

Design and development of a mechanism to store electricity using gravitational force

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Abstract- Natural gas, nuclear energy, and coal have historically been the primary sources for electricity generation in the nation. However, in the past few decades, renewable energy sources such as solar, wind, tidal, and geothermal energy have actively contributed to the power generation landscape. These renewable sources have become increasingly important in meeting the fluctuating demand for electricity throughout the day, especially during peak periods. However, renewable energy production itself is subject to fluctuations, necessitating the need to store excess energy for release when demand surpasses supply. Currently, pumped hydro storage and batteries are the prevalent methods for energy storage. The imperative for generating power from renewable sources has grown in recent times due to the detrimental effects of pollution and global warming, highlighting the importance of transitioning to sustainable energy alternatives. One popular solution to address this issue is to store the energy and convert it into a more stable form, allowing it to be transformed back into electricity during periods of high demand when the energy has a higher value. This approach enables economic viability for various energy storage projects, including less efficient and commonly used options like batteries. Presently companies like “Gravitricity” and “Energy Vault” are generating the electricity in large scale using gravitational potential energy. Consequently, this paper aims to propose a storage system that utilizes gravitational potential energy on a small scale.

Key words: Gravitation, Gear Box, S-SGES and Gear ratio.

1. INTRODUCTION

As industrialization, technological advancements, and economic growth continue to soar in developing nations, there has been a substantial increase in global energy consumption. Recent data from the International Energy Agency (IEA) reveals a projected 4.5% surge in worldwide energy demand, which translates to over 1000 TWh (terawatt-hours) in the upcoming years. Regrettably, this heightened energy demand has also contributed to a 5% rise in CO₂ emissions during 2021. To combat this urgent environmental issue, renewable energy systems are being swiftly embraced due to their ability to mitigate CO₂ emissions and their environmentally friendly operation, devoid of greenhouse gas or pollutant emissions. According to the IEA, electricity generation from renewable sources achieved a record-breaking high, experiencing an impressive 8% increase, reaching a total of 8300 TWh in 2021. To meet the objectives outlined in the Paris Agreement of limiting the global temperature rise to below 2 °C, the International Renewable Energy Agency (IRENA) underscores the importance of elevating the share of non-fossil fuel-based generation sources to 57% globally by 2030. Solar photovoltaic and wind energy are expected to play a pivotal role in this transition, accounting for two-thirds of the overall growth in renewable electricity generation, with an estimated increase of approximately 18% and 17% respectively. However, these renewable sources face intermittent challenges, such as reduced efficiency during cloudy or calm weather conditions and occasional energy overproduction that may strain the system. To address these hurdles and achieve a harmonious balance between energy generation and demand, energy storage systems (ESS) emerge as the most practical and effective solution, offering the potential for optimized energy management and control. ESSs capture and store energy from diverse sources for later utilization, encompassing various types, including gravitational energy storage systems. These gravitational systems leverage the force of gravity to generate electricity, providing a globally accessible and eco-friendly solution. The constant nature of gravitational potential energy at a specific height enables prolonged energy storage without significant losses, making gravity batteries an exemplary choice for energy storage.

2. LITERATURE SURVEY

1) J. Mitali et al. review of advancements in Energy Storage System(ESS) from 1850-2022.

The authors underline the significance of energy storage in facilitating the seamless integration of renewable energy sources and enhancing grid stability. Subsequently, the paper delves into the systematic categorization of energy storage systems. The authors meticulously classify ESS according to multiple criteria, including the nature of the stored energy (chemical, mechanical, electrical, etc.), storage duration and application.

2) The Fall and Rise of Gravity Storage Technologies, Aaron Fyke -2019.

This paper delves into the evolutionary journey of gravity storage technologies, shedding light on their initial decline and subsequent resurgence. Aaron Fyke, the author, meticulously analyzes the obstacles faced by gravity storage systems in the past and investigates the recent advancements that have revitalized their potential.

The paper commences by acknowledging the historical significance of gravity storage as a viable energy storage solution. It emphasizes the pivotal role played by pumped hydroelectric storage, which has gained widespread adoption and proven to be an efficient means of storing substantial amounts of energy. Nonetheless, despite its remarkable success, the widespread

implementation of pumped hydro has been hindered by site-specific requirements, geographical limitations, and environmental considerations.

3) Solid Gravity Energy Storage: A review, The Journal of Energy Storage July 2022 Wenxuan Tong, XifanWang, Zhengang Lu, Weijiang Chen, Minxiao Han, Guoliang Zhao and Zhanfeng Deng.

Solid gravity energy storage encompasses the process of storing energy by harnessing the potential energy stored in solid masses. The research paper extensively examines numerous facets of this technology, covering its operational principles, diverse types of solid gravity energy storage systems, as well as their respective advantages and challenges.

The authors emphasize that solid gravity energy storage holds several advantages over alternative energy storage technologies. It boasts high energy density, enabling the storage of substantial amounts of energy. Furthermore, it offers prolonged duration storage capabilities, allowing for the retention of energy over extended periods. In terms of cost-effectiveness, solid gravity energy storage proves to be relatively economical when compared to other methods such as pumped hydroelectric storage. An additional advantage lies in its versatility, as solid gravity energy storage systems can be constructed in various locations without being constrained by geographical limitations.

3.METHODOLOGY

Renewable energy is stored in the system as gravitational potential energy through the suspension of weights. Energy storage occurs by raising a mass, and during periods of high demand, the mass is released, allowing it to descend and discharge the stored energy.

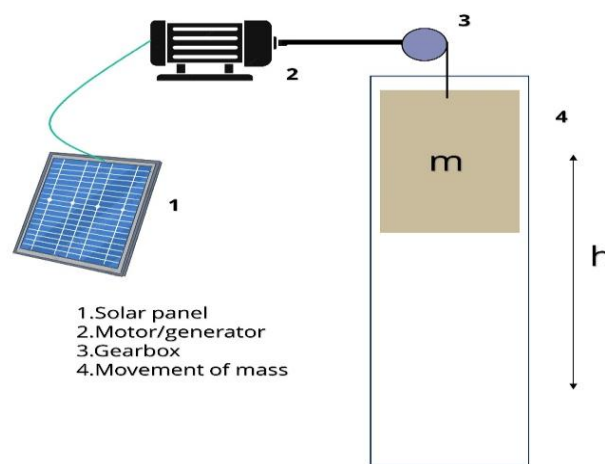


Figure 3.1: Basic model of SGES

Figure 2.1 shows the design of the gravity energy storage system consisting primarily of a block with some mass, gearbox, wire ropes, motor/generator, inverter, and the photovoltaic power generation system.

1.1. Shaft SGES (Solid Gravity Energy Storage)

The leading equipment of S-SGES includes weights, ropes, transmission equipment, and motor-generator units.

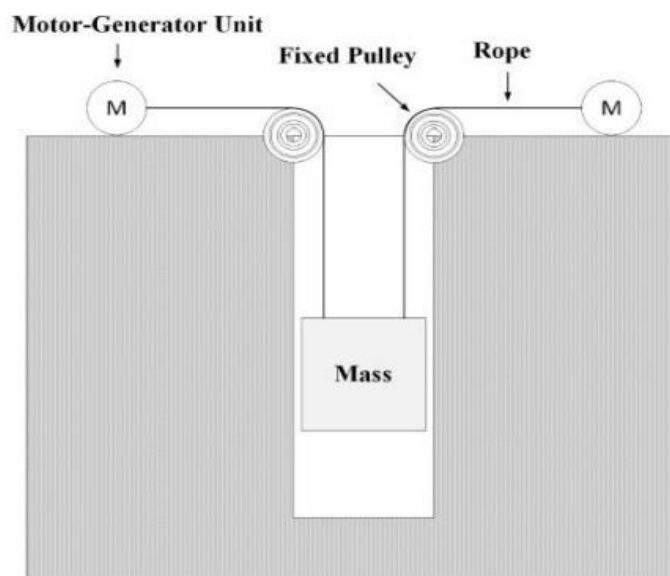


Figure 3.1.1: Schematic diagram of S-SGES

The technical route involves the conversion of electrical energy into mechanical energy through vertical movement of a weight. When there is an excess of electrical energy, the motor is activated to lift the weight, converting the electrical energy into gravitational potential energy stored within the weight and the vertical shaft. Conversely, when the stored energy is required, the weight is allowed to descend, and the gravitational potential energy is converted back into electrical energy through the motor. The storage capacity of S-SGES is determined by equation

$$E_s = mgh\eta_s \dots\dots\dots(1)$$

Where E_s is the storage capacity of S-SGES; h is the effective height of the weight; η_s is the output efficiency of the S-SGES.

The effective height of the weight can be expressed as :

$$h = H_s - h_M \dots\dots\dots(2)$$

Where H_s is the depth of the shaft, h_M is the height of the weight. Substituting equation (2) into equation (2) yields :

$$E_s = m\eta_s(H_s - h_M)$$

1.2. ENERGY STORAGE PROCESS

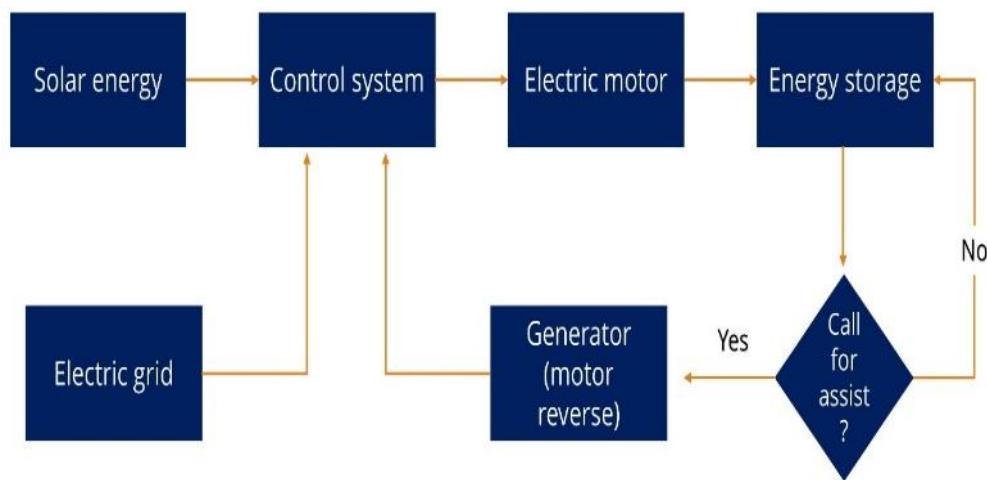


Figure 3.2.1: Flowchart of system process

Figure 2.2.1 illustrates the operational sequence of the proposed system. During sunny periods, the photovoltaic panel captures solar radiation, causing the movement of electrons and the generation of electric current within the panel cells. The combination of electric current and voltage produces power at the terminals of the photovoltaic cells. This electrical energy is then utilized by an electric engine, which converts it into mechanical energy to lift a piston through a pulley system, facilitating its ascent. As the mass of the piston increases, so does its potential energy. When the piston reaches the top, the mechanical potential energy is stored, marking the charging mode of the system. The discharge mode occurs when there is an increased demand for energy or during sunless periods, such as nighttime. During this phase, the mass is released, causing the piston to descend. The electric motor operates in reverse, functioning as an electric generator, converting the mechanical energy of the descending mass into electrical energy. In summary, the system harnesses solar radiation to generate electrical energy, which is then converted into mechanical potential energy during the charging mode. During the discharge mode, the stored energy is released as the mass descends, and the electric motor acts as a generator to produce electrical energy once again.

4. IMPLEMENTATION DETAILS

GEAR

A gear serves as a rotating component with teeth that interlock with the teeth of another gear or a similar toothed element. Its primary purpose is to transmit motion and power between rotating shafts, while also enabling adjustments in speed, torque, and direction of the transmitted motion.

Typically, a gear takes the form of a cylindrical or disk-shaped body featuring a set of evenly spaced teeth encircling its outer edge. These teeth are specifically designed to engage with the corresponding teeth of another gear, creating a gear pair. As the gears mesh together, the rotation of one gear induces the rotation of the other gear.

The size of a gear is determined by its diameter, which is measured at the pitch circle—a theoretical circle that passes through the centers of the gear teeth. The number of teeth present on a gear determines its gear ratio, establishing the relationship between the speed and torque of the driving and driven gears

GEAR BOX:

A gearbox, an essential mechanical device found in various machines and vehicles, serves the purpose of transmitting and regulating power. Its primary function revolves around altering the speed and torque produced by the power source, commonly an engine, to align with the specific output requirements.

A gearbox comprises a precise arrangement of multiple gears. Each gear possesses a specific number of teeth, and their interlocking engagement facilitates the transmission of power from one gear to another. These gears are mounted on shafts and rotate at varying speeds, contingent upon their sizes and the gear ratio.

The gear ratio plays a pivotal role in determining the relationship between the rotational speeds of the input and output shafts. A higher gear ratio entails a slower rotational speed on the output shaft accompanied by increased torque. Conversely, a lower gear ratio yields a higher output speed but with reduced torque. This dynamic enables the gearbox to deliver diverse power and speed levels tailored to the requirements of the respective machine or vehicle.

5. RESULTS

This study describes the Generation of Electricity using gravity. A small-scale energy storage system that can be used to power basic electrical components installed in a building. An energy storage solution with faster response time and better efficiency, in par with Li-ion batteries. An energy storage mechanism that can be installed onto any existing building that satisfies the structural requirements (height, unused terrace) in order to successfully install and operate the mechanism.

6. CONCLUSION AND FUTURE SCOPE

The project aims to assess the feasibility of storing electricity using gravitational force and explore its energy storage capacity. By lifting or raising heavy objects to a specific height, electrical energy is converted into potential energy and then released as electricity when required. The study examines factors such as the mass and height of elevated weights or masses, conversion process efficiency, and energy losses during storage and retrieval to determine the mechanism's storage capacity. Additionally, the project evaluates the efficiency of energy conversion, considering factors like friction, mechanical losses, and energy losses during conversion or storage. Enhancing efficiency is crucial for ensuring the economic viability of the mechanism. The future scope of generating electricity using gravity involves refining gravity-based energy storage systems, integrating them with renewable energy sources, exploring grid-scale applications, implementing off-grid solutions, developing hybrid energy systems, and promoting sustainable development. These advancements hold significant potential for enhancing efficiency, scalability, and sustainability in energy storage and generation.

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