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FACTS DEVICES OPTIMAL PLACEMENT AND PARAMETER SETTING TO IMPROVE POWER NETWORK SYSTEM PERFORMANCE

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Abstract

This paper focuses on the impacts of the flexible ac transmission system (FACTS) devices placement on the transmission power system. In recent decades, the rapid development of power electronics has made FACTS (Flexible AC Transmission System) devices effective in increasing the controllability and flexibility of power system operation. It is well demonstrated that an optimal placement in the network and a better parameterization of FACTS devices leads to reduced line losses and improved voltage profile, which in turn maintains stability, reliability and efficiency of the power system. In this work, two different FACTS devices were selected to be parameterized and placed in a suitable location in the network, the shunt compensation device (Static Var Compensator) SVC, and the series controllers (Thyristor controlled series capacitor) TCSC. The performances of the used system are analyzed without and with FACTS devices in order to confirm their importance in the power system. In this paper, both Moth-flame (MFO) and Grasshopper optimizations (GOA) algorithms are applied to find the suitable location and size of FACTS devices for a typical network (IEEE 14 bus and IEEE 30 bus). The outcomes achieved by the two algorithms are very similar. The best results in terms of loss reduction are obtained by integrating the TCSC unit, whereas the best results in terms of stability are obtained by installing the SVC unit relative to those obtained by incorporating the TCSC.

Keywords: FACTS devices, power loss reduction, voltage profile, MFO, GOA, SVC, TCSC.

1. Introduction

Nowadays, the concept of power supply in the world has changed profoundly, due to the impressive increase in electricity demand, the integration of uncertain and intermittent renewable sources, the uneven load distribution and its dynamic structure, etc. [1, 2], which leads to increased stress on transmission lines and in addition these problems are intensified by unstable natural resource prices. In order to be able to provide the consumer with electrical energy at minimal cost and with maximum reliability, electricity providers have a choice between the conventional approach of adding new transmission lines to the grid and building new power generation facilities that are tied to certain factors such as technical and economic limitations, or simply making optimal use of the existing generation and transmission network using new technologies [1-3]. Electricity suppliers have opted for the second choice, which consists in developing new technologies, among the solutions (technologies) that have been recently introduced; FACTS devices are an effective way to improve electrical power transmission capabilities without the requirement to build additional costly transmission lines [4].

By adopting FACTS technology, advancements in power electronics have made it possible to address the need for voltage stability and enhanced power quality. In modern electrical systems, the basic functions of these devices are voltage, power flow control and reactive power compensation, to improve power quality [4-7]. FACTS devices are therefore implemented within electrical systems for both economic and technical reasons.

Based on research and experimental results, FACTS technologies can be used to resolve numerous power system quality and reliability issues, such as optimizing line power transfer capability and load capacity, compensate reactive power, improving voltage and power system transient stability; enhancing system security, limiting short circuit currents, and improving general power system quality [5, 6].

Depending on their connection mode, FACTS controllers can be classified into four categories:

- Shunt controllers,
- Serial-shunt controllers,
- Serial controllers,
- Serial-serial controllers.

In recent years, the placement of FACTS controllers in power systems has demonstrated its effectiveness. To fully benefit from their performance, it is critical to select the proper location and dimensions as incorrect selection can lead to unsuitable results [2-5].

In the literature, various heuristic and meta-heuristic approaches are utilized to answer the problem of optimal placement and parameterization of FACTS devices. These methods include bacterial foraging search algorithm (BFA) [7] [3, 4], the whale optimization algorithm (WOA) [8], the gray wolf optimizer (GWO) [9], artificial bee colonies (ABC) [10], krill herd algorithms (KHA) [11], Filter Feeding Allogenic Engineering (FFAE) [12], and multi-objective teaching learning based optimization algorithm (MO-TLBO) [13].

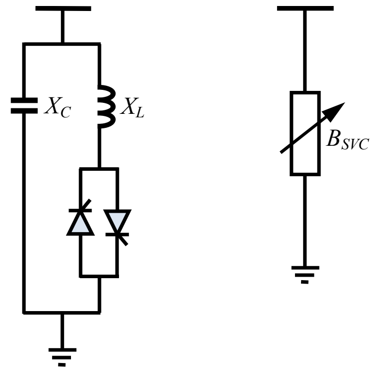
In the current study, two optimization approaches for FACTS device, placement and parameterization are investigated to enhance the stability of power systems, the voltage profile, and power loss reduction. FACTS devices such as the static var compensator (SVC) and the thyristor-controlled series compensator (TCSC) are being considered in this work.

In this investigation, two optimization algorithms are employed, Moth-flame optimization (MFO) [14] and Grasshopper optimization (GOA) [15] to increase the power system security by taking into account the voltage stability margin based on line voltage stability indices and the transmission line losses. Both standard IEEE 14 bus and standard IEEE 30 bus test equipment are used to assess the proposed algorithms.

1. FACTS devices modeling

FACTS devices based on power electronics, are integrated into the structure of existing transmission lines with the goal of increasing the controllability of the system and the capacity of energy transport to facilitate energy exchanges and overcome a certain constraint by controlling the different parameters in transmission line circuits. These devices can be mounted to operate either in parallel, in series, or in parallel series in the electrical network.

In this work, two different FACTS devices were selected to be placed in an appropriate location in the network. These are: the shunt compensation device (SVC) which supplements the reactive power of the system, and the series controllers (TCSC and TCPS) used to improve the load capacity and power flow of the line.



(a) (b)

Fig. 1 Static VAR Compensator
a) Basic structure, b) Model of SVC

2.2 Static VAR Compensator

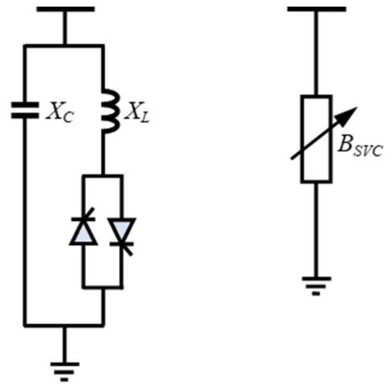
The SVC is mostly employed to optimize voltage profiles in high voltage systems. The SVC can be used for both inductive and capacitive compensation since it only provides or absorbs the desired reactive power. In this paper, the SVC is modeled as an ideal reactive power source connected to the bus i. The basic circuit structure of SVC is presented in Fig. 1.It consists of a capacitor in parallel with a coil controlled by a thyristor. The capacitor is used to supply reactive power, while the coil (controlled) is employed to absorb the reactive power [10].

The equivalent susceptance is computed as below:

$$\mathrm{B_{SVC}} = \mathrm{B_C} + \mathrm{B_L}(\gamma) \qquad (1)$$

The reactive power provided by the SVC can be expressed as follows:

$$Q_{SVC} = -V_m^2 B_{SVC} \qquad (2)$$



(a) (b)

2.3 Thyristor Controlled Serie Compensator

The Thyristor Controlled Serie Compensator (TCSC) is originally used as Rapid Adjustment of Network Impedance. A TCSC may be described as a capacitive reactance compensator that is a series capacitor bank shunted by a reactor controlled by a thyristor to provide a variable series capacitive reactance. The basic objective of the TCSC is to provide a variable reactance capacitor by partially eliminating the effective capacitance by injecting a reactance across the reactor controlled by the thyristor. Thus, the ability to change the line reactance lets the TCSC operate as an inductive or capacitive compensator [10].

The equivalent impedance as a function of the thyristor starting angle can be expressed as follows:

$$X_{TCSC}(\alpha) = \frac{X_C}{1-\frac{X_C}{X_L}\left(1-\frac{2\alpha - sin\alpha}{\pi}\right)} \qquad (3)$$

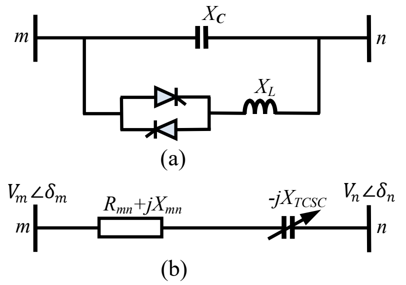


Fig. 2 Thyristor Controlled Serie Compensator
a) Basic structure, b) Model of TCSC

2. Problem formulation

The optimal seating and dimensioning of FACTS devices in a power system is formulated as a minimization problem. The objectives that have been taken into account in this paper are the minimization of power losses and the improvement of voltage stability.

In this section, two different objective functions are presented.

3. The Active Power Losses

Even though the transmission line conductor resistance per kilometer is low, it causes large power losses. Active power losses along transmission lines are normally expressed by Eq. 4 as follows:

$$P_{loss} = \sum_{q}^{NL} G_{q_{ij}}\left(V_i^2 + V_j^2 + 2V_iV_j\cos(\delta_{ij})\right) \qquad (4)$$

Where P_{loss} is the total active power losses, Gq is the conductance of the kth transmission line connected between bus i and bus j, NL is the number of transmission lines, V_i and V_j are the voltage, δ_i and δ_j are the voltage angles of bus i and bus j respectively.

3.2 Voltage stability indices

Among the many methods used to verify the safety level of the electrical system, the use of indices still plays a very important role in voltage stability analysis and helps operators measure how close the system is to voltage collapse. These indices incorporate the voltage stability index (*FVSI*), line stability index (L_{min}), and line voltage stability index (*LVSI*). Static line voltage stability indices are derived from the power transmission principle of a two-bus system figure 3.

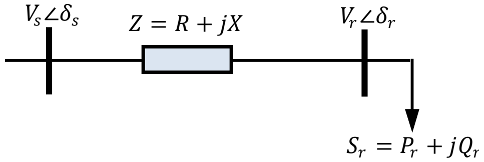


Fig. 3 Principle of a two-bus system

The voltage stability indices (*VSI*) that can be determined at each node as follows [16]:

3.2.1 Fast Voltage Stability Index (*FVSI*)

$$FVSI = \frac{4Z^2Q_{i+1}}{V_i^2X} \qquad (5)$$

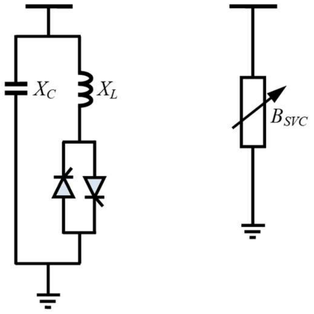
3.2.2 Line Stability Index (L_{mn}).

$$L_{mn} = \frac{4XQ_{i+1}}{[V_i sin(\theta - \delta)]^2} \qquad (6)$$

3.2.3 Line Voltage Stability Index (*LVSI*).

$$LVSI = \frac{4RP_{i+1}}{[V_i sin(\theta - \delta)]^2} \qquad (7)$$

Where P_{i+1} and Q_{i+1} are the active and reactive power at the receiving end V_i and V_{i+1} are the voltages at the sending and receiving ends. Z, R and X are the line impedance, resistance and the reactance of the line. θ is the line impedance angle. δ_i and δ_{i+1} are the phase angles at the sending and receiving buses.



(a) (b)

Fig. 1 Static VAR Compensator
a) Basic structure, b) Model of SVC

For all indices (*FVSI*, L_{mn} and *LVSI*), a value less than 1.00 indicates a stable condition, if the index value is close to 1.00, the particular line is close to instability and if the value is greater than 1.00, the system will undergo a voltage collapse. Noting that in this work, the *FVSI* index is the only one to be taken into account in the calculation as an objective function for stability improvement.

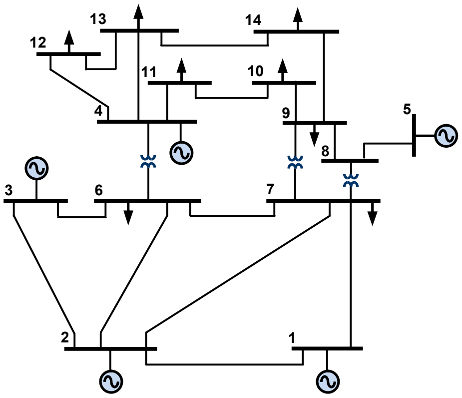
3.3 Constraints

1) Equality Constraints:
The equality constraints are active and reactive power balance equations:

$$\begin{cases} P_G = P_D + P_L \\ Q_G = Q_D + Q_L \end{cases} \qquad (8)$$

2) Inequality Constraints

- The voltage level that must be respected within the specified limits on each bus:



5 IEEE 14-bus system

$$V_{min} \le V_i \le V_{max} \qquad (9)$$

- The power limit generated.

$$\begin{cases} P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max} \\ Q_{Gi}^{min} \le Q_{Gi} \le Q_{Gi}^{max} \end{cases} \qquad (10)$$

4. Test Systems Description

In the present investigation, the MFO and GOA algorithms are evaluated in the implementation of the FACTS device planning problem, using the IEEE 30 bus and IEEE 14 bus test systems as sample cases. The algorithms are applied to get the optimal placement and parameterization of FACTS devices.

The IEEE 30-bus test system is shown in figure 4, which consists of 30 buses, 6 thermal generation units, 41 transmission lines of which 4 lines (4–12), (6–9), (6–10), and (27–28) are with the tap setting transformer, and a load equal to 100 MVA. The real power losses are 17.51 MW and the reactive power losses are 68.89MVar [25].

The 14-bus IEEE test system is illustrated in figure 5 and consists of 14 buses, 5 thermal generation units, 20 transmission lines, and 11 loads of 100 MVA.

5. Applied algorithms

For optimal placement and better parameterization of FACTS devices in the network, two optimization algorithms are proposed, the Moth-flame optimization developed by Seyed ali Mirjalili in 2015 [12] and the Grasshopper optimization developed by Shahrzad Saremi, in 2017 [13].

The principal parameters used for the two algorithms are described in Table 1.

Table.1: The algorithms input parameters

Algorithm	MFO	GOA
Search agents	25	25
Maximum iteration	250	250
TCSC sizing limits	$0 \leq TCSC \leq 1$	
SVC sizing limits	$-500 \leq SVC \leq 1000$ kVAr	
Voltage limits	$0.9 \leq Vi \leq 1.05$	

4. Results and Discussion

To examine the impact of integrating FACTS devices into power grids, two types of FACTS devices, namely TCSC and SVC, were added to two standard grids, the IEEE 14-bus system and the IEEE 30-bus system. The concept behind the use of FACTS is to secure operation by minimizing active power losses and increasing the safety level of the power system (voltage stability).The optimal sizing and placement of FACTS units was established on the basis of maximum enhancement of the respective objective functions.

The analysis, using the two optimization algorithms MFO and GOA, is as follows.

1. Without and with optimal TCSC allocation using standard IEEE 14-bus and 30-bus networks.
2. Without and with optimal allocation of SVC Using IEEE 14-bus and 30-bus standard.

When carrying out the simulations, the parameter values of the optimization algorithms used (MFO and GOA) are taken from the table 1. These parameters are selected after several tests, taking into account execution time and the accuracy of the optimal solution.

4.1Power losses minimization with optimal TCSC and SVC devices allocation

In this first step, the main objective is to minimize active power losses with optimal TCSC and SVC assignments, when applied to the IEEE 14-bus network and the IEEE 30-bus network.

A. Case 1: IEEE 14-bus

In this case, when applied to the IEEE 14-bus network, the simulation results for the two techniques and both FACTS under consideration are reported in the table 2.
The convergence curves for both algorithms to minimize active power loss when using both FACTS are illustrated in Figure 6, where both algorithms converged within less than 50 iterations. Furthermore, figure 6 shows that TCSC outperforms SVC, and that the former achieves a lower final value than the latter. In FACTS, the minimum power loss value obtained using TCSC is 0.1356 MW, and that obtained using SVC is 0.1368 MW, i.e., around 1% less. Losses in the reference case (without FACTS) are 0.1381 MW.
Thus, the aim is to minimize active power losses with optimal assignments of FACTS devices (TCSC and SVC) using the IEEE 14-bus network. Simulation results for the techniques considered are presented in the table. 2. Before the installation of FACTS devices, real and reactive power losses are 0.1381 MW and 0.4136 MVAr respectively, and the minimum voltage is 0.9841 pu at bus 3, as shown in figure 9. After installation of the TCSC device on Line 1, active network losses decreased by 2% to 0.1356 MW and reactive losses increased by 16% to 0.4809 MVAr, the voltage has also been improved with minimal voltage increase to 1.010 pu (on the same bus 3), compared with the base case. Similarly, for SVC, after the installation of SVC on bus 5, active network losses decreased by 1% to 0.1368 MW and reactive losses decreased by 1% to 0.4092 MVAr, and the minimum voltage also increases to 0.9845 pu (bus 3) relative to the base case. Figures 7 and 8 show the active and reactive power losses in each branch of the IEEE 14-bus system for the two devices (TCSC and SVC) connected to the selected line/bus; the branch 1 has the highest losses. While figure 9 shows the voltage at each bus.

Figure 10 shows the voltage stability index (*FVSI*) for each line, which decreases with the installation of FACTS devices, with line 11 having the highest value, and the latter having a value below 1, indicating a stable condition.

Table 2: 14-Bus system results

FACTS	Optim method	Location	Size	Losses		Vmin	Max FVSI
				Active	Reactive		
Base	--	--	--	0.1381	0.4136	0.9841	0.3729
TCSC	MFO	line 1	0.034343	0.1356	0.4809	1.0100	0.3607
	GOA	line 1	0.034343	0.1356	0.4809	1.0100	0.3607
SVC	MFO	Bus 5	343.2726	0.1368	0.4092	0.9845	0.36641
	GOA	bus 5	343.2726	0.1368	0.4092	0.9845	0.36642

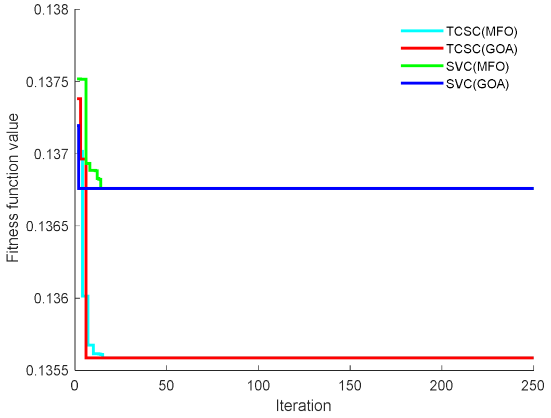


Fig. 6 The 14-bus system convergence curves for the active power loss minimization including FACTS devices

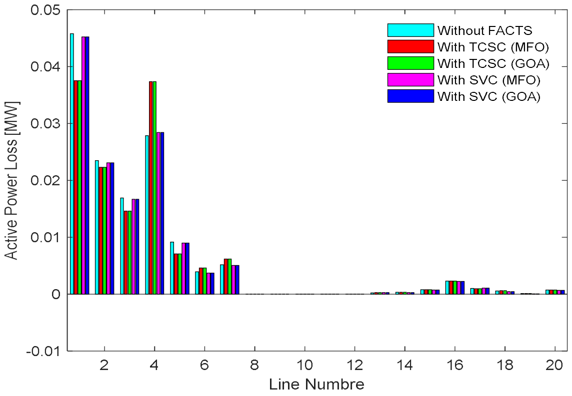


Fig.7 Active power loss (MW) IEEE 14-bus system

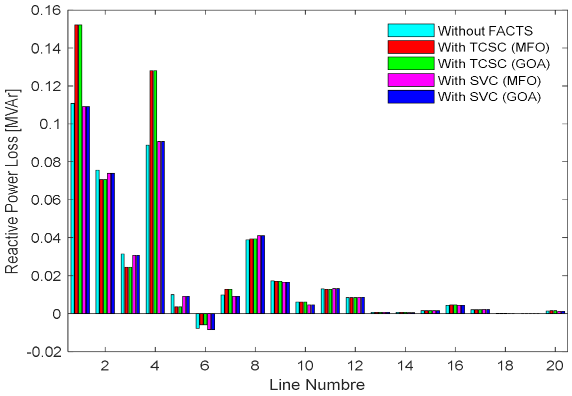


Fig.8 Reactive power loss (MVAr) IEEE 14-bus system

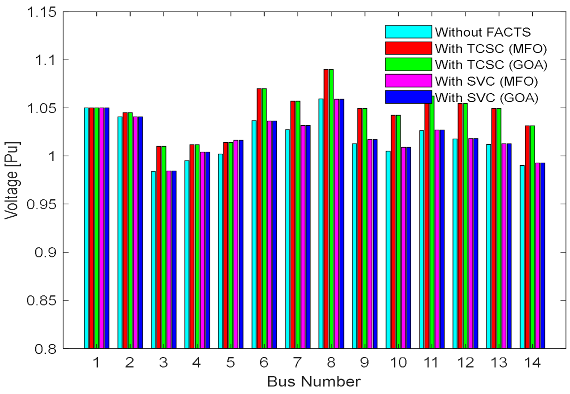


Fig.9 Voltage profiles IEEE 14-bus system

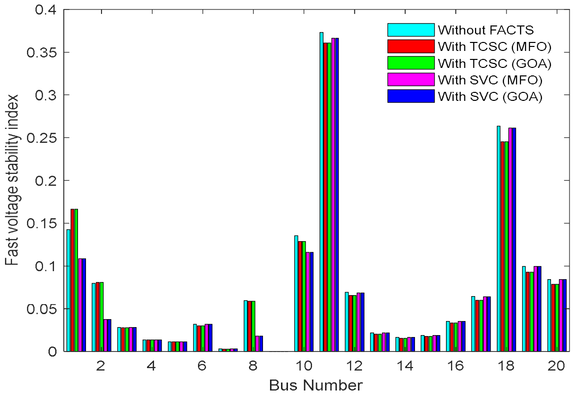


Fig.10 Fast Voltage Stability Index IEEE 14-bus system

B. Case 2: IEEE 30-bus

In this second case, the new network is the IEEE 30 bus, and the simulation results for the two techniques and the two FACTS considered are reported in Table 3.

The convergence curves for both algorithms to minimize active power loss when using both FACTS are illustrated in Figure 11, where both algorithms achieve convergence in no more than 50 iterations. Moreover, as in the previous case (14-bus network), TCSC outperforms SVC (Fig. 11), and TCSC achieves a lower final value than SVC. In fact, the minimum power loss value obtained with TCSC is 0.1739 MW, and that obtained with SVC is 0.1740 MW. The losses in the base case (without FACTS) are 0.1381 MW. Base case is 0.1751 MW.

The objective is to minimize active power losses through optimal allocation of FACTS devices (TCSC and SVC) over the IEEE 30-bus network. Simulation results for the considered methods are presented in the table 3. Before installing the FACTS device, the active and reactive power losses are 0.1751 MW and 0.6663 MVAr, respectively, and the minimum voltage on bus 30 is 0.9591 pu, as shown in figure 14. After installing the TCSC device on line 8, the active grid loss decreased to 0.1739 MW and the reactive loss increased to 0.6725 MVAr. Also, the minimal voltage improved to 0.9968 pu (on the same bus 3), compared to the base case. Similarly, after installing SVC on bus 4, the active grid losses decreased 0.1740 MW and the reactive losses decreased to 0.6625 MVAr compared to the base case. Figure 12 and Figure 13 show the active and reactive power losses in each leg of the IEEE 30-bus system for two devices (TCSC and SVC) connected to the selected line/bus. Branch 1 loses the most. Figure 14, on the other hand, shows the voltage on each bus.

Figure 15 shows the voltage stability index (*FVSI*) for each line, which becomes lower when a FACTS device is installed. Line 11 has the highest value, 0.3829, which is less than 1, indicating a stable state.

Table 3: 30-Bus system results

FACTS	Optim method	Location	Size	Losses		Vmin	Max FVSI
				Active	Reactive		
Base	--	--	--	0.1751	0.6663	0.9591	0.3829
TCSC	MFO	line 8	0.5052	0.1739	0.6724	0.9968	0.3695
	GOA	line 8	0.52163	0.1739	0.6725	0.9967	0.3695
SVC	MFO	bus 4	327.8854	0.1740	0.6625	0.9631	0.3795
	GOA	bus 4	327.8854	0.1740	0.6625	0.9631	0.3795

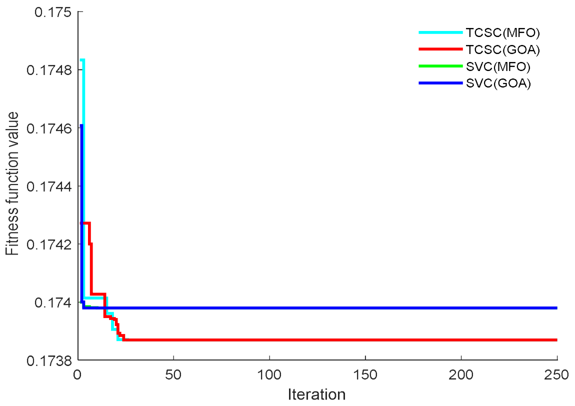


Fig.11 The 30-bus system convergence curves for the active power loss minimization including FACTS devices

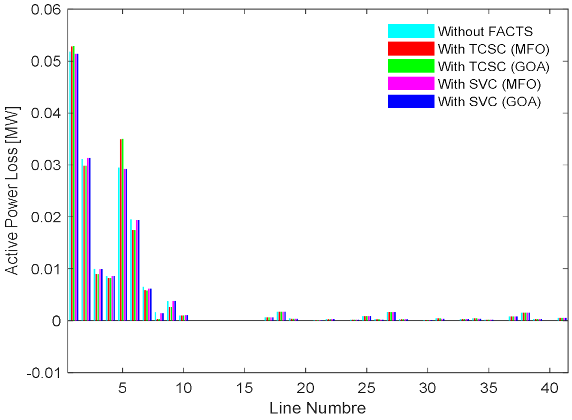


Fig.12 Active power loss (MW) IEEE 30-bus system

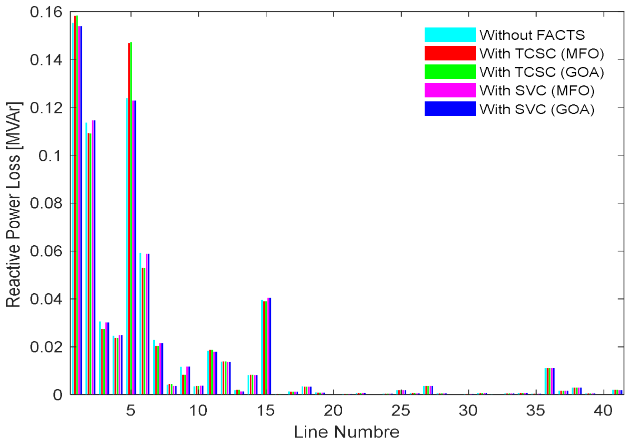


Fig.13 Reactive power loss (MVAr) IEEE 30-bus system

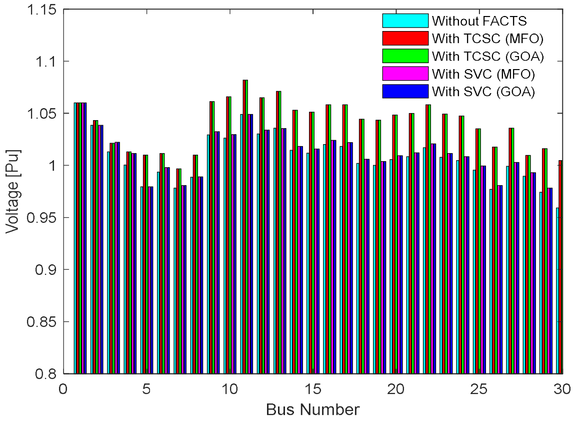


Fig.14 Voltage profiles for the IEEE 30-bus system

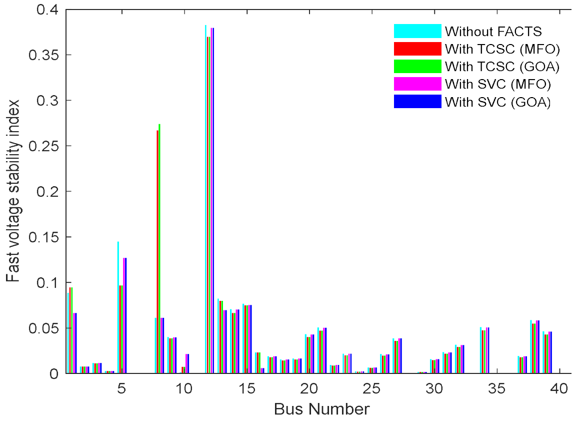


Fig.15 Fast Voltage Stability Index IEEE 30-bus system

4.2 Improving the voltage stability margin with optimal allocation of the TCSC and SVC devices

This section focuses on the incorporation of FACTS (TCSC and SVC) with the aim of improving the voltage stability margin. IEEE 14-bus and 30-bus test systems are used to assess and affirm the overall efficiency of the proposed approach.

A. Case 1: IEEE 14-bus

In this instance, when used on the IEEE 14-bus network, the simulation results of the objective function minimizations for the two techniques and both FACTS under consideration appear in the table 4.The convergence curves of the two algorithms for improving the voltage stability margin when using the two FACTS are shown in Figure 15. The two algorithms converge in no more than 50 iterations. Furthermore, in contrast to the first case, by using the second objective function, the SVC outperforms the TCSC device and gives better results. Indeed, the maximum value of the fast voltage stability index obtained with the SVC is 0.319256, and that obtained with the TCSC is 0.35950.Knowing that the maximum fast voltage stability index in the case without FACTS is 0.3729.

As already explained, the aim is to improve the voltage stability margin through optimal FACTS device (TCSC and SVC) positioning on the IEEE 14 bus network. The simulation outputs for the selected methods are shown in Table 4. Before the FACTS devices were installed, the maximum fast voltage stability index is 0.3729 on line 11, the minimum voltage is noted on bus 3 and is 0.9841 pu, and the active and reactive power losses are 0.1381 MW and 0.4136 MVAr respectively. Once the TCSC device had been installed on line 8, the active power loss increased to 0.1406 MW and the reactive power loss to 0.4493 MVAr. In addition, minimum voltage improved to 1.010 pu (on the identical bus 3) compared to the base case.By analogous means, after the installation of an SVC on bus 4, active power losses in the network increased to 0.1836 MW and reactive losses increased to 0.5564 MVAr compared to the base case.

Figures 17 and 18 show the active and reactive power losses in each branch of the IEEE 14-bus system for two devices (TCSC and SVC) connected to the chosen line/bus.It's branch 1 that has the most to lose.

Table 4: 14-Bus system results for voltage stability index objective function

FACTS	Optim method	Location	Size	Losses		Vmin	Max FVSI
				Active	Reactive		
Base	--	--	--	0.1381	0.4136	0.9841	0.3729
TCSC	MFO	line 8	0.31288	0.1406	0.4493	1.010	0.35950
	GOA	line 8	0.31288	0.1406	0.4493	1.010	0.35950
SVC	MFO	bus 4	1912.911	0.1836	0.5564	0.9855	0.31925
	GOA	bus 4	1912.911	0.1836	0.5564	0.9855	0.31925

Figure 19 depicts the voltage on each bus and illustrates a clear improvement in voltage. While figure 20 shows the voltage stability index (*FVSI*) for each line, which declines when a FACTS device is installed, line 11 has the highest value, 0.3729, which is less than 1, indicating a stable state.

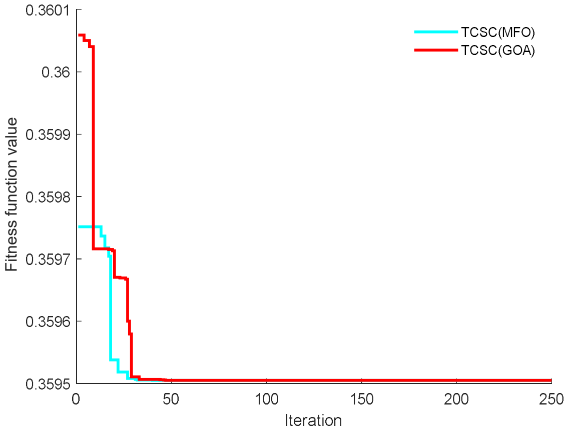


Fig.16 The 14-bus system convergence curves for the voltage stability index objective function minimization including FACTS devices

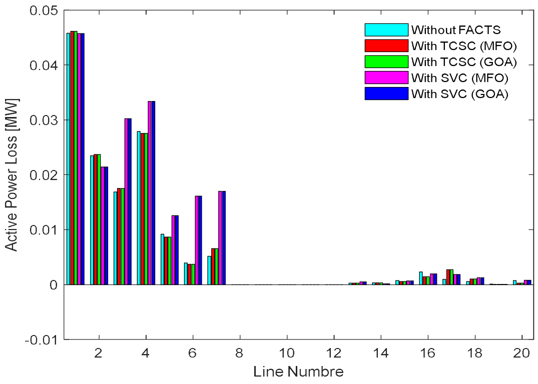


Fig.17 Active power loss for the IEEE 14-bus system

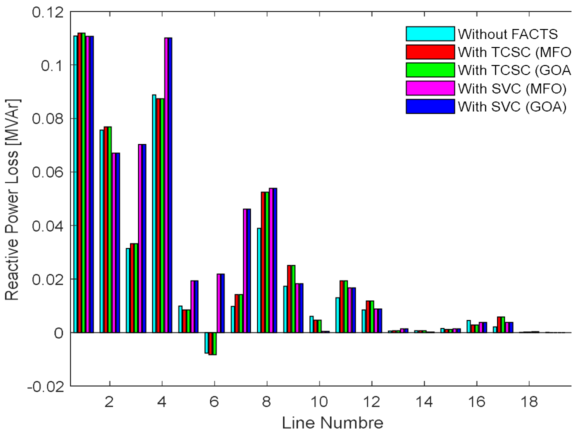


Fig.18 Reactive power loss for the IEEE 14-bus system

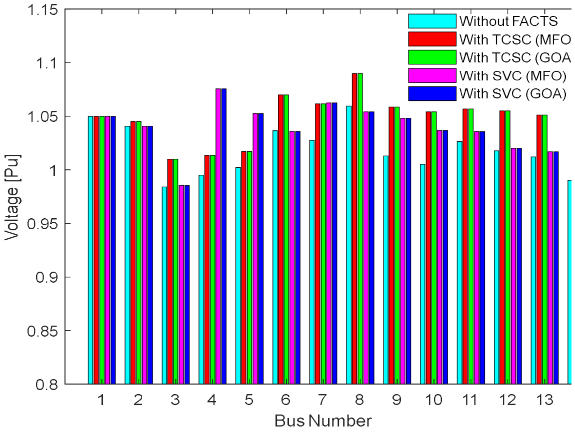


Fig.19 Voltage profiles for the IEEE 14-bus system

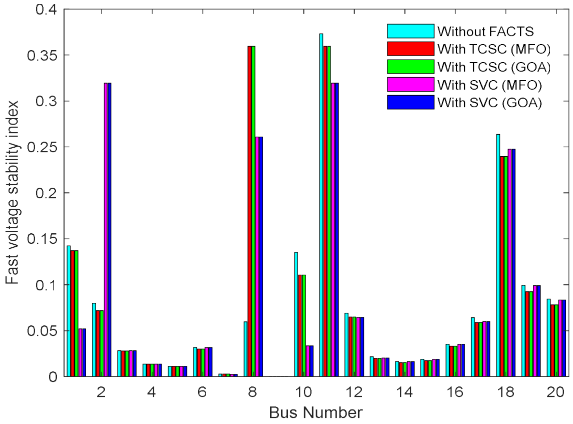


Fig.20 Fast Voltage Stability Index_IEEE 14-bus system

B. Case 2: IEEE 30-bus

In this alternative case, the new network is the IEEE 30 bus, and the simulation results for the two techniques and the two FACTS considered are presented in Table 5. The convergence curves of the two algorithms for improving the voltage stability margin while using the two FACTS are presented in figure 21. Noting that both algorithms converge in less than 50 iterations Moreover, as in the 14-bus network, SVC outperforms TCSC (Fig. 16). In fact, the maximum value of the fast voltage stability index obtained with the SVC is 0.14652, and that obtained with the TCSC is 0.36756. Knowing that the maximum fast voltage stability index in the absence of FACTS is 0.3729.

As stated above, the goal is to improve the voltage stability margin through optimal mapping of FACTS devices (TCSC and SVC) on the IEEE 30 bus network. Simulation results for considered methods are shown in the table. 5. Before installing the FACTS devices, as shown in Figure 25, the maximum fast voltage stability index is 0.3829 on line 12, the minimum voltage is observed on bus 30 and is 0.9591 pu, and the active and reactive power losses are 0.1751 MW and 0.6663 MVAr respectively. After installing the TCSC device on line 9, the active power grid loss increased to 0.1773 MW and the reactive power loss increased to 0.7096 MVAr. Also, the minimum voltage has improved to 0.9955 pu (on the same bus 30) compared to the base case. Similarly, after installing an SVC on bus 10, the active power grid losses decreased to 0.1608 MW and the reactive losses decreased to 0.6099 MVAr compared to the base case. Figure 22 and Figure 23 show the active and reactive power losses in each leg of the IEEE 30 bus system for two devices (TCSC and SVC) connected to the selected line/bus. It's branch 1 that has the largest amount to lose. Figure 24 illustrates the voltage on each bus, and reveals a clear improvement in voltage. While figure 25 shows the Voltage Stability Index (*FVSI*) for each line, which becomes lower when a FACTS device is installed, line 19 has the highest value, 0.3829, that is lower than 1, indicating a stable state.

Table 5: 30-Bus system results for voltage stability index objective function

FACTS	Optim method	Location	Size	Losses		Vmin	Max FVSI
				Active	Reactive		
Base	--	--	--	0.1751	0.6663	0.9591	0.3829
TCSC	MFO	line 9	0.78433	0.1782	0.7135	0.9955	0.36756
	GOA	line 9	0.65168	0.1773	0.7096	0.9964	0.3677
SVC	MFO	bus 10	-104.757	0.1608	0.6099	0.9574	0.14652
	GOA	bus 10	-104.757	0.1608	0.6099	0.9574	0.14652

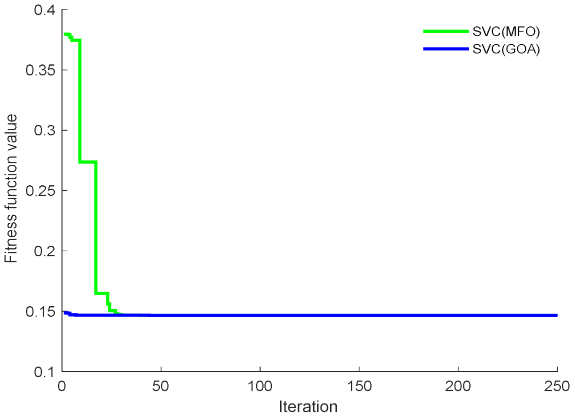


Fig.21 The 21-bus system convergence curves for the voltage stability index objective function minimization including FACTS devices

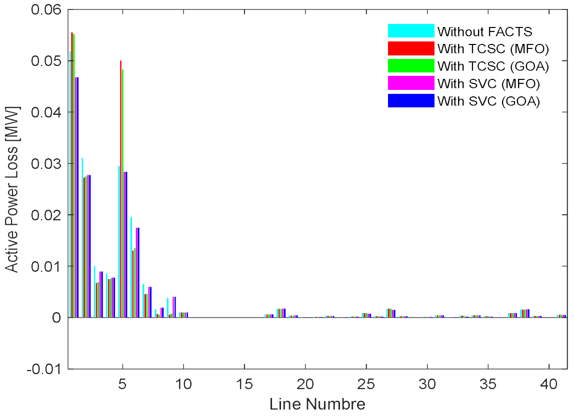


Fig.22 Active power loss for the IEEE 30-bus system

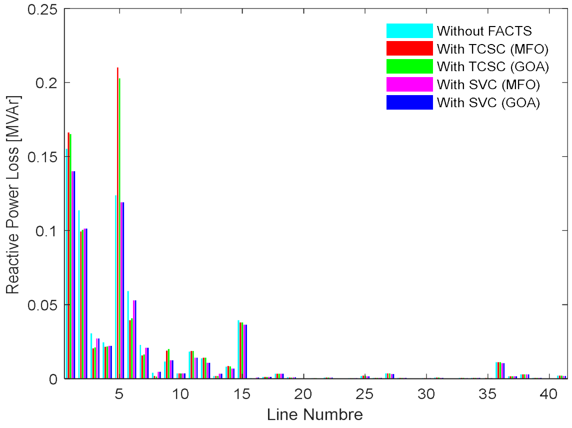


Fig.23 Reactive power loss for the IEEE 30-bus system

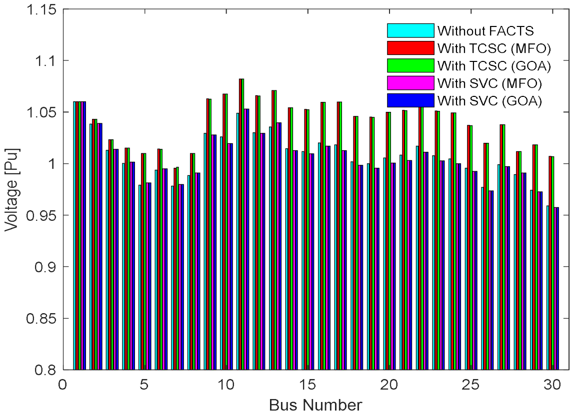


Fig.24 Voltage profiles for the IEEE 30-bus system

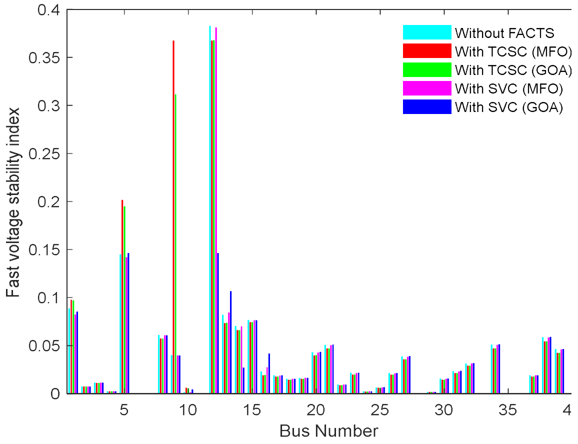


Fig.25 Fast Voltage Stability Index_IEEE 14-bus system

Noting that, the MFO and GOA algorithms have obtained close results for all optimal power flow cases. Also, integrating FACTS devices improve power network system performance.

5. Conclusion

Two metaheuristic algorithms, MFO and GOA, are developed in this research to handle optimal

FACTS allocation problems in power networks. The appropriate location for the FACTS device was determined by minimizing active power loss and improving voltage stability.

The study is carried out on both IEEE 14-bus and IEEE 30-bus networks using two types of FACTS devices: the TCSC serial device and the SVC shunt device.It's worth noting that by integrating FACTS units in the right place and operating them optimally, active power losses in the power grid are reduced, whereas the voltage profile improves considerably. The outcomesobtained reveal that the two algorithms achieve close results in all cases.

The best results in terms of loss reduction are obtained by integrating the TCSC unit compared to those obtained by integrating the SVC unit, while the best results in terms of stability are obtained by placing the SVC unit relative to those achieved by incorporating the TCSC unit.

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