A Magnetic Brake for Small Wind Turbines

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A magnetic brake system was fabricated for use with small wind turbines. The torque of the pivot did not change as the speed of revolution increased when the magnetic array disc was far from the salient of the aluminum housing, the torque abruptly increased as the magnetic array approached the salient of the aluminum housing. The torque increased as a quadratic function of the speed of revolution when the distance between the magnetic array and the datum point was 60 mm.

Keywords : small wind turbine (SWT), magnetic brake (MB), speed control, eddy current

1. Introduction

Electric currents can be sent in a certain direction so that the magnetic fields induced by these current will oppose changes in the original magnetic field, by Lenz's law [1, 2]. When a metal disc (typically copper or a copper/aluminum alloy) rotates between two rows of magnets, eddy currents are generated in the disc, this creates a magnetic field opposing the disc's motion [3]. The resultant opposing force is directly proportional to the speed at which the disc is moving through the rows of magnets. This very property, however is also one of the magnetic brake's disadvantages in which the eddy force itself can never completely stop a disc in ideal conditions [3].

Yawing systems and disc brakes are often utilized to control the speed of wind turbines (WT). Yawing system has a long response time for reducing speed, this especially problematic during a squall. Disc brakes are also used for stopping WTs, but they produce heat and noise due to friction with the turbine rotor. Rather than slowing a wind turbine via friction, which is often be affected by various elements such as rain, magnetic brakes (MBs) instead rely completely on certain magnetic properties and resistance. In fact, MBs never come in contact with the other components, so MBs do not produce heat or noise. MBs are intended to control a WT's speed during its operation rather than stopping completely. MBs have been applied in various fields, such as on roller coasters and high speed trains like the Shinkansen and ICE, but they not yet been used in WTs [3, 4].

In this work, we fabricated an experimental system for ascertaining the performance of MBs in small wind turbines (SWT), and measured the torque of the rotor against the speed of revolution by a toque meter. The relationship between the torque and the speed of revolution was measured. If magnetic brakes could be incorporated in SWTs, the quality of the electric power produce can be improved due to the precise control of the turbine rotor's speed given by MBs.

2. Fabrication of the Magnetic Brake

MB systems can potentially stabilize the output of SWTs, this prevents excessive output by controlling the speed of revolution of the blade at high wind velocity. Fig. 1 shows a block diagram of (a) the SWT including the MB and (b) the feedback system that controls the position of the magnet array disc (MAD) of the MB. The system controls the MAD position of the MB using a servo motor, as the speed of revolution of the blade is increased at high wind velocity it exceeds a set value, this is detected by a sensor attached to the disc brake. When the position of the MAD is adjusted by the servo motor, the eddy current produced at the aluminum housing brakes the revolution of the blade with out any physical contact with the MAD. The blade keeps a constant speed as the the speed sensor continuously feeds information to

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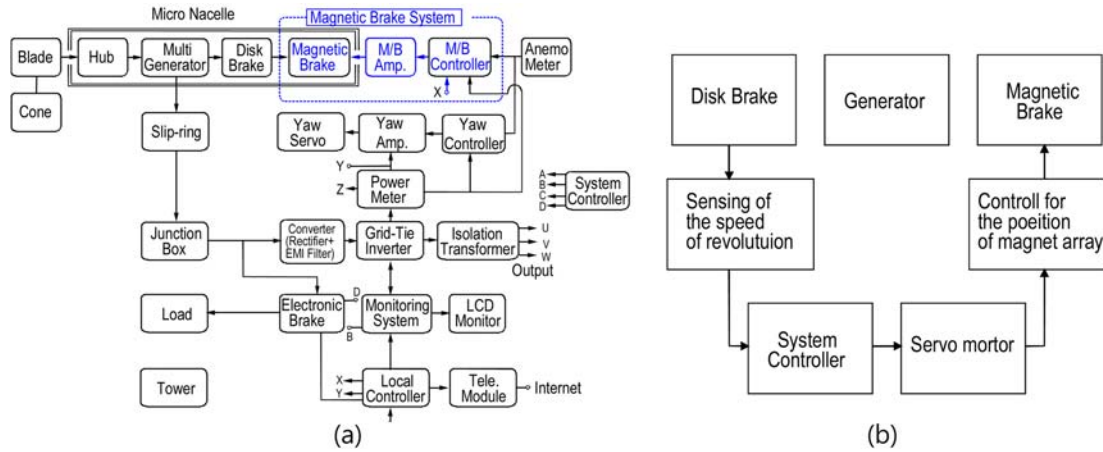Fax: +82-42-868-5018, e-mail: ryuks@kriss.re.kr

Fig. 1. (Color online) Block diagram of (a) the SWT including an MB system, and (b) feedback controlling the position of MAD.

the system controller, which in turn, controls the magnet position.

Fig. 2 shows (a) a schematic diagram and (b) a partial cross section of the MB [5]. The disc type magnet arrays were fixed at the pivot of the blade of the SWT. Two magnet arrays were used to improve the efficiency of the MB. NdFeB magnets with dimensions of 50 mm(l) × 25 mm(w) × 20 mm(t) were used in the two magnet arrays. The space between the magnet arrays and aluminum housing was 3 mm. The brake operates by initially having the magnet arrays set apart from the salient of the aluminum housing but moving them closer when braking is needed. The braking torque increases as the crossing surface between magnet arrays and salient increases.

A photograph of the setup of the break testing system, including the MB is shown in Fig. 3 A dynamometer rotates the generator and the MAD. The braking effect of the MB is measured by a torque meter. Torque may increase if opposing forces increase as the magnet array approaches the salient of the aluminum housing.

3. Results and Discussion

Fig. 4 shows the variation of torque as a function of distance between the MAD and the salient of the aluminum housing. When the MAD is far from the salient of the aluminum housing (A-domain), the torque does not change as the speed of revolution increases. When the MAD approaches the salient of the aluminum housing (B-domain), the torque abruptly increases. Torque increases as the speed of revolution increases with the MAD set at a certain fixed distance, this is because the resultant opposing force produced by eddy currents is directly proportional to the speed at which the blade is rotating through the salient of the aluminum housing. Torque increases as the distance between the salient of the aluminum housing and the MAD decreases, this is due to the fact that eddy currents are maximized as the crossing surface is maximized. The variation of torque with the speed of revolution at a distance of 60 mm is shown in Fig. 5 The relationship between torque and the speed of revolution is
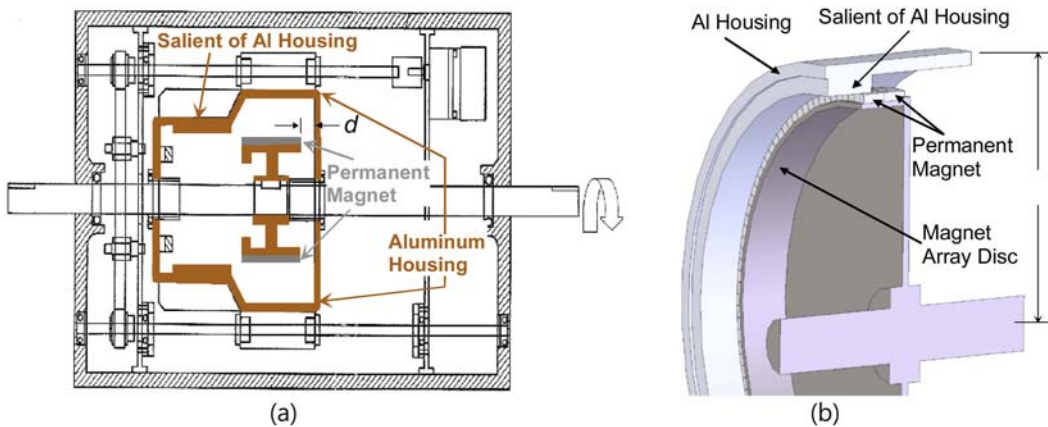

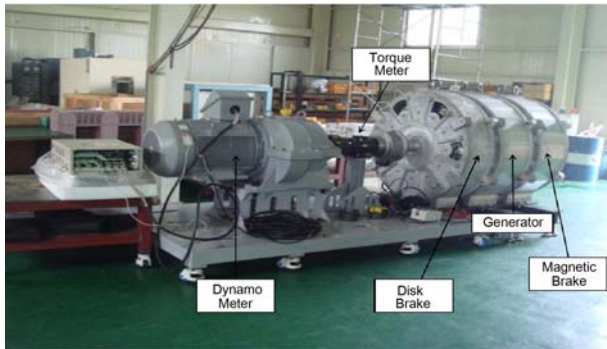**Fig. 2.** (Color online) (a) Schematic diagram and (b) partial cross section of the MB.

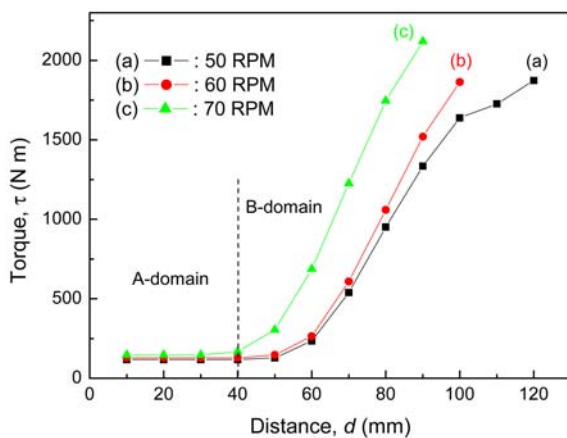**Fig. 3.** (Color online) Photograph of the brake system for a SWT.

Fig. 4. (Color online) Torque change for the distance at the speed of revolution (a) 50 rpm (b) 60 rpm, and (c) 70 rpm.

empirically fitted with a quadratic function. The relation between the torque (τ) and speed of revolution (ω) was found to be as follows:

$$\tau = A + B \cdot \omega + C \cdot \omega^2$$

where $A = -0.39$, $B = 0.55$, and $C = 1.45 \times 10^{-3}$. Torque increases as the speed of revolution increases, but the rate of increase decreases as speed increases. An increase in torque means that the braking effect from the MB increases.

Practical experience in other fields, in areas such as the railways, should encourage the application of magnetic braking. MBs offers a number of advantages compared to conventional friction brakes [4]. If the MB should be used in SWTs, there is no need for mechanical contact between the salient of the aluminum housing and magnet arrays, as the magnetic field operates across an air gap between them. Thus MBs are wear-free and silent, requiring minimal maintenance. Their braking force is independent of the coefficient of friction, ensuring high efficiency regardless of the aluminum housing adhesion. This means
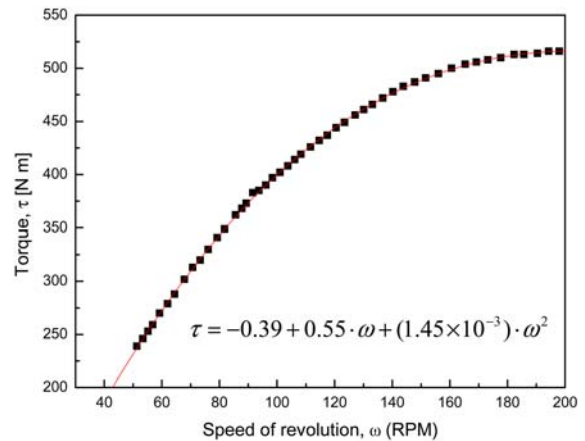

Fig. 5. (Color online) Torque change for the speed of revolution at the distance between the MAD and a datum point of 60 mm.

that relatively high braking forces can be applied, which remain almost constant, even in high-speed applications such as in a squall. The braking force can be accurately controlled by regulation of the magnetic field, which is governed by the position of the magnet arrays. Kinetic energy from the squall is absorbed by the aluminum housing and converted into heat.

4. Conclusion

A MB system for SWTs was fabricated and its braking performance tested. The torque of a pivot did not change as the speed of revolution increased when the MAD was far from the salient of the aluminum housing, however, the torque abruptly increased as the MAD approached the salient of the aluminum housing. The torque increased as a quadratic function of the speed of revolution when the distance between the MAD and the datum point was set to 60 mm. If an MB system is used in conjunction with a disc brake in SWTs, the output stability of the SWT will be improved because the blade speed of the SWT can be more effectively controlled.

References

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