

# A New Plug in EV Strategy for Mitigation of Power Variations in Distribution systems



J.T. Ramalingeswar, K. Subramanian

**Abstract**—Increasing penetration levels of renewable energy sources in electrical grid distribution systems causes rapid power variations drawing from the penetration levels variation in electrical vehicle charging creates the problem in the unity grid. In this paper a new artificial intelligence control technique is introduced in electrical vehicles in order to reduce the power variations caused by the solar power and high low demand. The fluctuations in electrical vehicle scheduling with energy storage has been studied the main effort is the minimizing of power variations in slack bus from the specified value and high utilization storage capability. Energy forecasting and renewable power generation are major considerations in electrical vehicle scheduling. The fuzzy technique is used to define power storage rate of electrical vehicles. Battery life time was taken as key aspect and parameters that cause battery degradation are considered while prioritizing PEVs for grid support. However, primary purpose of PEV (to travel) is given highest priority by ensuring maximum energy level before starting a trip.

**Index Terms** –PEV, ESU, Fuzzy controller, load scheduling and flattening.

## Nomenclature

$T$	Time period
$A$	Battery drain rate
$\eta$	Efficiency of storage unit
$P$	Charging and discharging ratio
$Q$	Effective storage of battery
$SoC$	State of Charge
$DoD$	Discharging depth
$P_{rate}^t$	Charge rate
$P_{rate}^{min}$	Storage unit power rating
$P_{rate}^{max}$	Storage unit maximum power rating
$P_{rate}^{dif}$	Change of rate of power
$P_{rate}^{ref,t}$	Reference Power
$P_{load}^t$	Power at average load demand
$P_{es}^{t,c}, P_{ev}^{t,c}$	Charging rate of EV and ESU
$ES^{in}, EV^{in}$	ES and EV storage capacity
$SoC^{ES}, SoC^{EV}$	ES and EV energy vectors

$ES^N, EV^M$	Energy storage vectors at grid side
$E_{bal}^t$	Required energy at time t
$E_{es}^{cap,i}$	Energy storage unit vector
$E_{ev}^{cap,i}$	Vehicle energy capacity
$E_{es}^{i,t}$	Levels of energy at time t
$E_{ev}^{i,t}$	Plug-in- EV energy
$E_{es(t)}^{4dish}$	ESU energy available for discharge in $t^{th}$ interval
$E_{es(t)}^{4chrg}$	Available energy of ES
$E_{ev(t)}^{4dish}$	EV energy available

## I. INTRODUCTION

Electric vehicle unscheduled charging and discharging creates many drawbacks to the utility operation which cause frequency of the grid and voltage deviation will occur. Photo voltaic systems generates maximum power at afternoon time is an another consideration to handle the distribution systems. ICT having an advantage of its effect on electrical vehicles integration [1]. Electrical vehicles can make simple grid ancillary utilities which are load fattening grid support electrical vehicle charge cost reduction. The integration of electric grid and renewable energy sources such as solar, tidal, wind and electrical vehicle have more advantages [2]. Wind power generation mainly depends on atmospheric conditions and solar power generation will depend on sun light irradiation intensity and temperature conditions. However this power generations are not constant and electrical vehicle plugging time period is and defendable. Hence this are the constrains which makes the grid complicity due to the overall power generation system efficiency get reduced.

In this continues power variation condition the real time controlling is required for the overall power generation system. If the controlled of power generation is not good that time the system gets unstable. In order to overcome the drawbacks of grid connected power systems a smart grid technology is used to control and monitor the enter power system. The distribution networks uses the sophisticated method is used in smart grid system to make the overall grid fully flexible [3]. Electrical vehicle is a main part in smart grid and its supply the energy to the grid when the power availability is excess. Otherwise it consume the power from the utility grid based on time schedule. Electrical vehicle technology has been growing worldwide and a huge different in the market during the years 2015-2017. Electrical vehicle integration with the grid causes voltage unbalance, huge power loss and higher frequency fluctuations.

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This disturbances occurred due to the high energy density and less cost of electrical vehicle [4].

In future excess member of electrical vehicles are going to be connected to the distribution systems. The uncertainty in electrical vehicle causes unbalanced charging in patterns. In other hand electrical vehicle will act as a shunt compensator with that the reactive power variation can be balanced in distribution grid connected systems [5]. Most of researchers working on multi way of using electrical vehicles for grid side management. The combination of electrical vehicle and energy storage systems playing a major role in order to determine the level of participation and flexibility in power clarity improvement.

Most of the researchers have been developed different technologies in order to make the electrical vehicles store energy by using different renewable sources. Which are wind and solar photo voltaic systems. In article 11, the authors proposed a technology to utilize the electrical vehicle charging with the wind power generation without fluctuating the power. The author marra proposed a technology in order to mitigate the impact of electrical vehicle on solar power generation. Electrical vehicle generation energy is used to mitigate the PV power fluctuation instead of using for butterfly storage. The author alam has been introduced a technology for supporting the peak-peak load at night time and it is reduced PV impact on energy storage o butterfly without using electrical vehicle [6].

Increasing number of electric vehicles on one hand and increases uncertainty of charging timings on the other hand imposes frequency deviations in the grid. The exploitation of bulk number of PEVs can be a resourceful thing at distribution level to mitigate the impact of solar and wind sources. Solar PV produces maximum power during noon time whereas maximum residential power demand will appear at evening and morning timings [7]. The excess amount of energy produced (during mid-day) by solar PV will be directed to grid (reverse power flow) and hence causes voltage rise. To ensure continuity of power supply from solar PV there must be sufficient storage capacity installed along with it to mitigate the fluctuations. And this is also true for wind power plant. So, to withstand fluctuations caused by both RES and load, large, low cost ESUs needed. To reduce extra investment on storage units, available storage capacity with PEVs can be used which needs no extract investment. Another advantage of storage units' distribution network is instantaneous power demand fluctuations can be compensated whereas conventional generation units takes much time [8].

In this article the unit commitment of plugging electrical vehicle and energy storage is explained by consideration of the features are variation demand and high charging capability.

## II. DETERMINATION OF FLUCTUATIONS IN SOLAR PV AND LOW DEMAND

At distribution level, all the residential loads will be concentrated at evening timings and morning timings, whereas the solar PV output power will be very less or zero during these two timings and also throughout the night. Coincidence of all the vehicles charging at a particular time zone affects the voltage and frequency and leads to power

system instability. Basically electrical vehicles charged during night times as a result the adding of electrical vehicle charging into load requirement causes most bad situation occurred due to the rapid fluctuations in power demand and frequency deviations. As a result, due to this effects caused by the electrical vehicle will be converted to advantage with planning of electrical vehicle plugging. This process can be obtained by strategic commitment at right time. In addition the charging and discharging scheduling can be applied in a proper manner. The electrical vehicle and energy storage systems are the major support to the grid in order to overcome the effect of renewable energy sources fluctuations. The author Danish has considered an active distribution system with to voltage level 20kb and 400v. In addition, four loads, five photo voltage systems, 13 electrical vehicles and three different energy storage units [9].

Consumption power (Loads and Storage (charging)) is taken as '-ve' and generation power (RES and Storage (discharging)) is taken as '+ve'. The balance in energy which is the algebraic sum of consumption and generation need to supplied (if deficit) or consumed (if excess) by grid. It is considered that the grid is always needed to supply some amount of energy to the distribution network. It means that the total generation in the active distribution network won't increase the load demand. Now the goal is to decrease the fluctuations in power flowing from the grid at the maximum possible extent by of exploiting ESU and PEV storage capacity.

In this article, a complete hour is divided into four time intervals and it is a time duration of fifteen minutes. The aggregate power source and load is given in Eq.1. From equation 1 right hand side part indicates photo voltaic power and left hand side part indicates energy storage. Electrical vehicle charging power and energy storage discharging power at fifteenth minute is given in Eq.2.

$$P_{bal}^t = P_{res}^t - P_{load}^t - P_{es}^{t,c} - P_{pev}^{t,c} + P_{es}^{t,dc} + P_{pev}^{t,dc} \quad (1)$$

$$E_{bal}^t = \int_{t=1}^{t+15} P_{bal}^t(t) * dt \quad (2)$$

$$E_{sneed}^t = E_{bal}^{t+1} - E_{spec}^{slack} \quad (3)$$

## III. DETERMINATION OF EXISTED ENERGY STORAGE CAPACITY

### A. Electrical Vehicle and Energy Storage Penetration.

The continues controlling of electrical vehicle and energy storage units energy levels are required to plan the charging and discharging time intervals. The term DOS is assumed that it is enabled that sophisticated information is available. In addition the owner of electrical vehicle has made a contract to participate Ingrid power generation activity such as voltage regulation and frequency management at demand side. The storage of butterfly charging and discharging are the constraints in order to determine the life time and performance of the butterfly.

Battery life time will depends on so many constraints and it is very complex problem to Annalise for a particular electrical vehicle application. In that the one as objective is to determine the rated power and energy fluctuations in an hour. The availability of energy storage capacity, energy required to store the energy at day time is given in below equations.

The storage capacity of energy is calculated from the energy storage levels. The energy storage levels during a time period t is followed as shown below.

$$P_{rate}^{min} \leq P(t) \leq P_{rate}^{max} \quad (4)$$

$$P_{rate}^t \leq | P_{rate}^{t-1} - P_{rate}^{ref} | \quad (5)$$

$$E_{es}^{4dish}(t) = \sum_{i=1}^N \{ [E_{es}^{i,t}] - [0.2 * E_{es}^{cap,i}] \} \quad (6)$$

$$E_{ev}^{4dish}(t) = \sum_i^M \{ [E_{es}^{i,t}] - [0.2 * E_{es}^{cap,i}] \} \quad (7)$$

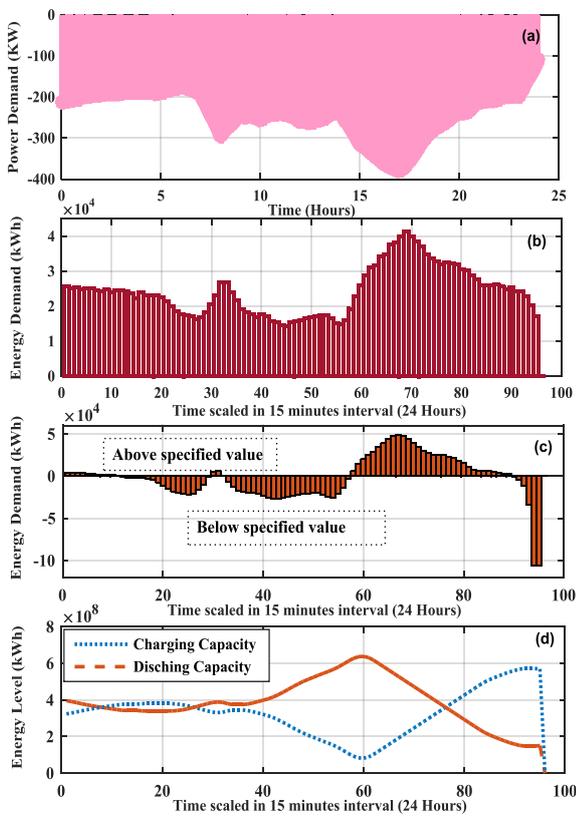


Fig. 3.1. Power and energy fluctuations (a) Load demand (24 hour scale) (b) Energy Demand (15 minute intervals) (c) Energy deviation on the grid over a specified value (d) Available storage capacity for charging and discharging.

$$E_{es}^{4chrg}(t) = \sum_{i=1}^N \{ [0.8 * E_{es}^{cap,i}] - [E_{es}^{i,t}] \} \quad (8)$$

$$E_{ev}^{4chrg}(t) = \sum_{i=1}^M \{ [0.8 * E_{ev}^{cap,i}] - [E_{ev}^{i,t}] \} \quad (9)$$

$$E_{avail}^{4disch} = E_{es}^{4disch}(t) + E_{ev}^{4disch}(t) \quad (10)$$

$$E_{avail}^{4chrg} = E_{es}^{4chrg}(t) + E_{ev}^{4chrg}(t) \quad (11)$$

$$E_{savail}^t = \begin{cases} E_{avail}^{4disch}(t) & \text{for discharging} \\ E_{avail}^{4chrg}(t) & \text{for charging} \end{cases} \quad (12)$$

$$E_{sneed}^t = \begin{cases} \text{For Discharging ;} & \text{if } p > 1 \\ \text{For Charing ;} & \text{if } p < 1 \end{cases} \quad (13)$$

In Fig. 3.1(a), load demand (equation. (2.1)) is shown in a 24 hour scale, and the same is represented in terms of energy (equation. (2.2)) in Fig.3.1 (b). Deviation from the specified energy drawing from the grid is represented in terms of energy deviations for each interval 't' (Fig.3.1(c)).

#### IV. ELECTRICAL VEHICLE MOBILITY MODEL

Electrical vehicle mobility model gives information regarding availability of vehicle during the day and change in its SoC. To determine the electrical vehicle arrival time period and departure time period by using below equation.

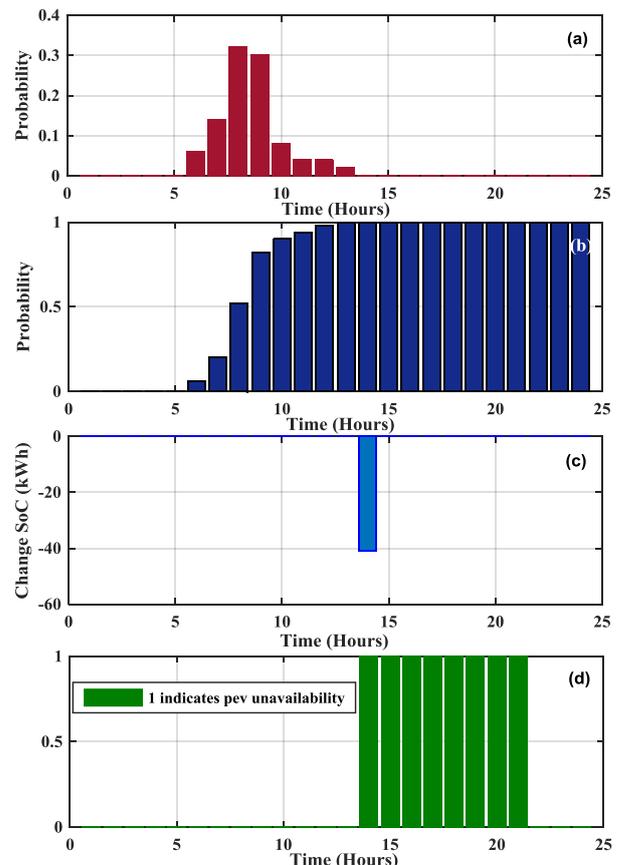


Fig. 4.1. (a) PDF to commute (b) CDF to commute (c) Change in SoC of PEV-5 (d) PEV-5 availability during a day

As an example, probability distribution function (PDF) and CDF are shown in Figure. 4.1(a) and 4.1(b) for commute trip (for PEV-5). Unavailability (away/trip) of the vehicle can be identified as the time zone where CDF value is in between its minimum and maximum. The time instant where the CDF is having its first non-zero value is taken as the starting time of a trip (Fig. 4.1(b)).

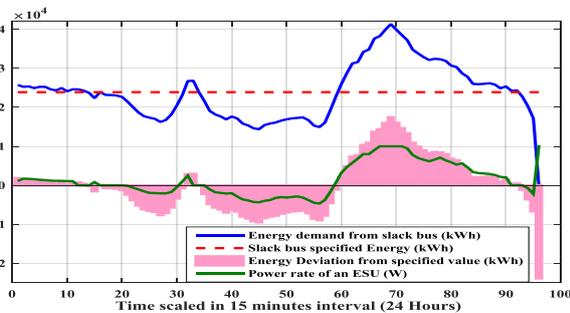
After the trip, vehicle's battery SoC change for a particular PEV (PEV 5) can be seen in the figure. 4.1(c) which is indicated as a negative value as it represents loss of SoC or discharging mode.

Vehicle unavailability (away/trip) of PEV 5 is shown in fig.4.1(d) where ‘1’ indicates away and ‘0’ indicates available at plug point/home. As the main purpose of the vehicle is to travel, ancillary support should not disturb the owner regular trips. In this regard, the prime constraint of PEV is to ensure maximum SoC before it starts for a trip. The SoC of the PEV at the time when PEV arrives at plug point after trip is calculated using equation (4.1). SoC and  $P_{rate}^t$  is taken as zero during trip hours which inturn helps to eliminate that particular PEV from grid support. The effect of unexpected trip delays and unscheduled plugging (mostly for charging) are not considered in this work.

**V. COORDINATION OF ELECTRIC VEHICLE AND ENERGY STORAGE UNIT**

If the electric vehicle in charging mode, the rate of change of power is greater than zero and it indicates that the charging space available in storage unit. In other hand, the electric vehicle in discharging mode then the rate of change of power is less than one which indicates that the storage capacity of electricity vehicle discharge. In this article, the strategy is proposed to control the charging and discharging rate of power. The fluctuations in storage power is shown in Fig.5.1.

In this article, it is desirable to maintain power drawing from grid closer to specified value in order to reduce the spinning reserves by the utility. In this work an attempt is made to effectively utilize all available storage capacity to maintain power drawing from the grid as flat as possible and closer to the specified value. Flowchart (Figure. 5.2) explains prioritization procedure while selecting storage units for grid support.

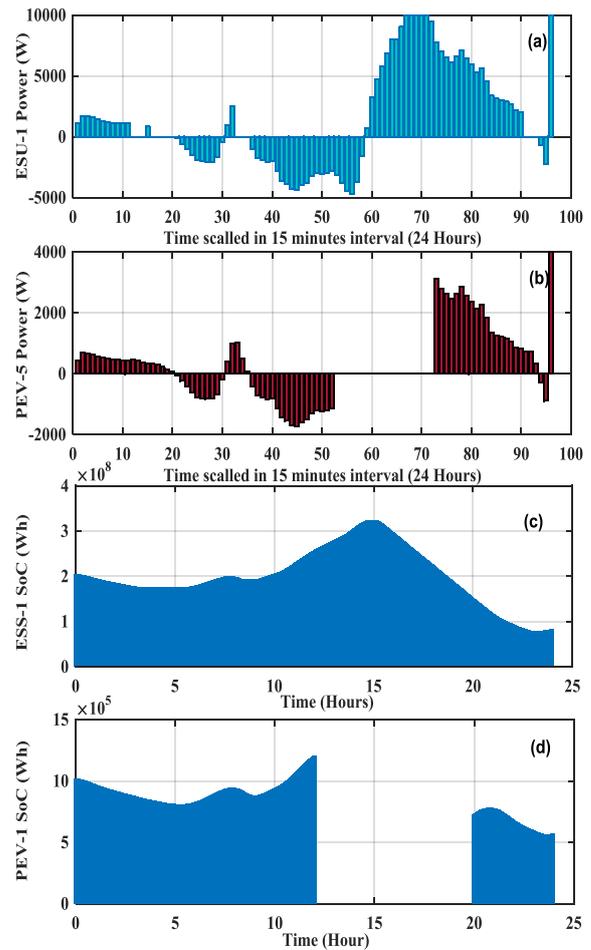


**Fig. 5.1. Power fluctuations of slack bus**

The flow of algorithm is explained as a flow chart in Figure. 5.2. It is assumed that the PEVs are under DSO monitoring control all the time and are authenticated for grid support. Smart tariff and incentives for grid support are not considered in this work.

**VI. SIMULATION RESULTS AND DISCUSSION**

Charging and discharging power rates for ESU and PEVs are shown in Fig. 6.1(a & b). Power rate of ESU-1 is shown in Fig. 6.1(a) and power rate of PEV-5 is shown in Fig. 6.1(b). During away period (during trip) PEV is assumed to have zero power rate and zero SoC level. This assumption is made in order to exclude respective PEV. Respective Energy or SoC levels of storage units are shown in Fig. 6.1(c & d). SoC level of ESU-1 is shown in Figure 6.1(c) and that of PEV-5 is shown in Figure. 6.1(d). The energy level of PEV before the trip time was ensured to be up to 80% of its maximum capacity (trip requirement).



**Fig. 6.1. Storage unit’s charging and discharging rates(‘-’ Charging, ‘+’ Discharging): (a) ESS-1 (b) PEV-5 and Storage unit’s SoC levels: (c) ESU-1 (d) PEV-5**

Different PEVs will have different trip conditions and mileages. At the time of arrival, SoC level is calculated by using trip length, mileage and battery efficiency.

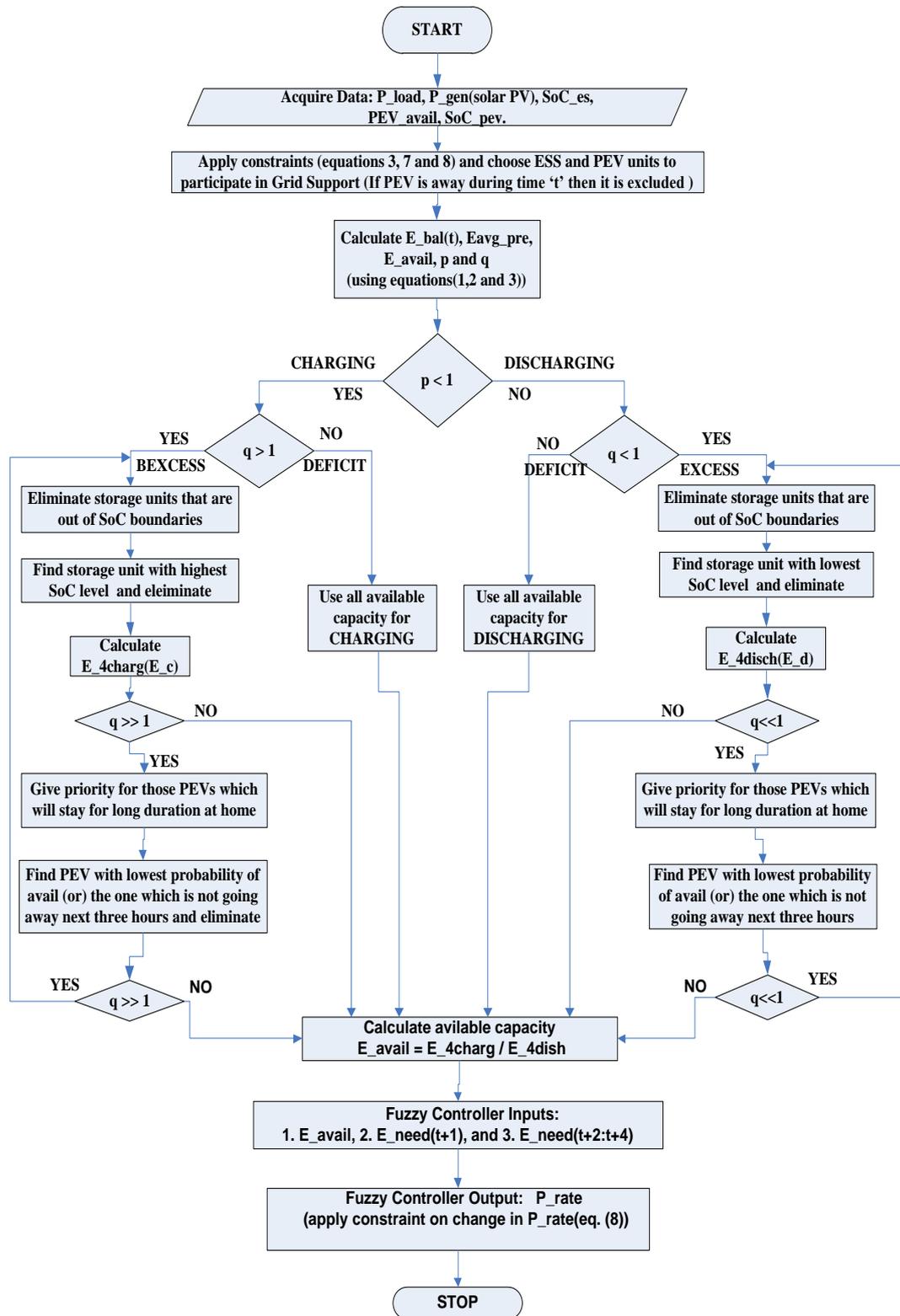


Fig. 5.2. Proposed PEV charging strategy flowchart representation.

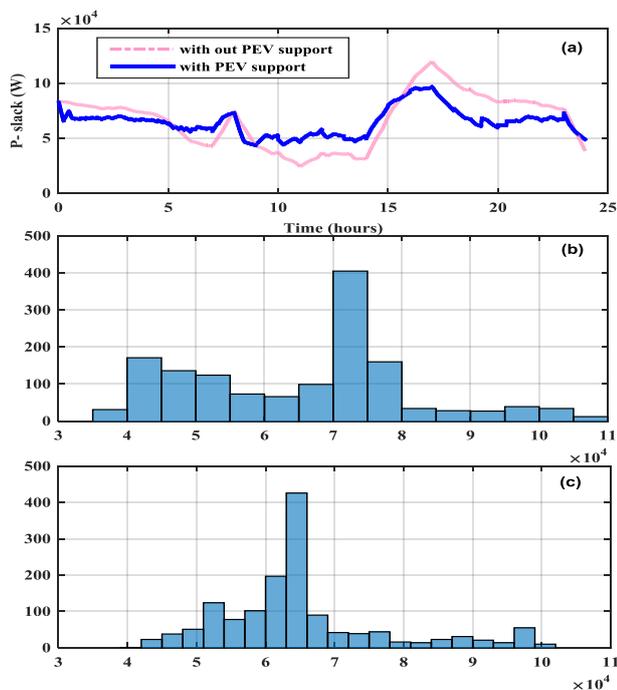


Fig. 6.2. Slack bus power comparison and its variation

## VII. CONCLUSION

The forecasted power fluctuations on slack bus during upcoming hours are taken into account. After elimination of storage units that are not suitable for grid support, power rate is decided based on current energy demand, energy demand estimated during next hour and available storage capacity. The proposed control strategy has considered all the factors that affect maximum utilization of storage capacity while minimizing battery degradation. Results shows that proposed control strategy effectively reduces deviations in power drawing from grid. It indirectly mitigates distribution side load and solar PV power fluctuations. Effect of time interval duration is also studied and it can be concluded that lesser the time interval more accurate will be the monitoring and scheduling of available storage. This paper mainly focuses on effective utilization of both ESU and PEV storage capacities in coordination. The forecasted power fluctuations on slack bus during upcoming hours are taken into account. After elimination of storage units that are not suitable for grid support, power rate is decided based on current energy demand, energy demand estimated during next hour and available storage capacity. The proposed control strategy has considered all the factors that affect maximum utilization of storage capacity while minimizing battery degradation. Results shows that proposed control strategy effectively reduces deviations in power drawing from grid. It indirectly mitigates distribution side load and solar PV power fluctuations. Effect of time interval duration is also studied and it can be concluded that lesser the time interval more accurate will be the monitoring and scheduling of available storage.

## REFERENCES

1. N. Rotering and M. Ilic, "Optimal charge control of plug-in hybrid electric vehicles in deregulated electricity markets," *IEEE Trans. Power Syst.*, vol. 26, no. 3, pp. 1021-1029, Aug. 2011.

2. F. Guo, E. Inoa, W. Choi, and J. Wang, "Study on global optimization and control strategy development for a PHEV charging facility," *IEEE Trans. Veh. Technol.*, vol. 61, no. 6, pp. 2431-2441, Jul. 2012.
3. Basha, CH Hussaian, C. Rani, and S. Odofin. "A review on non-isolated inductor coupled dc-dc converter for photovoltaic grid-connected applications." *International Journal of Renewable Energy Research (IJRER)* 7.4 (2017): 1570-1585.
4. S. Kushalini, J. M. Solanki, and N. N. Schulz, "Development of 3-phase unbalanced power flow using PV and PQ models for DG and study of impact of DG models," *IEEE Trans. Power Syst.*, vol. 22, No. 3, pp. 1019-1025, Aug. 2007.
5. Global, E. V. "Outlook 2016, Beyond one million electric cars." International Energy Agency: France (2016).
6. S. Deilami, A. S. Masoum, P. S. Moses, and M. A. S. Masoum, "Real-time coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile," *IEEE Trans. Smart Grid*, vol. 2, no. 3, pp. 456-467, Sep. 2011.
7. K. Clement-Nyns, E. Heasen, and J. Driesen, "The impact of charging hybrid plug-in electric vehicles on a residential distribution grid," *IEEE Trans Psys.*, vol. 25, no. 1, pp. 371-380, Feb. 2010.
8. H. Sikai and D. Infield, "The impact of domestic plug-in hybrid electric vehicles on power distribution system loads," in *Proc. Int. Conf. Power syst. Technol. (POWERCON)*, Hangzhou, china, 2010, pp. 1-7.
9. Padiha-Feltrin, Antonio, Darwin Alexis Quijano Rodezno, and Roberto Asnches Mantovani. "Volt-VAR Multi objective Optimization to peak-load relief and energy efficiency in distribution networks." *IEEE Transactions on Power Delivery* 30.2 (2015): 618-626.

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