By Tony Morcos, Principal • Morcos Magnetics

Harvesting Wind Power With (or Without) Permanent Magnets

As a designer of electric motors and magnetic circuits, my palette consists of permanent magnets, wire and iron. I use these tools to manipulate electric and magnetic fields to create motion, harness motion, sense motion or prevent motion. Most applications involve the conversion of electrical energy to mechanical energy (motors) and mechanical energy to electrical energy (generators). I specialize in permanent magnet motors, primarily those employing high-energy rare earth magnets. I am especially excited about the rising interest in harvesting renewable energy sources, particularly wind energy and the plan proposed by noted oil tycoon, T. Boone Pickens.

Electric generators are where the rubber hits the road with respect to converting wind energy to a usable form, namely electricity to feed the grid. With the proposed development of a “smart” electrical grid in the US being fed, in part, by wind farms concentrated in appropriately-windy regions, there will be a huge increase in demand for electric generators to convert mechanical to electrical energy. This energy conversion must be completed at the highest possible efficiency to minimize heat generation (an environmental and reliability issue) and to maximize profits and return on investment. Small improvements in overall system efficiency, with electric generators at the core of this system, will pay huge dividends. The cost of many such generators will certainly come from the US's economic stimulus package and I believe this to be among the most worthwhile of stimulus expenditures.

Permanent magnet manufacturers, primarily those concentrating in sintered NdFeB, are salivating over the prospect of skyrocketing demand for their products to accommodate the wind power revolution. Some magnet manufacturers and rare-earth metal mining interests project the demand for sintered NdFeB due to wind turbine generators will outstrip the available supply of rare-earth metals within the next 10 to 15 years. Though both sintered ferrite and sintered rare-earth magnets will be employed for a percentage of the large electrical generators used in wind turbines, I do not believe the penetration of permanent magnet generators will be anywhere near 100 percent.

A possible dwindling of the permanent magnet supply caused by the wind turbine market will be self-limiting for the following reasons: large electric generators can employ a wide variety of magnetic circuit topologies, such as surface permanent magnet, interior permanent magnet, wound field, switched reluctance, induction and combinations of any of the above. All of these designs employ large amounts of iron (typically in the form of silicon steel) and copper wire, but not all require permanent magnets. Electric generator manufacturers will pursue parallel design and development paths to hedge against raw material pricing, with certain designs making the best economic sense depending upon the pricing of copper, steel and permanent magnets. Considering the recent volatility of sintered NdFeB pricing, there will be a strong economic motivation to develop generator designs either avoiding permanent magnets or using ferrite magnets with much lower and more stable pricing than NdFeB.

One might think that on a pound-for-pound basis, permanent magnet generator using sintered NdFeB will provide the highest energy-conversion efficiency, but this is not necessarily true. In order to optimize the generator efficiency over a wide speed range, it is best to have some control over the amount of magnetic flux in the circuit, so that the flux can be weakened at higher wind speeds. Sintered NdFeB, with its extremely high flux density and high coercivity, is quite “permanent.” At high speeds, this “permanence” can saturate the generator with flux, leading to greatly increased iron losses. Also, sintered NdFeB is electrically conductive, causing eddy current losses and inductive heating in the magnets. At higher wind speeds, these parasitic losses increasingly eat into the efficiency and heat up the generator, causing a rapid degradation in performance.

Non-conductive sintered ferrite magnets are better in this regard, providing a bit more efficiency headroom at higher speeds. Though the energy product of sintered NdFeB is roughly 10 times that of sintered ferrite, the cost per kilogram of sintered NdFeB is 30 times that of ferrite. The higher cost of NdFeB provides, at best, an incremental gain in overall system efficiency, and I believe that sintered ferrite can provide the best return on investment for a permanent magnet wind turbine generator.

There are many interesting magnetic circuit topologies and control schemes that provide flux weakening at higher speeds, thereby increasing the overall system efficiency. With continuing advances in power electronics and control algorithms, these designs emphasize the “electro” part of the generator with copper and steel, at the expense of the “magnet” part. Several clever generator designs employ lower-energy permanent magnets, such as injection-molded ferrite, to boost the output of what would typically be a non-permanent-magnet machine. These “hybrid magnetic circuit” designs can produce the highest efficiency over the widest speed range, providing the best long-term bang for the buck in a wind turbine system. The cost of such generators is driven by the cost of power electronics and controls, more so than the permanent magnets, wire and steel.

I am excited about wind power and the positive implications it has for designers and manufacturers of electric motors and generators. Suppliers of copper wire, silicon steel, power electronics and permanent magnets should see increased demand for their products due to wind turbines, but I do not predict the wind turbine market will significantly affect the pricing of these commodities.

Tony Morcos has more than 25 years of experience in permanent magnet manufacturing and electric motor/electromagnetic device design and manufacturing. Tony has a B.S. and M.S. in Electrical Engineering from the University of Dayton. He can be reached at tony.morcos@acm-magnetics.com.