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Study on Super-Capacitor Based Metro Train

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ABSTRACT

We can produce power from a variety of sources, including solar, wind, hydro, coal as a plant fuel, and so on. However, most have expense issues with plant setup, operation, management, or the resource availability (fuels) that will be depleted at some point. To minimize energy utilization during the voyage, a new generation of fast transit trains requires more better power management. In India, where the population is rapidly increasing, it is essential to manage traffic in India's major cities as well as environmental damage in the atmosphere. As a result, the metro is the key to reducing traffic and these mass transit vehicles also facilitate a significant reduction in emissions. This metro is not entirely reliant on energy, which means that the continuous supply that is utilized to power the metro via an overhead line will be withdrawn. The metro train system's overhead lines and other electrical infrastructure were also decreased. We will operate the metro train with the assistance of a super-capacitor bank, which will serve as a source. This supercapacitor unit will provide a constant supply to the train's motor. It comes with a one-time setup fee. The super-capacitor-based metro train is one of the best future successes, given the current high utilization of coal and other fuel.

1. INTRODUCTION

Metro trains, in comparison to buses and private automobile services, have enabled easy and safe commuting and are thus recognized as the green transportation mode. Metro trains are mostly employed for speedy transit in large cities because the distance between stations is short. However, due to the large-scale operations of metros, particularly in large cities, and high-frequency services, daily operations consume a significant amount of energy. Railway traction systems currently use overhead contact lines to convey electrical energy from feeding substations to moving rail carriages through a conveyor system, a sliding current collector. A large number of losses are reported due to overhead lines, lowering the system's overall efficiency. We can reduce traction system losses by lowering the length of overhead lines. We're going to operate a metro train with the help of a super-capacitor, which is a large and hefty battery that needs to be installed somewhere on the train to provide power to the engine. At each location, the supercapacitor is charged using both conventional and non-conventional sources. Solar panels put on the station's roof are used as a non-conventional energy source. The super-capacitor technology has been employed for energy on the basis of metro-train operation in order to minimize overhead current and, as a result, voltage drops at the train pantograph. This will eliminate the need for overhead cables, signal poles, and electric wires, as well as lowering maintenance costs. By looking for speedy fuel consumption in the current scenario, the super capacitor-based metro train will be a major success in the future.

2. Related Work

Diego Iannuzzi et. al. (2014) proposed a supercapacitor Design Methodology for Light Transportation Systems Saving has been described. The supercapacitor design has been directed toward the energy efficiency improvement, voltage regulation and high reduction of peak powers requested to feeding substations during the acceleration and braking phases. More specifically, the supercapacitor design problem for light transportation systems energy saving has been handled in terms of the isoperimetric problem. Starting from this point, the problem has been tailored as a constrained multi-objective optimization problem that without restrictions has been proven able to face all the interest cases. The optimization procedure has been tested both for stationary supercapacitors and for onboard arrangement. The procedure outputs are the supercapacitor storage size and the supercapacitor reference voltage which can be employed as a reference time trajectory to track during operating conditions [1].

M. Khodaparastan et. al. (2017) comprehensive review of the various aspects related to supercapacitors applied in electric rail systems, such as their design, sizing, and modeling, has been presented [2]

Zhongping Yang et. al. (2017) the mathematical model of the DC traction power system, which includes trains, ESDs, and traction substations, is established. Next, based on this, the SC state-based control strategy (SCSCS) is proposed, which can adjust the charging voltage of the ESD according to the SC voltage and current, then the charging current of the ESD can be reasonably distributed under the voltage difference of ESDs, and the SC voltage and current stress can be reduced. In order to determine the optimal controlling parameters, the optimization model is proposed and solved by the genetic algorithm. The analysis of the case study also shows the effectiveness of the proposed control strategy and optimization algorithm. Finally, the rationality of the proposed strategy is verified by experiments. [3].

Clemente Capasso et. al. (2015) presented a laboratory 1:1 scale test bench to perform experimental analysis on a Zebra battery plus supercapacitor-based propulsion systems for electric urban transportation. The analyzed case study is focused on a 70kW electric drive, specifically manufactured for electric urban road applications, supplied by a parallel of two 550 V - 38 Ah Zebra batteries and a 63 F super-capacitors bank. The electric power train is connected, through a fixed ratio gearbox, to a 100-kW regenerative electric brake provided with speed and torque controls, in order to evaluate the propulsion system performance in steady-state and dynamic operative conditions. The two different storage systems can be tested when working together and providing the required power to the electric drive, with different contributions by each storage device in terms of electric energy and power. In addition, different control strategies can be experimentally evaluated, depending on the tested driving cycle and with reference to a specific vehicle under study. For the above configuration, an evaluation of the real vehicle performance, in various operative road conditions, can find validation through this laboratory dynamic test bench. Finally, this experimental procedure to characterize and study electric power trains supplied by different kinds of storage systems highlights the real potentialities for manufacturers of electric vehicles in taking advantage of laboratory experimentations on the electric power-train, in order to support their design processes.

E. Rahimi et. al. (2018) designed a storage system and also the determination of its control parameters using the Particle Swarm Optimization (PSO) algorithm with the objective of energy saving in the metro network. Simulations have been done in MATLAB / Simulink software and based on actual data of the Mashhad urban railway. The simulation has been done in two modes, with and without an energy storage system. Some operational parameters including bus voltage and currents of substations have been obtained in these two modes. A comparison of simulation results shows the effectiveness of the proposed method.

The proposed system used a supercapacitor. The supercapacitor unit is nothing but the battery unit which is used to drive the metro train. By using supercapacitor, elimination of overhead line, catenaries and other electrical equipment like pantograph which is used to take power from an overhead line. The supercapacitor has low maintenance and it having a one-time investment. It gives better attractiveness.

3. MATERIAL AND METHOD

A. *Components Used*

- Supercapacitoror
- Arduino Nano
- DC Motor
- Relay
- Diode
- IR Sensor
- ON/OFF Button
- Transistor

B. *Proposed System*

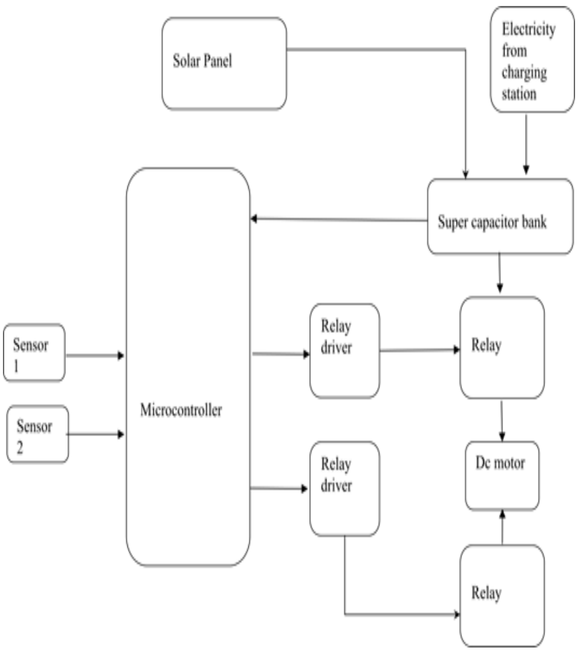

Figure 1: Proposed System

The proposed methodology decided is as given below.

As the aim of the paper is to drive the metro train on a super-capacitor, the super-capacitors are connected in series and parallel combinations according to the voltage and current requirement. This super-capacitor acts like a battery and is placed in the train so that it directly transmits its power to the motor of the metro train. Hence, the battery also gets discharged by giving its power for full filling the need of some system operations. Super-capacitor also gets discharged after some period of time by supplying continuous power to the motor, so it is necessary to charge this capacitor unit. The charging of the super-capacitor is done at every metro station by a pantograph which is mounted on the roof of the metro train. An overhead catenary is installed at every station to provide charging to the super-capacitor through the pantograph. When the train reaches any station, the pantograph is directly attached to the overhead catenary and the charging process takes place. We are using two sources as a power supply to the overhead catenary i.e., solar panel as a non-conventional source, and SMPS (switched-mode power supply) as a conventional source to perform the metro operation more efficiently.

The power that comes from both sources is stored in a battery which is also installed at the metro station, this battery supplies power to the overhead catenaries installed at that particular station for charging the supercapacitor bank. This same installation is done at every station for charging of super-capacitor. The forward and reverse operation of the motor is controlled by the microcontroller through the relays. There are two relays provided in the metro circuit which performs forward and reverse operation by switching one relay at a time. The microcontroller sends the signal to the relay and according to a signal received by the relay, switching is taking place and the motor will be operated.

C. *Working Procedure*

Consider the forward operation of the motor. The supply coming from the super-capacitor bank goes in relay RL1, and the relay shifts its contact from NO to NC. This shifting signal to relay is given by the microcontroller. At the same time, the relay RL2 is connected to ground contact i.e. NO. The motor starts moving in a forwarding direction and the train starts running in a forwarding direction. As the motor runs, the super-capacitor bank gets almost discharged when it reaches the next station. So on that station, the overhead catenary is provided to charge the supercapacitor bank through the pantograph. It takes near about 30 to 60 seconds to get charged. Once the capacitor bank is charged, it runs to the next station as explained above. This phenomenon is repeated at every station and for both forward and reverse operations of metro trains. Now, if the last station is reached by metro, we have to run the train in the reverse direction. For reverse direction movement of the motor, the microcontroller gives a signal to both relays and the relay RL1 contact is shifted to NO and the relay RL2 contact is shifted to NC. By shifting the relay contacts, the polarity of the motor gets reversed and the motor runs in the reverse direction.

If in case, there is any obstacle is founded on the track of the metro train, the infrared sensors which is provided at both ends of the metro train to detect the obstacle from a certain distance and give a signal to the microcontroller. To stop the train, if the motor is in the forward direction, the microcontroller reads the signal coming from that infrared sensor which is connected to the forwarding side of the metro train, and gives a stop signal to the relay RL1. For forward direction, the relay RL1 was connected to NC contact now it shifts to NO contact and both the relays are at NO contact so, the train will stop. If the motor is in the reverse direction and the obstacle is detected, the sensor connected to the other end sends a signal to the microcontroller, and further, the microcontroller sends a stop signal to relay RL2. For the reverse operation, the relay RL2 was connected to the NC contact but due to the stop signal given by the microcontroller, the NC contact is shifted to NO. Contact and train will stop.

4. Result Analysis

Table 1: One Time Charging

1.	Discharging time	90 sec
2.	Charging time	30 sec
3.	Load to be carried	584grms
4.	Run time of motor	90 sec

5. Advantages

- Low maintenance.
- Eliminate continuous use of overhead catenary.
- Eliminate other electric components.
- Elimination of transmission losses.
- Reduce the risk of line failure.

6. Conclusion and Future Scope

We conclude that our project aims to design a reliable system that has greater efficiency. The use of a super-capacitor has many advantages and prevents technical snags related to overhead catenary. It also reduces the risk of line failure as we reduced the overhead catenary. The use of solar energy to drive our metro train also reduces the consumption of conventional fuels required for the generation of electrical energy.

Conflict Of Interest

The authors declare that they have no conflict of interest.

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