# Designing Flexible Charging Optimization for Electrical Vehicles using Matlab/Simulink

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***Abstract*: The growing number of Electric Vehicles (EVs) will have remarkable impacts on the power grid as it leads to the increase in total energy consumption. This increases the overall burden on the grid which would require new power plants. However, it is possible to minimize the impact by proper scheduling for charging and discharging of electric vehicles. In this paper, three optimal schemes have been compared i.e. global optimal scheduling scheme and local optimal scheduling scheme and equal allocation scheme for EV charging and discharging. The first objective is to flatten the load profile. The EVs can be charged during off peak hours when the demand is less and can be discharged during peak hours when the demand is high. It will result in the constant power demand from the grid. The second objective is to minimize the total charging cost through scheduled charging and discharging.**

***Keywords*: Electrical Vehicles, charging, load profile, local optimal scheduling, global optimal scheduling Equal allocation**

## I. INTRODUCTION

Due to growing concern on environmental issues such as carbon dioxide emission and global warming, the electric vehicles (EVs) have come out to as a better alternative.

Moreover, it also reduces dependency on non-renewable sources such as oil. EVs have been accepted by public in past years. In 2016, more than 1, 30,000 electric vehicles were sold in U.S. only and sale of EVs grew by 37.5% to 22,000 units in India during last year. However some schemes only dealt with charging even without vehicle to grid while other schemes.

Electric Vehicle (EV) technology is more efficient than gasoline and diesel powered vehicles due to its less emission and simple drive train mechanism. The first EV invented in the year 1834 with a non-rechargeable battery [1]. The first rechargeable EV is built with the lead-acid battery in 1874. In the year 1894, Pedro G. Salom and Henry G. Morries developed an electric automobile named ‘Electroboat’ [2]. After 1894 different countries like England, the United States and France involved in developing electric automobiles [3].

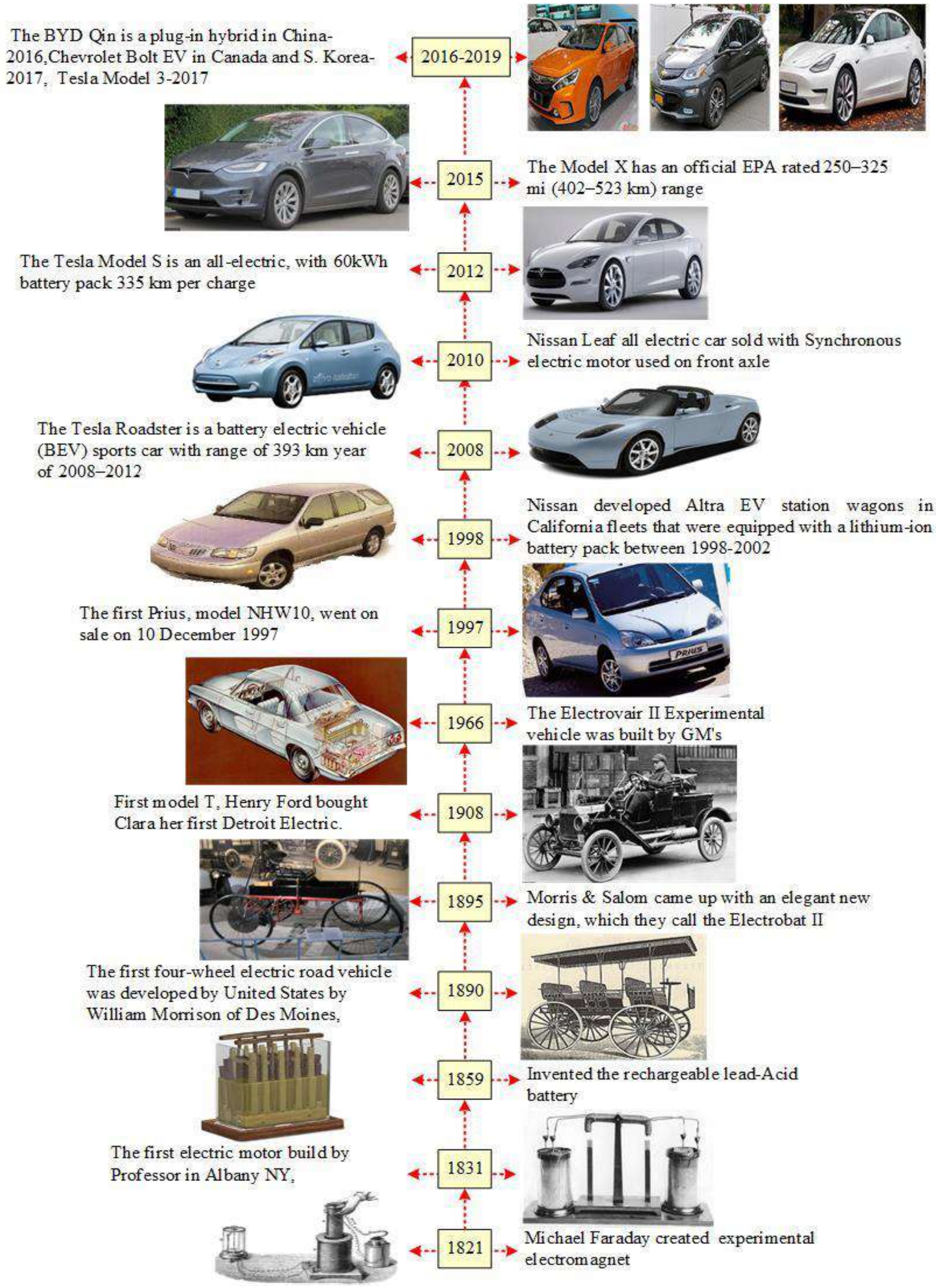

Figure 1 History of Electric Vehicles

After the invention of a rechargeable battery-based storage system, EVs had two significant developments. The first one was a reduction in the price of EV. Henry Ford did it in the year 1925 and named as Ford Model T by increasing the volume of the production even though the EVs are costlier than Internal Combustion Engine (ICE) based cars [4].

The second development was in the year 1950 by the California Air Resources Board (CARB), and the development was commercializing the EV usage, which is reducing the emission by 2% [5]. The general motors developed three experimental EVs named Electrovair, Electrovan and Electrovette in the years between 1966 to 1979 [6]. At the same time, the National Aeronautics and Space Administration (NASA) developed a lunar rover in 1971 that runs with the electricity [7]. This concept helped to raise the usage of the electric vehicle. The Nissan initialized the research and development of battery storage based on lithium-ion battery technology However, Nissan released the first lithium-ion battery based EV by the name

Prairie Joy EV [8]. Besides, Nissan developed another EV named Altera, which is driven by the permanent magnet synchronous motor drive. This popular product developed as

Nissan Leaf in 2010. The tesla Roadstar was more popular in the year 2008 because it covers 200 miles at one charge. The different companies followed tesla's model and developed their own hybrid and pure electric vehicles. The tesla developed EVs and named

as model S, model 3, model X and model Y with the different driving range like 630km, 519km, 565km, and 509km with different specifications. The development stages of EVs are shown in Figure 1.1.
In recent years, EVs are very popular because it leads the conventional road transportation. The prevalent model everyone knows is Tesla and Nissan. The company tesla developed and launched different electrical vehicles. For example, it is ranging from initial model Roadstar to recent model as model Y. This contemporary model gives the range of 370km in standard level and long-distance range as 507km with Environmental Protection Agency (EPA rated). Similarly, different companies produced EVs like BMW i3, Chevy's. But these are Plug-in Hybrid Electric Vehicle (PHEV).
Though the charging of EV does not depend on the coal-fired power plant, it is not a significant level of an emission reduction. Emission is reduced effectively by renewable-based power plant charging. Thus, the photovoltaic or wind-powered charging gives the solution.

## II. TYPES OF EV CHARGER

The EV chargers are classified into two types based on the location of the charger: on-board and off-board charger as shown in Figure 2 (a) [30]. The EV can be charged in three ways: 1) Conductive coupled charging, 2) wireless charging and 3) battery swapping [31, 32].

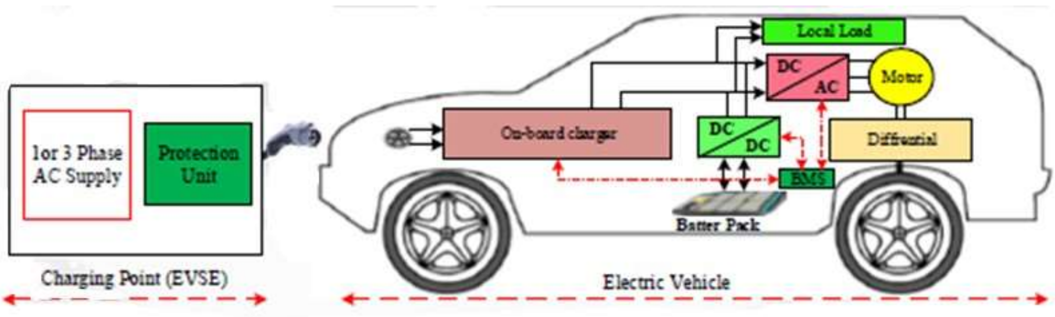


Figure 2 (a) On-board charger

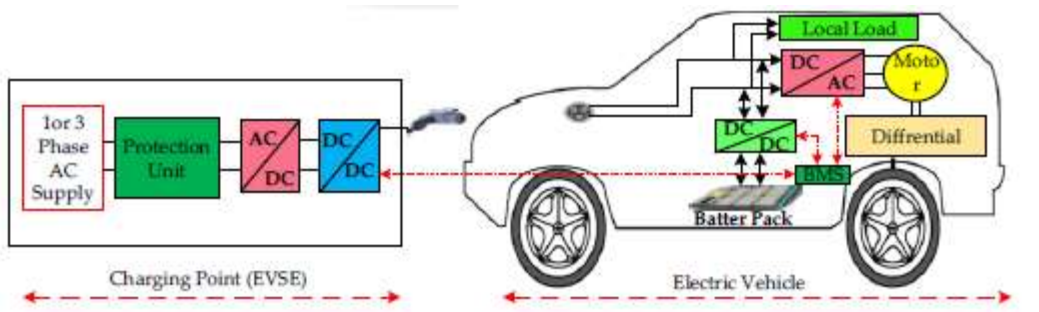


Figure 2 (b) Off-board Charger

The conductive coupled charging is simple, which has a conductive cable between the charging port and EV. Here, an electrical outlet with the plug-type connector is used to charge the EVs. The wireless charging is done by inductive and capacitive coupling.

## III. Proposed Global Optimization Scheduling

In this scheme, set of EVs are denoted by 'M' is considered which consist of two types of EVs. One is charging only set MCHG which includes EVs which only charge their battery. Other types of EVs are V2G, MV2G EVs which include EVs that perform charging as well as discharging. The total number of intervals is 'N' and the length of the interval is 'l'. Let $x_{mi}$ is the charging power of an EV m at interval i. For the charging power greater than zero, EV charges its battery. If the charging power is less than zero, EV discharging its battery. The EVs in the charging only set have power greater than or equal to zero while the EVs in V2G set may have positive, zero or negative power in interval i as they have bidirectional energy flow between power and grid. The charging period (Tm) must be fall between the arrival time and departure time of the EVs.

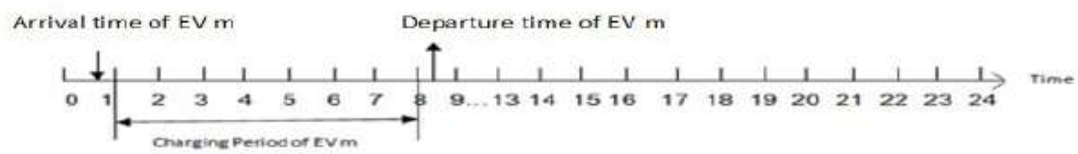


Fig. 3 Charging period of EV m

The battery capacity of EV m is denoted by $E_m^{cap}$.And the final energy of EV m is the energy of EV at departure time. And the final energy should be less than battery capacity. In the real pricing model, two assumptions have been made. The first assumption is that the losses between nodes are small and they can be neglected and the second assumption is that there is no congestion in transmission. By these assumptions variation of electricity price can be neglected and the electricity price at a time instant is the same regardless of the charging location. The optimizations of EV charging based on only temporal variation but not spatial variation of the price have be seen in [18], [20].The electricity price can be taken as a linear function of the instant load [18], which is given as follows:

$$g(Z_t) = k_0 + k_1 Z_t$$

Where $k_0$ is intercept and $k_1$ is slope and $Z_t$ is the total load at time t. The total load consists of two parts; base load and charging load. The load of all electricity consumptions in an interval except EV charging is considered as a base load. The charging load represents the load of EV charging. Base load is assumed to be constant in an interval. If the load from the grid to the batteries of EVs is greater than the batteries of the EVs to the grid in that interval, the charging load is positive. Otherwise, the charging load is negative. The total load in interval is given by the sum of base load and charging load. Since both the base load and the charging power remain constant in interval; the total load is constant in interval .Based on the pricing model, the charging cost in interval i is given by the charging cost can be positive or negative, if the charging load is positive, charging cost is positive or vice versa.

$$C_i = \int_{L_i^b}^{Z_i} (k_0 + k_1 Z_t)$$

$$= (k_0 + k_1/2z_i^2) - \left(k_0 L_i^b + k_1/2\left(L_i^b\right)^2\right)$$

To find a globally optimal scheduling scheme for the EVs that perform charging and discharging during the day, it is assumed that arrival time and the departure time of each EV in the EV set are known, the initial energy and the final energy of the battery for each EV in the EV set are known and the base load in each interval of the day is known. A central controller is installed which collects all the information of load and EVs and then performs the scheduling optimization. The total cost is the sum of the charging costs of all the EVs over the interval set N. The total cost is then given by

$$C_1 = (k_0 + k_1/2z_i^2) - \left(k_0 L_i^b + k_1/2\left(L_i^b\right)^2\right)$$

The main objective of the scheme is to minimize the total cost. This objective function is subjected to many constraints which are following:

$$\text{Objective : Minimize } (k_0 + k_1/2z_i^2) - \left(k_0 L_i^b + k_1/2\left(L_i^b\right)^2\right)$$

Subjected to

$$z_i = L_i^b + \sum_{m \in M} x_{mi} f_{mi} \ , \forall i \in N$$

$$0 \le E_m^{ini} + \sum_{k \in i} x_{mk} f_{mk} l \ \le \ E_m^{cap} , \forall m \in M , \forall i \in N$$

$$E_m^{ini} + \sum_{i \in N} x_{mi} f_{mi} l \ \ge \mu_m E_m^{cap} , \forall m \in M$$

$$0 \le x_{mi} \le P_{max} , \forall i \in N , \forall m \in M^{CHG}$$

$$-P_{max} \ \le x_{mi} \le P_{max} , \forall i \in N , \forall m \in M^{V2G}$$

Here, $L_i^b$ is base load and $f_{mi}$ is charging interval matrix and $x_{mi}$ is charging power at interval I of EV m. $E_m^{ini}$ is power of EV at arrival time and $E_m^{cap}$ is battery capacity of EV m. $\mu_m$ is the final energy ratio. $P_{max}$ is the maximum charging power of EV Fig. 4

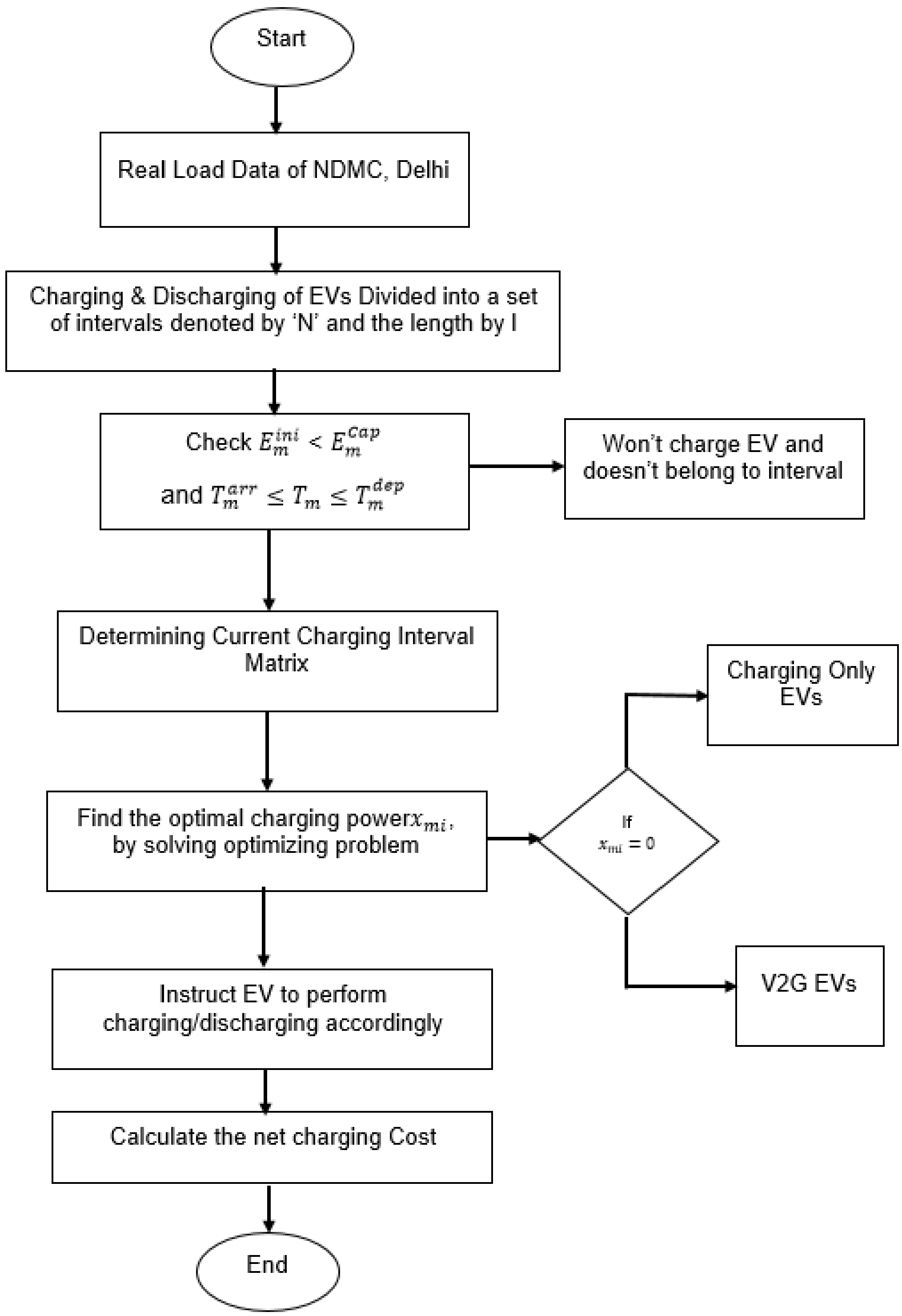


Fig. 4 Flow chart for globally optimization scheme

## IV. Conclusion

In this paper, we study the scheduling optimization problem for EV charging and discharging. It is important to schedule charging and discharging of EV battery as unscheduled charging may increase overall base load. The problem is formulated as a linear programming problem with a minimizing convex objective function of cost subjected to various linear constraints which have already discussed. Therefore optimization problem is convex optimization problem. The optimal charging/ discharging power and minimum cost can be obtained by two schemes i.e. globally scheduling and locally scheduling optimization schemes. The result of these two schemes are compared along with equal allocation scheme and it is seen that solution of globally optimal scheduling scheme provides the minimum charging cost but this scheme is not practical as it require future details such as base load and EVs charging load which cannot determine earlier so locally scheduling scheme is preferred as the performance to this scheme is very close to globally optimal scheduling scheme.

**References**

[1] T. Tazoe, et al., "Novel scheduling method to reduceEnergy cost by cooperative control of smart houses" International Conference on Power System Technology, IEEE, pp. 1 – 6, Nov 2012
[2] Christophe Guille and George Gross, "Design of a conceptual framework for theV2G implementation," in Proc. IEEE Energy 2030 Conference,pp. 1–3, Nov. 2008
[3] W.Shireen and S.Patel,"Plug-in hybrid electric vehicles in the smart grid environment," in Proc. IEEE PES Transmission Distribution Conference, pp. 1–4, Apr. 2010.
[4] Chris Hutsonet et al., "Intelligent scheduling of hybrid and electric vehicle storage capacity in a parking lot for profit maximization in grid power transactions," in Proceedings IEEE Energy 2030 Conference, pp. 1–8, Nov. 2008.
[5] Olivier Tremblay, et al., "A Generic Battery Model for the Dynamic Simulation of Hybrid Electric Vehicles" in IEEE Vehicle Power and Propulsion Conference, pp. 284 – 289, Sept. 2007.
[6] Iordanis Koutsopoulos and Lenandros Tassiulas, "Control and Optimization meet the Smart Power Grid : Scheduling of Power demand for Optimal Energy Management" in proceedings of the 2nd International Conference on Energy-Efficient Computing and Networking, pp. 41-50 Aug. 2011.
[7] Jay Taneja, et al., "Flexible Loads in Future Energy Networks" in proceedings of the fourth International Conference on Future energy systems pp. 285-286, May 2013.
[8] D. Madzharov, et al., "Integrating electric vehicles as flexible load in unit commitment modeling", Elsevier Journal, pp. 285-294, Feb 2014.
[9] Z. J.Ma, et al., "Decentralized charging controlfor large populations of plug-in electric vehicles: Application of theNash certainty equivalence principle," in Proceeding IEEE International Conference Control Application, pp. 191–195, Sep. 2010.
[10] Fangxing Li, et al., "Smart transmission grid: Vision and framework," IEEE Transaction Smart Grid, vol. 1, no. 2, pp. 168–177, 2010.
[11] K. Mets,et al., "Optimizing smart energy control strategies for plug-in hybrid electric vehicle charging," in Proceedings IEEE/IFIP Network Operations Management Symposium (NOMS), pp. 293–299, 2010.
[12] A. Y. Saber and G. K. Venayagamoorthy, "Optimization of vehicle-to-grid scheduling in constrained parking lots," in Proceeding IEEE Power Energy Society General Meeting (PES), pp. 1–8, July 2009
[13] S. Bashash, et al., "Charge trajectory optimization of plug-in hybrid electric vehicles for energy cost reduction and battery health enhancement," in Proceedings American Control Conference pp. 5824–5831, Jun. 2010.
[14] O. Sundstrom and C. Binding, "Optimization methods to plan the charging of electric vehicle fleets," in Proceeding International Conference Control Communication, Power Engineering (CCPE), pp. 323–328, Jul. 2010.
[15] P.S.Moses, et al., "Power quality of smart grids with plug-in electric vehicles considering battery charging profile," in Proceedings 2010 IEEE PES Innovation Smart Grid Technology Conference Europe, pp. 1–7, Oct. 2010.
[16] K. Clement, et al., "Stochastic analysis of the impact of plug-in hybrid electric vehicles on the distribution grid," in Proceeding International Conference Exhibition on Electricity Distribution, pp. 1–4 Jun. 2009.
[17] E. Sortomme and M. A. El-Sharkawi, "Optimal charging strategies for unidirectional vehicle-to-grid," IEEE Transaction on Smart Grid, 2011.
[18] S. Kabisch, et al., "Interconnections and communications of electric vehicles and smart grids," in Proceeding IEEE International Conference Smart Grid Communication, pp. 161–166,Oct. 2010.
[19] M. Singh, I. Kar, and P. Kumar, "Influence of EV on grid power quality and optimizing the charging schedule to mitigate voltage imbalance and reduce power loss," in Proceeding International Power Electron. Motion Control Conference, pp. T2-196–T2-203, Sep. 2010.
[20] Siddhartha Mal, et al., "Electric vehicle smart charging and vehicle-to grid operation" International Journal of Parallel, Emergent and Distributed Systems, vol. 27, no. 3. , pp. 249-265, Mar. 2012.
[21] S. Rahman and G.B. Shrestha, "An investigation into the impact of electric vehicle load on the electric utility distribution system" IEEE Transactions on Power Delivery, Vol. 8, No. 2, Apr. 1993.
[22] K. Clement, et al., "The Impact of Uncontrolled and Controlled Charging of Plug-in Hybrid Electric Vehicles on the Distribution Grid," in EET-2008 3d European Ele-Drive Transportation Conference, Geneva, Switzerland, Mar. 2008.
[23] T. Markel, et al., "Communication and Control of Electric Vehicles Supporting Renewables," in IEEE Vehicle Power and Propulsion Systems Conference, Dearborn, MI, USA, Sept. 7-10, 2009.
[24] W. Kempton and J. Tomic, "Vehicle-to-grid power implementation: Fromstabilizing the grid to supporting large-scale renewable energy," Journal of Power Sources, vol. 144, pp. 280–294, 2005.
[25] P. Denholm and W. Short, "An evaluation of utility system impacts and benefits of optimally dispatched plug-in hybrid electric vehicles, "National Renewable Energy Labortary, Technical Report NREL/TP- 620-40293, Oct. 2006.
[26] F. Koyanagi, et al., "Monte Carlo simulation on the demand impact by quick chargers for electric vehicles," in proceedings of the IEEE Power Engineering Society Summer Meeting, vol. 2, pp.1031–1036,18-22 July 1999.