TELKOMNIKA, Vol.17, No.3, June 2019, pp.1267~1274
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v17i3.9905

Optimal SVC allocation via symbiotic organisms search for voltage security improvement

Mohamad Khairuzzaman Mohamad Zamani*[1], Ismail Musirin*[2], Sharifah Azma Syed Mustaffa[3], Saiful Izwan Suliman[4]
[1,2,4]Universiti Teknologi MARA (Faculty of Electrical Engineering and Universiti Teknologi MARA)
40450 Shah Alam, Selangor, Malaysia
[3]Universiti Tenaga Nasional (College of Engineering and Universiti Tenaga Nasional)
Kajang, Selangor, Malaysia
*Corresponding author, e-mail: mohd_khairuzzaman@yahoo.com[1], ismailbm1@gmail.com[2], sharifahazma@uniten.edu.my[3], saifulizwan@salam.uitm.edu.my[4]

Abstract

It is desirable that a power system operation is in a normal operating condition. However, the increase of load demand in a power system has forced the system to operate near to its stability limit whereby an increase in load poses a threat to the power system security. In solving this issue, optimal reactive power support via SVC allocation in a power system has been proposed. In this paper, Symbiotic Organisms Search (SOS) algorithm is implemented to solve for optimal allocation of SVC in the power system. IEEE 26 Bus Reliability Test System is used as the test system. Comparative studies are also conducted concerning Particle Swarm Optimization (PSO) and Evolutionary Programming (EP) techniques based on several case studies. Based on the result, SOS has proven its superiority by producing higher quality solutions compared to PSO and EP. The results of this study can benefit the power system operators in planning for optimal power system operations.

Keywords*: fast voltage stability index, static var compensator, symbiotic organisms search, voltage deviation index*

1. Introduction

A healthy and stable condition is a must in power system operation. Therefore, it is an important responsibility of the power system operators to keep the power system operating within its normal condition. However, the increase in load demand has forced the power system to operate at a stressed condition, which eventually threatened the power system stability. Moreover, the increase in load demand can cause voltage reduction which links to the voltage collapse occurrence [1]. In order to solve this problem, the reactive power support compensation scheme can be employed to prevent voltage collapse condition. Installation of capacitor bank can be implemented for reactive power support compensation scheme due to its capability to inject capacitive reactive power into a power system network. However, capacitor bank was designed to be operated in steps. Hence, fine control of reactive power injected to a power system is impossible. In power system, the excess capacitive reactive power caused the voltage increase which leads to the occurrence of the over-voltage condition. Unfortunately, capacitor bank was unable to draw the excess capacitive reactive power from the system. Therefore, to alleviate this problem, SVC is employed for a finer and more flexible reactive power support device. In addition to that, it can be categorised as a shunt-connected FACTS device which is made up of Thyristor Controlled Reactor and shunt Fixed Capacitor.

Currently, meta-heuristic techniques have been implemented widely to determine the optimal allocation of SVC for solving various power system problems. In relation to that, Khandani *et. al.* implemented hybrid Genetic Algorithm and Sequential Quadratic Programming (GA-SQP) for optimal power flow solution and voltage profile improvement in the power system [2]. The purpose of the hybridisation is to overcome the weaknesses of both algorithms. Similarly, Nguyen *et. al.* conducted a study on optimal placement and sizing of SVC to improve voltage profile of IEEE 9-bus system, IEEE 30-bus system and IEEE 57-bus system [3]. The study has revealed that Cuckoo Search Algorithm has performed better compared to

Received May 16, 2018; Revised January 18, 2019; Accepted February 20, 2019

Improved Harmony Search (IHS) and Particle Swarm Optimization (PSO) algorithm. Also, the optimal SVC location and sizing have shown that it can improve the voltage profile of the power system as mentioned in [4-6] by using GA and PSO respectively.

Likewise, an attempt to improve the voltage profile of IEEE 30-bus RTS using Cultural Algorithm has been conducted by Bhattacharya *et. al.* [7]. On whole, several other optimisation techniques used to solve optimal SVC allocation problem are Flower Pollination Algorithm [8], Non-Dominated Sorting Particle Swarm Optimization [9], Non-Dominated Sorting Genetic Algorithm II (NSGA-II) [10], Kinetic Gas Molecule Optimization (KGMO) [11], Modified Artificial Immune Network [12], Hybrid Differential Evolution [13] and Self-Adaptive Firefly Algorithm [14]. Although existing optimisation algorithms are capable of solving the optimal SVC allocation problem, several optimisation algorithms unable to provide a good post-optimisation results due to their limitations. Several algorithms have reported to be very sensitive to the starting condition which can cause the solution to be trapped in local minima as mentioned in [2, 15]. A study conducted by Selvarasu *et. al.* revealed that optimality of results produced by Firefly Algorithm (FA) is dependent on its parameter choice [16]. In addition, GA has been widely implemented due to its easy implementation and capability to produce high-quality solutions. However, it is known to suffer premature convergence as well as deterioration of solution quality of large-scale optimisation problem [17, 18].

Therefore, to overcome the drawbacks imposed by these algorithms, this paper proposes the implementation of Symbiotic Organisms Search (SOS) algorithm to solve for optimal SVC allocation problem. Initially, SOS has been developed by Cheng and Prayogo in [19]. On the positive side, SOS is independent of parameters and has been adopted to solve various problems such as optimal FACTS device allocation for optimal power flow [20], economic dispatch [21], and structural design optimisation [22] as well as scheduling task problem [23]. Previously, initial research has been conducted to improve the voltage profile of IEEE 26-bus Reliability Test System (RTS) using SOS in [1] to determine only the optimal location of SVC. This paper presents the implementation of SOS algorithm to solve optimal SVC allocation problem by determining the optimal size of SVC as well as its location to improve the voltage security of IEEE 26-bus RTS via improvement in voltage profile and voltage stability index of the system. Comparative studies are conducted with respect to PSO and Evolutionary Programming (EP) algorithm which revealed the superiority of SOS over PSO and EP in solving for the optimal SVC allocation problem.

2. Research Method

2.1. Problem Formulation

In this paper, there are 2 objectives to be optimised simultaneously using the proposed optimisation technique. The first objective is to improve the voltage profile of the power system. In this paper, the voltage profile of the power system is indicated by total Voltage Deviation Index (VDI) value which is adapted from [24]. Hence, the first fitness function is the minimisation of the total VDI, f_1 and can be expressed as in (1):

$$f_1 = \min(VDI) = \min\left(\sum_{i=1}^{N_{bus}}\left(\frac{V_{ref,i} - V_i}{V_{ref,i}}\right)^2\right) \tag{1}$$

where V_i is the voltage magnitude of i^{th} bus of the test system and $V_{ref,i}$ is the reference voltage magnitude of i^{th} bus of the test system. N_{bus} is defined to be the total number of buses of the test system. The second objective is to improve the voltage stability of the power system by using the pre-developed voltage stability index known as the Fast Voltage Stability Index (FVSI) [25]. Therefore, the second fitness function is to minimise the highest FVSI value in the test system and can be mathematically expressed as in (2):

$$f_2 = \min\left(FVSI_{\max}\right) = \min\left(\max\left(\frac{4Z^2Q_r}{V_s^2X}\right)\right) \tag{2}$$

where V_s is the sending end voltage and Q_r is the receiving end reactive power. X and Z are defined to be the reactance and the magnitude of line impedance respectively.

In solving the multi-objective optimisation problem, both optimisation objectives are combined using the weighted-sum method. The weighted fitness value of the multi-objective optimisation problem can be expressed in (3) as:

$$f = w_1 f_1 + w_2 f_2 \quad (3)$$

where w_1 and w_2 are the weighing coefficients for the first and second fitness value respectively. Therefore, the main objective of the optimisation algorithm is to minimise the weighted fitness value. Hence, the objective function can be expressed as:

$$O.F. = minimise(f) \quad (4)$$

SVC is a device which is capable of injecting or absorbing reactive power. Various researchers have implemented different modelling approach. In this paper, SVC is modelled as an ideal reactive power injection since the power system is assumed to be in steady state condition. Reactive power injected by SVC is bounded in the range of its minimum and maximum power and it can be expressed as:

$$Q_{SVC}^{\min} \le Q_{SVC} \le Q_{SVC}^{\max} \quad (5)$$

where Q_{SVC}^{min} and Q_{SVC}^{max} is the minimum limit and maximum limit of SVC size respectively. Optimal location of SVC installation can help to improve voltage security of a power system. Therefore, it is proposed that the SVC is installed at the load bus since generator and swing buses have a generation unit which can produce reactive power. The constraint for SVC location, Loc_{svc} can be expressed as:

$$1 \le Loc_{svc} \le N_{lb} \quad (6)$$

where N_{lb} is the number of load buses in the test system.

2.2. Symbiotic Organisms Search for Optimal SVC Allocation

Authors in [19] have proposed a new optimisation algorithm known as Symbiotic Organisms Search (SOS). The algorithm was inspired by the interaction of organisms in a symbiotic relationship which lives together in an ecosystem. The explanation on the algorithm is given as follows:

Step 1: Initialization. Consider an ecosystem is made up of *N* organisms where each organism is made up of *k* sets of SVC size and its location. The SVC sizing and location are generated randomly according to (5) and (6) respectively. The fitness value of the organisms is then evaluated and organism with the best fitness value will be initialized as the best organism. Organism counter *i* was also initialized.

Step 2: Mutualism. An organism is randomly chosen from the ecosystem as the jth organism where ith organism and the jth organism is a different organism. This condition is expressed as in (7). Then, both organisms engage in a mutualistic relationship to produce 2 new organisms. Then, the fitness value of the new organisms will be compared with the older ones. Organisms with a better fitness value will be included in the ecosystem while the other organisms are eliminated. The mathematical expression of this relationship can be expressed as:

$$X_i \ne X_j \quad (7)$$

$$X_{i,new} = X_i + rand(0,1) \times (X_{best} - MV \times BF1) \quad (8)$$

$$X_{j,new} = X_j + rand(0,1) \times (X_{best} - MV \times BF2) \quad (9)$$

$$MV = \frac{X_i + X_j}{2} \tag{10}$$

where X_i and X_j are i^{th} and j^{th} organisms chosen from the ecosystem. $X_{i,new}$ and $X_{j,new}$ are the new organisms produced from the mutualism phase respectively. A random number ranged from 0 to 1 is noted by *rand(0,1)* while X_{best} and *MV* are defined as the best organism identified from best organism identification phase and the mutual vector of the organisms respectively. *BF1* and *BF2* is the benefit factor of the organisms and it is chosen randomly either 1 or 2.

Step 3: Commensalism. An organism is randomly chosen from the ecosystem as the j^{th} organism where the i^{th} organism and the jth organism is a different organism. This condition is expressed as in (7). Then, the chosen algorithm will engage themselves in commensal relationship. A new organism is produced from the relationship and its fitness value is then evaluated. The organism with a better fitness value will retain itself in the ecosystem while the other organism will be eliminated. This relationship can be expressed as:

$$X_{i,new} = X_i + rand(-1,1) \times (X_{best} - X_j) \tag{11}$$

where X_i and X_j are i^{th} and j^{th} organisms chosen from the ecosystem. $X_{i,new}$ is the new organism produced from the commensalism phase respectively. X_{best} is the best organism identified from best organism identification phase and *rand(-1,1)* is a random number ranged from -1 to 1.

Step 4: Parasitism. An organism is randomly chosen from the ecosystem as the j^{th} organism where the i^{th} organism and the jth organism is a different organism. This condition is expressed as in (7). A parasite is then produced by duplicating X_i while X_j serves as the host. Then, the random dimension of the parasite is then modified, and its fitness value is evaluated. In the case of the parasite having a better fitness value compared to the host, then the parasite will replace the host in the ecosystem. Otherwise, the host retains itself in the ecosystem and the parasite is eliminated

Step 5: Best organism identification. In this phase, the organism with the best fitness value will be defined to be the new best organism. Then, the fitness value of new and old best organism is compared and the organism with a better fitness value will be assigned as the best organism.

Step 6: Convergence test. In this stage, the organism counter is observed. If the organism counter has not reached the total number of organisms, then the counter is updated, and the process is continued at step 2. Otherwise, the iteration counter is checked. If the optimisation process has reached its maximum iteration number, then the optimisation process is halted. Else, the iteration counter is updated, and process is continued at step 2.

3. Results and Analysis

SOS algorithm has been implemented to solve for the optimal SVC allocation problem. The optimisation algorithm aims to improve the voltage security of IEEE 26-bus RTS. Figure 1 illustrates single-line diagram of IEEE 26-bus RTS. The parameter of the proposed optimisation algorithm is given as:

Number of organisms, *N*	:	20
Maximum number of iteration	:	200
Number of SVC to be installed	:	3
Weighing coefficient for first fitness value, w_1	:	0.5
Weighing coefficient for second fitness value, w_2	:	0.5

There are 3 case studies conducted in the optimisation process. Each case study represents the different operating condition of the test system. The case studies are:

Case 1 : Base case condition
Case 2 : Generation unit removal condition
Case 3 : Transmission line outage condition

The same optimisation problem was solved by using PSO and EP for comparative study among the optimisation techniques. The performance of the optimisation algorithm is assessed through the fitness value yielded by the optimisation algorithm.

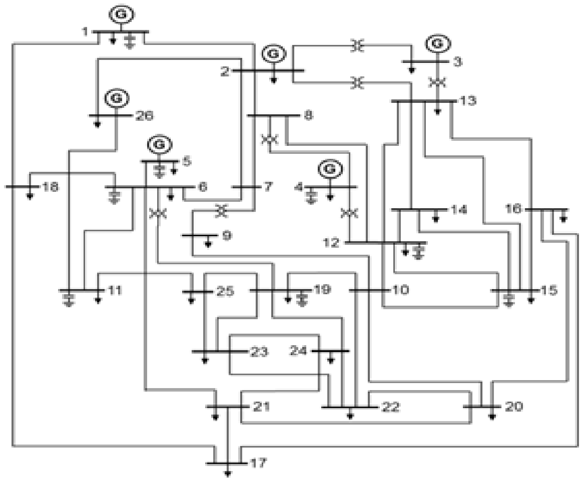

Figure 1. Single-line diagram of IEEE 26-bus RTS

3.1. Base Case Condition

During the base case condition, the operating condition of the test system is maintained at its initial state. SOS is applied to the system for solving optimal SVC allocation problem. The optimisation process is executed 20 times to observe the variation of results produced by the algorithm. Under the same condition, the process was repeated using PSO and EP. Table 1 tabulates the results of optimisation techniques solving optimal SVC allocation for voltage security improvement problem.

From the results, it can be observed that SOS algorithm is capable of solving the optimisation problem by producing lower post-optimised fitness value compared to pre-optimised fitness value. Comparatively, the post optimisation results produce by SOS is better than the one produced by PSO and EP. While SOS provides the worst VDI value, it also recorded the best value of worst FVSI which indicates the best improvement on the voltage stability index in the system. In addition, SOS has managed to yield better results compared to PSO and EP in terms of worst post-optimised fitness value. During this condition, SOS has managed to produce the best voltage deviation index and worst FVSI values. From all the optimisation attempts conducted in this study, SOS has managed to produce the best average fitness value compared to PSO, with PSO is performing better than EP.

Table 1. Optimisation Results during Base Case Condition

Parameter	Technique	Total VDI	Worst FVSI	Fitness value
Pre-optimised	-	0.00483	0.35376	0.17929
	SOS	0.00497	0.33836	0.17167
Best post-optimised	PSO	0.00162	0.34324	0.17243
	EP	0.00292	0.34294	0.17293
	SOS	0.00179	0.34327	0.17253
Worst post-optimised	PSO	0.00187	0.34409	0.17298
	EP	0.00390	0.34710	0.17550
	SOS	-	-	0.17228
Average post-optimised	PSO	-	-	0.17260
	EP	-	-	0.17397

3.2. Generation Unit Removal Condition

In this case study, a generation unit at bus 5 is removed from the test system operation. This case study is conducted to simulate the contingency condition where a generation unit is shut down. Removing a generation unit causes the reduction in the reactive power generation capability. The optimisation process is conducted for 20 times using SOS, PSO and EP while observing the variation of results produced. Table 2 tabulates the results of optimal SVC allocation for voltage security improvement using SOS, PSO and EP. Table 2 shows the results obtained by solving optimal SVC allocation problem using the proposed algorithms. From the results, it can be seen that the optimisation algorithms used in this paper have managed to solve the allocation problem. It is recognisable that SOS has performed better compared to PSO and EP by producing the lowest fitness value, voltage deviation index value as well as the worst FVSI value. This result implies that SOS algorithm has managed to determine the best SVC allocation solution which results in a good improvement on the voltage security of the system. In average, it is found that SOS has managed to produce a good result compared to PSO and EP regarding fitness value.

Table 2. Optimisation Results during Generation Unit Removal Condition

Parameter	Technique	Total VDI	Worst FVSI	Fitness value
Pre-optimised	-	0.01783	0.35589	0.18686
	SOS	0.00192	0.34289	0.17241
Best post-optimised	PSO	0.00221	0.34283	0.17252
	EP	0.00663	0.34466	0.17565
	SOS	0.00252	0.34287	0.17269
Worst post-optimised	PSO	0.00260	0.34350	0.17305
	EP	0.00492	0.35233	0.17862
	SOS	-	-	0.17254
Average post-optimised	PSO	-	-	0.17286
	EP	-	-	0.17733

3.3. Transmission Line Outage Condition

In this case study, a transmission line which connecting bus 13 to bus 15 of IEEE 26-bus RTS is removed from the test system operation. This case study is conducted to simulate the contingency condition of a transmission line being offline possibly due to fault or maintenance. Removal of transmission line in a power system can cause changes in power flow which then affects the power system stability. A total of 20 optimisation attempts has been conducted with respect to SOS, PSO and EP algorithm to solve for optimal SVC allocation problem. Table 3 tabulates the result of solving optimal SVC allocation for voltage security improvement using SOS, PSO and EP techniques. From the results obtained in Table 3, it can be observed that SOS, PSO and EP algorithm has managed to solve the optimal SVC allocation problem by producing lower post-optimised fitness value compared to pre-optimised fitness value. SOS has managed to produce results with the lowest best post-optimised fitness value and the lowest worst FVSI value although it clocked up the highest value of voltage deviation index. Although EP has manageto produce a solution which would yield a good voltage profile, it also witnesses only small improvement in voltage stability compared to results produced by SOS and PSO. On the other hand, SOS has managed to produce the best fitness value, voltage deviation index and worst FVSI value on its worst attempt. Although the results produced by SOS showed only a slight improvement on the voltage stability, however, it produces a better voltage profile compared to other algorithms used in this study. In average, the results produced by SOS are superior compared to PSO and EP in solving for optimal SVC allocation problem.

Table 3. Optimisation Results during Transmission Line Outage Condition

Parameter	Technique	Total VDI	Worst FVSI	Fitness value
Pre-optimised	-	0.00574	0.35860	0.18217
	SOS	0.00923	0.33324	0.17124
Best post-optimised	PSO	0.00554	0.33891	0.17223
	EP	0.00319	0.34350	0.17335
	SOS	0.00246	0.34317	0.17281
Worst post-optimised	PSO	0.00279	0.34346	0.17313
	EP	0.00347	0.34983	0.17665
	SOS	-	-	0.17190
Average post-optimised	PSO	-	-	0.17280
	EP	-	-	0.17429

4. Conclusion

This paper presents the implementation of Symbiotic Organisms Search (SOS) for solving optimal SVC allocation for voltage security improvement. To gain improvement in voltage profile and voltage stability of a power system, installation of SVC in the system should be at its optimum. From the case studies conducted in this research, it can be concluded that the proposed optimisation algorithm is capable of solving the optimal SVC allocation problem to improve voltage security of IEEE 26-bus RTS. From the results obtained, it can be observed that voltage profile of the system has been improved via the reduction of voltage deviation index and the voltage stability was also improved when the worst FVSI value in the system has been reduced. Comparative studies conducted among SOS, PSO and EP algorithms revealed that SOS had proven its superiority over PSO and EP by yielding the best fitness value which implies a better performance in solving the optimal SVC allocation problem.

Acknowledgement

The authors would like to acknowledge the Institute of Research Management and Innovation (IRMI), UiTM Shah Alam, Selangor, Malaysia for the financial support of this research. This research is supported by IRMI under BESTARI Research Grant Scheme with project code 600-IRMI/MYRA 5/3/BESTARI (027/2017).

References

[1] Zamani MKM, Musirin I, Suliman SI. Symbiotic Organisms Search Technique for SVC Installation in Voltage Control. *Indonesian Journal of Electrical Engineering and Computer Science*. 2017; 6(2): 318–329.
[2] Khandani F, Soleymani S, Mozafari B. *Optimal placement of SVC to improve voltage profile using hybrid genetics algorithm and Sequential Quadratic Programming*. 16th Electrical Power Distribution Conference. Bandar Abbas. 2011: 1–6.
[3] Nguyen KP, Fujita G, Tuyen ND, Dieu VN, Funabashi T. *Optimal placement and sizing of SVC by using various meta-heuristic optimization methods*. The 2nd IEEE Conference on Power Engineering and Renewable Energy (ICPERE) 2014. Bali. 2014: 7–12.
[4] Singh A, Dixit S. GA Based Optimal Placement of SVC for Minimizing Installation Cost And Voltage Deviations. *International Journal of Hybrid Information Technology*. 2015; 8(9): 281–288.
[5] Dixit S, Srivastava L, Agnihotri G. *Optimal placement of SVC for minimizing power loss and improving voltage profile using GA*. 2014 International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT). Ghaziabad. 2014: 123–129.
[6] Jumaat SA, Musirin I, Othman MM, Mokhlis H. *Optimal Location and Sizing of SVC Using Particle Swarm Optimization Technique*. 2011 First International Conference on Informatics and Computational Intelligence. Bandung. 2011: 312–317.
[7] Bhattacharya B, Chakraborty N, Mandal KK. *Multiobjective optimal placement and sizing of SVC using cultural algorithm*. 2014 Annual IEEE India Conference (INDICON). Pune. 2014: 1–6.
[8] Kumar BS, Suryakalavathi M, Kumar GVN. *Optimal power flow with static VAR compensator based on flower pollination algorithm to minimize real power losses*. 2015 Conference on Power, Control, Communication and Computational Technologies for Sustainable Growth (PCCCTSG). Kurnool. 2012: 112–116.
[9] Benabid R, Boudour M, Abido MA. Optimal location and setting of SVC and TCSC devices using non-dominated sorting particle swarm optimization. *Electric Power Systems Research*. 2009; 79(12): 1668–1677.
[10] Savić A, Đurišić Ž. Optimal sizing and location of SVC devices for improvement of voltage profile in distribution network with dispersed photovoltaic and wind power plants. *Applied Energy*. 2014; 134: 114–124.
[11] Panthagani P, Rao RS. *KGMO for multi-objective optimal allocation of SVC and reactive power dispatch*. 2017 International Conference on Power and Embedded Drive Control (ICPEDC). Chennai. 2017: 365–369.
[12] Khaleghi M, Farsangi MM, Nezamabadi-pour H, Lee KY. *Voltage stability improvement by multi-objective placement of SVC using modified artificial immune network algorithm*. 2009 IEEE Power & Energy Society General Meeting. Calgary, AB. 2009: 1–7.
[13] Yang C-F, Lai GG, Lee C, Su C-T, Chang GW. Optimal setting of reactive compensation devices with an improved voltage stability index for voltage stability enhancement. *International Journal of Electrical Power & Energy Systems*. 2012; 37(1): 50–57.
[14] Selvarasu R, Surya Kalavathi M. SVC Placement for Voltage Profile Enhancement Using Self-Adaptive Firefly Algorithm. *Indonesian Journal of Electrical Engineering and Computer Science*. 2014; 12(8): 5976–5984.

[15] Mahdad B, Srairi K. Security optimal power flow considering loading margin stability using Hybrid FFA–PS assisted with brainstorming rules. *Applied Soft Computing*. 2015; 35: 291–309.
[16] Selvarasu R, Kalavathi MS. *Self-Adaptive Firefly Algorithm based transmission loss minimization using multi type FACTS devices*. 2014 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2014]. Nagercoil. 2014: 626–631.
[17] Gerbex S, Cherkaoui R, Germond AJ. Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms. *IEEE Transactions on Power Systems*. 2001; 16(3): 537–544.
[18] Mahdad B, Srairi K, Bouktir T. Optimal power flow for large-scale power system with shunt FACTS using efficient parallel GA. *International Journal of Electrical Power & Energy Systems*. 2010; 32(5): 507–517.
[19] Cheng M, Prayogo D. Symbiotic Organisms Search: A new metaheuristic optimization algorithm. *Computers & Structures*. 2014; 139: 98–112.
[20] Prasad D, Mukherjee V. A novel symbiotic organisms search algorithm for optimal power flow of power system with FACTS devices. *Engineering Science and Technology, an International Journal*. 2016; 19(1): 79–89.
[21] Guvenc U, Duman S, Dosoglu MK, Kahraman HT, Sonmez Y, and Yilmaz C. *Application of Symbiotic Organisms Search Algorithm to solve various economic load dispatch problems*. 2016 International Symposium on INnovations in Intelligent SysTems and Applications (INISTA). Sinaia. 2016: 1–7.
[22] Tejani GG, Savsani VJ, Patel VK. Adaptive symbiotic organisms search (SOS) algorithm for structural design optimization. *Journal of Computational Design and Engineering*. 2016; 3(3): 226–249.
[23] Abdullahi M, Ngadi MA. Hybrid Symbiotic Organisms Search Optimization Algorithm for Scheduling of Tasks on Cloud Computing Environment. *PLOS ONE*. 2016; 11(6): e0158229.
[24] Sirjani R, Mohamed A, Shareef H. Optimal allocation of shunt Var compensators in power systems using a novel global harmony search algorithm. *International Journal of Electrical Power & Energy Systems*. 2012; 43(1): 562–572.
[25] Modarresi J, Gholipour E, Khodabakhshian A. A comprehensive review of the voltage stability indices. *Renewable and Sustainable Energy Reviews*. 2016; 63: 1–12.