Artificial Intelligence Based Load Scheduling for Plugged in Electric Vehicles in Smart Grid

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***Abstract*- Plugged in Electric Vehicles (PHEV's) are enormously eco friendly and highly appreciated transportation system in various developed countries. The PHEV's integration into the conventional grid required significant modifications in order to control load shedding, reducing unit cost, even out peak demands in quest to make a grid reliable. Recent research studies are mainly focusing to counter these issues by employing multi objective optimization techniques. The objective of this method is to reduce demand; energy cost and enhances the presence of PHEV's for charging and discharging by creating substantial scheduling vector. This research work has proposed split scheduling vector to charge and discharge an EV, to achieve the required results by minimizing peak to average demand ratio (PAR) and generate profit for the owners by decreasing the total energy cost.**

Keywords: Demand side management (DSM), Plugged in electric vehicles (PHEVs), Optimal load control, Smart Grid

I. Introduction

Plugged in electric vehicles have various impressive benefits as a main transportation mean. It increases grid reliability and provide protection from sudden power outages, reduce the higher load demands by diverting excessive load to off peak hours, as well as lowering the green house gas emissions (GHGs). These benefits have encouraged governing bodies to develop plans to practically implement this concept on brooder scale. However, current propagation of PHEV's is erratic, discrete and vibrant in conventional grid. Consequently, unsynchronized scheduling of many PHEV's at a time can lead a power grid to destruction [1]. Therefore, this is indispensable to upgrade the conventional utility grids to advance monitoring infrastructure, which should allow duplex communications with ease.

The advance, protected and dynamic communication network connects PHEV's fleets and isolated EVs to smart battery charging systems [2]. The advance ISO/IEC rules for suitable

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electric vehicles connection to the grid is explained in [3]. The precise and well coordinated measurements of energy dispatch can eliminate uncertainties in estimations that can cause serious problems in controlling and optimizing algorithms [4]. A decarbonizes demand response algorithm has been proposed in [5], which derive a method to minimize the GHG emissions and procurement electricity price by contacting retailers to implement localized algorithm for efficient V2G implementation. Many existed approaches focuses on fully independent demand side management (DSM) system by emptying central and scattered load scheduler scheme for PHEVs integration into the smart grid to control the demand. However, hurdles involved between implantation should be countered effectively by applying tertiary action ascendible approach, the first action evaluates the restriction of the EV aggregator, second action optimize the objectives while the last step governs the real-time controlling [6]. The multifunctional intent optimization has been catered to increase aggregator profit whereas it also manages the overall PHEVs being charged [7].

In contrast to the vehicle to grid (V2G) system, Vehicle to building (V2B) theory is particularly implantable, which could be deployed in less than 5 years. In [8] a concept is illustrated to avail PHEVs in vehicle to building system to reduce higher demands, as well as enhancing the atmosphere quality, and minimizing the power outages. In this model the scattered optimization constrains are countered through autonomous building controllers in quest to suppress power demand within a building by non-cooperative method for PHEVs scheduling by employing game theory [9]. A congestion price governing approach for internet traffic optimization is proposed in [10], which maintains the balance between demand and supply. A new EV charging technique is introduced for PHEVs, in which an owner can regulates electricity price according to inclination. Another autonomous method for load controlling for plugged in EVs is anticipated which reduces the higher demand, line losses, and counter voltage fluctuations [11].

The various advance optimization techniques, based on integral linear programming [12], model productive control [13], game theory based load management scheme [14] and credence aggregation based multipurpose particle swarm regulation [15], have been developed in recent research, for finest PHEVs load scheduling, in order to achieve lower energy cost, nominal PAR, suppressed voltage transients in power grid, and minimizing the environmental pollution. Although to generate enough profit margins for PHEV owners, it is still required to reduce charging time for better results.

In this paper a distributed autonomous power controlling technique is proposed, and effectively integrated into the smart metering infrastructure situated at each EV charging both, that regulates the charging and discharging time, leveling the excessive load and reducing the total cost, as well as it generate enticements for PHEV owners credits. To achieve better results linear programming is employed to overcome the multi-objective optimization constraints.

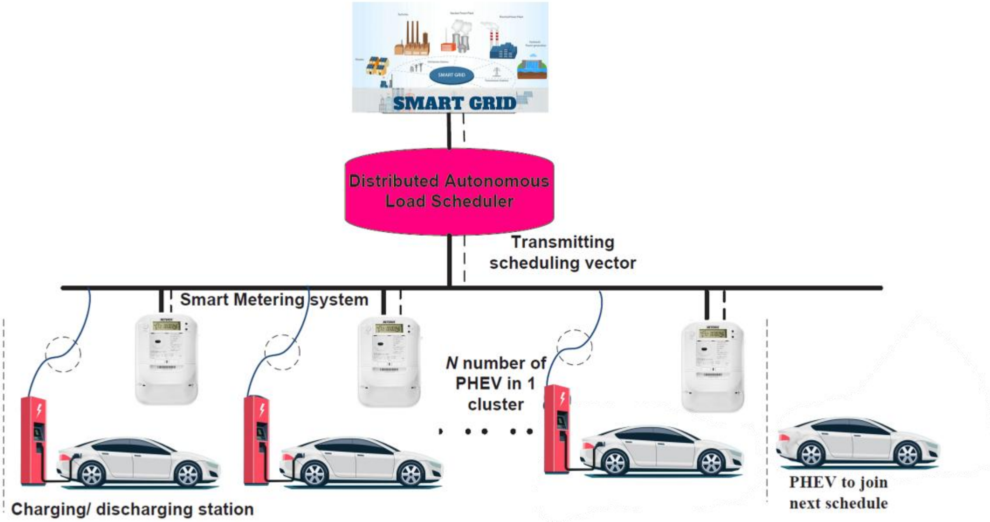

Figure 1: Proposed Model

In this research, we have proposed a distributed fully automatic technique for PHEVs aggregation, it starts working when a PHEV owner tends to charge or discharge its vehicle in a specific time period, with the coordination of smart metering infrastructure. The action begins after assessing the PHEV primary battery capacity, and desired time period. Various PHEVs are divided into different clusters, e.g. highly charged batteries would be discharged in a red time zone, whereas the lower charged batteries would be charge in green time zone. Hence, higher loads are diverted to off peak hours by employing the maximal PHEV numbers which also reduces the cost. By such system a PHEV owner can gain the profit after ten consecutive frequent charging and discharging.

Table 1: Proposed Charging Scheme for PHEVs

Multiple tariff segments	Defined charging schedule for PHEVs		
	Time slots	**Cost (Rs)**	**Preference**
Red (Peak hours)	18:00 to 23:00 hrs	Rs. 16/KWh	Minimum
Yellow (Average load)	07:00 to 23:00 hrs	RS. 10/KWh	Intermediate
Green (Least load)	23:00 to 07:00 hrs	Rs. 07/KWh	Maximum

The motive of this optimization constraint is to reduce energy cost, along with shifting the higher demands to off peak hours to minimize the charging and discharging time. Fig. 1 shows the model of our proposed system, which illustrates the vehicle to grid action (charging/discharging) directed through distributed autonomous load scheduling technique. The Table 1 and Table 2 represent the cost based time slots segmentations for PHEVs cluster management.

Table 2: Proposed Discharging Scheme for PHEVs

Multiple tariff segments	Defined discharging schedule for PHEVs		
	Time slots	**Cost (Rs)**	**Preference**
Red (Peak hours)	18:00 to 23:00 hrs	Rs. 15/KWh	Minimum
Yellow (Average load)	07:00 to 23:00 hrs	RS. 9/KWh	Intermediate
Green (Least load)	23:00 to 07:00 hrs	Rs. 06/KWh	Maximum

II. MATHEMATICAL MODELING

We presume that the real time power dispatch profile of the central grid is autonomously communicated to self updating load scheduler. Suppose there are C clusters containing g numbers of PHEVs at a charging station, which enables multidirectional charging. For charging and discharging, a day is divided into different time slots, given in Table 1 and Table 2. These time slots are represented by T, while v denotes the grid power dispatch profile at time T is:

$$v = [v^1, v^2, \dots \dots \dots \dots .. v^t, v^T] \quad (1)$$

$$PAR = \frac{v_{peak}}{v_{avg}} = \frac{Tmax\ v^t}{\sum v^t} \quad (2)$$

where, PAR shows the proportion of the peak to average load demand, whereas $t \in T$ represents the different time segments, while the charging and discharging is denoted by *(a_i) and (-a_i)* respectively and the vector of time segment T is derived as;

$$a_g = [a_g^1, \dots \dots \dots, a_g^t, a_g^T] \quad (3)$$

$$-a_g = [-a_g^1, \dots \dots \dots, -a_g^t, -a_g^T] \quad (4)$$

where, g denotes the PHEV numbers in a cluster. The encountered constraints faced by the lower and higher energy cluster N while PHEV was either charging or discharging for each individual g in a time division is;

$$-a_g^{max} \leq a_g^t \leq a_g^{max} \quad (5)$$

If an individual PHEV is being charged $a_g^t > 0$ or getting discharged $a_g^t < 0$. The initial charging limit of a battery is h_g^0 and the eventual level of PHEVs battery charging is H_g whereas for charge depleting is $-H_g$. The required power to fulfill user desire for battery charging is V_g^y while for discharging is V_g^z it can be described as;

$$V_g^y = H_g - h_g^0 \quad (6)$$

$$E_g^z = h_g^0 - H_g \quad (7)$$

There are some limitations for charging and discharging PHEVs during time segment t, therefore it should not cross the derived limit of charging and discharging;

$$0 \leq h_g^0 + \sum_{s=1}^{g} H_g \leq y_g \tag{8}$$

$$0 \leq h_g^0 - \sum_{s=1}^{g} H_g \leq y_g \tag{9}$$

where y_g is the total charging capacity of a PHEV. The energy consumed by a fleet of PHEVs while charging/discharging during time segment t is represented by Y_g,

$$Y_g = v^g + \sum_{g=1}^{N} a_g^t \tag{10}$$

$$Y_g = v^g + \sum_{g=1}^{N} -a_g^t \tag{11}$$

III. PROPOSED ALGORITHM

A In order to accomplish the optical load scheduling for PHEVs, we have proposed the following objective function as follows;

a. To minimize the peak demand and to balance the load dispatch profile. The mathematical model of the proposed optimization problem is given as;

$$\min_{\forall a \in C} \frac{T\, max(\sum v_a^t)}{\sum V_a} \tag{12}$$

b. Total energy price; while charging is represented as;

$$\min_{\forall a \in C} \sum_{t=1}^{T} Y_t \tag{13}$$

whilst discharging, the energy price in the proposed optimization problem is derived as;

$$\min_{\forall a \in C} \sum_{t=1}^{T} -Y_t \tag{14}$$

c. The unanimous time of charging/discharging in this optimization problem is depicts as;

$$\min_{\forall a \in C} T(\sum_{t=1}^{C} a_g^t) \qquad (15)$$

$$\min_{\forall a \in C} T(\sum_{t=1}^{C} -a_g^t) \qquad (16)$$

Table 3: Proposed Algorithm for Vehicle to Grid Aggregation

Actions	Proposed Algorithm for Load Scheduling
1	Initiate V_g, h_g^0, H_g and count the available PHEVs to create a cluster
2	If n cluster tend to charge or discharge a PHEV by using existed battery power h_g^0 then
3	Choose the preferred time slot, according to PHEVs desired action
4	Determine V_g^t and execute for finest scheduling vector
5	Momentarily attach the n PHEV cluster to charging both to evaluate limitations
6	If the grid PAR and energy price is suitable, then
7	Attach permanently until the requested task (charging/discharging) accomplished
8	Revise load dispatch profile and scheduling vector and forward it to load re-scheduler
9	End task and re-execute

IV. SIMULATION RESULTS

This section interprets the simulation results carried out to evaluate the performance of proposed model. A smart grid model connected to clusters containing fleet of PHEVs, 10 in each are used. Each PHEVs battery level is checked at initial stage. The distributed autonomous peak to average demand regulator share information with the central grid to allow admission of the load scheduler, to accomplish the charging or discharging requirements according to the requests of multiple PHEV clusters. It is predetermined that, electricity demand is high during morning to evening time and low during midnight to early morning. Hence, in order to soothe the grid profile, the clusters heaving higher battery levels will be initially selected to discharge at peak time, whereas the clusters contains low power will be charged during off peak hours, this strategy will reduce the energy cost as well.

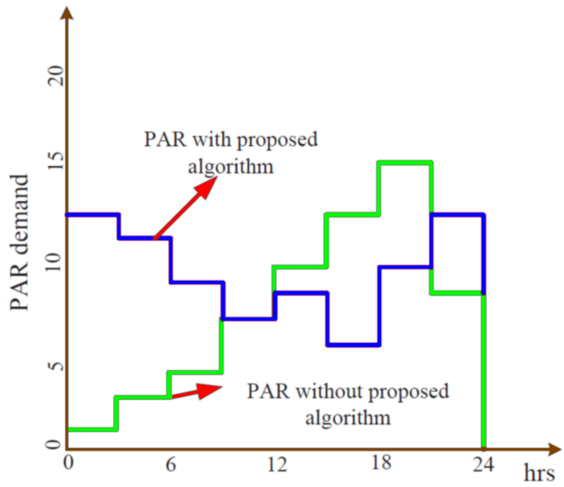

Figure 1: PAR compared to the used time

The time coordination for the derived algorithm is synchronized via employing the linear program based optimal load scheduling method. This algorithm consistently executes up till the convergence and obtaining the desired trade off. These following results are achieved in such manners that it shows the significant improvement in PAR profile, as well as reducing the overall energy price and charging time. Fig. 2 shows the peak to average demand ratio (PAR) in term of acquired time duration. It elaborates the contrast of PAR reduction with and without algorithm execution. The Fig. 3 presents the comparison of buying energy price and charging time of multiple PHEV clusters. The Fig. 4 illustrates the energy selling price as compared to the discharging duration of different PHEV clusters. The energy selling and buying rate is enhanced through tariff based time slot precedence. It eventually minimizes the comprehensive charging price and revamps PAR. It also reduces the required time for charging/discharging of a PHEV cluster by initially analyzing the battery charge state. Fig. 5 represents the total PHEV numbers being charged or discharged in contrast to the iteration numbers in algorithm. As a suitable PHEV enters in this system to accomplish the desired action requested from a fleet of PHEVs for tariff based time slots, it curtail the charging time of a charging station. Thus, this system perfumes efficiently.

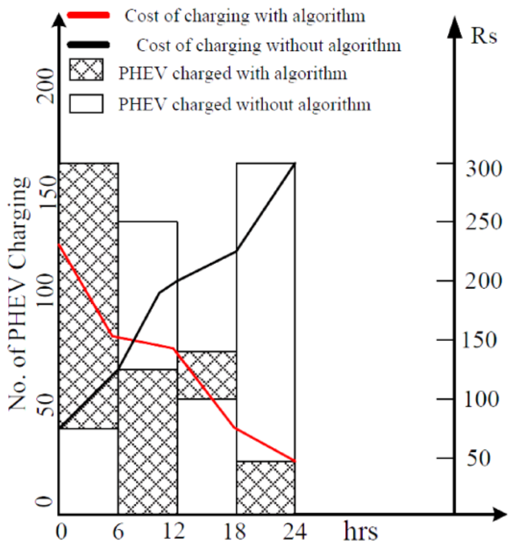

Figure 2: Charging price in contrast to used time

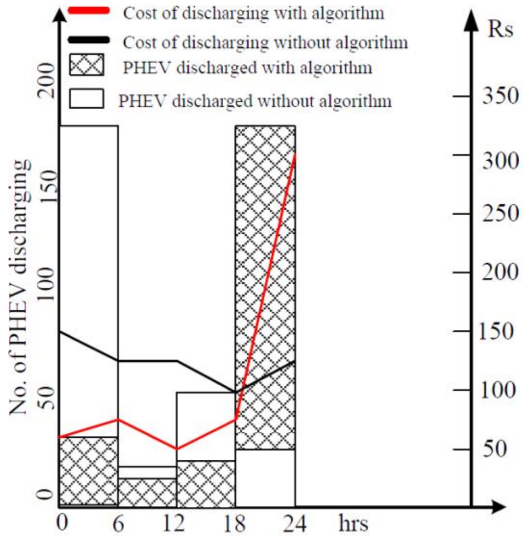

Figure 3: Battery discharging cost in contrast to used time

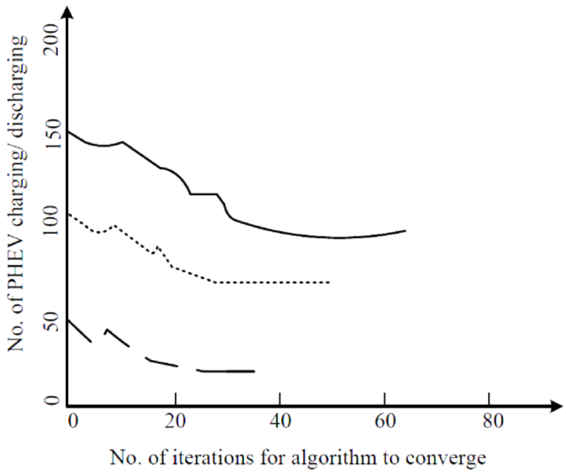

Figure 4: Required iterations for algorithm convergence

V. CONCLUSION

In this paper, a novel PHEV scheduling algorithm has been proposed, which exhibits the artificial intelligence based optimal load scheduling method and leniently integrated into the smart metering infrastructure in order to reduce PAR, energy cost, and also minimizes the charting and discharging time of PHEVs cluster. In contrast to the conventional scheduling algorithms, which only accommodates a single PHEV, or only executes one task, the proposed algorithm is able to simultaneously perform multiple tasks as well as managing various PHEV numbers. The simulation results ensure that the designed optimal algorithm is capable enough to reduce PAR, charging time and overall energy cost.

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