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A NOVEL APPROACH OF CONGESTION MANAGEMENT IN TRANSMISSION NETWORKS USING AN ADVANCED INTERLINE POWER FLOW CONTROLLER WITH CONSTRICTION FACTOR-BASED PARTICLE SWARM OPTIMIZATION ALGORITHM

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ABSTRACT

This paper presents a viable strategy for congestion management in power frameworks. Congestion in the power transmission networks is one of the specialized issues that show up in the electric power framework. Power dispatch is one of the significant control exercises and the Optimal Power Flow (OPF) is the main apparatus to acquire the least expense generation designs with transmission and operational requirements. Clog is eased utilizing without price techniques. Utilizing Flexible AC Transmission (FACTS) gadgets, blockage can be decreased without upsetting the financial issues. Advanced model of Interline Power stream Controller (AIPFC) is predominantly an arising FACTS gadget and it is utilized in this paper to decrease the clog. In clog management, the target work is nonlinear subsequently in settling this capacity a novel Constriction Factor-Based Particle Swarm Optimization (CFBPSO) algorithm was proposed for blockage the executives with the point of expanding social government assistance while minimization of generation price. CFBPSO strategy with AIPFC is tried on IEEE 30-bus framework and it tends to be stretched out to any down to practical framework. The outcome for the quality framework was gained by reproducing the check framework utilizing MATLAB/SIMULINK.

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

Nowadays, with the expanding interest in electrical power entirely everywhere the world, utilities of electric system ensure stayed compelled to see the equivalent through expanding their age. Notwithstanding, the electrical power that can be communicated among double areas on a power transmission lines is restricted via a few exchange cut-off points, for example, warm cut-off points, voltage cut-off points, and soundness restrictions through the maximum prohibitive put on at a assumed time. At the point at what time such a cut-off is reached, the framework is supposed to be clogged. Guaranteeing that the force framework works inside its cut-off points is fundamental to keep up force framework security, bombing which can bring about boundless power outages with conceivably extreme social and monetary outcomes. Congest the executives, that is, regulatory the power transmission line therefore that move boundaries stand noticed, is maybe the principal power line the board issue [1]-[3]. The strategies for the most part embraced to oversee clog incorporate rescheduling generator yields, providing responsive force uphold, or genuinely abridge exchanges.

Framework administrators for the most part utilize the primary choice however much as could reasonably be expected and the last one if all else fails.

A few strategies of blockage the executives have been accounted for in the writing. Various models to manage the various exchanges, communications among belongings and constraints of the power transmission framework, and the monetary productivity of the energy arcade need stayed referenced in [4]. Blockage the board procedures applied to different sorts of power markets are introduced. In [5], blockage the board guaranteeing voltage solidness is tended to. An ideal topological design of a force framework as a device of blockage the executives is introduced in [6].

Writing on an optimal power flow (OPF) - based blockage the board plans for numerous exchange frameworks are accessible. In [7], an OPF-based methodology that limits the price of congests and an administration rate takes been planned. A synchronization instrument among creating organizations and framework administrator on behalf of blockage the board utilizing. Sprees incisions takes been talked about in [8]. In [9], a procedure takes been planned designed for reducing clogs because of voltage flimsiness and warm over-burdens. This additionally utilizes OPF which is tackled by standard solvers. In [10], a procedure has been proposed for the determination of taking an interest generator dependent on affectability to the current stream on blocked lines just as the age offers. A strategy for over-burden mitigation by genuine force age rescheduling dependent on relative electrical distance (RED) idea has been presented in [11]. This method professes to limit the framework misfortunes and keep a superior voltage profile and thus greater soundness edge. Anyway at this time, the offers of single age elements and expenses of rearrangement stand not reserved into worry in this exertion. Generators taking the same RED however unique value offers should reschedule their yields so that the complete expense of rescheduling is the least. This issue has not been tended to in [11].

FACTS devices are favored in the advanced power frameworks dependent going on their general presentation [12], which give great arrangements. Of the multitude of FACTS gadgets, the consolidated compensators, for example, the brought as unified power flow controller (UPFC) and IPFC are viewed as the greatest remarkable and flexible ones. Encouraged by its two self-commutated, voltage-sourced switching converters (VSCs) with a typical dc voltage connect; UPFC is able to do autonomously controlling both the dynamic and receptive force streams in the line. IPFC likewise utilizes at any rate two VSCs; in any case, dissimilar to the ability of UPFC to regulator the power stream of just an only power transmission network, IPFC tends to the issue of remunerating numerous power transmission network at a specified substation since its VSCs are associated in arrangement through, normally, various lines [13]. Through the utilization of IPFC to regulator stream control and ideal force stream controller, legitimate numerical demonstrating of this FACTS gadget is required. Much the same as that the infusion models of UPFC are regularly utilized [14]-[15], and accurate pi-model of UPFC-embedded power transmission networks [16] can be inferred, the infusion models of IPFC and the transmission lines inserted with the IPFC are created dependent on the numerical model introduced by [17].

The motivation behind the current paper is to investigate the capacity of constriction factor based particle swarm optimization method in tackling the clog the executives' issue. The clogged framework is displayed as a streamlining issue. Customary techniques for arrangement of OPF depend on hunt heading decided from the subordinate of the capacity. Subsequently it gets basic to communicate the issue as consistent differentiable capacity; in any case, these strategies become less productive. To beat this issue, the current paper takes care of the improvement issue utilizing tightening factor based molecule swarm enhancement. By and large, in improvement calculations, the estimation of the target work is viewed as the wellness work and the coupling imperatives are dealt with as the punishment work strategy. This strategy has numerous detriments on the grounds that the punishment boundaries are experimentally doled out and are profoundly influenced by the issue model. In any case, in this paper, the limitations have been taken care of utilizing a novel strategy, for example, constriction factor based particle swarm optimization.

The past stage FACTS regulators employing one commutated voltage sourced converter (VSC) typically include the static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), unified power flow controller (UPFC), and interline power flow controller (IPFC). Nonetheless, the UPFC and SSSC can handle the force stream of unbiased an only power transmission network. Compared and the UPFC and SSSC, the IPFC has significantly new flexible geographies, contains of at several amount dual converters, and can be consumed to regulator power streams of a congregation of networks. It identical fit might be forecast that the IPFC strength be operated to address the mind-boggling power transmission lines congest the executives' problems. This inspires the creator to shape up alternative ideal for IPFC in force stream examination [18]-[21]. This paper delineates the adequacy of the proposed strategy on the congestion management issue considering the IEEE 30-bus system.

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

The current consistent formal prototypes can mostly be ordered interested in dual classifications: First is a decoupled model then the second is a coupled model. In a decoupled model, the FACTS gadgets are typically supplanted with an imaginary PQ or PV transport, which brings about the adjustment of the Jacobian grid structure. A coupled model by and large comprises of two significant models: voltage source model (VSM) [22], [26]–[28] and power infusion model (PIM) [23]–[25]. What's more, how to deal with the pragmatic requirements of FACTS gadgets is a significant issue [30]. This one stayed not complete in the deliveries just how the imperatives of IPFC are dealt with in their force stream databases.

This research paper portrays an advanced model of IPFC for power stream examination. Now in this this classical, series converter transformer and the line charging susceptance are all included. In the present circumstance, it is demonstrated that the first design and evenness of the induction grid can in any case be retained, and in this way, the Jacobian lattice can possess the square inclining properties, and the sparsity method can be useful. The IPFC state factors are changed all the while with the organization state factors to accomplish the predefined control targets. Additionally, the prototypical can consider the viable imperatives of AIPFC, and the definite execution of these in Newton power stream is introduced. [27]- [28].

2.1 Equivalent Circuit and Mathematical Model of AIPFC

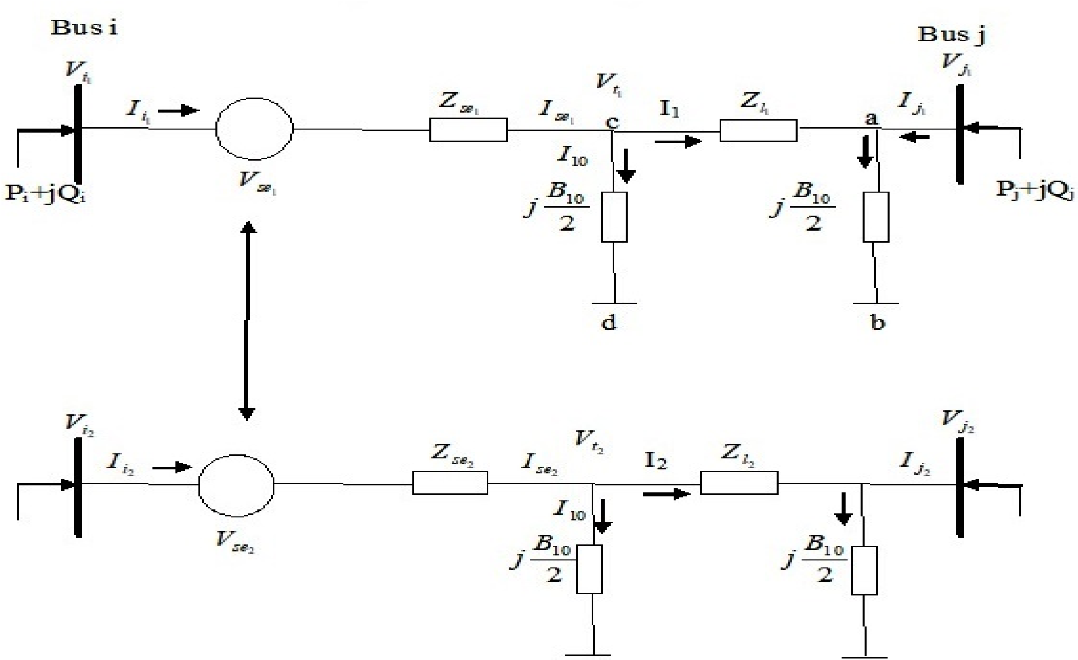

Figure 1: Equivalent Circuit diagram of AIPFC

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The mathematical derivation applies to an AIPFC with any number of 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

Since 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: By applying KCL at node 'a'

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

Where

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

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

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

We know equation (2) is

$$I_{i_n} = I \;\; + I_{10}$$

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

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

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

For reducing the complexity of equations (7) and (10) take

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

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

From equations (1), (2), (7) and (10): I_{i_n} & I_{j_n} in terms of V_{i_n}, V_{j_n} & V_{se_n} as, From (7) & (10) rewrite

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

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

Substitute equation (11) and (12) in equation (1)

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

For reducing the complexities of equation (13) take $N = Z_{se_n}E + Z_{l_n}$ 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 $A_{ii_n} = \frac{E}{N}, A_{jj_n} = \frac{M}{N},$

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

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

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

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

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

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

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

From the equation (16) the equivalent circuit shown in Figure 2:

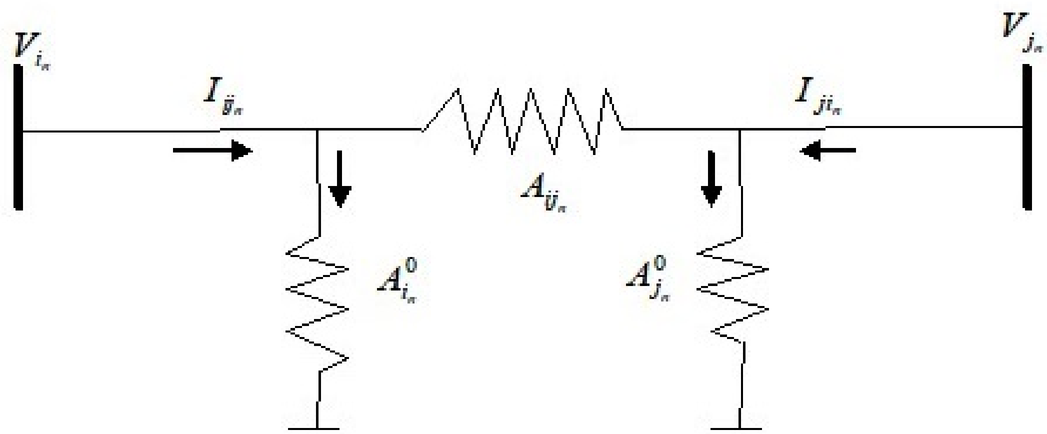

Figure 2: Representation of AIPFC using current source

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

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

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

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

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

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2.2 Power Injection Model of AIPFC

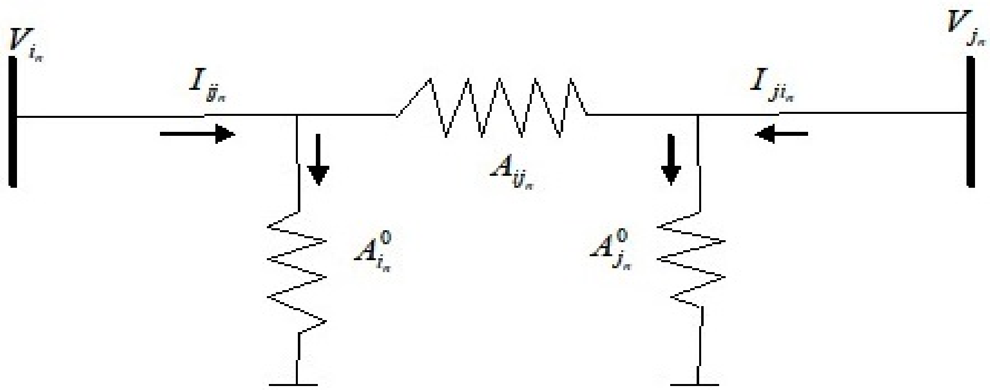

Figure 3: Power injections π-model of AIPFC

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

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

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

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

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

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

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

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

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

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

Where

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

3. PROBLEM FORMULATION

The OPF issue is a static non-direct compelled improvement issue, the arrangement of which decides the ideal setting for control factors in a power organization.

Minimize f(x)
Subject to h(x)=0
g(x)≤0 (31)

The target of congestion management issue is to mitigate the clog and limit the prices of

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generation. Numerically, this can be addressed as in the accompanying.

$$\min c(x) = \min \sum_{i=1}^{Ng} \left(c_i + b_i P_{Gi} + a_i P_{Gi}^2\right) \quad (32)$$

P_{Gi} : Active power generation of i^{th} bus

N_G is No. of generators in the test system

a_i, b_i and c_i are the cost coefficients of 'i^{th}' generating unit

a. Equality constraints

$$P_{Gi} - P_{Di} - \sum_{j=1}^{N_{bus}} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} + \delta_j - \delta_i) = 0 \quad (33)$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{N_{bus}} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} + \delta_j - \delta_i) = 0 \quad (34)$$

b. Inequality Constraints

Generation limits of Active Power

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \quad \text{i=1,…,NG} \quad (35)$$

Generation limits of Reactive Power

$$Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max} \quad \text{i=1,…,NG} \quad (36)$$

Demand of Active Power

$$P_{Di}^{\min} \le P_{Di} \le P_{Di}^{\max} \quad \text{i=1,…,NG} \quad (37)$$

Demand of Reactive Power

$$Q_{Di}^{\min} \le Q_{Di} \le Q_{Di}^{\max} \quad \text{i=1,…,NG} \quad (38)$$

Magnitude limits of Load bus voltage

$$V_i^{\min} \le V_i \le V_i^{\max} \quad \text{i=1,…,NL} \quad (39)$$

Transformer tap settings

$$T_i^{\min} \le T_i \le T_i^{\max} \quad \text{i=1,…,NT} \quad (40)$$

Lines loading of Transmission

$$S_i \le S_i^{\max} \quad \text{i=1,…,nl} \quad (41)$$

4. CONSTRICTION FACTOR BASED PARTICLE SWARM OPTIMIZATION (CFBPSO)

The method of PSO has just been applied in a few issues of streamlining in the force framework. In [34], PSO has been applied to tackle the financial dispatch of generators in a force framework. A procedure has been proposed in [31] to control receptive force and voltage to keep up force framework security from a voltage dependability perspective. Affectability-based clog the executives utilizing PSO has been examined in [32]. In any case, it doesn't uncover about system of dealing with limitations.

In this paper, the improved Constriction Factor Based Particle Swarm Optimization (CFBPSO) is implemented for solving the problem. Velocity of every agent can be adapted by the following equation:

$$\begin{aligned} v_i^{k+1} &= wv_i^k + c_1 rand_1 * (pbest_i - s_i^k) \\ &+ c_2 rand_2 * (gbest - s_i^k) \end{aligned} \quad (42)$$

v_i^k:i^{th} agent velocity at iteration k, w:Function of weighting, c_1 & c_2: Factors of weighting, $rand_1$ & $rand_2$: Random numbers within limits of 0 and 1, S_i^k: i^{th} agent current position at iteration k, $pbest_i$ & gbest: The pbest of agent i & gbest of agent i in the group.

$$w = w_{\max} - ((w_{\max} - w_{\min})/(iter_{\max})) * iter \quad (43)$$

w_{max}:Initial weight, w_{min}:Final weight, $iter_{max}$:Maximum iteration number,iter:Present iteration number. PSO using (42), (43) is called inertia weights approach. The present position can be customized by the next equation:

$$S_i^{k+1} = S_i^k + v \quad (44)$$

In order to ensure convergence of the PSO algorithm, the velocity of the constriction factor based approach can be expressed as follows:

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$$v_i^{k+1} = K[v_i^k + c_1 * rand_1 * (pbest_i - s_i^k) + c_2 * rand_2 (gbest - s_i^k)] \quad (45)$$

$$K = \frac{2}{2-\varphi-\sqrt{\varphi^2 - 4\varphi}}, \quad (46)$$

Where $\varphi = c_1 + c_2, \varphi > 4$

The convergence characteristic of the system can be controlled by ϕ. For example, if φ =4.1, then K=0.73. As 'w' increases above 4.0, K gets minor. For example, if φ =5.0, then K=0.38, and the damp result is even additional pronounced.

The constriction factor approach brings about the intermingling of the people after some time. In contrast to other developmental calculation strategies, the narrowing variable methodology guarantees the intermingling of the pursuit strategy dependent on the numerical hypothesis. In this way, the tightening factor approach can produce greater arrangements than the fundamental PSO approach. Be that as it may, the narrowing variable methodology just thinks about powerful conduct of one individual and the impact of the association among people. To be specific, the conditions were created with a fixed arrangement of best positions (Pbest and Gbest), in spite of the fact that Pbest and Gbest change during the inquiry methodology in the essential PSO condition. Thus, the CFBPSO can acquire preferred quality arrangements over the essential PSO approach.

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 transport voltage for every molecule, update line information and transport 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 dormancy weight as in condition (43)
8. Estimate the new molecule speed and positions as in (42)
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

5. RESULTS AND DISCUSSION

In a power system, one of the serious issues is network blockage, this issue happens in light of framework over-burdening. This part presents the aftereffect of the ideal position of a high level model of AIPFC by synchronous minimization of expected cost utilizing CFBPSO. The proposed technique has been exhibited on IEEE 30 transport test framework. An IEEE 30 transport test framework has six generators in which bus number 1 is considered as a slack bus and bus numbers 2, 5, 8, 11, and 13 are considered as PV buses while any remaining buses are load buses. This framework has 41 interconnected lines, four tap changing transformers and the complete load of the framework is 283.40 MW. The generator active power outputs, generator terminal voltages, transformer tap settings and shunt compensations are taken as control variables. The IEEE 30 bus test system load flow is gotten utilizing MATLAB programming and the outcomes have been introduced. Just load buses are considered for position of a high level model of AIPFC. The outcomes are given transmission clog because of over-burden investigation. Where the blockage has been made in the framework by expanding the interest for load transports. To exhibit the viability of the proposed CFBPSO calculation with AIPFC, two cases are considered for re-enactment contemplates that are base case condition and over-burden condition.

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To validate the OPF results obtained with the proposed method they are compared with some of the existing literature methods and are given in Table 1 and Figure 4. From this table and figure, it is observed that, the proposed CFBPSO method yields better results when compared to other methods.

Table 1: Comparison of Fuel Costs

Method	Fuel Cost ($/hr)
EP[29]	802.907
TS[29]	802.502
TS/SA[29]	802.788
ITS[29]	804.556
IEP[29]	802.465
MDE-OPF[30]	802.376
EP[19]	801.0204
PSO[30]	800.966
CFBPSO (Proposed)	800.235

Table 2: Optimal control variables settings for base case condition using CFBPSO with AIPFC

Control variables		Base Case condition	
		NR	CFBPSO with AIPFC
Real Power Generation (p.u)	P_{G1}	1.5929	1.7695
	P_{G2}	0.5812	0.4887
	P_{G3}	0.1287	0.2111
	P_{G4}	0.1871	0.1182
	P_{G5}	0.2242	0.2159
	P_{G6}	0.211	0.12
Generator Voltages (p.u)	V_{G1}	1.05	1.1
	V_{G2}	1.045	1.0878
	V_{G3}	1.01	1.0698
	V_{G4}	1.05	1.1
	V_{G5}	1.01	1.0619
	V_{G6}	1.05	1.1
Loss (p.u)		0.0911	0.0894
Cost ($/hr)		810.911	800.235

Base case condition

The planned CFBPSO with AIPFC is functional to locate the ideal planning of the power framework for base case conditions. The target work reflected is the reduction of fuel price of generator. The ideal control factors sets for base case condition utilizing CFBPSO with AIPFC is introduced in Table 2. The base fuel price of generator that is gotten through CFBPSO with AIPFC strategy is 800.235 $/hr, which is not as much as Newton Raphson (NR) technique. Additionally, it is discovered that all the got arrangements fulfill the imperatives on control variable cutoff points and transmission line stream limit.

Congestion due Overloading

This segment manages transmission blockage is because of over-burden, where the congestion has been made in the framework by expanding the interest. The proposed strategy has been tried for 10% burden, 15% burden, and 20% stacking conditions.

Table 3 showing the over-burden lines for various cases and the measure of power abused for every situation. It displays 311.74 MW in the principal situation when 10% of the burden is expanded on base load that is presented in Table 3 and Figure 5. In the next case load shows 325.91MW, for example, 15% of expansions in base load and it is represented in Table 5 and Figure 6. In the last caseload is 340.08 MW is acquired, for example, 20% of expansions in base load that is displayed in Table 6 and Figure 7. Under base case conditions, for example with a heap of 283.4 MW, the line stream cutoff of 130 MW isn't abused for lines 1-2. In tried cases line 1-2 is abused, as demonstrated in reproduction outcomes.

In the IEEE 30 bus system, dual lines are associated with lines 3–4. Thus, two experiments for AIPFC arrangement are thought of. For each experiment, blockage between transports is determined, and it is seen that it is greatest between lines associated with buses 3–4 and 4–12. Subsequently, lines between buses 3–4 and buses 4–12 are chosen for the ideal position of AIPFC. Area of AIPFC at ideal area will itself diminish congestion.

Table 3: Line flows under different overloading conditions of IEEE-30 bus system

Over loaded line		Increment in load (%)	Line flow Limit (MVA)	Line flow (MVA)
From bus	To bus			
1	2	10	130	131.062
1	2	15	130	131.305
1	2	20	130	133.423

Table 4: Control variables for 10% loading conditions of IEEE-30 bus system

Control variables		NR	CFBPSO with AIPFC
Real Power Generation (p.u)	P_{G1}	1.9473	1.6948
	P_{G2}	0.5412	0.6048
	P_{G3}	0.1287	0.35
	P_{G4}	0.1871	0.1734
	P_{G5}	0.2242	0.2474
	P_{G6}	0.211	0.12
Generator Voltages (p.u)	V_{G1}	1.05	1.05
	V_{G2}	1.045	0.9501
	V_{G3}	1.01	0.95
	V_{G4}	1.05	1.1
	V_{G5}	1.01	0.95
	V_{G6}	1.05	1.1
Loss (p.u)		0.1221	0.073
Cost ($/hr)		913.983	902.6309

Table 5: Control variables for 15% loading conditions of IEEE-30 bus system

Control variables		NR	CFBPSO with AIPFC
Real Power Generation (p.u)	P_{G1}	1.9902	1.787
	P_{G2}	0.66315	0.6255
	P_{G3}	0.189	0.35
	P_{G4}	0.1137	0.1909
	P_{G5}	0.2597	0.2509
	P_{G6}	0.1753	0.1201
Generator Voltages (p.u)	V_{G1}	1.05	1.05
	V_{G2}	1.045	0.95
	V_{G3}	1.01	0.95
	V_{G4}	1.05	1.1
	V_{G5}	1.01	0.95
	V_{G6}	1.05	1.1
Loss (p.u)		0.132	0.0652
Cost ($/hr)		969.725	949.477

Table 6: Control variables for 20% loading conditions of IEEE-30 bus system

Control variables		NR	CFBPSO with AIPFC
Real Power Generation (p.u)	P_{G1}	1.9385	1.8949
	P_{G2}	0.58675	0.6376
	P_{G3}	0.35	0.35
	P_{G4}	0.1569	0.202
	P_{G5}	0.2303	0.2561
	P_{G6}	0.12	0.12
Generator Voltages (p.u)	V_{G1}	1.05	1.05
	V_{G2}	1.045	0.9501
	V_{G3}	1.01	0.95
	V_{G4}	1.05	1.1
	V_{G5}	1.01	0.95
	V_{G6}	1.05	1.1
Loss (p.u)		0.1346	0.0599
Cost ($/hr)		1026.882	997.375

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Table 7: Summary of line flow of overloaded lines under overloading using CFBPSO with AIPFC

SB	RB	Increment in load (%)	Line flow Limit (MVA)	Without AIPFC	CFBPSO With AIPFC
1	2	110	130	130.7	114.02
1	2	115	130	131.3	121.74
1	2	120	130	131.0	129.31

Consequently, this shows the CFBPSO with AIPFC technique to take care of OPF issue in achieving the predefined objective having fulfilled requirements on control factors and transmission line stream limit. In view of the noticed outcomes it very well may be referenced that the CFBPSO with AIPFC strategy is eased blockage under over-burdening conditions in all cases as demonstrated in Table 7 and Figure 8.

6. CONCLUSION

The use of the CFBPSO strategy with FACTS gadgets, for example, AIPFC for tackling clog obliged ideal force stream issues under the chose three most extreme organization possibilities has been introduced. Recreation results got on IEEE 30 transport framework show the adequacy of the proposed CFBPSO technique with the FACTS gadget. It has been seen that the proposed strategy with FACTS gadget dependably met the ideal arrangement in achieving the predetermined goal having fulfilling imperatives on control factors and transmission line stream limit. The outcomes from the tried framework demonstrated that the CFBPSO with AIPFC strategy is extremely powerful in achieving the predetermined target and remember the blockage under over-burden conditions.

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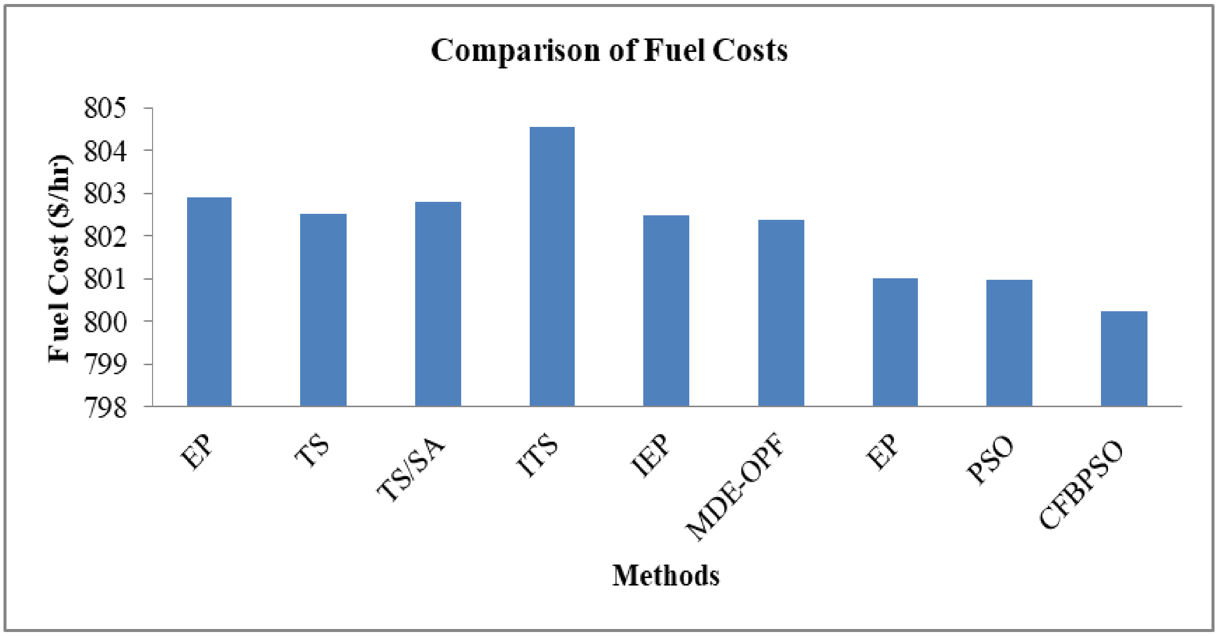

Figure 4: Comparison of Fuel Costs

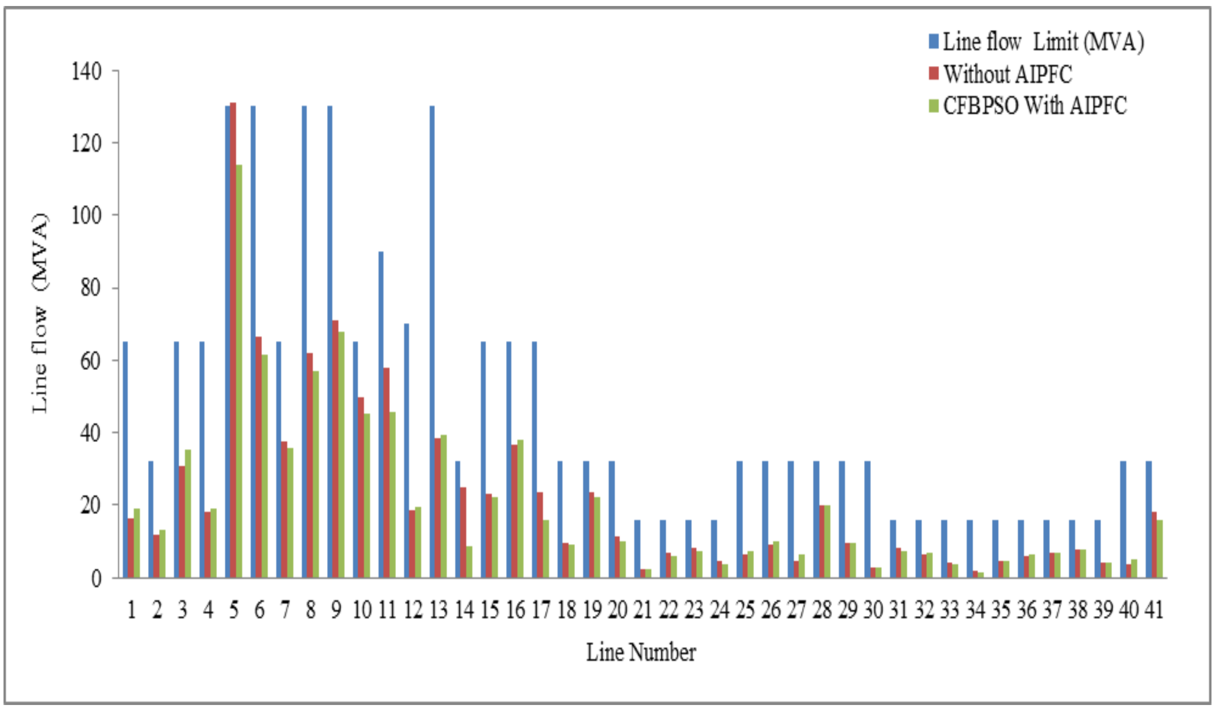

Figure 5: Line loadings under 10% loading condition

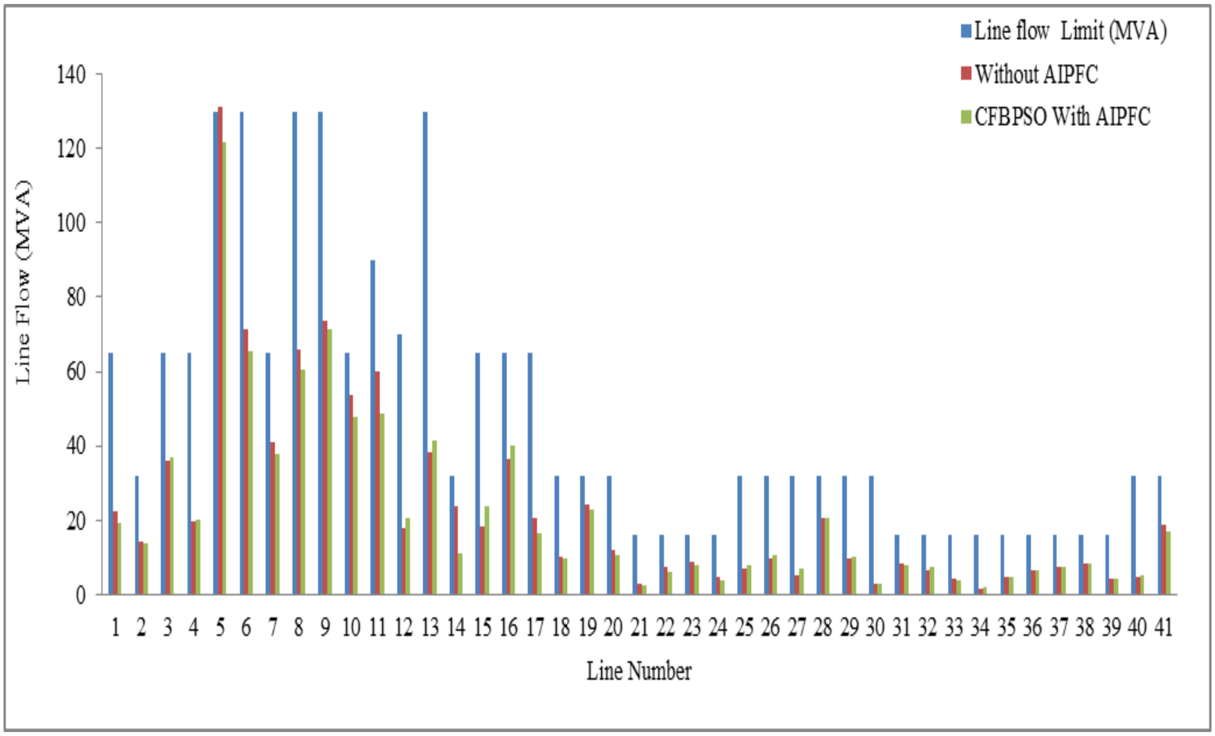

Figure 6: Line loadings under 15% loading condition

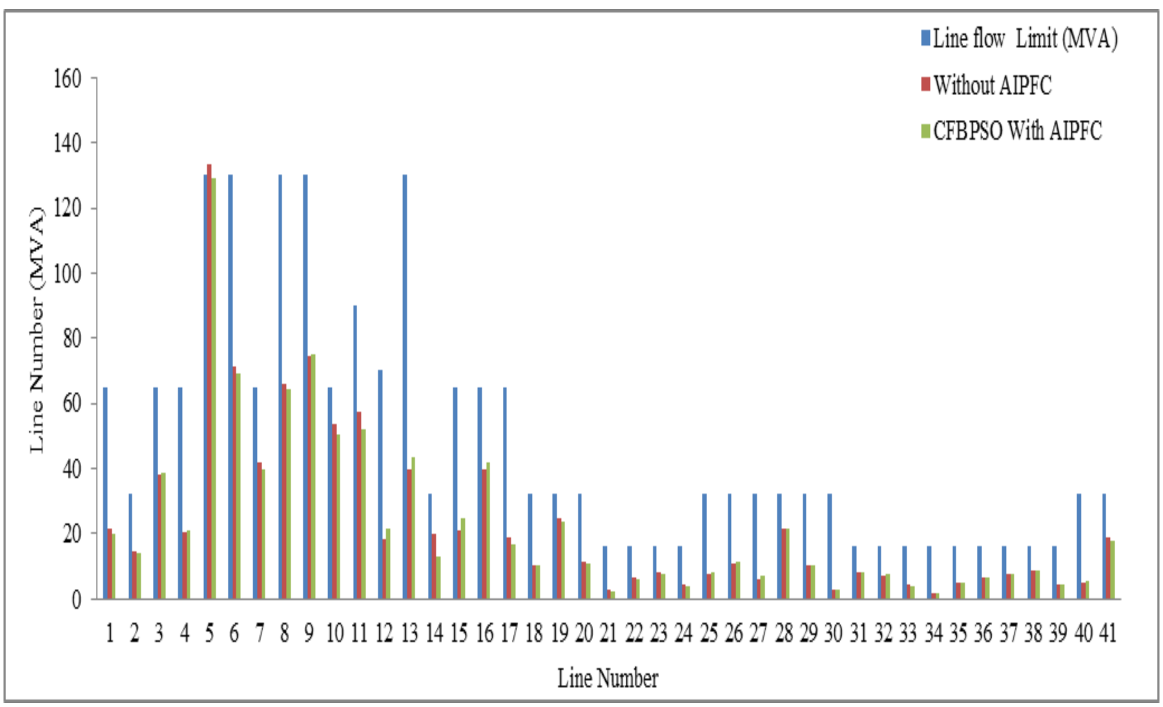

Figure 7: Line loadings under 20% loading condition

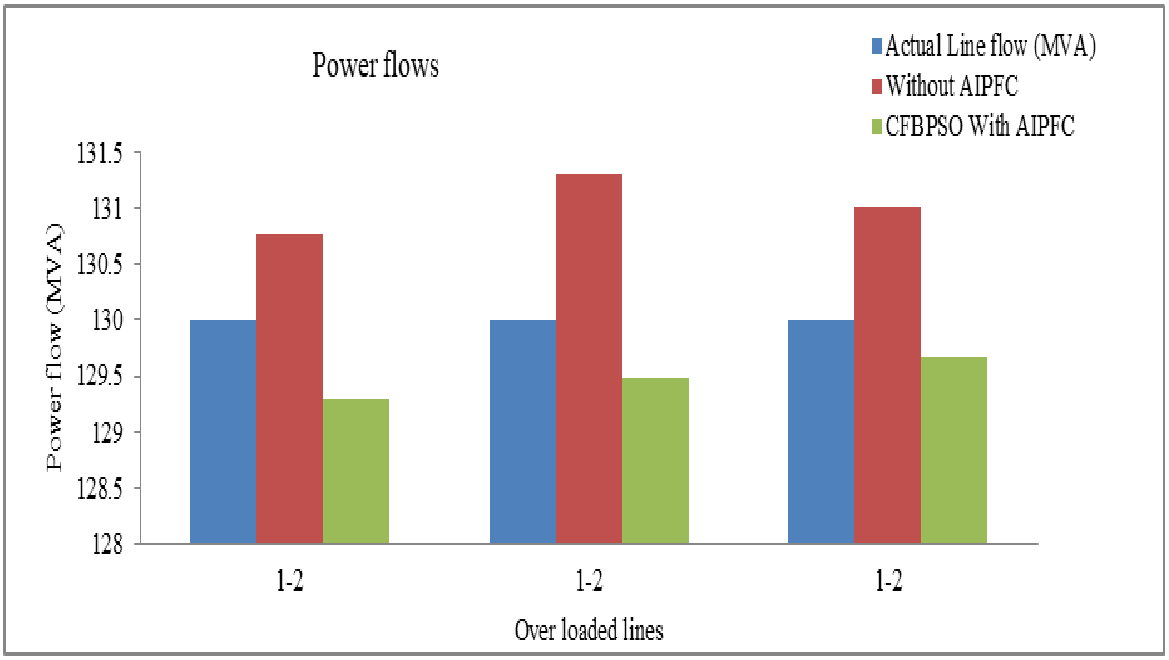

Figure 8: Summary of line flow of overloaded lines under overloading using CFBPSO with AIPFC