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A review on optimization algorithms and application to wind energy integration to grid

Sasmita Behera [a,*], Subhrajit Sahoo [b], B.B. Pati [b]

[a] Dept. of Electrical & Electronics Engg., VS.S. University of Technology, Burla 768018, Odisha, India
[b] Dept. of Electrical Engg., VS.S. University of Technology, Burla 768018, Odisha, India

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ABSTRACT

In order to meet power needs, with concern for economics and environment, wind energy conversion is gradually gaining interest as a suitable source of renewable energy. To maximize the power extraction from the wind, optimization techniques are used at the various module of a wind farm starting from wind farm design for siting, sizing, optimal placement and sizing of distributed generation (DG) sources, generation scheduling, tuning of PID controller, control of wind energy conversion system (WECS) etc. This paper mainly focuses on the optimization algorithms (mostly the swarm based) in relation to integration of the wind farm with the grid. The paper here gives a precise idea about different optimization techniques, their advantage and disadvantage with respect to a wind farm. This review will enable the researchers to open the mind to explore possible applications in this field as well as beyond this area.

Contents

* Corresponding author. Tel.: +91 9437367106.
E-mail addresses: sasmitabehera2000m@gmail.com (S. Behera), 89subhrajit@gmail.com (S. Sahoo), pati_bibhuti@rediffmail.com (B.B. Pati).

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1. Introduction

The present world craves for optimization with respect to every possible aspect of the nature and its happenings due to the rapid depletion of easy energy sources and profit maximization. Hence a lot of focus has been put on optimization of different fields of engineering problems and management problems mainly which are multi-dimensional and mathematical in nature. Faster depletion of the fossil fuels and concern over environmental pollution demand for clean energy generation. Wind being the clean green energy is preferred by many countries over other forms of energy. With rising power demand, wind energy conversion is gradually gaining more interest as a cost-effective suitable source of renewable energy.

Here an attempt has been taken to present a brief idea about the optimization algorithms, mostly the swarm based and their use in power system domain with advantages and disadvantages reviewed as per the works done by various authors. Researchers have reviewed earlier taking different aspects of optimization in relation to renewable energy. Herbert et al. [1] have mainly reviewed different assessment models, technological aspects in planning, design of wind farms and mechanical components of turbines, testing and performance evaluation of design. Banosa et al. have reviewed optimization methods in context of different categories of renewable sources [2]. But application in wind energy has not been detailed in depth and new optimization techniques have come up after their review. Salcedo-Sanz et al. [3] have detailed and summarized the algorithms for lay out optimization of on shore and off shore wind farms. In a latest review Iqbal et al. [4] have schematically pointed out main objectives considered for optimization with respect to renewable but mostly review for hybrids of renewable energy sources. But optimization in different areas of research on wind energy source has not been detailed. In earlier works on optimization, none of the papers have brought specific basic information of so many upcoming new algorithms under one roof which motivates the present one. Furthermore, this paper has focused on the major issues of the power system i.e. maximized generation and integration of wind power to grid. In Section 2 the salient features of the algorithms are narrated in brief followed by their applications in the area of wind energy in Sections 3–7. At the end the paper gives an exhaustive conclusion and indicates for future research.

2. Salient features of the algorithms

The optimization algorithms are broadly divided in to three categories according to the under laying principle shown in Fig. 1 namely:

1. Biology based algorithm;
2. Physics based algorithm;
3. Geography based algorithm.

2.1. Biology based

Biology based (Biology-derived) optimization algorithms are an important part of computational sciences, which are derived from or based on the analogy to natural evolution and biological activities [5]. These algorithms are sometimes termed as memetic algorithms [6] without any further division in to subcategories. The biology based optimization algorithms are broadly divided into two types, namely:

- Evolution based optimization algorithms and
- Swarm based optimization algorithms.

2.1.1. Evolution based algorithm

Evolutionary algorithms (EAs) are stochastic search methods that mimic the process of biological evolution and/or the social behavior of species. The species surpasses others by learning, adaptation, and evolution. There are a number of evolution based optimization algorithms, detailed as follows.

2.1.1.1. Genetic Algorithm (GA). GA is a stochastic global adaptive search optimization technique based on the mechanisms of natural selection. It is initialized to a population containing a number of chromosomes where each one represents a solution of the problem whose performance is evaluated by a fitness function. Basically, GA consists of three main stages: Selection, Crossover and Mutation. The application of these three basic operations allows the creation of new individuals which may be better than their parents. This algorithm is repeated for many generations and finally stops at the optimum solution to the problem [7].

Despite excellent performance by GA for globally optimum solution in search space, some researchers have pointed out some deficiencies in GA performance. Those deficiencies are (i) poor premature convergence, (ii) loss of best solution found, (iii) no absolute assurance that a genetic algorithm will find a global optimum and (iv) indefinite or long time for convergence, not suitable for real time applications [8].

2.1.1.2. Evolutionary Programming (EP). It is a technique in the field of computation developed by D. B. Fogel in 1990 [9,10]. It starts with a population of randomly generated candidate solutions and evolves towards a better solution over a number of generations or iterations. The main steps of EP are Initialization, Mutation, Competition and Selection.

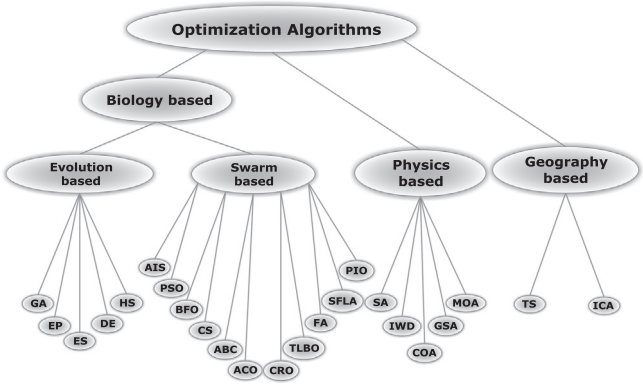

Fig. 1. Classification of optimization algorithms.