Electrical Power and Energy Systems 78 (2016) 356–367

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Quasi-oppositional group search optimization for multi-area dynamic economic dispatch

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ARTICLE INFO

Article history:
Received 18 September 2014
Received in revised form 11 November 2015
Accepted 25 November 2015
Available online 22 December 2015

Keywords:
Quasi-oppositional group search optimization
Group search optimization
Multi-area dynamic economic dispatch
Tie line constraints

ABSTRACT

Multi-area dynamic economic dispatch determines the optimal scheduling of online generator outputs and interchange power between areas with predicted load demands over a certain period of time taking into consideration the ramp rate limits of the generators, tie line constraints, and transmission losses. This paper presents quasi-oppositional group search optimization for solving multi-area dynamic economic dispatch problem with multiple fuels and valve-point loading. Group search optimization (GSO) inspired by the animal searching behavior is a biologically realistic algorithm. Quasi-oppositional group search optimization (QOGSO) has been used here to improve the effectiveness and quality of the solution. The proposed QOGSO employs quasi-oppositional based learning (QOBL) for population initialization and also for generation jumping. The QOGSO is tested on two multi-area test systems having valve point loading and mult-fuel option. Results of the proposed QOGSO approach are compared with those obtained from group search optimization (GSO), biogeography-based optimization (BBO), gravitational search algorithm (GSA), differential evolution (DE) and particle swarm optimization (PSO). It is found that the proposed QOGSO based approach is able to provide better solution.

Introduction

Multi-area static economic dispatch (MASED) is one of the important optimization problems in power system operation. Generally, the generators are divided into several generation areas interconnected by tie-lines. MASED determines the generation levels of online generators and interchange power between areas for a load demand which is constant for a given interval of time such that total fuel cost in all areas is minimized while satisfying power balance constraints, generating limits constraints, and tie-line capacity constraints.

The MASED has been the subject of investigation for several decades. Shoults et al. [1] solved economic dispatch problem considering import and export constraints between areas. This study provides a complete formulation of multi-area generation scheduling, and a framework for multi-area studies. Romano et al. [2] presented the Dantzig–Wolfe decomposition principle to the constrained economic dispatch of multi-area systems. Helmick and Shoults [3] solved multi-area economic dispatch with area control error. Wang and Shahidehpour [4] proposed a decomposition approach for solving multi-area generation scheduling with tie-line constraints using expert systems. Network flow models for solving the multi-area economic dispatch problem with transmission constraints have been proposed by Streiffert [5]. Yalcinoz and Short [6] solved multi-area economic dispatch problems by using Hopfield neural network approach. Jayabarathi et al. [7] solved multi-area economic dispatch problems with tie line constraints using evolutionary programming. The direct search method for solving economic dispatch problem considering transmission capacity constraints was presented in Ref. [8]. Manoharan et al. [9] explored the performance of the various evolutionary algorithms on multi-area economic dispatch (MAED) problems. Here, evolutionary algorithms such as the Real-coded Genetic Algorithm (RCGA), particle swarm optimization (PSO), differential evolution (DE) and Covariance Matrix Adapted Evolution Strategy (CMAES) are considered. Sharma et al. [10] have presented a close comparison of classic PSO and DE strategies and their variants for solving the reserve constrained multi-area economic dispatch problem with power balance constraint, upper/lower generation limits, transmission constraints and other practical constraints. In [11], multi-area economic dispatch problem has been solved by using teaching–learning-based optimization algorithm.

Multi-area dynamic economic dispatch (MADED) is an extension of multi-area static economic dispatch problem. It schedules the online generator outputs, and interchange power between

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http://dx.doi.org/10.1016/j.ijepes.2015.11.120
0142-0615/

areas with the predicted load demands over a certain period of time so as to operate an electric power system most economically. In order to avoid shortening the life of the equipments, plant operators try to keep gradients for temperature and pressure inside the boiler and turbine within safe limits. This mechanical constraint is transformed into a limit on the rate of increase or decrease of the electrical power output. This limit is called ramp rate limit which distinguishes MADED from MASED problem. Thus, the dispatch decision at one time period affects those at later time periods. MADED is the most accurate formulation of multi-area static economic dispatch problem but it is the most difficult to solve because of its large dimensionality. Further, due to increasing competition into the wholesale generation markets, there is a need to understand the incremental cost burden imposed on the system by the ramp rate limits of the generators.

Huda et al. [12] developed a hybrid approach of global and local search for constrained optimization problem. In [13], Huda et al. discussed about good convergence on global mathematical optimization approaches.

Group search optimization (GSO) is a biologically realistic algorithm which is inspired by the animal (such as lions and wolves) searching behavior. He et al. [14] proposed GSO in 2006, and discussed the effects of designed parameters on the performance of GSO in 2009 [15]. GSO employs a special framework, under which individuals are divided into three classes and evolve separately. This framework is proved to be effective and robust on solving multimodal problems [15]. Shen et al. [16] investigated the performance of GSO and concluded that GSO is an alternative for constrained optimization.

Due to its high efficiency, GSO has been applied to solve non-convex economic dispatch problem [17], distribution network reconfiguration [18], combined heat and power economic dispatch problem [19], etc.

The basic concept of opposition-based learning (OBL) [22–24] was originally introduced by Tizhoosh. The main idea behind OBL is for finding a better candidate solution and the simultaneous consideration of an estimate and its corresponding opposite estimate (i.e., guess and opposite guess) which is closer to the global optimum. OBL was first utilized to improve learning and back propagation in neural networks by Ventresca and Tizhoosh [25], and since then, it has been applied to many EAs, such as differential evolution [26], particle swarm optimization [27] and ant colony optimization [28]. In [29] quasi oppositional based differential evolution has been discussed.

The utilization of quasi-oppositional based learning (QOBL) improves the effectiveness and quality of the solution. In this paper, QOBL is implemented on group search optimization (GSO). The quasi-oppositional group search optimization QOGSO employs QOBL for population initialization and also for generation jumping.

The proposed QOGSO along with basic GSO is applied to solve MADED problem. Here, two types of MADED problems have been considered. These are (A) multi area dynamic economic dispatch with valve point loading, and transmission losses, (B) multi area dynamic economic dispatch with valve point loading multiple fuel sources, and transmission losses. Test results obtained from QOGSO are compared with those obtained from group search optimization (GSO), biogeography-based optimization (BBO), gravitational search algorithm (GSA), differential evolution (DE) and particle swarm optimization (PSO).

Problem formulation

The objective of MADED is to minimize the total cost of supplying loads to all areas over a certain period of time while satisfying power balance constraints, generating capacity constraints, ramp rate limits of the generators, and tie-line capacity constraints.

Two different types of MADED problems have been considered here.

Multi area dynamic economic dispatch with valve point loading and transmission losses

The objective function F_c, total cost of committed generators of all areas over T number of intervals in the scheduled horizon considering the valve-point effect may be written as

$$\begin{aligned} F_c &= \sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{j=1}^{M_i} F_{ijt}(P_{ijt}) \\ &= \sum t = 1T\sum_{i=1}^{N}\sum_{j=1}^{M_i} a_{ij} \quad + b_{ij}P_{ijt} + c_{ij}P_{ijt}^2 \\ &\quad + \left| d_{ij} \times \sin\left\{ e_{ij} \times \left(P_{ij}^{\min} - P_{ijt} \right) \right\} \right| \end{aligned} \tag{1}$$

where $F_{ijt}(P_{ijt})$ is the cost function of j th generator in area i at time t. $a_{ij},\ b_{ij}\ , c_{ij},\ d_{ij}$ and e_{ij} are the cost coefficients of j th generator in area i; N is the number of areas, M_i is the number of committed generators in area i; P_{ijt} is the real power output of j th generator in area i at time t. The MADED problem minimizes F_c subject to the following constraints.

Real power balance constraint

$$\sum_{j=1}^{M_i} P_{ijt} = P_{Dit} + P_{Lit} + \sum_{k,k\neq i} T_{ikt} \qquad i \in N, \quad t \in T \tag{2}$$

The transmission loss P_{Lit} of area i at time t may be expressed by using B-coefficients as

$$P_{Lit} = \sum_{l=1}^{M_i}\sum_{j=1}^{M_i} P_{ijt}B_{ilj}P_{ilt} + \sum_{j=1}^{M_i} B_{0ij}P_{ijt} + B_{00i} \qquad t \in T \tag{3}$$

where P_{Dit} real power demand of area i at time t; T_{ikt} is the tie line real power transfer from area i to area k at time t. T_{ikt} is positive when power flows from area i to area k, and T_{ik} is negative when power flows from area k to area i.

Real power generation capacity constraints

The real power generated by each generator should be within its lower limit $P_{ij}^{\min}$, and upper limit $P_{ij}^{\max}$, so that

$$P_{ij}^{\min} \leqslant P_{ijt} \leqslant P_{ij}^{\max}, \qquad i \in N, \qquad j \in M_i, \quad t \in T \tag{4}$$

Generator ramp rate limits constraints

The ramp rate limits of each generator should be within its ramp-up rate limit UR_{ij}, and ramp-down rate limit DR_{ij}, so that

$$\begin{aligned} &P_{ijt} - P_{ij(t-1)} \leqslant UR_{ij} \quad i \in N, \quad j \in M_i, \quad t = 2, 3, \ldots, T \\ &P_{ij(t-1)} - P_{ijt} \leqslant DR_{ij} \qquad i \in N, \quad j \in M_i, \qquad t = 2, 3, \ldots, T \end{aligned} \tag{5}$$

Tie line capacity constraints

The tie line real power transfer T_{ikt} from area i to area k at time t should not exceed the tie line transfer capacity for security consideration.

$$-T_{ik}^{\max} \leqslant T_{ikt} \leqslant T_{ik}^{\max} \tag{6}$$

where $T_{ik}^{\max}$ is the power flow limit from area i to area k and $-T_{ik}^{\max}$ is the power flow limit from area k to area i.