

Revolutionizing Renewable Energy Integration: The Innovative Gravity Energy Storage Solution

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Abstract. In recent times, energy storage has been a major concern in the renewable energy sector. Traditional batteries are becoming less effective and sustainable as the world is moving towards renewable energy. Gravity battery, also known as Gravitricity is a new energy storage technology that is gaining popularity in the renewable energy sector. Gravity battery uses excess energy to hoist heavy objects, and when needed, the objects are released, generating energy. This paper highlights the need for alternative energy storage systems and the potential of gravity batteries to address the limitations of traditional batteries. This paper provides an in-depth analysis of gravity battery technology including the need analysis, problem Statement, product producers, advantages, disadvantages, and how it can replace the present batteries in power systems. The paper concludes that gravity battery technology is a promising alternative to traditional batteries and requires further research and development to accelerate its adoption in the renewable energy sector.

1 Introduction

The storage of energy is the fundamental component of the renewable energy industry. By doing so, it makes it possible to include renewable energy sources into the power grid, it brings supply and demand into equilibrium, and it makes the system more stable. However, conventional batteries, such as lithium-ion and lead-acid batteries, are becoming less effective and sustainable as a result of their high cost, negative impact on the environment, and short lifetime. As a result, researchers are seeking for alternative energy storage methods that are more environmentally friendly, efficient, and cost-effective [1]. Recognizing the importance of renewable energy sources in the fight against climate change and the reduction of emissions of greenhouse gases is of the utmost importance. In the process of transitioning to a low-carbon economy, renewable energy sources such as wind and solar are becoming an increasingly significant component. The intermittent nature of these sources, on the other hand, makes energy storage an essential component of the renewable energy industry. Energy storage technologies make it possible to include renewable energy sources into the power grid, which contributes to the maintenance of a consistent and dependable energy supply. Over the course of many decades, the dominant technology for the storage of energy has been traditional batteries, which include lithium-ion and lead-acid

batteries. On the other hand, they are subject to a number of constraints that make them less efficient and less sustainably viable over the course of time. Because of this, there is a need for alternative energy storage systems that are capable of overcoming the constraints of conventional batteries and offering a solution that is both more environmentally friendly and technologically advanced.

The Gravity battery, which is often referred to as Gravitricity, is an example of such a technology for storing energy. The concept of potential energy serves as the foundation for the technology of gravity batteries. In order to hoist heavy things to a higher height, it makes use of extra energy. When the need for energy arises, the objects are released, which results in the generation of energy. The sustainability, scalability, and adaptability of this technology are contributing to its growing appeal in the field of renewable energy. In recent years, there has been a rise in interest in gravity battery technology, which is a relatively new energy storage technology. Traditional batteries have a number of benefits to gravity battery technology, including the fact that gravity batteries are more environmentally friendly, efficient, and cost-effective. Furthermore, the technology has the ability to replace conventional batteries in a variety of applications, which makes it an appealing alternative for the renewable energy industry.

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2 Problem Statement

Traditional batteries have a number of drawbacks, the most significant of which are their high cost, short lifetime, and negative effects on the environment. A significant amount of carbon dioxide is released into the atmosphere during the manufacturing and disposal of conventional batteries, which is problematic for the environment. In addition, conventional batteries have a short lifetime and need to be replaced, which adds to the overall expense of the product. It is essential to bring attention to a few of the shortcomings of conventional batteries, which, over time, render them less efficient than current alternatives. Their poor cycle life, which refers to the number of charge and discharge cycles a battery can endure before losing capacity, is one of the key drawbacks of conventional batteries. This is one of the most serious disadvantages of traditional batteries. Traditional batteries have a limited cycle life, which makes them less cost-effective in the long term. There are other options available. Additionally, typical batteries make use of toxic chemicals, which both have the potential to be hazardous to human health and the environment. The extraction and manufacturing of these chemicals may also have major implications on the environment, which makes conventional batteries less sustainable over the course of their lifetime. As an additional point of interest, they have a restricted capacity and can only store a certain quantity of energy. As a result, its use in large-scale energy storage applications, such as grid-scale storage, which need the storage of substantial quantities of energy and their subsequent release when necessary, is restricted. Therefore, there is a need for alternative energy storage systems that are capable of addressing the limits of conventional batteries and providing a solution that is more environmentally friendly, efficient, and cost-effective. In order to overcome the shortcomings of conventional batteries, gravity battery technology offers a method of energy storage that is not only environmentally friendly but also highly efficient and economical. On the other hand, there is a pressing need to investigate the possibilities of gravity batteries and analyze the ways in which they might replace conventional batteries in power systems.

3 Analysis

The transition that the world is making toward renewable energy sources is causing a fast increase in the demand for energy storage devices. For the world to be able to reach its climate commitments by the year 2030, the International Renewable Energy Agency (IREA) estimates that it will be necessary to develop 310 gigawatts (GW) of energy storage. As a result, there is a need for energy storage systems that are more environmentally friendly, efficient, and economical [2]. One of the most significant challenges that the profession is now experiencing is the intermittent nature of the energy that is produced from renewable sources. Wind and solar power are examples of renewable energy sources that suffer from inconsistency since their output

is dependent on the time of day and the weather conditions outside. This presents a dilemma for the power system, which should have a consistent and dependable supply of electricity in order to function properly.

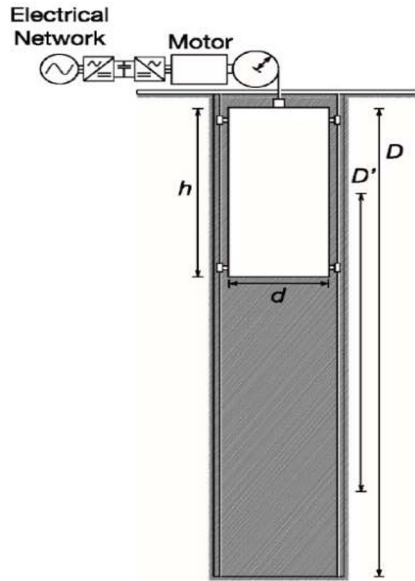
The unavailability of energy storage technologies that are both efficient and cost-effective is another challenge that we confront in the renewable energy field. Traditional batteries suffer from a number of drawbacks that make them less efficient and sustainable over the course of their lifetimes. As a result, they are not as appealing for use in applications that involve the storage of significant amounts of energy. In addition, the implementation of renewable energy sources in distant places that are not linked to the main grid presents a barrier [3]. In order to provide electricity, diesel generators are often used in these regions; nevertheless, these generators are not only costly but also generate dangerous greenhouse gasses. Because of this, there is a need for alternative energy storage systems that are capable of addressing the issues that the renewable energy industry is now facing and offering a solution that is more sustainable, efficient, and cost-effective simultaneously. The technology of gravity batteries has the ability to provide a solution to these issues that is both more effective and less harmful to the environment in terms of an energy storage solution.

4 Product Producers

The development of gravity battery technology is now being worked on by a number of different firms. Gravitrinity is one of these companies that is at the forefront of the development of technologies for gravity batteries now. It has been shown that the business has created a gravity battery prototype that is capable of storing up to 250 kWh of energy. In addition, an additional number of businesses, including Energy Vault, Advanced Rail Energy Storage (ARES), and Advanced Rail Energy Storage (ARES), are also engaged in the process of developing gravity battery technology [4].

5 Modeling of a Gravity Battery

Gravitational batteries are used to store the gravitational potential energy of an item, which is the energy that an object has as a result of its height above the ground [5]. The components that make up a battery, as seen in Figure 1, typically consist of a mass or weight that is raised to a certain height above the ground and a turbine or generator that converts the potential energy of the falling mass into electrical energy.



After the weight is released, it falls under the effect of gravity and generates kinetic energy as it accelerates. This occurs because gravity causes it to fall. Following this, the kinetic energy of the weight is transformed into electrical energy as it travels through the generator or turbine. In most cases, the generator is linked to an electrical circuit. This connection makes it possible for the electrical energy that is generated by the generator to be stored in a battery or utilized to power electrical equipment. The quantity of energy that may be created by a gravity battery is contingent upon the weight of the item that is falling, the height from which it is falling, and the efficiency of the generator or turbine that is being used. It is possible for the battery to store a bigger amount of potential energy if the weight and height of the object are both increased. The quantity of electrical energy that can be generated is also impacted by the efficiency of the generator or turbine, with a higher efficiency resulting in a larger amount of energy generation.

It is possible to construct gravity batteries such that they can function constantly, with the weight being raised back to its starting height after it has fallen. In light of this, the battery is able to continuously create and store energy, which enables it to function as a dependable and environmentally friendly form of energy storage, as seen in Figure 2. As an additional benefit, the use of a falling weight as a means of energy storage does not result in the generation of any hazardous pollutants or waste, making it an ecologically beneficial method of energy storage.

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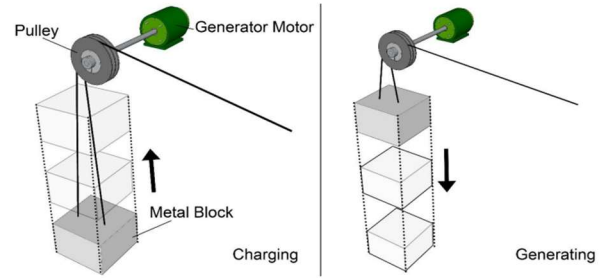


Fig 2. Charging and discharging modes of Gravity Storage

6 Flow Diagram of Gravity Energy Storage

The flow diagram of gravity energy storage is shown in Fig.3

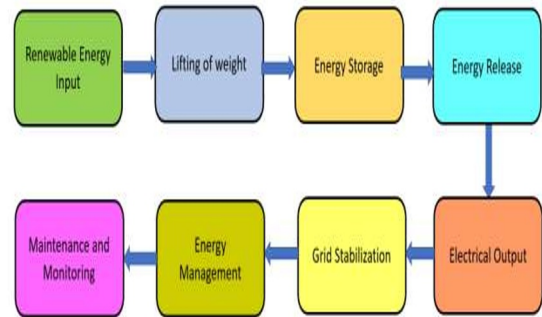


Fig 3. Flow Diagram of Gravity Energy Storage

The renewable energy source (e.g., solar, wind) is connected to the gravity battery system to charge the weights. The motor, gearbox, and winch lift the weights from the bottom to the top of the well or pit. The weights are stored at the top of the well or pit, holding potential energy. When energy is required, the weights are released from the top to the bottom of the well or pit, generating electrical energy. The electrical energy generated by the gravity battery system is supplied to the power grid. The gravity battery system helps to stabilize the power grid by providing a source of energy that can be used to balance fluctuations in supply and demand. The energy management system monitors and controls the energy flow in the gravity battery system, optimizing its performance and efficiency. Regular maintenance and monitoring of the system are carried out to ensure its continued efficient operation.

7 Theoretical Calculations

Let's assume we have a gravity battery that uses a 10,000 kg weight that falls from a height of 100 meters through a generator with an efficiency of 80%. Let's also assume that the battery undergoes 100 cycles.

The potential energy stored in the weight at the top of the tower can be calculated using the formula: Potential energy (PE) = mass(M) x gravity(G) x height(H) = 10,000 kg x 9.81 m/s² x 100 m = 9,810,000J

Assuming an 80% efficiency of the generator, the electrical energy produced by the generator can be calculated as: Electrical energy = potential energy x efficiency = $9,810,000 \text{ J} \times 0.8 = 7,848,000 \text{ J}$. The total energy generated by one cycle of the gravity battery is $7,848,000 \text{ J}$.

If the battery undergoes 100 cycles, the total energy generated by the gravity battery would be: Total energy generated = energy per cycle x number of cycles = $7,848,000 \text{ J} \times 100 = 784,800,000 \text{ J}$ or 784.8 MJ .

Let's assume that the gravity battery in the example above is discharged over a period of 10 seconds. The energy output of the battery was calculated to be 784.8 MJ . The power output can be calculated using the formula: Power = energy / time = $784,800,000 \text{ J} / 10 \text{ s} = 78,480,000 \text{ W}$ or 78.48 MW . Therefore, the final output power of the gravity battery in this example is 78.48 MW . It is important to note that the actual final output power of a gravity battery would depend on several factors, including the weight and height of the falling object, the efficiency of the generator or turbine, the capacity of the battery, and the rate of discharge. These factors affect the amount of energy that can be generated and the rate at which it can be discharged [6].

8 Features of gravity batteries and Factors Affecting Gravity Batteries

Features of gravity batteries includes they provide a reliable and scalable method of storing renewable energy, which can be used to meet fluctuating energy demands and reduce the need for backup power sources, they can achieve high efficiencies (up to 80-90%) due to the use of mechanical energy storage, which is more efficient than chemical energy storage used in conventional batteries, they have few moving parts and require minimal maintenance compared to other energy storage technologies, which can reduce operating costs and increase system lifespan, they have a longer lifespan (up to 30 years) than conventional batteries (5-10 years), reducing the need for replacement and disposal, they do not use hazardous chemicals or materials, reducing the environmental impact of energy storage and disposal, they can be cost-effective compared to other energy storage technologies, particularly in remote or off-grid locations where the cost of transmission and distribution infrastructure is high and can also help to stabilize the power grid by providing a source of energy that can be used to balance fluctuations in supply and demand, reducing the risk of blackouts and brownouts.

Factors Affecting Gravity Batteries includes Elevation difference i.e., the higher the elevation difference between the lifting and release points, the greater the potential energy that can be stored and generated, the material and size of the weights used in the system can affect its efficiency and performance. The efficiency and reliability of the lifting and release mechanism can impact the overall performance of the system. The energy management system plays a critical role in optimizing the performance and efficiency of the gravity battery system. Temperature and climate can

affect the performance and lifespan of the components in the system, such as the motor, gearbox. The frequency of charging and discharging the weights can affect the lifespan and performance of the system. Regular maintenance and upkeep of the system are crucial to ensuring its continued efficient operation. Some of the equipments commonly used in a gravity battery system, along with an estimated cost range for each item are weights used in a gravity battery system are made of a variety of materials, such as concrete, steel, or iron. The cost of weights can vary depending on the size, material, and quantity needed, but typically range from \$100 to \$500 per weight, A motor is required to lift the weights to the top of the well or pit. A suitable motor for a gravity battery system can cost between \$500 and \$1000, A gearbox is used to transmit the torque from the motor to the winch or pulley system. The cost of a gearbox can range from \$500 to \$1000; a winch or pulley system is used to lift and lower the weights. The cost of a winch or pulley system can range from \$1000 to \$5000, depending on the size and capacity needed, A well or pit is required to store the weights at the top and bottom of the system. The cost of constructing a well or pit can vary depending on the size and material used, but typically ranges from \$1000 to \$10,000 and monitoring and control systems are needed to optimize the performance and efficiency of the gravity battery system. The cost of monitoring and control systems can range from \$1000 to \$5000, depending on the complexity and features needed.

9 Drawbacks of present battery technologies and how Gravity Storage can replace present batteries

Present battery technologies, such as lithium-ion batteries, have several drawbacks that need to be addressed. Firstly, they have a limited lifespan, typically lasting for 5-10 years, due to degradation issues caused by the repeated charge and discharge cycles. Secondly, they have a high cost, particularly for large-scale applications, which limits their adoption in renewable energy systems. Thirdly, they have a limited storage capacity, which means that they may not be able to meet the energy demands during peak demand periods. Fourthly, they have a high environmental impact, as they require toxic and hazardous chemicals, such as lithium and cobalt, for their production. Lastly, their production and disposal processes have negative impacts on human health, particularly for the workers involved in the manufacturing and recycling processes. Gravity battery technology has the potential to replace traditional batteries in power systems. Gravity batteries are more sustainable, cost-effective compared to traditional batteries. They have a longer lifespan, lower cost per cycle, and do not use toxic chemicals. Moreover, gravity batteries can be used in various applications such as grid-scale storage, micro grids, and off-grid systems.

In grid-scale storage, gravity batteries can be used to store excess energy generated from renewable energy

sources such as wind and solar. The stored energy can be used to meet the energy demand during peak hours, increasing grid stability and reducing the reliance on fossil fuels. In micro grids and off-grid systems, gravity batteries can be used to provide reliable and sustainable energy storage. They can provide energy for remote areas that are not connected to the main grid, reducing the reliance on diesel generators.

10 Gravity Battery to Grid Connection

Once the electrical energy is produced by the generator, it needs to be converted into a form that can be fed into the grid. This involves using an inverter, which is a device that converts the direct current (DC) produced by the generator into alternating current (AC) that is used by the electrical grid.

The inverter is typically connected to the electrical circuit of the gravity battery, and it converts the DC output of the generator to AC energy that can be connected to the utility. Additionally, the inverter's function makes sure that the electricity generated by the battery is coordinated with grid's frequency and voltage specifications.

Before connecting the gravity battery to the grid, it is crucial to confirm the battery's suitability for the grid's electrical specifications. This may involve ensuring that the battery produces electricity at the appropriate frequency and voltage, and that it is capable of meeting the grid's power demand.

Connecting a gravity battery to the grid can provide several benefits, including the ability to store and generate renewable energy, solar and wind energy, as well as the capacity to supply backup power at times of peak demand or power disruptions. Gravity batteries are a desirable alternative for energy storage since they are frequently more affordable than conventional lithium-ion batteries is shown in Fig.4.

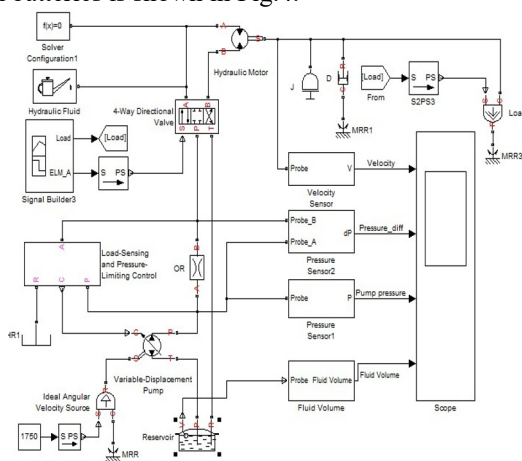


Fig.4. Simuink block diagram

For the purpose of effectively transmitting power and controlling mechanical motion, a hydraulic system incorporates a number of different components. Hydraulic energy is converted into either linear or rotational motion by the hydraulic actuator, which is commonly accomplished using cylinders or motors, respectively is shown in Fig.5. This hydraulic actuator

is the central component of the system. This actuator uses force to shift loads, and it is powered by hydraulic fluid that is pressured by a load-sensing variable-displacement pump is shown in Fig.6. Load-sensing pumps, in contrast to fixed-displacement pumps, are able to modify their fluid flow in response to the needs of the system is shown in Fig.7. This allows them to maximize energy efficiency while simultaneously reducing heat production. The transfer of power is accomplished by the use of hydraulic fluid, which is often based on oil. The variable-displacement pump is used in conjunction with control valves to adjust fluid flow and pressure is shown in Fig.8 and Fig.9. This helps to ensure that the pressure is matched to the load requirements, which in turn reduces energy losses and overheating. The use of pressure and flow control devices helps to further assure smooth operation by preserving the correct hydraulic characteristics. This enables accurate and efficient control over mechanical systems.

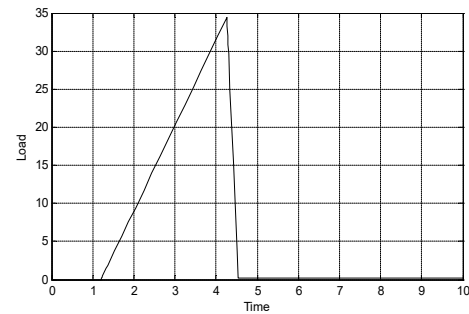


Fig.5. Load-Sensing Variable-Displacement Pump

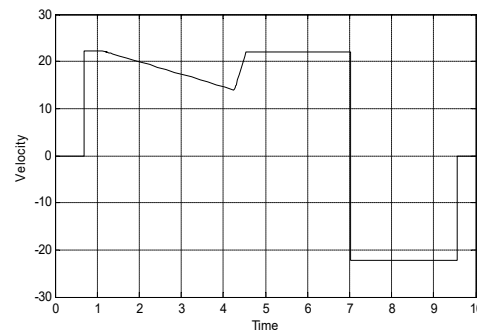


Fig.6. Velocity of the piston

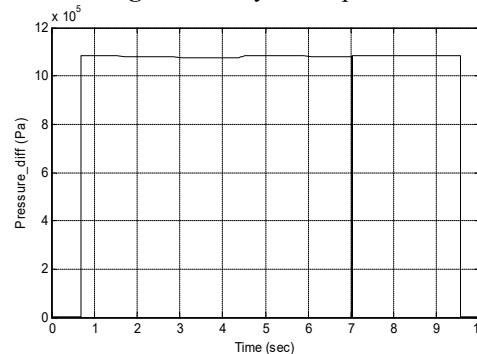


Fig.7. Pressure Difference

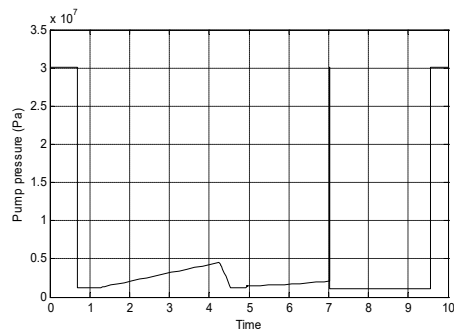


Fig.8. Pump Pressure

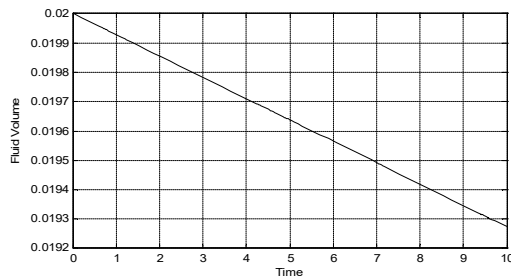


Fig.9. Fluid Volume

9 Conclusion

Gravity battery technology is a promising alternative to traditional batteries in the renewable energy sector. It offers several advantages such as sustainability, efficiency, and cost-effectiveness. Moreover, it has the potential to replace traditional batteries in various applications such as grid-scale storage, micro grids, and off-grid systems. However, further research and development are necessary to accelerate the adoption of gravity battery technology and address some of the challenges facing the technology, such as scalability and efficiency. Overall, the development and deployment of alternative energy storage solutions such as gravity batteries are critical in achieving a sustainable, efficient, and reliable energy system. The renewable energy sector, policymakers, and industry stakeholders need to work together to accelerate the adoption of alternative energy storage solutions and facilitate the transition to a low-carbon economy.

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