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Gravity Based Electrical Energy Storage System

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ABSTRACT: A creative energy storage technology known as a "gravity battery" produces electricity by harnessing the potential energy contained in an elevated mass. Gravity battery systems have emerged as a promising solution for storing energy efficiently. An object's gravitational potential energy is transformed into kinetic energy at a specific altitude. A gear train is attached to the wheel, which turns as the object descends. The generator shaft's pinion is further rotated by this gear train. At the generator's armature terminals, an electrical power is generated. This device can be utilized wherever on earth, regardless of fuel type, time of day, location, or weather conditions, while nearly all renewable energy sources have limited applications due to their operational parameters. It can be used in grid level energy storage system. The proposed system has the ability to replace the chemical batteries used in solar street lighting. The developed prototype is ready for use in real-world scenarios. Further, it can also serve as a backup power supply in the event of a natural disaster.

KEYWORDS: Proposed algorithm : Block Diagram , flow chart , working , Mechanism.

I. INTRODUCTION

We all need energy to get by in our everyday lives. Energy consumption by humans has increased since our arrival on the planet a few million years ago in order to survive. As a result, our demands on energy have risen over time, and electricity is a key topic in all aspects of modern society[1]. There is a quicker increase in the demand for electricity. Fossil fuels contribute around 65% of the total electricity generated [2]. Fossil fuels and non-renewable resources were both used to produce energy as a result of the industrial revolution and the expansion of industries, meeting the needs of manufacturers [3]. Perhaps because they are convenient to carry and utilize in stored form, fossil fuels continue to be the most widely used energy source. they do have a number of drawbacks, the two primary ones being that they are a non-renewable resource and cause global warming [2]. Global environmental concerns, along with the most recent 2016 Paris accord, have ended up resulting in tight monitoring of greenhouse gas emissions and their environmental impact [4]. An increasing number of nations are allocating resources towards the creation of novel, eco-friendly technologies aimed at mitigating the adverse effects of human actions on the environment [5]. Demand for all other fuels decreased in 2020 while the usage of renewable energy rose by 3%. There has been a reported increase of about 7% in the production of power from renewable sources. The percentage of renewable energy in the world's electrical generation climbed from 27% in 2019 to 29% in 2020. In response to traditional fossil fuel constraints and environmental degradation, the renewable energy sector has experienced tremendous growth in recent years. Such energy is characterized by unpredictability, volatility, and intermittency and is represented by solar and wind energy [4]. The shortcomings of alternative energy sources continue to be a barrier to their development. Utilizing nuclear energy raises costs since it necessitates a high level of security during operation and safe disposal of radioactive waste. Due to its sporadic nature, solar energy is ineffective in regions with a predominantly overcast climate. Hydro energy is area-specific and has an impact on biodiversity, as well as the vulnerability to earthquakes and terrorist attacks. Because wind energy is intermittent in nature, it is ineffective in places with very low wind speeds.

Both tidal and geothermal energy are quite region-specific. An energy source that is capable of producing electricity while taking into consideration features like efficiency, independence from location or environmental conditions, availability, lack of detrimental effects on the environment, accessibility, and a straightforward design with simple operation steps is required [6]. Using batteries is the most popular method of storing energy. Lithium-ion, lead-acid, nickel-cadmium, sodium-sulphur, zinc-air, and flow batteries with liquid electrolyte are among the battery types available [5].

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Li-Ion and lead acid batteries are frequently utilized in small and medium sized energy storage systems. These energy storage options have negative environmental repercussions, such as pollution, and the lead content of the batteries may have harmful effects on human health. Their storage capacity is also restricted [2]. Nonetheless, the economic viability of batteries' yearlong cycle of storage may never materialize due to the high cost of stored energy and, in certain instances, a significant daily self-discharge and/or loss rate. As of right now, no practical technology is available on the market that can provide low-generation capacity, particularly below 20 MW, long-term energy storage at a reasonable cost [7]. For this project, we'll use an effective kind of energy source to store power. The energy source will be gravity, which will also be utilized to store power. Therefore, we must employ the most effective utilization of traditional energy sources to overcome this problem [3].

Although there aren't many research on gravity energy storage systems in China, there are a few high-level patents on the concept. In order to achieve energy storage and generation, Cao Xinjiang suggested using big pillars and pulleys to create a vertical GESS that lifts and lowers massive boxes with the use of motors and generators [8]. In order to store or release energy, gravity energy storage technology (GES) relies on the vertical movement of a heavy item inside a gravitational field [9]. Numerous businesses are funding the use of gravitational energy storage. Of all the basic forces, gravitational force is the weakest. Gravity is a powerful factor that influences matter's interactions at the cosmic level. It determines the astronomical behaviour since it affects the genesis, trajectories, and forms of every celestial body. Life on Earth requires the presence of gravity. Gravity is the cause of ocean tides, winds, and the weight that is assigned to each item based on its mass.

The gravity of Earth is a result of its mass being 5.97237×1024 kg and its density being 5.514 g/cm^3, which makes it heavier than any other object on the surface. As a result, Earth's surface has a constant acceleration of 9.8 m/s^2 owing to gravity, which decreases with distance from the surface. The acceleration due to gravity at the equator is 9.789 m/s^2, whereas in the poles it is 9.832 m/s^2. A dynamo is used to transform an object's gravitational potential energy into kinetic energy and ultimately into electricity when it is lifted to a specific height. Light bulbs or other household appliances can be powered by the energy generated [6].

II. LITERATURE SURVEY

Planning for generation expansion the process of strategically organising and growing the infrastructure for power generation while optimising the integration of renewable energy sources is known as optimisation with renewable energy integration. This entails calculating the ideal blend of conventional and renewable energy technologies by utilising mathematical models and optimisation techniques, taking into account variables like cost, grid stability, environmental impact, and reliability. This strategy seeks to create an energy system that is more resilient and sustainable by wisely utilising renewables. This entails examining a number of variables, including demand projections, expenses, environmental effects, and grid stability, in order to identify the best cost-effective and environmentally friendly combination of energy technologies for upcoming requirements. The ideal mix of conventional energy sources and renewable energy sources, such as wind, sun, and hydropower, is determined using optimization algorithms [6]. Gravity lamps are a form of off-grid lighting that uses the potential energy stored in a weight, often a bag filled with rocks or sand, which slowly descends under gravity. As the weight falls, it drives a mechanism that generates electricity, typically through a dynamo or generator. This electricity can then be used to power lights or charge small electronic devices. While gravity lamps can provide a sustainable and environmentally friendly source of electricity in areas without reliable access to the power grid, they are generally less efficient, highly reliable than other renewable energy sources like solar or wind power. Additionally, they require manual resetting once the weight reaches the bottom, which may not be practical for continuous power generation. Gravity lamps typically consist of a weight that is lifted to a certain height, storing potential energy, and then released to fall; potential energy is converted into kinetic energy driving a generator to produce electricity. This method is sustainable and doesn't rely on traditional fuel sources, making it suitable for off-grid or remote areas where access to electricity is limited.

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III. PROPOSED ALGORITHM

A. Block diagram:

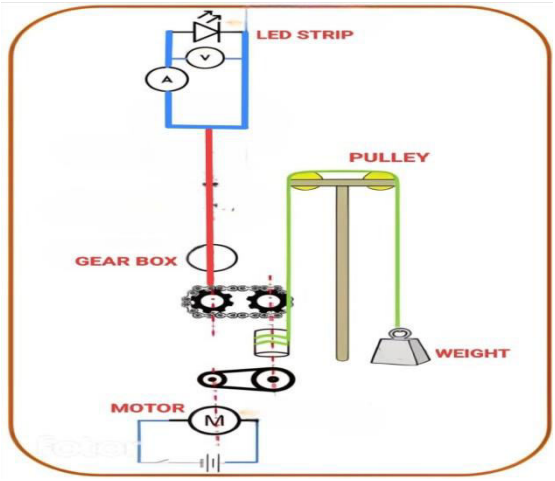

Fig: Block Diagram of Gravity Battery

The block diagram illustrates the process of depicting the flow of energy from the initial lifting phase to the release of stored energy for electricity generation. Additionally, it may include control systems for managing the operation of the pulley, gear, monitoring energy levels, and regulating power output. This diagram effectively communicates the key components and functionality of a gravity battery system**.** In the block diagram the single weight is used, which is lifted up by a string system. The weight is connected to one end of the string. The other end of the string goes over a pulley. It is then connected to the shaft of the motor. A weight hangs from the pulley with the help of this string. 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. The potential energy is directly proportional to the height and mass of the object, as expressed by the equation: Potential Energy (PE) = Mass (M) x Gravitational Acceleration (g) x Height (h). After the second step, the switch is changed from charger to alternator mode and generates power by rotating the string coil in the opposite direction.

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. For charging and discharging of this gravitational battery, gears 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. The efficiency of gravity energy storage systems is determined by the ratio of the electrical energy output during the discharge phase to the electrical energy input during the charge phase. This energy can be used at the time of need. The gravity battery can store large amount of energy without leakage and pollution. The capacity can be expanded without many modifications. Crane system can be installed to lift heavy multiple weights if needed, whose movement can be controlled and coordinated by different means, like microcontrollers or more specialized programmable logic controllers (PLCs), etc. This block diagram provides a high-level overview of the operation of a gravity battery system. Specific implementations may vary based on the design and requirements of the system.

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B. FLOW CHART:

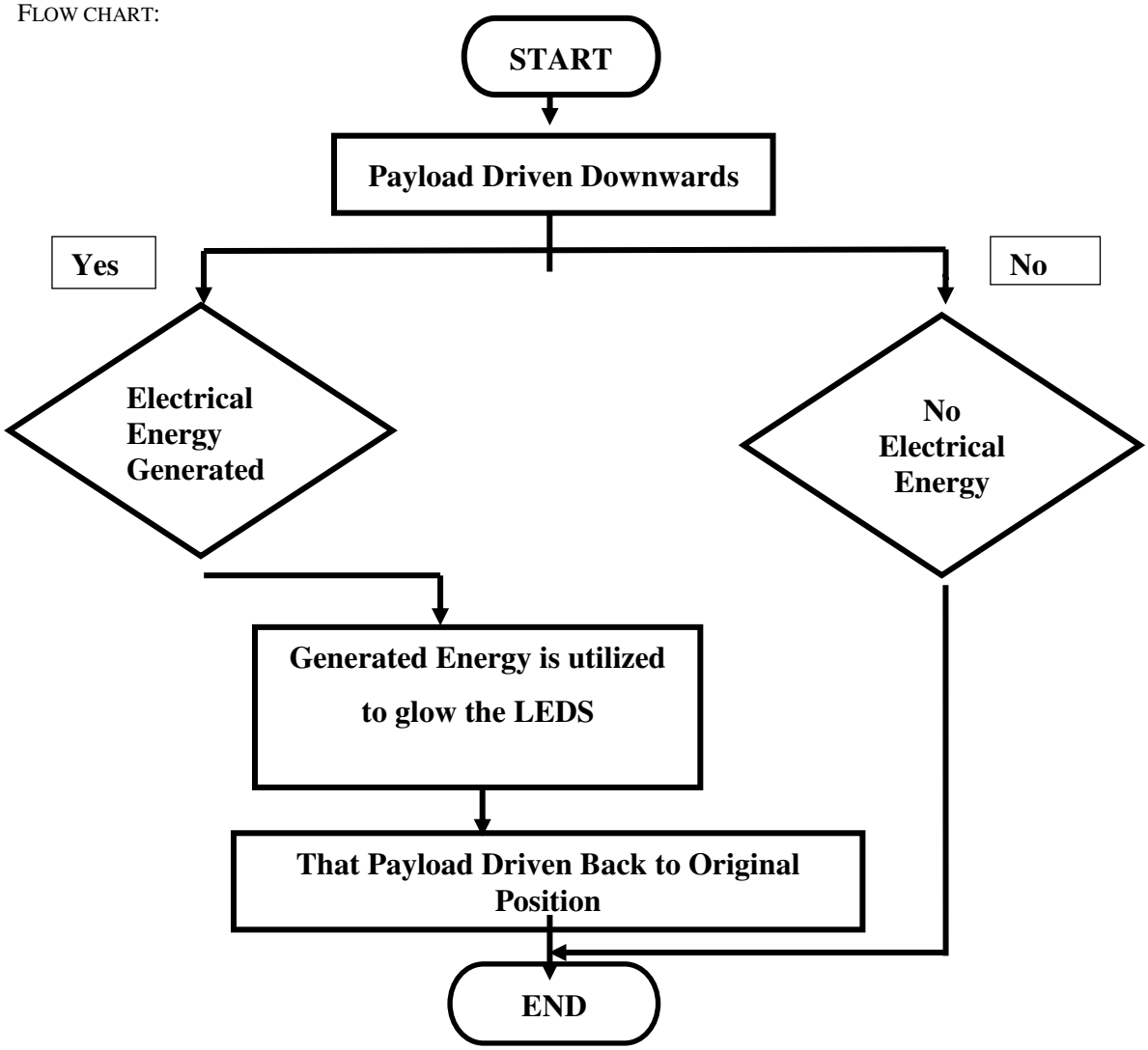

Fig: Flow chart of the proposed system

During starting phase, energy from an external source is used to lift a heavy mass, such as a container filled with rocks or water, to an elevated position. This lifting action stores potential energy in the system. Payload driven downwards likely refers to the process of lowering a heavy mass (the payload) to store potential energy. When electricity is needed, the stored potential energy is converted back into electrical energy by raising the payload upwards. This gravitational energy storage system can be used as a form of grid energy storage, providing a means to store and release electricity when needed.

When payload driven downwards the electricity is generated. When a load is connected, it utilizes the stored potential energy in the system. This typically involves allowing the heavy mass or payload to descend under gravity, converting potential energy into kinetic energy. The kinetic energy is then converted into electricity as the payload descends, providing power to the connected load. After the load has utilized the stored energy, mechanisms such as counterweights or lifting systems are employed to return the load to its original position. This process allows the battery to be recharged by lifting the load back up against the force of gravity, ready to store energy for future use. After stop phase cycle can be repeated as needed, providing a renewable and sustainable energy storage solution.

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C. WORKING:

Dead weight is been used as an agent to drop from the height which will travel the certain specified distance to rotate the pulley, the pulley is attached to the shaft which is supported by the bearings and then input to the Gear box, at the gear box the RPM which is available at the input shaft is amplified and the RPM is increased and made available at the output shaft of the gear box, that output high RPM shaft is attached to the generator/alternator to produce power and the power generated is directly sent to the grids to the consumers to run the load, this technology is used to produce power in peak demand hours. Gravity batteries can be designed in various configurations, such as using weights lifted vertically or utilizing containers of materials that are raised or lowered to different levels to store and release energy. The efficiency and practicality of these systems depend on factors like the height of the lift, the weight of the objects, and the overall design of the system.

GH

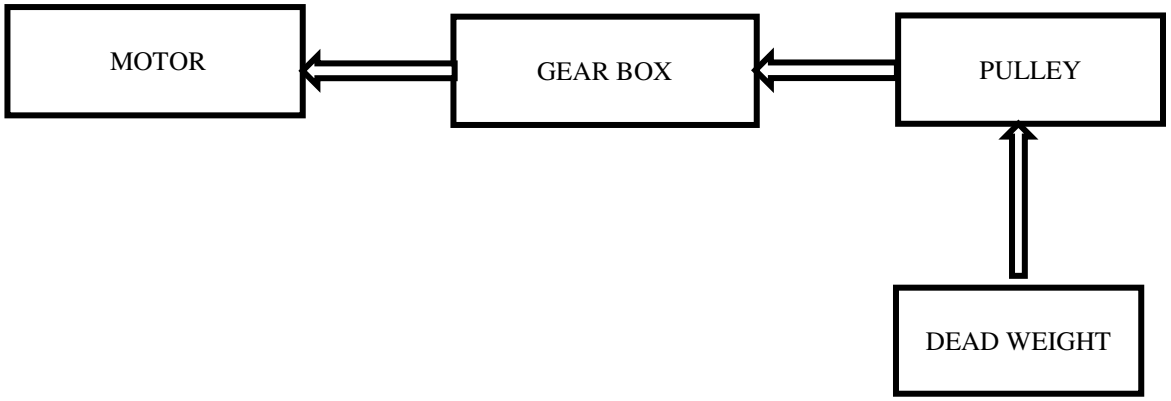

Fig: Basic working of the prototype

D. Mechanism:

Gravity batteries can have different designs and structures, but all gravity batteries use the same properties of physics to generate energy. Gravitational potential energy is the work required to move an object in the opposite direction of Earth's gravity, expressed by the equation.

$$U=mgh$$

Where U is gravitational potential energy, m is the mass of the object, g is the acceleration due to gravity (9.8 m/s^2 on earth), and h is the height of the object. Using the work-energy principle, the total amount of energy generated can be expressed by the equation.

$$\Delta E=mg\,(h1-h2)$$

Where E is the total amount of energy generated and h1 and h2 represent the initial and final heights of an object. The change of energy directly correlates to the vertical displacement of a mass; the higher a mass is lifted the more gravitational potential energy is stored. The change in energy also directly correlates to the mass of an object; the heavier the mass, the bigger the change in energy.

In a gravity battery, a mass is displaced, or lifted, to generate gravitational potential energy that is transformed into electricity. Gravity batteries store gravitational potential energy by lifting a mass to a certain height using a pump, crane, or motor. After the mass is lifted, it now stores a certain gravitational potential energy based on the mass of the object and how high it was lifted. The stored gravitational potential energy is then transferred into electricity. The mass is lowered to fall back to its original height, which causes a generator to spin and create electricity.

IV. RESULTS AND DISCUSSION

This prototype was mounted at a specific height. A Specific kg mass was suspended through it. The mass was a bottle filled with water in order to show that the operation of the prototype is independent of the type of object and is solely dependent upon the mass of the object. Time taken by the object to reach the floor was observed. Meanwhile a load was connected across the output terminals of the motor. Load was in the form of LED's which can easily verify the presence of electric current in the circuit. The designed prototype is successfully able to harness the energy from the

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object falling under gravity. The maximum weight that can be suspended through the thread has an upper limit. This is due to the fact that the object with more weight will experience more force due to gravity.

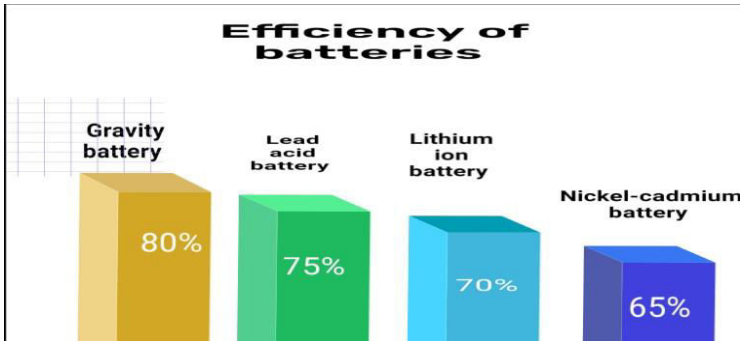

Fig: Comparison of batteries efficiency

Comparison of chemical battery over gravity batteries :

Parameters	Chemical batteries	Gravity battery
Cost	High	Low
Efficiency	Low	High
Factor affected	Electrolyte and Electrodes	Weight and Gravitational potential energy
Storage life	Low	High
Specific energy	30Wh/kg	45Wh/kg
Maintenance	High	Low
Life span	Low	High
Safety	Low	High
Temperature dependence	Required	Not required
Power	7.2kWhr	10kWhr

V. APPLICATIONS

Gravitricity has a minimum 50-year service life and estimated 80–90% efficiency. In a period of 15 to 8 hours, gravity may produce electricity with a power of 1 to even 20 MW. Over 13,000 families can have electricity for two hours thanks to its energy storage technology. It may deliver a very powerful short-term stimulus when needed. Long-term energy conversion, steady energy production, and a more ecologically friendly, straightforward construction are just a few benefits of gravity-based energy storage systems. Because of this project idea, we are looking for a good replacement for battery technology in big capacity storage. There is a lot of potential for this idea in the future.

VI. CONCLUSION AND FUTURE WORK

An overview of the Gravity-based Energy Storage System (GESS) has been provided in this work. A novel idea for energy storage called GESS promises to facilitate the seamless and more dependable integration of renewable energy sources into the electrical grid. Studies show these system have zero requirements of fossil fuels and do not emit any harmful gas. Leakage current is absent from the suggested gravity batteries, unlike lead acid and lithium ion batteries. Additionally, lead acid batteries do not release any acid vapors into the atmosphere. These batteries have a lengthy lifespan and don't require special disposal as other batteries do. Comparing the approach to chemical batteries, it is nearly carbon neutral and environmentally good. GESS is readily erected, has no topographic restrictions, and doesn't utilize any ecologically hazardous materials. However, in order to put the system into practice and make it

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operate as a more effective energy storage method, a significant amount of research and development effort is required. However, it will undoubtedly be crucial in the future in delivering a very stable, strong, safe, and efficient storage system that may be utilized to supply electricity during peak demand or to offer ancillary services to the electrical grid. The prototype may be utilized in rural regions to replace costly batteries used in solar panels, and it can also be used to illuminate houses during blackouts.

Further study can help refine and scale up the process to meet higher energy demands. The environmental stress caused by the chemical battery disposal process can be lessened by storing energy as gravitational potential energy. The most essential feature of these batteries is their high efficiency, which may range from 80 to 90%. Future improvements might increase the system's efficiency even further. Higher energy storage may be achieved by using the numerous weights. Energy storage solutions utilizing gravity batteries may incorporate a disaster management strategy.

The requirements and issues that people in rural regions deal with on a daily basis were taken into consideration when this initiative was established. The prototype may be further enhanced in terms of features and performance without having any upper bound.

A few minor adjustments that might be made to this prototype in the future include raising the model's overall efficiency, Automation of the mechanics for engaging and disengaging Using IOT and sensors, computing and keeping an eye on the system's charge, In order to increase overall performance, a larger model and analysis for the large-scale load in the shaft and its corresponding parts, as well as an enhanced compound gear train, improved methodology, a better electrical generator selection, and optimized circuitry, were designed and developed. The Gravitricity developers are now in Scotland developing a demo platform. They will next construct the energy storage facility prototype in South Africa, Australia, and Europe.

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