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Transmission Congestion Management in Restructured Power System by Generation Rescheduling and Load Shedding using Evolutionary Programming based OPF

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Abstract

In this paper, an evolutionary programming (EP) technique based optimal power flow (OPF) is proposed for transmission congestion management in deregulated power system using generation rescheduling and Load Shedding compared with Improved Quadratic interior point (IQIP) method based OPF. The restructuring of electric power systems has resulted in market-based competition by creating an open market environment. A restructured system allows the power supply to function competitively, as well as allowing consumers to choose suppliers of electric energy. According to this change, traditional methods for power generation operation and control need modification. As the real and reactive power dispatches play a vital role to relieve the congestion at low congestion cost. The effectiveness of the proposed algorithm has been analyzed on European UCTE 2383- bus system.

Keywords: Congestion Management, Generation Rescheduling, Load Shedding, Restructured power system, Evolutionary Programming, Optimum Power Flow, Improved Quadratic interior point method.

Introduction

After restructuring of power industry, congestion in electric grid becomes quite often. Recently, several congestion management schemes have been proposed in literature.

A power system continually experiences changes in its operating state. An emergency state may occur as a result of a sudden increase in system demand, unexpected outages of generators or transmission lines or failure in any of the system components. Alleviation of the transmission line overload is a critical problem in power system operation; hence, a control action strategy is necessary effectively to reduce the congestion to the security limits in the minimum time. The possible corrective controls actions are generation rescheduling, load shedding, operate taps of a transformer, interchange adjustments and network switching [1].

Many methods have been proposed in the literatures for determining a secure operating point. Non-linear programming methods have been introduced for finding the coordinated control actions to eliminate the line overloads [2].

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 order to relieve congestion, one can either use FACTS devices; operate taps of a transformer, re-dispatch of generation 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 that congestion so that the system remains in secure state. To relieve the congestion, ISO can use mainly two types of techniques, which are as follows [3]-[5]: Cost free means are outaging of congested lines, Operation of transformer taps/phase shifters and Operation of FACTS devices series devices. Non-cost-free means are Re-dispatching of generation 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 and Curtailment of loads and the exercise of (not-cost-free) load interruption options.

Flexible AC Transmission System (FACTS) devices are commonly used devices to relieve congestion and maintain system security. The main advantages of FACTS devices are enhancing system flexibility and increasing the load ability. The Congestion is relieved by FACTS in optimal location which has been arrived at by considering maximum line loading as an Objective Function [6].

The effect of FACTS devices for provision of voltage control ancillary service and allocation of these devices for fair and equitable procurement of reactive power is considered. The participants submit their offer to system operator and the best combination of participants for procuring of required reactive power are selected. This method has efficient role in minimizing the cost of reactive power procurement and maximizing the social welfare and distance to voltage stability margins [7].

The cascade line tripping is one of the main causes that can lead to power system breakdown. To avoid line tripping during the post-disturbance period, new fast algorithms are required. This paper describes a new approach to distributed coordination of FACTS which makes it possible to control power flow during the long-term transients [8].

Congestion management is one of the technical challenges in power system deregulation. It describe multi-objective optimization approaches for optimal choice, location and size of Static Var Compensators (SVC) and Thyristor Controlled Series

Capacitors (TCSC) in deregulated power system to improve branch loading (minimize congestion), improve voltage stability and reduce line losses [9]-[11].

In this paper congestion management using conventional OPF, EP based OPF has been tested on European UCTE 2383-bus system and compared to find the global optimal solution.

Problem Formulation

The objective of congestion management is to minimize the transmission congestion and the cost of generation.

Objective Functions Three objective functions are considered. They are fuel cost minimization, VAR planning, and loss minimization.

Line overloads minimization

$$\text{Minimize} \qquad F_O = \sum_{ij=1}^{NB} \left(P_{ij}(t) - P_{ij\max}\right)^2 \tag{1}$$

Fuel cost minimization

$$\text{Minimize} \qquad F_G = \sum_{i=1}^{N_G} \left(a_i P_{g_i}^2 + b_i P_{g_i} + c_i\right) \tag{2}$$

Loss minimization

$$\text{Minimize} \qquad P_L = F\left(P_{g_{slack}}\right) \tag{3}$$

where

F_o is the overload objective function.

$P_{ij}(t)$ is the overload flow on transmission line ij at time stage t.

P_{ijmax} is the transmission limit of line ij.

NB is the set of overload lines.

P_{gi} is the real power generation at generator i.

P_L is the system real power loss.

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \qquad i \in NG \tag{4}$$

$$\sum_{i=1}^{NG} P_{gi} = \sum_{k=1}^{ND} P_{dk} + P_L \tag{5}$$

$$P_{gi} - P_{dk} - F_i(V, \theta, T) = 0 \tag{6}$$

$$i = 1,2,......, N_{bus}, \qquad i \ne slack \tag{7}$$

$$Q_{gi} - Q_{dk} - G_i(V, \theta, T) = 0 \tag{8}$$

$$i = 1,2,\ldots\ldots,\ N_{bus}, \qquad i \neq slack \tag{9}$$

$$\frac{V_i^2 + V_j^2 - 2V_iV_j\cos\left(\theta_i - \theta_j\right)}{Z_L(l)^2} - I_{L\max}^2(l) \leq 0 \qquad l = 0,1,2,\ldots\ldots,\ Nl \tag{10}$$

$$Q_{gi}^{\min} \leq Q_{gi} \leq Q_{gi}^{\max} \qquad i \in NG \tag{11}$$

$$V_{gi}^{\min} \leq V_{gi} \leq V_{gi}^{\max} \qquad i \in NG \tag{16}$$

$$V_{di}^{\min} \leq V_{di} \leq V_{di}^{\max} \qquad i \in ND \tag{17}$$

$$T_i^{\min} \leq T_i \leq T_i^{\max} \qquad i \in NT \tag{18}$$

$$P_{slack} = F_{slack}\left(V, \theta, T\right) \tag{19}$$

where

P_{dk} is the real power load at load bus k.

Q_{di} is the reactive power load at load bus i.

V_{gi} is the voltage magnitude at generator bus i.

V_{di} is the voltage magnitude at load bus i.

Q_{gi} is the VAR generation of generator i.

Z_L is the impedance of transmission line L.

$I_L$max is the maximal current limit through transmission line L.

θ is the bus voltage angle.

P_L is the system real power loss.

NG is the set of generation buses.

NT is the set of transformer branches.

ND is the set of load buses.

Congestion Management using EP based OPF

The term congestion has come to power systems from economics in conjunction with deregulation, although congestion was present on power systems before deregulation. Then it was discussed in terms of steady state security, and basic objective was to control generator output, so that the system remained secured at the lowest cost.

Evolutionary Programming

Natural evolution is a population - based optimization process. The evolutionary programming is different from the conventional optimization methods, and they do not need to differentiate cost function and constraints. Theoretically, like simulated annealing, EP converges to the global optimum solution. Evolutionary programming is artificial intelligence method for optimization based on the mechanics of natural selection, such as mutation, recombination, reproduction, crossover, selection, etc.

Since EP requires all information to be included in the fitness function, it is very difficult to consider all OPF constraints. EP is generally used to solve a simplified OPF problem such as the classic economic dispatch, security - constrained economic power dispatch, and reactive optimization problem, as well as optimal reconfiguration of an electric distribution network.

Optimum Power Flow

The optimal power flow (OPF) was first introduced by Carpentier in 1962 [5]. The goal of OPF is to find the optimal settings of a given power system network that optimize the system objective functions such as total generation cost, system loss, bus voltage deviation, emission of generating units, number of control actions, and load shedding while satisfying its power flow equations, system security, and equipment operating limits. Different control variables, some of which are generators ’ real power outputs and voltages, transformer tap changing settings, phase shifters, switched capacitors, and reactors, are manipulated to achieve an optimal network setting based on the problem formulation. Optimal power flow (OPF) calculations determine optimal control variables and system quantities for efficient power system planning and operation. OPF has now become a useful tool in power system operation as well as in planning. Various techniques were developed to solve the OPF problem. The algorithms may be classified into three groups: conventional optimization methods, intelligence search methods, and non-quantity approach to address uncertainties in objectives and constraints.

Generator Bus Voltages and VAR Limits

The violation of generator MVAR limits, if any, may be examined and necessary adjustments in generator terminal voltages can be made at the end of line overload alleviation.

Generation Rescheduling

Some line overloads can be alleviated by generation rescheduling alone. The studies indicate the suitability of this alternative to smaller systems. The results, however, suggest an investigation of the possibility of alleviating line overloads by generation rescheduling alone before attempting generation rescheduling and load shedding. The computational expenses can be minimized by attempting generation rescheduling during the initial overload alleviation pass followed by generation rescheduling and load shedding in the subsequent passes.

Load shedding

When all available controls are unable to maintain the security of system operation during a disturbance or contingency, optimal load shedding will be used as the last resort to make the loss of blackout minimum.

Proposed Method

Generation Rescheduling and Load shedding

The proposed techniques can alleviate all line overload conditions occurring in practical systems. The results, however, suggest an investigation of the possibility of alleviating the line overloads by generation rescheduling alone, before attempting generation rescheduling and load shedding. The computational expenses can be minimized by attempting generation rescheduling during the initial overload alleviation pass, followed by generation rescheduling and load shedding in the subsequent passes

Algorithm for congestion management using EP based OPF

Step 1: The whole system data along with data for EP operator's like probability of initialization, mutation, competition and selection are read.

Step 2: Population is initialized randomly within the control variables limits.

Step 3: In the present population is fitness using fitness function for the same is evaluated.

Step 4: The populations are sorted according to their fitness values in descending order and EP operations are performed on the present set of population to get a new set of population.

Step 5: Check for convergence. If convergence is not met go to step 3 and repeat the process. If the convergence is met display the results.

Results and Discussion

This paper focuses on demonstrating a technique for optimum power flow by generators rescheduling and load shedding for congestion management. Transmission congestion management is a challenging issue in deregulated power systems and the system operator is usually faced with this problem. Many approaches have been proposed and applied to address this problem. In this paper, generators rescheduling as a new procedure for congestion management is discussed. To verify the effectiveness of the proposed method, simulations were carried out on the European UCTE 2383 bus test systems.

Table 1: Results Summary of European UCTE 2383 bus system.

Parameters	Quantity
Buses	2383
Generators	327
Loads	1822
Branches	2896
Transformers	170
Inter-ties	13
Areas	4
Cost	1796837.1 \$/hr

Table 2: Voltage of Europen UCTE 2383 bus system.

Parameters	Quantity (min)	Quantity (max)
|V|	0.977 p.u. @ 145	1.12 p.u. @192
θ	-40.77 deg @ 1858	7.68 deg @110

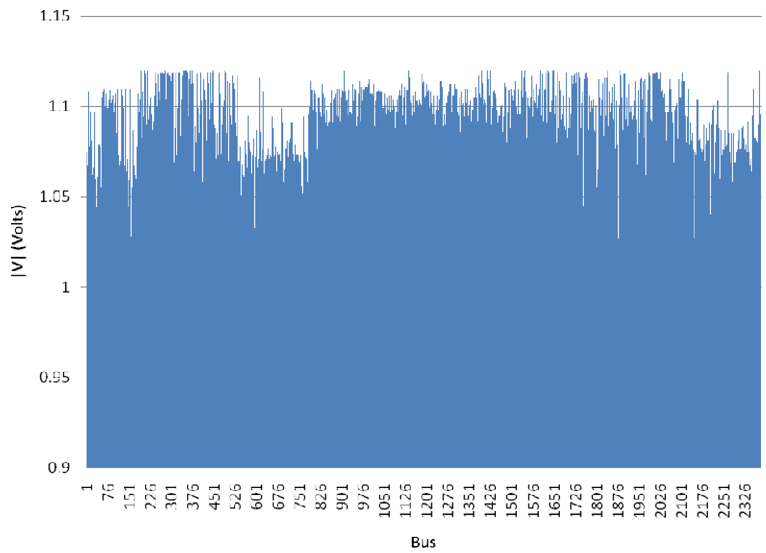

Figure 1: Voltages for European UCTE 2383 bus test systems.

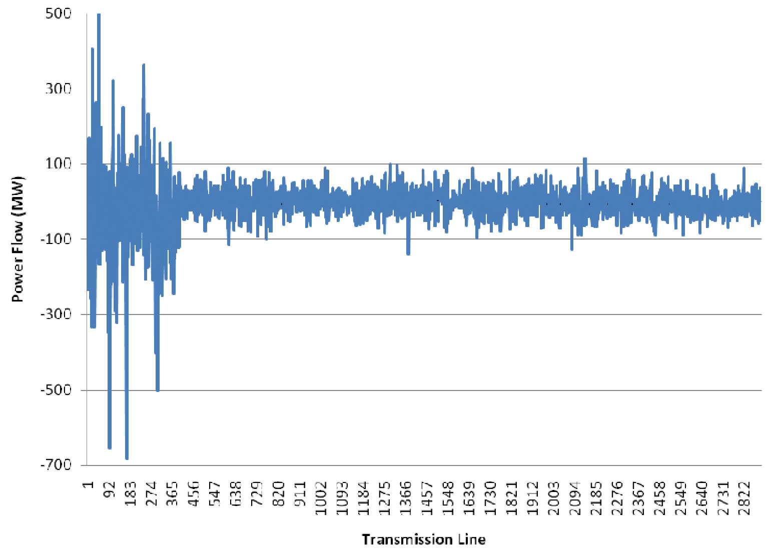

Figure 2: Power Flow for European UCTE 2383 bus test systems.

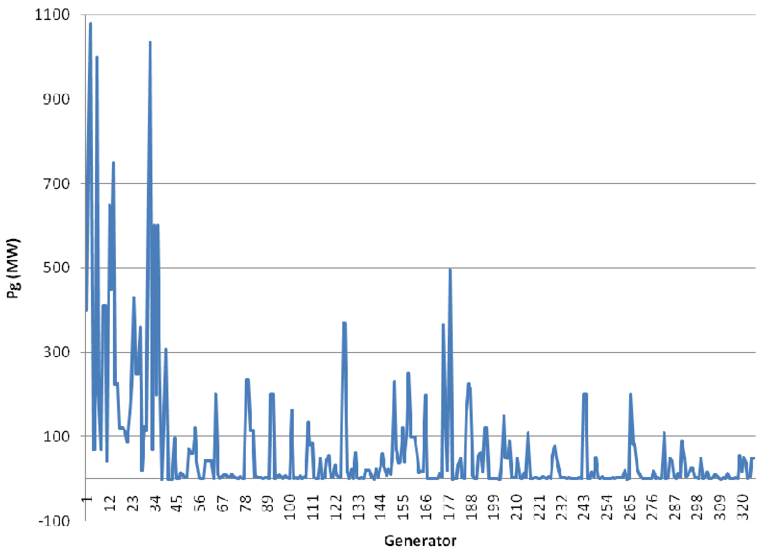

Figure 3: Power Generation for European UCTE 2383 bus test systems.

Conclusion

This paper presents a method for congestion management in transmission systems using cost-efficient generation rescheduling and load shedding. Two conflicting objects tolerable overload and cost of operation are minimized simultaneously and congestion is managed by means of generation rescheduling. If congestion cannot be removed by generation rescheduling, load shedding is done as a last resort at the participating load buses. A sensitivity analysis method which relates change in real and reactive power injections at bus bars to the change in line currents is proposed to select the participating buses.

The problem of generation rescheduling and load shedding for alleviation of line overloads is very important for operational planning, security studies and reliability evaluation of power systems. An efficient, reliable and direct method is always desirable. An Improved Quadratic interior point based EP model is developed for the same and is tested on European UCTE 2383 bus systems under both normal and contingency states. This method gives the proper results to alleviate line overloads. The proposed approach is easy to implement.

References

[1] Selvi, K. Meena, T. Ramaraj, N, 2007, "A Generation Rescheduling Method to Alleviate Line Overloads using PSO" Institute of Engineers, Vol. 88, pp. 10-13.

[2] A Shandilya, H Gupta and J Sharma, 1993, ‘Method for Generation Rescheduling and Load Shedding to Alleviate Line Overloads using Local Optimization’. IEEE Proceedings, vol 140, no 5, pp 337-342.

[3] A.K.David, 1998, “Dispatch methodologies for open access transmission systems,” IEEE Transactions on Power Systems, Vol. 13, No. 1, pp 46-53.

[4] R. S. Fang and A. K. David, 1999, “Transmission congestion management in electricity market”, IEEE Transactions on Power Systems, Vol. 14, No.3, pp. 877-883.

[5] Harry Singh, Shan You, and Alex Papalexopalos, 1998, “Transmission congestion management in competitive electricity market”, IEEE Transactions on Power Systems, Vol. 13, No. 2, pp.672-680.

[6] Nazanin Hosseinipoor, Syed M.H Nabavi, 2010, “Optimal Locating and Sizing of TCSC Using Genetic Algorithm for Congestion Management in Deregualted Power Markets”, International Conference on Environment and Electrical Engineering, pp. 136 – 139.

[7] M. Peikherfeh, M. Abapour, M. Parsa Moghaddam, A. Namdari, 2010, “Optimal Allocation of FACTS Devices for Provision of Voltage Control Ancillary Services”, International Conference on the European, pp. 1-5.

[8] D. A. Panasetsky, and N. I. Voropai, 2010, “A Distributed Control of FACTS Devices against Line Overloading”, International Conference on Power System Technology, pp. 1-6.

[9] S.Surender Reddy, M.Sailaja Kumari and M.Sydulu, 2010, “Congestion Management in Deregulated Power System by Optimal Choice and Allocation of FACTS Controllers Using Multi-Objective Genetic Algorithm”, Transmission and Distribution Conference and Exposition (IEEE PES), pp. 1-7.

[10] S. Chakrabarti, B.Jeyasurya, 2008, "Generation rescheduling using ANN-based computation of parameter sensitivities of the voltage stability margin", Engineering Applications of Artificial Intelligence 21, pp 1164–1169.

Authors Biography

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S.R. Paranjothi received his B.E. (Electrical) and M.Sc. (Engg.) from the University of Madras. He obtained his Ph.D. degree in 1977 from the Indian Institute of Technology, Kanpur. During his outstanding academic career spanning 44 years, he served as a Professor as well as Dean in College of Engineering, Guindy, Government College of Technology, Coimbatore and Anna University, Chennai. He has published several technical papers in national and international journals. He was a member of the Board of studies of many Technical Institutions. He has worked as a Member of the Academic Council of Anna University. He has also been the member of the Syndicate of the Anna University. He is also a Fellow member of many professional societies like Institution of Engineers (India), IET (UK), etc. and has served them with distinction from time to time.