Grey wolf optimizer for optimal design of hybrid renewable energy system
PV-Diesel Generator-Battery: Application to the case of Djanet city of Algeria

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The optimal sizing of a hybrid system of renewable electricity is an important phase in its design. As long as the cost of the capital equipment is the major component in the price of renewable electricity. This paper presents the application of one of the latest swarm intelligence algorithms, namely Grey Wolf Optimizer (GWO) which is inspired from grey wolves. The GWO algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature. The proposed strategy is applied for optimal design and minimizes the total cost of the hybrid power generation system in isolated rural village in south Algeria named “Djanet”. A power system consisting of a photovoltaic array panel, diesel generator, Battery banks and load is considered for tested the proposed approach. The results obtained by this new method are compared with Particle Swarm Optimization (PSO) algorithm; there are shows that the proposed methodology finds the optimal number of PV panels, diesel generators and battery banks easily with fast convergence, lower cost and the superior capabilities of this proposed method are demonstrated.

1. Introduction

The basic function of a modern electric power system is to provide an adequate electrical supply to its customers as economically as possible and with a reasonable level of reliability (Suryoatmojo, 2010).

The hybrid combination of PV-battery-diesel systems is economically feasible in many cases for electric energy supply in isolated areas where the electric utility is not available. PV-Diesel system has greater reliability electricity production than a PV only system or diesel only system. It means that hybrid power systems have greater flexibility, higher efficiency and lower costs for the same quantity of energy production (Ashari et al., 2001). In addition, the integration of PV system with battery storage and diesel unit as a backup system provides a reduction in the operational costs and emitted air pollutants to the atmosphere (Wies et al., 2004).

Optimizing the design of an hybrid renewable energy system is essential especially with the high present cost of an hybrid renewable energy system and consequently adopting a suboptimal design can significantly affect the economic performance of the hybrid renewable energy system on the long run (Masoud et al., 2014). Hence, Due to the complexity of optimal design of an hybrid renewable energy systems, classical optimization methods have failed to be either effective or efficient (Dufo-Lopez et al., 2007). Meta-heuristic optimization techniques have become very popular over the last two decades. Surprisingly, some of them such as Genetic Algorithm (GA) (Bonabeau et al., 1999), Ant Colony Optimization (ACO) (Dorigo et al., 2006), and Particle Swarm Optimization (PSO) (Kennedy and Eberhart, 1995) are fairly well-known among not only computer scientists but also scientists from different fields (Mirjalili et al., 2014)). Those techniques are the most used optimization techniques due to their simplicity, flexibility, derivation free mechanism, and local optima avoidance (Ahmed et al., 2015). The meta-heuristic optimization techniques have different advantages makes them the first choice for solving optimization problems, their simplicity comes from being reveal of natural phenomena, animals behaviors, or evolutionary concepts (Mirjalili et al., 2014). In other words, a particular meta-heuristic may show very promising results on a case, but the same algorithm may show poor performance on another. These reasons allow researcher to investigate of new algorithms in optimal design of hybrid renewable energy system problem.

Grey wolf optimizer (GWO) was originally presented by Mirjalili et al. (2014). It simulates hunting behavior and social leadership of grey wolves in nature. Some of the advantages of GWO are simplicity, flexibility, derivation-free mechanism, and local optima avoidance. Also, it is easy to implement; and it requires few control parameters to
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regulate. First, GWO is fairly simple. It is inspired by hunting behavior and social leadership of grey wolves in nature. The inspirations are related to animals’ behaviors that are pretty easy to understand. Furthermore, the simplicity assists some scientists engaging in different research fields to learn the algorithm quickly and apply it to their problems. Second, flexibility refers to GWO applying in different problems without any special changes in the structure of the algorithm. GWO is easily applicable to different problems because it supposes problems as black boxes. Third, GWO has derivation-free mechanisms. In comparison with gradient-based optimization methods, GWO optimizes problems stochastically. During the process of optimization, there is no need to calculate the derivative of search spaces. This will be effectively used for real problems with expensive or unknown derivative information. Finally, local optima avoidance compared to conventional optimization techniques is high due to the stochastic nature of GWO. This leads to GWO highly suitable for solving highly nonlinear, multi-variable, multimodal function optimization problems.

Several methods can be found in literature for optimal design of hybrid PV-Diesel- Battery system. El-Hefnawi (1998) presented an optimization method to design hybrid PV-Diesel-Battery system. The optimization method starts by modeling of diesel generator and then optimizing the PV and battery sizes in terms of minimum number of storage days and the minimum PV array area. Eke et al. (2005) developed a linear mathematical model to minimize total cost of an hybrid renewable energy system. They only considered solar panels and wind turbine and used a graphical method to solve the optimization problem. Dufo-Lopez et al. (2011) developed the hybrid optimization by genetic algorithms program that uses GA to determine the sizing and operation control of a PV-Diesel system.

Recent studies have shown that GWO is able to provide competitive results compared to other well-known meta-heuristics. Harma et al. (2015) have used GWO for automatic generation control of multi-area ST-Thermal power systems. Wong (2014) and Kamboj et al. (2016) have GWO utilized for solving economic dispatch problems. El-Gaafary et al. (2015) have applied GWO for optimum allocation of STATCOM devices on power system grid to minimized load buses voltage deviations and system power losses. Mirjalili et al. (2016) have been used GWO to estimate the parameters of the proportional integral controller (PI) for automatic generation control of two area power system. Mirjalili et al. (2016) proposed multi-objective grey wolf optimizer that is an essential in solving real problems.

As a well-known fact, any optimization algorithm has its own advantages and disadvantages. For example, GA is often used for its slow convergence. PSO is fast but commonly the accuracy of solutions is not increased by increasing the number of iterations (to be adjusted by trial and error). In general, algorithms with smaller number of parameters (to be adjusted by user by trial and error), faster convergence, and higher probability of skipping from local optimums are identified as more effective algorithms. It is very important to note that the effectiveness of a certain algorithm strictly depends on the problem it is going to solve. In other words, it may happen that a certain algorithm be very successful in dealing with a problem while it is quite unsuccessful in dealing with another one. For this reason and as a common practice, researchers apply different techniques to a certain problem to find the best method suited to solve it. Hence, proposing the most effective algorithm (the one at once with the highest accuracy, fastest convergence, most ease of use, etc.) to find the optimal sizing of a stand-alone hybrid PV/Diesel generator/Battery system is of high importance in practice.

In this study, grey wolf optimizer technique is applied to determine the optimal design PV-Diesel Generator-Battery, and minimizes the total cost of the hybrid power generation system in isolated rural village in south Algeria named “Djanet”. The results obtained by GWO are compared with Particle Swarm Optimization (PSO) algorithm. The comparisons show that the grey wolf optimizer used in this paper demonstrate a good balance between exploration and exploitation that results in high local optima avoidance and a very fast convergence simultaneously of proposed GWO technique for solving our problem. The great advantages of GWO are that the algorithm is simple, flexible, robust and easy to implement.

2. The case of Djanet city

2.1. The selected site

The site selected for this study is a rural village isolated Saharan named “Djanet”. This village is located in the province of “Illizi” and consists of a small number of homes. The electrification of the village by the traditional sectors (diesel, electrical network). For supplying the load electric company installed several units of diesel generators (DG). In addition to excessive implementation costs, had posed the problem of the delivery of fuel. In the case of the network. The daily condition of insolation and temperature in this rural city are shown in Fig. 1 and 2 respectively.

2.2. Meteorological data

The performances of photovoltaic modules are directly correlated to climatic data that is in principle the solar irradiation and the ambient temperature. These data are taken through the acquisition system.

![Daily insolation data](Fig. 1)

![Daily temperature data](Fig. 2)
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