Reducing the Lenz Effect in a Transformer

© by Jon M Flickinger 8-03-2019 (*Revised 9-15-19)

This paper will explain a means that will defeat or reduce the Lenz effect to near zero in a common transformer with two windings.

To understand the means, we first examine the Lenz Law. Fig 1 below was taken from the Hyper Physics website here-

http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

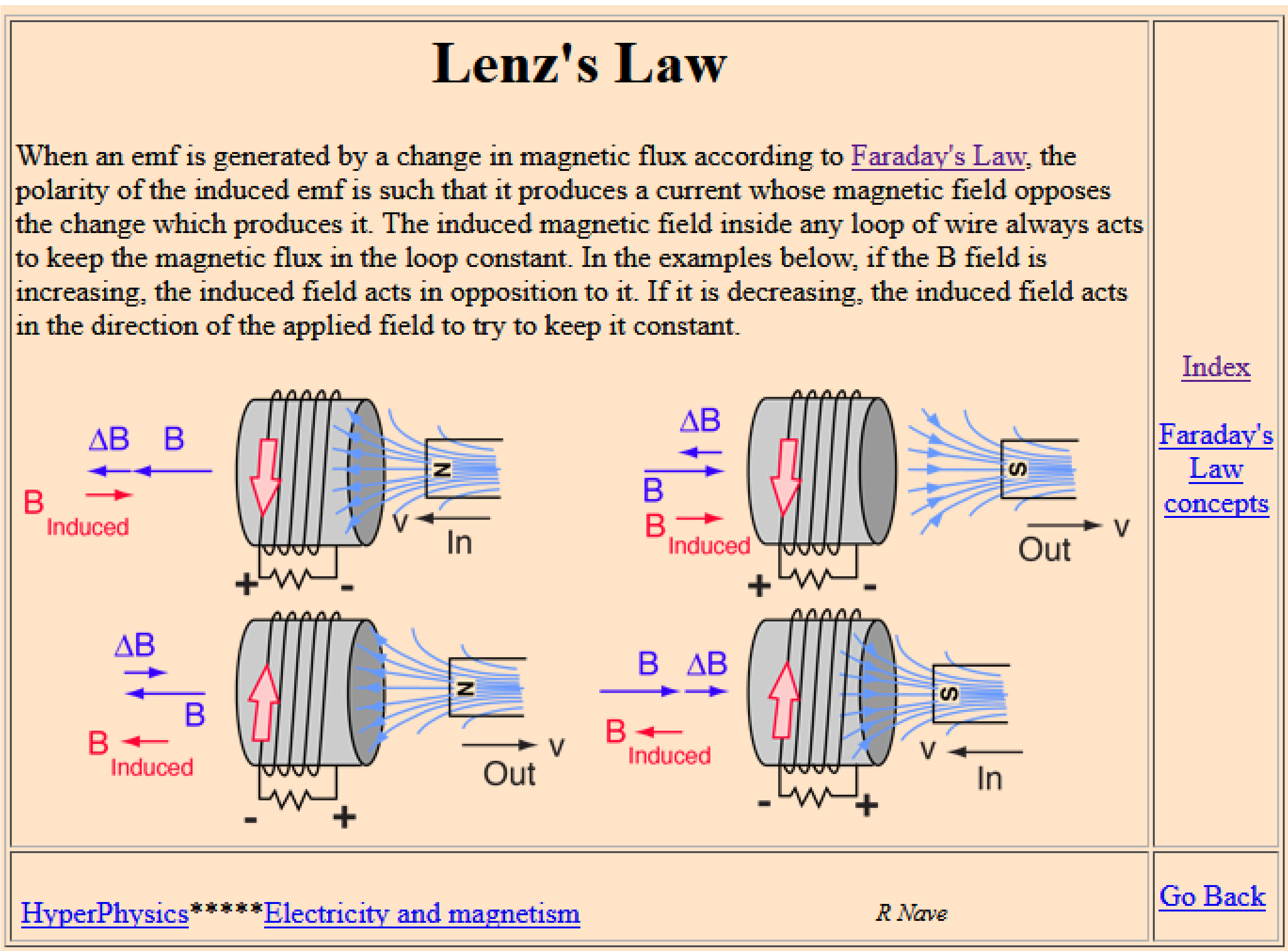

Figure 1

Therefore, when applying the Lenz law to a transformer with a primary and a secondary, we first apply a changing voltage or emf to the primary which in turn creates a changing current and flux in the primary winding. This changing flux generated in the primary will induce a voltage or emf in the secondary that will be opposite in polarity to the original primary voltage or emf. It is this opposing feedback that forces a traditional transformer to always be a conservative device with a COP (Coefficient of Performance) <1 or under unity.

Now we will look at the fore mentioned Faraday law for more insight. See Fig 2 below again taken from the Hyper Physics website.

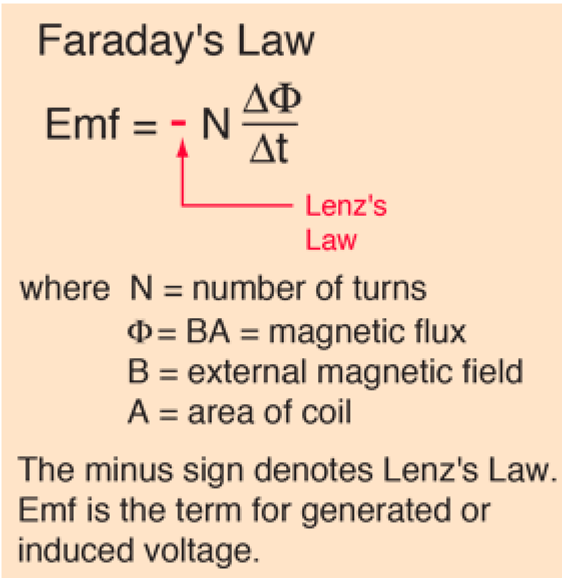

Figure 2

Using this basic equation below we arrive at the following:

$\boldsymbol{Emf} = \text{-}\ \boldsymbol{N} \times \boldsymbol{\Delta\Phi/\Delta t}$ (Faraday's Law of induction) {1}

$\boldsymbol{Emf} = \text{-}\ \boldsymbol{L} \times \boldsymbol{\Delta I/\Delta t}$ (Inductance defined in terms of Emf) {2}

$\therefore \boldsymbol{N} \times \boldsymbol{\Delta\Phi/\Delta t} = \boldsymbol{L} \times \boldsymbol{\Delta I/\Delta t}$ (Substitution) {3}

$\therefore \boldsymbol{N} \times \boldsymbol{\Delta\Phi} = \boldsymbol{L} \times \boldsymbol{\Delta I}$ (Reduce) {4}

$\therefore \boldsymbol{L} = \boldsymbol{N} \times \boldsymbol{\Delta\Phi/\Delta I}$ (Inductance in terms of flux) {5}

$\therefore \boldsymbol{\Delta\Phi} = \boldsymbol{L} \times \boldsymbol{\Delta I}$ (Flux over time verses inductance and current over time with 1 turn) {6}

Equation {6} is the key to understanding the means for Lenz reduction in a transformer. If we can somehow reduce the third term $\boldsymbol{\Delta I}$ in this equation, we also reduce the first term $\boldsymbol{\Delta\Phi}$. Therefore, if we reduce $\boldsymbol{\Delta\Phi}$ in equation {1}, we will also reduce the counter $\boldsymbol{Emf}$ over time and thus the Lenz effect as well.

So, what is required to reduce $\boldsymbol{\Delta I}$ in our transformer's secondary? Simply a **constant current load**! A constant current load will exhibit little to no $\boldsymbol{\Delta I/\Delta t}$ and therefore little to no $\boldsymbol{\Delta\Phi/\Delta t}$ so in essence, the primary will not "see" the constant current secondary resulting in little to no Lenz effect.

This can be accomplished with traditional discrete components, integrated circuits, or simply with an inductor. An inductor will be used in the following simulation examples.

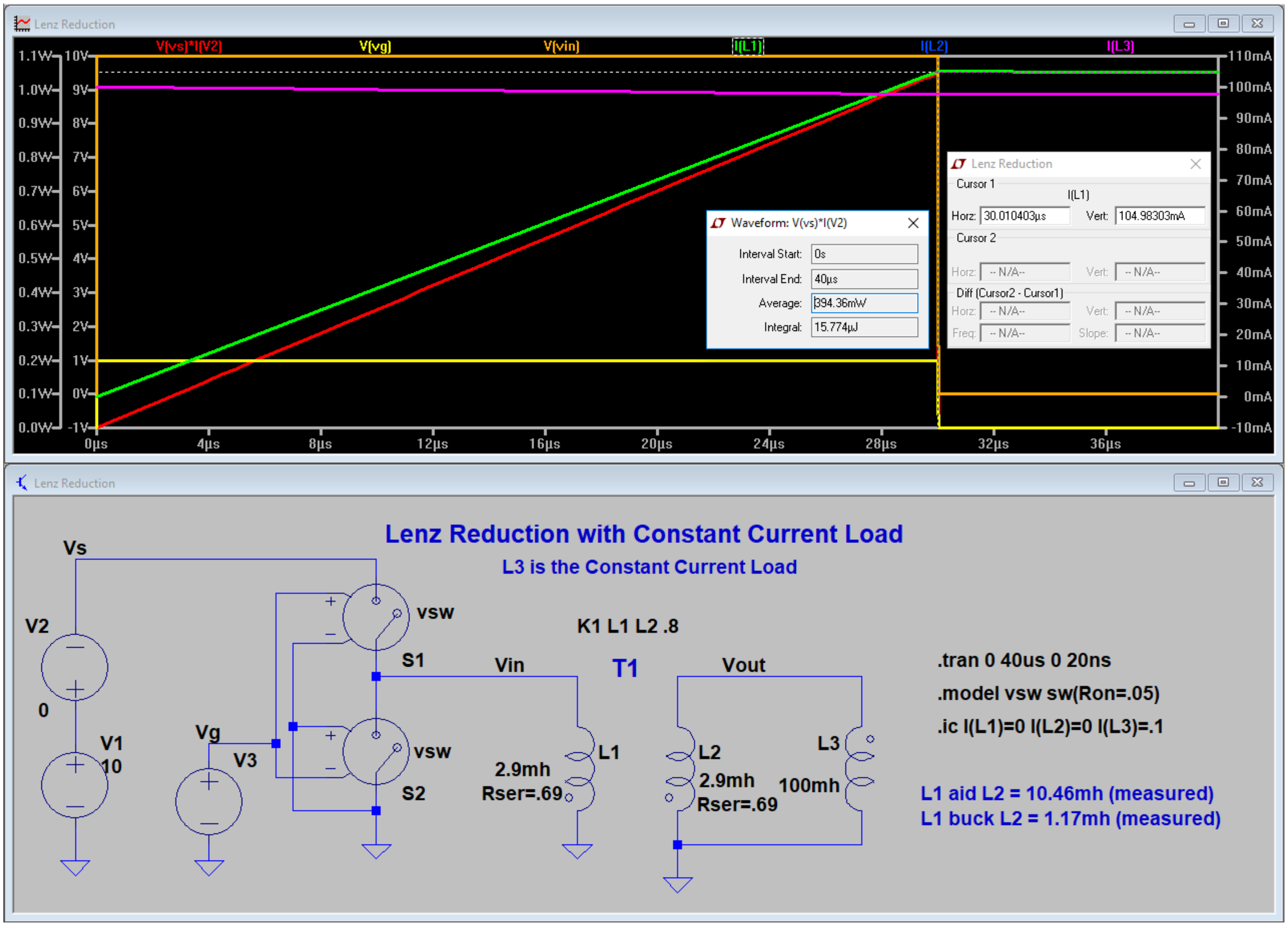

Figure 3

In Fig 3 we see a simulation of a model of an actual transformer with equal primary L1 and secondary L2 windings. The load for the secondary L2 is the 100mh inductor L3. An initial current of 100ma is set in L3 prior to the simulation running which establishes L3 as a constant load for T1.

The simulation starts with S1 connecting L1 to the 20 vdc supply Vs. The current in L1 begins to increase linearly as seen in the green trace I(L1) in the plot view. At the end of 30us, S1 turns off and S2 connects L1 to ground thus ending the input to T1's primary.

With cursor #1 placed at 30us, we see I(L1) has reached a magnitude of 104.98ma. From this we can calculate the effective input inductance of L1 which would be $\boldsymbol{L} = \boldsymbol{Emf} \times \boldsymbol{\Delta t} / \boldsymbol{\Delta I}$ = 10*30e-6/.10498 = 2.86mh. This reduced value is within 1.4% of the open primary value of 2.9mh which indicates that we have greatly reduced the Lenz effect. We do not have perfect Lenz reduction due to the slight $\boldsymbol{\Delta I}$ (current change) in the secondary due to the voltage reduction across the secondary as can be seen in the pink V(Vout) plot trace.

**- The above statement is not totally correct as to why the inductance in the primary L1 is slightly reduced as compared to the value with an open secondary. The true reason for the slightly reduced inductance in L1 is due to the voltage across L3 during the 30us of operation. This voltage drop with the polarities shown produces a small di/dt in L3 which creates a small Lenz reflection to the primary. The small drop in current in this configuration can be confirmed by the simple calculation di = E*dt/L . If L3 was a perfect current source, there would be no Lenz effect.*

We will now take a look at the same circuit with a .001 ohm load on the secondary which for all practical purposes is a short and we will compare to the constant current load.

Figure 4

In Fig 4 above, we see that the peak primary current reached in 30us is now 282.48ma with the shorted secondary. This results in an effective input inductance of 1.06mh as seen by the power supply. This reduced inductance is due to the increased Lenz effect.

The transformer modeled for this simulation has a coupling or K factor of .8 which could be considered a loose coupling say compared to K =.95 . With a higher K factor and a shorted secondary, the drop in effective primary inductance would be dramatically greater while with a constant current loaded secondary, the effective primary inductance would only be slightly less than the rated primary inductance.

Thus we show proof that a constant current load on a transformer can drastically reduce the Lenz effect.

I will term this means of Reduced Lenz Effect with a Constant Current Load as "RLE-CCL" for short.

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