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Design and Fabrication of Gravity Based Energy Storage System

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Abstract: Renewable energy sources are increasingly fulfilling the need for continuous energy supply. However, energy derived from these sources cannot be directly utilized and must be stored in energy storage systems such as Battery Energy Storage Systems (BESS), Compressed air systems, Mechanical systems, Hydraulic systems, among others. In this paper, we will discuss the study and analysis of a Gravity-based energy storage system and its fabrication of a model-based representation. The objective is to improve the overall concept and efficiency of the system. Gravity-based energy storage systems utilize gravity's force to store potential energy. The system functions by elevating a heavy object to a high altitude and subsequently releasing it to generate electricity. The lifting motion stores potential energy, which is then converted to kinetic energy as the weight descends and can be used to produce electricity. The paper will provide additional information about the specific gravity-based energy storage system being analysed, as there are different designs and configurations. Additionally, the paper will compare and contrast this method of energy storage with other methods such as battery storage and compressed air storage, highlighting the advantages and disadvantages of each. Lastly, the paper will touch on the development and testing of a physical model or simulation of the gravity-based energy storage system. The paper will provide details on the design and testing process, as well as any modifications or improvements made to the system based on the findings.
Keywords: Renewable energy, Gravity battery, BESS, Energy storage device, types.

I. INTRODUCTION

Battery Energy Storage Systems (BESS) are commonly utilized to store energy derived from renewable sources. However, this system uses lithium-ion batteries with a minimum lifespan of 5 years or 2000 charging cycles. BESS requires periodic maintenance, and the batteries pose a risk of catching fire. Additionally, they contain toxic metals such as cobalt, nickel, and manganese that can contaminate water supplies and ecosystems. If improperly disposed of in landfills, their energy storage capacity can diminish over time. Alternative energy storage techniques such as Compressed Air Energy Storage (CAES), Pumped Hydro Energy Storage technology (PHSE), and Solid Gravity Energy Storage technology (SGES) have been developed. This paper focuses on exploring the SGES technique. SGES uses an electric lifting system to raise one or more weights in a vertical direction, thereby converting electrical energy into gravitational potential energy for storage. Several companies, including Energy Vault, Gravity Power, ARES, and Gravitricity Ltd., are actively working on implementing this technology for practical use. This project aims to demonstrate how the Gravity-based Energy Storage System efficiently stores renewable energy without the use of Li-ion batteries. By utilizing SGES, we can reduce the environmental impact and safety concerns associated with BESS while achieving a reliable and sustainable energy storage solution.

II. METHODOLOGY

The primary goal of a gravity-based energy storage system is to store energy by elevating weights in an upward direction and collecting the energy through a DC motor during the release process. To achieve efficient use of this mechanism, the system must decrease the fall time of the weight while maximizing power collection or employ multiple weights to increase the overall discharge time. This research study utilizes both techniques to demonstrate the effectiveness of gravity-based energy storage in storing and utilizing energy. A model-based approach is used to analyse and optimize the performance of the system, considering various factors such as weight size, release height, and collection efficiency. The results of this study show that gravity-based energy storage systems can provide an effective and reliable energy storage solution, with the potential to store significant amounts of energy for extended periods. The research also highlights the benefits of utilizing multiple weights in the system, which can increase the overall discharge time and enhance the system's performance. Overall, this paper presents a comprehensive analysis of the gravity-based energy storage system and its potential for storing and utilizing renewable energy. The study provides valuable insights into the optimization of this system, which can help promote the use of clean and sustainable energy sources in the future.

III. COMPONENTS

The main components of model are below:
1) 12-watt dc electric gear motor
2) Pully for rope winding
3) Nylon cable
4) Concrete block (weight)
5) Solar panel

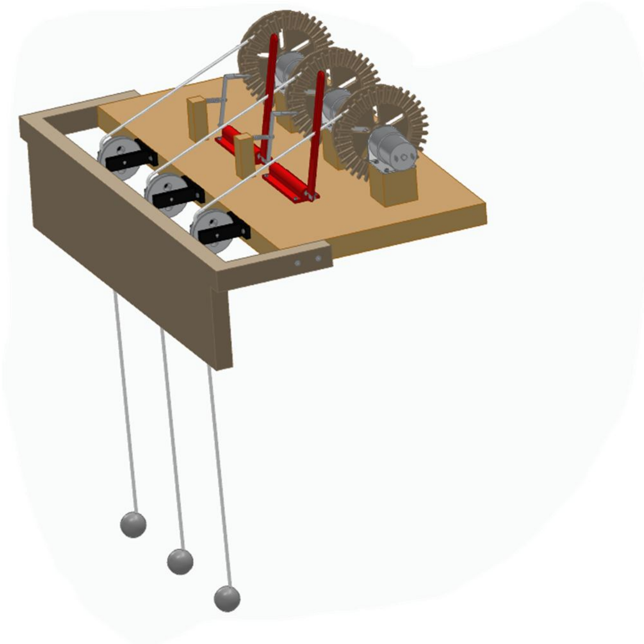

Fig. CAD model of GRAVITY BASED ENERGY STORAGE SYSTEM

IV. CONSTRUCTION, WORKING & DESIGN CALCULATION

A. Construction

A 12-watt DC gear motor is utilized to reduce the speed from 1000 RPM to 250 RPM, and it comes with an in-built gear. The pulleys connected to the motor are linked together to operate consecutively. Three weights are lifted one at a time during the charging process, and the same motor is used for discharging the power. To adjust the power range in relation to the motor power and facilitate slow discharge, a concrete block is used as the weight. The rope that holds the weight and drives the pulley has knots on both ends, which triggers the links to activate another motor. Additionally, small free-wheel pulleys guide the weight downward. all of these components are mounted on a wooden frame with electrical connections.

B. Working

The first step in the gravity-based energy storage system is the charging phase. During this stage, all the weights are initially in the rest position, or in the down position. When the first motor starts rotating, it also turns the pulley, which pulls the weight in an upward direction. For safety purposes, the pulley has a one-way rotating motion mechanism, with threads that enable this function. If the power supply weakens or gets cut off during the charging process, the one-way motion mechanism ensures that the pulley can only rotate in one direction. A small sensor attached to the horizontal wooden plate in the system's diagram facilitates the transfer of power to another motor when the first weight is lifted in the upward direction. This process continues until all three weights are lifted up. When all the weights have been lifted, the charging phase is complete, and the system is ready for the discharge phase. To utilize the stored power in the gravity-based energy storage system, the operator needs to rotate a knob or switch that disconnects the one-way mechanism and connects the motor connection to the output source. During the discharge phase, the last weight starts to fall downwards, which rotates the pulley and consequently, the motor. The gear inside the motor slows down this process while increasing the motor speed. All the motors then discharge themselves one by one, with the linkages facilitating the process. Once the last weight touches the ground, the discharge process is complete, and one cycle of the charging and discharging process is finished.

C. Calculations

To calculate the velocity of the dead weight (V): V = π × D × N / 60

V = π × 1.5 × 1000 / 60

V = 1.94 cm/sec

Where: D = Diameter of pulley N = Rotational speed of motor in RPM

The speed (S) is calculated using: S = 1.94 cm/sec

The distance traveled by the weight (D) is: D = 12 cm

The total discharge time (T) is then calculated as follows: T = D / S

T = 500 / 1.94 ((D = 500/60) => 8.33 rev/sec)

T = 8.33 / 1.94

∴ T = 4.29 seconds

The first experiment yielded good discharge time, and modifying the weight and gear ratio of the motor could potentially enhance the overall discharge time even further.

V. RESULT AND DISCUSSION

The efficiency of the system was improved by utilizing multiple motors that operate in a sequential manner, and by modifying the weight and applying multiple pulling mechanisms. As a result, the discharge time was reduced. By making modifications, the system is capable of generating 1 watt of power within 1 minute. Additionally, the amount of power generated can be increased by increasing the downfall length of the weight.

VI. CONCLUSION

The experimental model aims to demonstrate the efficiency of the gravity-based energy storage system. This system has several advantages over Li-ion batteries, such as longer lifespan, low maintenance, ease of construction, and small space requirements. Our model successfully showcases all these advantages of the system.

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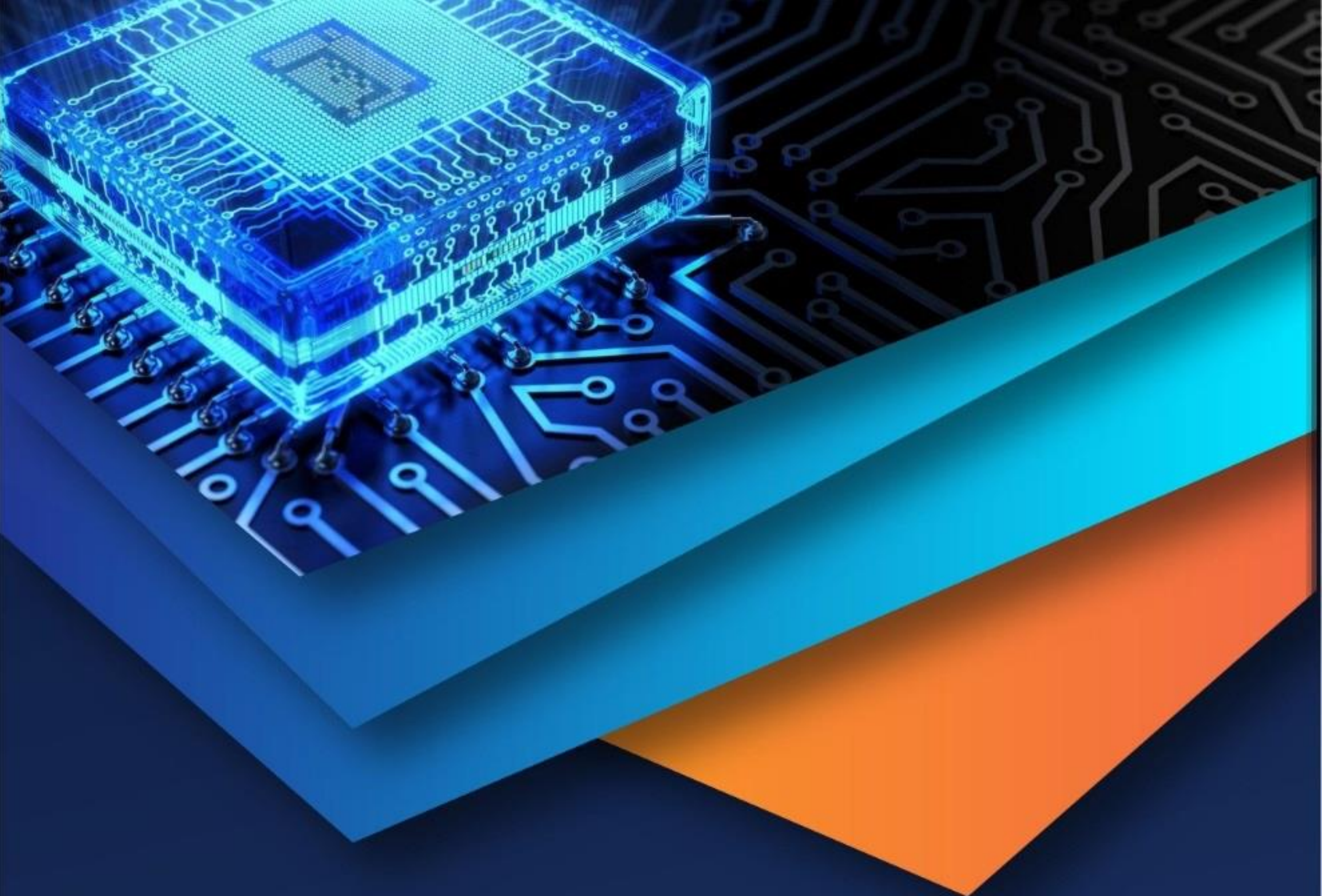

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