Enhancement of Power System Security Using Optimization Technique

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Abstract: The major challenge in power systems planning and operation is maintaining security and performance of the system. Maintaining a stable and secure operation of a power system is therefore very important. It is desirable to plan suitable measures to maintain and improve security of the power system. The contingency analysis has been an important tool in power system planning and Security analysis. In general an outage of one transmission line or transformer may lead to over loads in other branches and sudden system voltage rise or drop. This paper presents Newton-Ramphson (NR) and Particle swarm optimization (PSO) methods to solve the contingency constrained optimal power flow (OPF) in power system. This optimal power flow algorithm effectively relieves line flow violations under different single line contingencies. The efficiency of proposed algorithm is illustrated by carrying simulation studies on IEEE 14 bus system with different objectives that reflect fuel cost minimization. This analysis reveals that the proposed algorithm is quite simple and efficient for solving OPF problem.

Key Words: Optimal power flow, Contingency, Newton Ramphson, Particle swarm optimization.

I. INTRODUCTION

With the increase in power demand, operation and planning of large interconnected power systems are becoming more and more complex [1]-[2]. It is possible to alleviate power flow violation and enhance power system security in an electrical power system. The optimal power flow solution includes an objective function that is optimised by maintaining the system operating constraints and security [3]-[5]. Over the last three decades, OPF solution algorithms used different mathematical programming techniques such as sequential linear programming (SLP), quadratic programming (QP) and Newton based nonlinear programming methods [1]. NR method has potent convergence characteristics compared to other alternative processes and has low computation. This method has great flexibility and generality hence enables easy and efficient involvement of representational needs. One of the most important tasks in power system planning is contingency analysis. Contingency analysis ensures that the operation of the system is secure [6]-[8]. The main modern optimization techniques are genetic algorithm (GA), evolutionary programming (EP), artificial neural network (ANN), simulated annealing (SA), Ant Colony optimization (ACO). Recently, a new evolutionary computation technique, called particle swarm optimization (PSO), has been proposed. This technique combines social psychology principles in socio-cognition human agents and evolutionary computations. PSO is characterized as computationally efficient technique. Unlike the other heuristic techniques, PSO has a flexible and well-balanced mechanism to enhance and adapt to the global and local exploration abilities [9]-[12]. Thus, optimal power flow (OPF) with PSO is a good choice.

This paper presents a PSO algorithm for handling line overloads under single line contingencies.

II. OPTIMAL POWER FLOW

The optimal power flow problem is to optimize the steady state performance of a power system in terms of an objective function while satisfying several equality and inequality constraints. Mathematically the OPF problem can be formulated as follows:

$$\min F(x, u) \qquad (1)$$

$$\text{Subject to: } G(x, u)=0 \qquad (2)$$

$$H(x, u) \leq 0 \qquad (3)$$

Where F is the objective function to be minimized, G is the equality constraints and H is the system operating constraints.

X is the vector of dependent variables consisting of slack bus power P_{G1}, load bus voltages V_L generator reactive power outputs Q_G, and transmission line loadings S_1 and can be expressed as

$$X^T=[P_{G1},V_{L1}\dots V_{LNL},Q_{G1}\dots Q_{GNG},S_I\dots S_{Inl}] \quad (4)$$

Where NL is the number of load buses, NG is the number of generators and nl is number of transmission lines respectively.

U is the vector of independent variables consisting of generator voltages V_G , generator real power outputs P_G except at the slack bus P_{G1} , transformer tap settings T, and shunt VAR compensations Q_C and can be expressed as

$$U^T=V_{G1}\dots V_{GNG},P_{G2}\dots P_{GNG},T_1\dots T_{NT},Q_{C1}\dots Q_{CNC}] \quad (5)$$

Where NT and NC are the number of the regulating transformers and shunt compensators respectively.

1. Constraints

The OPF has two categories of constraints.

1.1. Equality Constraints

These are the set of nonlinear power flow equations that govern the power system,

$$P_{Gm}- P_{Dm}-\sum_{n=1}^{I} |V_m||V_n||Y_{mn}|\cos(\theta mn-\delta m+\delta_n)=0 \quad (6)$$

$$Q_{Gm}- Q_{Dm}+\sum_{n=1}^{I} |V_m||V_n||Y_{mn}|\sin(\theta_{mn}-\delta_m+\delta_n)=0 \quad (7)$$

Where P_{Gm} and Q_{Gm} are the real and reactive power outputs injected at bus m repectively, the load demand at the same bus is represented by P_{Dm} and Q_{Dm} , and elements of the bus admittance matrix are represented by Y_{mn} and θ_{mn}.

1.2 Inequality constraints

These are the set of constraints that represente the system operational and security limits like the following.

1.2.1. Generation constraints

Generator voltages, real power outputs, and reactive power outputs are restricted by their lower and upper limits
As follows.

$$V_{Gm}^{min}\leq V_{Gm}\leq V_{Gm}^{max},\quad m=1\dots NG \quad (8)$$

$$P_{Gm}^{min}\leq P_{Gm}\leq P_{Gm}^{max},\quad m=1\dots NG \quad (9)$$

$$Q_{Gm}^{min}\leq Q_{Gm}\leq Q_{Gm}^{max},\quad m=1\dots NG \quad (10)$$

Where NG: number of generators

1.2.2. Transformer Constraints

Transformer tap settings are bounded as follows:

$$T_m^{min}\leq T_m\leq T_m^{max},\quad m=1\dots NT \quad (11)$$

Where NT: number of regulating transformer

1.2.3. Shunt VAR Constraints

Shunt VAR compensators are restricted by their limits as follows:

$$Q_{Cm}^{min}\leq Q_{Cm}\leq Q_{Cm}^{max},\quad m=1\dots NSVC \quad (12)$$

Where NSVC: number of shunt var compensators

1.2.4. Security Constraints

These include the constraints of voltges at load buses and transmission line loadings as follows:

$$V_{Lm}^{min}\leq V_{Lm}\leq V_{Lm}^{max},\quad m=1\dots NL \quad (13)$$

Where NL: number of load buses

1.2.5.Transmission lines loading

$$S_m\leq S_m^{max},\quad m=1\dots nl \quad (14)$$

Where nl: number of Transmission lines

III.CONTINGENCY ANALYSIS

Contingencies are defined as potentially harmful disturbances for the steady state operation of an electrical network. A power system under normal operating conditions may face a contingency such as line outages or generator outages or loss of transformer, sudden change in the load or faults. These contingencies may cause transmission line over loading and bus voltage limit violations. The objective is to find the overloads or voltage violations under such contingencies and proper measures are needed to alleviate these violations. Load flow analysis plays a vital role in finding these contingencies and determining the corrective actions.

1. Contingency creation:

It is the first step of analysis. This process comprises of creating contingencies list.

2. Contingency selection:

It is the second step and it is the process which involves selection of severe contingencies from the list.

3. Contingency evaluation:

It is the third step and the most important one as it involves necessary control action and necessary security actions.

IV. PARTICLE SWARM OPTIMIZATION

The Particle Swarm Optimization (PSO) technique is motivated by the behaviour of social organisms such as fish schooling and bird flocking. It searches for near global optimum using a set of particles where each particle represents a feasible solution. Unlike other heuristic algorithms, PSO has the flexibility to control the balance between the global and local exploration of the search space. This unique feature of PSO overcomes the premature convergence problem and enhances the search capability.

In PSO, each single solution in search space is called as “particle”. All of particles have fitness values, which are evaluated by the fitness function to be optimized, and have velocities, which direct the flying of the particles. The particles are “flown” through the problem space by following the current optimum particles. PSO is initialized with a group of random particles and then searches for optima by updating generations. In each iteration, each particle is updated by using Pbest and Gbest values. Where Pbest is the best solution (fitness) it achieved by the particle called as local best and Gbest is the best solution among all particles in the population called as global best. By using the Pbest and Gbest values, the particle updates its velocity and positions.

The major steps involved in PSO approach are described as follows,

Step 1 (Initialization): Generate randomly n particles, by randomly selecting a value with uniform probability over the jth control parameter’s search range [xjmin, xjmax]. Evaluate fitness fi of all particles (i = 1,2,…n) in the swarm and obtain the Pbest of each particle and thereby compute the Gbest. Initialize the initial velocities of all particles to zero.

Step 2 (Velocity updating): Using the Pbest and Gbest compute the kth element’s velocity of the ith particle as,

$$V_i^{k+1}=wV_i^k+c_1\,rand_1*(pbest_i-s_i^k)+c_2 rand_2*\,(gbest-s_i^k) \qquad (15)$$

where, v_i^k : velocity of agent i at iteration k,
w: weighting function,
c_j : weighting factor,
rand : uniformly distributed random number between 0 and 1
s_i^k : current position of agent i at iteration k,
$pbest_i$: pbest of agent i,
gbest: gbest of the group.

The following weighting function is usually utilized in

$$w=wMax-[(wMax-wMin)xiter]/maxIter \qquad (16)$$

where wMax= initial weight,
wMin = final weight,
maxIter = maximum iteration number,
iter = current iteration number.

Where d=1, 2, 3 ...D is the number of members in a particle, i=1, 2 ...m is the number of particles in a swarm, k is the number of current generation. V_i^k is the velocity of i-th particle in dimension d-th, V_i^K ϵ [- vmin ,vmax] w is the inertia weight factor , c1, c2 are two positive constant parameters called acceleration coefficients,rand1 and rand2 are the random functions in the range [0, 1], gbest is the best position among all particles in the swarm and S_i^k is the current position of particle.

Step 3 (Position updating): Based on the updated velocities, each particle changes its position as,

$$s_i^{k+1} = s_i^k + V_i^{k+1}$$

If a particle violates its position limits in any dimension, set its position at the violating limit.

Step 4 (Updating Pbest and Gbest): With the updated position evaluate fitness of all particles in the swarm and obtain the Pbest of each particle and thereby compute the Gbest.

Step 5 (Stopping criteria): If the preselected maximum iteration is reached then the Gbest is the global optimal solution, otherwise increment the iteration count and repeat steps 2 to 4.
The flow diagram of PSO is shown below.

V.COMPUTATIONAL PROCEDURE FOR SOLVING THE PROBLEM

The implementation steps of the proposed PSO algorithm can be written as follows;

STEP-1: Initialize the parameters such as number of particles, the size of population, initial and final inertia weight, velocity of particle, number of iterations etc.

STEP-2: Assume several contingencies.

STEP-3: OPF calculation with PSO for most severe contingency in order.

STEP-4: If OPF is solvable go to step 2 else go to step 5

STEP-5: Checking the limit violation for security constraints. If iterations reached to its maximum value then go to step 6 else go to step 2.

STEP-6: STOP.

VI.SIMULATION RESULTS

The proposed PSO algorithm is tested on the standard IEEE 14-bus test system shown in Fig.1. and implemented using MATLAB software.

The IEEE 14 bus system has five generators at buses 1, 2, 3, 6, 8 and three transformers with off-nominal tap ratio in lines 5-6, 4-7, and 4-9.The network has total active power load of 259 MW. Totally there are 13 control variables which consist of five Generator Bus voltages, three tap changing transformers and five Shunt compensators.

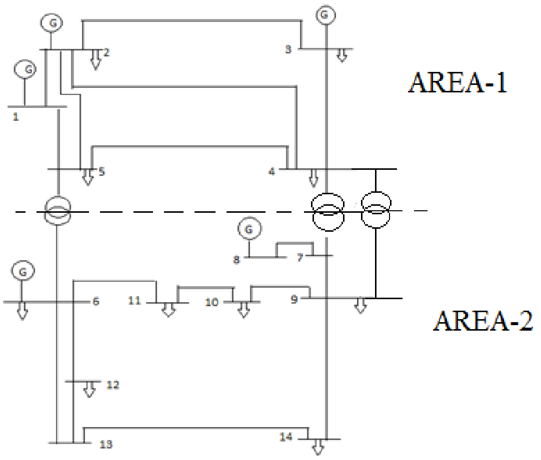

Fig.1 Single line diagram of IEEE 14 bus system

To check the effectiveness of the proposed PSO algorithm, the IEEE 14 bus system is divided into two areas. The area-1 network consists of total active power load of 171.3 MW, three generators and seven transmission lines.

The area-2 network consists of total active power load of 87.7 MW, two generators and 10 transmission lines. Contingency analysis for both areas was carried out and outage of lines 1-2 and 2-3 are found to be most severe contingencies as they are creating overloading on other lines.
The PSO parameters used for simulation are Summarized in TABLE 1.

Parameter	values
Population size	20
Number of iterations	100
Cognitive constant, c_1	2
Social constant ,c_2	2
Inertia weight ,w	0.3-0.95

Table 1 Optimal Parameter Settings for PSO

areas	Generating units	Regional Generation(MW)		Total Generation(MW)		Cost of generation($/h)		Total cost of generation($/h)		Saving cost($/h)
		Without PSO	With PSO	Without PSO	With PSO	Without PSO	With PSO	Without PSO	With PSO	
1	1	77.84	102.95	174.98	203.93	511.08	617.468	891.33	852.29	39.04
	2	70.00	73.34							
	3	28.09	27.64							
2	4	61.6	31.14	88.9	62.17	380.25	234.824			
	5	12.00	31.03							

Table 2 The Results of OPF With Line 1-2 Outage

TABLE 2 gives the results of OPF with line 1-2 outage. Considering, base case condition (without PSO) it is observed that some of the lines are overloaded, the total generation of area-1 is 174.98 MW and area-2 is 88.9 MW .The total cost of generation for both areas is 891.33 $/h. In order to rectify the problem of overload in lines, the two areas are combined and PSO algorithm has been implemented. Now it is observed that the total generation increased for area-1 by 203.93 MW and decreased for area-2 by 62.17 MW. The total cost of generation for both areas is 852.29 $/h. The security is improved by maintain all constraints within limits and overall net saving cost of generation is by 39.04 $/h.

areas	Generating units	Regional Generation(MW)		Total Generation(MW)		Cost of generation($/h)		Total cost of generation($/h)		Saving cost($/h)
		Without PSO	With PSO	Without PSO	With PSO	Without PSO	With PSO	Without PSO	With PSO	
1	1	76.98	104.35	175.07	204.97	508.04	622.63	888.29	854.93	33.35
	2	70.00	70.00							
	3	28.09	30.62							
2	4	61.6	29.63	88.9	61.6	380.25	232.30			
	5	12.00	31.97							

Table 3 The Results of OPF With Line 2-3 Outage

TABLE 3 gives the results of OPF with line 2-3 outage. Considering, base case condition (without PSO) it is observed that some of the lines are overloaded, the total generation of area-1 is 175.07 MW and area-2 is 88.9 MW. The total cost of generation for both areas is 888.29 $/h. In order to rectify the problem of overload in lines, the two areas are combined and PSO algorithm has been implemented. Now it is observed that the total generation increased for area-1 by 204.97 MW and decreased for area-2 by 61.6 MW. The total cost of generation for both areas is 854.93 $/h. The security is improved by maintain all constraints are within limits and overall net saving cost of generation is by 33.35 $/h.

VII. CONCLUSION

This paper presents an improved, efficient and reliable PSO algorithm for solving Optimal Power Flow problem under occurrence of various single line contingencies. The proposed method is tested on IEEE-14 bus system and the simulation results are reported.

From the results it can be concluded that PSO based Optimal Power Flow algorithm improves the system security by maintain all constraints within limits and also minimizes the total cost of generation. The result shows the effectiveness and robustness of the system with proposed algorithm in order to solve OPF problem.

REFERENCES

[1] K.S.Pandya, S.K.Joshi A SURVEY OF OPTIMAL POWER FLOW METHODS Journal of Theoretical and Applied Information Technology 2005 - 2008 JATIT.

[2] Ahmed M.Azmy “Optimal Power Flow to Manage Voltage Profiles in Interconnected Networks Using Expert Systems” IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 22, NO. 4, NOVEMBER 2007.

[3] Alberto Berizzi Enhanced Security-Constrained OPF With FACTS Devices IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 20, NO. 3, AUGUST 2005.

[4] James Jamal Thomas,and Santiago Grijalva “Flexible Security-Constrained Optimal Power Flow” IEEE TRANSACTIONS ON POWER SYSTEMS.

[5] Waqquas A. Bukhsh, AndreasGrothey, Ken I. M. McKinnon, and Paul A. Trodden “Local Solutions of the Optimal Power Flow Problem” IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 28, NO. 4, NOVEMBER 2013.

[6] Pablo A. Ruiz, Peter W. Sauer, *Fellow* “Voltage and Reactive Power Estimation for Contingency Analysis Using Sensitivities” IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 22, NO. 2, MAY 2007

[7] K.SrilakshmiLavanya, C.Kumar, Dr.Ch.Padmanabha Raju “ Contingency Constrained Optimal Power Flow by Hybrid Optimization Technique Using FACTS Device” IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 9, Issue 6 Ver. II (Nov – Dec. 2014), PP 91-98.

[8] Chengjun Fu Anjan Bose “Contingency Ranking Based on Severity Indices in Dynamic Security Analysis” IEEE Transactions on Power Systems, Vol. 14, No. 3, August 1999.

[9] NimaAmjady, *Member*, *IEEE*, and MasoudEsmaili “Application of a New Sensitivity Analysis Framework for Voltage ContingencyRanking”IEEETRANSACTIONS ON POWER SYSTEMS, VOL. 20, NO. 2, MAY 2005.

[10] Yamille del Valle, Ganesh Kumar Venayagamoorthy,Salman Mohagheghi,Jean-Carlos Hernandez and Ronald G. Harley, “Particle Swarm Optimization: Basic Concepts, Variants and Applications in Power Systems” IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION, VOL. 12, NO. 2, APRIL 2008.

[11] Qi Kang, MengChu Zhou, Jing An, and QiDi Wu “Swarm Intelligence Approaches to Optimal Power Flow Problem With Distributed Generator Failures in Power Networks” IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING, VOL. 10, NO. 2, APRIL 2013.

[12] M.A.Abido “Optimal power flow using particle swarm optimization” Electrical Power and Energy Systems 24 (2002) 563-571.

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