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APPLICATION OF PHOTOVOLTAIC POWER SYSTEM FOR DYNAMIC CHARGING SCHEDULING OF EV PARKING LOTS

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Abstract: The ideal charging timing for Electric Vehicles (EVs) in a workplace parking lot, which fed by both the PV system and the power grid, is discussed in this paper. Due to the rise in the number of electric vehicles, efficient charging scheduling for electric vehicles (EVs) in a workplace parking lot, is now required. The economic operation of charging station is difficult due to the fluctuations and uncertainty in solar energy availability, as well as the EV charging requirements are time variable. To handle this issue, the EV charging scheduling in the parking lot was structured as a optimal problem which can balance above two issues. The controller is designed for managing EV charging procedures, which incorporates real-time data. MATLAB simulation results of the designed controller also verified.

***Index Terms* - Ideal charging timing, Photovoltaic power system, Parking lot.**

I. INTRODUCTION

Climate change is now strongly linked to the emission of greenhouse gases (GHGs) around the planet. According to recent data, vehicles used for transportation release GHGs and the power plants where energy generation takes place also another significant source of GHGs, both of these are very crucial in growth and development of any nation. So, we can't avoid them in our day-to-day life [1]. Electric Vehicles (EVs) can fulfill our transportation with least emission of GHGs, hence are the best solution for promoting sustainable energy development and climate change challenges. Use of solar energy for Charging electric vehicles is environmentally friendly and sustainable. So, it is best practice to install Photovoltaic Power (PV) systems installed at parking lots and EVs can be charged during the day [2].

Availability of solar energy is inconsistent and fluctuating in nature, solar energy alone may not able to fulfill EV charging needs. So, we form a PV-grid which is a combination of solar energy and the power grid, which can fulfill charging needs of EVs in reliable and efficient manner [3]. But in this scenario, there arises another problem i.e., to match the available energy with energy required for EV charging. The available energy is not constant due to solar energy is inconsistent and EVs charging needs are also not constant. The goal of the economic operation is to install charging station in the parking lot which runs by utilizing available solar energy. Based on real-time information on Electric vehicle charging requirements and solar energy, an effective optimal charging scheduling strategy must be developed [4], which can balance charging needs and available energy.

The charging scheduling method was designed using Model Predictive Control (MPC) which can deal present problem. It allows the current time slot to be optimized while future time slots are taken into account. A dynamic model is framed which can determine charging requirements and available energy output in the present time slot and also estimates the same in the future time slots based on collected field information. The steps carried out to get optimal solution in this paper are summarized as follows:

- Formulation of optimal problem, i.e., the charging schedule for a vehicle parking lot, power supplied by both the PV system and the power grid.
- Analysis of the relationship among the available energy sources, charging requirements and total charging load on the PV-grid.
- Derive several necessary conditions to get the optimal solution by simplifying the primal problem.

II. OVERVIEW OF BOOST CONVERTER, SOLAR CELL AND MPPT CONTROLLER

In this section, the system components and their relationship were discussed. The focus here is on the system description, and input and output relationships. Methods for relating input and output equation for solar cell, DC boost converter topology and P-V curve are presented in this chapter. Furthermore, we discuss in detail about maximum power point tracking algorithm to get maximum power from the solar panel.

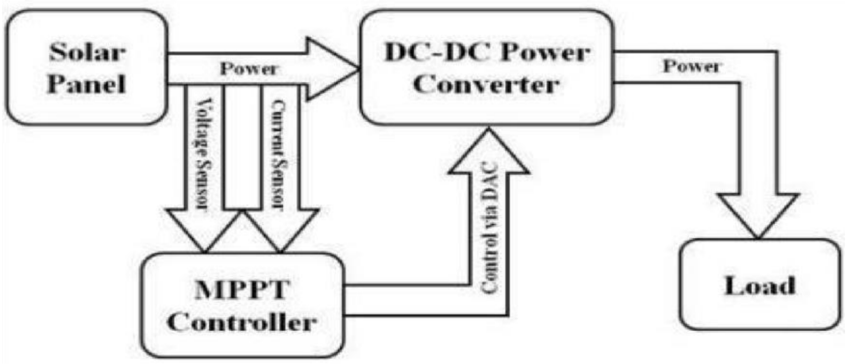


Figure 1. system overview

1. Solar Cell

PV systems are complex systems, some of the problems that are faced with PV model. Walker has proposed the simulation of PV array to study the characteristics of power versus voltage against insolation, temperature, and load changes. Alanson Garcia *et al* has experimentally obtained V-I graphs of solar PV module under partial shading condition.

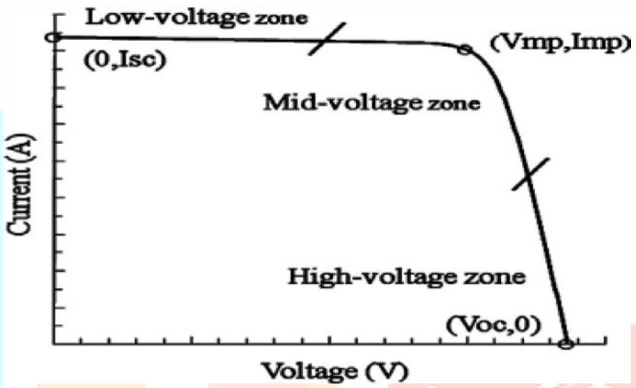


Figure 2. Typical I-V characteristics of PV cell

A solar cell constitutes the basic unit of the PV module. Series or parallel association of the cells are used to get the specified strength output of the PV module.

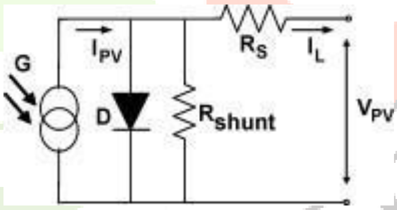


Figure 3. Equivalent circuit of PV cell

The overall efficiency of system comes down thus it is calculated by temperature derating factor $\eta_t$as shown below.

$$\eta_t = 1 - [\gamma * (T_c - T_{stc})] \quad (1)$$

Where ϒ is Power temperature coefficient

The maximum power output is the highest output power delivered by a solar cell at STC. The maximum power output of an array of n-solar panel each of power rating Wp is given by

$$kW_p = \frac{n * W_p}{1000} \quad (2)$$

STC stands for standard test conditions, it is the rated maximum power a solar cell can deliver at 1000 W/m^2, 25 °C.

The average power is given by, $E = kW_p \times \eta$ (3)

Where, η is the overall efficiency of the system. It can range anywhere from 0.7 to 0.85 for a properly designed system.

2. Tracking of Maximum Power Point

The power available at the output of a photovoltaic (PV) module is dependent on the load connected and the solar insolation. The operating point can be determined by connecting a variable load R and plotting a straight line intersecting the I-V module curve. The fig.4 shows the operating characteristics of a PV module. It shows two regions, zone 1 and zone 2. From the figure we can infer that the zone 1 covers a region of high internal impedance and zone 2 covers a low impedance region. The knee of the curve corresponds to a point of maximum power (P_{mp}).

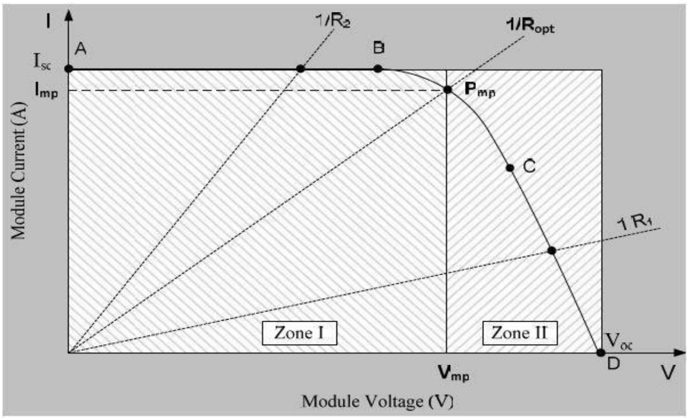


Figure 4. PV module V-I curve along with load line Characteristics

2.1 Details of Perturb & Observe Algorithm

In Perturb & Observe algorithm, the operating voltage of the PV panel is perturbed by a small increment. If the resulting value of Power is positive, then keep on perturbing in the same direction of maximum power point. If P is negative, then move away from the direction of Maximum Power Point and the sign of perturbation applied must be reversed.

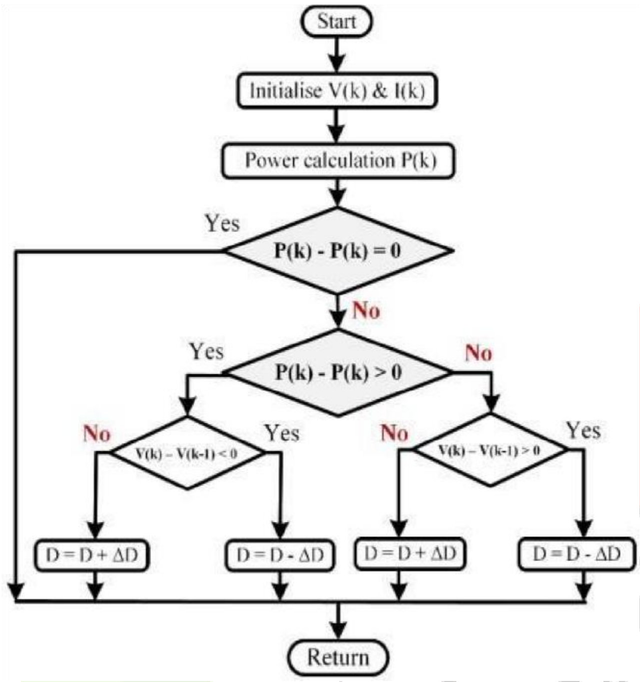


Figure 5. P & O Algorithm in flow chart

In P&O algorithm, the operating point of the system is controlled by varying Duty cycle of the switch ($0 < D < 1$). The maximum power is obtained from the PV cell by adjusting voltage and current values using duty cycle control.

3. Boost Converter (DC to DC Converter)

A DC-DC converter is a device that has a DC voltage as data and generates a DC output voltage. The output voltage levels are not same as the data. The basic function of a Boost converter is to increase the input voltage to a higher level based on the ON time of the switch as follows

$$Vo = \frac{Vg}{1 - D} \tag{4}$$

$$Io = \frac{Ig}{1 - D} \tag{5}$$

The input side resistance is given as:

$$R' = R \times (1 - D)^2 \tag{6}$$

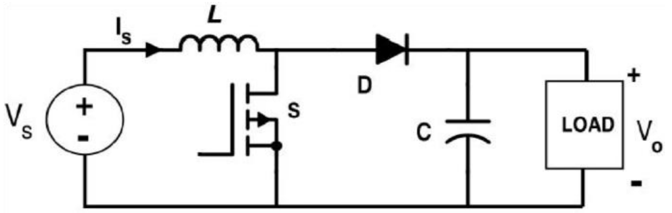


Figure 6. Boost Converter.

The load on source side can be reduced by varying D. When PV module's maximum power point current is greater than the original load (Zone I of figure 4), the tracker of boost converter will extract maximum power.

III. SYSTEM MODEL AND PROBLEM FORMULATION

Consider particular working time period of a vehicle parking lot of organization. Suppose parking lot contains N charging piles in AC charging mode. A centralized-controller is used to connect each charging pile to the power bus. This controller collects information from grid system, controls the on/off switches and manages the entire charging process of EVs. The power bus has two sources PV system and the power grid, the entire energy output of PV system can be used to the vehicle parking lot only. This is due to stability problems arise, if PV output energy is fed to grid. The system model is shown in Fig. 7.

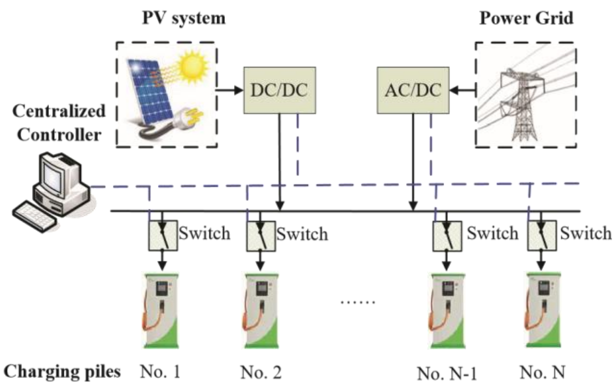


Fig. 7. Designed system model.

4.1. Charging Model of the Parking Lot

Consider one full day divided into T time slots. Let $\bar{t}$ - present time slot and t^0 – future time slot respectively. The charging decision ($x_{i,t}$) of EV i during time slot t, $t \in [t, \bar{T}]$, decided by the central controller satisfies

$$0 \le x_{i,t} \le 1, \forall t, \tag{7}$$

and the total energy $E_{i,t}$ charged to EV i during time slot t is

$$E_{i,t} = x_{i,t}\bar{P} \tag{8}$$

where $\bar{P}$ is the charging power of one charging pile for one time slot.

Let I be the expected set of EVs to be charged in the parking lot during the entire period and $\bar{\mathrm{I}}(t)$ be the set of EVs to be connected to the charging system during time slot t, respectively. Then, we have

$$0 \le x_{i,t} \le 1, \text{if } i \in \bar{\mathrm{I}}(t); \tag{9}$$

$$x_{i,t} = 0, \text{otherwise.}$$

Let $\bar{E}_t$ denote the total charging load of the vehicle parking lot during time slot t.

$$\bar{\mathrm{E}}_t = \sum_{i\in\prod(t)} E_{i,t} = \sum_{i\in\prod(t)} x_{i,t}\bar{P} \tag{10}$$

The maximal value of charging load is

$$\bar{E}_t^{\max} = \sum_{i\in\prod(t)} \hat{x}_{i,t}\bar{P}, \forall t, \tag{11}$$

where $\hat{x}_{i,t} = 1$ if EV i belongs to $\bar{\mathrm{I}}(t)$.

4.2. Charging Requirement Model of EVs

Charging decisions for various electric vehicles depends on their arrival and departure timings, amount of charging load. So, the central controller must be provided with a data of arrival and departure timings, charging capacities of each EV connected to parking lot. The central controller will estimate energy availability and load for present state and then update it for future state based on collected data.

For connected EV i, let A_i - arrival time, D_i - departure time and R_i^0 – amount of charging needed respectively. Obviously, If during time slot t, $t \in [A_i, D_i]$, EV i only charged and the EV i relates to $\bar{\Pi}(t)$ as

$$\begin{cases} i \in \bar{\prod}(t), if\ t \in [Ai\ ,\ Di\ ]; \\ i \notin \bar{\prod}(t), \text{otherwise} \end{cases} \tag{12}$$

Let M_t^A – number of vehicles arrive and M_t^L - number of vehicles leave the parking lot during time slot t, respectively. Then

$$\sum_{t=1}^{\bar{t}}(M_t^A - M_t^L) = \sum_{i \in \bar{\prod}(\bar{t})} \hat{x}_{i,\bar{t},}\ \forall \bar{t}. \tag{13}$$

For the upcoming EVs [23], For arrival times, the mean and standard deviation are μ_A and σ_A, departure times mean and standard deviation are μ_L and σ_L respectively. Assume λ be total number of the vehicles charged in the parking lot for the entire period. We have

$$M_{t'}^A = \lambda \int_{t'}^{t'+1} f_A(x) d_x = \lambda(F_A(t'+1) - F_A(t')) \tag{14}$$

where $f_A(t)$ - probability density function (PDF) of the arrival times,
$F_A(t^0)$ - corresponding cumulative distribution function (CDF)
In addition, a lognormal distribution function, with two parameters μ_D and σ_D, EVs' travel distances [23], given by

$$f_{\hat{D}}(x:\mu_D,\sigma_D) = \frac{1}{x\sigma_D\sqrt{2\prod}}\exp\{-\frac{(\ln x - \mu_D)^2}{2\sigma_D^2}\} \tag{15}$$

Let E_D - EV's energy consumption/km. The charging requirement of each upcoming EV can be expected by $E_D \exp\{\mu_D + \frac{\sigma_D^2}{2}\}$.
If R_i^t denote the charging requirement of EV i at time slot t. The charging requirement $R_i^{\bar{t}}$ at current time slot $\bar{t}$ can be given by

$$R_i^{\bar{t}} = \begin{cases} R_i^O - \sum_{t=A_i}^{\bar{t}-1} x_{i,t}\bar{P}, & \text{if } A_i < \bar{t}; \\ R_i^O, & \text{if } A_i = \bar{t}; \\ E_D \exp\{\mu_D + \frac{\sigma_D^2}{2}\}, & \text{if } A_i > \bar{t}. \end{cases} \tag{16}$$

4.3 Energy Supply Model of the Parking Lot

The parking lot power supplied by the PV system and the power grid. Let E_t^R be the collected solar energy of the PV system, E_t^{R0} be the excessive solar energy that cannot fed to any EV, and E_t^G be the total energy output of the power grid during time slot t, respectively. Apply constraint of energy conservation,

$$\bar{E}_t = E_t^G + E_t^R - E_t^R\ , \tag{17}$$

where

$$E_t^{RO} \leq E_t^R\ ,\ \ \forall t. \tag{18}$$

Generally, for safety and reliability, the output of power grid always less than available energy for the parking lot during one time slot, denoted by $\bar{E}^G$. Thus, for the total energy from the power grid, we have

$$E_t^G \leq \bar{E}^G\ , \forall t. \tag{19}$$

If charging load of the connected vehicles is minimum, the total energy from the power grid satisfies

$$E_t^G = \min\{\bar{E}_t - E_t^R - E_t^{RO}, \bar{E}^G\} \tag{20}$$

Note that the total amount of energy from the power grid, the charging load of the connected EVs and utilization of the solar energy during the time slot are interdependent. For given time period, the expected total charging load $\bar{E}_t$ of the parking lot

$$\bar{E}_t \leq E_t^R + \bar{E}^G\ ,\quad \forall t. \tag{21}$$

4.4 Operation Requirement of the Parking Lot

To meet charging needs of all vehicles in parking lot the charging decision will be

$$R_i^O = \sum_{t=\bar{t}}^{T} X_{i,t}\bar{P} = \sum_{t=\bar{t}}^{D_i} E_{i,t}$$

since $x_{i,t} = 0$ when $t \notin [A_i, D_i]$. It means that EV i's charging requirement should be satisfied when it is connected to the parking lot.

For connected EV i, since the charging requirement $R_i^{\bar{t}}$ has been changed as

$$R_i^{\bar{t}} = \sum_{t=\bar{t}}^{T} X_{i,t}\bar{P} = \sum_{t=\bar{t}}^{D_i} E_{i,t} \tag{22}$$

Similarly, for future time slot the charging decision, $\{x_{i,t}\ \forall t \in [t, \bar{T}]\}$, should satisfy

$$R_i^{\bar{t}} = \sum_{t=\bar{t}}^{T} X_{i,t}\bar{P} = \sum_{t'=\bar{t}}^{D_i} E_{i,t} \qquad \text{Where } A_i > \bar{t} \text{ and } D_i = \mu_L. \tag{23}$$

4.5 Operation Goals of the Parking Lot

The main goal is to get maximum benefit for given amount of charging load and available energy output. The benefit of the parking lot decided by cost of the available output energy and the income obtained from charging vehicles. Cost of the available output energy is mainly the cost of energy from power grid, since the cost of the solar energy collected is not significant.

The cost of the energy output is

$$C_t^G = a_1(\mathrm{E}_t^G)^2 + a_2 E_t^G \tag{24}$$

where $a_1 E_t^G$ and a_2 are load-dependent and load-independent prices respectively.

Let a_3 denote the Rs/ kWh energy charging to EVs. Since the total energy charged to EVs during time slot t is $\bar{E}_t$, the total income of the parking lot during time slot t is $a_3\bar{E}_t$.

The benefit of the parking lot during time slot t is up to end of the time period T,

$$C_t^{\bar{t}} = \sum_{t=\bar{t}}^{T}(\mathrm{a}_3\bar{\mathrm{E}}_t - (a_1(\mathrm{E}_t^G)^2 + a_2 E_t^G)) \tag{25}$$

4.6 Problem Formulation

We have to design an optimal charging scheduling algorithm to get optimal solution of the parking lot which can fulfill the charging needs of all the connected EVs. Let $X^{\bar{t}} = \{x_{i,\bar{t}}, x_{i,\bar{t}+1}, \cdots, x_{i,T}, \forall i\}$ be the charging decisions from present time slot $\bar{t}$ to T. The optimization problem for the parking lot to charge vehicles formulated as follows:

$$\textbf{P0}:\ \min_{X^{\bar{t}}} C_T^{\bar{t}} \tag{26}$$

$$\text{s.t. } \bar{E}_t \le E_t^R + \bar{E}^G, \qquad \forall t \in [t, \bar{T}] \tag{27}$$

$$0 \le x_{i,t} \le 1, \qquad \forall i \in \bar{\mathrm{I}}(t), t \in [t, \bar{T}], \tag{28}$$

$$R_i^{\bar{t}} = \sum_{t=\bar{t}}^{T} E_{i,t} \qquad \forall i \tag{29}$$

By analyzing the system parameters, several necessary conditions for optimal solution can be derived, and an algorithm also can be proposed to update the charging decision of vehicles for present and future time slots.

IV. SYSTEM PARAMETER ANALYSIS

The maximum charging load $\bar{E}_t^{\max}$ decided by the energy output of PV system and the power grid, as well as the number of connected vehicles during time slot t.

Each connected EV has charging load $\bar{P}$, the charging load for all the connected vehicles

$$\bar{E}_t^{\max} = \sum_{\bar{t}=1}^{t}(\mathrm{M}_{\bar{t}}^A - \mathrm{M}_{\bar{t}}^L)\bar{\mathrm{P}} \tag{30}$$

But we know that

$$\bar{E}_t^{\max} = E_t^R + \bar{E}^G \tag{31}$$

From (31) and (32), the maximal charging load $\bar{E}_t^{\max}$ during time slot t can be given by

$$\bar{E}_t^{\max} = \min\{\sum_{\bar{t}=1}^{t}(\mathrm{M}_{\bar{t}}^A - \mathrm{M}_{\bar{t}}^L)\bar{\mathrm{P}}, \mathrm{E}_t^R + \bar{\mathrm{E}}^G\}\forall \mathrm{t} \tag{32}$$

And the energy from the power grid E_t^G can be divided into three cases:

Case I: When $\bar{E}_t^{\max} \ge \sum_{\bar{t}=1}^{t}(\mathrm{M}_{\bar{t}}^A - \mathrm{M}_{\bar{t}}^L)\bar{\mathrm{P}}$, we have

$$\bar{E}_t = \bar{E}_t^R - \bar{E}_t^{RO} \Rightarrow E_t^G = 0.$$

Case II: When $E_t^R \le \sum_{\bar{t}=1}^{t} (M_{\bar{t}}^A - M_{\bar{t}}^L)\bar{P} \le E_t^R + \bar{E}^G$, we have

$$E_t^R \le \sum_{\bar{t}=1}^{t} (M_{\bar{t}}^A - M_{\bar{t}}^L)\bar{P} \Rightarrow E_t^G \le \sum_{\bar{t}=1}^{t} (M_{\bar{t}}^A - M_{\bar{t}}^L)\bar{P} \le E_t^R - E_t^R$$

Case III: When $\bar{E}_t \le E_t^R + \bar{E}^G \Rightarrow E_t^G \le \bar{E}^G$, we have

$$\bar{E}_t \le E_t^R + \bar{E}^G \Rightarrow E_t^G \le \bar{E}^G$$

V. PROBLEM TRANSFORMATION AND DCSS

In this section, we first transform Problem P0 into an easier to solve one. Then, we propose a DCSS to obtain the optimal charging decision in real time.

According to eqn. (23), the total amount of the expected charging needs of the vehicles $R_{\Pi}^{\bar{t}}$ at present time slot $\bar{t}$ is a constant. In addition, the amount of the solar energy during time slot $\bar{t}$ and future time slot t^0 are given. Thus, the total benefit of the parking lot, defined by (25), can be

$$C_T^{\bar{t}} = \xi - \sum_{t=\bar{t}}^{T} (a_1 (E_t^G)^2 - a_2 E_t^{RO}) \quad (33)$$

In order to maximize the total benefit, cost must be minimized, i.e. $\sum_{t=\bar{t}}^{T} \left(a_1 (E_t^G)^2 - a_2 E_t^{R0}\right)$ should be minimized.

After solving P0, we formulateP1 as: $\min_{X^{\bar{t}}} \sum_{t=\bar{t}}^{T} a_1 (E_t^G)^2$ (34)

$$\text{s.t. } \bar{E}_t \le E_t^R + \bar{E}^G, \quad \forall t \in [t, \bar{T}], \quad (35)$$

$$0 \le x_{i,t} \le 1, \quad \forall i \in \bar{I}(t), t \in [t, \bar{T}], \quad (36)$$

$$R_i^{\bar{t}} = \sum_{t=\bar{t}}^{T} E_{i,t} \quad \forall i. \quad (37)$$

The optimal charging decision obtained by above method is applicable for only small step changes [29].

An MPC is adopted which deals dynamic system parameters (Fluctuated solar energy and time varying EV charging requirements) since it optimizes the decision in the present time slot, and will track the the performance in future time slots. A central controller at current time slot $\bar{t}$, collects the charging load of arrived vehicles $\{R_i^{\bar{t}}, \forall i \in \mathbb{I}\}$ and amount of the solar energy $\hat{E}_{\bar{t}}^R$. Then, it find the optimal charging decision $X^{\bar{t}}$ and also for future time slot $\bar{t}+1$, the central controller updates $\{R_i^{\bar{t}+1}, \forall i \in \mathbb{I}\}$ and $\hat{E}_{\bar{t}+1}^R$ based on the collected information again, and then calculates and implements the optimal charging decision for time slot $\bar{t}+1$. This steps are continuously calculated and implemented by central controller until $\bar{I}(\bar{t}) = \emptyset$ or $\bar{t} = T$.

The operation flow of the designed DCSS can be found in Fig. 8.

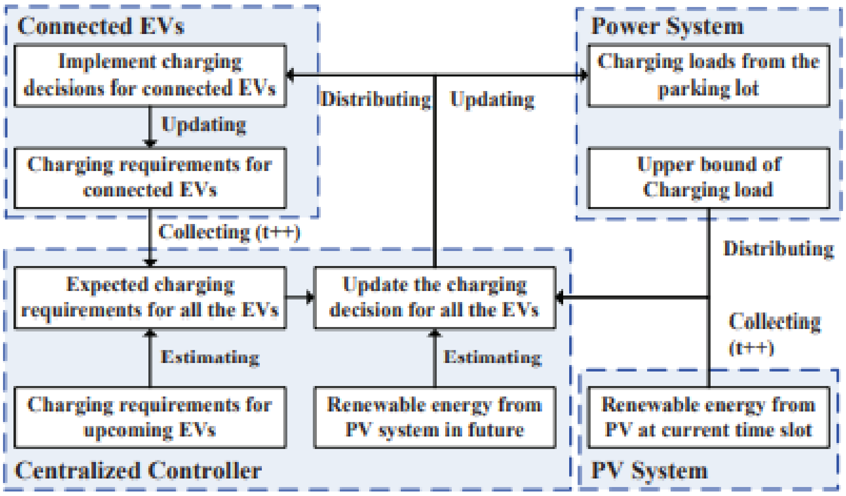
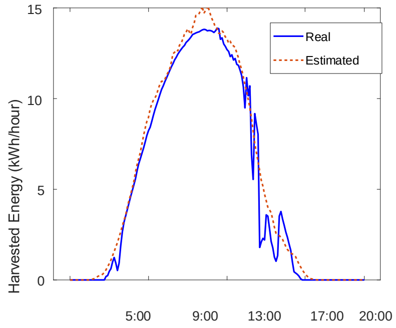


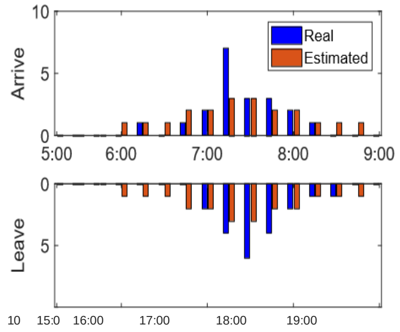
Fig. 8. The sequence of operation of the DCSS.

VI. RESULTS AND DISCUSSION

Simulation results are obtained by considering one day as a total time period and one quarter-hour be a time slot, such that T=96. The available solar energy is shown in 9(a) and the arrival and departure times of the vehicles are shown in Fig. 9(b).

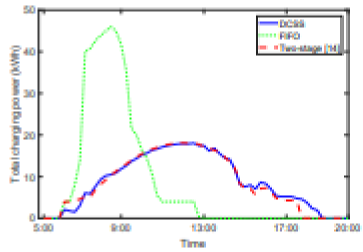


(a) The solar energy

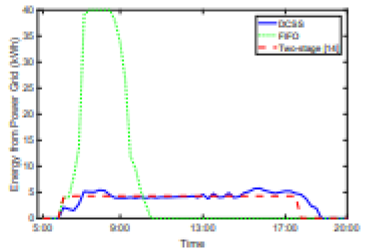


(b) The arrival and departure times of EVs

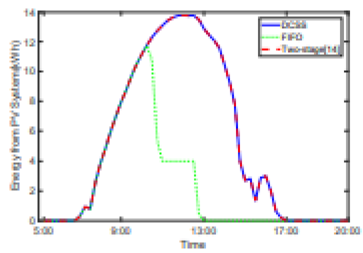
Fig. 9.Simulation of a) Collected Solar energy output b) Arrival and departure times of EVs



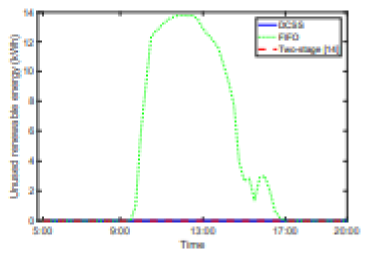
(a) $\bar{E}_t$



(b) E_t^G

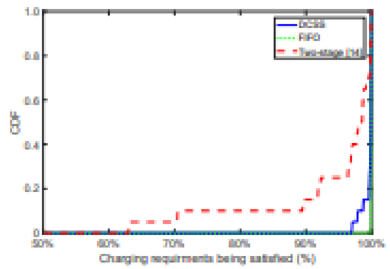


(c) $E_t^R - E_t^{R0}$

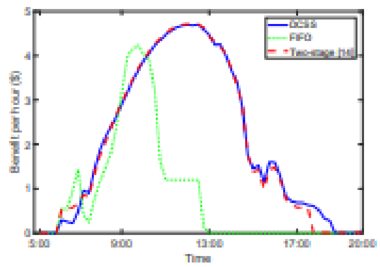


(d) E_t^{R0}

Fig.10. Simulation results: a) The total charging load needed for the parking lot; b) The total output energy of the Power Grid; c) The total output energy collected from the PV system; d) The total amount of excess solar energy.



(a) CDF of $\sum_t E_{i,t}/R_i^O$



(b) $C_t^{\bar{t}}$

Fig. 11. a) the CDF of the total charging load needed; b) The total benefit of the parking lot

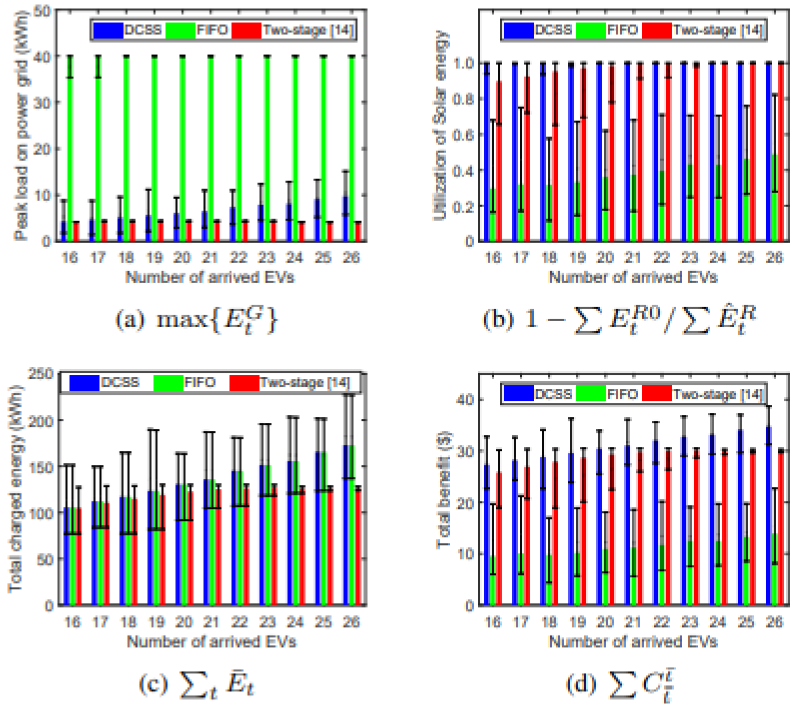


Fig.12. a) The Maximum load of the power grid; b) Amount of solar energy utilized; c) The energy charged to the EVs; d) The total benefit of the parking lot.

VII. CONCLUSION

An optimal solution is provided for the dynamic problem of charging electric vehicles in a parking lot at offices or institutions which are power supplied by PV-grid. We created a parking lot benefit maximization issue based on real-time data provided by the controller and forecast values charging load for upcoming EVs and available solar energy output. Then we derive the system parameters and their interrelations, from which necessary conditions are extracted to get the optimal solution for the problem. Finally, DCSS makes the optimal charging decision based on the data gathered by the controller. Simulation results proved the effectiveness of the suggested charging schedule strategy, which can considerably boost the parking lot's benefit while also meeting the charging needs of all linked EVs.

In many ways, the suggested DCSS can be expanded and enhanced. First, it reduces peak load on the power grid. It reduces wastage of solar energy as the vehicles connected to charge quickly and solar energy is used as effectively.

REFERENCES

[1] United Nations Framework Convention on Climate Change (UNFCCC). How human activities produce greenhouse gases. http://unfccc.int/cop3/fccc/climate/fact22.htm, 2000.

[2] P. Nunes, R. Figueiredo, and M. C. Brito. The use of parking lots to solar-charge electric vehicles. *Renew. Sustainable Energy Rev.*, 66:679– 693, 2016.

[3] X. Fang, S. Misra, G. Xue, and D. Yang. Smart grid the new and improved power grid: A survey. *IEEE Commun. Surv. Tutor.*, 14(4):944– 980.

[4] Z. M. Fadlullah, D. M. Quan, N. Kato, and I. Stojmenovic. GTES: An optimized game-theoretic demand-side management scheme for smart grid. *IEEE Syst. J.*, 8(2):588–597, 2014.

[5] R. Deng, Z. Yang, M. Chow, and J. Chen. A survey on demand response in smart grids: Mathematical models and approaches. *IEEE Trans. Ind. Informat.*, 11(3):570–582, 2015.

[6] A. Mohamed, V. Salehi, T. Ma, and O. A. Mohammed. Real-time energy management algorithm for plug-in hybrid electric vehicle charging parks involving sustainable energy. *IEEE Trans. Sustain. Energy*, 5(2):577– 586, 2014.

[7] W. Tushar, C. Yuen, S. Huang, D. B. Smith, and H. V. Poor. Cost minimization of charging stations with photovoltaics: An approach with EV classification. *IEEE Trans. Intell. Transp. Syst.*, 17(1):156–169, 2016.

[8] H. Liang, B. J. Choi, W. Zhuang, and X. Shen. Optimizing the energy delivery via V2G systems based on stochastic inventory theory. *IEEE Trans. Smart Grid*, 4(4):2230–2243, 2013.

[9] Z. Wei, Y. Li, Y. Zhang, and L. Cai. Intelligent parking garage EV charging scheduling considering battery charging characteristic. *IEEE Trans. Ind. Electron.*, 65(3):2806–2816, 2018.

[10] R. Wang, G. Xiao, and P. Wang. Hybrid centralized-decentralized (HCD) charging control of electric vehicles. *IEEE Trans. Veh. Technol.*, 66(8):6728 – 6741, 2017.

[11] Y. Kim, J. Kwak, and S. Chong. Dynamic pricing, scheduling, and energy management for profit maximization in PHEV charging stations. *IEEE Trans. Veh. Technol.*, 66(2):1011–1026, 2017.

[12] C. Jin, X. Sheng, and P. Ghosh. Optimized electric vehicle charging with intermittent renewable energy sources. *IEEE J. Sel. Topics Signal Process.*, 8(6):1063–1072, 2014.

[13] L. Zhou, F. Li, C. Gu, Z. Hu, and S. Le Blond. Cost/benefit assessment of a smart distribution system with intelligent electric vehicle charging. *IEEE Trans. Smart Grid*, 5(2):839–847, 2014.

[14] R. Wang, P. Wang, and G. Xiao. Two-stage mechanism for massive electric vehicle charging involving renewable energy. *IEEE Trans. Veh. Technol.*, 65(6):4159–4171, 2016.

[15] Y. Liu, R. Deng, and H. Liang. Game-theoretic control of PHEV charging with power flow analysis. *AIMS ENERGY*, 4(2):379–396, 2016.

[16] T. Zhang, W. Chen, Z. Han, and Z. Cao. Charging scheduling of electric vehicles with local renewable energy under uncertain electric vehicle arrival and grid power price. *IEEE Trans. Veh. Technol.*, 63(6):2600– 2612, 2014.

[17] M. Wang, H. Liang, R. Zhang, R. Deng, and X. Shen. Mobility-aware coordinated charging for electric vehicles in VANET-enhanced smart grid. *IEEE J. Sel. Areas Commun.*, 32(7):1344–1360, 2014.

[18] H. Farzin, M. Fotuhi-Firuzabad, and M. Moeini-Aghtaie. Reliability studies of modern distribution systems integrated with renewable generation and parking lots. *IEEE Trans. Sustain. Energy*, 8(1):431–440, 2017.

[19] L. Liu, F. Kong, X. Liu, Y. Peng, and Q. Wang. A review on electric vehicles interacting with renewable energy in smart grid. *Renew.*
Sustainable Energy Rev., 51:648–661, 2015.

[20] L. Yang, J. Zhang, and H. V. Poor. Risk-aware day-ahead scheduling and real-time dispatch for electric vehicle charging. *IEEE Trans. Smart Grid*, 5(2):693–702, 2014.

[21] W. Lee, L. Xiang, R. Schober, and V. W. Wong. Electric vehicle charging stations with renewable power generators: A game theoretical analysis. *IEEE Trans. Smart Grid*, 6(2):608–617, 2015.

[22] P. Ponticel. SAE standard on EV charging connector approved. *Development*, 2011:10–17, 2010.

[23] T. Ma and O. A. Mohammed. Optimal charging of plug-in electric vehicles for a car-park infrastructure. *IEEE Trans. Ind. Appl.*, 50(4):2323– 2330, 2014.

[24] P. Bacher, H. Madsen, and H. A. Nielsen. Online short-term solar power forecasting. *Solar Energy*, 83(10):1772–1783, 2009.

[25] B. Wolff, E. Lorenz, and O. Kramer. Statistical learning for short-term photovoltaic power predictions. In *Computational Sustainability*, pages 31–45. Springer, 2016.

[26] X. Liang, X. Li, R. Lu, X. Lin, and X. Shen. UDP: Usage-based dynamic pricing with privacy preservation for smart grid. *IEEE Trans. Smart Grid*, 4(1):141–150, 2013.

[27] E. Veldman and R. A Verzijlbergh. Distribution grid impacts of smart electric vehicle charging from different perspectives. *IEEE Trans. Smart Grid*, 6(1):333–342, 2015.

[28] Z. Liu, Q. Wu, S. Huang, L. Wang, M. Shahidehpour, and Y. Xue. Optimal day-ahead charging scheduling of electric vehicles through an aggregative game model. *IEEE Trans. Smart Grid*, pages 1–12, 2017.

[29] S. Boyd and L.n Vandenberghe. *Convex Optimization*. Cambridge university press, 2004.