# Smart Enhancement of Egyptian Electrical Transmission Network using BPSO

Rabab R. M. Eiada[1] and Ebrahim A. Badran[2]
[1] New Damietta High Institute of Engineering and Technology, Ministry of High Education, New Damietta, Egypt
[2] Electrical Engineering Department, Faculty of Engineering, Mansoura University, Mansoura , Egypt
rabab.reda@ndeti.edu.eg & ebadran@mans.edu.eg

**ABSTRACT**
Flexible Alternating Current Transmission Systems (FACTS) are installed to improve the electrical power systems performance. Unified Power Flow Controller (UPFC) is used for controlling both flow the active and reactive power in electrical transmission systems. In this paper, a proposed algorithm based on Binary Particle Swarm Optimization (BPSO) is designed to select the optimal location, and to find the optimal parameters setting for UPFC. This is carried out for achieving two objectives: minimizing the system transmission losses and minimizing the total cost. The validation of the proposed algorithm is implemented on part of Egyptian Electricity transmission Network. The simulation is carried out using MATLAB/Simulink. The simulation results ensure the ability of the proposed algorithm for achieving the goals.

**Keywords:** BPSO, UPFC, Egyptian Electricity Network, Smart Transmission System, Losses, Cost.

# I. INTRODUCTION

Flexible Alternating Current Transmission Systems (FACTS) is an advanced technology, and its key function is to improve the control of transmission systems and power handling capability.

Unified Power Flow Controller (UPFC) is considered to have the power capability, as one of the FACTS devices. Therefore, UPFC is used for increasing the transmission system performance. UPFC is able to control the power flow, voltage regulation and enhance the voltage stability [1]. UPFC is utilized with the properties of voltage regulation, series compensation and phase shifting [2]. It is able to control the power flow through transmission lines [3].

UPFC Mathematical modeling is progressed for calculating the steady-state and dynamic behaviors for power problems [4]. For systems without power controller and power system stabilizers design are used to achieve effective. The control methods are presented for UPFC control such as conventional control, Genetic algorithm GA [5], Artificial Neural Network (ANN) control methods and Fuzzy Logic (FL) [6].

The selection of an effective optimization technique is very critical for a nonlinear system with different operating constraints. Researchers have widely used different algorithms for overcoming nonlinear programming problems. Particle Swarm Optimization (PSO) is used to obtain better optimization results. PSO is a parallel multi-agent evolutionary algorithm. Particles are mathematical structures moving around multidimensional search spaces. At any given moment, each particle has its velocity and location. The positioning of a particle vector concerning the origin of the search space is an experimental solution to the search problem.

Binary Particle Swarm Optimization (BPSO) is a modified particle swarm optimization (PSO) that can be treated as a continuous PSO [7]. In BPSO, particles update local best and global best as in the real version worth. The difference between PSO and BPSO is that velocities of the particles are rather defined in terms of probabilities. Using this definition, a velocity must be restricted within the range [0, 1].

In this paper, a proposed algorithm using BPSO is designed to select the optimal placement, and to find the optimal UPFC element setting of UPFC in part of Egyptian Electricity transmission Network.

# II. PROBLEM FORMULATION

## 2-1 UPFC model:

Fig. 1 illustrates the schematic diagram of UPFC, which contains two voltage source converters, one in shunt, as static synchronous compensator (STATCOM), and the other in series, as static synchronous series compensator (SSSC) [8]. Each converter independently absorbs or generates reactive power at AC terminals by using NR algorithm to control the power flow in transmission lines [9].

The main reasons behind the wide spreads of UPFC are its ability to control the active power and reactive power flow, to maintain the regulated DC voltage in the operating conditions [9].

The controllable injected voltage of series converter controls the voltage magnitude Vser and the angle θser. The adjustable voltage at one end of the line would allow the power flow through the line to be controlled. Also, the shunt controller is like the series controller. The difference being that they inject current at the point where they are connected. If the injected current is in phase quadrature with the line voltage, the controller adjusts reactive power while if the current is not in phase quadrature, the controller adjusts active power [10].

Power flow through AC transmission lines depends on the line parameters, the voltages at the sending-end (at bus i), the voltage at the receiving-end (at bus j) and impedance of the line. UPFC is considered link between the two terminal, sending-end and receiving-end.

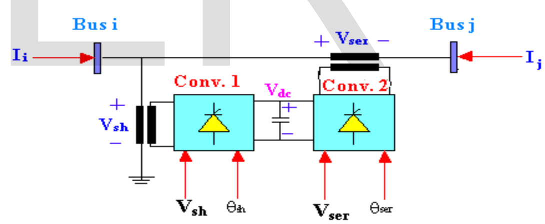



Fig. 1 Schematic diagram of UPFC

The major problems in the UPFC are identifying the location, and the optimal parameters of UPFC to enhance the voltage stability of the power system [11]. The location of UPFC is considered and the amount of voltage and angle to be injected are calculated. The optimal location and optimal parameters setting of UPFC can be determined by using BPSO [12].

The parameters of UPFC are modeled using power flow equations and thus they are used to evaluate the injected of voltage and power angle as given in equations (1) – (4) [13].

$$P_i = V_i^2 G_{ii} + V_i V_j \left(G_{ij}\cos(\delta_i-\delta_j) + B_{ij}\sin(\delta_i-\delta_j)\right) + V_i V_{ser}\left(G_{ij}\cos(\delta_i-\theta_{ser}) + B_{ij}\sin(\delta_i-\theta_{ser})\right) + V_i V_{sh}\left(G_{sh}\cos(\delta_i-\theta_{sh}) + B_{sh}\sin(\delta_i-\theta_{sh})\right) \quad (1)$$

$$Q_i = -V_i^2 B_{ii} + V_i V_j\left(G_{ij}\sin\left(\delta_i-\delta_j\right) - B_{ij}\cos\left(\delta_i-\delta_j\right)\right) + V_i V_{ser}\left(G_{ij}\sin(\delta_i-\theta_{ser}) - B_{ij}\cos(\delta_i-\theta_{ser})\right) + V_i V_{sh}\left(G_{sh}\sin(\delta_i-\theta_{sh}) - B_{sh}\cos(\delta_i-\theta_{sh})\right) \quad (2)$$

$$P_j = V_j^2 G_{jj} + V_j V_i\left(G_{ij}\cos\left(\delta_j-\delta_i\right) + B_{ij}\sin\left(\delta_j-\delta_i\right)\right) + V_j V_{ser}\left(G_{jj}\cos\left(\delta_j-\theta_{ser}\right) + B_{jj}\sin\left(\delta_j-\theta_{ser}\right)\right) \quad (3)$$

$$Q_j = -V_j^2 B_{jj} + V_j V_i\left(G_{ij}\sin\left(\delta_j-\delta_i\right) - B_{ij}\cos\left(\delta_j-\delta_i\right)\right) + V_j V_{ser}\left(G_{jj}\sin\left(\delta_j-\theta_{ser}\right) - B_{jj}\cos\left(\delta_j-\theta_{ser}\right)\right) \quad (4)$$

where $P_i$ and $P_j$ are the active power injection at bus i and bus j. $Q_i$ and $Q_j$ are the reactive power injection at bus i and bus j. $V_i$ and $V_j$ are the voltage at bus i and bus j. $\delta_i$ and $\delta_j$ are the phase shift angle at bus i and bus j. $\theta_{ser}$ and θsh are the injected phase shift angle. $V_{sh}$ and $V_{ser}$ are the injected voltage by shunt and series inverters. $G_{ij}$ and $B_{ij}$ are the conductance and susceptance between bus i and bus j. $G_{sh}$ and $B_{sh}$ are the conductance and susceptance by shunt inverter. $P_{ser}$ is the injected active power by series inverter. $Q_{ser}$ is the injected reactive power by series inverter. $P_{sh}$ is the injected active power at shunt inverter. $Q_{sh}$ is the injected reactive power at shunt inverter.

The controllable magnitude and phase angle of series inverter is controlled to inject a symmetrical three-phase voltage system to control active power flow and reactive power flow in transmission lines as given in equations (5) and (6).

$$P_{ser} = V_{ser}^2 G_{jj} + V_{ser} V_i\left(G_{ij}\,cos(\theta_{ser}-\delta_i) + B_{ij}\,sin(\theta_{ser}-\delta_i)\right) + V_{ser} V_j\left(G_{jj}\,cos\left(\theta_{ser}-\delta_j\right) + B_{jj}\,sin\left(\theta_{ser}-\delta_j\right)\right) \quad (5)$$

$$Q_{ser} = -V_{ser}^2 B_{jj} + V_{ser} V_i\left(G_{ij}\sin(\theta_{ser}-\delta_i) - B_{ij}\cos(\theta_{ser}-\delta_i)\right) + V_{ser} V_j\left(G_{jj}\sin\left(\theta_{ser}-\delta_j\right) - B_{jj}\cos\left(\theta_{ser}-\delta_j\right)\right) \quad (6)$$

Also, the shunt inverter is operated in such a way as to demand this dc terminal power from the line and maintaining the voltage across the storage capacitor as given in equations (7) and (8).

$$P_{sh} = -V_{sh}^2 G_{sh} + V_{sh} V_i(G_{sh}\cos(\theta_{sh}-\delta_i) + B_{sh}\sin(\theta_{sh}-\delta_i)) \quad (7)$$

$$Q_{sh} = V_{sh}^2 B_{sh} + V_{sh} V_i(G_{sh}\sin(\theta_{sh}-\delta_i) - B_{sh}\cos(\theta_{sh}-\delta_i)) \quad (8)$$

### 2-2 Objective functions

*1)* The main objective of this paper is to determine the optimal location and optimal parameter setting of the UPFC in the network for enhancing the system security. This enhancement can be achieved through minimizing the losses in lines with bus voltage limit violations and reducing the total cost under different conditions.

The objective functions are divided into two scenarios. **Firstly**, minimizing the total power losses as in equation (9*)*

$$P_{Loss} = \min\left(\sum_{n=1}^{N} P_i\right) = \min\left(\sum_{n=1}^{N} P_{Gi} - \sum_{n=1}^{N} P_{Di}\right) \quad (9)$$

**Secondly,** minimizing the total cost as in equation (10).

$$C(P_{Gi}) = \min\left(\sum_{i=1}^{N}(a + bP_{Gi} + cP_{Gi}^2)\right) \quad (10)$$

### 2.3 Constrains

**a) Equality constraints**

In this optimization, the equality constraints are the power flow equations, which are given in general form as follows:

$$P_{Gi} - P_{Di} = P_i \quad (11)$$

$$Q_{Gi} - Q_{Di} = Q_i \quad (12)$$

**(b) Inequality constraints**

$$V_{imin} \le V_i \le V_{imax} \quad (13)$$

$$Q_{imin} \le Q_i \le Q_{imax} \quad (14)$$

**(c) UPFC constraints**

In this paper, the following variables are considered as the optimization variables:

1. The series voltage source magnitude of the UPFC ($V_{ser}$) is considered between (0.02, 0.2).
2. The series phase angle of the UPFC ($\theta_{ser}$) is considered between (0, 2π).
3. The shunt phase angle of the UPFC ($\theta_{sh}$) is considered between (0, 2π).
4. The shunt reactive current of the UPFC (Iq) is considered between (0.05,0.4).
5. The shunt voltage source magnitude of the UPFC ($V_{sh}$) is considered between (0.9, 1.1).

where $P_{Gi}$ : the active power generation at bus i.
$P_{Di}$ : the active power load at bus i.
$Q_{Gi}$ : the reactive power generation at bus i.
$Q_{Di}$ : the reactive power load at bus i.
$V_{imin}$ and $V_{imax}$ : the minimum and maximum values of voltage at bus i.
$Q_{imin}$ and $Q_{imax}$ : the minimum and maximum values of reactive power at bus i.

## III. The Proposed Algorithm

Fig. 2 shows the flow-chart of proposed algorithm, which consists of five steps:

*2)* ***Input data of Egyptian Electricity Network,*** Input data of Egyptian Electricity Network, such as the active power and the reactive power at the generation and load buses, voltage and phase angle at all buses, type of buses, resistance and reactance of transmission lines, the connection of the buses are defined. The parameters of BPSO is given in Table 1.

*3)* ***Analysis of Power flow,*** power flow in the transmission lines, the reactive power and the voltages at all buses are calculated. In addition, the required reactive power is determined.

*4)* ***Optimal location of UPFC***, the optimal location of UPFC by ***using BPSO*** are determined based on the required reactive power at all buses.

*5)* ***Optimal parameters setting of UPFC,*** the best parameters setting of UPFC such as injected voltages ($V_{ser}$ ) and the injected voltage ($V_{sh}$) in series and shunt is carried out. Also, the active power and required reactive power (Pp, Qq), and the phase shift angle of series controller and phase shift angle of shunt controller ($\theta_s$ , $\theta_{sh}$) are evaluated by power flow control in Transmission lines.

*6)* ***Power flow Modification***, the new power flow results are calculated with the proposed algorithm.

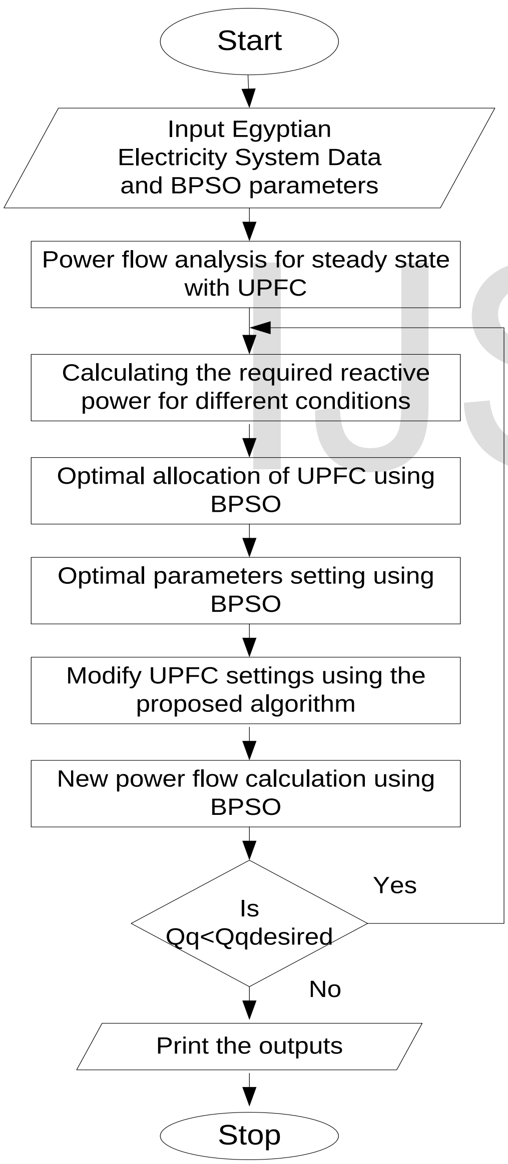



Fig. 2. The proposed algorithm flow chart

**Table 1:** Parameter Initialization of the Binary PSO Techniques

| Swarm Intelligence ( SI) | |
|---|---|
| **Particle Swarm Optimization** | |
| NP | 30 |
| $G_{max}$ | 100 |
| NV | 5 |
| LI | 5 |
| C1, C2 | 1.5 |
| $W_{max}$ | 0.9 |
| $W_{min}$ | 0.4 |
| Termination criterian | $1*e^{-6}$ or $G_{max}$ |
| Deviation of initial velocities | 10 |

## IV. Test system Description

The proposed Algorithm is tested on a part of the Egyptian Electricity Network system. The test system consists of twenty lines, fourteen buses interconnected through transmission lines, five power plants at buses1, 2, 3, 5, and 8 and load buses at buses 2, 3, 4, 5, 6, 7, 8, 9, 19, 11, 12, 13, and 14 as shown in Fig. 3 [14]. The system data include; load data, parameters of transmission lines, transformer data and generating units' data is given in [14].

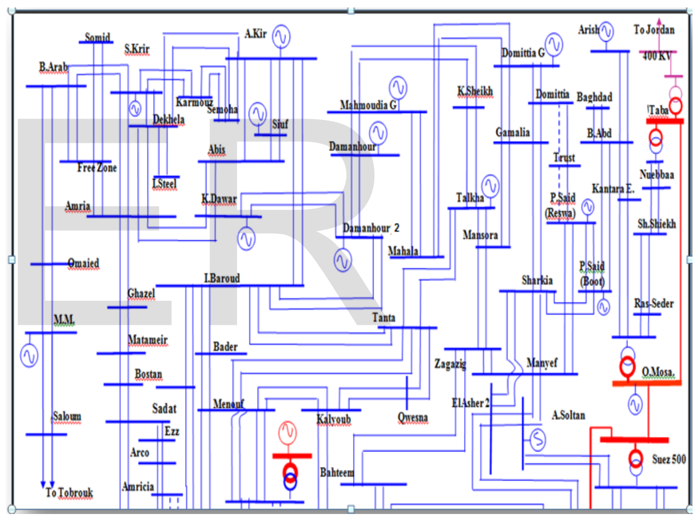


Fig. 3. The part of the Egyptian Electricity Network Test System

## V. RESULTS AND DISCUSSION

By applying the proposed algorithm on this case, the results obtain the optimal location and optimal parameters setting of UPFC. The optimal location of UPFC is determined between Damanhour (bus 2) and Damanhour 2 (bus 4).

Table 2 shows the optimal locations and optimal parameter setting of UPFC obtained by proposed algorithm (after 100 trials) at different condition. When line 1, 3, 4, 9, 14, 16, 17, or 20 is outage the proposed algorithm selects bus 6 as the optimal location of UPFC. And when line 10 is outage, the proposed algorithm selects the optimal location of UPFC at bus 19. Also, when line 2 is outage, bus 7 is selected as the optimal location of UPFC and when line 15 is outage, the optimal location of UPFC is selected at bus 17. In addition, when line 5, 7, 8, and 13 is outage the proposed algorithm selects the optimal location of UPFC at bus 20.

Also, Table 2 illustrates the optimal settings of UPFC for all cases given above. They include injected voltage by shunt inverter (Vsh ) and series inverter (Vser), and the optimal injected phase angle of shunt inverter (θsh ) and series inverter (θser ).

In addition, the proposed algorithm is used to reduce the total power losses, and to reduce the total cost. This is achieved using the proposed algorithm according to determining the required reactive power at all buses.

**Table 2:** The optimal locations and optimal parameter setting of UPFC obtained by applying BPSO techniques

| Outage line | From bus | To bus | Optimal location of UPFC | Parameters setting of UPFC | | | |
|---|---|---|---|---|---|---|---|
| | | | | $V_{ser}$ | $\theta_{ser}$ | $V_{sh}$ | $\theta_{sh}$ |
| 1 | 1 | 2 | 6 | .189 | -1.25 | 1.08 | .34 |
| 3 | 2 | 3 | 6 | .074 | -2.45 | 1.09 | -.67 |
| 2 | 1 | 5 | 7 | .229 | -2.54 | 1.05 | -.23 |
| 10 | 5 | 6 | 19 | .191 | 1.79 | 0.93 | -.42 |
| 4 | 2 | 4 | 6 | .101 | -2.76 | 1.09 | -.68 |
| 14 | 7 | 8 | 6 | .042 | 1.34 | 1.08 | -.73 |
| 15 | 7 | 9 | 17 | .805 | -1.23 | 0.95 | -.45 |
| 13 | 6 | 13 | 20 | .190 | -2.86 | 0.99 | .44 |
| 5 | 2 | 5 | 20 | .489 | -2.23 | 0.90 | -.76 |
| 7 | 5 | 4 | 20 | .014 | 1.43 | 0.90 | -.34 |
| 8 | 4 | 7 | 20 | .096 | -2.67 | 1.05 | .76 |
| 9 | 4 | 9 | 6 | .100 | -2.45 | 0.90 | -.72 |
| 16 | 9 | 10 | 6 | .100 | -2.23 | 0.90 | -.72 |
| 17 | 9 | 14 | 6 | .174 | -2.23 | 0.92 | -.23 |
| 20 | 13 | 14 | 6 | .984 | -2.36 | 1.09 | -.35 |

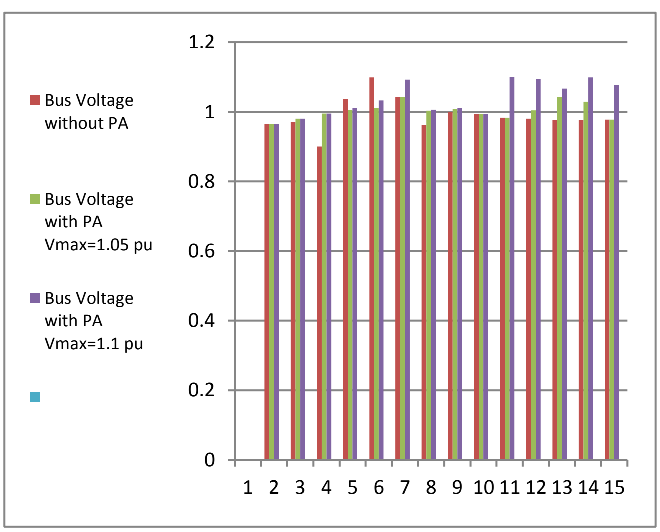
Thereafter, the required reactive power is calculated according to the optimized voltages. Also, the absorbed / injected reactive powers are determined for the controlled buses.

Fig. 4 shows the voltages of all buses with load variations at Damanhour 2 and with generation variations at Talkha (bus 3). Fig. 4a shows the voltage of all buses when Talkha generation unit is 200 MW & 80 MVAR and the load at Damanhour 2 are 100%, 110%, or 120% of the full load.

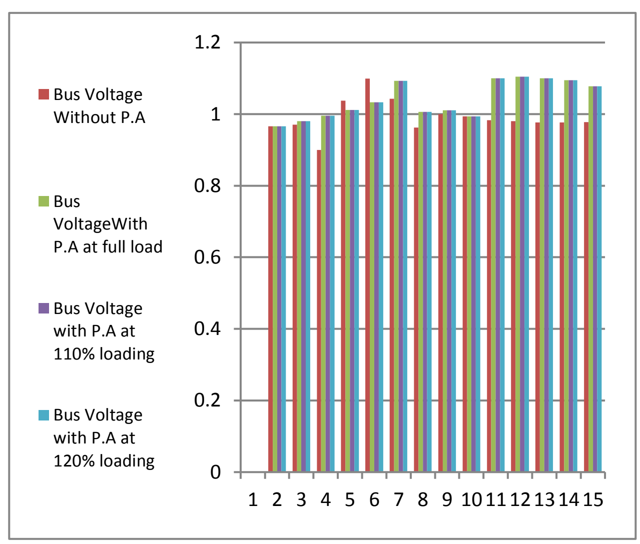
Also, Fig. 4b and Fig. 4c show the voltages when Talkha generation unit is 100 MW & 40 MVAR and 50 MW & 20 MVAR, respectively with the same load variation at Damanhour 2. It can be seen that, the proposed algorithm enhances the voltage buses to maintain the voltage from 0.9 pu to 1.1 pu within acceptable limits.

A different condition is used for verification of the proposed algorithm. The upper voltage constraint is change to 1.05 pu. Fig. 4d shows a comparison between the voltages of all buses for both constraints; 1.1 pu and 1.05 pu, and without the proposed algorithm. It is found that the proposed algorithm successes in adjusting the buses voltage within the new value of limit. Fig. 5 shows the reactive power at all buses with load variations at Damanhour 2 and with generation variations at Talkha.

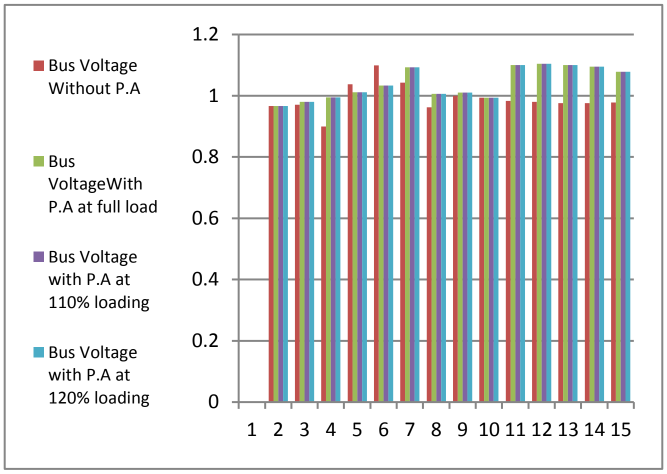
Figs. 5a, 5b, and 5c show the reactive power when Talkha generation unit is 200MW & 80 MVAR, 100 MW & 40 MVAR, and 50 MW & 20 MVAR respectively with the load at Damanhour 2 are 100%, 110%, and 120% of the full load. It can be seen that, the reactive power buses within the constraints by using the proposed algorithm are calculating. The proposed algorithm improves the reactive power flow of the transmission lines.



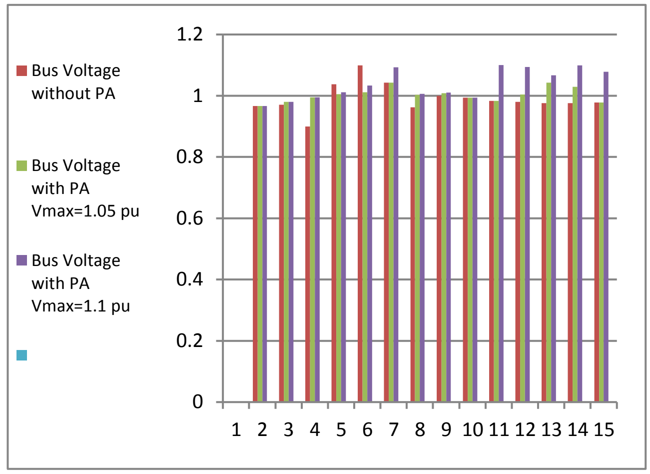

a) generation of 200MW& 80MVAR




b) generation of 100MW& 40MVAR




c) generation of 50MW& 20MVAR




d) generation of 200MW& 40 MVAR with different voltage constraints

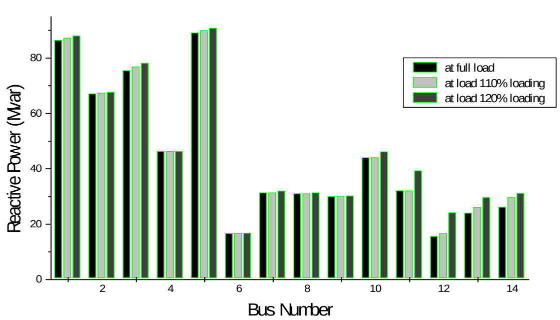
Fig. 4 The voltages of all buses based on different loads and generation at Damanhour 2 bus and Talkha bus

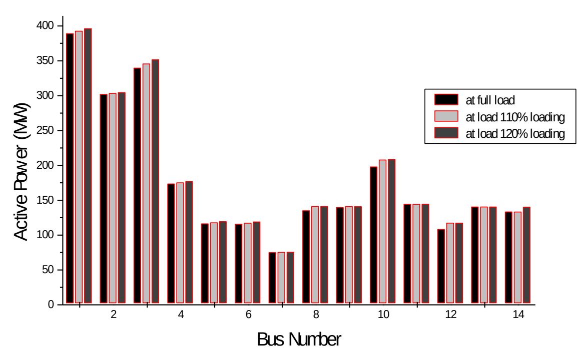
Also, Fig. 6 shows the active power at all buses with load variations at Damanhour 2 bus and with generation variations at Talkha bus. Figs. 6a, 6b, and 6c show the active power when Talkha generation unit is 200 MW & 80 MVAR, 100 MW & 40 MVAR, and 50 MW & 20 MVAR, respectively with the same load at Damanhour 2; at different condition of load. It can be seen that, the active power buses are within the constraints based on the proposed algorithm. So, the proposed algorithm improves the active power flow of the transmission lines.

Fig. 7a shows the total power losses during different load conditions without proposed algorithm and with proposed algorithm. It can be seen that the proposed algorithm reduces the power losses from 0.08056 pu to 0.08041 pu at full load, with the generation at Talkha bus of 200 MW & 80 MVAR, from 0.08046 pu to 0.08037 pu at generation of 100 MW & 40 MVAR, and from 0.08042 pu to 0.08032 pu at generation of 50 MW & 20 MVAR.

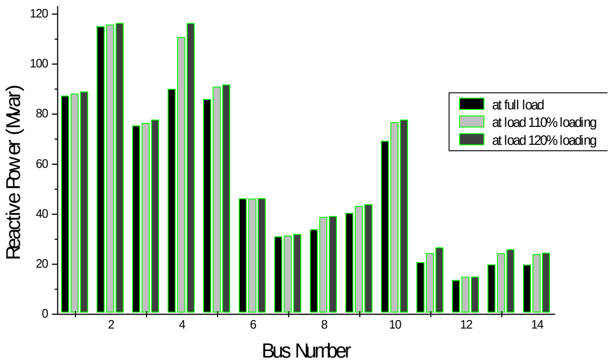
In addition, when increases the load, Fig. 7b explains the total power losses without proposed algorithm and with the proposed algorithm. It can be seen that, the proposed algorithm reduces the total power losses from 0.08043 pu to 0.08029 pu at 110% loading, with the generation at Talkha bus of 200 MW & 80 MVAR from 0.08034 pu to 0.08026 pu at generation of 100 MW & 40 MVAR, and from 0.08092 pu to 0.08021 pu at generation of 50 MW & 20 MVAR.

Fig. 7c gives the total power losses without and with the proposed algorithm. It can be seen that, the proposed algorithm minimizes the total power losses from 0.08031 pu to 0.08016 pu at 120% for increasing load, with the generation at Talkha bus of 200 MW & 80 MVAR, from 0.08022 pu to 0.087014 pu at generation of 100 MW & 40 MVAR, and from 0.08017 pu to 0.0801 pu at generation of 50 MW & 20 MVAR.

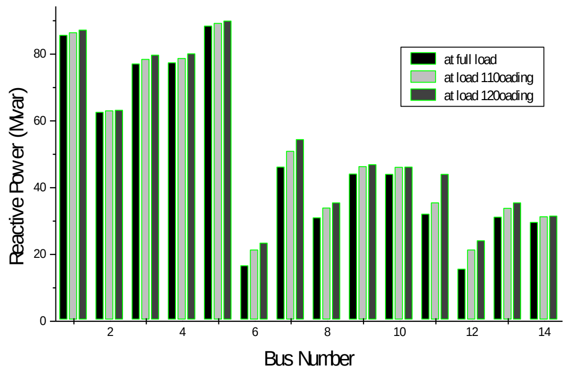


At generation of 200 MW& 80MVAR



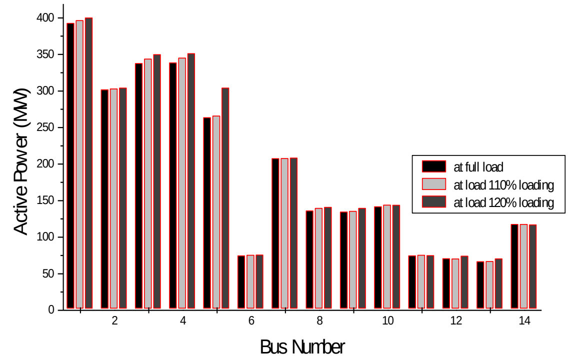

b) at generation of 100 MW& 40MVAR



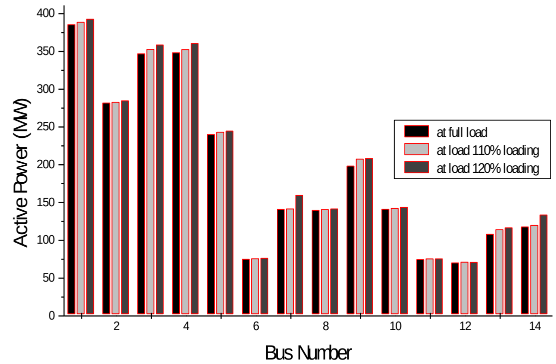

c) at generation of 50 MW& 20MVAR

Fig. 5 The reactive power based on different loads at Damanhour 2 bus and generation at Talkha bus

a) at generation of 200 MW& 80 MVAR




b) at generation of 100 MW& 40MVAR




c) at generation of 50 MW& 20MVAR

Fig. 6 The active power based on different loads at Damanhour 2 bus- bar and generation at Talkha bus

Fig. 8a illustrates the cost function during different load conditions without proposed algorithm and with the proposed algorithm. It can be seen that the proposed algorithm minimizes the cost function from 17.66 $/kWhr to 15.34$/kWhr at full load, with the generation at Talkha bus of 200 MW & 80MVAR from 17.5$/kWhr to 15.21$/kWhr at generation of 100 MW & 40 MVAR, and from 17.43 $/kWhr to 15.144 $/kWhr at generation of 50 MW & 20 MVAR.

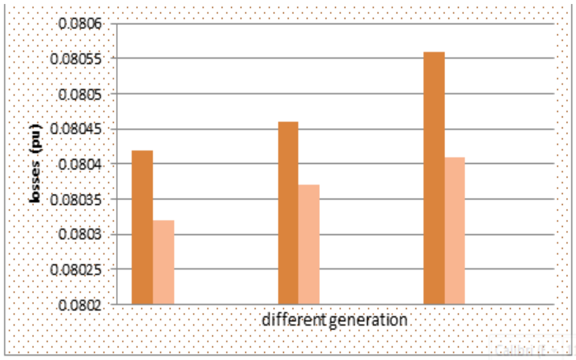
In adding, when increases the load, Fig. 8b a shown the cost function without proposed algorithm and with proposed algorithm. It can be seen that the proposed algorithm minimizes the cost function from 17.8 $/kWhr to 15.34 $/kWhr at 110% loading, with the generation at Talkha bus of 200 MW & 80 MVAR, from 176 $/kWhr to 15.99 $/kWhr at generation of 100 MW & 40 MVAR, and from 17.84 $/kWhr to 15.93 $/kWhr at generation of 50 MW & 20 MVAR.

Fig. 8c a shown the cost function without proposed algorithm and with using the proposed algorithm. It can be seen that the proposed algorithm reduces the cost function from 17.66 $/kWhr to 16.46 $/kWhr at 120% loading, with the generation at Talkha bus of 200 MW & 80 MVAR, from 17.66 $/kWhr to 16.46 $/kWhr at generation of 100 MW &40 MVAR, and from 17.7 $/kWhr to 16.44 $/kWhr at generation of 50 MW & 20 MVAR.

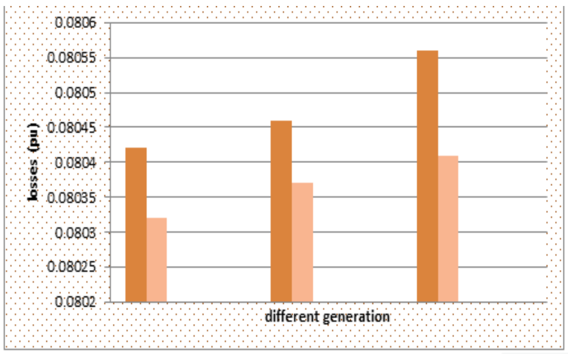
Also, the simulation results, it is showed the proposed algorithm gives the optimal performance for system to different values of load and generation; the power losses and cost function are minimized.

Fig. 9a shows the power losses during different v load conditions with the algorithm in [12], that used PSO and ANN and with proposed algorithm. It can be seen that, the proposed algorithm reduces the power losses in different conditions. When increases reduces the generation and the load within constrains, the proposed algorithm reduces the power losses from 0.095 to 0.092, from 0.09 to 0.087 and from 0.089 to 0.086 p.u.

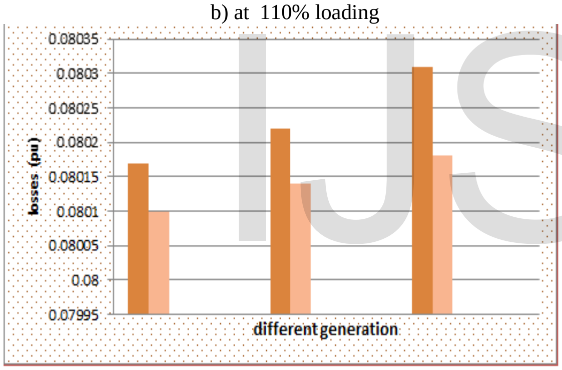
Fig.9b illustrates the voltage buses with the loading. It can be seen that, the proposed algorithm enhances the voltage buses compared to the results in [12] within acceptable limits from 0.9 to 1.1 p.u.




**a) at full load**

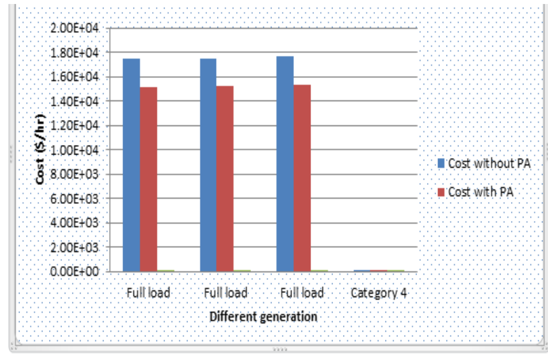



b) at 110% loading

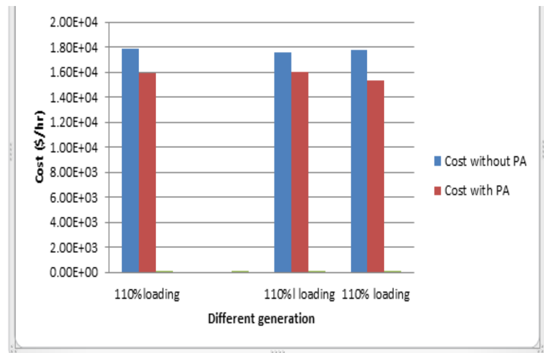



c) at 120% loading

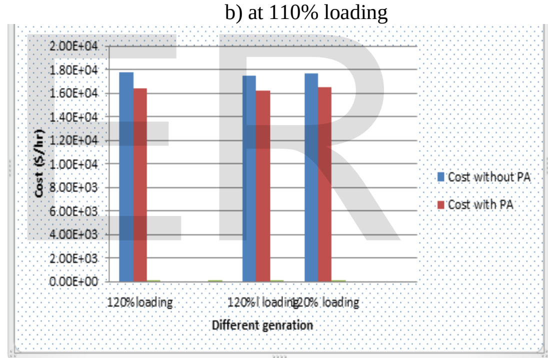
Fig. 7 Power Losses based on different generation at Talkha bus and loads at Damanhour 2 bus




a) at full load



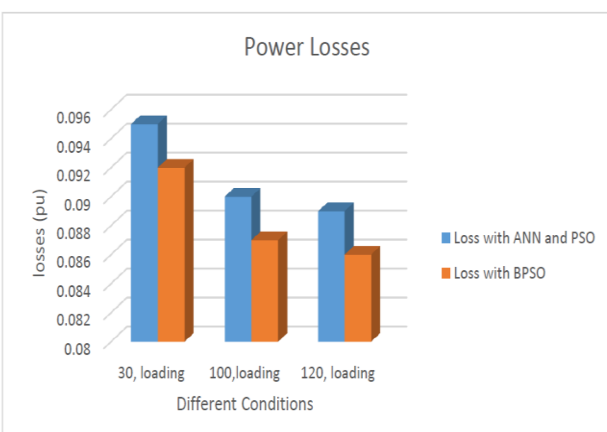

b) at 110% loading



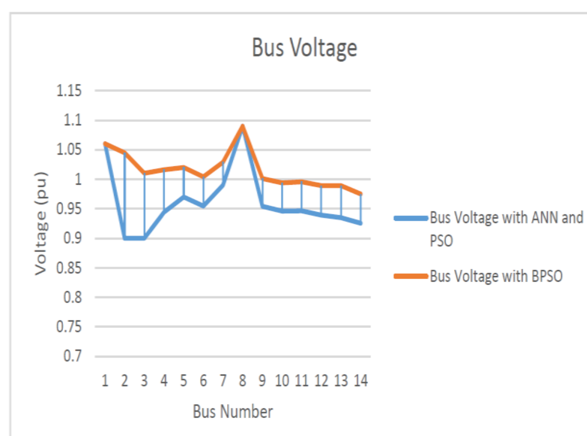

c) at 120% loading

Fig. 8 Cost function depend on different generation at Talkha bus and loads at Damanhour 2 bus






(a) Total power losses




(b) The voltages of all buses

Fig. 9 The comparison between the proposed algorithm results and results in [12]

## Conclusion

Smart enhancement of transmission system with UPFC by proposed algorithm is introduced in this paper. The proposed algorithm is depend on BPSO. The proposed algorithm is implemented on a part of Egyptian Electricity Transmission Network. The UPFC with Proposed Algorithm is able to maintain the voltage buses under various conditions and best location of UPFC is selected. The best location depends on required reactive power, the injected voltage and injected reactive power. In addition, the optimal setting of UPFC is achieved using BPSO.

The BPSO has been successfully applied on Egyptian Electricity Network by using Matlab/Simulink. The simulation results of the proposed algorithm have an excellent capability in power system voltage enhancement. It is found that the proposed algorithm illustrates the best performance for system to different of load and generation values. Therefore, it is concluded that the proposed algorithm can be used for smarting the transmission system; power losses and cost function are minimized and successes to effectively do the required tasks.

### References

[1] S. Ravindra, V. C. Reddy, and T. S. Sivanagaraju, "Artificial Neural Networks based UPFC for Damping Low Frequency Oscillations", International Journal of Computer Applications, Vol. 53, No. 7, September 2012.

[2] S. Sarfaraaz and M. M. Sudhan, "Enhancing the Performance and Stability of UPFC Control by Creating Co-ordination between Series and Shunt Converters", International Research Journal of Engineering and Technology (IRJET), Vol. 4, Iss. 12, Dec. 2017.

[3] T. Masood, N. Jamee, S. A. Qureshi, M. Tajamma, S. K. Haider, and G. Hashmi, "Unified Power Flow Controller (UPFC) Modeling and Analysis Technique by using Matlab and EMTP", International Conference on Renewable Energies and Power Quality (ICREPQ), Spain, 21th to 23th March, 2018.

[4] A. K. Mohanty and A. K. Barik, "Power System Stability Improvement Using FACTS Devices", International Journal of Modern Engineering Research (IJMER), Vol. 1, Iss. 2, pp. 666-672, 2013.

[5] G. Kannayeram, P. S. Manoharan, and N. B. Prakash, "PI-tuned UPFC Damping Controllers Design for Multi-Machine Power System", Journal of Vibro engineering, Vol. 6, Iss. 2, pp 81-92, April 2018.

[6] G. Ramana and B. V. Ram, "Power System Stability Improvement Using FACTS with Expert Systems", International Journal of Advances in Engineering & Technology, Vol. 1, Iss. 4, pp. 395-404, Sept. 2011.

[7] G. Kenne, R. F. Kuate, J. D. Nguimfack, and H. B. Fotsin, "A New Hybrid UPFC Controller for Power Flow Control and Voltage Regulation Based on RBF Neurosliding Mode Technique" Journal of Advances in Electrical Engineering, Vol. 1, pp. 11, 17, September 2017.

[8] K. S. L. Lavanya and P. Sh. Rani, "A Review on Optimal Location and Parameter Settings of FACTS Devices in Power Systems Era: Models, Methods", International Journal for Modern Trends in Science and Technology, Vol. 2, No. 11, November 2016.

[9] Z. V. Oluwagbade, S. T. Wara, I. A. Adejumobi, and A. O. Mustapha, "Effect of Unified Power Flow Controller on Power System Performance: A Case Study of Maryland 132/33/11 kV Transmission Station", International Journal of Emerging Technology and Advanced Engineering, Vol. 5, Iss. 6, June 2015.

[10] A. Mohanty, M. Viswavandya, D. Mishra, and P. Paramita, "Intelligent Voltage and Reactive Power Management in a Standalone PV based Microgrid", Science Direct Elsevier SMART GRID Technologies, Vol. 21, pp .443 - 451, August 2015.

[11] R. N. Banu and D. Devaraj, "Enhanced Genetic Algorithm Approach for Security Constrained Optimal Power Flow Including FACTS Devices", International Journal of Electrical and Electronics Engineering and Technology, Vol. 3, No. 4, pp. 2395-0072, 2009.

[12] R. R. M. Eiada, E. A. Badran, and I. I. I. Mansy "Smart Enhancement of UPFC Performance in Transmission Systems Using BPSO and ANNC" EJECE, European Journal of Electrical and Computer Engineering Vol. 3, No. 5, October 2019.

[13] M. Z. EL-Sadek, M. Abo-Zahhad, A. Ahmed, and H. E. Zidan, "Comprehensive Newton Raphson Model for Incorporaring Unified Power Flow Controller in Load Flow Studies", Journal of Engineering Sciences, Assiut University, Vol. 35, No. 1, pp.189-205, January 2007.

[14] M. Waqas, N. Rehman, K. Hussain, R. A. Talani, and J. A. Ansari, "Power Flow Enhancement of 220 KV Transmissions Line with Unified Power Flow Controller", Journal of Engineering, Science & Technology, Vol. 14, No. 2, July-Dec. 2015.