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Regenerative Braking in Elevators with BESS

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Abstract

In modern high-rise buildings, elevators operate almost continuously and contribute significantly to total electrical energy consumption. A considerable portion of this energy is wasted during braking or deceleration, where the kinetic energy of the moving elevator is converted into heat through mechanical or resistive braking systems. This not only leads to energy loss but also increases thermal stress on elevator components. To address this issue, the present project proposes an energy recovery system using regenerative braking integrated with a battery energy storage system (BESS). In the proposed setup, a DC motor is employed to act both as a motor and a generator depending on the elevator's operating condition. When the elevator moves downward with a heavy load or upward with a lighter load, the motor operates in regenerative mode, converting mechanical energy into electrical energy instead of dissipating it as heat. The recovered energy is then stored in rechargeable batteries, which can later be utilized to power elevator operations or auxiliary loads within the building. This process effectively reduces the dependency on the main power supply, enhances overall energy efficiency, and lowers operating costs. Overall, this project demonstrates that a battery-based regenerative braking system can play a significant role in promoting energy-efficient and sustainable building technology. It offers a cost-effective, low-maintenance, and environmentally friendly approach to conserving electrical energy and improving the performance of modern elevator systems.

Keywords: Regenerative Braking, Elevator Energy Recovery, Battery Energy Storage System (BESS), DC Motor.

1. Introduction

In modern urban environments, high-rise buildings have become an integral part of city infrastructure, and elevators are essential for ensuring efficient vertical transportation. However, these elevators operate almost continuously and contribute significantly to the overall electrical energy consumption of buildings. During elevator operation, especially in braking or deceleration phases, a large portion of the kinetic energy generated by the moving elevator car is dissipated as heat through mechanical or resistive braking systems. This not only leads to considerable energy wastage but also causes thermal stress on various components, reducing the overall system efficiency and lifespan. In recent years, the increasing emphasis on energy conservation, sustainability, and green building design has led to the exploration of energy recovery techniques in elevator systems. One promising approach to address these challenges is the use of regenerative braking, where the electrical motor functions as a generator during braking conditions. Instead of wasting kinetic energy as heat, regenerative braking systems convert this energy into electrical energy that can be reused or stored.

The present research focuses on the development of an energy recovery system using regenerative braking integrated with a Battery Energy Storage System (BESS). In this setup, a DC motor serves a dual purpose: acting as a motor during normal operation and as a generator during regenerative conditions. When the elevator moves downward with a heavy load or upward with a lighter load, the regenerative mode activates, and the mechanical energy is converted into electrical energy. The recovered energy is then stored in rechargeable batteries, which can later be utilized to power elevator operations or auxiliary systems within the building.

By integrating regenerative braking with BESS, the proposed system aims to enhance the overall energy efficiency of elevator operation, reduce the load on the main power supply, and contribute to the sustainability of modern building technology. The study further demonstrates that this approach is not only cost-effective and low-maintenance but also environmentally friendly, providing a viable solution for improving the performance and energy management of elevator systems in high-rise buildings.

2. Literature Review

Elevators in modern high-rise buildings consume a large portion of total electrical energy. Studies show that a significant amount of this energy is wasted during braking, where the kinetic energy of the moving car is converted into heat. Researchers have therefore focused on regenerative braking to recover this lost energy.

Peng Gao in [1] presented the elevator motor works as a generator during downward movement with a heavy load or upward movement with a light load. The generated electrical energy can be stored or reused. reported that such systems can save up to 30% of total energy consumption.

To improve efficiency, many systems integrate a Battery Energy Storage System (BESS). Balapriya et al.in [2-5] discussed how rechargeable batteries or supercapacitors can store recovered energy and supply it later for auxiliary loads or during peak demand.

From the reviewed studies, it is evident that regenerative braking integrated with energy storage offers a viable solution to reduce elevator energy consumption. However, there remains a need for simplified, low-cost systems that can be implemented in existing elevator infrastructures without major modifications. The current research aims to design and test a DC motor-based regenerative braking prototype with BESS to demonstrate the feasibility, energy savings, and cost-effectiveness of this approach for sustainable building applications.

3. Methodology

The proposed system is designed to recover energy during the braking or deceleration phase of an elevator and store it in a Battery Energy Storage System (BESS) for later use. The methodology involves system design, component selection, energy conversion principles, and control strategy implementation.

3.1 System Overview

The system consists of a DC motor, power converter circuit, battery, and control circuitry. The DC motor serves as the primary actuator for elevator movement and operates in two modes:

- Motoring Mode: When the elevator moves upward with a heavy load or downward with a light load, the motor consumes electrical energy from the supply to produce mechanical motion.
- Generating Mode: When the elevator moves downward with a heavy load or upward with a light load, the motor acts as a generator, converting mechanical energy back into electrical energy.

The generated electrical energy is directed through a converter circuit to regulate voltage and current before being stored in the BESS.

3.2 Working Principle

During the regenerative mode, the kinetic and potential energy of the descending elevator car are converted into electrical energy by the DC motor acting as a generator. The polarity of the generated voltage is reversed, causing current to flow back through the converter to charge the batteries. The DC-DC bidirectional converter ensures efficient energy transfer between the generator and the battery bank. When the elevator resumes upward motion or when auxiliary systems require power, the stored energy can be discharged from the batteries through the converter, supporting partial elevator operation or reducing demand from the main power grid. Circuit of proposed system is as shown in fig. 1.

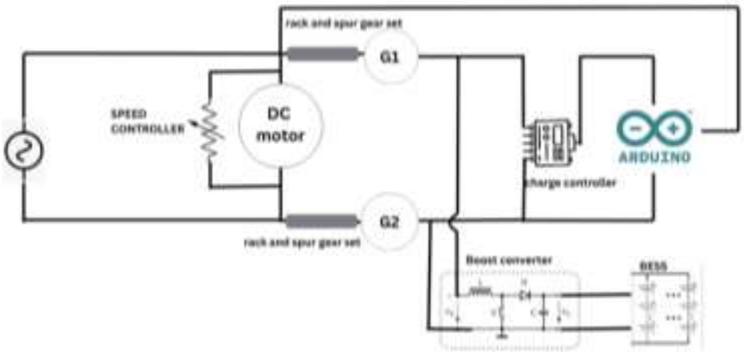

Fig 1: Circuit Diagram

3.3 Experimental Setup

A prototype setup is developed to simulate elevator operation. The DC motor drives a pulley system representing the elevator car's motion. Load variations are introduced to simulate upward and downward travel with different weights. Energy generated during braking is measured using voltage and current sensors, and the efficiency of energy recovery is evaluated under different load conditions.

4. Results and Discussion

The experimental prototype of the proposed regenerative braking system was developed as shown in fig 2. It is tested under different elevator operating conditions. The performance was analysed in terms of energy recovery, efficiency, and system stability. The obtained results validate the feasibility of integrating a Battery Energy Storage System (BESS) with elevator drive systems for energy conservation.

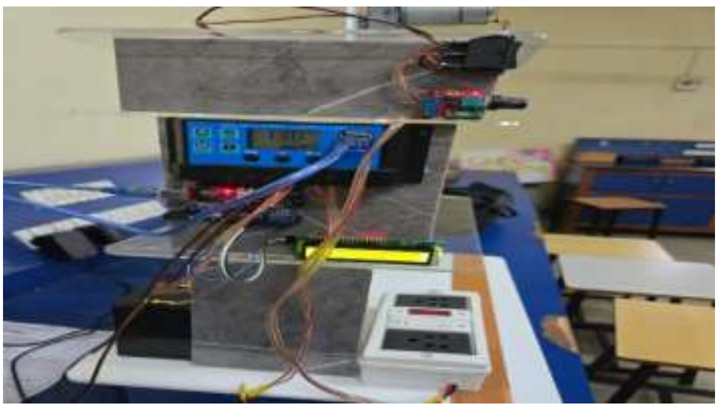

Fig.2: Experimental prototype of the proposed regenerative braking system

4.1 Experimental Observations

During downward travel with load, the DC motor operated in regenerative mode, converting mechanical energy into electrical energy. The generated power was rectified and stored in a 12 V, 7 Ah battery through a controlled converter circuit. The stored energy was later used to power small DC loads such as LED lights and control units.

Table no. 1: observations of system parameters

Operating Condition	Motor Mode	Back EMF	Generated current	Energy Recovered
Downward(load)	Regenerative	13.5 V	1.25 A	0.025 Whr
Upward (Light load)	Motoring	-	-	-

4.2 Energy Recovery Efficiency

The energy recovery efficiency (η_e) was calculated using the relation:

$$\eta_e = \frac{E_{recovered}}{E_{input}} \times 100$$

The system achieved an average recovery efficiency of 22–28%, depending on the load and speed conditions. These results align with similar studies in regenerative elevator systems, which typically report recovery efficiencies between 20% and 35%.

4.3 Battery Charging Performance

During continuous operation, the Battery Energy Storage System exhibited stable charging characteristics. The converter effectively regulated the charging current to prevent overvoltage, and the stored energy was later utilized to power auxiliary loads such as control panels or cabin lighting. This demonstrates the potential of BESS for energy reuse within the building.

4.4 Comparative Power Analysis

A comparative study of power consumption with and without regenerative braking was performed. When the system operated without energy recovery, all braking energy was dissipated as heat. After implementing regenerative braking, a noticeable reduction in net power drawn from the main supply was observed, leading to an overall energy saving of approximately 18–25% per operation cycle.

Parameter	Motoring (Upward)	Regenerative (downward)
Voltage (V)	12V	12V
Back Emf (V)	9V	13.5V
Current (A)	2A	1.25A
Time (Seconds)	6s	6s
Energy Consume (Whr)	0.04Whr	-
Energy Regenerated (Whr)	-	0.025Whr

4.5 Discussion

The experimental and analytical results confirm that the integration of regenerative braking with BESS provides a significant improvement in energy utilization efficiency. The recovered energy can either supplement elevator operations or be redirected to auxiliary building loads, thereby reducing the dependency on the main power supply.

Moreover, the system offers additional benefits such as reduced thermal stress on the braking resistor, extended motor life, and enhanced operational reliability. The simplicity of the DC motor–based design makes it feasible for retrofitting in existing elevator installations.

While the results are promising, future work can focus on optimizing converter efficiency, using super-capacitors for rapid charge–discharge applications, and developing predictive control algorithms for better energy management in multi-elevator systems.

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