed by low inductance. It is seen that the ΦI chart traces a CW loop.

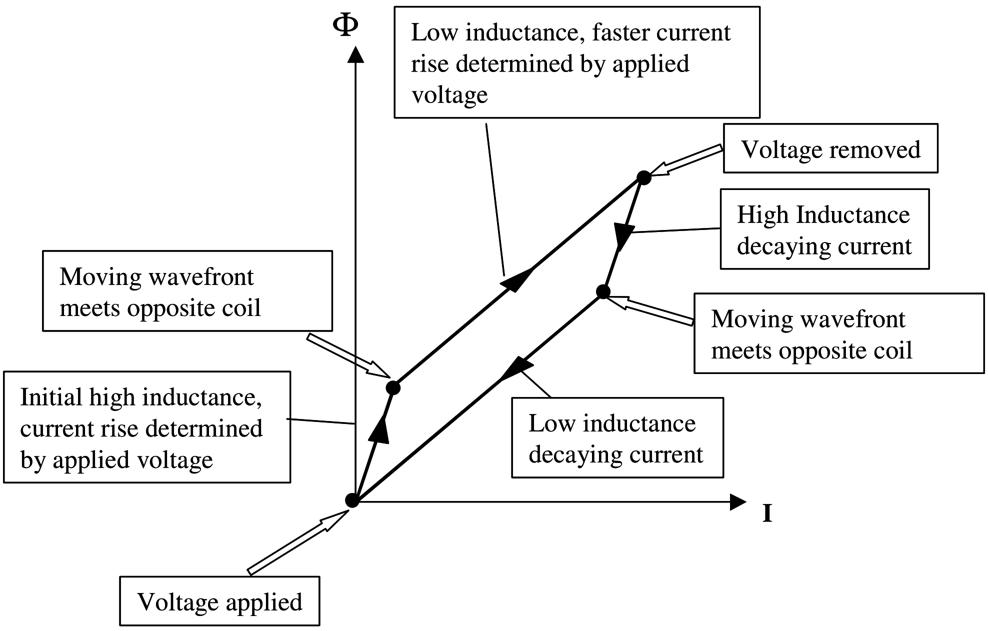

Figure 2. Φ v. I Loop

If we construct simplified voltage and current waveforms we obtain the waveforms shown in figure 3.

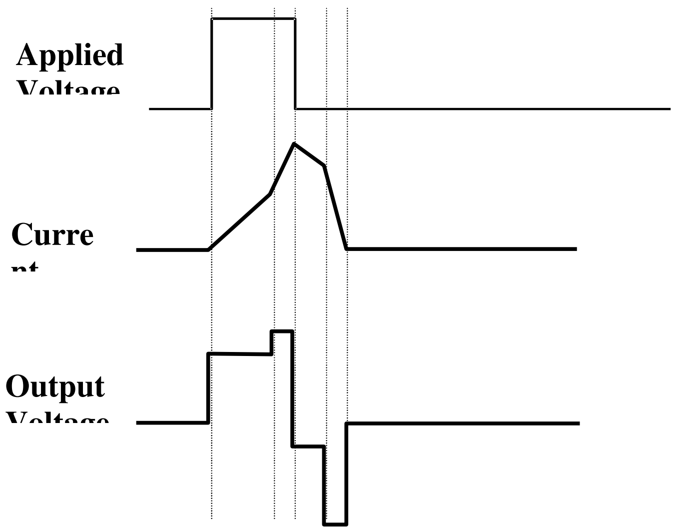

Figure 3. Voltage and Current Waveforms.

For comparison here is the waveform as given by Ide at the 2012 SPECIF conference.

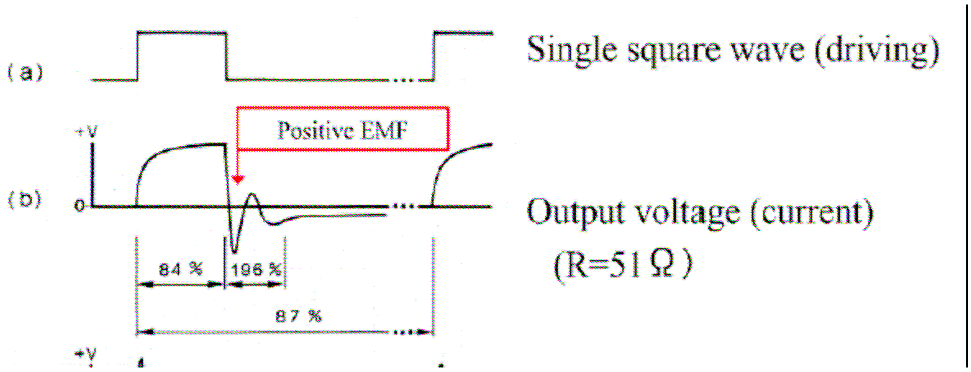

Figure 4. Ide's Waveform

Ide's claim is that the fly-back spike is "positive EMF" whereas it represents the excess energy gained from the CW loop.

3. Sine-wave Considerations

The above analysis assumed fast transients, however the OU characteristic from bucking coils is not limited to this case. Even for smooth waveforms the time delay in the magnetic path coupling the two coils will show itself as a CW Phi v. I loop. This can be demonstrated by the following analysis.

The inductance for two coils in series is given by the well known formula

$$L = L_1 + L_2 \pm 2L_{12} \qquad (1)$$

where L_1 and L_2 are the inductances of the two coils when isolated from each other (e.g. at great separation) and L_{12} is the mutual inductance between the coils. For bucking coils the negative sign applies. Now to a first approximation we can say that there are no time delays affecting the values of L_1 and L_2. However there could be a significant time delay concerning the coupling between the coils hence affecting voltage induced into the L_{12} term. Taking the current through the two coils to be of value $i\ \sin(\omega t)$ and using the classical voltage across an inductor as $V = -L\frac{di}{dt}$ we get from (1) the voltage across the series combination as

$$V = -\omega i\left[L_1 \cos(\omega t) + L_2 \cos(\omega t) - 2L_{12} \cos(\omega t + \phi)\right] \qquad (2)$$

where we have introduced a phase delay ϕ for the mutual coupling. Expanding the third term yields

$$V = -\omega i\left[L_1 \cos(\omega t) + L_2 \cos(\omega t) - 2L_{12} \cos(\omega t)\cos(\phi) + 2L_{12} \sin(\omega t)\sin(\phi)\right] \qquad (3)$$

Rearranging (3) to gather the $\cos(\omega t)$ and $\sin(\omega t)$ terms gives

$$V = -\omega i\left[\cos(\omega t)\{L_1 + L_2 - 2L_{12}\cos(\phi)\} + \sin(\omega t)\{2L_{12}\sin(\phi)\}\right] \qquad (4)$$

The phase angle θ between voltage and current is then

$$\theta = -\tan^{-1}\left(\frac{2L_{12}\sin(\phi)}{L_1 + L_2 - 2L_{12}\cos(\phi)}\right) \qquad (5)$$

This phase is perhaps more readily understood by dividing (4) by the current $i\ \sin(\omega t)$ to get the impedance of the series-connected bucking coils as

$$Z = \frac{V}{i \sin(\omega t)} = j\omega\left[L_1 + L_2 - 2L_{12}\cos(\phi)\right] - 2\omega L_{12}\sin(\phi) \qquad (6)$$

where j is the imaginary operator $j - \sqrt{-1}$. It is seen that the equivalent circuit of the series connected bucking coils is an inductance $L = L_1 + L_2 - 2L_{12}\cos(\phi)$ in series with a ***negative*** resistance $R = -2\omega L_{12}\sin(\phi)$. This is illustrated in figure 5.

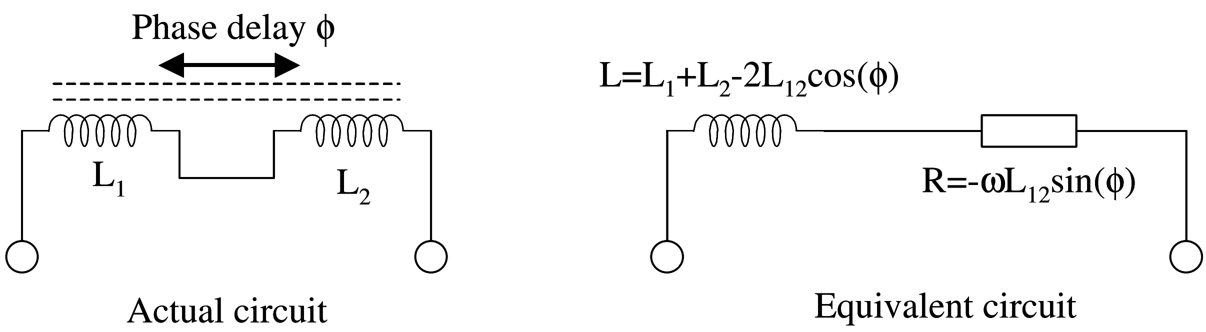

Figure 5. Series opposing coils and their equivalent circuit.

Note that value of the negative resistor increases with frequency. Unfortunately positive real losses associated with the core and the conductor also increase with frequency, so the presence of the negative resistance is not always readily discernible.

4. Discussion

If the coils were in series-aiding the resistance R would be positive representing an energy loss. It is well known that the magnetic propagation delay through ferromagnetic cores does generally result in a loss, and the delay has been given the name *magnetic viscosity* invoking the perception that friction causes the loss. The above analysis could be extended to the coupling between adjacent turns of a single coil to show that with a magnetic propagation delay between turns the mutual coupling between turns will produce a loss. However that only applies to the situation where the mutual coupling is aiding and not opposing. *When the opposing case is considered there is an energy gain*. This reasoning can apply to bifilar-wound opposing coils wound on magnetic cores that have significant magnetic propagation delay. The fact that series-aiding turns produce a loss but series-opposing turns produce a gain should tell us that there is more to magnetic propagation than the name *viscosity* implies.

5. Conclusions

It has been shown that the presence of a magnetic propagation delay along a ferromagnetic core will create an energy loss for series-aiding mutual coupling between coils, and an energy gain for series-opposing. The loss or gain can be accounted for by a series resistor in the equivalent circuit of positive or negative value. The formula for this resistor is given for two separated coils on a common core. The analysis can be extended to the mutual coupling between adjacent turns of a single layer coil to show that the presence of magnetic propagation delay in the core will produce the well-known loss associated with that phenomenon. That same analysis also shows that for a single layer bifilar coil where the current is reversed between adjacent turns will exhibit an energy gain.