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USABLE ENERGY OF ELECTRICAL VEHICLES AND CHARGING STATION EFFICIENCY ACCORDING TO E-SORT PROTOCOL

G. S. Milushev

Abstract: An important part of assessment according to the E-SORT (Standardised On Road Test cycles for Electrical vehicles) protocol is the Usable Energy measurement and as an addition, calculating the Energy Efficiency of the charging station. Even clear as a methodology, the measurement of the energy during the charging process has many specifics. The report present results from a real test of a charging of a fully electrical bus with a super-cap Rechargeable Energy Storage System (RESS) in compliance with the E-SORT 2017 UITP (Union Internationale de Transport Publique/ International Association of Public Transport) document. The obtained results were documented and certified by an independent accredited inspection body.

Key-Words: Electrical Vehicles, Electrical Energy Consumption, DC Electrical Energy, Energy Efficiency, Charging Stations, Rechargeable Energy Storage System.

1. Introduction

Usable energy measurement of the RESS is the difference between maximum level of State of Charge (SOC) allowed by the manufacturer during a normal charging phase until automatic stop of the charger - SOC_M and the minimum level allowed by the manufacturer during a normal operation of the vehicle until a warning signal on the dashboard appears SOC_W [1].

SOC_W is always over the minimum SOC defined by the producer. Usually SOCW is the condition when vehicle is not able to reach 30 km/h, or a warning signal appears.

The test for Usable Energy Measurement may be carried out before or after the Tests for the Energy Consumption Measurement, because it is required to be done once for a given bus configuration.

The aim of the present report is to formalize the results obtained during tests for Usable Energy Measurement according the E-SORT methodology under requirements of [1] and [2].

The inspection team applied the methodology over two types of Charging Stations (CS) which is reflected on the applied connection schemes [4]. The applied approach differ to the methodology used in [3] where the Load Profiles of CS ware used for Energy Consumption Measurement.

2. Methodology

The methodology used complies to [1].

The charging process happens in the following two steps:

1^{ST} STEP: battery discharge [1] is necessary to discharge the RESS close to the charging station until its SOC_W. The experience of the inspection team shows that it could be done during normal exploitation of the bus, if the line is long enough to discharge the RESS to acceptable level of SOC_W.

2^{ND} STEP: battery charge of the RESS until $SOC = SOC_M$ with a power rate allowing a full charge of the RESS [1]. The E-SORT foresee charging time within 6 hours, what has any reason if the RESS is an accumulator. In case of Supercap, the charging time takes several minutes. In the most cases the charging time is pre-set with limits depending of regular transport schedule what fix SOC_M by time and not by level.

This circumstance leads to decreasing of the parameter d^{Max}_i - the Maximal Range on $SORT_i$ and it is not suggested d^{Max}_i to be compared with the results obtained in other conditions.

$$d_i^{Max} = \frac{100.E_c^{Max}}{C_i} = \frac{E_c^{Max}}{E_i}\, d_i \qquad (1)$$

E_C^{Max} = energy measured downstream the charging station [kWh]

C_i = energy consumption on $SORT_i$ [kW.h/100 km]

E_i = energy measured on $SORT_i$ [kW.h]

$dMax_i$ = maximum range on $SORT_i$ [km]

2.1. Connection of the tools for energy measurement

The method applied on the second step - Battery Charge - is described on Fig.1

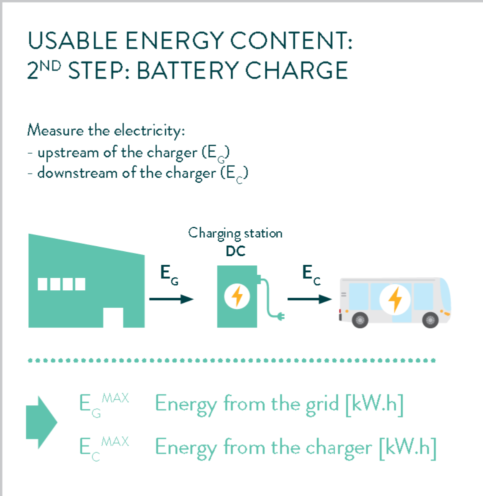

Fig. 1 Connection for Usable Energy Measurement, Source [1]

2.2. Connection upstream of the charging station on the AC panel

AC connection of the measurement tool (Network Power Analyzer) depends on the three-phase network type. In the most cases the network connection is near the MV/LV power transformer type 3Ph+N and the following connection (Fig 2) could be used.

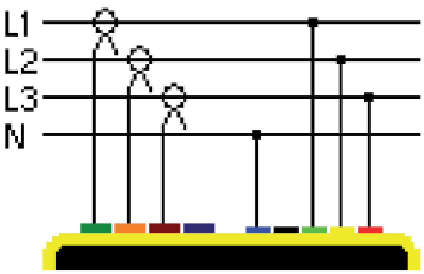

Fig. 2 AC Upstream Connection of the Analyser for Usable Energy Measurement, Source [4]

• Current connection with AC clamps toward each of the three phase cables;

• Voltage connection – four wire, three-phase connection (AC).

2.3. Connection downstream of the charging station

DC connection downstream of the charging station also depends on the construction of the charging station. If it is a single module CS the connection from Fig. 3 can be applied:

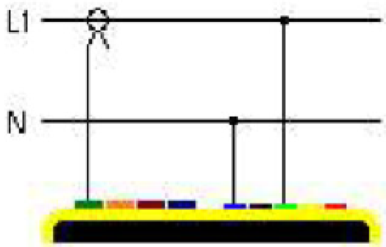

Fig. 3 DC Downstream Connection of single-module CS, Source [4]

If the CS is from several modules (for example Master and Slave on Fig. 4) each module shall be measured by a separate channel of the analyzer:

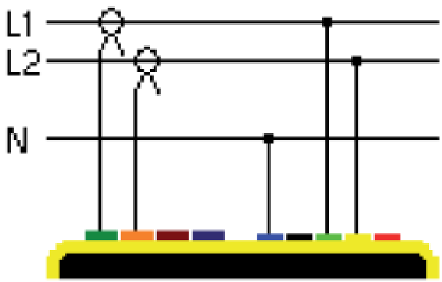

Fig. 4 DC Downstream Connection of multi-module CS, Source [4]

In this case the connections are:

• Current with DC clamps to the charging cables (+) toward each of the two modules of the charging station;

• Voltage directly to the charging cable terminals (+/-);

The DC energy transferred from each of the modules is measured. The respective currents, voltages and powers ware registered during the charging period. The energy analyzer makes the summation of the powers and the energies.

2.3. Points of inspection

There are some difficulties when the Upstream and the Downstream connection points are too separate. The synchronization of the start-stop time in this case shall be assured in advance adjusting the analyzer's clocks to one base and having live connection between the operational personal (Fig. 5 to Fig. 8).

Fig. 5 Upstream inspection point of the charging station: The currents, on the board of the electricity meter's LV panel and the voltages on the respective LV busbars in the directly adjacent protective panel

Fig. 6 Downstream inspection point between two CS modules

Fig. 7 Connection point to the Master Unit of CS

Fig. 8 Connection point to the Slave Unit of CS

3. Test Results

The test results presented hereafter are an example for representative case, despite the charging time is pre-set with the time limits of the final stop on a regular bus line.

3.1. Initial charge value in RESS

The yellow light for SOCW appear on 12% (Fig. 9). Start charge time fixed to 06.06.2018, 13:48:54 h

Fig. 9 SOCW appear on 12%

3.2. Final charge value in RESS

The final charge value in RESS, fixed by the charge time of the charging station is 92% (Fig. 10).

End charge time is fixed to 06.06.2018, 13:54:32 h what means that the charge duration is 5 min 34 s.

Fig. 10 SOCM level 92%

It is an acceptable level for SOCM taking into account the charging process power curve (Fig 11) where the voltage level adjustment process has started.

3.3. Energy from the grid

Active energy coming from the LV power supply is EGMax = 30,012 kW.h (Fig. 12)

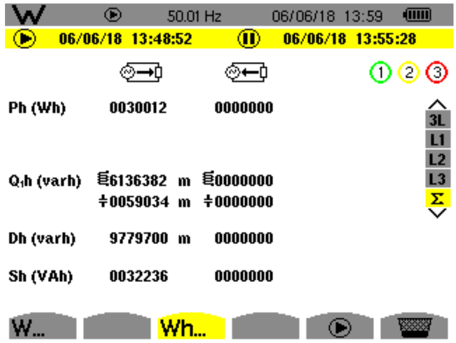

Fig. 12 AC Active Energy from the grid

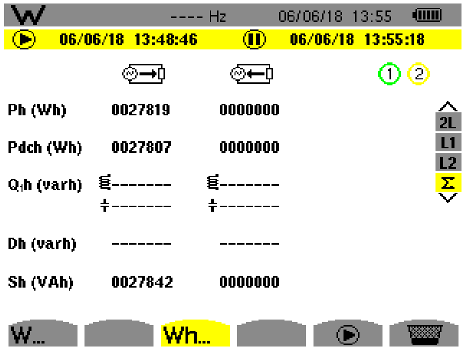

Fig. 13 DC energy transferred from the CS

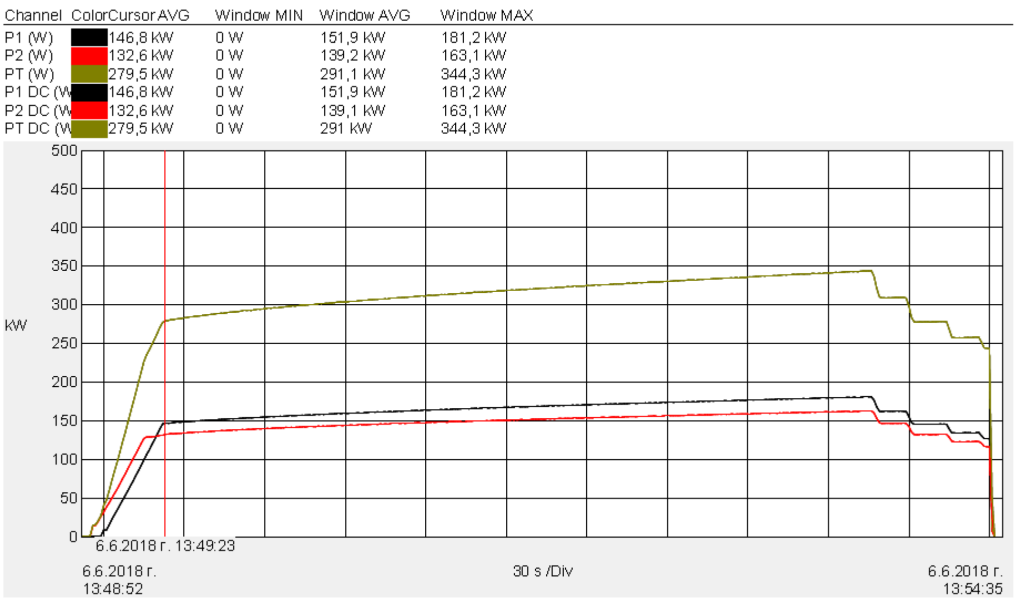

Fig. 11 DC Power profile during the charging process of the electrical bus

Table 1

№ by E-SORT	Item	Definition	Value	Unit
0.1	E_G^{Max}	Energy from the grid	30,012	kW.h
0.2	E_C^{Max}	Energy from the charger	27,807	kW.h
0.3	/	Nominal charging power	344,3	kW
0.4	/	Charge duration (maximum 6 hours)	0,0939	h

3.4. Energy from the charger

DC energy transferred from the charging station to the electrical bus is

$$E_C^{Max} = 27{,}807\ kW.h \qquad (Fig.\ 13)$$

3.5. Charging efficiency

Efficiency of the charge of electrical bus by the CS in compliance with E-SORT 2017 is:

$$\eta_C = E_C^{Max}/E_G^{Max} = 0{,}9265 \qquad (2)$$

$$\eta_C\% = \eta_C \,.\, 100 = 92{,}65\ \% \qquad (3)$$

3.6. Usable energy by E-SORT

The Usable Energy is presented according the requirements of [1] in the following Table 1

4. Used Energy Registration Tools

The technical tools used for this inspection are dully calibrated according the requirements of [1] and ISO 17025 to assure traceability and reliability of the results.

Energy Analyzer type C.A 8335 with a set of Current Clamps C 193 is used for the energy from the grid. Energy Analyzer type C.A 8335 with DC Current clamps PAC 93 is used for the energy from the charger

5. Conclusions

1) The most important characteristic during the test for Usable Energy Measurement is the value of the DC energy transferred from the charging station to the electrical bus E_C^{MAX}. It's value is used to calculate all the other comparative characteristics in E-SORT.

2) A correct value of the Usable Energy could be obtained, even the charging time is pre-set to any limit, only when it is reasonable analyzed from the point of view of the normal end of the charging process.

3) The synchronization between the two analyzers has an important role for correct measurements. On this aim, the record of all registered quantities is the verification for the proper actions.

6. References

[1] **UITP PROJECT E-SORT,** Cycles for Electric Vehicles, International Association of Public Transport (UITP), Rue Sainte-Marie, 6 | B-1080 Brussels | Belgium, Legal deposit: D/2017/0105/9

[2] **UITP PROJECT SORT,** *Standardised On-Road Test Cycles,* New edition UITP 2014, International Association of Public Transport, Legal Deposit: D/2014/0105/1

[3] **G. S. Milushev, K. S. Kirilova, K. S. Stanev,** *Method for Assessment of the Consumption of Elektrobus Using Load Profile of the Charging Stations,* Proceedings of XXV National Scientific Symposium with International Participation 'Metrology and Metrology Assurance 2015', Sozopol, 7-11 Sept. 2015

[4] http://www.chauvin-arnoux.com/en/ produit/ CA8335 **Chauvin Arnoux** C.A. 8335 *Operating Manual,* France, 02-2011, Code 692272C02 - Ed. 3

Information about the Author:

George Sashov Milushev, MSc in Electrical Measurements (1987), PhD in Measurement Systems (1992), Assoc. prof. (2010) in the Department of Electrical Measurements, Faculty of Automatics, Technical University Sofia, Bulgaria. Scientific field and interests: Electrical Measurements, Energy Measurements Energy Management and Efficiency, Electrical Power Quality, Safety Inspection and Conformity Assessment, Quality Control and Management. Workplace: Technical University-Sofia, Faculty of Automatics, Department of Electrical Measurements, Mailing address Sofia 1000, 8 Kliment Ohridski blvd,

Web address: *www.tu-sofia.bg*

e-mail address: gm@tu-sofia.com