Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2021, 8(2):48-58

Research Article ISSN: 2394 - 658X

Energy Management of Charging and Discharging Strategy of Electric Vehicles into Microgrid Containing PV Farm

Marwa R. Elkallah[1], Tamer F. Megahed[2], Sobhy M. Abdelkader[3] and Akram A. ELmitwally[4]

[1]*Researcher, Electrical Power Engineering, Mansoura University, Egypt, E-mail: marwaelkallah7@gmail.com*
[2]*Assistant Professor, Electrical Power Engineering, Egypt-Japan University of Science and Technology (E-JUST), Egypt, E-mail: tamer.megahed@ejust.edu.eg*
[3]*Professor, Electrical Power Engineering, Egypt-Japan University of Science and Technology (E-JUST), Egypt, E-mail: sobhy.abdelkader@ejust.edu.eg*
[4]*Professor, Electrical Power Engineering, mansoura university, Egypt, E-mail: kelmitwally@yahoo.co.uk*

ABSTRACT

The arrangement of charging and discharging between electric grid and vehicles is gaining attention as an environment-friendly approach that provides ancillary services through V2G strategy. The Microgrid aggregator acts as an intelligent interface between the electric grid and vehicles. It has the technical ability to match the network based on load, charging, and discharging (regulation) strategy management. This chapter discusses the effect of EV charging procedures into a grid-connected with a Microgrid system containing a PV farm as the energy source. The variety of charging strategies with different rated powers leads to an increase in the PV energy usage through the Microgrid that would lessen the unwanted peaks from EV loads integrated with the grid. We also discuss here the charge and discharge strategy for maintaining the grid voltage profile. Accordingly, a controlled EV charging and discharging procedure is developed for a Microgrid consisting of a PV farm. The intelligent charge and discharge method ensures the voltage regulation of the grid. This study aims to investigate two goals: 1) increasing the usage of renewable sources like PV and lessening the increasing effects of EV charging demand while ensuring that EVs are being charged; and 2) providing the system performance and stability by using EVs for the voltage regulation considering its charging/discharging flexibility and storage.

Key words: Microgrid, PV farm, electric vehicle,uncontrolled charging, V2G, discharging, power quality and voltage regulation

1. INTRODUCTION

The decrease of fossil fuel, oil, and their high costs, and the increase of awareness of the environment increase the motivation to search for alternative resources that are cleaner and safer for the environment. The newest research studies focus on generating energy from renewable resources like solar, wind, and hydro plants [1]. Renewable resources are set in industrial and residential areas combining with the electrical grid to form Microgrids to increase the reliability concerns of the system [2]. Microgrids and smart grids are considered a way to improve systemFlexibility [3]. Charging electric vehicles (EV)from the grid increase the demand for electricity which has effects on the power quality of the power system. Power systems are set by electrical engineers depending on the code of the country for handling the predicted loads with the generation. When a new technology like an EVis linked to the electric grid it should be matching with the grid to ensure the power quality of the system. The integration of EVs and renewable resources into grids will increase in the next decades [4]. Electric vehicle charging can be coordinated or uncoordinated. Uncoordinated charging, there is no control over the charge rate of the PEVs. They begin to charge immediately when plugged in or after a predetermined time and only cease charging when the battery is fully charged or the vehicle is disconnected from the grid. Coordinated charging control can only be done to limit or define the EV charging power rate or through active power injection. The first case is characterized by unidirectional power flow from the grid to vehicle (G2V), and the second case is characterized by bidirectional flow (from the G2V and V2G). It is through coordinated charging that the impacts and benefits of the previous section can be mitigated and availed. Thus, this type of power flow allows providing ancillary services to the grid and renewable energy sources entry support.

1.1 Related Works

The uncontrolled integration of EVs into Microgrids with high power rating lead to unwanted impacts like voltage and frequency deviation. Shifting EVs charging without a definite strategy to any time where renewable energy such as PV exists,will lead to unwanted peaks in the load profile [4, 5]. It also showed that shifting EVs charging without a definite strategy to any time where renewable energy such as PV exists,will lead to unwanted peaks in the load profile. Controlled EV charging can mitigate the unwanted effects on the grid by using a high share of renewable energy sources into the electric grid which leads to peak load shaving, providing the reliability of the service, reducing the cost of operation and voltage and frequency regulation[6, 7].Studies on EVs and microgrid's contribution are divided into two sections; the first section is to provide the system performance and stability by using EVs for voltage and frequency regulation due to its charging/ discharging flexibility and storage [3, 8, 9]. The second section aims to increase the usage of renewable sources like PV and lessening the increasing impacts of EVs charging demand while making sure that EVs are being charged [10, 11]. Also, vehicle to grid (V2G) is the newest development in electric vehicles which inject electric power back to grid when needful so as to ensur power quality. V2G is powered by electric vehicle battery and can supply power to grid during on-peak periods [12]. When PV is compined with the system, V2G can solve the problem of PV intermittence [13]. V2G is the suitable choice for the operation of microgrids which has positive impacts on energy managements [14, 15].

1.2. Contribution

This paper discusses algorithms for EV charging to increase the usage of renewable sources like PV and lessening the increasing impacts of EVs charging loads on the electric grid to ensure system voltage regulation. Due to this reason, a controlled EV charging and discharging procedure is developed for Microgrid consisting of a PV farm. The assumed procedure makes all charging profiles follow the PV farm energy generation leading to increasing PV usage as a source of energy, energy demand from the grid is lessened and improves the power quality and voltage performance.Also, it presents an intelligent charging and discharging method to ensure voltage regulation of the grid. This study will be organized to investigate two goals; firstly, increase the usage of renewable sources like PV and lessening the increasing impacts of EVs charging demand while making sure that EVs are being charged. The second goal, to provide the system performance and stability by using EVs for voltage and frequency regulation due to its charging/discharging flexibility and storage[16].

1.3. Organization

The paper is organized into five sections. Section 2 introduces the concept of vehicle to grid (V2G) and its different services; section 3 shows system equations for generation and load; section 4 illustrated different three cases study of Evs charging ; section 5 shows the proposed system description and discussion ; section 6 shows the conclusion of the study

2. CONCEPT OF THE VEHICLE TO GRID (V2G) AND GRID TO THE VEHICLE (G2V).

G2V permits providing energy from the grid for EV charging [53]. When renewable resources are integrated into the grid, EVs can be charged at periods of large renewable resource penetration levels. In addition to Evs act as a load to the distribution power system, the battery can be considered as a distributed storage for grid management to improve grid stability and reliability. It also supports the adoption of renewable energy generation and improves the system efficiency leading to the V2G concept. In V2G, EVs can supply power into the grid while being parked [34, 54]. Energy is injected into the grid in case of an energy shortage, particularly during low output power from renewable resources. EVs have to be charged at low demand periods and discharge at high demand periods. Fig. 1 illustrates the V2G and G2V configuration. V2G manages EV usage in many ancillary services into the power system for grid stability and regulation.

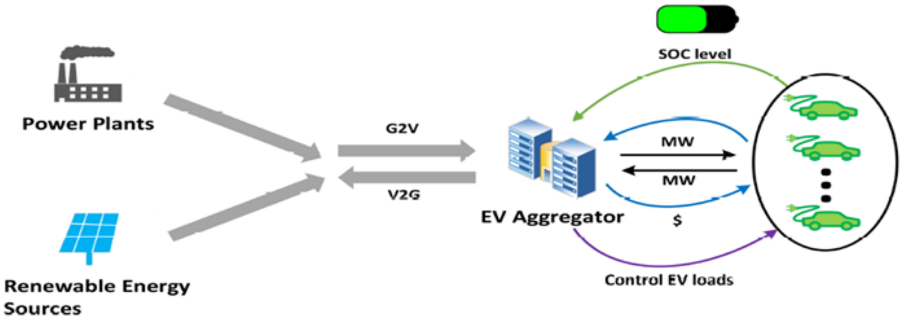


Fig. 1 Configuration of the proposed framework: G2V; V2G; SOC; system operator; and EVs.

The V2G strategy presents different services, such as these below:

a. Power supply reserve

The high penetration of the V2G system can maintain the demand and supply balance in the grid by power injection. For example; hundreds of EVs will provide the additional electric power required by discharging their batteries into the grid. Here EVs act as a spinning reserve or a storage system. This cannot be noticed by using individual vehicles due to its small battery capacity, but through a large scale of EVs.

b. Peak shaving

EVs can share in controlling battery charging and discharging. During normal days, at afternoon, it is observed peak values in the residential load curve. Integrating EVs also increases the load demand and generates new peaks; hence, charging EVs at off-peak hours and discharging them at peak hours can solve the problem.

c. Grid regulation

The V2G strategy can help in grid frequency and voltage regulation. The frequency must be regulated near the nominal frequency. The deviation in the frequency value requires actions from the operators. In case of a high frequency and a high generated power from the grid, the load demand must be increased, or the generation must be reduced to keep the system balance. EVs help by charging their batteries to raise the load demand. If the frequency is low, and the load demand is high, the generation must be increased, or the load demand must be reduced. This can happen by interrupting EV charging and starting discharging into the grid. The previous operation is called frequency regulation. The problem can also be solved by integrating renewable power resources. A large scale of EVs can help the grid in voltage regulation. The voltage falls from its nominal value when the load increases, leading to grid equipment and home appliance damage. Voltage compensation can be done by injecting reactive power into the electric grid. EVs can participate by discharging its power into the grid. Regulation is automatically coordinated by connecting from the operators.

d. Reactive power support

During the charging of EVs, the reactive power compensation is very important in maintaining the distribution grid voltage profile. The DC link through the charger contributes to provide reactive power to the electric grid through the V2G operation mode. In the past, the basic issue with EVs was their battery storage. This issue was recently resolved, and the EV can provide power to the electric grid when the distribution grid voltage profile needs to be improved. Integrating EV in the electric grid affects the grid voltage. Using the storing energy in EV batteries helps to provide system operation and efficiency. The reactive power compensation is done by the DC link capacitor, which provides voltage stability and enhances the power quality within electric grids.

3. EVs CHARGING SCENARIOS

The total load in the supposed Microgrid is expressed as:

$$\boldsymbol{p_{tot}}(\mathrm{t}) = \boldsymbol{p_{base}}(\mathrm{t}) + \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{p_{charg,i}}(\mathbf{t}) \qquad (1)$$

Where $\boldsymbol{p_{base}}(\mathrm{t})$ is the base load of the residential loads and factory, $\boldsymbol{p_{charg,i}}(\mathbf{t})$ is the charging power of each EV, n is EVs number. The overall power injected through the Microgrid must match the total load demand; therefore, the overall power injected from the grid is expressed as follows:

$$p_{\mathrm{grid}}(t) = \boldsymbol{p_{tot}}(\mathrm{t}) - \boldsymbol{p_{pv}}(\mathrm{t}) \qquad \text{if } \boldsymbol{p_{tot}}(\mathrm{t}) > \boldsymbol{p_{pv}}(\mathrm{t}) \qquad (2)$$

$$p_{\mathrm{grid}}(t) = 0 \qquad \text{if } \boldsymbol{p_{tot}}(\mathrm{t}) < \boldsymbol{p_{pv}}(\mathrm{t}) \qquad (3)$$

Where $\boldsymbol{p_{pv}}$, is the power generated by the renewable energy source (i.e., PV farm).

4. EVs CHARGING PROCEDURES

The charging strategies of EVs are divided into three strategies (Fig 2). The first strategy is uncontrolled charging, which charges EVs with the rated power of the charger at any time and everywhere without any control. The second strategy is shifting EV charging loads to the off-peak periods where the price of electricity and the load demand are low or where PV is maximum [17]. The third strategy is intelligent charging and regulation, in which vehicles will follow controlled charging and a regulator to ensure the power quality and voltage performance. This study introduces a Microgrid containing a PV system. In the first case, people charge their vehicles any time with no control, leading to PQ issues. In the second case, vehicles will be charged at the PV peak time to overcome this problem. PQ will be improved, but the charging time will face constraints. In the third case, vehicles will be divided into two categories, that is, vehicles in charge mode and vehicles in regulation mode, to improve the power quality and voltage regulation.

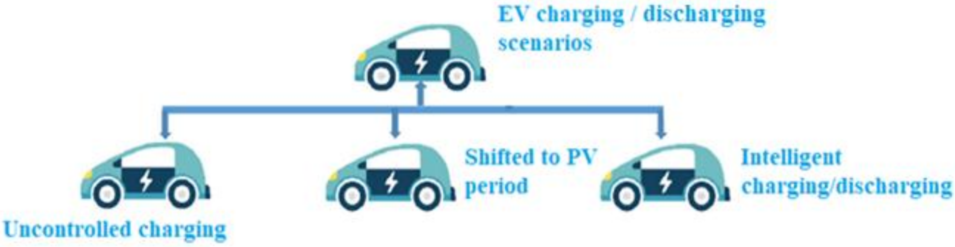


Fig. 2 EVs charging scenarios

a. Uncontrolled charging: To obtain the charging power for each EV, the required energy (kwh) for each EV to be 100% charged is expressed as follows:

$$\boldsymbol{E_{charg} = (1 - soc_{initial}) x \frac{C_{battery}}{\eta}} \qquad (4)$$

Where $\mathbf{soc_{initial}}$is the EV state of charge when it arrived, $C_{battery}$ is the capacity of battery, $\boldsymbol{\eta}$**isthe**charger efficiency which supposed to be 90% for all the study chargers. The total time required for each EV to be fully charged at the charger rated power is obtained with:

$$\boldsymbol{T_{charg} = \frac{E_{charg}}{p_{rated,i} x \eta}} \qquad (5)$$

Where $\boldsymbol{p_{rated,i}}$, is the rated power for each EV (kW).

The charging power for each EV is calculated as follows:

$$\boldsymbol{p_{charg}(\mathrm{t}) = p_{rated,i} , \quad \nabla t \epsilon \, [t_{arrival} , t_{arrival} + t_{charg}]} \qquad (6)$$

Where $\boldsymbol{t_{arrival}}$, is the time when each EV arrived to start charging.

b. Shifting charging time: EV charging can be shifted as follows without control actions: MGC shifts the EV time of charging to the period when the output power of PV is maximum. The charging power is then calculated as

$$p_{charg}(\mathrm{t}) = p_{rated,i} , \quad \nabla t \, \epsilon \, [t_1 , t_1 + t_{charg}] \qquad (7)$$

Where, t_1 is the starting period where PV generation is at its maximum value.

Intelligent charging–regulation scenario, this scenario aims to improve the efficiency, security of the grid and voltage performance due to EV integration at a large scale of PV. EV charging control can help to balance a discontinuous PV and ease the adoption of the PV into the grid. EV integration presents a challenge to grid operation and planning; hence, smart charging is required to ensure system stability. The aggregators of EVs play the main role in EV adoption with the grid by charging EV batteries or sharing in to the electricity market. In this case, EVs will be considered as an internal battery to achieve voltage regulation. EV batteries have three modes; charging, waiting, and discharging. In the charging mode or G2V; batteries are charged from the grid by buying electricity. In the discharging mode (regulation) or V2G; the power stored in batteries returns back to the grid. The waiting time is used to avoid periods with a high price. The voltage decreases below limits if the charging process is without control. EV aggregators react with the grid operators to define the EV mode depending on the voltage value. If the voltage decreases below the determined limit, EVs will discharge the power into the grid to reduce the costs, lessen system losses, and regulate the system voltage. EVs will be divided into zones. Each zone contains sockets in charge, by which the power flows in one direction from the source to the vehicles and sockets in charge and regulation, by which power flows into two directions Fig 3.

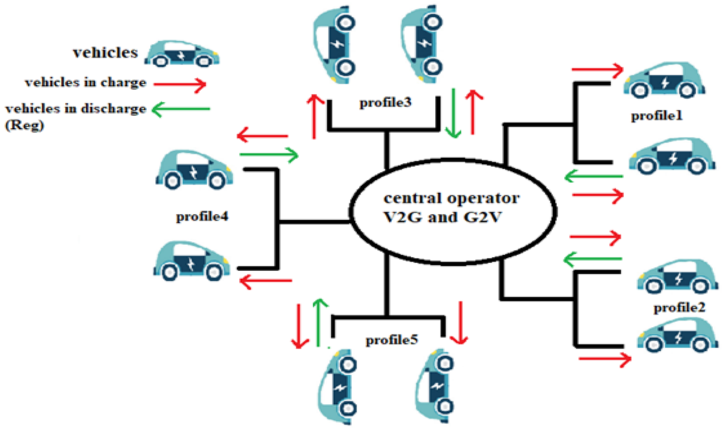


Fig. 3 Structure of the EV profiles

The cars in each profile are divided into cars in regulation and in charge. Each profile contains a charger control, which gives an order to charge or discharge the vehicles based on the voltage drop that occurs, plug state, and charge initialization state. In Fig. 4, SE% denotes the parameter which takes the charging or discharging action depending on the battery state of charge. Its idea is to compute the number of EVs connected to the charge based on the existing PV power at that moment.

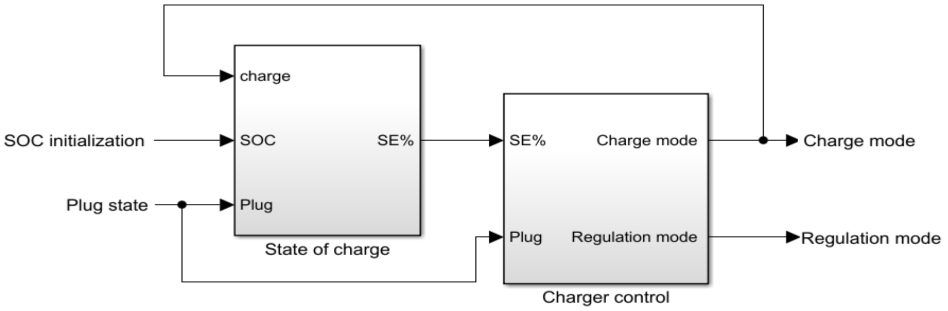


Fig. 4 Closed loop of charger control

connected EVs to the grid at each profile (Nbcharg) is entered to the state of charge control block and divided by the charged power (P_charg) to determine the rated power of each EV. The result is multiplied with the number of cars at each profile (Nb_{cars}). The results enter the switching blocks, which compare the values, and start to charge or discharge EVs considering the EV percentage in each profile. In the discharging loop; the total power of EVs needed to achieve system regulation (P_EV) is divided by the number of cars needed in the regulation (Nbreg). Two loops enter the switching block to compare all cases and start the control action at the SE block as shown below:

$$\begin{cases} if \left\{\begin{matrix}\left(\frac{P_{charg}}{Nbcharg}\right)^{\times}\text{Nbcars} \\ \text{P\_EV}^{\times}\text{Nbreg}\end{matrix}\right\} > Plimit \rightarrow \text{SE\% : discharge order (regulation);} \\ \qquad\qquad \text{otherwise,} \rightarrow \text{SE\% : charge order} \\ \qquad\qquad\qquad \text{plimit} \leq \text{Ppv} \end{cases} \qquad (8)$$

Where, P_{charg} is the charging power of EV, P_EV is the demand from vehicles to be discharged into the grid, p_{limit} is the determined limit of power for vehicles to be charged according to PV generation and grid source, Nbcharg the number of vehicles allowed to be charged at this moment, Nbregis the number of vehicles allowed to be discharged at this moment, Nbcars is the total number of vehicles, and SE% is the state of charge of EV battery which determine the charge or discharge order depending on voltage restriction and p_{limit}. The control action maintains the voltage and kept it constant and stable and do not be less than the limits during operation. If the voltage starts to decrease, the vehicles batteries discharge power in to grid so as to maintain the voltage.

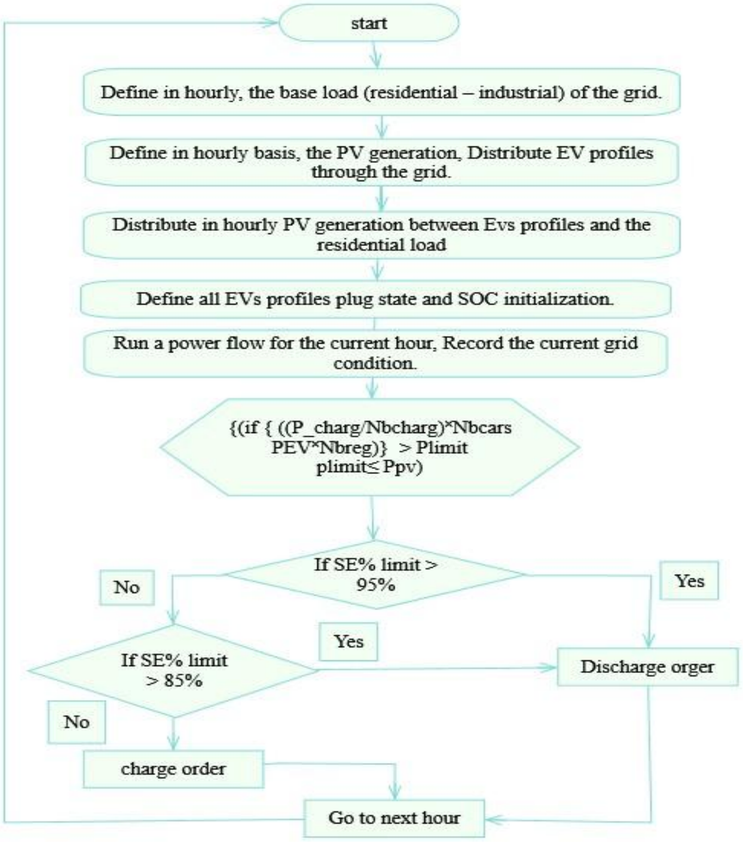


Fig. 5 Control and management algorithm of V2G and G2V

The charger control flow chart shown in Fig 5 compares the state of the system based on the voltage drop value and battery state of charge. The control is divided into three levels; the first level, if the system is stable and the SE% is higher than 95% ; there is no need to battery discharge and if the system is unstable and battery state of charge is higher than 95%; so the control system gives the order to batteries discharge for power quality improvement. The second level, if the SE% is higher or equal to 85%; it is possible to discharge in to grid with taking into account that SOC% does not fall below this limit. The third level, if SE% is lower than 85%, it is unfeasible for EVs to discharge even if the system is unstable. Vehicles will not be used as permanent source for injecting power for base loads. It is not allowed to consume a lot of batteries energy due to its main function which run the vehicles. If the system PQ is decreased, at this moment the system needs a fast response to maintain the system performance which represented by Evs.

5. SYSTEM DESCRIPTION

We introduce here a Microgrid consisting of an electric grid in addition to a PV farm as a generation system. Fig. 4.6 shows the structure of the proposed system. The system under study is a Microgrid a 33 kV, 20 MVA transformers. The system is divided into four important parts: a diesel generator, which acts as the base power generator; a PV farm for producing renewable energy; and a V2G system installed next to the last part of the system, which is the grid load. The Microgrid size represents community of approximately a thousand households during a low -consumption day in spring or fall. The distribution bus bar is connected to an 11 kV/600 V subsystem transformer that feeds the residential load with a nominal power of 10 MW, The factory; is an induction machine with 0.16 MVA. The PF is equal to 0.15 and connected into the grid at 3 pm. The lighting loads have an active power of 1 kW and an EV charging station with five different charging profiles. The total number of EVs for all profiles is 100 EVs with a total demand of 4 MW. The rated power for an individual charger is 40 kW (fast charger). The battery rated capacity is 85 kWh. The numbers of cars at profiles 1 to 5 are 35, 25, 10, 20, and 10, respectively. The number of EVs in the base model means that the cars and the households have a 1:10 ratio. The required state of charge (soc %) during the EV departure is 100%. The EV charging station contains a bidirectional AC/DC converter for charging or discharging purposes. The used chargers are three-phase and fast chargers. The EV state of plug-in for all profiles is illustrated below. The first profile consists of 35 EVs connected to the Microgrid when cars are parked at home with the possibility to plug in at work, and the connection time is from 12 pm to 5 am and from 8 am to the rest of the day, except 4 pm to 6 pm. The second profile consists of 25 EVs connected to the Microgrid only when cars are parked at home all night. The third profile comprises 10 EVs which connected to the Microgrid when cars are parked at home with the possibility to plug in at work. The fourth profile consists of 20 EVs connected to the Microgrid all day because people stay at home. Meanwhile, the fifth profile comprises 10 EVs connected to the Microgrid all throughout the day because people work in night shifts. The PV farm, which is the renewable energy source, is connected to the grid system through a DC/AC inverter. The power generated by PV is 8 MW with 10% efficiency. A PV farm produces energy proportional to three factors, namely size of the area covered by the PV farm, efficiency of solar panels, and irradiance data. Partial shading is also considered. V2G has two functions. First one is to control the charge of batteries connected to it and second one is to use the available power to regulate the grid when an event occurs during the day.

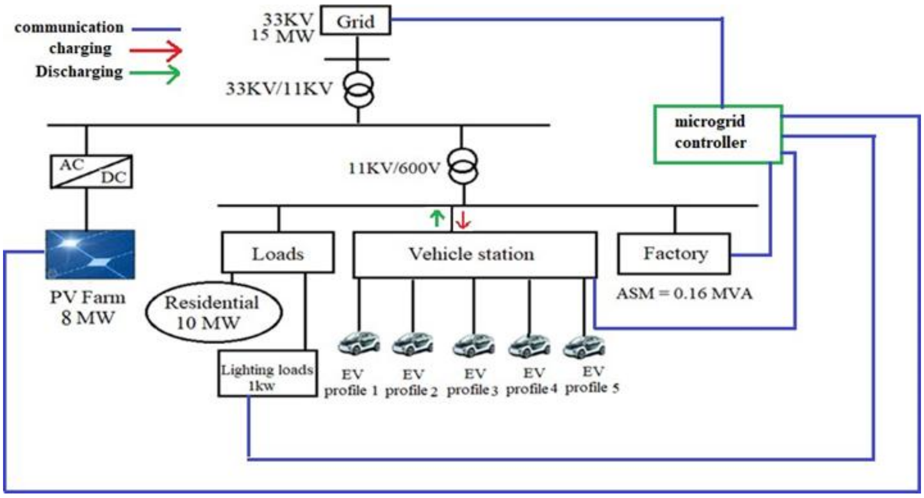


Fig. 6 Microgrid structure.

The total daily residential loads, factory, and lighting loads are referred to as the base loads. All the daily data of renewable resources represented by the PV farm are expressed by PV generation. The system data of the PV farm generation and the base loads are registered every hour throughout the day. Fig 7 illustrates the daily load curve and the PV farm generation. The Microgrid controller (MGC) is an important part of the Microgrid that controls the system and makes decisions based on the information from the electric grid, PV arrays through a DC/AC inverter, and EVs through the charging station. The other responsibilities of the MGC are matching between generation and demand, and Microgrid control. The MGC receives the PV generation, load profile, and information about the EV charging profiles to determine a definite strategy for each EV charging profile and make the EV charging process follow the PV generation.

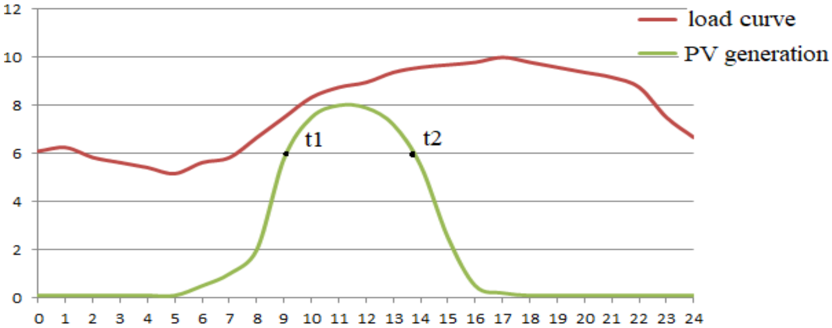


Fig. 7 PV generation and base load curves.

We introduced three different charging scenarios:

1) Uncontrolled charging: done to illustrate the effects of EV charging without any control action on the load demand. In this strategy, all EV profiles start to be charged after connecting with the Microgrid at any time with the charger power rating.

2) Shifted charging with an uncontrolled procedure: this scenario is done to illustrate the effects of EV charging when the charging process is shifted without a control strategy based on all EVs waiting until the PV farm generation is higher or equal to the demand load profile. Shifted charging with a controlled procedure: in this strategy, the charging process of EVs is shifted with a control action through the MGC to a period where the PV generation is massive. EV charging should track the difference between the PV output and load. The MGC is responsible for determining the proper time to start charging based on the battery type and capacity, charger rate, and soc (%) level.

3) Intelligent charging–discharging scenario: in this scenario, EVs will solve power quality and voltage performance problems by discharging their stored power into the grid when parked.

Fig 8 illustrates the performance of Scenario 1 on the Microgrid and grid profiles. Many EVs reach the station before 10 am and are charged with an uncontrolled behavior, which leads to an increase in the peak load because the PV generation does not reach the rated value, indicating that most of the loads are drawn from the electric grid. Fig 9 shows the power profiles for Scenario 2. We observed an unwanted peak demand from the electric grid because the EVs started to charge at the same time; however, the charging strategy is shifted to the PV generation period. Fig 10 illustrates the power profiles in Scenario 3. In this scenario, the PV farm utilization contributing to the grid is increased; thus, the load demand from the grid (LDG) decreases. The voltage disturbances occurred in the first two scenarios. In the third scenario, the voltage was stable between limits, and we encountered no problems. Hence, Scenario 3 is the best choice for achieving power quality and voltage regulation. The behavior of the proposed case studies was used to estimate the following parameters; PV usage and LDG. The PV usage (PVU) is the amount of the used PV energy calculated with the ratio of the PV energy used per day to the total amount of PV energy per day. LDG is the amount of power consumed from the grid. Table 1 illustrates the behavior of different case studies of the charging strategies.

$$PVU\% = \frac{\int\left(p_{tot}\ (\mathrm{t}) - \mathrm{pgrid}\ (\mathrm{t})\right)\mathrm{dt}}{\int\left(p_{pv}\ (\mathrm{t})\right)\mathrm{dt}} \times 100 \qquad (9)$$

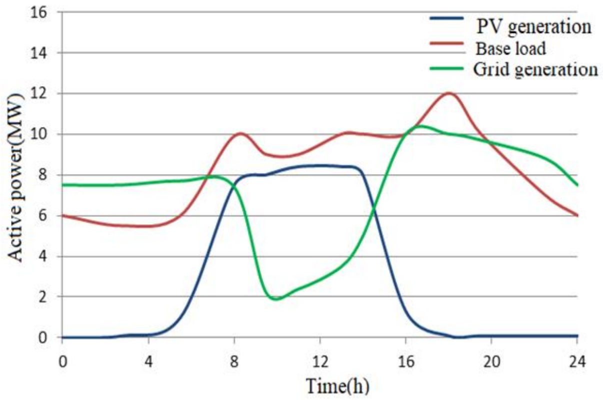


Fig. 8 Power profile of Scenario 1

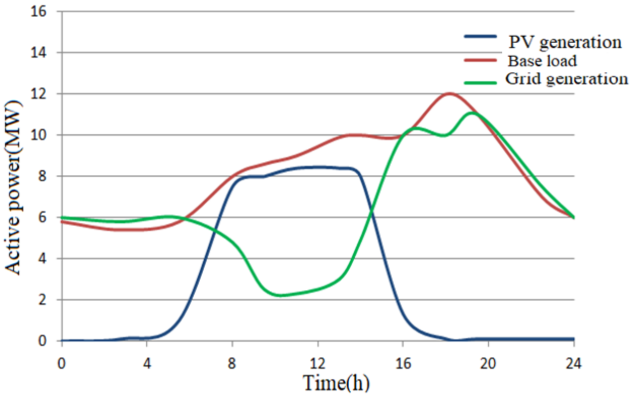


Fig. 9 Power profiles of Scenario 2

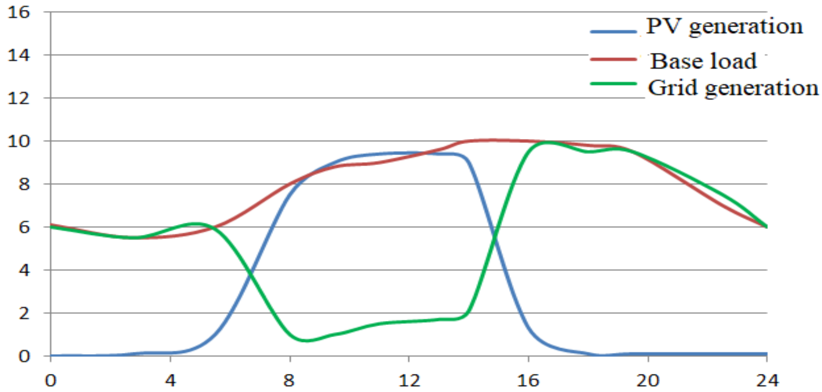


Fig. 10 Power profiles of Scenario 3

Table -1 Result of different case studies

Case study	PVU%	LDG(KW)
Scenario 1	41%	7110
Scenario 2	65%	6000
Scenario 3	80%	5110

The previously mentioned car profiles have the plug state, which illustrates whether or not the vehicle is connected to the grid. If the plug state is 1, the vehicle is connected to the grid for charging or discharging. If the plug state is 0, the vehicle is not connected to the grid. Table 2 shows the charging and discharging periods of all profiles.

Table -2 The charging and discharging periods among all profiles

	Plug-in periods (charging/regulation)	Plug-off periods
Profile 1	12 am–6 am 9 am–16 pm 18 pm–24 pm	6 am–9 am 16 pm–18 pm
Profile 2	12 am–6 am 18 pm–24 pm	6 am–18 pm
Profile 3	12 am–5 am 9 am–16 pm 20 pm–24 pm	5 am–8 am 16 pm–20 pm
Profile 4	All day	All day
Profile 5	4 am–20 pm	2 pm–24 pm

Based on the PV generation curve at Fig. 7, which was calculated along the day according to the solar radiation, the allowable percentage of EVs in the base model is 1:10 between cars and households. The PV generation at each hour is divided to 10 to obtain the power for EV charging in all profiles. The order with the allowable power of EVs to charge and discharge is taken based on the plug state, which measures the percentage of connected EVs and the state of charge (SOC), which measures the EV charging level of batteries. At the charger control, the SE measures the system disturbances and distributes the EVs between profiles. The decision to charge or discharge is based on the voltage drop percentage into the grid and the state of charge of Evs batteries. The amount of power needed to regulate the voltage is calculated by the current and the voltage in the three phase systems Eqs. P is computed to determine the vehicle rate to be charged and the vehicles rate for regulation. The reference in the charging-regulation scenario is voltage and battery state of charge. If the voltage decreases below the determined limit, EVs will discharge power into the grid. Voltage and current in charging and regulation mode are calculated below.

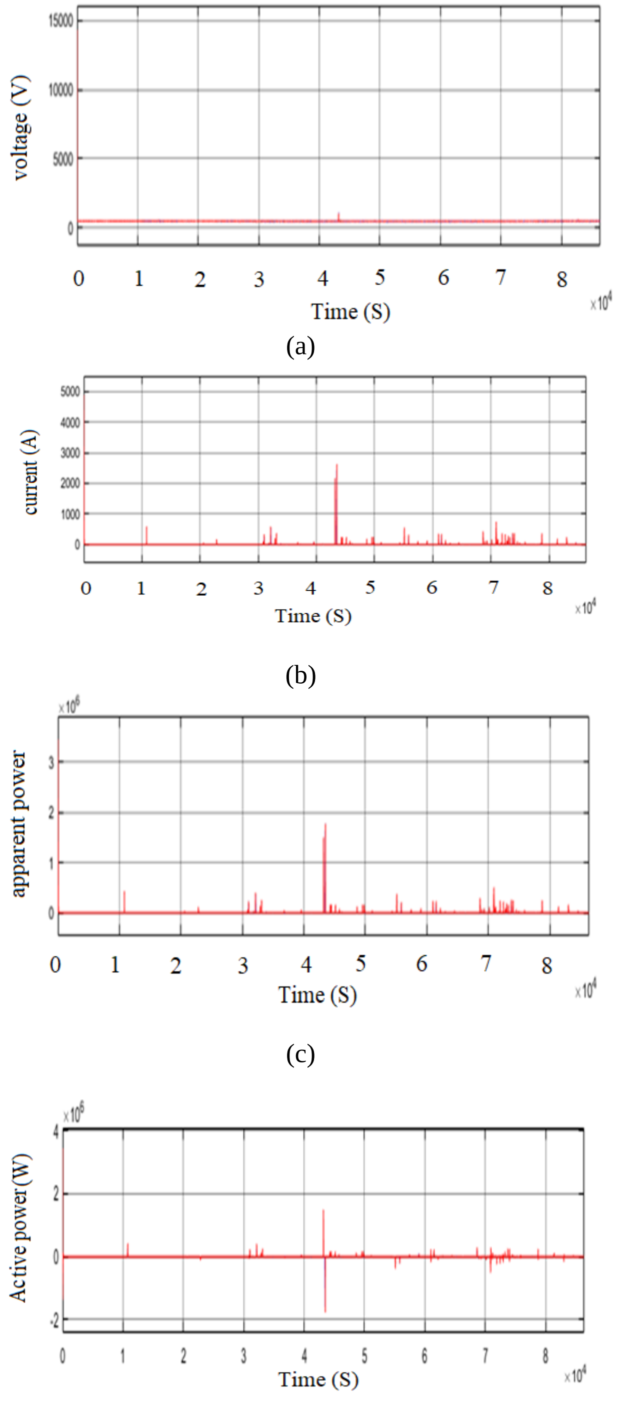
$$V1= 1/3(Vab -a^2*Vbc) \qquad (10)$$

$$Ia= I1 \qquad (11)$$

$$S = 3* (V * I') / 2 \qquad (12)$$

$$P= \sqrt{3} \times V_1 \times I_1 \times \cos \varphi \qquad (13)$$

Where Vab is the voltage between phase a and b, Vbc is the voltage between phase b and c, and Ia is current of phase a.When PV exists, EVs will be charged through the allowed percentage of 10% (difference between the PV output and the load) and the surplus power sent to the grid. In the absence of PV energy, EVs will be charged from the grid. The EV percentage is distributed between different five profiles with different charging and discharging periods. According to the plug state of each profile, the allowable time for charging or regulating EVs between profiles is presented in Table 2 depending on the hourly percentage of the charging and discharging power. Table 3 presents the allowable EV charging and discharging (regulation) power along the day to provide grid stability based on the calculated values of P illustrated in Fig 11 and Fig 12. The previously calculated values were based on the source voltage, current, active power, and reactive power shown in Fig. 13.



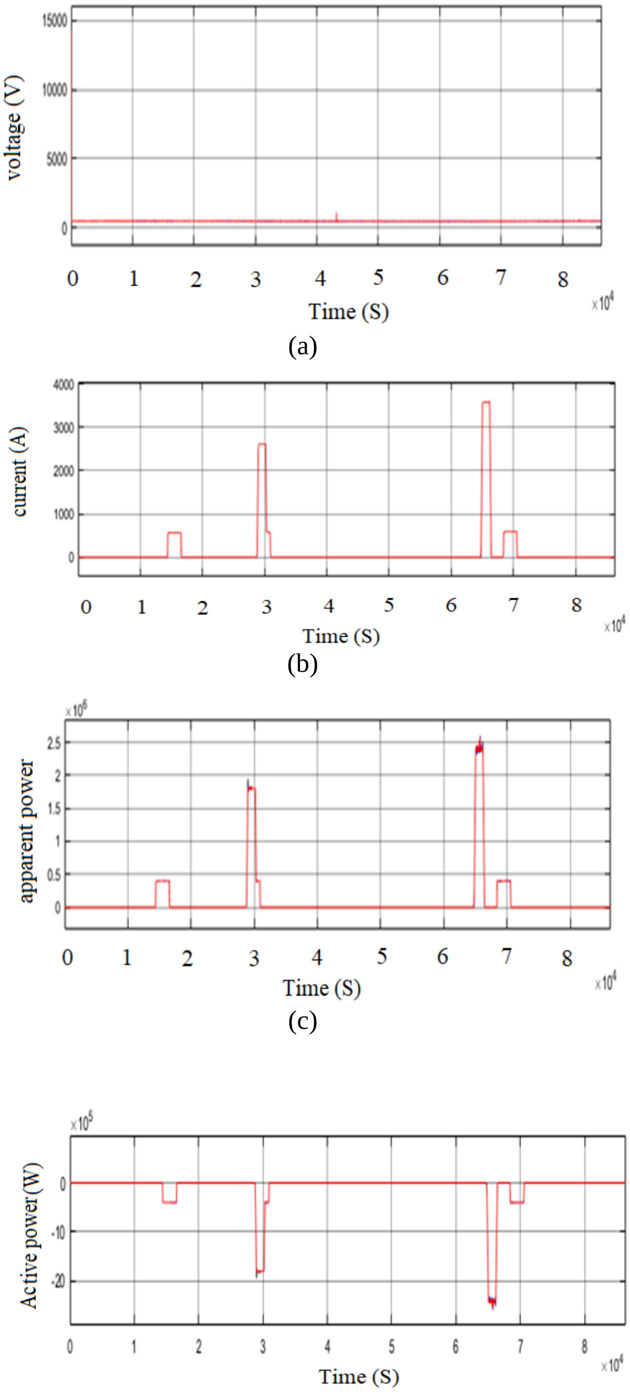
(a)

(b)

(c)

(d)

Fig. 11 Parameters for regulation under all profiles along the day: (a) voltage, (b) current; (c) apparent power; (d) active power



(a)

(b)

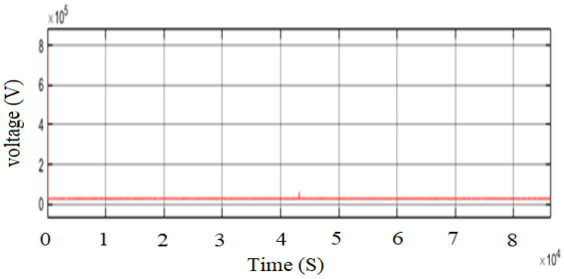
(c)

(d)

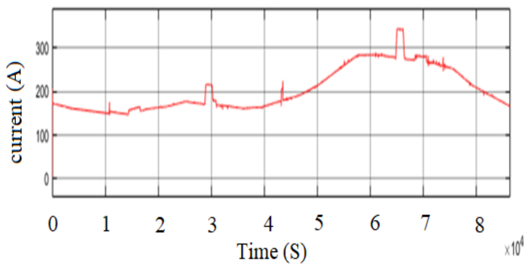
Fig. 12 Parameters for charging under all profiles along the day: (a) voltage, (b) current; (c) apparent power; (d) active power

Table -3 Allowable EV charging and discharging power for all profiles

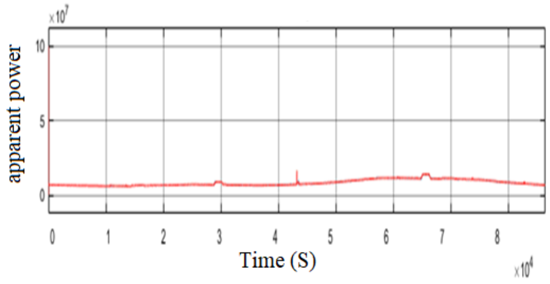
Hour	Allowable EV charging power	Allowable EV discharging power
12 am	0 kW	0 kW
1 am	0 kW	0 kW
2 am	0 kW	0 kW
3 am	0 kW	480kw
4 am	400 kW	0 kW
5 am	400 kW	0 kW
6 am	0 kW	0 kW
7 am	0 kW	100kw
8 am	1900 kW	230kw
9 am	400 kW	300kw
10 am	350 kW	450kw
11 am	0 kW	0 kW
12 pm	0 kW	1900kw
13 pm	0 kW	300kw
14 pm	0 kW	350kw
15 pm	0 kW	500kw
16 pm	0 kW	0kw
17 pm	0 kW	250kw
18 pm	2500 kW	0kw
19 pm	2500 Mw	300kw
20 pm	0 kW	600kw
21 pm	400 kW	400kw
22 pm	700 kW	360kw
23 pm	650 kW	200kw
24 pm	600 kW	150kw



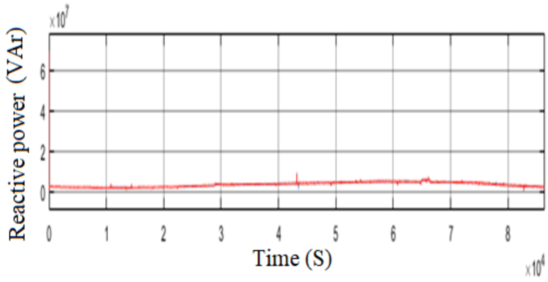
(a)



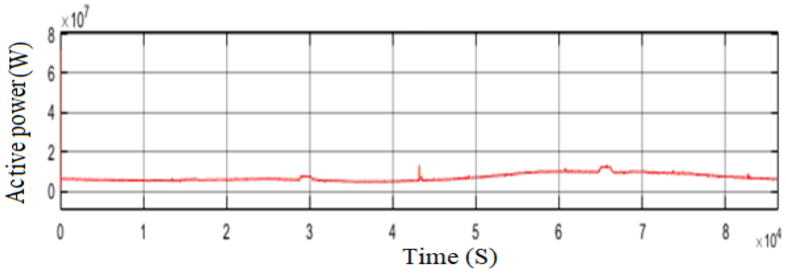
(b)



(c)



(d)



(e)

Fig. 13 (a) Voltage, (b) Current, (c) Apparent power, (d) Active power, (e) Reactive power at the source

6. CONCLUSION

In this study, the effect of EVs charging procedures through a Microgrid with PV farm generation was illustrated through a daily operation of a Microgrid consisting of a PV farm beside an electric grid. Three case studies were investigated; uncontrolled charging, shifted charging without control action; and shifted charging with control. The results illustrated that the third case is the most suitable for system stability due to decreasing and increasing the utilization of PV generation. The controlled strategy guarantees the wanted state of the charge level of the EV battery at the departure time of EVs from the charging station or plugged off. EVs play the main role in balancing the load demand and generation due to their flexibility and fast response. Part of the EVs is in the charging mode, while the other part is in the discharging mode, according to the system condition (voltage profile). The output power for the grid is different due to the PV generation. The control action for the EVs compensated the existing deviations. V2G is effective in peak periods. The grid generation is decreased at the V2G functions of EVs.

REFERENCES

[1]. Ahn, C. and H.J.E. Peng, Decentralized and real-time power dispatch control for an islanded microgrid supported by distributed power sources. 2013. 6(12): p. 6439-6454.

[2]. Gholami, A., F. Aminifar, and M.J.I.E.M. Shahidehpour, Front lines against the darkness: Enhancing the resilience of the electricity grid through microgrid facilities. 2016. 4(1): p. 18-24.

[3]. Gouveia, C., et al., Microgrid service restoration: The role of plugged-in electric vehicles. 2013. 7(4): p. 26-41.

[4]. Hemmati, R. and H.J.J.o.E.S. Mehrjerdi, Investment deferral by optimal utilizing vehicle to grid in solar powered active distribution networks. 2020. 30: p. 101512.

[5]. Sortomme, E., et al., Coordinated charging of plug-in hybrid electric vehicles to minimize distribution system losses. 2010. 2(1): p. 198-205.

[6]. Deilami, S., et al., Real-time coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile. 2011. 2(3): p. 456-467.

[7]. Tan, K.M., et al., Integration of electric vehicles in smart grid: A review on vehicle to grid technologies and optimization techniques. 2016. 53: p. 720-732.

[8]. Abdelaziz, M.M.A., et al., A multistage centralized control scheme for islanded microgrids with PEVs. 2014. 5(3): p. 927-937.

[9]. Fattori, F., N. Anglani, and G.J.S.E. Muliere, Combining photovoltaic energy with electric vehicles, smart charging and vehicle-to-grid. 2014. 110: p. 438-451.

[10]. Wu, T., et al., Coordinated energy dispatching in microgrid with wind power generation and plug-in electric vehicles. 2013. 4(3): p. 1453-1463.

[11]. Su, W., J. Wang, and J.J.I.T.o.S.G. Roh, Stochastic energy scheduling in microgrids with intermittent renewable energy resources. 2013. 5(4): p. 1876-1883.

[12]. Limmer, S., T.J.I.J.o.E.P. Rodemann, and E. Systems, Peak load reduction through dynamic pricing for electric vehicle charging. 2019. 113: p. 117-128.

[13]. Mehrjerdi, H.J.E., Modeling and optimization of an island water-energy nexus powered by a hybrid solar-wind renewable system. 2020: p. 117217.

[14]. González-Garrido, A., et al., Full-scale electric vehicles penetration in the Danish Island of Bornholm—Optimal scheduling and battery degradation under driving constraints. 2019. 23: p. 381-391.

[15]. Nunna, H.K., et al., Energy management in smart distribution systems with vehicle-to-grid integrated microgrids. 2016. 9(5): p. 4004-4016.

[16]. Solanke, T.U., et al., A review of strategic charging–discharging control of grid-connected electric vehicles. 2020. 28: p. 101193.

[17]. Yilmaz, M. and P.T.J.I.T.o.p.e. Krein, Review of the impact of vehicle-to-grid technologies on distribution systems and utility interfaces. 2012. 28(12): p. 5673-5689.