



Optimal Location of UPFC Controller in transmission network using Chemical Reaction Optimization Algorithm

Kothuri Ramakrishna¹,

¹Associate Professor,

B.V.Raju Institution of Technology,

Narsapur Medak(Dist),Telangana,

India

April 19, 2018

Abstract

Over the most recent couple of years next to no work has been done in creating appropriate models for surveying the UPFC's conduct in vast power systems. Also, since the UPFC parameters are figured after the heap stream has joined, there is no chance to get of knowing amid the iterative procedure regardless of whether the UPFC parameters are inside points of confinement. This has given the inspiration to building up another UPFC show appropriate for consolidating into a current Newton-Raphson stack stream calculation. It is additionally important to decide the ideal setting of the gadget at least cost. In this paper, another scientific model of UPFC is produced which can be effectively joined in Newton-Raphson stack stream calculation. Ideal area of UPFC is resolved in view of Voltage Stability Index. Synthetic Reaction Optimization (CRO) system is utilized to set the parameters UPFC. The target work defined comprises of two terms: cost for vitality misfortune and cost identified with UPFC, which must be expanded for net sparing. The outcomes got utilizing CRO is contrasted and that of results acquired utilizing PSO

1 INTRODUCTION:

The power supply industry is experiencing a significant change around the world. Scarcer common assets and a consistently expanding interest for power are a portion of the drivers in charge of such an extraordinary change. Against this foundation of fast advancement, the development projects of numerous utilities are being obstructed by an assortment of very much established, natural, arrive utilize and administrative weights that keep the authorizing and working of new transmission lines and power producing plants. An inside and out examination of the choices accessible for boosting existing transmission resources, with large amounts of unwavering quality and dependability has pointed toward control gadgets. In the long haul, such issues have generally been tackled by building new power plants and transmission lines, an answer that is expensive to execute and that includes long development time and restriction from weight gatherings. It is conceived that is new answer for such operational issues will depend on the updating of existing transmission passageways by utilizing the most recent power electronic gear and strategies another innovative reasoning that goes under the bland title of FACTS an acronym for Flexible AC transmission frameworks.

2 PROBLEM FORMULATION

As the load builds, control utilities are searching for approaches to amplify the usage of their current transmission frameworks, along these lines controlling the power stream in the transmission lines is an imperative issue in arranging and working of energy framework. Unified Power Flow Controller (UPFC) is a flexible FACTS's gadget which can autonomously or all the while control the dynamic power, the responsive power, and the transport voltage to which it is associated. This controller offers significant points of interest for the static and dynamic task of energy framework. Be that as it may, to accomplish such usefulness it is critical to locate the ideal area of is gadget to be introduced in control framework with suitable parameters. The dynamic power misfortune decreases, the security edge change, the influence transmission limit expanding, and the influence power outage counteractive action, are a few factors that

can be considered in determination fuse with UPFC thinking of one as or the greater part of the previously mentioned factors.

3 OPTIMAL UPFC PLACEMENT

Voltage stability record has been utilized to discover appropriate area of UPFC to enhance control framework execution. The objective of advancement calculation is to put UPFC with a specific end goal to improve voltage solidness edge of energy framework considering cost capacity of UPFC. The parameters of the UPFC are balanced by utilizing PSO&CRO.

4 MATHEMATICAL FORMULATION OF VOLTAGE STABILITY INDEX

Voltage soundness is turning into an expanding wellspring of worry in secure working of present-day control frameworks. The issue of voltage insecurity is for the most part considered as the failure of the system to take care of the heap demand forced regarding deficient receptive power support or dynamic power transmission ability or both. It is principally worried about the investigation and the upgrade of enduring state voltage strength in light of L-record [16].

Consider an n -bus system having $1, 2, 3, \dots, n$, generator buses (g), and $g+1, g+2, \dots, n$, the load buses ($r=n-g-s$). The transmission system can be represented by using a hybrid representation, by the following set of equations,

$$\begin{bmatrix} V_L \\ I_G \end{bmatrix} = H \begin{bmatrix} I_L \\ V_L \end{bmatrix} = \begin{bmatrix} Z_{LL} & F_{LG} \\ K_{GL} & Y_{GG} \end{bmatrix} \begin{bmatrix} I_L \\ V_G \end{bmatrix} \quad (1)$$

Where,

V_L, I_L , are the voltage and current vector at the load buses.

V_G, I_G are the voltage and current vector at the generator buses.

$Z_{LL}, F_{LG}, K_{GL}, Y_{GG}$ are the sub-matrices of the hybrid matrix

H.

The H matrix can be evaluated from the Y bus matrix by a partial inversion, where the voltages at the load buses are exchanged

against their currents, This representation can then be used to define a voltage stability indicator at the load bus, namely L_j which given by,

$$L_j = |1 + \frac{V_{0j}}{V_j}| \quad (2)$$

$$V_{0j} = \sum_{i \in G} F_{ij} V_i \quad (3)$$

The term V_{0j} is the representative of an equivalent generator comprising the contribution from all generators.

The index L_j can also be derived and expressed in terms of the power terms the following.

$$L_j = |\frac{S_j^*}{Y_{jj} + V_j^2}| \quad (4)$$

Where,

$S_j^* = S_j + S_{jcorr}$, * indicates the complex conjugate of the vector.

$$S_{jcorr} = (\sum_{i \in \text{Loads } i \neq j} \frac{Z_{ji}^* S_i}{Z_{jj}^* V_i}) \times V_j \quad (5)$$

$$Y_{jj} = \frac{1}{Z_{jj}} \quad (6)$$

The complex power term part S_{jcorr} speaks to the commitments of alternate loads in the framework to the framework to the record assessed at the hub j.

It can be seen that when a heap transport approaches an unfaltering state voltage fall circumstance, the record L approaches the numerical esteem 1.0. Subsequently for a general framework solidness condition, the file assessed at any of the transports must be not as much as solidarity. Along these lines the file esteem L gives a sign of how far the framework is from voltage fall. The L-files for a given load condition are registered for all heap transports. The condition for the L-record for j^{th} hub can be composed as,

$$L_j = |1 - \sum_{i=1}^{i=g} |F_{ji}| \frac{|V_i|}{|V_j|} \angle \theta_{ji} + \delta_i - \delta_j| \quad (7)$$

$$L_j = |1 - \sum_{i=1}^{i=g} \frac{|V_i|}{|V_j|} (F_{ji}^r + jF_{ji}^m)| \quad (8)$$

$$F_{ji}^r = |F_{ji}| \cos(\theta_{ji} + \delta_i - \delta_j) \quad (9)$$

$$F_{ji}^m = |F_{ji}| \sin(\theta_{ji} + \delta_i - \delta_j) \quad (10)$$

It can be seen that when a load bus approaches a steady state voltage collapse situation, the index L approaches the numerical value 1.0. Hence for an overall system voltage stability condition, the index evaluated at any of the buses must be less than unity. Thus the index value L gives an indication of how far the system is from voltage collapse.

5 UPFC COST AND FITNESS FUNCTION

Using Siemens AG Database [11], cost function for UPFC is developed as follows:

$$C_{UPFC} = 0.0003S^2 - 0.2691S + 188.22US\$/kVAR \quad (11)$$

Where, S is operating range of UPFC in MVAR

$$S = |Q_2 - Q_1| \quad (12)$$

Q_1 - MVAR flow through the branch before placing FACTS device.

Q_2 - MVAR flow through the branch after placing FACTS device.

The goal of optimization algorithm is to place FACTS devices in order to enhance voltage stability margin of power system considering cost function FACTS devices. So these devices should be placed to prevent congestion in transmission lines and transformer and maintain bus voltages close to their reference.

Fitness function is expressed as below:

$$Max.f = \{K_e \times T \times [TL - UPFCTL] - \alpha \times [C_{upfc} \times UPFC_{rating}]\} \quad (13)$$

Where

K_e =Energy Cost (3.5Rs/kwh)

T = Time Period (8760)

TL= Total power loss before UPFC placement

UPFCTL=Total power loss after UPFC placement

α = Depreciation factor is 0.1

C_{upfc} = UPFC Cost in Rs/kVAR

$UPFC_{rating}$ = Rating of the UPFC

6 RESULTS AND ANALYSIS

The proposed methodology of optimal allocation of fixed UPFC for transmission network is implemented using MATLAB on the IEEE 14-bus test system. The cost constants and their typical values for this problem are energy cost ($K_e=3.5$ Rs/Kwh). The payback period assumed is ten years with depreciation factor (α) as 0.1

A. IEEE 14-Bus test system

The problem of placement of the UPFC has also been solved of the IEEE 14-bus test system shown in [11]. By considering the Voltage stability index (L_j) value, it is observed that 14- Bus is more sensitive towards system security. Therefore 14-bus is more suitable location for UPFC to improve power system security/stability. Simulation results for Voltage magnitudes and phase angles without UPFC and With UPFC are shown in Table 1, respectively.

Table 1 Conventional Newton-Raphson method without and with UPFC Voltage magnitudes, Phase Angles for IEEE 14-Bus test system

Conventional Newton-Raphson Method					
Without UPFC			With UPFC		
Bus Number	Voltage Mag (p.u)	Phase Angle (deg)	Bus Number	Voltage Mag (p.u)	Phase Angle (deg)
1	1.0600	0.000	1	1.0600	0.000
2	1.000	-4.411	2	1.000	-4.413
3	1.000	-13.250	3	1.000	-13.247
4	0.982	-10.270	4	0.985	-10.330
5	0.990	-8.759	5	0.992	-8.775
6	1.000	-15.344	6	1.000	-15.143
7	0.976	-13.738	7	0.984	-13.873
8	1.000	-13.738	8	1.000	-13.873
9	0.959	-15.606	9	0.976	-15.753
10	0.958	-15.886	10	0.972	-15.972
11	0.975	-15.748	11	0.982	-15.702
12	0.982	-16.309	12	0.982	-16.076
13	0.975	-16.338	13	0.976	-16.079
14	0.946	-17.117	14	0.959	-16.647
			15	1.000	-18.362

Table 2 Conventional Newton-Raphson method without and with UPFC Power flows for IEEE 14-Bus test system

Line number	From Bus	To Bus	Conventional Newton Raphson without UPFC		Conventional Newton Raphson with UPFC	
			Active Power Loss (p. u)	Reactive Power Loss (p. u)	Active Power Loss (p. u)	Reactive Power Loss (p. u)
1	1	2	0.0494	0.1227	0.0494	0.1228
2	2	3	0.0270	0.0917	0.0269	0.0915
3	2	4	0.0178	0.0358	0.0181	0.0365
4	1	5	0.0301	0.0984	0.0300	0.0979
5	2	5	0.0099	0.0133	0.0099	0.0133
6	3	4	0.0059	0.0019	0.0055	0.0029
7	4	5	0.0051	0.0098	0.0053	0.0104
8	5	6	0	0.0522	0	0.0488
9	4	7	0.0001	0.0170	0.0001	0.0177
10	7	8	0	0.0033	0	0.0014
11	4	9	0	0.0157	0	0.0156
12	7	9	0	0.0117	0	0.0100
13	9	10	0.0001	0.0002	0.0001	0.0003
14	6	11	0.0013	0.0028	0.0008	0.0017
15	6	12	0.0009	0.0019	0.0009	0.0018
16	6	13	0.0028	0.0056	0.0026	0.0052
17	9	14/15	0.0011	0.0024	0.0037	0.0079
18	10	11	0.0006	0.0013	0.0002	0.0005
19	12	13	0.0001	0.0001	0.0001	0.0001
20	13	14	0.0011	0.0023	0.0009	0.0019

The IEEE 14-Bus test network is modified to include one UPFC to compensate the transmission line link Bus-14 and Bus-15. The UPFC is used to maintain active and reactive powers leaving the UPFC, towards 9-bus at 9.9 MW and 0.19 MVAR, respectively.

More-over the UPFC shunt converter is set to regulate the nodal voltage magnitude at Bus 15 at 1 p.u.

The starting values of the UPFC voltage sources are taken to be $V_{cR}=0.0099$ p.u., $\delta_{cR}=-89.978^\circ$, $V_{vR}=1$ p.u and, $\delta_{vR}=0^\circ$. The source impedances have values of $X_{cR} = X_{vR}=0.1$ p.u.

Convergence is obtained in tenth iteration to a power mismatch tolerance $1e^{-12}$. The UPFC held its target values. The power flow results are shown in above Table 2.

The PSO control parameters selected are maximum population (100), Swarm size (10), Acceleration Constants ($C_1 = C_2 = 2$). Simulation results for voltage magnitudes, phase angles, active and reactive power losses with UPFC in the system for Practical swarm organization (PSO) are shown in Table 3, respectively.

Table 3 Voltage magnitudes, Phase Angles; Active and Reactive power losses with UPFC by using PSO

Line Number	From Bus	To Bus	Active Power Loss (p. u)	Reactive Power Loss (p. u)	Bus Number	Voltage Mag (p.u)	Phase Angle (deg)
1	1	2	0.0494	0.1228	1	1.060	0.000
2	2	3	0.0269	0.0915	2	1.000	-4.414
3	2	4	0.0181	0.0364	3	1.000	-13.250
4	1	5	0.0300	0.0980	4	0.985	-10.330
5	2	5	0.0099	0.0134	5	0.992	-8.782
6	3	4	0.0055	0.0029	6	1.000	-15.206
7	4	5	0.0052	0.0103	7	0.984	-13.846
8	5	6	0.0000	0.0496	8	1.000	-13.846
9	4	7	0.0000	0.0174	9	0.976	-15.711
10	7	8	0	0.0014	10	0.972	-15.949
11	4	9	0.0000	0.0154	11	0.982	-15.721
12	7	9	0	0.0099	12	0.982	-16.163
13	9	10	0.0001	0.0003	13	0.976	-16.189
14	6	11	0.0008	0.0016	14	0.949	-16.921
15	6	12	0.0009	0.0019	15	1.000	-18.196
16	6	13	0.0027	0.0054			
17	9	15	0.0034	0.0073			
18	10	11	0.0002	0.0005			
19	12	13	0.0001	0.0001			
20	13	14	0.0010	0.0020			

Table 4 Voltage magnitudes, Phase Angles; Active and Reactive power losses with UPFC by using CRO

Line Number	From Bus	To Bus	Active Power Loss (p. u)	Reactive Power Loss (p. u)	Bus Number	Voltage Mag (p.u)	Phase Angle (deg)
1	1	2	0.0492	0.1226	1	1.059	0.000
2	2	3	0.0266	0.0910	2	1.001	-4.914
3	2	4	0.0178	0.0360	3	1.010	-13.750
4	1	5	0.0290	0.0976	4	0.980	-10.310
5	2	5	0.0097	0.0130	5	0.990	-8.282
6	3	4	0.0050	0.0022	6	0.990	-15.006
7	4	5	0.0032	0.0002	7	0.988	-13.946
8	5	6	0.0000	0.0490	8	0.999	-13.946
9	4	7	0.0000	0.0164	9	0.996	-15.211
10	7	8	0	0.0004	10	0.992	-15.249
11	4	9	0.0000	0.0104	11	0.992	-15.221
12	7	9	0	0.0009	12	0.992	-16.063
13	9	10	0.0000	0.0001	13	0.996	-16.089
14	6	11	0.0003	0.0010	14	0.989	-16.521
15	6	12	0.0001	0.0009	15	1.000	-18.496
16	6	13	0.0007	0.0024			
17	9	15	0.0030	0.0053			
18	10	11	0.0001	0.0001			
19	12	13	0.0000	0.0000			
20	13	14	0.0001	0.0002			

The summary of results comparing with the existing method, PSO and CRO is tabulated in Table 5.

Table 5 Summary of results of IEEE-14 bus test system

Aspect		Conventional Newton-Raphson Method with UPFC	Proposed Method	
			Particle Swarm Optimization	CRO
Total power loss without UPFC (MVA)		50.992	50.992	50.982
Total power loss with UPFC (MVA)		50.655	50.625	50.605
Cost of UPFC (Rs/kVAr)		8634.701	8643.682	8640.632
Net Saving (Rs/Annum)		1,02,17,769.757	1,00,47,095.179	1,00,45,065.189
UPFC Ratings	Series Converter (MVA)	5.7319	5.7319	5.7319
	Shunt Converter (MVA)	1.3969	1.3969	1.3969
Elapsed Time			18.253 Sec	18.213 Sec

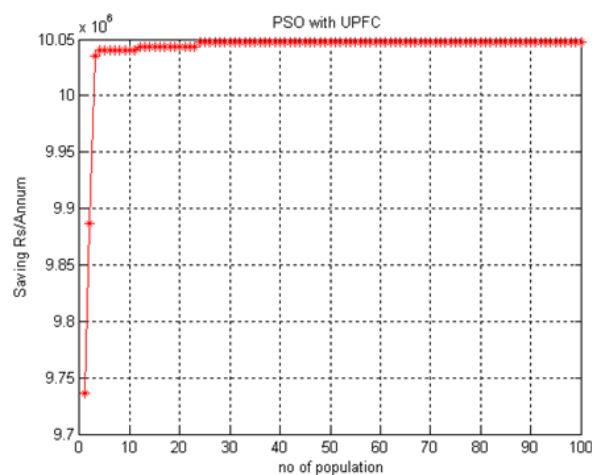


Fig.1 Fitness function maximization by using PSO for IEEE-14 bus test system.

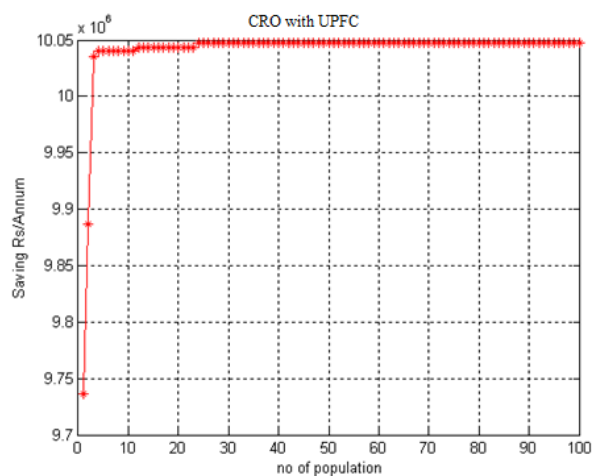


Fig. 2 Fitness function maximization by using CRO for IEEE-14 bus test system.

7 CONCLUSION

The proposed calculations were actualized to discover the best possible setting and establishment cost of the UPFC in IEEE-14 trans-

port test framework. Examinations of two proposed calculations are appeared in Tables 1, 2 and 3, From Figs.1 and 2; it is watched that wellness work is augmentation in CRO contrast with PSO. Tables 3, 4 and 5 demonstrates that CRO is quicker than PSO from the viewpoint of time and this is because of the reason that PSO has swarm estimate, number of cycles, choice of greatest and least speed and choice of increasing speed constants activities while CRO doesn't such tasks.

References

- [1] Piscataway, N.J, IEEE Power Engineering Society: FACTS overview. IEEE Service Center, 1995.
- [2] Piscataway, N.J, IEEE Power Engineering Society: FACTS applications. IEEE Service Center, 1996.
- [3] Gyugyi. L, A unified power flow control concept for flexible AC transmission systems, IEE Proc., Vol. 139, No. 4, pp.323-333, 1992.
- [4] Noroozian. M, Angquist. L, Ghandhari. M, and Anderson. G, Use of UPFC for optimal power flow control, IEEE Trans. on Power Delivery, vol. 12, No. 4, pp: 506- 511, 1997.
- [5] H. A. Abdelsalam, etal, Optimal location of the unified power floe controller in Electrical power system loadability, International Conferences on Future PowerSystem, Vol. 28, No. 30, pp: 41- 46, Jul 2004.
- [6] W. Ongskul, P. Jirapong, Optimal allocation of FACTS devices to enhance total Transfer capability using evolutionary programming, IEEE International Symposium on Circuits and Systems, Vol. 5, pp: 4175-4178, May 2005.
- [7] K. P. wang, J. Yurevich, A Li, Evolutionay-programming-based load flow algorithm For systems containing unified power flow controllers, IEE proc.-Gener. Transm. Distrib, Vol. 150, No.4, Jul. 2003.

- [8] W. L. Fang, and H. W. Ngan, Optimal location of unified power flow controllers the method of augmented lagrange multipliers, IEE Proc. Gener. Transm. Disturb, Vol. 146, No. 5, Sept. 1999.
- [9] P. P. Narayana, M. A. Abdel Moamen, and B.J. Praveen Kumar Optimal location and initial parameter settings of multiple TCSCs for reactive power planning using genetic algorithm, IEEE Power Engineering Society General Meeting, Vol. 1, pp: 1110-1114, Jun. 2004.
- [10] D. Radu, et al., A multi-objective genetic algorithm approach to optimal allocation of multitype FACTS devices for power system security, IEEE Power Engineering Society General Meeting, Vol. 1, pp: 18-22, Jun. 2006.
- [11] A. Mete Vural, Mehmet Tumay, Mathematical modeling and analysis of a unified Power flow controller: A comparison of two approaches in power flow studies and effects of UPFC location, Electrical power & Energy system Research, Vol. 29, 2007, pp: 617-629.
- [12] C.R. Fuerte-Esquivel, E. Acha, Unified power flow controller: a critical comparison of Newton-Raphson UPFC algorithms in power flow studies, IEE Proceedings on Generation, Transmission, Distribution, Vol. 144, No. 5, Sept 1997, pp. 437-443.
- [13] C.R. Fuerte-Esquivel, E. Acha, A Comprehensive Newton-Raphson UPFC Model for the Quadratic Power Flow Solution of Practical Power Networks, IEEE Trans. on Power System, Vol. 15, No. 1, Feb 2000, pp. 102-108.
- [14] N.G. Hingorani and L. Gyugyi, Understanding FACTS, New-York, IEEE Press, 2001.
- [15] Samina Elyas Mubeen, R.K Nema, and Gayatri Agnihotri, Power Flow Control with UPFC in power Transmission System, Proceedings of world Academy of Science, Vol. 30, July 2008, pp: 955-959.