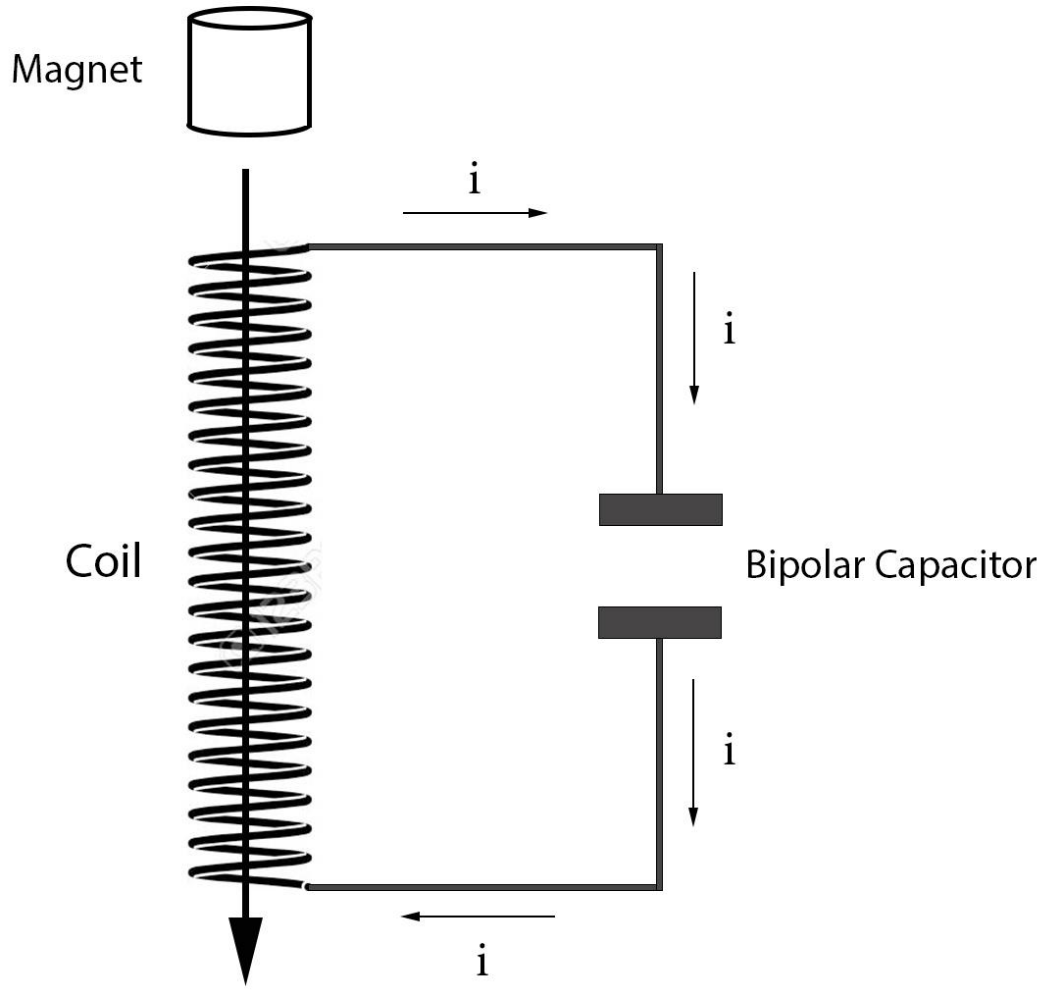
Lenz System Experiment Outline

Abstract

One of the main detriments to wind power is the effect of wind intermittency and turbulent air flow on power output. These natural phenomena arise from weather patterns, air flow obstruction, and the motion of surrounding wind turbines, and they disrupt the desirable, consistent air stream that wind turbines need to generate power. These effects can be mitigated if the rotational inertia of a wind turbine is higher, but this comes at the cost of its cut in speed, since higher wind speeds will be needed to initiate blade motion. The idea system to solve this problem, would be one that could vary the rotational inertia of a turbine blade depending on the rotational velocity of the wind turbine.

The Lenz System aims at solving this problem by moving a mass up and down the length of the blade using electromagnet forces, to optimize the rotational inertia for the given conditions. Ideally, this system would be a closed system, meaning that no energy would be needed from external sources, such as the generator for the operation of the system. The only input from the wind turbine would centripetal force, all other electrical and magnetic power would be internal to the system.

This experiment attempts to model the conditions that the system would be under to determine which parameters have to be adjusted in order for the system to function properly and be a closed system.



This is the general layout of the Lenz System. When implemented into a wind turbine blade, it will be much more compact in its arrangement and size. The force pulling the magnet through the coil is the inertial force caused by the centripetal force of the moving blade, in an experimental set up this can be simulated with gravity. As the magnet moves through the coil due to inertial forces, it charges a bipolar capacitor while the coil slows its movement. Eventually the wind turbine will reach peak angular velocity speeds and the magnet will be held at the tips of the blades due to centripetal inertial loads and maximize the moment of inertia to maintain this velocity. Eventually due to reduced wind speeds the angular velocity will begin to drop, this is when the bipolar capacitor discharges its stored energy. The current moving through the coil will accelerate the magnet towards the center of the wind turbine, this will increase the angular velocity due to the law of conservation of momentum, and the cycle will repeat, following the pattern of a dampened frequency response.

Experiment Details

Fig 1.

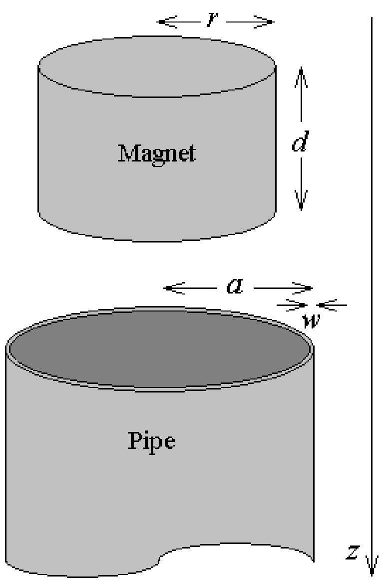


Figure 1 shows the general experimental set up for a cylindrical magnet falling through a conductive pipe. The parameters and assumptions of this experiment will be slightly modified to model the Lenz System.

For my experiment the magnet will be a D38-N52 neodymium magnet that is cylindrical in shape. The pipe is replaced with a conductive coil.

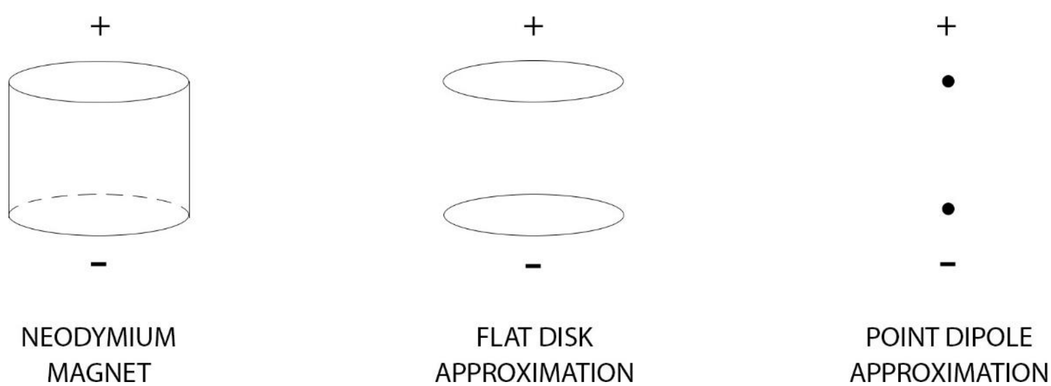
D38-N52 dimensions:

$$r = 0.00238\,m \quad d = 0.0127\,m$$

Coil dimensions (22-gauge wire):

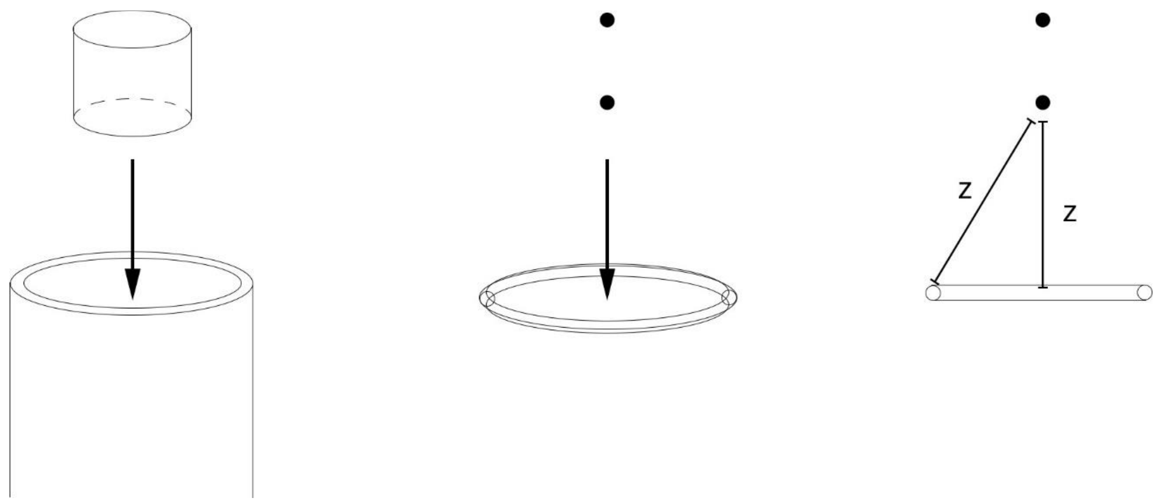
$$a = \ .00635\,m \quad w = 0.000635\,m$$

Fig 2.



To simplify the calculations, the cylindrical magnet will be modeled as two point dipoles.

Fig 3.



The original parameters have been modified to better model our experiment. The continuous cylinder has been replaced with a wire loop of thickness w.

The dipoles will still be treated as a cylinder in this approximation and the distance "z" that will be measured is the perpendicular distance from the bottom dipole to the center of the coil ring.

The goal of the experiment is to calculate the voltage generated as a function of coil and magnet properties and dimensions.

The formula for voltage generated by a magnet traveling through a coil is:

$$emf = -(n)\frac{d\Phi}{dt}$$

$Where$: $n = number\ of\ turns$ $d\Phi =$ change in magnetic flux $dt = change\ in\ time$

For our setup, change in flux is a function of z.

$$\Phi(z) = \frac{\mu_0 q_m}{2}\left[\frac{z+d}{\sqrt{(z+d)^2}} - \frac{z}{\sqrt{z^2+a^2}}\right]$$

The flux for each ring is calculated by varying z from the magnet's maximum effective range on either end.

The domain for Z is: $[\max range \leq z \leq -\max range]$

The flux at each Z interval is calculated and summed with all the other flux values.

$$d\Phi = \sum_i \Phi_i$$

To calculate change in time we calculate the terminal velocity of the magnet. For the sake of simplification, we will assume that the magnet travels at terminal velocity from beginning to end. We will also assume that the coils are close enough together to be approximated as a conductive pipe in regards to breaking force induced by the conductive material.

The formula for terminal velocity of a magnet in a conductive coil:

$$v_t = \frac{1024}{45} \times \frac{mg\rho a^4}{\mu_0^2 p^2}$$

$$Where:$$

The distance the magnet travels for each coil is:

$$(\max range) \times 2 = D$$

Therefore, the change in time for each coil is:

$$dt = \frac{D}{v_t}$$

The induced voltage for one coil is then:

$$\varepsilon(z) = -\frac{\sum_i \Phi_i}{dt}$$

And total induced voltage is:

$$emf = -(n)\frac{\sum_i \Phi_i}{dt}$$

References

Yan Levin, Fernando L. da Silveira, and Felipe B. Rizzato. February 2nd, 2008. Electromagnetic braking: a simple quantitative model: Instituto de F´ısica, Universidade Federal do Rio Grande do Sul.