PROPOSAL OF LRT USING RENEWABLE ENERGY

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1. Introduction

Is a vehicle that runs on electricity really environmentally friendly? In Japan, thermal power generation accounts for over 60% of all electric power. If railways, especially trams, could run on renewable energy such as solar power, wind power and micro hydropower, wouldn't that be truly environmentally friendly?
In this document, we propose an exactly environmentally friendly LRT (Light Rail Transit) system using renewable energy and we want verify feasibility.

2. Summary of the System

2.1. Method of Supplying Electric Power

How can we supply electric power by renewable energy to the railcar? First of all, the method of spreading the solar cells over the roof of the railcar like solar car is devised. But there are two problems in this method. The railcar cannot run in cloudy or rainy days and during the night. In addition, it's hard to use wind turbine and water wheels in this method.
Next, the method of replacing thermal and nuclear power plants with renewable energy power plants is devised. The electric power reaches from not the thermal or nuclear power plant but the renewable energy power plant though the electric power is supplied to the railcar as usual through the contact wire. However, the railcar cannot start in cloudy or rainy days even by this method. Moreover, the method of transmitting the long distance is unsuitable to power generation by renewable energy. Because power generation by renewable energy is not more efficient than thermal power generation and nuclear power generation. In Japan, the transmission loss of electricity is about 5.6%. The electric power of 168,120,000GJ was lost while transmitting electricity in 2008.
We propose the rechargeable run system. Solar cells are installed on the roof of the station and around the station. Wind turbines and water wheels are built around the station. The charging devices are installed at the station, and electricity from these generator is always charged to the charging devices. There is the short contact wire for rushing charge in the station. The charging devices are also installed in the railcar. When the railcar stops at the station, electricity is rapidly transmitted from the charging device of the station to the charging device of the railcar. The railcar charges with the electric power only to reach the next station at each stop. In this method, the railcar can run in cloudy or rainy day, and need not be considered the transmission loss.

2.2. Charging Devices

Rechargeable batteries are famous charging device. However, we propose to use EDLC (Electric Double Layer Capacitor) as charging device in this system. In this system, charging devices repeat charge and discharge. Advantages of EDLC such as long life, high input-output power, are suitable for our system.
The amount of energy stored per unit weight of EDLC is lower than that of the battery. But usually distance between stations of trams are shorter than that of railways. Therefore that cannot become a disadvantage in this system.

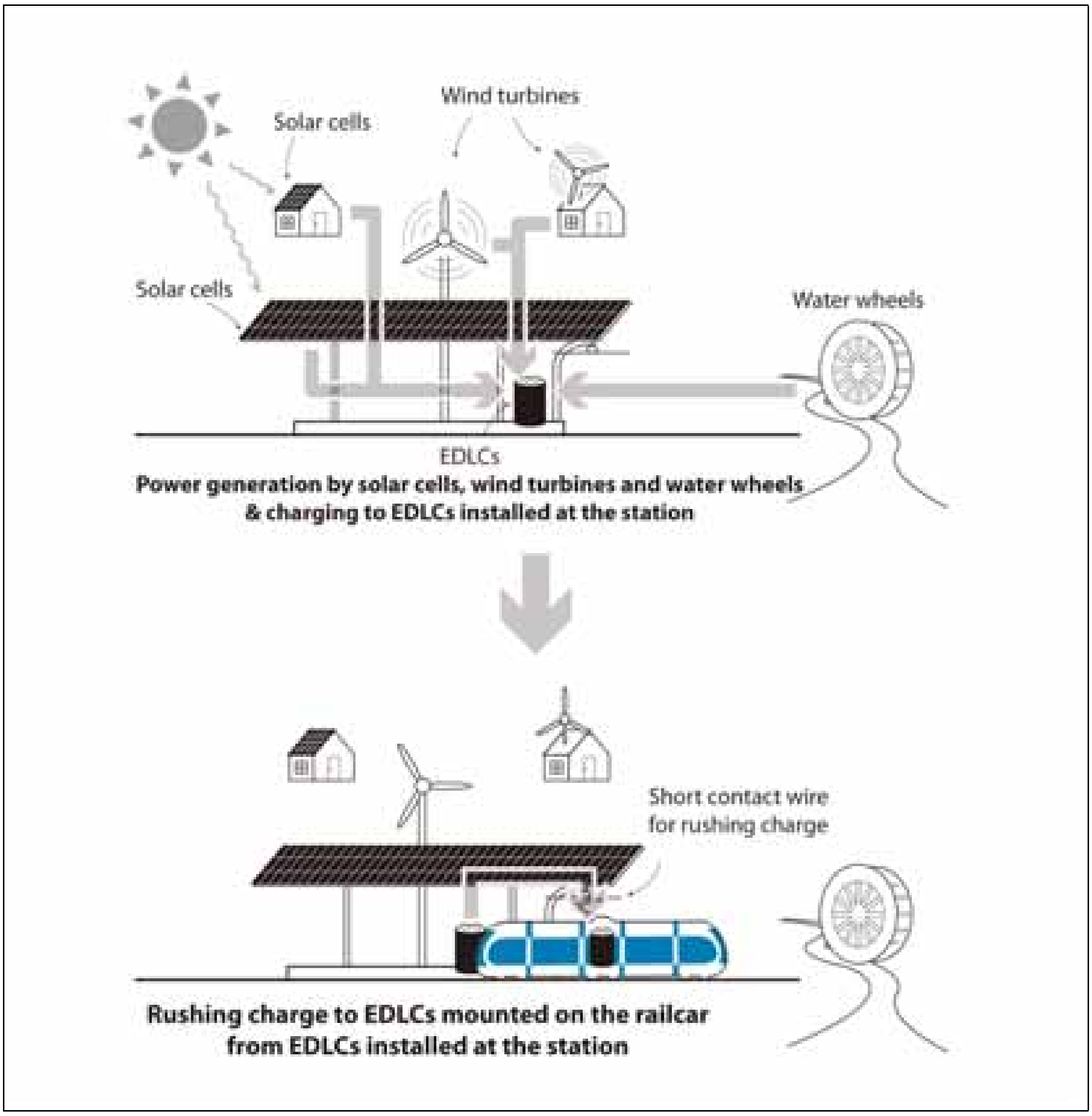

Fig.1 : Schematic diagram of power supply system

3. Verification

3.1. Amount of Required Electric Power

According to research on battery-driven LRV (Light Rail Vehicles) developed by the Railway Technical Research Institute, their LRV consumes the electricity of 8.9MJ per kilometers at the maximum air conditioning load. Assuming that interval between the stations is 500 m, a railcar requires 4.45MJ of electricity to reach the next station.

If a railcar arrives and departs every 10 minutes, a power generation capacity of 53.4MJ per hour is necessary for the station to transmit electricity to each railcar. When we assume that the first train of the day is 6:00 AM and the last train is 0:00 AM, the electric power necessary for a day is 961.2MJ, for one year is 350,838MJ.

Tab. 1: Quick charging at tram stops (test outcome)

Battery charging current & duration	Charged energy (at a battery terminals)	Running distance after charging (without air conditioning)	Running distance after charging (at the maximum air conditioning load)
1000A, 61sec.	35.6MJ	Equivalent to 7.9km	4.0km or over
500A, 3min. 16sec.	56.9MJ	Equivalent to 12.7km	6.4km or over

Fig. 2: Battery-driven LRV "Hi-tram"

3.2. Photovoltaic Generation

In Japan, the amount of power generation of the solar cells per year can calculate the rough estimate in *rated power* [kWh] × *1100* [hours]. If all electric powers of 350,838 MJ are supplied with the solar cells, the solar cells of about 89kW is needed. When the energy conversion efficiency of the HIT solar cells are assumed to be 19%, about 470 square meters are needed.

Roofless platforms or small roof platforms for tram are usual in Japan. If the roof of 2m in width and 30m in length is installed at each station, and the HIT solar cells is spread over the all aspects, about 12.8% of a necessary electric power can be secured. An insufficient electric power is filled with the solar cells installed in surroundings of the station, the wind turbines or the water wheels.

Fig. 3: Roofless platform and small roof platform for tram in Japan (left: Kumamoto / right: Osaka)

3.3. Wind Power Generation

Because it is set up in surroundings of the station, a small-scale wind turbine is suitable for this system. Assuming the wind turbines like Tab. 1, ten wind turbines of 10kW are necessary to generate 961.2MJ a day at the site of average wind speed 4m/s. "Kaze Nagasu Kujira" Daiwa Energy Co., Ltd. was referred to for these specifications.

The vertical axis wind turbine is suitable for this system because vertical axis wind turbine is more quiet than horizontal axis wind turbine.

There are street light that combine the savonius wind turbine with the solar cells. The supplemented role can be expected by setting these up on the road in the surrounding.

Tab. 2: Amount of electric power obtained by wind power generation and number of needed wind turbine

Rating output	Rating wind speed	Average wind speed	Capacity factor	Amount of power generation per day	Number of needed wind turbine
10 kW	11m/s	5m/s	21%	50.4kWh	6
		4m/s	12%	28.8kWh	10
2kW (max. 4kW)	9.5m/s	5m/s	21%	20.2kWh	14
		4m/s	12%	11.5kWh	24
1kW	12m/s	5m/s	18%	4.2kWh	65
		4m/s	9%	2.2kWh	123

Fig. 4: Wind turbine "Kaze Nagasu Kujira" 10kW by Daiwa Energy Co., Ltd.

Fig. 5: Solar cells & wind turbine hybrid tower "Kaze Kamome" by Panasonic Ecology Systems Co., Ltd.

3.4. Micro Hydropower

The micro hydropower can be used if there are a river or a waterway around the station. A steadier power supply can be expected compared with the photovoltaic generation and wind power generation.

$$P = 9.8QH\eta \quad [\mathrm{kW}] \quad (\text{eq. } 1)$$

The electric power obtained by hydropower can be calculated from eq. 1. The power generation capacity of 11.25kW is necessary to generate electricity by 970MJ a day. When we assume efficiency to be 0.72, the flowing quantity of 0.32 cubic meters per second is needed for the head 5m and 0.53 cubic meters per second for the head 3m.

Fig. 6: Pelton wheel in Wadayama Town (Hyogo Pref.)

3.5. Rushing Charge

Charging time is calculated from an electric energy necessary to run to the next station. Charging time means stopping time at the station. The EDLC trolley bus has already run in Shanghai (China). When EDLC of 600V-200F is charged by 200A, it takes 200 seconds to the full charge. This EDLC is used in the range from 400 to 600V. Therefore, the stop time of the station is computable from eq. 2, formula of the quantity of electricity of the capacitor.

$$Q = CV = It \qquad [C] \qquad (eq.\ 2)$$

If we assume the voltage of EDLC to be 600V in this system, the capacitance of EDLC is calculated from eq. 3 with 24.7F. It takes 30 seconds when EDLC of 600V-25F is charged by 500A, it takes 15 seconds when it is charged by 1,000A.

$$W = 1/2CV^2 \qquad [J] \qquad (eq.\ 3)$$

4. conclusion

It is feasible in the calculation to make trams run using renewable energy if electricity not only is generated at the station but also the electric power is supplied from the surrounding of the station. Moreover the stop time is a practicable range. The town where the trams run using renewable energy will be shown in Fig. 7.

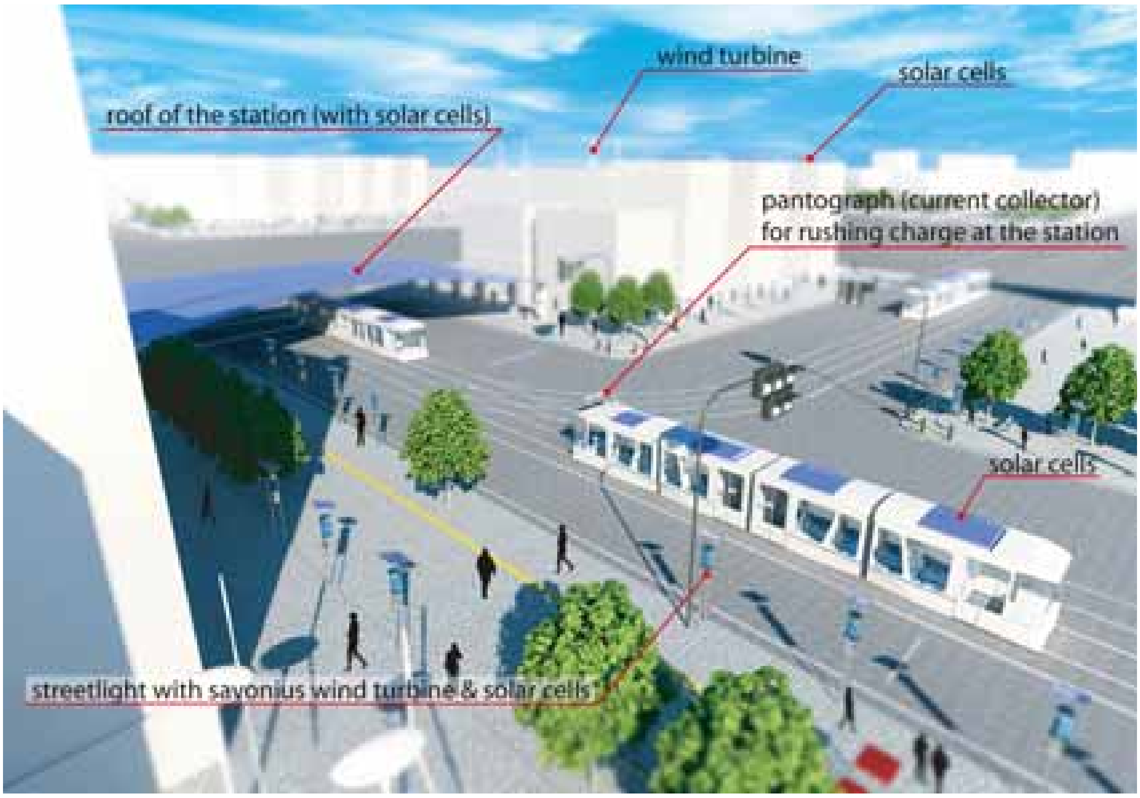

Fig. 7: The town where the trams run using renewable energy (illustrated by Takuma Shioguchi and Takuto Ichikawa)

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