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Impact of Crow Search Algorithm to Minimize Transmission System Power Losses

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Abstract

In the present world, generation of power is vital to meet the requirements and the growing demands of the end users but at the same time losses in the transmission line, optimization and planning of power systems is also equally indispensable. Therefore, keeping the voltage levels within the appropriate limit is a difficult job. The Crow Search Algorithm (CSA) is used in this paper to define the size of UPFC as well as to enhance the stability of the system. The CSA is a modern, effective solution that relies on the smart behaviour of crows. In the present scenario CSA is used to tackle several complex problems of engineering optimization where it has proven its reliability and flexibility. Moreover this algorithm emphasizes on reducing the transmission line's actual power losses and preserving voltage stability. In this paperCSA will accomplish this by choosing 125 percent, 150 percent, 175 percent and 200 percent over load cases on the IEEE 30 bus systemthe result reveals that CSA surpasses other meta-heuristic algorithms by doing well. Hence CSA turns into a viable technique to recognize UPFC size and position.

Keywords: CSA, UPFC, FACTS, Power system stability, Optimal Location**.**

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1 Introduction

Power generation and transmission system is the speedily expanding sector in the global arena. Heavy technological enhancement and huge transmission infrastructure are needed for the Supply of generated power to end users from the generating points. In order to provide uninterrupted supply there are some technical issues like power losses and resource limitations apart from this some other non-technical issues like environmental and land acquisition problems need to be addressed. Any how to address the technical issues we use FACTS devices such as shunt compensators or series compensators or combination of series and shunt compensators. The transmission capacity and versatility in power control can be enhanced by FACTS devices.[1] UPFC is chosen for implementation owing to its unique and outstanding functionalities like, excellent voltage stabilisation, especially in weak zones,Increased capability of transmission including reducedlosses, diminished requirement for establishment of new lines, If the UPFCis assembled in the correct place, the reactive power is either absorbed or generated in order to sustain the necessary voltage with loss reduction. [2-6] appropriatemethodology is adopted to determine the UPFC's ideal location and size. For this L-index [7] is used to identify the weak bus, location and to place the UPFC device with this voltage stability is maintained in the system.

Instead of applying Conventional optimization techniques for providing the solutions of optimizations we use evolutionary, meta-heuristic algorithms as they are highly significant to substantiate optimization solutions there by eliminating the non monotonic solution surface which are highly sensitive to initial points and unable to find the optimum value which is draw back of conventional optimization. Meta-heuristic algorithms are essentially built on population-based optimization methods. In order to resolve the above problems, this paper illustrates the crow search algorithm to define the optimum UPFC position andthere by eliminating real power losses (RPL) and improving bus voltage performance and to achieve greater stability of the system.[7] Hence CSA has been proved as novel meta heuristic optimizer, focused on crow's intellectual behaviour. It works on the premise that crows store and fetch theirsurplus food from hiding places when thefood is necessary. So in this regard IEEE 30-bus system is treated as a test system for simulation purposes. The system's key belief by implementing CSA is to achieve improved execution of reliability and Real power losses are limited there by improving bus voltages and retaining the same efficiency.

Here 7 segments are addressed in this paper, Introduction is in first Segment, 2 Segment highlights problem recognition, and objective functions effectively. 3 Segment works with UPFC Modelling.Segment 4 gives an index of voltage stability. Segment5 works on identifying UPFC's optimum position using CSA, is main objective of this paper. All the significant observations discussed in Section 5 and the thorough review. Finally, it precisely confines the results in segment 7.

2 Problem Identification

The ultimate goal of the proposed paper is to recognize size and position of UPFC there by limiting the losses in the line and to upgrade the system voltage profile.[9-10] Mathematically it is shown in the following equations.

min X=[X1, X2, X3] (1)

$$X1 = \sum_{k \in Ni} g_k \left(V_i^2 = V_j^2 - 2V_iV_j \cos\theta_{ij} \right) = P_{activeloss}$$ = real power losses. (2)

$$X2 = VD = \sum_{k=1}^{N_{PQ}} \left(V_K - Vrefk \right)^2 \quad (3)$$

Equation (3) gives the total voltage profile of load busesX3 gives the L-index of Lth bus [6] :

$$X3 = L_l = \left| 1 \pm \frac{V_{ok}}{V_l} \right| = \frac{S_l^*}{Y_{ll} V_l^2} \quad (4)$$

The minimisation problem involves the consequent equality and inequality li mits:

(i) Load Flow Constraints:

$$P_k - V_k \sum_{j=1}^{Ng} V_j \left(G_{kj} \cos\theta_{kj} + B_{kj} \sin\theta_{kj} \right) = 0, \quad (5)$$

k=1,2,….N_B-1

$$Q_k - V_k \sum V_j \left((G_{kj} \cos\theta_{kj} - B_{kj} \sin\theta_{kj} \right) = 0 \quad (6)$$

k=1,2,….N_{PQ}-1

(ii) Voltage limits:

$$V_i^{\min} \le V_i \le V_i^{\max}, i \in N_B \quad (7)$$

(iii) Reactive Power generation Limit:

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max}, i \in N_g \quad (8)$$

(iv) Reactive power generation at condensing banks:

$$Q_{ci}^{\min} \le Q_{ci} \le Q_{ci}^{\max}, i \in N_c \quad (9)$$

v) Limits of Transformer Tap setting are:

$$ta_{p,\min} \le ta_p \le ta_{p,\max}, p \in N_t \quad (10)$$

(vi)Transmission line power flow limit:

$$S_j \leq S_j^{\max}, j \in N_t \tag{11}$$

3 Unified Power Flow Controller

In the early 1990's Gyugyi proposed the novel concept of UPFC[3-4]. The basic model of UPFC constitutes DC link with two converters on either sides as shown in Fig.1. One of the two converters is connected in shunt named as converter1 and the other is connected in series named as converter 2. Further both these converters are linked up with two transformers along with transmission line. In this UPFC basic model converter 2 plays major role by supplying necessary voltage and phase angle to the line by analysingthe active, reactive power [5-6].

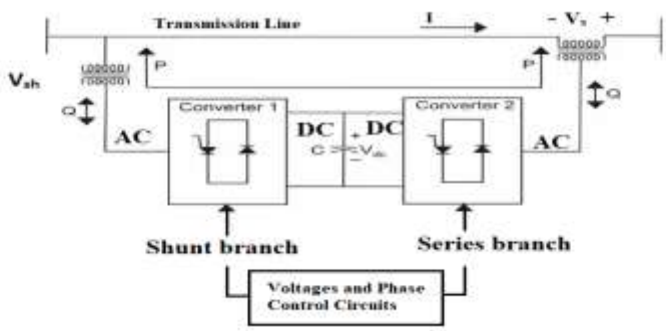

Figure 1 The UPFC's Schematic Diagram

The required converter 2 real power is supplied by converter1via DC link. Furthermore by giving major changes to the shunt compensation, this ensuresthereactive power of the line.[7-9] In this way both the converters regulates the entire parameters in the transmission line. For example, active, reactive power, voltage regulation andphaseanglecontrol.

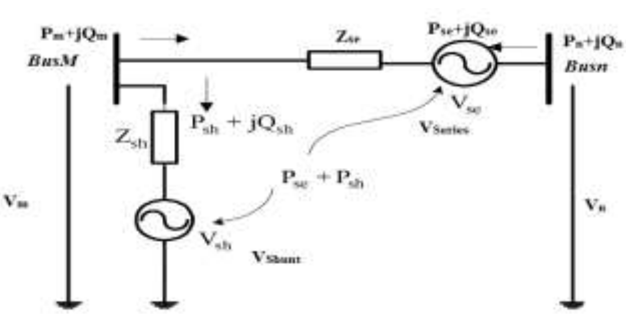

Figure 2 Mathematical modelling of UPFC

Figure 2 provides UPFC Mathematical Modelling. Under mentioned equation (12) expresses converter2injected real, reactive power.

$S_{series}=P_{series}+jQ_{series}$ (12)

Where

$P_{series}= rb_xV_mV_n\sin(\theta m-\theta n+\gamma)-rb_xV^2\sin\gamma$ (13)

$Q_{series} = -rb_xV_mV_n\cos(\theta m-\theta n+\gamma)+rb_xV^2_m\cos\gamma+r^2b_xV^2_m$ (14)

Generally the Converter1 produce manageable reactive power or consume it and provide the line with independent reactive shunting.

The model of the transmission line with a UPFC linked between bus m and bus n is shown in fig2. The vector diagram of power and control is shown in Fig. 3.

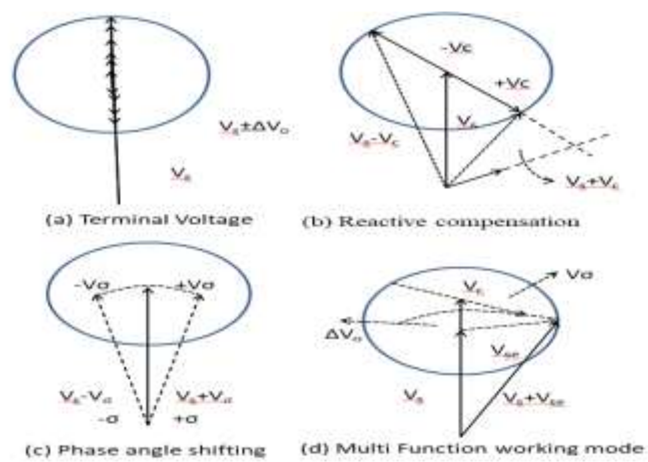

Figure 3 UPFC's Functional Capabilities

In Fig 3, the concepts of different power-flow control functions using the UPFC are demonstrated.

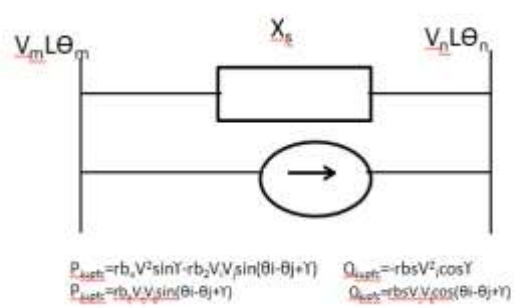

Figure 4 UPFC's Power-Injection Concept

Finally, the power injections and shunting at both bus m and n or constructed by attaching in series with the help of mathematical modelling of UPFC which is represented in figure 4.

4 Voltage Stability Index

Stability of voltage is characterizedas a system's ability tomaintainingvolt agewithin theappropriate limits at all nodes when exposed to disruption. Any how the device may suffered from a voltage collapse unless the device is unable to sustain the voltage within reasonable limits. It is crucial to enhance the operating requirements of a power system in order to monitor the event of voltage breakdowns. As a response to the power flow condition, Kessel [12] establishedthe L-index by offering a voltage stability index.

The L index is a quantitative measurement used to estimate the difference between the system's curr-ent state and the stability boundary. The L-index exhibits the entire system stability and is provided by

$$L_g = \left|1 \pm \frac{V_{xg}}{V_g}\right| = \frac{S_g^*}{Y_{gg} V_g{}^2} \tag{14}$$

Where $V_{xg} = -\sum_{i \in \alpha J} F_{gi} V_I$

The L index differs around 0 (no load) and 1(voltage collapse). Voltage stability is achieved whenever its value approaches '0'.

5 Crow Search Algorithm

The algorithms based on Swarm provide better performance. When the discovery and domination process can be perfectly balanced, assembles faster by preventing local optima trapping effectively. The Crow Search Algorithm (CSA) was recently launched as a swarm-based algorithminspiredbynaturein 2016 by A.Askarzadeh. [11] This will provide optimised solutions to non-linear, continuous complicated and on-going dynamic problems. In the current trending, therehas been a enormous progress in the CSA study that can be identified to solve various real-time application issues. CSA mimics the action of crows in storing and retaining extra food whenever required. The cultural behaviour of the crows depicts as follows.

- Self-awareness
- Recognising the faces
- Warn and flock
- usage of tools
- Highly advanced communication ways
- Recovering the secret location of food

Such keen birds live in gatherings and have little body size yet huge minds. Crows pursue different crows to notice their food's concealing spots and snatch it once they left. Whenever a crow thinks someone else is pursuing it, it travels to somewhere else to mislead the preceding birds, far from the food's concealing spot.

The ideas utilized in the CSA are prescribed in the given statements:

1. Crows live in a mass gathering.
2. Crows remember their food from secret places
3. Crows shield their reserved food from robbery
4. Crows steel the food by following other crows

In the CSA, singular totals are portrayed as crows. In this the key components of crows are flight length *fL*and awareness probability *AP*, respectively. The estimation of *fl* is utilized for a neighbourhood search (little worth) or worldwide hunt (enormous worth), the estimations of AP are utilized to regulate the strength (little worth) and diverse range (enormous estimation) of crows. Through CSA crows are arbitrarily produced according to the position.

Let the number of crows in a group (flock)= N
Thief crow is represented as i
Owner crow represented as j
Crow i at position x with iteration k is given by x_i^k

$$x_i^k = \left(x_{i1}^k, x_{i2}^{k,} x_{i3}^k, ...x_{id}^k\right) \tag{15}$$

The concealing spot of the food followed by crow I is retained. In the hunting area, crow travels and seeks to discover the perfect food source that is known as m_i^k.There are two probable scenarios
for the searching method in CSA:

1. The owner crow j,has no clue of crow i which reveals the secret location m_j^k, thus being the thief crow i new position is provided with following equation as shown in fig.5.

$$x_i^{k+1} = x_i^k + r_i \times fl_i^k \times \left(m_j^k - x_i^k\right) \tag{16}$$

Where
r_i is in the range of a random number (0,1)
At iteration k, fl_i^k is the flight length of the crow i.

2. The owner crow j, has clue of crow i which reveals the secret location m_j^k, thus being the thief crow i new position is provided with following equation
3. Whenever owner crow j knows thief crow i is pursuing it, ittravelsto somewhere else to mislead the thief crow i, crow j will shift to another location far from the food's concealing spot.

The second probable scenario is that the owner crow j knows that the thief crow i follows it therefore, the owner crow will deceive crow i by going to any further position of search space.

The position of crow i is updated by a random position.

$$x_i^{iter+1} = \begin{cases} x_i^{iter} + r_i \times fl_i^{iter} \times \left(M_j^{iter} - X_i^{iter}\right) & r_j \geq AP_j^{iter} \\ \text{A random position} & \text{otherwise} \end{cases} \tag{17}$$

where

AP_j^{iter} = the awareness probability of crow *j* at iteration *iter*.

This component determines whether to intensify or diversify the search area. As AP is expanded, the search space is thus increased, resulting in optimal global results and vice versa. Fig.5. explains the effect on the Search Process of the Flight Length of the Crow.

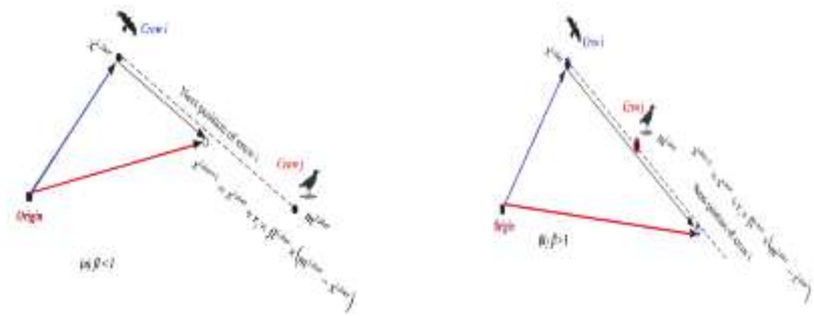

Figure 5 the Influence on the Search Process of the Flight Length of the Crow

5.1 CSA Functions on Following Steps [12]

1. Initiate parameters and constraints

Initiate flock of crows (N), number of iterations $iter_{max}$, flight length f l and awareness probability AP. Identify the decision variables and constraints.

2. Initialize position and memory of crows

Produce N crows arbitrarily in the d-dimensional hunt area. Every crow offers a suitable remedy to the problem. At first, crows have no insight; it is assumed that they have covered up their food in the underlying positions.

3. Evaluate fitness function

The position of every crow is calculated by fixing constraints which are given to the objective function.

4. Create new positions

In the d- dimensional hunt area crows explores new position by following way: for instance Crow i willing to explore latest position this can be done by selecting one of the crows arbitrarily, this is represented as crow j and going along with that crow to identify conceal food location (*mj*). The latest position of crow i is depicted by 1&2 equations. This step is iterated for 'N' crows.

5. Feasibility of latest positions examination

To determine optimization problem, It explores the viability of the latest location of every crow without any deviations by considering entire constraints. Finally it validates latest position by checking its viability by modifying its previous position otherwise it retains its previous position

6. Evaluate fitness function of new positions

The fitness function(objective function) is
analysed for latest location of all crows. The fitness function i.e. objective function value for the new position of each crow is evaluated
7. Update memory
The crow reconstructs its memory if the analysis of fitness function of all crows is better than the memorized fitness. The updated crow's memory is given by
8. Check termination criterion
Follow 4 to 7 steps, till iteration max is obtained. With this optimization solution is achieved by selecting the best memory location of objective function.

6 Results and Discussion

To check the capacity, resiliency, adaptability and viability of the suggested CSA for an optimum real power solution the IEEE 30- bus test system isused. There are 6 generator buses (1, 2, 5, 8, 11, 13)in the IEEE30 bus system,41 transmission lines, 24 load buses along with 4 transformers.[19] For test system, the load was raised by 125,150,175 and 200% from the base load. With this increase in load, raises the voltage deviation and real power losses at load buses. In addition to that to locate the weak buses in the system, L-Index is used to find the optimum position of the UPFC. At this point while the system load raises, buses 7,6, 4,25, 26,27, and 30 will have high L-index thus the above buses are the suitable areas to put the UPFC. To accomplish the objectives a swarm-based algorithm CSA is utilized to locate the ideal size of UPFC.

Finally, when the UPFC devices are plugged-in with optimum sizes atweakbuses, The related effects, such as Reactive Power injections, RPL are shownin table 1 and voltage profiles are in figures from (6-10) with various loading cases.

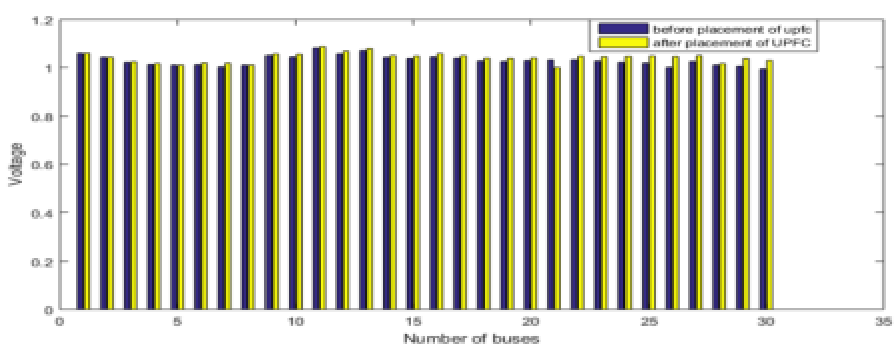

Figure 6 Voltages Profile for 100% of load

Table 1 Shows the Results of CSA for IEEE 30 Bus System

Loading condition	**Losses without UPFC (MW)**	**Optimal location of UPFC**	**Reactive injection in series with line (MVAr)**	**Reactive power injection in shunt with the bus (MVAr)**	**Losses with UPFC (MW)**
Normal loading	17.5985	7-6 24-25 25-26 27-30	6.2419 2.0398 4.8635 1.6353	5 4 12 15	17.1324
125% loading	30.3738	7-6 24-25 25-26 27-30	0.5265 34.9865 28.3264 1.0432	4 7 20 18	28.2264
150% loading	47.2228	7-6 24-25 25-26 27-30	7.0342 0.8653 4.2543 5.2342	10 5 40 36	43.3014
175% loading	69.3379	7-6 24-25 25-26 27-30	24.1642 14.8092 0.5692 0.7914	12 4 40 32	65.0243
200% loading	96.5636	7-6 24-25 25-26 27-30	10.2331 48.2651 1.8972 16.7812	14 8 58 52	91.2410

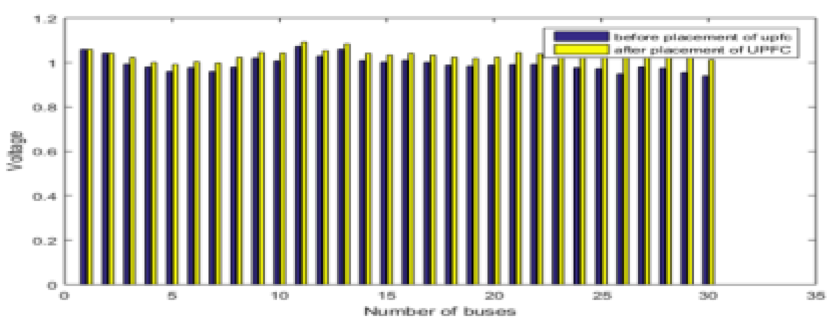

Figure 7 Voltages Profile for 125% of load

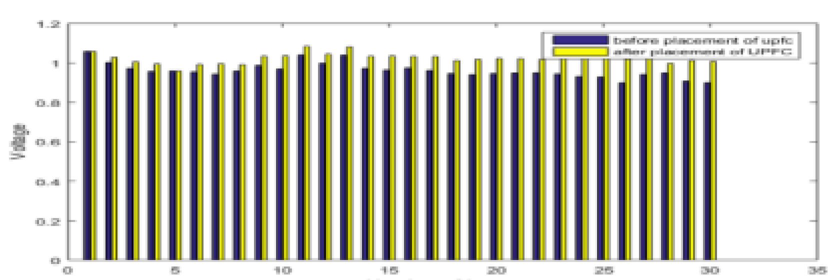

Figure 8 Voltages Profile for 150% of load

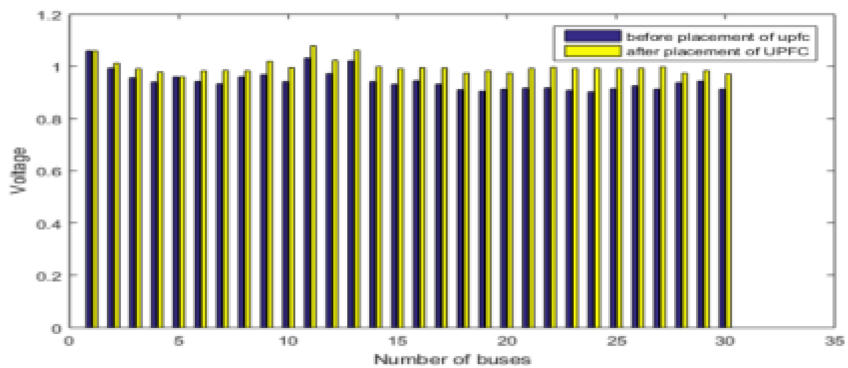

Figure 9 Voltages Profile for 175% of load

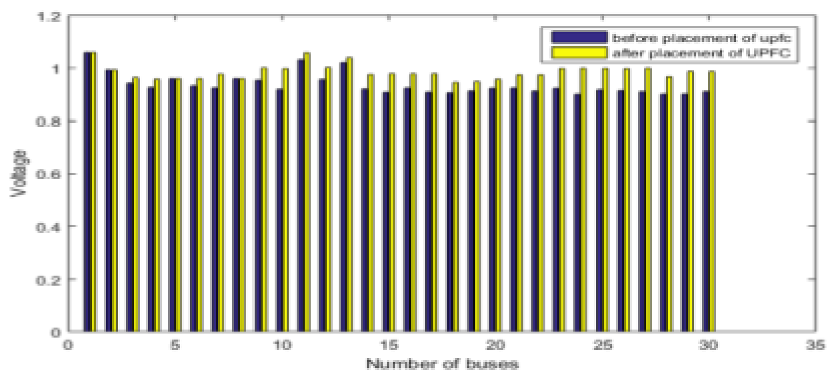

Figure 10 Voltages Profile for 200% of load

7 Conclusions

CSA is a Swarm based metaheuristic algorithm proposed to minimize RPL and maximize voltage stability by optimizing the control variables such as UPFC location, and its size simultaneously. With the consideration of UPFC the proposed algorithm gives much better results than other methods for multi-objective optimization problem. From the simulation results it can be concluded that the proposed algorithm is capable of finding optimum control variables and its problems in the presence of UPFC. With all the above mentioned facts it may be recommended as promising algorithm for solving complex engineering optimization problem.

References

[1] Hingorani NG, Gyugyi L. "Understanding FACTS: concepts and tech. of flexible AC transmission systems", Wiley Online Library, 1999.

[2] Verma KS, Singh SN, Gupta HO. "Location of unified power flow controller for congestion management", Electric Power Sys. Res, vol. 58, no. 2, pp. 89–96, 2001.
[3] Gyugyi L. "A unified power flow control concept for flexible AC transmission syst", IEE Proc Part C - Generation, Transmission and Distribution, vol. 139, no.4, pp.323–331, 1992.
[4] N.G. Hingorani and L. Gyugyi, "Understanding FACTS: concepts and technology of Flexible AC transmission systems", Wiley-IEEE Press, 2000.
[5] R. SrinivasaRao, V. SrinivasaRao. "A generalized approach for determination of optimal location and performance analysis of FACTs devices", International Journal of Electrical Power & Energy Systems, vol. 73, pp. 711–724, 2015.
[6]M. Noroozian, L. Angquist, M. Ghandhari and G. Anderson. "Use of UPFC for optimal power flow control", IEEE Trans on Power Delivery, vol. 12, no. 4, pp. 1629 - 1634 1997
[7] P.Kessel, H.Glavitsch."Estimating the Voltage Stability of a Power System", IEEE Transactions on Power Delivery, vol. 1, no. 3, pp. 346–354, 1986.
[8] P. Balachennaiah, "Optimizing real power loss and voltage stability limit of a large transmission network using firefly algorithm", Engineering Science and Technology, an International Journal, vol. 19, no.2, pp.800-810, 2015.
[9] Yasir Muhammad. "Review article Solution of optimal reactive power dispatch with FACTS devices:A survey", Energy Reports, vol. 6, pp. 2211–2229, 2020.
[10] Shaheen, A.M., Spea, S.R., Farrag, S.M., Abido, M.A.,."A review of metaheuristic algorithms for reactive power planning problem", Ain Shams Eng. Journal.vol. 9, no. 2, pp.215–231, 2018.
[11] R. Benabid and M. Boudour."Optimal Location and Size of SVC and TCSC for Multi-objective Static Voltage Stability Enhancement", RE&PQJ, vol. 1, no.6, 2008. Available online :http://www.icrepq.com/icrepq-08/256-benabid.pdf
[12] Rajesh Kumar Sahoo. "Nature Inspired Metaheuristic Algorithms-A Comparative Review", International Journal of Development Research, vol. 6, no.7, pp. 8427-8432, 2016.
[13] X. S. Yang, "Nature-Inspired Metaheuristic Algorithms", Second Ed. Luniver Press, 2010.
[14] ShaojianHou, "Power System Weak Bus Identification Based On Voltage Distribution Characteristic", IEEE Conference on Energy Internet and Energy System Integration (EI2), 2017.
[15] P. Kundur, J. Paserba, V. Ajjarapu, G. Andersson, A. Bose, C. Canizares, N. Hatziargyriou and et al, "Definition and classification of power system stability", IEEE/CIGRE joint task force on stability terms and definitions, vol. 19, no. 3, pp. 1387-1401, 2004.

[16] Thukaram D, Parthasarathy K, Khincha HP, UdupaNarendranath, Bansila. "Voltage stability improvement: case studies in Indian power networks", Elect Power Sys Res, vol. 44, no.1, pp.35–44, 1998.
[17] Yasir Muhammad, "Review article Solution of optimal reactive power dispatch with FACTS devices: A survey", Energy Reports, vol. 6, pp.2211–2229, 2020.
[18] Shaheen, A.M., Spea, S.R., Farrag, S.M., Abido, M.A., "A review of metaheuristic algorithms for reactive power planning problem", Ain Shams Eng. Jou.vol. 9, no. 2, pp. 215–231, 2018.
[19] M.VenuGopalaRao N.Kalpana."Optimal location of UPFC to minimize the real power losses using NSPSO Algorithm", International Journal of Innovative Technology and Exploring Engineering IJITEE, Blue Eyes Intelligence Engineering & Sciences Publication, vol. 8, no.12 , pp. 924-931,2019.
[20] Available Online: http://www.ee.washington.edu/research/pstca/pf30/pg_tca30bus.htm

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