Enhancement of Power System Security using Meta-heuristic Optimization Techniques

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Abstract

The genetic algorithm (GA) and particle swarm optimization (PSO) are search heuristic methods that mimics the process of natural evolution. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution. The project presents a genetic-algorithm (GA) and PSO based OPF algorithm for identifying the optimal values of generator output and enhance power system security. Equality and inequality constraints are considered and severity indices are calculated for over loaded lines. Contingences are ranked based on the severity indices. The proposed method is applied on the standard IEEE 30 bus system. Simulations are obtained and results are presented, with the objectives 1.To calculate the security Index for a given power system network by evaluating various contingencies. 2.Enhancing the Electrical Power System Security levels at the optimum power schedule.

I. INTRODUCTION

With the continued increase in the demand for the electrical energy with little addition to transmission capacity, security assessment and control have become important issues in power system-operation. Security assessment deals with determining whether or not the system operating in a normal state can withstand contingencies. If the present operating state is found to be insecure, action must be taken to prevent limit violation in the contingency state.

Transmission-line overload can be alleviated by rerouting power flows in the system. A change in line flow can be caused by an appropriate change in phase angles and magnitude of bus voltages, which are usually referred to as state variables. The state variables can, in turn, be modified by a variation in generated power. The linearized relationship between power flow in the overloaded lines and the generated power has been used to reschedule the power generation. A computationally simple algorithm has been developed for real-time security control. A fuzzy set theory based approach has been proposed for overload alleviation through real power-generation rescheduling. For secure operation of the system without any limit violation, complete modeling of the system through load flow equations and operational constraints is necessary. This project presents an optimal power flow with security indices for overload alleviation.

The OPF solution gives the optimal settings of all controllable variables for a static power-system Loading conditions. A number of mathematical-programming-based techniques have been proposed to solve the OPF problem. These include the gradient method, Newton method and linear programming. In mixed-integer linear programming has been applied to improve the loadability of the system. The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input-output function is to be expressed as a set of linear functions, which may lead to loss of accuracy. A rule-based OPF has been proposed to alleviate the line overload. The principal shortcoming of a rule-base approach is that the construction of rules requires extensive help from skilled knowledge engineers. Also, it does not provide a continuous fabric over the solution space.
Recently, global-optimization techniques such as the genetic algorithm have been proposed to solve the optimal power-flow problem. A genetic algorithm is a stochastic search technique based on the mechanics of natural genetics and natural selection. It works by evolving a population of solutions towards the global optimum through the use of genetic operators: selection, crossover and mutation. The proposed approach is based on the contingency ranking of IEEE 30 bus system.

II. PROBLEM FORMULATION

In order to quantify the various contingencies impact on a given power system security, it is proposed to implement an offline computing methodology in this project. It contains three units that verify the static, dynamic and transient security status having the aim to guarantee a safe global state of the grid. Security analyses are done as infinite loops for all the grid configurations and the grid status is monitored continuously. The Algorithms for Dynamic load scheduling, Network Re-configuration, Real and reactive power management, optimum power scheduling at maximum security index using Metaheuristic methods will be developed. This model finds a new operating point from the security perspective for a given disturbances or contingencies. This method will be tested for IEE 30 bus system

A. Mathematical Formulation of Optimal Power Flow Problem:

The conventional formulation of the optimal-power-flow (OPF) problem determines the optimal settings of control variables such as real power generations, generator terminal voltages, transformer tap settings while minimizing an objective function such as fuel cost given in (1).

$$F_T = \sum (a_i \; P_{gi}^2 + b_i P_{gi} + C_i) \quad \text{---} \quad (1)$$

During security control, the prime task of the power-system operator would be to remove the line overload. Hence, the severity index is taken as the objective function in this project. The minimization problem is subjected to the constraints.

(i) Load-flow constraints:

$$P_i = V_i \sum_{j=1}^{N_b} V_j (G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij}), i = 1,2,\ldots N_b \quad \text{---} \quad (2)$$

$$Q_i = V_i \sum_{j=1}^{N_b} V_j (G_{ij} \cos\theta_{ij} - B_{ij} \sin\theta_{ij}), i = 1,2,\ldots N_{pq} \quad \text{---} \quad (3)$$

Voltage constraints:

$$\underline{v_i} \le v_i \le \overline{v_i} \qquad i \in N_b \;\text{--} \quad (4)$$

(iii) Unit Constraints:

$$\underline{T_{ki}} \le T_{ki} \le \overline{T_{ki}} \qquad i \in N_g \;\text{--} \quad (5)$$

$$\underline{P_{gi}} \le P_{gi} \le \overline{P_{gi}} \qquad i \in N_g \text{---} \quad (6)$$

$$\underline{Q_{ci}} \le Q_{ci} \le \overline{Q_{ci}} \qquad i \in N_g \text{--} \quad (7)$$

here v_i-generator voltage

P_{gi} - generator active power

T_{ki} - transformer tapings

Q_{ci}- shunt reactor powers

The power-flow equations are used as equality constraints and the inequality constraints are the limit on active and reactive power generations, busbar voltage magnitudes and apparent power flows in branches.

B. Severity Index:

The severity of a contingency to line overload may be expressed in terms of the following severity index, which express the stress on the power system in the post contingency period:

$$severity\ index\ I_{sl} = \sum_{l=L_o}^{n} \left(\frac{S_l}{S_{max}}\right)^{2m}$$

Where

I_{sl}= Flow in line l (MVA).

S_l^{max} = Rating of line l (MVA).

L_o = Set of overload lines.

m = Integer exponent.

The line flows in are obtained from Newton-Raphson load-flow calculations. While using the above severity index for security assessment, only the overloaded lines are considered to avoid masking effects. For IEEE 30-bus system considered in this work, we have fixed the value of m as 1Page should be of A4 size with normal margin. All printed material, including text, illustrations, and charts, must be kept within a print area. Do not write or print anything outside the print area. All text must be in a two-column format. Text must be fully justified. A format sheet with the margins and placement guides is available in Word files as <format.doc>. It contains lines and boxes showing the margins and print areas. If you hold it and your printed page up to the light, you can easily check your margins to see if your print area fits within the space allowed.

III. PROPOSED METHOD

When applying GA and PSO to solve a particular optimization problem, two main issues must be addressed:

(a) Representation of decision variable.

(b) Formation of the fitness function.

A. Problem representation

In solving the OPF problem for security-control applications, two types of variable need to be determined by the optimization algorithm: generator active-power generation P_{gi} and generator terminal voltages V_{gi} which are continuous variables. Each individual in the population represents candidate OPF solutions.

B. Fitness function

GA searches for the optimal solution by maximizing a given fitness function. In the OPF problem under consideration, the objective function is to minimize the severity in the post-contingency state satisfying the equality and inequality constraints. With the inclusion of the penalty function the new objective function becomes

$$Min\ f = P_s + \sum_{i=1}^{N_{pq}} V_{pi} + \sum_{i=1}^{N_g} Q_{ci}$$

Here

Ps - the penalty terms for the reference bus bar generator active power limit violation,

P_{vi} - the penalty terms for the load bus bar voltage limit violation,

P_{Qi} -the penalty terms for the reactive power generation limit violation.

These quantities are defined by the equations,

$$P_s = \begin{cases} K_s(P_s - P_s^{max})^2 & if\ P_s > P_s^{max} \\ K_s(P_s - P_s^{max})^2 & if\ P_s < P_s^{max} \\ 0 & otherwise \end{cases}$$

$$VP_j = \begin{cases} K_v(V_j - V_j^{max})^2 & if\ V_j > V_j^{max} \\ K_v(V_j - V_j^{max})^2 & if\ V_j < V_j^{max} \\ 0 & otherwise \end{cases}$$

Where Ks and Kv are the penalty factors. The success of the approach lies in the proper choice of these penalty parameters. Using the above penalty-function approach, one has to experiment to find a correct combination of penalty parameters Ks, Kv. However, to reduce the number of penalty parameters, the constraints are often normalized and only one penalty factor R is used.

During the GA run, GA searches for a solution with the maximum fitness function value. Hence, the minimization objective function is transformed to fitness function to be maximized as

$$\text{Fitness} = \frac{1}{1+f}$$

In the denominator a value of 1 is added to avoid division by zero in case of complete overload alleviation

C. Particle Swarm Optimization

This is a population based optimization method first proposed by Kennedy and Eberhart in 1995 inspired by social behavior of bird flocking or fish schooling. The PSO as an optimization tool provides a population based search procedure in which individuals called particles change their position with time by flying around in a multi dimensional search space until a relatively unchanging position has been encountered, or until computational limitations are exceeded. During flight, each particle adjusts its position according to its own experience(this value is called pbest), and according to the experience of a neighbouring particle. (This value is called gbest), made use of best position encountered by itself and its neighbour. Basically, the hybrid method involves two steps. The first step employs NR to solve OPF approximated as a continuous problem and introduced into the initial populations of PSO. The second part uses PSO to obtain the final optimal solution. In initial population, all individuals (obtained from NR) are produced randomly. The main reason for using the NR is that it is often closer to optimal solutions than other random individuals. In the hybridization of NR and PSO, the NR generates best initial solutions from random initial solutions and PSO evaluate them by solving the OPF, which yields to the global optimal solutions for control variables.The implementation steps of the proposed PSO-NR based algorithm can be written as follows. The best values the particles updated its velocity and position with the following equations

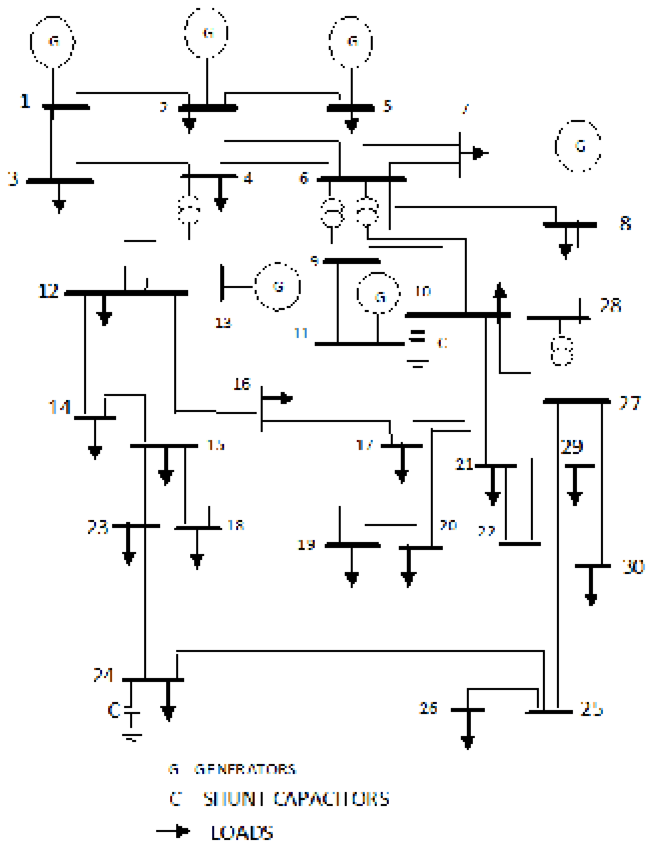
IV. TEST SYSTEM DATA

As the name specifies IEEE 30 Bus it consists of 30 buses. Out of which 21are load buses 6 are generator buses and the remaining 3 buses which neither load buses nor generator buses.

Generator buses are located at 1, 2, 5, 8, 11 and 13.

IEEE 30 Bus will normally have shunt at buses 10and 24. There are a total of 37 lines in this type of system, where as the regulating transformers are 4 in number, which are in between 6-9, 6-10, 4-12, 27-28 buses respectively.

Generally 10 percentage tolerance in voltage is agreeable for Generator Buses, where as 5 percentages tolerance in voltage is agreeable for Generator Buses. Similarly 5percentage tolerance is agreeable for Transformer Tapings. The IEEE 30 Bus is shown in the following figure.



V. SIMULATION RESULTS

In this project, the proposed algorithm was applied to alleviate overloads underline outage through generator rescheduling. The GA code was written in MATLAB and ETAP and executed on a 32 gb ram workstation.

The GA-based algorithm is used for corrective control under a contingency state. Contingency analysis was conducted under base-load conditions to identify the harmful contingencies. From the contingency analysis, it was found that the line outages 1-2, 1-3, 3-4 and 2-5 have resulted in overload on other lines. Capacitor banks are not considered in this work, rather the shunt injections are provided at buses 10, 12, 15, 17, 20, 21, 23, 24 and 29. The power flow on the overloaded lines and the calculated value of severity index for each contingency are given in Table 6.2. From this Table it is found that line outage 1-3 is the most severe one, and results in overloading on three other lines.

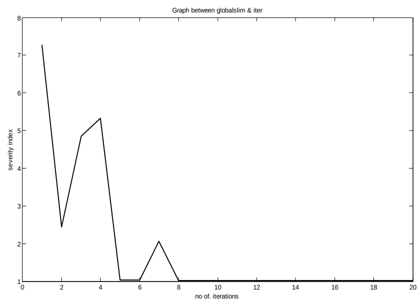
The GA-based OPF algorithm was applied to alleviate the line overload in all four severe-contingency cases. To test the ability of the proposed algorithm to alleviate overload under severe conditions the real and reactive load in all the load busbars were increased to 1.2 times the base load condition. The maximum reactive-power generation of all the generators was also increased correspondingly. Generator active power, shunt reactors and transformer tapings are taken as the control variables.

For standard IEEE 30 Bus System GA has been run 10 times for a population of 20, generations of 20.

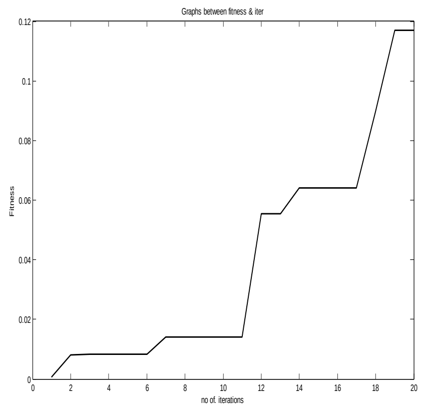
The severity index was taken as the objective function of the GA. The algorithm was run for a maximum of 25 generations and was made to stop if the targeted value of IS=0 was reached.

The control variables for each outage line:

Variables	1-2	1-3	3-4	2-5
Pg1	1.3089	1.9639	1.5073	1.4295
Pg2	0.7278	0.2717	0.3652	0.5564
Pg3	0.1097	0.1170	0.1308	0.1991
Pg4	0.1964	0.1290	0.2279	0.1599
Pg5	0.2719	0.2996	0.4947	0.2294
Pg6	0.3245	0.1920	0.2772	0.3640
Vg1	1.0528	1.0919	1.0909	1.0207
Vg2	1.0230	1.0566	1.0735	0.9686
Vg3	0.9839	1.0217	1.0572	0.9506
Vg4	1.0511	1.0074	1.0366	1.0834
Vg5	0.9561	1.0061	1.0813	0.9622
Vg6	1.0260	1.0381	1.0782	0.9686
T1	0.9309	0.9925	.0272	0.9758
T2	1.0766	0.9198	0.9555	1.0079
T3	1.0583	1.0111	0.9347	1.0572
T4	0.9360	0.9281	0.9225	1.0039
Qsh1	0.0341	0.0639	0.0563	0.0212
Qsh2	0.0174	0.0130	0.0400	0.0059
Qsh3	0.0522	0.0169	0.0845	0.0625
Qsh4	0.717	0.0577	0.0974	0.0476
Qsh5	0.239	0.0988	0.0681	0.0118
Qsh6	0.251	0.0348	0.0901	0.0600
Qsh7	0.713	0.0941	0.0898	0.0091
Qsh8	0.273	0.0328	0.0501	0.0923
Qsh9	0.244	0.0111	0.0110	0.0418



Severity index v/s no. of iterations for the outage line 1-2



Fitness v/s no. of iterations for the outage line 1-2

Author names and affiliations are to be centered beneath the title and printed in Times 12-point, non-boldface type. Multiple authors may be shown in a two- or three-column format, with their affiliations below their respective names. Affiliations are centered below each author name, italicized, not bold. Include e-mail addresses if possible. Follow the author information by two blank lines before main text.

VI. CONCLUSION

This project has proposed a PSO method to enhance security index and flexible optimization tool based on a N-R method. The application of this tool for scheduling the power system during contingencies has been presented. The security index for a 30 bus IEEE is evaluated for various contingencies. The security levels are enhanced by using PSO method at optimum power scheduling. Equality and inequality constraints are considered and severity indices are calculated for over loaded lines. Contingences are ranked based on the severity indices. The proposed mehod is well suitable for real-time applications.

ACKNOWLEDGEMENTS

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