A Gravitation Based Search Algorithm for Improvement of Maximum Power Transfer by Optimal Placement of UPFC

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ABSTRACT

In regulated electricity markets, there is trading of large volume of power over existing transmissions lines. Due to this, some corridors experience congestion and may endanger system security, stability and reliability. To overcome this, Unified Power Flow Controller (UPFC) can act as a decongestion device and can improve power flow. The proposed method uses a modified gravitational search algorithm to improve maximum power transfer capability of UPFC. This is tested on IEEE-57 bus system.

Keywords- Congestion, UPFC, maximum power flow, optimal location

I INTRODUCTION

With the deregulation of electricity sector, large numbers of market players are trading electricity over existing transmission lines. The growth of transmission lines is hampered by right of way issues, environmental concerns, cost etc. among others. So under these constraints, the existing transmission lines need to be put to optimum use. The FACTS (Flexible AC Transmission System) devices can play a major role in congestion mitigation. UPFC (Unified Power Flow Controller) is a versatile member of FACTS family which not only can provide active power support but also reactive power support. UPFC also helps to reduce system losses, improve stability reduce sub synchronous resonance (SSR) etc. The proposed new adaptive search algorithm reduces the complexity and improves the convergence characteristics of traditional gravitational search algorithm. Following section II gives brief literature survey, section-III describes mathematical modeling & section-IV gives power loss calculation followed by simulation results and conclusion.

II BRIEF LITRATURE REVIEW

K. Vijay Kumar et al [1] used genetic Algorithm to find optimal location and rating of TCSC (Thyristor Controlled Series Capacitor) and UPFC. The optimal location was decided by overall system cost. Serhat Duman et al [2] used gravitational search algorithm for solving optimal power flow problem. They tested the proposal on IEEE-30 and IEEE-57 bus system. Multi-objective optimal power flow problem was worked out using gravitational search algorithm by Bhattacharya et. al [3]. They used three independent objectives i.e. cost minimization, active power loss minimization and voltage deviation minimization. The results were compared with Varied Integer Particle Swarm optimization, Evolutionary Programming and Genetic Algorithm and found that Gravitational Search Algorithm has better global search capability & convergence speed. Mohammed Khajehzadeh [4] successfully used modification of traditional gravitational search algorithm. The approach used an adaptive maximum velocity restrain for better global exploration & better convergence speed. Harinder Sawhney et. al [5] used UPFC to obtain better power transfer capability in deregulated electricity market. Purwoharjono et al [6] used gravitational search algorithm to find optimal location of TCSC. H. Farahmanda et al [7] determined available transfer capability using Particle Swarm optimization technique, genetic algorithm & hybrid mutation particle swarm optimization technique. He solved multi-objective optimization problem connected with optimal installation & capacity allocation of FACTS devices. He compared all the three methods.

Currently large number of algorithms such as genetic algorithm (GA), particle swarm algorithm (PSO), ant colony search algorithm (ACS), simulated annealing algorithm (SA), pareto- differential evolution algorithm (PDE), bacteria foraging algorithm (BF) etc. are used for determination of optimal power transfer ability of power system. For a specific type of problem, specific optimization techniques are relevant. So, searching an appropriate algorithm for the given task is necessary. For finding optimal transmitted power, gravitational search algorithm is best suited. However, as the search space rises exponentially with the problem size, the GSA is unable to provide solution. The proposed adaptive search algorithm overcomes this limitation by improving global search ability and increases convergence speed.

III MATHEMATICAL MODELLING OF UPFC

The power system operation is constrained by various network parameters such a as bus voltage, power loss, line impedance, phase angle etc. UPFC is able to regulate the parameters so that maximum power transfer capability is maintained.
Newton-Raphson method is used to determine active and reactive power flow.

$$P_m = V_m V_n \sum_{n=1}^{N_B} [G_{mn} \cos\delta_{mn} + B_{mn} \sin\delta_{mn}] \quad (1)$$

$$Q_m = V_m V_n \sum_{n=1}^{N_B} [G_{mn} \sin\delta_{mn} - B_{mn} \cos\delta_{mn}] \quad (2)$$

Where V_m and V_n are voltages of m and n buses respectively, N_B is the total number of buses, S_{mn} is the angle between m and n buses respectively; G_{mn} and B_{mn} are conductance and suscceptance respectively.

The proposed system identifies maximum power-loss buses and reduces the power loss using UPFC.

Without UPFC, the power flow between the buses is given by

$$P_{mn} = V_m V_n \sin\delta_{mn} / X_{mn} \quad (3)$$

Where X_{mn} is the reactance between the bus m and n. The power balance equation is described by equations-

$$\begin{bmatrix} S_M \\ S_N \\ . \\ . \\ . \\ S_T \end{bmatrix} = \begin{bmatrix} P_{GM} + j\,Q_{GM} \\ P_{GN} + j\,Q_{GN} \\ . \\ . \\ . \\ P_{TN} + j\,Q_{TN} \end{bmatrix} = \begin{bmatrix} (P_{DM} + P_{LM}) + j\,(Q_{DM} + Q_{LM}) \\ (P_{DN} + P_{LN}) + j\,(Q_{DN} + Q_{LN}) \\ . \\ . \\ . \\ P_{DT} + P_{LT}) + j\,(Q_{DT} + Q_{LT}) \end{bmatrix} \quad \text{.... (4)}$$

Power loss of m bus is calculated by following equation-

$$P_{lm} = V_m V_n Y_{mn} \sum_{n=1}^{N_B} \cos(\alpha_{mn} - \delta_m - \delta_n) \quad (5)$$

$$Q_{lm} = V_m V_n Y_{mn} \sum_{n=1}^{N_B} \sin(\alpha_{mn} - \delta_m - \delta_n) \quad (6)$$

Where P_{gm} and $Q_{gm}$are active and reactive power generation, P_{lm} and Q_{lm} are active and reactive power demand, Y_{mn} is the bus admittance matrix, α_{mn} is the angle between buses m and n, δ_m and δ_n are load angle of m and n.

IV DETERMINATION OF MAXIMUM POWER LOSS AND UPFC CAPACITY

The proposed algorithm (Modified Gravitational Search Algorithm) considers agents as objects. The gravity force attracts all these objects and causes global movement of all objects towards heavier mass objects. The lighter objects move faster than heavier objects and correspond to good solutions. Inertial mass, active gravitational mass and passive gravitational mass are positions of each mass in the algorithm. The position of mass corresponds to a solution of the problem and its gravitational and inertial masses are determined by a fitness function. So, each mass represents a solution and the algorithm is navigated by appropriate adjustment of gravitational and inertial masses. It is expected that masses would be attracted by heaviest mass over a period of time and it will represent most favourable solution.

Flow chart of proposed modified gravitational search algorithm is given below-

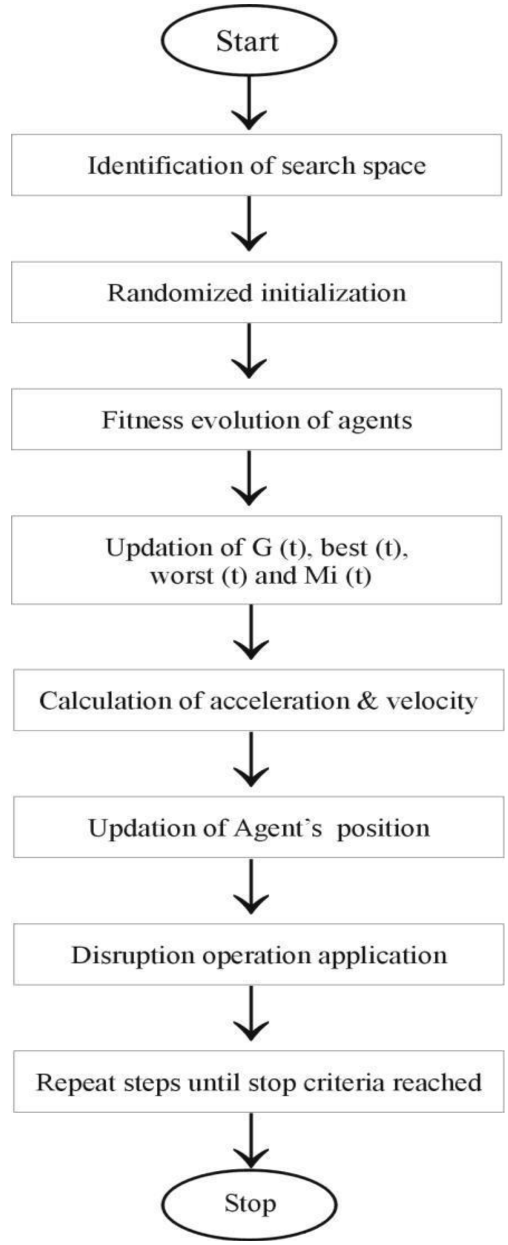

Fig. 4.1 Flow Chart for modified gravitational search algorithm

where G (t) is gravitational constant, Mi (t) is inertial mass of i^{th} agent, best (t) and worst (t) are fitness values of agents.

The optimal location of UPFC for maximum power flow was determined based on lowest investment cost. The investment cost function is given below-

$$COST_{UPFC} = 0.0003S^2 - 0.2691\ S + 188.22$$
(US $ /KVAR.) (7)

Where S is operating range of UPFC in MVAR.

V. SIMULATION RESULT & DISCUSSIONS

The modified gravitational search algorithm was used in IEEE-57 bus system using MATLAB. Newton – Raphson method was used to carry out load flow analysis. The IEEE-57 bus system contains 7 generator buses, 50 load buses and 80 transmission lines.

Table 5.1 shows power loss of the system. The power loss was determined using the proposed algorithm. The best fitness buses are found to be 8-9, 1-16, 9-13, 9-10 and 2-3. The optimum capacity of UPFC was determined based on cost function (equation -7) which gives minimum investment cost of UPFC shown in graph 5.1. Among the best fitness buses, the lowest UPFC cost was found to be in bus 2-3 (151.671, $/hr.) as shown. Hence, installation of UPFC in bus 2-3 in IEEE-57 test bus system will provide optimal location for UPFC based on investment cost for maximum power flow. This is represented in Graph 5.2.

Table 5.1 System power loss &maximum power transferred

Bus No.		**Maximum Power Transferred by UPFC**		**Power loss after connecting UPFC**
From Bus	**To Bus**	**Real power (MW)**	**Reactive Power (MVAR)**	**Modified Gravitational Search Algorithm (MW)**
8	9	27.574	20.85	19.541
1	16	21.364	4.792	18.384
9	13	21.889	102.871	14.809
9	10	27.574	20.565	16.091
2	3	41.860	8.100	20.371

Table 5.2 UPFC cost Vs bus location

From Bus	**To Bus**	**UPFC cost (US $ / hr)**
8	9	188.22
1	16	179.204
9	13	188.22
9	10	188.23
2	3	151.67

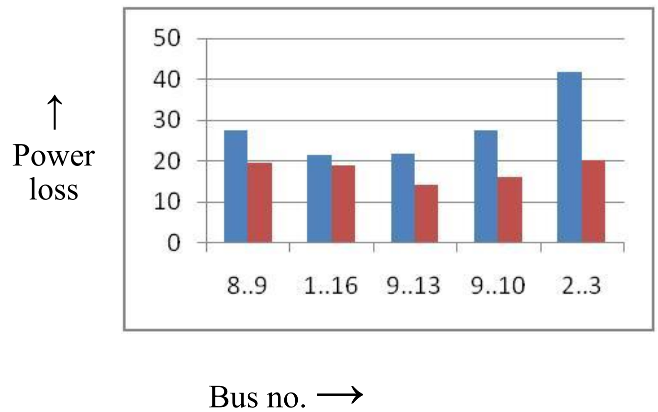

Fig. 5.1 Power loss with & without UPFC

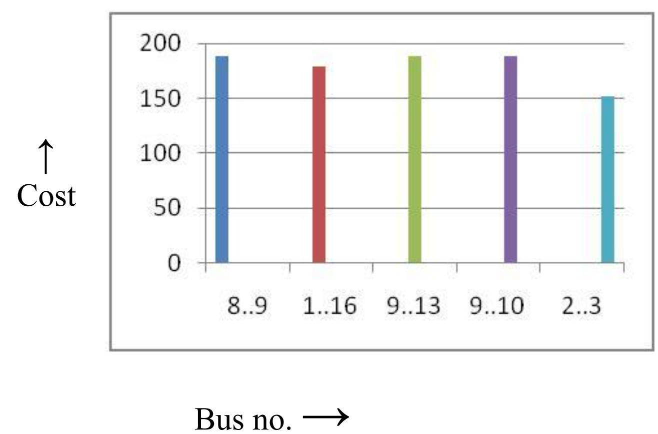

Fig. 5.2 UPFC cost Vs bus location

VI. CONCLUSION

The proposed adaptive search algorithm finds optimal location of UPFC for sustaining maximum power transfer capacity of UPFC. The proposal was tested on IEEE-57 bus system. The proposed adaptive search algorithm shows less computational complexity compared to traditional

Gravitational Search Algorithm (GSA) and the convergence characteristics is also improved. The result shows superior performance of proposed algorithm compared to GSA.

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Biography

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