Site Investigation for Wind Potential Assessment and Development of Permanent Magnet Generator for Roof Top Application

Kapildev Ramarao Pawar
Department of Energy Systems Engineering
KLE Technological University, Hubballi – 580031, India

Abstract— Presently alternate energy resources are replacing conventional energy sources to produce electric power to minimize the usage of non-renewable energy sources. Wind power is one of the potential alternate energy resources and is being exploited and deployed actively. The wind energy system is basically composed of two core components one is wind turbine and another is electrical generator. The wind potential is not same at the entire region, Hence it important to do assessment on the sites for better power output. In the present project investigation on four different locations has been assessed based on annual probability density function. The probability density function at each site has been determined using Weibull, Rayleigh and graphical method distribution function. The shape parameter(k) and scale parameter(c) values were found for selected locations. Based on the energy production of each wind turbine at each location, the suitable wind turbine was recommended. The second part of this project deals with development of small scale permanent magnet generator. For the construction of permanent magnet generator indigenous materials are used, due to which the cost of module is reduced Study on the performance characteristic of the permanent magnet generator was made through a small motor coupled with permanent magnet generator in absence of wind turbine. The observation on variation of efficiency at load and no load condition was made though experimentally. The torque produce and its variation with rotational speed were determined. Permanent magnet generator was tested to check its efficiency and power output at load and no load condition. Radial flux permanent magnet generator has been developed subject to satisfying the features of low operating shaft speed, higher power density, cost effectiveness and compact size.

Key words: Shape Parameter, Scale Parameter, Permanent Magnet Generator and Wind Turbines

I. Introduction

Wind energy is the indirect form of solar energy. Atmospheric air in motion is termed as wind and is caused by uneven heating of the atmosphere by sun, rotation of the earth and the irregularities of the earth surface. The wind turbine is the conversion system that captures the natural wind in the atmosphere and converts it into mechanical and then electrical energy. The process of wind produced electrical energy generation begins when the force of the wind pushes the turbine blades, causing the wind turbine blades to rotate, creating mechanical energy. The blades are connected to the hub and then to low speed shaft which rotate along with the blades. The low speed shaft is connected to high speed shaft through gearbox and then to the generator producing electrical energy. The installation of wind turbine requires preliminary work to be done on the selected site which includes the calculation of the amount of wind at the site, the latitude and the longitude of the site, site analysis for a particular period for better wind speed data, selection of a suitable wind turbine blade is one of the key tasks for wind turbine installation which later determines the total electric energy yield form the installed system. Investigations for the calculation of total number of blades, blade length, rotor diameter and the total electrical load for determining the capacity of turbine must also be done at the selected site for available wind speeds. The selection of suitable generator for the selected wind turbine is the next step after turbine selection as the generator is that part of wind generation system which converts mechanical energy to electrical energy

II. Literature Survey

Several work that has been carried out and recommendation of several researchers has been gone throw.

Some of recent work and published paper discussed below.

[1] Present a new topology of direct driven Axial Flux Permanent Magnet Generator (AFPMG) for micro wind power applications. An AFPMG novel topology proposed in this paper eliminates the constraint of magnetic flux in air gap imposed by rotor permanent magnets by providing an innovative arrangement of permanent magnets on the rotor that enables higher magnetic flux in air gap even if low remanence magnets are used. The proposed generator in this paper can be used in micro wind generation applications due to its added advantages like cost effectiveness, higher efficiency and double sided rotor design.

[2] Present a new topology of single rotor and two stator having identical structures. A non-ferromagnetic type of material is used for stator and rotor leading to reduction in cogging torque, rotor-stator axial attractive forces and the overall weight of the machine. Halfback Array type of arrangement of magnets is employed in the rotor part increasing the magnetic flux in the air gap because of magnetic field vector making an angle of 900 with its adjacent pieces. The arrangement is validated by designing a part of rotor in FEMM software and is found that the peak value of flux density in the air gap depends on properties and height of the magnets

[3] Present a method to calculate the total losses in an Axial Flux Permanent Magnet Generator (AFPMG) on theoretical basis. In addition to loss calculation the work also focuses on the design of a double rotor, slot less laminated stator core type AFPMG. The stator core consists of various numbers of laminations with a specific design giving lower cogging torque value. The proposed design has a very good efficiency of 92.5% at its rated speed 1000rpm

[4] Present the design of three phases AFPMG contrary to that of conventional generator, each stage consists of one phase winding, as a result terminal voltage and unit power of the machine increases to approximately 60% of output voltage compared to usual design that has same

volume of windings and active material. In addition, a novel shape of winding that improves the inductance and resistance values is presented and a coreless and slot less AFPMG resulting in low cogging torque and lower inductance is proposed. The new design presented in the work consists of four rotor and three stator comprising NdFeB magnets. Hence, the output power increases due to increase in number of stages of rotors and stators. The work presented a suitable selection of AFPMG for driving electromagnetic induction launchers and the simulation was done using commercially available JMAG software

[5] Present a method for calculation of conduction, eddy current and stator core losses in AFPMG. The losses were calculated using Quasi-3D FEA analysis method where the stator conductor portion was divided into several elements and the flux density at each element was calculated as a function of rotor position. The topology, double stator single rotor type AFPMG used in this work has a complex geometry thereby increasing the stator losses which are validated by calculation using the computational tool MATLAB

[6] Obligate proposed the surface magnet generators energized by the (NdFeB) magnet. 501kW, 10 kW and 5.4 kW machines have been streamlined utilizing a hereditary calculation joined with the limited component technique. A 10 kW model machine has 12 posts and q is 1.5. The aftereffects of the examination are show in large detail in this theory.

A large portion of the previously mentioned uncommon low-speed machines are still in a creating stage. The mechanical outline of the direct acceptance machine is straightforward yet the productivity is low. The transverse-flux machine is little, effective and light, however the mechanical outline is exceptionally confounded. Some exploratory uncommon machines have been fabricated and tried. The work on designing generator with optimal air gap between stator and rotor is very much important since proper flux distribution affects the output efficiency. Lots of researcher has worked on improvement of overall efficiency of the generator. One such step has been taken though this module to improve the output efficiency of the generator and wind potential assessment for better output.

III. METHODOLOGY

Fig. 3.1: Wind Energy Conversion System

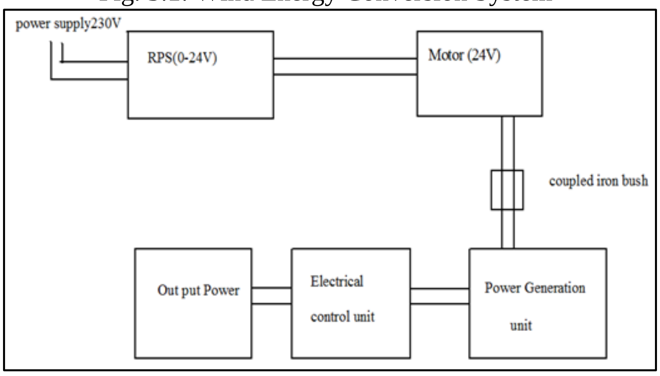


Fig. 3.2: Block Diagram

Fig. 3.3: Flow Chart

IV. WINDING OF ARMATURE

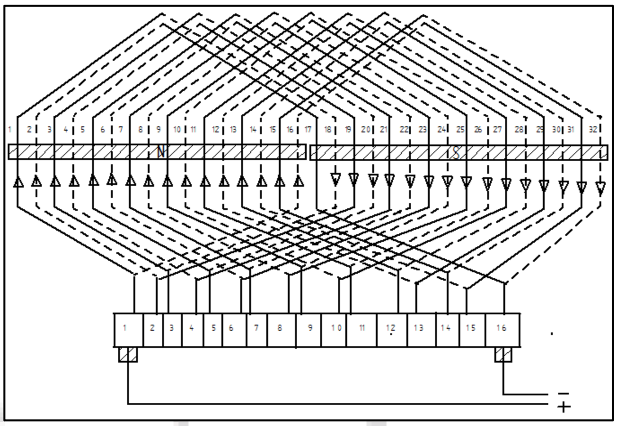


Fig. 4.1: Double Layer Lap Winding Diagram of PMG

Coil 1	Coil 2
1+17= 18	18-15=3
3+17=20	20-15=5
5+17=22	22-15=7
7+17=24	24-15=9
9+17=26	26-15=11
11+17=28	28-15=13
13+17=30	30-15=15
15+17=32	32-15=17
17+17=34(2)	34-15=19
19+17=36(4)	36-15=21
21+17= 38(6)	38-15=23
23+17=40(8)	40-15=25
25+17=42(10)	42-15=27
27+17=44(12)	44-15=29
29+17=46(14)	46-15=31
31+19=48(16)	48-15=33

Table 1: Winding Connections Table

Above listed wind turbines are most commonly used turbines in India. They are small scale wind turbines ranging from 1kW to 1.5kW. The rated speed, curling speed and cut in speed has been noted down from the manufacturer websites.

A. Wind Density Functions

The wind speed variations can be described by several density functions and the most commonly used density functions are Weibull and Rayleigh distribution functions. The Weibull distribution function is most widely used as it is more adaptable and versatile than other density functions.

The Weibull density function is given by

$$f(u) = \frac{k}{c}\left(\frac{u}{c}\right)^{k-1} \exp\left[-\left(\frac{u}{c}\right)^{k}\right] \quad 1)$$

Where, k and c are shape and scale parameters which is given by

$$k = d_1\sqrt{u_m} \text{ or} \quad 2)$$

$$k = \left(\frac{\sigma}{\bar{\upsilon}}\right)^{-1.086} \quad 3)$$

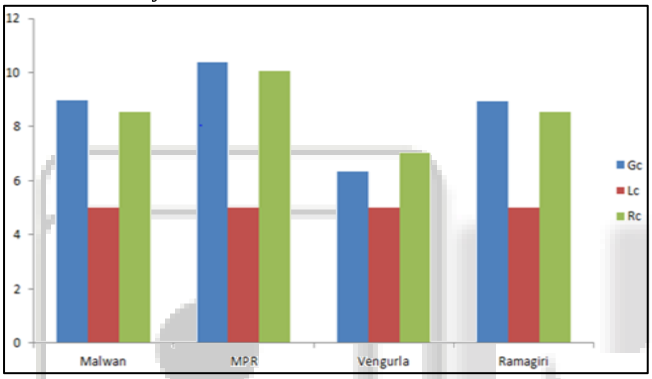
And scale factor c is given by

$$c = \frac{u_m}{(1 + 1/k)} \quad 4)$$

Where, u_m is average wind speed throughout the year and is given by

$$u_m = \frac{1}{n-1}\sum_{i=1}^{n-1} u_i \quad 5)$$

The weibull density function f (u) can be calculated by least squire method to plot a graph between wind speed and weibull density function.



B. *Rayleigh Distribution*

The other popular probability density function in wind power studies, the Rayleigh or chi-2. The Rayleigh probability density function is given by

$$f(u) = \frac{\pi u}{2u`^2}\left[-\frac{\pi}{4}\left(\frac{u}{u`}\right)^2\right] \quad 6)$$

The Rayleigh cumulative distribution function is

$$F(u) = 1 - \exp\left[-\frac{\pi}{4}\left(\frac{u}{u`}\right)^2\right] \quad 7)$$

	Annual Energy Production, kWh			
Wind Turbines	MPR dam	Vengurla	Malwan	Ramagiri
1. Unitron	59.5	106.49	93.49	55.79
2. Fortis Passaat	112.33	101.28	101.18	93.873
3. Wind care	39.24	103.28	77.01	11.586
4. L Whisper	21.945	55.623	44.2	12.744
5. Wind spot	96.72	114.63	12.268	11.672

Table 2: Most Commonly used Small Scale Wind Turbines

The variance of this density function is

$$\sigma^2 = \left(\frac{4}{\pi} - 1\right)u`^2 \quad 8)$$

It can be noted that the variance is only a function of the mean wind speed. This means that one important statistical parameter is completely described in terms of a second quantity the mean wind speed.

C. *Regression Method*

This is another method to calculate the probability density function. The idea is to determine the value of a and b in the fallowing equation

$$a\,\frac{\sum_{i=i}^{w} p^2(ui)(xi - x`)(yi - y`)}{\sum_{i=1}^{w} p^2(ui)(xi - x`)^2} \quad 9)$$

Where, a = k

$$b = y`_i - a(x_i)b = \frac{1}{w}\sum_{i=1}^{w} y_i - \frac{a}{w}\sum_{i=1}^{w} x_i \quad 10)$$

$$c = \exp\left(-\frac{b}{k}\right) \quad 11)$$

One of the implied assumptions of the process described above is that each pair of data points is equally likely to occur and therefore would have the same weight in determining the equation of the line.

V. COMPONENT

Fig. 5.1: PMG Stator

Fig. 5.2: PMG Armature

Fig. 5.3: Front and Rear Bearings

Fig. 5.4: Armature Winding

The figure 5.1 shows stator of PMG which is a stationary part. Stator has to fit onto the armature in which magnet is mounted.

Figure 5.2 shows the drill machine armature which was in damaged state. This armature was isolated from the drill machine. Similar armature can be used for development of rotor part for permanent magnet generator. In the present scenario an armature of damaged hand drilling machine is taken.

Figure 5.3 shows the type of bearing used for development of PMG. The ball or roller orientation is fitted at last lodgings. The capacity of the orientation is to decrease grinding between the pivoting and stationary parts of the machine. For the most part high carbon steel is utilized for the development of course as it is hard material.

Figure 5.4 shows the method of winding. In the present armature use of lap type of winding has been done. The advantage of lap winding is to reduce the winding complicity. Rewinding of Armature damaged armature coils are taken off and rewinding has been done with the help of rewinding machine. Care was taken in process to provide proper insulation to avoid losses and the Insulating material used is Mica, which is a good insulator.

VI. RESULTS

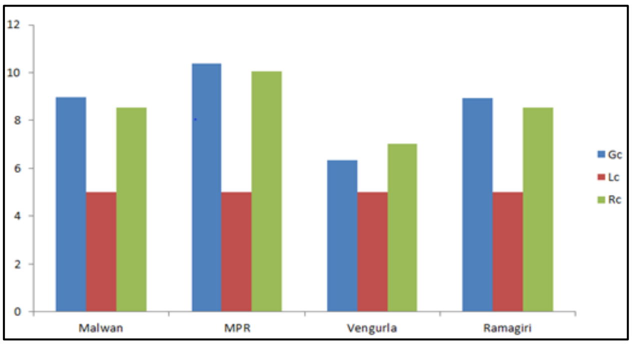


Fig. 6.1: Variation of Scale Parameter for Different Site by Different Methods

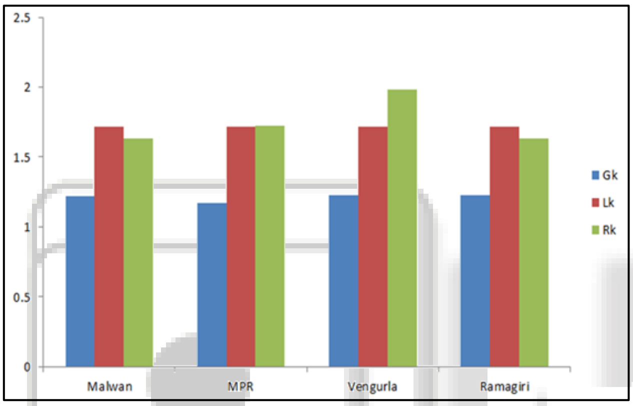


Fig. 6.2: Variation of Shape Parameter for Different Sites by Different Methods

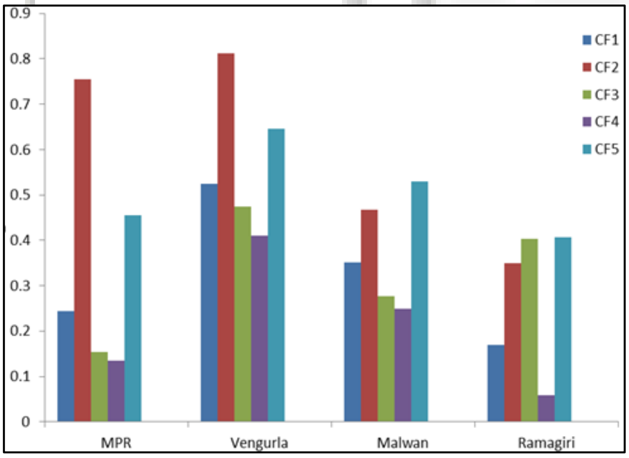


Fig. 6.3: Capacity Factor of Different Turbine at Different Locations

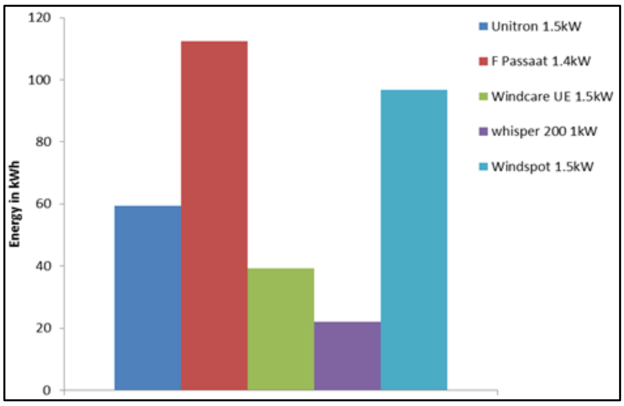


Fig. 6.4: Annual Energy Production by Different Wind Turbines

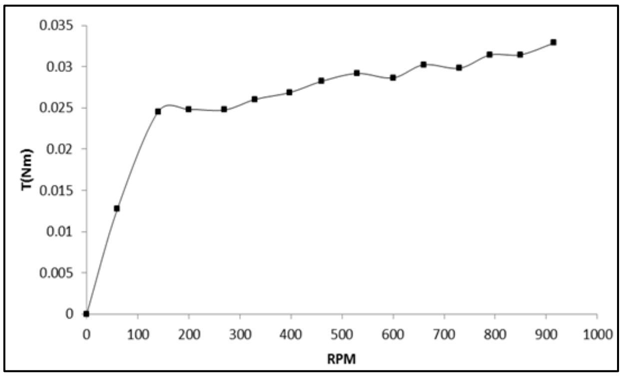


Fig. 6.5: Variation of Torque with Rotational Speed

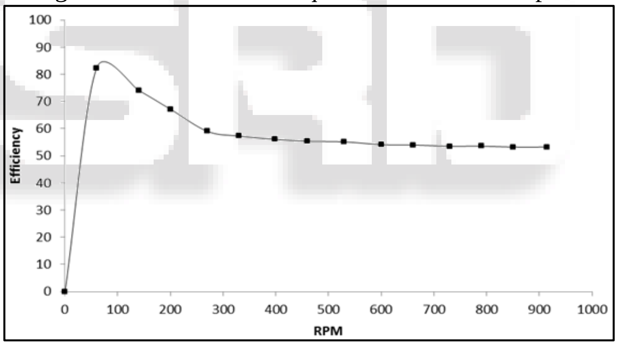


Fig. 6.6: Speed of Generator at No Load
Variation of Generator Efficiency with Speed

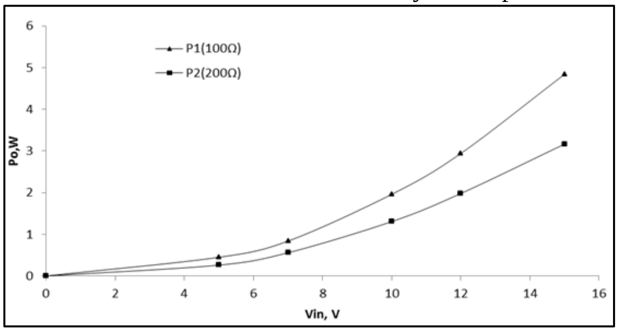


Fig. 6.7: Power Variation with Load of Generator at No Load

VII. CONCLUSION AND FUTURE SCOPE

A. *Conclusion*

1) The analysis based on weibull and Rayleigh probability density functions for collected wind speed data at four different locations indicated that Rayleigh based

predictions were closer to actual data recoded at the locations. The maximum probability density function for actual at MPR dam was found to be 0.083. That of Raleigh's and weibull probability functions was found to be 0.078 and 0.073 respectively.

2) From the different small scale wind turbine modules, it was seen that module2 produced large amount of energy compare to other wind turbines hence recommended for MPR dam and Vengurla location. Module5 was found to be well suitable for Ramagiri and Malwan city.
3) The maximum output power generated by permanent magnet generator was 12.16 W at the rotational speed of 915 RPM. The maximum torque developed by the motor over no load range tested was about 0.03287 Nm and concentrated efficiency developed was 83.26% at low rotational speed during no-load test
4) The results of generator operation under load condition of 100 Ω and 200 Ω indicated that the output power was lower for higher load conditions as compared to low load condition.

B. Future Scope

a) Practically working small scale wind turbine can be developed for the pm generator and use for the domestic purposes.
b) Present generator is designed for low RPM application; there is scope to improve the same for high rpm generators.
c) The air gap between stator and rotor need to optimize further for better flux distribution and get more efficient
d) In the present design neodymium magnet is used, a magnet with height grade can lead to get more power.

ACKNOWLEDGMENT

At the outset, I would like to express my deep sense of gratitude towards my guide Prof. R S HOSMATH for his valuable and motivational guidance throughout the course of this project. I would also like to thank him for providing me an excellent research and freedom of thought. I have always been admiring his punctuality, perseverance, patience and hard work. He has delivered me to an everlasting depth of gratitude through his valuable guidance and support in bringing out this project the most valuable accomplishment of my live.

REFERENCES

[1] Mihai chirca "Axial-flux vs. radial-flux permanent-magnet synchronous generators for micro-wind turbine application" Power Electronics and Applications (EPE), September 2013 15th European Conference.
[2] Daniyal Ahmed and Aftab Ahmad "An optimal design of coreless direct-drive axial flux permanent magnet generator for wind turbine" 6th Vacuum and Surface Sciences Conference of Asia and Australia.
[3] H. Gor M. Demirtas E. Kurt "A new permanent magnet wind energy generator design with axial and radial directed fluxes" European Workshop on Renewable Energy Systems (EWRES) 17-28 Sep. 2012 Antalya Turkey.
[4] Ceyhun Sezenoglu (2016) "Design of Axial Flux Permanent Magnet Generator for Generator Driven Electromagnetic Launcher" International conference at Electronics Engineering Gebze Technical University Gebze, Kocaeli
[5] T.M.Hijazi(1995),"Comparison of Design and Performa nce Parameters in Switched reluctance and Induction M otors" IEEE international Conference of Electrical Machines and Drives, pp. 303-307
[1] P. Lampola and J. Perho, "Electromagnetic analysis of a low-speed permanent-magnet wind generator", International Conference on Opportunities and Advances in International Electric Power Generation, pp. 55-58, March 1996