Transmission Line Congestion Management using Hybrid Fish-Bee Algorithm with IPFC

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Abstract -*There is a widespread changeover in the electrical power industry universally from old-style monopolistic outline towards a horizontally distributed competitive structure to come across the demand of rising consumption. When the transmission lines of derestricted system are incapable to oblige the entire service needs, the lines are overloaded or congested. The governor between customer and power producer is nominated as Independent System Operator (ISO) to lessen the congestion without obstructing transmission line restrictions. Among the existing approaches for congestion management, the frequently used approaches are reorganizing the generation and load curbing. There is a boundary for reorganizing the generators, and further loads may not be supplemented with the prevailing resources unless more ivate power producers are added in the system by considerably raising the cost. Hence, congestion is relaxed by appropriate Flexible AC Transmission Systems (FACTS) devices which boost the existing transfer capacity of transmission lines. The FACTs device, namely, Interline Power Flow Controller (IPFC) is preferred, and the correct placement of IPFC is more vital and should be positioned in the highly congested line. Hence, the weak line is identified by using power flow performance index with the new objective function with proposed hybrid Fish – Bee algorithm. Further, the location of IPFC at appropriate line reduces the branch loading and minimizes the voltage deviation. The power transfer capacity of lines is determined with and without IPFC in the identified congested line of IEEE 30 bus structure and the simulated results are compared with prevailing algorithms by placing UPFC and IPFC. It is observed that the transfer capacity of existing line is increased with the presented algorithm and thus alleviating the congestion.*

Keywords—Available line transfer capability, congestion management, FACTS device, hybrid fish-bee algorithm, ISO, UPFC, IPFC

I. INTRODUCTION

THE electric power industry is deregulated with healthy competition in the market to expand the customer benefits by efficient management and application of technical novelties. The generation and distribution of power are carried out by many entities in a horizontally distributed deregulated power system. Generating companies (Gencos) will try to maximize their profit by selling all the generated power, whereas Distribution companies (Discos) will tend to buy power at cheaper cost. Transmission system still being a natural monopoly plays a key role in maintaining healthy competition through open access. The transmission network of electric power system should be strengthened to adapt the new changes in electricity market as well as to serve the changing requirements of the grid.

The ISO is one of the entities of the deregulated power system, matches the supply and demand by forecasting load, coordinating transmission capacity, planning and maintaining the reliability of grid without getting involved in market competition. ISO approves a proposed transaction after analyzing the feasibility of transaction of a particular bid with respect to system operating conditions. Most of the times, the transmission network is unable to oblige the entire service requests in a deregulated environment. This leads to overloading of one or more transmission lines, and the system is said to be congested.

Most of the modern approaches for congestion management employ Optimal Power Flow (OPF) based schemes. They either use reorganizing of generators or improving the line capacity. The application of generator reorganizing beyond a particular point increases the congestion management cost heavily. Hence, the line transfer capacity is improved with the help of FACTS devices to mitigate congestion.

There are various algorithms and FACTS devices reported in literature. The optimal location of Thyristor Controlled Series Compensation (TCSC) is discussed in [1] using min-cut algorithm to relieve line congestion in restructured environment based on benefit index. The allocation of TCSC and DG Unit in appropriate places is designed to relieve congestion [2]. A new methodology for congestion relief by locating UPFC and IPFC using a hybrid meta-heuristic approach is suggested [3]. The optimal sizing of a SVC based on PSO has been described [4]. For optimal location of TCSC, a parameter Z, the quotient of the resonant frequency and the network frequency is used [5]. An effective location of TCSC for power system congestion management by reducing total reactive power loss in the system and load curtailment is suggested [6]. A multi-objective PSO is employed to find Pareto solutions of secure congestion management [7]. A hybrid Cat-Firefly algorithm with TCSC and SVC is proposed to alleviate the congestion [8]. Locational Marginal Price congestion controlling by means of enriched STF-LODF is suggested [9]. Singh and Verma [10] presented the use of cost- free technique for discharging congestion. A congestion management scheme via ideal location of TCSC in deregulated power systems through Mixed Integer Nonlinear Programming (MINLP) is offered [11]. A technique for congestion controlling with the help of IPFC in a competent market is developed by considering bid functions as linear [12]. The objective of the present work is to manage congestion in deregulated power systems using FACTS devices.

II. BASIC PRINCIPAL OF INTERLINE POWER FLOW CONTROLLER

This is the actual model of a interline power flow controller. Its Employ a number of DC to AC voltage source converter. In Both Converters providing the series compensation to the different Line. The interline power flow controller is designed by Joining the two static synchronous series compensator (SSSC) shown in below figure. Both converters are providing the sinusoidal voltage to the line for controlled the magnitude and phase Angle. Active power which transferred between the two Voltage sources converters is through the DC link. This DC Link is bidirectional link.

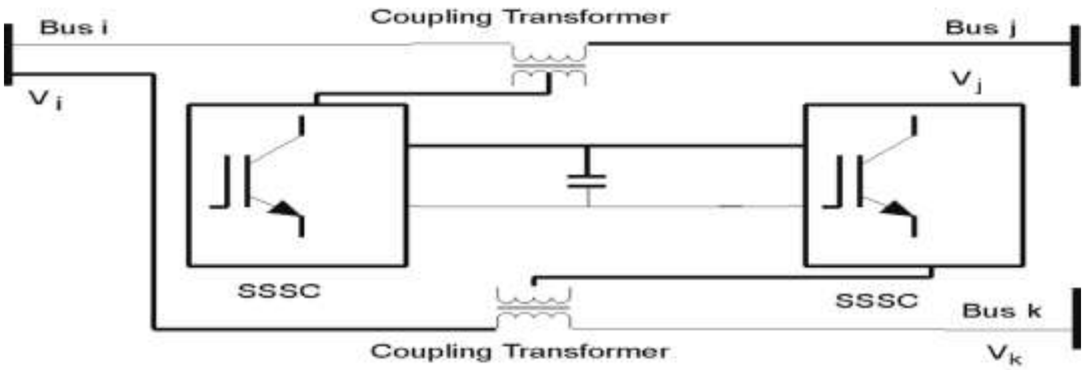

Figure-1: schematic representation of IPFC

The power flow model of a interline power flow controller is given is shown in below figure.2. It is also applied in power quality improvement of a system in multiline.

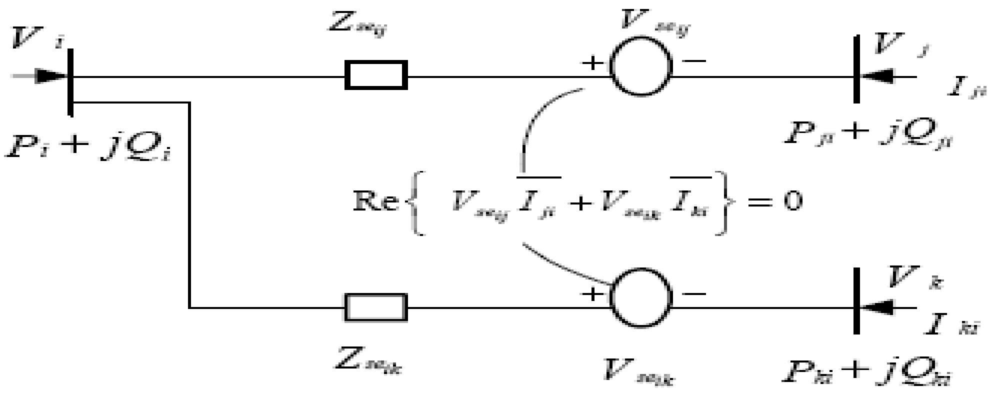

Figure- 2: power flow model of the IPFC

II.I POWER INJECTION MODEL OF IPFC

The power injection model of IPFC is useful for calculating the injecting active power, voltage and voltage angle in each bus. The power calculation is based on the NR load flow algorithm. It is used to check the loss variation before and after connecting IPFC. The equivalent circuit for the power injection model of IPFC is shown in Figure.2.

In this mathematical model V_a, V_b and V_C are the bus voltages of bus *a*, *b* and *c* respectively. Under normal conditions, real power across the two transmission lines is $R_e\ \{V_{AB}\ I\ ab + V_{ac}\ I\ ac\} = 0$. The impedance value of these two lines is Z_{ab} and Z_{ac}.

The current between the buses V_A and V_b is I_{ab} and I_{ac} . The power flow equation of the injection model IPFC is calculated as follows

$$P_a = V_a^2 g_{aa} - \sum_{b=1,b\neq a}^{n} V_a V_{ab}(g_{ab} \cos(\theta_b - \theta_a) + h_{ab} \sin(\theta_b - \theta_a)) - \sum_{b=1,b\neq a}^{n} V_a V_{ab} (g_{ab} \cos(\theta_a - \theta_{ab}) + h_{ab} \sin(\theta_b - \theta_{ab})) \quad (1)$$

$$Q_a = V_a^2 h_{aa} - \sum_{b=1,b\neq a}^{n} V_a V_{ab}(g_{ab} \cos(\theta_b - \theta_a) + h_{ab} \sin(\theta_b - \theta_a)) - \sum_{b=1,b\neq a}^{n} V_a V_{SE_{ab}} (g_{ab} \cos(\theta_a - \theta_{SE_{ab}}) + h_{ab} \sin(\theta_b - \theta_{SE_{ab}})) \quad (2)$$

Where

V: is the voltage magnitude

θ Is the bus angle

v_{se} Is the magnitude injected voltage

θ_{se} : Angle of injected voltage

III. PROPOSED HYBRID FISH – BEEALGORITHM

The proposed hybrid Fish–Bee algorithm accelerates the search for finding the optimum solution. It employs parallel technique for hybridization in which the search by individual algorithms is performed simultaneously. It selects the specified number of best individuals from each system after exchanging many user defined iterations. Generally, individuals having larger fitness value are selected. Thus, the proposed algorithm parallelizes the two algorithms such that the local behavior of ABCO and global search of FSO are effectively used to find the optimal solution.

The basic steps of hybrid Fish – Bee algorithm are:

–Step 1: Create initial random solution
–Step 2: Evaluate fitness and select best solutions
–Step 3: Divide population between the two algorithms.
–Step 4: Start FSO and ABCO algorithm
–Step 5: Fish plans to move position to find food and Bees plans to move position to find better food.
–Step 6: Fish movement is based on searching of food or following another fish for finding the food's position.
–Step 7: Once food search is over, a movement policy based on weighted local search is chosen.
–Step 8: Similarly, bee movement is based on computing internal and external irregularities.
–Step 9: Once searching process is over, a movement policy based on weighted local search is chosen.
–Step 10: Recombine both solutions
–Step 11: Check whether the objective is met
–Step 12: Iterate the process

The proposed algorithm is used for finding the location of IPFC employ in the proposed objective function. Fig. 2 shows the flowchart to derive the optimal location of IPFC.

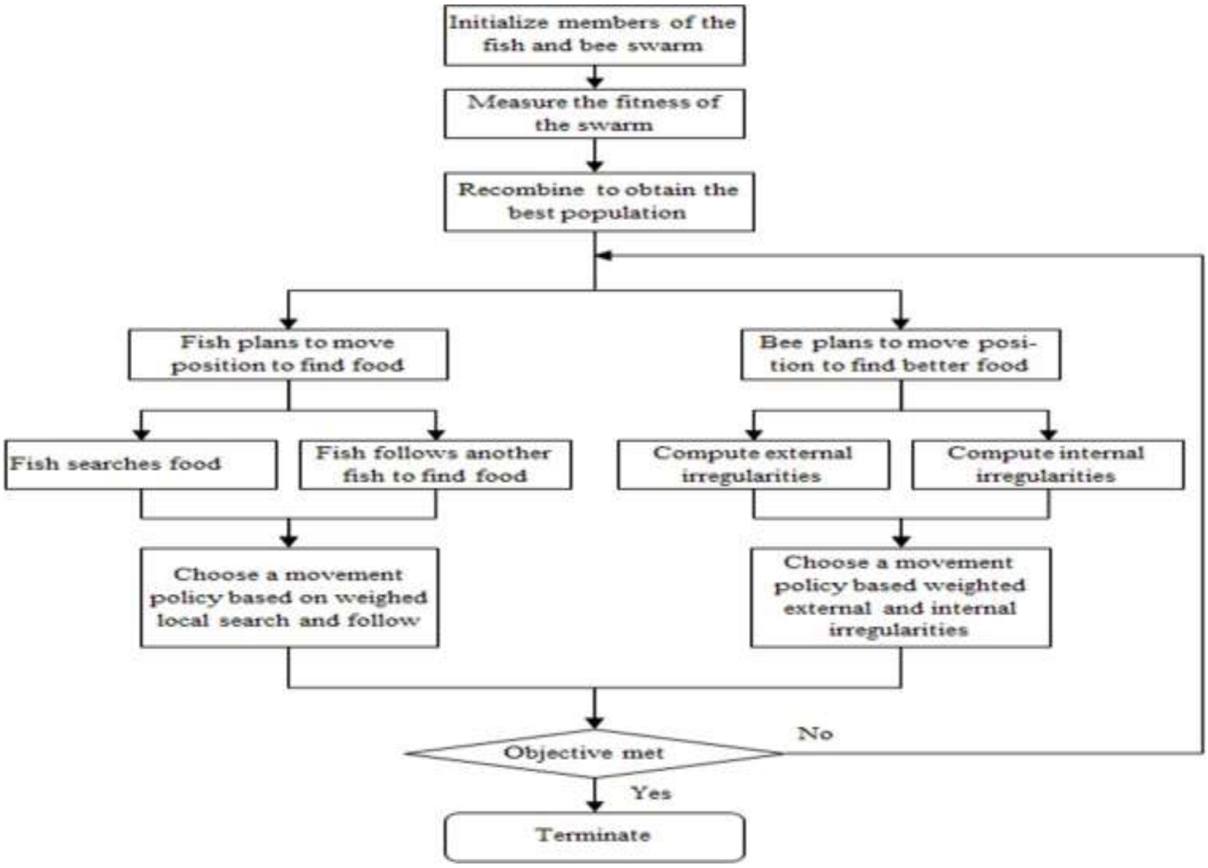

Fig-3: Flow chart to derive the optimal location of IPFC

For implementing the objective function with the proposed algorithm, identification of a highly congested line is necessary. Hence, a factor to determine the severity of transmission line congestion is used to identify the most congested line. The system loading severity under normal and contingency cases is explained by a real power flow performance index

IV. POWER FLOW PERFORMANCE INDEX (PI)

Transmission line congestion occurs when voltage/thermal limits are violated. Line outages or high load demands are the cause of congestion in the transmission network. The severity of the system loading under normal and contingency cases depends on real power line flow performance index [13]. The degree of congestion in a transmission line is determined by using power flow performance index, PI, which is mathematically expressed as:

$$PI = \sum_{all\ branches\ i} \left(\frac{p_{flow\ i}}{p_i^{max}}\right)^{2n} + \sum_{all\ branches\ i} \left(\frac{\Delta|E_i|}{\Delta|E_i^{max}|}\right)^{2m} \quad -1$$

where PI: Performance Index, $p_{flow\ i}$: Real power flow in the line, p_i^{max}: Maximum power limit, E_i: Transmission Line voltage and E_i^{max}: Maximum voltage limit. After computing the PI values, a priority list is created for congestion analysis. The power flow is executed based on the priority list to identify the weak transmission line in which the actual MVA exceeds the acceptable limit. The PI value would be high during overloading or congestion. IPFC improves the power transfer capacity by properly adjusting its control parameters. Thus, the line with highest PI is the appropriate location for installing IPFC.

IV.I PROPOSED OBJECTIVE FUNCTION

The costs related with congestion and voltage profile improvement are included in the objective function for congestion management using IPFC [14]. The main aim of congestion management is to relieve congestion by reducing branch loading, minimizing voltage deviation after load disturbance and to improve the transfer capacity of the line. This can be achieved by the use of IPFC in appropriate location. Hence, the objective function for finding the optimal location of IPFC includes all these factors. The objective function is represented as given by (2):

$$\text{Minimize } f(g,h) \qquad -(2)$$

$$where\ f(g,h) = \alpha\left[\frac{1}{branch\ loading}\right]^2 + \beta\left[\frac{e^{\left(\sum_1^k V_{diff}\right)^2}}{\sum_{n-1}^{m}(L_{nmax} - L_n}\right] - (3)$$

where, L_n: Utilized line capacity, L_{nmax} :Maximum line capacity, V_{diff}: Difference from reference voltage, m: Number of transmission lines, k: Number of buses (All values in objective function are normalized).
Subject to the following conditions:

a. Total power generated - total load -total losses = 0
b. Line utilization is less than the line capacity
c. Voltage variation is minimal and is within the limits.
d. þ = 1- a;

where, a is the weighting factor with respect to branch loading, and þ is the weighting factor with respect to voltage deviation and line capacity. The value of a and þ are taken as 0.5 to ensure maximum transfer capacity. The appropriate location of IPFC is identified by using the proposed objective function employing the proposed hybrid Fish – Bee algorithm. An index namely, power transfer capacity index is defined to analyze the performance of IPFC.

IV.II Power Transfer Capacity Index

To ascertain the performance of IPFC, a power transfer capacity index which is the ratio of real power in the line to the maximum MW of the line is used and is measured by using (4) with and without IPFC.

$$powe\ transfer\ capacity = \frac{p}{p_{max}} \qquad -(4)$$

where, P = Real power actually flowing in the line, P_{max} = the maximum real power flow limit of the line.

Maintaining power transfer capacity index value near to unity is an indication of transfer capability improvement.

V.IDENTIFICATION OF LOCATION OF IPFC

The locations of IPFC are identified by using the proposed objective function for IEEE 30 bus test system with a = þ =0.5 to improve the power transfer capability of the line. It is assumed that the rating of IPFC is given.

A. IEEE 30 Bus System

The test case of IEEE 30 Bus system is shown in Fig. 4. The location of FACTS devices is identified by using the existing and proposed algorithms for the selected line outage is tabulated in Table I. The power transfer capacity index with and without IPFC is tabulated in Table II

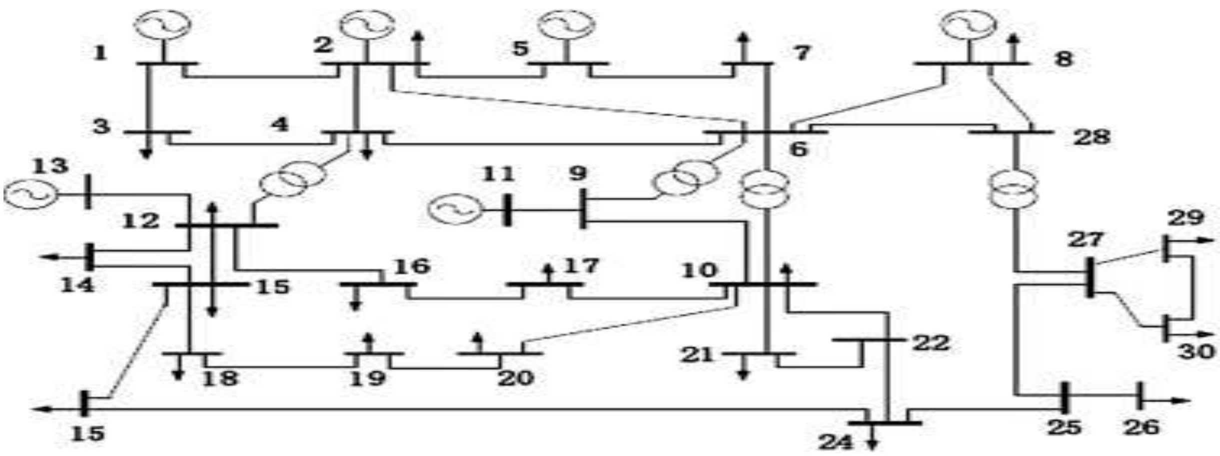

Fig-4: IEEE **30 Bus system**

TABLE- 1: LOCATION OF IPFC FOR CONGESTION MANAGEMENT – IEEE 30 BUS SYSTEMS

Tripped line	From bus	To bus	Identified locations			
			Using existing algorithm			Using proposed Algorithm
			PSO	ABCO	FSO	
1	1	2	7	7	7	7
14	9	10	25	25	14	25
8	12	15	7	7	7	7
10	6	8	32	27	27	25

After analyzing the location of IPFC in IEEE 30 bus test system, it is observed that the power transfer capability of both underutilized and overloaded lines is improved. This is validated with new objective function with proposed algorithm.

TABLE -2: POWER TRANSFER CAPACITY INDEX – IEEE 30 BUS SYSTEM WITH LINE 1 OUTAGE

Line no	Line b/w buses	P/Pmax without UPFC/IPFC	P/Pmax with UPFC Using existing algorithm			P/Pmax with IPFC Using proposed algorithm
			PSO	ABCO	FSO	HYBRID FISH- BEE
2	1-3	1.74	1.38	1.32	1.28	1.02
3	2-4	1.54	1.22	1.16	1.13	1.04
6	3-4	1.72	1.43	1.36	1.32	1.06
4	2-5	1.38	1.18	1.12	1.09	1.08
5	2-6	1.36	1.22	1.15	1.12	0.84
7	2-4	1.21	0.98	1.06	1.03	0.99
9	4-6	1.24	1.01	0.95	1.02	0.96
10	5-7	0.32	0.36	0.39	0.37	0.44
11	6-7	0.87	0.93	1.00	1.06	1.0
12	6-8	0.92	0.98	1.05	1.02	0.89
13	6-9	0.98	1.04	0.97	1.06	1.00
16	6-10	0.96	1.02	0.95	1.03	0.90
8	9-10	0.88	0.93	1.00	1.10	1.06
21	4-12	0.91	0.96	1.03	0.99	0.92
22	12-13	0.94	0.99	1.06	1.02	0.98
23	12-14	0.98	1.04	0.97	1.02	0.77
24	12-15	0.88	0.93	1.01	0.98	1.00
27	14-15	0.78	0.82	0.89	0.95	1.03
25	16-17	0.67	0.70	0.76	0.81	0.45
28	15-18	0.84	0.88	0.95	1.01	0.87
29	18-19	0.54	0.61	0.66	0.69	0.96
18	19-20	0.96	1.00	1.08	1.05	1.01
17	10-20	0.94	0.98	1.05	1.01	0.77
19	10-17	0.91	0.96	1.03	1.00	1.05
20	10-21	0.36	0.37	0.4	0.42	0.46
30	10-22	0.92	0.96	1.03	0.99	1.04
26	21-22	0.93	0.96	1.03	0.99	1.08
31	15-23	0.94	0.97	1.04	1.00	1.04
32	22-24	0.87	0.9	0.98	1.05	1.01
33	23-24	0.92	0.95	1.03	1.00	1.00
34	24-25	0.96	0.99	1.07	1.04	1.00
35	25-26	0.89	0.92	1.00	1.07	1.03
36	25-27	0.90	0.93	1.00	1.06	1.02

37	27-28	0.48	0.49	0.53	0.56	0.59
38	27-29	0.63	0.65	0.70	0.73	0.80
39	27-30	0.89	0.91	0.98	1.07	1.02
15	29-30	1.27	0.96	1.03	1.00	1.0
14	8-28	0.94	0.96	1.03	1.00	0.80

V. CONCLUSION

IPFC has been selected as one of the best FACTS devices for enhancing the power transfer capability of transmission lines because of its ease of control. A new objective function is proposed for identifying the optimal location of IPFC. The power flow performance index (PI) is taken as reference for identifying the congested line. The optimal location of IPFC for IEEE 30 bus is identified by using the proposed hybrid Fish – Bee algorithm by making line outage a finding corresponding overloaded lines. The power transfer capacity index is computed by using the proposed hybrid Fish – Bee algorithm before and after placing IPFC, and the results are compared with UPFC already existing results.

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