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Optimal Energy Management Algorithm for Plug in Hybrid Electric Vehicles

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ABSTRACT: Plug in Hybrid Electric Vehicles (PHEVs) charging and discharging, renewable energy resource generation and utilization is most important in future power system control. Proper integration of these energy sources gives solution to the challenges. In this paper Mixed Integer Linear Programming (MILP) was proposed for plug in Hybrid Electric Vehicles charging and discharging in a charging station. Charging station consists of Photo Voltaic (PV) system with practical constraints, power balance constraints, battery charging and discharging constraints are considered. The results proposed that the proposed algorithm minimize the charging cost of PHEVs and optimal power flow for the grid connected PHEVs systems. Likewise, PHEVs owners could yield more profit by discharging their vehicles to the grid in addition to having preferred charge in the departure time.

KEYWORDS: Mixed Integer Linear Programming, Plug in Hybrid Electric Vehicles, Charging Park, Voltage Stability.

I.INTRODUCTION

The importance of energy savings is increasing and governments are encouraging the use of renewable energy. A clear correlation can be observed between vehicle density (cars per 1000 inhabitants) and a country's GDP (Gross Domestic Product); this suggests that as densely populated countries such as China, India, and Brazil achieve higher economic status, it can be expected that the demand for personal transportation will increase accordingly. Today, this demand can be directly translated into increased demand for petroleum, a fact that is hardly compatible with current data on oil production. Plug-In Electric Vehicles are receiving a great deal of interest in the United States due to their energy efficiency, convenient and low-cost recharging capabilities and reduced use of petroleum. PHEVs are an important of an electric power system in the upcoming days.

PHEVs give the solution to the fossil fuel shortage and air pollution problems [1].The emission reduction is achieved by using the PHEVs with combination of renewable energy resources. Beyond these advantages, the power system may face significant challenges due to the huge electricity demand of these loads [2-4]. PHEVs use battery as an energy storage system by using this battery PHEVs supply the power to the electric drive motor. Whenever PHEVs connected to charging station it will be operated in two modes such as Vehicle to Grid (V2G) mode and Grid to Vehicle (G2V) mode [5-6]. In V2G mode the state of charge of battery can go up or down, depends on the power demand. PHEVs owner get profit by using V2G capabilities. The design of PHEVs energy storage is mainly for transportation sector. So it provides sufficient energy to drive the vehicle. In order to maximize the customer satisfaction and minimize the grid disturbance, PHEVs charging station gives the solution for the energy management challenges [7-8].

An estimation of distribution algorithm to schedule the large number of PHEVs charging in a charging station has been proposed. The method optimizes the energy allocation to the PHEVs in the real time while considering various constraints. This paper has only proposed the charging method of PHEVs and the V2G option does not consider [9].The authors in [10] proposed simulated annealing approach and heuristic technical validation of the obtained solutions to solve the energy resources scheduling. In this paper, charging station with PV system on the roof, bidirectional utility grid for charging and discharging of PHEVs are presented. The grid connection is to satisfy the demand. Excess PV output is sent to the grid during peak hours. An energy management system with PV based

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charging station is proposed here in which the PV generation uncertainty and V2G capability of PHEVs are considered [11]. Moreover, the proposed model considers system constraints and customer's preferences. The contributions of the proposed method are highlighted as follows:

The rest of the paper is organized as follows: in Section 2, the proposed system components are introduced. Section3 presents the problem formulation; including the resources and PHEVs constraints. Analysis of the results is shown in Section4. Finally, conclusion is presented in Section5.

II.COMPONENTS OF PROPOSED SYSTEM

This section deals with the architecture of the proposed system which includes the multiple PV panel on the roof of the charging station and PHEVs are shown in fig 1. In addition there is a point of connection to the utility grid to enable the electricity trading with utility grid. In this paper the charging station plays the important role for the Energy Management System in (EMS) PHEVs. PHEVs are parked in the charging station can deliver the power to the grid or absorb the power from it according to the State of Charge (SOC) presents on their battery. The PHEV's owner not only uses the space for parking the vehicle and also benefit from V2G capabilities.

A. Charging Station

The charging station is compared to conventional one present's new facility to PHEV's owners and the utility grid. This energy management system automatically receives and sends data to vehicles and makes a smart decision regarding the scheduling of charging and discharging of the PHEVs. The PHEVs owner can submit their desired parameters of charging as previous day by using smart phone application. The charging station receives parameters from each PHEVs owner, such as arrival time, duration of presence in the charging station approximately and the minimum required state of charge at the departure time. These parameters are considered as input data. Charging station first receives the day-ahead electricity prices, PHEVs owners' preferences and the forecasting data of solar radiations as the input data. Then PV power and PHEVs charge/discharge program is determined by charging station control itself. Finally the result of optimum charge/discharge scheduling is sent to each PHEVs owner.

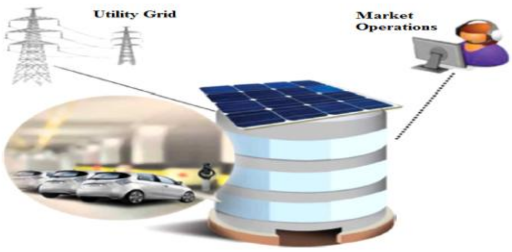

Fig. 1 Architecture of Charging station

B. Bi-Directional Converter

The purpose of the Bi-Directional converter in the PHEVs charger system is to interface the battery with the system enabling it to charge and discharge when needed. In a buck mode, this converter will lower the output voltage going to the input of the battery to a safe level enabling the battery to safely charge to a full level. The Bi-Directional converter is shown in fig 2.If the system is not charging; the converter can be switch into its next mode. In this mode, the battery will discharge and increase the voltage to drive the load.

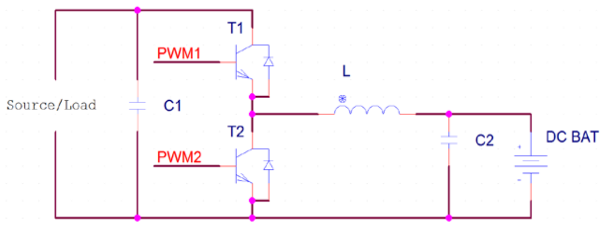

Fig. 2 Bi-Directional Converter

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The bi-directional function of this circuit is given by two switching transistors, T1 and T2. These transistors will receive control signals from the controller directing the flow of current. When the current through the inductor is positive means it will act as buck converter. When the current through the inductor is negative means it will act as boost converter.

C. Photovoltaic Panels

Solar power varies in the day-time as a result of the changing position of the sun and the motion of clouds. Such variability and uncertainty should be carefully considered in the proposed energy management system design. In recent years, a large number of techniques have been proposed for tracking the Maximum Power Point (MPP). Maximum Power Point Tracking (MPPT) is used in PV systems to maximize the photovoltaic array output power. PV array output power is used to directly control the DC to DC converter, thus reducing the difficulty of the system. Incremental conductance of MPPT flow chart is shown in fig 3. The method is based on use of an Incremental conductance of the PV to determine an optimum operating current for the maximum output power. In incremental conductance method the array terminal voltage is always adjusted according to the MPP voltage it is based on the incremental and instantaneous conductance of the PV module. The MPPT regulates the PWM control signal of the Dc to DC boost converter until the condition: $(\partial I/\partial V) + (I/V) = 0$ is satisfied.

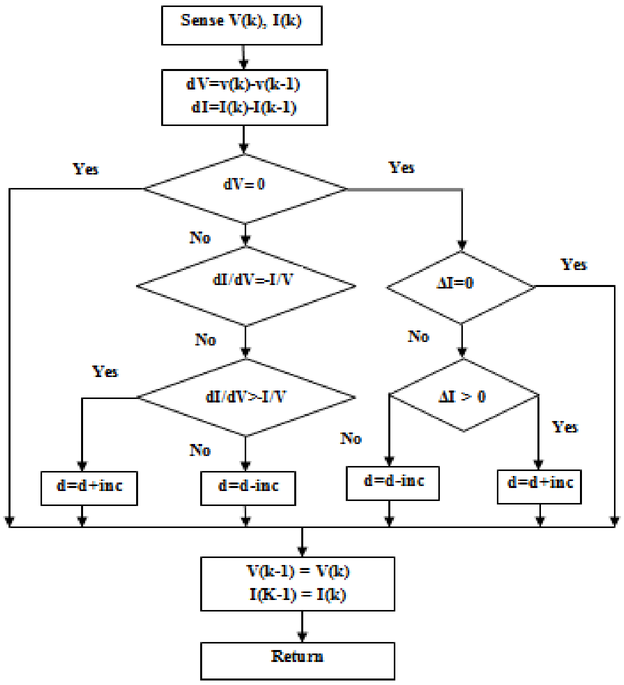

Fig. 3 Incremental Conductance of MPPT Flow Chart

D. Li-Ion Battery

One of the primary goals is to optimally charge a high power battery. A single Lithium cell break-down of the charging stages is shown in fig 4. The selected battery consists of 400 Cell for charging purpose (288V). Lithium-Ion battery with a total rated capacity of 13.9 [Ah] is used for charging the PHEVs. Each lithium-Ion cells has a voltage of 4.2V at maximum capacity. Maintaining maximum state of charge on a Li-Ion battery puts a large amount of stress on the cells, and shortens the overall lifespan of the battery.

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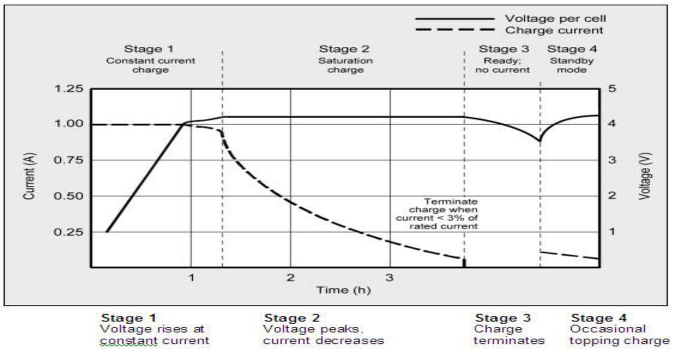

Fig. 4 Charging Stages of a Lithium-Ion Battery

III. IMPLEMENTATION OF MIXED INTEGER LINEAR PROGRAMMING METHOD TO SOLVE THE EMS PROBLEM

The objective function and various constraints for solving mixed integer linear programming are formulated as follows:

$$OBJ = \sum_{x=1}^{x} prob^{x} \sum_{t=1}^{T} (P_{C,PHEV}^{x,i,t} \ \Pi_{Ch}^{t}) + \sum_{t=1}^{T} (P_{D,PHEV}^{x,i,t} \ (C_{OM}^{t} - C_{Dch}^{t})) - \ P_{UG}^{x,t} \ C_{OM}^{t} - \sum_{i=1}^{N} (\lambda BNCE^{x,i,t}))\Delta t$$

$prob^{x}$ represents the probability of each scenario, $P_{UG}^{x,t}$ represents the transferred power between the grid and PHEVs in period ‘t’ under scenario ‘x’. Its positive values determine sold power to the utility while negative values determine purchased power from the utility. $P_{C,PHEV}^{x,i,t}$ and $P_{D,PHEV}^{x,i,t}$ are the charge or discharge powers of the ith PHEVs in period ‘t’ under scenario ‘x’ respectively. C_{Ch}^{t}, C_{OM}^{t} and C_{Dch}^{t} are the open market electricity price and the PHEVs specified charging and discharging price in period ‘t’ respectively, $BNCE^{x,i,t}$ is the departure stored energy deviation from the customer preferences of the ith PHEVs in period ‘t’ under scenario ‘x’, λ is the penalty cost of uncharged batteries, N indicate the number of PHEVs. T is the scheduling time horizon.

A. Constraints

The main objective function is charging cost minimization with respect to various constraints [12].That constrains are explained as follows:

a) Power Balance Constraint:

$$P_{UG}^{x,t} + P_{PV}^{x,t} + \sum_{i=1}^{N} P_{D,PHEV}^{x,i,t} + \sum_{i=1}^{N} BNC^{x,i,t} = \sum_{i=1}^{N} P_{C,PHEV}^{x,i,t} \qquad (1)$$

$P_{PV}^{x,t}$ is the produced photo voltaic power in period ‘t’ under scenario ’x’ and $BNC^{x,i,t}$ is the battery not charged in period ‘t’ under scenario ‘x’ respectively.

b) Remaining Battery Power for each PHEVs:

The stored energy in the battery is considered together with the energy remaining from the previous period and the charge or discharge in the period‘t’.

$$E_{PHEV}^{x,i,t} = E_{PHEV}^{x,i,t-1} + \eta_{G2V} P_{C,PHEV}^{x,i,t} \Delta t - \frac{1}{\eta_{V2G}} P_{D,PHEV}^{x,i,t} \Delta t; \qquad (2)$$

Where $E_{PHEV}^{x,i,t}$ is the stored energy in the battery of PHEVs in period‘t’ under scenario ‘x’ and η_{G2V} and η_{V2G} are PHEVs battery charging and discharging efficiencies.

c) SoC Limits:

$$SoC_{min}^{i} \leq SoC^{s,i,t} \leq SoC_{max}^{i}; \qquad \forall x, i, t; \qquad (4)$$

SoC_{max}^{i} is maximum SoC of ith PHEVs. SoC_{min}^{i} is minimum SoC of ith PHEVs.

d) Charging/Discharging Rate Limits:

$$-\Delta SoC_{max}^{i} \leq \Delta SoC_{max}^{i}; \quad \forall x, i, t; \qquad (5)$$

Where ΔSoC_{max}^{i} is the change in maximum SoC.

e) Battery Charging Constraint:

$$(P_{C,PHEV}^{x,i,t} + R_{dn,PHEV}^{i,t}) \ \eta_{G2V} \Delta t - E_{PHEV}^{x,i,t}; \qquad (6)$$

f) Battery Discharging Constraint:

$$(P_{Dh,PHEV}^{x,i,t} + R_{up,PHEV}^{i,t})\frac{1}{\eta_{V2G}}\Delta t \le E_{PHEV}^{x,i,t}; \quad (7)$$

g) Departure SoC Constraint:

$$E_{PHEV}^{x,i,T} \ge (SoC_{Desired}^{i}\ Cap^{i}) - BNC^{x,i,t} \quad (8)$$

$SoC_{Desired}^{i}$ is the desired SoC at departure time of the ith PHEVs.

h) Transmitted Power Limits:

$$|P_{UG}^{x,t}| \le P_{UG}^{max}; \quad (9)$$

P_{UG}^{max} is the maximum transmitted power between the PHEVs and the grid.

To solve the EMS problem the MILP method has two specific advantages compared to other optimization methods. In the proposed model, the MILP optimization guarantees to find the globally optimum solution [13]. Also, The MILP optimization finds the optimum solution in lower runtime [14, 15]. Moreover, the proposed model is a day-ahead energy and reserve scheduling. The computation time is also an important aspect of the applicability of the proposed method. For a real size charging parks with large number of EVs the MILP shows its benefits in a light execution time.

IV.RESULTS AND DISCUSSION

The simulink model for the proposed MILP method were developed using MATLAB 7.10 software package and the system configuration is Intel Core i5-2410M Processor with 2.90 GHz speed and 4 GB RAM. In proposed work two energy sources are considered. Computational results of EMS problem attained by the proposed MILP method for the two energy sources analyzed.

A. Waveform of Utility Grid

Utility grid connects with the charging station through the DC bus. The output voltage waveform of utility grid is shown in fig. 5. It produces 20 kW output voltages from generating station. Output is transferred to DC bus through the bi directional converter. Utility grid is synchronized by using VSC control

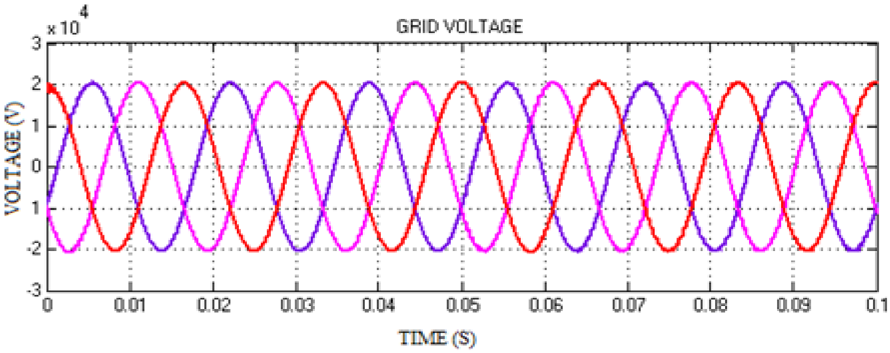

Fig. 5 Voltage Waveform of Utility Grid

B. Waveform of DC Bus

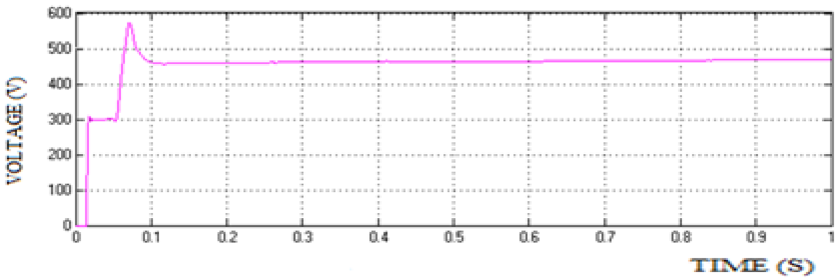

Fig. 6 Voltage Waveform of DC Bus

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Photo voltaic system's maximum power point is continuously tracked and integrated into the dc-bus linking the PHEVs' batteries to the main grid. The output voltage waveform of DC bus is shown in fig. 6. DC bus is connected with utility grid and charging station. DC bus voltage is maintained at 480v.

C. V2G and G2V

Power output of the various V2G and G2V conditions is shown in Table I. the main objective of the proposed method is to minimize the charging cost of plug in hybrid electric vehicles. The various algorithm techniques and its charging cost of PHEVs are shown in Table II.

Table I. Power Flow Conditions in PHEVs

Plug-in	Pv	Soc (%)	Power
1	1	60	80 W(V2G)
1	1	50	50 W (V2G)
1	0	30	-49 Kw (G2V)

Table II. Charging Cost of PHEVs

Method	Charging Cost ($/day)
Dynamic Programming	0.46 to 0.40
Mixed Integer Linear Programming	0.38 to 0.35
Fuzzy	0.22 to 0.18

V. Conclusion

The proposed method provides the optimal power flow and charging cost minimization of plug in hybrid electric vehicles. It improves the performance of V2G and G2V functionalities by using renewable sources. The photovoltaic and Fuel cell model was designed using MATLAB. The excess energy which is produced from photovoltaic and fuel cell power is transferred to the electrical network. PHEVs system is designed and charging cost is minimized by using MILP method. The proposed method satisfies the optimal power flow in the PHEVs system and also improves the system efficiency and minimizes the losses. The excess energy from renewable energy resources can also be sent to the utility grid and also satisfies the power demand.

References

1. H.A.Sher, K.E.Addoweesh, M.E.Webber, "Power storage options for hybrid electric vehicles—a survey," J. Renew. Sustain. Energy, vol. 4, no. 5, pp. 1-11, 2012.
2. Q.Zhang, N.K.Ishihara, C.B.Mclellan, T.Tezuka, "Scenario analysis on electricity supply and demand in Japan," Sustain.Energy, vol. 38, no. 1, pp. 376-385, 2012.
3. M. Pantos, "Stochastic optimal charging of electric drive vehicles with renewable energy," Sustain. Energy, vol. 36, no. 11, pp. 6567–6576, 2012.
4. B. Soares, M.C.Borba, A.Szklo, R.Schaeffer, "Plug in hybrid electric vehicles as a way to maximize the integration of variable renewable energy in power system: the case of wind generation in north eastern Brazil," Sustain Energy, vol. 37, no. 1, pp.469-481, 2012.
5. Z. Ma, D. Callaway, I. Hiskens, "Decentralized charging control for large populations of plug-in electric vehicles: application of the nash certainty equivalence principle," IEEE International Conference on Control Applications (CCA), Yokohama, Japan, 2010.

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Vol. 4, Issue 2, February 2015

6. S.Rezaee,E.Farjah, B.Khorramdel, "Probabilistic analysis of plug-in electric vehicles impact on electrical grid through homes and parking lots," IEEETrans.Sustain.Energy, vol. 4, no. 4, pp. 1024–1033, 2013.
7. M. Honarmand, A.Zakariazadeh, S.Jadid, "Optimal scheduling of electric vehicles in an intelligent parking lot considering vehicle-to-grid concept and battery condition," Renewable Energy, vol. 65, pp. 572–579, 2014.
8. S. Shahidinejad, S.Filizadeh , E.Bibeau, "Profile of charging load on the grid due to plug-in vehicles," IEEE Trans. Smart Grid, vol. 3, no. 1, pp. 135-141, 2012.
9. W. Su, M.Y.Chow, "Performance evaluation of an EDA-based large-scale plug-in hybrid electric vehicle charging algorithm," IEEE Trans. Smart Grid, vol. 3, no. 1, pp. 308–315, 2012.
10. T. Sousa, H.Morais, Z.Vale ,P.Faria, J.Soares, "Intelligent energy resource management considering vehicle-to- Grid: a simulated annealing approach," IEEE Trans. Smart Grid, vol. 3, no. 1, pp. 535–542, 2012.
11. Ahmed Mohamed, Vahid Salehi, Osama A. Mohammed, "Real-Time Energy Management Algorithm for Plug-In Hybrid Electric Vehicle Charging Parks Involving Sustainable Energy," IEEE Trans. Sustainable Energy, vol. 5, no. 2, pp. 577-586. Apr 2014.
12. Masoud Honarmanda, Alireza Zakariazadeha, Shahram Jadid, "Self-scheduling of electric vehicles in an intelligent parking lot using stochastic optimization," sciencedirect, Journal of the Franklin Institute,Jan 2014.
13. T.Koch, T.Achterberg, E.Andersen, O.Bastert, T.Berthold, R.E.Bixby, etal., "MIPLIB2010",Math.Program. Comput., no. 3, pp.103–163, March 2011.
14. A. Zakaria zadeh,S.Jadid,P.Siano,"Economic-environmental energy and reserve scheduling of smart distribution systems: a multi objective mathematical programming approach," Energy Convers. Mag, vol. 78, pp. 151–164. April 2014.
15. H.Falsafi, A.Zakaria zadeh, S.Jadid, "The role of demand response in single and multi-objective wind-thermal generation scheduling: a stochastic programming," Energy Convers.Mag, vol. 64, pp. 853–867, June 2014.