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Green Energy in Power Grid Using Flywheel Energy Storage System, Technology by Using Partial Magnetic Levitation

[1]Ms.Ramya.V,
Assistant Professor, EEE Department
KCG College of Technology, Chennai.

[2]Dr.R.Ramaprabha
Associate Professor, Department of EEE
SSN Engineering College, Chennai

***Abstract*-- Storage of energy is necessary in many applications because energy may be needed when it is not available and may be available when not required. Sometime the needed energy may exhibit some peaks where the supply energy may be uniform in character. Energy can be stored in many ways .It is seen that kinetic energy storage in flywheel provides the highest specific energy compared to any other alternative source. Especially when the flywheels are made with composite materials they provide very high efficiency. In this paper flywheel has been analyzed using FEA (Ansys12.0) for various materials and specific energy has been calculated**

Keywords-flywheel energy storage, FEA, Increasing efficiency, applications

I. INTRODUCTION

In the 1970s flywheel energy storage was proposed as a primary objective for electric vehicles and stationary power backup[1]. At the same time fiber composite rotors where built, and in the 1980s magnetic bearings started to appear [2]. Thus the potential for using flywheels as electric energy storage has long been established by extensive research.

More recent improvements in material, magnetic bearings and power electronics make flywheels a competitive choice for a number of energy storage applications. The progress in power electronics, IGBTs and FETs, makes it possible to operate flywheel at high power, with a power electronics unit comparable in size to the flywheel itself or smaller. The use of composite materials enables high rotational velocity with power density greater than that of chemical batteries. Magnetic bearings offer very low friction enabling low internal losses during long-term storage. High speed is desirable since the energy stored is proportional to the square of the speed but only linearly proportional to the mass.

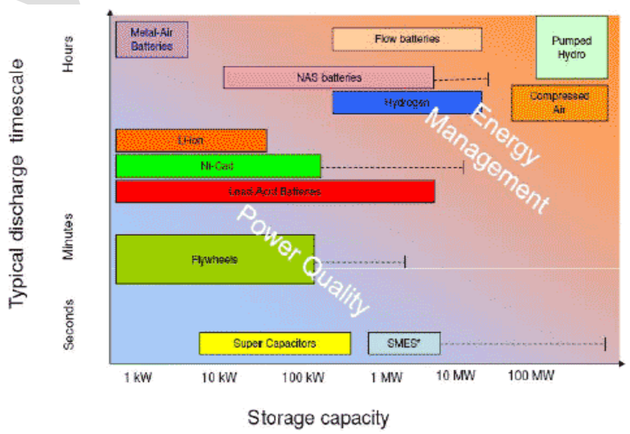


Fig.1.Comparing flywheel with other storage equipment

There are a number of attributes that make flywheels useful for applications where other storing units are now used.

- High power density.
- High energy density.
- No capacity degradation, the lifetime of the flywheel is almost independent of the depth of the discharge and discharge cycle. It can operate equally well on shallow and on deep discharges. Optimizing e.g. battery design for load variations is difficult.
- The state of charge can easily be measured, since it is given by the rotational velocity.
- No periodic maintenance is required.
- Short recharge time.
- Scalable technology and universal localization.
- Environmental friendly materials, low environmental impact.
- One of the major advantages of flywheels is the ability to handle high power levels.

This is a desirable quality in a vehicle, where a large peak power is necessary during acceleration and, if electrical breaks are used, a large amount of power is generated for a short while when breaking, which implies a more efficient use of energy, resulting in lower fuel consumption. Individual flywheels are capable of storing up to 500MJ and peak power ranges from kilowatts to gigawatts, with the higher powers aimed at pulsed power applications [3] and also in powerfoemers [4-8]

The fast response time in flywheels makes them suitable to balance the grid frequency. As the energy contribution from more irregular renewable energy sources increases, this can be an important quality which will grow in importance.

A. Bearing and Air Friction

- Friction is the biggest enemy to eat away, most of the energy stored in the flywheel. More over at very high speed of rotation, the friction is very high.
- Air friction at very high speed can increase to alarming levels. The rotating flywheel is preferably kept in a vacuum chamber or in a chamber at low air pressure

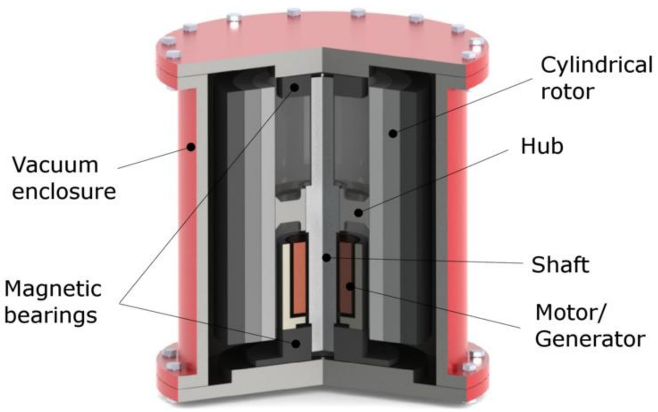


Fig.2. An example of a typical flywheel assembly

B. Reducing the Bearing Friction

Bearing friction can be completely eliminated by using magnetic levitation technique. The shaft can be lifted away from the lower thrust bearing and also the guiding bearing. A passive magnetic levitation technique using super conductors is difficult to maintain due to need of liquid nitrogen to maintain the temperature. So electromagnets or permanent magnets are used.

C. Partial Magnetic Levitation to Reduce the Friction

Magnetic bearings are very appealing for application to high rotating speeds and/or in severe environments such as low temperatures or vacuum due to the lack of mechanical contact between a rotor and a stator. The suspension of a rotor in a magnetic bearing is achieved by using interactions of an electromagnetic nature.

By the use of a permanent magnet to pull the shaft up, the force on the lower thrust bearing can be considerably reduced. A 10 Kg load on the thrust bearing can be reduced to only 1 Kg by using this technique. No electronic circuits are required but a little eddy currents are produced due to the permanent magnet used.

D. Magnetic bearings

Mechanical bearings used in the past cannot, due to the high friction and short life, be adapted to modern high-speed flywheels. Instead a permanent or electro permanent magnetic bearing system is utilized fig [1]. Electro permanent magnetic bearings do not have any contact with the shaft, has no moving parts, experience little wear and require no lubrication. It consists of permanent magnets, which support the weight of the flywheel by repelling forces, and electromagnets are used to stabilize the flywheel, although it requires a complex guiding system. An easier way to stabilize is to use mechanical bearings at the end of the flywheel axle, possible since the permanent magnet levitates the flywheel and, thus, reduce the friction. The best performing bearing is the high-temperature super-conducting (HTS) magnetic bearing, which can situate the flywheel automatically without need of electricity or positioning control system.

E. Flywheel basics

FEA model is described to achieve a better understanding of the mesh type, mesh size and boundary conditions applied to complete an effective FEA model. The fly wheel is modeled as a series of concentric rings through the software. The thickness within each ring varies linearly in the radial direction. A planar finite element model is used to represent a flywheel in which symmetry about the transverse direction and about the axis of rotation is used.

II. DESIGN OF FLYWHEEL

A. Structural analysis

It is the computation of deformation, internal forces and stresses. There are many methods for structural analysis. But here the structural analysis is done using finite element method (FEM).In FEA computer model of a material is stressed and analysed.There are two types of analysis. They are 2D and 3D analysis. Mesh analysis of flywheel can be done using free mesh and mapped mesh. With the help of solid works software the flywheel which was designed was analysed.The stress analysis was also done. Here the flywheel is assumed to be on mechanical bearings. The same analysis can be done using magnetic bearings.Energy stored by a flywheel is proportional to its inertia constant I and to the square of its angular velocity ω.

Moment of Inertia = (Rim Density) (Rim Volume) (Rim Radius)2
ENERGY = (1/2) (Moment of inertia) (Spin Speed)2.

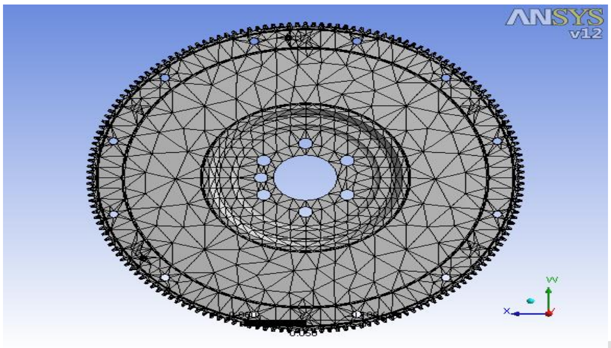
III. STRUCTURAL ANALYSIS

Based on the consideration of rotational deformations in the flywheel, the element solid 72 is used. The model is meshed and defined by 4 nodes with all DOF at each node. It is made to have stress stiffening capability.

IV. MESHING

Meshing is done using smart mesh since it does not have any restrictions. The flywheel is meshed using edge2.then by using the ANSYS12.0, the maximum equivalent von misses stress and the total deformations are computed. The results are shown graphically.Two types of materials were taken and analysed.They are the gray cast iron and structural steel.The structural steel wear mashed using 89512 nodes and 48374 elements, the total deformation analyzed were 77.94*10-3m max and 58.15.*10-3m min.

Then gray cast iron were meshed using89512 nodes and48374 elements, the total deformations were less than the structural steel.



Flywheel has been meshed before being analyzed. Fully parametric model of the flywheel is created and it is imported to ansys. Computer aided analysis and optimization procedure helps us to design flywheel geometry of high specific energy performance. Specific energy depends on rotational speed, material strength and geometry.When composite materials are used instead of steel or carbon fibres their specific energy is much more than the metallic ones and if potential failure occurs at high angular velocity the composite flywheel will develop crack in the circumference and the flywheel breaks apart gradually.

Materials	Modulus of elasticity(Gpa)	Density (kg/m^3)	Poisson's ratio
Gray Cast Iron	101	7510	.23
S-Glass epoxy	90	1590	.25

A. Materials used

Composite material having high tensile strength and low density for near centre and high density for periphery are preferred for the flywheel

B. Boundary conditions and loads.

The moment MX is applied on the nodes .The ANSYS workbench together with workbench project and tools were used for finite element analysis. Structural analysis was done and stress was calculated. Specific energy for various materials

Mass of flywheel= 60 kg for grey cast iron
Mass of flywheel= 11.9 kg for S Glass epoxy
Moment of inertia (I) = Kmr2

Where K is inertia constant. Here we have taken as 5

material	Specific energy KJ/kg
Grey cast iron	.097
S Glass epoxy	.485

V. POWER ELECTRONICS USED WITH FLYWHEEL

Two pole machines are generally used along with a flywheel. Frequency of input/output electric power is of the order of a few kilo hertz. If this power is used to be fed/removed to a grid for stabilizing the grid frequency, a power electronics circuit is required. The circuit should convert high frequency power from the flywheel system to D.C. by using a Rectifier/Inverter bridge. This DC is converted into grid frequency AC by another rectifier/inverter bridge.

Power can flow from flywheel to the grid if at the grid side, the voltage generated by the inverter leads the grid voltage. Reverse will happen for the power to flow from grid to the flywheel. On the flywheel side, power will flow into the flywheel when the inverter phase angle leads the shaft angle and vice versa. Phase angles of both side inverters should be so controlled that the power output from the flywheel is equal to the power fed to the grid plus losses. Or in other words, voltage of the D.C. supply should be kept constant.

VI. A FEW FLYWHEEL STORAGE SYSTEMS AVAILABLE

- Small scale
- Peak power buffers
- Wind-Diesel system with flywheel storage
- Flywheel with photovoltaic system
- Harmonics
- Flywheel in distribution network system
- UPS System
- Aerospace application

VII. CONCLUSION

Flywheel storage system has been used for a long time. Material and semiconductor development are offering new possibilities and applications previously impossible for flywheels. When we take two materials and compare composite materials show a vide improvement in specific energy storage. Fast rotation of flywheel offer new possibilities of direct generation of high voltage. The motor/generator part has high possibilities of development.

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