Optimal Allocation of SVC and TCSC for Improving Voltage Stability and Reducing Power System Losses using Hybrid Binary Genetic Algorithm and Particle Swarm Optimization

A. Esmaeili Dahej, S. Esmaeili, A. Goroohi

Abstract — *some applications of FACTS devices show that they are proper and effective instruments to control the technical parameters of power systems. However determination of optimal location, size and type of these devices is a difficult problem. Moreover, applying a suitable objective function for optimal placement of FACTS devices plays a very important role in economic improvement of a power market. In this paper, an advantageous method have been presented for multi-type FACTS placement to increase the voltage stability and to decrease the losses with considering costs of installation of the equipments and the general costs of operation of the power system. So the hybrid binary genetic algorithm and particle swarm optimization (HBGAPSO) is used in this paper for simultaneous locating and for determining the sizes of two types of series and parallel devices (TCSC,SVC) in a multi objective structure, and the method of hierarchical analysis process is used for achieving an optimal response of the fitness function. After that, the suggested method is implemented on the modified 30-bus IEEE system. By comparing the results achieved from the suggested algorithm with PSO and GA algorithms, the proper efficiency of the presented algorithm will be enforced.*

Key Words — FACTS devices, Hybrid binary genetic algorithm and particle swarm optimization, Voltage stability, Losses of system, Optimal allocation, Costs of installation and operation.

I. INTRODUCTION

FACTS devices, with their unique structures, can provide an opportunity for the user to control the current powers of lines and thus improve the limitations related to the stability of transmission lines and the security of the system [1]. Using FACTS devices, as compared with conventional approaches such as load shedding and generation rescheduling, seem to be more economical because these devices excluding installation cost do not impose extra cost at the time of operation [2]. FACTS devices can control active and reactive power simultaneously; furthermore, they can control the magnitude of voltage. These devices can decrease the charge of power on the lines which have overload by creating an optimal voltage level. On the other hand, FACTS devices can improve the span of the small signal and transient stability and also decrease the losses of the power system [3, 4]. Thus, considering the costs of the installation of FACTS devices for locating of these devices make the achieved results more actual [5].The effect of FACTS devices on the security of the power system is considered in the studied references [6, 7]. One of the distinct usages of FACTS devices is to overcome the voltage instability in the power system. Actually, voltage stability is the capability of a system to keep the acceptable magnitude of voltage for buses of the system in all of the present conditions [8, 9]. The ability of transmitting the reactive power from the bus of production to the place of consumption in the persistent status of the power system is one of the important issues in the voltage stability. Generally, a power system becomes unstable in a situation such as creation of an accident in the system, increase of the consumable load, or a change in the condition of the system because of a progressive and uncontrollable decrease of voltage.

The voltage instability is removed by some methods such as load-shedding and cutting the consuming loads of the network, using tap-changers on the load and reactive power compensators (series and parallel) [10]. The issue of the voltage stability can be analyzed by the methods of P-V and Q-V curves, so the voltage stability is highly dependent on the balance of the f reactive power and also on the balance of the active power [11]. By increasing the loading on the power system, a lot of errors are made in these systems, and the functions of the power systems will become complicated and will become less secure. Voltage instability is the main subject in designing and functioning of the power system [12, 13]. Some of references have been used the heuristic and intelligent algorithms for finding the proper places and sizes of these devices. Some of these algorithms, such as Genetic Algorithm (GA) [14], Evolutionary Planning (EP) [15], and Particle Swarm Optimization (PSO) [16], have been used successfully for solving the complicated issues. In this paper the HBGAPSO Algorithm is applied in order to optimal allocation

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of SVC[1] and TCSC[2] to increase the voltage stability and decrease the losses of the system by considering the costs of installation of these devices and in a way that the total operation cost from the power systems becomes optimal. Suggest algorithm is tested on the modified 30-bus IEEE system and The effectiveness of the simultaneous use of two series and parallel types of FACTS devices in improving the voltage stability and decreasing the losses simultaneously is shown in this paper as well.

II. A REVIEW OF THE HYBRID BINARY GENETIC ALGORITHM AND PARTICLE SWARM OPTIMIZATION (HBGAPSO)

The hybrid algorithm of Genetic algorithm and particle swarm optimization has been introduced an actual code. That in this paper, by using the presented coding for the present controlling equipments, this algorithm has been used as Binary code [17].

This section discusses the infrastructure and rationale of the hybrid algorithm. Fig. 1 depicts the schematic representation of the proposed hybrid GA-PSO. As can be seen, GA and PSO both work with the same initial population. When solving an N dimensional problem, the hybrid approach takes 4N individuals that are randomly generated. These individuals may be regarded as chromosomes in the case of GA, or as particles in the case of PSO. The 4N individuals are sorted by fitness, and the top 2N individuals are fed into the real-coded GA to create 2N new individuals by crossover and mutation operations, as shown in Fig. 1. The crossover operator of the binary-coded GA is implemented by borrowing the concept of linear combination of two vectors, which represent two individuals in our algorithm, with a 100% crossover probability. The random mutation operator proposed for the binary-coded GA is to modify an individual with a random number in the problem's domain with a 20% probability. The new 2N individuals created from binary-coded GA are used to adjust the remaining 2N particles by the BPSO (binary PSO) method. The procedure of adjusting the 2N particles in the BPSO method involves selection of the global best particle, selection of the neighborhood best particles, and finally velocity updates. The global best particle of the population is determined according to the sorted fitness values. The neighborhood best particles are selected by first evenly dividing.

The stages of implementing of the above algorithm can be shown as follow:

First step: producing a 4n-member-population accidentally

Second step: evaluating of this primary population based on the goal function, and then arranging of this primary population based on its suitability.

Third step: imposing Genetic Algorithm on the above 2n members of the arranged population that have the most suitability.

Fourth step: imposing BPSO Algorithm on 2n members of the underneath population and considering the new population which created by Genetic Algorithm as a regulator during the implementation of the BPSO algorithm.

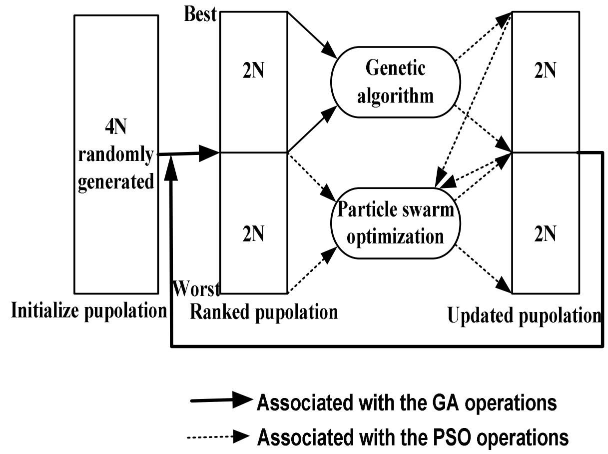

Fig. 1. Schematic representation of the binary GA-PSO hybrid

Fifth step: if the accurate results not obtained, return to Second step and run the algorithms again.

Fig. 2 illustrates the general flowchart of this algorithm.

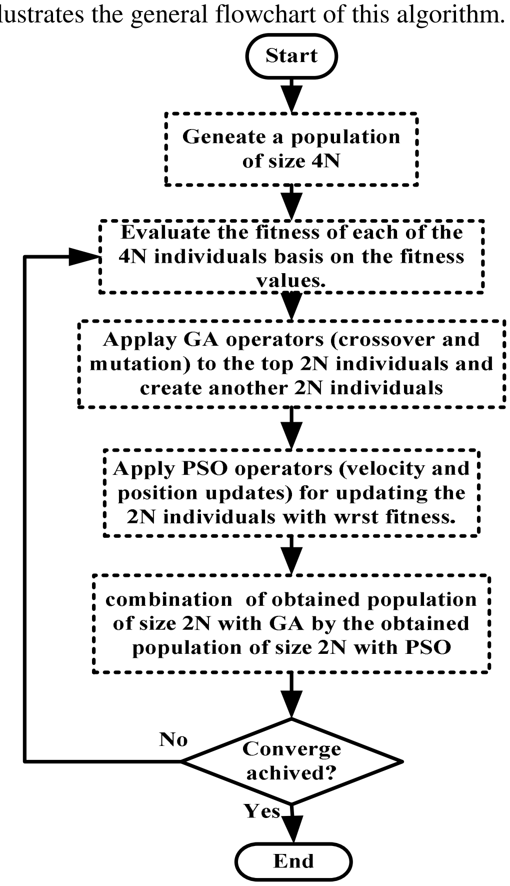

Fig. 2. The binary GA-PSO hybrid algorithm

[1] Static VAr Compensator

[2] Thyristor Controlled Series Capacitor

III. MODELING OF FACTS DEVICES

In this paper, SVC and TCSC devices have been used to improve the voltage stability and decrease the losses, with considering the costs of installation of the devices and the costs of operation of power plants.

A. TCSC

TCSC is a series compensation component which consists of a series capacitor bank shunted by thyristor controlled reactor. The basic idea behind power flow control with the TCSC is to decrease or increase the overall lines effective series transmission impedance, by adding a capacitive or inductive reactive correspondingly. In this paper, TCSC is modeled by the change in the reactance of the lines that has been shown as follows:

$$X_{ij} = X_{Line} + X_{TCSC} \tag{1}$$

$$X_{TCSC} = r_{TCSC} + X_{Line} \tag{2}$$

In the above relations, X_{Line} is the reactance of the transmission line, and r_{TCSC} is the compensatory factor of TCSC that is chosen between $-0.5X_{Line}$ to $0.5X_{Line}$. TCSC model and its structure have been specified in Fig. 3.

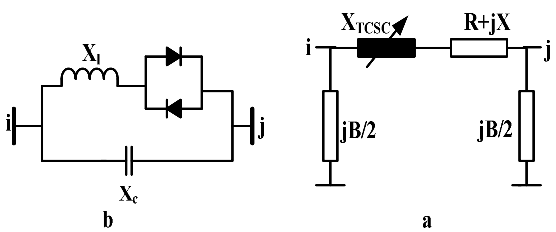

Fig. 3. The utilized TCSC
a: TCSC model b: basic structure

B. *SVC*

The SVC is defined as a shunt connected static VAr generator or consumer whose output is adjusted to exchange capacitive or inductive so as to maintain or control specific parameters of electrical power system, typically a bus voltage. Like the TCSC, the SVC combines a series capacitor bank shunted by thyristor controlled reactor. In this paper, the SVC is considered as a synchronous compensator modeled as PV bus, with Q limits. SVC model and its structure have been specified in Fig. 4 as follows:

$$\Delta Q_i = Q_{SVC} \tag{3}$$

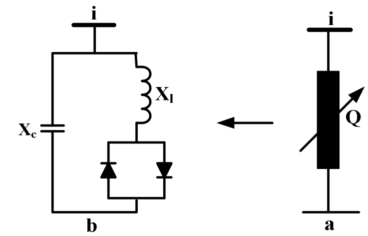

Fig. 4. The utilized SVC
a: SVC model b: basic structure

The chosen parameters for TCSC and AVC equipments are shown in Table I.

TABLE I
PARAMETERS OF THE UTILIZED FACTS DEVICES

	Parameter	Minimum	Maximum
TCSC	X_{TCSC}	- 0.5 XL	0.5 XL
SVC	Q_{SVC}	-100 MVAr	100 MVAr

IV. STATIC VOLTAGE STABILITY INDEX

The static voltage stability in a power system is imposed as much as the capability of that system in keeping the magnitude of its own voltage against the increase of the consuming load [8, 10]. If this capability does not exist, the voltage instability might occur. Evaluating the degree of security in the power systems needs an index from the viewpoint of the static voltage stability to create an evident engineering perception for the user and also to be free of any need to future definitions and explanation, and to express directly the level of the tolerability of the system against the increase of the consuming load [13]. In this paper, the index of the level of loadability that is directly shown the maximum imposable load on a power system with keeping its static stability of the voltage has been considered as the evaluative index of the degree of security. Loadability limit is a realistic index from engineering point of view because it can provide system operator a more practical sense of system security margin in terms of engineering parameters like system loading. Thus, the level of loading in the power systems can be modeled as a limited nonlinear optimizing issue in which the limitations of equality are the algebraic equations of the power flow in a power system.

The presented model can be evaluated by means of a non-linear optimizing issue that can be solved by the method of Repeated Power Flow (RPF). RPF method enable to increase the loadability limit by increasing the complex load with uniform power factor at every load and increasing the injected real power at generator buses in the generation in incremental steps until happen collapse in network and power flow not converge.

The mathematical formulation of loadability limit using RPF can be described as follows:

Maximize λ

Subject to:

$$\begin{cases} P_{Gi} - P_{Di} - \sum_{j=1}^{n} |U_i|.|U_j|(G_{ij}\cos\delta_{ij} + B_{ij}\sin\delta_{ij}) = 0 \\ Q_{Gi} - Q_{Di} - \sum_{j=1}^{n} |U_i|.|U_j|(G_{ij}\sin\delta_{ij} + B_{ij}\cos\delta_{ij}) = 0 \end{cases} \tag{4}$$

λ : scalar parameter representing the increase in the load and generation, $\lambda = 0$ corresponds to base case and $\lambda = \lambda_{max}$ corresponds to the collapse state.

P_{Gi}, Q_{Gi} : Real and reactive power generation at bus i

P_{Di}, Q_{Di} : Real and reactive loads at bus i

$|U_i|, |U_j|$: Voltage magnitude at bus i and bus j

G_{ij}, B_{ij} : Real and imaginary parts of the ij$_{th}$ element of bus admittance matrix

δ_{ij} : Voltage angle of bus i and bus j

n: Total number of buses

In the power flow equations P_{Gi}, P_{Di} and Q_{Di} are calculated as:

$$P_{Gi} = P_{Gi}^{0}.(1 + \lambda.K_{Gi}) \tag{5}$$

$$P_{Di} = P_{Di}^{0}.(1 + \lambda.K_{Di}) \tag{6}$$

$$Q_{Di} = Q_{Di}^{0}.(1 + \lambda.K_{Di}) \tag{7}$$

P_{Gi}^{0} : Original real power generation at bus i in the generation buses

P_{Di}^{0}, Q_{Di}^{0} : Original real and reactive load demands at bus i in the load buses

K_{Gi}, K_{Di} : Constants used to specify the change rate in the generation and load as λ varies.

Loadability limit is calculated as follows:

$$Max : PT = \sum_{i=1}^{NB} P_{D_i} \equiv Max.Loadability \tag{8}$$

V. OBJECTIVE FUNCTION

The objective function in this paper is according eq. 9 to increase the voltage stability and decrease of the losses of the power system with considering the costs of operation of the system.

$$Fitness = k1 \times \frac{Normal\ Loadability}{(Loadability)} + k2 \times \frac{(Total\ Operation\ Cost)}{Normal\ Operation\ Cost} + k3 \times \frac{(Losses)}{Normal\ Losses} \tag{9}$$

The first term of the fitness function shows the index of the voltage stability. The second term is used for minimizing the costs of operation the power plants and is defined by equation (10):

$$f(X,U) = \sum_{i=1}^{NG} (a_i + b_i P_{Gi} + c_i P_{Gi}^2) \tag{10}$$

In this equation, P_{Gi} is the actual power produced in the generator i. a_i , b_i and c_i are the invariant factors and NG is the number of generators in the system. The third term in the goal function shows the amount of the losses in the system. The constraints that are considered for this optimizing issue are defined by the following:

$$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max} \quad i = 1,...,N_C \tag{11}$$

$$V_{Gi}^{min} \le V_{Gi} \le V_{Gi}^{max} \quad i = 1,...,N_C \tag{12}$$

$$X_{Si}^{min} \le X_{Si} \le X_{Si}^{max} \quad i = 1,...,N_1 \tag{13}$$

$$Q_{Si}^{min} \le Q_{Si} \le Q_{Si}^{max} \quad i = 1,...,N_2 \tag{14}$$

$$V_{Li}^{min} \le V_{Li} \le V_{Li}^{max} \quad i = 1,...,N_L \tag{15}$$

$$-S_{Li}^{min} \le S_{Li} \le S_{Li}^{max} \quad i = 1,...,N_E \tag{16}$$

VI. THE COST FUNCTION OF FACTS DEVICES

Using Siemens AG Database [18, 19], cost function for SVC and TCSC are developed as follows:

$$C_{TCSC} = 0.0015S^2 - 0.7130S + 153.7 \tag{17}$$

$$C_{SVC} = 0.0003S^2 - 0.3051S + 127.38 \tag{18}$$

$$Minimize\ IC = C \times S \tag{19}$$

In which IC is the optimal cost of installation of FACTS equipments based on US$ and C is the cost of FACTS devices based on US$/KVAR. S is the operating factor of FACTS devices based on MVAr.

$$S = |Q2| - |Q1| \tag{20}$$

Q2 is the current reactive power of in the system after installing FACTS devices and Q1 is the current reactive power in the system before installing FACTS devices. Thus, the fitness function is defined as eq. 21 considering the normalize cost of installation of FACTS devices.

$$Minimize\,(Ft + k4 \times \frac{Max\ Install\ Cost - Total\ Install\ Cost}{Max\ Install\ Cost - Min\,Total\ Install\ Cost}) \tag{21}$$

These cost functions are shown in Fig. 5.

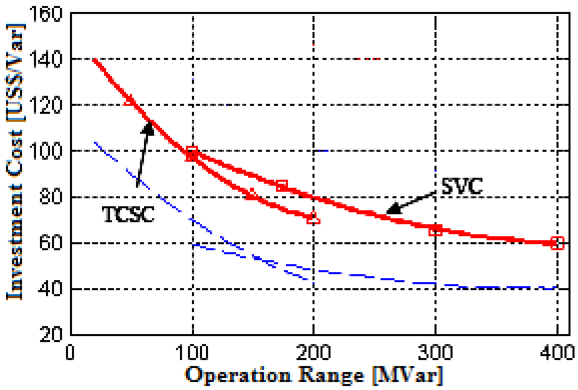

Fig. 5. Cost Function of the FACTS devices: SVC and TCSC
----: Upper limit: Total investment Costs
- - - -: Lower limit: Total investment Costs

Since the results of each term in the objective function is in a certain range, for balancing the objective function's terms, Coefficients K1, K2, K3 and K4 are defined weight coefficients of a combined function which indicates the degree of individual function in relation to the other functions. In This paper analytic hierarchy process method (AHP) is used to obtain these coefficients. For achieving this purpose, Table II shows the judge matrix of the above criteria, which reflect the importance and priority criteria toward the other.

TABLE II
CRITERIONS JUDGESHIP MATRIX

	loadability	Loss	Installation cost	Operation cost
loadability	1	2	3	4
Loss	1/2	1	2	3
Installation cost	1/3	1/2	1	2
Operation cost	1/4	1/3	1/2	1

Here it is assumed that loadability limit is more important than the value of losses, while the losses have priority to the value of installation cost and also installation cost is more important than the value of operation cost. The final weight of criteria is obtained using the arithmetic average method [20]. This is as shown in Table III.

TABLE III
CRITERIONS FINAL WEIGHT

loadability (K1)	Operation cost (K2)	Loss (K3)	Installation cost (K4)
0.465	0.1	0.275	0.16

VII. THE STUDIED SYSTEM

Optimizing process and placement of FACTS devices has been implemented on the modified 30-bus IEEE system [21]. This system has 6 generators on bus 1, 2, 13, 22, 23, and 27. The maximum changes for measuring the voltage are considered 0.05 P.u. To shown the efficiency of the proposed algorithm in optimizing the multi-objective issues and also the efficiency of FACTS devices in improving the costs, voltage stability and decrease of the losses, the system has been studied in different statuses.

VIII. SIMULATION AND RESULTS

Simulation studies were done for different scenarios in modified 30-bus IEEE power system by the proposed algorithm, GA and PSO. Four different scenarios are considered:

- Scenario1: power system normal operation (without FACTS devices installation).
- Scenario 2: one SVC is installed
- Scenario 3: one TCSC is installed
- Scenario 4: Multi-type (TCSC and SVC) FACTS devices are installed.

The obtained results from the above stages are shown in Table IV.

TABLE IV
THE RESULTS OF SIMULATION IN DIFFERENT SCENARIOS

	Method	Loadability Limit(MW)	Losses (MW)	Installation Cost (USD)	Operation Cost
Scenario1 (Normal)	-	822.31	2.4433	-	593.42
Scenario 2	HBGAPSO	868.72	2.323	5575761	592.588
	PSO	863.81	2.341	5575943	592.741
	GA	862.54	2.374	5576542	592.823
Scenario 3	HBGAPSO	853.48	2.2344	6467543	593.126
	PSO	853.14	2.2539	6467596	593.184
	GA	854.21	2.2793	6467238	593.258
Scenario 4	HBGAPSO	897.59	2.1316	8641264	591.301
	PSO	898.31	2.1736	8641197	591.471
	GA	893.67	2.1843	8641762	591.518

The results in table IV shows that installing one type of FACTS devices cannot improve the voltage stability and decrease losses of the system simultaneously, but the simultaneous installation of SVC and TCSC improve the voltage stability and also decrease losses of the system. Table V is shown the size and the place of installation of FACTS devices with HBGAPSO algorithm in different scenarios of simulation.

In Fig. 6, voltage profile of the system has been shown in different scenarios, and as it is obvious in the figure, the best status of voltage of the system is related to the scenario of the simultaneous installing of SVC and TCSC.

TABLE V
FACTS LOCATION AND SIZES RESULTS WITH HBGAPSO ALGORITHM

Devices/Type	**SVC**		**TCSC**	
Size / Location	Size (MVAr)	Location (bus)	Size (X_{TCSC}/X_{line})	Location (branch)
SVC	49.3	9	-	-
TCSC	-	-	1-3	0.3086
Multi-Type	38.49	8	6-10	0.2621

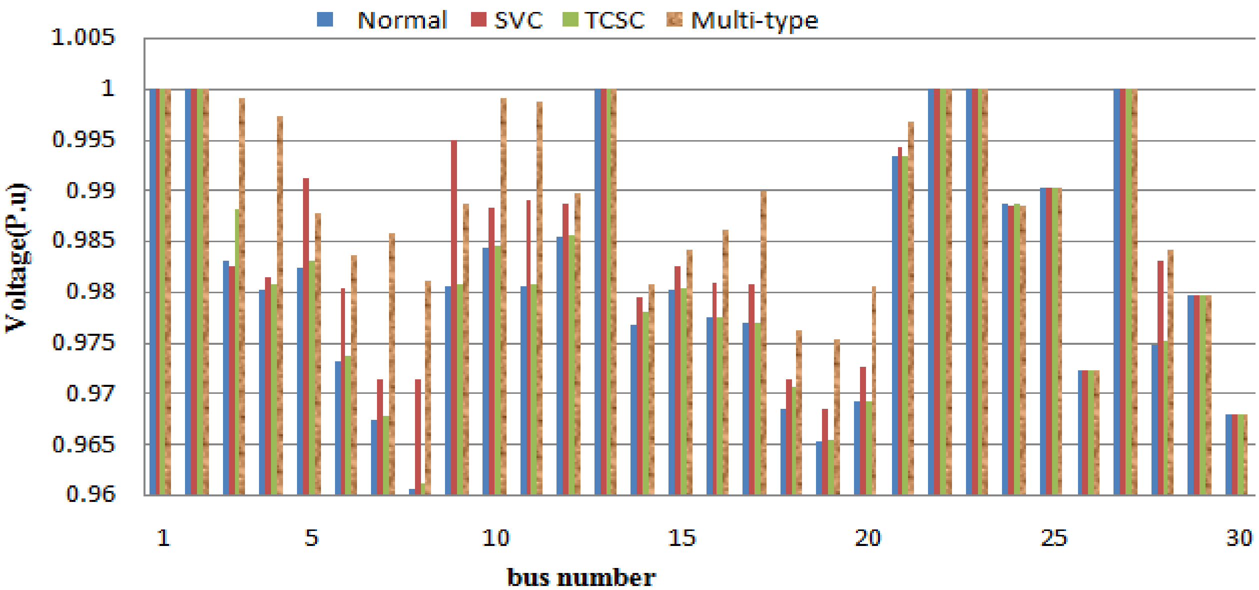

Fig. 6. Voltage profiles for different scenarios

Fig. 7 also is shown the level of loadability the systems that this index has improved in the status of the simultaneous installation of multi-type FACTS devices in comparison with the other statuses, and the system has more security.

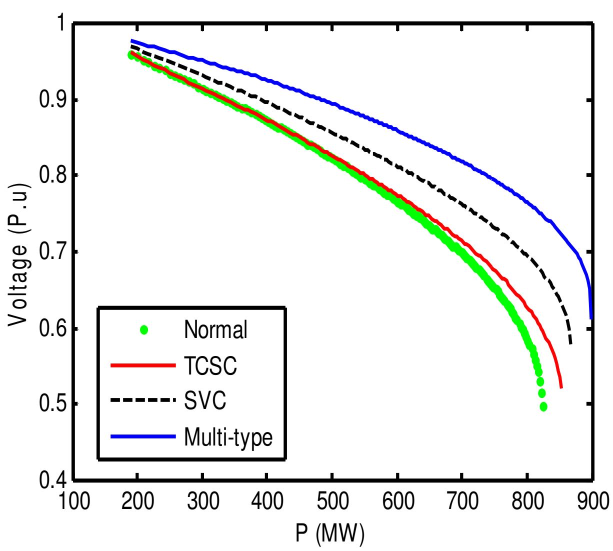

Fig. 7. P-V diagram for weakest bus in different scenarios

For validation of the optimization algorithm, the results obtained by HBGAPSO are compared with the results of other algorithm such as GA and PSO. It is obvious that the HBGAPSO algorithm has better overall performance than two other methods. It is worth mentioning that HBGAPSO has better computational efficiency than the other methods. For proving this matter Fig. 8 shows the convergence diagram for the three heuristic approaches. It can be seen that the HBGAPSO converges in about 32 iteration, while GA and PSO iterates 60 and 68 respectively for convergence to be achieved. This advantage makes significant reduction in simulation time for HBGAPSO algorithm.

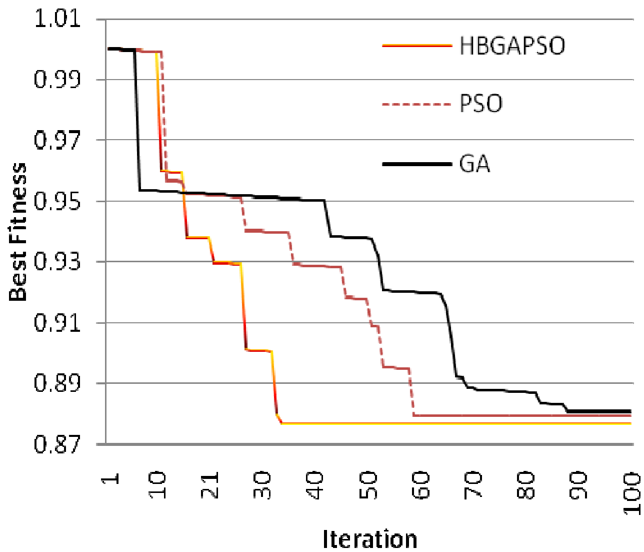

Fig. 8. Convergence characteristics of the GA, PSO and HBGAPSO for the best solutions in scenario 4

IX. Conclusion

This paper presents an effective method for multi-type FACTS devices sizing and placement based on a multi-objective function for improvement of system operating conditions. FACTS devices including SVC and TCSC which are disused here has parallel, and series performance respectively. A perfect multi-objective function consists of improving voltage stability, minimizing losses, decreasing cost of installation FACTS devices and cost of operation is formulated for optimization problem. For achieving this purpose, analytic hierarchy process (AHP) makes it possible to ranking the objectives in a comparative manner. The optimization of developed fitness function is performed using a noel heuristic algorithm named hybrid binary Genetic algorithm and particle swarm optimization (HBGAPSO). The proposed algorithms have been implemented on modified IEEE 30-bus test system. The results indicates that simultaneously allocation and sizing of multi-type FACTS devices has more advantages than single-type FACTS to improve the defined terms of objective functions. To verify the performances of HBGAPSO, results are compared with those obtained using other heuristic methods such as PSO and GA. The results show better accuracy and convergence characteristic for HBGAPSO in comparison with GA and PSO.

References

[1] AR. Etemad, H.A. Shayanfar and R. Navabi , Optimal location and setting of TCSC under single line contingency using mixed integer nonlinear programming", International Conference on Environment and Electrical Engineering (EEEIC), pp , 2010, 250-253.

[2] W. Shao and V. Vittal, "LP-based OPF for corrective FACTS control to relieve overloads and voltage violations", IEEE Trans. on Power Systems, 2006-10-30.

[3] H.R. Baghaee, M. Jannati, B. Vahidi, "Improvement of Voltage Stability and Reduce Power System Losses by Optimal GA-based Allocation of Multi-type FACTS Devices"Optimization of Electrical and Electronic Equipment, 2008. OPTIM 2008. 11th.

[4] F.D. Galiana, K. Almeida, M. Toussaint, J. Griffin, and D. Atanackovic: "Assessment and Control of the Impact of FACTS Devices on Power System Performance", IEEE Trans .Power Systems, Vol. 11, No. 4, Nov 1996.

[5] S. Sung-Hwan, L. Jung-Uk, M. Seung-Il, "FACTS Operation Scheme for Enhancement of Power System Security," in Proc of IEEE Power Tech Conference, Bologna, 2003, Vol. 3, pp. 36-41.

[6] K.S. Verma, S.N. Singh, and H.O. Gupta, "Location of Unified Power Flow Controller for Congestion Management", Electric Power System Research , Vol. 58, pp 89-96,2001.

[7] S. Gerbex, R. Chekaoui, A.J. Germond, "Optimal Location of Multi-type FACTS Devices in a Power System by Means of Genetic Algorithm", IEEE Trans. on Power Systems, Vol. 16, August 2001, pp. 537-544.

[8] M. Mohammadian, M.R. Aghamohammadi, and S.M.T. Bathaee, Power plants generation scheduling constrained to voltage stability limit based on sensivity Characteristic Of Neural Network, the 17th international Power System Conference, Tehran, Iran. (2002).

[9] M.R.Aghamohamadi, M.Mohammadian, and H.Saitoh, Sensitivity Characteristic of Neural Network as a Tool for Analyzing and Improving Voltage Stability, IEEE PES Transmission and Distribution Conference and Exhibition (Asia Pacific). 2 (2002) 1128 – 1132.

[10] M.Mohammadian, Power System Voltage stability and Security assessment by neural network technique, Ms Dissertation, Dept. Elect. Eng., K.N.Toosi University of technology, Iran, Tehran. (1997).

[11] M.R. Aghamohammadi, M.Mohammadian, "Loadability limit assessment in Iran Power Network with respect to voltage stability constrain", the 11th international Power System Conference, Tehran , Iran . (1996) 1-12.

[12] M.R. Aghamohammadi, M.Mohammadian, A. Golkar, Generation scheduling constrained to voltage stability limit, the 16th international power system conference, Tehran, Iran. (2001).

[13] M. Mohammadian, M.R. Aghamohammadi ,S.M.T. Bathaee, Power plants generation scheduling constrained to voltage stability limit based on sensivity Characteristic Of Neural Network, the 17th international Power System Conference, Tehran , Iran. (2002).

[14] S. Gerbex, R. Cherkaoui, A.J. Germond, Optimal location of multi-type FACTS devices by means of genetic algorithm, IEEE Trans. Power Syst. 16 (3) (2001) 537–544.

[15] T.T. Ma, Enhancement of power transmission systems by using multiple UPFC on evolutionary programming, in: IEEE Bologna Power Tech Con- ference, vol. 4, June 2003.

[16] M. Saravanan, S. M. R. Slochanal, P. Venkatesh and J. P. S. Abraham, "Application of particle swarm optimization technique for optimal location of FACTS devices considering cost of installation and system loadability", Electric Power Systems Research, Vol 77 ,pp. 276-283, 2007.

[17] A. kaveh1 and S. malakouti rad, "hybrid genetic algorithm and particle swarm optimization For the force method-based simultaneous Analysis and design", Iranian Journal of Science & Technology, Transaction B: Engineering, Vol. 34, No. B1, pp 15-34, 2010.

[18] L.J. Cai, I. Erlich, Optimal choice and allocation of FACTS devices using genetic algorithms, in: Proceedings on Twelfth Intelligent Systems Appli-cation to Power Systems Conference, 2003, pp. 1–6.

[19] L.J. Cai, I. Erlich, Optimal choice and allocation of FACTS devices in deregulated electricity market using genetic algorithms, in: IEEE Conference (0-7803-8718-X/04), 2004.

[20] Kevin D. Young, Tamim Younos, Randel L. Dymond, David F. Kibler, and David H. Lee "Application of the Analytic Hierarchy Process for Selecting and Modeling Stormwater Best Management Practices", Universities Council on Water Resources Journal of Contemporary Water Research & Education Issue 146, Pages 50-63, December 2010.

[21] Ferrero,R.W.,Shahidehpour,S.M.,Ramesh,V.C., "Transaction analysis in deregulated power systems using game theory", IEEE Transactions on Power Systems, Vol. 12, No. 3, Aug 1997, pp. 1340-1347.

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