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Optimization by Inspection Method and its Application to Voltage Stability

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Abstract: Optimization is a relevant issue for researchers of various fields. Several soft computing techniques like Particle Swarm Optimization (PSO), Ant Colony Optimization, Genetic Algorithm, Fuzzy logic based Optimization etc in the general practice now days. In most of these methods, generally few particles are created and they move in the search space in order to find best possible solution. These methods differ from each other, the way particles move in search space with few other advantages. But the movement of particles itself is cumbersome for few objective functions e.g. Load Flow related problems especially for beginners and in academic projects developing a computer program becomes a tough task just because of the movement of the particle i.e. velocity and position update formulas. In the proposed method, equally distributed particles are created in the entire search domain and by inspection best local area is determine. In the next iteration, around that found best local particle, again few new particles are created, in-spite of dragging of all the particles towards the best local particle. Again, we find the next best local particle. This process is repeated until it converges. This method is applied to a voltage stability problem for minimizing total reactive power loss at the stressed condition of transmission system. For this two standard test systems Modified IEEE-14 bus test system and IEEE-30 bus system are used. First of all, voltage stability analysis was done using Fast Voltage Stability Index [1] and weakest areas cluster. At the weakest bus optimal amount of reactive power to be injected were found using the proposed method. The main objective is to minimize total reactive power loss at stress condition. The control variables are voltages of generator buses, on-line tap changing ratio of transformers, and reactive power injected at the weakest bus. The results obtained were compared with the classical method 'Davidson-Fletcher Powel Method' as given in [2] and a good agreement is observed in the results obtained in both the results.

Index Terms: Optimization, weak area clustering, reactive power loss minimization, voltage stability index, soft computing.

1. INTRODUCTION

Optimization is used in various fields of research and is of major concern now-a-days. It may be based on rigorous mathematical procedures or on soft computing. Classical mathematical methods are used when exact solution is expected. However, in various engineering applications approximate answer might be sufficient. In the last decade, various soft computing techniques have been developed for example, developed genetic algorithm, particle swarm optimization, ant-colony optimization etc are the few popular optimization techniques. Once these programs are understood and applied to a problem, it is very easy to optimize the problem within fraction of seconds. But for beginners applying these algorithm is little difficult, especially when it is multi-objective function with various constraints. In case, it is load flow problem, in power systems, conducting power flow again and again along with the equations of that particular optimization technique, is sometime difficult. Most of these techniques are based on social movement of particle or creation of genes etc, where velocity update formulae, best local practice is required to update the position of particle again and again. This is time consuming process.

For the problems, where very exact solution is not required a novel and simple optimization technique is proposed, which is based on simple inspection. It is something hit and trial method. First of all, equally distributed particles are created in the search space. The number of particles created is taken very large. So that, it must cover entire search domain. This first step itself will give approximate answer, minimum or maximum. Now around this local best particle, small area is considered and again a large number of new particles are created in spite of dragging other particles towards this local best, which is time consuming.

Soft computing technique uses random values of variables so answer obtained in first run are noted down and the same program is run again and again in order to inspect best possible answer. Though running the program again and again is time consuming but applying this method to various problems is very easy especially for beginners. This method of optimization has been applied to voltage stability problem.

Two standard test systems modified IEEE-14 bus test system and standard IEEE-30 bus test system is used for testing. A Voltage Stability Index called Fast Voltage Stability Index [1] is chosen for analysis and the weakest bus is determined. There are three control variables, voltage of generator buses, OLTC ratio of transformers and reactive power injected. In this work, the amount of the reactive power to be injected is calculated by the proposed optimization technique.

The objective function is to minimize overall total reactive power loss. For power flow Newton-Rapson Method has been used. The result obtained for modified IEEE-14 bus test system is compared with the classical Davidson-Fletcher-Powell-Method [2] and a good agreement is observed in the results obtained in both the results.

2. INDEX FORMULATION

The main objective of determining the Voltage Stability Index is to determine the weakest bus of the system and the critical line referred to a bus, which is the main reason for voltage instability of the system. The main objective of this work is to determine the optimal amount of reactive power, which is to be injected in the system for the enhancement of the voltage stability.

In this work, the Fast Voltage Stability Index [1] is used for Voltage Stability Analysis. Although, there are many indices available to find out the stability of the system based on bus data and line data. The main objective of this work is to minimize the total reactive power loss of the system. The total reactive power loss can be minimize by using different ways like:

- (i) By injecting optimal amount of reactive power at the weakest bus of the system.
- (ii) By changing generator bus voltage and tap setting ratio.
- (iii) By changing tap setting ratio, changing generator bus voltage and injecting reactive power from outside at the same time.

In the present work, we shall focus on the third solution for minimizing the total reactive power loss and we shall compare our results with the standard IEEE-14 bus test system.

Fast Voltage Stability Index

We have calculated the weakest bus of the system by using FVSI technique. Then, with the help of Inspection Method optimization technique we shall solve the instability problem. The voltage stability index [1] is given by

$$FVSI = \frac{4Z^2Q_j}{V_i^2X}$$

where, Z = Line impedance, X = Line reactance, Q_j = Reactive power at the receiving end, V_i = Sending end voltage. If the value of FVSI is '0' it means system is stable and if '1' the system is unstable. If the value of index is closer to 1, it means; system is in the verge of instability. Hence, it should be always much less than one.

3. OBJECTIVE FUNCTION AND CONTROL VARIABLES

The objective function used in this proposed technique is explained below:

$$\min(I) = Q_{\text{loss}} \quad (1)$$

$$Q_{\text{loss}} = \sum_{i=1}^{NL} Q_{l-i} \quad (2)$$

$$Q_{l-i} = b_i(V_k^2 + V_m^2) - 2b_iV_kV_m \cos(\delta_k - \delta_m) \quad (3)$$

where, $b_i = r_i / \sqrt{r_i^2 + x_i^2}$ and $b'_i = b_i - b_{sh-i}$

Subject to constraints:

- (i) Real and reactive power flow equation, i.e. :

$$F(V, \delta) = 0 \quad (4)$$

- (ii) Inequality constraints on load bus voltages:

$$V_{i, \min} < V_i < V_{i, \max} \quad (5)$$

- (iii) $L_i > L_{i, \text{th}}$ where, $I = 1, 2, 3$: Voltage of generator buses, OLTC (On Line Tap Changing) ratio and injected reactive power are considered as control variables.

4. THE PROPOSED OPTIMIZATION TECHNIQUE

Optimization by Inspection Method can be simulated as follows

Step I: Creating the particles: These particles are uniformly distributed in the search space. The particles are uniformly distributed because the function is non linear and complicated.

Step II: After the creation of particles. The second step is to find out the best area in the search space. Now, create new particles in this space around the best particles in this small area. This step is known as **first iteration**.

Step III: In the third step, again find out the best particle area in the first iteration area.

Step IV: Now in the fourth step, create the new particle in a small selected random area. This step is known as **second iteration step**.

Step V: After performing the above mentioned step, we will be able to find out either clear convergence or the variation in two successive local best particles to be very small.

In case, if it is multi-objective function then Pareto Dominance method should be used.

Implementation

Inspection method of optimization program was developed in MATLAB. In this method, new particles are created around the local best particles, in spite of using velocity formulas as we use in Particle Swarm Optimization technique.

Several sets of particles are created and this complete set created at a time is called population. The objective function itself is fitness function. However, this method can also be applied to a multi objective function.

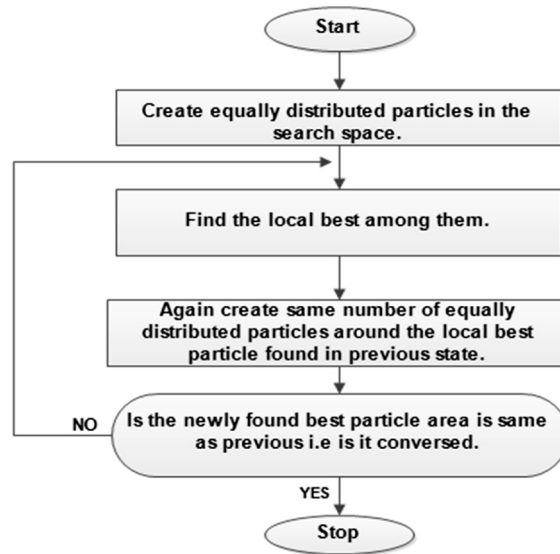


Figure 1: Flow chart showing the concept of Inspection Method

5. SIMULATION RESULTS

In the present work, we have considered two transmission systems. One is modified IEEE-14 test bus system and second is IEEE-30 bus test system. First by using MATLAB program for FVSI, we have calculated the weakest bus for these two systems. We have found the bus having least load-ability limit. The bus having least load-ability limit will be the weakest bus in the whole Transmission system. We will inject optimal reactive power on that bus. The modified IEEE-14 bus test system is shown in Figure 2. It consists of five generator buses i.e. 1, 2, 3, 6, 8 and 11 loads consuming total active and reactive powers of 259MW and 77MVAR through 14 transmission lines. Another system i.e. IEEE-30 bus transmission system which is considered here consists of 6 generator buses i.e. 1, 2, 5, 8, 11 & 13 and that 41 transmission lines and 20 loads as it is shown in Figure 3.

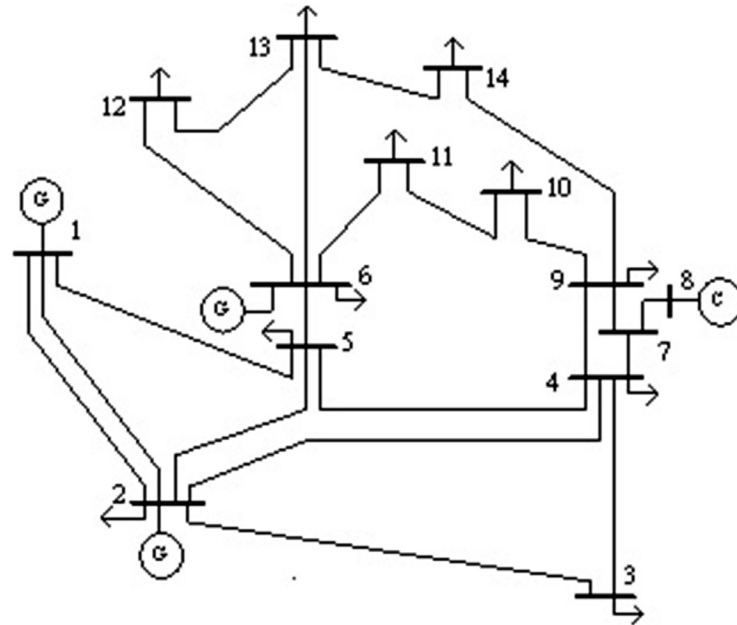


Figure 2: Single Line Diagram of IEEE 14-bus test system

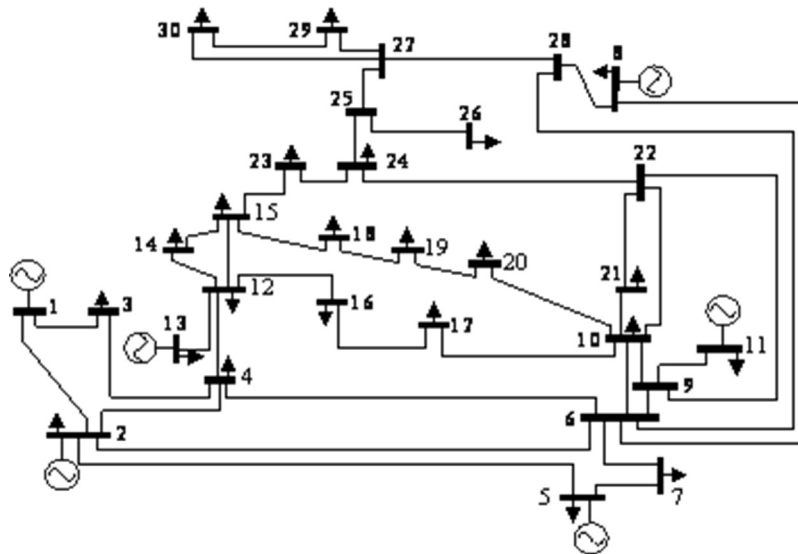


Figure 3: Single Line Diagram of Standard IEEE 30 bus test system

By using FVSI method, we have found that 14th bus is the weakest bus in modified IEEE-14 bus test system and 26th bus is the weakest bus in standard IEEE 30 bus test system. At these two buses, we inject reactive power step by step taken one at a time. The simulation results are shown in Table 1 and Table 2 for selected bus. The weakest bus is also shown in Figure 4 & 5 for modified IEEE-14 bus test system and IEEE 30 bus test system respectively.

After finding the weakest bus of the IEEE-30 Bus Test System, we apply inspection method and get the reactive power loss. After calculating the losses for IEEE-30 Bus Test System, we compare it with modified IEEE 14 Bus Test System, and we find that the reactive power loss by Inspection Method is minimum than any other method.

Table 1
Simulation Result of Inspection Method for Modified IEEE-14 Bus Test System

<i>S.No.</i>	<i>Iteration steps</i>	<i>Reactive power losses</i>
1	First step	1.420890
2	Second step	0.847163
3	Third step	0.810189
4	Fourth step	0.778044
5	Fifth step	0.753625
6	Sixth step	0.739403
7	Seventh step	0.738013
8	Eight step	0.738003

Table 2
Simulation Result of Inspection Method for IEEE-30 Bus Test System

<i>S.No.</i>	<i>Iteration steps</i>	<i>Reactive power losses</i>
1	First step	0.185799
2	Second step	0.177356
3	Third step	0.171129
4	Fourth step	0.167817
5	Fifth step	0.158993
6	Sixth step	0.137887
7	Seventh step	0.137645
8	Eighth step	0.130661
9	Ninth step	0.130661

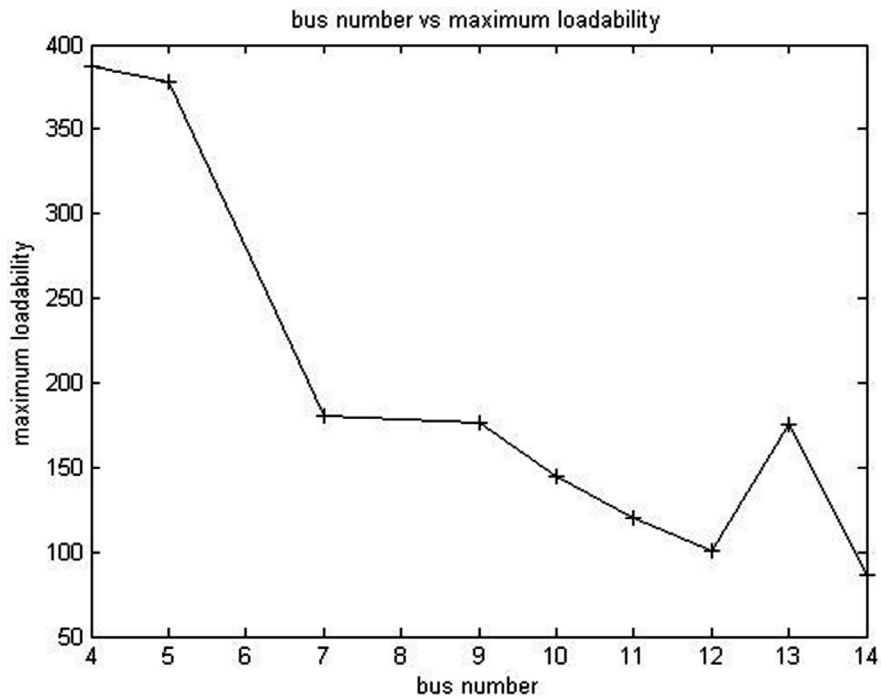


Figure 4: Bus Number Vs Maximum Load-Ability Plot of modified IEEE 14 Bus Test System

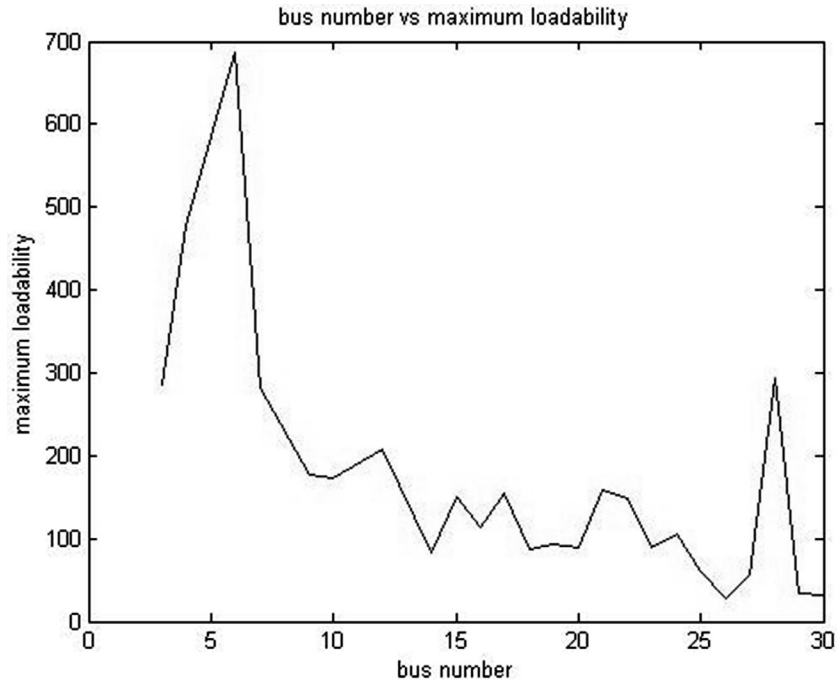


Figure 5: Bus Number Vs Maximum Load-Ability Plot of IEEE-30 Bus Test System

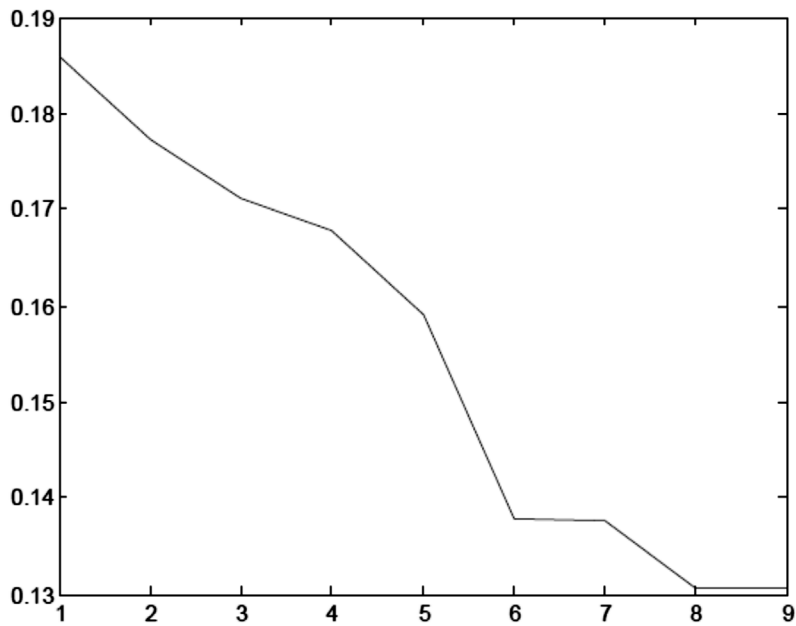


Figure 6: Minimization of total reactive power loss for several iteration of IEEE-30 Bus Test System

6. CONCLUSION

A novel optimization technique by simple inspection method is tried for an existing voltage stability problem. Weak area clustering was done by using voltage stability index [1]. At the stressed condition total reactive power loss was minimized by providing external reactive power injection, managing the values of voltages at generator buses and setting the OLTC ratio of transformers in the system. Losses were minimized up to a great extent and the results were compared with classical method ‘Davidson-Fletcher Powel Method’ [2].

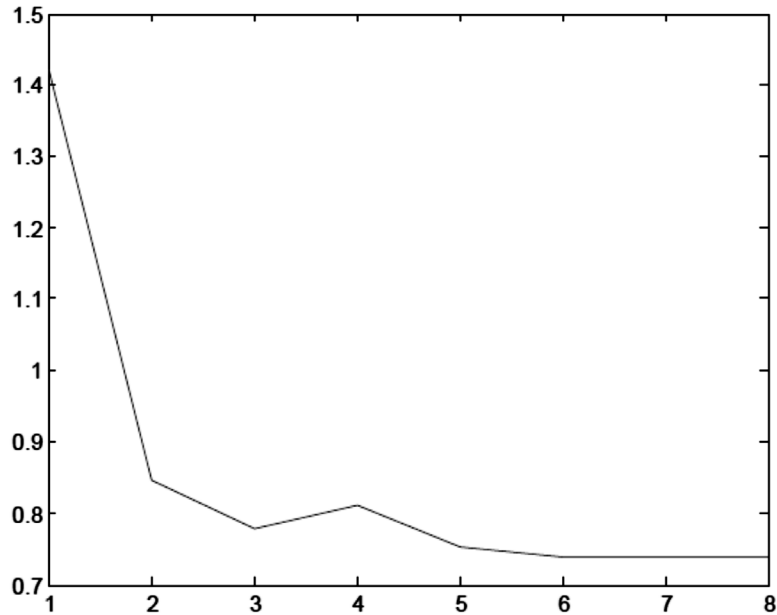


Figure 7: Minimization of total reactive power loss for several iteration of IEEE-14 Bus System

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