Flywheel Energy Storage: Viable Alternative

M.M. Limaye
Project Manager
Novatech Software Pvt.Ltd.
Nagpur
mandar_limaye@hotmail.com

P.M. Bapat
Principal
Wainganga College of Engineering &Management
Dongargao,Nagpur
pakyabapat2@yahoo.co.in

J.P. Modak
Professor & Dean R&D Priydarshini College of Engineering,Nagpur

ABSTRACT
In this paper, Energy Storage is becoming vital over the Period. The various conventional technologies are already in use to support the various types of applications. This paper tries to justify the flywheel energy as viable alternatives to conventional energy storage system. It also suggests the various areas which needs focused research to make flywheel energy storage working option.

General Terms
Energy Storage Systems, Energy Storage Applications,

Keywords
Flywheel Energy Storage, Applications of Energy Storage

1. INTRODUCTION
There are countless ways by which it is possible to currently produce energy. The various options are coal power plants, heat engines running off various fuels, fuel cells and batteries; the list goes on. In addition there are countless ways this energy is consumed. Undoubtedly, there are various time patterns associated with how to produce and gather energy and how to use them. These patterns at some point will vary and somewhere in the process there is a need for energy storage.

The various alternatives for energy storage are chemical energy storage, potential energy storage and kinetic energy storage. In chemical energy storage the batteries are primary source of storing energy and utilizing it when required. As typical example of use potential energy is hydro-electric power plant which starts when the peak load requirement increases and shuts off when the peak load reduces down to normal. Flywheel is one of the example where in kinetic energy is used.

2. TYPES OF ENERGY STORAGE APPLICATIONS
There are wide ranges of applications to use the energy storage devices which could be classified as under. This list is generic and representative and not all inclusive.

DOI: http://www.researchpublications.org

End use applications [1], Emergency backup, Transmission and distribution stabilization, Transmission upgrade deferral, Load management, Renewable energy integration

2.1 End Use Applications
The most common end use application for energy storage is power quality, which primarily consists of voltage and frequency control. Transit and end use ride through are applications requiring short power durations and fast response times, in order to level fluctuations, prevent voltage irregularities, and provide frequency regulation. This is primarily used on sensitive processing equipment and thus the capacities required are usually less.

2.2 Emergency Backup
This is a type of uninterruptable power supply (UPS) except the units must have longer energy storage capacities. The energy storage device must be able to provide power while generation is cut altogether.

2.3 Transmission and distribution stabilization
Energy storage devices are required to stabilise the system after a fault occurs on the network by absorbing or delivering power to generators when needed to keep them turning at the same speed. These faults induce phase angle, voltage, and frequency irregularities that are corrected by the storage device. Consequently, fast response and high power ratings are essential.

2.4 Transmission upgrade deferral
Typically, transmission lines must be built to handle the maximum load required and hence it is only partially loaded for the majority of each day. Therefore, by installing a storage device the power across the transmission line can maintained a constant even during periods of low demand. When the demand increases, the storage device is discharged to prevent the need for extra capacity on the transmission line.

2.5 Load Management

There are two different aspects to load management: load levelling and load following. Load levelling uses offpeak power to charge the energy storage device which can then be discharged during peak demand. Therefore, energy storage devices can be charged during these off - peak hours at night and then used to generate electricity when it is the most expensive, during short peak production periods in the evening. Not only does this enable the energy storage unit to maximise its profits, but it can also reduce the cost of operating the system. For load following, the energy storage device acts as a sink when demand falls below production levels and as a source when demand is above production levels. Therefore, the storage can be used to maintain ancillary services and reserve on the electricity grid.

3. TYPES OF ENERGY STORAGE SYSTEMS

There are many types energy storage systems which are in use either commercially or under research they are as follows, Pumped hydroelectric energy storage (PHES),Battery energy storage (BES),Flywheel energy storage (FES),Compressed air energy storage (CAES), Supercapacitor energy storage (SCES), Supermagnetic energy storage (SMES), Hydrogen energy storage system (HESS),Thermal energy storage (TES) Out of the above top two are more common and universal in nature and paper tries to suugest the third one could also become viable with focused research and optimization in design.

3.1 Pumped hydroelectric storage system

Pumped hydroelectric energy storage is the most mature and largest storage technique available. It consists of two large reservoirs located at different elevations and a number of pump/turbine units. During off - peak electrical demand, water is pumped from the lower reservoir to the higher reservoir where it is stored until it is needed. Once required (i.e. during peak electrical production) the water in the upper Reservoir is released through the turbines, which are connected to generators that produce electricity.

Hydroelectric power requires a considerable volume of water to produce energy. The following equation describes the relationship between the volume of water (V, in cubic meters), the stored energy (E, in kWh), and the average head driving a turbine (h, in meters), and assumes 0.90 efficiency in energy conversion for electricity production.

$$V(m3) \approx 400\ E(kWh)\ h(m)$$

These systems are generally big installations, they are quite economical but constraints with suitable geological location and huge initial cost of construction and grid connectivity.

3.2 Battery storage system

Battery storage system converts the checmical energy into electrical energy and use electrical energy to for stroing chemical energy. There are various types of electrical batteries which are used but this is not a main topic of this paper so the details are excluded. In general there are two configurations to use battery storage system. In one configuration the battery source is always connected to load and power source is connected to battery and in second case power source is connected to load and battery is connected to power bus so as to rapidly switch when power source fails. Both the scenarios have some or other limitations but because of simplicity of and compactness of conversion unit and switching unit this is the most common energy storage system used across all types of energy storage applications.

The primary limitations of this system is high operational & maintenance cost and replacement cost. They are also poses the environmental problem in disposal and could not be considered as green power.

3.3 Flywheel storage system

A FES device is made up of a central shaft that holds a rotor and a flywheel. This central shaft rotates on two bearings to reduce friction. Flywheels store energy by accelerating the rotor/flywheel to a very high speed and maintaining the energy in the system as kinetic energy. Flywheels release energy by reversing the charging process so that the motor is then used as a generator. As the flywheel discharges, the rotor/flywheel slows down until eventually coming to a complete stop.

3.4 Components of Flywheel energy storage system

The various components which constitute the system are flywheel, mechanical casing, bearings, power transmission system and control system.

The equation[2] that governs the energy storage capacity of flywheel is as follows

$E=1/2 * I\ w^2$

E- Energy

I- Moment of Inetrtia

w- angular velocity

The maximum velocity which can be attained by flywheel is govern by following equation

$s=d*w^2*r^2$

s- Strength

d- Density

w- Angular velocity

It is to be mentioned that I moment of inertia is govern by design of flywheel i.e. Geometry, where as angular speed is function of time. The factors like aerodynamic drag and parasitic losses such as frictional losses in bearings are counterproductive.

3.5 Advantages and Limitations of Flywheel energy storage system

There are many advantages to using flywheel technology rather than the alternatives. Flywheels have very high power and energy densities. Contrary to traditional technologies, flywheels are extremely clean and environmentally friendly. It is possible to design the flywheels of wide range of shapes and sizes, ranging from kilograms to hundreds of tons, which make them viable for various applications. The concept of a flywheel is very simple; they just convert electrical energy into mechanical energy, and then back to electrical energy. They can also be connected to a shaft to output mechanical work rather than electricity. This makes a flywheel seem like a "mechanical battery." The outputting of mechanical work can be useful, but it is more common for the energy to be converted to electricity.

There are some disadvantages to using flywheels for energy storage It has complex designs, require materials that can withstand the amount of angular momentum that the flywheel itself possesses. Flywheels need complicated and heavy equipment to be able to function properly. This makes for high initial costs and can also lower the efficiency and energy density of the system.

3.6 Probable Applications of Flywheel energy storage system

The various areas of energy storage applications are mentioned above, following are the few applications wherein the flywheel energy storage is deem to be suitable.

3.6.1 End Use Applications

In many of the industries stable power supply at constant frequency and voltage is essential. Flywheel could certainly be used for such applications to improve the quality and provide the stable output. The critical component for such system will be controller, which decides when to put flywheel in action and for how much time.

3.6.2 Energy backup Applications

Uninterrupted power supply is important area for which Batter energy storage is commonly used. In many industrial applications the Battery back is used for short time till the diesel generator starts and picks up load. In such application it is possible to connect the flywheel directly to alternator so that till the time diesel sets starts, the alternator will be driven by flywheel.

3.6.3 Transmission and distribution stabilization

The flywheel energy storage can be utilize to stabilize the grid. Because of existence the hybrid power sources connected to grid the frequency variation is imminent causing the instability. The flywheel at the source of connection point could be used to stabilize the grid frequency.

3.6.4 Other Application Areas

The flywheel energy storage system could work as hybrid[3] system for unconventional energy sources. The unconventional energy sources like solar power, wind power are becoming common but by nature they have unstable characteristics. The flywheel in tandem with them could provide the stability to overall system

4. PROBABLE SCHEMATIC ARRANGEMENTS

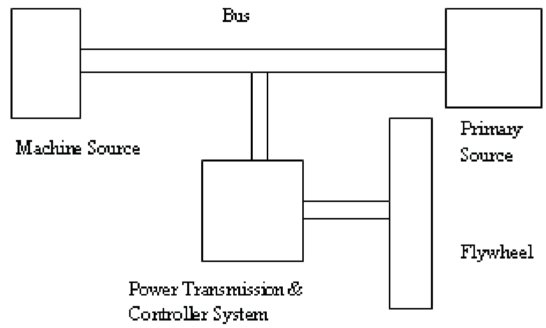

Fig1. For Stabilization & Power Backup Systems

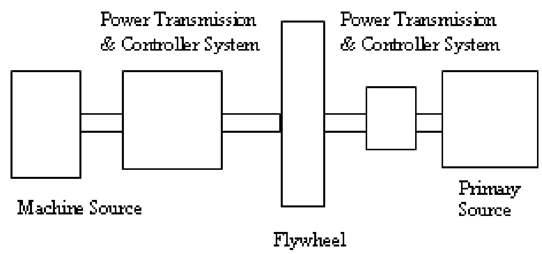

Fig2. For directly using Flywheel as Source

5. CONCLUSION

Energy storage is becoming vital area of research. Flywheels are in use from quite many years in on or the other form. The advancements in material sciences provides much better options for flywheel design. It is now necessary to look back and again reinvent the flywheel as potential energy storage as viable means. This will require to do focus research on power transmission system and controller system. These two components are pivotal to make the flywheel energy storage as viable energy storage.

6. REFERENCES

[1] David Connolly. A Review Of Energy Storage Technology. 2010. University of Limerick

[2] Nick Meeker and Brian Walker. Flywheel Technology for Energy Storage.2010.RIT

[3] Susan M. Schoenung and William V. Hassenzahl. Long- vs. Short-Term Energy Storage Technologies Analysis. 2003. Sandia National Laboratories