Chapter 5
Optimal Utilization of Solar Energy for Electric Vehicles Charging in a Typical Microgrid

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Abbreviation

AER	All electric range
BCG	Binary conventional generation
CG	Conventional generation
ECPM	Energy consumption per mile
EV	Electric vehicle
HEV	Hybrid electric vehicle
HGC	Home general controller
PEN	Percentage of energy needed
PHEV	Plug-in hybrid electric vehicle
PNNL	Pacific Northwest National Laboratory
SOC	State of charge
TGC	Transformer general controller
V2G	Vehicle to grid

5.1 Introduction

The modernization of power grids has been the chief issue for power industry in different countries. As well as, the lack of energy and the growth of the electrical energy consumption are the major threats to the countries' economy. Thus

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increasing grid security during use of renewable energy, reduce the greenhouse gas emissions, and reduce losses in power transmission are the effective ways in order to be a smart power grid [1].

There are three main purposes of the smart grid: (i) improved reliability, (ii) optimal usage of distributed production resources, and (iii) energy efficiency. Demand response is one of the most important program in the energy efficiency issue, which is designed to change the pattern of consumers' consumption and load management. On the other hand, using demand response program and raise the generation efficiency by assuming creating smart grid will be reduced the load and the pollution caused by energy generation [2].

The used PHEV that is one of the electrical devices with charging feature through grid connection. The PHEV's batteries have high capacity, so needed to much energy to recharge them. It causes a peak load in the distribution grid and reduces the penetration of renewable resources into residential distribution grid. Demand response programs, PHEVs charging management can be solved such challenges. The aim of load managing is to change the PHEVs charging into other hours that decreases the received power from the conventional generation and increases the renewable resources consumption.

Additionally, the chapter is examined a residential grid model to optimize the use of renewable resources through of the plug-in vehicles charging & discharging management on 24 h. The residential grid consists of 5 smart houses which each of them has 14 photovoltaic panels to produce require power for houses. The loads of these houses are divided into static loads and Flexible loads. The smart home is equipped with the planned intelligent charging device for PHEV with able to exchange energy into a distribution grid through two ways [3].

Due to the static loads time of residential consumers the meteorological data are extracted of one-year period for renewable resources modeling. In addition, the cars features are derived from the manufactures cars as the flexible loads. so, the researcher used of Monte Carlo simulation algorithm with taking into account the uncertainty the mileage by the car owners during daytime, the initial capacity of the battery, and the time of the vehicle usage at different hours of the day; as well as used of the (PSO) algorithm to optimize the issue.

The aim of conduct this chapter is to increase the use of renewable energy resources by consumers. Hence, the objective function defined through minimized potential received from the conventional power grid. The results showed that, the received energy from conventional power grid is reduced significantly of control charging by use of the proposed method through transfer the time of the vehicle charging to hours with maximum renewable resource access. Moreover, the cost of consumers had decreased significantly by adding V2G and discharge control without reducing the comfort of the car owners, which indicates the effectiveness of this method.

5.2 Renewable Energy Resources

Since the beginning of the design and construction of power systems has always been raised the issue of uncertainty in the failure of units and equipment or the error in forecasting of demand. Nowadays with the advent of renewable energy especially solar energy, the uncertainty in the utilize of power systems has intensified. Hence the energy policy makers hope that the new energies will have a significant impact in supplying needed human energy. There has been proposed solar energy more than other types of energies, thus must take be considered an important role for planning and operating power systems. The uncertainty in output is one of the most important features of this energy so it must be considered properly in the planning of power systems generation; A smart home with solar panels, smart appliances and an electric vehicle shows as Fig. 5.1.

5.2.1 Solar Energy

In recent year, the process of using solar energy has been growing and evolving, in a way that technology has become more advanced in use of solar energy and it has an acceptant efficiency. The generation of solar systems depends on the amount of solar radiation. Some of the advantages of using solar panel as follows:

Fig. 5.1 Residential smart grid

1. Simple technology
2. The conversion of solar radiation into electrical energy directly
3. Low noise
4. Low cost and high efficiency through the advancement of science

5.2.2 Math Model of Solar Energy Output Power

The output power of solar panels is obtained by Eq. (5.1) [3]:

$$P_{pv} = N \times \frac{G_t}{1000} \times P_{mpv} \tag{5.1}$$

Where PPV is the output power of solar panels (w), Pmpv is the nominal power of each panel in terms of $G_t = 1000$, N is the number of solar panel, and Gt is the solar radiation intensity $(w/_{m^2})$.

5.3   Electrical Vehicle

Due to the reduction of fossil fuel resources and high environmental pollution by the high consumption of the vehicles as cars, motorcycles, and etc., that has attracted more attention to the use of equipment that use of other energy sources. The result of studies has shown that if the energy consumption continues to exist, the emission of carbon dioxide rate will be expected to double by 2050 than in 2005 which is not acceptable in terms of environmental perspective. According to global plans by 2050, this rate must be halved in the level of CO_2 in 2005.

To this end, the safest methods as the use of distributed generation of energy, simultaneous generation of electricity and warm, and use of motor vehicles that their driving forces supplied from electric power grid or batteries. The use of motor vehicles has been more important in all countries especially in developed countries such as united states and japan, or China and India that have made significant advances in this regard.

PHEVs are the electric vehicle whose use at least two types of energy resources to drive. The new generation of hybrid vehicles, two fuel and electric motors provide the required driving force to drive. But why used of two engines to drive these vehicles? The internal combustion engine (gasoline or gasoil) generates a bit power in the low engine rpm engine that has the higher efficiency, in contrast, the electric engine generates high torque with high efficiency in a low engine rpm. Therefore, simultaneous use of both engines can be reduced fuel consumption meanwhile achieving enough power to drive and accelerate. One of the most important features of an PHEV is that if the internal combustion engine generates
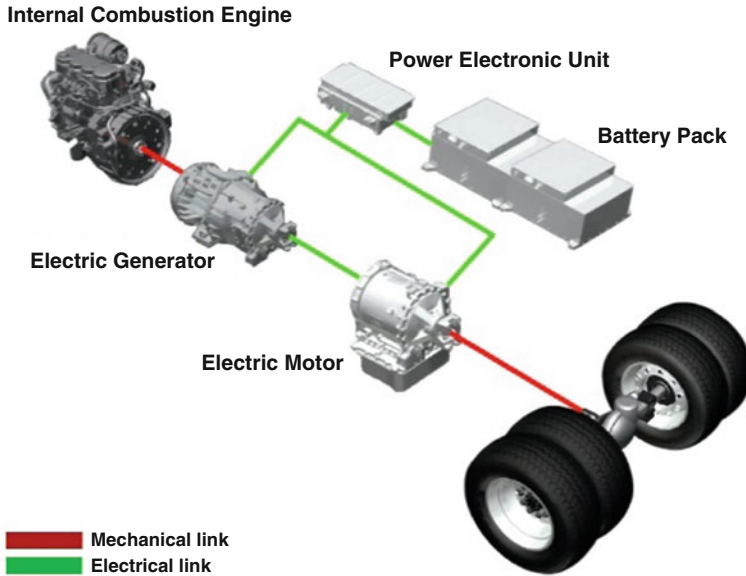
Fig. 5.2 The components of a hybrid vehicle

more force driving than needed, its battery will recharge by utilizing power engine directly during braking or moving downhill then provide the required power. All PHEVs have three factors: management, electronic and smart balance of engines connection. Hybrid vehicles are the progressed pure-electric vehicles that have modified somewhat defects of pure-electric vehicles and internal combustion engines vehicles. The main benefits of these vehicles than the internal combustion: (i) the function in the stable load and rpm and operating at the optimal point, which will be caused raise the engine efficiency, reduce pollution, and reduce fuel consumption; (ii) the energy store electrically in the battery during braking or negative accelerating which will be reduction of the combustion engine efficiency and thus reduce pollution and reduce fuel consumption, for instance, the Toyota Prius consumes 2.4 L fuel on per 100 km with the capacity of 1500 cc and four-cylinder engine; (iii) high mileage per battery charge. Although hybrid vehicles have different structures, but they must include of a power transmission system, a power generation unit, and an energy storage system. The initial choices for the energy storage system are the batteries, capacitors, and flywheels. Batteries are the first energy storage device due to their cheapness, being commercial, and lack of movable parts, but the major shortcoming is their short lifespan. However, the batteries are very expensive in new technology but today they are developing. So due to the fact that batteries are the major choice in this field, the research has started on other energy storage fields. The components of a hybrid vehicle are shown in Fig. 5.2.

5.3.1 The Components of a Hybrid Vehicle

5.3.1.1 Gasoline Engine

The nature of the gasoline engine in this car resembles to ordinary gasoline engines with two main differences: the higher technology and the smaller engine which reduces pollution and increases performance.

5.3.1.2 Electric Engine

Electric engine is very progressed in hybrid vehicles so it can operate as a generator and engine. For instance, whenever the engine is required, it will be able to provide the desired acceleration by using batteries and when the electric engine is not required (moving on a downhill) be able to restore the power to the battery as a generator.

5.3.1.3 Electric Generators

The engine and the generator are almost similar in the construction, but the generator just has the duty to provide the electricity required by the engine. The generator is used series in most hybrid vehicles.

Types of the hybrid systems were explained in more detail in the next sections.

5.3.1.4 Battery

The batteries are an energy storage device for the electric engine in the hybrid vehicle. Not only electric engine can be transferred fuel to the gasoline engine such as the gasoline in the tank (a one-way transfer from the fuel tank to the gasoline engine), but it can be restored energy to the battery which the gasoline engine cannot do that.

5.3.1.5 Comparing of the Efficiency of the Pure-Electric Vehicles and Hybrid Vehicles

Although electric vehicles have been introduced as the first way to reduce pollution, but due to the fact they did not succeed in long driving cycles thus was a failed product. The hybrid electric vehicles have such advantages than pure-electric vehicles. Due to the use of two sources of energy for the stimulus driving system generation has been minimized the pollution and fuel consumption issues and resolved the problems caused by pure-electric vehicles.

5.3.2 Performance of Hybrid Electric Vehicles

The gasoline engines of vehicles have a main problem. In order to drive at high speeds on highways, the cars have been designed to maximize their power. So the cars efficiency decreases when they barely move in heavy traffic. To this end, dual-engine hybrids vehicles are designed to use of the low-power electric engine in situations that low power is required, and use of the gasoline engine where needs to high power. The engines switching is automatically.

The gasoline engine simply turns off in the red lights and is often designed to operate on a limited range of power, thereby increasing its efficiency. The vehicle's battery is recharged by a gasoline engine. The generators are connected to the brake for convert some of the braking momentum (which is usually lost as heat) into electricity in order to recharge the battery.

5.3.3 Introducing Electric Vehicles

Electric vehicles are generally divided into three categories:

1. Electric vehicles (EV)
2. Hybrid electric vehicles (HEV)
3. Plug-in hybrid electric vehicles (PHEV)

5.3.3.1 Electric Vehicles (EV)

These vehicles have an electric engines and some batteries to provide electric energy that the energy of the batteries is used as the propulsion of the vehicles' electric engine and to provide the necessary energy for other equipment. The batteries could be recharged through power grid connection, the vehicle's braking power, and even of off grid electrical resources like solar panels.

The main advantages of electric vehicles:

- Completely free from greenhouse gas emissions
- very low-noise pollution
- Much higher efficiency than internal combustion engines
- Cheaper electrical engine
- The main defect of these vehicles is dependence on the battery (whose capacity and energy density is not comparable to fossil fuels)

5.3.3.2 Hybrid Electric Vehicles (HEV)

The vehicles have both fuel and electric engines with the proper battery capacity (1–3 kWh) that has the energy storage capability from the engine and the brakes. At the time of need, vehicles' batteries aid to generate the auxiliary force power or at low speeds by shutting off fuel engine provide vehicle propulsion.

In the past decade almost 1.5 million hybrid electric vehicles were sold. In developed countries including United States, the hybrid electric vehicles account for around 3% of all vehicles.

The disadvantages of these vehicles:

- Non-rechargeable batteries of the power grid
- Dependence on the fossil fuels engine (inability to move the vehicle by using only the electric engine)

5.3.3.3 Plug-in Hybrid Electric Vehicles (PHEV)

PHEVs are designed to eliminate the defects of hybrid electric vehicles so rechargeable from the grid thus need to more batteries than HEVs (about 5×). PHEVs have a complete fossil fuel engine system. The main difference between PHEV and HEV's batteries is that the PHEV batteries must have rapid dis/charging capability, while HEV batteries are usually keep fully charged and are rarely discharged.

The cost of PHEV batteries ranged between 1.3 to 1.5 times than EV batteries which due to fewer batteries, the total cost of PHEVs' batteries will be less than EVs.

The following can be mentioned for these vehicles:

- With the abundant battery production, the costs of battery may be reached to 750 dollars per kilowatt-hour so the total of its cost will be about 6000 dollars for each all electric range vehicle (40 k with 8 kWh battery capacity).
- If the car's life span is 200,000 km, the amount of the savings in the cost of fuel would be about 4000 dollars which is less than the cost of battery.
- Reducing the cost of the battery to 500 dollars per kilowatt-hour will be created the competition between plug-in hybrid electric vehicles and gasoline vehicles.

5.3.3.4 Comparing PHEV and HEV

The HEVs is a good start for changing the fuel of electric vehicles, but the mileage possible on one charge is limited. Hence, the PHEVs were raised which have the ability to connect to grid at the point where the electrical energy output is embedded. They have a battery and internal combustion engine. In general, most of PHEVs provide the required energy through electrical energy, but the internal combustion engine is also used when battery is not enough.

5.3.3.5 The Effect of PHEVs Performance on the Power Grid

Whenever the PHEVs are not used, the energy be received from the power grid to recharge them. The widespread use of PHEVs will bring challenges to the power grid because they have high electrical energy consumption and could be

Table 5.1 Consumption and battery capacity of various PHEVs

Vehicle type	ECPM (kWh/Mile)	PHEV (33-mile Battery) (kWh)
Compact Sedan	0.26	8.6
Mid-size Sedan	0.30	9.9
Mid-size SUV	0.38	12.5
Full-size SUV	0.46	15.2

connected to the distribution grid at any hours to charge. As well as, the distribution grid is usually used at their maximum capacity then the stability of the system will be compromised by the added load caused by improper use of electric vehicles.

In other words, the PHEVs should be charged at non-peak times or at other times such as energy storage devices.

5.3.4 Mathematical Model of the Electric Vehicles Battery

The battery capacity is the main factor to determining the mileage by a PHEV in the electrical mode. The PNNL[1] Institute has shown the power consumption per mile for all types of PHEV with a capacity of 33 miles and AER[2] = X in Table 5.1.

As it mentioned that AER determines the probable distance with the PHEV and the battery with fully charged. So the battery capacity is obtained of ECPM[3] multiplication in AER.

$$C = ECPM * AER \tag{5.2}$$

Where C is the applied capacity of PHEV [4].

The Table 5.2 is shown the battery capacity for PHEVs with 30, 40, and 60 miles AERs based on the above-mentioned equation. Due to the table, there can be said that the PHEVs have the domain size of batteries from 7.8 to 27.6 kWh. Since the required energy to charge the PHEV depends on the capacity of the battery, so determining the types of AERs and PHEVs to analysing the impact of such vehicles is essential [5].

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[1]Pacific Northwest National Laboratory

[2]All electric range

[3]Energy consumption per mile

Table 5.2 The size of PHEV batteries with various AERs [5]

Vehicle type	PHEV 30 mile AER (kWh)	PHEV 40 mile AER (kWh)	PHEV 60 mile AER (kWh)
Compact Sedan	7.8	10.4	15.6
Mid-size Sedan	9	12	18
Mid-size SUV	11.4	15.2	22.8
Full-size SUV	13.8	18.4	27.6

5.3.5 The Stored Energy in PHEVs' Batteries

SOC[4] is the amount of stored energy in the battery. Although it is assumed that PHEVs use of the charging system on the electric mode, but the combination of the function of the electric engine and the internal combustion engine is appropriate. Thus, PHEVs can be operated at any mode based on their required energy so they receive some part of energy from the battery at the lack of energy in the battery mode. In order to analyse all functions of PHEVs battery is used of the parameter λ for each PHEV. λ is the maximum mileage of a PHEV in the electric mode so $\lambda = AER$. Then SOC o a PHEV is obtained through of the Eq. (5.3).

$$SOC = \begin{cases} \left(\dfrac{\lambda - d}{\lambda}\right) * 100 & d < \lambda \\ 0 & d \geq \lambda \end{cases} \tag{5.3}$$

Where λ is the AER and d is the total mileage by the car, hence the usable capacity of the battery is completely consumed in $d \geq \lambda$ mode and the SOC is zero [6].

Whenever the vehicle has travelled all the distance in electric mode the Eq. (5.3) be applied. In order to determine the battery capacity (SOC) in simultaneous use of both electrical and internal fuel consumption, a parameter should be introduced to determine the vehicle's mileage percentage in electric mode. There is assume that α represents this issue, in this case SOC is obtained of Eq. (5.4) [5].

$$SOC = \begin{cases} \left(1 - \dfrac{\alpha d}{AER}\right) * 100 & \alpha d < AER \\ 0 & \alpha d \geq AER \end{cases} \tag{5.4}$$

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[4]State of charge

Table 5.3 Electrical specification of vehicles of various companies

Vehicle name	Type of battery	Battery capacity	Full charge time	Power charge	Maximum electrical distance	Electrical function
Chevy Volt	Lithium-ion	16 kWh	4 h-240 V	3.3 kW	64 km-40 miles	0.25 kWh/km
						0.4 kWh/mile
Renault Fluence Z.E	Lithium-ion	22 kWh	6–9 h-240 V	3.5 kW	185 km-115 miles	0.11 kWh/km
						0.19 kWh/mile
Toyota Prius	Lithium-ion	4.4 kWh	1.5 h-240 V	3.3 kW	23 km-14 miles	0.19 kWh/km
						0.31 kWh/mile
Ford C-max	Lithium-ion	7.6 kWh	3 h-240 V	3.3 kW	32 km-20 miles	0.23 kWh/km
						0.38 kWh/mile

5.3.6 The Amount of the Energy Required to PHEVs' Battery Charging

PEN[5] is the percentage of energy needed to fully charge the battery. The percentage of energy required to PHEVs' battery charging after the last time span is determined based on the SOC.

Such energy is obtained through the Eq. (5.5) to fully charge the battery.

$$PEN = 100 - SOC \qquad (5.5)$$

The PEN is the energy needed to fully charge the battery.

As regards the efficiency of the converters to charge the battery is not 100% so the amount of energy that the grid should provide to charge the battery is achieved by follow equation.

$$PEN_R = \frac{PEN}{\eta} \qquad (5.6)$$

The η is the efficiency of the battery converter charger and PENR is the actual energy needed to fully charge the battery which should be transferred from the grid to the battery. In References [7–9], the battery efficiency is assumed to be 88%, 90%, and 90%, respectively.

In other words, there supposed that a PHEV is a type of mid-size SUV with AER = 40 (mile). As Table 5.3 shown that a PHEV battery capacity must be equal to 2.15 kWh. If the vehicle mileage is 6.25 per day, then the SOC is calculated through the formula (5.4) 36% and the PEN should be equal to 73.9 kWh. According to Eq. (5.6), if assumed that the charging efficiency is 88%, PEN_R will be equal to 11.06.

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[5]Percentage of Energy Needed

5.3.7 Required Time to Fully Charge

The required time to complete the vehicles battery charging depends on the amount of SOC battery at time t and the battery's efficiency. Due to the battery specification can be calculated required time through Eq. (5.7).

$$T - charging = \frac{capacity \times PEN_R}{charging\ power} \tag{5.7}$$

The capacity and the vehicle charging power is shown in the Table 5.3.

5.3.8 Technical Specifications of Electric Vehicle Battery

The private vehicles are often used to commuting miles between home, work, shopping, and entertainment. In Table 5.3 presented some of the vehicles' features, such as charging specifications and AER. However, it is possible to charging a vehicle in the home, work place, and large public places such as theatres or chain stores, but assumed that consumers charge their vehicles at home.

The energy demand of each PHEV depends on the specification of the vehicle's battery and the driving habits of each user in the vehicle charging process. Generally, the battery determines a maximum level "e_{max}" and a minimum level "e_{min}" of energy. The level of energy is a part of the full capacity of the battery at the initial charge mode and the vehicle connection to grid which depends on the vehicle mileage. Furthermore, the initial mode of vehicle charging can be provided as Eq. (5.8) which is the function of the vehicle mileage [3].

$$E(D) = \begin{cases} e_{max} & D = 0 \\ e_{max} - (D\xi) & 0 < D < d_{max} \\ e_{min} & D \geq d_{max} \end{cases} \tag{5.8}$$

d_{max} is the maximum distance that the PHEV can travel based on their electrical specification. D is the vehicle mileage before connecting to grid, ξ is the electrical performance of the vehicle (the energy consumption of the battery per unit of mileage).

In this research investigated Chevy volt with the specified features in the Table 5.3 [10].

Table 5.4 Voltage values and the authorized current for two level 1 and 2 of charge

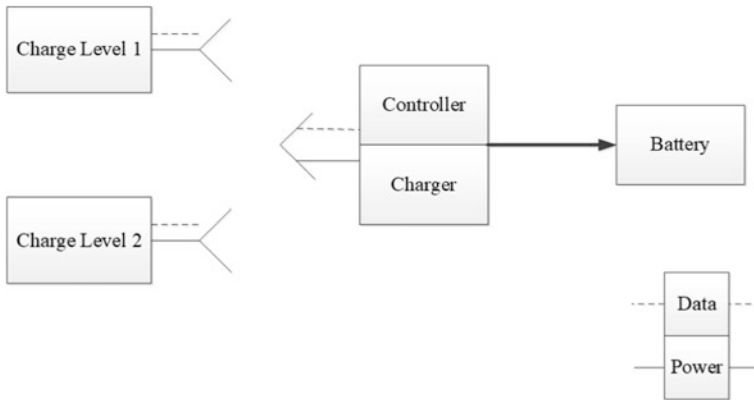| Charging method	Nominal voltage power supply	Highest current rates
AC Level 1	V AC 120– single phase	A 16 – A 12
AC Level 2	V AC 240- 208- single phase	A 80 >

Fig. 5.3 Schematic of charge battery by two levels of charge

5.3.9   PHEV Charge Battery

The battery charging rate determines the speed of filling the battery that it depends on the charging place and the user. The various mode of the battery was discussed in the next sections. According to SAE J1772, in charging an electric vehicle connects to the power grid in order to energy transfer to charge the battery and for exchange the control information between vehicle and source. Generally, the charging process has three operations: one mechanical and the rest electrically. The electrical grid sends the electrical energy at different nominal voltage. The electric vehicle battery is a DC device that can operate based on the nominal voltage of the battery and the dis/charging rates at the variable voltages.

In the first electrical operation, AC is converted to DC, which is known as a rectifier. The second electrical operation, control and regulate of the source voltage in that the battery charge rate is compromised to the battery specification (voltage, capacity and other parameters). The mechanical operation is the physical coupler as it performs by the user.

Home charging system with charge rates shown in Table 5.4 which can be used in accordance Fig. 5.3.

5.3.9.1 Charge Level 1

The charge level 1 uses a standard single-phase-120 V, 12 A or 16 A. In fact, this is the lowest voltage level in residential areas in the United States. In the level 1 provides a less power (1.44 kW) to charge the battery so the batteries with a capacity greater than 10 kWh are charged at the over longer time which causes customers dissatisfaction. Therefore, Level 1 is just a basic voltage level and not the ultimate solution to the battery charging issue.

5.3.9.2 Charge Level 2

The charge level 2 uses a single-phase voltage 240–220 V with a maximum current 80 A and it is preferred due to the less charging time than the previous method. Due to the small size of the existing vehicles batteries, some chargers are limited to the level 2 with 15 A which the maximum charge power is 3.6 kW.

5.4   Related Study

In reference [3], the researchers presented a charging management program based on the availability of PHEVs in the distribution grid due to the renewable energy resources. The results show that the proposed program in addition to prevent of transformer overload, but also increase the dependence of subscribers on the use of renewable sources.

Paper [11], Modifying PEV parking behaviour due to exchange with solar energy sources. In this paper, a model has been proposed to illustrate the effects of different RERs on the profit and behaviour of PEV parking. Parking participation in different markets was modelled by considering energy and energy sources, as well as the uncertainty of PEV behaviour. Numerical results show that the parking behaviour changes in the participation in the electricity market by using different RERs [12].

In a study [13], the planning of a micro grid in the vision of EV was studied. The purpose is to decrease the electricity costs and optimize the charging of EV. The article [14] was aimed at intelligent grid optimization features that included renewable energy sources, which were carried out by a large number of EV parked in intelligent parking that has a V2G capability. In another study, the use of a Monte Carlo simulation to reduce the cost of consumers in managing the charging of PHEV is used to obtain charging patterns without vehicle management [15].

In the research [16], PHEV charging introduced as a way for Demand Side Management (DSM) problem and the researchers have proposed the methods to solve this problem: Multi-Agent Systems (MAS) and Quadratic Programming (QP). The second degree of planning has able to smooth the peak load optimization and appropriate charging vehicles, but not scalable; however, MAS solution is scalable adapted to complete and unanticipated information. The researchers are investigating the impact of the cars on micro grids with renewable resources [17].

The research [18] proposed that a home energy management system with the aim of reduce electric energy consumption, Peak to Average Ratio (PAR) and increase the consumers' welfare. The researchers used of an optimization Hybrid Bacterial Harmony algorithm (HBH) that consists of two algorithms: Bacteria Foraging Algorithm (BFA) and Harmony Algorithm Search (HAS). Their findings showed that it is possible to reduce the price of electric energy for consumers and increase the consumers' welfare by provide a coordinated program and in line with the generated electrical energy information of grid in order to use of appliances.

The researchers in article [19] proposed an Intelligent Residential Energy Management System (IREMS) for smart residential buildings that its benefits showed in a case study. The main object of IREMS was decrease in electricity, costs while less than the maximum power demand is limited to the various parameters such as the operation of residential loads and renewable energy resources. Moreover, the researchers used the battery as a suitable solution to reduce the loss of the power generation of renewable resources.

The research [20] provided an optimal overall framework for energy efficiency management and its components, which include a smart house with storage, the PHEV and photovoltaic. The aim of the researchers was to increase home profits provided that demand response and supply the energy required for PEV. in addition to that, the Battery Energy Storage System (BESS) is used in this model. In this project, according to different optimization times analysed the cost of the home battery energy storage system, the types and various modes of PEVs control, the parameters of the BESS and the electricity costs of in a systematic way. Their results showed that with the implementation of the CP (Convex programming) control program in V2H and H2V modes, the houses with a battery energy storage system will not purchase electricity at peak load hours.

In research [21], a home energy management system including photovoltaic panels and battery energy storage system was investigated. The researchers have examined the following items: (i) the effect of the electricity price mechanism using the Time-Of-Use pricing (TOU), the Real-Time Pricing (RTP), and the Stepwise Power Tariff (SPT); (ii) the impact of solar panels; and (iii) the variability of solar panels in different seasons. The management plan presented in this study was also programmable in the GAMS.

Research [22] examined the use of the Fuel Cell as an energy carrier to use in off grid mode. In this research, an Energy Management Algorithm (EMA) is used for Alternative Energy Sources (AES) in smart home systems. The fuzzy control logic is used to this purpose and is simulated in MATLAB.

5.5 Smart Charge

Normal charge is a mode where the vehicle is connected to the power to supply to fully charge the battery with the maximum power possible, or charge it until it is plugged in. The required time to charge a battery 10 kWh will be between 2 to 5 h

based on the infrastructure of introduced charge. Since such vehicles don't need to much time to charge and most of them are charged at night so timing flexibility can be used to reduce the peak grid along with providing the vehicle owner's needs which is the smart charge. In fact, the smart charge not only is charge transfer to low-load times but is proper control charge per vehicle in order to provide the vehicle owner's needs (for example, prevent a high increase in peak distribution grid). There is a fact that a PHEV can be used of fossil fuels except the batteries so it has a high flexibility in the charging. Because it uses of fossil fuel when the vehicle is required and the battery is not fully charged.

Whenever the vehicle charging is carried out by the controller, the charge rate is unstable and the battery can be charged at various times and levels.

5.6   Determine the PHEV Specifications for Study

The PHEV specification is derived from reference information [23] and depends on the vehicle owner's usage which consists of mileage per day, start charging time, the number of appliances in each house and its type. The reference [24] assumes that PHEV owners charge the vehicle immediately upon arrival to home so the start charging time is the completion of driving and arrive to the destination. The data and arguments is needed to analyse this issue include the level of PHEV penetration, AER, daily load profile, home grown load. All data is needed to investigate the impact of PHEV on the distribution system in this model [5].

5.6.1   PHEV Charge Specification

5.6.1.1   Estimate the PHEVs Load Charge on a Large Scale

The charge and PHEVs capacity should be thoroughly investigated in order to coordination of the PHEVs large-scale. There is supposed that 1 day is evenly divided into T time and the number of considered PHEVs is N that each of them is independent. Thus, it is possible that the charged PHEV loads per day is equal to the total of each PHEV charge. As is shown in Eq. (5.9).

$$L_{PHEV}(t) = \sum_{i=1}^{N} P_i(t) \tag{5.9}$$

LPHEV(t) is the total charged loads (N) of PHEV at t time and Pi(t) is the power of each PHEV that is obtained through Eq. (5.10).

$$P_i^{CH}(t) = CR_i(t) \times P_i(t) \tag{5.10}$$

Pi(t) is the charging power that used to charge the PHEV, CRi(t) is the PHEV charging mode that can be zero or one (assumed that each PHEVs charge at their nominal power). The charging method is usually determined in accordance with the power grid of each country or region which includes predetermined voltage and current parameters. For instance, the authorized charging method in the Chinese government network has three main levels: level 1 (slow charge), level 2 (regular charge), and level 3 (fast charge). The period starts charging until its completion $(t_{start}$ to $t_{end})$ is the charging process. There assumed that a PHEV requires to K times per day recharged, the PHEV arrival time to charging process is recognized by $t_{i,start}^k$ and the ending time of charge by $t_{i,end}^k$ which $K = 1, 2, 3, \ldots, k$ so charging mode of SOC at the $t_{i,start}^k$ and $t_{i,end}^k$ time are $SOC_{i,start}^k$ and $SOC_{i,end}^k$ respectively. The various charging modes including un/coordinated charge will be estimated in the following.

5.7   Random Charge

In the uncoordinated charge mode supposed that each PHEV enters the charging process at a desired time or immediately after entering the home so each PHEV charged based on $SOC_{i,start}^k$ of the battery $(t_{i,start}^k)$ and the plug of PHEV is disconnected of the power grid at their $SOC_{i,end}^k$ or at $(t_{i,end}^k)$ time. The time of PHEV dis/charging recognize by its nominal power. Each PHEV is connected to power grid for start charging process at $t_{i,start}^k \leq t \leq t_{i,end}^k$ time and disconnected at $t < t_{i,start}^k,\ t > t_{i,end}^k$ time.

$$CR_i(t) = \begin{cases} 1 & t_{i,start}^k \leq t \leq t_{i,end}^k \\ 0 & t < t_{i,start}^k,\ t > t_{i,end}^k \end{cases} \qquad K = 1, 2, \ldots, K \qquad (5.11)$$

The charging time shows as d_i^k that can be obtained by the Eq. (5.12):

$$d_i^k = \frac{\left(SOC_{i,end}^k - SOC_{i,start}^k\right) \times B_{i,c}}{P_i \times \eta_{ch}} \qquad k = 1, 2, \ldots, k, \quad i = 1, 2, \ldots, N \quad (5.12)$$

$B_{i,\,c}$ is the battery capacity of each PHEV and η_{ch} is the charge efficiency. The uncoordinated charging scenario has two modes: full charge which each PHEV is fully charged and the charging is constantly increasing.

$$SOC_{i,end}^k = SOC_{i,\,max}^k \qquad (5.13)$$

$SOC_{i,\,max}^k$ is for the time that the charge is completed. The ending time of charge is obtained through Eq. (5.14).

$$t_{i,end}^k = t_{i,start}^k + d_i^k \qquad (5.14)$$

In the continuous charge increase mode, the PHEV is charged at the predetermined constant time by the consumer. The start charging time should be predetermined and be available on the charge pattern chart. The charging process stops at the ending time of charge regardless of whether the PHEV is fully charged or not. The probability distribution functions of random variables in this field of the study can be derived from the official traffic reports.

5.8 Managed Charge

In order to investigate and control the status of PHEV loads, the coordinated charging scenario is provided that is based on the relationship between domestic load consumption and the amount of the renewable resources generation. The PHEVs is considered as the main factor of overloads and the penetration of renewable resources controller in this research. Hence, the coordinated charging scenario and time management of vehicle charging are presented to change in charging time to other times to the balance between load consumption and renewable resources generation. In this scenario, the priority of charging vehicles is possible in two ways that in accordance to their account and the load profile: (1) fast charge, (2) delayed charging.

The fast charge belongs to vehicles that when enter into the charging process the difference between renewable resources generation and load consumption is at the lowest level. Since, due to the fact that the urban power grid may be used to provide part of the required vehicles energy then the cost of consumers may be increased. This option is listed as the charging with priority time.

The second way delays charging time to hours with high renewable resources generation and to avoids of extra charge that can be lead to further financial savings; although, the vehicle will be charged in a longer time. This option is listed as the charging without priority time.

The choice of one of the two modes depends on whether consumer desire to save money through preventing of charging the vehicle at the times with a shortage of solar energy resources than consuming or trying to finish as soon as possible the process of charging battery and increasing the costs of energy.

The coordinated charging scenario relies on two basic subsystems:

- Home general controller (HGC)
- Transformer general controller (TGC)

Basically the HGC's performance is as follows: (i) increase demand energy of home loads to the demand energy of existing vehicle at a fixed time; (ii) checking the generated energy by renewable resources (solar), combination of two sources of generation, and estimate the amount of generated energy; (iii) calculating the differences in the total generation of the total consumption in which if the demanded energy exceeds of the amount of generation, the power grid will be compensated its shortages, otherwise their residue will be transferred to the power grid; (iv) after processing, all HGC's data will be presented as a report.
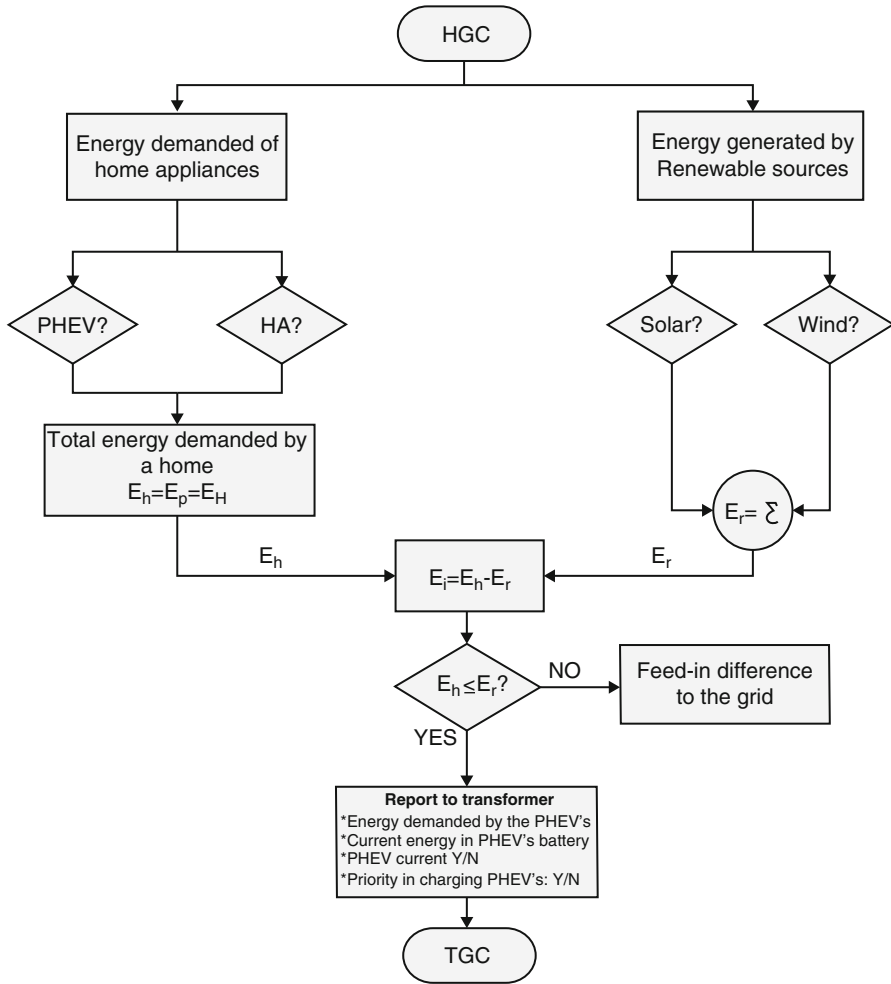
Fig. 5.4 the flowchart of the vehicle charging management by HGC [3]

This report contains some information on PHEV's terms:

- Whether connected to the grid or not?
- Demand energy by PHEV
- Energy in the PHEV battery
- Whether the PHEV has the priority for charging?

The HGC implements the coordinated charging scenario through this information.

The function of HGC is presented as flowchart in Fig. 5.4.

E_p represents the demanded energy by the vehicle and Eh is the energy of the home loads. E_r shows the total renewable resources generation (solar), Ed is the energy of vehicle discharge.

The HGC grid sends the report to the TGC, then TGC combines the report with the total available loads seen by the current transformer in order to determine the conditions of the residential grid.

There is a comparison between overall load and the nominal power of the transformer then if not exceed this capacity, the transformer provides the required energy of each home. On the other hands, if the overall load is greater than the nominal power, the TGC will enable coordinated charging algorithm in order to recognize vehicles and delay to charging them or discharging battery of some of the vehicles at a time interval. Charging vehicle causes overloads so this load should be managed and transferred to other time. The flowchart is the coordinated charging scenario on the TGC as it presented in the Fig. 5.5, (The target grid is supposed for 5 houses).
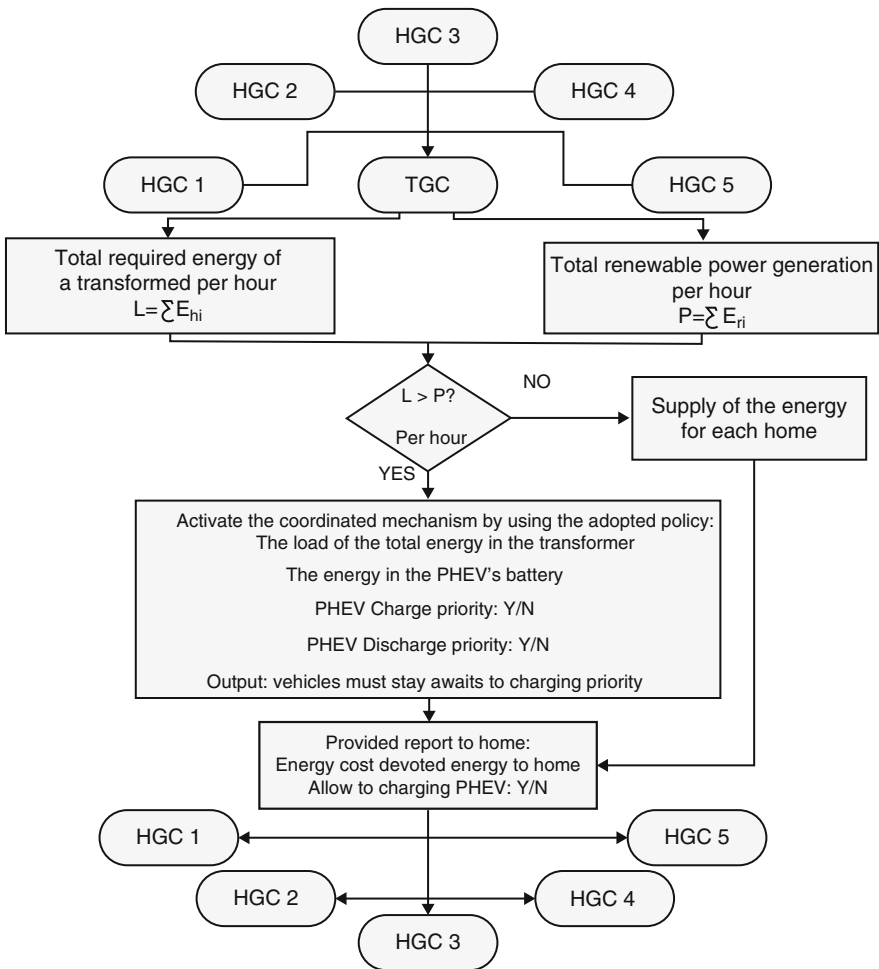
Fig. 5.5 the flowchart of the vehicle charging management by TGC [3]

5.9 The Coordinated V2G Mode

In managed V2G mode, the PHEV can be considered as a grid energy storage unit and a controller. Each PHEV has three modes: charge, deactivated and discharge that the optimal coordination PHEV dis/charging modes can be reduced the peak load as well as increases the penetration of renewable resources in the grid.

In any mode, the require to the charging and discharging PHEV should be considered.

The aim of this project is respond to consumer needs and minimize the total peak load through controlling $CR_i(t)$ and $DCR_i(t)$.

The subject has such limitations:

There is no charge and discharge in the outside of the dis/charging period. For example, dis/charging mode should be zero:

$$CR_i(t) = 0 \qquad t \notin \left[t_{i,start}^k, t_{i,end}^k\right] \qquad i = 1, 2, \ldots, N; \quad k = 1, 2, \ldots, K \quad (5.15)$$

$$DCR_i(t) = 0 \qquad t \notin \left[t_{i,start}^k, t_{i,end}^k\right] \qquad i = 1, 2, \ldots, N; \quad k = 1, 2, \ldots, K \quad (5.16)$$

Charge power should be as:

$$CR_i(t) \in \{0, 1\} \quad t \in \left[t_{i,start}^k, t_{i,end}^k\right] \quad i = 1, 2, \ldots, N; \quad k = 1, 2, \ldots, K \quad (5.17)$$

Charge power should be as:

$$DCR_i(t) \in \{0, -1\} \quad t \in \left[t_{i,start}^k, t_{i,end}^k\right] \qquad (5.18)$$

The PHEV mode could be charging, discharging, or deactivated, as a result $CR_i(t)$ and $DCR_i(t)$ cannot be active at the same time.

$$|CR_i(t)| + |DCR_i(t)| \le 1 \qquad t = 1, 2, \ldots, T; \quad i = 1, 2, \ldots, N \qquad (5.19)$$

And SOC should not be less than the specified value:

$$SOC_i(t) \ge B_l \qquad (5.20)$$

The B_l is the lower limit of the SOC which it is set to 20% in this program.

In the V2G mode, the car is not allowed to discharge when the battery capacity reached to this value.

5.10 Mathematical Model of the Issue

The aim of this project is to increase the renewable resources usage in the smart grid and to reduce the use of the conventional generation (CG). To this end, there should be obtained the power differences between the required energy for PHEVs charging, the amount of consumers' consumption, and above all the renewable energy resources. For doing this, the Eq. (20.3) is used.

So, the V2G process and discharge mode are considered to reduce the peak load in this equation.

$$
\begin{aligned}
E^j(t) = P_G{}^j(t) - \sum_{i=1}^{N}\left(P_i{}^j(t) \times (CR_i(t) + DCR_i(t))\right) \\
- P_L{}^j(t) \qquad t = 1, 2, \ldots, T; \quad j = 1, 2, \ldots, m
\end{aligned}
\tag{5.21}
$$

The variables that used in the Eq. (5.21):

- The $E^j(t)$ is the energy differences between renewable resources generation and consumption at t time.
- "j" represent the considered house $\forall j \in (1, m)$
- The $P_G{}^j(t)$ is the total of the renewable resources generation, which equal the generation of the solar resources, it obtains through below equation:

$$
P_G{}^j(t) = P_{pv}
\tag{5.22}
$$

- $P_i{}^j(t) \times (CR_i(t) + DCR_i(t))$ expresses the amount of consumption of PHEV charging power or V2G in discharging mode. Therefore, due to the Eqs. (5.17) and (5.18) equations, the value may be positive or negative.
- $P_L{}^j(t)$ is static load consumption by consumer that include all furniture, regardless vehicle energy.

According to Eq. (5.21), if $E^j(t)$ is obtained a positive value so the renewable resources more than of the consumer consumption which the load response is completed without any problems in the distribution grid. Otherwise, if $E^j(t)$ is obtained a negative value, the power should be transferred of conventional generation (CG) into the house in order to supply required energy of consumer which the received energy from CG is obtained by Eq. (5.23):

$$
CG^j(t) = \begin{cases} P_L{}^j(t) + \sum_{i=1}^{N}\left(P_i{}^j(t) \times (CR_i(t) + DCR_i(t))\right) - P_G{}^j(t) & E^j(t) < 0 \\ 0 & E^j(t) \geq 0 \end{cases}
\tag{5.23}
$$

The difference in consumer demand energy is equal to the renewable resources.

5.10.1   Optimization of the Issue

The minimizing the received power from conventional generation is the main factor of the objective function which contains such limitations:

$$\text{Min} \sum_{t=1}^{T} \sum_{j=1}^{m} CG_{t,j} \tag{5.24}$$

1. The value of $E^j(t)$ must be smaller than zero, otherwise $CG_{t,\,j}$ is equal to zero.

$$E^j(t) < 0 \tag{5.25}$$

2. In order to completing load response, the total resources generation that consist of renewable resources and conventional generation should be higher than or equal to the total consumer load.

$$P_G^{\,j}(t) + CG_{t,j} - \sum_{i=1}^{N} \left(P_i^{\,j}(t) \times (CR_i(t) + DCR_i(t)) \right) - P_L^{\,j}(t) \geq 0 \tag{5.26}$$

3. The received energy of the power grid has the following limitation. BCG[6] is a binary number that indicating whether the energy is received of the conventional generation or not $CG \in \{0, 1\}$.

$$CG_{min}.BCG \leq CG \leq CG_{max}.BCG \tag{5.27}$$

4. The vehicle capacity i at t time is equal to the vehicle capacity i at $(t - 1)$ time and the amount of received power for charge or discharge [6].

$$SOC_{i,t} = SOC_{i,t-1} + (P_{i,t} \times (CR_i(t) + DCR_i(t))) \tag{5.28}$$

5. The limitation of the charge and discharge power are determined by the Eq. (5.29) [6].

$$DCR_{i,t}.P_{i,t_{min}} \leq P_{i,t} \leq CR_{i,t}.P_{i,t_{max}} \tag{5.29}$$

6. Finally, the battery capacity has some limitations [6].

---

[6]Binary Conventional Generation

$$20\% \leq SOC_{i,t} \leq 100\% \tag{5.30}$$

The $SOC_{i_{max}}$ is considered 100% in the Eq. (5.30) and there is not allowed to discharge the vehicle with the capacity of less than 20%. This limitation is considered to increase battery life.

5.11 Multiple Results of Exploitation of the Studied Grid

The main purposes of this research chapter are discovering a suitable, automatically, and optimized way to managing PHEV charging, for minimize received energy from CG, and to increase energy consumption from renewable resources by using of PSO algorithm. In addition to Monte Carlo simulation used to obtain random variables and probability function. The result of PHEV charging program is generally seen on the grid for every home. As maintained above regarding smart homes, the houses equipped with the planned smart charging devices for their PHEVs and consumers declare the allowed time for their PHEVs charging. The allowed charging time for each of PHEV is assumed which is equal to time of return to home after the last travel and the start of first trip on the next day.

In the previous section provided an objective function which related to the operation of the proposed network, and all components were modelled separately. Then, the uncertainty mileage by cars during the day, the battery capacity of the vehicle at the first time, and also the absence of cars in the house is described. It is necessary to achieve optimum operation conditions of this grid by use of suitable tool. For do this, PSO algorithm is selected to optimize objective function. This algorithm optimized scenarios generated scenarios by Monte Carlo method.

It is simulated in the MATLAB program. A grid of solar and wind units with PHEVs as flexible loads also a transformer with the identified capacity to exchange houses energy with upstream grid is considered. Figure 5.1 Indicates sample grid of this work which consists of five smart houses with equipment for the renewable generation [3]. Next, is considered the effect of PHEVs charging in three modes: unmanaged charge, managed charge, and managed charge V2G, then the study will analyse the results of the simulation.

In order to managing energy is provided an initial scenario as well as used of Monte Carlo simulation to find a consistent driving pattern with current situation. For doing this, it is assumed that each house has a PHEV. The houses 1 and 2 use of their vehicle for commuting to workplace while the houses 3, 4, and 5 use of public transport vehicles and do not have a timing plan to use of their vehicles.
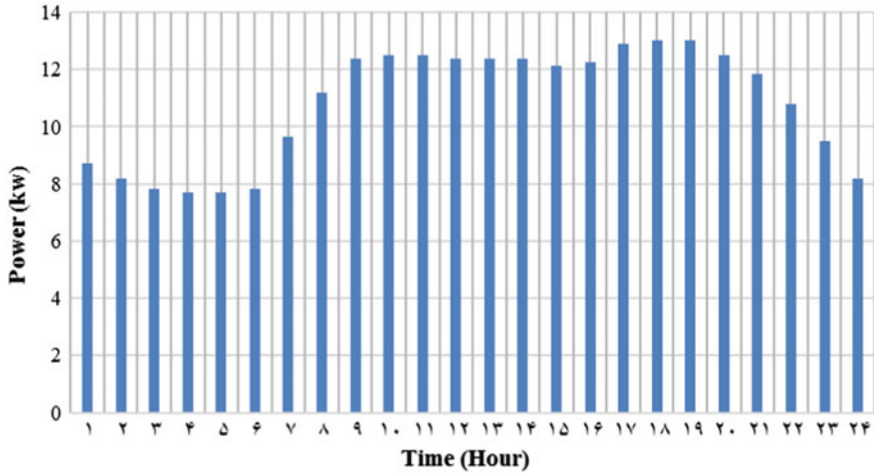
Fig. 5.6 The household consumption curve

5.11.1 Charging without Vehicle Management and V2G Capability

A distribution grid consists of five house with specified features. The loads of the houses are divided into two categories: static loads (such as lighting, cooling and heating systems; household appliances like washing machines, dishwashers, and electrical appliances) and flexible loads (such as electric vehicle battery). The Fig. 5.6 shows the static loads per house [25].

As it shown in the Fig. 5.6, the static load curve of the distribution grid represents the all of five houses, regardless of the loads of charging vehicle. The investigated grid is powered by a transformer that has the power 22.75 kW and is a ranged between 25 to 75 kVA per phase. (it is a standard power to supply between 4 to 7 houses) [3].

In Fig. 5.7 the daily generation of renewable resources with household consumption regardless of the load of charging PHEV were compared. In charging mode without management, vehicle owners are connected to the grid regardless of the grid status and the amount of the generation of renewable resources at the return time to home. This charging method has some problems: charging a large number of vehicle at the same time and creating a peak load in the distribution grid, which will be increased the load and consumers' cost. The lack of the amount of available renewable resources leads to a loss of electricity generated resources and increasing the conventional generation usage. The load curve without vehicle charging management shown in Fig. 5.8.

In Fig. 5.8, the amount of the generation of renewable resources with the curve of the household load were compared by take into account to PHEV charging. As it can be seen in the figure, there is no charging at the time with the maximum generation of
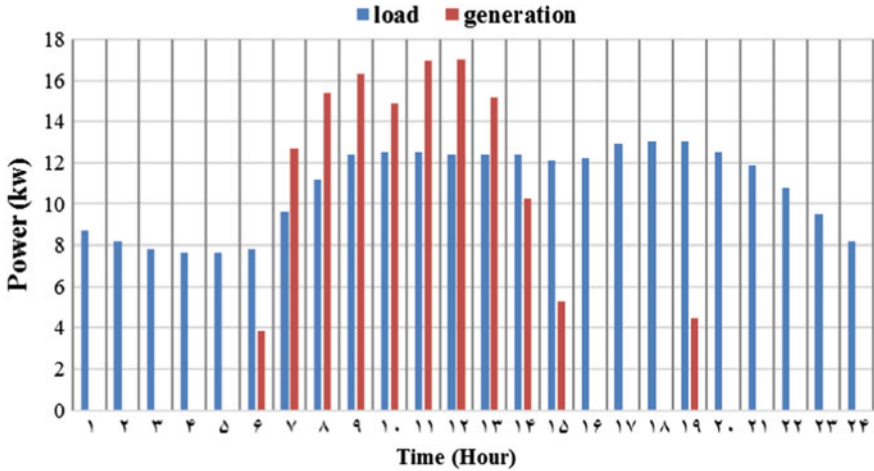
Fig. 5.7 The ratio of the generation of the renewable resources to static load consumption in the distribution grid
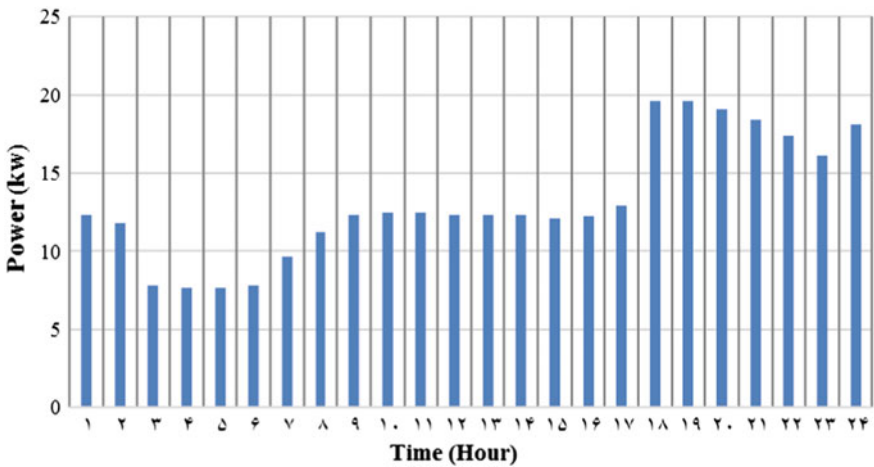

Fig. 5.8 The curve of household load without charging management

the renewable resources that increases demand energy of power grid and increases consumers' cost so the importance of PHEV charging management is revealed.

In Fig. 5.9, the use of photovoltaic panels and high-temperatures of the sun at 8–18 PM, the renewable resources generation is at its highest level which decrease at night. It is not taken into consideration in unmanaged electric vehicle charging so the vehicles enter to the charging process at the minimum level of renewable resources generation, which increases the demand energy from the power grid.
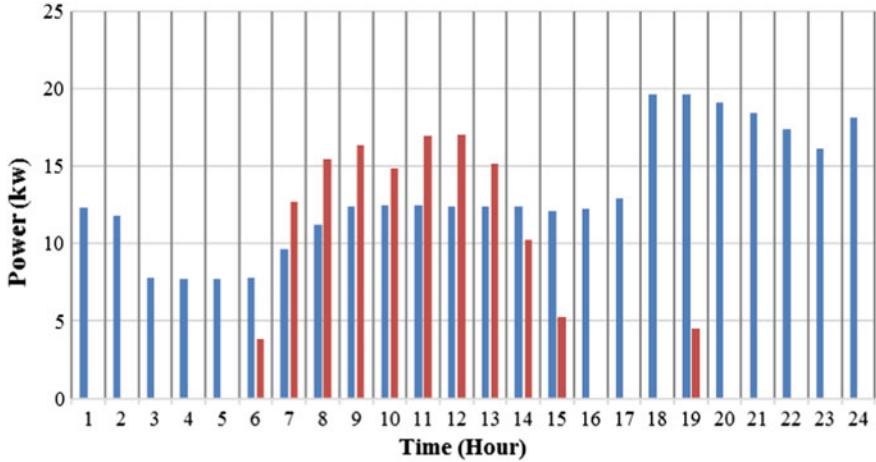
Fig. 5.9 The curve of the comparison of the generation of renewable resources and unmanaged loads
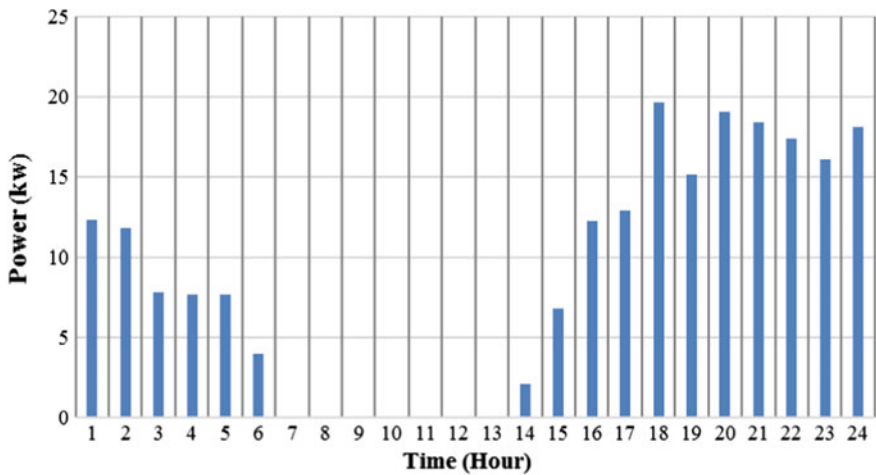
Fig. 5.10 The amount of received energy of the power grid in the unmanaged charge scenario

The Fig. 5.10 presented the house demand energy of power grid. There is indicated that the vehicles enter to charging process at late in the day with low level of renewable resources generation which increases peak load in the distribution grid and the costs. It's assumed that when two vehicle go back to home will be connected to the grid, but in order to complete the capacity of the battery, some of the vehicles enter to charging process at the end of day. For this reason, the rate of the

renewable energy permeability drastically reduces at this time moreover the received energy from conventional generation increase to 80 KWh during 24 h. The effect of the management on the amount of received energy from the conventional generation before and after the managing will be discussed by applying vehicle charging management program.

5.11.2   Vehicle Managed Charging without V2G Capacity

In order to investigate and control the status of PHEV loads, the coordinated charging scenario is provided that is based on the relationship between domestic load consumption and the amount of the renewable resources generation. The PHEVs is considered as the main factor of overloads and the penetration of renewable resources controller in this research. Hence, the coordinated charging scenario and time management of vehicle charging are presented to change in charging time to other times to the balance between load consumption and renewable resources generation. In this scenario, the priority of charging vehicles is possible in two ways that in accordance to their account and the load profile: (1) fast charge, (2) delayed charging (Sect. 5.7).

According to Sect. 5.9, the curve of the load of the grid is presented in Fig. 5.11 through implementing the vehicle charging management program.

In Fig. 5.12, the loads compered in random and managed charge with the curve of generation of the renewable resources. The effect of charge management on the more efficiency of renewable resources is recognized.
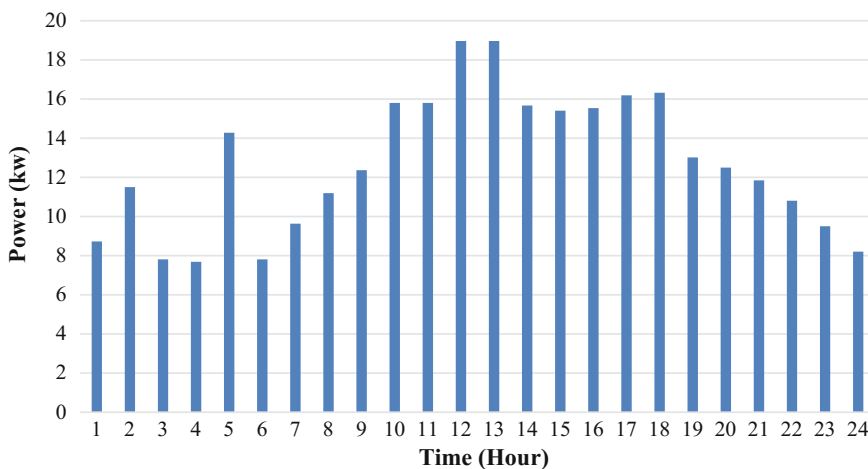

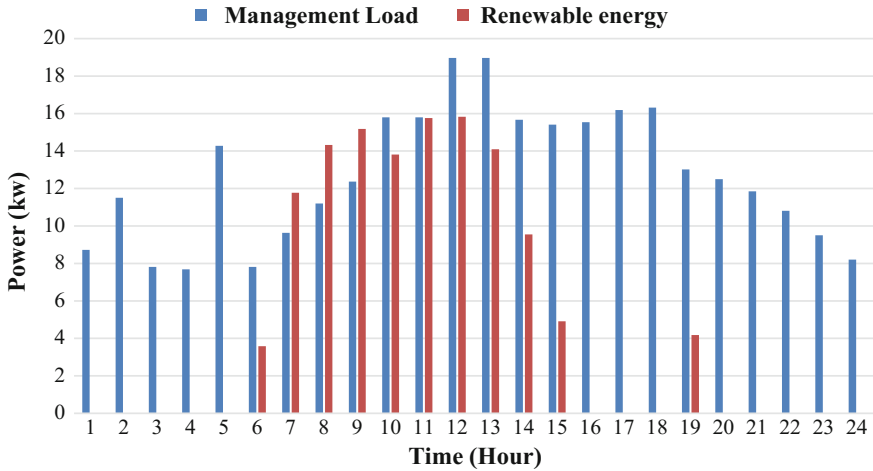**Fig. 5.11** The curve of the grid load with vehicle charging management

Fig. 5.12 The curve of the manage load without V2G capacity and the curve of the generation of the renewable resources
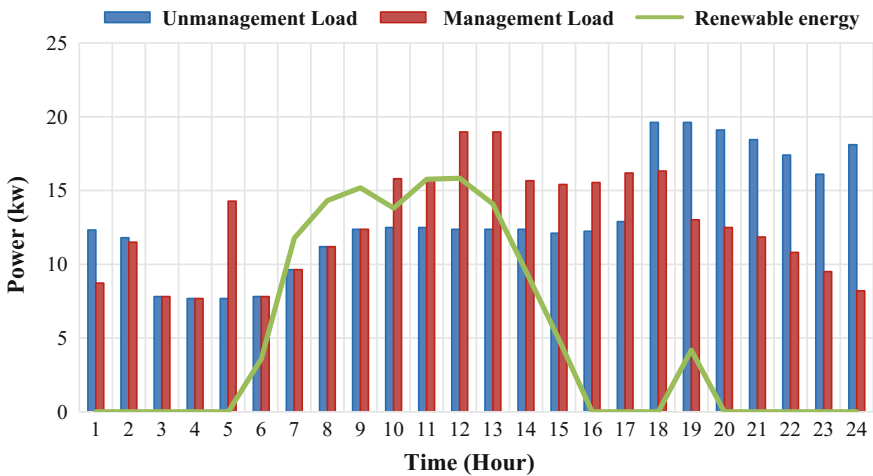

Fig. 5.13 The comparison of generation with domestic load curves in two managed and randomized modes

According to Fig. 5.13, the charging process of some of vehicles that are not in a priority of charge is transferred to 9 and 18 PM. through implementing charging management. As well as due to the high level of the renewable resources generation at these hours, the demanded energy from conventional generation is reduced to 58 kWh which the majority of this energy was cheaper-rate electricity at 3–5 A.M. Certainly, charging management program diminishes the consumers' charges. Figure 5.14 shown received energy from the power grid.
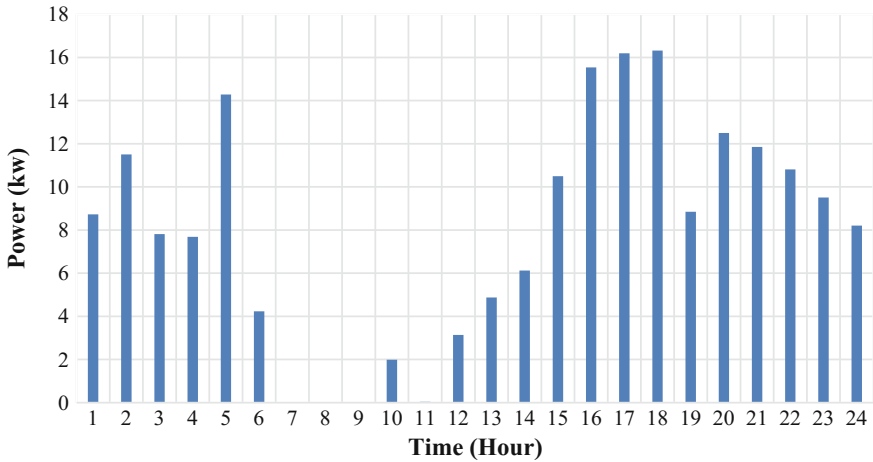
Fig. 5.14 The amount of received energy of power grid in managed and without V2G capacity modes
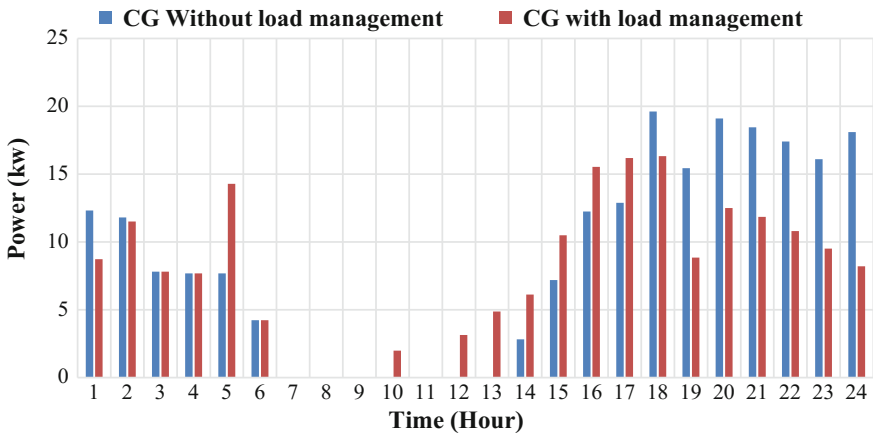

Fig. 5.15 The difference in received energy from the grid before and after charge management

Figure 5.15 is shown the difference in received energy from the power grid with vehicle no/charge management.

5.11.3 Managed Charge with V2G Capacity

In V2G mode, the PHEV may be considered as a grid energy storage system. Every PHEV has three modes: charge, deactivated and discharge that the optimal PHEV dis/charging modes can be reduced the peak load as well as increases the renewable
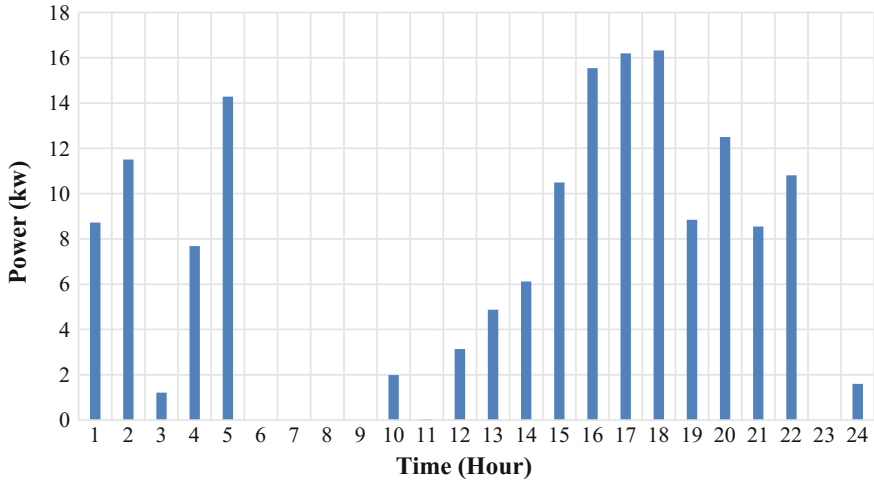
Fig. 5.16 The grid load curve with using V2G

resources penetration in the grid. The main purpose of current project is to minimize the received energy from conventional generation respond in accordance with the consumer needs. The curve of the load grid by use of this feature is presented in Fig. 5.16.

There is compared the new load curve with the amount of renewable generation. After adding V2G to the grid, some of the vehicle's owner are desire to participate in the discharging process at the times with the lower renewable resources generation which increases the penetration of the renewable resources in load response. Figure 5.17 is shown the functionality of the program through comparing generation, load, and V2G capability.

There can be discharged the vehicles depending on the time constraints and the consumers' welfare in use of vehicles which not only reduces received energy from conventional generation, but also increases financial saving for costumers. Considering the vehicle power transmission to grid, the conventional energy generation reduce to 29 kWh. Figure 5.18 shown the conventional generation ratio in two managed and unmanaged modes with V2G capability.

In order to represent the effect of charging management and V2G capability in grid on randomized charge, the graph of the received energy of grid is divided into three modes: (1) unmanaged vehicle charging, (2) managed vehicles charging without V2G capacity, (3) managed cars charging by consideration of V2G capacity with other and the generation of renewable resources curves (Fig. 5.19).

The correlation is used to indicate accuracy of the applied management. Correlation is the statistical indicator which describes the relationship between two dependent variables in other word, it is an statistical indicator that determines various degree of relationship between two dependent variables in a fixed and limited scale.
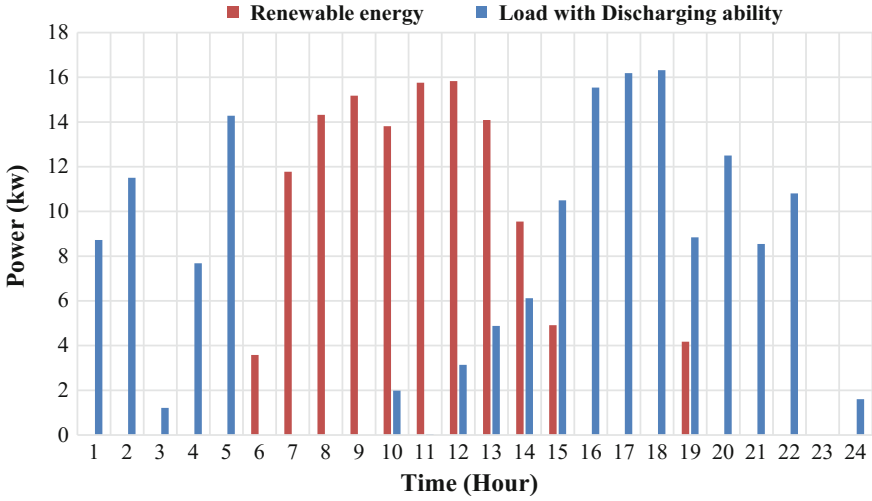
Fig. 5.17 The managed vehicle load with V2G capability and the generation of the renewable resources curve
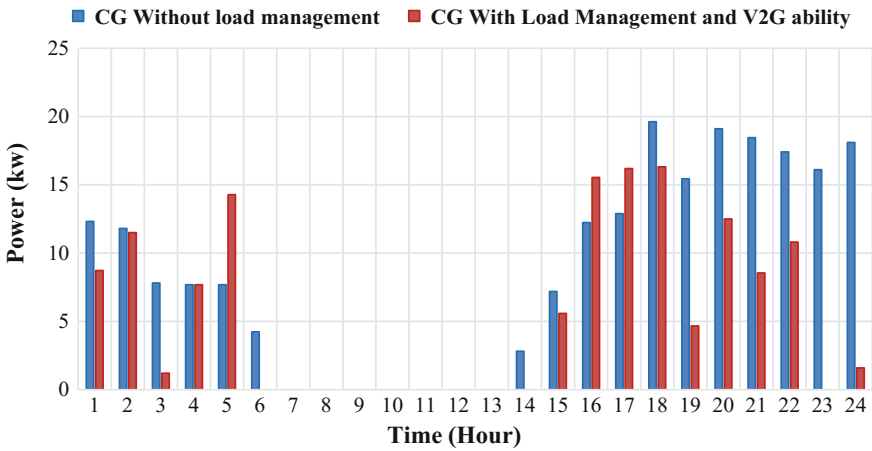

Fig. 5.18 The difference of received energy of grid before and after load management

The Eq. (5.31) indicates correlation between two set of statistic data x and y. The correlation between renewable generation and all household loads in both randomized and managed modes increased from 0.29 to 0.74.
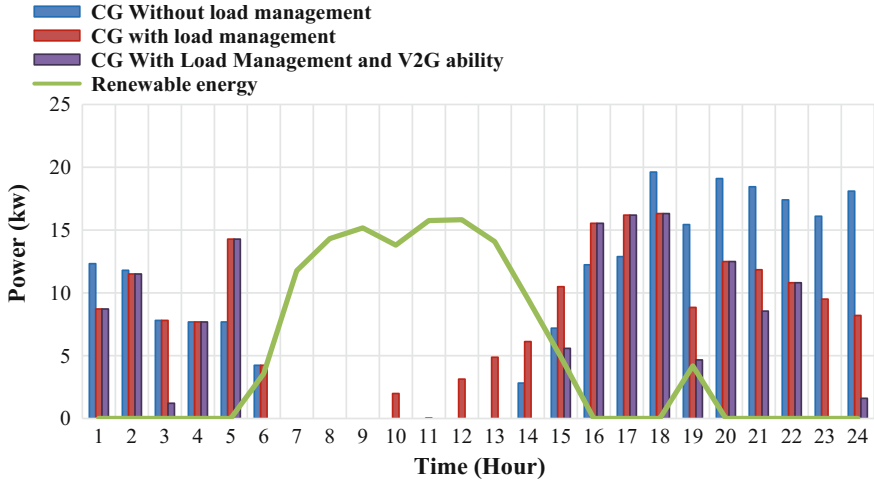
Fig. 5.19 The comparison of the received energy of conventional generation in vehicle charge management modes

$$r_{x,y} = \frac{\mathrm{cov}(x, y)}{\sigma_x . \sigma_y} = \frac{\frac{\sum x_i y_i}{n} - \left(\frac{\sum x_i}{n}\right)\left(\frac{\sum y_i}{n}\right)}{\sqrt{\left(\frac{\sum x_i^2}{n} - \left(\frac{\sum x_i}{n}\right)^2\right)\left(\frac{\sum y_i^2}{n} - \left(\frac{\sum y_i}{n}\right)^2\right)}} \qquad (5.31)$$

The increased correlation confirms the performance of the vehicle charging management program.

$$\mathrm{Corr}\,(\mathrm{Renewable\ Energy}, \mathrm{Load\ Unmanaged}) = 0.29$$

$$\mathrm{Corr}\,(\mathrm{Renewable\ Energy}, \mathrm{Load\ managed}) = 0.6821$$

$$\mathrm{Corr}\,(\mathrm{Renewable\ Energy}, \mathrm{Load\ managed\ with\ V2G}) = 0.7474$$

5.12 Conclusion

Due to optimize the use of the renewable energy resources, a model to more efficient of the residential grid usage through the managing PHEV dis/charging during 24 h was provided. The grid consists some smart houses which has photovoltaic panels for generate needed home power. The loads are divided into static loads and flexible loads. As well as, the houses equipped with the smart charge planning system for the

PHEVs that has double-sided energy exchange capabilities with distribution grid. It worth mentioning that a 25 kV transformer powered to the homes.

In the modelling of renewable resources generation, meteorological information was extracted over a period of 1 year based on the time of information used of the static loads of residential consumers' information. On the other hand, the used specifications of the vehicles as the flexible loads in this modelling are extracted from the relevant automotive companies.

The considerable points in this research are the uncertainty on vehicle mileage per day, the use of vehicle at the different time, and the initial capacity of the battery.

For this purpose, used of Monte Carlo simulation algorithm to cover a variety of probable situations then provided a probabilistic variable for each of the decision variables. Additionally, particle swarm optimization is used to optimize grid utilization in this research. In the depend environment, the performance of the issue with the high number of decision-making variables was acceptable and in a relatively short time reaches to the optimal point. The problem with the high number of decision variables and function well in a relatively short time is relative to the optimal point.

- In order to optimize the grid utilization, various scenarios and plans have simulated and is examined that the model presented in this research.
- Carrying out a charge and discharge management plan to cover renewable energy changes that can be reduced consumer costs.
- Decrease the costumers' cost and reduce their dependency to conventional generation through administrating the PHEV discharging and charging management.
- Due to the dependence of this program on people's driving patterns, the use of a definitive planning method is not appropriate and the possible method should be used.
- Drastically decrease the costumers' dependency to generated energy of fossil fuels which is essential for the environmental.
- Increase the grid security through preventing the creation of peak-loads in the grid and transferring the vehicles charging time which prevents of the overload on a distribution transformers and power grid outage.

Appendix

Indexes	
N	Number of solar modules
J	Considered house
I	Considered car
t	Time interval (24 h)
$CR_i(t)$	Charging mode
$DCR_i(t)$	Discharging mode
$BR_i(t)$	Binary of charge sum discharge
Constants	
P_{pv}	Solar generation (kW/m^2)
P_{mpv}	*max* power of solar module (kW/m^2)
G_t	solar radiation intensity (kW/m^2)
SOC	State of charge (%)
λ	maximum distance mileage in electric mode (mile)
d	total distance mileage by the car (mile)
$P_G^j(t)$	total generation of renewable resources (kW)
$P_i^j(t)$	Power consumption of PHEV charging or discharging (kW)
$P_L^j(t)$	static load (kW)
$CG^j(t)$	conventional generation (kW)

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