ELECTRIC VEHICLE CHARGING CHARACTERISTICS

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Abstract. During the recent years interest about electric vehicle use on public roads is increasing. One of the most important and unsolved topics is about infrastructure creation for electric vehicle charging. It is not clear how much and what kind of connections to electricity network will be needed. In this study there is a practical research about Fiat Fiorino Elettrico HC-S automobile– about its needed connections and ability to charge batteries from household electricity connection 230 V, 16 A and AC 50 Hz. The experiment results show that there is a need to carefully reconsider the options for untroubled electric vehicle battery charging from household electricity connections, without disturbing the whole electricity connection operation. It was established that for the researched automobile in 7 hour charging cycle with voltage 230 V AC, the current from electricity network was 12 – 13 A, which is a remarkable part of the connection maximal value. At the beginning of the charging, during the first 60 seconds, the current from the electricity network was increasing gradually before reaching its nominal value 12 A, avoiding from the protection equipment interference.

Keywords: charging, batteries, electric vehicle.

Introduction

The world's population and standard of living is only growing, so there is an increase in energy demand. Fossil fuel prices are high, but alternative fuel implementation is slow and fragmented. Electric vehicles seem to be the next direction or trend, and are slowly gaining interest also in Latvian society. Most popular electric vehicles are bicycles, cars, scooters, senior and golf carts. Electric vehicles have 2 major disadvantages- the driving range and charging time. The range depends on the vehicle, terrain, weather, performance of the driver, weight and battery capacity. The electric vehicle charging time depends on many factors- the battery type, capacity, charger power, charging program, temperature etc. The charging time can range from 30 minutes to 20 hours or more depending on these factors. Development of compact and efficient electronic power converters allows some electric vehicles to be fitted with on-board chargers, to be connected directly to the electricity network, greatly improving the flexibility for the vehicle. Some chargers are also designed to maintain batteries in full working condition during storage. Electric vehicles need to be tested, so it is important to develop methods for gathering the characteristic data of charging. Using modern equipment and data loggers, it is possible to measure the charging characteristics continued and without assistance.

Every electric accumulator battery can be described with: voltage (V), capacity (Ah) (describes indirectly how much energy is stored), current (A) (depends on the capacity and load regime), electrolyte density (g·cm^{-3}) (ratio of the weight of a solution to the weight of an equal volume of water at a specified temperature), internal resistance (Ω) (all resistance sum from the active mass, electrolyte, connectors, temperature and charge rate) and temperature (°C).

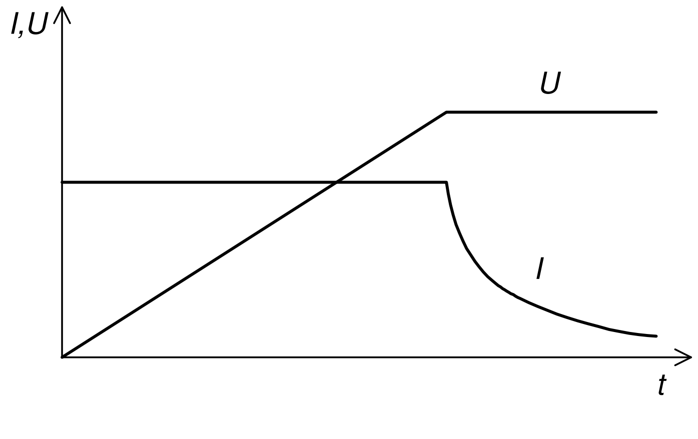

Fig. 1. **Accumulator I-U charging characteristics**

And the charging mode can be described with:

- charging time, h;
- charging voltage, V;
- charging current, A.

The charging mode consists of:

- main charging phase, where the bulk of energy is recharged into the battery;
- final charging phase, where the battery is conditioned and balanced.

Most chargers in use today use the so-called I - U characteristic, where the constant current I is used for the main charge and the constant voltage U for the final charge (see Fig. 1).

IEC61851-1 is an international standard for a set of electrical connectors and charging modes for electric vehicles and it has introduced 4 different charging modes [1].

- Charging mode 1 – slow charging from a household socket. The electric vehicle is connected to a single-phase or three-phase AC network with a standardized socket. This charging mode is not permitted in few countries due to that the required earthing is not present in all domestic installations.
- Charging mode 2 – slow charging from a household socket with a cable protection device. The electric vehicle is connected to a single-phase or three-phase AC network, with a charging control function, with an in-line module in the charging cable. The use of this charging mode requires both, an overcurrent protective device and a residual-current circuit breaker on the network side. Use of a surge arrester is recommended.
- Charging mode 3 – slow or fast charging using a specific socket with monitoring and protection controller. The electric vehicle is connected to a single-phase or three-phase AC network, with a charging control function, via an electric vehicle on-board charging device and a control module in the charging installation. The use of this charging mode requires both, an overcurrent protective device and a residual-current circuit breaker (RCCB) on the network side. Use of a surge arrester is recommended.
- Charging mode 4 – fast charging with external charger. The electric vehicle is connected to a single-phase or three-phase AC network with a rectifier. The use of this charging mode requires an AC/DC-sensitive RCCB on the network side, as well as overcurrent protective devices for AC and DC. Use of surge arresters is recommended.

Materials and methods

The experiments were carried out on Fiat Fiorino Elettrico HC-S automobile (see Fig 2). Specifications: 2 passenger vehicle, full mass 1700 kg, engine power: 30 kWh (nominal) 60 kW (peak), maximum gradient: 24 %, batteries: lithium 31.1 kW, motor: asynchronous three-phase, braking: regenerative, charger input: 230 VAC/ 16 A/ 3 kW, maximum speed 100 $km \cdot h^{-1}$, maximum distance 100 km [2].

For electrical characteristics measurement and data storage a Pico Technologies PicoLog ADC-24 data logger was used. Specifications: 24-bit resolution, accurate to within 0.1 %, up to 8 true differential inputs, up to 16 single-ended inputs, fast conversion time, digital output for control, galvanic isolation from the PC to eliminate noise pickup, dimensions 135 x 184 x 36 mm, power supply 100 mA (max.) from USB port, weight approx. 505 g.

The inertial rolling stand operates with the automobile driving wheels proportionally to the driving speed, imitating driving conditions and in this case it was used for discharging of the electric vehicle. Our tested vehicle was equipped with a battery safety feature that does not let the batteries to go bellow certain voltage, thus making sure that the batteries do not lose their capabilities during exploitation time by switching off power supply from the batteries. It can happen on a road, so it is safer to use a dynamometer for this purpose. The Mustang MD-1750 chassis dynamometer consists of mechanical, electro-mechanical, and electronic modules, that simulate actual road loads to get data not only for performance, but also for emission and driving cycle tests. Specifications: maximum power – 1283 kW, maximum absorbed power – 294 kW, maximum speed – 100.56 $m \cdot s^{-1}$, Pentium-based PC controls, MD-7000 control platform. The vehicle must be fixed on the chassis dynamometer with straps from front and back, to keep the automobile straight and in place.

Fig. 2. **Experiment object during charging**

REV digital energy measuring tool (190 – 276 V, 20 mA – 16 A, 5 – 3680 W, ± 0.01 kWh) was used for measurement of the consumed energy. The electricity characteristics were measured with 10 second intervals during the charging measurements. PicoLog ADC-24 data logger was used for gathering the experiment results. The data logger was equipped with a current converter A1 and current transformer T1 (see Fig.3.). The actual power, current and voltage values were controlled by REV digital energy measuring tool P1, which also was registrating the total consumed electric energy.

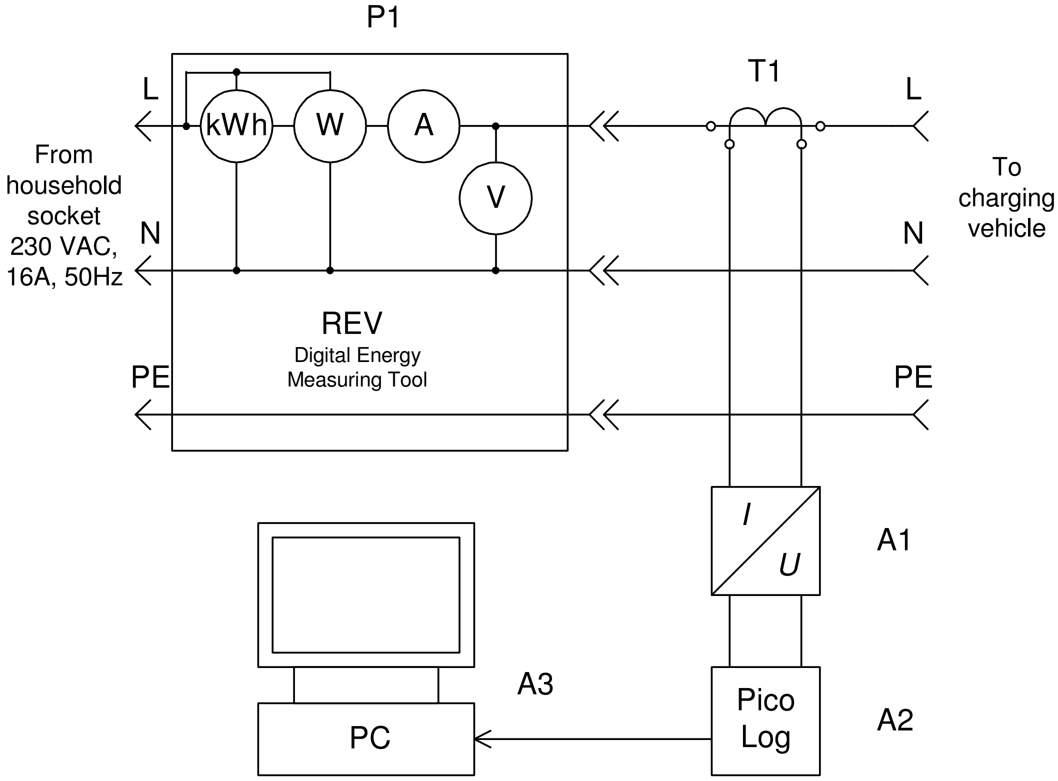

Fig. 3. **Electric measurement diagram**

Results and discussion

Charging current increase is very important at the beginning of the charge, there should not be any high peaks that can cause overloading of the power source.

The experiments were carried out 5 times, in which the total consumed electric energy curves were similar, the charging time differed because the automobile batteries could not be discharged absolutely similarly. The consumed electricity current value and change in the time was very similar. When the batteries were fully charged, the electricity network current value decreased to 1.86 A. Then it increased to 6.29 A, then decreased to 1.86 A, after that increased to 4.47 A and again shortly decreased to 1.86 A. The final increase was to 3.12 A, which followed by decrease to 1.86 A and switched off (Fig. 4).

The average total consumed electricity energy during the charging cycle was 20.02 kWh, averaging 98 km driven distance. Maximal charging power 2923 W was registered by the energy measuring tool REV. After the charging cycle ended, the current decreased to 0.13 A. The electricity network voltage was average 230 V during charge.

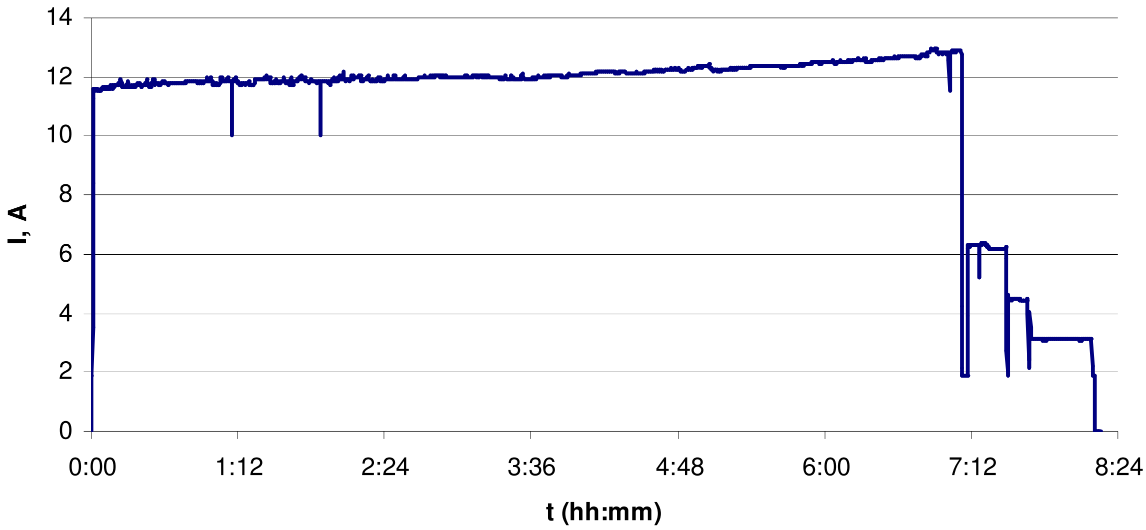

Fig. 4. **Full charging cycle current characteristics**

The experiment results confirmed that the Fiorino charging type corresponds to mode 2 and can be used in household typical sockets with ground wire. The standard household one phase electricity connection is 230 V and 16 A inlet fuse. This kind of electricity connection can provide electric vehicle charging on condition, that the household consumed electricity does not exceed 4 A. That means, other household electricity consumer loads need to be reduced to guarantee stable connection operation. The remaining theoretical usable power reaches 4*230=920 W. That means, no electric kettles, washing machines, irons or water boilers can be used during charging, the remaining power could be used for lighting and computer use, or there is a need that more efficient home appliances are introduced.

Precisely planning the electrical power consumption, the vehicle charging can be coordinated with home appliance use. The simplest solution is to charge the electric vehicle during the night, when home appliances are not in use. A more advanced and expensive solution is to increase the power of electricity connection. There is also a solution to introduce a smart electrical load distribution system, determining the priorities for electricity consumers and vehicle charging. The worst impact on effective connection use is given by short time big loads, for example, electric kettles, ovens and water flow heaters.

Table 1

Charging current increase at the beginning of charging

Time, s	0	10	20	30	40	50	60
Charging current, A	0	1.867	1.904	3.509	8.425	11.249	11.586

During the study of the charging results, we established that at the beginning of charging, the current value is steady increasing before reaching its nominal value in 60 second time. This technical solution provides a stable connection to the electricity network. The experiment results are given in Table 1. The Fiorino automobile charging current gradual increase is a very important factor for the occasion when there is a need to use alternative energy sources, where for current transformation an electronic inverter is used, which has protection for a short period overload. This can be related also to portable autonomic internal combustion engine generators used for battery charging in urgent situations.

Conclusions

1. From the study results it is clear that the Fiat Elettrico Fiorino HC-S automobile battery full charge needs 7 hours, with electricity connection that can provide 12 - 13 A, 230 V, 50 Hz alternating current, that means that a regular household connection is used near to its maximal current.
2. Charging electrical automobile at home means reducing other household electricity consumer total power used simultaneously.
3. In case of automobile charging, it is worth exploring new technical solutions for creation a smart charging system, dividing the electricity consumer connection priorities in a household.
4. With growing of the electric vehicle popularity, there will be increased electricity network load expected, that can lead to the necessity for household connection power upgrade.

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