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Ideal Setting of FACTS Devices for Voltage Stability Improvement Utilizing Flower Pollination Algorithm

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Abstract

In this paper, another and inconceivable estimation called Flower Pollination Algorithm (FPA) is proposed for perfect position and estimation of FACTS in various power systems. First the most candidate transports for presenting capacitors are suggested using Power Loss Index (PLI). By then the proposed FPA is used to determine the size of capacitors and their regions from the picked transports. The objective work is intended to reduce the total cost and, in this manner, to grow the net saving each year. The proposed figuring is taken a stab at IEEE 30 transport extended movement structures. The obtained results by methods for the proposed count are differentiated and various figuring's like Genetic Algorithm (GA), Particle Swarm Optimization (PSO) to highlight the benefits of the proposed computation. Also, the results are exhibited to affirm the ampleness of the proposed figuring to confine the setbacks and outright cost and to redesign the voltage profile and net setting something aside for various transport systems.

***Keywords**: Critical voltage, Reactive power, Voltage stability, Stability limits, Two bus system.*

1. Introduction

A multipart structure all round depicts a present electricity system which incorporates the transmission traces that interface the entire generator stations, transformers, and the all-out stacking focuses within the manipulate framework [1]. The assistance of the voltage in the reasonable degrees is the noteworthy commitment of a dependable control shape, to guarantee the superlative concept of client advantage, riding the purchaser to the pinnacle of appeal [2]. Notwithstanding, sadly the difficulty of voltage immovable high-quality has held up first rate as a reliably zooming constraining figure in the improvement and the running of the strength frameworks [3,4]. The prickly trouble of the voltage thwarted expectation may be considered as the error of the manipulate shape to bypass on the responsive electricity or by means of strategy for an avoidable assimilation of the open strength [5].

In such manner, there are apparent conduct via which the voltage fluctuation inconvenience is feasibly managed. In spite of the reality that the first method is focused across the parity of the circumstance, the instant framework contributes its concept on fine-tuning the Voltage Stability Margin (VSM) of the shape for the picked supportive circumstances [6]. The precept decision to keep the structure freed from the voltage unhappiness is relative down the open manipulate stack or interface covered responsive control before arriving at the motivation at the back of the voltage unhappiness [6]. To gain a safe and monetarily keen work, the Flexible AC Transmission System (FACTS) devices are fittingly introduced inside the structure [7]. The deft arrangement of these FACTS devices activates the terrific redecorate in one-of-a-kind features, for instance, the voltage steady best, the decent kingdom and the fleeting reliable characteristics of an astounding manipulate shape [9,10]. In sort out to utilize the Certainties devices inside the appropriate area, more than one imaginative frameworks

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much like the natural calculation, swarm techniques, SOL estimation, differential motion figuring and the repeated toughening are flawlessly applied [11]. Help, exceptional estimations are looking forward to for discovering the right vicinity of the FACTS devices. Inside the record, the FPA approach is as it should be utilized for finding the correct domain of the FACTS devices by way of propelling the voltage size.

2. Problem Formulation

The voltage security of the system is fundamentally subordinate on the genuine control, voltage enormity and the point, and in this manner, it is kept up by controlling the previously mentioned parameters. As well, the issue of finding and estimating of the FACTS controller can be figured as a multi-target issue with the taking after destinations and goals.

$$Min\, O(u,v) \tag{1}$$

Following constraints are part of objective function

$$C(u,v)=0 \tag{2}$$

$$D(u,v)\le 0 \tag{3}$$

Where, O is the objective function, C is the equality constraint and D is the inequality constraint that depends on the control variables u and v. The limits of the generation are classified into upper and lower bounds, which lie in between the actual limits. The balance and imbalance imperatives are used for distinguishing the ideal area and estimating of the FACTS devices. A point by point record of the relative limitations is outfitted in the accompanying segment.

Equality Constrain

Equality Constraints deal with the power balance of both real and reactive power. Power balance equation for real power is given by

$$P_{sup_n} = P_{G_n} - P_{D_n} \tag{4}$$

Power balance equation for reactive power is given by

$$Q_{sup_n} = Q_{G_n} - Q_{D_n} \tag{5}$$

Where P_{sup_n} represents the real power supplied to bus n, P_{G_n}, real power generated by generator 'n' and P_{D_n}, real power demand at bus n. Similarly, Q_{sup_n} denotes reactive power supplied to bus n, Q_{G_n} is the generated reactive power at bus 'n' &Q_{D_n} is the reactive power demand at bus 'n'

Inequality Constraint

The limits of the generation are classified into upper and lower bounds, which lie in between the actual limits.Voltage, Reactance, Real & Reactive power constraints of FACTS devices are as follows:

$$P_{G_n}^{min} \le P_{G_n} \le P_{G_n}^{max} \tag{6}$$

$$Q_{G_n}^{min} \le Q_{G_n} \le Q_{G_n}^{max} \tag{7}$$

$$V_n^{min} \le V_n \le V_n^{max} \tag{8}$$

Where $P_{G_n}^{min}$, $P_{G_n}^{max}$ are the limits for real power flow in the bus 'n', $Q_{G_n}^{min}$ &$Q_{G_n}^{max}$ are the limits for reactive power flow in bus 'n', V_n^{min} &V_n^{max} are the limits for voltage magnitude at bus 'n'.

Stability index is calculated using the equation below.

L= $\max_{j\in\alpha D} L_j$, where

$$L_j = \left|1-\left(\textstyle\sum_{i\in\alpha G} B_{ij} V_i\right)/V_j\right| \tag{9}$$

αD and αG are the nodes of consumers and generations respectively. The bus at which the collapse may happen is determined by L_j. Based on the equations above, the objective function can be formulated as follows.,

$$O = \begin{cases} \max(V, P_s) \\ \min(Q_s, P_D) \end{cases}$$

where $V = \sum_{i=1}^{NL} v_n$, $P_s = \sum_{i=1}^{NL} p_n$ and $Q_s = \sum_{i=1}^{NL} q_n$.

The ideal area and measuring are resolved dependent on the above condition for the arrangement of FACTS devices. This paper concentrates to infer out the ideal area The soundness is improved dependent on the voltage profile values which is an accomplished by least force misfortune once subsequent to setting FACTS devices.

3. Facts Devices Placement and Determination using Flower Pollination Algorithm

Overview of FPA

FPA was exhibited in 2012 by Yang [24]. It was pushed by the treatment task of blooming plants. The most goal of a sprout is basically spread using preparation. Blossom preparation is associating with the trading of residue, which is consistently related with pollinators like winged animals and dreadful little animals. Preparation appears in two crucial sorts: abiotic and biotic. Most blossoming plants rely upon the biotic preparation task, in which the residue is transmitted by pollinators. The remainder of preparation takes after abiotic outline that doesn't ask for. Any pollinators like grass. Wind and spread support inside the treatment task of such blooming plants. Then again, treatment can be executed without anyone else's input fertilization or cross-fertilization. Self-fertilization is the treatment of one sprout from the residue of a similar sprout or different blooms of a similar plant. Cross treatment is the preparation from the residue of a bloom of different plants. The explanation of the FPA is natural selection and the perfect age of plants as far as numbers just as the fittest. This might be treated as an improvement task of plant species. These factors and assignments of bloom preparation made perfect proliferation of the blossoming plants. In addition, FPA exhibits its capacity to unwind various issues in charge system. Thusly, it has been gotten in this paper to understand the issue of perfect estimating and zones of capacitors in transport structures.

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Algorithmic Steps

For FPA, the taking after four steps are used:
Stage 1: Worldwide treatment addressed in biotic and crosspollination assignments, as dust conveying pollinators fly taking after Lévy flight [26].
Stage 2: Neighborhood treatment appeared in abiotic and self-fertilization as the task doesn't ask any pollinators.
Stage 3: Blossom relentlessness which can be displayed by creepy crawlies, which is on standard with an age probability that is relative to the likeness of two flowers included.
Stage 4: A switch probability p ∈ [0,1] is used to control the connection of close by and overall preparation.

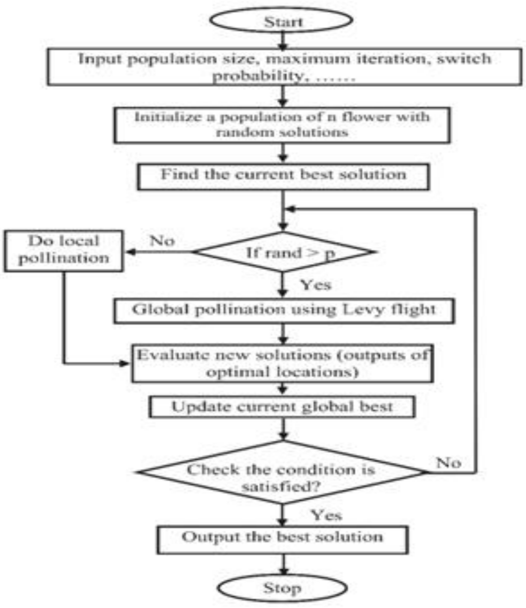

Figure 1: Flowchart for Flower Pollination Algorithm

4. Results & Discussions

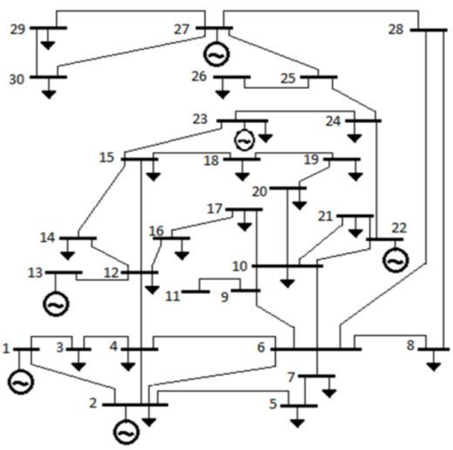

Figure 2: IEEE 30 bus system single line diagram

At first, in the proposed system, Newton Raphson (NR) power flow technique is applied and the voltage magnitudes are calculated for each bus and tabulated below.

Table 1: Voltage Profile using NR

Bus Number	Voltage Profile
1	1.06
2	1.045
3	1.021771
4	1.013178
5	1.01
6	1.011411
7	1.003062
8	1.01
9	1.051939
10	1.046583
11	1.082
12	1.061236
13	1.071
14	1.048815
15	1.046211
16	1.047877
17	1.041661
18	1.034284
19	1.030325
20	1.03362
21	1.040327
22	1.042772
23	1.04665
24	1.055636
25	1.04092
26	1.023658
27	1.040043
28	1.009309
29	1.020558
30	1.009287

Load Flow

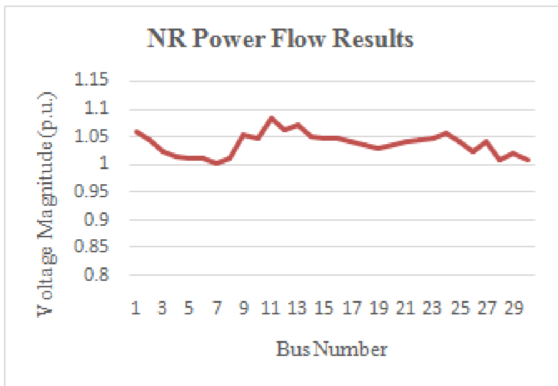

Figure 3: Power Flow results using NR Load Flow

As a next step, the Flower Pollination Algorithm is applied as a power flow technique and the voltage magnitude are plotted below.

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Table 2: Voltage Profile using FPA

Bus Number	Voltage Profile
1	1.1
2	1.1
3	1.048934
4	1.037117
5	1.1
6	1.026643
7	1.049332
8	0.996516
9	1.056515
10	1.049611
11	1.07814
12	1.053955
13	1.037863
14	1.042878
15	1.041447
16	1.044854
17	1.042849
18	1.032234
19	1.029897
20	1.034046
21	1.04312
22	1.045477
23	1.044556
24	1.057186
25	1.04466
26	1.027462
27	1.045136
28	1.017638
29	1.025757
30	1.014546

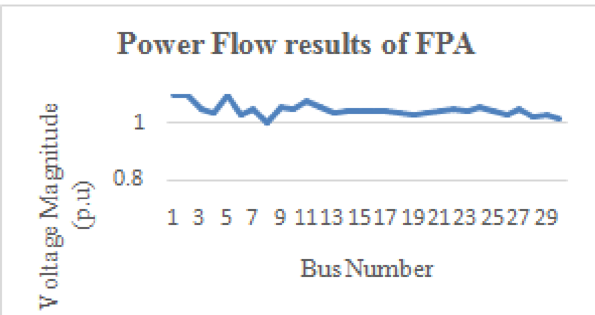

Figure 4: Power Flow results using FPA

Finally, as per the proposed method FPA is combined along with FACTS in-order to improve the voltage profile of the system.

Table 3: Voltage Profile using FPA with FACTS Device

Bus Number	Voltage Profile
1	1.1
2	1.1
3	1.051577
4	1.038519
5	1.1
6	1.027172
7	1.049648
8	0.996516
9	1.056868
10	1.050051
11	1.07814
12	1.054464
13	1.037863
14	1.043387
15	1.041952
16	1.045339
17	1.043305
18	1.032723
19	1.030373
20	1.034514
21	1.043573
22	1.045932
23	1.045055
24	1.057673
25	1.045135
26	1.027946
27	1.045601
28	1.018051
29	1.026231
30	1.015025

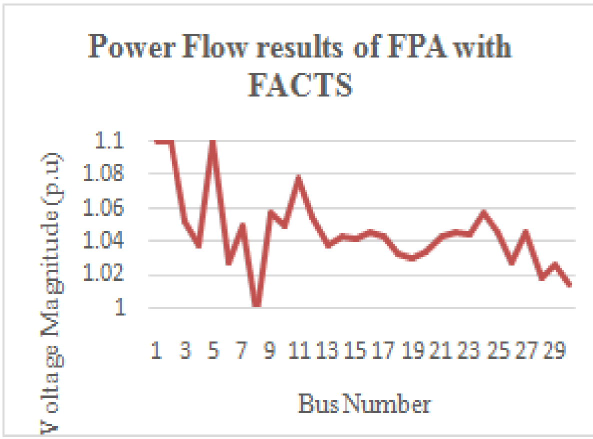

Figure 5: Power Flow results of FPA along with FACTS

Table 4: Comparison of Voltage Profile at all buses

Bus Number	Voltage Profile		
	NR	**FPA**	**FPA with FACTS**
1	1.06	1.1	1.1
2	1.045	1.1	1.1
3	1.021771	1.048934	1.051577
4	1.013178	1.037117	1.038519
5	1.01	1.1	1.1
6	1.011411	1.026643	1.027172
7	1.003062	1.049332	1.049648
8	1.01	0.996516	0.996516
9	1.051939	1.056515	1.056868
10	1.046583	1.049611	1.050051
11	1.082	1.07814	1.07814
12	1.061236	1.053955	1.054464
13	1.071	1.037863	1.037863
14	1.048815	1.042878	1.043387
15	1.046211	1.041447	1.041952
16	1.047877	1.044854	1.045339
17	1.041661	1.042849	1.043305
18	1.034284	1.032234	1.032723
19	1.030325	1.029897	1.030373
20	1.03362	1.034046	1.034514
21	1.040327	1.04312	1.043573
22	1.042772	1.045477	1.045932
23	1.04665	1.044556	1.045055
24	1.055636	1.057186	1.057673
25	1.04092	1.04466	1.045135
26	1.023658	1.027462	1.027946
27	1.040043	1.045136	1.045601
28	1.009309	1.017638	1.018051
29	1.020558	1.025757	1.026231
30	1.009287	1.014546	1.015025

From the simulation results tabulated in the Table it is clear that the FPA when combined with FACTS devices helps to improve the voltage profile and hence the voltage stability.

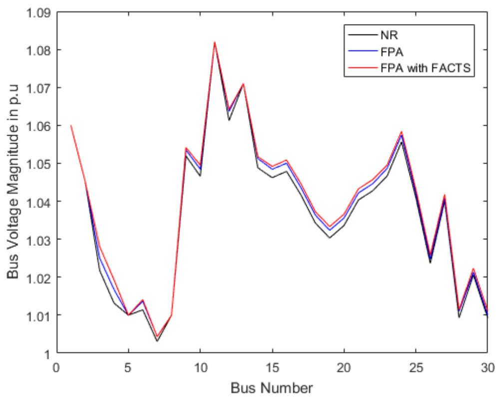

Figure 6: Graph for comparison of Voltage Profile between different methods

In order to validate the work further, the simulation results are compared with other computational heuristic algorithms and the results of voltage stability index are tabulated as follows:

Table 5: Comparison of VSI for various algorithms

Heuristic Method	**Voltage Stability Index**
GA	0.1409
PSO	0.1402
PSO-GSA	0.1404
Proposed Method	**0.1381**

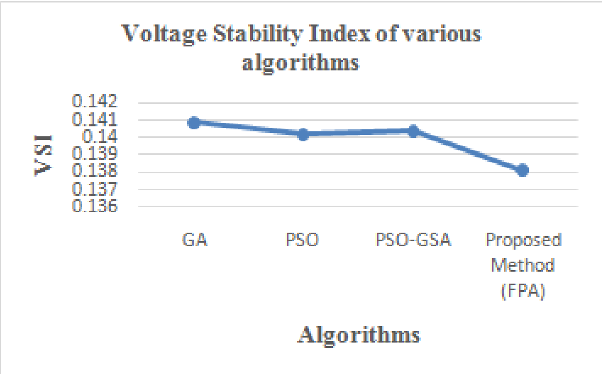

Figure 7: Comparison of VSI for various algorithms

From the graph, it is very clear that the stability index is low for FPA and thus FPA with FACTS will have a higher voltage stability than the other algorithms used in the literature. Thus, TCSC will provide VAR support to maintain the voltage stability and the location of TCSC as obtained by the proposed method along with its size is as follows;

Table 6: Placement & Rating of TCSC obtained from the FPA algorithm

Bus Number	TCSC Rating (V., p.u)
1	0.6
5	0.6
2	0.6
4	0.6
7	0

5. Conclusion

The projected procedure was actual inside the MATLAB platform. Here, the FPA methodology was investigated to maneuver forward the stableness of the transmission framework supported the voltage and therefore the management misfortune. At first, the voltage collapse rating of the framework was analyzed and determined by the perfect space of the FACTS devices. From the situation, the infused management rating of the FACTS decided reckoning on the voltage greatness and therefore the purpose. During this method, the management misfortune and therefore the injected voltages were analyzed and their examination results were talked concerning. By interfacing the IPFC in between 2 buses, the voltage values and their management misfortunes were assessed. Hence, the management misfortune and therefore the injected voltages were analyzed and their examination results were talked concerning. Inside the projected technique, the computation time was assessed supported their performance analysis. From the execution examination, the passed time for the projected strategy was less compared thereto of the FPA methodology. during this manner, the projected methodology was able to reach higher comes concerning for progressing the voltage soundness and reducing losses. In future work, the target of the paper is modified and therefore the ideal state of affairs of FACTS devices is identified utilizing latest improvement calculation. Be that because it might, the perfect state of affairs of the FACTS devices was chosen a lot of exactly.

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