ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
Tome XX [2022] | Fascicule 3 [August]

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CHARGING TIME AND PRICE OF CHARGING OPTIMIZATION FOR AN ELECTRIC VEHICLE RESIDENTIAL CHARGING STATION BASED ON RENEWABLE ENERGIES

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Abstract: One important concern of the future customers is related to the poor charging infrastructure available for EVs. The EVs will need a new infrastructure for energizing. Using Electricity from the nowadays networks is not helping in terms of pollution too much, considering the classical sources, and the today Electric network would be overcharged. In this paper the authors are dealing with some economic consideration arising from the studied system, namely Residential Smart MicroGrid with EV Charging Station, exploitation. Considering different scenarios, in the paper we will try to show what are the financial bases for the maximum and minimum charging prices, what are the maximum and minimum charging times available and which the trade-off between prices and charging times are.
Keywords: Electric Vehicles (EVs), sustainable e-mobility systems, Residential Smart MicroGrid, renewable energy sources (RES)

1. INTRODUCTION

Electric Vehicles (EVs) are considered an important part of a sustainable e-mobility systems. One important concern of the future customers is related to the poor charging infrastructure available for EVs. The EVs will need a new infrastructure for energizing. Using Electricity from the nowadays networks is not helping in terms of pollution too much, considering the classical sources, and the today Electric network would be overcharged. EVs are "zero" polluting and highly efficient, but these qualities are valid only if the EV is supplied from renewable energy sources (RES). The research data from [1] shows that, taking Ireland as an example, "EV users prefer to carry out the majority of their charging at home". Due to the rapid spread of EVs worldwide, it is important to provide such a charging infrastructure that answers these needs and concerns of the EV customers.

In the cities, there is a lot of available space to install small RES on roofs of residential and enterprise buildings, building walls, parking lots, etc. the PV and the small wind turbines RES should be able to use these places to supply EVs with clean energy. Such a solution will help the today Electric network to not be overcharged.

In a research project financed in Horizon 2020 EU frame we developed the following Residential Smart MicroGrid based on the use of RES (Figure 1).

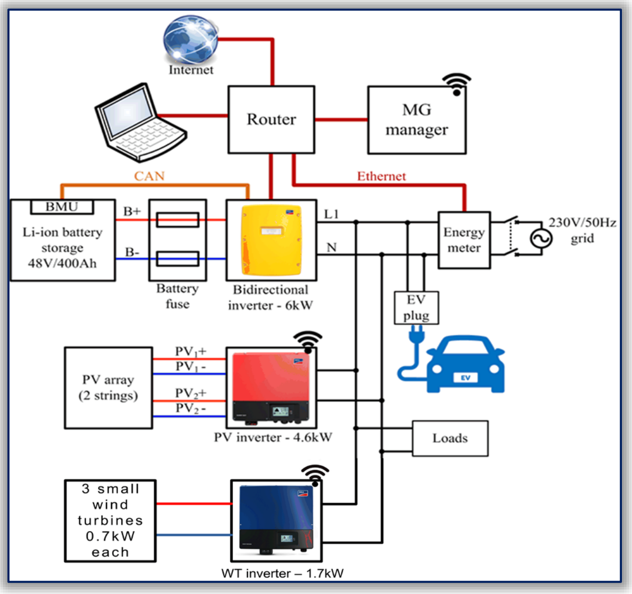


Figure 1. Developed Residential Smart MicroGrid with charging capabilities

The RES PV source has the PV array which consists in 32 panels, in our case, connected in 2 strings of 16 series panels, the rated DC voltage produced by the string being around 480V dc at maximum solar irradiation. Three small wind turbines of 0.7 kW power each were considered in order to exploit the local wind power availability. That because the predominant wind in our location is of small velocity and bigger turbines are starting at higher wind speed. A 48V, 20.3 kWh Li-ion stationary battery is connected to the Residential Smart- Micro Grid, S-MG by a 6kW inverter to counter the inherent variability of the RES. Some of the residential loads, the local consumer may also include active loads, in order to improve S-MG power controllability. Our network can provide Electricity to EVs through a Mode 2 (Level 2) charging capability of around 7 kW using adequate interchangeable plugs using the IEC 61851 or SAE J1772 standards.

All the S-MG controllable components are connected by the communication infrastructure, which ensures the controllability and the data transfer between the S-MG components and connects the Residential S-MG to the outer world. More details about our Residential S-MG solution can be find in [2-8].

The S-MG can work either (a) connected to the single-phase grid or (b) islanded in the case of a grid failure. In the grid-connected mode, the power flow is measured by a smart meter and it can run in either directions, importing or exporting electricity. The switch between the two states is carried out automatically by the battery bidirectional converter, acting as an inverter whenever an outage affects the grid. In islanded mode, first ensured is the critical supply of the residential consumer, with the electricity coming from the local RES and the energy storage system.

In this paper we are dealing with some economic consideration arising from the studied system exploitation. Considering different scenarios, in the paper we will try to show what are the financial bases for the maximum and minimum charging prices, what are the maximum and minimum charging times available and which the trade-off between prices and charging times are.

Section 2 is presenting Electric Vehicles charging considerations. Section 3 is dealing with The Evolution of Energy exchange.

2. ELECTRIC VEHICLES CHARGING CONSIDERATIONS

In order to ensure the economic viability of the Residential Charging Station is useful and necessary to integrate it in the City's public charging system.

According to our studies and experiments carried out over more than 3 years, the proposed Residential Charging Station, RCS, can properly supply around 2 EVs per day with Electricity mainly coming from Renewable sources [9].

Also our solution allows due to the Storage device to reduce the Charging time with around 50%. Due to the inherent variable Renewable Sources, sometimes the CS and the storage device cannot offer purely Clean energy. Depending on custumers options, the charging time can vary if there is not enough Renewable Energy available, as the Figure 2 is presenting. If the Electricity comes from the utility network also the price of Electricity can increase.

Figure 2. Charging power and time: above with energy storage available; below without storage

In order to study the economic behaviour different scenarios can be used.

In a previous research, [9], simulations, using HOMER Pro software, aimed at maximizing both renewable power and SMG battery usage. But this strategy comes with higher prices, especially when the battery usage is maximized. This time we run the simulations in the view of an optimal usage of the batteries and an optimal energy exchange with the grid. According to these considerations the first result is regarding the percentage of the Renewable Energy, RE, used to charge the EVs. As can be seen from Table 1, the optimal use of the RE is about 50%.

Table 1. Energy exchange with the grid related to the amount of used RE

Renewable Fraction [%]	25		50		75	
Daily energy [kwh]	Import	Export	Import	Export	Import	Export
January	20.55	12.58	20.55	12.58	10.35	12.58
February	17.68	13.9	17.68	13.9	8	13.93
March	17.35	17.78	17.35	17.78	7.26	17.84
April	16.5	17.43	16.5	17.43	6.6	17.63
May	15.9	17.42	15.9	17.42	6.32	17.58
June	16.43	18.5	16.43	18.5	6.57	18.7
July	16.42	18.97	16.42	18.97	6.52	19.13
August	17.22	18.42	17.22	18.42	7.13	18.45
September	17.23	16.37	17.23	16.37	7.2	16.47
October	17.22	12.19	17.22	12.19	7.29	12.29
November	18.97	9.47	18.97	9.47	9.23	9.47
December	19	10.1	19	10.1	8.93	10.1

Considering the 50% RE case, the optimal use of the storage and optimal charging intervals between hours 3-6 (EV1) and 12-15 (EV2) as the simulation results are recomanding, the evaluation of the energy exchange in the case of 50% RE are displayed in Table 2. EV1 will be set to be charged during the 02-06 hours range, according to the assumption that the EV belongs to the MG owner and so no uncomfortable consequences occur.

Here we tried to maximize in the above mentioned conditions the use of the RE in charging the EVs, as the simulations indicated that in the case of 75% use of energy from RES, the available one for EVs charging is only 14 kWh. The use of 50% RE to charge the EVs is coming out in these conditions.

Table 2. Evaluation of the energy exchange in the case of 50% RE (24 kWh/20 kWh) when the amount of RE is divided between the 2 charging time intervals

Energy EV [kWh]	Energy VE1 [kWh]	Energy VE2 [kWh]	Imported Energy [kWh]	Exported Energy [kWh]	Energy balance [kWh]	Battery charging [kWh]	Battery discharge [kWh]
24	9	15	3435	2573	-862	3059	2919
	15	9	4314	3491	-823	2797	2670
	12	12	3619	2744	-875	3143	2999
20	7.5	12.5	2414	3073	659	2652	2532
	12.5	7.5	3137	3767	630	2842	2713
	10	10	2593	3206	613	2959	2823

One important result from battery use optimization, in this 50% RE case, is the variation of the State of Charge, SoC, during a year. It has to be mentioned that all the simulations were made considering one standard year working conditions for the RES. The standard year was computed as arithmetic media of the years since the R S-MG is operating. According to Figure 3 very few times, less than 14 %, the SoC of the battery exceeds 80%. This helps to prolong the lifetime of the battery and the number of operating cycles, as we foreseen. We also imposed a limited discharge to a minimum SoC of 30%.

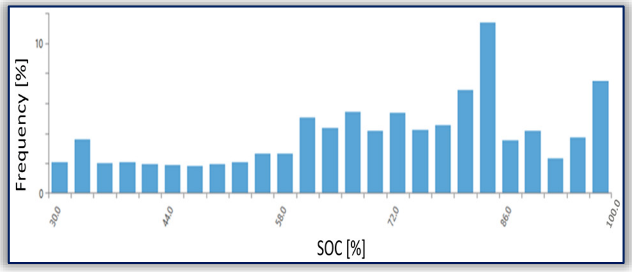
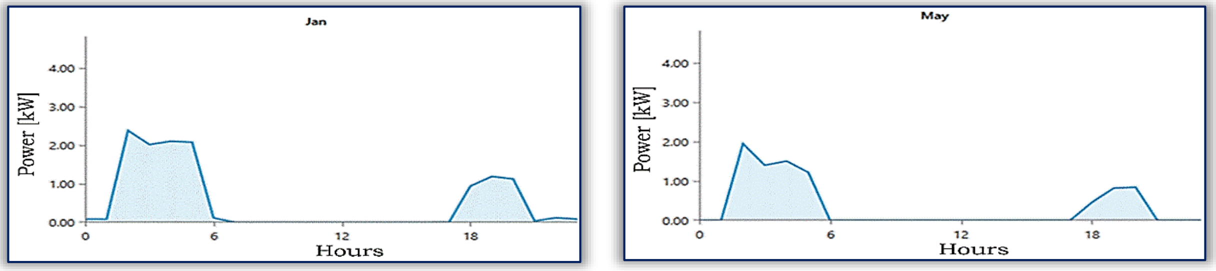


Figure 3. The distribution of battery SOC value (50% RES case)

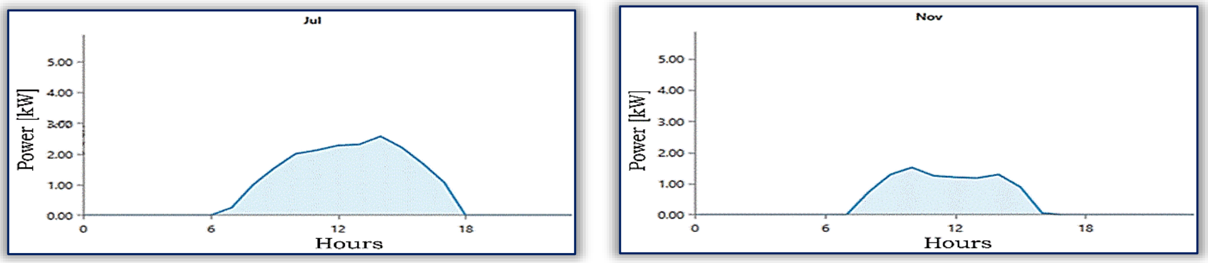
3. THE EVOLUTION OF ENERGY EXCHANGE

The charging strategy can be established by seasonal RE evolution, too. The charging and discharging processes of the battery are controlled by its Battery Management Unit (BMU), which further gives information about the battery operation to the bidirectional converter using a CAN communication bus, which further exchange data and command with the MG Controller using a RS485 interface, as Figure 1 shows.

a)


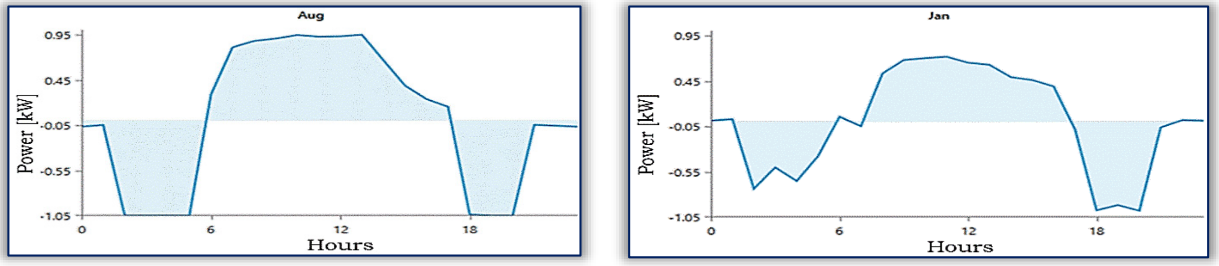
b)

Figure 4. Daily variation in the months with the highest a) and lowest b) RE import from the grid

a)


b)

Figure 5. Daily variation in the months with the highest a) and lowest b) RE export to the grid

a)


b)

Figure 6. The months with the highest/lowest power circulated through the battery

Simulations of the energy exchange on the daily bases were made. To be mentioned that the day power variation profiles are for the mean day of the respective month. The most ssignificant months were chosen from the point of view of the power and RE amplitude variation in Figure 4-6. Of course that the profiles can be obtained for every mean months and their mean day. But our interest was to establish the maximum and minimum mean values in order to evaluate a maximum and a minimum bases for the price of the EV charging electricity. That to answer to the concerns of an investor who intend to evaluate the financial balance in investing in an R S-MG.

4. FINANCIAL CONSIDERATIONS

Financial aspects are very important for those interested in investing in such an R S-MG with EV charging capabilities. For this reason the authors are trying to offer economic data related to the exploit of such system. It is well known that the price for importing electricity is significantly higher than that for exporting, (it was RON 0.78 for importing and RON 0.22 for exporting to the network in Romania in 2018). Additionally, the electricity price will increase in the next decade in the EU as Frans Timmermans, the executive vice-president of the European Commission, mentioned in a press release referring to the EU Green Deal law package [11], which will boost the interest in increasing self-RE generation. We can see these days the electricity price turbulences in action. The Energy cost produced by the R S-MG cost was computed according to the equations from [10].

The equations were applied for each component. From a 20 years exploitation time of the components and considering an annual profit rate of r=7% the following costs resulted: 0.132 RON/kWh for the solar energy, 0.284 RON/kWh for the wind energy and 0.5 RON/kWh for the power given by the MG storage system (as both charging/discharging cost were included).

At the time of writing this paper (mid September) for the financial analysis, three energy prices ranges were considered by Electrica Furnizare SA, one major Utility company: 0.85RON/kWh when buying energy from the grid during weekdays in the 07-22 hours range and 0.69RON/kWh during weekends and in the 22-07 hours range during weekdays and 0.227RON/kWh when selling energy to the grid. It is to be mentioned the fact that other Electricity supplying companies are not offering the day/night (weekend) price facility.

5. CONCLUSIONS

Based on the above financial details and using the data from Table 1 and Table 2, the interested investor can build his/hers investment feasibility study. He (or she) has to consider the local RES potential, of course. In this respect one can use the graphs from Figures 3-5 and Section 2 to evaluate the charging hours intervals.

According to our studies and experiments carried out over more than 3 years, the proposed Residential Charging Station, RCS, can properly supply around 2 EVs per day with Electricity mainly coming from Renewable sources, besides energizing the other loads of the residence. The described solution allows to reduce the Charging time with around 50% in comparison with a CS supplied by the utility network due to the Storage device.

Note: This paper was presented at CNAE 2022 – XXth National Conference of Electric Drives, organized by University POLITEHNICA Timisoara, Faculty of Faculty of Electrotechnics and Electroenergetics (ROMANIA), in Timisoara, ROMANIA, in 12-13 May, 2022.

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