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Straight forwardly controlled engine generator plan and model for minuscule breeze turbines

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Abstract. It is the goal of this article to design and test an outer rotor permanent magnet generator for a small wind turbine. A initial draft of the generator's design is shown here. Permanent magnet selection and demagnetization risk assessment, machine losses, and heat analysis are all treated in this article. The final specs and test results of the prototype generator are also provided.. Since this is made evident, more investigation will be necessary..

Introduction ;

There has been a stabilization in the global market for small wind turbines (1 to 300 kW) after the severe decrease in 2013 [1]. In 2014, 945, 000 small wind turbines were installed across the world, with steady increase in the three most important markets. (China, the United States, and the United Kingdom).

To spin the blades, a gearbox drives the shaft of a standard gearbox-operated wind turbine [2]. This means that even the slightest defect in a gearbox's numerous wheels and bearings may cause the turbine to shut down. [2]. As a consequence, gearbox maintenance is required on a regular basis. A gearbox decreases the overall reliability of wind turbines in wind energy installations. However, direct-drive has significant limitations in terms of cost and weight. It has been shown in the last two years[2] that geared systems are lighter and cheaper than direct-drive systems. The cheaper cost of permanent magnets used in direct drives and the more compact generator architecture are to blame for this volatility [2].

Direct-driven low-speed generators with more poles and a larger outer diameter than traditional generators are the most frequent kind of gearless wind energy producing technology. The wind rotor may be linked directly to the generator with this kind of turbine, making construction simpler. First, you don't need to build the outside rotor structure. More easily, the exterior rotor structure has magnets installed, as opposed to more cumbersome installation of magnets within. Alternately [3] a heat-limiting inner stator design is used to minimize stator-winding heat transfer.

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Sync generators using permanent magnet excitation are a viable option since that the price of magnets has dropped significantly over the past few decades Electrical excitation has lower active weight and cop- per losses, whereas permanent magnet excitation has a larger energy yield [4]. [*] That's why they're so effective and reliable [5].

Design Criteria

Before commencing the generator design process, it is critical to know how the generator will be utilized. In this study, a wind turbine generator with a battery charging converter is evaluated in order to retain the battery terminal DC voltage at the necessary level. In this application, the machine's design specifications are also laid down. The converter determines the output voltage, while the wind turbine determines the rated mechanical power and the rotational speed. Figure 1 depicts the properties of the Darrieus and Savonius type blades, which are both often employed in this setting

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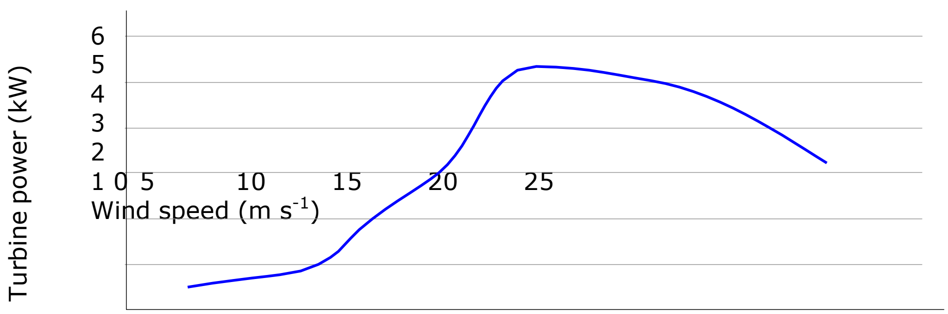

When the wind speed is roughly 12 m/s and the associated rotational speed of 200 rpm, the turbine reaches its maximum power. With a nominal three-phase input voltage of 400 V, the converter charges the batteries. Customer-specified specifications for the wind turbine's in-and-output parameters and output needs.

Tab. 1: The customer's specifications for the generator's output.

Parameter	Symbol	Value	Unit
Amount of power	S_n	5000	VA
The rate at which the wheel spins.	N	200	rpm
Load voltage on the power line	U_{ll}	400	V
Classification of temperature increase		F	

1. Generator Design

Before designing a generator, know how it will be utilized. This study examines a wind turbine generator with a battery charging converter to maintain battery DC voltage. This application also specifies machine design. The converter decides output voltage, while the wind turbine sets mechanical power and speed. Figure 1 shows the properties of Darrieus and Savonius blades.

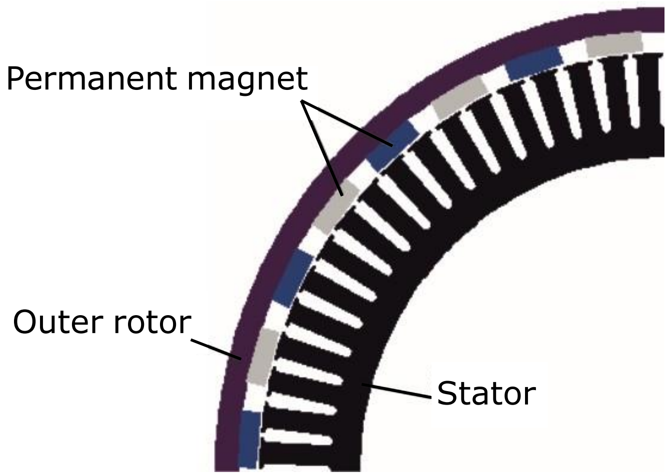

Fig. 2: Cross section of the designed PM generator with outer rotor.

The saturation curves of the electrical steel, given in Fig. 4, are used to determine the magnetic core's size. Material for making the machine was sourced from type M800-65A steel, which is readily accessible on site. Because the machine operates at low frequencies and there is no special need for magnetic material with decreased losses, this was judged a cost-effective option.

A flux density distribution across a radius from the outer to the inner core may be observed in Figure 5 (below), which shows an example. According to the graph above, the stator teeth have the maximum flux density.

Cogging Torque Reduction

It is important to note that the kind of magnetic field, the number of slots per pole per phase, slot openness and filling factor, and pole pitch all contribute to cogging torque. Start-up torque for the PM generator is influenced by the rigging torque as well. An excessively high starting torque might significantly impact the generator's performance.

Various methods are available for determining cogging torque. These two approaches are the most often employed for estimating cogging torque: virtual torque and Maxwell stress computation [6]. It is possible to lessen the undesirable cogging torque in electric machines by using a variety of ways and options.

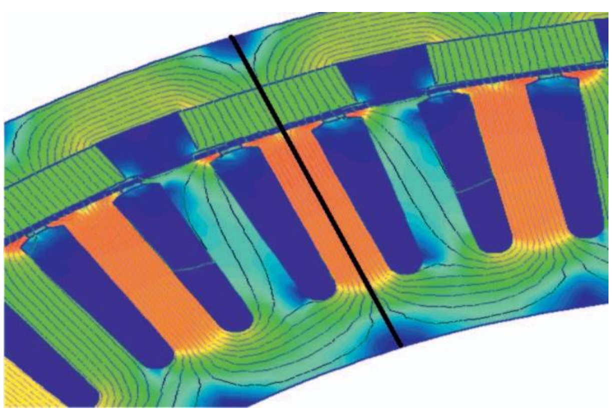

Fig. 6: Flux density distribution throughout the machine's radius as modeled using a finite element method.

Because of the magnets' placement on the machine, the cogging torque is decreased. According to simulations, surface-mounted magnet machines have more than twice as much cogging torque than those with embedded magnets.

Slotless permanent magnet devices [7] are often utilized to reduce cogging torque these days. [8] Coreless windings are employed in this design, which reduces inductance and eliminates cogging torque. As the quantity of magnetic material required for the structure rises, so does the cost of production.

A variety of options were considered in order to develop a prototype generator. To learn more about the impact simulations and different approaches have on machine parameters, [6,] an in-depth examination is recommended.

Slot skewing was used to minimize cogging torque in the prototype generator. Our research on the potential reduction in cogging torque as a result of skewing is summarized in Tab 2.

The scenario of a single pole pitch skew has the lowest cogging torque (100 percent). As the skewing angle was increased further, the cogging torque amplitude increased once again. Following this research, a generator prototype was created with a single pole pitch skew in the stator slots [3].

Tab. 2: Differences in cogging torque values with varying skewing levels.

Slot skew from slot pitch (%)	**Cogging torque (Nm)**
0	15.30
20	3.73
40	3.06
60	2.18
80	1.55
100	0.23
120	1.32

4. Prototype and Testing

It was made at the Konesko AS motor plant, where it was also tested as a prototype generator. It is shown in Figures 11 and 12 as the proto-type generation tool.

prototype generator's loading was made

It was necessary to utilize an induction machine to turn the prototype around. We used a customized load bank that has 26 distinct active resistance stages for loading the machine. The easier as a result of this.

Fig. 11: a generator with an outer rotor prototype

No-Load Test

The projected and calculated no-load voltage was 1.6% lower than the observed one, according to the findings of the no-load testing. A prediction of 435 V turned out to be incorrect. Magnets with a greater power than estimated during calculations may be to blame for this discrepancy. Calculations had anticipated that increasing the magnets' temperature would weaken their magnetic strength. Less than one percent was found to be the generator's maximum total harmonic distortion (THD). Windings, stator slots, and permanent magnets were all used to attain this result. Fig. 13 shows the generator's no-load characteristics

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Fig. 12: Prototype generator has been assembled.

Load Test

In order to ensure that the generator could handle the 5 kVA active load, it was subjected to a 4.5-hour load test. Figure 14 shows the prototype generator's load characteristics. A nominal load has a 5% voltage loss, as seen in the graph. In the grand scheme of things, this is a pittance.

Stator slot between winding and wedge is fitted with PT100 sensors to ensure accuracy. On its own, the generator's temperature stabilized at 115 C when no extra cooling was used. Prototype generator cooling is inadequate due to the rotor and shaft being completely sealed off. Stator and shaft aeration holes might be considered to enhance cooling conditions; however, this is not required. The generator's size would be reduced as a result.

The measured findings deviate from the estimated values by a few percentage points. There are no concerns about overheating since the machine is intended for use in wind applications, which have a superior natural cooling system than the laboratory setup, therefore results may be regarded adequate and there is no risk of overheating.

Prototype Generator

According to the findings of the tests, the planned and manufactured generator performed as expected.

Fig. 15: It has been put in a vertical-axis wind turbine prototype generator

5. Conclusion

The compact wind turbine generator has been developed, manufactured, and tested. It was clear from the calculations and testing that they were in perfect harmony. Permanent magnet demagnetization and cogging torque reduction have all been carefully investigated throughout the design phase. As a consequence of the research, the most effective and safest design was determined.

It is possible to do thermal analysis using finite element techniques. The rotor movement within the machine creates air movement, which should be taken into consideration for more exact cooling circuit modeling. Outside cooling air circulation should also be considered.

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