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Solar Carport

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Abstract. A Solar Carport integrated with second-life EV batteries was installed at Óbuda University. It collects and stores solar energy and charges electric vehicles. It is a fully green concept, not just because of the solar panels or EV charging, but it is giving a 2nd life to electric vehicle batteries that are produced in a huge amount for the automotive market and ready to be utilized for green energy storage. The system demonstrates how an average household can combine the second-life EV batteries with a solar system and charger.
The system consists of Solar panels, Inverter, EV batteries, EV chargers and Battery Management Unit (BMS). The remotely controlled element of the Solar Carport can be a detail of the city-wide microgrid too.

Keywords. Solar Carport, EV Batteries as storage, PV, EV charger.

1. Introduction

The number of the EV's is strongly increasing by any forecast (see Fig.1.). One of the main elements of an EV is the battery. The EV batteries span from 20 kWh up to 200 kWh [1]. So 10 million 100 kWh EV cars require 1000 GWh battery capacity.

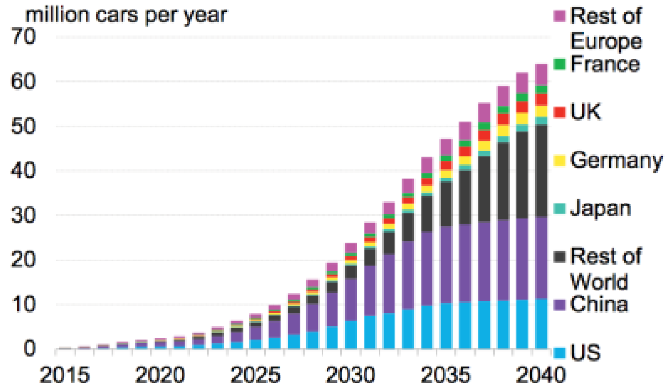

Fig. 1. Annual global EV sales by market [2]

The future lithium-ion battery need is shown in Fig.2. Let us mention that now "we are" in the figure, the first five years are facts. The world's lithium-ion battery production was about 345 GWh in 2020 [3].

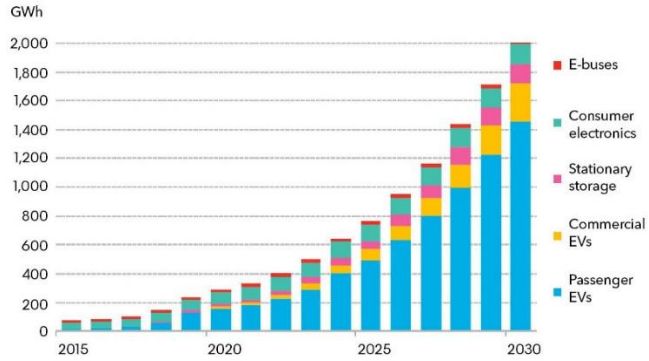

Fig. 2. Forecast of annual lithium-ion battery demand [4]

In spite of the high expectations the lifetime of the batteries is limited and strongly depends on the usage of the EV. It is hard to find an EV with 10 years old batteries. The batteries are working but with limited characteristics (see Fig.3.).

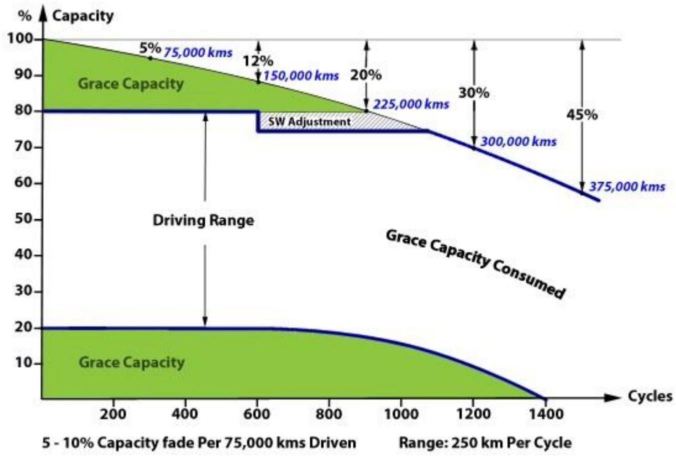

Fig. 3. Aging of batteries by usage [5]

After 10 years the battery becomes waste. That can be deposited or recycled. The energy invested by the battery production won't be utilized any further.
Meanwhile, in another market, the power storage need is growing. It has two directions as the concentrated high dynamic power system inertia and FACT tools and the distributed low capacity (5-30 kWh), low dynamic household storages. It is estimated to reach 305 Gwh by 2030 (see Fig.4.).

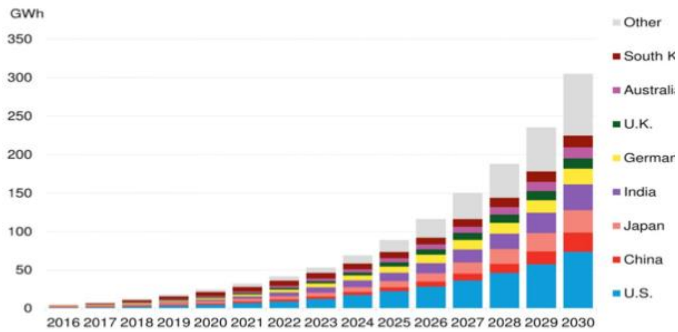

Fig. 4. Forecast of global storage capacity forecast [6]

The specific European household storage deployment is shown in Fig.5. It is roughly 1 % of the total storage need but a well isolable group of application.

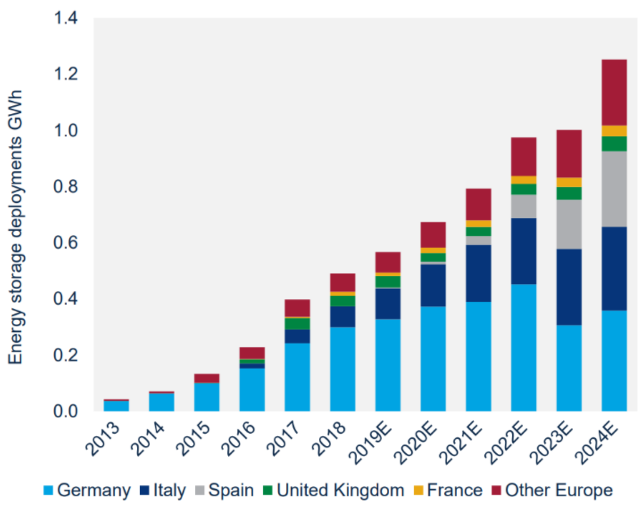

Fig. 5. The annual Europe residential storage deployments [7]

If we match the storage need with the emerging second-hand EV batteries we gain a lot of energy and material. It helps sustainability and saves the environment.

2. The environmental effects

All human activities have environmental impacts. The effects are mainly negative such as the exhaust of the materials, waste depository, CO_2 emission, energy usage…By the Life Cycle Assessment methodology [17], the environmental load can be calculated for all steps of the EV battery process such as mining, transportation, drying, coating, filling, packing, welding, etc. The many diverse affections are condensed in the specific equivalent numbers as all the greenhouse gases are going to CO_2 equivalent and all the acidic emission goes to the SO_2 equivalent. This CO_2 footprint can be projected in per km unit (see Fig. 6.).

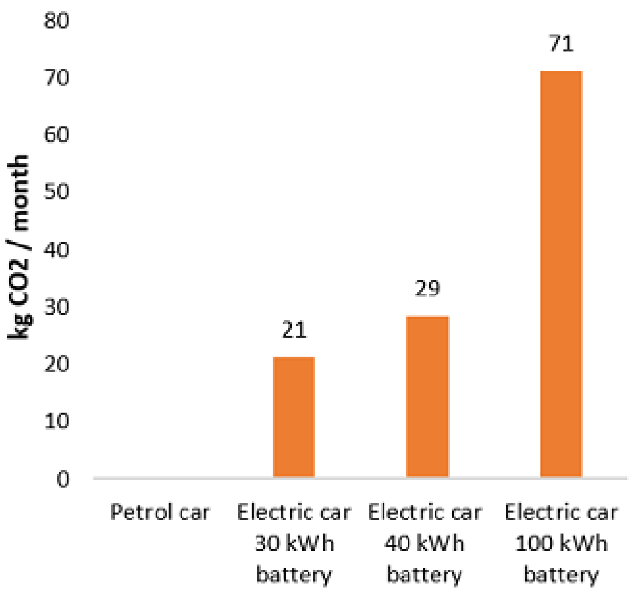

Fig. 6. CO_2 footprint of battery production [8]

The battery production of the EV requires so much energy and produce so much CO_2 like the production of the car chassis [9]. Moreover, this energy and emission are doubled if we produce a brand new battery explicitly for storage purposes.
We aim to double the useful lifetime of the EV batteries with the extension of the usage period in a quiet household storage mode.

But how can we put it into action in our close ambiance?

3. The novel application

In this innovative development we applied the following elements:

- the PV (photovoltaic) generation is known for decades it is widely spread over -> PV
- the household battery systems are used for the intraday storage of PV energy -> storage
- It is useful if the parking lot (carport) is shielded against the strong solar irradiation for extending the lifetime of the car and to decrease the air conditioning energy need -> shadowing
- thousands of new electric cars are coming into service today but these will leave millions of battery units that must be treated -> used battery
- the slow and medium speed (3-22 kW) EV chargers typically work at night when the car owner arrives at home -> EV charger
- instead of serially connected high voltage battery systems we put parallel the 48 V DC packs

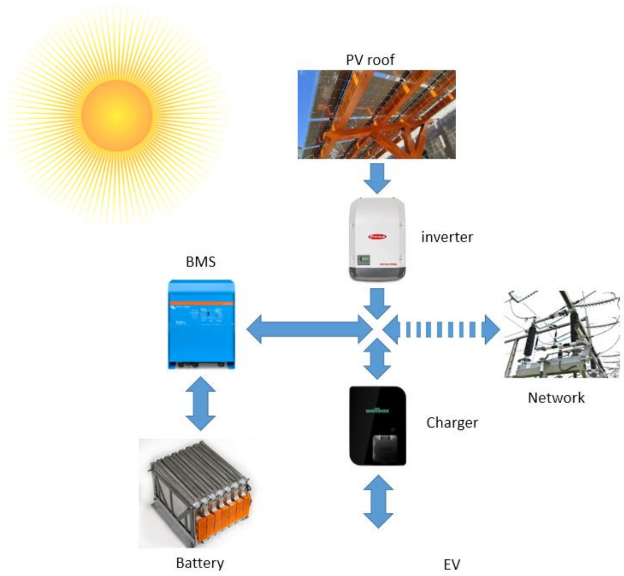

Fig. 7. The Solar Carport System

4. The system

The Solar Carport demonstrational unit includes the followings (see Fig.8.):

- 7 kW Glass-Glass, high-quality solar panels
- 7 kW Fronius inverter with smart meter and remote control functionality
- 2 units of 22 kW Wallbox Copper SB smart charger with remote control functionality
- 2 units of flexible Victron Battery Management System with remote control functionality
- 2 units of Nissan LEAF 2nd life batteries, some of the battery modules
- A wooden (green message) strong (laminated technology) stand, designed for this purpose
- The full system can be remotely monitored and controlled
- Every single component of the system is produced in Europe (including the EV battery)

A. The roof

The Solar Carport is a roof holder structure made of cemented layer wooden parts with 3 legs. It covers/shadows twin EV charging park slots. The PV panels are on the roof. The chargers are fixed on the legs and the other electronic parts as the inverter, batteries and battery management system are put in a steel box close to the roof.

B. The PV panels

We applied monocrystalline double glass semi-transparent PV panels, a product of Soli Tek company, Lithuania. The 24 pcs of 320 W_p panels provides 7,680 W_p. The high-quality panels have 30 years 90% capacity guarantee.

Fig. 8 The transparent PV panels with wooden holders

C. The charger

The system is mounted with 2 pcs of Wallbox Copper S AC charger with Charge Mode 3. / Connector Type2. It has built-in DC fault identification. It can be remotely controlled (web access) and also integrated with an RFID key card.

D. *The inverter*

The elements of the system are connected to a one-phase 230 VAC bus. The PV generation flows through an 8,2 kW Fronius Inverter. We built in a Fronius Smart Meter that is capable of load control till 63 A, data log, load optimization, web access and visualization.

E. Batteries

We built in 4 - 8-year-old Nissan Leaf Lithium-Ion $LiMn_2O_4/LiNiO_2$ battery modules. The early Nissan LEAF in 2012 contained a 24 kWh capacity battery – 24 modules, 4-cells / module, 0.25 kWh / cell. The 2018 LEAF has already 40 kWh capacity in 24 modules, 8-cells / module, 0.21 kWh / cell.

Fig. 9. Compact EV battery packs [10]

F. *Battery Management System*

The Battery Management System (BMS – Victron Energy Quattro 48V 8KW inverter/charger manages the battery depending on the SOC (State of Charge). It is possible to remotely control through Web access (Victron Color Control GX). Although in the normal operation in the EV the typical voltage level is 400 V od above, in the second-hand mode we connected 48 V battery packs parallel. The BMS also includes integrated protection from sc., overload, overheating, deep discharge, overcharge, and other irregularities.

Fig. 10. The Charger with RFID card and the EV batteries

G. Protections

The system contains various protections:
Electric Shock protection

- DC side double insulation
- AC side TN-S system
- In the inverter integrated Residual Current Device = RCD

Overvoltage

- DC side T2 overvoltage protection
- AC side Noark Ex9UE2 20, T2 surge protection

Overcurrent

- DC side 16 A fuse
- AC side overcurrent 3x16A breaker

For cabling, we applied at DC lines 4 mm^2 UV resistant solar cables and at the AC lines 1000 V 5x6 mm^2 FG16OR16 cable.

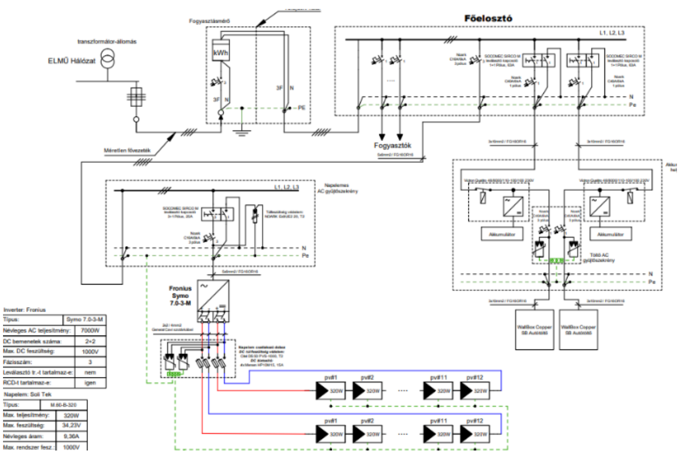

Fig. 11. The general scheme

H. Operational modes

The following operational modes can be tested

- PV generation directly to EV charger
- PV generation to Battery
- PV generation to the network
- Battery discharge to EV charger (Island mode operation)
- Network supply to EV charger
- In the future, the system will be extended by V2G (Vehicle-to-grid) capacity when the EV can inject energy into the grid

5. Scalable solution

At the application site, the annual irradiation is approx. 1200 kWh/m2. The yearly energy yield is about 1240 kWh / kWp. In this manner, the average energy yield is about 27 kWh by the 8 kW system (of course it depends on the season and the weather). The average consumption by an EV is 0,15 kWh/km, so the daily solar energy is enough for a 180 km daily run for EVs. We started with a 6 x 1,1 kWh battery pack that stores only a quarter of the daily solar production.

The demonstration application system is scalable by the extension of the storage capacity and also by the number of the PV panels. We may store energy for more days and more cars. We use for storage the power network (feed in the surplus).

6. Multipurpose application

With this demonstrational system

- we gave a second life to the used EV batteries
- the students can practice the PV system sizing
- with this application, we realized a dream/plan that was published an 8 years ago [11]
- we can teach energy consciousness and we show a more sustainable solution
- further PV panel characteristics, tests and measurements can be continued [12-16]
- we can plan and simulate larger-scale solutions with more charger, more battery and PV capacity
- this is a testbed for island mode operation and later for theV2G test

Fig. 12. The Solar Carport

7. Conclusion

In the yard of the Óbuda University, we realized an innovative solar carport that includes second-life EV batteries, double glass PV panels and EV chargers. It is a recommendation to realize hundreds of similar and larger-scale systems for a more sustainable future.

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