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VOLTAGE GENERATION USING EARTH MAGNETIC FIELD

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Key words: Geo magnetic field, Modified earth magnetic field (EMF) equation, Stator-less generator.

This paper represents of an idea of generating voltage from a stator-less dc generator using the earth magnetic field. As per the composition, a dc-generator consists of two parts, one is stator and another is rotor. The working principle for both the part is different from one to another. This stator creates an electromagnetic field and the rotor moves inside of that field at a rated speed by a prime mover. The flux which is linked with the rotor changes with its movement. As per Faraday's law, if the flux changes in a coil it will induce an electro-motive force. In stator-less generator the required magnetic field is given by earth magnetic field, this magnetic field is present everywhere in the earth. Rotor have to place along the direction of maximum intensity of this field in a particular location. There is no requirement to create magnetic field and no requirement of stator winding or any magnet, only rotating part of the machine is required to generate the voltage by using earth magnetic field and this value changes as per the change of height and inclination angle and based on the proposed idea the previous conventional electro-motive force equation of generator can also be modified.

1. INTRODUCTION

Earth magnetic flux density vector is denoted by B. Its unit is same like other magnetic fields. The intensity of Tesla is very high comparing to earth magnetic field. As the science progresses a modified instrument named magnetometer is used for determination of geomagnetic field intensity by a sensitivity of 10^{-9} T which is known as nT. Here , from the Gauss's equation of geomagnetic field potential the relationship between magnetic flux density B and its potential at any point can be written as, [1]

$$W = R\sum_{n=1}^{\infty}\left(A_n r^n + \frac{B_n}{r^{n+1}}\right)\sum_{l=0}^{n} Y_n^i(\theta,\varphi), \tag{1}$$

where W is the potential of the geomagnetic field, R is the radius of the earth,(r , θ, φ) are the spherical polar coordinates, B_n is the constant of the potential that arise from the outside of the earth, A_n is the constant of the potential that arise from the inside of the earth, Y is the function of W , when r is constant then $\sum_{l=0}^{n} Y_n^i(\theta,\phi)$ describes the variation of potential. It is spherical harmonic function. Magnetic field of earth is different at different places or position.

Overall earth magnetic field is weaker. Its maximum value of field intensity is nearer to the magnetic poles and its value is $6.4\cdot10^{-5}$ T. The magnitude of the magnetic vector is given by the field strength F , its direction is specified by two angles (inclination & declination) as shown in Fig. 3 to Fig. 7.

The declination D is the angle between the magnetic meridian and the geographic meridian; the inclination is the angle at which the magnetic vector dip below the horizontal and I is inclination angle of geo magnetic field. The

Cartesian (X , Y , Z) and spherical polar (F , D, I) sets of geomagnetic elements are related to each other as follows,

$$X = F\cos I\cos D, \tag{2}$$

$$Z = F\sin I, \tag{3}$$

$$Y = F\cos I\ \sin D. \tag{4}$$

From the above equation (3)–(4) it can be written as,

$$F^2 = X^2 + Y^2 + Z^2, \tag{5}$$

$$D = \arctan\left(\frac{Y}{X}\right), \tag{6}$$

$$I = \arctan\left(\frac{Z}{\sqrt{X^2+Y^2}}\right). \tag{7}$$

External origin of earth magnetic field is very complicated. Solar wind strongly affects this origin of earth magnetic field. A plasma solar wind consists of electron proton and helium nuclei. Solar wind density is 7 ion/cm^3 and it is able to produce a very weak magnetic field of 6 nT. [2]. This field intensity of geo magnetic field is changing every year due to magnetization contrast. This magnetization contrast can be expressed as, [1]

$$\Delta M = (k - k_0)F. \tag{8}$$

Here k represents the susceptibility of an ore body. k_0 is the susceptibility of the host rocks and F the strength of the

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inducing magnetic field. This relates with the vertical magnetic anomaly. This relationship is as follows,

$$\Delta B_z \propto \frac{(\sigma A)\cos\theta}{r^2} \propto (\Delta M)\Omega \quad (9)$$

Here ΔB_z is the vertical magnetic anomaly , σ is the surface density of poles, A is the surface area, distance from the distribution of poles, r makes an angle with the vertical magnetization M, which is θ, the vertical component of the anomalous field is found by multiplying by $\cos\theta$. Ω is solid angle subtended distribution at the point.

In the inner core of the earth due to the temperature and pressure all the metals are in a flow able liquid state. That flowing condition of metal molecules converts them into charged particles which causes earth magnetic field. Movement of a charged particle through a magnetic field causes a deflecting electrical field proportional to the magnetic flux density B and particle velocity v, and acting in the direction normal to both B and v. This is one of the internal source of earth magnetic field which is natural and given by [3]

$$\frac{\partial B}{\partial t} = \frac{1}{\mu_0 \sigma}\nabla^2 B + \nabla \times (v \times B). \quad (10)$$

Here B is the earth magnetic field flux density, v is the fluid flow rate at the core and σ is the conductivity in earth core. This current is responsible for the earth magnetic field. This field is present everywhere in the earth and even it presents in the atmosphere. With increasing the distance from earth surface the field intensity gradually decreases[4, 5].

2. MODIFIED EMF EQUATION

Utilizing this weak field intensity voltage can be generated using a stator-less generator.[6] the generated voltage magnitude is very low. This way of voltage generation can be consider as non-conventional energy source. This generated voltage can be calculated by the formula given below,

$$e = N B l v \sin I \quad (11)$$

where N = number of turns of armature coil in rotor,
B = magnetic field intensity at the experimental place,
l = length of the rotor, v = rotor speed, I = earth magnetic field's inclination on experimental place.

In this experiment value of generated voltage had taken respect to three different heights as follows:

i) at the ground level,

ii) 10 ft above from the ground level and

iii) 20 ft above from the ground level.

Here, the smallest possible height h is expressed as the function of e^t where e is Euler's number. Here, h_0 is the unit height and t_0 is the unit time. As the ratio of same quantity remains unit-less then the natural log and exponential function can be applicable on that. In this process $\frac{h}{h_0}$ and $\frac{t}{t_0}$ remains unit less, so natural log and exponential function is applied on that [7].

$$\frac{h}{h_0} = e^{\frac{t}{t_0}}. \quad (12)$$

It signifies that continuous differentiable position of h in the upward and downward direction from the mean sea level.

Now taking the natural log in both sides of the above equation can be written as,

$$t = t_0 \ln\frac{h}{h_0}. \quad (13)$$

Let

$$f(t) = \ln\frac{h}{h_0}. \quad (14)$$

It has been observed that if the height (h) increases gradually from the sea level, the magnetic field flux density (B) decreases exponentially, therefore . B can be treated as a function of e and B can be written as,

$$B(t) = Bf(t). \quad (15)$$

Here from equation (14),

$$f(t) = \ln\frac{h}{h_0}.$$

It is evident from the above equation that B is not only the function of e, but also it is a function of t. In order to get the modified emf equation $B(t)$ it is required to be introduced with the previous emf equation as given below,

$$e = N B l v \sin I. \quad (16)$$

At ground

$$e = N(B\ln\frac{h}{h_0})lv\sin I. \quad (17)$$

Below sea level

$$e = \frac{N B l v \sin I}{\ln\frac{h}{h_0}}. \quad (18)$$

Above sea level, equation number (18) can be termed as modified electromotive force equation where e is the function of height $\frac{h}{h_0}$.

3. EXPERIMENTAL SETUP

In this experiment two sets of stator less generator having two different specifications has been utilized. Specification details are given in Table 1.

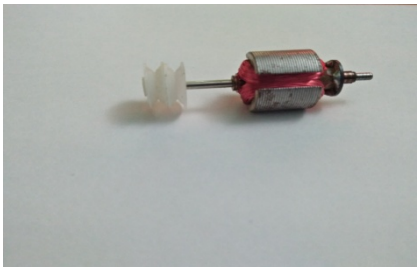

Fig. 1– Stator-less Rotor of a dc generator.

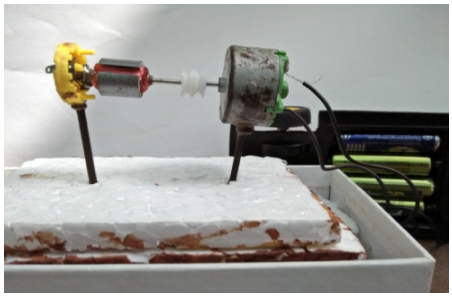

Fig. 2– Experimental setup

As per the equation [16], greater the length will offer greater induced emf. On the other hand increment of the rotor slot will cause higher induced emf and many number of turns *N* of the conductor in the rotor can also increase the intensity of induced emf.

The intensity of the earth magnetic field increases with the increase of depth below the earth surface, so at the setup of the machine, this aspect can be very efficient. As per the variation of the atmosphere of various places on the surface of the earth, the value of the induced emf can be different for various components of geomagnetic field so by experimenting that the setup of the machine can be effective.

By these values relationship between generated voltage and field flux density can be made.

This table signifies the change of the elements of geomagnetic field.

As per the increment of height the geomagnetic field decreases inversely with the height. The geomagnetic field is also affected by time as it is a function of time [10].Two stator-less rotor has been selected whose specification is given earlier in table1.This prime mover which rotates two different rotors at different time at a speed of 100rpm. As the rotor moves by prime mover, earth magnetic field flux linked with the rotor changes and the production of emf takes place.

Table 1

Specification table for stator less generator

Instrument name	Dc supply	Total length	Motor diameter	Motor length	Brush type	Output shaft type	Shaft diameter	Shaft length	Weight	Speed
Prime mover(dc motor)	6 V	30 mm	36 mm	25 mm	Fresher's metal	Centre	6 mm	22 mm	100 g	100rpm
Setup1 (dc motor and stator-less rotor)	6 V	30 mm	36 mm	25 mm	Fresher's metal	Centre	6 mm	22 mm	100 g	100rpm
Setup2 (dc motor and stator-less rotor)	9 V	45 mm	40 mm	35 mm	Fresher's metal	Centre	6.8 mm	27 mm	110 g	100rpm

Table 2

Values of earth magnetic field on this experimental place

Height (feet)	Type of value	Declination	Inclination	Horizontal intensity	North component (+N/-S)	East component (+E/-W)	Vertical component (D/-U)	Total field
20 ft	Value	-0.1667°	35.3113°	37729.8nT	37729.7nT	-109.8.nT	26725.4nT	46236.2nT
20 ft	Change per year	0.0467°/Yr	0.1335°/Yr	-21.9nT/Yr	-21.8nT/Yr	30.8nT/Yr	116.6nT/Yr	49.5nT/Yr
10 ft	Value	-0.1667°	35.3113°	37729.9nT	37729.7nT	-109.8nT	26725.4nT	46236.3nT
10 ft	Change per year	0.0467°/Yr	0.1335°/Yr	-21.9nT/Yr	-21.8nT/Yr	30.8nT/Yr	116.6nT/Yr	49.5nT/Yr
0 ft	Value	-0.1667°	35.3113°	37729.9nT	37729.8nT	-109.8nT	26725.5nT	46236.4nT
0 ft	Change per year	0.0467°/Yr	0.1335°/Yr	-21.9nT/Yr	-21.8nT/Yr	30.8nT/Yr	116.6nT/Yr	49.5nT/Yr

4. EXPERIMENTAL VERIFICATION

Here at first an experimental site is selected and the value of earth magnetic field's parameter is collected which is presented in Table 2. All the parameters of this field including intensity, inclination, declination and change per year of those parameters are collected [8, 9].

Two different setup produce six different sets of result depending on the variable height from the sea level. Even change in the direction results into change in generated voltage. The instrument(stator-less generator) has been placed at different positions and the corresponding figure is depicted below in the Figs. 3–7 and values from two different set up is given below in the Tables 3–8.

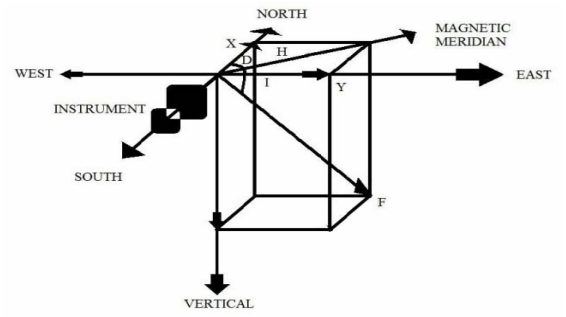

Fig. 3 – Stator-less generator (instrument) placed at South direction

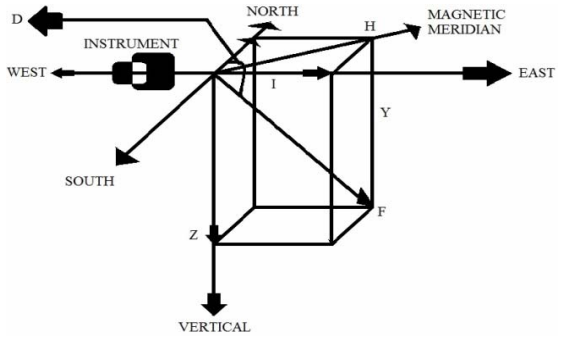

Fig. 4 –Stator-less generator (instrument) placed at West direction

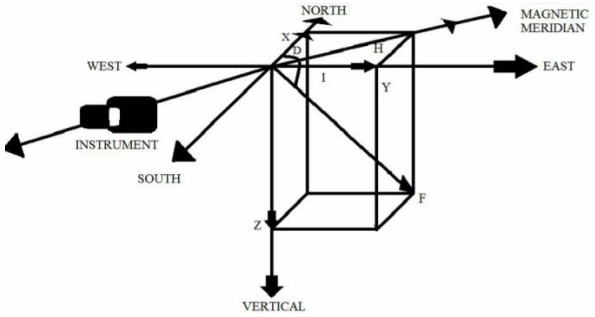

Fig. 5 – Stator-less generator (instrument) placed at South-West direction

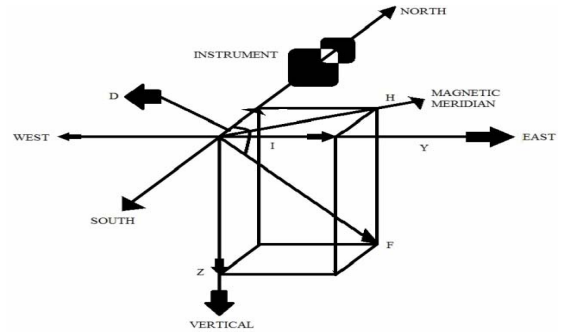

Fig. 6 – Stator-less generator (instrument) placed at North direction

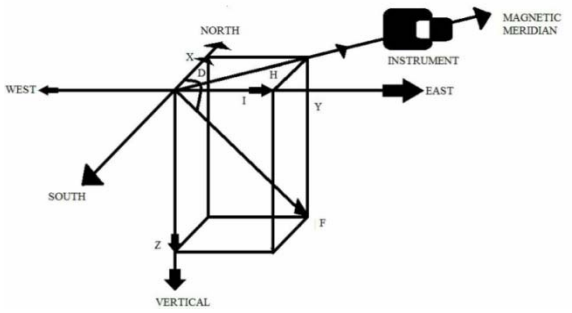

Fig. 7 – Stator-less generator (instrument) placed at North-East direction

Table 3

Values for first setup at ground

Direction	Value of magnetic field	Value of generated emf
South-North	-37729.8 nT	6 mV
West	-109.8 nT	1.5 mV
South-West	-30142.71 nT	4.5 mV
North-South	37729.7 nT	7.4 mV
North-East	30142.71 nT	5.13 mV

As per the change in direction geomagnetic field elements are changing, now intensity of this field is changing due to the change in direction causes also a change in induced emf . From every graph it is seen that induced emf is lowest in the west direction as intensity of this field is lowest in that direction. After that induced emf increased when the rotor is placed in South-west. Then in South it is slightly increased. In north- east the value of induced emf is decreased as the intensity of the geo-magnetic field is decreased. The emf is maximum at the direction of North as the intensity of the geo-magnetic field in that direction is maximum.

Fig. 8–Experimental setup with results

Figures 9 to 14 represent the plot of induced emf *vs*. magnetic field. As the earth magnetic field decreases or increases, a value of emf changes accordingly. Maximum value of emf has been found at the ground level in the north south direction.

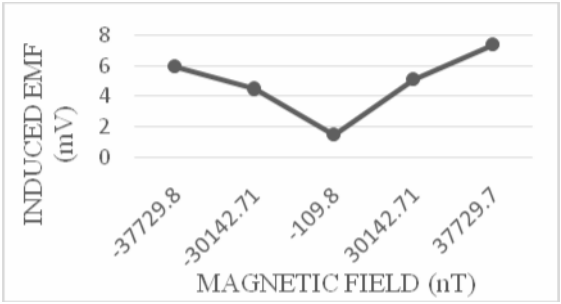

Fig. 9 – Graph for Table 3.

Table 4

Values for first set up at 10ft from ground

Direction	Value of magnetic field	Value of generated emf
South-North	-37729.7 nT	3.5 mV
West	-109.8 nT	0.9 mV
South-West	-30142.5 nT	1.7 mV
North-South	37729.7 nT	4.85 mV
North-East	30142.5 nT	2.23 mV

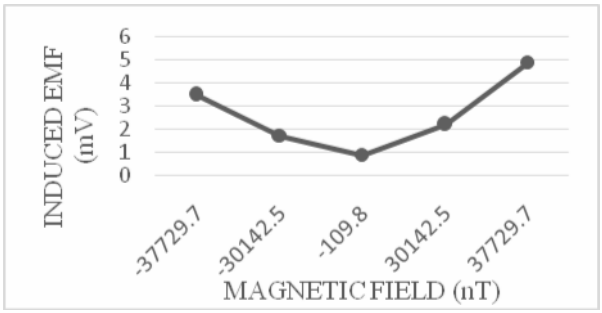

Fig.10 – Graph for Table 4.

Table 5
Values for first setup at 20 ft. from ground

Direction	Value of magnetic field	Value of generated emf
South-North	–37729.7 nT	1.4 V
West	–109.8 nT	0.4 mV
South-West	–30142.5 nT	1.1 mV
North-South	37729.7 nT	1.9 mV
North-East	30142.5 nT	1.34 mV

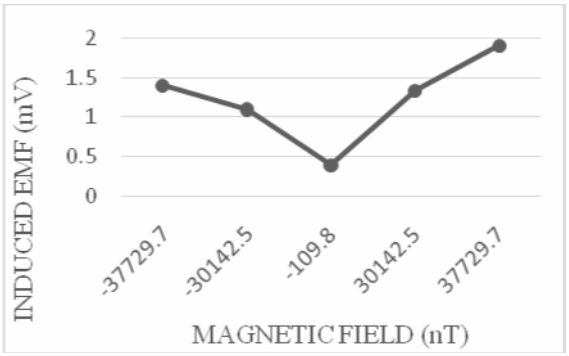

Fig. 11 – Graph for Table 5.

Table6:
Values for second setup at ground

Direction	Value of magnetic field	Value of generated emf
South-North	-37729.7 nT	11.0 mV
West	-109.8 nT	6.6 mV
South-West	-30142.7 nT	10.8 mV
North-South	37729.7 nT	17.4 mV
North-East	30142.7 nT	11.4 mV

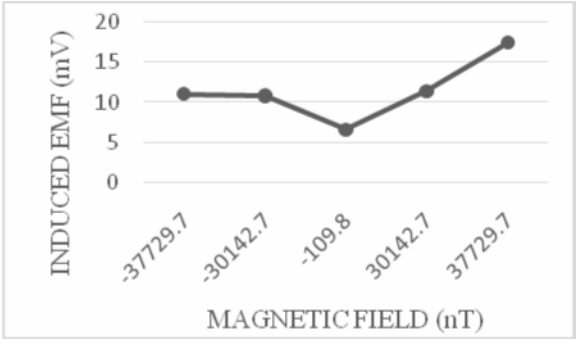

Fig. 12–Graph for Table 6

Table 7
Values for second setup at 10 ft from ground

Direction	Value of magnetic field	Value of generated emf
South-North	–37729.7 nT	8.89 mv
West	–109.8 nT	3.1 mV
South-West	–30142.5 nT	8.1 mV
North-South	37729.7 nT	11.5 mv
North-East	30142.5 nT	8.5 mV

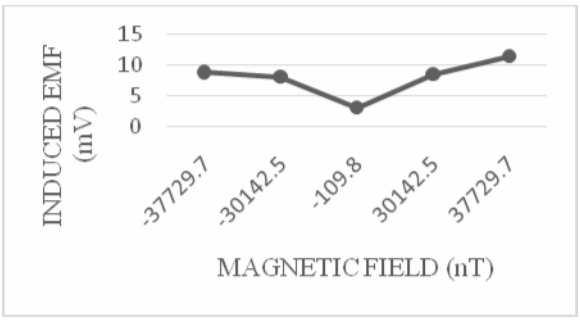

Fig. 13– Graph for Table 7.

Table 8
Values for second setup at 20 ft from ground

Direction	Value of magnetic field (nanotesla)	Value of generated emf (millivolt)
South-North	–37729.6 nT	6.61 mV
West	–109.8 nT	2.2 mV
South-West	–30142.5 nT	4.7 mV
North-South	37729.6 nT	7.6 mV
North-East	30142.5 nT	5.2 mV

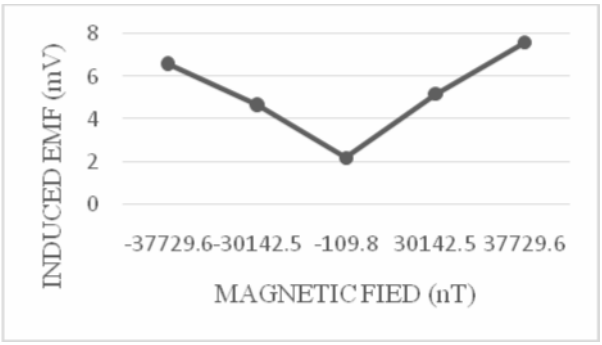

Fig. 14 – Graph for Table 8.

Some parasitic effect of prime mover will be surely there in the rotor. But as induced emf is very low and in the millivolt range. So the parasitic effect is negligible for this paper. The main cause behind the change of emf with a change in direction is the different value of different components of the earth magnetic field described in table2. For different direction, the geomagnetic field flux density is different which produce different induced emf.

This machine is very useful in the pollution aspect as there is no generation of carbon-di-oxide at the time of generating electricity. Apart from this at any types of underground work where electricity is required, this machine can be very useful at the position setup aspect. During underwater construction works and if electricity is

required for aquatic vehicles, the setup of this machine will going to be very efficient.

5. **CONCLUSION**

This paper introduces the new idea of non-conventional energy source. It is a new kind of a stator-less generator which uses earth magnetic field instead of the electromagnetic field produced by the stator winding. Though the induced emf is very low it can be increased by using strong earth magnetic field intensity. As the rotor come closer to the core of the earth it results in increment of the earth magnetic field intensity. The mathematical modification of the emf equation has been done to show the changes in geomagnetic field intensity with respect to height. Therefore this type of stator-less generator is applicable on the account of generating electricity by using earth magnetic field in the underground atmosphere. It also reduces the expenses as the generator is stator-less as well as less spacious for the same case. In this context it can be said that as it is stator-less, the loss due to stator doesn‘t exists hence the efficiency increases. So this non-conventional machine can produce electricity with less space, less cost and greater efficiency.

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