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Research Article

Optimal Placement of DG in the Distribution System considering Electric Vehicle Charging Station

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ABSTRACT

The increasing acceptance of electric vehicles in the transport industry has led to a significant increase in the number of these vehicles being sold. However, their impact on the electric power market can cause significant changes in the voltage profile and real power losses. The installation of electric vehicle charging station (EVCS) electric vehicle on the distribution system, it is important that distributed generators (DG) are placed at optimal locations. Hence this paper presents a multi-objective Particle Swarm Optimization (PSO) technique that can be used to achieve optimal placement and size DG considering EVCS. The proposed methodology is implemented on IEEE 33 bus system. Optimal sizing and placement of DG is implemented when EVCS is placed at strong, medium and week buses. The results of the study revealed that the proposed multi-objective PSO technique improved the system performance in all the cases.

Key words: Distributed Generators, Electric Vehicle Charging Station, IEEE 33 Bus, Particle Swarm Optimization

1. INTRODUCTION

The rapid increase in temperature and the release of carbon due to the usage of fossil fuels such as coal, crude oil, and natural gas have degraded the ecosystems. Global warming can affect various ecological systems such as the weather and uneven rains. Since most of the population is already looking for other fuel sources, the transportation sector is the primary source of crude oil. Various countries are promoting the use of battery-powered transportation to reduce air pollution. The implementation of this concept can be done through the establishment of a sufficient infrastructure for the charging of electric cars. The need for additional capacity for the electric vehicle charging stations will also be increased.

The electric vehicle charging station should be placed in the appropriate locations in the distribution system. However, this should not be done without conducting an evaluation of its effects on the electrical grid. In order to study the effects of this technology on the electrical grid, a statistical analysis of the electric vehicle charging station is performed using an R&D model in [1]. The addition of the electric vehicle charging station to the distribution system will increase the power requirements of the branches. This issue can affect the thermal stability of the system. In order to minimize the effects of this technology on the electrical grid, the study is conducted in Canada's Ontario [2]. The study aims to analyze the multiple limitations of the electric grid in this region. In [3] A multi-objective function is built to analyze the performance of the electrical distribution network and traffic conditions in order to improve the efficiency of the electric vehicle system. It takes into account the various factors that affect the charging behavior of an EV, such as the time it takes to recharge, the power loss, and the traffic conditions.

The optimal location of an electric vehicle charging station is not only dependent on the type of bus used, but also on the power losses and the voltage profile. In [4] analyzes multiple factors that affect the charging behavior of an EV and develop a strategy that will improve its efficiency.

In [5] proposes a fast charging station (FCS) load that takes into account both the power consumption and the grid voltage of electric vehicles. It is compared to the constant power load and ZIP models. In [6] genetic algorithm is used to optimally position the EVCSs in a distribution system. This method can affect the reliability of the system due to the presence of charging stations. Re-designing the system's RDS could minimize the effects of these stations [7]. In [8] the location of the EVCSs is determined in two stages. The first stage involves calculating the operation spectrum of the vehicle. The second stage involves optimizing the CS location. The operation spectrum is calculated by taking into account the variability of the electric charge and the trip success ratio. In [9] A tri-objective optimization process is performed to minimize the levelized cost of energy and emissions associated with the charging station. It involves the use of batteries and photovoltaic cells. Most studies are focused on the optimal size and location of the charging stations [10]-[14].

2. MULTI-OBJECTIVE PARTICLE SWARM OPTIMIZATION

The Particle Swarm Optimization is inspired by the social behaviours of various organisms such as bird rooking and fish schooling. In a PSO system, the particles are constantly changing their positions in a search space. This method allows the user to perform a population-based search. During flight, the particles' positions are changed according to their experience and the position of their neighbours. The goal of this process is to make the most of the available position of the particles in the search space. The swarm direction of a given particle is determined by the set of particles that are nearby it. The flow chart of PSO technique is shown in Fig. 1.

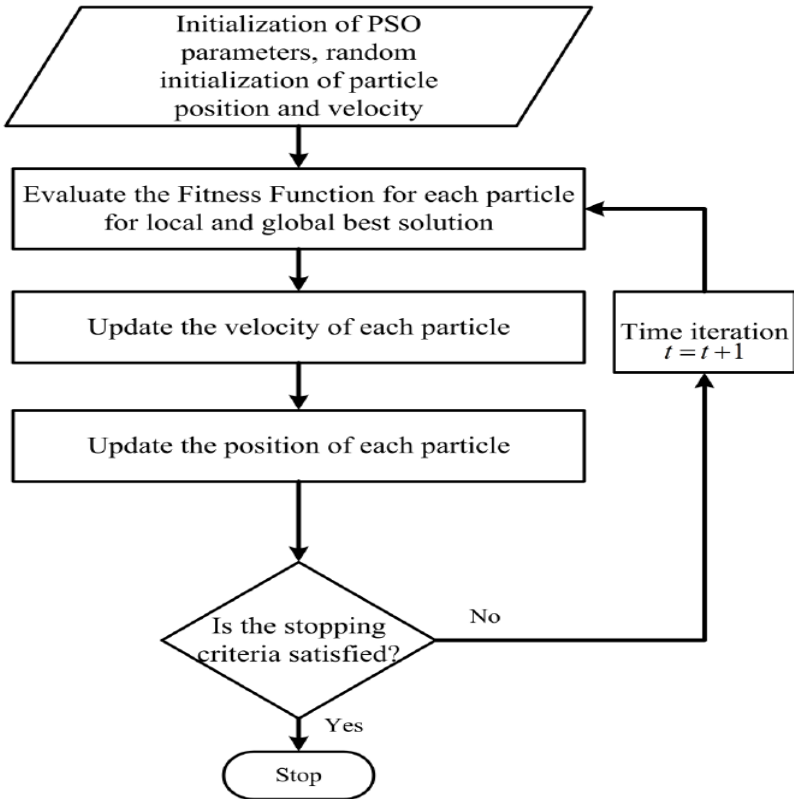

Figure 1: PSO Flow Chart

3. PROBLEM FORMULATION

In this paper a multi-objective Particle Swarm Optimization (PSO) technique is implemented to achieve optimal placement and size DG considering EVCS. The proposed methodology is implemented on IEEE 33 bus system.

The power at any bus is given as

$$S_i = V_i I_i \; or \; P_i + jQ_i = V_i I_i \qquad (1)$$

Where

$V_i = Voltage\ at\ Bus\ i$

$I_i = Current\ at\ Bus\ i$

From the Eq. 1 Current at i[th] bus is given as

$$I_i = \frac{P_i + jQ_i}{V_i} \qquad (2)$$

The real and reactive power at i[th] bus is shown below.

$$P_i = \sum_{K=1}^{n} |Y_{ik} V_i V_k| \cos(\theta_{ik} + \delta_k - \delta_i) \qquad (3)$$

$$Q_i = -\sum_{K=1}^{n} |Y_{ik} V_i V_k| \sin(\theta_{ik} + \delta_k - \delta_i) \qquad (4)$$

The real power losses are given as $I_i^2 R_k$, i.e.,

$$P_{ilosses} = \left(\frac{P_i + jQ_i}{V_i}\right)^2 R_k \qquad (5)$$

The reactive power losses are given as $I_i^2 X_k$, i.e.,

$$Q_{ilosses} = \left(\frac{P_i + jQ_i}{V_i}\right)^2 X_k \qquad (6)$$

4. RESULTS AND DISCUSSION

Now In this paper the proposed Multi-objective PSO algorithm is implemented for optimal allocation of DG considering EVCS on IEEE 33 bus system under the following cases.

1. Placement of EVCS at Strong Bus
2. Placement of EVCS at Medium Bus
3. Placement of EVCS at Week Bus

The standard IEEE 33 bus system is shown in Fig. 2

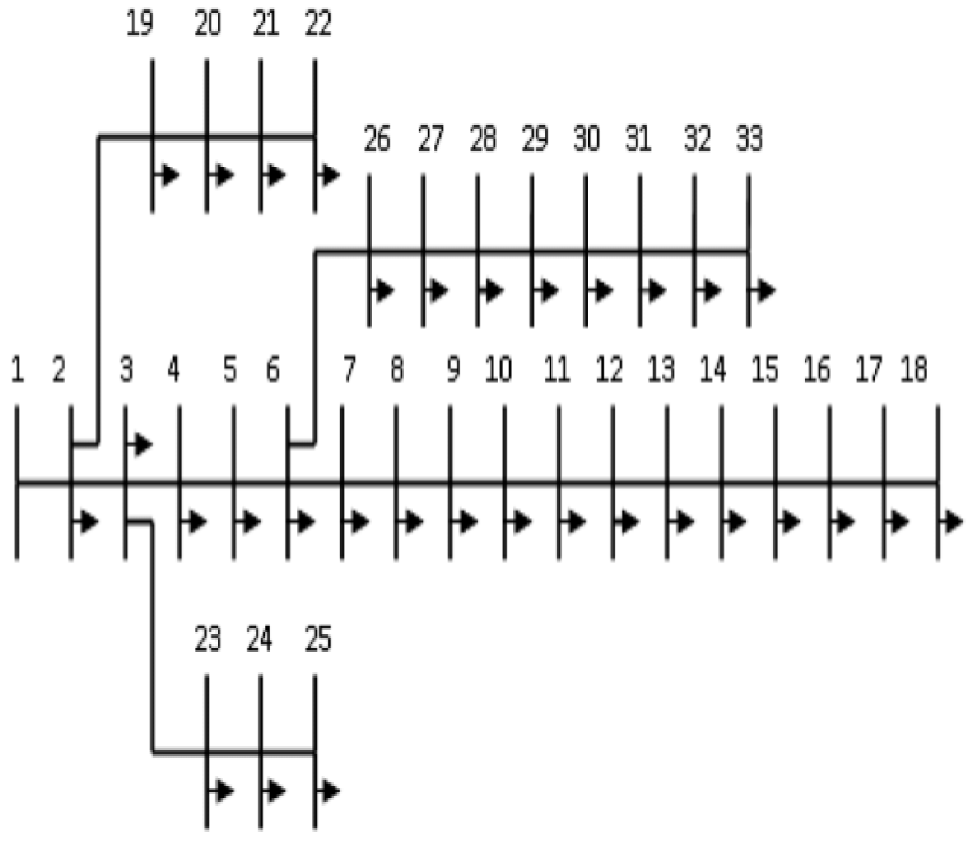

Figure 2: IEEE 33 Bus System

4.1. Placement of EVCS at Strong Bus

In this case EVCS is placed at strong buses i.e., 3, 19, 26. Load flow is applied using proposed Multi-objective PSO technique and voltage profiles are obtained with and without optimal allocation if DG. The voltage profile is shown in Fig. 3.

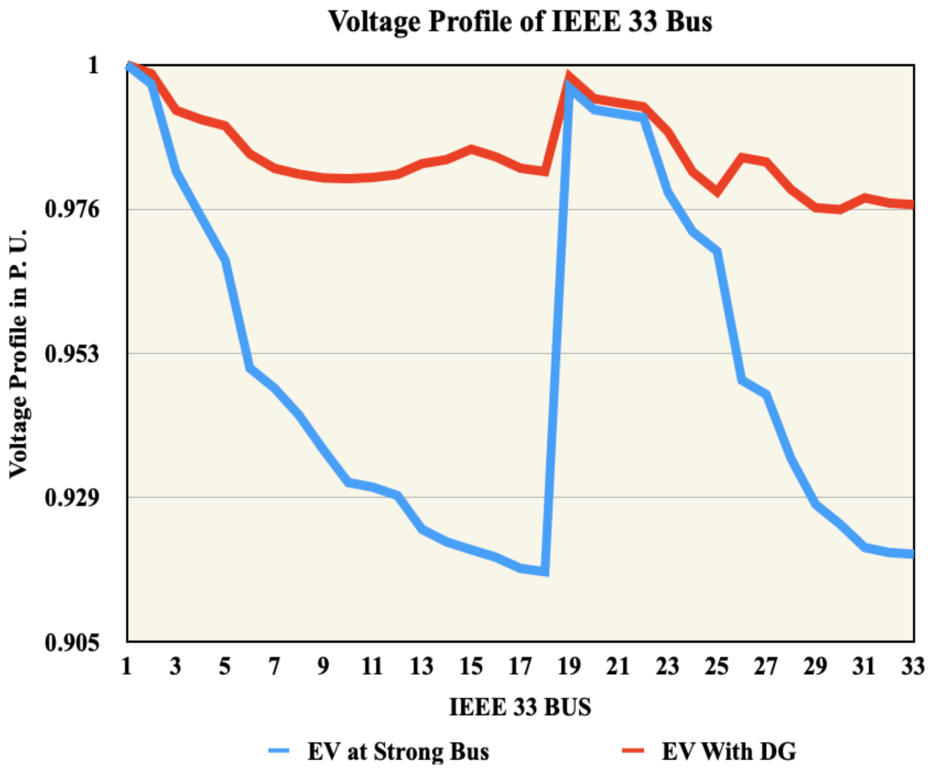

Figure 3: Voltage Profile when EVCS is placed at Strong Bus

Here three DG's are optimally placed at buses 14, 26, 31, and from the above plot it is clearly observed that the voltage profile of IEEE 33 bus system is improved and the total power losses are decreased from 0.231 MW to 0.0996 MW as shown in Fig. 4.

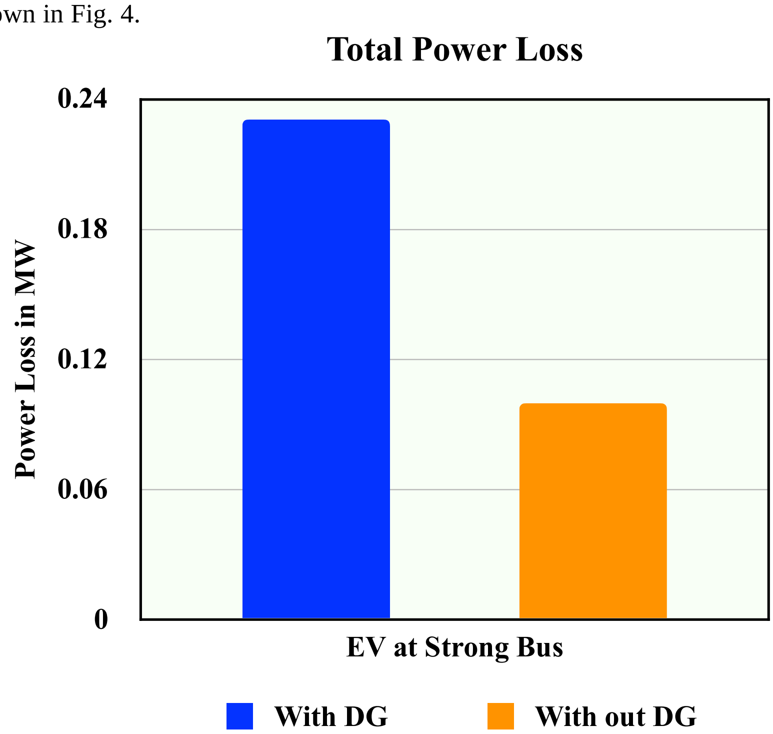

Figure 4: Total Power Loss

4.2. Placement of EVCS at Medium Bus

In this case EVCS is placed at medium buses i.e., 11, 20, 30. Load flow is applied using proposed Multi-objective PSO technique and voltage profiles are obtained with and without optimal allocation if DG. The voltage profile is shown in Fig. 5.

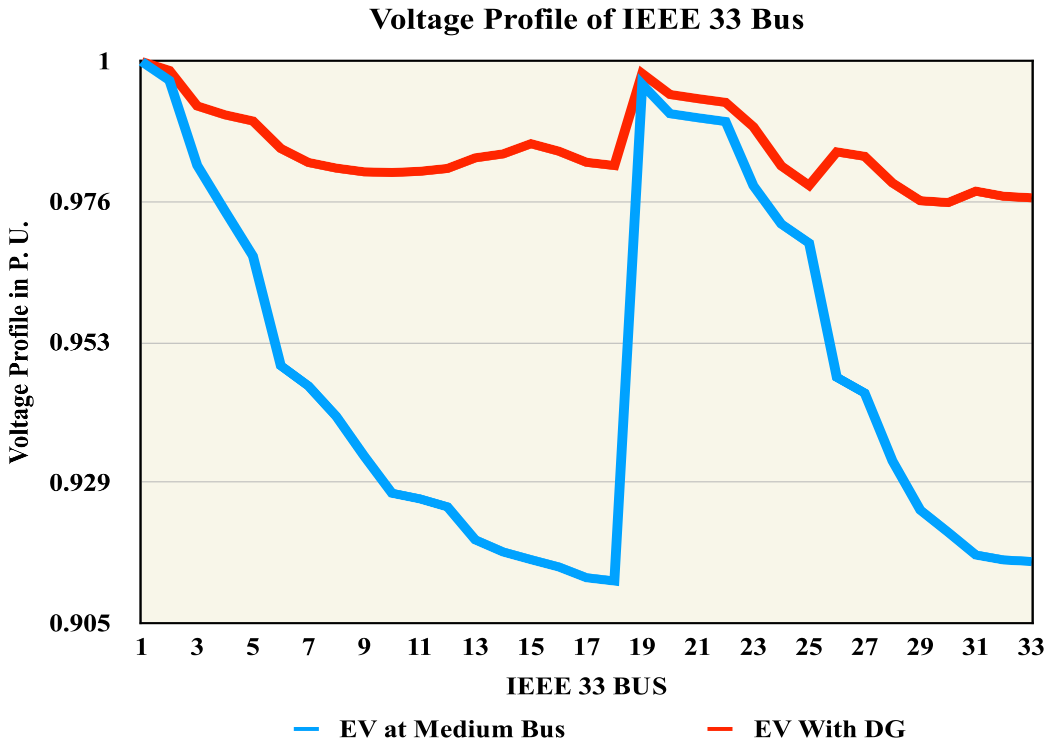

Figure 5: Voltage Profile when EVCS is placed at Medium Bus

Here three DG's are optimally placed at buses 14, 26, 31, and from the above plot it is clearly observed that the voltage profile of IEEE 33 bus system is improved and the total power losses are decreased from 0.2518 MW to 0.1043 MW as shown in Fig. 6.

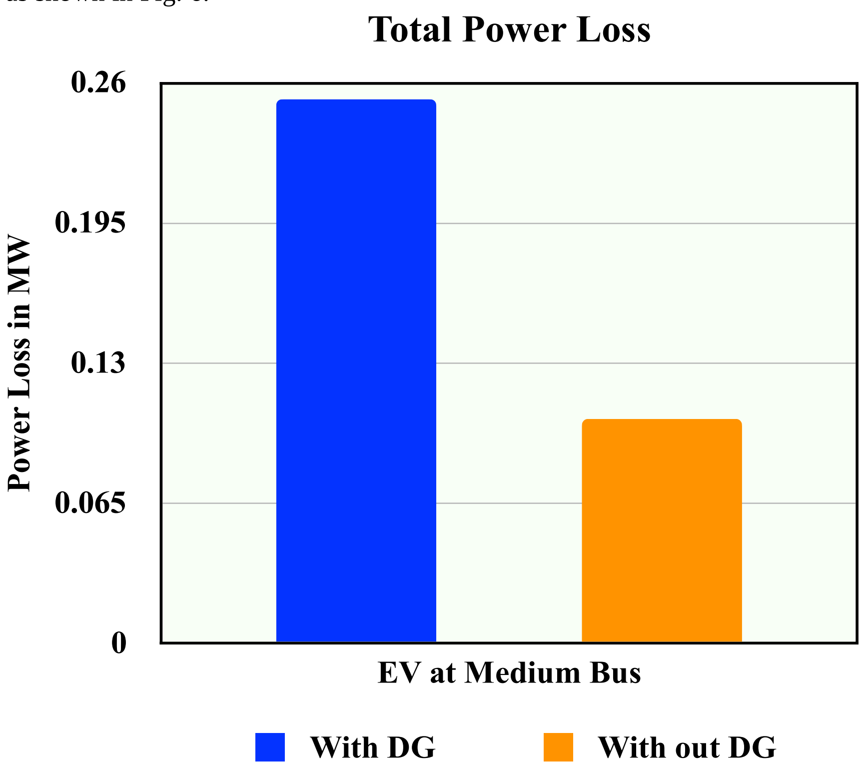

Figure 6: Total Power Loss

4.3. Placement of EVCS at Week Bus

In this case EVCS is placed at week buses i.e., 18, 22, 33. Load flow is applied using proposed Multi-objective PSO technique and voltage profiles are obtained with and without optimal allocation if DG. The voltage profile is shown in Fig. 7.

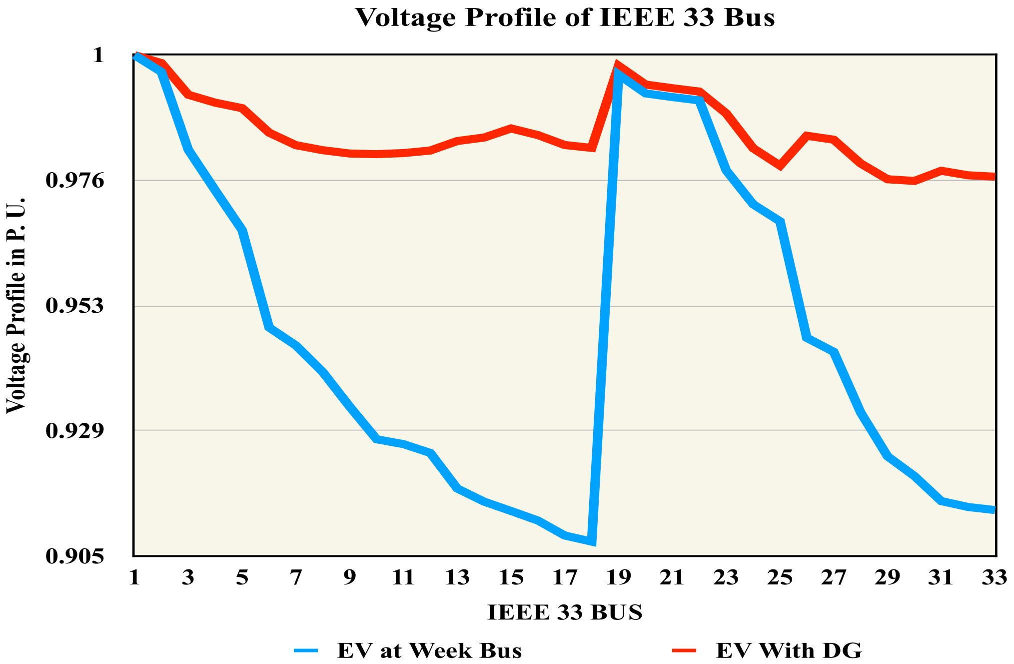

Figure 7: Voltage Profile when EVCS is placed at Week Bus

Here three DG's are optimally placed at buses 14, 26, 31, and from the above plot it is clearly observed that the voltage profile of IEEE 33 bus system is improved and the total power losses are decreased from 0.2585 MW to 0.1 MW as shown in Fig. 8.

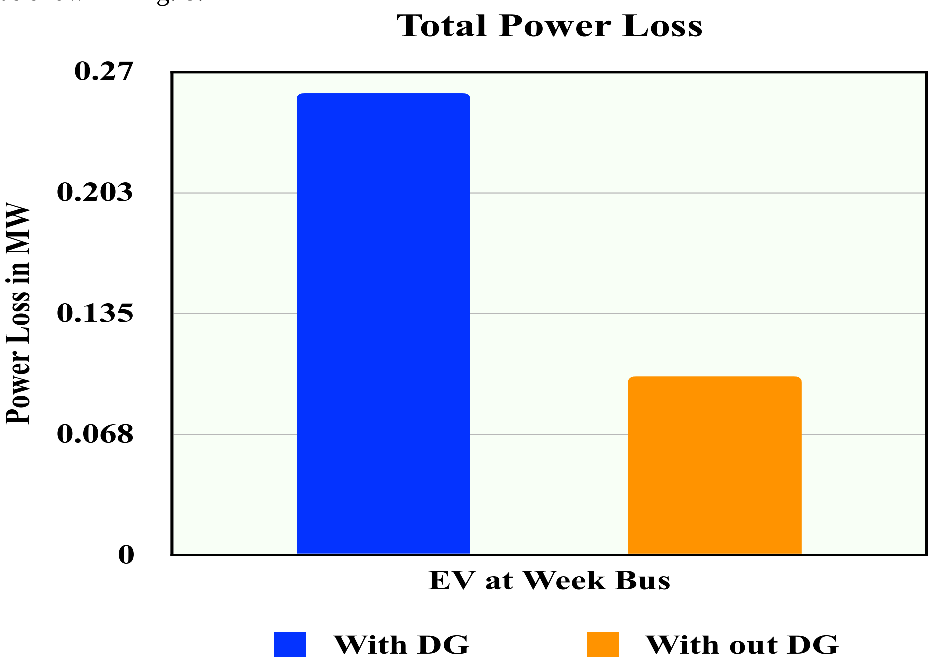

Figure 8: Total Power Loss

4.4. Comparison Analysis

The voltage profile and total power loss are compared and plotted as shown in Fig. 9 and Fig. 10 respectively.

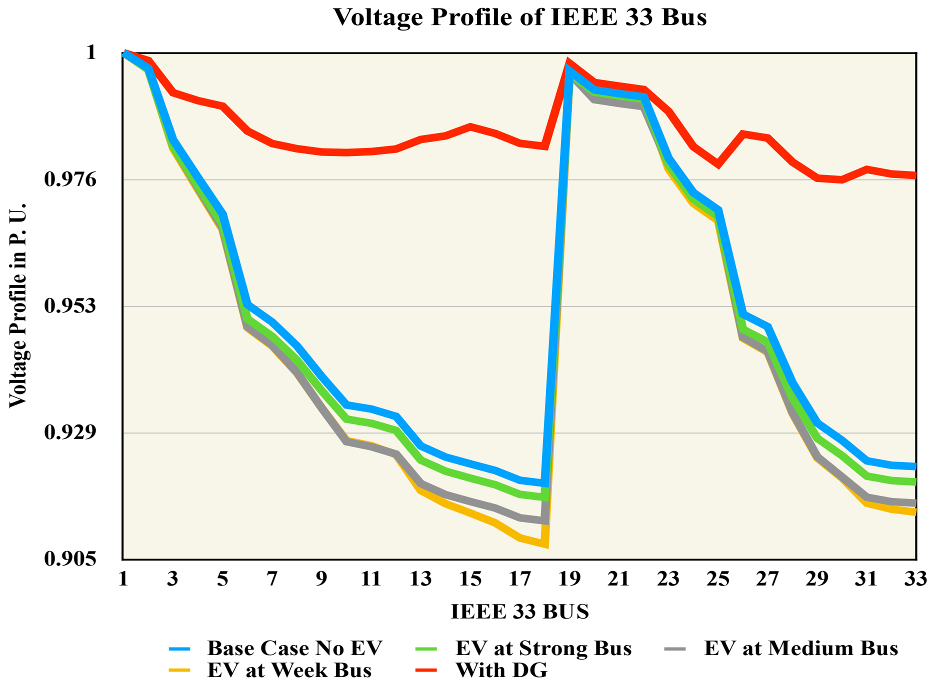

Figure 9: Voltage Profile Comparison

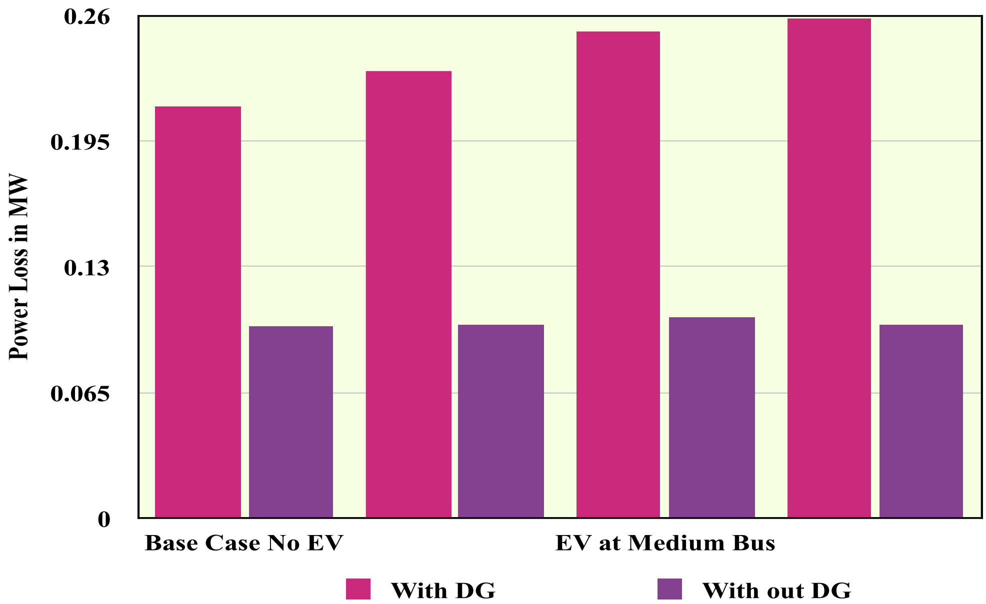

Figure 10: Total Power Loss Comparison

The above results revealed that the proposed multi-objective PSO technique improved the system performance in all the cases.

CONCLUSION

In this paper a multi-objective Particle Swarm Optimization (PSO) technique is implemented to achieve optimal placement and size DG considering EVCS. The proposed methodology is implemented on IEEE 33 bus system. Optimal sizing and placement of DG is implemented when EVCS is placed at strong, medium and week buses. In EVCS at strong bus case total power losses are decreased from 0.231 MW to 0.0996 MW, In EVCS at medium bus case total power losses are decreased from 0.2518 MW to 0.1043 MW, In EVCS at week bus case total power losses are decreased from 0.2585 MW to 0.1 MW. The results of the study revealed that the proposed multi-objective PSO technique improved the system performance in all the cases.

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