How Does The Use Of Permanent Magnets Make Wind Turbines More Reliable?

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Renewables, Wind Turbines

For all of its soaring elegance, it is easy to forget just how complex a machine the modern-day commercial-scale wind turbine really is. In this article I will focus on the massive, highly engineered electromechanical system sitting at the top of every wind turbine tower. We'll explore how the use of permanent magnets in the generator sub-system can lead to greater overall mechanical reliability and generation efficiencies.

Until relatively recently, almost all commercial wind turbines had the same type of power train features. A typical configuration is shown in Figure 1. The rotor blades, typically made from fiber glass, are mounted to a cast-iron hub. The hub is mounted onto the drive shaft which passes into the nacelle via a rotor bearing, into a mechanical gearbox. The gearbox is then coupled to a doubly fed induction generator [a special electrical machine that uses two sets of electrically-excited windings to create magnetic fields as part of the mechanical-to-electrical energy conversion process]. It does not use permanent magnets.

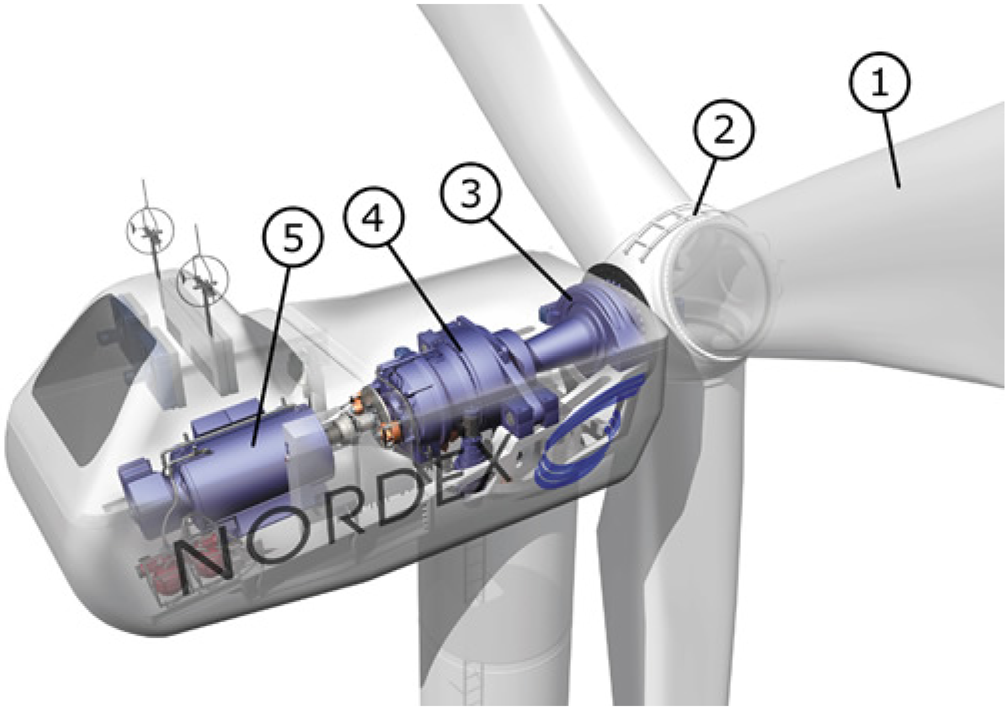

Figure 1: Conventional commercial-scale wind turbine. 1 - blade; 2 - hub; 3 - rotor bearing; 4 - gearbox; 5 - generator. Courtesy of Nordex GmbH (2008).

The typical rotor speed for commercial-scale wind turbines is anything from 10-20 RPM under normal conditions. Because doubly fed induction generators of this type require high RPM in order to operate properly [at least 750-1500 RPM], the gearbox is required to convert the low speed of the rotor into the high speed needed by the generator.

Unfortunately – the bigger these gearboxes get, the more prone they seem to be to all kinds of mechanical problems. In recent years, there have been improvements in the design and manufacture of wind turbine gearboxes, but there are still a variety of issues to be overcome. According to a paper published by the National Renewable Energy Laboratory in 2007, the majority of gearbox failures originate in the bearings. Without regular maintenance and observation, it doesn't require an active imagination to see how catastrophic a full gearbox failure would be to the turbine.

These challenges led to a re-think in the structure of the wind turbine power train, and in 2005, the first commercially-available hybrid turbine generator solution came on the market. This configuration uses an innovative gearbox design in conjunction with a permanent magnet generator, with the end result being a significantly increased reliability for the system as a whole [see Figure 2].

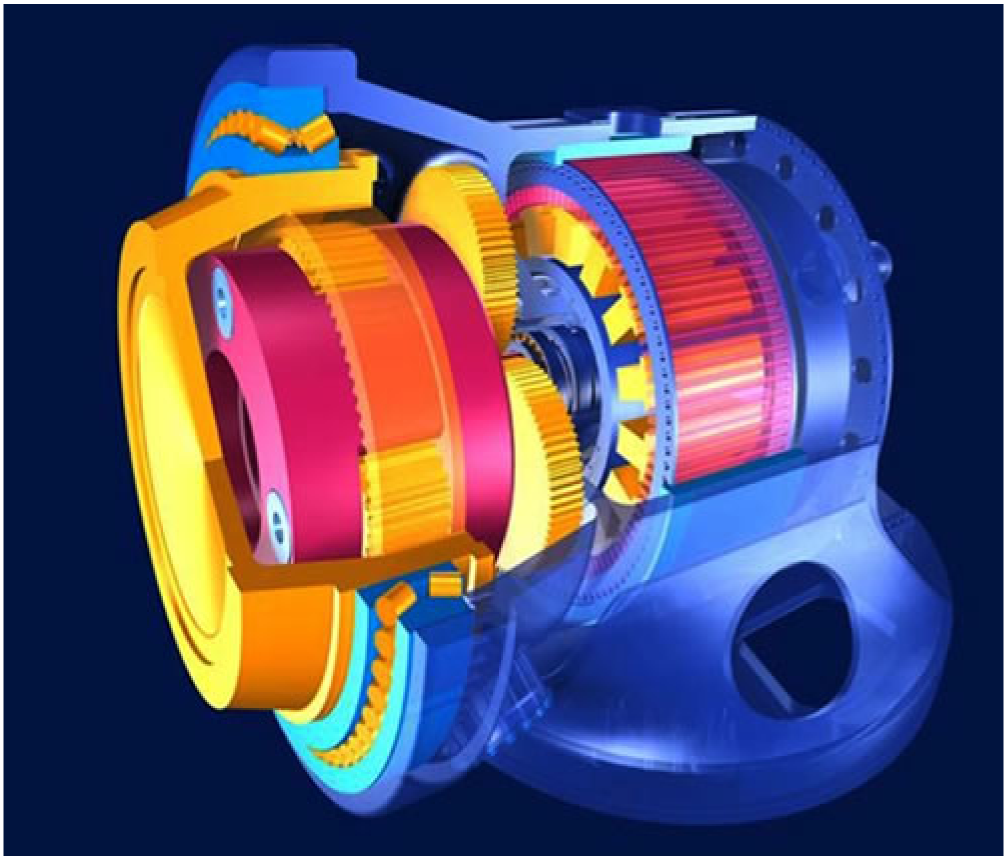

Figure 2: Combined gearbox - permanent magnet generator system. Courtesy of Multibrid (2008).

This type of set up reduces the overall weight in the nacelle, and requires a generator speed of 60-150 RPM – significantly lower than that for the doubly fed inductor generator design. All of this also means that the turbine power train is more reliable, has fewer moving parts to go wrong, and requires less maintenance.

So – the next logical step in the evolution of the turbine power train, would be to come up with a design that removes the need for a gearbox altogether – and this is indeed where we are at with these designs today. The last couple of years has seen the emergence of commercial-scale, direct drive permanent magnet generator [PMG] systems, with the hub directly connected to the generator. In order to achieve this, we need a much larger diameter generator, to accommodate the required increase in the number of magnetic poles on the rotor.

The result is a system with significantly increased reliability and reduced maintenance costs. Reduced downtime for maintenance also means less non-producing time offline. The elimination of associated mechanical losses that are inevitable with gearboxes, also leads to improved efficiencies in the power conversion process. The generator itself is also much more robust than conventional systems, and gives greater efficiencies when wind speeds are not at full rating, compared to the earlier designs.

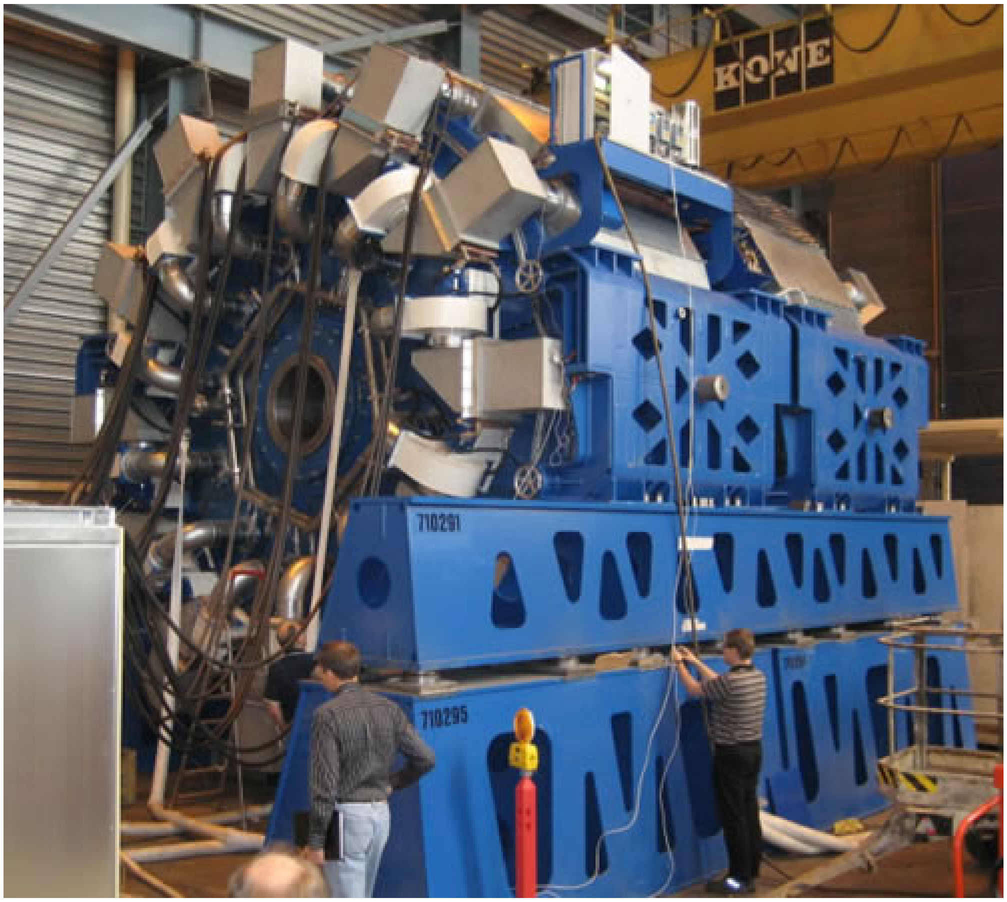

Figure 3: Direct drive neodymium-based permanent magnet generator for 3.5 MW wind turbine. Courtesy of The Switch (2008).

Of course, this being the real world, the direct drive PMG is not entirely without challenges. Finnish company The Switch produces PMGs for the Scanwind 3500 DL wind turbine, rated to 3.5 MW of power, and shown in Figure 3. This PMG uses over 2,000 kg [4,400 lb] of high energy neodymium-based [Nd-Fe-B] permanent magnet material. This equates to approximately 0.6 kg [1.3 lb] / kW produced. The obvious supply chain implications for these quantities of Nd-Fe-B magnets are beyond the scope of this article, but have been discussed elsewhere at here at Terra Magnetica.

So, I hope that this article has given you some insight into the evolution of wind turbine electromechanical systems, and how the use of permanent magnets has allowed engineers to design more robust, more reliable power trains.

In my next post, the fourth in this series, we'll take a look at developments in the use of cutting edge superconducting materials, to produce generator systems that might surpass those presently available. Will these new designs be the next step in the evolution of wind turbine systems? We'll discuss that too. In the meantime, if you missed the previous article in this series, titled "Why Are Wind turbines Getting Bigger?", you can find it here.

Finally, some of the content of these articles is drawn from a paper that I presented at the Magnetics 2008 Conference in Denver, Colorado, titled "Going Green: The Growing Role of Permanent Magnets in Renewable Energy Production and Environmental Protection". You are welcome to download a copy of the presentation from here.