学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

Estimation of Hosting Capacity of Photovoltaic Generations in Distribution Networks using Hybrid Particle Swarm and Gradient Descent Optimization
（粒子群最適化と勾配降下法のハイブリッド最適化による配電系統における太陽光発電接続可能量の推定）

The excessive dependence on fossil fuels such as coal, oil and gas for energy production has led to massive emission of CO2. This huge emission of CO2 in the atmosphere has led to deterioration of the ozone layer. The subsequent impact of this has been rapid global temperature rise and, ultimately, climate change. To avoid further deterioration of the ozone layer and avoid deepening the climate change crisis, the world has, over the last few decades, resorted to the use of clean green-energy resources such as wind, photovoltaic (PV) etc., for the world's energy needs. In the same vein, electrical vehicles (EV) with battery energy storage systems (BESS) have increased in the share of the transportation industry to replace fossil fuel dependent transportation.

PV power sources have been increasingly adopted in large quantities and account for nearly ninety percent of green-energy power sources in the electrical power distribution networks (DN). This is because PV is relatively easy to install, has higher scalability and is cheaper than other renewable energy options. However, the adoption of PV in huge quantities can lead to various challenges in the operation of the distribution networks. The greatest challenge posed by PV is the risk of over-voltage occurrence during times of high solar irradiation (with subsequent high-power output), at times of low power demand. Other risks include thermal capitulation of network lines and cables, reverse power flows, and high harmonics. Therefore, there is a need to determine the amount of PV power which a particular DN can accommodate without abrogating the network's operational limits. This amount is referred to as the PV hosting capacity (PVHC).

This study proposes an efficient method for estimating the PVHC of a DN. This method uses swarm intelligence in combination with gradient descent technique. The method harnesses the excellent exploration capabilities of particle swarm optimization (PSO) to search for optimum solutions in the solution space, and the powerful exploitation of the sub-optimal solution espoused by the gradient descent algorithm to move towards the optimum solution. In hybridizing the PSO and the GD algorithms, the proposed method not only develops an efficient optimizer but also gets rid of the ills present in standard PSO and steepest gradient descent methods.

The proposed method's efficacy in depth and speed of calculation was tested on several DN test systems including the IEEE 33 bus test DN, the IEEE 69 test DN and the existing 136 bus in Sao Paulo, Brazil to estimate the PVHC of these networks. The proposed method was also used in the study to investigate the impacts of BESS and EV on the PVHC of a DN. The results of the calculations were compared with several other methods for comparative and similar studies.

The study also proposes the use of the deterministic approach in combination with the stochastic methods to produce a fast optimization algorithm for estimating the PV hosting capacity for distribution networks operating under the uncertainties which are inherent in the network variables. In this part of the research, the PSO-GD was combined with the PEM-based probabilistic load flow analysis to synthesize a powerful tool for estimating the acceptable limit of PV which can be safely installed into the distribution network without violating the network performance limits. This tool can be used for network planning purposes at the conception stage of the DN or for system expansion planning purposes.

The numerical results of the simulations proved that the proposed method was more efficient compared with other methods found in literature. The results also showed that the proposed method has a high computational speed. Furthermore, the method was validated to be order-1 and order-2 stable.