Proceeding Paper

Transforming Decommissioned Mines to a Gravity Energy Storage System †

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Abstract: A new gravitational energy storage system is studied, which uses a reversible conveyor belt to elevate granular material and a regenerative motor for energy harvesting during the downward movement of material. This system can be installed in decommissioned open-pit mines, which offer suitable topography and available material. The parameters affecting the performance of this energy storage system are examined by employing sensitivity/uncertainty analysis. Results showed that the inclination of the conveyor, the filling factor of the conveyor belt, and the efficiency of the motor/generator had the greatest impact on the overall energy storage efficiency.

Keywords: statistical quality control; gage R&R; aluminium recycling

1. Introduction

Energy transition is driven by renewable sources like wind and solar, but their intermittency requires energy storage systems to balance supply and demand. Batteries, which can provide short-term storage solutions, and pumped hydro storage, which can provide long-term energy storage with large generation capacities, are the most commonly used energy storage systems worldwide.

Battery-based energy storage systems have a limited number of cycles and a severe environmental footprint (difficulties in recycling lithium-ion batteries). On the other hand, pumped hydro storage has specific topographical requirements (two large water reservoirs at elevations with a suitable vertical separation); thus, building new sites is difficult. This study investigates the possibility of converting a conveyor belt system used for transporting bulk materials into an energy storage system. By harnessing the gravitational potential energy of the material at a certain height and utilizing its movement on inclined conveyor belts, the gravitational energy is converted into electrical energy using regenerative motors.

This gravitational energy storage system (GESS) is based on the same principle as the hydro-pumped storage system, but instead of using water reservoirs, it employs piles of loose bulk materials (such as sand, gravel, or other granular materials) at different elevations [1]. It can provide a solution for energy storage in areas where water pumping is not feasible, and it can also be utilized in former mining areas where sufficient quantities of loose bulk materials and suitable height differences are available [2].

This investigation is preliminary and aims to estimate the conveyor belt-based GESS performance range considering its main design parameters and to examine if it is comparable to other existing energy storage systems. The selected parameters in the analysis included conveying distances (travel length) and inclinations, type of conveyed materials and filling factor, piles heights, rubber belt and idlers rolling resistances and trough angle, motor, and generator efficiency.
2. Conveyor Belt-Based Gravitational Energy Storage System

The operating principle of the conveyor belt-based GESS revolves around a reversible conveyor belt using a regenerative motor (motor/generator). For energy storage, the reversible conveyor receives granular material from feeder conveyors positioned below the low-elevation stockpile and transports the material onto the high-elevation stockpile. The conveyor changes direction to release energy, accepting material from feeder conveyors placed below the high-elevation stockpile and transporting it back to the low-elevation stockpile.

The capacity of this conveyor-based GESS is limited only by the size and geometry of the stockpiles and elevation difference [1,3]. Conveyor belt-based GESS can be installed in decommissioned open-pit mines, which offer suitable topography and granular bulk material.

The model (Figure 1) used for energy calculation of the belt conveyor is based on existing computational models for calculating the required operating power of conveyor belts according to ISO 5048 and DIN 22101 standards. These standards specify methods for calculating the operating power requirements on the driving pulley of a belt conveyor based on the resistance calculation methodology. They combine design and operation parameters to calculate the power needed to drive the belt conveyor under certain operating conditions.

![Energy model used to estimate the performance of the conveyor belt-based gravity energy storage system.](image)

The key performance indicator of the conveyor-based GESS was selected as its overall energy storage efficiency, \( n_s \), defined as the ratio of output energy (\( E_{out} \)) to input energy (\( E_{in} \)), \( n_s = E_{out} / E_{in} \) [4]. The parameters affecting the performance of conveyor-based GESS are examined by employing sensitivity/uncertainty analysis. Travel length, belt width, speed, and conveyor inclination were selected as the key decision variables. Motor/generator efficiency, the belt filling factor, the coefficient of friction, transported material specific weight, and the resistance coefficient due to friction on the idlers were selected as the uncertain factors. Two scenarios corresponding to an optimized conveyor belt system and a typical one were examined, and the effect of uncertainty and decision parameters on the system performance was calculated. The optimized scenario considers a highly inclined (36.5 degrees) long (2000 m) conveyor belt, while the typical one considers a 1000 m long conveyor belt with an inclination of 12 degrees. The auxiliary equipment, such as reclaimers and stackers required for granular material handling, has also been considered in the energy model used to estimate its performance as an energy storage system.

3. Uncertainty/Sensitivity Analysis Results—Conclusions

Results of the uncertainty/sensitivity analysis indicated that regarding the uncertain parameters, the filling factor of the conveyor belt and the efficiency factor of the motor/generator had the greatest impact on the overall energy storage efficiency of the conveyor belt-based energy storage system. The calculated value for the overall energy
storage efficiency $n_s$ ranged from 0.84 to 0.90 for the optimized system (Figure 2) and from 0.44 to 0.75 for the typical system.

![Figure 2](image-url) - Uncertainty analysis results for overall energy storage efficiency $n_s$ for the optimized system (Monte Carlo simulation, 1000 repetitions). Values of $n_s$ in blue region are within 95% confidence interval.

Regarding the key decision parameters of the conveyor belt-based energy storage system, the results showed that the inclination of the conveyor had the greatest impact on overall energy storage efficiency, followed by the travel length and stockpile height of the granular material. The effect of the idler trough angle and the belt width on the overall energy storage efficiency $n_s$ was insignificant (Figure 3).

![Figure 3](image-url) - Effect of decision variables on overall energy storage efficiency $n_s$. 

**Figure 3.** Effect of decision variables on overall energy storage efficiency $n_s$. 

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The estimated values of overall energy storage efficiency are comparable to other existing energy storage systems (pumped storage, compressed air, batteries, and flywheels) [4]. Furthermore, energy storage systems based on conveyor belt operation have lower construction costs, longer lifespan, no storage losses, and do not produce waste during their operation. Dust produced during transportation could be prevented by selecting suitable material with low dustiness tendency and using dust suppression or fully closed systems.

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