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An Overview of Energy Scenarios, Storage Systems and the Infrastructure for Vehicle-to-Grid Technology

Tohid Harighi ¹ , Ramazan Bayindir ¹ , Sanjeevikumar Padmanaban ^{2,*} ,
Lucian Mihet-Popa ^{3,*}  and Eklas Hossain ⁴

¹ Department of Electrical and Electronics Engineering, Gazi University, Ankara 06500, Turkey; tohidharighi@gmail.com (T.H.); bayindir@gazi.edu.tr (R.B.)

² Department of Energy Technology, Aalborg University, 6700 Esbjerg, Denmark

³ Norway Faculty of Engineering, Østfold University College, Kobblerstredet 5, 1671 Kråkeroy-Fredrikstad, Norway

⁴ Department of Electrical Engineering & Renewable Energy, Oregon Tech, Klamath Falls, OR 97601, USA; eklas.hossain@oit.edu

* Correspondence: san@et.aau.dk (S.P.); lucian.mihet@hiof.no (L.M.-P.);
Tel.: +45-716-820-84 (S.P.); +47-922-713-53 (L.M.-P.)

Received: 21 June 2018; Accepted: 13 August 2018; Published: 20 August 2018



Abstract: The increase in the emission of greenhouse gases (GHG) is one of the most important problems in the world. Decreasing GHG emissions will be a big challenge in the future. The transportation sector uses a significant part of petroleum production in the world, and this leads to an increase in the emission of GHG. The result of this issue is that the population of the world befoils the environment by the transportation system automatically. Electric Vehicles (EV) have the potential to solve a big part of GHG emission and energy efficiency issues such as the stability and reliability of energy. Therefore, the EV and grid relation is limited to the Vehicle-to-Grid (V2G) or Grid-to-Vehicle (G2V) function. Consequently, the grid has temporary energy storage in EVs' batteries and electricity in exchange for fossil energy in vehicles. The energy actors and their research teams have determined some targets for 2050; hence, they hope to decrease the world temperature by 6 °C, or at least by 2 °C in the normal condition. Fulfilment of these scenarios requires suitable grid infrastructure, but in most countries, the grid does not have a suitable background to apply in those scenarios. In this paper, some problems regarding energy scenarios, energy storage systems, grid infrastructure and communication systems in the supply and demand side of the grid are reviewed.

Keywords: vehicle-to-grid; grid-to-vehicle; electric vehicles; batteries; harmonic distortion; IEEE Bus standards

1. Introduction

The world population is growing rapidly, so the outcome is greenhouse gas (GHG) emission and energy consumption increase year by year. There is not a traditional fuel for transportation systems at hand that is both clear and efficient (mostly fossil fuels), while on the other hand, electric fleet systems can work with lower GHG emissions and energy losses. Therefore, changing fuels seems the best idea to get the best result here. To make this happen, in the first step, the electric grids that are used must be smart (as is mostly the case in North America, Europe and pacific Asia) [1–3]. The Electric Vehicle (EV) is one of the electric transportation technologies; therefore, EV and the smart grid have been integrated to execute our plan. EVs should connect to the smart grid in the form of Vehicle-to-Grid (V2G) or Grid-to-Vehicle (G2V). In V2G technology, the EV and grid share energy from the vehicle to the grid,

and vice versa in G2V. Hence, it could be said that EVs are the subdivision of electric fleet systems and grids. The result of this integration is to have critical specific features such as having high storage and low GHG emissions. According to some existing options, technologies and disadvantages, all the energy arena actors have developed energy strategies. They have planned to change the transportation system to an electric fleet system to meet the targets made by IEA 2030 and 2050. The Paris agreement (UNFCCC, 2015a) has contributed to decrease GHG emissions in the world, so this agreement declares that countries should come up with plans to decrease the global average temperature up to 2 °C. The IEA 2DS trajectory sets the goal, which is reducing GHG emissions from 33 GtCO₂ approximately to 15 GtCO₂ in 2050, which is roughly 45% of the CO₂ that was emitted in 2013. Besides, in the 6DS IEA trajectory, GHG emission is approximately 55 GtCO₂. Some predictions of IEA and UNFCCC until 2030 and 2050 on the EV plan are as follows [1]:

- About one billion electric vehicles, comprising above 40% of the total LDV stock, which is trajectory 2DS.
- More than 400 million electric two-wheeler vehicle will be produced in 2030.
- All of the cars will be electric two-wheeler vehicles by 2050.
- The EVI members are comprised of 16 governments today.
- Between 2014 and 2015, new enrolment of EV (BEV, BEV) increased by 70% (more than 550 K sold worldwide)
- The annual sale list of 2015 in comparison to 2014, increased more than 75% EVs in these countries: France, Germany, Korea, Norway, Sweden, The UK and India.
- The cost of the PHEV batteries decreased from USD 1000/kWh in 2008 to USD 268/kWh in 2015, and the target for 2022 is USD 125/kWh.
- The density of the PHEV batteries increased from 60 Wh/L in 2008 to 295 Wh/L in 2015, and the target for 2022 is 400 Wh/L.

Some countries have taken actions to reach the IEA 2030 and 2050 targets. For example, Ireland created a roadmap from 2011–2050. In this plan, 800K tons of oil and 4 million tons of CO₂ emissions will be reduced by 2050 per annum [4]. Renewable energies such as wind and solar are very important because they produce energy with zero GHG emissions, and the grids supplied by both energy types are more flexible than grids supplied by only fossil energy [5–7]. All types of renewable energies are only available in special situations because they are not stable energy sources. However, all of them can be constructed at any size and everywhere. V2G, the smart grid and micro grid are supplementary to each other and also can expand one another. All of the renewable energy conversion procedures include AC to DC or the inverse. The DC type of energy supplies batteries, and the EVs' energy storage system plays a big role in the grid when it needs energy exchange. EVs can save energy when the demand side of the grid strongly decreases, for example a decrease between 23:00 and 05:00. Hence, reducing the energy level immediately in power plants (in every condition) is not economical. Fossil ICE efficiency in the best condition and with the latest technology is 18~20%. However, the fossil power plant efficiency is 38~40%, and CHP energy efficiency is 60~75% [8]. This clearly shows that EVs' benefit is not limited only to having zero GHG emissions. Thus, the EVs are supplied with electric energy, which is generated as 38~75%, which depends on the energy generating condition, and all mentioned benefits (EVs are supplied by high efficiency energy and reduce GHG emissions) can be improved by V2G technology or similar technologies. This is based on a bidirectional energy transmission system, and some targets are easily reachable, such as peak reduction, stability and reliability of energy. EVs' batteries, the quantity of the EVs, the time of charge and the power electronic systems' topologies are forced to use an energy storage system in charging stations, and this is sensible in grids that are used in the DC line. In this situation, energy is conveyed to the grid in critical situations such as peaks and down time by the stable energy storage in charging stations and the temporary energy storage in EVs [9–14].

This paper covers discussions about energy scenarios, storage systems and the infrastructure of the grid related to V2G technology. The scenarios, policies and targets of the governments and agencies of the world for lower GHG emissions and high-energy efficiency have been suggested. They change the grid target and duty, but the collection of infrastructures cannot respond to the requirements mentioned in the scenarios. According to the scenarios (created for grid upgrades), storage systems (such as batteries and chargers) and the infrastructures of the grid should be replaced by the latest technologies in each section.

2. Energy Scenarios

Each energy plan has some scenarios. Energy efficiency and GHG emission are targets for energy efficiency and GHG emission for each energy scenario in the world, and scenarios for V2G technology depend on their own location, so different requirements and energy stocks exist all over the world. The road maps created by IEA give the result for general scenarios for 2050. Table 1 gives the number of EVs and PHEVs that will be sold in 2050. It is clear that EVs have lower GHG emissions than PHEVs. According to the 2050 road map, the North American, European and Pacific countries will have less PHEVs than China and India. This means that their fossil energy consumption in the transportation sector will be lower than India and China.

Table 1. Electric vehicles that will be sold in 2050 according to the IEA scenario.

Location	EV	PHEV
North America	8800 K	3800 K
Europe	6400 K	3100 K
China	9400 K	11,400 K
India	8600 K	9600 K
Pacific	2400 K	1300 K

For example, China's government has tried to reduce GHG emission more than other countries. However, the mentioned countries updated their grid from the cyber security, smart and micro grid side of the grid [15]. Energy efficiency is possible, if only the mentioned parameters are used together. Today, energy providers provide energy in different forms such as oil, gas (LPG, CNG and LNG) or electricity. The energy usage method is very important, and it must be observed in all parts of the energy consumption. Energy use percentages, in some places, could be as follows: electricity 30%, heat 40% and transport 30%. In addition, they can be supplied with renewable energy by the CEESA 2050 (Research project Coherent Energy and Environmental System Analysis (CEESA) financed by the Danish Council for Strategic Research.) scenario [16]. Control of supply and demand is the primary parameter of energy quality, so reduction of the GHG emissions and the efficiency of energy are possible by assuming supply and demand accurately [17–19]. The control of the mentioned items results in facilitates integrating the renewable energy network with the grid and EVs, but it requires data from metrology, the supply and demand of the grid, the infrastructure of the grid and some additional algorithms to provide good and predictable data [20–22]. V2G technology should be economical, so all of the mentioned items should have a reasonable relation between technical benefits and the economic condition of the investor. The performance of the V2G technology depends on the grid infrastructure and the type of electric vehicle storage system. Their quality and size directly influence the performance of the grid [23,24]. Hence, not all of them are completely controllable, but they are predictable. Predictable means that the management team can modify the demand time schedule [25–27]. Here, some scenarios are reviewed one by one, so all of them are issued for a special location and condition, also any changes in the main scenario can generate different results. According to the scenario (can be different in each location), the design of the grid have to be more developable, flexible and manageable than what grids use currently, so grids after design, will be more complex and comprehensive. Scenarios of the grid have some algorithms to use in normal and critical situations

and all sections of the grid have a connection with another section of the grid, which is very important to control the grid and one of the grid designing protocols [28–30].

3. Storage Systems in V2G Technology

3.1. Batteries Use on the Electric Vehicles

Energy storage types are different in each situation. For example, the hydro power plant uses the pumping of water to save energy. The type of energy storage is categorized by some environmental and advanced parameters, such as GDR or technical aspects, and both must consider each other [31,32]. The type depends on the rating of power, charge and discharge, the density of power and energy, response time, efficiency, self-discharge and lifetime. EVs batteries must be solid and have the mentioned parameters [33]. Today, four types of batteries are better used in electric vehicles, such as Li-ion, NiCd, NaS and ZnBr. However, the specifics are different for each material. The properties of EVs' batteries are given in Table 2 [34]. The cost of each type of battery is different, but the technical side of this issue clearly shows that Li-ion batteries are the best choice for EVs in every situation. Li-ion batteries with some alloy such as Fe and Mn give the best performance, so they boost the battery capacity and safety. In the latest measurements, EVs can travel between 250 and 350 miles with Li-ion batteries. Generally, LiFePO₄, LiCoO₂ and LiMn₂O₄ types of batteries are used in EVs. All of them are produced as anode and cathode types [31,34,35]. Table 3 illustrates the type of Li battery and its specifications.

Table 2. Type of batteries and their specifications [34].

Battery Parameters	NiCd	NaS	ZnBr	Li-ion
Power rating (MW)	0~40	0.05~8	0.05~2	0~0.1
Discharge time	S~h	S~h	S~10 h	Min~h
Power density (W/l)	75~700	120~160	1~25	1300~10,000
Energy density (Wh/l)	15~8	15~300	65	200~400
Response time	<S	<S	S	<S
Efficiency (%)	60~80	70~85	65~75	65~75
Lifetime in years	5~20	10~15	5~10	5~100
Lifetime in cycles	1500~3000	2500~4500	1000~3650	600~1200
Cost \$ (kW)	500~1500	1000~3000	700~2500	1200~4000
Cost \$ (kW/h)	800~1500	300~500	150~1000	600~2500

Table 3. Some type of Li batteries and their specifications [35].

Type of Li-ion	Practical Energy Density (Wh/kg)	Cycle Life	Safety
C/LiCoO ₂	110~190	500~1000	Poor
C/LiMn ₂ O ₂	100~120	1000	Safer
C/LiFePO ₄	90~115	>3000	Very safe
LTO/LiCoO ₂	70~75	>4000	Extremely safe
LTO/LiFePO ₄	~70	>4000	Extremely safe

The batteries' performance depends on the alloy used, so to know the grade of battery quality, manufactures of EVs or users of the Li battery check the result of tests performed on it. Current, voltage, mechanical strike and temperature are important parameters to be considered in all tests on the batteries, as these parameters fluctuate during the day.

3.1.1. Mechanical Strike Influence

Mechanical strike is an unavoidable problem, whether the EVs are in the normal or an abnormal condition. In the normal condition, the EV battery is abused by the mechanical strike effect of the road, but the EV batteries have an unreliable behavior in the case of an accident. Thus, it must pass some tests such as the T4 and FMVSS 305 mechanical absorb tests or the battery should conform to some standards such as SAE j2464 (Safety and Abuse Testing) [36,37]. The battery is strongly sensitive,

when the SOC ratio is up to 80%. Figure 1 shows how important mechanical strike and temperature are. They influence the life and all other aspects of the battery [38–44].

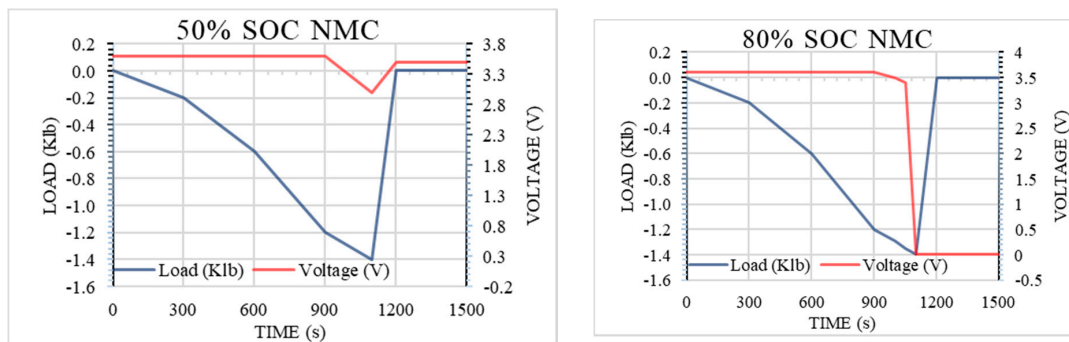


Figure 1. Effects of NMC battery mechanical strike [43].

For example in 2013, during flight JA829J, Japan Airline's (JAL) Boeing 787 APU (Auxiliary Power Unit) battery presented thermal runaway after 52,000 flight hours. Until grounding JA829J, their battery type was lithium cobalt oxide (LiCoO_2). According to the U.S. National Transportation Safety Board (NTSB) report, this problem was a result of T5 and T6 mechanical absorbance in the APU battery, and finally, a fire broke out [45].

3.1.2. Temperature Stability Significance

Temperature stability should be considered in all situations, as the battery has different behaviors at each temperature. It does not work perfectly at very extreme temperatures such as -20°C or $120\text{--}130^\circ\text{C}$, in this situation, the runaway threat is greater than in the normal condition. Hence, the EV battery must be protected against temperature (battery heating and cooling system) and the mechanical strike issue [46–48].

3.1.3. Control on the Storage Systems

Grid integration contributes to the grid's power efficiency in each branch of the electric grid. The storage system needs more control than other parts of the grid, so the health of the storage systems is critical and sensitive [49]. The storage control system is not limited to grid storages: EV batteries are part of the grid storage, and thereby, it can control all EVs' storage and the grid storage system, because EVs represent a short-term energy storage for the grid. Therefore, local governments can achieve a storage system without any payment. This is one of the economic benefits of V2G technology for the grid. The control system and EVs' storage systems protect the grid from shocks when the demand strongly decreases or increases. For the infrastructure of the grid response control for V2G technology and some environmental conditions, the control of the grid requires scenarios, plans and data about the grid's future, so the grid should predict data based on old data, plans and scenarios [49–52].

3.1.4. Longevity of the EVs' Batteries

The lifetime of the Li-ion batteries is a complex issue, and it depends on the mentioned parameters such as charge, discharge, thermal condition and some other parameters. Hence, the electric grid can assume batteries' life and capacity by controlling the grid fully [53,54]. EVs' batteries are used in AM and SM; however, they are used for both sides of the grid. This option encourages the economics and eventually the cost of the electric power and energy system to change in each location [55–62]. Ageing is one of the important problems in V2G technology and bidirectional energy systems. According to battery aging, calendar ageing depends on standing time and SOC, and temperature and cycling

ageing depends on cycle number, DOD and charging rate. For V2G technology, it is recommended to use LiFePO₄/C cell battery and avoid LiNiCoAlO₂/C-based batteries [63,64].

3.2. Charging System

The charging system in the electric grid is a bidirectional system, which supports V2G technology. The charging system quality has a special aspect: it is almost determined as the efficiency of the V2G system. The charging system has almost covered the core of V2G. Charging systems are changed in each grid, and this depends on the infrastructure of the grid. Some charging systems support only DC or AC or both of them. Therefore, the chargers produce the considered infrastructure of the grid with various power electronic parts. IEC 62196-2 Type 1, 2, hybrid, SAE J1772 (SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler) Type 1, 2, Combo and CHAdeMO are types of the charger connectors. All of the connectors work in some critical scenarios. For example, CHAdeMO only works in a DC system [65,66]. Table 4 gives some charger connectors and types of charge models.

Table 4. EV charger connectors' power types [65,66].

Type of Port	AC	DC
IEC 62196-2	*	Hybrid version
SAE J1772	*	Combo version
CHAdeMO		*

*: its availability depends on the condition.

The bases of energies, like power plants or renewable energy, have to convert it to DC type of energy, if the grid has a connection to the storage network. When increasing the number of DC convertors, the ratio of the THD is automatically increased on the grid. The creation of DC lines in the infrastructure of the grid is beneficial to the grid, which are used in smart grids and V2G technology; for example, the DC line improves charging stations' performance in public places with solar energy or using a wireless charging system. Power electronic converters always change energy alongside the loss of energy, especially when changing from DC to AC. The infrastructure of the electric grid and THD issues are critical problems, and nowadays, countries are trying to reduce both problems. Table 5 mentions that the balance of the energy is a big future challenge, and a number of EVs, chargers, populations and spaces of the location have a crucial role in the load spread balance. All of them are important for control and modelling of the grid. Computing their data accuracy contributes to predicting the future of the grid. Nowadays, energy consumption should be efficient. Hence, heating, cooling and transportation systems are eager to use the electric type of energy as much as possible. The solutions of the grid modelling are different in each location. Creating energy nodes in the urban environment and redistributing energy and DC reserve lines to supply DC base energy equipment are ways to reinforce the infrastructure of the grid [67–71]. The support of the infrastructure and EVs has induced positive opinions in people's minds, so people are looking at all the facilities of V2G technology [72].

Table 5. Some numerical location data related to V2G technology.

EV and Population Information	US	China	Japan	UK	The Netherlands
EV (k)	404	312	126	49.67	87.53
Chargers (k)	28.15	46.65	16.12	8.716	17.78
Fast chargers (k)	3.524	12.1	5.99	1.158	0.465
Population (m)	324.6	1373.5	126.8	65.11	17.10
Population per square km	35	145	346	255	412
Area in square km	9,833,520	9,596,961	377,972	242,495	41,543

Potentials to Build Charging Stations for Renewable Energies

Having a sensible effect on people's life is important. It is one of the effective factors. Charging systems must be available at EV drivers' homes or offices. In fact, the charging system converts energy and transfers it from EV or grid to the storage system. The storage side of V2G technology (home, office, parking and some public places) might be one of the Virtual Power Plants (VPPs). VPPs can support the grid, and their efficiency is at a medium–high level, such as WPP, solar energy and CHP. Renewable energies can generate energy everywhere and at every scale [73]. Table 6 shows the major VPPs. This means that EVs complete the energy circle by using V2G technology. In this circle, EVs perform the transmission line and temporary storage duty. If both the home and office are equipped with VPP and V2G technology and personal EVs could always be connected to grid, all of them would provide some benefits to the energy sector, and these are mentioned below [74–77]:

- ✓ Low GHG emissions on the supply and demand side
- ✓ Strong reduction of grid shock
- ✓ Reduction of energy cost to help the economy of the home and office
- ✓ Reduction of fossil, coal and nuclear energy contribution

Table 6. Accessible VPP distribution by place and source type.

	Home	Office	Parking	Urban
Solar PV	*	*	*	*
Micro turbine	*	*		*
Regular turbine		*1		
CHP		*1		
Battery	*	*	*	*

*: available/executable condition; *1: its availability depends on the condition.

Some projects related to V2G have been accomplished, and all mentioned parameters are considered in projects; for example, Taiwan, the U.S. (Florida), The Netherlands and China [78–81]. The priority of the source to supply the charging station is local energy production. Electric storage systems and their charging systems in V2G technology, as well as similar technologies (for which, the energy transfer between them is bidirectional) are important part of the grid, so the reason for having this technology is the electric storage systems, which have good energy efficiency. According to the mentioned advantages and disadvantages, it seems that the LiFePO₄ type of Li batteries is the best choice between various types of batteries; it is very safe in comparison to other types of batteries.

4. Infrastructure

4.1. Strategy

The strategy of V2G technology works according to some plans and targets. Besides, the targets have zero GHG emissions and energy efficiency, such as stability and reliability. Some parameters cause changes in the plan. Infrastructure, energy sources, budget and some other parameters in each country are determined by the energy plan, which is necessary to develop V2G technology. Energy sources and the ability to generate renewable energy are determined with the benefits and market share of V2G technology. Renewable energy developments, V2G technology and the smart grid are impelled alongside [82,83].

4.1.1. Pricing of Energy

The energy sector pricing system is different from other sectors. The supply/demand and determining the cost of the energy by time and other grid priorities give balance and discipline to all of the grid. However, in the energy systems, the supply/demand balance is the second important factor.

Balancing is a means to distribute energy correctly in the electric grid. The density of the population is not constant in each location, but the specification of the population is clear for governments. Hence, the location and density of the population, the time of supply/demand, the measure of supply/demand and the balancing of supply/demand [84–86] influence the price of the energy. The location and density of the population determines the average grid demand in all electric grids. There is a high population density mostly located in the downtown of cities or the capitals of counties. In this condition, the density of the transmission lines is increased, so the ratio of the loss energy is increased. For example, when energy demands are at a high level and the energy generation is low, the cost of energy in these locations is at the highest level [87–90]. The time of the electric energy consumption is important; sometimes, all customers of the grid use energy. In this condition, the grid works at full capacity, and this means that it is prone to overload. Hence, the electric supervisors encourage people to use electric energy from the grid, except for the demand peak time (18:00–22:00) [91–93] considering the peak/down time; in some countries, the time zones differs between two and six hours across the country. Figure 2 gives some countries' populations in 2016 and 2050 [94]. Today, everyone can generate energy in their own house or office by using renewable energies, but this depends on the environmental condition. On the other hand, by using V2G technology, one can share energy with customers or the grid. Generating energy contributing to the grid and supervising of the pay cache for energies generated from customers [95], supervisors have to balance energy on the grid, as an unbalanced grid can damage the grid. They use some methods such as building switching centers to balance energy in the grid [96].

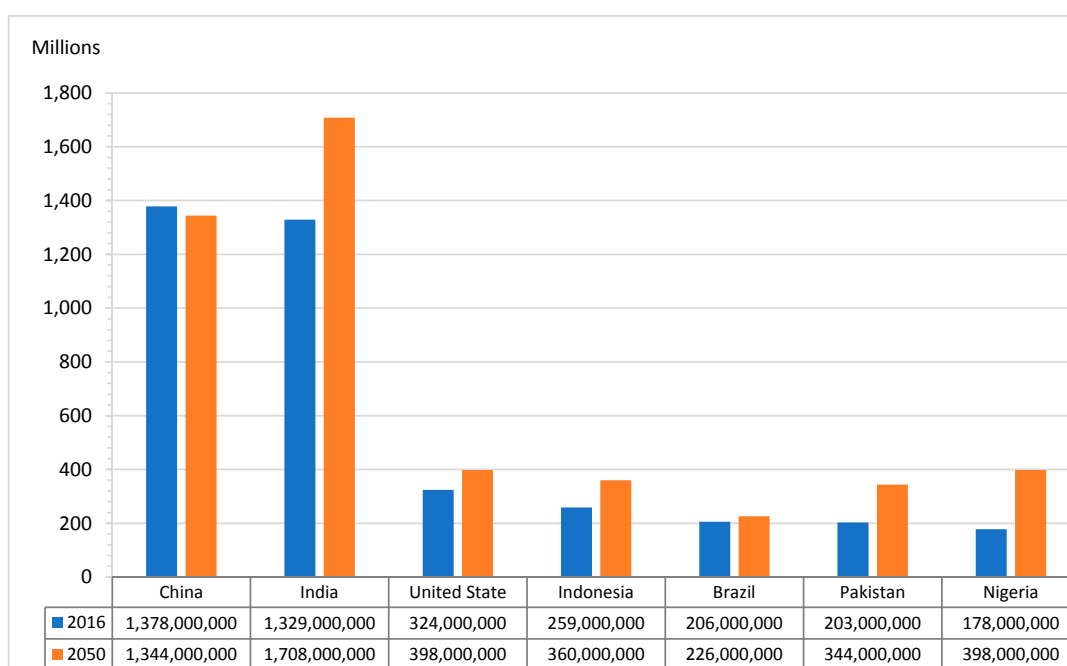


Figure 2. Population from 2016–2050 in some countries [95].

This clearly shows that the mentioned issues influence the electric grid directly. Social infrastructures, such as the economy, psychology, applied and cognitive science, should be prepared to use EVs with people. People of the world have to use EVs, as fossil energies are going to deplete and people who use the transportation system with fossil energies would increase if the world population continues the present energy consumption method in the transportation system. For other types of energy, consumption differs in each area depending on sunrise and sunset, where in some countries' grids work synchronously. The management group must organize this considering local time and other local abilities [97–100] V2G technology helps to reduce the mentioned problems, and governments

can create perfect charging and energy-sharing designs and pricing and grid infrastructure control plans with the challenging problems mentioned for the background and future targets. A good control system must be tested in international sample electric grids, and each part of the grid must be tested with international grid patents such as IEEE 33 Node, IEEE 34 Node and IEEE 300-Bus Network. Grid coordination under the mentioned standards provides a wide facility for development, such as grid behavior prediction, charging scheduling and risk management [101–105].

4.1.2. Control System Communications

One of the control systems duties is online observation, as the EVs are mobile devices, and they can be on the supply or demand side of the grid (charge/discharge). This provides some favorably strong aspects for people. EVs users can see online the existing charging centers and their status. In the online system, all variable parameters change in each condition. This gives facility to provide fine pricing and a managing system via control system communications such as WAN, HAN, NAN, SCADA, DSL, GSM, satellite and GPS [106]. In fact, they have a chain connection with other parts of the grid. They are illustrated in Figure 3. This also depends on the location and situation, for example using GSM, DSL and satellite as the connection method to connect some data centers with other parts of the grid, and all of them are available everywhere [107–110].

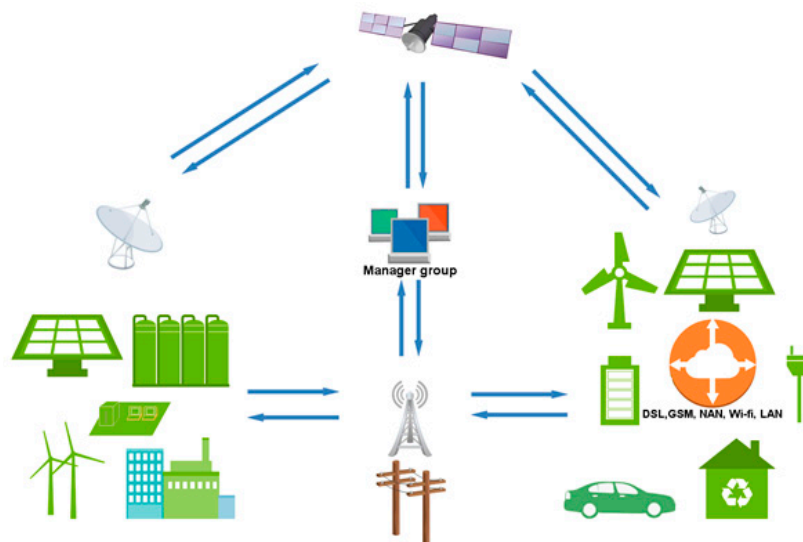


Figure 3. Communication system in the electric grid.

Data of the EVs are sent to the EVs' controller operator to control all EVs in each location. However, in some situations, the grid works in uncertain conditions, and uncertain conditions result in different behaviors of the grid. Some methods contribute to calculating the energy cost in uncertain conditions such as the ENTRUST (Energy trading under uncertainty in smart grid systems) algorithm [111], and some other algorithms estimate the active demand load on the grid; this means that the grid has high reliability and is ready for uncertain threats and conditions.

4.2. Grid Modelling

The infrastructure of the model of the grid is based on V2G technology. The mentioned topics are impelled toward the best efficiency and GHG emission targets. Thus, reforming some sections of grid is too hard and needs to be investigated deeply. Fossil power plants, renewable energies and V2G-G2V (subsets of renewable energies) are the inputs of grids. Today, the policy and planning of countries are to require grids to be supplied by renewable energy, and it is subsets to consume green and efficient energy. All energies injected to the grid should be managed, so all types of energies

have particularities. For example, convertors of the renewable energies such as DC to AC and reverse generated THD or energies on the storage system should be controlled on the supply/demand side. Electric distribution is the last node of grid electrification. In this section, the grid supplies all demand side of the grid, and the energy distribution condition depends on the location. Grid modelling with V2G technology is the same as the smart grid, so the grid in both systems works unidirectionally. The grid can supply both AC and DC electric energies [112]. Most of the electric devices work with the AC type of electric power. In this situation, energy providers have to provide the AC type of energy and the DC type of energy achieved by DC/AC convertors. The different types of energies are some of the causes of the energy loss. Today, having one of the DC lines from the source to the consumer is compulsory. In such a condition, the AC type of energy has the THD problem. The DC type of energy can respond to a wide range of customers of the grid. Different chargers, different convertors and different sources are examples of the energy type problems. AC and DC customers are also connected, and energy exchange will result in loss of energy and increased THD; however, the DC line has some critical advantages such as reducing energy loss, the response of the local renewable energy source and the other sources that work with the DC type of energy, which can work in a hybrid manner. For example, Egypt and India have tested DC lines in some projects [113–122].

4.2.1. Frequency Control

Electric power frequency is one of the most important parameters in the grid. The grid frequency is not controllable when supply and demand are not balanced; usually, the demand side of the grid overcomes the supply. In V2G technology, the charge and discharge influences the grid frequency, especially in the charge condition. EVs have batteries with a large capacity, and the quantity of EVs is high, which means overall energy exchange is homogenized; however, this is not true all the time. All of this has a negative effect on the grid frequency. Hence, the solution of the frequency issue is to control all parameters and equipment of the grid and demands such as the quantity of the EVs that are active or the EVs' energy capacity. Power systems must be controlled with special control nodes depending on the area, demand and sources [123–127].

4.2.2. System Integration

A smart and unidirectional power system must be an integrated system. Therefore, all its parts should be connected and work synchronously. The process of the integration needs to provide the capacity and limit some factors depending on the grid design. Each part of the materials mentioned in this paper plays a big role in the power system integration. Why is power system integration important? Because V2G technology disrupts the power system and V2G works correctly when the supply/demand condition is fine. For example, the status of the charging station, the battery status of the EVs and the grid supply/demand power are some aspects of V2G technology related to power system integration. Figure 4 gives these facts clearly [128]. The power system is integrated to provide low energy loss and high efficiency, so with this technology, the gap of the supply/demand is reduced and the power of the control system is increased; for example, home or office grid integration to generate energy by some local renewable energy sources [129–133].

The power system infrastructure should be designed according to some parameters such as accessibility, reliability and being able to be developed. Result of this action is that the grid can be updated with some technologies such as V2G and the subset technologies. The grid should support the energy traffic, which is achieved by newer technologies such as V2G or energy storage systems. The grid designers must care about communication between the grid and people. Therefore, in emergency situations, the grid management group may increase or decrease the supply/demand according to people. This is only a recommendation, which would work with the grid infrastructure.

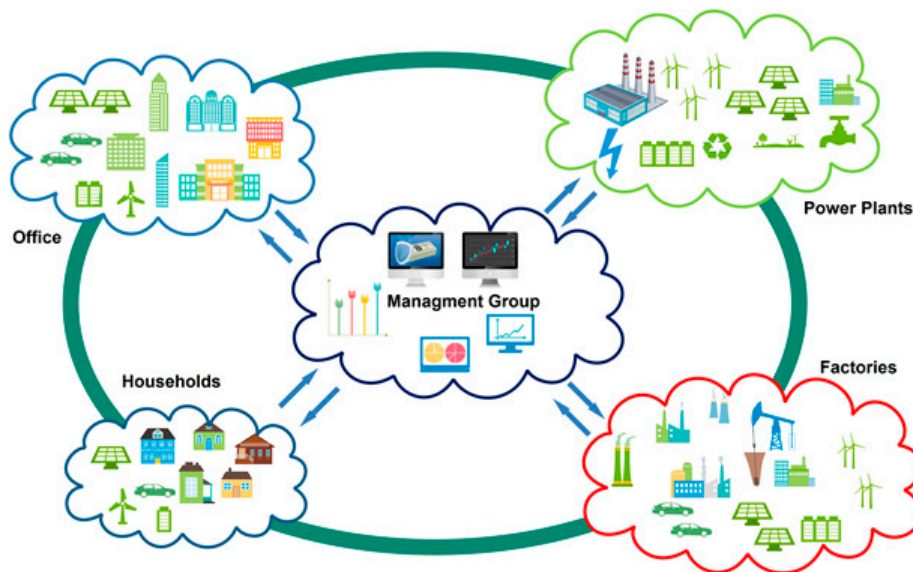


Figure 4. All grid energies connect to other sources and customers [128].

5. Conclusions

In the infrastructure of the world's electric grid, some revisions have been made. In addition, all energy scenarios after increasing GHG emissions in the world have changed according to some agreements and conferences such as UNFCCC 2015a in Paris. The infrastructure of each system should be changed when the enrolment scenarios change. The ratio of revisions depends on old infrastructure conditions and future targets, which are mentioned in context. Storage systems are some of the sensitive parts of the latest grid models such as micro and smart grids, but their development does not satisfy and respond to the grid requirements. Hence, batteries need to be further developed to comply better with the charge/life cycle and to provide more safety. At a glance, all mentioned problems force the infrastructure of the grid to work with poor quality. Today, after the development of the lithium type of batteries and power electronic systems, the researchers who are working on V2G technologies can easily take some actions so that the battery and power electronic systems will provide fast charging, on the supply and demand side of the grid. With those benefits, the grid could work properly, so the lack of energy and temporary storage are solved.

- ✓ The life/charge cycle, energy density and safety problems are solved with some polymer types of lithium batteries.
- ✓ The problems of the infrastructure of the grid can be detected quickly with a synchronized communication system.

The V2G technology has received great acceptance from people, but a greater market share is needed to develop this technology. The psychology of people is important, so people must have satisfaction with and a great viewpoint of EVs. Hence, officials have to achieve people's acceptance and create encouragement plans. For example, in some countries the tax of EV is zero and in some countries the benefits of V2G technology using Li batteries, mobile energy stations and ultra-capacitors are explained for people so that they use them more.

Author Contributions: All authors contributed for bringing the manuscript in its current state. Their contributions include detailed survey of the literatures and state of art, which were essential for the completion of this paper.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Nomenclature

GHG	Green House Gas
ICE	Internal Combustion Engine
EV	Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
HEV	Hybrid Electric Vehicle
V2G	Vehicle-to-Grid
G2V	Grid-to-Vehicle
GDR	Generalized Demand-side Resources
IEA	International Energy Agency
UNFCCC	United Nations Framework Convention on Climate Change
IEC	International Electro technical Commission
SAE	Society of Automotive Engineers
GTCO ₂	Giga Tonnes of Carbon dioxide
2DS	2 °C Scenario
6DS	6 °C Scenario
W h/L	Watt hour per liter
TWh	Terra Watt hours
KWh	Kilo Watt hour
EVI	Electric Vehicles Initiative
AC	Alternating Current
DC	Direct Current
CHP	Combined Heat and Power
CHAdemo	CHArge de Move
SOC	State of Charge
AM	Automotive Mode
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
IEEE:	Institute of Electrical and Electronics Engineers
WAN	Wide Area Network
HAN	Home Area Network
NAN	Neighborhood Area Network
SCADA	Supervisory Control and Data Acquisition
DSL	Digital Subscriber Line
GSM	Global System for Mobile Communications
GPS	Global Positioning System
THD	Total Harmonic Distortion
VPP	Virtual Power Plant
WPP	Wind Power Plant
LDV	Light-Duty Vehicle
Fe	Iron
Li	Lithium
Li-ion	Lithium-ion
NiCd	Nickel–Cadmium
NaS	Sodium–Sulfur
ZnBr	Zinc–Bromine
LiFePO ₄	Lithium Iron Phosphate Oxide
LiCoO ₄	Lithium Cobalt Oxide
LiMn ₂ O ₄	Lithium ion Manganese Oxide
NMC	LiNiMnCoO ₂
DOD	Depth of Charge
SM	Storage Mode
CNG	Compressed Natural Gas

HAN	Home Area Network
NAN	Neighborhood Area Network
SCADA	Supervisory Control and Data Acquisition
DSL	Digital Subscriber Line
GSM	Global System for Mobile Communications
GPS	Global Positioning System

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