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AN INNOVATIVE APPROACH CONGESTION MANAGEMENT IN POWER TRANSMISSION LINES WITH ADVANCED CONTROL

KUMAR CHERUKUPALLI[1], BADDU NAIK BHUKYA[2]

[1]Associate Professor, Department of Electrical & Electronics Engineering,

Prasad V Potluri Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India.

[2]Assistant Professor, Department of Electrical & Electronics Engineering,

Prasad V Potluri Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India.

E-mail: [1]kumarcherukupalli77@gmail.com, [2]baddunaik@gmail.com

ABSTRACT

Due to power line overloading, it is sometimes difficult to allocate all of the necessary power to a supply in a modern power system. The traditional power framework inside seeing Flexible AC Transmission Framework (FACTS) regulators is a choice to deal with this issue and can extend the electrical power framework's ability to manage quick variations in the framework's working conditions. This paper proposes an optimal power flow control strategy for transmission line executives by combining an advanced model of interline power flow controller (AIPFC) calculation with constriction factor-based particle swarm optimization (CFBPSO). When all factors are considered, multi-line FACTS regulators outperform single-line FACTS regulators. The complete exact displaying of an advanced level Interline Power Flow Controller (AIPFC) is presented in this paper and the effect of an ideal area is investigated. To address OPF issues in the context of the advanced model IPFC, an imaginative calculation, such as CFBPSO, is proposed. The proposed method is validated using a standard IEEE 30 bus test framework. The exploration paper revealed the accuracy of the projected calculation through a reduction in the value of the goal work.

Keywords: *Flexible AC Transmission System (FACTS), Advanced Interline Power Flow Controller (AIPFC), Optimal Power Flow (OPF), Constriction Factor Based Particle Swarm Optimization (CFBPSO).*

1. INTRODUCTION

Electric companies have been forced to increase their generation in order to meet the world's growing power consumption. The transmission framework serves as the primary medium of communication between demand and generation power networks. Power transmission frameworks and arrangements are becoming increasingly important in light of changes in power conveyance arrangements. As a result, more careful power system planning is required. New technologies are being developed to achieve such delivery performance. The possibility of adding another device to the network will be investigated. This could happen during the individual planning stage or later during the expansion planning stage.

The legitimate activity and execution of this present framework in distinct and consistent state conditions play a significant role in the overall power frameworks satisfactory and secure operation. In consistent state conditions, the reduction in power losses and voltage drop in the path between generation and burden has consistently been critical for influencing framework productivity. The capacity of the power framework to maintain its soundness amid transient conditions following unsettling influences is the other component of a solid power framework. When this threshold is reached, the framework is supposed to be blocked. If the outage persists, the office framework will experience a power outage. Furthermore, if responsive power is lacking, voltage changes may occur, resulting in voltage breakdown. [1]-[6].

Maintaining power framework security necessitates ensuring that the power framework operates within its limits, as failure to do so may result in endless blackouts with potentially serious social and financial consequences. The most fundamental transmission in the board challenge [7], [8] is presumably executive outage, which includes overseeing transmission to ensure that move limitations are met. Congestion can be reduced by rescheduling generator yields, providing responsive power, or genuinely confining exchanges.

As a result, a few strategies have been proposed and implemented by specialists and designers to alleviate the outage and further develop the power framework execution. There are two types of executives' congestion their techniques: specialized and non-specialized. Non-specialized arrangements can be market-based or non-market-based. Market-based methodologies include counter exchanging, creating redispatching [9], [10], load abbreviation, selling, market parting, nodal valuing, and zonal evaluating. Favorable rates and the early bird gets the worm are examples of non-market arrangements.

[11] Introduces an OPF-based solution for reducing congestion and administration costs. [12] Discusses a congestion control coordination method involving Benders cuts between delivering organizations and framework administrators. [13] Suggested a method for reducing outage caused by voltage shakiness and warm overburdening. This also makes use of OPF, which can be solved with standard solvers. [14], [15] proposed a zonal model based on ac load stream. Zones have also been defined in these works based on affect ability esteems. However, in both [12] and [14], the affect ability esteems for each bus in the framework should be recorded, which, given a pragmatic power framework, necessitates a lot of handling exertion.

FACTS gadgets are preferred in modern power frameworks because of their general presentation [16], which provides excellent arrangements. The combined power stream regulator UPFC and IPFC, for example, are the most impressive and adaptable of the FACTS gadgets. IPFC infusion models and IPFC-equipped transmission lines are developed using the numerical model presented by [20], just as UPFC infusion models are commonly used [17], [18], and the specific pi-model of UPFC-embedded transmission lines [19] is not fixed.

In traditional OPF solutions, the search direction is derived from the function's derivative. As a result, the problem must be expressed as a continuous differentiable function; otherwise, these methods become ineffective. To address this issue, the current paper solves the optimization problem using constriction factor-based particle swarm optimization. The fitness function is used to represent the value of the objective function in most optimization methods, and the penalty function method is used to represent the binding constraints. This study demonstrates the efficacy of the proposed solution to the congestion management problem using the IEEE 30-bus system.

2. ADVANCED MODEL OF INTERLINE POWER FLOW CONTROLLER (AIPFC)

The static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), unified power flow controller (UPFC), and interline power flow controller are typically included in the last generation of FACTS controllers that use the self-commutated voltage sourced converter (VSC) (IPFC). The IPFC has a much more flexible topology than the UPFC and SSSC, consists of at least two converters, and can be used to control the power flows of a group of lines. The IPFC is expected to be used to solve complex transmission network congestion management problems. This inspires the author to create a new IPFC model for power flow analysis.

Existing steady-state models can be divided into two types: decoupled models and coupled models. In a decoupled model, the FACTS devices are typically replaced with a fictitious PQ or PV bus, causing the Jacobian matrix structure to change. A coupled model is made up of two major models: the voltage source model (VSM) [21], [25], [26] and the power injection model (PIM) [22]-[24]. Furthermore, how to deal with the practical constraints of FACTS devices is a significant issue [27]. It was not stated in the publications how the IPFC constraints are dealt with in their power flow programs.

This paper presents a novel IPFC power injection model for power flow analysis. The impedance of the series converter transformer and the line charging susceptance are both included in

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this model. In this case, it is demonstrated that the admittance matrix's original structure and symmetry can still be preserved, and thus the Jacobian matrix can retain its block-diagonal properties and a sparsity technique can be used. In order to achieve the specified control targets, the IPFC state variables are adjusted concurrently with the network state variables. Furthermore, the model can account for IPFC's practical constraints, with a detailed implementation in Newton power flow presented [28], [29].

2.1 Mathematical Model of AIPFC

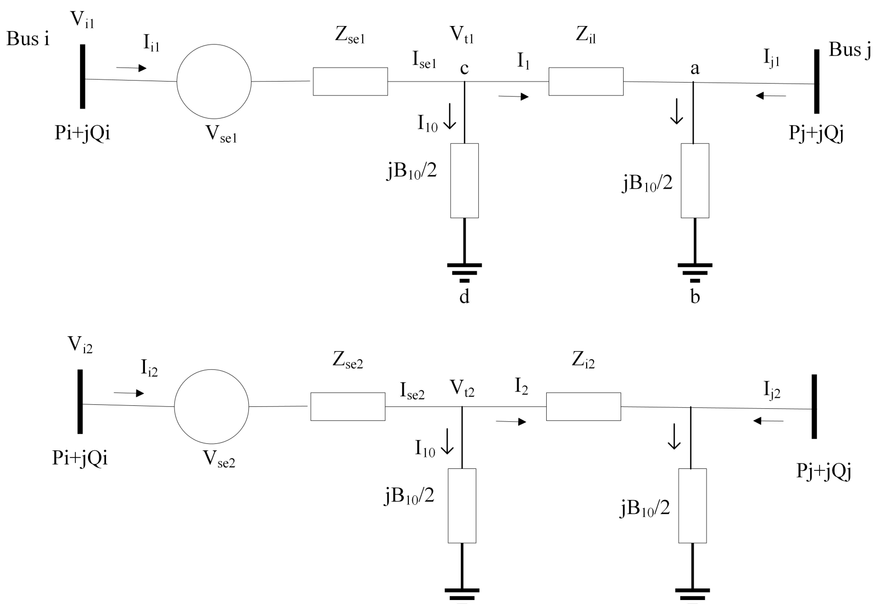

Figure 1: Equivalent Circuit Diagram of AIPFC

The numerical induction applies to an AIPFC with quite a several series converters.

$V_{i_n} = V_{i_n} \angle \theta_{i_n}$ and $V_{j_n} = V_{j_n} \angle \theta_{j_n}$

The complex bus voltages at buses i_n and j_n

I_{i_n} and I_{j_n}

The complex currents injection at buses i_n and j_n

$V_{se_n} = V_{se_n} \angle \theta_{se_n}$

The complex controllable series injected voltage

$Z_{se_n} = R_{se_n} + jX_{se_n}$

The series transformer impedance

$Z_{l_n} = X_{l_n} + jX_{l_n}$

The line series impedance

B_{10} : The line charging susceptance

From Figure 1:

$$V_{i_n} = V_{se_n} + I_{i_n} Z_{se_n} + V_{t_n} \quad (1)$$

$$I_{i_n} = I_1 + I_{10} = \frac{\left(V_{t_n} - V_{r_n}\right)}{Z_{l_n}} + V_{t_n}\left(j\frac{B_{10}}{2}\right) \quad (2)$$

We can express V_{t_n} and I_{i_n} according to V_{j_n} and I_{j_n} as

$$V_{t_n} = I_1 Z_{l_n} + V_{j_n} \quad (3)$$

$$I_1 = -I_{j_n} + I_{ab} \quad (4)$$

Where

$$I_{ab} = \frac{V_{ab}}{Z_{ab}} = \frac{V_{j_n}}{\left(\frac{2}{jB_{10}}\right)} = V_{j_n}\left(j\frac{B_{10}}{2}\right) \quad (5)$$

$$I_1 = -I_{j_n} + V_{j_n}\left(j\frac{B_{10}}{2}\right) \quad (6)$$

$$V_{t_n} = V_{j_n}\left[1+\left(j\frac{B_{10}}{2}\right)Z_{l_n}\right] - I_{j_n}\left[Z_{l_n}\right] \quad (7)$$

$$I_{10} = I_{cd} = \frac{V_{cd}}{Z_{cd}} = \frac{V_{t_n}}{\left(\frac{2}{jB_{10}}\right)} = V_{t_n}\left(\frac{jB_{10}}{2}\right) \quad (8)$$

$$I_{10} = V_{j_n}\left(\frac{jB_{10}}{2}\right) + V_{j_n}Z_{l_n}\left(\frac{B_{10}^2}{4}\right) - I_{jn}Z_{l_n}\left(j\frac{B_{10}}{2}\right) \quad (9)$$

$$I_{i_n} = V_{j_n}\left[\left(jB_{10}\right)+Z_{l_n}\left(\frac{B_{10}^2}{4}\right)\right] - I_{jn}\left[1+Z_{l_n}\left(j\frac{B_{10}}{2}\right)\right] \quad (10)$$

$$D = \left[\left(jB_{10}\right)+Z_{l_n}\left(\frac{B_{10}^2}{4}\right)\right]$$

$$E = \left[1+Z_{l_n}\left(j\frac{B_{10}}{2}\right)\right]$$

$$V_{t_n} = V_{j_n}E - I_{j_n}Z_{l_n} \quad (11)$$

$$I_{i_n} = V_{j_n}D - I_{jn}E \quad (12)$$

$$I_{jn} = \frac{V_{se_n}}{Z_{se_n}E+Z_{l_n}} - \frac{V_{i_n}}{Z_{se_n}E+Z_{l_n}} + \frac{V_{j_n}\left[Z_{se_n}D+E\right]}{Z_{se_n}E+Z_{l_n}} \quad (13)$$

$N = Z_{se_n}E + Z_{l_n}$ and $M = Z_{se_n}D + E$

$$I_{jn} = V_{j_n}\frac{M}{N} - \frac{V_{i_n}}{N} + \frac{V_{se_n}}{N} \quad (14)$$

$$I_{i_n} = V_{j_n}\left(D-\frac{EM}{N}\right) + V_{i_n}\frac{E}{N} - V_{se_n}\frac{E}{N} \quad (15)$$

$$\begin{bmatrix} I_{i_n} \\ I_{j_n} \end{bmatrix} = \begin{bmatrix} A_{ii_n} & A_{ij_n} \\ A_{ji_n} & A_{jj_n} \end{bmatrix}\begin{bmatrix} V_{i_n} \\ V_{j_n} \end{bmatrix} + \begin{bmatrix} W_{ii_n} \\ W_{ji_n} \end{bmatrix}V_{se_n} \quad (16)$$

Where $A_{ii_n} = \frac{E}{N}, A_{jj_n} = \frac{M}{N}$,

$$A_{ij_n} = D - \frac{ME}{N},\ A_{ji_n} = -\frac{1}{N}$$

$$W_{ii_n} = -\frac{E}{N},\ W_{ji_n} = \frac{1}{N},$$

$$A_{ij_n} = A_{ji_n} \quad (17)$$

$$A_{ii_n} = -A_{ij_n} + A_{i_n}^0,$$

$$A_{i_n}^0 = D + \frac{E(1-M)}{N}$$

$$A_{jj_n} = -A_{ji_n} + A_{j_n}^0,$$

$$A_{j_n}^0 = D + \frac{M-N}{N} \quad (18)$$

$$P_{i_n}^{se} = \frac{\left(1-\frac{B_{10}}{2}X_{l_n}\right)}{H}V_{i_n}V_{se_n}\sin\left(\theta_{i_n}-\theta_{se_n}\right) \quad (19)$$

$$Q_{i_n}^{se} = \frac{-\left(1-\frac{B_{10}}{2}X_{l_n}\right)}{H}V_{i_n}V_{se_n}\cos\left(\theta_{i_n}-\theta_{se_n}\right) \quad (20)$$

$$P_{j_n}^{se} = \frac{-V_{j_n}V_{se_n}}{H}\sin\left(\theta_{j_n}-\theta_{se_n}\right) \quad (21)$$

$$P_{j_n}^{se} = \frac{V_{j_n}V_{se_n}}{H}\cos\left(\theta_{j_n}-\theta_{se_n}\right) \quad (22)$$

Where $H = X_{se_n}\left[1-\left(\frac{B_{10}}{2}\right)X_{l_n}\right] + X_{l_n}$

$$I_{ij_n} = \left(V_{i_n}-V_{r_n}\right)A_{ij_n} + V_{i_n}A_{i_n}^0 \quad (23)$$

$$I_{ji_n} = \left(V_{j_n}-V_{i_n}\right)A_{ij_n} + V_{j_n}A_{j_n}^0 \quad (24)$$

$$P_{ij_n} = \mathrm{Re}\left(V_{i_n}I_{ij_n}^*\right) = \frac{-1}{H}V_{i_n}V_{j_n}\sin\theta_{ij_n} \quad (25)$$

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$$Q_{ij_n} = \mathrm{Im}\left(V_{i_n} I^*_{ij_n}\right) = \frac{-\left(1+\frac{B_{10}}{2}X_{l_n}\right)V^2_{i_n} + V_{i_n}V_{j_n}\cos\theta_{ij_n}}{H} \quad (26)$$

$$P_{ji_n} = \mathrm{Re}\left(V_{j_n} I^*_{ji_n}\right) = \frac{-1}{H}V_{i_n}V_{j_n}\sin\theta_{ji_n} \quad (27)$$

$$Q_{ji_n} = \mathrm{Im}\left(V_{j_n} I^*_{ji_n}\right)$$

$$Q_{ji_n} = \frac{V_{j_n}}{H}\left(-V_{j_n} + V_{i_n}\cos\theta_{ji_n}\right) - V_{j_n}\left[X_{se_n}\left(B_{10} - \frac{B^2_{10}X_{l_n}}{4}\right) + \frac{B_{10}X_{l_n}}{2}\right] \quad (28)$$

$$P_{dc} = \sum_n P_{ex_n} = 0 \quad (29)$$

Where $P_{ex_n} = \mathrm{Re}\left(V_{se_n} I^*_{i_n}\right)$

$$P_{ex_n} = \left(B_{10} - \frac{B^2_{10}X_{l_n}}{4} + \frac{G}{H}\right)V_{se_n}V_{j_n}\sin\left(\theta_{se_n} - \theta_{j_n}\right) - \frac{\left(1-\frac{B_{10}X_{l_n}}{2}\right)V_{i_n}V_{se_n}\sin\left(\theta_{se_n}-\theta_{i_n}\right)}{H} = 0 \quad (30)$$

Where

$$G = \left[\begin{array}{l} -X_{se_n}\left(B_{10} - X_{l_n}\left(\frac{B^2_{10}}{4}\right)\right) \\ +1 - X_{l_n}\left(\frac{B_{10}}{2}\right)\end{array}\right]\left[1 - X_{l_n}\left(\frac{B_{10}}{2}\right)\right]$$

3. PARTICLE SWARM OPTIMIZATION

Kennedy and Eberhart devised the molecule swarm advancement method in 1995 [30], and it is a game-changing calculation. Fish tutoring and bird running were used as examples of animal social behavior. A flock of birds has been spotted searching for food in an irregular space. Although not all birds in a herd are aware of the specific location of food, they are aware of the position that is closest to it (the food). The simplest and best way to find food is to search the area surrounding the current best position, i.e. the position closest to food.

PSO has already been applied to a number of power system optimization issues. In [31], a PSO was used to solve the problem of economic generator dispatch in a power system. [32] Proposes a method for controlling reactive power and voltage in power systems to ensure voltage stability. [33] Describes the use of PSO for sensitivity-based congestion management. It does not, however, provide a method for dealing with constraints.

3.1 Constriction Factor Based PSO (CFBPSO)

Velocity of each agent can be modified by the following equation:

$$v_i^{k+1} = wv_i^k + c_1 rand_1 * (pbest_i - s_i^k) + c_2 rand_2 * (gbest - s_i^k) \quad (31)$$

$$w = w_{\max} - ((w_{\max} - w_{\min})/(iter_{\max})) * iter \quad (32)$$

$$s_i^{k+1} = s_i^k + v_i^{k+1} \quad (33)$$

PSO's basic system equation [(31), (32), and (33)] can be seen of as a difference equation. As a result, the eigen values of the difference equation can be used to study the system dynamics, or the search operation.

$$v_i^{k+1} = K[v_i^k + c_1 * rand_1 * (pbest_i - s_i^k) + c_2 * rand_2 (gbest - s_i^k)] \quad (34)$$

$$K = \frac{2}{2 - \varphi - \sqrt{\varphi^2 - 4\varphi}}, \quad \varphi = c_1 + c_2, \varphi > 4 \quad (35)$$

Where φ and K are coefficients.

For example, if φ=4.1, then K = 0.73. As w increases above 4.0, K gets smaller.For example, if φ=5.0, then K =0.38, and the damping effect is even more pronounced.

Individuals who employ the restriction factor strategy tend to converge over time. Unlike other evolutionary computation approaches, the constriction factor approach guarantees the convergence of the search procedure based on mathematical theory. As a result, the restriction factor strategy can yield better results than the traditional PSO strategy. The restriction factor method, on the other hand, only addresses one individual's dynamic behaviour and the effects of inter-individual interactions. As a result, the CFBPSO approach produces higher-quality solutions than the basic PSO approach. [34]-[36].

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4. PROBLEM FORMULATION

The optimal power flow (OPF) problem is a static non-linear constrained optimization problem whose solution determines the optimal setting for power network control variables.

Minimize f(x)
Subject to h(x)=0
g(x)≤0 (36)

Mathematically, this can be represented as in the following

$$\min c(x) = \min \sum_{i=1}^{Ng} \left(c_i + b_i P_{Gi} + a_i P_{Gi}^2\right) \quad (37)$$

$$P_{Gi} - P_{Di} - \sum_{j=1}^{nb} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} + \delta_j - \delta_i -) = 0 \quad (38)$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{nb} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} + \delta_j - \delta_i) = 0 \quad (39)$$

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \quad \text{i=1,…,NG} \quad (40)$$

$$Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max} \quad \text{i=1,…,NG} \quad (41)$$

$$P_{Di}^{\min} \le P_{Di} \le P_{Di}^{\max} \quad \text{i=1,…,NG} \quad (42)$$

$$Q_{Di}^{\min} \le Q_{Di} \le Q_{Di}^{\max} \quad \text{i=1,…,NG} \quad (43)$$

$$V_i^{\min} \le V_i \le V_i^{\max} \quad \text{i=1,…,NL} \quad (44)$$

$$T_i^{\min} \le T_i \le T_i^{\max} \quad \text{i=1,…,NT} \quad (45)$$

$$S_i \le S_i^{\max} \quad \text{i=1,…,nl} \quad (46)$$

4.1 Process for Congestion Management by AIPFC Using CFBPSO Algorithm

1. Set the underlying factors of the PSO and the force framework factors alongside the boundaries of IPFC.
2. Initialize the ith molecule with irregular arrangement alongside its underlying position, greatest speed, and inactivity weight.
3. Check the IPFC for legitimate course of action and figure bus voltage for every molecule, update line information and bus information.
4. Calculate the target work for all particles.
5. Calculate the individual best situation of the ith molecule, at that point set Pbest and monitor the general best worth (Gbest), and its area.
6. Calculate the worldwide best position Gbest, with the end goal that the most amazing aspect Pbests as Gbest
7. Update the inertia weight as in equation (32)
8. Estimate the new molecule speed and positions as in equation (34)
9. Checking the breaking point infringement for security imperatives. In the event that cycles arrive at their maximum worth, at that point go to step-10, or, in all likelihood go to stage 2.
10. Stop

Figure 2 shows flowchart of CFBPSO algorithm for transmission congestion management.

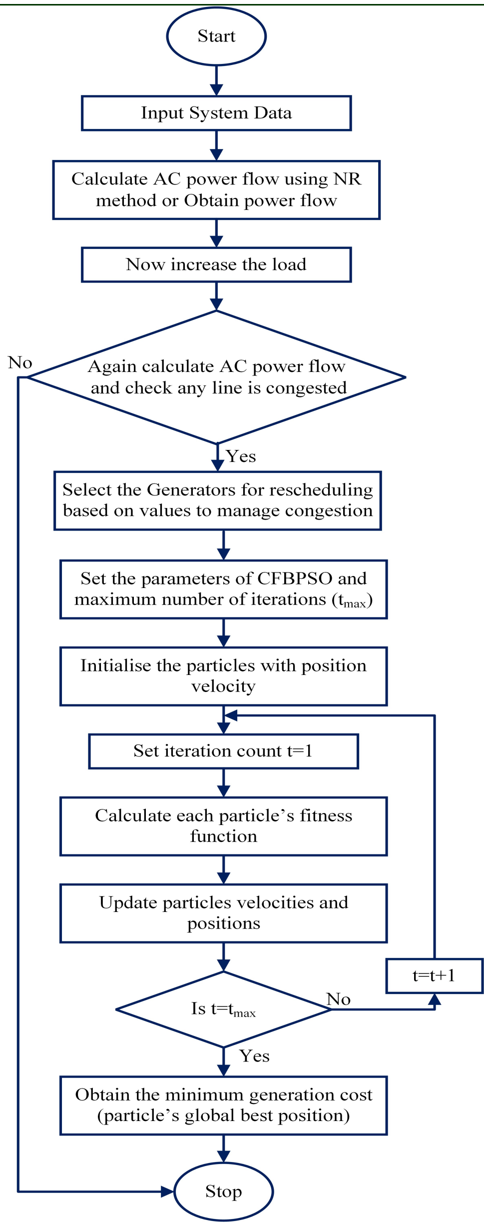

Figure 2: Flowchart of CFBPSO Algorithm for Transmission Congestion Management

5. CASE STUDIES AND RESULTS

One of the serious issues in the power framework is network congestion. This problem occurs as a result of framework overburdening. This section describes the outcome of the ideal situation of a high-level IPFC model by concurrent minimization of expected expense using CFBPSO. On the IEEE 30 bus test framework, the proposed technique was demonstrated. The increased demand for load buses has been caused system congestion. Three cases are considered for recreation to demonstrate the viability of the proposed CFBPSO calculation with AIPFC, focusing on the base case condition, over-loading condition, and possibility examination.

Figure 3 compares the OPF results obtained with the proposed strategy to a portion of the current writing techniques in order to approve them. It shows that when compared to other strategies, the proposed CFBPSO strategy produces better results.

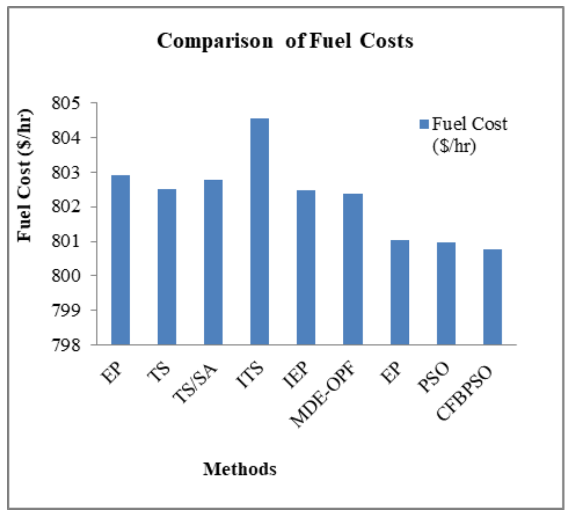

Figure 3: Comparison of Fuel Costs

Over loaded line		Load increment in (%)	Power flow Limit (MVA)	Power flow (MVA)	Congestion
From bus	To bus				
1	2	10	130	**142.051**	Congested
1	2	15	130	**144.204**	Congested
1	2	20	130	**146.401**	Congested

Case a: Base case condition

The genuine power taken into account is the reduction of generator fuel costs. Table 1 shows the optimal control factor settings for the base case condition using CFBPSO with AIPFC. The base generator fuel cost obtained via CFBPSO using the AIPFC technique is **800.124 $/hr,** which is less than the Newton-Raphael (NR) method.

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Receiving bus	Power flow Limit (MVA)	Power flow under over loading	Power flow with AIPFC using CFBPSO	Congestion
1-2	130	**142.051**	**115.031**	Relieved
1-2	130	**144.204**	**122.732**	Relieved
1-2	130	**146.401**	**128.207**	Relieved

Table 1: Optimal Control Factors Settings for Base Case Condition Utilizing CFBPSO with AIPFC

Variables		NR	CFBPSO with AIPFC
Real Power Generation	P_{G1}	159.29	176.95
	P_{G2}	58.12	48.87
	P_{G3}	12.87	21.11
	P_{G4}	18.71	11.82
	P_{G5}	22.42	21.59
	P_{G6}	21.1	12
Generator Voltages	V_{G1}	105	110
	V_{G2}	104.5	108.78
	V_{G3}	101	106.98
	V_{G4}	105	110
	V_{G5}	101	106.19
	V_{G6}	105	110
Loss (MW)		9.11	8.94
Cost ($/hr)		**810.911**	**800.124**

Case b: Congestion due overloading

This section handles transmission congestions caused by overloading, where the congestion was created in the framework by increasing the load. The proposed technique was tested for ten percent, fifteen percent, and twenty percent burden stacking conditions, as shown in Tables 2-3 and Figures 4-7. Congestion between buses is determined for each experiment, and it is discovered that it is most severe between line associated with buses 1-2. Following that, lines between buses 3-4 and buses 4-12 are chosen for the optimal AIPFC configuration. The presence of AIPFC in an ideal location will relieve the congestion.

Table 2: Power Flows Under Various Over-Burdening States of IEEE-30 Bus System

Table 3: Rundown of Power Flows of Over-Burden Lines Under Over-Burdening Utilizing CFBPSO with AIPFC

According to the results, the CFBPSO with AIPFC method relieves congestion under overloading conditions in all cases, as shown in Table 3 and Figure 7.

Case c: Contingency Analysis

This section handles transmission congestions caused by line blackouts. Table 4 proposes a contingency examination for the IEEE 30 bus framework. It is accepted that four lines 1-2, 1-3, 3-4, and 2-5 are congested at all times for the recreation of outage cases. According to the possibility investigation, line outages 1-2, 1-3, 3-4, and 2-5 have caused significant over-loaded on various lines, as shown in Tables 4.

Table 4: Analysis of Power Flows Under Contingency for IEEE 30-Bus System

Outage of lines	Effected lines	Power flow limit (MVA)	Power flow (MVA)	Congestion
1-2	1-3	130	**166.622**	Congested
	3-4	130	**151.701**	Congested
	4-6	90	**103.002**	Congested
1-3	1-2	130	**156.221**	Congested
3-4	1-2	130	**156.431**	Congested
2-5	2-6	65	**72.171**	Congested
	5-7	70	**84.183**	Congested

Thus, the CFBPSO with the AIPFC method is used to solve congestion problems in order to achieve the specified goal by satisfying constraints on transmission line flow limit. Based on the observed results, the CFBPSO with AIPFC method accurately reproduces congestion under contingency conditions as shown in Tables 5.

Table 5: Overview of Power Flow of Overloaded Lines Under the Selected Four Network Contingencies Using CFBPSO with AIPFC Method

Line outage between buses	Over Loaded lines	Line flow limit (MVA)	CFBPSO with AIPFC	Congestion
1-2	1-3	130	**102.563**	Relieved
	3-4	130	**83.401**	Relieved
	4-6	90	**62.983**	Relieved
1-3	1-2	130	**99.776**	Relieved
3-4	1-2	130	**93.594**	Relieved
2-5	2-6	65	**52.030**	Relieved
	5-7	70	**55.677**	Relieved

6. CONCLUSION

The CFBPSO method was used in conjunction with FACTS devices such as AIPFC to solve congestion-constrained optimal power flow problems under overloading conditions and the most severe network contingencies. Congestion is modeled as an optimization problem and solved using the CFBPSO technique in conjunction with AIPFC. The method was successfully tested on IEEE 30-bus system, and the cost results obtained on the systems were compared to the results obtained using other techniques. It was discovered that the proposed method with the AIPFC device consistently converged to the best solution for achieving the specified goal, while satisfying constraints on control variables and transmission line flow limit. The CFBPSO algorithm has many advantages, including a simple concept and ease of comprehension. The algorithm's robustness is demonstrated by solving under overloaded and contingency conditions. The test results, on the other hand, show that the proposed implementation is effective at managing congestion and outperforms under overloaded and contingency conditions.

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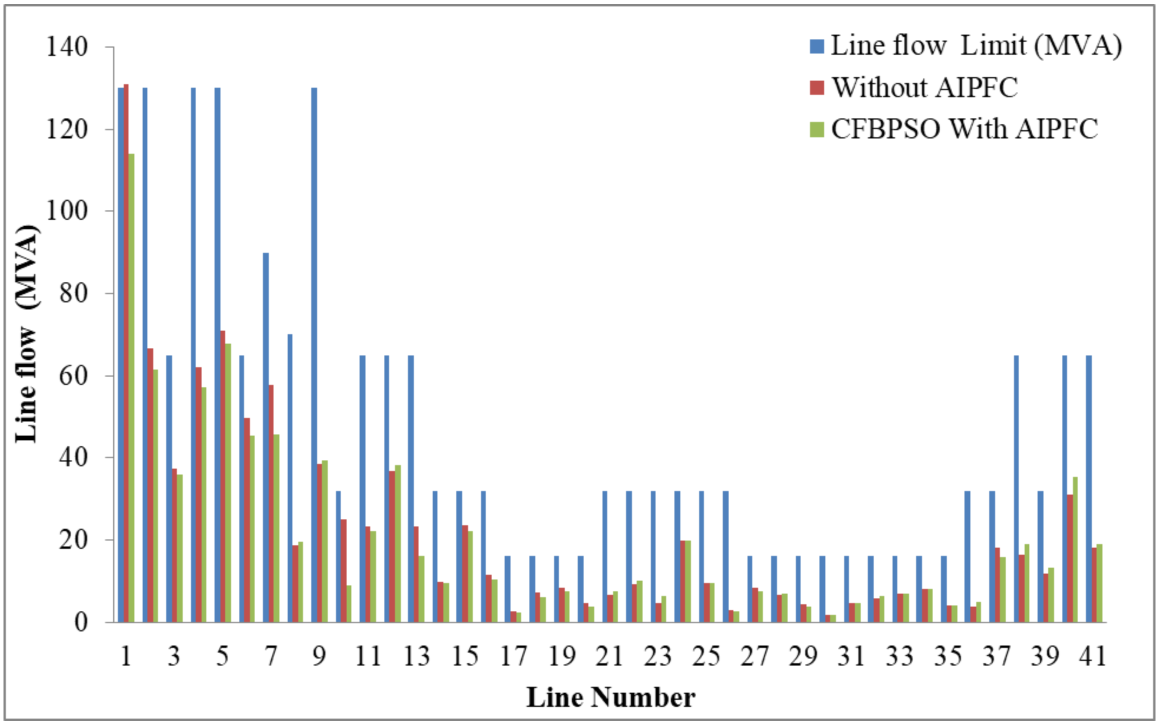

Figure 4: Power Flows in 10% Loading Situation

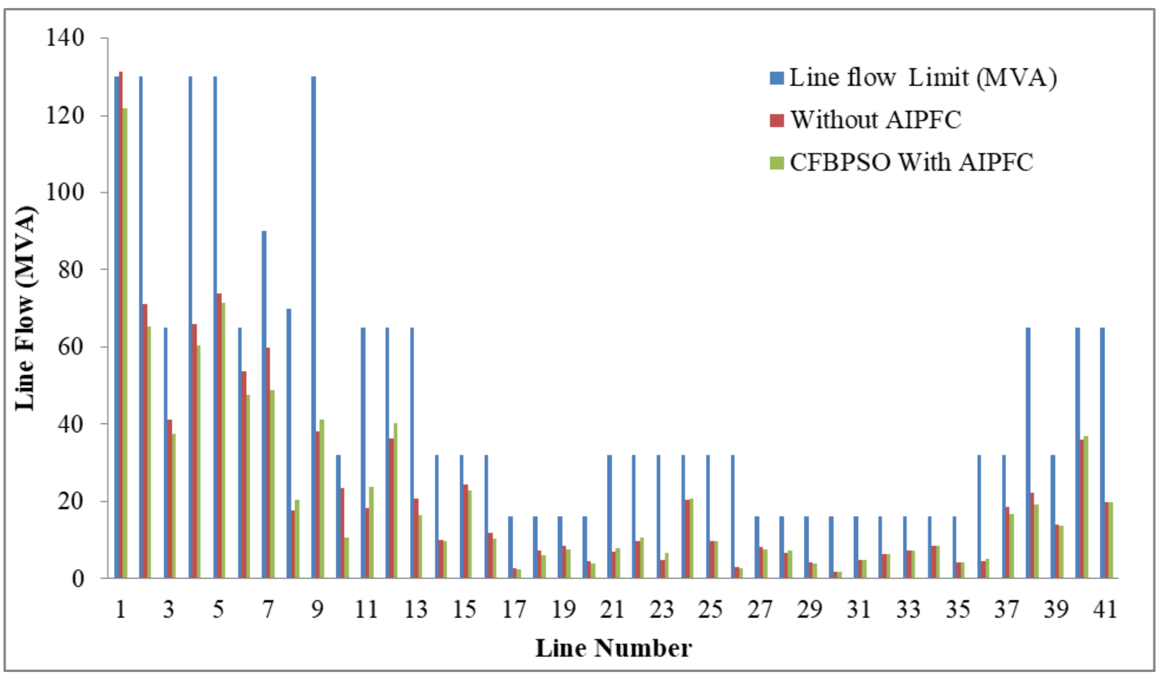

Figure 5: Power Flows in 15% Loading Situation

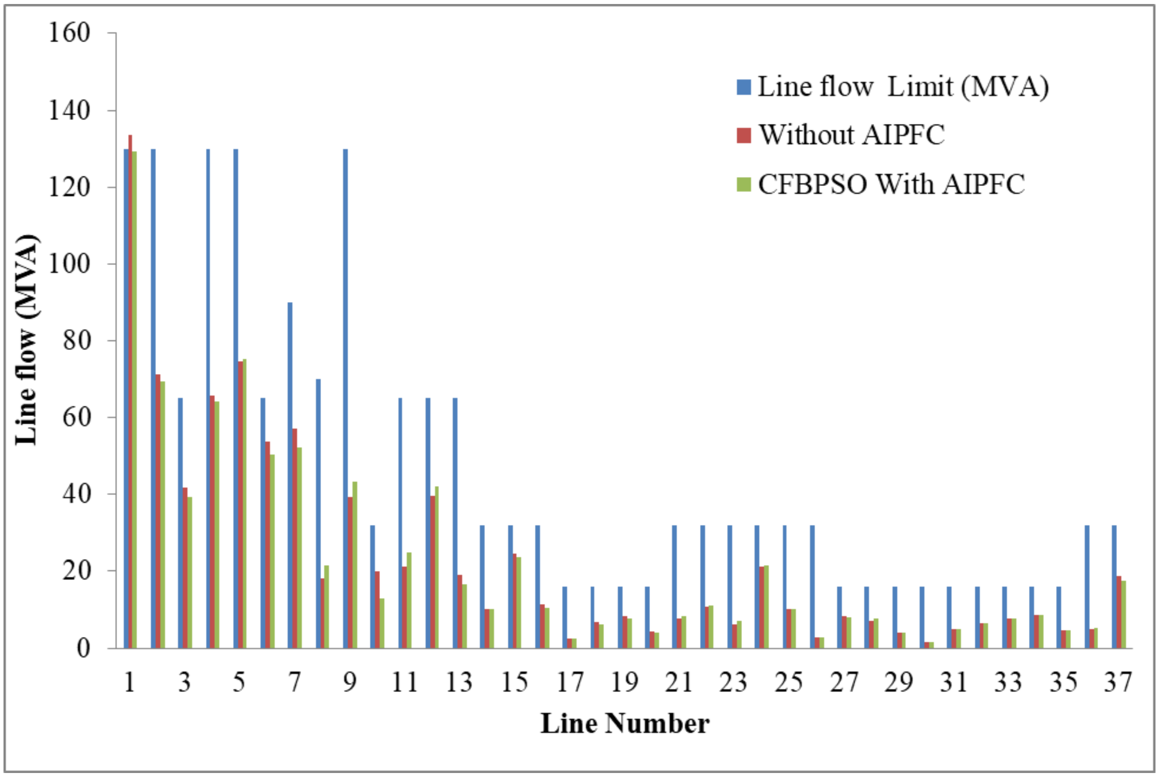

Figure 6: Power Flows in 20% Loading Situation

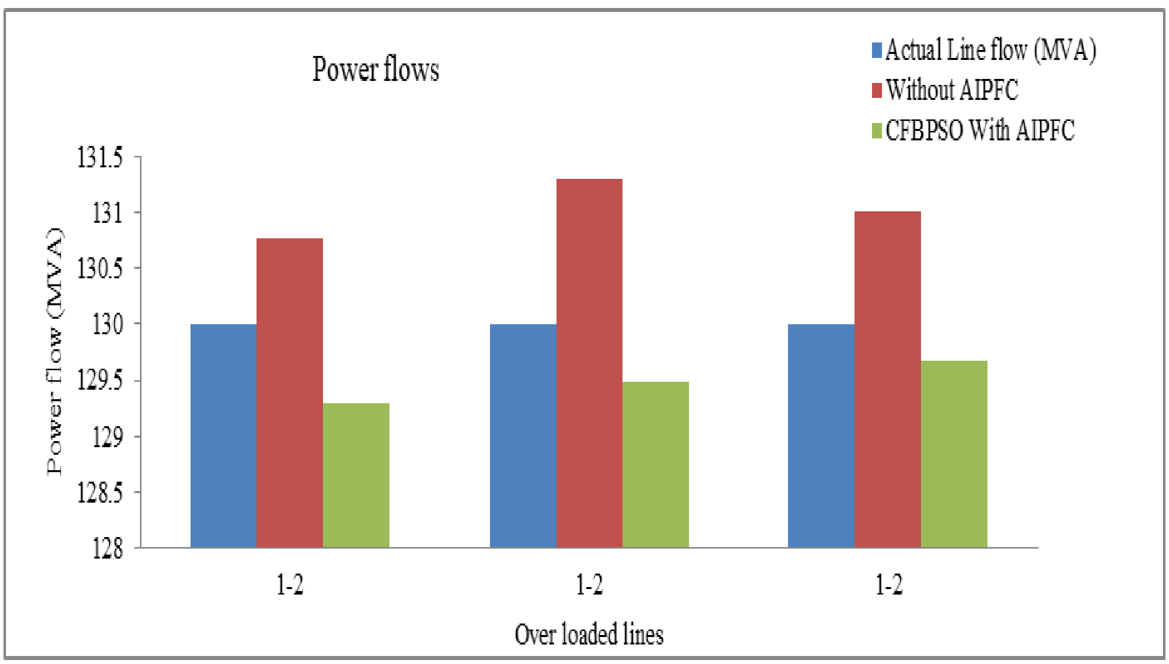

Figure 7: Rundown of Power Flows of Over-Burden Lines Under Over-Burdening Utilizing CFBPSO with AIPFC