Design And First Test Results Of A Superconducting Magnetically Borne Flywheel Energy Storage System Of 10 Kwh And 250 Kw

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(NOTE: Due to last-minute complications, Mr. Reiner was unable to attend and present his Final Paper at EESAT07. The following is the Extended Abstract of his Final Paper which, considering the circumstances, has been accepted in lieu of Mr. Reiner's Final Paper.)

Flywheel energy storage systems are suited for a number of applications and have already been applied for a number of years using mechanical bearings. The initial short overview of some successfully realized projects, applying L-3 MM flywheels "Magnetodynamic Storage Systems, MDS" is followed by the introduction of a new flywheel using a superconducting magnetic bearing.

In 1988 MDS flywheels of 2 kWh/150 kW were first applied in two communal diesel-electric buses in Munich, Germany. Further diesel-electric demonstration buses followed. In those years experiences could be gained on the operation of flywheels in vehicles, their interaction with the electric propulsion system, the potential of energy saving in buses, reliability and maintenance needs. At the EESAT 2000 conference the results of the first 12 years of flywheel experience were reported on. One important result was that energy savings of 30-35% can be obtained if you regard only the energy balance of the diesel-electric propulsion system including the MDS. With new, more efficient propulsion and MDS components even up to 40% of the propulsion energy could be saved. In 1994/95 a small fleet of 12 trolleybuses in the Swiss city of Basel was built, equipped with MDS units to relieve the overhead network and to recover the brake energy on board. Today these buses have been in operation for more than 12 years. Most of these flywheels have operation hours of more than 50,000. They operate very reliable, provide energy savings of 20-25 % and have a MBTF of about 38,000 hours, which means that a repair on a flywheel is necessary only every 8 years.

In stationary applications purely magnetically borne flywheels offer a number of advantages. Maintenance at the flywheel is only necessary once every few years, losses are minimized and non-contact, very low-noise operation is possible.In the field of magnetic bearings the high temperature superconducting (HTS) bearing is definitely the most fascinating and promising technology. Due to its physical properties it needs no electronic controller and operates passively. Using liquid nitrogen as a cooling fluid the HTS- superconductor is operated at fairly low temperature, far below critical operation points and is therefore very safe and reliable.

L-3 MM is currently building a flywheel of 10 kWh and 250 kW. Final mounting is scheduled to be in late summer 2007. The energy capacity of 10 kWh is obtained at a speed of 10,000 rpm. The integrated permanent magnet motor/generator unit operates with a maximum power of 250 kW as a motor as well as a generator. The diameter of the evacuated flywheel housing is 1m and the height is also 1m. The weight of the complete flywheel unit is about 1200 kg plus the external periphery such as power electronics and cooling system. Figure 1 shows an outline sketch of the MDS flywheel as well as the manufactured carbon fiber rotor.

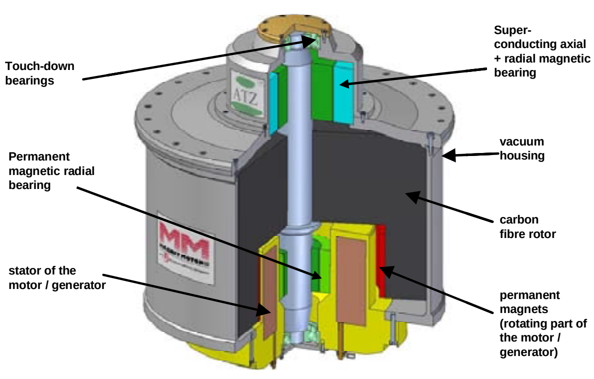

Figure 1: Outline sketch of the MDS flywheel and manufactured carbon fiber rotor of the 10 kWh / 250 kW flywheel

The superconducting bearing developed and manufactured by ATZ is located at the top of the flywheel. It consists of stacked high-temperature superconducting (HTS) material rings forming a hollow cylinder. It is cooled by liquid nitrogen. Inside the superconducting cylinder rotating permanent magnet rings are arranged around the shaft, concentrically to the superconductor rings. The magnetic forces between these two materials, superconductor and permanent magnet, bear the weight of the rotor (about 600 kg), cause it to hover and provide the necessary stiffness.

To prepare the technology for this bearing and to investigate its features, a 1 t test bearing with the original dimensions for the flywheel was manufactured and tested. It consists of a HTS cylinder with a total OD of 230 mm x ID 205 mm x 120 mm and is assembled from 28 pieces melt textured YBCO bulks, 64 mm x 34 mm x 12 mm in size each. The YBCO ring is glued into an outer double wall Cu hollow cylinder with a capacity of about 1.5 liter LN_2. The LN_2 is cooling the YBCO indirectly by thermal conduction. The melt textured YBCO blocks are machined into segmented shape to fit into the Cu ring.

The concentrically arranged permanent magnet counterpart of the HTS cylinder consists of axially stapled rings with OD of 200 mm x ID 150 mm x 8 mm in size each, with Fe shims in-between providing the high magnetic flux gradient.

Figure 2 provides a view of the test bearing for the flywheel. The graphic alongside shows the magnetic forces in dependence of the displacement. The force of the bearing at a displacement of 3 mm is about 10 kN in axial direction and the stiffness is about 4 kN/mm.

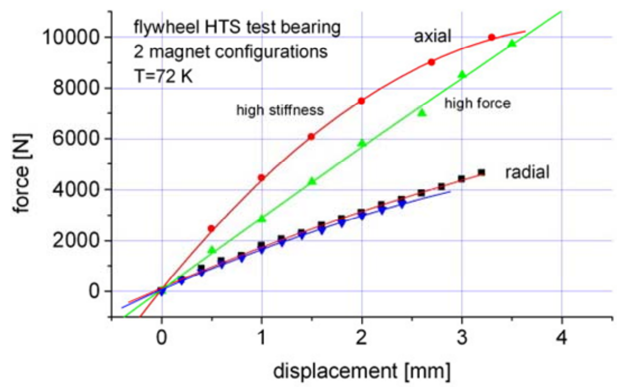

Figure 2: 1t-test bearing for the 10 kWh / 250 kW MDS flywheel and a diagram of measured force – displace behavior

With 2.5 mm the air gap of the bearing is relatively high in order to provide enough margins for the HTS bearing to develop its retraction forces. A permanent magnetic bearing at the bottom of the flywheel (see Figure 1) supplements the magnetic bearing system of the flywheel unit.

Rotor dynamics calculations show a resonance of the flywheel at very low speed. To overcome this, special precautions were taken. The range of rated speed is considerably higher than the resonance frequency which means that we will operate the flywheel in overcritical condition. The asymmetry forces of the motor/generator act mainly on the permanent magnetic bearing at the bottom of the MDS and are calculated to be only a fraction of the centering and stabilizing forces of the bearing.

First measurements on the bearing and the flywheel are scheduled to begin in September 2007 and will be reported during the conference depending on availability.

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