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Optimization Technique for Congestion Management in Restructured Power Market

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***Abstract*: Power system congestion has become one of the most significant problems faced by system operators (SO) around the globe after the restructuring of the electricity industry. It creates hurdle in the smooth functioning of deregulated electricity market and causes an increased cost associated with it. So the investigation of congestion management techniques is of vital interest. This project presents a congestion management algorithm by optimally rescheduling the generator active power outputs. But all the generators in the system may not be taking part in the rescheduling process. Participating generators are optimally selected based on the generator sensitivities to power flow on congested lines. The algorithm manages congestion effectively ensuring minimum rescheduling cost of participating generators satisfying power balance, generator operating limits and line flow constraints. Algorithm is based on Particle Swarm Optimization (PSO) which minimizes the deviation between the rescheduled and scheduled generator power output levels. The usefulness of this methodology has been studied using the IEEE standard test systems. The IEEE Standard test system used is IEEE 30 bus.**

***Keywords*: Particle swarm optimization, congestion, generator rescheduling, system operator.**

1. Introduction

Due to the restructuring of electricity industry there is a wide change in planning, operation and management of power system. Deregulation of electricity markets has a lot of advantages; however it made the electricity industry to face many unprecedented problems. Electricity market has some major complexities like lack of major storage capability, the just-in-time-manufacturing nature of electricity and the central role played by the transmission and distribution networks. The deregulated electricity industry introduces increased number of market participants, i.e. generation, transmission and distribution companies and so the number of transactions in the system will be more in number. A transaction means the energy transfer between two points in the power system. All the transactions depend on the transmission system as a means of transportation. In the conventional electricity market the utilities had control over the generation and transmission facilities. The current transmission system was designed long before and was not planned for the deregulation in the market. This causes congestion in the transmission system. The demand for electric power is increasing day by day and the utilities are increasing the generation in order to meet the demand. But the transmission lines have some limits in terms of thermal stability and voltage limits. When such limits are exceeded, the system is said to be congested and the system operator has to ensure that these limits are not exceeded. When there is congestion in the transmission system, all the desired transactions may not be realized. These unrealized transactions may cause additional costs in the system. Energy may not be able to purchase from the supplier who offers it at the lowest cost and the same amount of power has to be purchased from a different supplier at a higher cost. The situation is severe where the demand is more, supply is less and to keep the balance power has to be imported from the neighboring systems. So the transmission congestion occurs at the tie lines. After some years of restructuring, operating rules and procedures are still constantly changing. The main effort lies in providing an effective market design for the restructured environment. One of the key requirements for the implementation of competitive markets is an effective management of congestion.

This paper mainly intended to present a technique for reducing the number of participating generators in rescheduling. It also optimally reschedules their real power outputs while managing congestion at minimum rescheduling cost. In a congested power system, the incremental or detrimental change in power outputs of all the generators may not equally affect the power transmitted on the congested line. So there is no need to reschedule the outputs of generators whose generations are less significant to the congested line flow. The sensitivities of the generators to the congested line are used to optimally select the participating generators. The second major purpose of this paper is to discuss the ability of particle swarm optimization algorithm in solving the congestion management problem.

2. Need of optimization

In the restructured power system, the transmission stability limits violation results in the form of system imbalance in the system operation and controlling cost. Thus for stable system operation the system operator (SO) should manage the congestion in the transmission system. For congestion management, rescheduling of the generation is most efficient method. The generation rescheduling is done by using Particle Swarm optimization Technique.

3. Particle swarm optimization

In computational science, particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a solution with regard to a given measure of quality. It solves a problem by having a population of solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position, but is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions. The flow chart of Time Varying Acceleration Coefficient is shown below.

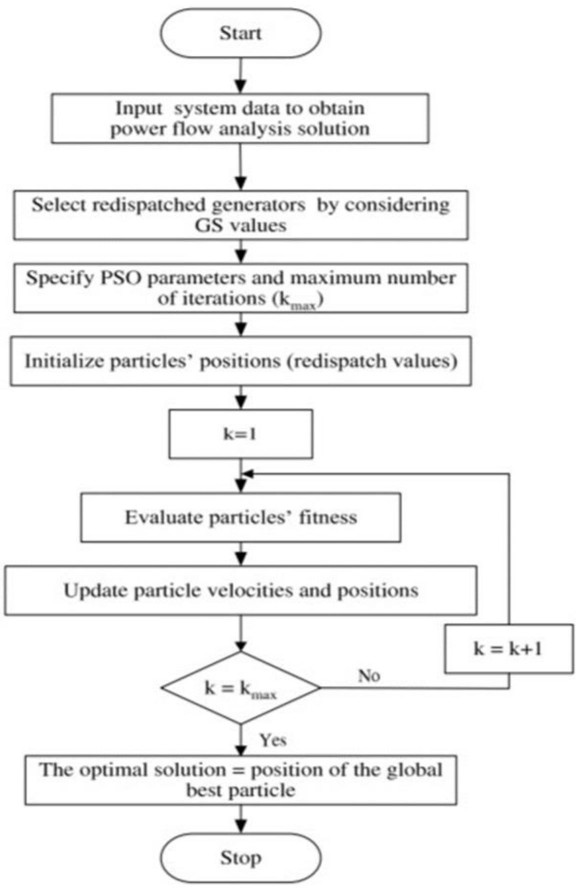

Fig. 1. Flowchart

4. Problem formulation for congestion management

Based on the bids received from the participating generator the required amount of real power for rescheduling is calculated by solving the optimization problem as,

$$Minimize \sum_{g}^{Ng} C_g\left(\Delta P_g\right)\Delta P_g$$

Subjected to

$$\Delta P_g^{min} \le \Delta P_g \le \Delta P_g^{max} \qquad ;g=1,2,\ldots,N_g$$

$$\Delta P_g^{min} = P_g - P_g^{min}$$

$$\Delta P_g^{max} = P_g^{max} - P_g$$

$$\sum_{g=1}^{Ng} \Delta P_g = 0$$

$$\sum_{g=1}^{Ng}\left(\left(GS_g^{ij}\right)\Delta P_g\right) + F_l^0 \le F_l^{max} \qquad ;l=1,2,\ldots,n_l$$

Where,
g =Participating generator.
Ng= Number of participating generators.
ICg= Incremental and decremental cost of generator g.
ΔPg=Active power adjustment at bus g.
ΔPgmin = Minimum adjustment limit of generator g.
ΔPgmax=Maximum adjustment limit of generator g.
Pg= Active power output.
Pgmin= Minimum generation limit of generator g.
Pgmax=Maximum generation limit of generator g.
Fl0= Power flow caused by all contracts requesting the transmission service.
Flmax=Power flow limit of line l.
Nl= Number of transmission lines in the system.
ΔPij = Changed in active power flow on the line connected between buses i & j.
ΔPGg=Changed in active power of generator g.
n =Number of all the buses in the system.

5. Generator sensitivity factor

The generators in the system have different sensitivities to the power flow on the congested line. A change in real power flow in a transmission line n connected between bus j and bus k due to change in power output of generator G is called generator sensitivity to congested line (GS). Mathematically, GS for line k can be expressed as,

GS =ΔPjk / ΔPGG

Where,
Pjk is the real power flow on congested line-n;
PGG is the real power output of the Gth generator.

6. Results

The proposed PSO algorithm for congestion management has been implemented using MATLAB tool box. The performance of the algorithm has been studied on IEEE 30 bus system. The influence of various parameters of PSO is also studied in this work.

The IEEE 30 bus system: The IEEE30 bus system is considered for showing the effectiveness of the proposed algorithm IEEE 30 bus system has 6 generators, 30 buses, 37 lines, 4 transformers and 21 loads.

Table 1
Line outage and power flows

Type	Congested Line	Line flow	Total Power Violation
Outage of Line 1-3	1-2	130 MW	177.77MW

Table 2
Losses and Rescheduling

S. No.	Losses (IEEE30 bus system)	Losses before Rescheduling	Losses after Rescheduling
1	Active power losses(MW)	3.355	2.015
2	Reactive power losses(MVAR)	11.63	9.78

Table 3
Parameter Selection for PSOTVIW

S. No.	Wmax	Wmin	C1	C2	Partical size	Amount of power after Rescheduling	Cost of Rescheduling
1	0.9	0.2	2	1.5	70	86.73MW	1387.68$/MWhr

The system configuration is shown below:

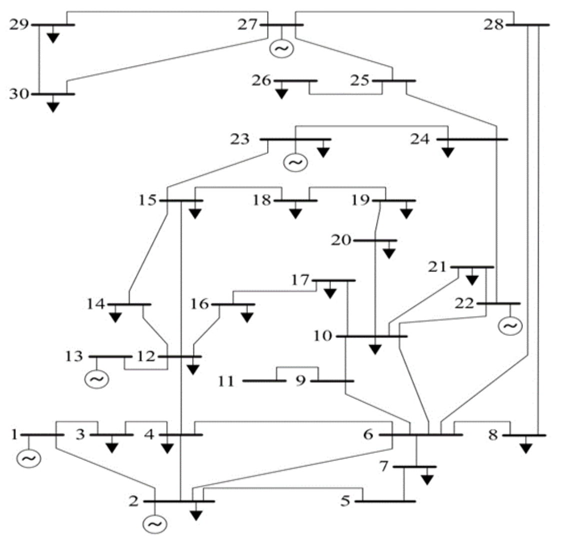

Fig. 2. IEEE 30-bus system

In power system, congestion may occur due to several reasons including line outage. From the analysis done it is found that line outage in the line 1-3 results in severe overload in the line 1-2. Simulated test case is shown in the Table 1.

For the test case N.R. Power flow analysis is carried out and amount of power overload is identified as shown in Table 1.

In the test case the power flow limit for the line is 83MW and a power flow violation of 177.77MW is found in the line 1-2. For secure system the power flow in the transmission line should not exceed the power flow limit. Hence the suitable corrective actions are to be done to alleviate the above said overload. So using Particle swarm optimization algorithm the optimal power reallocation is done to manage this overload.

7. Conclusion

The paper concentrates on presenting a technique for optimum selection of generators for congestion management based on their sensitivities to the active power flow of the congested. The optimization technique discussed in this paper is particle swarm optimization with time varying inertia weight.

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