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Renewable Energy Based Economic Emission Load Dispatch Using Grasshopper Optimization Algorithm

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ABSTRACT

This article presents an integrated approach towards the economical operation of a hybrid system which consists of conventional thermal generators and renewable energy sources like windmills using a grasshopper optimization algorithm (GOA). This is based on the social interaction nature of the grasshopper, considering a carbon tax on the emissions from the thermal unit and uncertainty in wind power availability. The Weibull distribution is used for nonlinearity of wind power availability. A standard system, containing six thermal units and two wind farms, is used for testing the dispatch model of three different loads. The GOA results are compared with those obtained using a recently developed quantum-inspired particle swarm optimization (QPSO) optimization technique available in the literature. The simulation results demonstrate the efficacy and ability of GOA over the QPSO algorithm in terms of convergence rate and minimum fitness value. Performance analysis under wind power integration and emission minimization further confirms the supremacy of the GOA algorithm.

KEYWORDS

Economic Load Dispatch (ELD), Emission Tax, Grasshopper Optimization Algorithm (GOA), Renewable Energy, Wind Energy

1. INTRODUCTION

Renewable energy is the most important aspects of energy in today's world, to mitigate the challenges that arise due to excessive environmental degradation from the greenhouse gases that emits from conventional power plants to meet the exponentially rising demand of electrical energy. The sources of the fossil fuels are like coal, oil and gases used in the thermal power plants. The exhaust gas contains several hazard gases like CO_2, NO_2, and SO_2 and these gases are directly ejected into the atmosphere. So, environmental degradation in this way is a major problem of today. Several international organizations like UNFCCC (united nation framework on the convention on climate

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change) are working in this field to control these emissions through several international protocols like Kyoto protocol. Recently, in the year 2015 on COP (conference of parties) 21 Paris the members agreed to reduce their carbon output and to do their best to keep global warming below 2°C. So this will encourage both the devolved and developing countries to integrate its renewable sources like wind, solar, bio energy, etc., with conventional thermal power plants to meet their energy demand.

Wind power is readily available in nature, but due to its uncertain and stochastic characteristics, it creates challenges in the load dispatch model. As wind speed variation controls windmill outputs, so wind power forecasting errors will bring a major problem while estimating system reserve margin to provide the guarantee of secure and reliable operation. The uncontrolled penetration of wind power is risky for a power system as it may bring out difficulties. Composite forecast model is used to statistically produce optimal forecasting by computing prediction result from numbers of different methods. If the errors of forecasting generated by different methods have a low degree of correlation among each other, the random error from the individual forecasts will tend to offset each other with the result thus composite forecast will have very fewer errors than individual forecast. Wind power generally follows Weibull distribution shown in so many papers (Patel, 2006). In several articles (Liu, and Xu, 2010; Hetzer et al., 2008), probabilistic optimization strategies are used to deal with wind power uncertainty.

Economic load dispatch (ELD) is a technique to allocate the generating units according to the load demand and to minimize operating cost. ELD with consideration of carbon emission tax and integration of renewable source is a recent trend and an emerging technology. In this paper, economic load dispatch of six conventional thermal generators under different loading condition is performed, with and without tax imposed on carbon emission. Afterward, two windmills are included in the system and ELD is performed with and without considering carbon emission tax.

A meta-heuristic is an iterative technique that helps to find out the near-optimal solution in a more efficient way. The objective of this method is to enlarge the aptitude of heuristics by joining more and more heuristic method. Due to the significant achievements of meta-heuristics approaches in solving different kinds of non-linear optimization problems, interest has been gradually shifted to applications of population-based approaches to handling the complexity involved in the nonlinear problem. Recently, so many researchers have expressed their interest in solving ELD problems with constraint using evolutionary algorithms such as PSO (Meng et al., 2010), genetic algorithm (GA) (Chung, & Chan, 2012), evolutionary programming (EP) (Vlachogiannis, & Lee, 2008), differential evolution (DE) (Bhattacharya & Chattopadhyay, 2010), pattern search (PS) (Al-Sumait et al., 2007), tabu search (TS) (Lin, 2010), and simulated annealing (SA) (Precup et al., 2012).

GA is one of the oldest heuristic technique, its searching property relies on the principle of genetics such as selection, crossover, mutation, and inheritances (Goldberg, & John, 1988). Some advantages of GA are: high probability of getting success at finding the global optimal to widow variety of functions do not require derivatives, and it can be implemented in discrete and continuous parameters. The main drawback of the aforesaid method is its susceptibility in getting trapped on local optimum solution. Katsigiannis et al. (Katsigiannis et al., 2012) used GA to optimize hybrid PV/wind/battery/diesel energy system to supply three isolated islands in Japan.

SA is an algorithm used to solve the combination of optimization problems that destroy the crystallization process in a physical system when the search space region is discrete in nature (Santoso et al. 2007). Some advantages of exploitation is that it usually leads to very high convergence rates, but its disadvantage is that it can get stuck in a local optimum as well as it requires large computation time. In the paper (Aly et al., 2010) Aly et al. implemented a simulated annealing algorithm for multi-objective distributed generation planning.

TS is a meta-heuristic approach which is based on the method of adaptive memory and responsive exploration that starts searching the solution space economically and efficiently until any improvement is reached. The advantage of TS technique is that, it can have explicit memory as well as it can be applied to the discrete and continuous type variable. Disadvantages of this method is that it is depended