Electrical energy amplifying generator

To cite this article: Yajnesha P Shettigar et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 376 012129

View the article online for updates and enhancements.

You may also like

- Improvement of integrated technology for restoring surfaces of steel and iron parts
  V Tareinyk, V Martsenykovskyy, A Sarzhanov et al.

- Preliminary Design for Manufacture and Assembly (DFMA) Cost Analysis of Low Temperature, Co-Generative Proton-Conducting Solid Oxide Fuel Cells (SOFC)
  Whitney Goldsborough Colella

- Integrated assessment of global climate, air pollution, and dietary, malnutrition and obesity health impacts of food production and consumption between 2014 and 2018
  Christopher S Malley, W Kevin Hicks, Johan C I Kulyenstierna et al.
Electrical energy amplifying generator

Yajnesha P Shettigar¹, Akshay B N², Abhishek R³

¹Assistant Professor, Department of mechanical Engineering, Manglore Institute of Technology and Engineering, Moodabidri, Karnataka state, India.
²,³ Student, Mechanical engineering Branch, Manglore Institute of Technology and Engineering, Moodabidri, Karnataka state, India.

E-mail: akshaymonappa1994@gmail.com
abhi.aa423@gmail.com
yajnesh92@gmail.com

Abstract: In electric power generation, there is always compromise in terms of efficiency. Now a days, modern turbo-generators have efficiencies greater than 98%. Although this amount of efficiency is not obtained from all kinds of generator. The efficiency and the cost will always be one of the major parameters for customer choice. Electrical Energy Amplifying Generator (EEA generator) consists of permanent magnet rotor having high polarity and running at low speed to amplify the electrical energy obtained from solar panels using the newly designed coil and magnet arrangement. In the special design of the coil of EEA generator is completely utilizes the magnetic flux of the rotating magnetic rotor. The cost of this generator is less than the commercial generators available in the market. This setup describes the construction of state of art of permanent magnet generators. Design aspects of permanent magnet generators are presented. The prototype of the generator is fabricated and tested and the output variations at different inputs of the generators is discussed.

Keywords: EEA.

1 Introduction:

A generator is a device that converts any available energy into electrical energy. Source of available energy includes steam turbine, wind turbine, hand crank, diesel engine, water turbines, and other mechanical sources. Even the chemical and light energy source can be used to produce electricity, such devices are also called generators.

Now we are concentrating on the generators that converts mechanical energy into electrical energy. It is important to understand that a generator doesn’t actually create electrical energy. Instead, it uses the mechanical energy supplied to it to force the movement of electric charges present in the wire of its windings through an external electric circuit.

The modern day generator works on the principle of electromagnetic induction discovered by Michael Faraday in 1831-32. Faraday discovered that the flow of electric charges could be induced by moving an electrical conductor, such as a wire that contains electric charges, in a magnetic field. The movement creates a voltage difference between the two ends of the wire or electrical conductor, which in turn causes the charges to flow, thus generating electric current. Generators are useful appliances that supply electrical power during a power outage and prevent discontinuity of daily activities or disruption of business operations. Generators are available
in different electrical and physical configurations for use in different applications. In the following sections, we will look at how a generator functions, the main components of a generator, modifications that can be done in generators to improve efficiency, and how a generator operates as a secondary source of electric power in residential and industrial applications.

The reason behind the struggle of improving the performance of generators is Energy Crises. Generator is leading a major role because the world is nothing without electricity.

2 Amplification of electrical energy of a generator:

To amplify the electrical energy of a generator we are concentrating on possible reduction of power losses present in the normal induction generators. The major power losses present in any generators are

- Core loss
- Joule loss
- Magnet loss
- Air gap loss
- Rotor loss
- Mechanical loss

If these losses are removed completely then the efficiency of the generator is 100% which is practically impossible. But the losses can be reduced and the efficiency can be increased.

| Losses       | Induction generator                                                                 | EEA generators                                                                                           |
|--------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Core loss    | The rotor and stator both have iron core, the eddy current in the soft iron core and the hysteresis loses in the core material increases the loss therefore core loss is more. | The rotor has no core, instead permanent magnets are placed hence the core loss is seen only in stator therefore core loss is less. |
| Joule loss   | Joule loss is found in the copper wire winding. Both in rotor and stator heat is generated during current flow due to the resistance of the copper metal. More the copper used more is the joule loss. | The stator has concentrated copper winding, joule loss is less because the copper used is less, the rotor has no winding, hence joule loss in the rotor is zero. |
| Air gap loss | The gap between the rotor and stator increases to increase air gap loss due to the wastage of magnetic flux. More the air gap less emf is induced. | The gap between the rotor and stator increases to increase air gap loss due to the wastage of magnetic flux. More the air gap less emf is induced. |
Magnet loss

Magnet loss is the loss in the magnetised core where the field strength decreases at higher temperature due to the raise in resistance of the conductor, this raise in temperature is due to the friction between brushes and armature. Here there is no raise in temperature in the rotor because the rotor carries permanent magnet and there is no brushes or armature used. Hence magnet loss due to high temperature is reduced.

Rotor loss due to weight

The rotor is made up of iron core and distributed copper winding, this increases weight of the rotor and hence, the initial torque required to start the generated is more. Here the rotor is made up of light weigh cylinder with neodymium magnets placed on the layer of cylinder, the rotor is completely light in weight. Input torque required is less, hence loss is reduced.

Mechanical loss

Friction in the generator increase due to the heavy weight of the rotor as well as the brushes and armature increases friction, the friction increases more and more due to the expansion of metal due to raise in temperature. The rotor weight is low, no brushes or armature is used in the generator, no heat generation to expand the metal. The friction is completely low and hence the mechanical loss is low.

Electrical loss

A small part of induced current is used to magnetize the rotor and this induced current is not obtained at the output of generator. There is no requirement of magnetizing the rotor or stator. The rotor is already a permanent magnet hence no such electrical loss.

From the above discussion we can prove that the efficiency of the EEA generator can be made more than induction generator by elimination of losses.

2.1 Upgrading the rotor:

Permanent magnets are of few types, neodymium magnet is one of the strongest magnets available on earth. Using these magnets in generator rotor makes the generator a brushless permanent magnet generator. But these permanent magnets doesn’t sustain its power for long time. By studying the properties of magnets and its power variations at higher temperature we can come up with alterations in generator setup. Magnets loses its power when it is placed in opposite magnetic pole fields, also magnets loses its power when it is physically damaged or even by application of impact loads.

Our objective is not just increasing the power output. The term higher efficiency includes more power output, more life span as well as reduced maintenance cost.

Therefore permanent magnets are used in the rotor, stator has concentrated winding coils, The generator produces alternating current, a DC 12v portable mini refrigeration system which runs with solar energy is assemble in the body of the generator. This refrigeration system cools the magnets to increase the flux density and sustain the magnet life.

The refrigeration system also reduces the temperature of the copper winding and this reduces the resistance of copper. The joule loss in the copper winding is reduced by the refrigeration system.
In this generator, the neodymium magnets used will have certain grade values, more the grade value more is the flux density and temperature withstanding capacity. When the flux density increases the electro motive force induced is also increased.

2.1.1 Magnets used in the rotor:
It depends on the types of magnet. Yes, within a detectable amount of time ceramic and alnico magnets will lose their strength. The neodymium iron boron magnets have the strongest resistance to demagnetization of any magnet material and it is generally estimated that it may take over five hundred years before they start to see noticeable loss of magnetic strength.

2.1.2 Neodymium iron boron (NdFeB) magnets:
- These are the most powerful magnets available.
- They are the first choice for maximum performance from minimum size.
- They exist with several maximum recommended temperature ratings from +60deg C up to +230deg C.
- The actual maximum temperature rating depends on the shape of the magnet and the total magnetic circuit.
- Exceeding the actual maximum temperature results in demagnetisation.
- They all require a protective coating to prevent and minimise corrosion.
- The coating is usually a Ni-Cu-Ni plating although other coatings/finishes exist (24hour available for the 47grade).
- NdFeB magnets can be made in blocks, discs, rings, arcs, spheres, triangles, trapezoids and many other shapes.

2.2 Winding style in the stator for better efficiency:
The winding arrangement of an electrical machine determines the configuration of the coils in the stator. Coils can be placed in the slots around teeth, in the stator. The turns of a coil can then be placed, concentrated in one slot, or they can be distributed over several slots when it concerns a slotted design or around the air gap circumference when it concerns a spotless design.

The drawback of distributed winding is the length of the end windings are out of the active part.
Fractional slot concentrated windings has no such drawback.

2.3 Combination of poles and coils number in rotor and stator for better performance:
Number of slots per pole per phase determine how the winding layout is arranged it is also disclosing the information about the winding factor and its harmonics.

If the number of slots per pole phase is an integer; then the winding is called integer slot winding.
If the number of slots per pole per phase is fractioned and superior to the winding then it is called fractional slot winding.
If the number of slot per pole per phase is fractional and interior to the winding then it is called concentrated winding.

During the running of generator the induced emf in stator coil produces an opposite torque at higher applied load. This torque is called “Cogging torque” to reduce it the perfect combination of number of poles and slots for required phase of current is to be identified depending upon the other configuration.

2.4 Reduction of generator weight:
The rotor winding is eliminated, instead the light weight neodymium magnet is used. The weight of the rotor can be reduced by using high strength, low weight material like carbon fibre. There is no requirement of armature and brushes, hence the rotor can be of any material with strength and low weight.

The stator of the generator consist of insulated iron core. The required number of coils for the generator is decided and the core can be designed based on the number of coils.
Since concentrated winding is used. There is large reduction in the weight of copper wire usage. The casing and covering of the generator can be made using carbon fibers which is lighter and stronger. Anyways the heat generation is very much reduced.
2.5 Bearings for the generator rotor:
The weight of the rotor is too low this helps in the free motion of the shaft on the bearings. The best bearing used in skateboards can be used here.
Magnetic bearing are the most efficient bearings available. It can also be used.

3 Loss analysis:
3.1 Core loss:
Losses due to hysteresis, eddy current and residual losses in the core material is called core loss. Power loss due to eddy current loss is given by,

\[ P_a = B_o V \delta \delta / 4 \rho_{fe} \]

Where,
- \( P_a \) = power loss due to eddy current loss
- \( B_o \) = Amplitude of flux density
- \( V \) = Relative speed of flux density
- \( \delta \) = Skin depth
- \( \rho_{fe} \) = Back iron resistivity = \( 2 \times 10^{-7} \)\( \Omega \)m

Skin depth is given by,

\[ \delta = \sqrt{\frac{2\mu_0 f e \omega}{\mu \mu_{fe}} \mu_{fe}} \]

Where,
- \( \mu_0 \) = Absolute permeability = \( 4 \pi \times 10^{-7} \)
- \( \mu_{fe} \) = Relative permeability back iron = 200

The relative permeability of wood or any other non-magnetic material is 1, hence from the above expression the power loss due to eddy current loss can be reduced.

3.2 Copper loss:
Power loss due to copper material is given by,

\[ P_{cu} = R_{cu} I_{in}^2 \]

Where,
- \( R_{cu} \) = winding resistance
- \( I_{in} \) = rms value of generator

From the above equation we can say that power loss is directly proportional to resistance of the wire, at lower temperature the conductivity of metal increases and decreases the resistance of copper hence power loss can be reduced.

3.3 Joule loss:

From joule’s lenz law we have,

\[ P_j \propto I^2 R \]

Where,
- \( I \) = current in a wire
- \( R \) = resistance of a wire
From the above expression we can say that the decrease in resistance of the coil, the power output can be increased, which means the Joule loss can be reduced.

### 3.4 Ferromagnetic materials losses:

Power loss due to ferromagnetic material is given by,

\[
P_{fe} = \int p J f^2 dv
\]

Where,

\[
J_f = \text{rms value of the current density of the Foucault current}
\]

\[
\sigma = \text{Electrical conductivity of the material}
\]

From the above expression the conductivity of copper coil increases to increase the power output. Hence the ferromagnetic material loss is reduced.

### 3.5 Mechanical loss:

Since it depends on the quality of bearing we used and their properties so we can reduce 10 to 20% of a power loss due to friction by using good material in shaft, good quality bearing system and good lubrication system so we can reduce a frictional loss.

### 4 Practical testing of the concept:

The above concept explained was experimented by making a prototype and was tested for the purpose of proving the concept with the reduction of power losses. The prototype was tested with a DC motor and the comparison between the input DC power to the motor and the output AC power from the fabricated generator is made to see the possible power loss reduction in EEA generator.

#### 4.1 Fabrication part:

The generator is an AC generator with 6 copper coils of concentrated winding style of single phase configuration. Stator has inner diameter of 12.14cm and outer diameter of 22.14cm, it has 24 slots for winding.

![Figure 1. Stator iron core.](image)

---

From the above expression we can say that the decrease in resistance of the coil, the power output can be increased, which means the Joule loss can be reduced.

### 3.4 Ferromagnetic materials losses:

Power loss due to ferromagnetic material is given by,

\[
P_{fe} = \int p J f^2 dv
\]

Where,

\[
J_f = \text{rms value of the current density of the Foucault current}
\]

\[
\sigma = \text{Electrical conductivity of the material}
\]

From the above expression the conductivity of copper coil increases to increase the power output. Hence the ferromagnetic material loss is reduced.

### 3.5 Mechanical loss:

Since it depends on the quality of bearing we used and their properties so we can reduce 10 to 20% of a power loss due to friction by using good material in shaft, good quality bearing system and good lubrication system so we can reduce a frictional loss.

### 4 Practical testing of the concept:

The above concept explained was experimented by making a prototype and was tested for the purpose of proving the concept with the reduction of power losses. The prototype was tested with a DC motor and the comparison between the input DC power to the motor and the output AC power from the fabricated generator is made to see the possible power loss reduction in EEA generator.

#### 4.1 Fabrication part:

The generator is an AC generator with 6 copper coils of concentrated winding style of single phase configuration. Stator has inner diameter of 12.14cm and outer diameter of 22.14cm, it has 24 slots for winding.

![Figure 1. Stator iron core.](image)
The generator has a light weight wooden rotor with 48 neodymium magnets of grade N45 glued on the rotor surface. The rotor has 6 poles. Rotor has a diameter of 5.5cm and length of 20cm has having shaft of diameter 1.4cm.

Normal journal bearings are used in the rotor rotation.

The source of input energy is a 100W 24V DC motor with 5kgcm torque at 2000 RPM.

The motor shaft is coupled with the generator shaft with flexible coupling.

The motor is powered by a 17Ah battery and the battery is charged using 100W solar panel.

Voltmeters and ammeters for both DC input and AC output are connected to the setup for readings.

A small 12v dc input refrigerator is used in the setup for cooling the interior region of generator.
• The refrigerator has a capacity to cool 7.5 liters of volume.

![Figure 6. Refrigeration system.](image)

• The solar panel charges the battery, at the same time the DC motor runs to drive the EEA generator to produce AC voltage. The input and output voltage is measured using voltmeters. The input and output powers are calculated to estimate the reduction of power losses in the generator.

![Figure 7. EEA generator.](image)

### 4.2 Calculations:

The power input is given by

\[ P = V \times I \]

\[ P = 24 \times 3.7 \]

\[ P = 88.8 \text{ watts} \]

Where,

- \( P = \) DC power input of a generator.
- \( V = \) Input DC voltage.
- \( I = \) Input DC current.

Frequency of a generator is given by,

\[ f = \frac{p \times N}{120} \]

\[ f = 6 \times 5600 / 120 \]

\[ f = 280 \text{ Hz} \]

Where,

- \( f = \) frequency of a generator.
p=number of poles.
N=speed of the rotor.

Experimental power output:
Power of each bulb which glows,
\[ P_{exp}=40+40+40+60+60=240 \text{ watts} \]

To find actual AC power output:
\[ P_a = VI\cos\phi \]
\[ P_a = 290 \times 0.82 \times 1 \]
\[ P_a = 237.8 \text{ watts} \]

Where,
\[ \cos\phi = \text{power factor which is assumed to be unity.} \]
\[ V = \text{AC output voltage} \]
\[ I = \text{AC output current} \]

Therefore total power is,
\[ P_{total}=\text{power transmitted from motor to rotor} + \text{power generated due to coil and magnets} \]
\[ P_{total}=88.8+237.8=326.6 \text{ watts} \]

Hence Torque required to generate power is given by,
\[ T = P_{total} \times 60 / 2\pi N \]
\[ T = 326.6 \times 60 / (2\pi \times 5600) \]
\[ T = 0.5569 \text{ N-m} \]

| Table 2. prototype outputs: |
|-----------------------------|
| For V=12v and I=3.7A input  |
| \[ P_i = VI = 12 \times 3.7 = 44.4 \text{ watts} \] |
| Experimental results for this voltage is |
| V=100v and I=1.5A          |
| N=3200rpm                 |
| \[ P_o = 150 \text{ watts} \] |
| For V=24v and I=3.7A input |
| \[ P_i = VI = 24 \times 3.7 = 88.8 \text{ watts} \] |
| Experimental results for this voltage is |
| V=290v and I=0.82A        |
| N=5600rpm                 |
| \[ P_o = 237.8 \text{ watts} \] |
5. Results

1. Power output is greater than power input:
   \[ P_o/p > P_i/p = 326.6 > 88.8 \text{ watts} \]
2. Output torque is greater than input torque:
   \[ T_o/p > T_i/p = 0.556 > 0.45 \text{ N-m} \]
3. Output voltage is greater than input voltage:
   \[ V_o/p > V_i/p = 290 > 24 \text{ volts} \]

6. Conclusion

- In this paper we have discussed how several power losses in an induction generator can be reduced and also we have discussed about the construction and testing of EEA generator.
- The input 24volt dc current is converted to the required 290volt ac current all though this satisfies the basic requirements of the project. The motor is generating 5kg-cm torque. It uses 100watts maximum power. The output generated by the EEA generator is 290watts with this motor. We can generate more voltage with bigger motors. By using motor of higher torque the generator can produce more power. But EEA generator can produce more than the induction generator.
- The prototype proves that this EEA generator gives more output from given input. Here we are not creating energy we are utilizing the high magnetic flux from the neodymium magnets with a proper dynamic action and proper arrangement for emf amplification.

7. References

[1] Sang-heon kim, hansoo kim 2015 Brittle intermetallic compound makes ultrastrong low-density steel with large ductility
[2] Sai Krishna, allani, mallavolu sai nithish, sitaram Prasad 2013 generation of electricity using permanent magnets on the working principle of magnetic repulsion (magnetic lamp) (Hyderabad A.P India)
[3] Prof. parag G shewane, Abhishek singh, mayuri Gite, Amit Narkhede vol,2 issue12 An overview of neodymium magnets over normal magnets for the generation of energy, (Nagpur, India)
[4] Olivier Barre and Bellemain Napame 2016 Concentrated windings in compact permanent magnet synchronous generators; magnetic efficiency (France)
[5] Peiteng Xu, Kai Shi, Yuxin Sun and Hungqiu Zhua 2017 Effect of pole number and slot number on performance of dual rotor permanent magnet wind power generator using ferrite magnets (American institute of physics)
[6] Luc G. frechette, Stuart A jacobson 2005 High speed microfabricated silicon turbomachinery and fluid film bearings
[7] Agus Jamal, Slamet Suripto, Ramadoni Syahputra 2016 Performance Evaluation of wind turbine with doubly fed induction generator (Indonesia)