

Integration of Electric Vehicles for Grid Support in Urban Environments: A Case Study of Amman

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To

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Cover Page

Project Title	Integration of Electric Vehicles for Grid Support in Urban Environments: A Case Study of Amman"
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1. Abstract-

The study is centered on creating a relationship between Electric Vehicles (EVs) and Vehicle-to-Grid (V2G) technology in Amman as a solution to the problem of grid stability and energy optimization. The research looks into controlled charging models and V2G scenarios while laying more emphasis on Smart Grid transition with regards to the possible merits that come with use of EVs as distributed energy resources. Through looking at how photovoltaic systems together with electric vehicles affect grids, the project brings out the significance of renewable incorporation as well as upgrading of power networks. A conclusion arrived at by the researcher(s) indicates that using EVs for supporting grids can improve their reliability thereby making them sustainable thus paving way towards smarter greener energy future within cities such as Amman.

2. Introduction

Background and context

The increase in GHG emission is an important global concern. High costs and substantial energy waste from voltage regulation, daily load demand fluctuations and frequency adjustments are the main reasons why operational efficiency of power grids is still unsatisfactory. In times where the amount of energy required surpasses that which can be supplied by base load power plants, peak load plants come into operation. Conversely, on days with minimal electricity needs, unwanted energy from base load generators ends up as waste. Also, Voltage/frequency control of this nature has high operating costs.

This issue can be solved through Vehicle to Grid (V2G) technology that uses electric vehicle's (EVs) extensive energy storage capacity as a buffer for both power grid and renewable sources of electricity. EVs can be attached to the smart grid either in V2G or G2V modes. The vehicle-to-grid involves flow of energy from EV to grid while grid-to-vehicle mode involves movement of electric charges from the grid to the EVs.

Smart grids and V2G systems are interconnected and have a symbiotic relationship between them. An important function is played by AC to DC (and vice versa) conversions during energy exchange processes. Energy storage systems in electric vehicles become very useful when exchanging electrical power with a grid system. as an example, when grid demand goes down sharply, the cars can take on extra energy overloads which in turn help to reduce power plant strains.

It is during low periods of network load demand that electric vehicles can be used as storage for excess electricity to avoid wastage. When prices drop, purchasers of EVs may prefer to import power from the distribution companies only to sell them back during peak periods at high costs, thus providing a chance for gains .

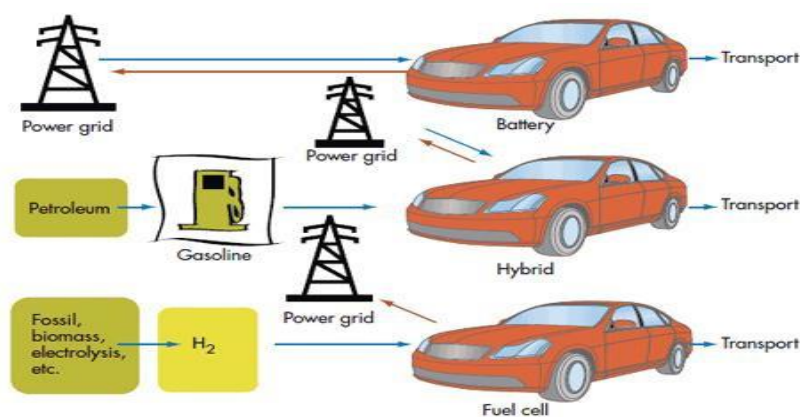


Fig. 1: The schematic diagram of V2G (Harighi et al., 2018).

2. Problem statement/research problem-

The research aims to investigate the technical, economic, and environmental challenges associated with the integration of EVs into the grid in urban settings, focusing on Amman as a case study. It seeks to address the need for innovative solutions to optimize grid performance, reduce carbon emissions, and enhance energy efficiency.

3. Research significant-

The study is significant as it explores the potential benefits of leveraging EVs for grid support, demand-side management, and sustainability in urban areas. By analyzing the implications of EV integration on grid stability and energy management, the research aims to contribute to the transition towards a more resilient and efficient energy ecosystem.

4. Research questions.

1. What is the impact of EV integration on grid reliability and energy distribution in urban environments like Amman?
2. How can controlled charging strategies optimize grid performance and support renewable energy integration in urban grids?
3. What are the technical and economic implications of implementing Vehicle-to-Grid (V2G) technology for grid support and energy trading?
4. How can the transformation of the traditional grid into a Smart Grid model enhance grid flexibility and sustainability in urban settings?

5. Research aims, research objectives-

- To assess the influence of EV integration on grid stability, peak demand management, and energy distribution in urban environments.
- To evaluate the effectiveness of controlled charging strategies in balancing grid loads, reducing energy costs, and promoting grid reliability.
- To analyze the feasibility and benefits of V2G technology for grid support, energy trading, and peak shaving in urban grids.
- To propose strategies for transitioning the traditional grid infrastructure into a Smart Grid model to enhance energy efficiency, grid resilience, and sustainability.

6. Research hypotheses & Research Mode-

H1: The integration of EVs will lead to significant improvements in grid reliability and energy management in urban environments.

H2: Controlled charging strategies will enhance grid efficiency, reduce peak demand, and optimize energy distribution in urban grids.

H3: V2G technology implementation will provide grid operators with enhanced flexibility, demand response capabilities, and revenue opportunities.

H4: Transforming the traditional grid into a Smart Grid model will result in improved grid management, sustainability, and customer engagement in urban settings.

7. Empirical research /Scope of the study-الدراسة الميدانية

Collaborate with local utility companies, EV manufacturers, regulatory authorities, and academic institutions in Amman to conduct empirical studies, field trials, and data collection for the research project.

8. Methodology- Research

Opening section

The research methodology will commence with an introductory section outlining the overall approach and rationale for the study. This section will provide a brief overview of the research design, sampling strategy, data collection methods, and statistical analysis techniques to be employed in the investigation

Research Design تصميم البحث

The research design will be structured around a mixed-method approach, incorporating both quantitative and qualitative elements to comprehensively address the research questions and objectives. The study will utilize a combination of simulation modeling, stakeholder interviews, field surveys, and scenario analysis to capture diverse perspectives on the integration of Electric Vehicles for grid support in urban environments.

Sampling

The sampling strategy will involve selecting a representative sample of stakeholders, including utility companies, EV manufacturers, regulatory authorities, and academic institutions in Amman. The sample will be chosen based on their relevance to the research objectives and their potential contribution to the empirical study. A purposive sampling technique will be employed to ensure the inclusion of key informants with valuable insights into the topic.

Data collection

Data collection will be conducted through various methods, including surveys, interviews, and document analysis. Surveys will be distributed to EV users, grid operators, and other relevant stakeholders to gather information on EV adoption rates, grid infrastructure, energy demand patterns, and perceptions of V2G technology. Interviews will be conducted with industry experts and decision-makers to gain in-depth insights into the challenges and opportunities associated with integrating EVs into urban grids.

Statistical Analysis Techniques

Statistical analysis techniques will be applied to analyze the collected data and derive meaningful insights from the research findings. Descriptive statistics, regression analysis, and hypothesis testing will be used to examine the relationships between variables, assess the impact of EV integration on grid performance, and evaluate the effectiveness of V2G technology in supporting grid operations. The statistical analysis will be complemented by qualitative data analysis methods to provide a comprehensive understanding of the research outcomes.

9. Project Structural Overview

Abstract:

Summary of the project objectives, methodology, key findings, and implications.
Table of Contents:

Introduction:

Background and context of the research
Research problem statement.
Objectives of the study
Significance of the research

Literature Review:

Overview of existing literature on Electric Vehicles, Vehicle-to-Grid (V2G) technology, and grid integration
Discussion of key concepts, theories, and previous studies relevant to the research topic
Research

Methodology:**Case Study:**

Description of the selected neighborhood in Amman
Overview of the MV-LV transformer and grid infrastructure
Data collection methods and sources

Results and discussions :

Presentation of empirical findings
Analysis of data related to EV adoption, PV integration, and grid impact
Discussion of controlled charging and V2G scenarios

Conclusion:

Summary of key findings
Contributions to the field
Recommendations for future research
additional data tables

10. Project timelines

Activity	February	March	April	May	June	July	August	September
Collection of Literature								
Study of Literature								
Model Setup								
Controlled charging Model								
Vehicle to grid Model								
Vehicle to grid scenarios								
Transforming the traditional grid into a SG								
Analysis and results								
Final Write-up Submission								

11. Chapter of Literature Review

11.1 Electrical Vehicle Technology

Electric vehicles (EVs) have lately experienced enormous technological advancements that make them strong rivals for traditional internal combustion engine vehicles (ICEVs). EV adoption is being encouraged by nations globally as a measure of reducing greenhouse gas emissions. For instance, Electric Vehicle Market in Jordan is expected to grow at a CAGR of 34.0% from 2019 to 2025. In Jordan, government initiatives like installing 3,000 charging stations and fiscal reliefs are stimulating the demand for electrical cars.

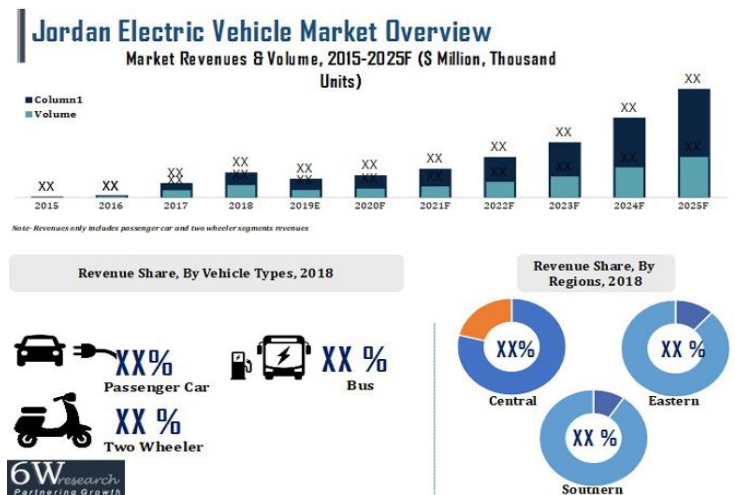


Fig. 2: Jordan Electric Vehicle Market Overview (Harighi et al., 2018)

The expansion of the electric vehicle (EV) market necessitates continuing research and development for wide EV adoption in days to come (Sarlioglu et al., 2017). Different types of EVs are available including hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), plug-in electric vehicles (PEVs), and battery electric vehicles (BEVs). This study concentrates on BEVs, which run exclusively on battery power. The larger capacity batteries allow for greater range besides enabling compatibility with grid integration to use them as vehicle-to-grid (V2G) systems. Powertrain, energy storage systems (ESS) and charging infrastructure will be some key areas of EV development that will support future V2G scenarios (Yong et al., 2015).

11.1.1 Power Train

In an automotive system, the power train transfers drive from the engine to the axle. A Battery Electric Vehicle (BEV) operates simply using a battery as its source of power, where it is used for locomotion by an electric motor. The BEV power train consists of three main components namely: a battery; an electric motor; and a transmission. Figure 3 shows a basic power train diagram for a BEV (Sarlioglu et al., 2017).

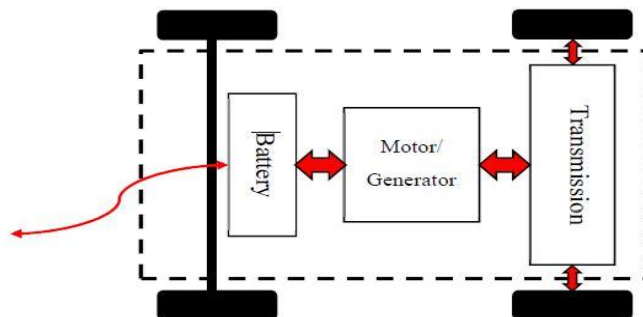


Fig. 3: Schematic diagram of BEV power train (Sarlioglu et al., 2017).

BEVs can be charged from external sources such as the electrical grid or regenerative braking (Ergon Energy, 2017). The focus in this study is limited provisionally to external charging techniques only but eliminates any reference to recharging batteries through

regenerating braking in model construction.

11.1.2 Energy Storage System

As a car battery, the energy storage system (ESS), is an important part of Battery Electric Vehicles (BEVs). At present, batteries are one of the costliest components in BEV technology. However, there are limitations to battery technology that have hindered widespread EV adoption in the transport sector. Battery technologies are the best suited to attracting global attention towards electric vehicles in relation to matters concerning range, acceleration, and costs (Yong et al., 2015).

Ongoing research and experimentation has resulted in two main types of batteries for EVs – Nickel-Metal Hydride (NiMH) and Lithium-ion (Li-ion). Earlier on NiMH batteries were used but this changed with the advent of Li-ion batteries which revolutionized EV technology enabling long distance models as well as more powerful ones that can compete with traditional internal combustion engine vehicles (ICEVs) (Yong et al., 2015).

In today's market, major EV manufacturers predominantly utilize Li-ion batteries due to their the main Li-ion batteries user by leading manufacturers of electric cars today include having longer ranges, higher energy densities, affordability and being nontoxic among other advantages. Moreover, Li-ion also enables fast charging hence removing any concerns about lengthy charge times (Yong et al., 2015). Such major brands as Nissan Leaf, Mitsubishi i-MiEV, Tesla Model S and Chevrolet Bolt all feature Li-ion-battery-based ESS. Table I provides a comparison of NiMH and Li-ion cell types used in BEVs.

TABLE I
COMPARISON OF NiMH AND Li-ION CELL TYPES IN EVs (SARLIOGLU ET AL., 2017).

	NiMH BEV	Li-ion Plug-in Hybrid EVs - BEVs
Nominal cell voltage [V]	1.2	3.3-3.8
Energy density [Wh/l]	250	200-400
Specific Energy [Wh/kg]	100	120-200
Power density [W/l]	500-800	800-2200
Specific power [W/kg]	200-400	500-1200

There are some disadvantages associated with Li-ion batteries, such as the potential for fire or explosion if they malfunction (Battery University, 2022). Although this technology is still developing, it looks set to be an ideal battery solution for future Evs (Yong et al., 2015).

11.1.3 Charging infrastructure

Rectifiers are commonly included in electric vehicle (EV) chargers, i.e., AC-DC converters. Furthermore, DC-DC converter is also available in fast charging stations for

better power conversion efficiency. The chargers can either be on-board or off-board depending on their configuration and the capacity of the charging (Yong et al., 2015)

The design of onboard chargers must be compact and lightweight to enable effective movement of an EV. However, one problem that they have is that they are low powered making them ideal only for slow charging purposes. In contrast, off-board chargers usually occupy specific locations thus being larger due to the presence of charger units incorporated with a rapid charger DC-DC converter (Yong et al., 2015).

Further still, there are global guidelines governing electric vehicles' recharging process. International Electromechanical Commission (IEC), Society of Automotive Engineers (SAE), CHAdeMO EV standards among others are some of the bodies that influence these regulations. This table II refers to SAE charging levels as per SAE electric vehicle conductive charge coupler standard (Insideevs,2017).

TABLE II
SAE CHARGING STANDARDS (INSIDEEVS,2017).

Charging level	Charge rating	Charge time	Remark
AC level 1	120 V, 1.4 kW (12 A) 120 V, 1.9 kW (16 A)	PHEV: 7 h (SOC-0% to full) BEV: 17 h (SOC-20% to full)	On-board charger
AC level 2	240 V, up to 19.2 kW (80 A)	For 3.3 kW charger: PHEV: 3 h (SOC-0% to full) BEV: 7 h (SOC-20% to full) For 7 kW charger: PHEV: 1.5 h (SOC-0% to full) BEV: 3.5 h (SOC-20% to full) For 20 kW charger: PHEV: 22 min (SOC-0% to full) BEV: 1.2 h (SOC-20% to full)	On-board charger
AC level 3	> 20 kW, single phase and three-phase	To be determined	To be determined
DC level 1	200-450 V _{DC} , up to 36 kW (80 A)	For 20 kW charger: PHEV: 22 min (SOC-0% to 80%) BEV: 1.2 h (SOC-20% to full)	Off-board charger
DC level 2	200-450 V _{DC} , up to 90 kW (200 A)	For 45 kW charger: PHEV: 10 min (SOC-0 to 80%) BEV: 20 min (SOC-20 to 80%)	Off-board charger
DC level 3	200-600 V _{DC} , up to 240 kW (400 A)	For 45 kW charger: BEV (only): <10 min (SOC-0 to 80%)	Off-board charger

Table II and Figure 4 show that DC fast charging systems can allow electric vehicle (EV) users to charge their vehicles in less than an hour, with some systems taking as low as 10 minutes to charge. Presently, DC fast charging systems are available in two power flow configurations: from the grid to the EVs and vice versa Wang et al. (2012).

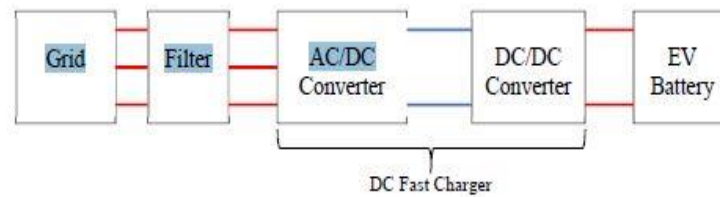


Fig. 4: Block diagram of DC fast charging station Wang et al. (2012).

The first kind is unidirectional DC fast charger which permits drawing power from the grid for recharging EV batteries. Its benefit is that it does not severely affect battery life span due to lesser recharging cycles (Channegowda et al., 2015). However, this kind of chargers can't be involved into V2G system when power from car flows back into the grid. In contrast, bi-directional DC quick chargers work both ways by being able to both charge and discharge energy. Nonetheless, battery life is affected by bidirectional arrangement because more cycles are required (Channegowda et al., 2015)

11.2 Smart Grid

A smart grid is a comprehensive energy system that enables integration, two-way communication, and optimal control over formerly fragmented components of the electricity infrastructure for producers and consumers alike. By enabling information exchange and analysis, smart grids enhance the efficiency of electricity utilization (International Energy Agency, International Low-Carbon Energy Technology Platform, 2015).

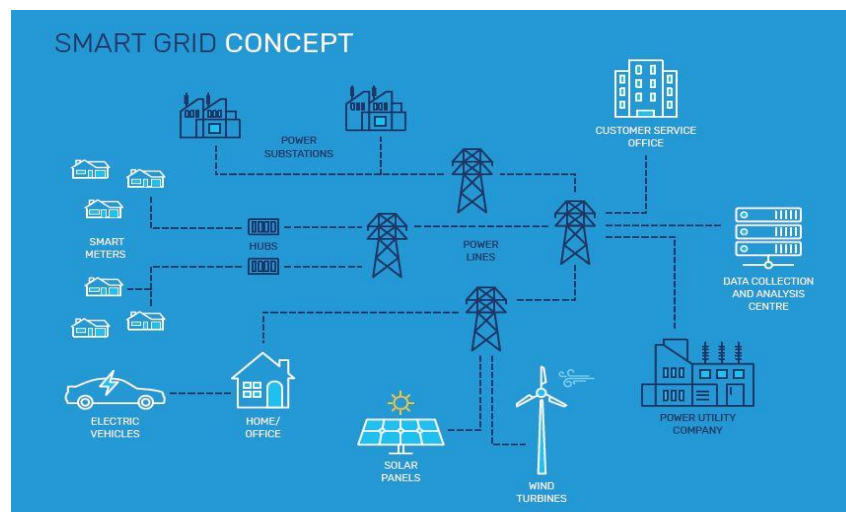


Fig. 5: Schematic diagram of smart grid (International Energy Agency, International Low-Carbon Energy Technology Platform, 2015).

Efficient electricity use and management are essential responses to increasing environmental protection requirements, including the imperative to reduce CO₂ emissions and reliance on primary energy resources. According to the SMARTer2030 report by The Global e-Sustainability Initiative, smart grid technology has the potential to reduce CO₂ emissions in the power sector by up to 15% by 2030 and generate an additional USD 0.8

trillion in income compared to 2015 (The Global e-Sustainability Initiative, 2015) .

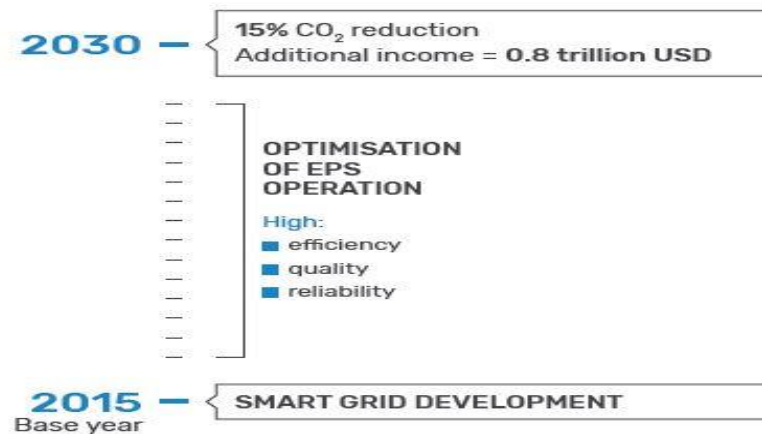


Fig. 7 Schematic diagram of smart grid development (The Global e-Sustainability Initiative, 2015).

11.3 State of the art V2G

11.3.1 Methods of Power flow for V2G

The integration of EVs with smart grids has undergone extensive development. However, only one-way power flow is considered; that is from the electric grid to the EV battery pack. This was because realization of unidirectional power flow did not require much development cost because of the presence of regular EV chargers modified with communication (Sortomme & El-Sharkawi, 2012). The idea was to use load shifting control for load management. In this case, electric vehicles were charged during off-peak hours. The more services we need from EV batteries, the more advanced devices are needed such as bidirectional chargers.

However, recently people started talking about bidirectional power flow between EV batteries and electric grid. This concept is known as vehicle-to-grid (V2G) technology. Electric cars can transfer electricity to/from the electric grid using this approach. The vehicle charges during times when consumer demand is low and discharges into the system when required urgently or in high demand periods. Additionally, more opportunities came up with bidirectional V2G which prompted industry and utilities companies to advocate V2G concept on a whole new level (Channegowda et al., 2015). A schematic framework for V2G technology is shown in Figure 8. Different types of V2G depend on how they are used. For example, there are vehicle-to-home (V2H), vehicle to-vehicle (V2V), vehicle-to-building (V2B) and vehicle-to-grid (V2G). All these types utilize EV battery power to support power network. Table III shows the comparisons between V2G and V2H (Shariff et al., 2019).

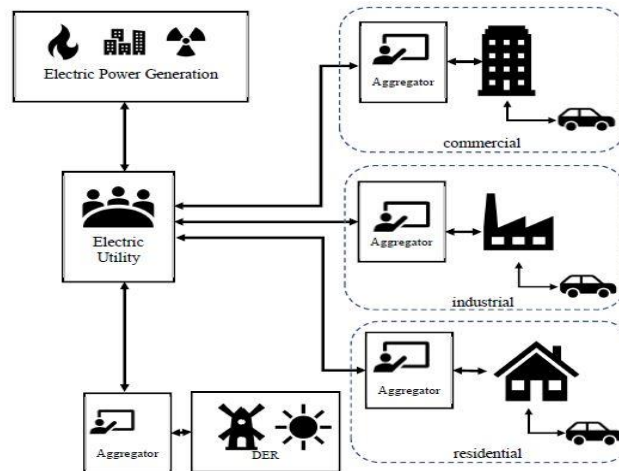


Fig. 8 Schematic framework of V2G (Shariff et al., 2019).

TABLE III
COMPARISON BETWEEN V2G, V2H (SHARIFF ET AL., 2019).

	KEY POINTS	FACTORS	FUNCTIONS
V2G	• A number of GEVs • Less simplicity and more flexibility • Complex Control • Operation at a large scale • Significant transmission losses	• Control and Coordination from the grid operator • Number of aggregators • Battery capacity • Arrival and Departure time • Cost of Electricity • Driving habits of the user	• Reactive power support • Operating with Renewable Sources • Release stored energy back to the grid at peak demands • Grid Ancillary Services

V2H	• Simple Infrastructure • with negligible transmission losses • Easy installment • More simplicity • A single GEV to a single home	• Type of Battery used • Characteristics of Battery Capacity • Charging State • Driving habits of the user • Cost of Electricity	• Acts as a home back-up generator with a controllable load • Sell stored energy back to the grid at peak demand • Cost of Electricity is less at an off-peak time • Used for load shift by cooperating domestic electrical appliances
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11.3.2 Management of V2G system

The V2G system is a combination of Optimal Energy Management, Intelligent Energy Resource Management and Battery Management System (Wang & Liang, 2017) (Sousa et al., 2012) (Sousa et al., 2012). EVs have different charging plans (Yilmaz & Krein, 2013) (Mwasilu et al., 2014). In terms of the grid point in the V2G system, EVs' charging should be properly arranged to avoid conventional peak-load periods, hence reducing the impact on power grid. V2G is a new technology and therefore, the research on V2G is at its infancy. Research on V2G is concerned with structure, feasibility analysis and working of each component. Power grid shaving may be done by EVs. Among these are mobile mode and parking mode which are some of the charging schemes for EVs. The strategies for control energy management, as well as algorithms for supervisory control that were used in EVs according to S.Tie-C.Tan (Tie & Tan, 2013).

11.3.2.1 Centralized V2G management

Centralized V2G is a system where energy from electric vehicles is collected in defined areas depending on grid demand to manage charging/discharging strategies in these specific locations (Sekyung et al., 2010). Grids work with charging stations to adjust peak-load for EV charging. Different types of EVs have control strategies provided by F.Salmasi (Salmasi, 2007).

11.3.2.2 Independent V2G management

Centralization cannot manage a mess of EVs scattered everywhere. V2G technology

has imbibed smart chargers that are responsible for their costs, reactive power demand and electrical attributes like voltage variations. In their article “Smart charging strategies for plug-in electric vehicles,” A.Farghali,-A. Zaki, et al. (Farghali et al., 2016) describes the structure of G2V and V2G charging proposed in the developed world. Power load characteristics differ from one region to another as well as the number of EVs available in each region. Therefore, it is not advisable to organize all scattered EVs under one scheduling system. Based on the hierarchy control, there are three levels within controlling structure of EVs and the grid: scheduling of distribution system, scheduling of transmission system and EV control center itself. The authors D. Liu - Q. Zhong et al. (Liu et al., 2018) presented a concept about modeling and control of a V2G charging station of EVs utilizing synchro converter technology. A technique was proposed by A.Affanni,A.Bellini et al. (Affanni et al., 2005) on manufacturing process for controllable EV charger Each location where this charger is used represents a domestic area, hence its design purposefulness.

11.4 V2G services and advantages

The advantages of V2G technology for Plug-in Hybrid EVs are presented by M. El Chehaly-O. Saadeh et al. (El Chehaly et al., 2009). In various countries in the world, there are several advantages that can be realized by using V2G technology. There are several benefits to EV owners, charging station and grid and utilities. Some of them include the following.

11.4.1 Ancillary Services

According to Y. Tu- C. L et al. (Tu et al., 2011), ancillary services are provided for. The spinning reserve and the power grid regulation make up two categories of ancillary services. Unidirectional V2G controls the EVs charging rate and thus provides the load only “ancillary services”. In obtaining these ancillary services, a large fleet of EVs is communicated with by the aggregator to achieve the same objective. Power grid regulation maintains frequency for satisfying generation and load demand while spinning reserve has fast response duration for compensating outage in generation which last within 10 minutes.

11.4.2 Active Power Support

The V2G system is where the Grid uses the extra energy of electric vehicles. These are only made possible by a two-way V2G. This service intends to smooth out grid load profile through “peak load shaving” and “load leveling”. Usually, for a small time in a day there is demand. It will be cheaper during peak load to take supply from EVs. This technique can help in minimizing the pressure on power system elements easily. Another advantage is that owners of EV would receive premium prices for electricity. Housing Peak Shaving Algorithm (HPSA) used in houses that have a Plug-in Hybrid EVs was made by H. Turker-A., Hably et al. (Turker et al., 2013).

11.4.3 Backup energy for home

L. Yao- Z. Damiran et al. (Yao et al., 2017) ,F.Fazelpour- M.Vafaeipour et al. (Fazelpour et al., 2014) propose solving the problem of RES with storage through EV fleets. Solar and wind, which are types of renewable energy sources (RES), serve as back-ups or alternatives for V2G systems. Centralized power plants should lower their production if RES generates overcapacity.

11.4.4 Reactive power compensation

C. Silvestre- D.Sousa et al. (Silvestre et al., 2012) discusses the reactive power compensation as a key feature in-built to the V2G technology. Voltage regulation is very essential for the proper functioning of the V2G system. Reactive power compensation provides voltage regulation in the grid. With the help of reactive power, there is an improvement in the power factor. Usually, reactive power compensator draws reactive power to the system. But, in most of the cases, a capacitive reactive power is preferred.

11.5 Challenges behind V2G Technologies

For the implementation of infrastructure for EVs, the current scenario, latest development and challenges should be taken into consideration in relation to charging codes and international standards. However, it has several challenges despite its advantages and services to power grid. V2G does not yet exist in full. Also, there are many hurdles that we have encountered in adopting this technology like economic social technical challenges. The V2G system has a huge effect on the distribution grid (Ready & Grid, 2009).

11.5.1 Degradation of the battery

Battery degradation is a major barrier to EV adoption. The battery system consumes 1/3rd of all EVs costs. A complete electric scooter prototype is presented by A.Affanni- A.Bellini et al. (Affanni et al., 2005) based on battery design . Li-on technology makes up this battery. This electric scooter is efficient. Every battery has specific number of cycles of charging and discharging; after that the efficiency starts reducing with a passage of time while irreversible chemical reaction will decrease its capacity as well as aging effect depend upon DOD, Temperature, Voltage etc., whose values are considered here as independent variables. V2G technology requires a battery with the highest number of charges and discharges. A. Millner (Millner, 2010) has developed a model for the Lithium Ion used in EVs. Table IV is all about charging information for Nissan Leaf and Tesla Models (Lehtola & Zahedi, 2016).

TABLE IV
BATTERY CHARGING TIMES FOR NISSAN LEAF AND TESLA MODELS (LEHTOLA & ZAHEDI, 2016)

Specification	Nissan Leaf	Tesla Model
Battery Capacity (kWh)	24	85
Range (km)	121	426
Slow Charger (kW)	1.8	10
Charge Time (hours)	21	9
Normal Charger (kW)	3.3	20
Charge Time (hours)	7	4.5
Quick Charger (kW)	50	120
Charge Time (1 hours)	0.5	1.25

11.5.2 Investment Cost

The Another major challenge that hinders V2G implementation is its huge investment cost. As per this, the power system for V2G needs to be upgraded accordingly. For

efficient V2G implementation, hardware and software infrastructure must be improved significantly or else it will be ineffective. Has one more need for each of participating EVs within the V2G system; bidirectional battery charger should be able to make both operations happen; charging and discharging as well (Kempener et al., 2006). The complex control unit as well as high voltage cable which is bidirectional battery charger consists of these components among others. High-voltage cables require safety measures since they are often needed during charge exchange processes resulting in losses in the energy conversion cycle (Lehtola & Zahedi, 2016).

11. Conclusion

To sum up, the Amman project concerning the combination of Electric Vehicles (EVs) and Vehicle-to-Grid (V2G) technology conveys how beneficial it would be to use electric vehicles as resources for grids. The research probes into various V2G scenarios as well as a smart grid transition thereby showing how important they are in improving sustainability and flexibility of energy supply systems. What these discoveries do is underline why we should control charging activities, integrate renewable sources of power into them together with storage facilities that optimize operations within electricity distribution networks. Therefore, one can say that from now on if we utilize EVs in supporting our grids this will lead us into having an energy efficient city such as Amman which is also environmentally friendly.

References & Appendices

6Wresearch. (2019). Jordan Electric Vehicle Market (2019-2025). Retrieved from <https://www.6wresearch.com/industry-report/jordan-electric-vehicle-market-2019-2025-ev-forecast-by-vehicle-types>

Affanni, A., Bellini, A., Franceschini, G., Guglielmi, P., & Tassoni, C. (2005). Battery choice and management for new-generation electric vehicles. *IEEE Trans. Ind. Electron.*, 52(5), 1343–1349.

Battery University. (2017). Safety Concerns with Li-ion Batteries. Retrieved from http://batteryuniversity.com/learn/article/safety_concerns_with_li_ion

Channegowda, J., Pathipati, V., & Williamson, S. (2015). Comprehensive review and comparison of DC fast charging converter topologies: Improving electric vehicle plug-to-wheels efficiency. In 2015 IEEE 24th International Symposium on Industrial Electronics (ISIE).

El Chehaly, M., Saadeh, O., Martinez, C., & Joos, G. (2009). Advantages and applications of vehicle to grid mode of operation in plug-in hybrid electric vehicles. In 2009 IEEE Electrical Power Energy Conf. EPEC 2009.

Ergon Energy. (2017). Types of Electric Cars. Retrieved from <https://www.ergon.com.au/network/smarterenergy/electric-vehicles/types-of-electric-vehicles>

Farghali, A. A., Zaki, A. H., & Khedr, M. H. (2016). Smart Charging Strategies for Optimal Integration of Plug-In Electric Vehicles Within Existing Distribution System

infrastructure. *Nanomater. Nanotechnol.*, 6(1), 12.

Fazelpour, F., Vafaeipour, M., Rahbari, O., & Rosen, M. A. (2014). Intelligent optimization to integrate a plug-in hybrid electric vehicle smart parking lot with renewable energy resources and enhance grid characteristics. *Energy Convers. Manag.*, 77, 250–261.

Foley, A., Winning, I., & O Gallachoir, B. (2010). State-of-the-art in electric vehicle charging infrastructure. In 2010 IEEE Vehicle Power and Propulsion Conference.

Habib, S., Khan, M. M., Abbas, F., Sang, L., Shahid, M. U., & Tang, H. (2018). A Comprehensive Study of Implemented International Standards, Technical Challenges, Impacts and Prospects for Electric Vehicles. *IEEE Access*, 6, 13866–13890.

Harighi, O., Bayindir, R., Padmanaban, S., Mihet-Popa, L., & Hossain, E. (2018). An Overview of Energy Scenarios, Storage Systems and the Infrastructure for Vehicle-to-Grid Technology. *Energies*, 2(8).

Inside EVs. (2022). Welcome to 2009, SAE Officially Approves New Fast-Charging Combo: Coupler Standard (SAE J1772) for Plug-In EVs. Retrieved from <http://insideevs.com/welcome-to-2009-saereleases-new-fast-charging-combo-coupler-standard-sae-j1772-for-plug-in-evs/>

International Energy Agency, International Low-Carbon Energy Technology Platform. (2015). How to guide for smart grids in distribution networks: Roadmap development and implementation. Paris.

Lehtola, T., & Zahedi, A. (2016). Electric vehicle to grid for power regulation: A review. In 2016 IEEE Int. Conf. Power Syst. Technol. POWERCON 2016

Liu, D., Zhong, Q., Wang, Y., & Liu, G. (2018). Modeling and control of a V2G charging station based on synchronverter technology. *CSEE J. Power Energy Syst.*, 4(3), 326–338.

Millner, A. (2010). Modeling lithium ion battery degradation in electric vehicles. In 2010 IEEE Conf. Innov. Technol. an Effic. Reliab. Electr. Supply, CITRES 2010.

Mwasilu, F., Justo, J. J., Kim, E. K., Do, T. D., & Jung, J. W. (2014). Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. *Renew. Sustain. Energy Rev.*, 34, 501–516.

Rahimi-Eichi, H., Ojha, U., Baronti, F., & Chow, M. Y. (2013). Battery management system: An overview of its application in the smart grid and electric vehicles. *IEEE Industrial Electronics Magazine*, 7(2), 4–16.

Ready, A. W., & Grid, S. (2009). Grid of the Future. *IEEE Power Energy Mag.*

Salmasi, F. R. (2007). Control strategies for hybrid electric vehicles: Evolution, classification, comparison, and future trends. *IEEE Trans. Veh. Technol.*, 56(5 I), 2393–2404.

Sarlioglu, B., Morris, C., Han, D., & Li, S. (2017). Driving Toward Accessibility: A Review of Technological Improvements for Electric Machines, Power Electronics, and Batteries for Electric and Hybrid Vehicles. *IEEE Industry Applications Magazine*, 23(1), 14–25.

Sekyung, H., Soohye, H., & Sezaki, K. (2010). Development of an Optimal Vehicle-to-Grid Aggregator for Frequency Regulation. *IEEE Trans. Smart Grid*, 1(1), 65–72.

Shariff, S., Iqbal, D., Alam, M., & Ahmad, F. (2019). A State of the Art Review of Electric Vehicle to Grid (V2G) technology. *IOP Conference Series: Materials Science and Engineering*, 561.

Silvestre, C., Sousa, D. M., & Roque, A. (2012). Reactive power compensation using onboard stored energy in Electric Vehicles. In *IECON Proc. (Industrial Electron. Conf.)*.

- Sortomme, E., & El-Sharkawi, M. (2012). Optimal Combined Bidding of Vehicle-to-Grid Ancillary Services. *IEEE Transactions on Smart Grid*, 3(1), 70-79.
- Sousa, T., Morais, H., Vale, Z., Faria, P., & Soares, J. (2012). Intelligent energy resource management considering vehicle-to-grid: A simulated annealing approach. *IEEE Transactions on Smart Grid*, 3(1), 535–542.
- The Global e-Sustainability Initiative. (2015). SMARTer2030. Brussels.
- Tie, S. F., & Tan, C. W. (2013). A review of energy sources and energy management system in electric vehicles. *Renew. Sustain. Energy Rev.*, 20, 82–102.
- Tu, Y., Li, C., Cheng, L., & Le, L. (2011). Research on vehicle-to-grid technology. In *Proc. - Int. Conf. Comput. Distrib. Control Intell. Environ. Monit. CDCIEM 2011*.
- Turker, H., Hably, A., & Bacha, S. (2013). Housing peak shaving algorithm (HPSA) with plug-in hybrid electric vehicles (PHEVs): Vehicle-to-Home (V2H) and Vehicle-to-Grid (V2G) concepts. In *Int. Conf. Power Eng. Energy Electr. Drives*.
- Wang, S., Crosier, R., & Chu, Y. (2012). Investigating the power architectures and circuit topologies for megawatt superfast electric vehicle charging stations with enhanced grid support functionality. In *2012 IEEE International Electric Vehicle Conference*.
- Wang, X., & Liang, Q. (2017). Energy management strategy for plug-in hybrid electric vehicles via bidirectional vehicle-to-grid. *IEEE Systems Journal*, 11(3), 1789–1798.
- Yao, L., Damiran, Z., & Lim, W. H. (2017). Optimal charging and discharging scheduling for electric vehicles in a parking station with photovoltaic system and energy storage system. *Energies*, 10(4).
- Yilmaz, M., & Krein, P. T. (2013). Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles, 28(5), 2151–2169.
- Yong, J., Ramachandaramurthy, V., Tan, K., & Mithulananthan, N. (2015). A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects. *Renewable and Sustainable Energy Reviews*, 49, 365-385.
- Zhou, Y., & Li, X. (2015). Vehicle to Grid Technology: A Review. In *IEEE 2015 34th Chinese Control Conference*.