International Journal of Research in Engineering, Science and Management
Volume 6, Issue 8, August 2023
https://www.ijresm.com | ISSN (Online): 2581-5792

GUPFC Optimum Position and Parameters for Reducing Transmission Loss Using the BAT Algorithm

A. S. Kannan[1], V. Suryanarayana Reddy[2*]

[1]Associate Professor, Department of Electrical Engineering, Annamalai University, Chidambaram, India
[2]Research Scholar, Department of Electrical Engineering, Annamalai University, Chidambaram, India

***Abstract*: In a power system, the transmission losses are the major and most important losses. Reducing transmission losses is going to benefit us by saving a lot of energy. The transmission losses can be reduced by insertion of FACTS devices in the power system. Among all FACTS devices, preeminent is the Unified Power Flow Controller (UPFC) and Generalized Unified Power Flow Controller (GUPFC). Reduction of transmission losses is possible by integrating the GUPFC into the power system, placing it at an optimal location and its output being set at acceptable values. This paper discusses how to locate GUPFC's optimal position and also discusses the PSO algorithm and bat algorithm to find the optimal setting for overall loss reduction in transmission. Variation in voltage is taken as the location criteria and PSO is used to find GUPFC settings. This work is carried out using MATLAB engineering on an IEEE 14-bus network.**

***Keywords*: Transmission losses, FACTS, UPFC, GUPFC, PSO, LSF, CPF.**

1. Introduction

The size of the power system is growing with increase of demand in energy day by day. The transmission process involves a large complex network integrating many transformers, transmission lines, cables etc., as most of the generating stations are located far from the loads. could be transmitted via a large complex network interconnecting many transformers, transmission lines, cables, etc. For this reason, huge quantity of transmitting capacity is lost. This increases the damage of generating stations and transmission line capability as the transmission loss is higher in the current power grid. If a significant amount of power can be saved, the transmission loss can be reduced. The transmission losses can be minimized by adding some alteration of the structure. But since the power system network is vast in India, it is more complicated to modify each and every transmission line. The other approach is to go for a substitute way that reduces the transmission losses. The integration of different FACTS controllers in the power system helps to improve its output in a lot of ways [1]. A better solution will be to use the FACTS controllers that control or differ more than one device parameter.

Among all the UPFC and GUPFC FACTS tools are those that can simultaneously control multiple process parameters. By proper setting and placement of GUPFC, the transmission losses and congestion can be reduced [2]. The application of congestion management with FACTS devices is given in [3]. The approach to lessen losses by placing UPFC into the network is explained in [1]. UPFC can also be used to boost system security [4], and GUPFC is only the changed UPFC version. It is clear in [5] that, the use of UPFC mitigates transmission losses and boosts the profile of node voltage.

The FACTS controllers ' optimum position places an significant role in the power system's functioning status. In particular, the uses of the Non-Dominated Sorting Genetic Algorithm (NSGA-II) are given in [6] to find the UPFC's optimal position. The voltage tolerance factor and line stability factor of NSG Algorithm helps to place UPFC at the best position. This results in reduction of the active power loss. The value of UPFC is also included in its objective feature. An algorithm that helps to find the optimal FACTS controller location is also shown in [7] and [8]. The optimization algorithm for particle swam is used with three different criteria. Using the sensitivity factor, the location of FACTS controllers is found in [ ] and [10]. The N-1 contingency and the tolerance variable are used together in [11] to find the optimum UPFC position. The performance index is used in [12] to obtain UPFC's location.

In this paper, an IEEE 14-bus test system is considered and GUPFC is placed at most favourable condition with the help of the load scaling factor and the optimum location of GUPFC is set up using Particle Swam Optimization (PSO) algorithm and is contrasted with the bat algorithm. The mathematical model of GUPFC is concised in the next section.

2. Mathematical Modeling of GUPFC

From the literature, the modelling of FACTS devices can be done in two ways, the current injection modelling and power injection modelling. Amongst these, the uncomplicated and simple model is the power injection model, as the alteration of Jacobian matrix is not essential. This results in reduction of complex computations during load flow studies. A clear and detail explanation of GUPFC power injection model is given in

*Corresponding author: vemireddysnr@gmail.com

[14, 15]. The below figure [1] shows GUPFC with power injection model, integrated in lines [14].

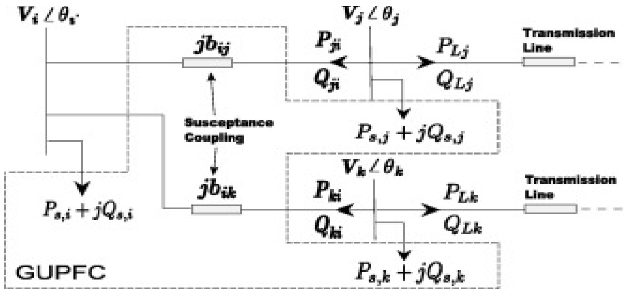


Fig. 1. GUPFC with power injection model

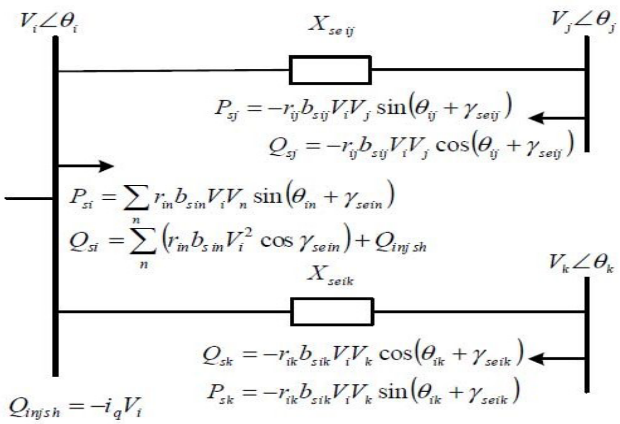


Fig. 2. GUPFC with complete power injection model

Here 'r' and 'γ' are the variables whose optimal values need to be found out.

r: Per unit value of injected voltage

γ: Phase angle of injected voltage.

3. Optimal Location and Parameters of GUPFC

Kennedy and Eberhart invented PSO in 1995 which is a population-based optimization method. This algorithm runs on the reference of behavior of birds searching for food. To know the optimal location of UPFC and control parameters, PSO algorithm is used in [16, 17] for attaining stability of power system. From [18], it is known that, improved PSO algorithm is also used for placing FACTS devices. In PSO technique, the local and global search can be done separately, since; it is an accurate and simple optimization tool. PSO do not have any crossovers and alterations when compared with genetic algorithm, making the computation easy. In PSO, all particles are kept as members of population during the procedure, making the analysis simpler. Due to the factors mentioned above, PSO is used in this paper for optimizing the parameters of GUPFC.

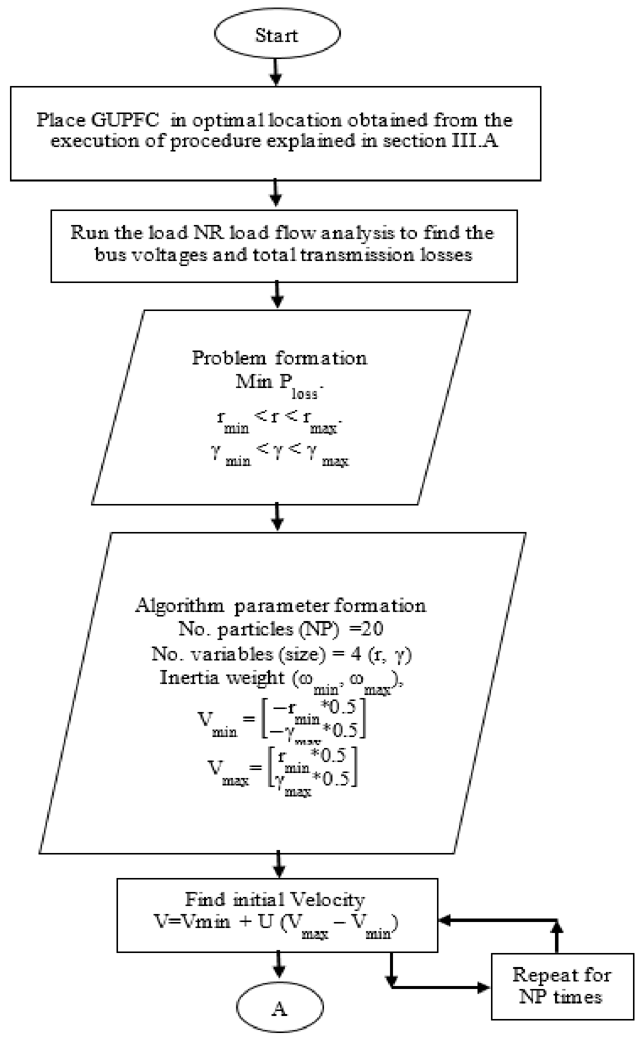
A. Proposed Method for Finding GUPFC Location

The following steps have been followed to identify GUPFC location.

- Based on the ratios of maximum capacity of individual generator, the total load in the system is to be distributed among all the generators.
- Find the base case losses and voltage profile at each bus by performing load flow analysis.
- Using load scaling factor (LSF), the loads and generations are to be incremented.
- Perform the load flow analysis and find the voltages at all buses at each increment.
- Increase the LSF, if for any generator, maximum generation limit is violated and the process is to be repeated.
- With the variation of LSF, find the bus with the greatest voltage variation.

B. PSO Algorithm for Parameters Optimization

The optimal setting of GUPFC is determined using the flow chart given below in figure 2. The location for placing the shunt converter of GUPFC will be the bus with the greater voltage difference and attach the series converters to the transmission line connected with this bus.



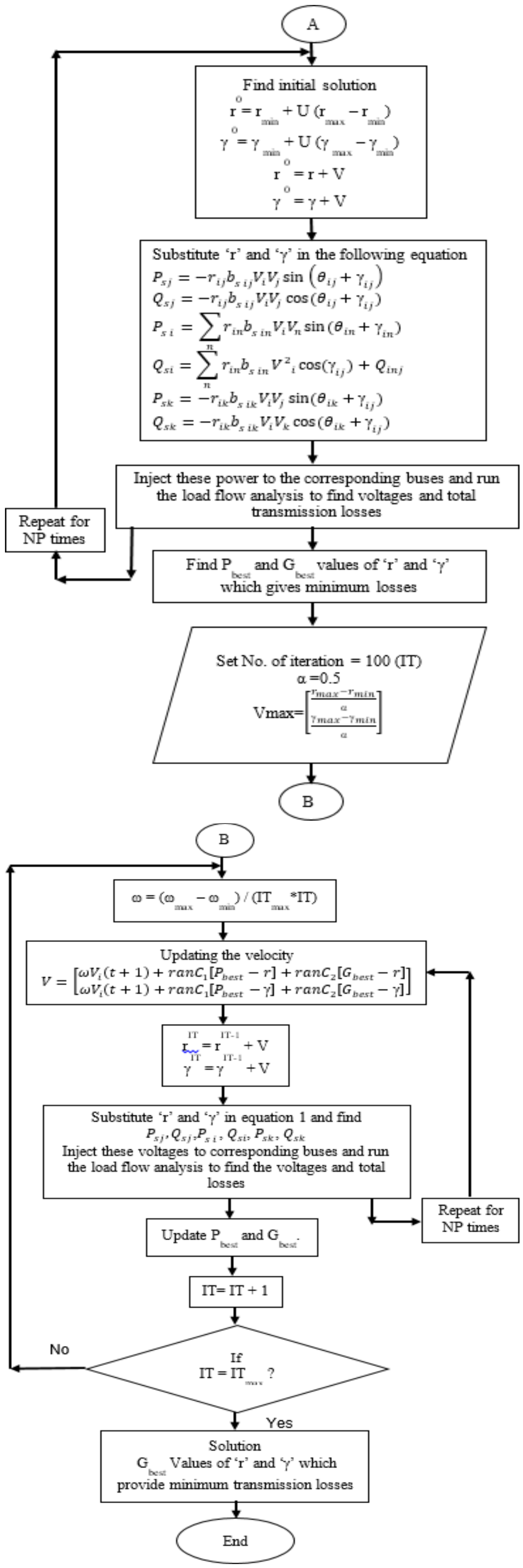


Fig. 2. Flowchart

GUPFC can be associated to more than two transmission lines. The number of series converters of GUPFC can be chosen according to the number of lines connected to the selected bus for placing the shunt converter of GUPFC. The system becomes more controllable and flexible as the controllable parameters increases with increase in number of series converters.

4. Results and Discussion

An IEEE 14 –bus test network with five generator buses and nine load buses, carrying twenty transmission lines is considered; with a total base load of 259MW. The generator buses being located at 1st, 2nd, 3rd, 6th, and 8th buses.

A. Optimal Location in IEEE 14-bus Test System

In conventional loading capacity calculations, the increasing load on the system is dispatched by slack bus resulting in extra burden on slack bus and further on lines that are incident to reference bus. So, decreasing the burden on slack bus is one of the ways to increasing transmission loading capability. Hence, this paper gives in detail about distributed generation, where the increase in load is to be compensated by all the generators. The generation schedule for a particular load is calculated using the equation (1). The total load is distributed among each generator based upon its maximum capacity which is similar to sharing losses with all the generators to reduce burden on the slack bus (as given in [21]). The total load distributed to all the five generators is done using following equation (1).

$$s_{jib} = \frac{s_{Ji,max}}{\sum_{i=1}^{n} s_{Ji,max}} * S_{Db} \tag{1}$$

Where, $$S_{Db} = \sum_{i=1}^{NLB} S_{Di} \tag{2}$$

$$S_{Dn} = (1 + LSF)S_{Db} \tag{3}$$

$$S_{Dn} = \sum_{i=1}^{NLB} (1 + LSB)S_{Di} \tag{4}$$

s_{jib}: Base case generation
$s_{Ji,max}$: Maximum capacity limit of unit
i S_{Db}: Total load under base case on the system
N_{Lb}: Number of load buses
S_{Di}: Load at each bus
S_{Db}: New load.

This new total load is distributed over again to all the generators by making use of equation (1). Then the value of LSF is increased to some extent every time. This procedure is repeated until it reaches the violation of maximum generation limit. Taking the base case, the generation of each generator using equation (1) is obtained as: G1= 111.46 MW, G2= 46.94 MW, G3= 33.53 MW, G6= 33.53 MW and G8= 33.53 MW

At each generation, these values are replaced. Then the load stream model is used to calculate the losses and energy flow at each transmission line. The Newton Raphson load stream method is used to determine voltage at each line and at each bus. Under the base case result the total active power losses is 4.639 MW. Power loss in the transmission lines are interlinked to the voltages in the buses and thus the locating of the GUPFC can be found out by finding out the bus which has the greatest voltage fluctuation.

The test system makes use of load scaling factor (LSF) for

Table 1
Losses comparison with PSO and BAT algorithm

Line no	Line b/w buses	P/P_{max} without GUPFC	P/P_{max} with GUPFC using existing algorithm PSO	P/P_{max} with GPFC using proposed algorithm BAT
2	1-3	1.74	1.38	1.02
3	2-4	1.54	1.22	1.04
6	3-4	1.72	1.43	1.06
4	2-5	1.38	1.18	1.08
5	2-6	1.36	1.22	0.84
7	2-4	1.21	0.98	0.99
9	4-6	1.24	1.01	0.96
10	5-7	0.32	0.36	0.44
11	6-7	0.87	0.93	1.0
12	6-8	0.92	0.98	0.89
13	6-9	0.98	1.04	1.00
14	8-28	0.94	0.96	0.80

increasing the loads simultaneously. LSF's value has a limit. This increase in load should be up to a value so that each generator's generations should be within its rated limit, and the convergence of NR method must be within 10 iterations. With an increase in load factor to a value 2.98, the bus 1 generation value is out of the limit. The maximum limit of all the generators is satisfied at LSF=2.629. At this condition, the total load is 680.911MW, a total loss 39.32 MW and generations of each generator: G1= 332.375 MW, G2= 123.405 MW, G3= 88.150 MW, G6=88.150 MW and G8= 88.150 MW.

B. Optimal Parameter Settings of GUPFC

The placing of GUPFC at an optimal location is also an important factor in operation point of view for a power system. As discussed in the mathematical model, the injected voltage (v in p.u) and phase angles of injected voltage (β*)* are varied for the control of transmission losses using PSO algorithm. Here, we are going to use a GUPFC with one shunt converter and two series converters, since dual transmission lines coming out from 14^{th} bus. The connection of series converters is between 13^{th} - 14^{th} bus and 14^{th}-9^{th} bus resulting in two variables being PU value of injected voltage and two variables being their phase angles. From section III. B, using proposed algorithm, the values of the four variables are determined for minimizing the transmission losses. The NR load flow program is run every time for determining the bus voltages and losses. The clear information about NR load flow studies and line losses is given in [19] and [20]. The total loss taken place are given:

(v1)$r_{14-13} = 0.9693pu$
(v2) $r_{14-9} = 0.9965pu$
(β1) γ_{14-13} =6.2006rad
(β2) γ_{14-19} =5.2006rad

Using the above settings in 14 bus test system with GUPFC, the total losses occurred is 3.718MW with a power saving of 0.928 MW. The figure 3 shows total loss variations in every iteration. Using GUPFC, the rate of power saving increases, with the increase in size of the system.

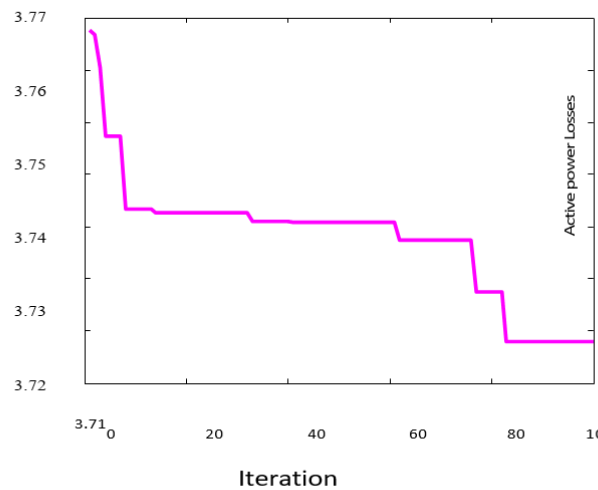


Fig. 3. Active power losses measuring

Figure shows the comparison of voltage profile with placing and without using of GUPFC in the system under no load, which shows enhancement in voltage profile apart from power saving.

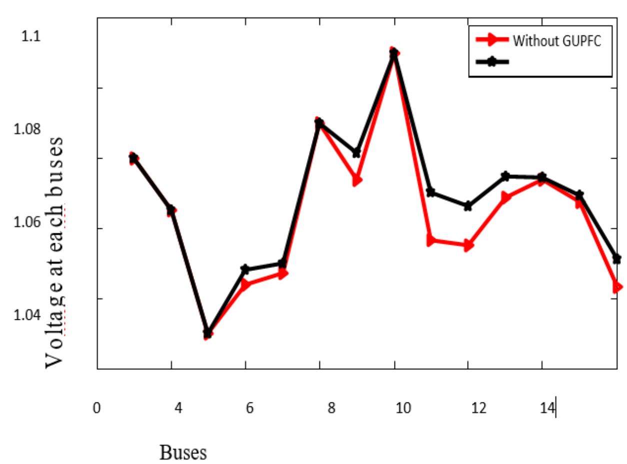


Fig. 4. With and without GUPFC placement

5. Conclusion

This paper discusses one of the ways in which GUPFC's optimum position tested in IEEE 14 bus system which shows reduction of active power losses. The total active power losses are eliminated by proper location and settings of GUPFC, the optimum position and optimum setting of G-UPFC are determined by changing the voltage level with use of load scaling factor and the G-UPFC's PSO algorithm respectively. From these studies, it is clear that the line losses are eliminated to a certain level by suitable placing and setting of G-UPFC in a network and that cause to better running of the total electrical system.

References

[1] D. Chandana and V. Suryanarayanareddy, "Transmission Line Congestion Management Using Hybrid Fish-Bee Algorithm with interline Power flow controller," IRJET, Vol.6, Issue 9, September 2019.

[2] G. Sudeep and V. Suryanarayanareddy, "Improvement of voltage stability by placing UPFC using fuzzy logic", IRJET, Vol. 6, Issue 9, September 2019.

[3] V. Suryanarayanareddy, A. Lakshmi devi, "Minimizing the Transmission Line Loss by Using Interline Power Flow Controller," in International Journal of Engineering Trends and Technology, 27(5), 269-273, September 2015.

[4] J. S. Amirtham and V. Uma, "Optimal location of unified power flow controller enhancing system security," in *proceeding of Second International Conference on Science Technology Engineering and Management (ICONSTEM)*, Chennai, pp. 326-331, 2016.

[5] S. P. Jaiswal and V. Shrivastava, "Allocation of UPFC in distribution system to minimize the losses," in proceeding of Innovative Applications of Computational Intelligence on Power, Energy and Controls with their impact on Humanity (CIPECH), Ghaziabad, pp. 202- 205, 2014.

[6] I. M. Wartana and N. P. Agustini, "Optimal placement of UPFC for maximizing system loadability and minimizing active power losses in system stability margins by NSGA-II," in proceeding of *International Conference on Electrical Engineering and Informatics (ICEEI),* Bandung, pp. 1-6, 2011.

[7] A. Kumar, "Advantages of Using FACTS Controller in AC - HVDC Transmission Lines," in *proceeding of International Journal for Research in Applied Science & Engineering Technology,* vol. 2, pp. 2321-9653, December 2014.

[8] Nireekshana, T., G. Kesava Rao, and S. Raju, "Incorporation of unified power flow controller model for optimal placement using particle swam optimization technique," in *proceeding of 3rd International Conference on Electronics Computer Technology (ICECT)*, 2011.

[9] Rajalakshmi, L., M. V. Suganyadevi, and S. Parameswari, "Congestion management in deregulated power system by locating series FACTS devices," in *proceeding of International Journal of Computer Applications*, 2011.

[10] Suresh, Ch V., et al., "Power flow analysis in the presence of Power Injection Model of IPFC," in *proceeding of First International Conference on*. IEEE *Automation, Control, Energy and Systems (ACES),* 2014.

[11] Lubis, R. S., Hadi, S. P., & Tumiran, "Using the UPFC and GUPFC controllers to maximize available transfer capability (ATC)," in *International Journal on Electrical Engineering and Informatics,* vol. 6, no. 2, pp. 374-393, 2014.

[12] C. V. Suresh and S. S. Raju, "Mathematical modeling and analysis of a generalized unified power flow controller with device rating methodology," International Journal on Electrical Engineering and Informatics, vol. 7, no. 1, pp. 59-78, Mar. 2015.

[13] V. Janamala, C.S. Koritala, "Optimal location of UPFC for congestion relief in deregulated power system," in *Journal of Electrical Engineering,* Vol. 4, 2014.

[14] R. S. Lubis, S. P. Hadi, and T., "Modeling of the generalized unified power flow controller for optimal power flow," in *proc. of the 2011 International Conference on Electrical Engineering and Informatics*, 17-19 July, Bandung, Indonesia, 2011.

[15] Vyakaranam, B., and F. E. Villaseca, "Dynamic modeling and analysis of generalized unified power flow controller," *Electric Power Systems Research,* vol. 106, pp. 1-11, 2014.

[16] A. T. Al-Awami, Y. Abdel-Magid, and M. Abido, "A particle-swarm-based approach of power system stability enhancement with unified power flow controller," in *International Journal of Electrical Power & Energy Systems*, vol. 29, no. 3, pp. 251–259, July 2007.

[17] Nireekshana, T., G. Kesava Rao, and S. Raju, "Incorporation of unified power flow controller model for optimal placement using particle swam optimization technique," in *proceeding of 3rd International Conference on Electronics Computer Technology (ICECT),* 2011.

[18] Ravi, K., and M. Rajaram, "Optimal location of FACTS devices using improved particle swarm optimization," in *International Journal of Electrical Power & Energy Systems.* vol. 49, pp. 333-338, 2013.

[19] Allen J. Wood and Bruce F. Wollenberg, "*Power Generation, Operation and Control,*" J. Wiley & Sons, Feb. 1996.

[20] Hadi Saadat, "*Power System Analysis*," PSA Publishing, 2010.

[21] Shiqiong Tong and K. N. Miu, "A network-based distributed slack bus model for DGs in unbalanced power flow studies," in *IEEE Transactions on Power Systems*, vol. 20, no. 2, pp. 835-842, May 2005.