Design and Construction of Low Speed Axial Flux Generator with Stationary Bike

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Abstract- There are some rural areas in Myanmar where have no electricity. They rely on solar cells, small windmills, hydropower and generators which can produce electricity to use for domestic. Solar, Windmill and Hydropower depend on climate and Generator needs fuel to electrify. We cannot forecast the weather conditions and cannot afford the today's fuel price. This paper presents the design and construction of Low Speed Axial Flux Generator with stationary bike that utilizes locally available materials. This cannot depend on weather conditions, fuel and can use anytime at anywhere without pollution. By taking the stationary bike it will be like doing physical exercise which can lead us to being well. The goal is to design, fabricate and test the performance of the AFPM generator for renewable (Green) energy power generation. In this project, consists of three main parts: AFPM generator, stationary bike and control unit. AFPM generator contains two rotor disks, permanent magnets, stator support, windings, and car hub bearing. This AFPM generator is coreless generator which does not have any core in the stator. And then generating efficiency is high as there is no hysteresis loss. This generator attains a maximum efficiency of nearly 93%. This AFPM Generator can also be linked with Windmill, Hydropower and Stationary Bike to generate renewable electrical energy. The desired output electrical energy will be rectified and charged the 24V battery by digital charged controller. The battery will convert DC to AC with 500W Inverter to utilize rural electrification.

Index Terms- Coreless Axial Flux, Low Speed, Permanent Magnet, Rural electrification.

I. INTRODUCTION

In the last decade, the climate has changed in the world because of Global Warming. We are facing with the lack of mineral resources, thus people are searching the renewable energy (Green) with various ways. There are so many things that can generate renewable energy such as Solar, Windmill and Hydropower which are the most common ways. There are some rural areas in Myanmar where have no electricity. They rely on solar cells, small windmills, hydropower and generators which can produce electricity to use for household applications. Solar, Windmill and Hydropower depend on weather and location and Generator needs fuel to electrify. Weather condition cannot forecast exactly and fuel price is still rising nowadays. There is a better way that cannot depend on weather, location and fuel price it is connecting the generator with Stationary Bike. This can use anytime at anywhere without pollution. By taking the stationary bike it will be like doing physical exercise which can lead people to being well and will convert the wasted energy into electrical energy. But this generator with stationary bike needs low speed only as people cannot take the bike with high speed like one thousand RPM. So Axial Flux Permanent Magnet Generator is being used for low speed application t. Because of the permanent magnet that is the main items of this generator can effectively generate desired electrical power. The desired electrical energy will save in battery and use with Inverter for rural electrification. Thus AFPM generator with stationary bike is initial part and battery and inverter are the last part that can use household application. This is like Stand-alone systems.

II. DESIGN PROCESS FLOW

In this design approach the rated frequency is set to 50 Hz. The permanent magnets used in these designs are rectangular neodymium magnets (NdFeB) which are rare material used in the construction process of this Axial Flux Permanent Magnet Generator.

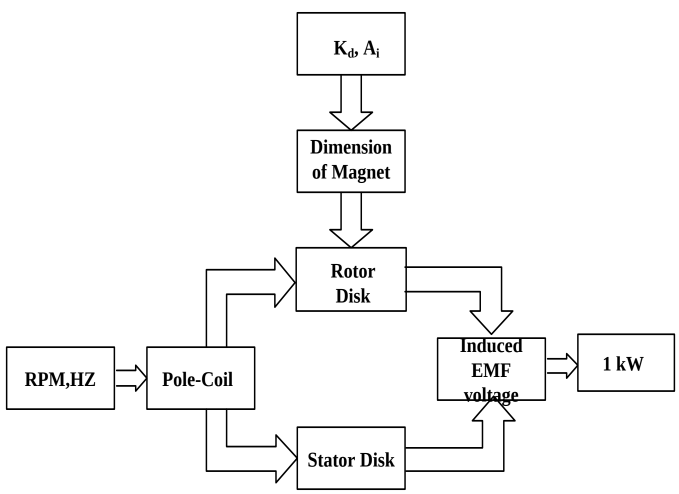

Fig.1 Process Flow

K_d is the magnet inner to outer diameters ratio. It is equal to 0.577 and can get the inner radius, outer radius and magnet length.

The parameter A_i is pole arc to pole pitch ratio and the value between 0.4 and 0.7 and can get magnet width is nearly equal to the pole arc.

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A. Generator Fixed Parameter

The geometry of the AFPM generator is described in Figure2.

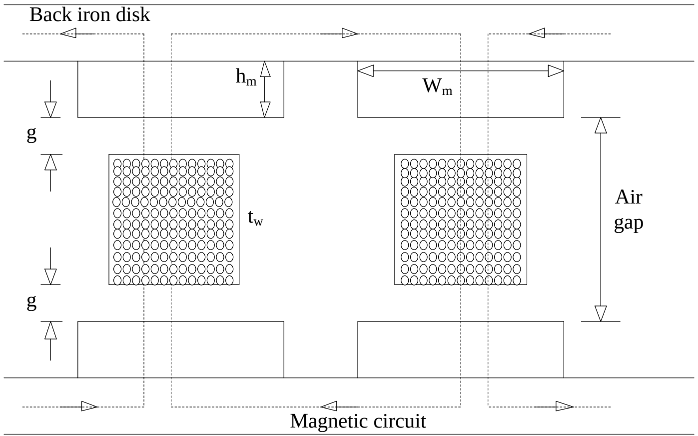

Fig.2 Top View of AFPM Generator System

The following dimensions are used during the design procedure.

In this project, AFPM generator has rated power 1 kW, rated speed 375 rpm, rated voltage 24 V, number of poles 16, 3 phase star connection and rotor diameter 300mm. For a coreless stator AFPM generator, the inner and outer radii of rotor disk are equal but stator disk is slightly larger than rotor disk. The diameter of hub bearing and shaft assembly is used the inner radius of rotor r_i

B. Generator Dimensions

The following equations are used for design of AFPM generator

Stator Axial Length, (L_s):

$$L_s = t_w \qquad (1)$$

Rotor Axial Length, (L_r):

$$L_r = t_r + h_m \qquad (2)$$

Effective Air-gap, (g_e):

$$g_e = 2h_m + 2g + t_w \qquad (3)$$

Average Pole Pitch, (τ_p):

$$\tau_p = 2\, r \sin\left(\sin\frac{\theta}{2}\right) \qquad (4)$$

Where, r = magnet outer radius

Number of Stator Coils, (Q):

$$\frac{2Q}{3p} = 0.5 \qquad (5)$$

Flux Density of the magnet, (B_m):

$$B_m = \frac{B_r h_m}{h_m + g + t_w} \qquad (6)$$

Where, B_r is the remanent magnetic flux density

Number of Turns per Coil, (N_c):

$$N_c = \frac{\sqrt{2}E_f}{q.2\pi.k_w.\phi_{max}.n.\frac{p}{120}} \qquad (7)$$

C. General characteristics of 1 kW AFPM generator

TABLE I
Generator Dimensions

Rotor	
Outer radius of rotor	150mm
Inner radius of rotor	86.6mm
Ratio of inner to outer rotor radius	0.577
Diameter of machine	300mm
Axial length of stator	17mm
Axial length of rotor	18mm
Axial length of machine	53.47mm
Thickness of rotor disk	9.5mm
Stator	
Air-gap between stator and rotor	1.5mm
Effective air-gap	35.47mm
Average pole pitch	58.53mm
Number of stator coils	12
Number of turns per coil	72
Flux density in the air-gap	0.5T

III. THE MANUFACTURING PROCESS

A. Winding coils

For winding the coils it is essential to carefully count the turns, to make sure one turn of copper conductor is set next to the other and to tense the conductor enough, as this results in less gaps in between the turns of copper conductors and thus more successful coils.

Fig.3 Two Strings 18 SWG wire 70turns winding

B. Constructing molds

A mould is a shaped container in which resin castings are formed. stator and rotor moulds were cut from plywood together with the stacks. The stacks are the boards serving as the lid and base of mould. The finished moulds for stator and rotor are shown below.

Fig.4 Stator mold

Fig.5 Rotor Mold

C. Constructing Rotor Disks

The rotor component consists of the two rotor disks, permanent magnets and the bearing assembly.

Fig.6 Completed Rotor Disk

D. Constructing Stator Disk

The stator consists of the windings and the epoxy resin winding support. The polyester epoxy mixture was made according to manufacturer‘s specifications and poured to make the stator cast. Fiber cloths were used to strengthen the cast. After a period of about 24 hours, the stator manufacture is completed. Three mounting holes equally spaced and marching those of the mounting frame were then drilled.

Fig.7 Completed Stator Disk

E. Axial Flux Permanent Magnet Generator

First, the car hub was inserted before being mounted onto the stator frame. And then inserting one by one the back rotor, stator and front rotor respectively. Appropriate air-gap 1.5 mm between each rotor disk and the stator was observed. The final generator assembly is shown in the Figure below.

Fig.8 Completed AFPM Generator

F. Assembling the AFPM Generator with Stationary Bike

Finally the AFPM generator and stationary bike are assembled by gear ratio 3.3:1. Thus, we give 100 RPM for front driven, the rear driven will 330 RPM.

$$\text{Gear Ratios} = \frac{(Front\ Gear\ Driven)}{(Rear\ Gear\ Driven)} = \frac{48}{16} \times \frac{44}{40} = 3.3{:}1$$

Fig.9. Assembled AFPM Generator with Stationary Bike

IV. POWER CONTROL UNIT

The control unit as shown in Figure.10 consists of 8 Pin 12 V AC relays, bridge rectifier (Three-phase diode), charge controller, Ammeter, Volt-meter, inverter, dump load and fuse (circuit breaker). The relays choose the operation that is normally closed or open. This means that AC power will flow to the 3 phase rectifier which converts the AC power to DC or AC power will flow to the dump load which is delta connection stove coils. If the relays choose the normally closed operation, AC power will flow to the Ammeter and Volt-meter through bridge rectifier. And then DC output from the rectifier will flow to the Batteries (flowing in one direction) via charge controller to charge and the diodes in each bridge ensure that current will only flow in one direction into the battery and not discharge it. The connection of charge controller to batteries and batteries to inverter are such that the positive terminals are connected to battery positive via the fuse while all the negative terminals are connected to the battery negative.

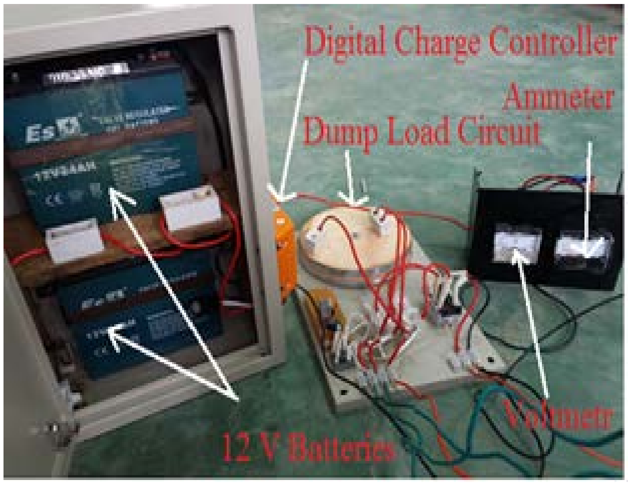

Fig.10 Power Control Unit

V. TEST FOR AFPM GENERATOR WITH STATIONARY BIKE

After assembly the whole power bike machine, the generator performance tests were started. There are two types of test that were carried out.

a) No load test
b) Load test

A. No-load Test Situation

Firstly, the AFPM generator is tested with no load for various speeds.

TABLE II
Output No load Voltages for Variable Speed

Speed (RPM)	Output (Voltage)
50	5
100	8
150	11.2
200	16.9
250	19.8
300	22.9
326	24
375	28.5

B. Load Test Situation

For 190 W Load, the following table is the value of voltage and current for variable speed

.

TABLE III
Load Test

Speed(rpm)	Voltage(V)	Current(A)
50	4.5	1.12
100	6.3	2.33
150	9	3.54
200	11.9	4.97

C. Household application

After testing this project, we will start using the household application for our country. The following table is the most common loads for rural electrification.

TABLE IV
Common Loads for Rural Electrification

Load	Quantity	Wattage	Time
TV(LED)	1	80W	6.25 h
Fluorescent Tube	1	34W	14.7 h
Sound Speaker	1	100W	5 h

VI. SPECIFICATION OF AFPM GENERATOR WITH STATIONARY BIKE

General Characteristics

Nominal Power	1kW
Nominal Frequency	50Hz
Pole Pair Number (p)	16
Coil Number (Q)	12
Air-gas between rotor and stator	1.5mm
Efficiency	93 %

Rotor Disks

Thickness	10mm
Outer Radius	150 mm
Inner Radius	86.5mm
Inner/Outer Radius (k_d)	0.577

Magnet

Length	49mm
Width	24mm
Thickness	9.5mm
Pole arc / Pole pitch (a_i)	0.41

Stator Disk

Axial Thickness (t_w)	16mm

Coils	
Thickness of the coil	20mm
Number of turns per coil	70turns
Stationary Bike	
Gear Ratio	3.3: 1
Solar Charger Controller	
Operating Voltage	12/24 V
Operating power	450 W
Battery	
Operating Voltage	24V
Operating Current	24 Ah
Inverter	
Operating power	500 W
Over voltage Protection Circuit	
Operating Voltage	> 28 V
Power Bike Machine	
Rated Speed	375 rpm
Cut-in Speed	~150 rpm
Cut-off Speed	~200 rpm

VI. CONCLUSION

In this paper, the design and construction processes of AFPM generator with stationary bike (power bike machine) in rural electrification applications was made using simple methods, partially open source type, and simple construction techniques. The processes of this machine have proved to be easily applicable and understood. These constructed AFPM generators with stationary bike have proved to have strong designs. This machine is the portable type, so this can move at any places. This machine can be easily used by the adult person, and it cannot risk the person's safety. This machine can be easily modified by the technicians that construct them to suit local needs and use local materials with the basis for the formation of open source AFPM generator with stationary bike.

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