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ALLEVIATION OF VOLTAGE LIMIT VIOLATIONS USING GENETIC ALGORITHM

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Abstract— This paper presents an algorithm for the selection of corrective control actions for bus voltage and generator reactive power in a power system. A genetic algorithm (GA) using linear approximation of load flow equations and a heuristic selection of participating controls were combined in a search method for the minimum number of control actions. The calculation time in this method was proven to be small enough to allow real-time application of the algorithm. The GA was compared with a integer programming-based solution method and showed a considerably reduced calculation time. The results show that the heuristic method of pre-selecting a set of control devices, together with the GA for finding the ultimate set of required control actions, produce a sufficient solution to the voltage/reactive power problem.

Index Terms—Genetic algorithm (GA), reactive power control, voltage control.

INTRODUCTION

Modern power systems are often operated near capacity. During periods of peak demand, power lines may be loaded to near capacity. Operating a power system near capacity requires quick response by operators in the event of an unexpected change in the system-operating configuration [2]. Rapid security assessment is needed in order for the system to continue to operate normally when contingencies occur. As the demand for power increases, existing power grids are being more frequently loaded nearly to capacity. As a result, system operators must rapidly respond to sudden or unexpected changes in the systems operating configuration. Complex power systems are able to provide reliable electric service at low cost with the help of automatic control. Simultaneously tracking the randomly varying system load, optimizing generation to minimize cost, and coordinating the action of many independent control centers. When an emergency develops in one of these systems, however, the picture changes completely and new control objectives must be met if the system is to be restored successfully to normal operation. A situation in which operational limits are violated is described as an emergency state and the actions required to correct this state are called emergency control actions or corrective control actions.

Reactive power and Voltage control (RPVC) is one of the important control schemes in power system **[1]**.RPVC conventionally involves regulation of voltage and Reactive power at a substation.

This Paper presents an algorithm for the control of bus voltage and generator reactive power in an electricity supply system. Classic solution methods such as linear programming make use of linear approximations of system equations and as such have a limited precision.

Genetic algorithms, connected to standard load flow calculations, do not need such approximations and are capable of finding numerous solutions for the emergency control of disturbed bus voltages. The disadvantage of **GA's** is the heavy computational burden. Hear we have to deal with the selection of control actions for the elimination of bus voltage and generator reactive power constraint violations. The alleviation of these violations is usually achieved by adjusting generator voltages, transformer taps and switching shunt devices. Since the number of available control devices is frequently large, it is possible to make an optimal choice of control actions and most published algorithms deal with the selection of control actions as an optimization problem. The primary task is to find the control actions that change the load flow in such a way that all system constraint violations are eliminated in time.

PROBLEM FORMULATION

The theoretical background of the reactive power/voltage control problem will be presented, using the following equations governing the energy balance in every node of an electricity system:

$$F_{Pi} = P_{Gi} - P_{Li} - \sum_{j=1}^{n} V_i V_j \left[g_{ij}\cos(\theta_j - \theta_i) - b_{ij}\sin(\theta_j - \theta_i) \right]$$

$$F_{Qi} = Q_{Gi} - Q_{Li} - \sum_{j=1}^{n} V_i V_j \left[g_{ij}\sin(\theta_j - \theta_i) + b_{ij}\cos(\theta_j - \theta_i) \right]$$

where

F_{Pi}, F_{Qi} energy balance of active and reactive power of bus i ;

P_{Gi} ,Q_{Gi} active and reactive power generated at bus ;

P_{Li}, Q_{Li} active and reactive parts of load at bus i;

V_i, V_j voltage amplitudes at buses i and j;

g_{ij} ,b_{ij} active and reactive parts of admittance of the line between buses i and j;

θ_i ,θ_j phase angle of the voltages at buses I and j;

n number of buses.

For the solution of the load flow problem, the above-used variables and constants are traditionally classified in the following vectors:

- State variables **[x]** which consist of generator reactive power and voltage phase angle, load voltage amplitude, and phase angle.
- Control variables **[u]** which consist of generator active power and voltage amplitude.
- Disturbance variables **[d]** which consist of load active and reactive power.
- Constants **[z]** which consist of line admittance and the relevant transformer ratio.

In generalized form, the energy balance for all buses is presented by vector. A solution of the load flow equations is obtained when **f (x, u, d, z) = 0**, where d, z are considered constant. The elimination of voltage constraint violations is achieved by adjusting generator voltages, transformer ratio, and switching shunt devices. This means that what distinguishes the voltage control problem from the load flow problem is that transformer ratio and load reactive power are no longer to be considered as constants but are controlled quantities as well.

The analytical methods were based on classic optimization methods such as linear programming **[9]** and **[10]**. In the majority of the studies, the load flow problem is presented by linear approximation of system equations around an initial solution, such as

$$\Delta x = S.(\Delta u, \Delta d, \Delta z)$$

In this incremental network model, matrix S, the so-called sensitivity matrix, represents the sensitivity of state variables (bus voltages and generator reactive powers) to changes of controls (generator voltages, transformer taps, and VAr devices). For a system of n buses, m generators, r VAr devices, and q tap changing transformers, the model can be written as:

$$\begin{bmatrix} \Delta Q_{G1} \\ | \\ \Delta Q_{Gm} \\ \Delta V_{m+1} \\ | \\ \Delta V_n \end{bmatrix} = \begin{bmatrix} S_1 & S_3 & S_5 \\ S_2 & S_4 & S_6 \end{bmatrix} \begin{bmatrix} \Delta V_1 \\ | \\ \Delta V_m \\ \Delta Tap_1 \\ | \\ \Delta Tap_q \\ \Delta Q_{L1} \\ | \\ \Delta Q_{Lr} \end{bmatrix}$$

Where ΔV_1 ………. ΔV_m changes in generator voltage amplitude;

ΔQ_{G1} ….…. ΔQ_{Gm} changes in generator reactive power;

ΔV_{m+1} ……. ΔV_n changes in load bus voltage amplitude;

ΔQ_{L1} …….. ΔQ_{Lr} changes in reactive load;

ΔTap_1 ……. ΔTap_q changes in transformer taps;

S_1 ,………, S_6 sub matrices of S

THE PROPOSED METHOD

The RPVC is obviously a mixed-integer programming problem; in other words, it includes both continuous and discrete variables. GAs is adopted here because they are efficient in dealing with mixed-integer programming and inequality constraints.

Genetic algorithm is an optimization method based on the mechanics of natural selection and natural genetics. Its fundamental principle is that *the fittest member of population has the highest probability for survival.* The most familiar conventional optimization techniques fall under two categories viz. calculus based methods and enumerative schemes. Though well developed, techniques possess significant drawbacks. Calculus based optimization generally relies on continuity assumptions and existence of derivatives. Enumerative techniques rely on special convergence properties and auxiliary function evaluation. The genetic algorithm, on the other hand, works only with objective function information in a search for an optimal parameter set.

ALGORITHM

The algorithm developed here combines the benefits of both the linearized system model and the GA, in the following steps:

- Calculate sensitivity coefficients for all available control devices.
- According to the estimated ability of the control devices to decrease the constraint violations, select a first set of controls that will take part in the next calculation stage.
- Use the GA to find a proper set of control actions. The fitness of a solution is determined by the remaining constraint violations and the number of controls used.

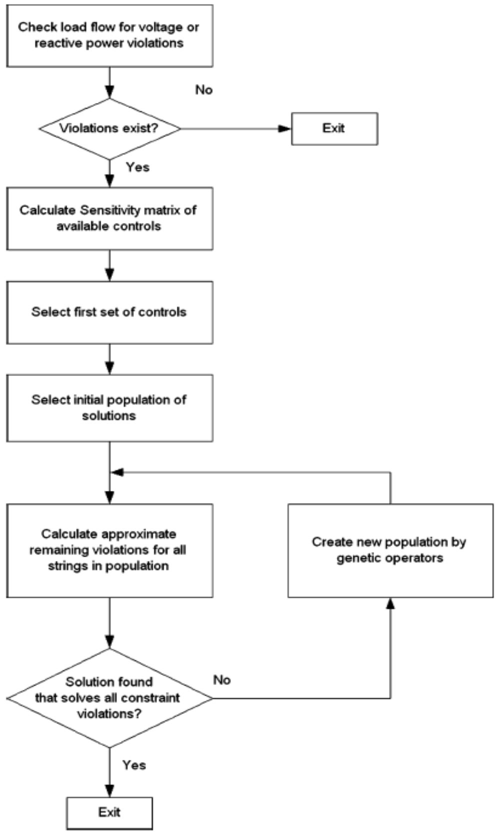


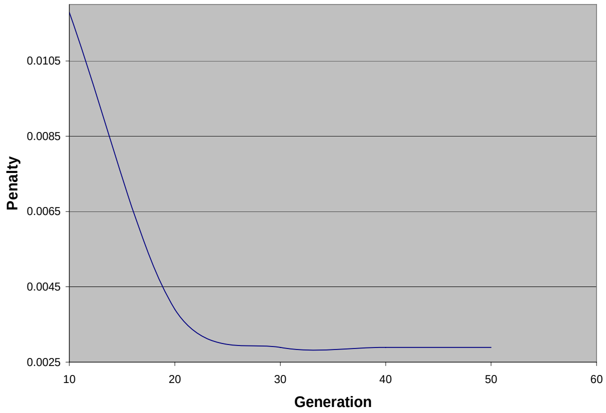
Fig1: Flowchart of algorithm

RESULT

In this paper, the primary goal is the elimination of constraint violations. The topic of minimizing the number of operator actions is included in the paper through a pre selection of control devices participating in the GA and afterward by neglecting control commands of less than prescribed thresholds. The novel approach for algorithm is that the number of control actions will be explicitly part of the search objective. Because of the stochastic nature of the GA, results may differ slightly for different calculation runs. The following are typical results for a single calculation run.

Fig-2 shows the penalty of constraint violation. The initial base case violation and correction of this violation (by using GA) is shown in Fig-3 and values are shown in Table-I. The control action found by the algorithm were checked with a Newton Raphson load flow calculation. This results show that no significant violations of constraints i.e. 0.9 p.u. to 1.0 p.u. remained after application of control action.

Fig2: Penalty to the Fitness of the best solution



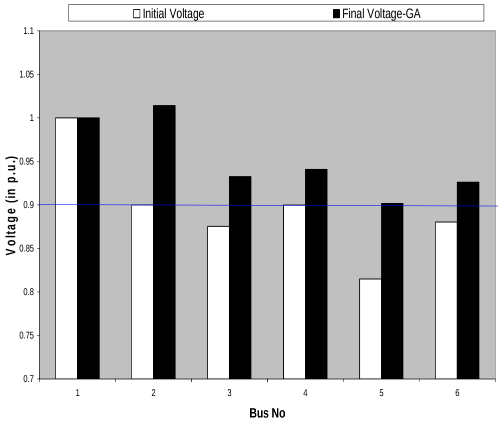


Fig3: Voltage at different buses, before & after execution of GA.

Table-I Voltage Correction

Bus Voltage	In Base Case (p u)	After GA (p u)
1	1	1
2	0.9	1.01397
3	0.87536	0.932343
4	0.89978	0.940812
5	0.81486	0.901478
6	0.88028	0.92587

CONCLUSION

A computationally efficient Genetic Algorithm for voltage profile improvement has been developed taking into account the voltage limit violation of power network. The solution to such a problem is computationally extremely demanding. The results show that the heuristic method of pre-selecting a set of control devices, together with the GA for finding the ultimate set of required control actions, produce a sufficient solution to the voltage violation problem.

FUTURE SCOPE

This paper has made significant advances in the area of power system visualization. The proposed algorithm has been implemented and verified on a standard test network. The results show that the method is able to propose solutions that improve significantly the bus voltages profile. Thus, the voltage profile obtained by GAs solution methods has decreased number of control actions which may compensate for the extra calculation time involved for getting the best result. This way it is possible to alleviate voltage limit violation at many buses where it was not possible to alleviate with classical method. There are following area in power system on which the proposed work can be extended:

- Reactive Power Optimization problem can be solved by using GAs.
- GAs is used in contingency analysis for line outage and generator outage.
- MW line flows constraints may be included.

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