ENERGY PRODUCTION OF A HYBRID SOLAR ELECTRIC VEHICLE CHARGING SYSTEM

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Abstract: As a consequence of increasing electric vehicle number, the number of electric vehicle chargers are increasing too. The main advantage of electric vehicle is the zero CO_2 emission. One of the biggest advantage of solar electric vehicle charger built at Óbuda University is that offer the possibility to charge the electric vehicle with energy which are coming from a solar system. The system contains a solar part, an energy storage part and the electric vehicle charger part. The internet connection of the system gives the possibility to have real time information about the system. Continuous monitoring of the system, assure an overview on source and on amount of energy consumption.

Keywords: electric vehicle, solar panel, electric vehicle charger, lithium ion batteries, hybrid solar system

1. INTRODUCTION

This is a fact that the number of electrical vehicles are increasing continuously. For example, in Hungary at the end of 2021 the number of cars with green license plates were 42633 (in Hungary the electric and plug in hybrid cars has green license plat). This number mean a 57% annual increasing [1]. In Romania this increasing was harder, where in 2021 the annual increasing was 118% [2]. This situation determines an increasing of demand for electric vehicle charging stations too. One of the biggest advantage of the electric car is that the CO_2 emission is zero. The best situation is when the electric energy used for electric vehicle charging are coming from green energy sources too. One of the best solution is represented by the solar carports located over parking spaces, which produce electrical energy [3-6]. The electric vehicle charging possibilities is another advantage of the solar carport [7-10]. Another advantage of the solar carport is that it shading the vehicle and reduce the urban heat [11-13]. From this reason at Óbuda University was built a solar electric vehicle charger system with storage capacity. The storage system assures an optimization for solar energy [14]. This kind of system play an important role in development of green energy systems [15, 16]. The connection of the system to the internet network gives the possibility to have an online monitoring and a control of the system and [17, 18]. Another advantage of the internet connection is the possibility to be involved in different parking management systems [19, 20].

2. SOLAR ELECTRIC VEHICLE CHARGER SYSTEM

The system built at Óbuda University contains three parts: Solar, energy storage and the charger parts. The energy used for electric vehicle charging should coming from solar system, power supply network, and from batteries. In the Figure 1 is presented the schematic diagram of the system.

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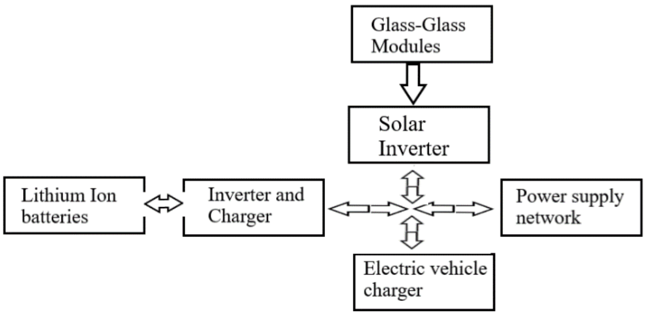

Fig. 1. Schematic diagram of solar electric vehicles charger system.

2.1. Solar panels

The solar panels are glass-glass 320 Wp solar panels type. This type of solar panel has more advantages compare to glass-foil solar panels: it is damp proof, it has 30 years product and 87% efficiency warranty. The system contains 24 solar panels what is mean that the total solar capacity is 7680 W.

2.2. Solar inverter

The voltage conversion is done by an 8.2 kW solar inverter. The inverter is situated as close as possible to the solar panels to reduce the losses. In Figure 2 is presented the web page with status of the solar inverter. There are information's about the daily energy production 43.26 kWh, about the predicted energy production for "today" and "tomorrow". The prediction was 48.2 kWh, and the real energy production for "today" was 48.39 kWh. The prediction for "tomorrow" was 51.3 kWh, and the real energy production for "tomorrow" was 47.15 kWh. The bigger difference between predicted and real energy production for tomorrow are coming from the fact that the weather of "tomorrow" was not a perfect sunny day. There were some clouds too. The prediction is closer to real production in sunny days. Another information offered by web page of the inverter is regarding to daily and weekly weather, and from green energy point of view an important information is the amount of CO_2 which was saved.

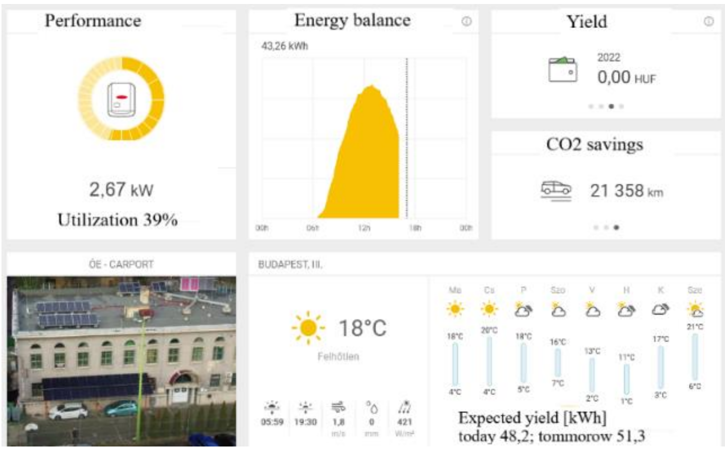

Fig. 2. Status of the solar inverter.

2.3. Inverter and charger

The Inverter & Charger, is a combination of an inverter and a charger. The Inverter & Charger interconnect the batteries, the solar system, the power supply grid and the electrical vehicle chargers too. This interconnection is presented in Figure 3 It is presented not only the interconnection of the system, but real-time information regarding the actual status of the system. The instantaneous energy production of the solar system is 2641 W. There is no vehicle connected to the chargers, and the batteries are 100% charged, that is mean the produced energy 2493 W is fed in power supply network. The rest of energy is consumed by the system.

2.4. Lithium ion batteries

One of the biggest advantage and the novelty of the system is energy storage system. The storage of the energy is done with used batteries. The batteries are coming from a first generation Nissan Leaf. The capacity of the batteries was enough only for 100 km compared to 200 km (on JC08 mode) [21]. In case of an electric car this travel distance is not the best. The only one solution was to change the batteries of the electric car with higher capacity batteries. The recycling of the electric car batteries is not the cheapest solution [22]. This was the reason why the remained charging capacity of the used batteries from electric car was used in solar system.

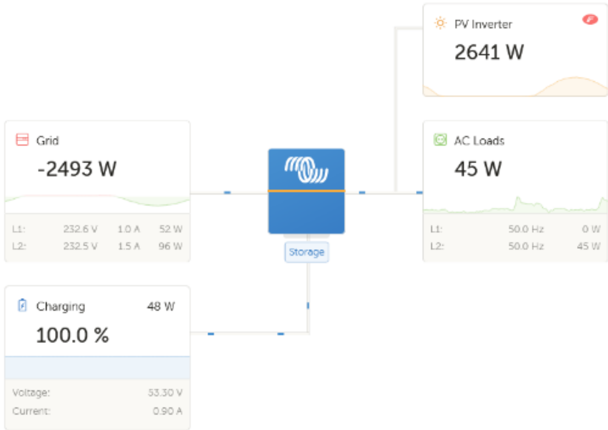

Fig. 3. Interconnection of BMS.

2.5. Electric vehicle charger

The system contains two smart chargers, which are connected to the internet. One of the most important features of the system is that the output current of the chargers should be modified trough web page of the chargers. The maximum output current is 32 A, that is mean 7360 W. This is important from CO_2 saved point of view, because with help of this feature the electric vehicle should be charged only with energy produced by solar system.

3. MEASUREMENT RESULTS

The system is working from the middle of April, start from this date the total energy production was 10.05 MWh. This amount of energy means that 5.37 t of CO_2, and fuel for 21544 km were saved too. In Figure 4 is presented the monthly energy production and the simulated energy production for 2021. For the simulation of the system's energy production the PVGIS program was used (Photovoltaic Geographical Information System) [23]. The simulated and the measured results are quite the same. The highest difference appears on May.

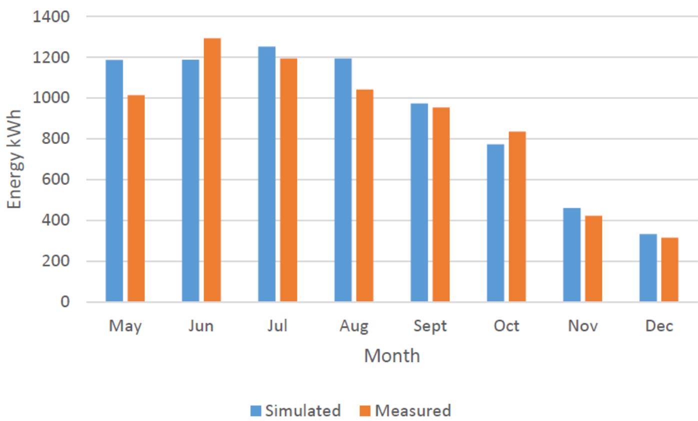

Fig. 4. The monthly solar energy production and the simulated energy production for 2021.

In Figure 5 is presented the dispersion of energy production for May and June 2021. It can be seen that in case of May, there is a high variation of energy level production compare to June, where the daily energy production was between 30 kWh and 50 kWh compare to May where the variation of daily energy production was between 10kWh and 52 kWh. This high variation of the energy production distribution is coming from the weather. In May the weather was more rainy and cloudy compared to. In June the weather was quite the same as a typically June weather.

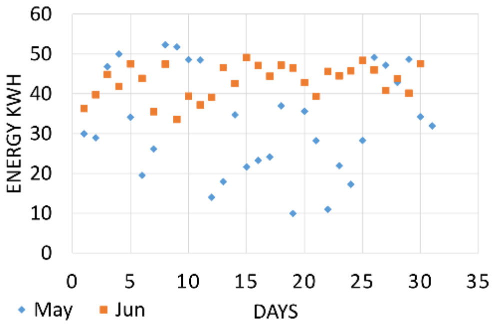

Fig. 5. Dispersion of energy production for May and June 2021.

In 2021 the total energy production was 7.56 MWh. The maximum energy production was in June when it was 1924 kWh, the minimum energy production was in December 313.89 kWh.

The chargers are not public chargers, that is the reason why the most part of produced energy was fed in power supply network. In Figure 6 is presented the total energy used for electric vehicle charging. The 124.97 kWh energy used for charging means 53.65 kg CO_2 saved and 59.98 L fuel replaced.

Fig. 6. Energy used for electric vehicle charging.

In Figure 7 is presented the utilization of the produced solar energy. The measurement time period is from September 2021 till April 2022. The total solar energy production for this period was 4576 kWh, 155 kWh energy was fed to batteries and the rest of energy was fed in power supply network.

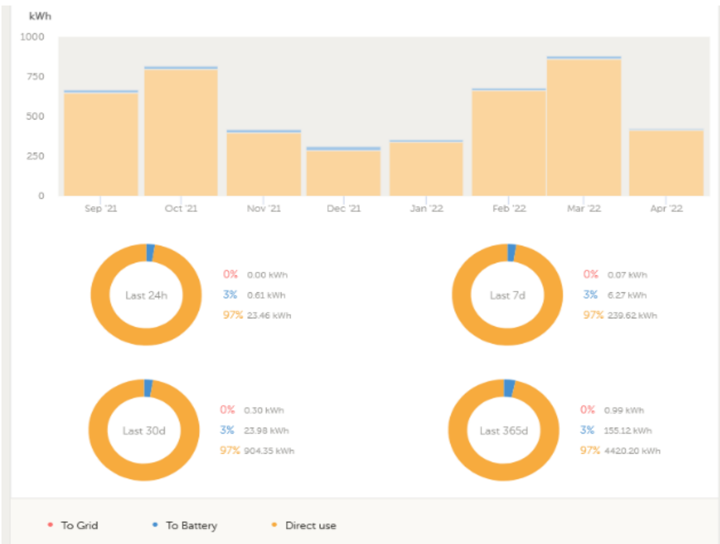

Fig. 7. Destination of produced solar energy.

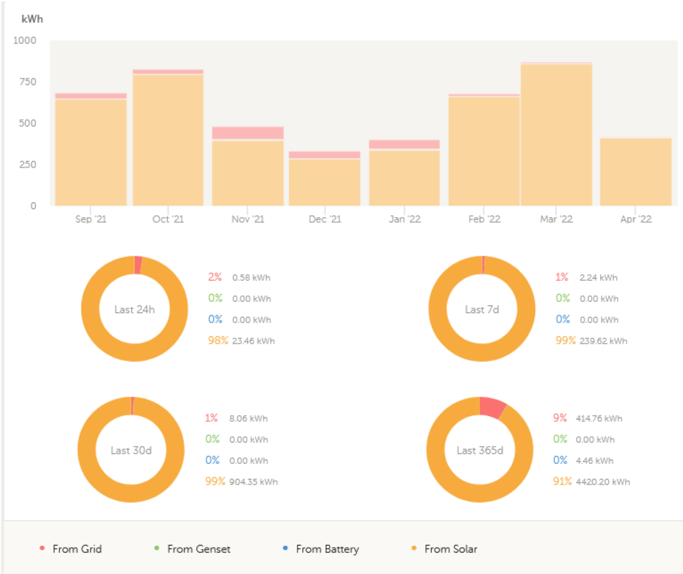

Fig. 8. Sources of input energy.

From energy input (from outside inverter/charger) point of view, in Figure 8 is presented the sources of input energy. It is important to mention that this system is not able to work in island mode, that is mean, from functionality point of view the inverter/charger and the solar system are connected to power supply network and use energy for their functionality, the necessary energy for functionality of the system is around of 90 Wh. The total input energy for inverter/charger point of view for this time period was 4709 kWh. The energy comes from all three sources: from solar system there was 4420 kWh, from batteries 4.5 kWh, and from power supply network was 284 kWh. A part of this energy was used for electric vehicle charging, a part for system functionality and the rest was fed in powers supply network. The system takes energy from grid not only for their functionality, but for electric vehicle charging too. For example, when the power used for charging is higher than the power produced by the solar system, then the difference of power is coming from grid. This situation is presented in Figure 9. The electric car is charging with 6836 W. This energy is coming from all three sources, 2811 W are coming from solar system, 980 W are coming from batteries, and the rest of 3119 W are coming from power supply network.

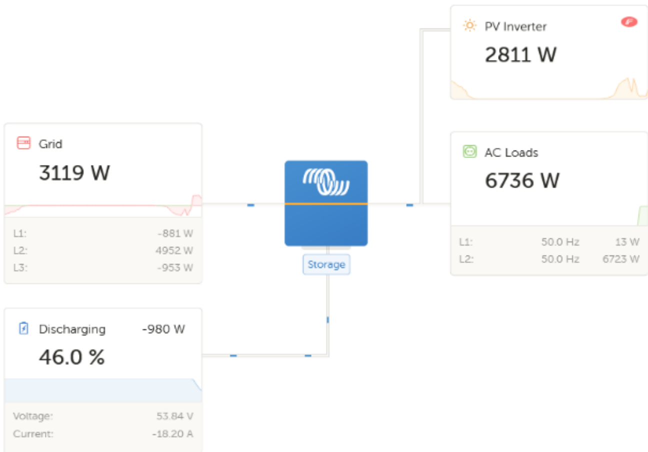

Fig. 9. Sources of charging energy.

Increasing of the reactive power injection in power supply network should determine and increasing of voltage level on its [24-27]. In Figure 10 is presented the voltage drop distribution on a power supply line, which should appear due to reactive power which is produced by the solar system. For the simulation was used a typically 3 phase power supply line, 95 mm^2 3 core aluminum, r = 0.397 Ω/km, x=0.0762 Ω/km. The injected power is P=6.696 W, Q=65.83 var and the current I=9.57 A.

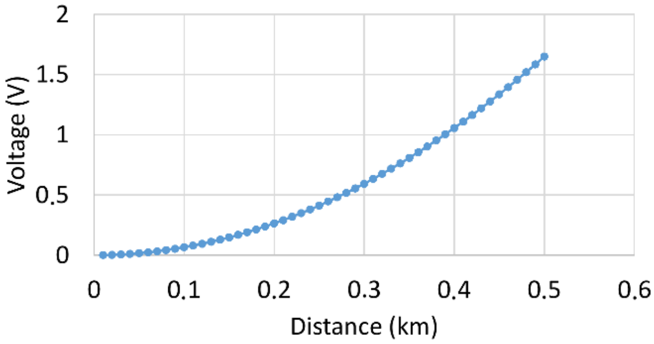

Fig. 10. Voltage drop on power supply line due to reactive power injection.

It can be seen that at the end of the line the voltage increasing should be 1.6 V. This is a real problem which appear typically on villages with long streets, and a lot of houses with solar systems.

4. CONCLUSION

The paper present a solar electric vehicle charger system. The energy used for vehicle charging should coming from three sources: solar, lithium ion battery, and/or power supply lines. The energy production of the solar system was 10.05MWh. Most of this energy was fed in network. 124.97 kWh was used for electric cars charging. There is presented the monthly measured and simulated solar energy production, which show us the influence of the weather on the measured results compare to simulated results.

The paper present information about the utilization of the solar energy production and information about amount of input energy, from power network, batteries or solar system. The reactive power produced by the solar system should produce a voltage increasing through of power supply line.

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