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PII: S2314-7172(18)30030-8
DOI: https://doi.org/10.1016/j.jesit.2018.03.004
Reference: JESIT 201

To appear in:

Received date: 30-10-2017
Revised date: 24-12-2017
Accepted date: 9-3-2018

Please cite this article as: Mostafa A.Algabalawy, Almoataz Y.Abdelaziz, Said F.Mekhamer, Shady H.E.Abdel Aleem, Considerations on optimal design of hybrid power generation systems using whale and sine cosine optimization algorithms (2010), https://doi.org/10.1016/j.jesit.2018.03.004

Considerations on Optimal Design of Hybrid Power Generation Systems Using Whale and Sine Cosine Optimization Algorithms

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Abstract—Nowadays, the continuous increase of power demand leads to various challenges for distribution system operators (DSOs) such as power quality, system stability and reliability. Microgrids (MGs) and hybrid power generation systems (HPGSs) can play a significant role in solving these issues while improving the performance of electrical power systems. In this paper, an optimal multi-criteria design of a grid-connected HPGS is introduced, taking into consideration involvement of a natural gas distribution network (NGDN) in the proposed configuration, where the NGDN supplies natural gas to a gas turbine. The HPGS system consists of wind turbines (WT), photovoltaic (PV) arrays, battery banks (BBs), gas turbines (GTs), in addition to a utility grid (UG). Two different meta-heuristic optimization algorithms, namely whale, and sine cosine, are employed to find the optimal design of the system for minimizing the total annual cost and system emissions. A detailed comparative study of the results with results of the cuckoo search and firefly optimization algorithms is presented to show the robustness of the used techniques.

Keywords*:* Distributed generation; power generation systems; natural gas; optimization algorithms.

1. INTRODUCTION

Hybrid power generation systems (HPGSs) have been given much attention in the last years because they introduce partially or entirely solutions for several power systems problems. They can meet the increase in power demand, improve power quality, reduce the emissions of conventional power generation systems, and improve the system reliability. Currently, renewable energy-based power generation is rapidly developing across the world in response to technical, economic, and environmental developments, as well as political and social initiatives. On the other hand, if these renewable energy-based power generations are not properly sized, or efficiently integrated with the utility, many problems in the distribution systems may occur such as over and under voltages, excessive line losses, overloading of transformers and feeders, and protection failure [1].

In the literature, several configurations are managed for sizing of HPGSs. In most of these arrangements, one can notice that photovoltaic (PV) arrays, wind turbines (WTs), fuel cells (FCs) or battery banks (BBs), and diesel generators (DGs) are the most widely used units in hybrid energy systems [2]. Many techno-economic design strategies are manipulated for their optimal planning, whether as standalone or grid-connected systems, such as power loss reduction, system security and reliability improvement, cost minimization, and for maximizing the renewables penetration [3–7]. The term cost includes capital, running, maintenance, operation, consumed fuel, or their combination. However, incorporating natural gas distribution network (NGDN) in the HPGSs is rarely discussed, although of benefits of natural gas such as its low emission and price. Besides, in some countries, it is noticed that the natural gas (NG) consumption increases during winter months and the opposite decreases during the summer months. On the contrary, the electricity consumption decreases during the winter months and increases during the summer months. This can neutralize the consumption if incorporated together.

In Egypt, there is a surplus of the natural gas resources, which should be utilized efficiently. Also,