4th International Engineering Research Symposium
INERS'22

March 04-06, 2022, Düzce, Turkey
ISBN: xxxxxxxxxxxxxxxxx

www.umas.duzce.edu.tr

Integration of the Electric Vehicle Charging Station for Campus Parking Lot with Renewable Energy Sources

Musa Terkeş[a], Said Mirza Tercan[a], Alpaslan Demirci[a], Erdin Gökalp[a]

[a] Department of Electrical Engineering, Faculty of Electrical-Electronics Engineering, Yildiz Technical University, İstanbul/Turkey.

*Corresponding Author: f4920065@std.yildiz.edu.tr,
stercan@yildiz.edu.tr, ademirci@yildiz.edu.tr, gokalp@yildiz.edu.tr

ABSTRACT

The increasing penetration of electric vehicles (EV) has increased the installation of EV charging stations (EVCS). Companies believe that the intensive establishment of EVCS will solve the EV range anxiety. However, the increase in the local grid loading due to EVCS should be considered. Although traditional energy generations would be decreased continuously with the technological developments due to greenhouse gas emissions, local networks still need these systems when demand is high. Therefore, an alternative proposal is necessary to alleviate the burden of the local grid and overcome the environmental pollution problems. This study was carried out to meet the regional needs of EVCS installed in the parking lot of Yıldız Technical University Faculty of Electrical and Electronics using HOMER Grid for techno-economic optimization. The impacts of hourly and daily demand variations on the optimal sizing of hybrid systems are examined.

Keywords: Electrical Vehicle Charging Stations, HOMER Grid, Hybrid Power System, Techno-Economic Optimization, Uncertainty, energy storage system

I. INTRODUCTION

Today, the electricity demand is increasing day by day. Clean and efficient transportation besides sufficient energy generations is the primary concern for the countries' policies. The generator that consumes carbon-based fuels does not seem possible within the framework of these policies. Governments are more likely to use renewable energy sources (RES) to generate environmentally friendly electricity in this context. However, the stochastic and intermittent nature of RES does not allow use alone. RES, traditional production units, and energy storage systems (ESS) are brought together uninterruptible to meet demand in an optimal way known as Hybrid Power Systems (HPS) in scientific studies. The intense demand increase is not only in the industry and domestic consumption but also, the transportation sector will remind its importance even more in the next years. Countries implement policies that encourage electric vehicles (EV) by considering clean living standards, just like RES production. However, with the expansion of EV sales, various problems related to the EV charging station (EVCS) have appeared. Issues can be exemplified such as charging time, range problems, suitable siting of EVCS, network fatigue, losses, the inadequacy of protection both in transmission systems and facilities, power cuts, increase in environmental pollution, etc. To overcome such problems, EV companies and researchers have focused on: creating new technologies, adding efficient ESS to the station that will perform the backup task, establishing alternative and traditional generation units to meet the regional demand, managing charging profiles, that is, smart charging applications, increasing battery exchange stations, increasing the load, shifting in coordination with the grid, energy exchange between buildings or distribution networks, that is, smart grids with communication.

A. Electric Vehicles and Charging Infrastructure

EVs contain electric motor/s and ESS that will feed the electric motor to provide its movement. On the other hand, hybrid vehicles include the internal combustion engine and the electric motor and ESS, driving the vehicle from two sources. Today, EVs are classified as battery-powered (BEV), hydrogen fuel cell (FCEV), hybrid (HEV), and plug-in (PHEV). As ESS technology, primarily batteries, fuel cells, supercapacitors, and hybrid types are used [1]. The EVCS should be evaluated together with EV

increases. There are four charge modes for EVs İn EVCS. The first mode is charged from the standard socket and has no communication or security measurements (Cable only). It is possible to charge with a limited communication or security box on the cable (Both box and cable). The third mode is full communication or safe charging from a specially designated socket instead of a standard socket. The fourth mode is DC fast charging. Nowadays, the most preferred charging types are AC Level-2 charging and DC fast charging. Thus AC Level 2 charging was preferred in this study. A typical AC Level 2 Charging Method (IEC 62196-2 standard) includes 230/400 V, 16/32/64 A, 3.7-43 kW [2].

B. Integration of EVCS with RES

HPS combines RES and ESS and traditional energy production. These issues show partial changes according to EV infrastructures. Installation of EVCS for fuel-cell EV in garages of home and commercial buildings and stations is common to supply the hydrogen demanded. Some studies have applied to HPS structures and tried to obtain a hybrid solution at minimum cost [3]–[7]. Additionally, photovoltaic (PV) panels, biodiesel generators, and chemical ESS were added to HPS to avoid excessive energy production, unlikely other studies. Thus, the fast EVCS has obtained a minimum cost, maximum environmental and technical hybrid solution [8]. Environmentally friendly, technical, and cost-effective hybrid solutions have been sought to meet the demands of customers and EVCS. Consequently, RES estimation was carried out precisely depending on the various RES brands, electricity tariffs, and EV traffic conditions were also considered [9]–[13]. In addition, all points from the design stages to the approval process in rooftop PV installations were mentioned [14]. Other hybrid studies were sought for plug-in hybrid vehicles, including an electric motor and an internal combustion engine and battery banks that provide power from the grid. Many factors such as EV and consumer demand uncertainty, grid tariff, tariff rates, V2G technology, renewable fraction, and limiting RES in energy production have been considered to fulfill this healthily [15], [16], [25]–[28], [17]–[24]. A different study replaces these factors; network reliability values, transformer and line loading rates, power losses, voltage drops seen in the voltage profile are discussed. A hybrid solution was sought and tested for EVCSs that will become widespread in the future [29]. At the same time, most studies look for a hybrid solution, the design of the most cost-effective fast EVCS, optimum sizing, and performance in the real test environment. This study has presented a good summary of the related literature by including EV demand, renewable energy production, grid tariff, and future projections [30]–[32]. There is a gap among the related studies that address the effects of hourly and daily variabilities in the demand profile of households and EVCS on the financial, technical outputs, and dimensions of HPS. In this study, the essential results for the base scenario are shared. Then the financial, technical, and dimensional changes variabilities reflected on the HPS are examined within the sensitivity analysis framework.

The study is organized as follows. Part 1 includes a literature review. Part 2 contains material and methods describing technical and economic system input, assumptions, and scenarios. Part 3 and 4 include the conclusions and discussions of the system outputs. Finally, part 5 concludes the study by summarizing the significant findings of the research and has future suggestions.

II. MATERIALS AND METHOD

This section presents the HPS structure, preferred optimization program, design criteria, study area, design inputs, and scenarios.

A. HPS Structure and Optimization Program

The preferred HPS components in this study are as follows: PV, wind turbines (WT), diesel generator (DG) to ensure reliability and perform a backup, lithium-ion battery banks (ESS) to gain storage advantage, converter that performs AC/DC power conversion system (PCS), future-frame EVCS, public building electricity consumption that creates demand (Primary Load). In this study, the Hybrid Optimization of Multiple Energy Sources (HOMER) is preferred for optimization calculation of HPS. HOMER is a program for distributed generation and microgrid modeling developed by NREL (National Renewable Energy Laboratory) in the USA, which is preferred by more than 250.000 users in 193 countries today. Conducts optimization and feasibility studies to create cost-effective and reliable hybrid microgrid, grid-connected systems and off-grid systems that combine traditional generation and renewable energy technology with storage and load management. HOMER offers three programs; HOMER Pro, HOMER Grid, HOMER Front [33]. HOMER Grid has been chosen because it contains the EV structure within its body. The HPS model in which this study was carried out is presented in Figure 1.

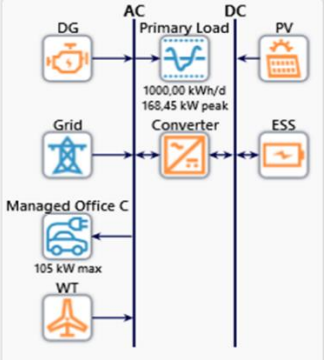


Fig. 1 The configuration of HPS

B. *Case Study and Design Inputs*

This study applies to RES providing on-site energy generation to meet the load demands of the faculty and EVCS in the faculty parking lot connected to the university campus. The amendment made by the Ministry of Environment and Urbanization in the Parking Lot Regulation has been taken into account to increase the number of EVCS in especially working areas. The third article of this regulation is based on conditions are specified for the relevant parking lot owners to obtain a license for the parking lots to be established: 2% of the total number of parking lots is required to be allocated to 2023 and 5% to EVs and charging units until 2030 [34].

a) RES, Load, EVCS Profiles, and Assumptions

The study was carried out in Yıldız Technical University (YTU) Davutpaşa Campus, located in the Esenler district of Istanbul province, in the Faculty of Electrical and Electronics parking lot. The study area is located at 41° 0′ 44″ North latitude, 28° 58′ 34″ East longitude. The working area is shown in Figure 2.



Fig. 2 Satelite view of YTU Electrical-Electronics Faculty

The annual average solar irradiation and temperature values for the province of Istanbul were obtained as 4.103 kWh/m^2/day and 16.17 °C, respectively. Based on the 25-year data of the General Directorate of Meteorology Energy Affairs, affiliated to the Ministry of Energy and Natural Resources, and the WeatherOnline website, the annual average wind speed value for the province of Istanbul were obtained as 4.45 m/s, the annual average clarity (clearness) index was determined as 0.51 from the NASA surface methodology database. Figure 3 shows the monthly distribution of average solar energy data for the province of Istanbul.

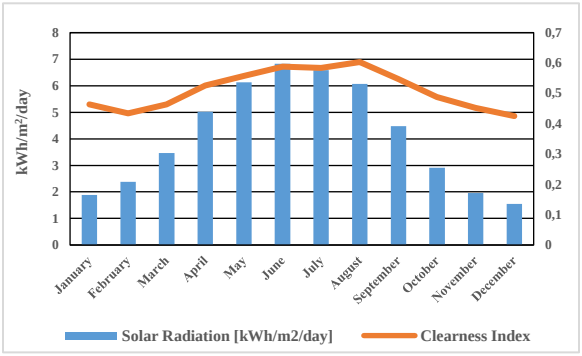


Fig. 3 Solar energy estimation for Istanbul province

In the faculty, working starts at 7 am and ends at 5 pm. Because HOMER recommends load profile like a commercial, where peak demand is more likely in the winter months, was used. Annual load profile scaling is considered as 1000 kWh/year. In addition to the load profile, the EVCS demand profile can also be determined from the HOMER. The EVCS demand profile for commercial buildings offered to users has been updated by considering the EV sales values in Europe and Turkey. For new EVCS installations, the mandatory number of parks in Turkey until 2023 and 2030 requires that the total number of parks be between 2% and 5%. Therefore, the number of charging units was found to be 7 and 187 parking lots, and it was thought that each charging unit would charge 2 EV per day. In addition, HOMER enables AC Level 2 or DC Fast Charging. In this study, Level-2 AC charging type is considered. In Figure 4, the load and EVCS profiles are summarized.

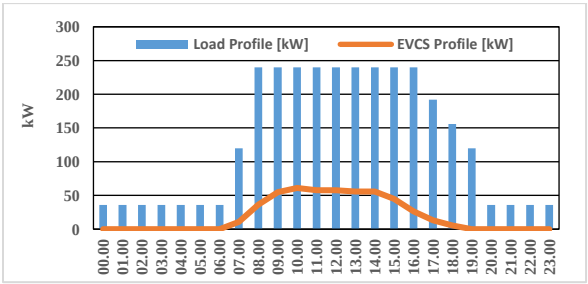


Fig. 4 Daily load and EVCS demand profiles

b) HPS Components

This section presents the financial values in Table 1, other inputs in Table 2, assumptions for load and EVCS in Table 3, and optimization variables in Table 4.

Table 1. Financial inputs of HPS's components

Component	PV	WT	DG	ESS	PCS
Capital Cost [$/kW] or [$/kWh]	1000	2800	600	300	300
Replacement Cost [$/kW] or [$/kWh]	900	2500	500	250	300
O&M [$/kW/year or hour]	10	30	0,02	2	0,02
Fuel Price [$]	-	-	1,2	-	-

Table 2. Other inputs of HPS

Project Life [years]	20
RF_{MIN} [%]	0
Interest Rate [%]	14
Inflation Rate [%]	19,5
Grid Tariff [$/kWh]	0,1

Table 3. Assumptions for EVCS and Load

Load Profile Scaling [kWh/year]	1000
Power Consumption [kW]	41,67
Peak Power [kW]	168,45
Load Factor [%]	25
Power of Charger [kW]	15
Average Charge Time [hr]	6
Number of Chargers	7
Daily Average Charge Sessions	14

Table 4. Variables in HPS

Variable	Variability [±%]
Daily Load Profile	10
Hourly Load Profile	20
Charge Time	20
Charge Energy	30
Daily EV Charging Profile	20
Hourly EV Charging Profile	10

The assumption related to the grid is that any long or short-term interruptions that occur during the project lifespan are made in the context of the baseline scenario. And it is assumed that no electricity is sold to the grid.

c) Scenarios

Initially, techno-economic outputs of the baseline scenario and monthly energy production data were shared. Then, the effects of hourly and daily changes in load and EVCS demand profiles on the main outputs of the HPS are discussed, and their effects on system sizing are reviewed. Accordingly, as indicated in Table 5, different scenarios were developed and implemented.

Table 5. Scenarios in HPS

Demand	Sensitivity Variable [%]	Scenarios
LOAD	Day-to-day	1-5
	Timestep	6-10
EVCS	Day-to-day	11-15
	Timestep	16-20

III. RESULTS

In this section, the findings of the baseline scenario are shared, and the important inferences from the sensitivity analysis are presented. Key outputs play an important role when evaluating HPS. Parameters such as cost of energy (COE), net present cost (NPC), amount of greenhouse gas (GHG), the renewable fraction (RF) are important in HPS optimization. Table 6 summarizes the key results of the HPS for the base case.

Table 6. Findings of the Base Scenario

Output	Important Parameters	Value
Component Dimensions	PV [kW]	344
	DG [kW]	1
	ESS [kWh]	238
	PCS [kW]	166
Economical	COE [$/kWh]	0,0643
	NPC [M$]	1.18
	Utility Bill Savings [$/year]	37.404
	Simple Payback Period [year]	13,9
	Return on Investment [%]	2
	Internal Rate of Return [%]	3,4
Other	GHG [ton/year]	105
	RF [%]	69,3
Energy	PV [kWh/year]	486.026
	Grid Purchases [kWh/year]	165.981
	Excess energy [kWh/year]	87.873

As optimization result, the WT was not selected due to its cost, while DG was assigned by the program depending on the power outage that will occur once a year. While both of them did not have much benefit, the main energy production source for Istanbul was the sun, and ESS were used as backup. Since the month with peak demand throughout the year is scaled to January, the energy production of the HPS, the energy taken from the grid, and state of charge (SOC) of ESS for sample cloudy day, is summarized as Figures 5, 6, and 7.

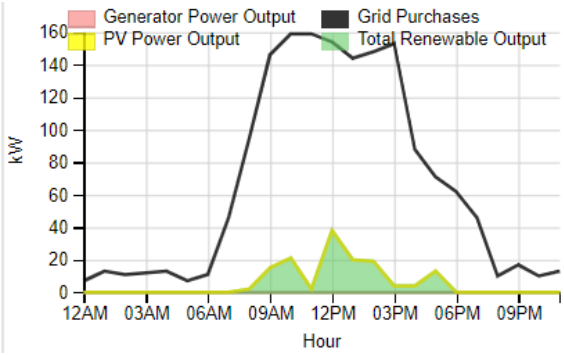


Fig. 5 Energy output of HPS in sample cloudy day

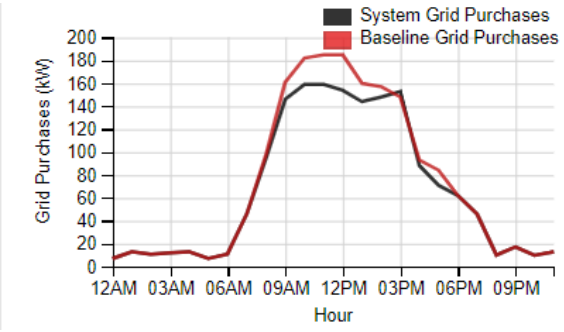


Fig. 6 Comparison of only grid and HPS on sample cloudy day

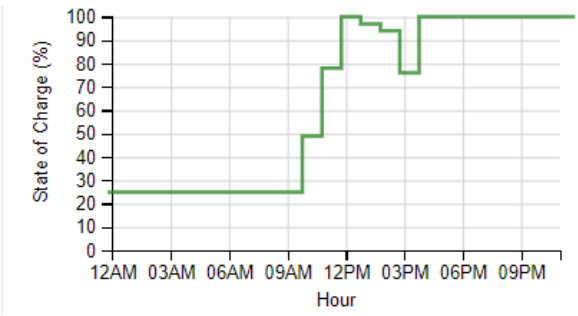


Fig. 7 SoC of ESS on sample cloudy day

There is no apparent difference between the HPS installation and the case of only the grid in Figures 5, 6, and 7. However, it has been observed that an auspicious result cannot be obtained in the winter months. Contrary to a cloudy day, solar energy has revealed its dominant role on a sunny day. In Figure 8, it can be seen that the electricity from the grid has decreased. In contrast, the energy production of the HPS has increased. In Figure 9, while it is quite unreasonable to eliminate the demand by purchasing electricity only from the electricity grid, the grid has become considerably lighter with HPS in the system. Figure 10 shows the SOC of the ESS experienced on a sunny day compared to a cloudy day thanks to HPS.

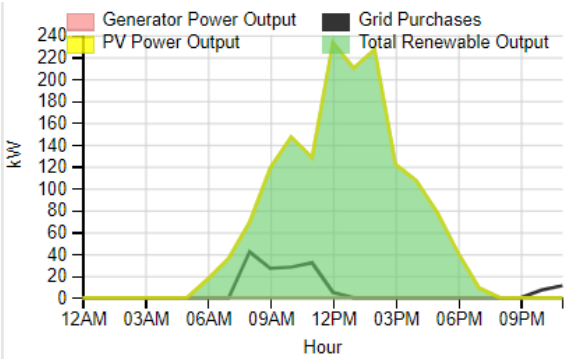


Fig. 8 Energy output of HPS on sample sunny day

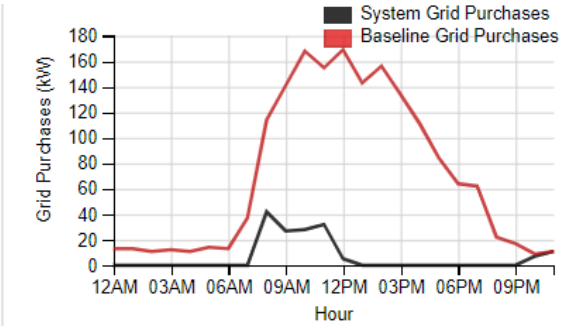


Fig. 9 Comparison of only grid and HPS on sample sunny day

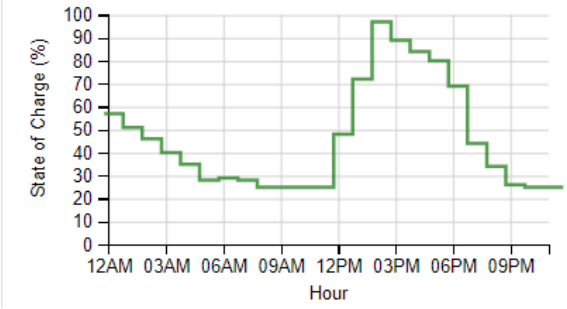


Fig. 10 SoC of ESS on sample sunny day

A. Sensitivity Analysis

Subtitle a discusses the effects of a daily and hourly change in the load profile on the HPS structure. In subtitle b, the same method was followed as in subtitle a. However, the EVCS demand profile was taken into account as demand. In subtitle c, the effect of hourly and daily changes in load and EVCS demand profiles on system sizing is given. In addition, the technical and financial evaluations in a and b; according to Table 7 in c, the table summarizing the optimal HPS sizes suggested by HOMER Grid, depending on the daily and hourly demand uncertainty in both demand profiles, has been examined.

a. Load Profile

HOMER Grid can calculate adding variabilities such as Day-to-day and Timestep to present the stochastic nature of the load demand changing from day to day and hourly. Essentially, the program iterates through the HPS configuration and results based on peak power and load factor variation. This study has examined that a change in the range of ± 5-30% that can be experienced in load demand will create differences in HPS cost and energy outputs. In addition, the size change to be experienced in HPS components is shared in the sub-heading c. In Figures 11 and 12, the peak power and load factor curves that will occur due to daily and hourly changes in load demand, respectively, are shared. As can be seen in both figures, the load factor decreases, and the peak power increases with variation.

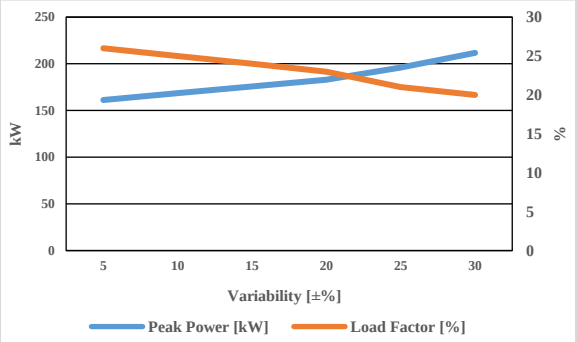


Fig. 11 The effect of day-to-day variabilities of Load Profile on Peak Power and Load Factor

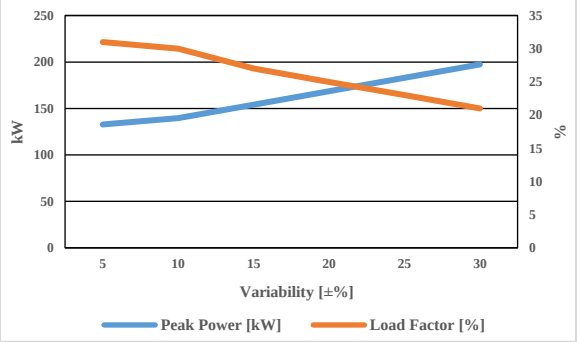


Fig. 12 The effect of timestep variabilities of Load Profile on Peak Power and Load Factor

In Figures 13 and 14, COE and the amount of savings to be experienced in annual electricity purchases from the grid are compared despite the daily and hourly demand uncertainty in the load profile for only HPS.

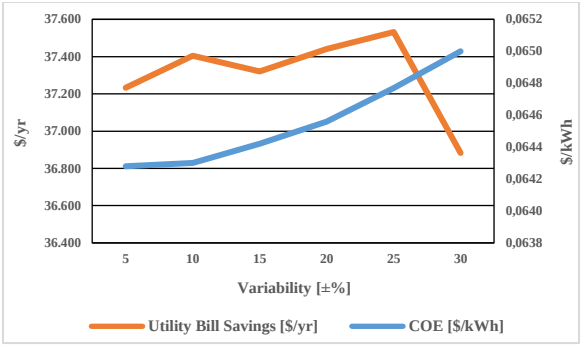


Fig. 13 The effect of day-to-day in the Load Profile on the COE and Utility Bill Savings

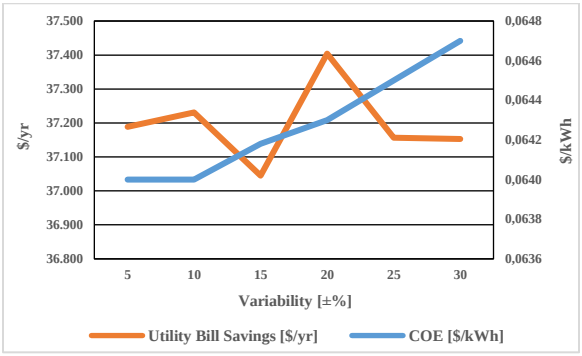


Fig. 14 The effect of timestep in the Load Profile on the COE and Utility Bill Savings

If the daily or hourly load profile uncertainty is high, COE has increased. On the contrary, there has been a decrease in electricity purchase from the grid in general, and the amount of savings has varied as can be seen from the figures. The amount of savings to be experienced in the electricity bill changed by a maximum of 1.76% in the daily demand uncertainty, and by a maximum of 1% in the hourly demand uncertainty. Although the uncertainties directly affect the energy production cost, the amount of savings to be experienced in the electricity bill did not differ much depending on the HPS sizing. In Figures 15 and 16, the daily and hourly demand uncertainty change to be experienced in the load profile; the amount of electricity to be taken from the grid and how much more electricity the most appropriate HPS assigned by the program will produce are shown.

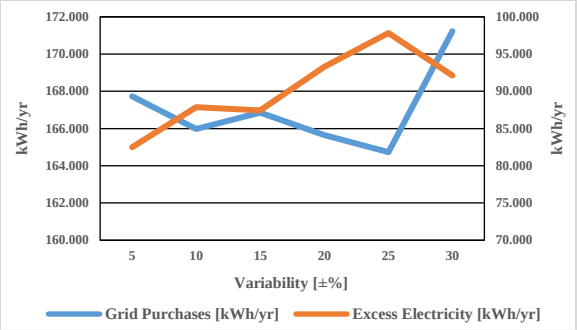


Fig. 15 The effect of day-to-day in the Load Profile on the Grid Purchases and Excess Electricity

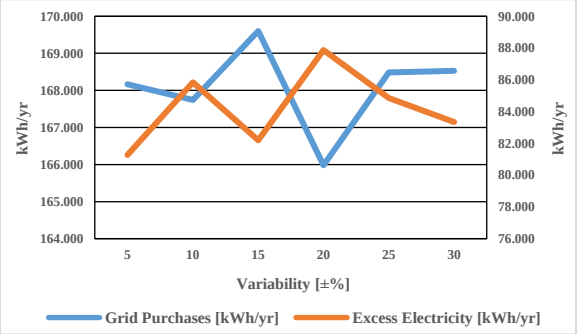


Fig. 16 The effect of timestep in the Load Profile on the Grid Purchases and Excess Electricity

As shown from Figure 15, the increase in demand uncertainty in the load profile increases the excess electricity value to be produced by the HPS. The more electricity the HPS will produce, the more it will cause inefficient sizing. Likewise, although the grid load has decreased, the amount of electricity purchased from the grid has changed depending on demand uncertainty. While the maximum electricity supply from the grid occurs at 30% demand change, the minimum electricity supply is at 25% demand change. Therefore, the grid was used more at a rate of 3.95%, and this will affect the choice of HPS. In Figure 16, on the other hand, with the increase in the hourly demand uncertainty in the load profile, the excess electricity value produced by the HPS and the amount of electricity taken from the grid has changed. While the amount of electricity received from the grid fluctuated around 1.5%, the amount of excess electricity that the HPS would generate fluctuated around 7.5%. Although the electricity purchase from the grid does not affect the HPS structure much, the excess electricity value to be produced should be evaluated. As much electricity production value as possible should be reduced, and an HPS should be selected accordingly.

b. EVCS Demand Profile

EV daily and hourly demands will inevitably change in the load profile. Day-to-day and Timestep variables offered by HOMER Grid were used. A change in the range of ± 5-30% is foreseen, and financial and technical changes in the HPS are examined. Change in COE and the variation of the annual electricity amount served to the EV are shown in Figures 17 and 18, depending on the daily and hourly uncertainty, respectively.

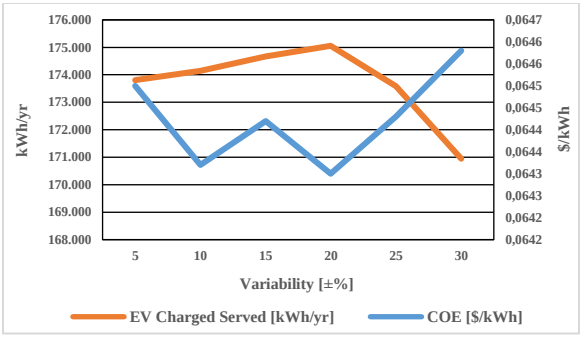


Fig. 17 The effect of day-to-day in the EVCS Profile on the COE and EV Charged Served

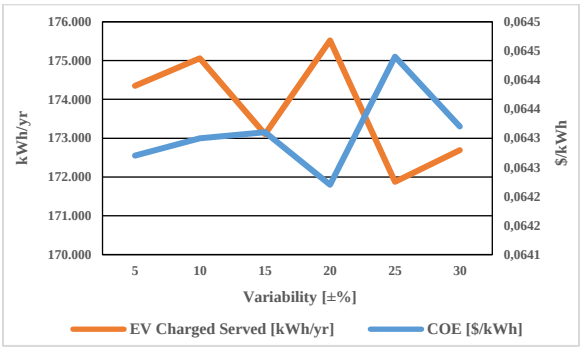


Fig. 18 The effect of timestep in the EVCS Profile on the COE and EV Charged Served

As can be seen from Figures 17 and 18, COE and the amount of electricity served to the EV per year have varied, whether the daily or hourly EV charge demand variations. The amount of electricity served to the EV fluctuated by a maximum of 2.4% in the case of a daily variation and 2.12% in the case of an hourly variation. As a matter of fact, it can be said that the daily change affects the HPS more than the hourly change. The energy production cost fluctuated between 0.063 $/kWh and 0.0645 $/kWh for both cases. However, no significant changes were observed in terms of COE.

c. Sizing HPS Based on Demand Uncertainty

The important effects of the daily and hourly demand uncertainty in the load and EVCS profiles on HPS were discussed in sub-headings a and b. Here, the effect of daily and hourly demand uncertainty on the sizing of the HPS is examined. Table 7 shows the component dimensions of the most suitable HPS structures proposed by the program due to daily and hourly demand changes.

Table 7. Effect of demand uncertainty on HPS component sizes

Demand	Variable	Comp.	Variability [±%]					
			5	10	15	20	25	30
LOAD	Day-to-day	PV	339	344	343	348	352	343
		ESS	239	238	237	236	238	225
		PCS	165	166	168	170	172	174
	Timestep	PV	338	341	337	344	340	339
		ESS	231	227	228	238	237	245
		PCS	162	160	162	166	168	172
EVCS	Day-to-day	PV	337	346	345	344	341	338
		ESS	223	239	239	238	227	221
		PCS	165	170	166	166	168	164
	Timestep	PV	345	344	341	342	342	349
		ESS	237	238	227	228	237	245
		PCS	168	166	168	168	166	170

As can be seen from Table 7, the component dimensions of the HPS due to the daily and hourly demand uncertainty in the load profile are more affected than the EVCS. In case of demand uncertainty in the load profile, the size of each HPS component changed on average around 10 to 20 kW or kWh. Likewise, in the case of demand uncertainty in the EVCS profile, the size of each HPS component changed on average between 5 and 20 kW or kWh. In both demand profiles, while the energy of the battery bank changed the most, it was followed by the solar panel power to be installed and the converter power, respectively. In addition, the demand uncertainty in the EVCS profile did not affect the converter dimensions much compared to the others.

IV. DISCUSSION

The results obtained in this study were evaluated as follows, respectively, according to their processing:

- In such a place where there are no electricity sales to the grid, COE was found to be suitable for most, with 0.0643 $/kWh compared to the references listed in the introduction.
- In case of increased daily demand uncertainty in the load profile, COE increased by 1.12% to 0.065 $/kWh, while in case of increased hourly demand uncertainty in the load profile, COE increased by 1.094% and reached 0.0647 $/kWh. It can be seen from here that demand uncertainty does not significantly affect COE. The same is seen in electricity bill savings. In the daily demand uncertainty of the load profile, electricity bill savings fluctuated at a maximum of 1.73%, reaching a minimum value of 36,883 $/yr. In addition, in hourly demand uncertainty, electricity bill savings fluctuated by a maximum of 1%, reaching a minimum value of 37,045 $/yr.

- If the daily demand uncertainty in the load profile changes, the electricity received from the grid changes by 3.95% and reaches a maximum value of 171.228 kWh/yr. Likewise, in the case of hourly demand uncertainty, the value of electricity received from the grid changed by 1.5%, reaching a maximum value of 169,602 kWh/yr. Apart from this, the amount of excess electricity produced by the HPS fluctuated by a maximum of 18.6% in the daily demand uncertainty, while this value fluctuated by a maximum of 7.5% in the hourly demand uncertainty. Therefore, it was emphasized that the electricity intake from the grid did not change much, and the excess electricity amount to be produced by the HPS should be considered.

- In the case of daily and hourly demand uncertainty in the EVCS profile, the COE value fluctuated between $0.063/kWh and $0.0645/kWh. In addition, in the case of daily demand uncertainty of the EVCS profile, the amount of electricity served to the EV fluctuated by a maximum of 2.3%, reaching a minimum value of 170.946 kWh/yr. The same is true for hourly demand uncertainty, with a maximum of 2.1% and a minimum value of 171.876 kWh/yr. Therefore, it has been observed that demand uncertainty does not change the amount of electricity served to the EV and the COE of the HPS.

- It has been observed that in case of demand uncertainties in the load profile, the HPS component dimensions will be affected more

than the EVCS profile. It was seen in both demand profiles that the battery bank is the HPS component whose energy changes the most. After the battery bank, the components that changed the HPS component size the most were PV and PCS, respectively.

V. CONCLUSION

This study combines renewable and conventional energy generation systems and ESS, considering energy management to meet the demands of load and EVs. HOMER Grid was used for the optimization of the HPS structure. According to the assumptions made at the beginning, the important results of the baseline scenario are shared. Hourly and daily demand uncertainties are appropriately reflected in the load and EVCS profile. According to the most suitable HPS solutions proposed by the program, depending on the newly formed demand profiles, the technical, financial, and dimensional changes that will occur in the HPS within the framework of these uncertainties are examined. The study was carried out in a simulation environment for the parking lot of Istanbul Yildiz Technical University, Faculty of Electrical and Electronics, with a vision for the future. The program did not prefer wind turbines because of the insufficient wind speed data for the province of Istanbul and its high cost. In addition, it is assumed that no electricity is sold to the grid, and it is assumed that there is no minor or major power outage.

In future studies: the performance of EVCS can be improved with smart charging methods; optimum positioning for EVCSs can be included in transportation networks, taking into account customer demands; studies can be carried out to increase the life of EV batteries; innovative and technological studies can be carried out for EVCS and EVs; it can be examined what kind of changes will be brought to the HPS structures in case of power outages or selling electricity to the grid.

ACKNOWLEDGMENT

This work has been supported by Yildiz Technical University Scientific Research Projects Coordination Unit under project number 4886.

REFERENCES

[1] M. K. Hasan, M. Mahmud, A. K. M. Ahasan Habib, S. M. A. Motakabber, and S. Islam, "Review of electric vehicle energy storage and management system: Standards, issues, and challenges," *J. Energy Storage*, vol. 41, no. July, p. 102940, 2021, doi: 10.1016/j.est.2021.102940.

[2] TEHAD, "Elektrikli Araç Şarj Yöntem ve İstasyon Tipleri, https://www.tehad.org/2017/07/15/elektrikli-arac-sarj-yontem-ve-istasyon-tipleri/." 2021.

[3] M. M. Rahman, G. A. Ghazi, E. A. Al-Ammar, and W. Ko, "Techno-Economic Analysis of Hybrid PV/Wind/Fuel-Cell System for EVCS," *3rd Int. Conf. Electr. Commun. Comput. Eng. ICECCE 2021*, no. June, pp. 12–13, 2021, doi: 10.1109/ICECCE52056.2021.9514084.

[4] Q. Chen, Y. Gu, Z. Tang, D. Wang, and Q. Wu, "Optimal design and techno-economic assessment of low-carbon hydrogen supply pathways for a refueling station located in Shanghai," *Energy*, vol. 237, 2021, doi: 10.1016/j.energy.2021.121584.

[5] S. Turkdogan, "Design and optimization of a solely renewable based hybrid energy system for residential electrical load and fuel cell electric vehicle," *Eng. Sci. Technol. an Int. J.*, vol. 24, no. 2, pp. 397–404, 2021, doi: 10.1016/j.jestch.2020.08.017.

[6] M. S. Islam, "A techno-economic feasibility analysis of hybrid renewable energy supply options for a grid-connected large office building in southeastern part of France," *Sustain. Cities Soc.*, vol. 38, no. November 2017, pp. 492–508, 2018, doi: 10.1016/j.scs.2018.01.022.

[7] Y. Xiang, H. Cai, J. Liu, and X. Zhang, "Techno-economic design of energy systems for airport electrification: A hydrogen-solar-storage integrated microgrid solution," *Appl. Energy*, vol. 283, no. November 2020, p. 116374, 2021, doi: 10.1016/j.apenergy.2020.116374.

[8] A. Al Wahedi and Y. Bicer, "A case study in qatar for optimal energy management of an autonomous electric vehicle fast charging station with multiple renewable energy and storage systems," *Energies*, vol. 13, no. 19, pp. 1–26, 2020, doi: 10.3390/en13195095.

[9] Q. Dai, J. Liu, and Q. Wei, "Optimal photovoltaic/battery energy storage/electric vehicle charging station design based onmulti-agent particle swarm optimization algorithm," *Sustain.*, vol. 11, no. 7, 2019, doi: 10.3390/su11071973.

[10] H. N., S. Hampannavar, D. B., and S. M., "Analysis of microgrid integrated Photovoltaic (PV) Powered Electric Vehicle Charging Stations (EVCS) under different solar irradiation conditions in India: A way towards sustainable development and growth," *Energy Reports*, vol. 7, pp. 8534–8547, 2021, doi: 10.1016/j.egyr.2021.10.103.

[11] A. K. Karmaker, M. R. Ahmed, M. A. Hossain, and M. M. Sikder, "Feasibility assessment & design of hybrid renewable energy based electric vehicle charging station in Bangladesh," *Sustain. Cities Soc.*, vol. 39, no. February, pp. 189–202, 2018, doi: 10.1016/j.scs.2018.02.035.

[12] B. Ye, J. Jiang, L. Miao, P. Yang, J. Li, and B. Shen, "Feasibility study of a solar-powered electric vehicle charging station model," *Energies*, vol. 8, no. 11, pp. 13265–13283, 2015, doi: 10.3390/en81112368.

[13] Çetin Berk Güvel, "İzmir İli için Güneş-Rüzgar Hibrit Enerjili Elektrikli Araç Şarj İstasyonu Tasarımı," *Ege Üniversitesi, Güneş Enerj. Anabilim Dalı, Yüksek Lisans Tezi*, 2018.

[14] T. Boyekin, "Çatı Tip Güneş Enerjisi Santrali ile Beslenen Elektrikli Araç Şarj İstasyonu," *Marmara Üniversitesi, Elektr. Mühendisliği Programı, Yüksek Lisans Tezi*, 2020.

[15] N. Chowdhury, C. A. Hossain, M. Longo, and W. Yaïci, "Optimization of solar energy system for the electric vehicle at university campus in Dhaka, Bangladesh,"

Energies, vol. 11, no. 9, pp. 1–10, 2018, doi: 10.3390/en11092433.

[16] O. Ekren, C. Hakan Canbaz, and Ç. B. Güvel, "Sizing of a solar-wind hybrid electric vehicle charging station by using HOMER software," *J. Clean. Prod.*, vol. 279, p. 123615, 2021, doi: 10.1016/j.jclepro.2020.123615.

[17] M. M. Rahman, E. A. Al-Ammar, H. S. Das, and W. Ko, "Optimal design of grid connected pv battery system for probabilistic EVCS load," *2020 Adv. Sci. Eng. Technol. Int. Conf. ASET 2020*, 2020, doi: 10.1109/ASET48392.2020.9118225.

[18] O. Hafez and K. Bhattacharya, "Optimal design of electric vehicle charging stations considering various energy resources," *Renew. Energy*, vol. 107, pp. 576–589, 2017, doi: 10.1016/j.renene.2017.01.066.

[19] P. V. Minh, S. Le Quang, and M. H. Pham, "Technical economic analysis of photovoltaic-powered electric vehicle charging stations under different solar irradiation conditions in Vietnam," *Sustain.*, vol. 13, no. 6, pp. 15–25, 2021, doi: 10.3390/su13063528.

[20] Y. L. Long *et al.*, "Impact of EV load uncertainty on optimal planning for electric vehicle charging station," *Sci. China Technol. Sci.*, vol. 64, no. 11, pp. 2469–2476, 2021, doi: 10.1007/s11431-021-1897-x.

[21] S. Bimenyimana *et al.*, "Integration of Microgrids and Electric Vehicle Technologies in the National Grid as the Key Enabler to the Sustainable Development for Rwanda," *Int. J. Photoenergy*, vol. 2021, 2021, doi: 10.1155/2021/9928551.

[22] A. M. Schetinger, D. H. N. Dias, B. S. M. C. Borba, and G. D. Pimentel da Silva, " Techno-economic feasibility study on electric vehicle and renewable energy integration: A case study ," *Energy Storage*, vol. 2, no. 6, pp. 1–12, 2020, doi: 10.1002/est2.197.

[23] Y. Firat, "Utility-scale solar photovoltaic hybrid system and performance analysis for eco-friendly electric vehicle charging and sustainable home," *Energy Sources, Part A Recover. Util. Environ. Eff.*, vol. 41, no. 6, pp. 734–745, 2018, doi: 10.1080/15567036.2018.1520354.

[24] C. Filote, R. A. Felseghi, M. S. Raboaca, and I. Aşchilean, "Environmental impact assessment of green energy systems for power supply of electric vehicle charging station," *Int. J. Energy Res.*, vol. 44, no. 13, pp. 10471–10494, 2020, doi: 10.1002/er.5678.

[25] S. Aggarwal and A. K. Singh, "Impact analysis of electric vehicle charging station integration with distributed generators on power systems," *Int. J. Circuit Theory Appl.*, vol. 49, no. 6, pp. 1811–1827, 2021, doi: 10.1002/cta.2974.

[26] T. Nasir *et al.*, "Optimal Scheduling of Campus Microgrid Considering the Electric Vehicle Integration in Smart Grid," pp. 1–20, 2021.

[27] D. Yan and C. Ma, "Stochastic planning of electric vehicle charging station integrated with photovoltaic and battery systems," *IET Gener. Transm. Distrib.*, vol. 14, no. 19, pp. 4217–4224, 2020, doi: 10.1049/iet-gtd.2019.1737.

[28] F. B. Enstit and A. Ç. Dan, L U, "Elektrikli kara araçlari için güneş enerjisi destekli bir şarj istasyonunun tasarimi," *Ege Üniversitesi, Güneş Enerj. Anabilim Dalı, Yüksek Lisans Tezi*, 2020.

[29] Doruk Güneş, "Araç Şarj İstasyonlarının Dağıtım Şebekesine Entegrasyonu ile Meydana Gelen Olumsuzlukların Belirlenmesi," *Kocaeli Üniversitesi, Elektr. Mühendisliği Anabilim Dalı, Yüksek Lisans Tezi*, 2017.

[30] J. A. Domínguez-Navarro, R. Dufo-López, J. M. Yusta-Loyo, J. S. Artal-Sevil, and J. L. Bernal-Agustín, "Design of an electric vehicle fast-charging station with integration of renewable energy and storage systems," *Int. J. Electr. Power Energy Syst.*, vol. 105, no. July 2018, pp. 46–58, 2019, doi: 10.1016/j.ijepes.2018.08.001.

[31] P. Bastida-Molina, E. Hurtado-Pérez, M. C. Moros Gómez, and C. Vargas-Salgado, "Multicriteria power generation planning and experimental verification of hybrid renewable energy systems for fast electric vehicle charging stations," *Renew. Energy*, vol. 179, pp. 737–755, 2021, doi: 10.1016/j.renene.2021.07.002.

[32] A. O. Erick and K. A. Folly, "Power flow management in multi-source electric vehicle charging station," *IFAC-PapersOnLine*, vol. 53, no. 2, pp. 12590–12595, 2020, doi: 10.1016/j.ifacol.2020.12.1824.

[33] HOMER Energy, "https://www.homerenergy.com/." 2021.

[34] TEHAD, "https://www.tehad.org/2021/03/25/otopark-yonetmeligine-sarj-duzenlemesi-geldi/." .