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ORBUS

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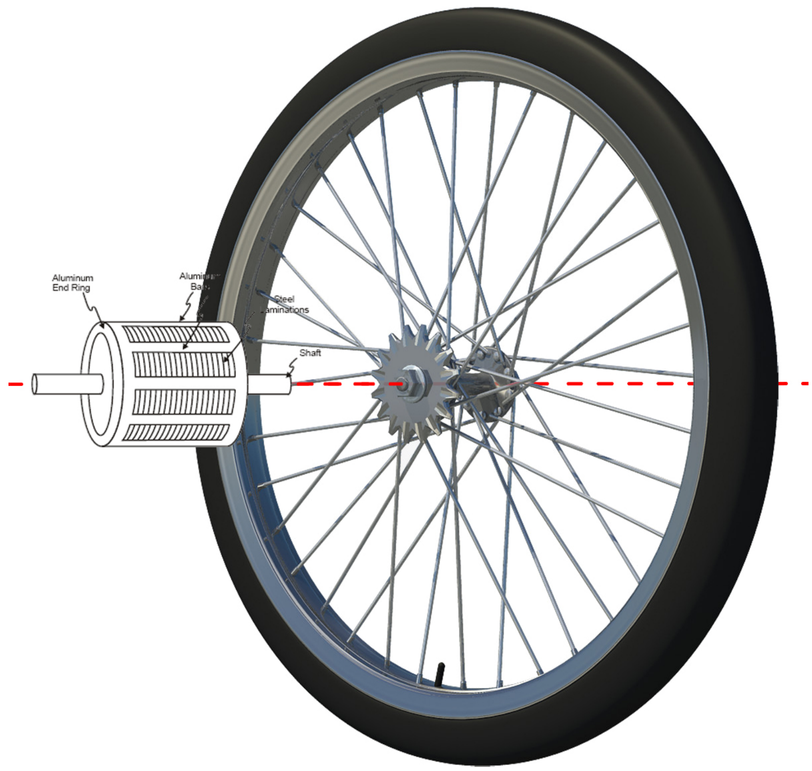
Part I
Introduction

Basic Principle: Conversion of rotational kinetic energy in a bicycle wheel into usable electrical energy with the use of the induction motor.

Idea:



The basic idea is to use the rotational kinetic energy of the wheel to rotate the coil in the induction motor and generate electricity. This, in turn, can be stored and used later as an energy source to temporarily power the bike to journey rougher terrains more easily. For example, this could be used to power the bike when cycling uphill.

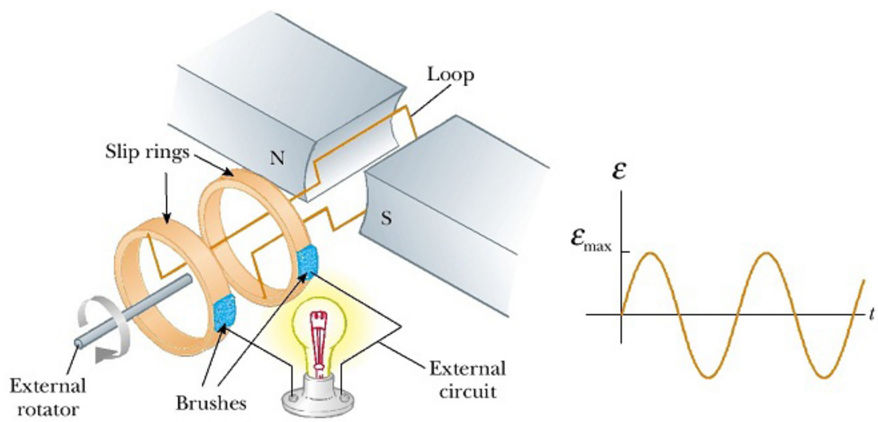
This not only promotes the use of clean and green energy but also encourages people to cycle more often. People choose their cars over other modes like the bicycle due to the amount of effort required. This would reduce the amount of effort and thereby increase the popularity of the bicycle. Furthermore, the amount of cars on the road will gradually reduce as people use bicycles more often.

Part II

Design and Development

1 AC Induction Motor

Basic Principle: The induction motor is primarily founded upon Faraday's Law of Electromagnetic Induction. The idea is that a coil rotating in a magnetic field causes an e.m.f. (electromotive force) to be induced in the coil. This, in turn, causes a current to be induced in the coil. Specifically an alternating current.



Here the induction motor, being attached to the wheel, will be generating electricity each time the user goes on a bike ride. This electricity will be stored in a type of battery and will be used later on to power the bike when travelling uphill.

Construction: The main components of the induction motor are the rotor and the stator. In most induction motors, the coil is stationary and the field exciters are rotating. The stator is used to hold the armature winding. This stator core is made up of a lamination of steel alloys or magnetic iron. Here, the lamination is important in order to reduce eddy current losses.

It's important to keep the armature winding stationary for three primary reasons:

1. It is a lot easier to insulate the winding if it is kept stationary. This is crucial when dealing with high voltages (30 kV or more).

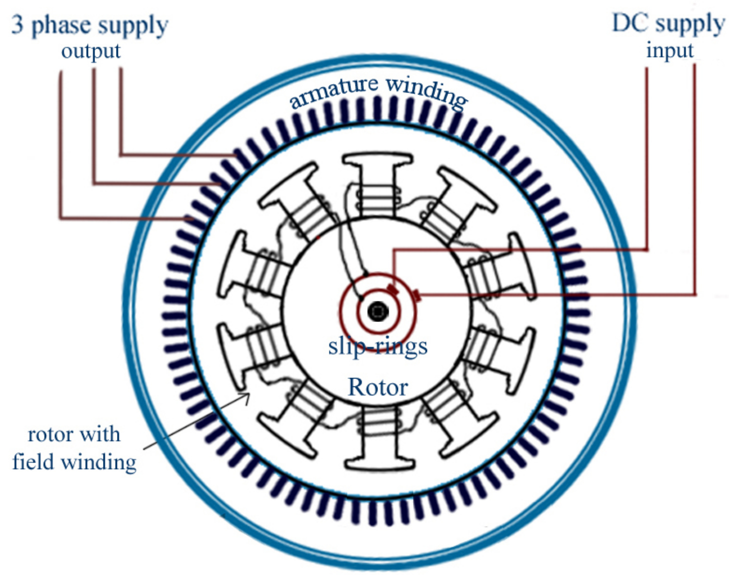
2. The high voltage ouptut can be taken out directly from the stationary armature.

3. The armature winding, being stationary, can be braced well reducing deformation of the motor caused by the high centrifugal force.

There are two types of rotors that can be used in an AC induction motor:

1. **Salient Type:** This is used in medium or low speed motors. This type of rotor consists of large number of projected poles bolted on a magnetic wheel. These poles are also laminated to minimize the eddy current losses.

2. **Cylindrical Type:** Cylindrical type rotors are used in high speed motors. This type of rotor consists of a smooth and solid steel cylinder havingg slots along its outer periphery.



For this product, we will be using the salient type model as the motor will be of medium speed. Furthermore, the cylindrical type model is only used in machines that require high speeds. For example, inside the petrol engines of cars. Such massive power will not be required for this project. In addition to this, the cylindrical type is more expensive as well.

2 Induction Motor Concepts

When talking about an induction motor, there are two types of speed that we need to define. Mainly *synchronous speed* (n_s) and *rotor speed* (n_r). **Synchronous speed** in any alternating current machine is dependent on the frequency of the supply circuit because the rotating member passes one pair of poles for each alternation of the alternating current. **Rotor speed** is the speed at which the rotor rotates with. The **difference** between the *synchronous speed* and *rotor speed* is known as the **slip** (s). Slip is either represented by a fraction or percentage.

The formula for slip is given below:

$$s = \frac{n_s - n_r}{n_s}$$

Frequency: The relationship between $frequency(f)$, $number\ of\ pole\ pairs$ (p) and *synchronous speed* (n_s) is given to us as:

$$f = n_s p$$

Within the rotor, the frequency $f_r$is given by the speed difference between that of the rotor and stator:

$$f_r = (n_s - n_p)p$$

Combining the above equation with *slip* gives us:

$$f_r = sn_s p$$

$$\Rightarrow f_r = sf$$

Synchronous speed in revolutions per second:

$$n_s = \frac{f}{p}$$

and in minutes (**rpm**):

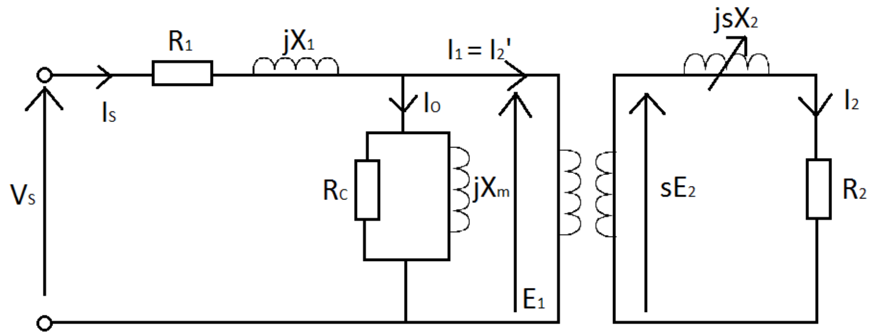
$$n_s = \frac{60f}{p}$$

However, we assume that the rotor itself is rotating at n_r giving a total rotor speed of:

$$sn_s + n_r = (n_s - n_r) + n_r = n_s$$

3 Circuit Design

Circuit Diagram:



R_1 =Resistance of the stator winding
X_1 =The stator leakage reactance
X_m =Magnetising reactance required to cross the air gap
R_c =Core losses (eddy currents, hysterisis)
Since,

$$I = \frac{V}{R}$$

And for I_2,

$$V = sE_2$$

And,

$$R = \sqrt{(R_2)^2 + (sX_2)^2}$$

$$\Rightarrow I = \frac{sE_2}{\sqrt{(R_2)^2 + (sX_2)^2}}$$

$$\Rightarrow I = \frac{E_2}{\sqrt{\left(\frac{R_2}{s}\right)^2 + (X_2)^2}}$$

4 Performance

Motor Current: Once the equivalent circuit parameters are known, we can easily calculate the motor current.

By reducing the circuit into an equivalent impedence Z_{eq} giving:

$$I_s = \frac{V_1}{Z_{eq}}$$

Inspection of the equivalent circuit gives:

$$Z_{eq} = R_{eq} + \frac{R_2^{'}}{s} + jX_{eq}$$

Motor Power: By neglecting the core losses ($R_c giving\ I_s = I_2^{'}$) the power P_{in} delivered to the motor per phase is given by,

$$P_{in} = I_s^2 \left(R_1 + \frac{R_2^{'}}{s} \right)$$

The power loss dissipated by the windings:

$$P_w = I_s^2 (R_1 + R_2^{'})$$

The power P_m delivered to the load is given by the difference between the power supplied to the motor and losses.

That is,

$$P_m = P_{in} - P_w$$

$$\Rightarrow P_m = I_s^2 \left(\frac{1-s}{s} \right) R_2^{'}$$

Note: For all three phases:

$$P_{m3\phi} = 3I_s^2 \left(\frac{1-s}{s} \right) R_2^{'}$$

Motor Torque: We know motor torque (T) multiplied by the angular velocity (ω) is equal to power ($P_{m3\phi}$).

$$\therefore T = \frac{P_{m3\phi}}{\omega}$$

And,

$$\omega = \frac{2\pi n_r}{60}$$

$$\Rightarrow \omega = \frac{2\pi}{60}(1-s)n_s$$

Combining this with the power equation gives:

$$T = \frac{3I_s^2\left(\frac{1-s}{s}\right)R_2^{'}}{\frac{2\pi}{60}(1-s)n_s}$$

$$\Rightarrow T = \frac{90I_s^2\left(\frac{1-s}{s}\right)R_2^{'}}{\pi s n_s}$$

Power Flow:
⇒**Power input to the stator** (P_{in})
→Stator Winding losses
→Core iron losses
→Rotor winding losses
⇒**Power to Load** (P_m)
→Winding and Friction losses
⇒**Output Power** (P_{out})

Part III
Conclusion

5 Testing and Results

Using the actual specifications of a motor we are considering to use for our prototype, we will try to approximate the amount of electricity generated by the bicycle.

The average bicycle diamter is 25 inches.

$\therefore$Average bicycle circumference $= 25\pi$inches

$\Rightarrow Circumference = 78.5$inches ≈ 2m

Let's assume the premise that the bicycle is on a flat road, travelling at a constant 10 km/h.

At a speed of 10 km/h, the wheel of the bicycle is rotating at $\approx$ 83rpm

And with the motor attached to the wheel, $n_s = 83$rpm

Let's take a look at the specifications of the motor:

Voltage $(V) = 120$V

Frequency $(f) = 60$ Hz

Horse Power $(HP) = 0.25$ HP

Power Factor $= 0.72$

Assume Efficiency $= 0.75$

Using the formula,

$$I = \frac{746HP}{V \times Efficiency \times PF}$$

$$\Rightarrow I = \frac{746 \times 0.25}{120 \times 0.75 \times 0.72}$$

$$\Rightarrow I \approx 3A$$

As we see, we are generating 3A of electricity every minute of cycling. And this is just using a small motor and going at a low speed on a flat surface. When taking into consideration of the downhill journey and faster rpm, the amount of electricity will be greater. Furthermore, this can be improved by using a better motor with a higher horse power and lower power factor. However, the above number is just an estimate of the actual number. But they should be fairly close. We haven't taken into account of the energy losses through friction, hysterisis, etc. so they will affect the actual electricity stored.

6 Conclusion

The initial product will not be as efficient as possible but as technology develops, so will this. And this could potentially revolutionize transportation in the long run. Furthermore, this also promotes a lot of good things that benefit the environment namely clean energy and reduced pollution. This also has the possibility of increasing the popularity of the bicycle industry and could completely change the transportation industry as we know it.

Part IV
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