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Sine-Cosine Algorithm for the Dynamic Economic Dispatch Problem With the Valve-Point Loading Effect

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ABSTRACT

Dynamic economic dispatch (DED) deals with the allocation of predicted load demand over a certain period of time among the thermal generating units at minimum fuel cost. The objective function of DED becomes highly complex and nonlinear after considering various operating constraints like valve point loading, ramp rate limit, transmission loss, and generation limits. In this study, the sine-cosine algorithm has been presented to solve the DED problem with various constraints. The randomly placed swarm finds an optimum solution according to their fitness values and keeps the path towards the best solution attained by each swarm. The swarm avoid local optima in the exploration stage and move towards the solution exploitation stage using sine and cosine functions. The proposed technique has been tested in several test systems. The results obtained by the proposed technique have been compared with those obtained by other published methods employing the same test systems. The results validate the superiority and the effectiveness of the proposed technique over other well-known techniques.

KEYWORDS

Dynamic Economic Dispatch, Ramp- Rate Limit, Sine-Cosine Algorithm, Transmission Loss, Valve Point Loading Effect

1. INTRODUCTION

The operation of a power system depends upon the system's security, reliability, and economy (Bhattacharjee, Bhattacharya, & Nee Dey 2014). The Economic Dispatch (ED) is the main function of power system operation to reduce the cost of different fuel types. The main aim of the ED is to allocate load demand among committed thermal generators at a minimum price while satisfying power balance and other system constraints (Nourianfar & Abdi 2021). Thus, the ED problem is a highly complex and nonlinear optimization problem. The ED can be classified into Static Economic Dispatch (SED) and Dynamic Economic Dispatch (DED) (Verma et al. 1AD). In SED, the thermal generating units have been allocated economically to satisfy load demand for a specific time interval.

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The SED does not consider the fundamental relation of the system between the different periods (Soni et al., 2020). The DED, an extension of SED, issues time-varying load demand among the generators by satisfying various operating constraints. The DED considers the relation of different operating times to meet multiple constraints (Bhattacharjee, Shah, & Soni 2022a). Traditionally, the valve point loading effect (VPLE) has been ignored in DED to make the problem tractable (Bhattacharjee & Patel 2020). The solution becomes inaccurate and imprecise. The DED problem with VPLE has been considered to make the system more (Soni & Pandya, 2018).

DED problem was introduced in 1971 to obtain optimal operation of thermal units for a certain pe with satisfying physical and operational constraints such as ramp-rate limits, power generation limits, and power balance constraints. The transmission loss should not be ignored due to the large-scale power systems. The DED problem becomes more complicated after considering transmission loss and VPLE. The different optimization methods have been used to get the solutions of the DED problem (Bhattacharjee, Shah, & Soni, 2022b). These optimization methods have been classified into traditional methods and artificial intelligence methods. Conventional methods like linear programming, nonlinear programming, quadratic programming, Lagrange relaxation, and dynamic programming have been used to DED problems. These traditional methods suffer from the curse of dimensionality and fail to get an in large-scale DED problems (Bhattacharjee & Patel, 2018). With the massive development of artificial intelligence methods, their use for DED problems increases due to their effectiveness and feasibility. Stochastic search techniques like simulated annealing (SA) (Soni & Bhattacharjee, 2022), artificial immune system (AIS) (Bhattacharjee & Patel, 2018), differential evolution (DE) (Barisal, 2013), and genetic algorithm (GA) (Mohajeri, Seyedi, & Sabahi, 2015) have been successfully applied to solve DED problems due to their ability to find near an optimal global solution. The meta-heuristics methods have been developed by the behavior of insects. The swarm intelligence techniques like harmony search (HS) (Sivasubramani & Swarup, 2011), particle swarm optimization (PSO) (Abarghooee & Aghaei, 2011), cuckoo search (CS) (Chandrasekaran, Simon, & Padhy, 2014), artificial bee colony (ABC) (Barisal, 2013), Symbiotic organisms search algorithm (SOC) (Guvenc et al., 2018), and imperialist competitive algorithm (ICA) (Morshed and Asgharpour 2014) have been successfully applied to the DE problem. These techniques use the probabilistic rule to get a solution. Thus, these methods do not guarantee finding the global optimum solution. Many researchers have recently combined probabilistic and deterministic approaches to solve DED problems. Hybrid methods like hybrid bee colony optimization and sequential quadratic programming (BCO-SQP) (Balamurugan & Subramanian, 2008), hybrid PSO and sequential quadratic programming (PSO-SQP) (dos Santos Coelho & Mariani, 2006), Enhanced adaptive particle swarm optimization algorithm (EAPSO) (Niknam and Golestaneh 2012), hybrid bacterial foraging and simplified swarm optimization algorithm (MBF-SSO) (Balamurugan and Subramanian 2008), Time-varying acceleration coefficients IPSO (TVAC-IPSO) (Ghasemi et al., 2020), Covariance matrix adapted evolution strategy algorithm (CMAES) (Manoharan et al. 2009), and hybrid Hopfield neural network and quadratic programming (HNN-QP) (Jayabarathi & Sadasivam, 2000) have been applied to get solutions of DED problems. These above-mentioned methods take more computation time to get the optimum solution (Bhattacharjee et al., 2021). Thus, a strong and effective optimization technique is required to solve highly complex and nonlinear DED problems (Kaluri and CH 2018).

Recently, the population-based Sine Cosine Algorithm (SCA) has been proposed by Mirjalili et al. (Mirjalili, 2016). The nineteen unimodal, multimodal, and composite benchmark functions have been solved by Mirjalili et al. (Mirjalili, 2016).In SCA, the multiple initial random populations are generated and moved outward or toward the best solution. The trigonometric sine and cosine function of SCA is used to find the fitness value of populations. SCA has the exploration and exploitation property. The randomly generated solution by SCA gets to benefit from higher exploration and avoids local optima value. Such a feature is not available in other algorithms. These properties help to prevent local optima and move directly to global optima in significantly less computational time.