A NOTE ON VEHICLE-TO-GRID SIMULATION FOR A SMART MICROGRID

Dürdane Yıldırım,
Cemal Keleş*

Inonu University,
Malatya, Türkiye

Abstract:

In recent years, the energy system and the environment have faced major problems. For this reason, electric vehicles (EVs) have attracted great attention in terms of energy systems and transportation. When EVs are evaluated together with the smart grid, they provide great gains such as energy security, promoting energy savings, reducing greenhouse gas emissions, and preventing air pollution. In this study, the operating performance of the microgrid-connected vehicle-to-grid (V2G) system consisting of household and industrial loads and renewable energy (solar, wind, and hydroelectric) generation was investigated. A total of 100 vehicles were considered in the V2G system, which has three different types of EV profiles. The system is modeled and simulated in MATLAB/Simulink. The effectiveness of V2G was evaluated in the simulation study. The simulation results show that V2G effectively regulates the grid voltage for a wide variety of inputs.

Keywords:

Electric Vehicle, Renewable Energy Sources, Smart Grid, Vehicle-to-Grid.

INTRODUCTION

The majority of the current global population lives in cities and this number is expected to continue to increase in the future [1]. However, different energy demands in urban areas of the world will continue to grow with increasing population. In recent years, the environment has been struggling with major problems due to greenhouse gases resulting from the combustion of fossil fuels [2]. This expected increase in energy demand will require new and innovative solutions for emerging problems [3]. While people in cities continue their daily lives, general trends in energy demand can be followed. While energy consumption tends to be high in business areas during rush hour morning traffic, the same situation can be observed in living areas during waking hours and just after people come home from work [4]. Considering this difference in energy demand over time, it is useful to evaluate it in terms of peaks and troughs. A sudden increase in energy demand causes a peak in consumption, while a sudden decrease in demand creates a valley. Overcoming these sudden increases and decreases in demand is one of the most important problems for electricity distribution systems [5].

Correspondence:
Cemal Keleş

e-mail:
cemal.keles@inonu.edu.tr

DOI: 10.15308/Sinteza-2023-220-226

It can be very useful to offer solutions to reduce the irregularities between these hills and valleys. In the last quarter century, great attention has been paid to the solution of this problem in the world. Governments around the world provide incentives and devote a large portion of their national budgets to promoting the research and development of solutions to improve the world's emission levels [6]. One of the most important steps to be taken for a cleaner future is to reduce unnecessary energy use as well as reducing excessive consumption. One way to help would be to maximize the use of available energy by providing solutions to put the power held in reserve where it is needed. The electricity grids of the future, also known as Smart Grids, aim to assist these goals of modernizing energy management [7]. Smart grids are seen as a vital tool in tackling many of the problems we face with grid optimization and maintenance. EVs attract attention and are proposed as a solution due to their ability to reduce greenhouse gas emissions and fuel consumption, and increase sustainable energy use in transportation [2]. One of the most remarkable innovations that emerged as a result of this is V2G charging technology. This technology aims to return backup power to the grid when EVs are connected to a charger [8]. By doing this, it can benefit in reducing the imbalance between peak and valley in grid load. Existing studies on related topics are mostly conceptual and are just beginning to be applied to real systems.

The generation systems in the microgrid structure use renewable energy sources to meet the demand as much as the energy deficit. The integration of microgrid systems has many benefits for both power generation companies, consumers and power distribution companies. Integration of microgrid into grid; can increase the efficiency of the grid, reduce greenhouse gas emissions and reduce costs for consumers. EVs used as energy storage are generally recommended for intermittent sources since renewable energy generation is affected by weather conditions [9]. The idea of using EVs as energy storage facilitates their integration into renewable energy sources and microgrid. Because EVs are parked at work or home 22 hours a day; microgrid can treat EVs as an energy storage unit. EVs can consume and store energy, while generating power for the grid when parked and connected to the utility grid [10]. As EVs grow and the transition accelerates, charging units should become more common and charging times for EVs should be reduced. Reducing the charging time is important to popularize the use of EVs. However, this will increase the load on the power system. Therefore, the main goal for EVs is to reduce charging time and improve the power quality of the grid. [11].

In this study, the operating performance of the microgrid-connected V2G system, which consists of industrial and household loads as well as renewable energy (solar, wind and hydroelectric) generation, was investigated.

2. STRUCTURE AND FEATURES OF THE SIMULATION SYSTEM

EVs are used as a distributed power source for the grid in addition to being a controllable load [12]. In this study, it is aimed to transfer power from the V2G and at the same time to ensure optimum energy conversion in harmony with renewable energy sources. In this study, wind power plant (WPP), solar power plant (SPP) and hydroelectric power plant (HPP) were used as renewable energy sources. Unlike fossil energy sources, wind energy is a renewable energy source that does not cause any harm to the environment and can also be obtained with high efficiency. The WPP source, which produces electrical energy in direct proportion to the wind, produces a nominal power when the wind reaches a nominal value. However, if the wind speed exceeds the maximum wind speed value, the WPP will be off the grid until the wind returns to its nominal value. The WPP source used in this study is 4.5 MW. SPP systems convert solar energy into energy that can be used without causing carbon emissions. Carbon emissions occur during the generation of solar panels, which are only used in SPP systems. In SPP systems, the solar intensity follows a normal distribution and reaches its highest intensity at noon. The SPP source used in this study has a power of 8 MW. Another renewable energy source used in the study is the HPP system. HPP, which uses the potential energy of heightened water and converts it first into mechanical energy and then into electrical energy, has a power of 15 MW in this study.

The loads in this study; they consist of asynchronous machine and residential loads used to represent the effect of industrial inductive load on the microgrid. The residential load follows a consumption profile with a certain power factor. Asynchronous machine; it is controlled by the relationship between the mechanical torque and the rotor speed. The load power used in this study is 10 MW.

However, a fleet of 100 EVs with an average power of 40 kW was considered. A V2G system was created to have 3 different EV profiles. This groups are listed in Table 1. The average power for each vehicle was considered to be 40 kW.

Thus, the total power of the V2G system is considered as 4MW. The fleet of 100 EVs in total is divided into three groups for ease of inspection according to different travel and charging times. It can be stated that if the charge rate of vehicle batteries is less than or equal to 85%, it is in the charging group, and if it is greater than or equal to 95%, it is in the regulation group.

- **Group 1**: Those who arrive at the workplace in a short time and have the opportunity to charge their vehicle at the workplace (30%) There are 30 vehicles in total in this vehicle group. The hours of 7:00-8:00 in the morning are taken as the departure time of the vehicles in the 1st group, and the hours of 17:00 and 18:00 in the evening are taken as the basis. Vehicles are traveling during these hours. During the rest of the day, they are in charging cases.
- **Group 2:** Those who reach the workplace in a longer time than the 1st group and have the opportunity to charge their vehicle at the workplace (60%) There are 60 vehicles in total in this vehicle group. Vehicles in this group travel for a longer period of time compared to the vehicles in the 1st group on their way to and from their workplaces. Vehicles in this group, which are on the move between 6:00-7:00 in the morning and 17:00, 18:00 and 19:00 in the evening, are in charging position for the rest of the day.
- **Group 3:** Vehicles used in night shifts (10%) There are 10 vehicles in total in this vehicle group. Since the vehicles in this group work at night shift, it is assumed that they are at the workplace between 21:00 and 05:00, and that they are in the charging state for the remaining hours of the 24-hour period.

After the 100 EVs in this study were divided into three different groups according to their different travel and charging status, various examinations were made. By means of the three-phase contactor of the asynchronous machine in the settlement in the study;

- It was ensured that it was activated on 11:00 hour.
- A short circuit fault has occurred in the system within the [12:00-12:02] time interval.

When the system is in balance, it creates an extra load and its effect on the system is examined. The model discussed in this study is simulated for a 24-hour scenario. The general view of the system is shown in Figure 1.

Table 1 - Groups of EVs.

Group No	Number of Vehicles	Vehicle usage time intervals
Group 1	30	07:00-08:00/17:00-18:00
Group 2	60	06:00-07:00/17:00-19:00
Group 3	10	21:00-05:00

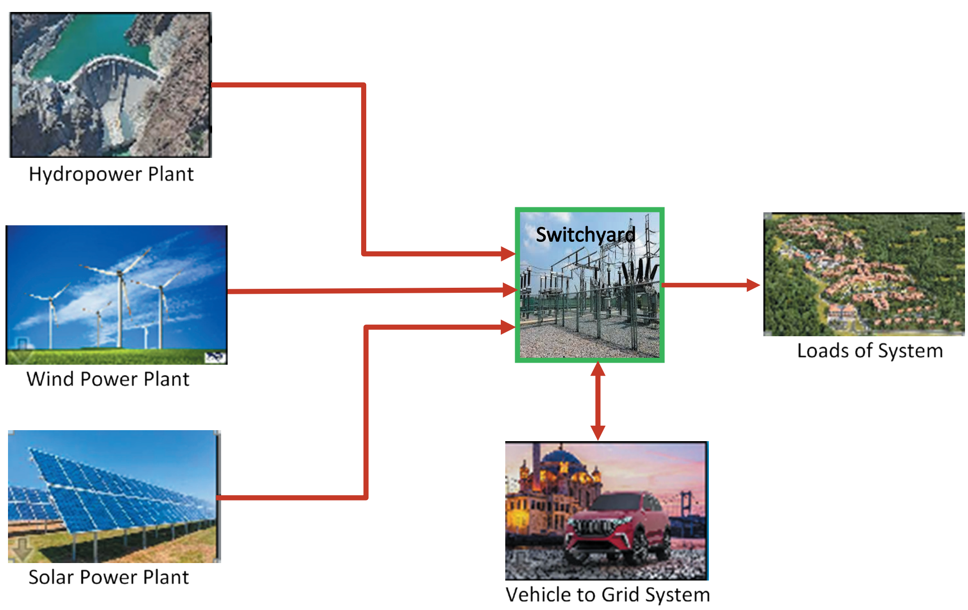

Figure 1 - Structure of proposed microgrid system.

3. V2G SYSTEM CONCEPT AND MICROGRID INTEGRATION

EVs offer many advantages such as increasing the efficiency of the charging system, reducing greenhouse gas emissions and dependence on oil. Also, the biggest advantage of EVs is to use technology known as V2G. The V2G application is basically a direct power flow from the vehicle to the distribution grid, which is applied only in the EV. With V2G, existing distributed energy storage devices are instantly available. With this concept, various applications of battery types enter the market. Two important connections are required in the implementation of the V2G concept: The first, the power connection used for the transmission of electrical energy from the vehicle. The second one, logic and control connections to give feedback signals when power is needed, in the direction the power is sent. When the EV has V2G implementation, it includes the following features: active power regulation, reactive power supply, load balancing, harmonic filtering, and reduction of operating cost and total cost of the system, improvement in load factor, emission reduction, monitoring of variable renewable energy sources, generating revenue. EVs with V2G system offer backup source for renewable resources. These features can provide ancillary services including frequency and voltage control, rotating reserve.

Reactive power compensation is one of the methods used to provide voltage regulation to the power grid. Reactive power support also provides power factor correction, reducing current flow in generation and power losses in power lines. Moreover, this service reduces the load on the power equipment, resulting in increased efficiency in the operation of the power system. In these cases, capacitive reactive power is required for power grid compensation. Grid connected EV can provide reactive power compensation service. The EV does not cause any degradation in battery life as active power compensation is provided by the DC coupling capacitor of the bidirectional battery charge. With the development and design of bidirectional fast charging stations, power compensation control is also provided in EV fast charging control. Active power compensation control controls the grid voltage during EV fast charging. Therefore, the grid voltage drop problem due to EV charging can be addressed with the proposed reactive power compensation control of the EV charging station.

4. SIMULATION RESULTS AND DISCUSSION

The system is modeled and simulated in MATLAB/Simulink. If the state of charge (SoC) of EV batteries is less than or equal to 85%, it is considered to be in the charging group, and if the SoC is greater than or equal to 95%, it is in the regulation group. Here, the state of being in the regulation group; it is the case of using the batteries as a source by connecting them to the microgrid (SoC ≥ 95%).

Thus, it means that EV battery groups will be used as a source in order to eliminate the problems that may occur in the grid such as power outage, voltage and frequency changes, supply-demand imbalances.

When a voltage drop occurs in the system, the system is activated and the EV battery can regulate the grid in order to return the voltage to the allowable limit range. The industrial load was activated at 11:00 by means of a 3-phase contactor. A short circuit fault occurred at 12:00.

Figure 2 shows the change in grid voltage. A decrease in the grid voltage was observed with the activation of the industrial load at 11:00 am. However, the system recovered and managed to bring the voltage back to the nominal level. In addition, although there was a critical change in the voltage in the short-circuit fault that occurred at 12:00, it reached the nominal value range in a short time. In Figure 3 (a) and (b), the active and reactive power values of hydroelectric, solar and wind power plants are shown, respectively. In Figure 4 (a) and (b), the active load power and total real power values are given, respectively. The change in regulation voltage is given in Figure 5 (a). As can be seen from the figure, a decrease in the regulation voltage was recorded at 12:00 at the time of the short-circuit fault. However, it is seen that the voltage value reaches the nominal value in a short time. A close view of this moment is given in Figure 5 (b). Figure 6 shows the number of EVs in regulation and charging, respectively, during the day. The vehicles in the regulation work in the V2G position. In the case of charging, it is understood that the vehicles switch to the load position.

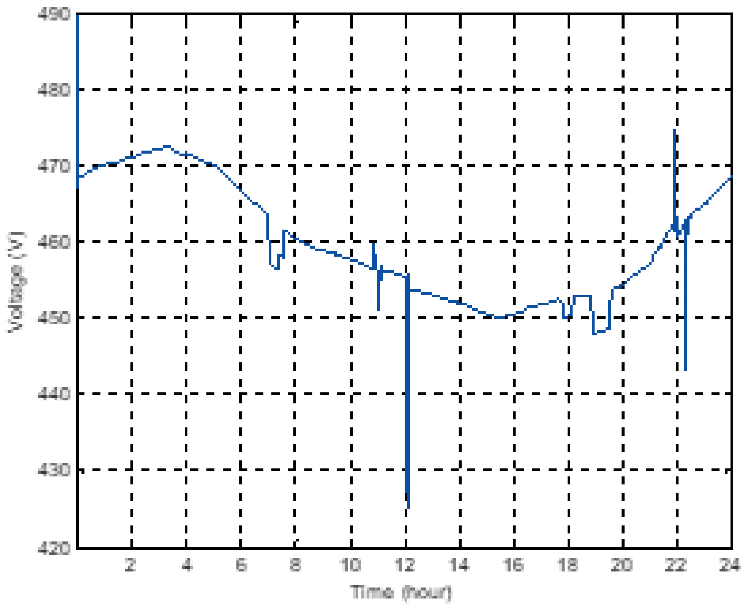

Figure 2 - Change in microgrid voltage.

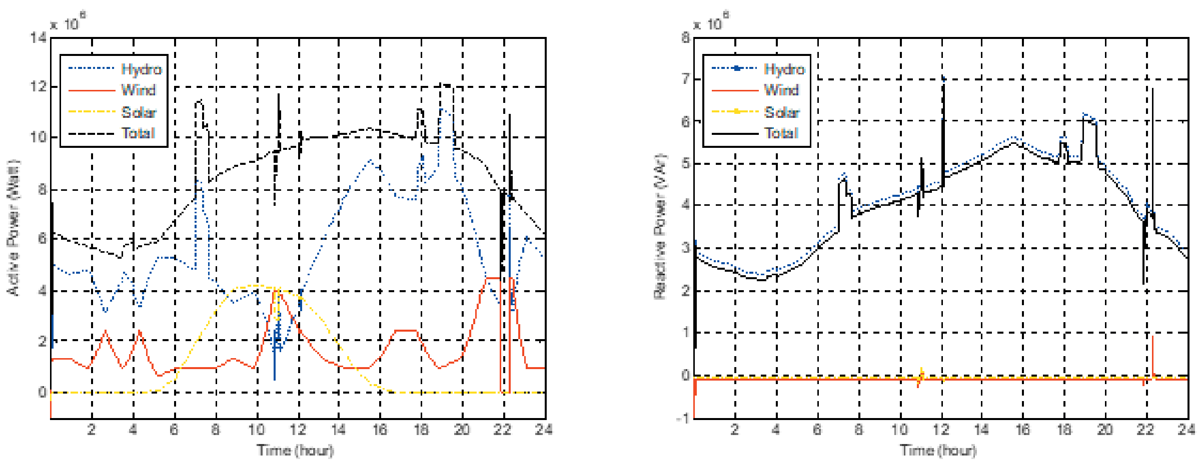

Figure 3 - (a) Active and (b) Reactive power values of energy generation units.

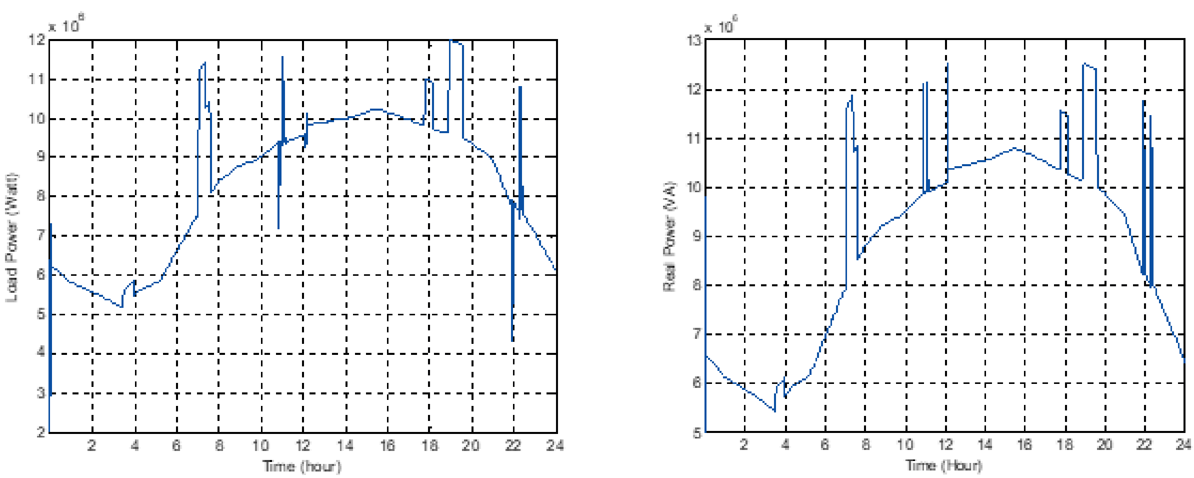

Figure 4 - (a) Active power values of the load and (b) Total real power values.

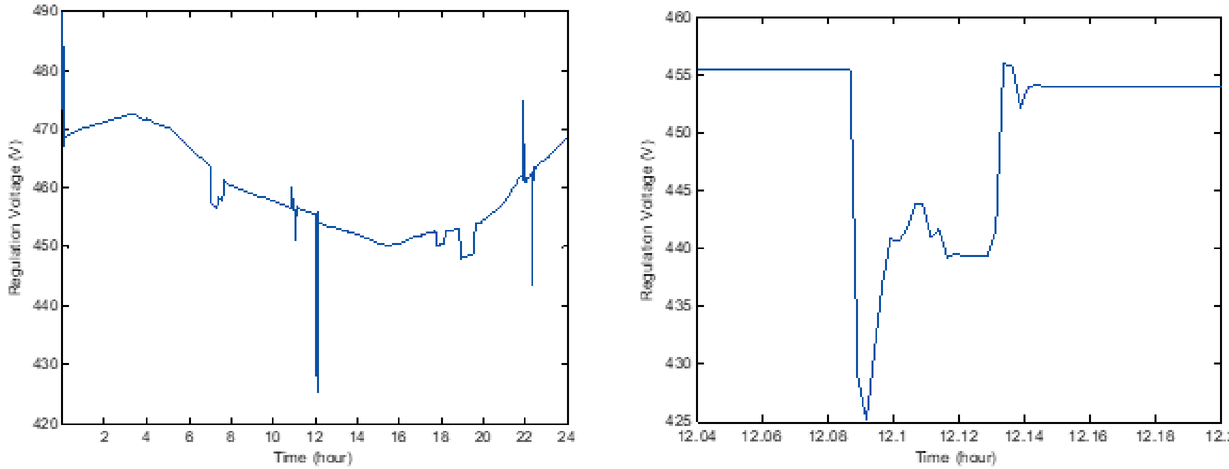

Figure 5 - (a) Change in regulation voltage (b) Close view of the change in regulation voltage.

5. CONCLUSION

With the increase in industrial and household loads, the energy demand is increasing day by day. The increase in the use of fossil fuels both causes environmental problems and causes the search for alternatives to these resources, whose reserves are about run out. In addition, the increase in energy demand brings along various problems such as low energy quality and power outage, voltage drop, etc. In this study, in order to solve these problems, a microgrid system with EV and renewable energy sources is discussed. When EVs are evaluated together with the smart grid, they provide great gains such as energy security, promoting energy savings, reducing greenhouse gas emissions and improving energy quality. In this paper, the operating performance of the V2G system connected to the microgrid consisting of domestic and industrial loads and renewable energy (solar, wind and hydroelectric) generation units was investigated. A total of 100 vehicles were handled in the V2G system, which has three different types of EV profiles. The system is modeled and simulated in MATLAB/Simulink. The effectiveness of V2G was evaluated in the simulation study. The simulation results showed that V2G effectively regulates the grid voltage.

6. REFERENCES

[1] S. G. Evans, *casEV - Modelling smart power grids with V2G charging as complex systems within an urban context*, Master Dissertation, p. 81, 2020.

[2] D. D. Chauhan, H. Yadav, M. Sogna, M. K. Meena, N. Jain, "A study on electric vehicle to grid implementation," *International Journal for Research in Applied Science and Engineering Technology*, vol. 9, no. 5, pp. 1543–1553, 2021.

[3] S. Deb, K. Tammi, K. Kalita, and P. Mahanta, "Impact of electric vehicle charging station load on distribution network," *Energies*, vol. 11, no. 1, p. 178, 2018.

[4] S. Iqbal, S. Habib, M. Ali, A. Shafiq, A. ur Rehman, E. M. Ahmed, T. Khurshaid, and S. Kamel, "The impact of V2G charging/discharging strategy on the microgrid environment considering stochastic methods," *Sustainability*, vol. 14, no. 20, p. 13211, 2022.

[5] B. Shrimali, J. K. Meharchandani, A. A. Chhipa, "V2G Simulation for Frequency Regulation in Micro Grid with Solar, Wind and Diesel Power Generation Environment," *International Research Journal of Engineering and Technology (IRJET)*, vol. 7, no. 10, p. 366, 2020.

[6] H. F. Tafti, "Load-Balance via Scheduling Grid-Enabled Vehicles Charging and Discharging Using V2G Systems to Energy Consumption Modification by Counting the Cost," *TechRxiv*, Preprint, 2022. https://doi.org/10.36227/techrxiv.21779960.v1

[7] P. Connor, O. Fitch-Roy, *Chapter 14 - The Socio-Economic Challenges of Smart Grids*, Pathways to a Smarter Power System. Academic Press, pp. 397-413, 2019.

[8] K.T. Chau, 21 - *Pure electric vehicles*, Alternative Fuels and Advanced Vehicle Technologies for Improved Environmental Performance, Ed. by Richard Folkson, Woodhead Publishing, pp. 655-684, 2014.

[9] M. Khalid, X. Lin, Y. Zhuo, R. Kumar, and M. Rafique, "Impact of energy management of electric vehicles on transient voltage stability of Microgrid," *World Electric Vehicle Journal*, vol. 7, no. 4, pp. 577–588, 2015.

[10] J. Tomić and W. Kempton, "Using fleets of electric-drive vehicles for grid support," *Journal of Power Sources,* vol. 168, pp. 459-468, 2007.

[11] Y. Ota, H. Taniguchi, T. Nakajima, K. M. Liyanage, J. Baba, and A. Yokoyama, "Autonomous distributed V2G (vehicle-to-grid) satisfying scheduled charging, " *IEEE Transactions on Smart Grid*, vol. 3, pp. 559-564, 2012.

[12] F. Justin, G. Peter, A. A. Stonier, and V. Ganji, "Power Quality Improvement for Vehicle-to-Grid and Grid-to-Vehicle Technology in a Microgrid, "International Transactions on Electrical Energy Systems, vol. 2022, p. 17, 2022. https://doi.org/10.1155/2022/2409188