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# Fuzzy-based PSO algorithm for transmission line Losses minimization with UPFC

**Abstract**: *In this paper, one of the essential types of flexible alternating current transmission systems (FACTS), the Unified Power Flow Controller(UPFC), was used to reduce the losses in transmission lines. A particle swarm optimization (PSO)-based modified fuzzy logic (FL)controller with UPFC was proposed to obtain the optimal location of UPFC and optimum parameters of the normalized fuzzy controller to achieve the objective function of the research and compare the results with the PI-controller. The Newton-Raphson method was employed to perform load flow analysis by MATLAB code/M-file. The proposed method was tested in the IEEE-14bus system, and the results showed that the PSO-FL minimized losses better than PSO-PI.*

***Streszczenie***: *W artykule wykorzystano jeden z podstawowych typów elastycznych systemów przesyłowych prądu przemiennego (FACTS), czyli Unified Power Flow Controller (UPFC), w celu zmniejszenia strat w liniach przesyłowych. W celu uzyskania optymalnej lokalizacji UPFC i optymalnych parametrów znormalizowanego kontrolera rozmytego w celu osiągnięcia celu badań i porównania wyników z PI zaproponowano zmodyfikowany sterownik z logiką rozmytą (FL) oparty na optymalizacji roju cząstek (PSO) z UPFC. -kontroler. Do wykonania analizy przepływu obciążenia za pomocą kodu MATLAB/pliku M zastosowano metodę Newtona-Raphsona. Zaproponowana metoda została przetestowana w systemie IEEE-14bus, a wyniki wykazały, że PSO-FL minimalizuje straty lepiej niż PSO-PI.* (***Rozmyty algorytm PSO dla linii przesyłowej Minimalizacja strat z UPFC***)

**Keywords:** UPFC, PSO, FL Controller, Loss minimization.
**Słowa kluczowe**: UPFC, PSO, kontroler FL, minimalizacja strat.

## Introduction

Minimizing power losses is one of the critical objectives of putting FACTS devices on power grids; hence, practically all studies concerning these devices have addressed this topic[1–5]. Numerous publications have investigated the performance benefits of UPFC implantation. However, UPFC devices must be placed in optimal locations due to their high cost. The literature provides several methodologies for tackling these FACTS optimization problems, including classical, heuristic, and mixed techniques. However, in addition to their benefits, each strategy has disadvantages. Optimization issues frequently involve heuristics approaches such as genetic algorithms (GA), differential evolution, particle swarm optimization (PSO), evolutionary programming, and evolution strategies. These methods can calibrate optimal results with minimal complexity [6].

In reference [7], particle swarm optimization (PSO) is used to fix many problems with electrical power transmission networks. It can reduce system losses, improve line voltages, and increase transmission c apacity. Authors in [8] employed genetic algorithms (GA) to identify the best location for UPFC devices to optimize voltage profiles, reduce power losses, Control power flow in overloaded transmission lines, and decrease power generation in the local Iraqi network (Diyala 132 kV). Two types of artificial algorithms, Imperialist competitive algorithm (ICA) and PSO, were compared in [9], and FACTS devices effects are displayed to minimize network losses. It has been shown that the PSO algorithm with UPFC reduces both active and reactive power losses more than other FACTS device types and intelligent algorithms. Although UPFC has several advantages, its controller design remains a problem because it is a multi-variable controller. Numerous control strategies have been implemented to control UPFC for various power system applications.

The author in [10] presents the MATLAB Simulink fuzzy UPFC model based on PI to improve the power quality by correcting the load voltage and changing the active and reactive power. In reference [11], Analyses are performed on PI &FLC closed loop controllers with UPFC systems for voltage profile improvement. It has been observed that the UPFC with FLC is faster than the PI-controlled system.

The following are the primary contributions of this paper:

1)Proposed PSO-based optimum Fuzzy logic (FL) controller parameters to find the optimum performance of UPFC by controlling the voltage of the two converters of the UPFC device and finding the optimal location of this device. The proposed algorithm is coded in MATLAB code /M-file.
2)The objective function of the research is to minimize the transmission line's active and reactive power loss.
3)The proposed method was tested on a standard IEEE-14 bus system

## 1. Unified Power Flow Controller

The unified power flow controller (UPFC) concept was proposed by Gyugyi in 1991 [12]. The use of UPFC makes it possible to simultaneously control the impedance of a transmission line, the phase angle, the magnitude of the voltage, and the active and reactive power flow [13]–[16]. As shown in Fig.1 [8], UPFC comprises two voltage-sourced converters, one coupled in a shunt (i.e. STATCOM) and the other in a series ((i.e. SSSC) [17],[18]. By injecting an AC voltage with a controllable magnitude and phase angle in series with the transmission line via a series-connected coupling transformer, the series converter performs the primary role of a UPFC. On the other hand, the main job of the shunt converter is to give or take the actual power that the series converter needs at the common DC link . Fig 2 [8] shows the UPFC's electrical model.

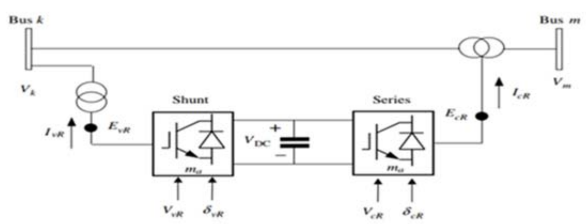


Fig. 1. The basic scheme of UPFC

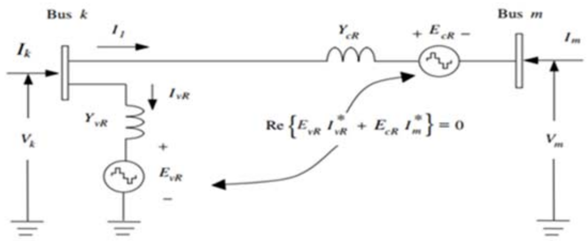


Fig. 2. The electrical model of UPFC

The essential operation of UPFC and the equations needed to apply PSO to it to find the location and parameters normalization of FL-based UPFC controller on the power transmission network; as a result, equations (1) through (16) [8] are used to implement the PSO program. To achieve the given goals that will be discussed using equations in the following section:

(1) $$E_{vR} = V_{vR}(\cos\delta_{vR} + j\sin\delta_{vR})$$

(2) $$E_{cR} = V_{cR}(\cos\delta_{cR} + j\sin\delta_{cR})$$

(3) $$\mathrm{Re}\{-E_{vR}I_{vR}^{*} + E_{cR}I_{m}^{*}\} = 0$$

(4) $$\begin{bmatrix} \mathrm{I}_K \\ \mathrm{I}_m \end{bmatrix} = \begin{bmatrix} (\mathrm{Y}_{cR}+\mathrm{Y}_{vR}) & -\mathrm{Y}_{cR} & -\mathrm{Y}_{cR} & -\mathrm{Y}_{vR} \\ -\mathrm{Y}_{cR} & \mathrm{Y}_{cR} & \mathrm{Y}_{cR} & 0 \end{bmatrix} \begin{bmatrix} \mathrm{V}_K \\ \mathrm{V}_m \\ \mathrm{E}_{cR} \\ \mathrm{E}_{vR} \end{bmatrix}$$

where: $E_{vR}, E_{cR}$ - UPFC voltage sources; $V_{vR}$ - the controllable magnitude supplying the shunt converter $((V_{vR}\ \mathrm{min}) \leq V_{vR} \leq (V_{vR}\ \mathrm{max}))$; $\delta_{vR}$ - the phase angle of the shunt converter $(0 \leq \delta_{vR} \leq 2\pi)$; $V_{cR}$ -the controllable voltage magnitude supplying the series converter $((V_{cR}\ \mathrm{min}) \leq V_{cR} \leq V_{cR}\mathrm{max}))$; $\delta_{vR}$ - the phase angle of the series converter $(0 \leq \delta_{vR} \leq 2\pi)$

Bus K:

(5) $$P_K = V_k^2\, G_{KK} + V_K V_m[G_{Km}\cos(\theta_K - \theta_m) + B_{Km}\delta in(\theta_K - \theta_m)] + V_K V_{cR}[G_{Km}\cos(\theta_K - \delta_{cR}) + \delta in(\theta_k - \delta_{cR})] + V_K V_{vR}\,[G_{vR}\cos(\theta_K - \delta_{vR}) + B_{vR}\,\delta in(\theta_K - \delta_{vR})$$

(6) $$Q_K = -V_K^2\, B_{KK} + V_K V_m[G_{km}\delta in(\theta_K - \theta_m) - B_{Km}\cos(\theta_K - \theta_m)] + V_K V_{cR}\,[G_{Km}\,\delta in(\theta_K - \delta_{cR}) - B_{km}\cos\,(\theta_K - \delta_{cR})] + V_K V_{vR}[\,G_{vR}\,\delta in(\theta_K - \delta_{vR}) + B_{vR}\cos(\theta_K - \delta_{vR})]$$

Bus m:

(7) $$P_m = V_m^2 G_{mm} + V_m V_K[G_{mK}\cos(\theta_m - \theta_K) + B_{mK}\delta in(\theta_m - \theta_K)] + V_m V_{cR}[G_{mm}\,\cos(\theta_m - \delta_{cR}) + B_{mm}\delta in(\,\theta_m - \delta_{cR})]$$

(8) $$Q_m = -V_m^2 B_{mm} + V_m V_K[G_{mK}\delta in(\theta_m - \theta_K) - B_{mK}\cos(\theta_m - \theta_K)] + V_m V_{cR}[G_{mm}\,\delta in(\theta_m - \theta_{cR}) - B_{mm}\cos(\,\theta_m - \delta_{cR})]$$

where: $P_K$ - Active power of bus k, $P_m$ - Active power (bus m) ; $Q_K$ - Reactive power (bus k), $Q_m$ - Reactive power (bus m); $V_K$ , $V_m$ -Voltage magnitudes of bus k and bus m, respectively; $B_{Km}$, $B_{mK}$ - Substances between connecting buses k and m; $G_{Km}$ , $G_{mK}$ - Conductance between bus k and m, respectively; $B_{mm}$ ,$\mathrm{B}_{KK}$ - Substances of bus k and bus m, respectively; $G_{mm}, G_{kk}$ - Conductance at bus k and n

**Series converter**

(9) $$P_{cR} = V_{cR}^2 G_{mm} + V_{cR}V_K[G_{km}\cos(\delta_{cR} - \theta_K) + B_{Km}\,\delta\mathrm{in}(\delta_{cR} - \theta_K)] + V_{cR}V_m[G_{mm}co\,s(\delta_{cR} - \theta_m) + \,B_{mm}\,\delta in(\delta_{cR} - \,\theta_m)$$

(10) $$Q_{cR} = -V_{cR}^2\, B_{mm} + V_{cR}V_K[G_{Km}\delta in(\delta_{cR} - \theta_K) - B_{Km}\cos(\,\delta_{cR} - \theta_K)] + V_{cR}V_m[G_{mm}\delta in(\delta_{cR} - \theta_{mm}) - B_{mm}\cos(\,\delta_{cR} - \theta_m)$$

(11) $$P_{vR} = -V_{vR}^2 G_{vR} + V_{vR}V_K[G_{vR}\cos(\,\delta_{vR} - \theta_K) + B_{vR}\delta in(\delta_{vR} - \,\theta_K)]$$

(12) $$Q_{vR} = V_{vR}^2 B_{vR} + V_{vR}V_K\,[G_{vR}\delta in(\delta_{vR} - \theta_K) - B_{vR}\cos(\delta_{vR} - \theta_K)]$$

(13) $$\Delta P_{bb} = P_{vR} + P_{cR} = 0$$

(14) $$P_{vR} + P_{cR} = P_K + P_m = 0$$

Where: $P_{c_R}$ , $P_{v_R}$ - Series and shunt converters active power, respectively; $Q_{cR}$, $Q_{vR}$ - Series and shunt converters reactive power, respectively; $\Delta P_{bb}$ - Represent the power mismatch

(15) $$\begin{bmatrix} \Delta P_K \\ \Delta P_m \\ \Delta Q_K \\ \Delta Q_m \\ \Delta P_{mK} \\ \Delta Q_{mK} \\ \Delta P_{bb} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_K}{\partial\theta_K} & \frac{\partial P_K}{\partial\theta_m} & \frac{\partial P_K}{\partial V_{vR}}V_{vR} & \frac{\partial P_K}{\partial V_m}V_m & \frac{\partial P_K}{\partial\delta_{cR}} & \frac{\partial P_K}{\partial V_{cR}}V_{cR} & \frac{\partial P_K}{\partial\delta_{vR}} \\ \frac{\partial P_m}{\partial\theta_K} & \frac{\partial P_m}{\partial\theta_m} & 0 & \frac{\partial P_m}{\partial V_m}V_m & \frac{\partial P_m}{\partial\delta_{cR}} & \frac{\partial P_m}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial Q_K}{\partial\theta_K} & \frac{\partial Q_K}{\partial\theta_m} & \frac{\partial Q_K}{\partial V_{vR}}V_{vR} & \frac{\partial Q_K}{\partial V_m}V_m & \frac{\partial Q_K}{\partial\delta_{cR}} & \frac{\partial Q_k}{\partial V_{cR}}V_{cR} & \frac{\partial Q_K}{\partial\delta_{vR}} \\ \frac{\partial Q_m}{\partial\theta_K} & \frac{\partial Q_m}{\partial\theta_m} & 0 & \frac{\partial Q_m}{\partial V_m}V_m & \frac{\partial Q_m}{\partial\delta_{cR}} & \frac{\partial Q_m}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial P_{mK}}{\partial\theta_K} & \frac{\partial P_{mK}}{\partial\theta_m} & 0 & \frac{\partial P_{mK}}{\partial V_m}V_m & \frac{\partial P_{mK}}{\partial\delta_{cR}} & \frac{\partial P_{mK}}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial Q_{mK}}{\partial\theta_K} & \frac{\partial Q_{mK}}{\partial\theta_m} & 0 & \frac{\partial Q_{mK}}{\partial V_m}V_m & \frac{\partial Q_{mK}}{\partial\delta_{cR}} & \frac{\partial Q_{mK}}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial P_{bb}}{\partial\theta_K} & \frac{\partial P_{bb}}{\partial\theta_m} & \frac{\partial P_{bb}}{\partial V_{vR}}V_{vR} & \frac{\partial P_{bb}}{\partial V_m}V_m & \frac{\partial P_{bb}}{\partial\delta_{cR}} & \frac{\partial P_{bb}}{\partial V_{cR}}V_{cR} & \frac{\partial P_{bb}}{\partial\delta_{vR}} \end{bmatrix} \begin{bmatrix} \Delta\theta_K \\ \Delta\theta_m \\ \frac{\Delta V_{vR}}{V_{vR}} \\ \frac{\Delta V_m}{V_m} \\ \Delta\delta_{cR} \\ \frac{\Delta V_{cR}}{V_{cR}} \\ \Delta\delta_{vR} \end{bmatrix}$$

(16) $$\begin{bmatrix} \Delta P_K \\ \Delta P_m \\ \Delta Q_K \\ \Delta Q_m \\ \Delta P_{mK} \\ \Delta Q_{mK} \\ \Delta P_{bb} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_K}{\partial\theta_K} & \frac{\partial P_K}{\partial\theta_m} & \frac{\partial P_K}{\partial V_K}V_K & \frac{\partial P_K}{\partial V_m}V_m & \frac{\partial P_K}{\partial\delta_{cR}} & \frac{\partial P_K}{\partial V_{cR}}V_{cR} & \frac{\partial P_K}{\partial\delta_{vR}} \\ \frac{\partial P_m}{\partial\theta_K} & \frac{\partial P_m}{\partial\theta_m} & \frac{\partial P_m}{\partial V_K}V_K & \frac{\partial P_m}{\partial V_m}V_m & \frac{\partial P_m}{\partial\delta_{cR}} & \frac{\partial P_m}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial Q_K}{\partial\theta_K} & \frac{\partial Q_K}{\partial\theta_m} & \frac{\partial Q_K}{\partial V_K}V_K & \frac{\partial Q_K}{\partial V_m}V_m & \frac{\partial Q_K}{\partial\delta_{cR}} & \frac{\partial Q_K}{\partial V_{cR}}V_{cR} & \frac{\partial Q_K}{\partial\delta_{vR}} \\ \frac{\partial Q_m}{\partial A_K} & \frac{\partial Q_m}{\partial\theta_m} & \frac{\partial Q_m}{\partial V_K}V_K & \frac{\partial Q_m}{\partial V_m}V_m & \frac{\partial Q_m}{\partial\delta_{cR}} & \frac{\partial Q_m}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial P_{mK}}{\partial\theta_K} & \frac{\partial P_{mK}}{\partial\theta_m} & \frac{\partial P_{mK}}{\partial V_K}V_K & \frac{\partial P_{mK}}{\partial V_m}V_m & \frac{\partial P_{mK}}{\partial\delta_{cR}} & \frac{\partial P_{mK}}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial Q_{mK}}{\partial\theta_K} & \frac{\partial Q_{mK}}{\partial\theta_m} & \frac{\partial Q_{mK}}{\partial V_K}V_K & \frac{\partial Q_{mK}}{\partial V_m}V_m & \frac{\partial Q_{mK}}{\partial\delta_{cR}} & \frac{\partial Q_{mK}}{\partial V_{cR}}V_{cR} & 0 \\ \frac{\partial P_{bb}}{\partial\theta_K} & \frac{\partial P_{bb}}{\partial\theta_m} & \frac{\partial P_{bb}}{\partial V_K}V_K & \frac{\partial P_{bb}}{\partial V_m}V_m & \frac{\partial P_{bb}}{\partial\delta_{cR}} & \frac{\partial P_{bb}}{\partial V_{cR}}V_{cR} & \frac{\partial P_{bb}}{\partial\delta_{vR}} \end{bmatrix}$$

$$\begin{bmatrix} \Delta\theta_m \\ \frac{\Delta V_K}{V_K} \\ \frac{\Delta V_m}{V_m} \\ \Delta\delta_{cR} \\ \frac{\Delta V_{cR}}{V_{cR}} \\ \Delta\delta_{vR} \end{bmatrix}$$

**Fuzzy logic (FL) control**

The Fuzzy Logic (FL) controller is one of the most effective applications of fuzzy set theory; its defining characteristic is linguistic variables instead of numerical ones. This quality control method is founded on the assumption that people can comprehend how a system behaves. Fuzzy logic offers a straightforward method for reaching a firm conclusion based on hazy, ambiguous, inaccurate, noisy, or missing input data. FLCs are created using a specific "If x and y, then z" rule. These guidelines were developed with the assistance of individuals' experiences and knowledge of system behaviour. The right combinations of these rules increase the system's performance. Each rule establishes a single membership, which serves as FLC's purpose [19]. Fig.2 shows an FLC's general structure, which is made up of four main parts:

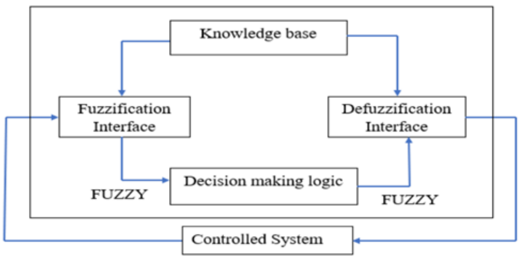


Fig .2. Basic structure of FL controller

•A Fuzzyification interface that transforms input data into appropriate linguistic values.
•A knowledge base is comprised of a database containing the required linguistic definitions and a control rule set.
• A decision-making logic that simulates the human decision-making process by deriving the fuzzy control action from the control rules and linguistic variable definitions.
•A defuzzification interface transforms an inferred fuzzy control action into a nonfuzzy control action.

The fuzzy logic controller's inputs are error and error rate, and its output is the magnitude of the voltage controller of the two converters, shunt and series, separately. Before the input, a normalized number is used to ensure that the error value and error rate are within the data membership range. These values of normalization are obtained from the PSO algorithm. This controller used a triangular type of membership, and the number of members used was five.

## 2. Particle Swarm Optimization(PSO)

In 1995, Kennedy and Eberhart proposed a PSO algorithm. This algorithm could be found in the congestion intelligence branch. This algorithm allows users to share knowledge and experiences.
Simulating simplified versions of society was used to generate PSO [20]. The following is how the system works [21][22]:
1)The process is used to research swarms like fish schools and flocks of birds.
2)It is founded on basic ideas. As a result, it only uses a small amount of memory and computes quickly.
3)It was designed for non-linear optimization problems with continuous variables initially.
The velocity equation may be used to express this modification, and the following equation can be used to change the speed of each agent [23],[24],[25]:

(17) $\quad {}^{Ko+1}_{id} = wV^{Ko}_{id} + C_1 \times \mathrm{rand}(\,Pbest_{\,id} - X^{ko}_{id}) + C_2 \times rand\ (Gbest_{id} - \ X^{ko}_{id})$

(18) $\quad X^{ko+1}_{id} = X^{ko}_{id} + V^{ko+1}_{id}$

Where: I-1,2,3…….n, d - 1,2,3…….m, n group's number of particles, m particle members
$X^{ko}_{id}$ and $X^{ko+1}_{id}$ - represent a current and modified searching point, $V^{Ko}_{id}$ and $V^{Ko+1}_{id}$ represents the current velocity and modified velocity, $V_{pbest}$ and $V_{gbest}$ represents velocity based on $p_{best}$ and $g_{best}$
$Pbest$ $i_{th}$ particle's best position, $Gbest$ is the group's best particle, $w_i$ the agent's weight function velocity,
$C_1, C_1$: Acceleration constant

(19) $\quad w_{(i)} = w_{max} - \left(\frac{w_{max}-w_{min}}{ko_{max}}\right) * k_0$

Where: $w_{max}$ , $w_{min}$ : represent maximum and minimum weight,; $k_0$ , $ko_{max}$ : represent current iteration and maximum, respectively.

In this paper, the proposed PSO-based optimum FL controller with UPFC system and location design procedure is shown in Fig. 3, and the flow chart of this proposal is shown in Fig. 4. The PSO parameters used in the proposed work are given in Table 1.

Table 1. The parameters of PSO

| Parameters of PSO | |
|---|---|
| Number of Particles | 20 |
| Number of iteration | 100 |
| Number of variables | 5 |
| C1,C2 | 1.5 |
| W | 0.5 |

The objective function of the research is to minimize the power losses of the transmission lines. The equation of the main objective is :

(20) $\quad objective\ function = min \sum_{i=1}^{Nb} (S_{loss})$

$S_{loss}$ - represent the total active and reactive power loss of the lines, and Nb - is the number of transmission lines.

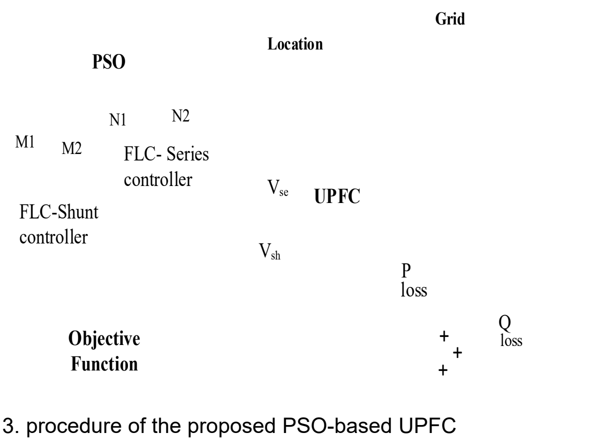


Fig. 3. procedure of the proposed PSO-based UPFC

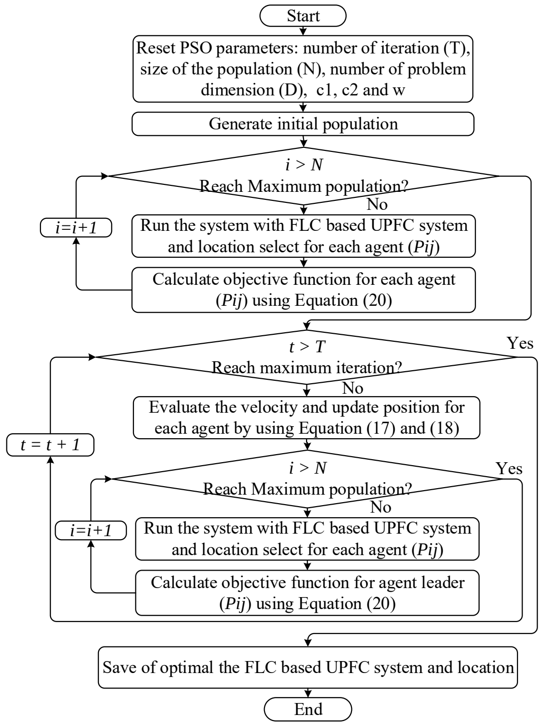


Fig .4. Flow chart of the Proposed PSO-based optimum FL controller with UPFC system and location design procedure

**Results and discussion**

The proposed method is applied to the IEEE-14 system in three scenarios that have been examined:
1-Case1: Pre-optimization (without UPFC)
2-Case2: with PSO-PI-based UPFC installation
3-Case3: with PSO-FL-based UPFC installation

**5.1. Case1: Pre-optimization (without UPFC)**

The IEEE-14 bus system [26] comprises nine load buses, twenty transmission lines, and five power generators. The single-line diagram of the IEEE -14 bus system and the test system IEEE-14 bus is shown in Fig.5. From the load flows analysis, the active and reactive power losses before placement of UPFC devices are shown in Fig .6.

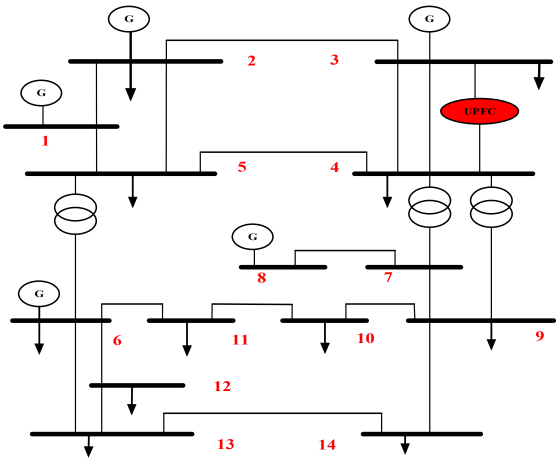


Fig.5. The single-line diagram of the IEEE -14 bus system

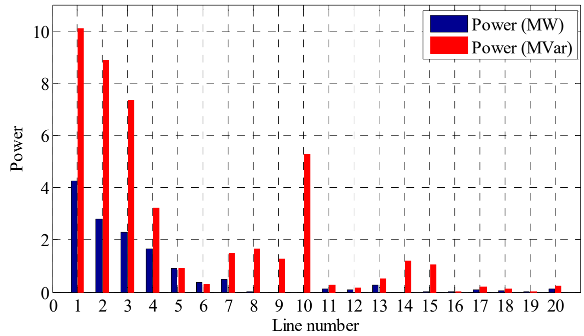


Fig. 6. The active and reactive power losses without UPFC

**5.2. Case2: with PSO-PI-based UPFC installation**

The Newton-Raphson method was employed to perform load flow analysis, and loss minimization of active and reactive power losses was chosen as this work's primary goal by equation (20). The response of the objective function with the PSO-PI controller is shown in Fig 7.

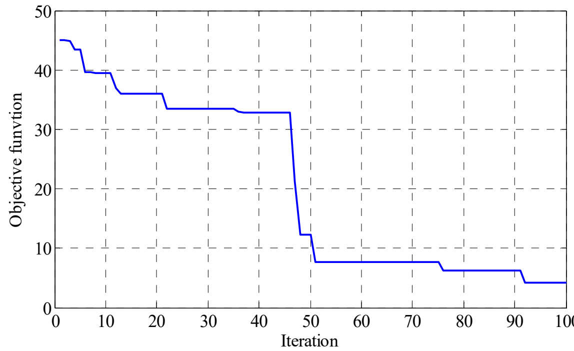


Fig. 7. The response of the objective function with the PSO-PI controller

The active and reactive power losses with PSO-PI-based UPFC are shown in Fig 8.

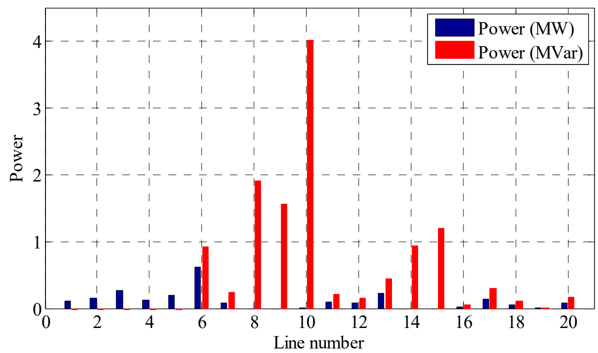


Fig .8. The active and reactive power losses with PSO-PI-based UPFC

**5.3. Case3: with PSO-FL-based UPFC installation**

The result of the objective function is shown in Fig 9. And the output of fuzzy membership is shown in Fig. 10. The losses minimization of active and reactive losses is shown in Fig. 11.

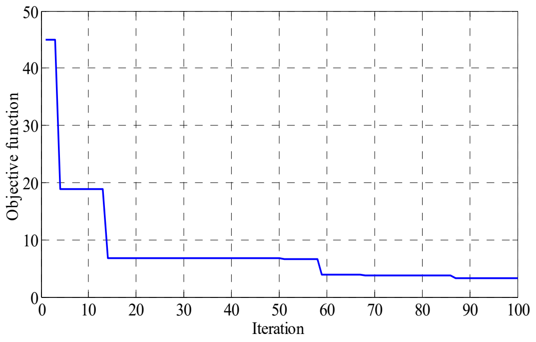


Fig .9. With PSO-FL controller

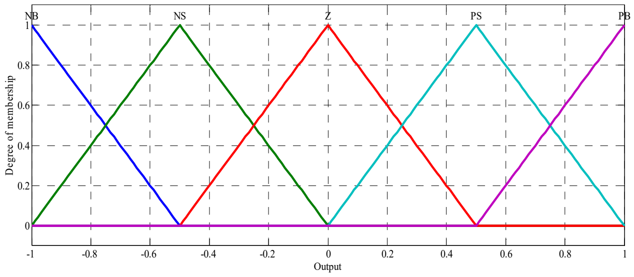


Fig .10. The output of the membership function of FL

From the PSO-FL, the optimal location of the UPFC between buses (3 - 4) and the optimum normalization values for two converters N1, N2 for series and M1, M2 for shunt converter.

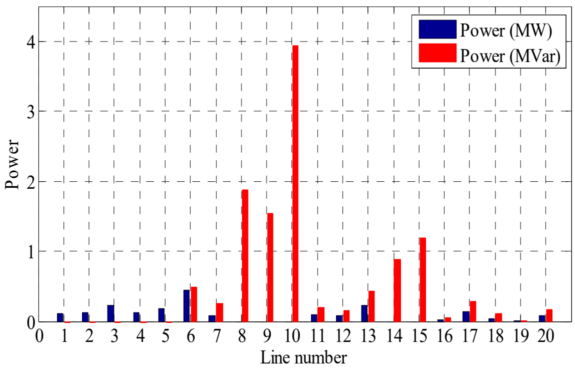


Fig. 11. The active and reactive power losses with PSO-FL-based UPFC

The total active and reactive power losses of all cases illustrate in Table 4. And Fig 12.

Table 4. total active and reactive power losses

| Case type | without UPFC | UPFC (PSO-PI) | UPFC (PSO-FL) | Improvement | |
|---|---|---|---|---|---|
| | | | | PI | FL |
| P total(MW) | 13.5299 | 2.2341 | 1.9883 | 83% | 85% |
| Q total (MVAR) | 44.2537 | 3.6103 | 2.6813 | 91% | 94% |
| Location | - | (3-4) | (3-4) | - | - |

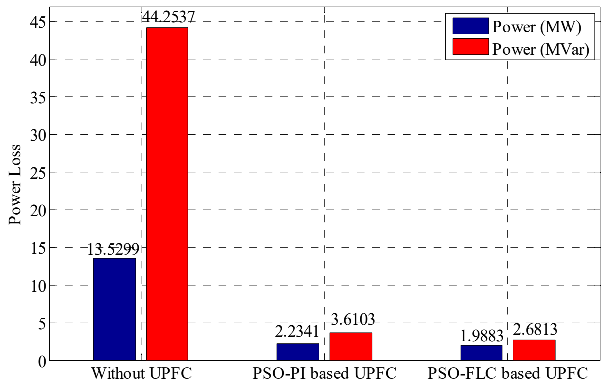


Fig .12. The total active and reactive power losses in all cases

## 3. Conclusion

This paper proposes an optimized FL controller to control the UPFC. In the proposed system, a particle swarm optimization algorithm has been used to find the optimum values of normalization of FL and the optimal location of the UPFC. This proposed method was tested on the standard IEEE-14 bus system. The results show that the proposed method has good performance for minimizing losses, with an 85% reduction in active power losses and a 94% reduction in reactive power losses; the optimal location of the UPFC is between buses( 3 – 4). The system's total active and reactive power losses with PSO-FL-based UPFC minimized losses better than PSO-PI.


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