

Design and Implementation of Gravity Battery for Electric Energy Storage

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ABSTRACT

The increasing penetration of renewable energy sources such as solar and wind has created a growing requirement for reliable and sustainable energy-storage technologies. Conventional electrochemical batteries, including lead-acid and lithium-ion batteries, are associated with limitations such as environmental concerns, disposal requirements, degradation, and charging-related issues. This paper presents the design and implementation of a prototype gravity battery for electric energy storage, in which electrical energy is converted into gravitational potential energy by lifting a mass and subsequently recovered as electrical energy during its descent. The developed prototype consists of a 12 V DC wiper motor, a 2 kg mass, pulley and belt mechanism, gearbox, flywheel, dynamo, electrolytic capacitor, diode, battery, and LED load. During charging, the motor lifts the mass to a height of 0.65 m, thereby storing energy in the form of gravitational potential energy. During discharge, the descending mass drives the dynamo through the mechanical transmission system to generate electrical energy. For the prototype, the theoretical stored energy is 12.74 J. Experimental observations recorded a rise time of 4 s, fall time of 3.41 s, instantaneous maximum output voltage of 8.46 V, and instantaneous maximum output current of 0.14 A. The project demonstrates the feasibility of gravity-based energy storage for small-scale applications and highlights its potential for renewable-energy integration, backup power, microgrids, remote-area supply, and other energy-storage applications.

Keywords— Gravity battery, gravitational potential energy, energy storage, renewable energy,

INTRODUCTION

The rapid growth of technology and industrialization has resulted in continuously increasing electrical-energy demand. At the same time, conventional fossil-fuel resources are limited and their utilization contributes to environmental pollution and global warming. Consequently, renewable energy sources such as solar and wind are increasingly being adopted. However, their intermittent nature creates a requirement for effective energy-storage systems capable of storing surplus energy and delivering it when required.

Gravity-based energy storage provides an alternative approach in which energy is stored in the form of gravitational potential energy. The basic principle involves raising a mass to a particular height using electrical or renewable energy and subsequently allowing the mass to descend. During descent, the stored potential energy is converted into mechanical energy and then into electrical energy through a generator. The amount of energy stored is primarily dependent on the mass, elevation, and gravitational acceleration.

Unlike chemical energy-storage technologies, gravity-based systems do not depend on electrochemical reactions for their primary storage mechanism. The project report identifies environmental impact, disposal problems, efficiency limitations, and lifespan concerns associated with conventional batteries as motivations for developing the proposed system.

The objective of this work is therefore to design, construct, and experimentally demonstrate a small-scale gravity battery capable of storing energy through a lifting mechanism and recovering it through a dynamo. The developed

prototype uses a motor-driven pulley and gear mechanism for lifting the mass and a dynamo for energy recovery. The experimental results are used to evaluate the feasibility of the proposed storage concept.

LITERATURE SURVEY

Research on gravity-based energy storage has explored its potential as a sustainable alternative to conventional battery technologies. Karuppiyah *et al.* investigated gravity energy storage as a method for renewable-energy integration and highlighted its potential as an alternative to conventional storage systems [5]. Al-Hilfi *et al.* investigated grid-connection methods for gravity energy-storage generator motors using voltage-index sensitivity analysis, with emphasis on improving grid integration and stability [6]. The project report also identifies solid gravity energy storage as a technology in which heavy solid masses are elevated during periods of excess energy generation and subsequently lowered to recover stored energy [7].

Elsayed *et al.* studied parametric optimization of gravity energy-storage systems using the Taguchi method and ANOVA, identifying parameters such as piston diameter, height, and material density as important factors affecting performance. Bowoto *et al.* investigated the integration of solar energy with gravity-based storage for residential applications using MATLAB simulation. These studies indicate the potential of gravity storage for renewable-energy integration; however, the present work focuses on the physical design and experimental demonstration of a compact prototype using a mechanical lifting and generation arrangement.

PROBLEM STATEMENT

The intermittent nature of renewable energy sources such as solar and wind requires an efficient and environmentally sustainable energy-storage method. Conventional lead-acid and lithium-ion batteries have limitations associated with environmental impact, disposal, degradation, and operational life. Therefore, a gravity-based energy-storage system using gravitational potential energy is proposed as a sustainable and scalable alternative.

OBJECTIVES

1. To design and develop a prototype gravity battery system that stores electrical energy as gravitational potential energy by lifting a mass and converts the stored energy back into electrical energy during its descent.
2. To experimentally evaluate the performance of the developed gravity battery by measuring its output voltage, current, energy conversion, and identifying factors affecting system efficiency.

PROPOSED SYSTEM

The proposed system stores energy by lifting a 2 kg mass through a motor-driven pulley arrangement. The major components include a 12 V DC wiper motor, 12 V 7.5 Ah battery, pulley and belt system, gearbox, flywheel, dynamo, electrolytic capacitor, diode, measuring instruments, and LED strip. The system combines electrical and mechanical energy conversion stages.

The motor provides the mechanical input required to raise the weight. The pulley transfers the motor motion to the lifting mechanism, while the gearbox adjusts speed and torque. During the discharge process, the falling mass rotates the mechanical transmission system and drives the dynamo. The generated electrical energy is temporarily smoothed using the capacitor and supplied to the LED load. A diode provides unidirectional current flow and prevents backflow.

BLOCK DIAGRAM

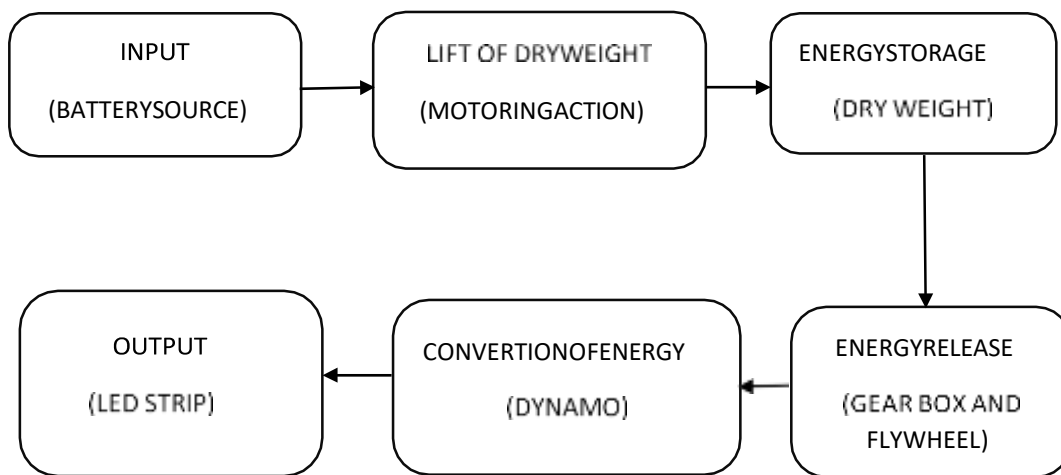


Fig 1 block diagram

CONNECTION DIAGRAM

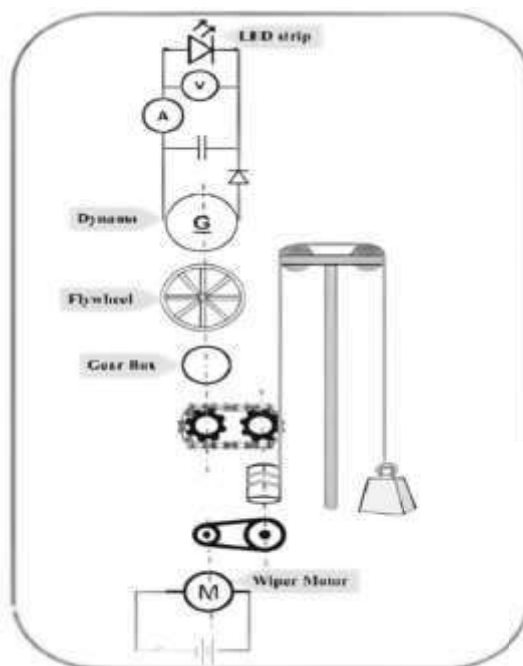


Fig 2 connection diagram

METHODOLOGY

The prototype was constructed using a hook-string lifting arrangement. One end of the string is connected to the weight through a hook, while the other end passes over a pulley and is wound around a drum connected to the motor shaft. When the motor is energized, the shaft rotates and lifts the weight. The elevated mass stores gravitational potential energy according to its height.

After the mass reaches the required height, the system is switched from charging mode to generating mode. The mass descends under gravity and rotates the mechanical system in the opposite direction. The gearbox and flywheel increase

the effectiveness of the mechanical transmission and help provide smoother energy release. The resulting mechanical rotation drives the dynamo, which produces electrical energy for the connected load.

RESULTS AND DISCUSSION

The developed prototype successfully demonstrated the conversion of electrical energy into gravitational potential energy and its subsequent conversion back into electrical energy. The theoretical energy storage for the selected mass and height was 12.74 J. During experimental operation, an instantaneous maximum voltage of 8.46 V and current of 0.14 A were obtained across the load. These results confirm the fundamental operating principle of the proposed gravity battery.

The reported generator efficiency of approximately 85% indicates that the mechanical-to-electrical conversion stage can provide useful output at prototype scale. Nevertheless, the difference between theoretical and practical performance is influenced by friction in the pulley and gear system, generator resistance, mechanical alignment, and other losses. The project report also identifies intermittent energy generation and the requirement for a mechanism to reset the mass as important limitations.

Another important consideration is energy density. Gravity batteries require sufficient mass and elevation to store significant quantities of energy, resulting in comparatively larger physical structures for higher storage capacity. Therefore, while the developed prototype demonstrates feasibility for small-scale applications, larger systems require improved structural design, automated mass-reset mechanisms, high-efficiency generators, and optimized mechanical transmission.



Fig 3 experimental setup

CONCLUSION

This paper presented the design and implementation of a prototype gravity battery for electric energy storage. The developed system stores energy by lifting a 2 kg mass to a height of 0.65 m and subsequently recovers the stored gravitational potential energy through a pulley, gearbox, flywheel, and dynamo arrangement. The theoretical energy-storage capacity of the prototype was calculated as 12.74 J. Experimental testing produced an instantaneous maximum output of 8.46 V and 0.14 A, demonstrating the feasibility of converting gravitational potential energy into useful electrical energy.

The proposed technology provides an environmentally friendly alternative to chemical-based energy storage and offers potential benefits such as long operational life, low maintenance, scalability, and reduced disposal concerns. However, the prototype is limited by mechanical losses, intermittent generation, space requirements, and relatively low energy density. Future improvements involving multiple weights, automated mass resetting, higher-efficiency generators, optimized mechanical transmission, and renewable-energy integration can improve the practical performance and scalability of gravity-based energy-storage systems.

REFERENCES

- [1] J. Tan and Y. 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] D. M. Davies, M. G. Verde, O. Mnyshenko, and Y. R. Chen, "Combined Economic and Technological Evaluation of Battery Energy Storage for Grid Applications," *Nature Energy*.
- [3] H. C. Chen, Y. L. Qin, H. Cao, X. Song, C. Huang, H. Feng, and X. S. Zhao, "Synthesis of Amorphous Nickel Cobalt Manganese Hydroxides for Supercapacitor-Battery Hybrid Energy Storage System," *Energy Storage Materials*, vol. 17, pp. 194–203, Feb. 2019.
- [4] Gravitricity, "Gravity Energy Storage," 2024.
- [5] N. Karuppiah, P. Mounica, J. N. Bhanutej, S. Saravanan, R. Reddy, and R. Israni, "Revolutionizing Renewable Energy Integration: The Innovative Gravity Energy Storage Solution," *IEEE Transactions on Sustainable Energy*, vol. 15, no. 2, pp. 1048–1056, Apr. 2024.
- [6] L. M. A. Al-Hilfi, S. Morris, J. Wang, B. Venkatesh, C. K. Wai, and H. C. K., "Grid Connection Method of Gravity Energy Storage Generator Motor Based on Voltage Index Sensitivity Analysis," *IEEE Transactions on Industry Applications*, vol. 60, no. 2, pp. 1339–1346, Mar./Apr. 2024, doi: 10.1109/TIA.2024.2895134.
- [7] W. Tong and X. Wang, "Solid Gravity Energy Storage: A Review," *Journal of Energy Storage*, vol. 53, Art. no. 105226, 2022.