STATCOM device incorporation for optimal power flow with voltage deviation and active power losses based on sea horses optimization method

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***Abstract*— Based a new metaheuristic optimization method called "Sea horses" which is inspired from the behavior of the sea horses movement, hunting and unique characteristic of pregnancy, this work deals to find the optimal power flow solution, minimize voltage deviation and reduce total losses of active power ensuring the best fuel cost of power generations by using STATCOM device. For that, the three objectives function are used to formulate the global objective function analyzed by the proposed technique to find the optimal solution. To perform the efficiency of this study, the IEEE 30-bus system is chosen as test network and in the purpose of comparison, the obtained results was compared with another studies with same objective and using different devices and technique. This comparison shows clearly the powerful of STATCOM device based on Sea-Horses method to improve the target objective function.**

Keywords: Sea Horses, Optimization, STATCOM, Voltage deviation.

I. INTRODUCTION

The optimal power flow problems still an attractive domain due to increasing of complexity of modern power network requires best manage and control of its different parameters. One of most important parameter need to focus on it and requires more supervision is the voltage profile of the network, because the integration of new technologies such the electrics cars and distributed generation makes the operation of transmission line close to its capacity limit [1, 2].

Owing to lack of new generation, transmission facilities and over exploitation of the existing facilities leads to power system instability. Conventional power systems are controlled mechanically. However, control through mechanical devices is not as reliable as they tend to wear out quickly compared to the static devices. This necessitates power control to shift from mechanical devices to static devices [2].

On the other hand, the rapidity of changing in behavior of the power network at a very short time for example: charging a very important number of EV in the same time than disconnect it, hold the network manager's job difficult especially with the classical mechanical controller which need to shift to advances devices like the statistics one [3, 4].

Since year and with the development of the electronic power switch, the Flexible Alternating Current Transmission System (FACTS) device takes its important place in the control of power flow and attracts many researchers to focus on its benefits to the power network. This type of devices which have been introduced in 1980's, prove their performance in a lot of operation and application by providing a high efficiency to control the power transfer in AC power grids. Unfortunately, without a good setting of parameters and installation position, the performance of FACTS devices can be degraded [4]. The main function of these devices is to controlling the power flow, it can used in the network to improve the voltage profile and maintaining its stability, to reduce upon active and reactive power, to enhance the capability of transmission line to support more power, etc… [5, 6].

The Static Synchronous Compensator (STATCOM) is an efficient power system specially designed for connection to demanding networks. The flexibility of the system allows it to be used in a wide range of applications such as dynamic voltage stabilization, voltage balancing of unbalanced loads, mitigation of voltage flicker created by arc furnaces electrical and active filtering of harmonics. The STATCOM is particularly competitive in terms of its installation time and its size. In addition, its high efficiency and the low maintenance it requires, translate it into low operating costs [7, 8].

This research work aims to find the optimal size of STATCOM by introducing a new Meta heuristic optimization technique called Sea Horses optimization method to reduce voltage deviation that influence directly on the stability of this important characteristic and also reduce the power losses in line with minimum cost of power generation. Its performance is compared with Genetic Algorithm (GA) technique. The limits of different characteristics such the active and reactive power generation and voltage for the buses are taken as unequally constraints.

The obtained results show that the STATCOM based on Sea horses optimization can be represent an effective combination hard/soft that can significantly decrease the voltage deviation, reduce the power losses and ensure a best cost of active generation. IEEE 30 bus system is taken as the test network for computer simulation.

II. Review of the optimization method

In this part we will present the SHO optimization method based on the work done in [9, 10]. This method proposed by Zhao S., Zhang T., Ma S and Wang M in 2022, represents a new Meta heuristic based on the intelligence of swarms called Sea Horses optimizer (SHO), which is inspired by the behaviors of movement, predation and reproduction of seahorses in the wild. In the first two steps, SHO mimics different movement patterns and the probabilistic predation mechanism of seahorses, respectively [9]. In detail, the modes of movement of a seahorse are divided into spiral floating affected by the action of sea eddies or drifting along the waves of the current. For the predation strategy, it simulates the success or failure of the hippocampus to capture prey with a certain probability. Moreover, due to the unique feature of male pregnancy, in the third stage, the proposed algorithm is designed to raise the offspring while retaining the positive information of the male parent, which is conducive to increasing diversity population. These three smart behaviors are mathematically expressed and constructed to balance local exploitation and global exploration of SHO.

A. Seahorse Processes

Seahorses reproduce in unusual ways. The male seahorse becomes pregnant instead of the female. Most seahorse pregnancies last about 2-3 weeks. The male seahorse has a brood pouch where it carries the eggs deposited by the female. Seahorses are famous for their mating rituals in which they dance together before mating. Watch the short video cited in [11] to see these graceful creatures perform their mating dance. The mating pair entwines their tails, and the female aligns a long tube called the ovipositor with the males' pouch. The eggs travel through the tube into the male's pouch where he then fertilizes them. Embryos develop in ten days to six weeks, depending on species and water conditions. When the male gives birth, he pumps his tail until the baby seahorses emerge.

Fig. 1 Seahorses

The males' pouch regulates salinity (dissolved salt content of a body of water) for the eggs, slowly increasing in the pouch to match the water outside as the eggs mature. Once the offspring hatch, the male releases the fry (baby seahorses) and does not provide parental care for them. Most will not consume their own offspring, however, they have been known to do so. Once released, the offspring are independent of their parents. Some spend time among developing ocean plankton before settling. Sometimes the male hippocampus may try to consume some of the previously released offspring. Other species such as the dwarf seahorse (Hippocampes zosterae) hatch immediately and begin life in the benthos (seabed organisms and habitats). Seahorses are generally monogamous, although several species such as the fat-bellied seahorse (Hippocampus abdominalis) are highly gregarious. In monogamous pairs, the male and female greet each other with courtship displays in the morning and sometimes in the evening to strengthen their pair bond. Seahorses spend the rest of the day separated from each other hunting for food [12]. It swims vertically: the seahorse is definitely a fish like no other. Despite its harmless appearance, and although it is a poor swimmer, it is also a formidable predator: its ambush hunting technique allows it to catch its prey with extreme efficiency. Seahorses have a unique way of catching copepods: when one is close enough, they bob their head back while sucking up the water – swallowing the unfortunate crustacean in the process. Before attacking a prey, however, the seahorse must approach it only a millimeter away, so that it is within reach of its snout. However, this is not simple with copepods. The little creatures are indeed able to spot minute movements of the water and escape at high speed; they would even be among the fastest animals in the world, since they can cover a distance equivalent to several hundred times the length of their body in one second! "The task of the seahorse is particularly complicated when it evolves in seagrass beds, because the water there is very little agitated, in particular compared to a coral reef, and therefore each eddy is perceptible there by the prey"[13].

B. Mathematical model of the optimization method based on Seahorses

It is noted that all the equations in this part are taken from [10], we are interested here by the hunting phase. Similar to other existing Meta heuristics, ‘SHO’ also starts from population initialization. Let each hippocampus represent a candidate solution in the problem search space, and the entire hippocampus population (called the hippocampus) can be expressed as:

$$Seahors = \begin{bmatrix} X_1^1 & X_1^{Dim} \\ X_{pop}^1 & X_{pop}^{Dim} \end{bmatrix} \quad (1)$$

With:

X: indicates the variable, Dim Indicates the dimensionality of the variable and pop Indicates the number of individuals in the population.

Each solution is randomly generated between the lower and upper bounds of the specified problem, respectively, with LB and UB. is the search space [L_B, U_B]. The vector of individual variables X_{je} is written as follows:

$$Xje = \left[X_{je}^1, \dots \dots \dots, X_{je}^{Dim}\ \right] \quad (2)$$

Where:

$$X_i^j = rand \times \left(U_{bj} - L_{bj}\right) + L_{bj} \quad (3)$$

The best individual is expressed as follows:

$$X_{elite} = argmin(f(Xi)) \quad (4)$$

Where: f is the evaluation function or objective function.

C. Movement behavior of the hippocampus

For hippocampal movement behavior, the different hippocampal movement patterns approximately obey the normal r and rand(0,1) distribution. To arbitrate exploration and exploitation performance, let put r1 = 0 be the demarcation point, half is used for local development and the other half is used for global search. Therefore, they can be divided into the following two situations:

1) Case 1: Spiral movement

The spiral movement of the hippocampus is accompanied by eddies in the ocean. When the normal random value r_1=1.

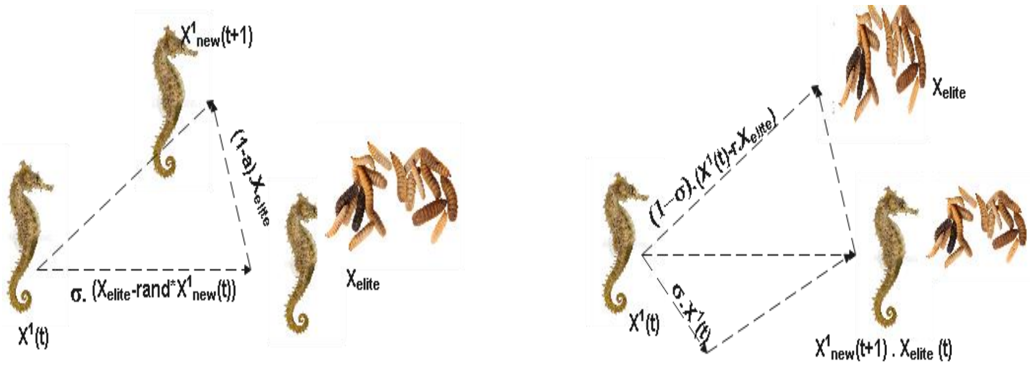


Fig. 2 Spiral movement of the hippocampus

When it is located at the right of the demarcation point, it mainly carries out the local development of SHO. The hippocampus moves along the spiral towards the elite individual X_{elite} mobility, in particular the use of Levy flight to simulate the step size of hippocampal movement, favors hippocampi crossing to other locations with greater probability early in the iteration, avoiding local development excessive SHO. At the same time, this helical movement of the hippocampus continuously changes the angle of rotation. To expand the neighborhood of the existing local solution. In this case, which can be expressed mathematically, the new location of the generated hippocampus is as follows:

$$X_{new}^1(t+1) = X_i(t) + levy(\gamma)\left(X_{elite}(t) - X_i(t)\right) \times x \times y \times z + X_{elite} \quad (5)$$

With:

$$x = \rho \times \cos(\theta) \quad et \;\; y = \rho \times \sin(\theta) \;\; et \;\; z = \rho \times \theta \qquad (6)$$

Represents the three-dimensional components of the coordinates (x, y, z) under the spiral motion, respectively. This is useful for updating the search agent location.

$$\rho = \times \, e^{\theta} \qquad (7)$$

Represent the length of the rod defined by the logarithmic helical constants μ and ϑ with: μ=0.05, ϑ=0.05.

θ is a random value between [0, 2π]; Levy(z) represents the distribution function of Levy flights, and represented by the formula (8) Calculated:

$$Levy(\, z\,) = s \times \frac{\omega \times \sigma}{|k|^{1/\gamma}} \qquad (8)$$

In formula (8), λ is a random number between [0, 2], s is a fixed constant of 0.01, ω and |k| are random numbers between [0, 1], σ is calculated by equation (9):

$$\sigma = \langle \frac{\Gamma(1+\gamma) \times \sin(\frac{\pi\gamma}{2})}{\Gamma\left(\frac{1+\gamma}{2}\right) \times \gamma \times 2(\frac{\gamma-1}{2})} \rangle \qquad (9)$$

2) Case 2: Brownian motion of the hippocampus with waves

Under drift, when you are on the left side of the demarcation point, perform an SHO exploration. In this case, the search operation is very important to avoid local SHO extrema. Brownian motion is used to simulate another motion length of the hippocampus to ensure that it is best explored in the search space. The mathematical expression in this case is:

$$X_{new}^{1}(t+1) = X_i(t) + rand \times l \times \beta_r (X_i(t) - \beta_r X_{elite}) \qquad (10)$$

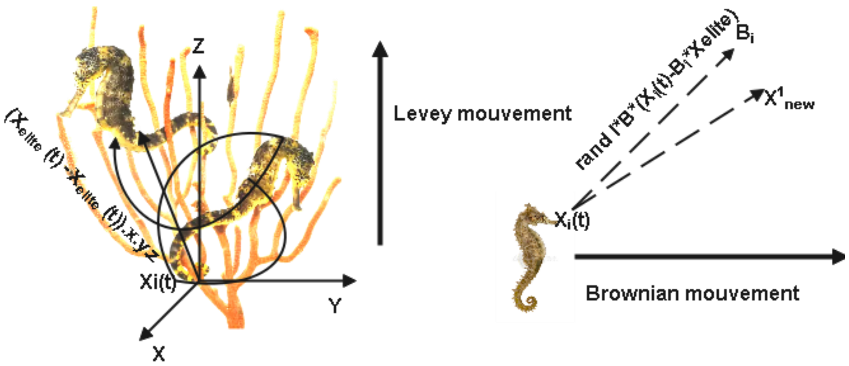


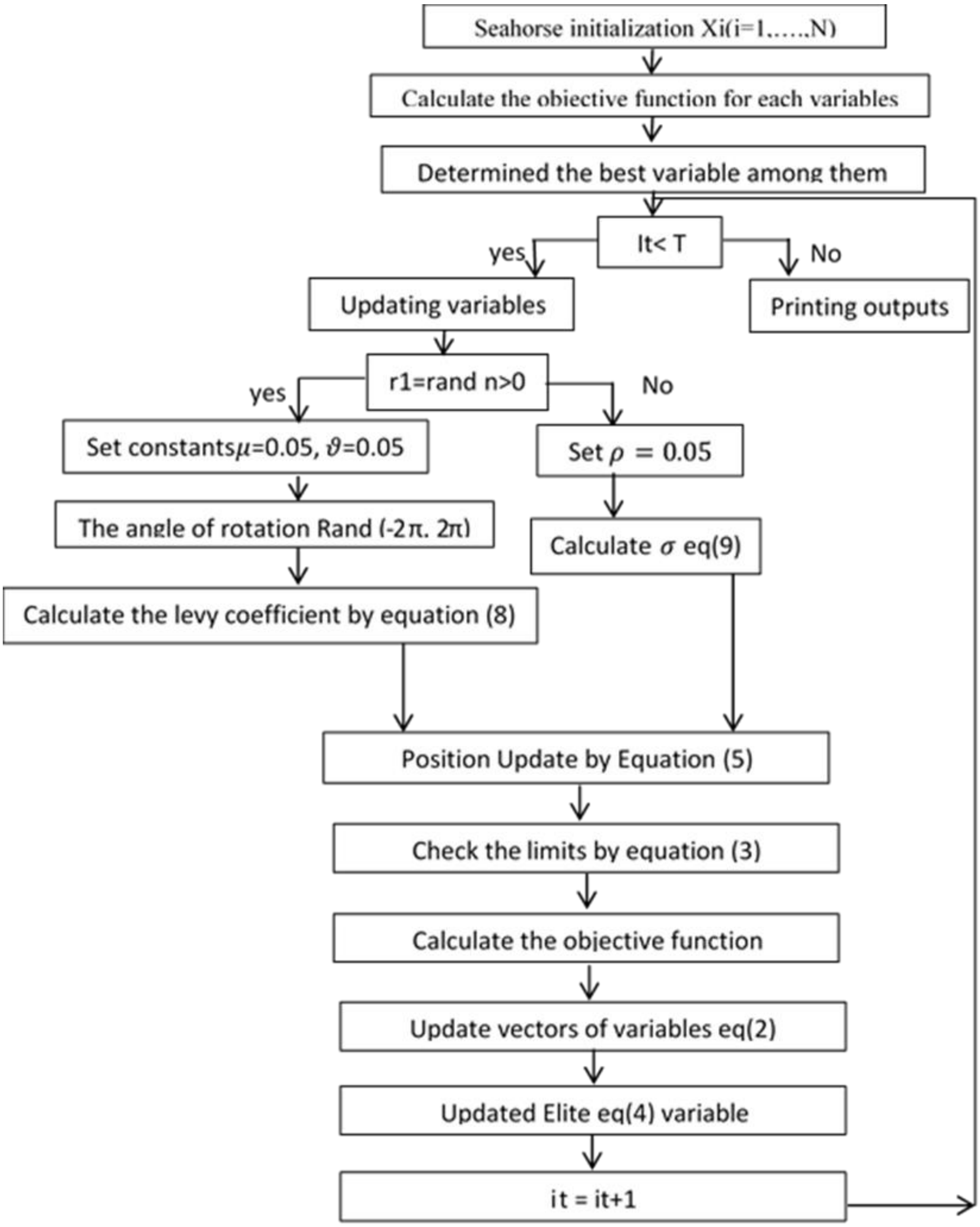
Fig. 3 Brownian motion of the hippocampus

D. Seahorse Optimization Algorithm

Here is the algorithm of the hunting phase of this method:

Inputs: pop: number of hippocampi, T : maximum number of iterations, Dim: variable vector dimension

Output: Xelite: local opimum and f : elite objective function



Algorithm 1. Seahorse Optimization

1. III. FACTS DEVICES

A FACTS is an element based on power electronics consisting in improving the capacity of an interconnected electrical network. In 1988, the Electric Power Research Institute (EPRI) launched a project to study FACTS systems based on power electronics (thyristors and GTO thyristors) in order to better control the transit of powers and the operation of electrical networks. The problem with conventional electromechanical systems is their slow response time. On the other hand, the technology of the FACTS systems which includes static switches, ensures a fast response time due to the absence of inertia. FACTS can therefore control the transit of power in the networks and increase their transmission capacity while maintaining or even improving the stability of the networks [4, 5].

The active power P transited between two voltage networks V1 and V2 phase shifted by δ and connected by a reactance link X is given by equation (11):

$$P = \frac{V_1 * V_2}{X} \sin\delta \qquad (11)$$

This equation shows that it is possible to increase the power transmitted between the two networks either by increasing the voltage and the angle δ, or by artificially reducing the impedance of the link [4, 5].

Playing on one or more of these parameters, FACTS allow precise control of active and reactive power transits, and improved dynamic stability of networks. They also allow industrial consumers to reduce load imbalances and control voltage fluctuations created by rapid variations in reactive power demand, thereby increasing production, reducing costs and extending service life equipment [5].

A. STATCOM Compensator

Figure 4 shows the STATCOM schematic. It is made up of a DC power source, or a capacitor associated with a static converter based on IGBT type semiconductors or GTO thyristors. This converter makes it possible to adjust the level Vs of the voltage at the output of the converter and to maintain the output current Is in quadrature with Vs [6, 7].

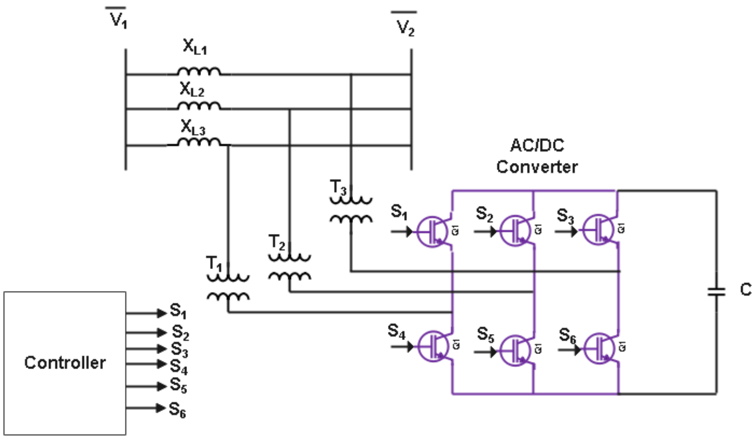


Fig. 4 STATCOM

STATCOM has the advantage of reacting quickly. It can respond in less than one cycle to variations in voltage by supplying or absorbing the appropriate reactive power [7]. The exchange of reactive energy is done by controlling the voltage of the converter ($\overline{V_{sh}}$) which is in phase with the voltage ($\overline{V_s}$) of the busbar. The flow of active and reactive power between these two voltage sources from the network is given by:

$$P_{sh} = \frac{V_s V_{sh}}{X_{sh}} \sin\delta \quad (12)$$

$$Q_{sh} = \frac{V_s}{X_{sh}} (V_{sh} \cos\delta - V_s) \quad (13)$$

δ: is the phase difference between the voltages ($\bar{V_s}$)and ($\overline{V_{sh}}$)

δ being zero, equation (1.63) shows that there is no active power flow between the FACTS device and the network. Equation (1.64) shows that the reactive power exchanged between the network and the FACTS device depends on the difference between ($\bar{V_s}$) and ($\overline{V_{sh}}$). It is given by the expression (14) below:

$$Q_{sh} = \frac{V_s}{X_{sh}} (V_{sh} - V_s) \quad (14)$$

If $V_s = V_{sh}$: no generation or absorption of reactive power.

If $V_s > V_{sh}$: the FACTS device absorbs reactive power causing a decrease in Vs. An inductive current is established between the two voltage sources through the reactance Xsh. This current lags 90° with respect to (V_s) as shown in Figure 5a.

If $V_s < V_{sh}$:: the FACTS device generates reactive power causing an increase in the voltage Vs. The current is capacitive. It is 90° ahead of the node voltage as shown in Figure 5b.

a) Inductive current b) Capacitive current

Fig. 5 Vector diagram of the STATCOM device

2. IV. Global objective function

In order to ensure the object of our study, the global objective function is formulated, for that we based on three main subject function to minimize them which can be expressed mathematically as follows as [1]:

$$Min\, Fg = Min\, (\omega_1 . F_1 + \omega_2 . F_2 + \omega_3 . F_3) \quad (15)$$

Where : $\omega_1, \omega_2, \omega_3$ are the weighting coefficients and $\omega_1 + \omega_2 + \omega_3 = 1$

The first subject function to be considering for the minimization is the total generation cost, this last one represented by following quadratic equation:

$$F_1 = \min(\sum_{n=1}^{ng} \alpha_n + \beta_n P_{gn} + \gamma_n P_{gn}^2) \quad (16)$$

Where: α, β, γ are the fuel cost coefficients of a generator unit.

The second one to be minimized is the active power losses, it can be expressed as:

$$F_2 = \min(P_{losses}) = \min(\sum_{n=1}^{ntl} \lfloor P_{ij}^k - P_{ji}^k \rceil \quad (17)$$

Where: ntl is the number of transmission line and P_{ij}^k is the transmitted power between buses i-j for the line k.

Finally, to enhance the voltage profile performance, we must reduce the voltage deviation in each bus as possible, this one is the third subject function and can be written as :

$$F_3 = \min(VD) = \min(\sum_{n=1}^{Nbus} |V_n - 1.00|^2) \quad (18)$$

Where: 1.00 is the referenced voltage of the load bus in per unit and V_n is the voltage is the voltage of the bus.

B. Equality and Inequality Constraints

To meet the physical aspect of the global objective function, we need to respect some constraints which are the equality and inequality constraints.

1) Equality Constraints

For the manager of the network power, the important and the first mission to be established is the satisfaction of active and reactive demand power including the losses, based on this condition, we can formulate the equality constraints as:

For active power:

$$\sum_{n=1}^{ngn} P_g = \sum_{n=1}^{nd} P_d + \sum_{n=1}^{ntl} P_l \quad (19)$$

For reactive power:

$$\sum_{n=1}^{ngn} Q_g = \sum_{n=1}^{nd} Q_d + \sum_{n=1}^{ntl} Q_l \quad (20)$$

2) Inequality Constraints

Ensuring the active and reactive power demanded must done with respect the limits of such parameters like the voltage limits, active power generation capacity and the reactive one also, this constraint can be summarized as:

$$V_i^{min} < V_i < V_i^{max} \quad (21)$$

$$P_{gi}^{min} < P_{gi} < P_{gi}^{max} \quad (22)$$

$$Q_{gi}^{min} < Q_{gi} < Q_{gi}^{max} \quad (23)$$

For designed the optimal capacity of the STATCOM device, its limit of injected or absorbed reactive power must be defined and respected, for that, we define its Inequality Constraints as :

$$Q_{stat}^{min} < Q_{gstat} < Q_{stat}^{max} \quad (24)$$

1. V. Results and Discussion

Consider the IEEE30 bus system as test system, the performance of the Sea Horses algorithm to find the optimal solution of the power flow included the STATCOM device is performed by using Matlab code. Table 1 and 2 show respectively the input parameters of proposed method and the generator coefficients and limits. For best demonstration of results, comparisons between cases are done:

Firstly, we performed a comparison between the solution of global function using the Sea horses and GA technique [14, 15]; this comparison can show the efficiency of Sea horses algorithm to resolve the optimization problems.

Secondly, the comparison is between the two cases without and with STATCOM using the Sea Horses algorithm in order to show the performance of STATCOM device in reducing the voltage deviation and the power losses.

TABLE I. PARAMETERS OF USED METHODS

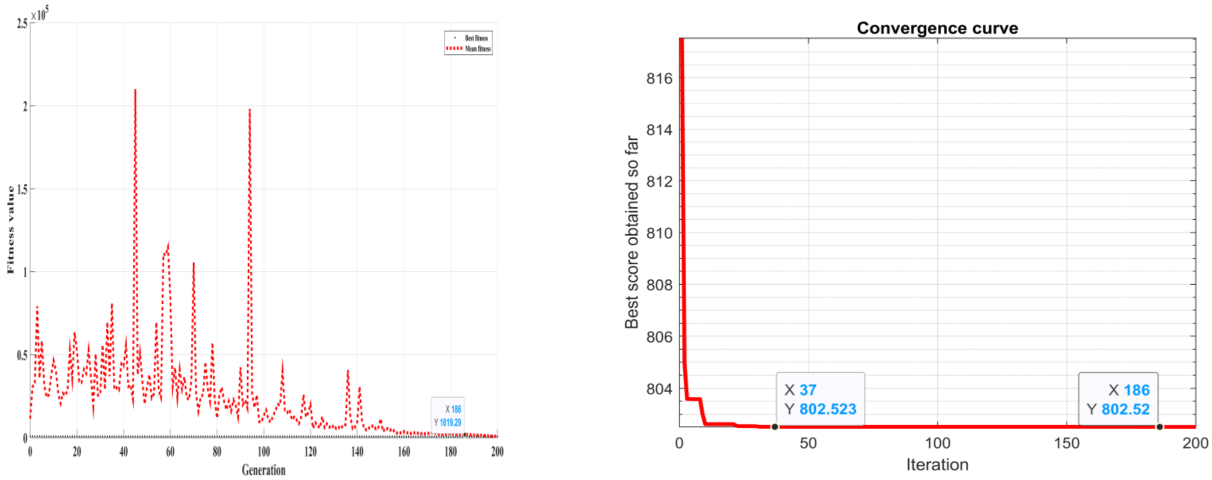
Parameters	GA	SHO
Population Size	100	100
Generations	50	50
Max iteration	//	200
Max Generations	500	//
Dimension	6	6

TABLE II. GENERATOR CHARACTERISTICS OF IEEE 30 BUS SYSTEM

Bus	α	β	γ	P_{gmin}	P_{gmax}
1	0.00375	2	0	50	200
2	0.0175	1.75	0	20	80
5	0.0625	1	0	15	50
8	0.0083	3.25	0	10	35
11	0.025	3	0	10	30
13	0.025	3	0	12	40

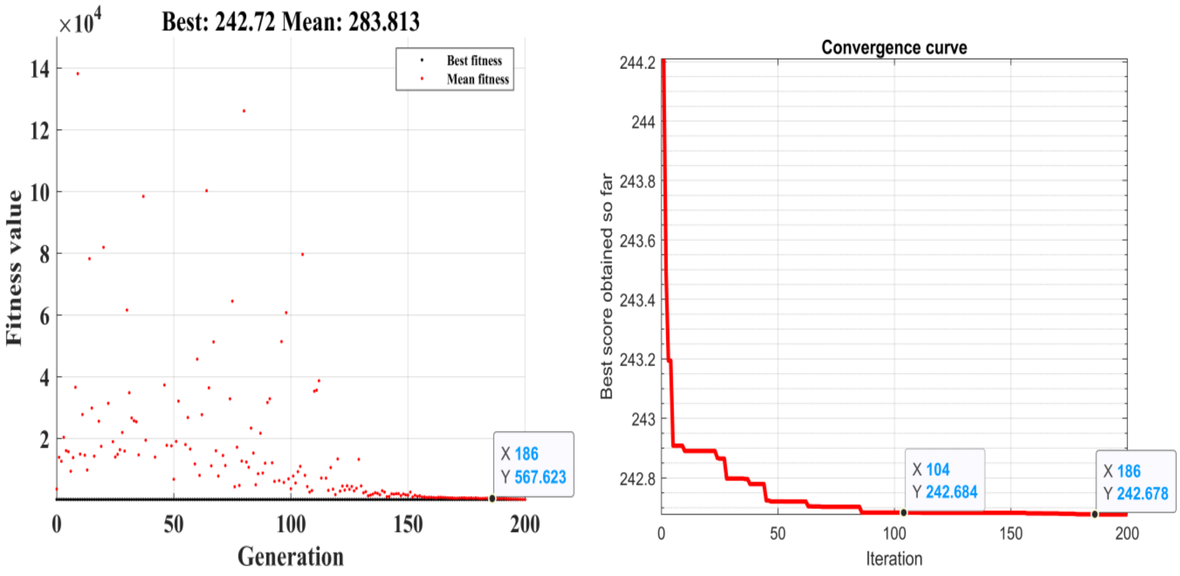
A. SHO vs GA optimization without STATCOM

As mentioned above, the objective of this part is to show the effectiveness of SH to find the best solution to the global objective function. Figures 6a and 6b show the convergence of function ‘F1’ and Figures 7a and 7b show the convergence of the global function ‘F’, using GA and SHO respectively.



(a) (b)

Fig. 6 Convergence of the cost Function (F1)



(a) (b)

Fig. 7 Convergence of the global Function (F)

Based on this results, its clearly that's the SHO method is more efficiency than the GA one, not just in the best solution but also in the convergence time and generation to find the solution, table III resume the output parameters using the two methods:

TABLE III. SHO VS GA OUTPUT

Method	F1	Global F	Convergence Generation/iteration	P_{gt}	Q_{gt}	P_{losses}	DV_{loads}
SHO	802.5233	242.7097	37	293.0052	119.4530	9.7596	0.0015
GA	802.6417	242.7517	200	293.0366	119.5969	9.7921	0.0015

This numerical results can give a clearly comparison between the two methods, the first remark attract the reader is the convergence iteration where the SHO need just 37 iteration to reach the solution, but using GA algorithm need all the generation (200 generation) to reach the best solution. For the other output, we can see a bit enhancement between the SHO and the GA, such the active power losses and the objective function. For the deviation voltage, the two methods give the same value.

In order to choose the best position placement of STATCOM, we focus on the objective function "F3" which represent the DVloads index in PQ bus type that's need to reduce it as possible, figure 8 and figure 9 indicates the magnitude voltage and the DVloads in each bus respectively.

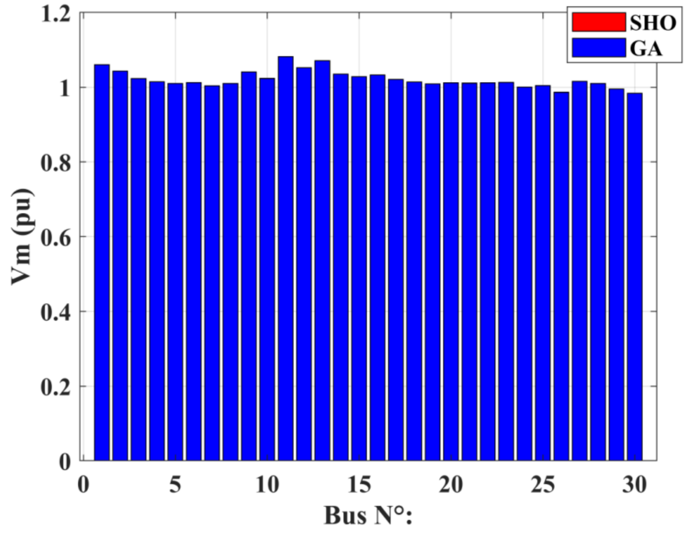


Fig. 8 Voltage magnitude

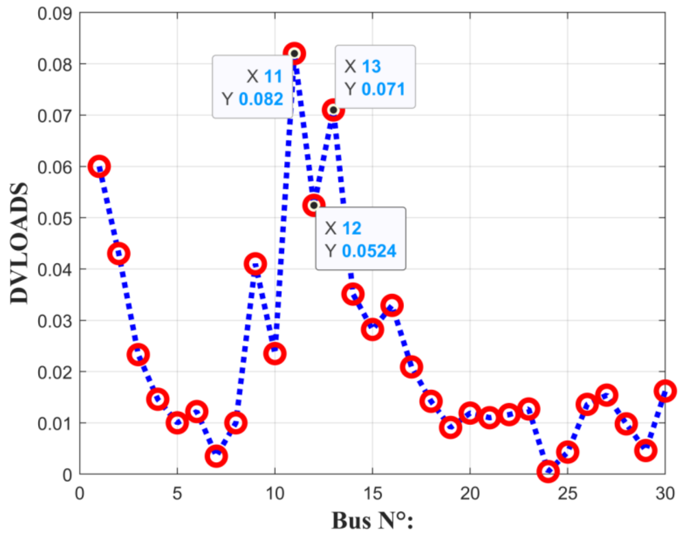


Fig. 9 Voltage Deviation

On the two figures, we can see that the two methods propose the same voltage magnitude, for the voltage deviation, there are three bus mention a great deviation voltage which are : bus 11, bus 12 and bus 13, because the type of bus 11 and 13 is PV one, so the high voltage deviation for PQ bus is 12. Based on this conclusion, the best position to incorporate the STATCOM device is bus 12.

B. SHO optimization with incorporating of STATCOM

In this part, we incorporate the STATCOM in the network, as mention above the best placement position in our case is bus 12. To show the best performance and effect of the STATCOM on the behavior of power network, we examine its effect on all of parameters of this last one. Firstly, Table 4 indicates the output parameters with and without STATCOM

TABLE IV. OUTPUT PARAMETERS WITH AND WITHOUT STATCOM

Method	F1	Global F	P_{gt}	Q_{gt}	P_{losses}	D_{Vloads}
Without STATCOM	802.5233	242.7097	293.0052	119.4530	9.7596	0.0015
With STATCOM	726.4925	220.5766	292.2243	161.6378	8.8243	0.0010

As we can show in table 4, the effect of using STATCOM is very clearly, by fixed the voltage of bus 12 on 0.98pu, we can perform the parameters of our studied network, the cost function “F1” and also the global function “F” are reduced from 802.5233 $/MWh to 726.4925 $/MWh and from 242.7097$/MWh to 220.5766 $/MWh respectively, this result represent an important gain in the objective function which affect all other parameters like the active power losses which reduced from 9.7596MW to 8.8243MW and the voltage deviation in the PQ bus from 0.0015pu to 0.0010pu.

To confirm the obtained results, figure 6 shows the magnitude voltage of each bus before and after insertion the STATCOM device.

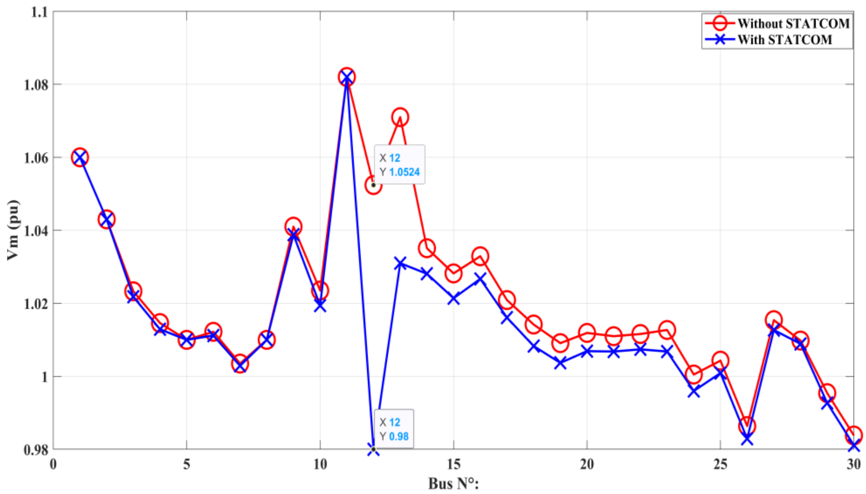


Fig. 10 Magnitude voltage with and without STATCOM

As we can see in the figure, using STATCOM give the opportunities to controller the voltage in the inserting position, by maintaining the magnitude voltage of bus 12 in 0.98pu, affect all other voltage buses and then make a change in the load flow.

The effect on controlling the voltage bus using STATCOM device and SHO optimization method demonstrated by Figure 11 that show the voltage deviation in each bus in case of integrating the STATCOM device.

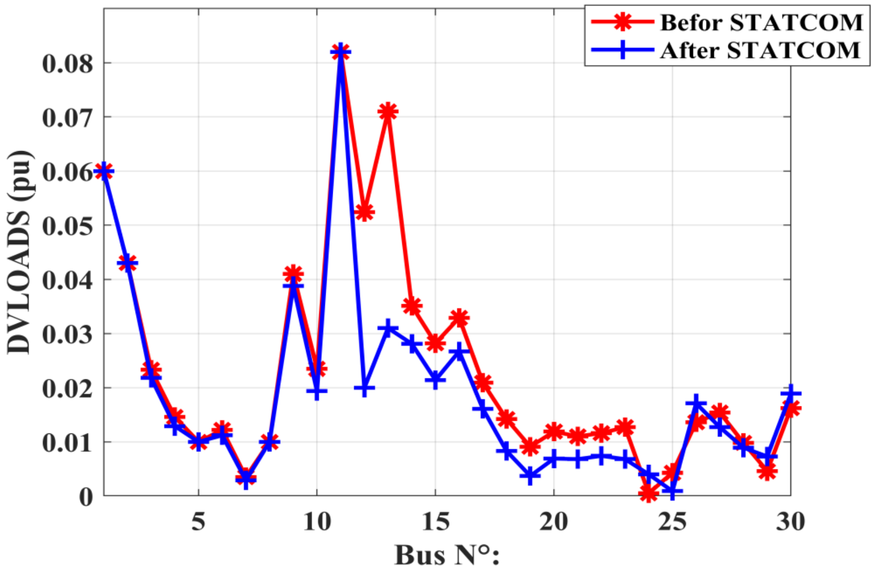


Fig. 11 DVLOADS

Finally, the effect of the setting voltage value of bus 12 by the STATCOM on the different output parameters is shown by table 5 below:

TABLE V. SETTING VOLTAGE VALUE EFFECT

Setting value	F1	F	P_{losses}	DV_{loads}	Injected Q_{statc}
1.05	726.4925	220.5866	13.2474	0.0015	2.3990
1.00	726.4925	220.5766	11.3372	0.0010	2.1312
0.98	726.4925	220.5766	8.8243	0.0010	2.0024
0.95	726.4925	221.4028	17.2727	0.0010	1.7641

It is clearly seen that the bus voltage setting value by the STATCOM plays a crucial role in improving the performance of the electrical network and reducing the objective functions as well as the active power losses and the deviation in the voltage.

1. IV. CONCLUSION

In this work, an application of SHO optimization for installing the STATCOM device in the best position to improve the behavior of the power system network, with the objective of reducing total generation cost, total active power losses and voltage deviation is also presented. To show the performance of SHO in solving the optimal power flow problem under different conditions, a comparison with GA has also been done. Based on the obtained results, the proposed approach presents its effectiveness. This analysis based on SHO Algorithm optimization method has been used to identify the optimal location of the STATCOM. The results show that using this FACTS device type in the IEEE 30 bus system can minimize the total cost of generation, reduce the total active power losses and the voltage deviation and then improve the voltage profile of the system.

As perspective for this work, the next one is to test the proposed method on other IEEE bus system and with different objectives functions and under different conditions such the integration of Renewables energies sources in the network

REFERENCES

[1] S. A. Adegoke and Y. Sun, "Optimum Reactive Power Dispatch Solution using Hybrid Particle Swarm Optimization and Pathfinder Algorithm", International Journal of Computing., vol *21., no.4, pp. 403-410. 2022. DOI 10.47839/ijc.21.4.2775*

[2] B. Venkateswara Rao and G. V. Nagesh Kumar, "Sensitivity Analysis based Optimal Location and Tuning of Static VAR Compensator using Firefly Algorithm", Indian Journal of Science and Technology., vol 7., no.8, pp. 1201–1210, August 2014.

[3] C. Zhang, C. Chen, J. Sun, P. Zheng, X. Lin and Z. Bo, "Impacts of electric vehicles on the transient voltage stability of distribution network and the study of improvement measures," in IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), Hong Kong, China, 2014, pp. 1-6, doi: 10.1109/APPEEC.2014.7066085.

[4] K. K. Sen and M. L. Sen, "Mechanically Switched FACTS Controllers in Introduction to FACTS Controllers: Theory, Modeling, and Applications", IEEE, 2009, pp.107-116, doi: 10.1002/9780470524756.ch5.

[5] M. Eremia; C. Liu and A. Edris, FACTS Technologies in Advanced Solutions in Power Systems: HVDC, FACTS, and Artificial Intelligence, IEEE, 2016, pp.269-270, doi: 10.1002/9781119175391.part2.

[6] Y. Yuan, J. Zhou, Y. Zhang, and al. "Low-capacitance cascaded H-bridge STATCOM for full power operation", J. Power Electron., vol 22, pp. 287–296. 2022. DOI: https://doi.org/10.1007/s43236-021-00349-y

[7] X. Wang, M. Wang, L Wang, and al. "Parameters optimization design for LCL-type STATCOMs under complex power grid". J. Power Electron., vol. 20, pp. 566–579, 2020. DOI: https://doi.org/10.1007/s43236-020-00041-7

[8] A. Bilbao and al., "Current References Limitation Method Considering Voltage and Current Maximums for STATCOMs Providing Simultaneously Reactive Power and Current Harmonics," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 10, no. 2, pp. 2559-2575, April 2022, doi: 10.1109/JESTPE.2022.3146203

[9] S. Zhao, T. Zhang, S. Ma, et al. "Sea-horse optimizer: a novel nature-inspired meta-heuristic for global optimization problems". Applied Intelligence, September 2022., DOI: https://doi.org/10.1007/s10489-022-03994-3

[10] (2022) Function search algorithm based on Sea horses optimization algorithm. [Online]. Available: https://blog.csdn.net/weixin_43821559/article/details/127358197

[11] Aquatiks (2021), Seahorse Giving Birth 'Full Reproductive Cycle, [Online]. Available: https://www.youtube.com/watch?v=6zKcNC8Bp3Y.

[12] S. A. Lourie, S. J. Foster, E. W. T. Cooper and A. C. J. Vincent, "A Guide to the Identification of Seahorses", Project Seahorse and TRAFFIC North America, March 2004.

[13] B. Gemmell, J. Sheng and E. Buskey, "Morphology of seahorse head hydrodynamically aids in capture of evasive prey"., nature communications vol 4., no 2840., November 2013.DOI : https://doi.org/10.1038/ncomms3840

[14] R. S. Danaraj, "Solution to Optimal Power flow by Genetic Algorithm", EEE Department Jubail Industrial Collge, Jubail,Kingdom Of Saudi Arabia.

[15] R. Effatnejad, H. Aliyari, and M. Savaghebi, "Solving Multi-Objective Optimal Power Flow Using Modified GA and PSO Based on Hybrid Algorithm", Journal of Operation and Automation in Power Engineering, vol 5., no 1., Pages: 51-60., June 2017. DOI: 10.22098/JOAPE.2017.548