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Demand Side Management Technique to Optimally Schedule Electric Vehicle Loads in Smart Grid

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***Abstract*: Demand-side management (DSM) in smart grids helps the problem of reducing peak load of utilities during certain hourly periods. Based on DSM techniques, peak load hours can be equalized to non-peak load hours therefore users will have less bill payments. In this paper optimal scheduling of Electric Vehicles (EVs) is done based on an objective function formulated to minimize the load variations. Firstly, hourly consumption of load during a day at Koneru Lakshmaiah Education Foundation is considered, EVs load is assumed and flattened the aggregated load curve by optimally scheduling the EVs during off peak hours.**

Keywords: PV Demand Side Management, Electric Vehicles, Load Scheduling.

I. INTRODUCTION

The electricity demand of the World has fully grown apace within the last few years. EVs are increasing day by day and has a significant effect on the grid. Demand side management is an excellent solution against energy demand and electricity price, concern for seasonal change and climate uncertainty in power demand [1]. Demand side management allows grid operators the accessible to develop efficiency and stability of the power grid by levelling the electricity load curve and will play crucial role in the development of grid efficiency and reliability for years to exist. Simultaneously, Demand side management provides a solution for electricity consumers to lower their operating costs by reacting to time-dependent electricity price. Basically, Demand side management has been divided as direct load control (DLC), indirect load control and local energy storage. Direct load control allows utility to regulate isolate their client load demand separately [2]. Indirect Direct load involves consumer participation for their load demand variations according to the change in electricity price changes from time to time and finally, local energy storage authorize both consumer and utility to maintain energy during off-peak and less load phase and make use of the same during peak load period. Demand side management has great impact on liberalized electricity exchange. In general, electricity charge is low during off-peak and low load period and high during peak period [3]. Demand side management supports end user stuff to transfer their load demand from peak to off-peak period or decrease energy consumption during peak period which in turn results in energy saving and cost depletion. Furthermore, with Demand side management policies, optimal scheduling of generated power is also again a challenging task.

In [4] discussed the perspective means of implementing one of the DSM technique DLC. Best suitable technique was developed for the user based on their load profile. In [5] highlighted the impact of DSM during peak load periods, shifted the peak load to off peak hours which maximises the load factor and minimises the system electricity bill.

The consumers load profile on the hourly basis was taken as reference, charging and use of electric vehicles was done with the less use of energy during the peak period in a best possible way. The impact of shifting EVs load from peak periods to off peak periods in [6]. Authors in [7] Maximized the utility revenue by introducing the effects of load shape which resulted in overall increase in sales by means of rise in load demand and total energy consumption.

Energy Conservation technique is used as an effective means of reducing the end-user's consumption which resulted in both peak demand and total energy consumptions thereby reduced the cost of the customers electricity bill in [8]. System load factor is maximized by valley filling technique where there is a net increase in total energy consumption, effects on the load shape were examined in [9]. Distributed algorithms were proposed in [10] for optimally scheduling the EVs in a decentralized manner.

Smoothening the load curve under different pricing strategies of the power grid in a decentralized optimization problem is discussed in [11]. Different types of DSM techniques available in smart grids and load management using genetic algorithm was proposed in [12]. Customers can alter their energy usage with the help of demand response programs to transfer the consumption from high cost hors to low cost hours [13]. Power generation very nearer to load is important in the present scenario instead demand side management can help the situation [14]. Monitoring the power system in real time using cloud computing in smart grids was proposed in [15].

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Penetration of EVs is continuously expected to increase in future therefore there is a need to optimally schedule their charging with the existing resources.
So, in this paper KLEF data of a day is analysed with five EVs and discussed the minimization of the load variations when EVs are connected
along with the base load by optimally generating the schedule of EVs to connect.

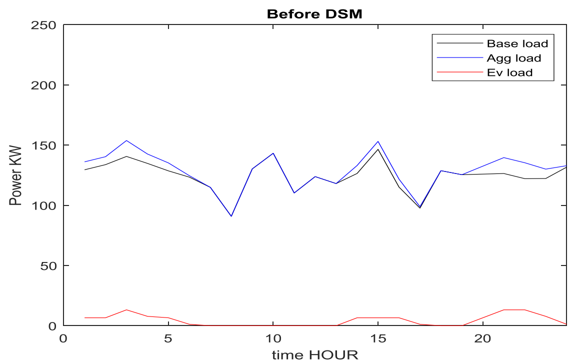

Fig 1: Base load, EV load, aggregated load before DSM

II PROBLEM FORMULATION

It is well known that the peak periods correspond to higher prices. To minimize load fluctuations in the peak hours an objective function is formulated to generate optimal scheduling of EVs which transfer the load from peak period to off peak period. The load curves shown in figure 1 includes base load of a day and EVs load and total aggregated load for each hour. EVs considered here are of 2017 Nissan Leaf model with a total battery capacity [16] of 30 KWh and connected to an onboard charger rating of 6.6 KW. While leaving all EVs [17] are expected to charge to 90% of their capacity.
Objective function can be defined as follows,

$$min \sum_{t=1}^{T} (P_{load}(t) - P_{avg})^2$$

P_{load} can be defined as the sum of the base load and summation of electric vehicle [19] [20] load.

$$P_{load} \text{ (t) =Base load (t) + } \sum_{i=1}^{n} EV_i(t)$$

P_{avg} can be defined as the ratio of sum of base load at each hour and electrical vehicles load [21] to time period of a day (T).

$$P_{avg} = \frac{\sum_{t=1}^{T} Base\ laod\ (t) + \sum_{i=1}^{n} EV\ (t)}{T}$$

Subjected to,

$$\sum_{t=1}^{T} EV_i(t) \leq Battery\ capacity\ \ \forall\ i$$

$$0 \leq EV_i(t) \leq E_{imax}$$

III METHODOLOGY

After considering the daily load curve EVs are placed randomly for charging their batteries in the time periods as mentioned in the Table 1. Zeros indicated in the Table 1 reflects that no EV is connected during that time. EVs are connected to charge in the evening around 16:00 and some in the night around 20:00 till early morning at 6:00 and there by peak loads gets increased during these periods.
Algorithm for scheduling the charging of EVs is shown in Fig 2. After performing the quadratic optimization EVs were scheduled optimally. Fig 3 shows scheduling of EVs before and after DSM.
Fig 4 shows the base load, EV load, aggregated load during each hour of a day after optimal scheduling of EVs.
Fig 5 compares the total aggregated load of a day for each hour before and after DSM results in shifting the EV load from peak hours to off peak hours and there by minimising load variations, minimising the electricity bill in the smart grid [18] environment.

Time	EV1	EV2	EV3	EV4	EV5	Total
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	6.6	0	0	0	0	6.6
5:00	6.6	0	0	0	0	66
6:00	6.6	6.6	0	0	0	13.2
7:00	1.2	6.6	0	0	0	7.8
8:00	0	6.6	0	0	0	6.6
9:00	0	1.2	0	0	0	1.2
10:00	0	0	0	0	0	0
11:00	0	0	0	0	0	0
12:00	0	0	0	0	0	0
13:00	0	0	0	0	0	0
14:00	0	0	6.6	0	0	6.6
15:00	0	0	6.6	0	0	6.6
16:00	0	0	6.6	0	0	6.6
17:00	0	0	1.2	0	0	1.2
18:00	0	0	0	0	0	0
19:00	0	0	0	0	0	0
20:00	0	0	0	6.6	0	6.6
21:00	0	0	0	6.6	6.6	13.2
22:00	0	0	0	6.6	6.6	13.2
23:00	0	0	0	1.2	6.6	7.8
24:00	0	0	0	0	1.2	1.2

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Table 1: Randomly connected EVs before DSM

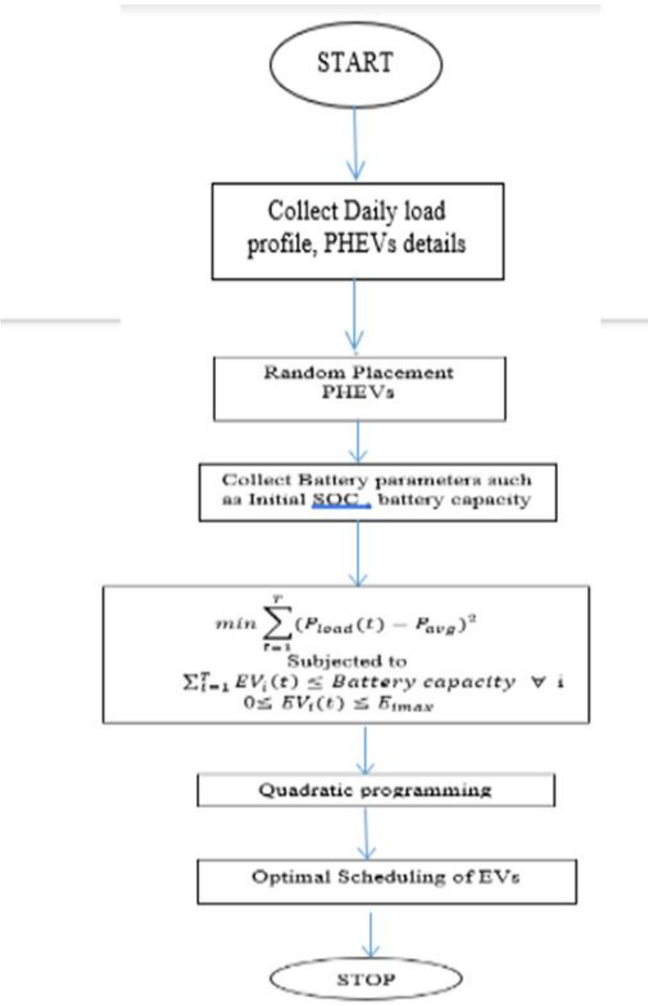

Fig 2: Flow Chart for Optimal Scheduling of EVs

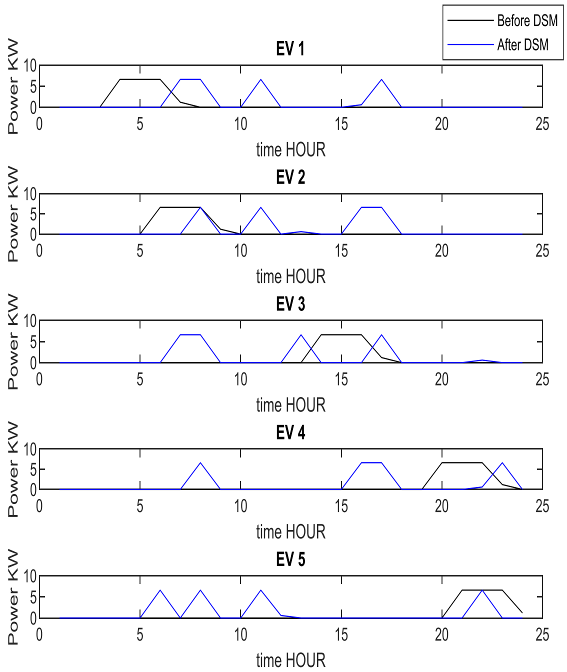

Fig 3: Schedule of EVs before and after DSM

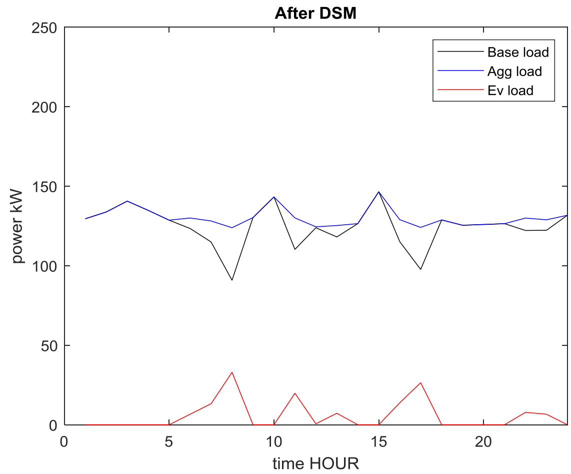

Fig:4 Base load, EV load, aggregated load before DSM

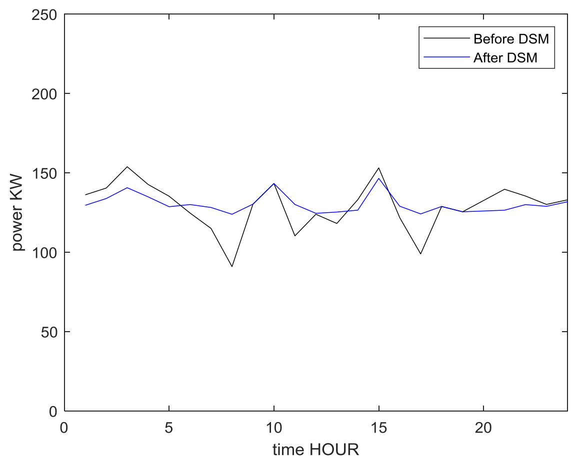

Fig 5: Aggregated load of a day before and after DSM

IV CONCLUSION

The proposed objective function has been worked out in MATLAB environment. Results shows that EVs were optimally scheduled by the proposed objective function for DSM. The results clearly indicate that Peak load caused due to EV charging has been shifted to off peak load and there by overloading in the system is reduced considerably and therefore an impact can be found on reduction in payment of the electricity bill. This paper assumed similar kind of EVs in fast charging mode. It is preferable to consider different models of EVs and different charging rates in future. Stochastic modelling of EVs load based on their trips, system constraints can be included in the work for most efficient execution of the results.

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