Spin Injection Magnetization

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1. Introduction

It has been suggested that a current of spin-polarized electrons injected into a transformer core could take the place of a primary winding, yielding power into an external load via an output winding. This paper looks into that possibility and examines the potential over-unity performance.

2. Basic Scheme

The basis idea is as shown in Figure 1.

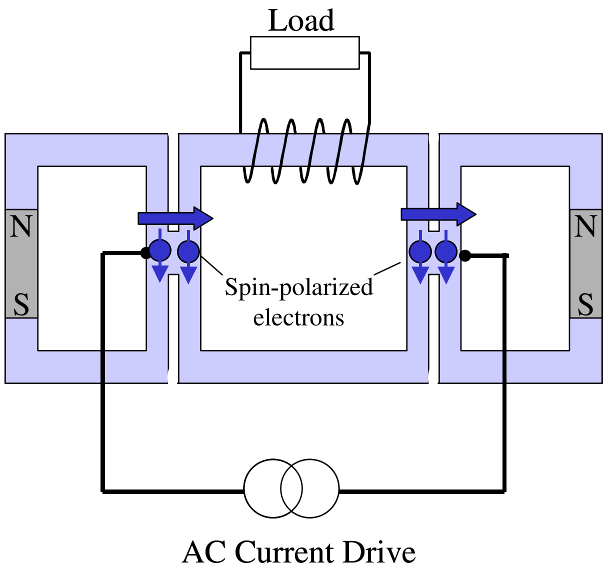

Figure 1. Current Driven Transformer

A transformer lamination is stamped into the shape shown. The two outer magnetic circuits have magnets inserted to magnetize the material. When a current is passed through the lamination as shown, on the left spin-polarized electrons supporting a CCW magnetization of the inner magnetic circuit are transported *into* the inner core, while on the right spin-polarized electrons supporting a CW magnetization are transported *out* of the inner core. The net result is an increase of CCW magnetization, which is reversed on the next half cycle. The alternating flux in the inner core develops a voltage in the output coil to deliver power to the load.

3. Analysis

Electrons flowing in a ferromagnetic conductor such as Fe can be spin-polarized if the Fe is magnetized. Each electron has a dipole moment of value the Borh magneton μ_B, so a current of spin-polarized electrons not only transport charge but also magnetic-moment. The quantity of magnetic-moment transported per second by a current i is given by

$$\frac{d\mu}{dt} = i\left(\frac{\mu_B}{e}\right) \quad (1)$$

where e is the electron charge. If that current is injected into a transformer core whose magnetic path length is l and cross section A, this results in the core receiving magnetization M at a rate

$$\frac{dM}{dt} = \frac{i}{Al}\left(\frac{\mu_B}{e}\right) \quad (2)$$

If the injected current is sinusoidal at angular frequency ω, by taking the time integral the magnetization magnitude becomes

$$M = \frac{i}{\omega Al}\left(\frac{\mu_B}{e}\right) \quad (3)$$

Since $B = \mu_R \mu_0 (H + M)$, in the absence of applied H this magnetization has the same effect as an effective H_{EFF}

$$H_{EFF} = \frac{i}{\omega Al}\left(\frac{\mu_B}{e}\right) \quad (4)$$

We can immediately see that, for a given current, H_{EFF} is maximised at low frequency and with small core volume, so for power applications the picture that emerges is of an array of tiny toroidal cores much like the core-store of early computers. With this in mind we shall restrict ourselves to single turn output coils so that a single wire threaded through many cores effectively puts all their outputs in series. H_{EFF} can be visualised as an effective single turn primary input current i_{EFF} of value $H_{EFF}l$.

$$i_{EFF} = \frac{i}{\omega A}\left(\frac{\mu_B}{e}\right) \quad (5)$$

With the output single turn loaded with a resistor R_L we now have an equivalent transformer. The input current i_{EFF} will have two components, a load current i_L in phase with the output and a magnetizing current i_M in phase quadrature. The phase angle θ between i_L and i_{EFF} is given by

$$\tan\theta = \frac{R_L}{\omega L} \quad (6)$$

where L is the inductance of the single turn

$$L = \frac{\mu_R \mu_0 A}{l} \quad (7)$$

The magnetizing current gives rise to the flux Φ by

$$\Phi = \frac{i_M \mu_R \mu_0 A}{l} \quad (8)$$

which is responsible for the transformer voltage $V = \omega\Phi$, then since $i_M = i_{EFF}\sin\theta$

$$V = \frac{\omega i_{EFF} \mu_R \mu_0 A \sin\theta}{l} \quad (9)$$

The load current $i_L = i_{EFF}\cos\theta$ flows through R_L yielding the same voltage V, hence the output power P_{OUT} becomes

$$P_{OUT} = \frac{\omega i_{EFF}^2 \mu_R \mu_0 A \sin\theta\cos\theta}{l} \quad (10)$$

This is a maximum when $\theta = 45^o$ (which occurs when $R_L = \omega L$) so using (5) the output power becomes

$$P_{OUT} = \frac{i^2 \mu_R \mu_0}{2\omega A l}\left(\frac{\mu_B}{e}\right)^2 \qquad (11)$$

The injected current i flowing through the core will dissipate input power given by

$$P_{IN} = \frac{i^2 \rho l}{4A} \qquad (12)$$

where ρ is the electrical resistivity of the core. Taking the ratio of (11) and (12) yields the efficiency η as

$$\eta = \frac{2\mu_R \mu_0}{\omega \rho l^2}\left(\frac{\mu_B}{e}\right)^2 \qquad (13)$$

which leads to the overunity condition $\eta > 1$ when

$$l^2 < \frac{2\mu_R \mu_0}{\omega \rho}\left(\frac{\mu_B}{e}\right)^2 \qquad (14)$$

Thus we require a high relative permeability, low frequency and small magnetic length. Since $\frac{\mu_B}{e} = 5.788\times10^{-5}$, $\mu_0 = 4\pi\times10^{-7}$ and for Fe $\rho = 10^{-7}$ and in pure state Fe could have $\mu_R = 10^5$, we can look into a transformer operating at 60 Hz where we obtain $l < 4.7mm$. This is a tiny core size, so to achieve useful power levels an array of cores must be considered.

4. Self Oscillation

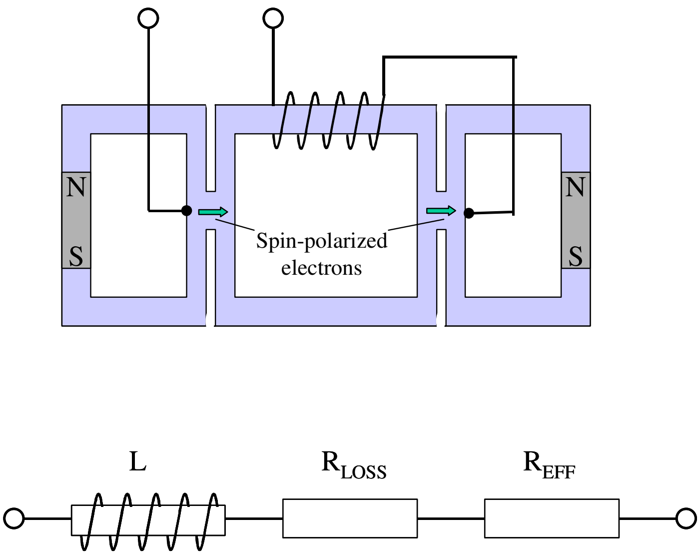

Figure 2. Series connection and equivalent circuit

If the output is connected in series with input so that the current i is common, as shown in Figure 2, the equivalent circuit becomes an inductor L (equation (7) in series with two resistors, (a) a resistor representing the losses (12) of value

$$R_{LOSS} = \frac{\rho l}{4A} \qquad (15)$$

and another representing the voltage induced by the spin injection.

$$V = \frac{\omega i_{EFF} \mu_R \mu_0 A}{l} = \frac{i \mu_R \mu_0}{l} \left(\frac{\mu_B}{e} \right) \quad (16)$$

which is an effective resistance of value

$$R_{EFF} = \frac{\mu_R \mu_0}{l} \left(\frac{\mu_B}{e} \right) \quad (17)$$

R_{EFF} can be positive or negative depending on the spin polarity and it is the negative case that is of interest. For self-oscillation the condition $R_{EFF} > R_{LOSS}$ is met when

$$l^2 < \frac{4 A \mu_R \mu_0}{\rho} \left(\frac{\mu_B}{e} \right) \quad (18)$$

Note that this differs from the transformer case (14) and the condition is no longer frequency dependent. Also (18) implies an aspect ratio where the magnetic cross section *A* is large while the length *l* is small. This could be important in respect of the Hans Coler Stromerzeuger where the current is injected into a sheet of (possibly magnetic) conductive material, see Figure 3.

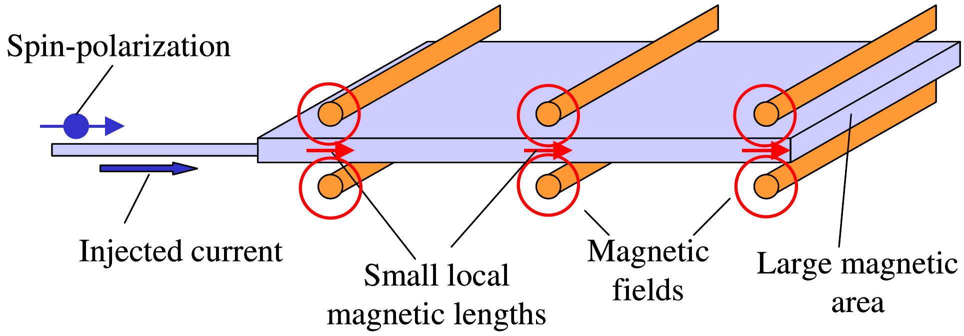

Figure 3. Stromerzeuger configuration

5. Conclusion

The injection of spin-polarized current into ferromagnetic cores presents anomalous voltages that could provide for overunity performance. Using that spin injection in place of the normal primary of a transformer will create overunity under the conditions of (a) low frequency, (b) when the relative permeability is very high and (c) the magnetic path length is very small. A matrix of small cores offers the potential for creating larger overunity devices. If the current is in series with a winding on the core the resultant complex impedance will contain negative resistance, hence self oscillate, at any frequency if (a) the relative permeability is very high and (b) the magnetic path length is small compared to the magnetic cross section. This latter insight could be important in understanding the Stromerzeuger.