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An Energy Storage and Rapid Charge System Using Supercapacitor for a Light Rail System which Runs on Renewable Energy

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ABSTRACT

A light rail system which runs on 100% renewable energy named the "Solar Light Rail" has been proposed by authors. Experiments using a prototype model have been carried out to demonstrate the availability of the rechargeable power supply method using supercapacitors. In the experiments using the updated equipment, the experimental condition is changed from the passed experiments, and the energy consumption per run is decreased. Low energy consumption causes running for a longer time after sunset. The handmade equipment is more efficient and makes the better result by the improvement.

1. Introduction

A light rail which is also known as a tram or a streetcar is a useful transport system to get around a city. A light rail system runs on renewable energy, such as photovoltaic, wind power, and micro hydro power and this system is named the Solar Light Rail [1, 2]. Fig. 1 shows the power supply method of the Solar Light Rail.

- Solar panels are mounted on the roof of the platform and around the station. Wind turbines are also built around the station. If there is a river, the micro hydro should be used. A supercapacitor unit is installed at the station as an energy storage device. This supercapacitor which is also known as an Electric Double Layer Capacitor (EDLC) is called the "primary EDLC" in this system. The primary EDLC is always charged with solar panels, wind turbines, and water wheels.
- Another supercapacitor unit is mounted on the railcar. This supercapacitor is called the "secondary EDLC" in this system. When the railcar stops at the station, the secondary EDLC is charged rapidly from the primary EDLC.

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– The railcar runs to the next station with the charged electricity.
– There are similar power generation system and the primary EDLC at the next station; the secondary EDLC is charged at the next station.

Demonstration experiments using the solar panels and a handmade small scale model have already been carried out. From conventional experiments carried out under disadvantage condition for photovoltaic such as in winter or in cloudy day, it is confirmed that the proposed power supply system functions effectively in the daytime. However, the railcar could continue running for only one hour after sunset in passed experiments, since the maximum voltage of the conventional primary EDLC is lower than the open circuit voltage of the solar panel. Electricity has to be consumed to keep lower voltage, and the electricity is not stored for after sunset.

The experimental equipment is renewed this time. The gauge of rail is widened to 15 inches (381 mm) from 5 inches (127 mm). The voltage of the solar panel and the breakdown voltage of supercapacitors roses. In this paper, the experiment using the new equipment has been reported.

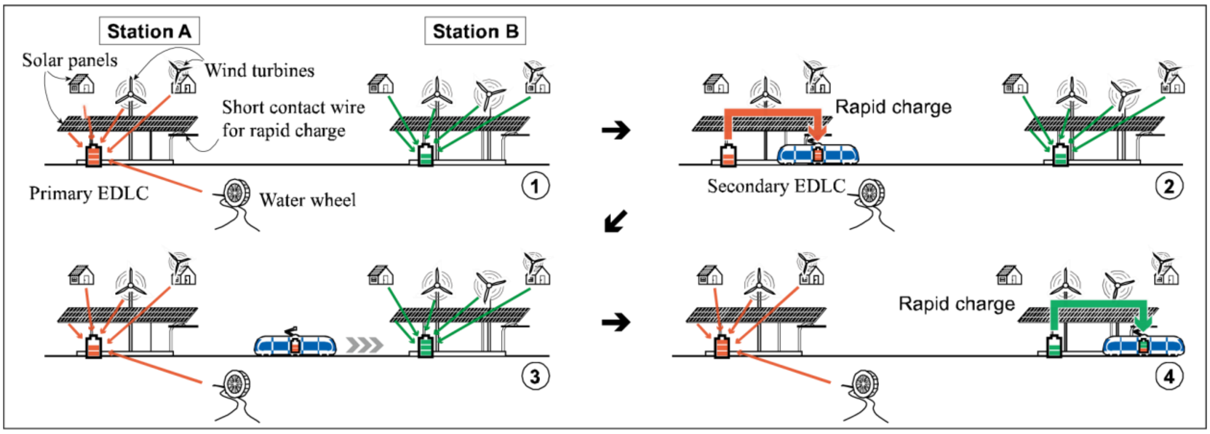

Fig. 1. *Power supply method of the solar light rail.*

2. Experimental Equipment

Fig. 2 shows the schematic diagram of the experimental equipment. Two solar panels are used in this experiment. One is a mono-crystalline silicon solar panel made by ARCO Solar, Inc. The open circuit voltage of 19 V and short circuit current of 3 A are measured in preliminary experiments. This solar panel is called as "solar panel 1" in this paper. The other is a handmade solar panel using 56 poly-crystalline silicon solar cells made by Suntech Power Co. The measured open circuit voltage for one cell is 1.75 V and the short circuit current is 1A. The 14 cells are wired in series and four sets of the wired cells are connected in parallel. The open circuit voltage of 24.5 V and the short circuit current of 4 A is expected for this panel. This solar panel is called as "solar panel 2" in this paper.

A supercapacitor unit model BMOD0165-E048 manufactured by Maxwell technologies, Inc. is used for the primary EDLC. The capacitance of the primary EDLC is 165 F and the maximum voltage is 48 V. The secondary EDLC is fabricated with cylindrical EDLC cells. The capacitance for one cell is 600 F and the maximum voltage is 2.5 V. The 9 cells are wired in series, and two sets of them connected in parallel. The secondary EDLC becomes the capacitance of 133.3 F and the maximum voltage of 22.5 V.

A limited current circuit is installed between the primary EDLC and the secondary EDLC for safety. The current during the rapid charge is limited up to 12.5 A.

A 15 inches (381 mm) gauge four-wheel car is fabricated with four independent wheels. Driving force from the 100 W DC motor is decelerated at 22.25:1 and is transferred to the left-rear wheel through the chain. A 1.8 m of iron angle bar is used for rail trucks. The total extension of the straight rail becomes 14.4 m.

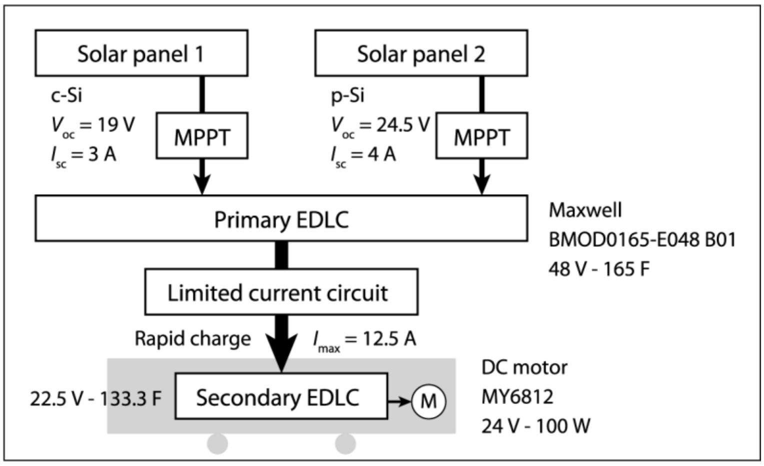

Fig. 2. *Summary of the experimental equipment.*

3. Results and Discussion

After the renewal of equipment, the voltage of the solar panel 2 roses to 24.5 V from 17.5 V; the maximum voltage of the primary EDLC roses to 48 V from 17.5 V; the secondary EDLC roses to 22.5 V from 15.0 V. Since the voltage of the primary EDLC became higher than the voltage of solar panels, it was not necessary to worry about the overcharge of the primary EDLC.

The experimental condition is also changed. In conventional experiment, the railcar went forward and back 3 to 5 times on the 9 m of straight rail after rapid charge. In this experiment, the railcar goes forward and back 1 time on the 14.4 m of straight rail. Running distance is decreased from 90 m to 28.8 m for each run. The time for the rapid charge has been fixed to 2 minutes. The experiment using the updated equipment has been carried out on 1st November 2016 at Hachioji Campus of Tama Art University (Tokyo, Japan). The rail truck has been laid on the corridor of the building and the solar panels are put on the balcony facing south west. The sunrise was 6:03 and sunset was 16:46 in Tokyo. It was rainy in the morning and became overcast in the afternoon. Fig. 3 shows the voltage transition of the solar panel 2, the primary EDLC, and the secondary EDLC under the experiment. The voltage of the primary EDLC has reached to 16 V at 10:55 and the first rapid charge has been carried out at 11:00. The second rapid charge has been carried out at 11:30 and the interval of rapid charge has been fixed to 15 minutes from the third rapid charge. The voltage of the solar panel 2 became lower than of the primary EDLC at 15:38 since the sun disappeared behind a building. The final rapid charge has been carried out at 22:50 and the railcar has been stopped at 22:56. The railcar has continued running for 6 hours after sunset. Interval of the rapid charge has been shortened from 15 minutes to 10 minutes after 19:00. The final rapid charge would be carried out at 24:45 if the interval is not changed.

In the conventional experiments, the voltage of the secondary EDLC fells about 2.8 V in average after run. The capacitance of the secondary EDLC is 100 F, so the railcar consumes 280 C of electric charge per run. In this experiment, the voltage of the secondary EDLC fells about 1.0 V in average. The capacitance of the secondary EDLC is133.3 F, so the railcar consumes 133.3 C of electric charge per run. 68% of shortening of distance per run causes 47.6% of decrease in energy consumption. The lower energy consumption brings running longer time after sunset. This handmade equipment, such as the rail trucks, a power controller, a power transmission system, and electric circuits can be more efficient. Better result is expected from improvement of the equipment.

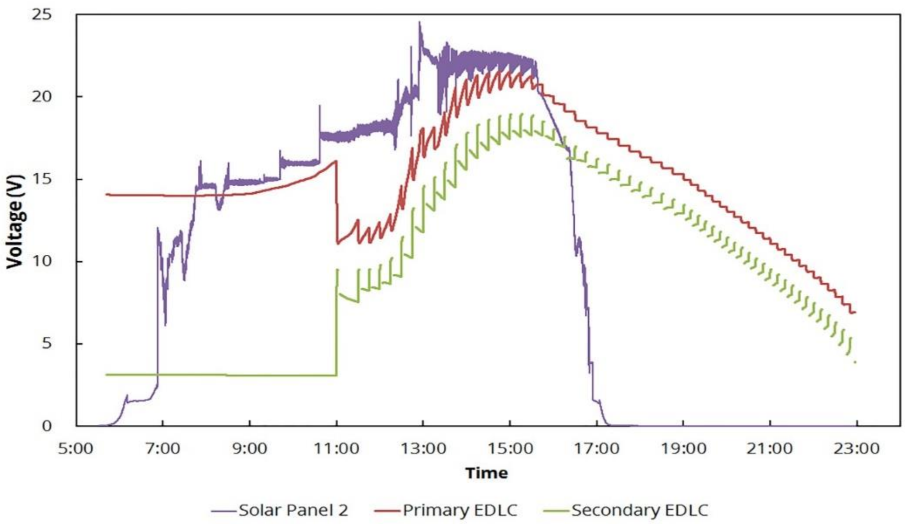

Fig. 3. *Voltage transition under the experiment.*

4. Conclusion

In this paper, a power supply method for a light rail which runs on 100% renewable energy was proposed. In the experiment using the updated equipment, the railcar could continue running for 6 hours after sunset by 47.6% of reducing energy consumption per run. It was confirmed that the low energy consumption caused running for long time after sunset. The handmade equipment was more efficient, so made better result by improvement of equipment.

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