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Renewable Delhi Metro

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Abstract

Many countries are already switching to renewable energy. Apart from looking for clean energy sources from the environment point of view, the search for new energy sources as substitutes for fossil fuel is another reason providing such drive with a projected world population of 10 billion by the year 2050, the increasing global energy demand will propel a more rapid depletion of the world’s fossil fuel reserves .such possible tightening of energy supplies in the future will inevitably result in an upsurge of fuel and electricity prices.

We propose an electricity supply system suitable for public transportation. In this system, solar cells are installed on the roof of the platform. Wind turbines and water wheels are built around the station. Electric double layer capacitors (EDLCs) are installed at the station, and EDLCs are always charged by renewable energy. EDLCs are also mounted on the railcar. When the railcar stops at the station, EDLCs of the railcar are rapidly charged from EDLCs of the station. The battery driven light rail vehicle developed by Railway Technical Research Institute consumes the electricity of 2.5kWh per kilometre. Assuming that interval between stations is 500m, a railcar needs 1.3kWh to reach the next station. If we assume that railcars arrive and depart every 10 minutes, and railcars are operated for 18 hours a day, the power generation capacity of 99,000kWh is necessary at each station in one year.

1. Introduction

Is a vehicle that runs on electricity really environmentally friendly? fossil fuel power generation accounts for over 60% of all electric power. This means that more fossil fuels are consumed, when electric vehicles spread. If railways, especially light rails, 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 metro system using renewable energy and we are going to verify feasibility.

1.1 Delhi Metro Profile

Delhi Metro Rail Corporation (DMRC) Limited registered on 03.05.1995 under the Companies Act, 1956 for implementation and operation of Delhi Mass Rapid Transit system (MRTS), has equal equity participation from the Government of India and the Government of National Capital Territory of Delhi.

DMRC has a mission to cover the whole of Delhi with a Metro Network by the year 2021 and to operate on sound commercial lines obviating the need for Government support. Delhi Metro Rail Corporation has already commissioned three lines comprising of 65.10 kms route with 59 stations with an average inter-station distance of 1.1 km in Phase–I and construction of 121 kms of Phase–2 with 78 metro stations is in progress, which is scheduled to be completed by October 2010.

Metro trains are energy intensive by its inherent service requirement of start, accelerate fast, attain maximum speed and stop at every station a km apart, within 85–90 seconds. For the existing network, DMRC has 6 nos. 220kV/33/25kV and 66kV/33/25 kV receiving substations and 72 nos. of 33kV/ 0.415 kV auxiliary substations, with total contract demand of 52 MVA and the annual energy consumption of around 200 million units. With the completion of phase–2, the contract demand is expected to rise to 150 MVA and with the annual energy consumption of around 600 million units.

Delhi Metro is member of NOVA an elite group of international metros and is the only metro in the world to have been approved for Carbon Credits for the regenerative braking in traction system.

DMRC being a Non–Governmental Railway, its indices are comparable with Zonal Railways, an enlisted category of industry of BEE.

1.2 Energy Consumption

The consumption of electrical energy is nearly equally divided between Traction (49%) and station auxiliary (non–traction) (51%). The underground stations being air-conditioned & with higher lighting requirements consume higher electrical energy, as compared to elevated stations. The operation of Delhi Metro be it the running of trains, air-conditioning of underground stations, lighting of stations, lifts, escalators, etc. involves electric energy consumption of 200 million units / Year, which constitutes around 25 % of the total operation cost.

Delhi Metro had adopted energy conservation measures right from the design stage by judicious evaluation on selection of system and technology. This has left limited scope for achieving further Energy conservations / saving in operations.

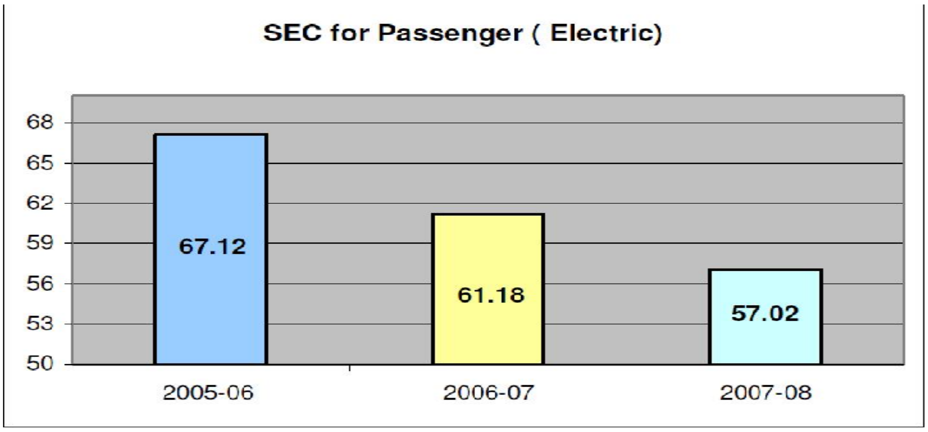
Discoms are metering the power supplied to DMRC on kVAh basis, therefore technology is so selected that the power factor of the traction and auxiliary supply system is being maintained close to unity.

2. Specific Energy Consumption Reduction Electric Traction

Table 1

	2005-06	**2006-07**	**2007-08**
Electric Units Consumed (Lakhs kVAh)	592.20	880.97	970.70
GTKM for Passenger	882275526	1440046730	1702270254
SEC for Passenger (kVAh / 1000 GTKM)	67.12	61.18	57.02
% SEC reduction during 2006–07 & 2007 – 08 for Passenger w.r.t. preceding year	-------	- 8.86%	- 6.79%

1.3 Graphical representation



For the purpose of bench–marking, the Specific Energy Consumption for Delhi is compared with the only other MRTS system in the country, i.e. Kolkata Metro. Specific Energy Consumption for Electric Traction of Delhi Metro for year 2007-08 is 57.02 against the Kolkata metro’s SEC of 73.0 (as ascertained) for the same period, i.e.

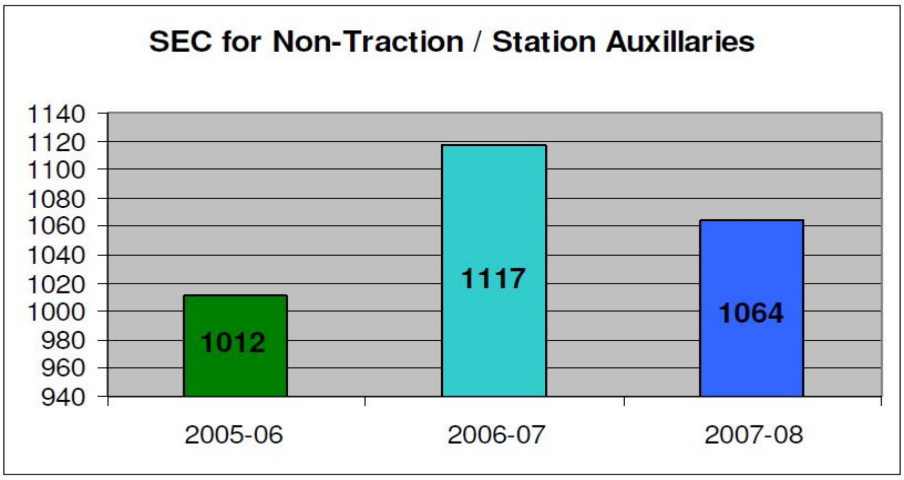
28% higher than that of Delhi Metro. For the DMRC passenger GTKM, the energy requirement for Traction would have been 1242.66 Million units based on SEC for Kolkata metro and 1514.10 Million units if the measures listed in Annexure–1 during design stage were not adopted.

3. Non–traction / Station Auxiliaries Electric Energy

Table 2

	2005–06	**2006–07**	**2007–08**
Electric Units Consumed (Lakhs kVAh)	607	1076.8	1025.4
Connected Load (in kW)	60000	96400	96400
SEC (kVAh / kW)	1012	1117	1064
% SEC reduction during 2006–07 & 2007 – 08 for Passenger w.r.t. preceding year	-------	10.41 %	- 4.77 %

Graphical Representation



Energy Conservation Commitment, Policy and Organizational Set up
Delhi Metro is committed to strive for providing a clean and environment friendly public transport network of international standard to the capital of the country and to set the bench-mark in India for operating a metro on sound commercial lines, which can be achieved only by ensuring an Energy efficient system at design stage and to make constant endeavour to operate in the most energy efficient manner.

Environment and Safety

a) The Environment Management System of Delhi Metro Rail Corporation has been awarded ISO 14001:2004 since 22.12.2005, and which is valid up to 28.08.2011.
b) The Occupational Health and Safety Management System of Delhi Metro Rail

Corporation has been awarded BS OHSAS 18001 since 22.12.2005, and which is valid up to 28.08.2011.

c) Delhi Metro is the first Railway project in the world to be registered by the United Nations under the Clean Development Mechanism (CDM), which will enable it to claim carbon credits. The Project has been registered on 29 December 2007 with the Project number 1351 with the title "Installation of Low Green House Gases (GHG) emitting rolling stock cars in metro system" and with credit period of 10 years up to 28.12.2017. Under the project, DMRC will earn Certified Emission Reductions (CERs) for the using regenerative braking system in its rolling stock (trains). This is the first time in the world that the United Nations Framework Convention on Climate Change (UNFCCC) has registered a project based on regenerative braking. Under the regenerative braking system, whenever a train applies brakes, the kinetic energy released starts a converter-inverter, which supplies electrical energy back to the Over Head Electricity (OHE) lines. This electrical energy is used by other accelerating trains in the same service line, resulting in 30 % saving of electricity requirement of the system.

DMRC can now claim 400,000 CERs for a 10-year crediting period beginning December 2007 when the project was registered by the UNFCCC. This translates to Rs 1.2 crore per year for 10 years.

4. Summary of the System

4.1 Method of supplying electric power

How can we supply electric power by renewable energy to the railcar? First of all, we can devise easily the railcar on which the solar cells are mounted on th roof, like a solar car. But there are two problems in this method. The railcar cannot run in cloudy or rainy days and during the night. In addition, it is hard to use wind turbine and water wheels in this method.

Next, the method of replacing thermal power plants and nuclear power plants with renewable energy power plants is devised. The electric power is supplied to the railcar from not the thermal power plants and nuclear power plants but the renewable energy power plants through the contact wire. However, the railcar cannot start in cloudy or rainy days even by this method. Moreover, the power transmission loss cannot be neglected. The transmission loss in India is about 10.7%. In 2008, while being sent from the power plants which exist in the distance, not less than 87 billion kWh electric power was lost.

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 charging devices are always charged from these generator. There is the short contact wire for rapid charge at the station. The charging devices are also mounted on 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 the electric power only to reach the next station at each stop. By this method, the railcar can run on the day of cloudy weather and rain. Moreover, we do not need to worry about transmission loss. Fig. 1 shows the schematic diagram of this system.

4.2Charging devices

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

5. Verification

5.1 Amount of required electric power

According to research on battery-driven light rail vehicle (LRV) developed by the Railway Technical Research Institute in Japan, their LRV consumes the electricity of 8.9MJ (about 2.5kWh) per kilometers at the maximum air conditioning load (13) (14) . Table shows the experimental result. Assuming that interval between the stations is 500m, a railcar requires 4.5MJ (about 1.3kWh) of electricity to reach the next station.

If a railcar arrives and departs every 10 minutes, a power generation capacity of 16kWh 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 a.m. and the last train is 0:00 a.m., the electric power necessary for a day is 270kWh, for one year is 99000kWh.

5.2 Photovoltaic generation

In India, the amount of power generation of the solar cells per year can be calculated the rough estimate in rated power [kWh] 1100 [hours]. If all required electric powers of 99,000kWh are supplied by the solar cells, the solar cells which are rated at about 90kW are needed. When using the HIT solar cells (energy conversion efficiency: 19%), about 470 square meters is required.

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 whole surface is covered with HIT solar cells, about 13% of required electric power is obtained. An insufficient electric power is filled with the solar cells, wind turbines and water wheels which were installed near the station.

5.3 Wind power generation

Since they are installed around the station, the small-scale wind turbines are suitable for this system. Assuming the wind turbines like table, ten wind turbines of 10kW are necessary to generate 270kWh a day at the site of average wind speed 4m/s.

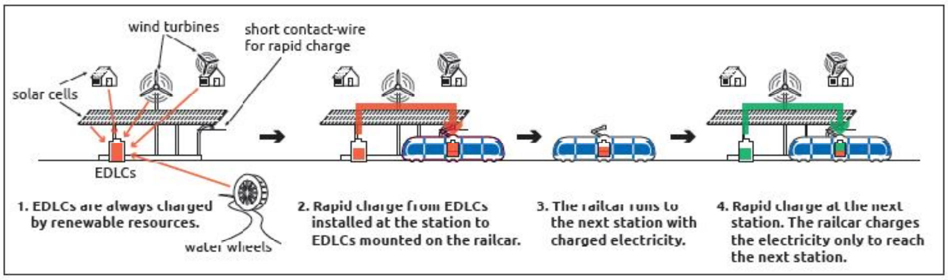


Fig. 1: Schematic Diagram of Power Supply System.

Table 3: Quick charging at tram stops.

Battery charging current & duration	Charged energy (at battery terminal)	Running distance after charging (without air conditioning)	Running distance after charging (with air conditioning)
1000A x 61sec	35.06MJ	Equivalent to 7.9km	4.0km or over
500A x 3min 16sec	59.69MJ	Equivalent to 12.7km	6.7km or over

Table 4: Amount of obtained Electric power and number of required wind turbines

Rating Output	Rating wind speed	Average wind speed	Capacity factor	Amount of per generation per day	No. Of required wind turdine of producing 270kwh a day
10kw	11m/s	5m/s	21%	50.4kwh	6
10kw	11m/s	4m/s	12%	28.8kwh	10
2kw(max 4kw)	9.5m/s	5m/s	21%	20.2kwh	14
2kw(max 4kw)	9.5m/s	4m/s	12%	11.5kwh	24
1kw	12m/s	5m/s	18%	4.2kwh	68
1kw	12m/s	4m/s	9%	2.2kwh	123

The supplementary role is expected by installing these along the street. 3.4 Micro hydropower The micro hydropower can be used if there are rivers or waterways near the station. A steadier power supply is expected compared with the photovoltaic generation and wind power generation.

$$P=9:8QH[kW] \tag{1}$$

The electric power obtained by hydropower can be calculated from eq. (1). The power generation capacity of 11kW is necessary to generate electricity 270kWh a day.

When we assume efficiency to 0.72, and a fall is 5m, the flowing quantity of 0.32m 3/s is needed. Similarly, when a fall is 3m, the flowing quantity of 0.53m 3/s is needed.

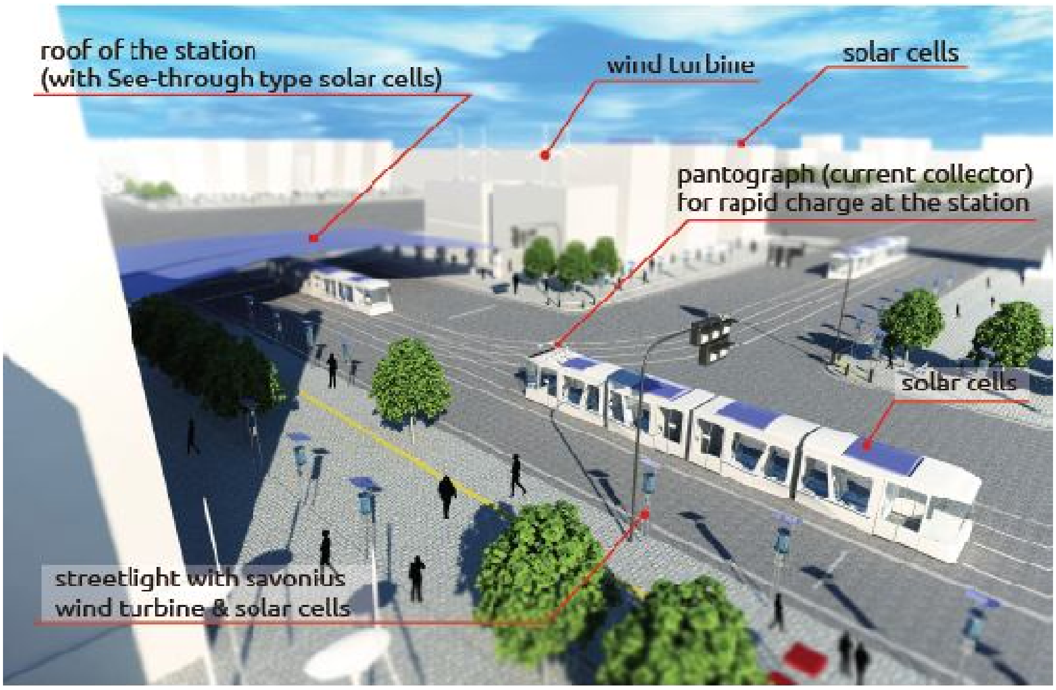
Rapid charge

Charging time is calculated from an electric energy required to run to the next station. Charging time means stoppage 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 (11). Their EDLC is used in the range from 400V to 600V. Therefore, the stop time of the station is computable from eq. (2), formula of the quantity of electricity of the capacitor.

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

$$Q=CV=It\ [C] \quad (2)$$

$$W=1/2\ CV^2[J] \quad (3)$$



6. Discussion

6.1 Feasibility to obtain electricity by renewable energy

It is unstable to obtain electricity only by renewable energy. Then, we make two proposals for obtaining electric power more efficiently. Since it is obtained only 13% of required electric power with a roof 2m in width and 3m in length, we would like to propose the style of roof which covers the whole road including a platform. Although priority was given to the design over efficiency when installed, the power generation for rated power [kW] _ 1000 [hours] has been kept every year. If the big roof is covered with see-through solar cells, it is expected that sufficient electric power can be obtained.

Moreover, although electric power is not insufficient in this system in the calculation, fuel cells are mounted on the railcar in preparation for electric power shortage. Since we use a fuel cell only to reach a nearby station, a mass fuel cell is not required. Although the hydrogen used for a fuel cell is usually generated from natural gas, we use bio-hydrogen (17).

6.1 Problem with safety

Compared with a battery, the danger of EDLC of ignitionor explosion is low. However, very low internal resistance causes rapid discharge when shorted. The container of EDLC which does not break even if a traffic accident occurs is required. Furthermore, it is effective to make it locomotive style. Safety improves by not installing EDLC on passenger cars.

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