AC Induction Motor Construction

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April 26, 2012

1. <u>Background</u>

An induction motor is the most common type of electric motor that takes advantage of electromagnetism and angular momentum to drive a rotor (2). When online, an induction motor alternates current between individual electromagnets in order to create a "rotating magnetic field" in the center of the system. The rotors usually consist of iron because of its responsiveness to magnetic fields. While the magnetic field rotates, it drags along the rotor.

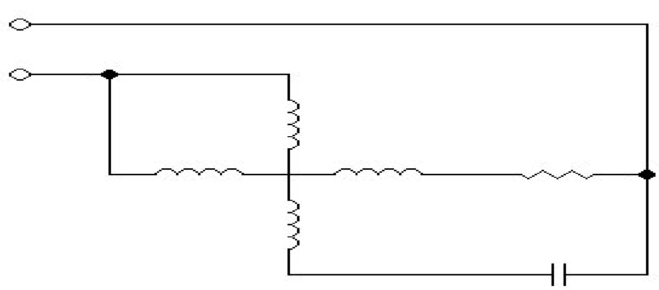
2. <u>Design</u>

2.1 Original Design (see Figure 1)

Inspired by a larger 120VAC motor design (1), the motor was going to be created out of two series of coils connected in parallel with one series attached with a resistor and the other with a capacitor. The series with the resistor, when plugged into an AC power source, would have an alternating current directly related to the voltage with respect to time. This means that the electromagnet would be producing an alternating field in perfect unison with every cycle of the AC current.

The series with the capacitor, however, when plugged into the same AC power source, would have an alternating current flowing through it, but because of the capacitor, it would delay the actual current flowing through the series, therefore delaying the alternating of the magnetic field

Figure 1: Original Design

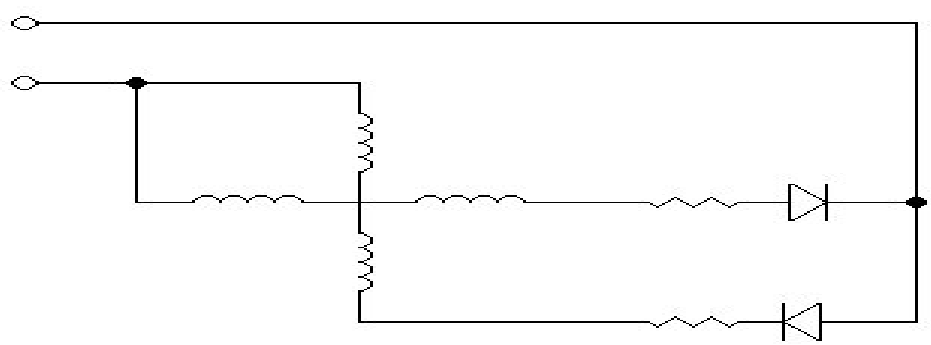


Note: wavy wires = coils

2.2 Actual Design (see Figure 2)

It turned out that the original design would only have worked if the rotor and the amount of capacitance were fine-tuned for a target frequency, so that design was scrapped for a freshman-friendly design, suggested by Dr. Stewart. Instead of two different series with different components, there are now two almost identical series of components-- each series has a resistor, a pair of coils, and a diode. The only difference between the two series is that the diodes face opposite directions. This means that only one pair of coils are ever on at any given time. This defers from the original design in that the magnetic fields do not alternate direction at all, but rather the two series alternate between being off and on. This means that the magnetic fields, when active, will always point in the same direction. This has the advantage of being able to function on any frequency, whereas in the last design, the amount of capacitance required scaled with frequency.

Figure 2:   Actual Design



2.3 Theory

Every time the current switches direction in the system, the magnetic field, assuming both coil pairs are identical, will simply alternate its direction by 90 degrees without changing magnitude. Because starting up the system will create some initial momentum, the rotor will rotate beyond the temporary equilibrium point just in time for the magnetic field to switch, constructively adding to the momentum of the rotor. There is a point where the internal resistance of the rotor and the amount of momentum that is added to the system reach an equilibrium, and it will begin to move at a constant angular velocity (3). This means that there is an ideal frequency to alternate the magnetic field in order to create the highest possible velocity.

3. Construction

3.1 Materials

For the physical circuit, the project used two 1Ω resistors, two diodes, and copious amounts of #32 gauge copper magnetic wire. Its thinness was in order to wrap around as many loops of wire as possible in as little space as possible in order to create the most efficient electromagnets possible. In the first round of construction, toilet paper rolls were used as scaffolding for the loops of wire. The rolls were abandoned afterward because the magnetic field produced was tiny-- its large radius and its lack of an iron core failed miserably at creating a large enough magnetic field to overcome Earth's magnetic field. In round two, the coils were re-created and a steel rod was used as scaffolding for two reasons: it had a smaller radius and it was made of iron.

3.2 Assembly

Each coil was created by wrapping the ends of the steel rods with 220 loops of wire. Using cardboard as a platform and scaffolding, the coils were arranged to all point inward toward a central point (4.25 cm away from the designated center). The coils were raised above the platform by 6 cm of cardboard scaffolds in order to leave space for a more advanced rotor than a compass (which wasn't created because of the lack of support cardboard could offer, so the raised coils ended up being a vestigial structure). Each coil was connected to the coil directly opposite it from the center point, making sure the coils were wound in the same directions. Lastly, the programming board with the circuitry attached was connected to the system. The system was connected to a device that could deliver an adjustable frequency AC current.

4. Results and Calculations

The system worked, and using a compass needle as a makeshift rotor, it worked best at approximately 3 Hz for the specific rotor. While running, an ammeter was attached and the peak current was recorded at 0.14 A. The magnetic field at the center of the system was calculated from the infinite solenoid approximation, $B = k * \mu_0 (N / l) I$, where $k = 200$, the permeability of magnetic iron, $N = 440$ turns, and $l = 0.036$m:

$$B = 200 * 4\pi * 10^{-7} \text{ Tm / A} * (440 / 0.036 \text{ m}) * 0.14 \text{ A}$$

$$B = \underline{0.43 \text{ T}}$$

This value is the calculated MAGNITUDE of the magnetic field at the center of the system at all times, assuming both series are identical. It is a decent electromagnet that easily overpowers any interference by the Earth's magnetic field.

Resources:

1. “Induction motor,” All About Circuits, accessed April 23, 2012.

http://www.allaboutcircuits.com/vol_6/chpt_4/9.html.

2. Rakesh Parekh, “ AC Induction Motor Fundamentals,” *Microchip(*2003*):* 1-8, accessed April 23

18, 2012. http://ww1.microchip.com/downloads/en/appnotes/00887a.pdf

3. William J. Eccles, *Pragmatic Power* (Rose-Hulman Institute of Technology, 2008), 55-60.