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Optimal Location and Improvement of Voltage Stability by UPFC using Genetic Algorithm (GA)

E. Nanda Kumar[1], R. Dhanasekaran[2] and R. Mani[1]

[1]Sri Krishna College of Technology, Kovaipudur, Coimbatore – 641008, Tamil Nadu, India; enk_pas@yahoo.co.in
[2]Syed Ammal Engineering College, Ramanathapuram – 623502, Tamil Nadu, India; rdhanashekar@yahoo.com, manieee@gmail.com

Abstract

Background/Objectives: This paper proposed the Optimal Location and Improvement of Voltage Stability in Electrical power transmission lines using Unified Power Flow Controller. **Methods/Statistical Analysis:** The optimization technique Genetic Algorithm is used to find the optimal location and rating of UPFC to improve the voltage stability of the system. The Unified Power Flow Controller is one of the important devices that are used to control the voltage magnitude and corresponding angle of sending end and receiving end bus. **Results/Findings:** Simulation has been implemented in MATLAB software and IEEE 39 bus system used. **Conclusion/Application:** The results shows that voltage profile is enhanced at buses and power losses are considerably decreased, minimization of power losses and minimization of generation cost. Thus it proves that the efficiency of GA is better than the conventional method.

Keywords: FACTS - Flexible A.C. Transmission Systems, GA - Genetic Algorithm, UPFC - Unified Power Flow Controller

1. Introduction

The power system is a complex network comprising of transmission lines interconnecting all the generator stations, transformers and load. The important requirement of a reliable power system is to maintain the voltage within the possible range to ensure a high quality of customer service. The voltage collapse occurs in power system to supply the reactive power or by an excessive absorption of reactive power[1]. Therefore it is difficult to provide voltage stability even in normal condition. Voltage problem mainly associated with the reactive power imbalance. Voltage instability problem is being addressed in two different ways. The first approach is to mitigate the problem and the second approach is to enhance the voltage stability of the system for selecting the operating condition. The only way to save system from voltage collapse is to reduce reactive power load or add additional reactive power. To achieve secure and economic operation Flexible AC Transmission System devices are properly installed in the system[2]. The function of FACTS devices is to control the transmission line power flow. There are various types of FACTS devices are used such as Static Series Compensator (SSSC), Static Synchronous Compensator (STATCOM), Static VAR Compensator (SVC), Unified Power Flow Controller (UPFC), and Interline Power Flow Controller (IPFC). The principle function of UPFC is to control the flow of real and reactive power by injecting voltage in series with transmission line[3].

2. Problem Formulation

A multi-objective optimization problem consists of multi objective function with equality and inequality constraints to be optimized[4]. The equality constraints represent the typical load flow equations. The inequality constraints represent the operating limits of the UPFC. Here a problem real power loss minimization taken Based on the real power loss value UPFC rating calculated[5]. Better results can be obtained by minimizing the objective function and

**Author for correspondence*

satisfy all the constraints.

2.1 Calculation of Real Power Loss

The objective function of this problem is to find the optimal place and rating of the UPFC based on real power loss calculation[6]. Hence, the objective function is expressed as in equation.

Power loss = $P_{ij}F + P_{ij}T$ (2.1)

Real power loss = abs (sum (power loss)) (2.2)

Where,

$P_{ij}F$ = real (complex power from bus)

$P_{ij}T$ = real (complex power to bus)

2.2 Fitness Function

Considering the power loss as the objective function and the Fitness Function is expressed as in equations (2.3) and (2.4)

$$f(x) = fitness\ func(variable) \quad (2.3)$$

$$f(x) = loss + sum((1.1 - abs(v)^{\uparrow}2) \quad (2.4)$$

2.3 Constraints

The minimization problem is subjected to the equality and inequality constraints as follows[7].

2.3.1 Equality Constraints

2.3.1.1 Load Flow Constraints

The real and reactive power constraints are according to equations (2.5) and (2.6) respectively as given below[8]:

$$P_{Gi} - P_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} \cos(\delta_{ij} + \gamma_j - \gamma_i) = 0 \quad (2.5$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} \sin(\delta_{ij} + \gamma_j - \gamma_i) = 0 \quad (2.6)$$

2.3.2 Inequality Constraints

Bus voltage inequality constraint:

$$V_{Gi}^{min} \le V_{Gi} \le V_{Gi}^{max} \quad (2.7)$$

Bus Voltage angle inequality constraint:

$$\delta_{Li}^{min} \le \delta_{Li} \le \delta_{Li}^{max} \quad (2.8)$$

Real power inequality constraint:

$$Q_{Ci}^{min} \le Q_{Ci} \le Q_{Ci}^{max} \quad (2.9)$$

Reactive power inequality constraint:

$$p_{Gi}^{min} \le Q_{Gi} \le p_{Gi}^{max} \quad (2.10)$$

3. UPFC Power Calculation

UPFC injected power from the bus

$$upfiF = bs(fb, tb) * v(fb) * (v(tb) * \sin(\theta + \delta) + (v(fb) * \cos(\delta)) \quad (2.11)$$

UPFC injected power for the bus

$$upfiT = bs(fb, tb) * v(fb) * v(tb) * \sin(\theta + \delta) + \cos(\theta + \delta)) \quad (2.12)$$

Where,

fb = from bus, tb = to bus, bs = Y_{bus} value

v(fb), v(tb) = voltage value from bus to bus

4. Genetic Algorithm

GA is a search heuristic method based on the Darwinian theory of the fittest which was developed by John Holland in 1970. It is an iterative procedure used to provide optimal solutions by solving multi-objective optimization problems. At each step of iteration, the individuals are selected randomly from the current population to be parents and the next generation is formed by those parents. Optimal solution can be obtained in repeated iterations9. GA can be used to solve to optimization problems with a variety of objective functions even it is highly non-linear, no differentiable or discontinuous. New generation can be obtained through the genetic operators[10].

4.1 Step by Step Procedure for GA

UPFC placed in IEEE 39 bus with GA, the following steps are to be followed:

Step 1: Initially create a population
First string = UPFC location
Second string = Serious injection voltage
Third string = Serious injection voltage
Angle

Step 2: Perform power flow program.
Newton power flow program for IEEE 39 bus system is given below.

Step 3: Find the fitness values for each individual fitness value after placing a FACTS device in a particular place11.

Step 4: Based on the fitness values, a new population has been selected from the old population based on the evaluation
function as given.

Step 5: Genetic operators (crossover and mutation) applied to the population that has been selected to create new solution.

Step 6: Fitness value is evaluated for new chromosomes and use them into the population.

Step 7: If it exceeds the time, stop the process and provide the best Individual if not, proceed from step 4.

5. Simulation Results

IEEE 39 bus system was used for testing GA and the result was obtained. In which location of the UPFC ware optimized and the objective such as minimizing real power loss and improvement of voltage in power system ware obtained. The parameter used by GA is shown in Table 1.This proves the GA is more efficient than the conventional method.

Table 1. GA Parameters

Dimension of search space	3
Population size	8
Number of generation	50
Mutation	0.2
Crossover length	0.3

The optimal location of UPFC in IEEE 39 system is identified bus number 16–24 and series injection voltage 0.0300 p.u., series injected voltage radians 2.275000 by GA by considering all three mentioned objectives. Hence UPFC placed between bus number 16 and bus number 24 and the real power loss 0.344471 p.u. calculated.

The voltage profile in IEEE 39 bus system before placing UPFC is shown in Figure 1.

5.1 Voltage Profile in IEEE 39 Bus System before placing UPFC

The voltage profile in IEEE 39 bus system before placing UPFC is shown in figure below.

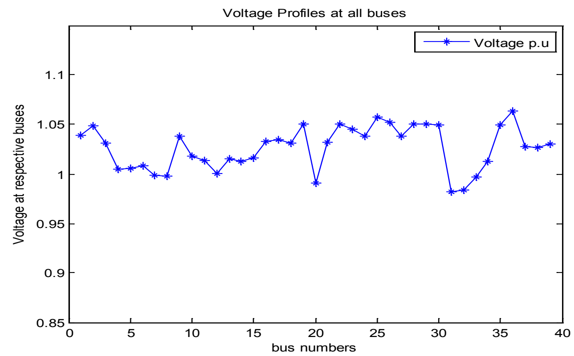

Figure 1. Voltage profile before placing UPFC.

5.2 Voltage Profile in IEEE 39 Bus System after placing UPFC

The voltage profile in IEEE 39 bus system after placing UPFC is shown in Figure 2.

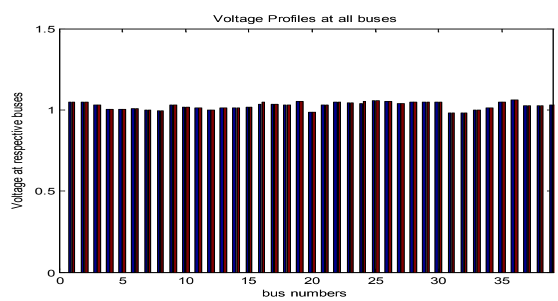

Figure 2. Voltage Profile after placing UPFC.

5.3 Convergence Speed of Genetic Algorithm

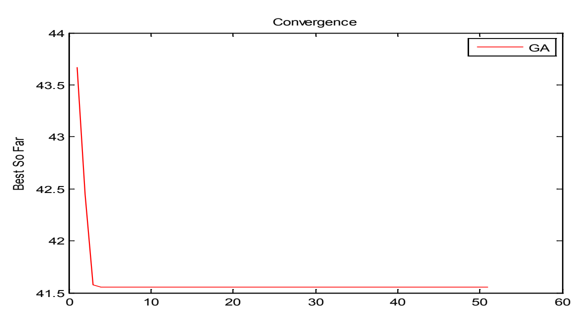

Figure 3. Convergence Speed of GA.

Table 2. Voltage value (p.u.) before and after placing UPFC

Bus No.	Before placing UPFC	After placing UPFC	Bus No.	Before placing UPFC	After placing UPFC
1	1.047	1.047	19	1.050	1.052
2	1.049	1.049	20	0.991	0.987
3	1.030	1.031	21	1.032	1.032
4	1.004	1.004	22	1.050	1.050
5	1.005	1.006	23	1.045	1.045
6	1.008	1.008	24	1.037	1.038
7	0.997	0.997	25	1.058	1.058
8	0.996	0.996	26	1.052	1.052
9	1.028	1.028	27	1.038	1.038
10	1.017	1.017	28	1.050	1.050
11	1.013	1.013	29	1.050	1.050
12	1.000	1.000	30	0.048	1.048
13	1.014	1.015	31	0.982	0.982
14	1.012	1.012	32	0.983	0.983
15	1.015	1.016	33	0.997	0.997
16	1.032	1.033	34	1.012	1.012
17	1.034	1.034	35	1.049	1.049
18	1.031	1.031	36	1.064	1.064
19	1.032	1.033	37	1.028	1.028
20	1.036	1.016	38	1.027	1.027
21	1.012	1.015	39	1.030	1.030

Table 3. Real Power Loss Values

From Bus to Bus	Real Power Loss (MW)	From Bus to Bus	Real Power Loss (MW)	From Bus to Bus	Real Power Loss (MW)
1-2	0.496	6-5	0.414	11-10	0.537
1-39	0.185	6-7	1.101	11-12	0.029
2-1	0.496	6-11	0.917	12-11	0.029
2-3	1.698	6-31	0.000	12-13	0.035
2-25	4.161	7-6	1.101	13-10	0.320
2-30	0.000	7-8	0.139	13-14	0.670
3-2	1.698	8-5	0.831	13-12	0.035
3-4	0.289	8-7	0.139	14-4	0.593
3-18	0.028	8-9	0.184	14-13	0.670
4-3	0.289	9-8	0.184	14-15	0.007

4-5	0.149	9-39	0.004	16-15	1.046
4-14	0.593	10-11	0.537	16-17	-4.296
5-4	0.149	10-13	0.320	16-19	-0.838
5-6	0.414	10-32	-0.000	16-21	-3.830
5-8	0.831	11-6	0.917	16-24	-4.622
17-16	0.355	19-16	3.814	21-16	0.821
17-18	0.293	19-33	2.876	21-22	2.782
17-27	0.012	19-20	0.116	22-23	0.025
18-3	0.028	20-34	2.580	22-35	0.000
18-17	0.293	20-19	0.116	23-24	2.529
24-16	0.030	27-17	0.012	23-36	1.430
25-2	4.161	27-26	0.957	32-10	-0.000
25-37	1.656	28-26	0.788	33-19	2.876
26-28	0.788	29-38	5.234	34-20	2.580
26-29	1.914	31-6	0.000	35-22	0.000
36-23	1.430	37-25	1.656	38-29	5.234
39-1	0.185	39-9	0.004	-	-

5.4 Comparison of Voltage before placing UPFC and after placing UPFC

The following Table 2 compare the voltage before and after placing the FACTS device UPFC.

5.5 Real Power Loss Value

The following Table 3 compare real power loss values in MW after the incorporation of FACTS device UPFC.

6. Conclusion

Recently power losses and voltage instability problems are the major problems in power system and generation cost also goes high. FACTS concept made a revolution in power system which overcomes all the problems. Many techniques are used to optimize the location of FACTS devices. GA belongs to a class of evolutionary algorithms is used as an optimization technique in this project. The location and ratings of UPFC optimally identified by GA and, NR method used power flow calculation. The results shows that voltage profile is enhanced at buses and power losses are considerably decreased, minimization of power losses and minimization of generation cost. Thus it proves that the efficiency of GA is better than the conventional method.

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