Alofi gravity energy storage

Thank you for visiting nature . You are using a browser version with limited support for CSS. To obtain the best experience, we recommend you use a more up to date browser (or turn off compatibility mode in Internet Explorer). In the meantime, to ensure continued support, we are displaying the site without styles and JavaScript.

Renewable energy (RE) generation has increased in recent years and is expected to continue to grow over the coming years. Electricity generated by RE is expected to rise from 10% in 2010 to 35% by 20501,2. However, renewable resources usually cannot be used as a stand-alone power plant or as a primary source of electricity due to their intermittent nature and significant fluctuation, especially wind and solar energy3,4. This defect encouraged researchers to develop a solution for this irregular nature. Two immediate solutions have been suggested to address this problem. The first solution is the mixed-use of renewable energy resources, i.e., wind and solar energy. The second is using energy storage devices coupled with renewable energy resources.

There are three critical reasons for storing energy5,6,7,8; the first reason is transferring power from a non-portable energy source to a portable one. The second is controlling the power-to-energy (PTE) ratio of the energy generation source, which means that the generated output can be directed to meet the changes in energy demand. The last reason is using it later whenever needed to satisfy the increase in demand. An energy storage system that fulfills the second and third reasons can be beneficial in overcoming the intermittent nature of renewable energy. It is worth mentioning that the energy storage systems can also provide flexibility for smart electric grids in the future since they can meet the variation in demand.

Different energy storage systems have been studied and developed over the last two decades. Most of the systems introduced were the electrical, chemical, electrochemical, thermal, and mechanical energy storage9,10,11. Mechanical systems, such as flywheel energy storage (FES)12, compressed air energy storage (CAES)13,14, and pump hydro energy storage (PHES)15 are cost-effective, long-term storage solutions with significant environmental benefits for small- and large-scale renewable energy power plants to overcome energy generation fluctuation16.

A relevant study proposed three approaches for combining gravitational storage systems with renewable energy resources17. The first was the "Energy Vault Tower", which employs ropes to raise masses using the generated energy. The stored energy can be retrieved by lowering these masses (concrete blocks) while driving an electric generator with ropes18. The second method, which can be used in abandoned mine shafts, uses a massive suspended weight rather than multiple concrete blocks19. The third method utilizes a heavy piston that moves vertically inside a cylinder by compressing fluid flow through a valve.

According to20, the first closed hydraulic circuit was developed by a company called Gravity Power. The main idea was to pump water from a low-pressure side to raise a piston in a closed hydraulic circuit; in this case, this is called the storage phase. When there is a need to recover the stored energy, the piston is allowed to descend by opening a valve, allowing water to flow through a hydraulic turbine and generate electricity. According to Heindl21, the efficiency of the round-trip gravitational energy storage system can reach more than 80%.

Gravity storage systems were studied from various perspectives, including design, capacity, and performance. Berrada et al.22,23 developed a nonlinear optimization model for cylinder height using a cost objective function. Their findings demonstrated that the Levelized price of gravity energy storage is competitive with other techniques. Furthermore, the proposed small-scale gravity storage systems could be stand-alone renewable energy storage systems. Berrada et al.24 also numerically examined the use of various materials in gravity storage systems. They suggested using "iron ore" for the piston and reinforced concrete for the system container.

On the other hand, valuable efforts were made to avoid the use of heavy pistons and improve system performance25. Botha and Kamper26 investigated a waterless gravity energy storage system with a wire rope hoist and drive train technology up to 90% efficiency27,28.

Statistical analysis of energy storage systems should be considered as they reduce experimental costs, which helps minimize the research cost and time. It also offers a comprehensive view of parameters influencing the system performance29. In a relevant study, Elsayed et al.30 added a fuzzy control system to a gravity energy storage system, employing three fuzzy membership functions, triangular, trapezoidal, and Gaussian, to determine the appropriate design parameters criteria for various sized power plants. Their results showed that the Gaussian membership function best represents the fuzzy model of the storage system.

On the other hand, the statistical design of experimental methods provides a straightforward and equally efficient approach. The evolutionary operation, factorial, regression, response surface, and Taguchi methods are the most used for experimental design34,35,36. Ibrahim et al.37 presented Taguchi optimization of tribological behaviors of composite materials. They concluded that Taguchi and analysis of variance (ANOVA) techniques are promising for predicting tribological behavior and can then be used to guide the design and implementation of tribological materials.

Taguchi"s method is superior to other optimization methods because it allows simultaneous optimization of multiple factors. Furthermore, fewer experimental trials can yield more quantitative information. Taguchi"s method has been used in various fields, including renewable energy generation and energy storage systems38,39,40,41.

This paper presents a novel comprehensive model that predicts and optimizes the most influencing parameters on the performance of gravitational energy storage systems. The simulated model using MATLAB-SIMULINK was created and validated against experimental data from the literature before applying the statistical approach. The Taguchi method was then used to predict the contribution of design parameters to system performance and to determine the best combination of parameters to maximize system performance due to its simplicity and dependability.

Contact us for free full report

Web: https://www.kary.com.pl/contact-us/
Email: energystorage2000@gmail.com
WhatsApp: 8613816583346