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# Genetic Algorithm Optimization of Generator Reactive Power

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Abstract

Reactive power optimization in the power system tends to maintain good voltage profile by improving the voltage quality other than decreasing the power loss. This paper presents an improved Genetic algorithm (GA) approach for voltage stability enhancement. The proposed technique is based on the minimization of the maximum of L-indices of load buses. Generator voltages, switchable VAR sources and transformer tap changers are used as control variables. A case study is made on all the optimization variables mentioned and the effect on generators reactive power output is analyzed. The comparison of two optimization techniques is explained in detail. The results obtained for the IEEE-24 bus power system had indicated that the GA not only improves the voltage stability but also reduces the effect on generators for the Reactive Power.

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*Keywords*: Reactive Power Optimization; Voltage Stability; Genetic Algorithm; Natural Selection.

1. Introduction

The unmatched generation and transmission capacity expansion, voltage instability is troubling the power engineers to optimize power system operation, while maintaining system security and quality of supply to customers. Under many disturbed conditions the operation of the power systems has to be restricted to design limits. It is turning complex to the power engineers to ensure the quality and reliability of supply to the customers by maintaining load bus voltages in their permissible limits. Despite of all, overloading in existing power transmission systems, voltage collapse and voltage stability are concerned as the major problems, to power system planning and operation engineers, which has to be enhanced. Voltage profile can be improved with reallocation of reactive power generations, by adjusting the controller parameters of transformer taps, generator exciters and Switchable VAR Compensator (SVC) settings to its best optimal values. Several have

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emerged earlier to solve this type of complex problems, like Linear programming (LP)[1] , Non-Linear Programming (NLP) [3]and Interior point method[4]. Though these techniques were applied for solving the reactive power dispatch problem, still some backdrops are associated with them. Linear Programming techniques with iterative schemes are proved to be the most promising tools for solving these types of problems earlier, with better results and good evaluation time. But this kind of approach is only limited to local minimum[5], where Genetic Algorithm technique (GA)[2] is being used as a recent trend which is a global minimum based optimization technique yielding to much more better results. The main advantages of GA[6]: It can find near optimal solution regardless the initial parameter values, Its convergence is fast It uses few number of control parameters. The system parameters Ve , Vs and ΣL2 are calculated, along with the effect on the generators reactive power output. This paper presents an effective algorithm with GA approach with selected mutation rate and population size to find the optimized control settings for the given controllers. The optimized controller settings are considered and the power system parameters are again analyzed with new settings to minimize the sum of the squares of the L indices (V stability) and also to reduce the required reactive power through the generators in parallel. The algorithm is successfully applied to IEEE-24 bus system and is compared with the existing LP optimization values and presented for illustration purpose.

1. Analysis of Voltage Stability

A slow variation in the system operations, due to increase in loads results in the gradual decrease in the voltage magnitude. Careful monitoring and control action has to be taken from the operator when the operating point approaches the voltage stability limit. Recent literature presents many voltage stability and voltage collapse prediction methods. Among them, L index method is adopted in this paper for the calculation of Voltage stability which is described as follows.

* 1. *L-index method*

Consider a system where,

n=total number of busses, g=generator busses , s= SVC busses , t =number of OLTC transformers.A load flow result is obtained for a given system operating condition, which is otherwise available from the output of an on-line state estimator. Using the load flow results, the L-index [6] is computed as

L = |1- ∑g 𝐹 𝑉𝑖 | (1)

j 𝑖=1

j𝑖

𝑉j

where *j*=*g*+1... *n* and all the terms within the sigma on the RHS of (1) are complex quantities. The values *Fji*

are obtained from the *Y* bus matrix as follows

𝐼𝐺

𝑌𝐺𝐺 𝑌𝐺𝐿

𝐼𝐿

[𝐼𝐿 ]= [𝑌𝐿𝐺 𝑌𝐿𝐿 ] [𝑉𝐺 ] (2)

Where *IG, IL* and *VG , VL* represent currents and voltages at the generator nodes and load nodes. Rearranging (2)

we get

𝑉𝐿

𝑍𝐿𝐿 𝐹𝐿𝐺

𝐼𝐿

[𝐼𝐺 ]= [𝐾𝐺𝐿 𝑌𝐺𝐺 ] [𝑉𝐺 ] (3)

where *FLG*=-[YLL]-1[YLG] are the required values. The L-indices for a given load condition are computed for

all load busses.

For stability, the bound on the index Lj must not be violated (maximum limit=1) for any of the nodes j. Hence, the global indicator L describing the stability of the complete subsystem is given by L= max of Lj for all j. An L-index value away from 1 and close to zero indicates an improved system security. For a given network, as the load/generation increases, the voltage magnitude and angles change, and for near maximum power transfer condition, the voltage stability index Lj values for load buses tends to 1, indicating that the system is near to voltage collapse. The stability margin is obtained as the distance of L from a unit value i.e. (1-L).

1. Modeling of Reactive Power Optimization Problem.
   1. *Objective function*

The algorithm proposed is the single-objective optimization and the objective function is to minimize the sum of squares of the voltage stability L-indices of all the load buses. The objective function is shown as follows:

j

𝐹(𝑥) = 𝑉𝐿 = ∑𝑛

j=g+1

(𝐿2)

(4)

* 1. *Equation constraints*

Equation constraints of reactive power optimization are the power flow equations. Each node in the system has active and reactive power functions [2], which are given by

𝑃𝑖 = 𝑉𝑖 ∑𝑁

j=1

𝑄𝑖 = 𝑉𝑖 ∑𝑁

j=1

𝑉j(𝐺𝑖j𝑐𝑜𝑠ð𝑖j + 𝐵𝑖j𝑠𝑖𝑛ð𝑖j)

𝑉j(𝐺𝑖j𝑠𝑖𝑛ð𝑖j + 𝐵𝑖j𝑐𝑜𝑠ð𝑖j)

(5)

(6)

In the above equations,Vi and Vj are the voltages at bus i and j;*Gij* and Bij are the conductance and susceptance of the line connecting bus i and j; δij is the phase angle difference of voltage from bus i to j.

* 1. *Inequality constraints*

In reactive power optimization, generator bus voltage, transformer taps and reactive power compensation capacity are selected as control variables. So, the control variable constraints are given by:

VGimin ≤ VGi ≤ VGimax ; Timin ≤ Ti ≤ Timax ; Qimin ≤ Qi ≤ Qimax ;

VGi = Generator output Voltage, Ti = Transformer tap position

Qi = SVC setting positions, V*Gi*min =Minimum output Voltage of Generator V*Gi*max = Maximum output Voltage of Generator T*i*min = Minimum tap position of Transformer T*i*max = Maximum tap position of Transformer Q*i*min = Minimum output of SVC's

Q*i*max *=* Maximum output of SVC's

As the voltage of load and value of generator reactive power can be obtained after the power flow calculation, they are treated as state variables generally. The state variable constraints are given by:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Vimin | ≤ | Vi | ≤ | Vimax ; | QGimin | ≤ | QGi | ≤ | QGimax ; |
| Vi | = | Bus Voltage | | | QGi = | | Reactive power generation | | |
| V*i*min | = | Lower limit of load voltage | | | V*i*max = | | Upper limit of load voltage | | |
| Q*Gi*min | = | Lower limit of generator output of  reactive power | | | Q*Gi*max = | | Upper limits of generator output of  reactive power | | |

1. . Procedure for problem solving.
   1. *Computation of Power System operation*

Figure 1: Flow chart for power system operation.



Start

Evaluate objective function and find the optimized system parameters

Obtain the values of L-index and other system parameters

Print the Results

Increase the load demand to 20%

Read the system data

Read optimal controller values from GA

Figure 1 explains the step by step computational procedure for evaluation of objective function and calculation of system parameters like Ve, ΣL2, Ploss , Q output at Generators.

* 1. *Computation of GA optimization*



Define Cost Function, cost, variables Select GA parameters

Generate initial population

Mating

Mutation

No

If global minimum is found then Converge

Yes

End

Select Mates

Find the cost for each chromosome

Figure 2: Flow chart for Genetic Algorithm Optimization.

Figure 2 explains the procedure of Genetic Algorithm optimization [7] to find the optimized cost and best setting value with respect to the cost function. The GA Optimized controller values obtained here are replaced with initial system controller setting

1. Case Study
   1. *System data*

The proposed approach has been tested on the IEEE-24 Bus system. Details are as follows:

|  |  |
| --- | --- |
| No. of. Generators | 4 |
| No. of. Transformers | 11 |
| No. of SVC buses | 4 |
| No. of. Transmission lines | 16 |
| P-generation in MW | 2850 |
| P-Load in MW | 2620 |
| Q-Load in MVAR | 980 |

* 1. *Results*
     1. *The initial system parameters*

Table 1: The initial system parameters

|  |  |  |  |
| --- | --- | --- | --- |
|  | Ve | ΣL2 | Ploss(MW) |
| Initial values | 1.148 | 3.14359 | 73.63 |

* + 1. *The Optimized controller Settings*

Table 2: Controller settings initial and optimized

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Control Variables | Initial settings | GA optimized |  | Control Variables | Initial settings | GA  optimized |
| V1 | 1 | 0.9881 | T1(16-5) | 0 | 0.93714 |
| V2 | 1 | 0.9881 | T2(19-6) | 0 | 0.92866 |
| V3 | 1 | 0.9881 | T3(20-7) | 0 | 0.9726 |
| V4 | 1 | 0.9881 | T4(14-8) | 0 | 0.9392 |
| Q5 | 0 | 9.5201 | T5(23-9) | 0 | 1.0262 |
| Q6 | 0 | 13.0186 | T6(18-10) | 0 | 0.9272 |
| Q7 | 0 | 18.514 | T7(22-13) | 0 | 0.9787 |
| Q8 | 0 | 8.06 |  |  |  |

* + 1. *The system parameters after replacing initial control settings with optimized values.*

Table 3: Optimized System parameters

|  |  |  |  |
| --- | --- | --- | --- |
|  | Ve | ΣL2 | Ploss(M) |
| GA Optimized system parameters | 0.152 | 2.3989 | 64.07 |

* + 1. *Comparison of GA optimized values with Linear Programming technique*

Table 4: Initial and optimal system parameters

|  |  |  |  |
| --- | --- | --- | --- |
|  | ΣL2 | Ve | Ploss |
| Initial | 3.14359 | 1.148 | 73.62 |
| LP | 2.5088 | 0.232 | 66.02 |
| GA | 2.3989 | 0.152 | 64.07 |

From the table 4 it can be observed clearly that the sum of squares of the voltage stability L-indices (i.e., Vstability objective) is minimized much better even when compared to the conventional Linear Programming Technique, and it is also observed that Power loss is much reduced.

* + 1. *Analysis of Effect on the generator reactive power.*

Table 5: Reactive power output of each generator at different conditions.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Initial | LP method | GA method |
| Q at G1 | 5.5455 | 5.3455 | 4.5643 |
| Q at G2 | 1.03 | 0.7607 | 0.47 |
| Q at G3 | 1.7985 | 1.5985 | 1.0021 |
| Q at G4 | 3.0926 | 2.8926 | 2.2151 |

From the obtained values of the Q output at different generators it is clearly observed that the burden on generators for supply of reactive power is being reduced. This can be helpful when there is much more requirement of reactive power during any sudden violations of voltages. Hence satisfactory results are obtained from the applied Vstability.

6

4

2

0

Initial

LP method GA method

Q at G1 Q at G2 Q at G3 Q at G4

Figure 3: Change of Reactive power outputs of various generators

Figure 3 clearly explains the variations of effect of reactive power output of generators. When Linear Programming technique is considered, the Reactive Power(Q) output at generators is slightly reduced whereas reduction is much better when the Genetic Algorithm Technique is considered.

Conclusion

An approach for Reactive power Optimization is proposed in this paper with voltage stability objective using Genetic Algorithm technique and after comparing it with the existing LP technique betterment is seen. The ΣL2 values obtained after optimization indicates improvement in Voltage stability. This objective of Vstability is also helpful for finding the Reactive Power(Q) output at generators. The Q output requirement at generators is much reduced by GA optimization. Totally GA technique is proved to be far better optimization technique than any other techniques.

References:

1. Dhadbanjan and Yesuratnam,“ Comparision of Optimum Reactive Power schedule with Different Objectives using LP Technique ” *Int. Journal of Emerging Electrical Power Systems,* Vol.7, Iss.3, article.4, 2006.
2. Xin MA and Rui-Lan LIU “Reactive Power Optimization in Power System Based on Improved Niche Genetic Algorithm” *Int conference on Computer Design and Applications*, Vol.3, pp 413-416, 2010.
3. M.O. Mansour, T.M. Abdel-Rahman, "Non-linear VAR optimization using decomposition and

coordination," IEEE Transactions on Power Systems , Vol. 9 , pp.597-598, May 1994.

1. S. Granville, "Optimal reactive dispatch through interior point methods," IEEE Transactions on Power Systems, Vol. 9 , pp. 136-146,January, 1994.
2. B. Zhao, C.x. Guo, YJ. Cao, "A multi agent-based particle swarm optimization approach for optimal reactive power dispatch," IEEE Transactions on Power Systems, Vol. 20, pp.1070-1078, 2005.
3. Wu Q H, Cao Y J and Wen J Y, "Optimal reactive power dispatch using an adaptive genetic algorithm," Int. Journal on Electric power & Energy Syst., vo1.20, pp.563-569, August, 1998.
4. Randy L. Haupt and Sue Ellen Haupt ”Practical Genetic Algorithms”, USA: John Wiley & sons press, 2004.