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Optimal Setting of Interline Power Flow Controller for Overload Management

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ABSTRACT

Modern deregulated power systems are increasingly facing the problem of congestion. This paper proposes a Flower Pollination Algorithm (FPA) based optimum regulation of an Interline Power Flow Controller (IPFC) for a multi objective function consisting of reduction of active power loss, minimization of total voltage deviations, and maximization of security margin with Minimalistic IPFC Installation. Disparity Line Utilization Factor (DLUF) has been used for the placement of the IPFC. The IPFC is placed in the lines with maximum DLUF. The proposed method is implemented on an IEEE-30 bus test system to establish the effectiveness on the reduction of congestion.

Keywords: Congestion, FACTS, Line Utilization Factor, Optimal placement, Optimal tuning

1. INTRODUCTION

Due to the competition in the electrical industry and the rise in the demand of the consumers, various methods have been employed by the engineers to improve the electrical transmission and distribution systems [1-4]. Still the problem of congestion of the transmission lines seems to be unresolved.

Kumar et al. performed a massive survey on the congestion issue and on the methods to overcome the problem [5]. Several authors have employed FACTS devices to overcome the issue of line overloading. Talukdar et al. [6] have suggested a computational method for generation rescheduling and load shedding for the reduction of overloading of the transmission lines. Singh et al. [7] and Besharat et al. [8] have suggested optimal placement of FACTS devices especially TCSC for the reduction of loading in the transmission system. Rao et al. [9-11] employed static VAR compensator using Voltage collapse proximity indicator (VCPI) to improve the performance of the power systems. Several authors [12, 13] recommended use of metaheuristic algorithms for the optimal positioning of the FACTS devices.

IPFC is one of the FACTS devices developed by N.G. Hingorani and Lazlo Gyugi [14]. Some authors [15, 16] have dedicated their study on the use of IPFC for overcoming various problems in the transmission systems and have found the device to be highly effective for the purpose. Nature inspired algorithms are among the most powerful algorithms for optimization [17]. FPA has also been extended to multi-objective optimization with promising results. FPA has been found to be superior to PSO and GA with almost exponential convergence rate [18]. FPA has only two important parameters, namely, size of population and probability switch. Thus the use of the algorithm is much simpler in comparison to others [19].

In this paper, the concept of Disparity Line Utilization Factor (DLUF) has been used for the placement of the IPFC converters. DLUF calculates the difference between the loading of the transmission lines.

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Later the IPFC is tuned for multiple objectives using Flower Pollination Algorithm (FPA). The proposed method has been implemented on an IEEE 30 bus system for normal loading. It is observed from the results that the introduction of an FPA tuned IPFC is very effective in the reduction of system loading, voltage deviation and lossess.

2. DISPARITY LINE UTILIZATION FACTOR

Disparity Line Utilization Factor is an index especially suited for the placement of IPFC in the transmission system. It calculates the relative loading of the transmission lines. Thus, it provides a specific location for each converter of the IPFC.

$$DLUF_{(ij)-(ik)} = \left| \frac{MVA_{ij} - MVA_{ik}}{MVA_{\max}} \right| \tag{7}$$

Where,

$DLUF_{(ij)-(ik)}$ is the Disparity line utilization factor (DLUF) of the line ij and ik connected to bus- i and bus-j.

MVA_{ij} is the MVA flow in the line connected between i^{th} j^{th} bus.

MVA_{MAX} is the rated MVA of the line.

MVA_{ik} is the actual MVA rating in the line between i^{th} and k^{th} bus.

3. OPTIMAL TUNING

An objective function comprising of the following is chosen

- Active power loss [12]
- Voltage deviation [17]
- Security margin [18]
- Size of IPFC [19]

FPA is a new nature-inspired algorithm, based on the characteristics of flowering plants, developed by Xin-She Yang in 2012. The main work of a flower is to reproduce through fertilization. Fertilization can be regarded as self-fertilization or cross-fertilization. For mathematical details refer [19].

4. RESULTS AND DISCUSSION

The load flow analysis is done using MATLAB for an IEEE 30 bus system. Only load buses are considered for IPFC placement. Table I presents the line loadings in terms of LUF without and with IPFC. It is found

Table 1
Loading in transmission lines of IEEE 30 bus system

S. No.	*Sending Bus*	*Receiving Bus*	*LUF-IPFC Lacking*	*LUF – IPFC Present*	*LUF – IPFC Tuned*
1.	1	2	1.8029	1.7979	1.7677
2.	1	3	0.9483	0.9039	0.8902
3.	2	4	0.4939	0.4768	0.4591
4.	3	4	0.8415	0.8334	0.8240
5.	2	5	0.8532	0.8451	0.8374
6.	2	6	0.6473	0.6279	0.6125
7.	4	6	0.7173	0.7439	0.6966
8.	4	12	0.5284	0.5028	0.5026

Table 2
Implementation of DLUF

Sl. No.	*Line 1*	*Line 2*	*Line1 LUF*	*Line 2 LUF*	*DLUF*
CASE-1	3-4	4-6	0.8415	0.7173	0.1242
CASE2	3-4	4-12	0.8415	0.5284	0.3131

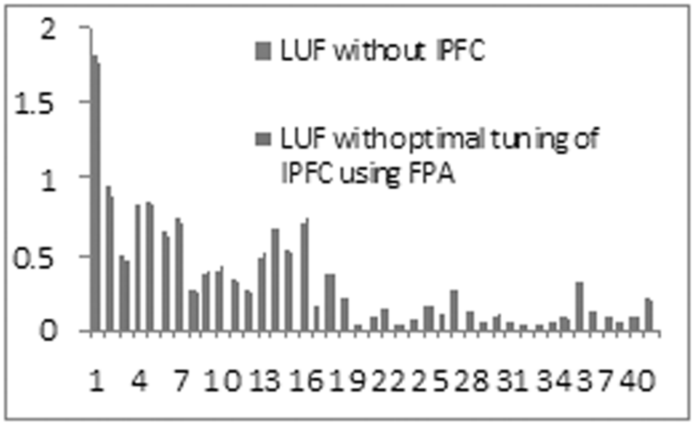

Figure 1: LUF without IPFC and with FPA tuned IPFC

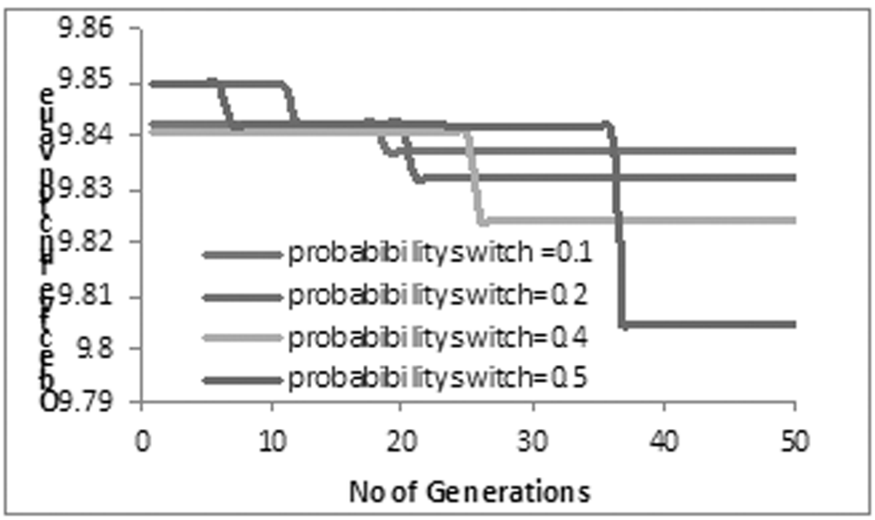

Figure 2: Objective Function vs. parameter values of FPA

Table 3
Comparitive Analysis for Various Population Size

Prob. Switch = 0.5	*Population Size 20*	*Population Size 50*
Active Power Loss	20.586	21.19
Security Margin	15.2277	15.3675
Voltage Deviation	2.3255	2.34
IPFC Size	2.52e-6	4.324e-8
Computation Time	198.0316	582.34

that the line 3-4 is the most overloaded line of the system. DLUF is calculated for all lines connected to the line 3-4 and the results are shown in Table II. DLUF has been calculated for each test case and it is observed that DLUF is maximum between lines connected to buses 3-4 and 4-12. Hence, the line 3-4 and line 4-12

Table 4
Flower pollination Parameters for IPFC Tuning

S. No.	*Parameter*	*Value*
1.	Population Size	20
2.	Probability Switch	0.5

has been selected for the placement of IPFC. It is observed that placement of IPFC at the location, reduces the congestion in line 3-4 from 0.8415 to 0.8334. The LUF values before and after placement of IPFC have been compared in Fig. 1.

Fig. 2 shows the objective function vs. number of generations' characteristics for different probability switch values for a population size of 20. It is observed that when probability switch is 0.5, although the number of generations required is more, but the objective function's value is minimized to a maximum extent. Table III compares the objective function and computation time for different population size. It is observed that increase in population size increases the computation time extensively without much minimization in the objective function values. Hence, the probability switch is chosen to be 0.5 and population

Table 5
IPFC Voltage magnitude and angle pre and post IPFC tuning

IPFC parameters	IPFC Un tuned	IPFC FPA Tuned
VSe1	0.0050	0.0012
VSe2	0.0100	0.0071
Θse1	-140.1182	-152.176
Θse2	180	180

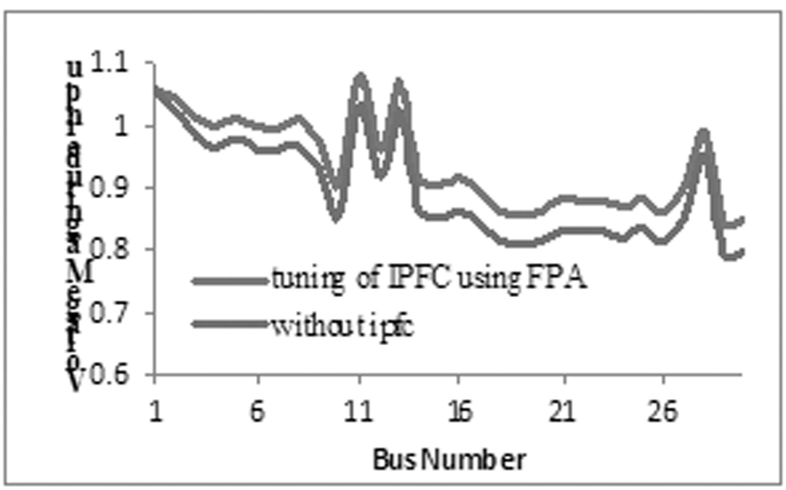

Figure 3: Voltage Outline pre and post IPFC tuning

Table 6
Comparison of objective funxction for Untuned and With Flower pollination Tuned IPFC

Parameters	*Untuned IPFC*	*Tuning of IPFC using FPA*
P_{Loss} in MW	21.909	20.586
VD in P.U.	2.3889	2.3255
SM in p.u.	18.2714	15.2277
IPFC Size in MVA	0.000406	0.00000252

Table 7
Comparison of Total Real and Reactive Power Loss in the system without IPFC, With Untuned IPFC and with FLOWER POLLINATION Tuned IPFC Normal

	Real Power Losses in MW	*Reactive power losses in MVAR*
IPFC Lacking	22.941	107.370
IPFC Untuned	21.909	101.334
IPFC FPA tuned	21.386	98.774

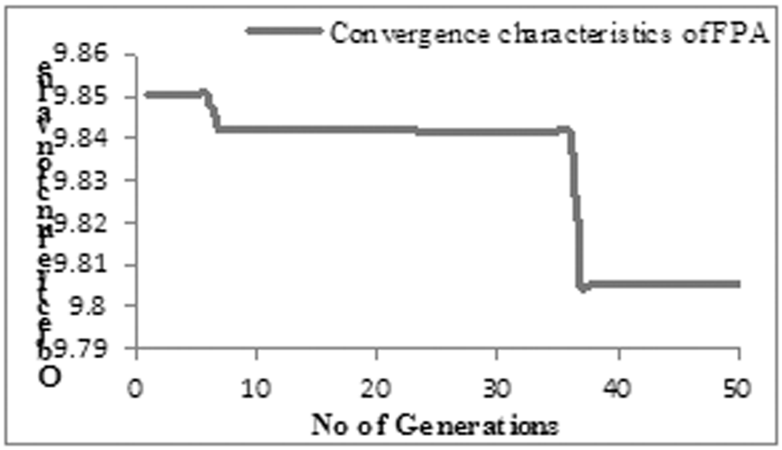

Figure 4: Convergence characteristics of FPA with normal loading

size is 20 as listed in table-IV. After FPA based tuning of the congestion in the line reduces to 0.8240 p.u. The values of voltage mag. and angle of the IPFC have been specified in Table V.

Fig.3 shows a noticeable enhancement in voltage mag. of the buses with optimal placement of tuned IPFC in comparison to voltage profile of the system without IPFC. Thus, the Voltage Deviation (VD) of the overall system is reduced. Table VI shows a reduction in the values of all the objective functions by optimal placement of IPFC. Thus it is established that by Optimal tuning of IPFC Using FPA the system loss, voltage deviation and also security margin (SM) is reduced with the use of minimum capacity of IPFC. Fig.4 shows the fast convergence of FPA 38 generations.

5. CONCLUSION

In this paper, a DLUF based method has been used for the placement of the IPFC converters. It is found that the placement of the IPFC is effective in the reduction of line loading. The tuning of the device using FPA is further very effective in the reduction of the system congestion and losses. FPA technique is found to be very effective to attain the multiple objectives and to determine the optimal parameters of the IPFC under different loading conditions. A decrease in Ploss, VD, SM has been achieved with much smaller size of IPFC.

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