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V2G FACTS AND FACETS WITH MODELING OF ELECTRIC VEHICLE FAST-CHARGING STATION-STATUS AND TECHNOLOGICAL REVIEW

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ABSTRACT: Electric vehicles(EV) are directed as a bequest to the intelligent grid to elevate efficient functions environmentally and economically in different working scenarios. It considerably sustains the resiliency of the local grid during disturbing events. The interaction of electric vehicles to an intelligent grid by accomplishing a synergistic affiliation to disseminate power is vibrant for refining on its way. The aptitude of EVs fleets to turn as one unit for surplus energy storage allows for the mass integration of renewable sources into a conventional grid structure. In this study, a vehicle equipped with V2G functionality offers numerous features such as support for actual and reactive power, load leveling, filtration of current harmonics, etc. Nevertheless, the concept of V2G additionally arises noticeable issues, like depletion of batteries, communiqué bottleneck between grid and vehicle, a modification for the design of a distribution network. In this review, the feasibility of an intelligent V2G system along with its impacts and limitations is thoroughly discussed with the modeling of hybrid generating sources to charge/discharge of EVs by the efficient energy management system.

Keywords: Microgrid, medium voltage direct current, renewable energy sources, power converter.

INTRODUCTION

Due to continuous climatic change and growing concerns of greenhouse gases, there is dire need to establish a standard for a fast-charging station to combat the diminishing fossil fuel resources. For this grid stability, charging time and battery chemistry are the areas that have to dig in this regard. In addition, the photovoltaic panels, in respect of fuel, natural which is absolutely maintenance free but at the expense, it covered a large surface area. Interacting with EVs fleet at various charging modes needs a comprehensive analysis of suitable management strategy. Therefore, EV Charging Station (EVCS) which basically relies on conventional controllers and each generation source works in a decentralized manner is understudied. The real advantage of this local control that there are no needs for communication linkage between the energy management system (EMS) and the generating source or among the sources and load. Moreover, it accommodates the modern means of the charging system and to supervise the power control by notice the voltage at the medium-voltage DC (MVDC). It has the ability to add new renewable sources with compliance with energy storage buffer or new EVs both as a source and load irrespective of EMS does not need to be altered.

The pioneer which firstly given the concept of V2G well said at the end of the nineteenth century (Kempton and Letendre, 1997) that over just a quarter of a century, V2G could reform the ancillary facilities to the energy stakeholders, enhance grid strength, sustainability and provide improved generation from RES. V2G also be integrated by means of two-directional DC-DC power chargers to a medium voltage dc bus where the proprietor can realize a balance between discharging and charging cycles. V2G technology dealt with numerous benefits which include regulation of real and var power, load leveling, mitigate current harmonics, reduce peak demand load, utility operating price and generate more revenues. These appealing features can empower ancillary services which include spinning reserve and regulation of voltage and frequency.

The V to G method also originates from some technical matters like depletion or over-charging of batteries, additional communication appliances like smart meter between EV and local grid, modification in the whole set-up of the distribution network and other problems.

In this review, the solar panel charging station connected with the grid is understudied to make efficient usage of the PV power and to extract excess power by maximum power point controller. This method permits the energy storage buffer's connection in view of the energy transmission price (ETP) and the battery SoC. A simple moving average (SMA) algorithm is used by the researchers in (Chanhom *et al.*, 2017) for a control method of V2G to increase the (f_L) load factor in the power network. In (Ma et al., 2016) authors overview the use of V2G with the origin of harmonic pollution, load fluctuation by the use of the dual-directional charger and discharging/charging means. In (Habib *et al.*, 2018) the detailed idea about the implementation of multi-mode power chargers are explored. The authors in his article prove that the single way charging deals simple hardware requirement and lessen the interconnection concerns. Two-way charging runs the advanced feature of vehicle-to-grid in order to get more revenues.

The organization of the review is organized as; modeling of EV fast-charging station in section 2. Facts and facets of the vehicle to grid advancements with uni and bi-directional V2G technology are given in the third section. The fourth section describes the barriers and overheads in the deployment of V2G technology. Lastly, the fifth section concludes the paper with future directions.

MATERIALS AND METHODS

The studied systems are composed of 50 KW charger power units (CPU), photovoltaic panels, Lithium-ion batteries as an energy storage buffer, and an AC grid assembly. The elements are joined to medium voltage common dc bus (>500 V) via their required specification power converter devices. It ensures the charge requirement of the EVs with an uninterruptable power supply and adoptively gains voltages with respect to the DC bus link. Moreover, it also monitors and controls the power steadiness between the generating sources and the DC network. The grid side consists of a two-directional DC/AC power converter with a three-phase transformer. Agreeing to compliance of international standards SAE J1772, all the CPU are considered as DC level 2 and it habitats the fast charging mode with an off bound charger. Besides, the rated capability of the vehicle's battery is approximately 25 kWh. Table 1 shows the range of the parameters for the fast power charger.

Table-1. DC Fast charging defined by SAE J1772 standard.

	Voltage (V)	Current (Amp)	Power (KWs)
DC stage--1	200-450	80	36
DC stage--2	200-450	200	90
DC stage--3	200-600	400	240

Configuration of an energy management system with indicated solar cells, battery storage unit, utility grid, and electric vehicles as shown in Figure 1.

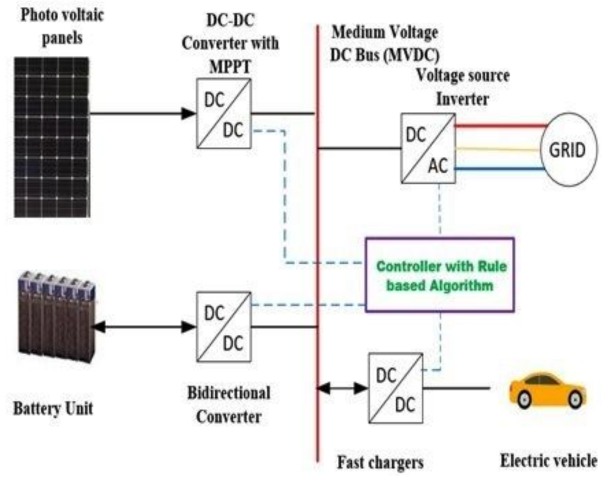

Figure-1. Model of Fast charging station (Arfeen *et al.*, 2019)

Modeling of PV Module: An equivalent circuit of a solar cell consist of a single diode model is selected for this configuration. It comprises a current source in parallel with a PN diode with shunt and series resistance as shown in Figure 2. The equations next for calculating the output current are;

$V_T = akT/q$ (1)

where V_T is the terminal voltage, q, electronic charge - 1.6018×10^{-19} Coulomb, a, the ideality factor - ($1 < a < 2$), k, Boltzmann constant - 1.3806×10^{-23} Joule/Kelvin.

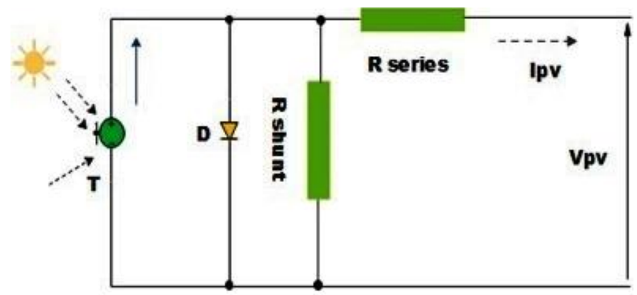

Figure-2. PV Module.

The PV parameter of power output is computed by using a single diode model. The current output of the solar panel depends on temperature (T) and solar irradiance intensity (G). The current output of PV, ie, I_{pv}, as given in next;

$$I_{pv} = I_{ph} + I_{sat}\left(e^{q\left(\frac{V+I_{pv}*R_S}{NKT_{PV}}\right)}\right) - \frac{V+I_{pv}*R_S}{R_{sh}} \quad (2)$$

$$I_{ph} = I_{pho}(1+k_0(T-300)) \quad (3)$$

$$I_{sat} = K_1 T^3 e^{\frac{-qV_g}{KT}} \quad (4)$$

I_{ph} solar induced current, I_{pho} solar induced current at 300oC, I_{sat} saturation current of the diode, V_g voltage applied to the terminals of diode, k_0, k_1 constants depend on the value of PV system, T_{PV} operating temperature, N diode quality factor, Rs, Rsh series and shunt resistances.

Modeling of AC Grid Voltage Source Converter (VSC): Voltage Source Inverters (VSIs) are generally used to regulate the system voltage, frequency, and power output despite satisfying the requisites of the power utility. VSCs are fabricated with self-commutated regulators with turn-off adeptness usually Insulated Gate Bipolar transistors (IGBTs). VSCs use a pulse-width modulated (PWM) control scheme to synthesize a voltage level which is operated for the computation of power converter switches. It operates both as inverters and rectifiers, depending on the energy flow direction.

DC-DC Boost Converter: The grouping of the MPPT algorithm along with the dc-dc boost converter is utilized to fix and sustain the dc medium bus voltage, which ropes to a cost-efficient scheme to extract the most power from the solar panels. However, in this paper implement the *(*P&O) Perturb and Observe rules owing to its simplicity and efficiency, in spite of some constraints, for example, the slow response and the recurrent swings nearby the MPP. Due to dynamic irradiance and temperature duty cycle also have variations.

$$\frac{v_{DC}}{v_{PV}} = \frac{1}{1-D_R} \quad (5)$$

$D_R - Variable\ duty\ ratio$

DC-DC Buck Converter: In buck power converter it is needed to acclimate the voltage rate, yet the duty cycle of the chopper control is firm to stabilize so that it can certify the possible output voltage. The battery charger is basically a dc-dc converter that links the electric drive vehicle to the medium bus (Khan *et al.*, 2019). The power converter which supports the battery charging/discharging engages fixed voltage/fixed current strategy. It has the principal job of regulating current and voltage parameters appropriately for recharging the vehicle battery. The buck converter system equation can be represented in the next equation;

$$\frac{V_{EV}}{V_{DC}} = D_f \quad (6)$$

D_f $is\ the\ fixed\ duty\ cycle\ of\ buck\ converter$

$V_{EV} - output\ voltage\ of\ a\ vehicle$

$V_{DC} - DC\ bus\ voltage$

Generic Lithium Battery Model: Compared with conventional technologies of battery, lithium-ion battery charges faster lasts longer and possesses a high power density for a considerable number of charging/discharging processes. Li batteries that function generally at ambient temperature are mostly Li-poly and Li-ion batteries, which are best suited for EV industry and telecommunication gadgets. Li-ion batteries are famous for energy storage and for portable small and medium voltage products due to their compact size, lightweight, and potential. It possesses high energy and power density (Fergus, 2010) with long lifetimes, does not exhibit any memory effect. Moreover, contemporary lithium-ion batteries have been exposed to the latter more than 3K complete discharge cycles (Leadbetter and Swan, 2012). Further significant features of this battery have a quick charge/discharge capability (Zaghib *et al.*, 2011), high open-circuit voltage and intrinsically safe from an environmental perspective due to the absence of free lithium metal. The major downside of Li-ion batteries is the fabrication cost since it relies on the lifespan, electrical efficiencies and protection of the device. The life cycle of the Li-ion battery is seriously marked by temperature and is reduced substantially in fast deep discharge.

The Lithium-ion battery model comprises a variable voltage element and an internal resistance $\mathrm{R_{int}}$. Hence, the battery output voltage can be found in the next equations.

$$V_{bat} = E_{bat} - R_{int} I_{bat} \quad (7)$$

$$E_{bat} = E_0 - K\frac{Q}{i_t - 0.1Q} i^* - K\frac{Q}{Q - i_t} i_t + Ae^{(-Bi_t)} \quad (8)$$

E_{bat} open circuit voltage of the battery depends on the operation modes of the battery(charge or discharge), I_{bat} battery current, R_{int} internal resistance of the battery, E_0 No load battery voltage, K Polarization voltages, Q capacity of a battery Ah, Aagnitude of exponential zone (V) , B Exponential zone time constant inverse Ah.

RESULTS AND DISCUSSION

V2G technology: V2G scheme operates well by monitoring and controlling the power handshake between the intra grid and EVs using duplex communication. As EVs may be treated as dynamic mobile distributed power storages, thus, appropriate V2G supervision of a fleet of vehicles is significant to attain several features, like the integration of renewable energy, harmonic filtering, reactive power compensation, active power regulation and ancillary service (Hota *et al.*, 2014).

V2G makes it conceivable to stock and generate energy from the vehicle to poise intermittent renewable sources, enhance grid power stability, clean environment and maximize profit especially in peak hours. Two modes are generally adopted for the charging of EVs (unidirectional and bi-directional). In unidirectional mode, it bridges the energy market and electrification transportation together. Table -II gives a complete overlook of uni and bi-directional vehicle 2 grid technology.

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Table-II. Characteristics of V2G.

V2G system	Explanation	Services	Advantages	Scope
One directional V2G	Adjusts EV charging rate (C) of flow of power from local grid to vehicle-based on power incentives and energy rescheduling	Auxiliary service - Load balancing	Added profit less power loss less operation cost less emission	confined service range
Two directional V2G	Two way flow of power between the grid and EVs to obtain a range of benefits	Ancillary service – Spinning reserve Harmonic filtering Voltage regulation Support for integration for RES, Load balancing; Peak power shaving Real & reactive power control	Maximization of renewable energy generation Deterrence of grid over-loading Failure recovery Improved load profile	Quick battery degradation Compound hardwar Social barriers High capital price

Single directional V2G: A single directional V2G regulatory service bridges the energy market and electrification transportation together. It monitors the charging power rate of a vehicle battery in a single flow path. A modest inexpensive controller is required to manage the charge rate of EV for the realization of simplex V2G around a preferred operating point (POP). The setting of operating point straightly convinces the quantity of regulation down or up competence that EVs can facilitate, the EV charging time and profits gain accordingly. By providing ancillary services like spinning reserves and supply grid regulation enhances the flexibility and sustainability of power grid operations. For the implementation of bidirectional V2G flexible rates policy, striking power trading policy is generally required for their existence between the power utility and vehicle's personnel (Wang and Wang, 2013). To come in the ground and participate EVs personnel in the energy market, a lucrative energy trading program that ensures revenues or pervasive incentives will be given when the energy citizen limits their vehicles charging at peak hours and charging during the off-peak time. At the grid side perspective, it should avoid overloading during peak hours. By using the optimization algorithm, unidirectional V2G achieves less emission and maximize profits. However, unidirectional V2G has some limitation to supply ancillary services like voltage & frequency regulation, peak load shaving, load leveling active & reactive power stand which are exceptional services only get with two-directional V-2-G.

Bi-directional V2G: It takes the premium of the dual power flow path between the utility grid and the ground EVs to gain various ancillary benefits (Ferreira *et al.*, 2011). During the regulation down mode, the rectifier alters the AC supply from the utility grid to dc power. In regulation up mode, the dc/ac inverter injects the electron back to the grid in the feeding process. It provides support with greater flexibilities and advances the operation of the power system. The main benefits are load leveling, peak load shaving, mass integration of RES, voltage and frequency regulation, and peak harmonic filtering. Load leveling and peak shifting services achieved by charging at non-peak hours and injecting additional EVs power into the supply grid during peak hours. Bidirectional V2G also supports reactive power compensation for grid regulation. Reactive support service begins with proper sizing of dc-link charger capacitor and control topologies. Power losses also reduced to a substantial extent by utilizing the premium services gifted by two-way V2G technologies.

Applications of Vehicle 2 Grid: V to G technology offers various applications to attain various advantages. The inclusion of V to G can give better harmonics filtration, frequency regulation, and even breakdown retrieval to the power network. The merits of V to G not only avail the opportunity for the electric grid but surely for the vehicle personnel (Kempton and Tomić, 2005). Some of the advantages achieved by the V to G technology are given. Figure 3 shows the features of V2G;

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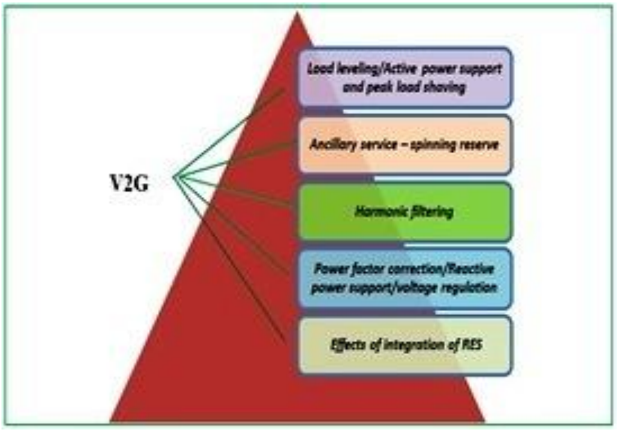

Figure-3. Flight of V2G Implementation

i. **Ancillary Services:** V2G facilitates by the subsidiary provision to the intelligent grid using the less polluted free stand by generators, where the surplus power accumulated with the grid-interfaced vehicles is treated as extra production capability to reimburse power breakdown and forestall load shed. With the benefits of spinning reserve provided by V2G, it can give outage gain, with the highly reduced cost as compared to backup generation. In the paper (Knezović *et al.*, 2017), the authors explore the field validation test in the Danish distribution system with EV providing multiple ancillary facilities like congestion reduction management, frequency regulation, local voltage support, through one-directional AC charging mode.

ii. **Peak load shaving:** EVs have a moment charging and discharging rates it's the competent alternatives for frequency regulation within the V2G system. Peak power usually occurs for a few hours, it's best to flatten the load demand by EVs battery energy (Yiyun *et al.*, 2011). This conjointly prevents the overloading of system parts, equipment aging, and system losses. The owners of EVs get a premium energy rate at the time once to shave off the peak demand. By load leveling, it maximizes the equipment capacity and defers extra equipment up-gradation cost.

iii. Power factor Correction: In the past, a generic method of power-factor alteration and voltage regulation is done with the use of static VAR compensator to give reactive power. By introducing the V2G method, the reactive power recompense for cos ϕ power correction. Grid VR can be solved with the grid-interfaced two-directional dc chargers. The adequate sizing of the DC-link capacitor has the capability to facilitate reactive power compensation to the supply grid with a proper regulatory mechanism for the vehicle power electronics-based converter. Bi-directional V2G offers quality services for power factor improvement which reduces the line losses and overloading in the supply grid.

iv. **Harmonic sifting:** The modern grid includes many advances and stochastic characteristics of non-linear loads like EVs, which originates ample content of current and voltage disturbance in the smart grid context. An EV bidirectional chargers are the main sector to the origination of current and voltage harmonics in power converter switching (Shareef *et al.*, 2016). EV chargers with a built-in advanced controller are exploited to reduce the harmonics incurred by vehicle ultra-charger and also by non-linear loads. It behaves as a variable impedance for discrete frequencies and settles the harmonic matters with an adequate filtering process. The rise in EV chargers finds in the possible likelihood of harmonic cancellation.

v. **Valuation of Renewable Energy Generation (REG):** Besides the growing environmental concerns, the supply power by RES is inherently unpredictable, non-dispatch able and mostly relied on the climate situation. The value of using RES in a low power distribution network includes investment deferral, loss reduction, improving system reliability (Amini *et al.*, 2017).

V2G encounters and impediments: V2G deployment will provide a lot of laurels and suppleness to the supply grid. However, V2G is a novel concept that is under the development phase. New challenges originate by the V2G system include battery deterioration, modification within the entire network infrastructure, the additional communication exchange between the vehicles and power grid, the effect on distribution networks and its parameters, energy line losses and other technical, political, financial and social obstacles. Some are listed below;

a. **Status of battery longevity:** Battery cells will be depleted progressively with the frequent cycles of energizing and de-energizing. The non-reversible chemical reaction with high depth of discharge, state of health (SoH), current charging rate (C) of a battery build aging and increases internal resistance and decrement the battery useable capacity (Dogger *et al.*, 2011).

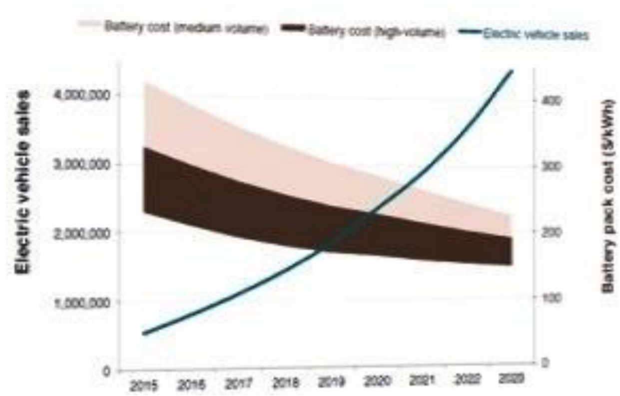

Figure 4 Sales of EV increases with battery cost falls.

b. **High-Cost Infrastructure:** To uplift the modern power system implementing V2G a high investment cost will be required. Advancements in software and hardware frame are desired for practical V2G employment. Moreover, V to G has the physics to increase power line failure, which is an added drawback as it straightly influences finance matters.

c. **Social blockades:** The involvement of a huge flux of electric vehicles is keen desires for the V to G foundation. Nonetheless, the social blockade has barred the civic recognition of the V to G framework, which seems to be a great contest for its absorption. Consumers have an inclination to resist new methods that are reflected un-accustomed. Since taking an active share in V2G implementation, it creates uneasiness among ground electric vehicle owners because of its use of its battery power to the smart grid supply (Sortomme and El-Sharkawi, 2012). The shortage of fast charging facility station makes the scenario even more worst.

d. **System Security:** Cybersecurity for the smart grid is an emerging talk of research. V2G technology must possess cybersecurity requirements for seamless operation. Confidentiality of V2G systems should be secure otherwise causes serious business consensus by cyber-attacks; Perfect authenticity should be optimized and customized for EVs; Integrity which ensures the data exchanged between EV's and aggregator will not be changed by malicious software; Availability of data communication, is the main issue for efficient and seamless data transfer from mobile EVs to static infrastructure.

Conclusion: Innovative decentralized has a simple and effective control scheme used in modeling of medium voltage dc bus with sources and loads. It uses the control variable and PID controllers to handle the power sources of the MVDC microgrid. This paper expansively reviews the recent trends of holistic electric transportation with an energy management scheme. Inroad to V2G, the impediments, and barriers to the existing distribution system are thoroughly investigated. Presently, electric vehicles replacing fossil fuel-based vehicles very rapidly, by subject to four edges of puzzle joining together at focal set-point. These mysteries are vehicle charging scenario, battery standard, improved vehicle mileage distance and lowered the pride of ownership. In fact, V to G has an influence on the life of EVs battery but it is more cost-effective for EVs 999owners and grid aggregators. Smart connection to the local grid, efficient communication between vehicles and grid operators, and net metering are essential for the beneficial performance of the V2G. The economic benefits of V 2 G technology depend on the strategies of charging/ discharging and vehicle aggregation. When EVs have smart power electronics devices, intelligently connections to the grid, and proper charger control hardware henceforth EVs act as a stored energy source and also assist as a reserve for unforeseen outages.

The initial requirement to realize the V-2-G boom is the accessibility of the relevant technologies indicated as mentioned above. Despite many benefits of electric vehicles, in terms of economics, and environmental concerns, still face hurdles regarding its initial cost, driving mileage, charging periods, security, longevity and safety. Advanced battery chemistry, fall of mass/size, and optimal consumption of the battery are desired for realizable operation. Thus, more research needs to be directed on this matter. Furthermore, the whole EV charging dock infrastructure with dual information is vital for forthcoming V2G placement. Nevertheless, the V2G concept is a convincing prospect, which reforms environmental settlements and provides numerous facilities to the utility grid. The insight of the V2G wants dynamic involvement and alliance to government, power companies and definitely EV owners. Proper V2G management with the incentive-based policy will be a significant contribution to the effective V2G technology execution.

REFERENCES

Amini, M.H., M.P. Moghaddam and O. Karabasoglu (2017). Simultaneous allocation of electric vehicles' parking lots and distributed renewable resources in smart power distribution networks. *Sustainable Cities and Society, 28*, 332-342.

Arfeen, Z.A., A.B. Khairuddin, R.M. Larik and M.S. Saeed (2019). Control of distributed generation systems for microgrid applications: A technological review. *International Transactions on Electrical Energy Systems*, e12072.

Chanhom, P., S. Nuilers and N. Hatti (2017). A new V2G control strategy for load factor improvement using smoothing technique. *Advances in Electrical and Computer Engineering, 17*(3), 43-51.

Dogger, J.D., B. Roossien and F. D. Nieuwenhout (2011). Characterization of Li-ion batteries for intelligent management of distributed grid-connected storage. *IEEE Transactions on Energy Conversion, 26*(1), 256-263.

Fergus, J.W. (2010). Recent developments in cathode materials for lithium ion batteries. *Journal of Power sources, 195*(4), 939-954.

Ferreira, R.J., L.M. Miranda, R.E. Araújo and J.P. Lopes (2011). *A new bi-directional charger for vehicle-to-grid integration.* Paper presented at the Innovative Smart Grid Technologies (ISGT Europe), 2011 2nd IEEE PES International Conference and Exhibition on.

Habib, S., M.M. Khan, F. Abbas and H. Tang (2018). Assessment of electric vehicles concerning impacts, charging infrastructure with unidirectional and bidirectional chargers, and power flow comparisons. *International Journal of Energy Research*, *42*(11), 3416-3441.

Hota, A. R., M. Juvvanapudi and P. Bajpai (2014). Issues and solution approaches in PHEV integration to smart grid. *Renewable and Sustainable Energy Reviews*, *30*, 217-229.

Kempton, W. and S.E. Letendre (1997). Electric vehicles as a new power source for electric utilities. *Transportation Research Part D: Transport and Environment*, *2*(3), 157-175.

Kempton, W. and J. Tomić (2005). Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. *Journal of Power sources*, *144*(1), 280-294.

Khan, W., F. Ahmad and M.S. Alam (2019). Fast EV charging station integration with grid ensuring optimal and quality power exchange. *Engineering Science and Technology, an International Journal*, *22*(1), 143-152.

Knezović, K., S. Martinenas, P.B. Andersen, A. Zecchino and M. Marinelli (2017). Enhancing the role of electric vehicles in the power grid: field validation of multiple ancillary services. *IEEE Transactions on Transportation Electrification*, *3*(1), 201-209.

Leadbetter, J. and L.G. Swan (2012). Selection of battery technology to support grid-integrated renewable electricity. *Journal of Power sources*, *216*, 376-386.

Shareef, H., M.M. Islam and A. Mohamed (2016). A review of the stage-of-the-art charging technologies, placement methodologies, and impacts of electric vehicles. *Renewable and Sustainable Energy Reviews*, *64*, 403-420.

Sortomme, E. and M.A. El-Sharkawi (2012). Optimal scheduling of vehicle-to-grid energy and ancillary services. *IEEE Transactions on Smart Grid*, *3*(1), 351-359.

Wang, Z. and S. Wang (2013). Grid power peak shaving and valley filling using vehicle-to-grid systems. *IEEE Transactions on Power Delivery*, *28*(3), 1822-1829.

Yiyun, T., L. Can, C. Lin and L. Lin (2011). *Research on vehicle-to-grid technology*. Paper presented at the 2011 International Conference on Computer Distributed Control and Intelligent Environmental Monitoring.

Zaghib, K., M. Dontigny, A. Guerfi, P. Charest, I. Rodrigues, A. Mauger and C. Julien (2011). Safe and fast-charging Li-ion battery with long shelf life for power applications. *Journal of Power sources*, *196*(8), 3949-3954.