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An efficient particle swarm optimizer for congestion management in deregulated electricity market

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Abstract

This paper proposes a method to manage congestion in deregulated environment using particle swarm optimization technique with improved time-varying acceleration coefficients (PSO-ITVAC). The congestion is alleviated by optimally rescheduling the active power outputs of generators selected based on the magnitude of generator sensitivities to the congested line. The cost of rescheduling is minimized using PSO-ITVAC. The proposed algorithm is tested on IEEE 30-bus system and IEEE 118-bus system. A 33-bus Indian network is also taken as a test network for analyzing the effectiveness of the proposed algorithm. The results obtained using proposed algorithm is compared with those obtained by using particle swarm optimization with time-varying acceleration coefficients (PSO-TVAC).

Keywords: Deregulation; Congestion management; Generator sensitivity; Generation rescheduling; Particle swarm optimization

1. Introduction

The success of deregulation in other sectors such as communication and airlines motivated the deregulation of electrical industry. During the last two decades, the deregulation of electricity sector has been witnessed all over the world. This has resulted in change in electricity sector operation philosophy. The introduction of competition due to deregulation causes the cost based electricity to transform into price based market commodity. This increased competition reduces the net electricity cost as the price of electricity is driven by market forces. The competition in new liberalized market causes each independent generating utility to sell all their generated power to the consumers. Hence they try to accommodate all their generated power on transmission line which may cause violation of transmission line limits such as thermal limit, voltage limit, stability limit etc. and thus makes the transmission line congested. The transmission line congestion may lead to tripping of overloaded lines, power system instability etc. and obviously

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increase the electricity cost as it causes the power system to deviate from its optimal operation. Hence the congestion needs to be alleviated as soon as possible.

A number of congestion management techniques (Christie et al., 2000) and algorithms have been reported in literature till date. Congestion management in two different forms of electricity markets models i.e. pool market and bilateral market models had been discussed in (Singh et al., 1998) and the congestion cost in these market models were minimized by generators' active power re-dispatch. In (Fang and David, 1999), a load curtailment strategy in bilateral and pool market structure was discussed wherein a factor called "willingness to pay to avoid curtailment" was introduced in order to fix the prioritization of transaction of electricity and its related load curtailment in these market models. An analytical tool to help the independent system operator for congestion management was proposed in (Shirmohammadi et al., 1998). Application of different FACTS devices and their optimal location in the power system to mitigate congestion was discussed in Singh and David (2001). In Acharya and Mithulananthan (2007), congestion was relieved using optimal location of TCSC based on a congestion rent and locational marginal price difference. A relative electrical distance based active power rescheduling for congestion management was discussed in Yesuratnam and Thukaram (2007). Congestion management using optimal transaction by load curtailment was discussed in Padhy (2004). A hybrid fuzzy model was developed for the optimization of congestion management problem. A multi-objective particle swarm optimization (PSO) technique was utilized in Hazra and Sinha (2007) to relieve congestion thereby minimizing the total cost of generation. In Dutta and Singh (2000), optimal numbers of generators for congestion management were selected based on generator sensitivities to the flow of power on congested line. PSO was used to minimize the amount of active power rescheduling cost of participating generators. Rescheduling cost was calculated for different values of inertia weight. However it did not consider the effect of constriction factor and time-varying acceleration coefficients on PSO performance for calculating the rescheduling cost of participating generators. The effect of acceleration constants on PSO performance in minimizing the active power rescheduling cost of participating generators for congestion management was considered in Boonyaritdachochai et al. (2010). It had developed a new algorithm for PSO in which the values of acceleration coefficients vary linearly with iteration count. However, the values of acceleration coefficients vary such that their sum was less than value of φ taken for the calculation of constriction factor k (Thangaraj et al., 2011).

A large number of conventional optimization techniques such as Newton's method, interior point method, gradient method etc. are available in literature to optimize a non-linear function (Rao, 1996; Yamille del Valle et al., 2008). Since these conventional methods are iterative in nature and their search direction is determined from derivative of the function, therefore it becomes necessary to express the objective function in the form of continuous differential function. In order to overcome this problem, nowadays heuristics methods such as evolutionary algorithm, genetic algorithm, artificial ant colony optimization, simulated annealing, tabu search, PSO etc. become popular (Thangaraj et al., 2011). Since PSO is a computational intelligence based optimization technique that is not largely affected by nonlinearity and size of the optimization problem and also can converge to the optimal solution in many problems where most analytical methods fail to converge, therefore it can be efficiently utilized for different optimization problems in power systems (Yamille del Valle et al., 2008).

Although PSO is an efficient optimization approach as compared to conventional optimization methods in solving the non-convex optimization problems, its searching performance should be analyzed through its statistical results. The major intent of this paper is to explore the ability of PSO-ITVAC in optimizing the congestion management problem.

In this paper a technique of congestion management based on PSO-ITVAC is proposed. The selection of generators participating in generation rescheduling for congestion management are done based on their sensitivities to the change in power flow on congested line. The minimization of generation rescheduling cost is done using PSO-ITVAC such that the value of φ is equal to sum of acceleration coefficients and greater than 4.0 in each iteration count. The searching performance of PSO-ITVAC is compared with other PSO-TVAC in minimizing the generation rescheduling cost in order to relieve congestion.

2. Particle swarm optimization (PSO)

PSO is an efficient and promising optimization technique used for non-convex optimization problems. It was first proposed by Kennedy and Eberhart in 1995 (Kennedy and Eberhart, 1995). It is a population based optimization algorithm which is motivated by social and cooperative behavior of organisms such as fish, birds etc. It consists of a population of potential solution called particles. Each particles search for a potential solution in multi-dimensional