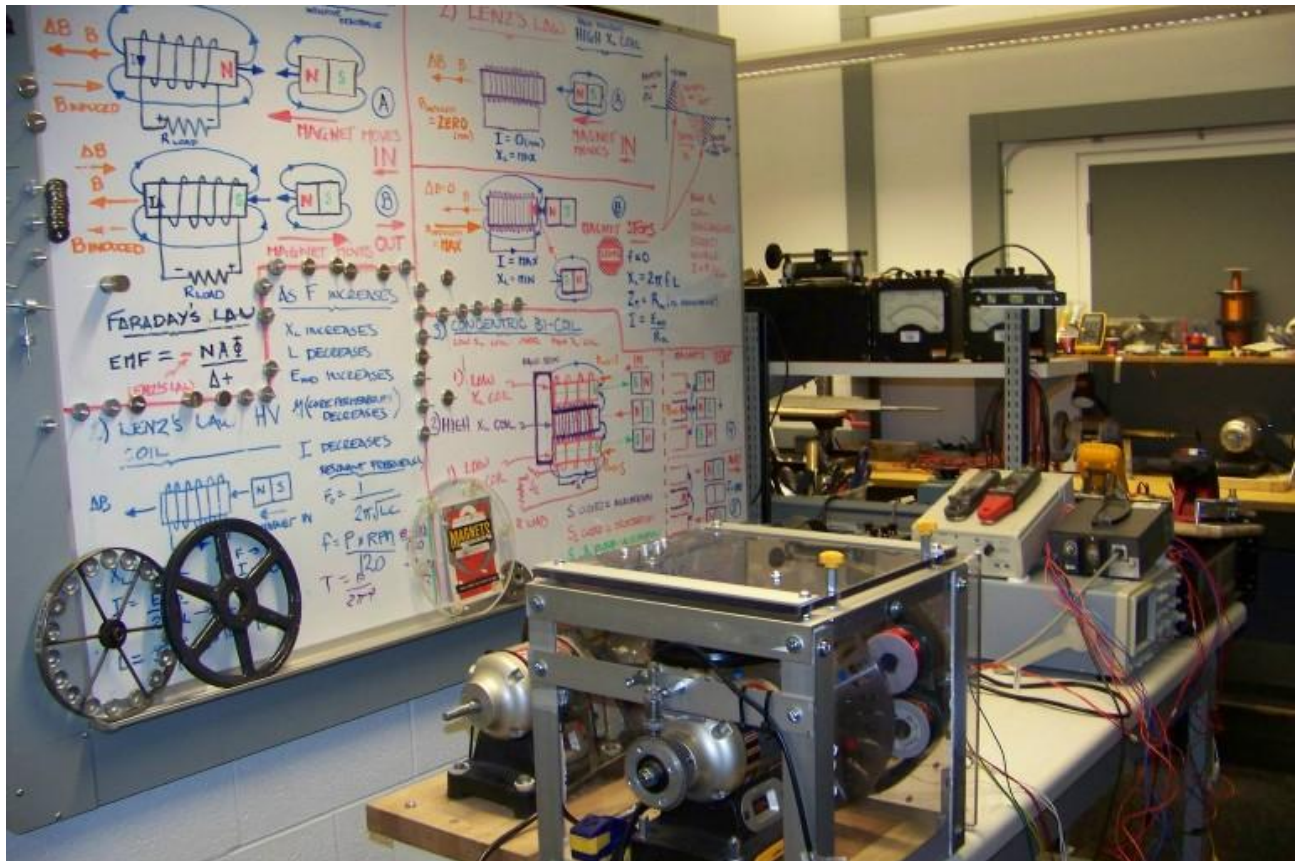


# POTENTIAL +/- DIFFERENCE INC.

## BASIC PHYSICS - Regenerative Acceleration Generator (RM)



Regenerative Acceleration Satellite Lab – University of Ottawa 2010

This document will explain how the electric vehicle regenerative braking paradigm produced by a conventional generator can be reversed and create regenerative acceleration in its place.

A good mechanical analogy would be like an air compressor blowing air into a balloon. As long as the inflow pressure exceeds the air pressure (potential energy) being built up inside the balloon, the balloon will continue to inflate. If however the pump's inflow pressure ceases the air pressure inside the balloon will begin to deflate the balloon. If the air pressure is immediately resumed but in the exact opposite direction – now away from the balloon the net air pressure exiting the balloon will equal the balloon's air pressure plus the compressor's air pressure which is now flowing away from the balloon.

The Regenerative Acceleration Generator Coil stores (potential) energy as voltage when a magnetic field approaches the coil. Pressure (voltage potential) builds inside the coil, but only as long as the magnetic field continues to approach the coil. Once the magnet "stops" at TDC and just prior to moving in the opposite direction the potential energy (voltage) inside the coil is released. This stored potential is now dissipated through the coil as current flow and this current creates a delayed magnetic field which has the same polarity as the now receding magnetic field.

**The net effect is threefold;** 1) the receding magnetic field is accelerated (or kicked) away from the coil faster than it otherwise would be, 2) the next opposite magnetic pole on the rotor is attracted with additional force as well, 3) electrical power is delivered to the electric vehicle's batteries.

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Differences between a **Conventional Generator Coil** and a **Regenerative Acceleration Generator Coil**

## A Conventional Generator Coil:

**Operates as an inductor** and stores energy in the **electromagnetic field outside the coil** - this external magnetic field is responsible for the electric vehicle (EV) braking force.

**A Regenerative Acceleration Generator Coil** on the other hand;

**Operates as a capacitor** and stores energy in the **electrostatic field inside the coil** between the wires - this internally-stored, delayed and then released magnetic field is responsible for the EV accelerating force.

## What is EV Regenerative Braking?

Regenerative braking is created when an electric vehicle's inertia is used to turn a conventional generator. Inside the conventional generator (while it is sending power to the batteries) a **magnetic field** is produced. The polarity of this magnetic field resists rotation and because the conventional generator is connected to the EV - this resistance causes the EV to decelerate.

As it turns out now the polarity of this magnetic field can now be reversed.

## HOW TO REVERSE THE POLARITY OF A GENERATOR INDUCED MAGNETIC FIELD AND CHANGE IT FROM A **RESISTIVE** FORCE TO AN **ASSISTIVE** FORCE.

The **magnetic field strength** produced inside the conventional generator is directly related to the amount of electrical **current** flowing in the conventional generator coils. If no current flows there is no resistive magnetic field produced, no deceleration and no braking effects.

Normally, the scenario where there is no current flow in the generator coil is called a **no-load** condition. In a no-load condition the generator is not sending any power to the batteries.

**There is now a way to simulate a no current flow "condition" while the generator is on-load,** meaning the generator is actually supplying power to the batteries.

REMEMBER - If we remove the current flow in our generator coil, we also remove the coil's ability to create a resistive magnetic field and the corresponding regenerative braking effects that go along with it.

## How do we remove the current from a generator coil?

Simple, we employ Ohms Law, which states that the magnitude of current flow is directly related to the electrical resistance. As electrical resistance increases, current flow decreases. If we increase the electrical resistance high enough all current flow will cease.

**We can use AC resistance (impedance) to restrict (and even choke) the current flow in our coil.** All we have to do is increase the operating frequency.

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## To recap:

The magnitude of current that can flow in a coil is a function of the impedance of the coil. Impedance is another term for AC resistance. **The magnitude of AC resistance is a function of the frequency of the alternating magnetic field** (operating frequency).

If the operating frequency of a coil is increased, the impedance (AC resistance) also increases. If the frequency is increased high enough, then at some point the impedance will also be high enough so that no current will be able to flow in the coil. The AC resistance will stop it – choke it in other words.

The magnitude of AC resistance (impedance) can be calculated by the equation:

$$ZL = 2\pi fL + RDC$$

where:

**ZL is Total Coil Impedance**

**F is Frequency**

**RDC is DC Resistance of the Coil**

As we can see from the above equation, **coil impedance increases as frequency increases.**

The Regenerative Acceleration Generator operation is based on **frequency dependant generator coil impedance.**

As the rotor frequency increases the coil impedance also increases so its current carrying capacity decreases accordingly.

As the coil's ability to carry current decreases the coil's ability to produce a resistive magnetic field also decreases (is required to create generator braking force) while at the same time the coil's induced voltage is also increasing.

What we end up with is:

- A High Voltage, High Impedance **Regenerative Acceleration Generator Coil** where **current cannot flow** because the **operating frequency/coil impedance is high enough** and will not allow it.
- **A coil that stores energy in the electrostatic field internally like a capacitor.**
- As opposed to;
- A High Current, Low Impedance **Conventional Generator Coil** where **current can flow** because the **operating frequency/coil impedance is low enough** and will allow it.
- **A coil that stores energy in the (resistive) electromagnetic field like an inductor.**

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**BUT FREQUENCY CAN ONLY EXIST WHEN THERE IS MOVEMENT.**

- **When a magnet approaches a coil there is movement and frequency.**
- **When a magnet recedes from a coil there is movement and frequency.**
- When a magnet is **TDC (top dead centre)** – it is neither approaching nor receding.
- If a magnet is neither approaching nor receding - **frequency ceases**.
- If frequency ceases impedance ceases.
- If impedance ceases current can now flow through the coil's low DC resistance.
- Coincidentally at TDC the induced voltage is at maximum.
- **So now we have a scenario where we have maximum voltage and lowest coil impedance possible in our AC cycle.**
- **The induced voltage in our coil is MAXIMUM.**
- **At this TDC moment the coil produces the MAXIMUM DELAYED MAGNETIC FIELD POSSIBLE because our coil impedance is reduced to the low DC resistance of the coil.**
- This delayed magnetic field pushes away on the now already receding magnet,
- while attracting the next approaching opposite pole magnet on the rotor.

## **To recap:**

When the magnet is TDC (top dead centre) to the coil (neither approaching nor receding) the previously high coil impedance drops to the low DC resistance of the coil and the self induced voltage is maximum.

This high voltage is then able to be dissipated through the small DC resistance of the coil - producing a maximum delayed magnetic field which now pushes away on the already receding magnet while attracting the next opposite magnet pole on the rotor.

If a Regenerative Acceleration Generator Coil is engaged at a low rotor speed (or frequency) where current can flow in the coil (because the frequency/coil impedance is low) - then the coil ceases to act as a Regenerative Acceleration Coil and acts like any normal conventional coil and produces a repelling magnetic field as per the regenerative braking paradigm.

## **2008 Basic Physics Ottawa University Lab Demo**

First prototype: <http://www.youtube.com/user/ThaneCHeins?feature=mhee#p/u/7/Ps5BqEiFK74>

## **2011 Current Salient Pole "In the Wheel" Axial Flux Generator Design**

Shows conventional regenerative braking and regenerative acceleration based on coil frequency.  
<http://www.youtube.com/user/ThaneCHeins?feature=mhee#p/u/6/u3qVfltiO-E>