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Penetration of Plug-in-Hybrid Electric Vehicles via Distribution Network Reconfiguration with Improved Electric Vehicle Charging Load Model

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Abstract: Decarbonisation of future auto industry and depletion of energy reserves, have promoted plug-in-hybrid electric vehicles (PHEVs) to receive mass acceptance as economical alternative to gasoline fuelled vehicles among the general public. However, power losses due to charging demand of high penetration of PHEVs on distribution grid remain as the main issue. In addition, uncertainties associated with PHEVs have complicated the operations of distribution systems. This paper presents a simulation model to determine the PHEV battery charging load on the power system load profile. Moreover, network reconfiguration technique based on binary particle swarm optimization has been employed to minimize the losses. Case study has been performed on IEEE 33-bus system. Results show that the proposed model can generate a reliable PHEV load profile.

Keywords: distribution system, plug-in-hybrid electric vehicles, power losses, reconfiguration.

I. INTRODUCTION

PHEVs penetration level is expected to increase significantly due to accelerated growth of the PHEV market. This new load will increase power losses of the system. Therefore to accommodate PHEVs, researchers either propose coordinated charging schemes or suggest upgrading of existing system infrastructure [1, 2]. This paper employs second option and handles the issue with reconfiguration technique.

By definition reconfiguration is a method that alters the status of switches in the system to generate new network topology subject to necessary operating constraints.

II. PHEV CHARGING MODEL

PHEVs battery state of charge between 0-80% represents a constant current zone [3]. Thus for system buses at time *t*, vehicle demand is given as:

$$P_{Phev}(t) = E_{Phev}(t) \times I_{Phev}(t) \times m(t) \quad (1)$$

$$P_{\text{phev}}(\text{t}) = \text{D} \times \text{W} \times (1\text{-SOC})/(\text{C-R}) \quad (2)$$

$$P_T = nP_{phev} \quad (3)$$

where P_{phev} is estimated power of each PHEV at time t, P_T is total charging demand of entire vehicle fleet, *D* is vehicles' mileage, *W* is consumed energy, *C* is net capacity of vehicle in kWh, *R* is charging rate and *m* is the loading status of any bus.

III. OBJECTIVE FUNCTION

Reconfiguration problem for power loss minimization is formulated in Eq.(4) where *I* and *R* are *ith* branch current and resistance respectively. Power flow analysis is carried out with Newton raphson power flow.

$$\min P_{loss} = \sum_{i=1}^{N} I_i^2 R_i \quad (4)$$

IV. METHODOLOGY

Step 1- PHEV load profile Generation

It is assumed that all PHEVs are plugged into a 120V/15A electricity outlet and the battery pack could hold 7.21kWh of total energy. PHEVs are deployed on the 33-bus radial distribution system as in study [4]. Refer Fig. 1

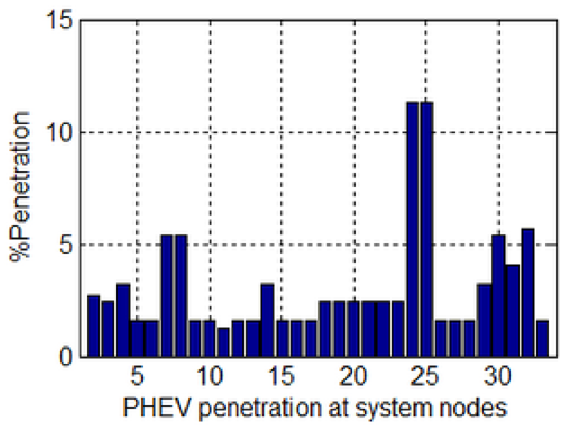

Fig.1. Plug-in-hybrid electric vehicle loading

For simplicity, vehicle charging is considered during

1800 hours to 2300 hours, when the owner returns home from work. The vehicle's start charging time and battery capacity are randomly generated. Depending on battery power, charging duration for each PHEV is determined according to different charging rates. The vehicle load pattern is obtained according to the proposed model. This additional load is aggregated with system base load profile as depicted in Fig.2.

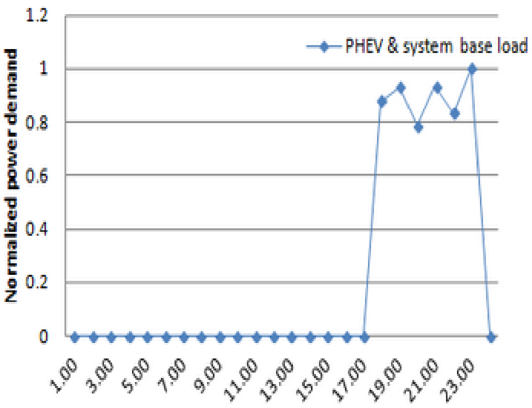

Fig.2. System aggregated load profile

Step 2- Network reconfiguration

Binary particle swarm optimization is utilized to serve the purpose. The algorithm involves random initialization of particles, followed by particle velocity upgrade till optimal solution is obtained.

V. RESULTS

IEEE 33- bus system as shown in Fig.3 has been examined. The power loss with and without reconfiguration with additional vehicle demand at different time slots is tabulated in Table 1. It is evident that maximum base load has increased more than 600 kW for time horizon when PHEVs are connected to the grid. However, reconfiguration has effectively reduced the losses and has enhanced the voltage profile as shown in Fig.4.

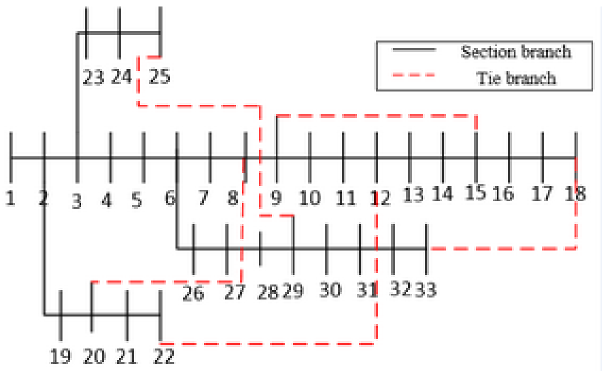

Fig.3. Single line diagram for IEEE 33-bus system

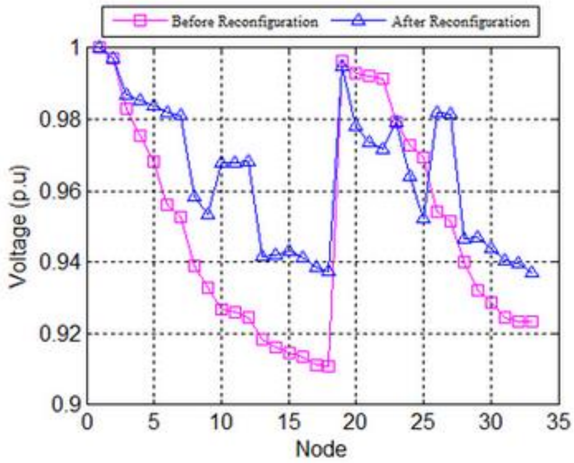

Fig.4. System voltage profile

Table 1 Results for 33-bus system

Hours	**Losses kW**		**Total load MW**	**Tie switches**
	Before NR	**After NR**		
Base case	208.45	138.92	3.7150	7,9,14,32,37
18:00	265.48	172.16	4.3886	7,9,14,32,37
19:00	299.95	129.21	4.6339	2,10,14,28,36
20:00	288.45	182.31	4.4797	7,9,14,28,32
21:00	277.47	184.24	4.5043	7,9,14,32,37
22:00	289.90	197.41	4.5304	6,11,34,36,37
23:00	293.30	190.49	4.6428	7,9,14,32,37

VI. CONCLUSION

In this study, the presented vehicle charging model has determined practical load profile for PHEV fleet proliferation, considering battery uncertainties. The demand growth has been efficiently handled with reconfiguration approach based on BPSO algorithm. Performance of the system has been evaluated on the basis of minimum active power losses. Hence reconfiguration schemes can be used to alleviate the adverse impacts of PHEVs on the distribution system.

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