ULTRA LOW RPM ELECTRIC MOTORS AND GENERATORS

The present invention relates to electric motors and generators and in particular to adjusting the orientation of fixed magnets in a rotor to obtain efficient operation at various RPM.

Brushless DC motors are often required to operate at various RPM but can only achieve efficient over a limited RPM range.

Further, generators and alternators are often required to operate over a broad RPM range. For example, automotive alternators operate at an RPM proportional to engine RPM and windmill alternators operate at an RPM proportional to wind speed. Unfortunately, known alternators generate electricity at a voltage proportion to RPM. Because RPM cannot be controlled, other elements are required to adjust the output voltage, adding inefficiency, complexity, and cost to the alternator systems.

Some designs have attempted to broaden RPM range using “field weakening” to allow the motor base speed (Kt or torque sensitivity) to be wound to be efficient at very low RPM, which is proportional to torque (lower RPM higher torque and vice versa), and to obtain efficient high RPM operation. Such field weakening can be in an Interior Permanent Magnet Synchronous Motor (IPMSM) or AC synchronous induction motors three to four times base speed with reasonable efficiency at high RPM but a motor with a ten times base speed RPM would have two and one-half to three and one-half times the starting torque of an AC motor. Unfortunately, field weakening with conventional methods can sacrifice efficiency and increase the complexity of controller algorithms and software.

In a generator/alternator application, the output voltage is proportional to magnetic flux strength requiring an inverter or separate electromagnetic exciter coil in automotive alternators that are only 60-70% efficient because of the very wide RPM range the alternators must operate over. Similar issues are present in wind power generation where variations in wind speed encountered resulting in operating inefficiencies.

BRIEF SUMMARY OF THE INVENTION

The present invention addresses the above and other needs by providing apparatus and method for tuning the magnetic field of brushless motors and alternators to obtain efficient operation over a broad RPM range. The motor or alternator includes fixed windings (or stator) around a rotating rotor carrying permanent magnets. The permanent magnets are cylindrical and have North (N) and South (S) poles formed longitudinally in the cylindrical magnets. The magnets reside in magnetic conducing pole pieces (for example, low carbon or soft steel, and/or laminated insulated layers, of non-magnetizable material). Rotating the cylindrical permanent magnets inside the pole pieces either strengthens or weakens the resulting magnetic field to adjust the motor or alternator for low RPM torque or for more efficient high RPM operation. Varying the rotor magnetic field adjusts the voltage output of the alternators allowing, for example, a windmill generator, to maintain a fixed voltage output. Other material used in the rotor is generally non-magnetic, for example, stainless steel.

In accordance with one aspect of the present invention, there are provided apparatus and methods to vary the flux strength of rotor/armature in an electric motor to provide improved starting torque and high RPM efficiency.

In accordance with another aspect of the present invention, there are provided apparatus and methods to vary the magnetic flux strength of rotor/armature in generator/alternator applications to control output voltage independent of RPM. Many known alternator applications cannot control alternator RPM, for example, automotive alternators which must operate at an RPM proportional to engine RPM and wind power generation which are subject to wind speed. Varying the magnetic flux strength of rotor/armature allows output voltage to be controlled independently of RPM thereby eliminating the need for an inverter or separate electromagnetic exciter coil.