Modified alternator for low wind applications: Rat Trap Generator

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Abstract. Modified tractor alternator was designed and constructed to suit a 300 W low speed high altitude wind turbine. The tractor alternator did not produce the required power output design speed of the turbine. A modification was thus required and this paper describes the redesign and construction techniques. The analysis is focused on the design aspects, topologies, modeling, and testing of the alternator. The final results were still not up to expectation, but nevertheless, some promising results were obtained and some of them are discussed.

1. Introduction

A project to design and construct a 300 W micro wind turbine was begun in Nepal. Most villages do not have electricity supplies. If the lighting is provided through WLEDs (White light emitting diodes) in such villages, even a small generator can provide light to whole village of 50 houses, because most of the houses normally have only one or two small rooms [1].Though the project was aimed to suit the small villages of Nepal and designed accordingly, these units can be modified for any given site. For example, can be used in normal house hold to reduce the electricity bills or can be used for water pumps etc. As a part of this project, different possibilities for generators were studied. A modified tractor alternator was among the cheaper alternatives. Hence a locally designed and modified alternator was constructed and was named the 'rat trap alternator' due to its physical appearance.

2. Design Issues and Results

The tractor alternator in its original form contains a permanent magnet rotor with six poles. Three independent stators (stacks of laminated steel plates) surround the rotor with 100 turns of wire (phase winding) in each. No technical information is available for the original alternator. Most parameters had to be measured and determined in the lab.

Figure 1 shows the general layout of the modified alternator. Instead of one, this setup uses two rotor magnet discs and eighteen individual stators. A set of six stator windings will make a phase. These six windings can be connected in series or parallel depending upon the current and voltage requirements.

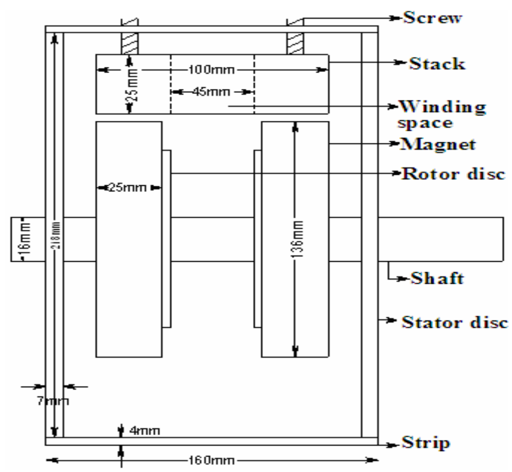

Fig. 1. Design Layout.

To estimate the total turns needed in each stator, a specimen was prepared with 38 turns and mounted on the generator (see figure 2). For the given airgap and speed the no-load voltage was measured. Total magnetizing flux was calculated from the voltage equation (1) [3].

$$E = 4.44\phi N f k_{\phi} \quad (1)$$

The winding constant k_{ϕ} was assumed to be one to make calculation suit for both the parallel and series connection of the winding. Obviously for the series connection, the value would have been less.

$$\phi = 1.86\times10^{-6} Wb$$

Using as a base point, a new number of turns was calculated for the given power. At 500 rpm, the no-load voltage was measured for the specimen. The standard voltage required to change a 12V battery is 13.5V. Assuming battery is connected all the time the dc voltage is given by eq: 2 [2]. Considering the voltage drop in the diode, V_d, the per phase peak voltage, V_m, can be calculated by eq: 3 [2].

$$V_{dc} = \frac{3 \times \sqrt{3} \times V_m}{\pi} \quad (2)$$

$$V_m = \frac{13.5 \times \pi}{3 \times \sqrt{3}} + 2 \times V_d \quad (3)$$

The cut-in speed for the wind turbine is 100 rpm. The ratio by which the turns had to be increased was determined by:

$$N_{new} = 38 \times 7.295$$

Once ready, the per phase electrical parameters of the machine were determined. The dc resistance was measured to be 5.75 Ω.

Fig. 2. Generator view

Due to mechanical construction constraints, the air gap was slightly bigger than the design value, and thus the measured leakage inductance at nominal speed and load was higher than the expected, 154 mH. With these parameters, terminal voltage was calculated for a given load. For the same load, when measured, the terminal voltage was less. This was concluded to be due to armature reaction. For further proof, one of the stator was wound four independent turns. The voltage across this coil was measured for the no-load condition and the load condition of the main winding at the nominal speed and load. Calculated from the decrease in voltage at load condition, the flux reduction was 25% due to the armature reaction. With variable compensating capacitors, the power could be increased.

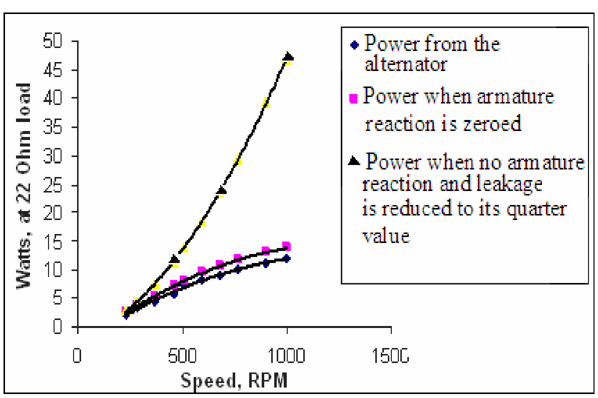

Fig. 3. Generator per phase power curve

Figure 3 shows the increase in phase power when the armature reaction is neglected. The problem, however, was mainly associated with the leakage flux due to the relatively large and uneven airgaps. This can be significantly decreased and predicted effect can be seen in figure 3.

Measurements of the torque were also performed as seen in figure 4. Especially at low speed, the torque level is very low. The laminated steel plates that make up each stator were slightly skewed in order to reduce the cogging torque. The skew offset was decided for a lower torque and minimal construction difficulty.

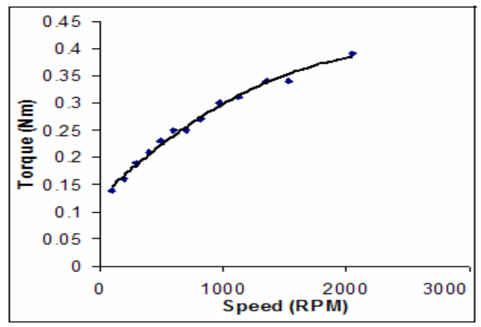

Fig. 4. Torque measurement

3. Conclusions

The main conclusion is that the design power did not match what was measured, the major reasons being leakage flux, armature reaction and higher resistance. Nevertheless, the results were promising, and few should improve performance. Resistance can be reduced but not without comprising the size of the generator. The leakage flux can be minimized by precise mechanical construction. The estimated power output is still lower than required. The magnetic flux calculation of the generator was over predicted or calculated. To compensate for this, two magnet discs can be series connected in each end of the rotor instead of one. The output power should increase approximately by factor of two, and the power will thus be within the required range. The project still continues and future generations are being planned.

4. Acknowledgements

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