Electricity storage system: A Gravity Battery

D.K. Chaturvedi[1], Shubham Yadav[1], Tamanna Srivastava[1], Tanvi Kumari[1]
[1]Dept. of Electrical Engineering, Faculty of Engineering
Dayalbagh Educational Institute (Deemed to be Univ.), Dayalbagh, Agra, U.P., India 282005
Email: dkchaturvedi@dei.ac.in

Abstract - **The present energy storage systems such as lead acid batteries or lithium ion batteries have many drawbacks. The most important drawback is their adverse environmental impact, disposal problem, efficiency and charging time. We have renewable sources of energy such as solar and wind which can solve the environmental problems to a great extent. We all are aware of the fact about intermittency of wind and solar, hydro has the limitation of space requirement. Resources are free but not always usable and storable. To overcome these problems, a gravity battery is proposed in this paper. These proposed batteries will store the electrical energy in the form of potential energy and when needed this potential energy is converted back into kinetic energy and run a generator to produce electrical energy. A physical prototype is designed, developed and demonstrated in this paper.**

Keywords **- Energy Storage system, Electricity storage, High efficiency battery, Pollution free battery, renewable energy.**

I. INTRODUCTION

Electrical demand is increasing at a faster rate . About 65% of total power is produced by fossil fuel and affects the environment. The energy policymakers and engineers are continuously trying to increase the share of renewable energy in the grid. The renewable energy production like solar, wind or biomass are weather dependent and changes drastically during the generation. Hence the energy storage becomes essential, to maintain its continuity and reduce variability. Indeed, energy storage can help address the intermittency of solar and wind power[1-3]; it can also, in many cases, respond rapidly to large fluctuations in demand, making a better and responsive grid. It also helps in minimizing the requirement of backup generation plants. The usefulness of an energy storage solution is mainly determined by its response time to any changes in demand, energy loss during storage, energy density and rate of recharging.

Various energy storage methods have been introduced amongst which most popular is Lithium Ion batteries and pumped storage hydropower. Since the early 1800, batteries have been used for storage while pumped-storage hydropower is being operated since the 1920s. For better, greener and dynamic grid needs significant, new and better energy storage solutions. The detailed review of different energy storage solutions have been discussed and compared them based on size, eco-friendliness, life, charging time etc. [4-7].

Fossil fuels are still the most used form of energy, maybe due to the ease in their transportability and also the practicality of their stored form. This allows generators considerable control over the rate of energy supplied. However there are numerous disadvantages of fossil fuels mainly:-

i. Leads to global Warming

Fossil fuels are not eco-friendly sources of energy. Fossil fuels consist of high amounts of carbon as a result of which they have been blamed for being the great contributor to global warming.

ii. Non-Renewable Resource

Fossil fuels are non-renewable sources of energy. Their availability is not going to be forever; rather they will get exhausted someday. And it takes millions of years for them to get replenished naturally.

iii. Unsustainable

In contrast, the energy that is generated by renewable energy sources i.e. solar and wind is intermittent and reliant on the weather and climate. Hence, they cannot be readily available at the time of need, as there is no storage system.

978-1-7281-6823-4/20/$31.00 ©2020 IEEE

Thus, there arises a need to store the energy generated by renewable sources of energy.

Several energy storage solutions can help in meeting the demand of electrical energy during the peak hours. The cost of electricity is generally higher during peak hours because generators operate on ramp characteristics to meet the increased energy requirements. These energy storage solutions can offer energy during off-peak hours when excess cheap energy is available and put up for sale when there is a shortage of energy in the grid. This is one of the major points in formulation of smart grid, which is two way power flow. Unlike the one way power flow which was possible before introduction of smart grid as shown in Fig. 1.

Lead acid batteries and Li-Ion batteries are commonly used for small and medium scale energy storage solutions. These energy storage solutions have adverse effects on the environment like environmental pollution and lead content of the battery has potentially dangerous health impacts. Also their storage capacity is limited. [8-9].

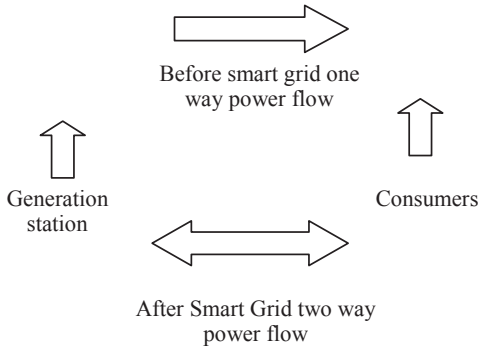

Fig.1: Depiction of power flow when renewable energy resources contribute to the grid and consume from the grid.

Recent development in energy storage solutions offers several economic and ecological benefits.

The modern large interconnected grids presently do not have any storage. These storage systems will definitely add to grid resilience. The large storage solutions in MW such as pumped hydropower, in which water is pumped to uphill during excess electrical power and this high head water is made to flow back downhill to generate power when it is required. This energy storage system needs a specific geographical location, which is not available everywhere. Other problems are its installation cost, very large space and evaporation of water.

For better use of renewable energy sources, latest energy storage solutions can be used as they have many advantages such as:

- A more efficient grid which is more resistant to any disturbances in the load or source end.
- Reduction in carbon dioxide as well as other emissions such as fumes of acids from other energy storages.
- Increase in the economic value of wind and solar power helps in increasing the economy of the nation generating energy with these renewable resources.
- New income sources for rural landowners as well as for people from various sectors such as management, technical etc. Tax revenues for wind and solar development areas. Many jobs created in this sector for engineering, manufacturing and R&D.

PROBLEM FORMULATION

If more clean energy is generated and efficiently stored, then this not only satisfies their demand but also becomes the source of income. The best example of this is the Solar farming in which the sun trekking pole mounted PV solar panels at the height of about 15-20 feet and below that the agriculture farming can be done. This gives double income, one from solar farming and other from agriculture. Similarly the wind power farming can also be done. This reduces the carbon footprint. The only problem of these renewable energy sources is its variability, which can be overcome by an efficient energy storage system.

Thus, there exists a need to store clean energy in a different form, thinking out of the box.

NEED ANALYSIS

The battery energy storage is the oldest solution for small power storage and pumped storage for large power storage. There are no great modifications in these energy storage devices to improve its efficiency or energy density specially for large power storage systems.

Hence, there is a need for such a grid storage system that is required to commercialize new battery technology and draw inspiration instead from the granddaddy of grid storage, pumped hydro.

DESIGN CONCEPTS

A gravity battery in which energy is stored in the form of potential energy by elevating a large weight using an electrical power to rotate an electrical drive as shown in Fig. 2. At the time of discharge using this potential energy to convert into K.E. by decreasing the height of this large weight and rotating a generator depending on the necessity. The gravity battery is able to store large amounts of surplus energy for medium to long periods of time whenever the excess power is available from renewable sources of energy.

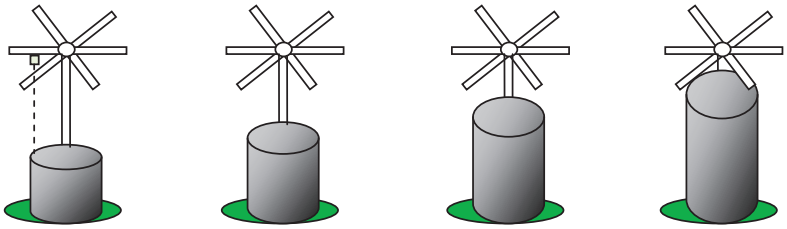

Fig. 2 Gravity battery charging

1. II. DESIGN AND DEVELOPMENT OF PROTOTYPE

This paper demonstrate the working concept of the gravity battery which fulfils the need of storing clean energy by developing the prototype model of it in Electrical Power System Research Lab, Dept. of Electrical Engineering, Faculty of Engineering, Dayalbagh Educational Institute (Deemed to be Univ.), Dayalbagh, Agra, U.P., India.

PROCEDURAL STEPS

1. In our prototype we have used a single weight, which is lifted up by a hook-string system. The hook is connected to one end of the string. The other end of the string goes over a pulley which is then wound on a drum. It is then connected to the shaft of the motor. A weight hangs from the pulley with the help of this hook.

2. When the motor runs on electrical energy, then the shaft rotates and consequently the string lifts the weight up. The gravity battery gets charged by rotating the pulley to lift large weights at maximum height and therefore,stores the energy by virtue of its position, which is known as gravitational potential energy.

3. After the second step, the switch is changed from charger to generator mode and generates power by rotating the string coil in the opposite direction.

4. The weight being at some height possesses gravitational potential energy that can be released when the weight is brought down and in turn produces energy.

5. For charging and discharging of this gravitational battery, gears and flywheel system has been used so that less distance travelled can produce sufficient number of rotations for the generation process. Multiple elevating and lowering of heavy weights sequentially can give smoother charging and discharging of the battery.

6. This energy can be used at the time of need.

The Schematic diagram of the prototype of gravity battery is illustrated in Fig. 3.

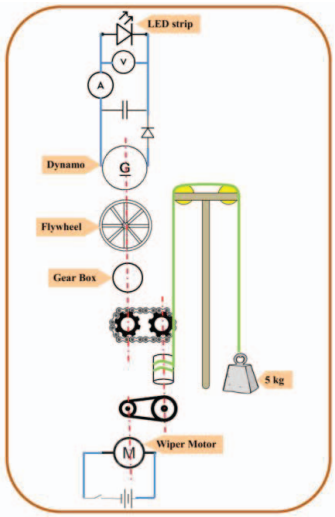

Fig. 3 Schematic diagram of gravity battery

Fig. 4 Prototype model of gravity battery

PARTS & SPECIFICATION

1. Wiper Motor: 12V, 10-25 rpm
2. Battery: 12V, 7.5 Ah
3. Dynamo
4. Electrolytic Capacitor: 16V, 1000uF
5. Electronic Diode
6. Two Gears and a gear box
7. Flywheel
8. Pulley and belt system
9. LED strip: 12V, 3metres
10. 2 Multimeters
11. 5 kg weight
12. A Capacitor of 1000uF is used to store some voltage and to avoid deep discharging.
13. Battery 12V - Solar panel is used as a source of energy to give the supply to the motor, but here we are using a 12V battery.

THEORETICAL CALCULATIONS

Theoretically,

Potential Energy = (mass) * (acceleration due to gravity) * (height)

$$= mgh \quad \text{--(1)}$$

In this prototype model,

mass, m = 5kg

height, h = 1.62 m

therefore,

Maximum Energy = (5 kg)*(9.8 m/s)*(1.62 m) --(2)

$$= 79.38 \text{ joules}$$

This is the maximum amount of energy which can be stored in this model in the form of Potential Energy.

Now, calculating the ideal time of fall, if all this energy gets converted into Kinetic Energy when the weight falls down in ideal conditions (no loss conditions).

energy balance equation

Potential Energy (Stored) = Kinetic Energy (Delivered) --(3)

$mgh = 0.5\ m * v * v$

$gh = 0.5\ v * v$

so,

v = (2gh)^½ = (2*9.8*1.62)^½ = 5.634 m/s

Now, taking out the velocity at the ground point Using Newton's laws of motion (considering free fall)

v = u + gt
-- (4)

So the ideal time for free fall is, while the weight lowers from height h, can be calculated from the above equation.

2. III. OBSERVATIONS

Here, we have used gear mechanism, so readings observed for a particular observation are:

Time of fall, t fall = 9.41 sec

Time taken to reach at a height of 1.62 m, t rise = 10 sec

velocity fall = distance / time of fall

= 1.62/9.41

velocity fall = 0.172 m/sec

On the load side, we connected LEDs (12 V).

Instantaneous maximum output voltage and current were observed in two separate multimeters, with naked eyes.

Output voltage (instantaneous maximum),

Voutinst. max = 8.46V

Output current (instantaneous maximum),

Ioutinst. max = 0.14A

The gravity battery can store large amount of energy without and leakage and pollution.The capacity can be expanded without much modifications. It has some problems such as Initial cost is higher is high, huge space required, no plan for disasters management [10-11].

Crane system can be installed to lift heavy multiple weights whose movement can be controlled and coordinated by different means, like microcontrollers or more specialized programmable logic controllers (PLCs),etc.

IV. CONCLUSION

The proposed gravity batteries do not have any leakage current as in lead acid / lithium ion batteries. Also there is no environmental pollution like acid fumes in lead acid batteries. The life of these batteries is quite long and no disposal problem as in other batteries. The most important thing in these batteries is quite high efficiency. In future the system efficiency may further be improved. The multiple weights may be used for higher energy storage. The disaster management plan may be included in gravity battery energy storage solutions.

REFERENCES

1. Jin Tan ; Yingchen Zhang, Study of Wind and PV Frequency Control in U.S. Power Grids—EI and TI Case Studies, IEEE Power and Energy Technology Systems , 2017.
2. DM Davies, MG Verde, O Mnyshenko, YR Chen , Combined economic and technological evaluation of battery energy storage for grid applications, Nature Energy, 4, pages 42–50, 2019.
3. Hai ChaoChen, Yan liang Qin, Haijie Cao, Xinxin Song, Chenghao Huang, Hongbin Feng, X.S. Zhao, Synthesis of amorphous nickel–cobalt–manganese hydroxides for super capacitor-battery hybrid energy storage system, Energy Storage Materials, Vol. 17, February 2019, Pages 194-203.
4. D.K. Chaturvedi, Tamanna Srivastava, Tanvi Kumari, Shubham Yadav, Technologies for the Energy Storage Solutions: A State of Art, International Journal of Scientific & Engineering Research Volume 11, Issue 5, May-2020 ISSN 2229-5518.
5. M.S. Guney, Y. Tepe, Classification and assessment of energy storage systems, Renew Sust. Energy Rev. 75 (2017) 1187–1197.
6. T. R. Ayodele, A. S. O. Ogunjuyigbe & N. O. Oyelowo, Hybridisation of battery/flywheel energy storage system to improve ageing of lead-acid batteries in PV-powered applications, International Journal of Sustainable Engineering, 21 Feb 2020. https://doi.org/10.1080/19397038.2020.1725177
7. Ruby-Jean Clark, et.al., State of the art on salt hydrate thermo-chemical energy storage systems for use in building applications, Journal of Energy Storage, 27, 2020.
8. Daniel Kucevic, et.al., Standard battery energy storage system profiles: Analysis of various applications for stationary energy storage systems using a holistic simulation framework, Journal of Energy Storage, 28, 2020. https://doi.org/10.1016/j.est.2019.101077
9. Bora Novakovic, Adel Nasiri, Introduction to electrical energy systems, in Edited book Electric Renewable Energy Systems, Academic press, 2016.
10. Energy Vault | https://energyvault.com/
11. Gravitricity | https://www.gravitricity.com/