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Fuzzy adaptive bacterial foraging congestion management using sensitivity based optimal active power re-scheduling of generators

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ABSTRACT

This paper presents a new method of fuzzy adaptive bacterial foraging (FABF) based congestion management (CM) for the first time by optimal rescheduling of active powers of generators selected based on the generator sensitivity to the congested line. In the proposed method, generators are selected based on their sensitivity to the congested line to utilize the generators efficiently and optimal rescheduling of the active powers of the participating generators was attempted by FABF. The FABF algorithm is tested on IEEE 30-bus system and Practical Indian 75-bus system and the results are compared with the Simple Bacterial Foraging (SBF) and Particle Swarm Optimization (PSO) algorithms for robustness and effectiveness of congestion management. It is observed from the results that FABF is effectively minimizing the cost of generation in comparison with SBF and PSO for optimal rescheduling of generators to relieve congestion in the transmission line.

1. Introduction

A system is said to be congested when the producers and consumers of electric energy desire to produce and consume in amounts that would cause the transmission system to operate at or beyond one or more transfer limits [1]. The Independent System Operator's (ISO) principal challenge in a deregulated environment is to maintain the power system security and reliability by maximizing market efficiency when the system is congested. The ISO has to create a set of transparent and robust rules that should not encourage aggressive entities to exploit congestion to create market power and maximize their profits at the cost of market. Congestion in a transmission system cannot be allowed beyond a short duration as there is an onset of cascading outages with uncontrolled loss of load.

In the literature survey as detailed in Section 2 of the paper on various evolutionary approaches to congestion management, it is observed that researchers have not attempted so far to dynamically adjust the run length vector of the SBF algorithm for optimal rescheduling of the active powers of the participating generators by applying fuzzy criterion to relieve congestion in the congested line. Further, no attempt has been made so far to employ SBF for optimal rescheduling of active power of the select participating generators to relieve congestion in the congested line. To incorporate the innovativeness into congestion management, a new method of FABF is attempted for the first time to relieve congestion in the congested line by optimal rescheduling of active powers of the select participating generators.

Instead of selecting all the generators to relieve congestion, in this paper it is proposed to select only those generators which are very sensitive for relieving congestion in transmission lines. This is done by the selection of participating generators using generator sensitivities to the power flow on congested lines. Further, it is proposed to solve congestion management problem by optimal rescheduling of active power of participating generators employing the FABF algorithm for the first time. Subsequently, the FABF algorithm is compared with SBF and conventional PSO algorithms to determine the best optimal solution for rescheduling the active power of participating generators to relieve the congestion.

In this paper static congestion management by optimal rescheduling of active power of the generators selected based on their sensitivities to the congested line is attempted by FABF for the first time and compared the test results with SBF and conventional PSO. The main advantage of this approach of relieving congestion in the congested line is quite efficient as it is a non-cost free means technique. This paper illustrates the effectiveness of the proposed method on the congestion management problem considering IEEE 30-bus system and the Practical Indian 75-bus system.

This paper is organized as follows. Section 2 details the literature survey on various recent evolutionary approaches to congestion management and Section 3 gives an insight into the proposed FABF algorithm. Section 4 details the problem formulation of congestion management by rescheduling the active power in participating generators selected based on their sensitivities with the congested

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line power flow and the methodology of implementation of FABF algorithm. The FABF algorithm effectiveness on IEEE 30-bus system and Practical Indian 75-bus system is being illustrated in Section 5 and the final outcome of the paper is summed up in Section 6 of the paper as Conclusions.

2. Literature survey

R.D. Christie et al. [1] explained in detail the congestion management and felt that controlling the transmission system so that transfer limits are observed is perhaps the fundamental transmission management problem. In order to relieve congestion, one can either use FACTS devices [2]; operate taps of a transformer, re-dispatch of generation [3] and curtailment of pool loads and/or bilateral contracts. In a deregulated environment, all the GENCOs and DISCOs plan their transactions ahead of time. But by the time of implementation of transactions there may be congestion in some of the transmission lines. Hence, ISO has to relieve the congestion so that the system remains in secure state. ISO use mainly two types of techniques to relieve congestion and they are as follows:

i) Cost free means:
  a. Out-aging of congested lines.
  b. Operation of transformer taps/phase shifters.
  c. Operation of FACTS [2] devices particularly series devices.
ii) Non-cost free means:
  a. Re-dispatch of generation [3] in a manner different from the natural settling point of the market. Some generators back down while others increase their output. The effect of this is that generators no longer operate at equal incremental costs.
  b. Curtailment of loads and the exercise of (non-cost-free) load interruption options.

R.S. Fang et al. [4] considered an open transmission dispatch environment in which pool and bilateral/multi lateral dispatches coexist and proceeded to develop a congestion management strategy for this scenario. K.L. Lo et al. [5] presented congestion management techniques applied to various kinds of electricity markets. Ashwani Kumar et al. [6] reviewed extensively the literature for reporting several techniques of congestion management and informed that the congestion management is one of the major tasks performed by Independent System Operators (ISOs) to ensure the operation of transmission system within operating limits. In the emerging electric power markets, the congestion management becomes extremely important and it can impose a barrier to the electricity trading. Ashwani Kumar et al. [7] proposed an efficient zonal congestion management approach using real and reactive power rescheduling based on AC Transmission Congestion Distribution factors considering optimal allocation of reactive power resources. The impact of optimal rescheduling of generators and capacitors has been demonstrated in congestion management. H.Y. Yamina and Shahidehpour [8] described a coordinating mechanism between generating companies and system operator for congestion management using Benders cuts. F. Capitanescu and Van Cutsem [9] proposed two approaches for a unified management of congestions due to voltage instability and thermal overload in a deregulated environment. J. Fu and Lamont [10] discussed a combined frame work for service identification and congestion management while a new approach were applied to identify the services of reactive support and real power loss for managing congestion using the upper bound cost minimization.

J. Kennedy and Eberhart [11] described the Particle Swarm Optimization (PSO) concept in terms of its precursors, briefly reviewing the stages of its development from social simulation to optimizer and discussed application of the algorithm to the training of artificial neural network weights. Y. Shi [12] surveyed the research and development of PSO in five categories viz. algorithms, topology, parameters, hybrid PSO algorithms and applications. In general, the search process of a PSO algorithm should be a process consisted of both contraction and expansion so that it could have the ability to escape from local minima, and eventually find good enough solutions. Y. del Valle et al. [13] presented a detailed review of the PSO technique, the basic concepts and different structures and variants, as well as its applications to power system optimization problems. Z.X. Chen et al. [14] introduced PSO for solving Optimal Power Flow (OPF) with which congestion management in pool market is practically implemented on IEEE 30 Bus system and proved that congestion relief using PSO is effective in comparison with Interior Point Method and Genetic Algorithm approach. J. Hazra and Sinha [15] proposed cost efficient generation rescheduling and/or load shedding approach for congestion management in transmission grids using Multi Objective Particle Swarm Optimization (MOPSO) method. S. Dutta and Singh [3] proposed a technique for reducing the number of participating generators and optimum rescheduling of their outputs while managing congestion in a pool at minimum rescheduling cost and explored the ability of PSO technique in solving congestion management problem. D.M. Vinod Kumar and Venkaiah [2] obtained an optimal solution for static congestion management using PSO based OPF method. Here, the congestion has been created in the transmission line by loading the lines and it is relieved by placing a Static Synchronous Series Compensator (SSSC) in an optimal location in the transmission line. D.N. Jeyakumar et al. [16] demonstrated the successful adaptation of the PSO algorithm to solve various types of economic dispatch (ED) problems in power systems viz. Multi-area ED with tie line limits, ED with multiple fuel options, combined environmental ED and ED of generators with prohibited operating zones. The better computation efficiency and convergence property of the PSO technique shows that it can be applied to a wide range of optimization problems. Z.-L. Gaing [17] proposed a PSO method for solving the ED problem with the generator constraints and demonstrated that the PSO method can avoid the shortcoming of premature convergence of Genetic Algorithm (GA) method while obtaining higher quality solution with better computation efficiency and convergence property.

K.M. Passino [18] explained in detail the biology and physics underlying the chemotactic (foraging) behavior of *Escherichia coli* bacteria that formulated Simple Bacterial Foraging (SBF) Optimization Algorithm for optimization process represented by the activity of social bacterial foraging. The algorithm presented in [18] has been utilized in this paper for optimal generation of active power of the participating generators. The SBF algorithm along with the procedure to create fuzzy logic rules using fuzzy toolbox of MATLAB 7.01 package to fuzzify the run length vector $C(i)$ for optimal value is incorporated in Appendix A of this paper for easy reference and the pseudo code of modified algorithm viz. FABF is detailed in Section 3 for solving the optimization problem. Janardan Nanda et al. [19] made a maiden attempt to examine and highlight the effective application of Bacterial Foraging algorithm to optimize several important parameters in Multiarea Automatic Generation Control (AGC) of a thermal system and compared its performance to establish its superiority over Genetic Algorithm (GA) & classical methods. B.K. Panigrahi and V Ravikumar Pandi [20] presented a novel stochastic optimization approach to solve constrained economic load dispatch problem using hybrid bacterial foraging technique. M. Tripathy et al. [21] observed that simultaneous tuning of the UPFC lead-lag type controller parameters with the bacterial foraging algorithm gave robust damping performance with variable operating conditions and severity of faults. It is concluded that the bacterial foraging algorithm is quite efficient in solving highly nonlinear optimization problems. B.K. Panigrahi and