APPLICATION OF GREEN ENERGY FOR EV BATTERY CHARGING STATION

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Abstract

The Well-to-Wheel (WtW) CO_2 emission of the electric vehicle (EV) strictly depends on amount of a carbon dioxide (including transmission and conversion losses) required to produce an electric energy used to charge EV batteries. Value of the WtW emission may be lowered by increasing a share of low-pollutant power plants i.e. using renewable energy or nuclear power, however it needs a large financial investments and it is very long process, taking over a dozen years. Even in the case of countries having a large share of low-emission power plants (Germany), a smart grids must be applied in order to optimize a value of WtW CO_2 emission. Usually batteries are charged during night, where energy demands are relatively low and at the same time wind turbines supplies majority of electric energy to the grid.

Presented idea of the battery charging station described in this article has a local character. It uses photovoltaic panels as a source of "green" electric energy. As a consequence the value of WtW emission for an EV batteries charged in this station equals to 0 g/km. The charging station uses EV battery swap thus the time of staying in the station is shorter in comparison with normal or even fast charging. The battery swapping technology uses replacing of the discharged units mounted in EV by fully charged ones. The batteries are placed in special try, which enables a quick mechanical and electrical connecting and disconnecting. Moreover, batteries stored in the station may be used as an energy storage devices and makes charging process optimization easier; moreover, they can be used as an element of a smart grid system.

The article describes model of charging station using both photovoltaic and quick EV battery swap.

Keywords: *CO_2 emission, photovoltaic, electric vehicle, charging station, renewable energy sources, batteries*

1. Introduction

Electrification of road transport envisaged in the coming years is caused by the limited reserve of energy resources, the fight against global warming as well as legal considerations [1, 2]. The concept of reducing greenhouse gas emissions (including CO_2) emissions from transport has found wide support among the governments of many countries, resulting in an extensive system of incentives and rewards under the ownership of electric cars. Depending on the country, they may include: subsidies, reduction of excise duty, free entrance to the city centres. One of the problems occurring during the operation of an electric car is to determine the total CO_2 emissions and to develop the methods of reducing it.

The energy stored in the traction batteries used in the electric propulsion system of a vehicle must be supplemented as far as depletion by charging from the power grid. During the production of electricity CO_2 is emitted to the atmosphere, the volume of which depends on the structure of the given power system. Thus, it is possible for the electric car, as in the case of vehicles with internal combustion engines, to determine the total emissions of CO_2 per km (WtW), which depends on the type of the power station supplying a given grid, transmission and distribution losses and efficiency of the propulsion system [3].

Table 1 presents the results of tests carried out by van Vliet [4] concerning the total CO_2 emissions from the cars of the compact class fitted with different types of drive. The emission ranges shown in Tab. 1 for the cars powered by electricity from the grid (PHEV and BPEV) mean the values obtainable depending on the type of the power plant from which the current used for charging becomes. For the electric car, BPEVWM 2015 the total emission amounts to 0 g/km in the case of the energy from renewable sources of energy, and 47 g/km for the energy from a gas power plant and 139 g/km with the use of energy from old-type coal plants [3].

Tab. 1. The total CO_2 emissions of a compact car, depending on drive configuration [4]

Drive configuration*	Fuel	Total emission, [g/km]
SZC	Diesel	156±5
SZI	Petrol	163±6
Parallel hybrid	Petrol	129±4
SHEV central engine	Petrol	108±21
SHEV motors in the wheels	Petrol	93±20
PHEV CM 2010	Electric energy/petrol	25-151
PHEVWM in the future	Electric energy/petrol	22-129
BPEVCM 2010	Electric energy	0-166
BPEVCM 2015	Electric energy	0-163
BPEVWM 2015	Electric energy	0-139
BPEVWM in the future	Electric energy	0-136

**) SZC - compression-ignition engine; SZI - spark-ignition engine, SHEV - serial hybrid drive; PHEV CM - "plug-in" hybrid drive with the central engine, PHEVWM- "plug-in" hybrid drive with motors in the wheels, BPEVCM - electric drive with a central motor, BPEVWM - electric drive with motors in the wheels.*

This paper presents a solution, which makes the WtW emission of an electric vehicle independent from the power structure of the given country. In the proposed method of the traction battery charging a local solar power station and battery exchange system were used. This makes it possible to obtain an electric vehicle with the total emission equal to zero.

2. EV battery charging station powered by PV

The charging station can be powered from the public grid or have their own power source. This solution has many advantages: it reduces the installed power of the power connection, which can be great in the charging stations, reduces operating costs, and enables the use of renewable energy regardless of the structure of electricity production in the given country. In the world-wide scale there are the solutions based on various sources of renewable and alternative energy, namely solar, wind, tidal, geothermal, biomass. The most frequently used source of energy is photovoltaic panels [5]. The Motor Transport Institute implements the project titled "Development and testing of the battery charging station for electric vehicles based on photovoltaic panels" [6]. The principle of operation of the charging stations is presented in Fig. 1. The source of electricity is photovoltaic panels on the roof of the building. In the event of insufficient energy from solar sources, it is taken from the public grid. In the case of excess energy supplied by photovoltaic cells, it is possible to give it back to the grid. The charging station is equipped with an energy storage system that facilitates the flow of energy between the station and the grid. The energy management system controls the co-operation of individual energy sources. An electric car is connected to the station via a charging controller. The main task of the controller is to optimize the charging process using a digital interface for battery management systems of individual vehicles.

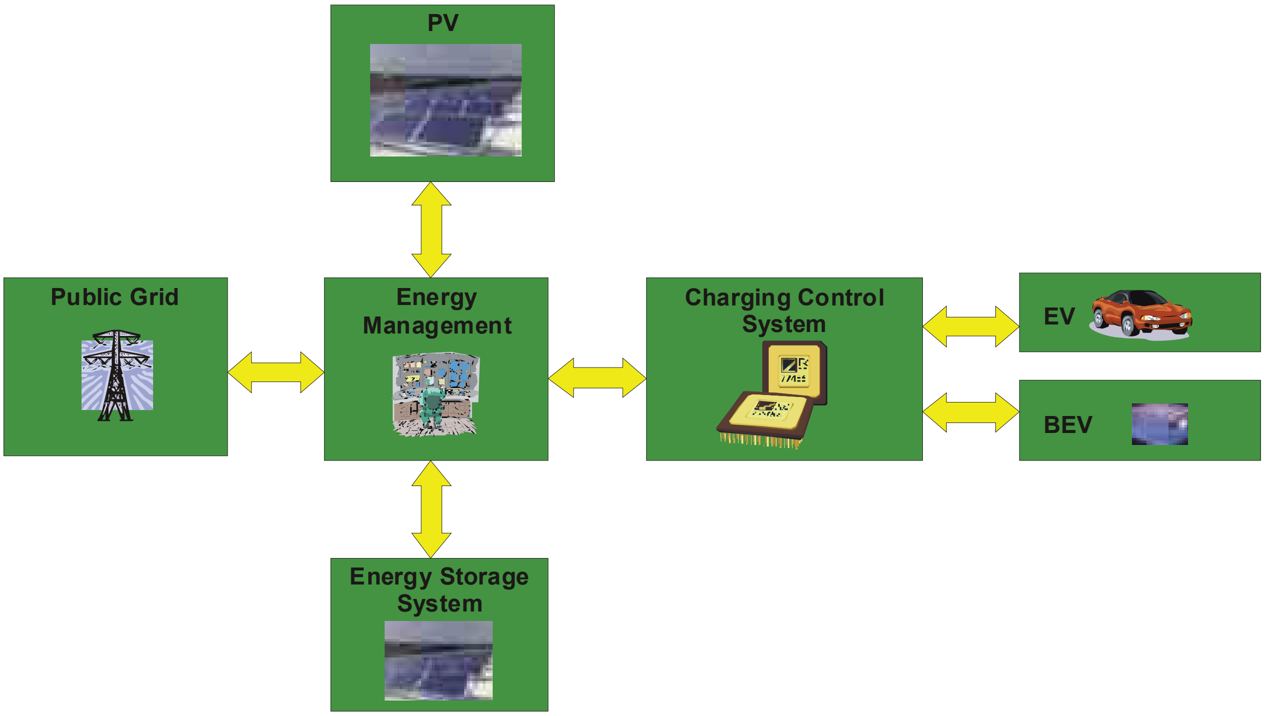


Fig. 1. Scheme of the charging station operation

Under the project in question a demonstrator has been developed that will be used to study the possibility of using the solar energy for charging electric vehicle batteries. To reduce the costs and boost the project implementation the demonstrator was executed as a reduced version of the planned station, i.e. the power of photovoltaic panels, capacity of charged batteries and constant voltage in the system were reduced. The principle of operation and the topology of the basic elements allow you to re-scale your model to the actual conditions of use. The view of photovoltaic panels mounted on the roof of the ITS laboratory is shown in Fig. 2 a). The power of the system at rated conditions is 1kWp. The panels have been combined into sections, each with a capacity of 250 W and a voltage of 12V U_{MPP}. The DC bus of the power electronics system operates at a voltage of 60V. The entire control equipment is placed in the cubicle shown in Fig. 2 b). Their compact design makes it easy to supervise the work of the unit and allows the use of equipment for teaching purposes.

The mounted device has a modular design. The power of photovoltaic panels and the number of rechargeable batteries can be increased by installing the additional converter modules. In the next stages of research, the charging station can be extended by an optional power supply from a different type of renewable energy sources such as wind turbine.

a) b)

Fig. 2. View of photovoltaic panels (a) and control cubicle (b) of the charging station demonstrator

3. EV battery swap

The charging station is equipped with 4 pieces of model lithium-ion packets. Their task is to simulate the traction batteries of electric vehicles using the station. Each package is built on a 13 IBR26700 type cells. Basic parameters of the packets used are shown in Tab. 2. The batteries were equipped with BMS (Battery Management System), which allows:

- monitoring system of many types of Li-ion batteries,
- monitor the individual cell voltages,
- monitoring the battery temperature,
- balancing the cells during charging/ discharging,
- up to 4 galvanic separated outputs to control external circuits,
- precharge system tailored to the customer application,
- protection against overcharging and deep discharge,
- overcurrent and short circuit protection.

Application of CAN interface in packages enables the power station communication with the packages to optimize the charging process. The view of the packages installed in the control cubicles is shown in Fig. 3 a), while the scheme of the package designs in Fig. 3 b). The demonstrator is equipped with optional package discharge, thus providing the simulation of the battery exchange station operation. The development of the strategy including the charging sequence, priorities, distribution of power into individual packages, the use of energy from the power grid, energy buffering or exporting the excess electricity to the grid will be the subject of further work.

Tab. 2. Package parameters

Rated capacity	11.2 Ah
Rated operating voltage	48.1 V (3.7 V/cell)
Rated charging voltage	4.18V/cell +/-0.05V = 54.3 V
End discharging voltage	2.7 V/cell +/-0.05V = 35.1 V
Max. charging voltage	4.20V/cell +/-0.05V = 54.6 V
Max. charging current	10 A
Min. discharging voltage	2.0 V/cell +/-0.05V = 26.0 V
Max, continuous discharging current	10 A (100 A in a peak of 1 s)
Rated operating temperature	+20 ºC
Permitted working temperature – discharging	-20 ºC-+60 ºC
Permitted working temperature – charging	-0 ºC-+40 ºC
Dimensions (W x D x H)	480 x 300 x 90 mm

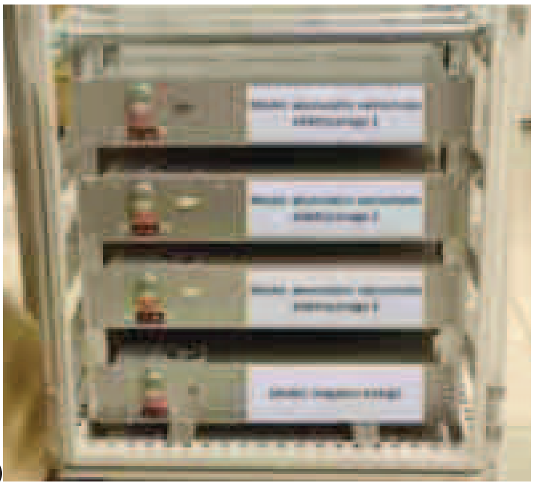
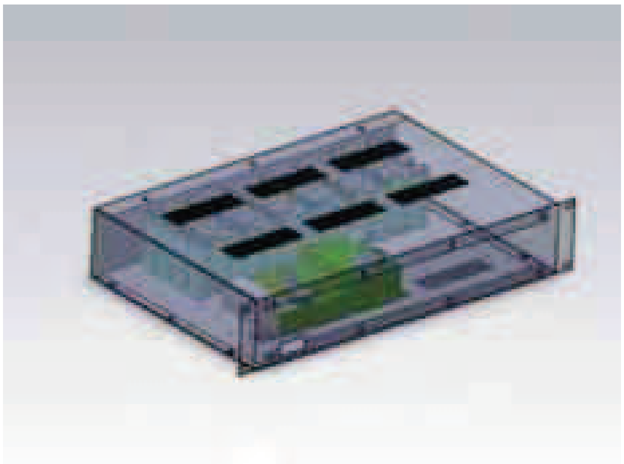
a)  b) 

Fig. 3. View of the batteries in the control cubicle (a) and internal scheme (b)

The concept of the battery exchange stations assumes that a vehicle leaves the discharged electric energy storage, and in its place installs the charged one. The exchange time is comparable with the classical refuelling at the petrol station. Then, the car is ready to continue the journey.

4. Summary

The developed demonstrator of the technology enables the analysis of the possibilities of using solar energy for charging batteries in electric cars. By using four independent battery packs simulating the traction batteries it is also possible to design and examine the concept of the battery exchange station operation.

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