International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 11, No. 2, June 2020, pp. 886~894
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v11.i2.pp886-894

Optimal location of unified power flow controller genetic algorithm based

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Article Info

Article history:

Received Sep 17, 2019
Revised Nov 9, 2019
Accepted Feb 7, 2020

Keywords:

FACTS,
GA,
Loadability,
MATLAB,
PSS\E,
UPFC,

ABSTRACT

Now-a-days the Flexible AC Transmission Systems (FACTS) technology is very effective in improving the power flow along the transmission lines and makes the power system more flexible and controllable. This paper deals with overload transmission system problems such as (increase the total losses, raise the rate of power generation, and the transmission line may be exposed to shut down when the load demand increase from the thermal limit of transmission line) and how can solve this problem by choosing the optimal location and parameters of Unified Power Flow Controllers (UPFCs). which was specified based on Genetic Algorithm (GA) optimization method, it was utilized to search for optimum FACT parameters setting and location based to achieve the following objectives: improve voltages profile, reduce power losses, treatment of power flow in overloaded transmission lines and reduce power generation. MATLAB was used for running both the GA program and Newton Raphson method for solving the load flow of the system. The proposed approach is examined and tested on IEEE 30-bus system. The practical part has been solved through Power System Simulation for Engineers (PSS\E) software Version 32.0 (The Power System Simulator for Engineering (PSS/E) software created from Siemens PTI to provide a system of computer programs and structured data files designed to handle the basic functions of power system performance simulation work, such as power flow, optimal power flow, fault analysis, dynamic simulations...etc.). The Comparative results between the experimental and practical parts obtained from adopting the UPFC where too close and almost the same under different loading conditions, which are (5%, 10%, 15% and 20%) of the total load. can show that the total active power losses for the system reduce at 69.594% at normal case after add the UPFC device to the system. Also, the reactive power losses reduce by 75.483% at the same case as well as for the rest of the cases. in the other hand can noted the system will not have any overload lines after add UPFC to the system with suitable parameters.

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1. INTRODUCTION

It is important to take into consideration in our life the increase in demand this will need to increasing in the rate of electric power, so this will make power networks are operating under high stress and complex pressure conditions. This complexity and increase in energy supply requires providing the system with modern control devices that help in the development of the electrical networks [1, 2]. FACTS technologies and its advantages like can be used as power flow control, maximum transmission capability, voltage regulation, reactive power compensation, stability improvement, Power quality improvement and Power conditioning. [3]

Unified Power Flow Controller (UPFC) is a versatile and flexible device in the FACTS family of controllers which has the ability to the simultaneous and independent control of the bus voltage and the real and reactive transmission-line power flows.[4, 5] The problem of optimizing the location, number and size of FACTS devices have become an important requirement for a best advantage of these devices in order to achieve a number of a desired objective function. Genetic algorithms (GAs), which are probabilistic global optimization techniques inspired by a natural-selection process and the solving of complex optimization problems. [6, 7]. This research deals with using the GA to solve the optimal UPFC-location problems for redistributed power systems in consideration of the system loadability, improve voltages profile, reduce total power losses, control of power flow in overloaded transmission lines and reduce power generation [8, 9].

In this paper we have relied on the use of GA to achieve the following:

- show that all control parameters of UPFCs in each case are within their limits.
- To installed the UPFC device in each case in right position with safely operation
- what strengthens the performance indicator of GA search process in finding the optimal locations of UPFC devices with respecting its limits
- GA makes the calculations limited within a narrow space with minimal time, therefor facilitates the search for optimal number, optimal placement and size of UPFC devices.

In [10] the author found by applying the genetic algorithm (GA) in the standard IEEE 14 bus test system can determine the optimal number, optimal placement and size of UPFC device to enhance voltages profile and reduce overall system losses. genetic algorithm (GA) can be considered a new technique for the installation of FACTS devices in the transmission system by limit the optimal placement of FACTS devices in a transmission network can increased loadability of the power system as well as to minimize the transmission loss, this was mentioned in[11].

2. MODELING OF UPFC

The Unified Power Flow Controller concept called UPFC is a power electronics-based system which can provide simultaneous control of the transmission line impedance, phase angle, voltage magnitude and active and reactive power flow [12, 13]. It’s has to voltage source convertor: The shunt converter acts like a STATCOM and the series converter acts like a SSSC. The series converter controls the phasor voltage in series with the line.[14] The transmission line current flows through this voltage source resulting in real and reactive power exchange between it and the ac system [15]. In addition, the shunt converter can independently exchange reactive power with the system through the transformer connecting it with the power system. Both converters are connected through by a dc capacitor. The controllers for both the series and shunt converters are used [16]. The controller can control active and reactive power in the transmission line [17]. As it is shown in Figure 1, the basic structure of UPFC device is a combination of two compensators [18]: one connected in parallel called Static Compensator (STATCOM) and the other in series called Static Synchronous Series Compensator (SSSC). Both compensators are connected with "DC" link to exchange the real power between the output terminals of STATCOM and SSSC [12, 19].

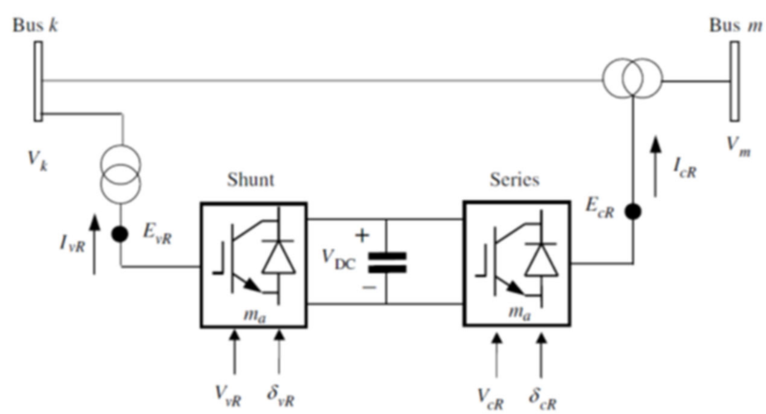

Figure 1. The schematic diagram of UPFC

The equivalent circuit of UPFC is presented in Figure 2. The series part is modeled by a controllable voltage source, and the shunt part is modeled by a controllable current source. UPFC has three controllable parameters namely: voltage magnitude, phase angle of the voltage and shunt reactive current [2, 19, 20], Based on the equivalent circuit of UPFC shown in Figure 2. the active and reactive power injection equations at buses k and m are given by the following expressions [21, 22].

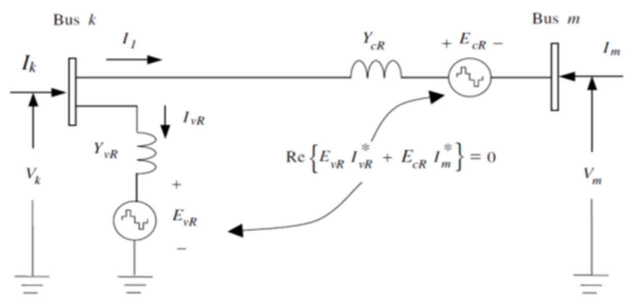

Figure 2. equivalent circuit of UPFC model

at bus k:

$$P_k = V_k^2 G_{kk} + V_k V_m [G_{km} \cos(\theta_k - \theta_m) + B_{km} \sin(\theta_k - \theta_m)] + V_k V_{cR} [G_{km} \cos(\theta_k - \delta_{cR}) + B_{km} \sin(\theta_k - \delta_{cR})] + V_k V_{vR} [G_{vR} \cos(\theta_k - \delta_{vR}) + B_{vR} \sin(\theta_k - \delta_{vR})] \quad (1)$$

$$Q_k = -V_k^2 B_{kk} + V_k V_m [G_{km} \sin(\theta_k - \theta_m) - B_{km} \cos(\theta_k - \theta_m)] + V_k V_{cR} [G_{km} \sin(\theta_k - \delta_{cR}) - B_{km} \cos(\theta_k - \delta_{cR})] + V_k V_{vR} [G_{vR} \sin(\theta_k - \delta_{vR}) + B_{vR} \cos(\theta_k - \delta_{vR})] \quad (2)$$

at bus m:

$$P_m = V_m^2 G_{mm} + V_m V_k [G_{mk} \cos(\theta_m - \theta_k) + B_{mk} \sin(\theta_m - \theta_k)] + V_m V_{cR} [G_{mm} \cos(\theta_m - \delta_{cR}) + B_{mm} \sin(\theta_m - \delta_{cR})] \quad (3)$$

$$Q_k = -V_m^2 B_{mm} + V_m V_k [G_{mk} \sin(\theta_m - \theta_k) - B_{mk} \cos(\theta_m - \theta_k)] + V_m V_{cR} [G_{mm} \sin(\theta_m - \delta_{cR}) - B_{mm} \cos(\theta_m - \delta_{cR})] \quad (4)$$

3. THE IMPLEMENTED IEEE 30 BUS ELECTRICAL NETWORK

The implementation of UPFC in IEEE 30 bus as a test system. The system consists of 6 generators, 30 buses, 21 loads and 41 lines [23]. in Figure 3. can show Depending on the PSSE program, the IEEE-30 network can be represented as well as the implementation of UPFC and connecting it with the transmission line on the one hand to represent the SSSC part and with the bus on the other to represent the part STATCOM as shown in Figure 4. The program is the practical part of the research where its results are compared with the results obtained from the GA and know the extent of its impact on the distribution of power in a balanced and get the highest tolerance [10].

4. GENETIC ALGORITHM PROCESS AND PROBLEM FORMULATION

Genetic Algorithm (GA) is considered as one of the most important evolutionary algorithms based on mechanism of natural selection and genetics for solving the constrained and unconstrained optimization problems. It is worth noting that GA can search simultaneously several possible solutions without require to prior knowledge or special properties of the objective function. A GA is a simple and practical algorithm that can be easily implemented in a power system A GA have three important part, followed by, crossover rate, and mutation operations that are carried out until the best population is found and population size. [6]. In this paper the objective (fitness) function of the GA is reach to the minimum losses with maximum loadability and controller power flow. Taking into consideration the total number of UPFCs that can be inserted in a power system is limited, due to the cost of the devices and the influences on the operating characteristics of the power system.[24]. Also, in this algorithm to achieve the target function the flowing constrain should be specified:[25, 26].

- Location of UPFC: No more than one UPFC can be installed in one branch of power-flow computations, also cannot connect UPFC device with PQ buses.
- Control parameters: The performance of the GA depends on the control parameters such as population size, crossover probability, and mutation probability.

The optimal location and size of the UPFC device that can be used in IEEE-30 bus network is given in MATLAB coding at in the following steps below based on Genetic Algorithm: [2]

Step 1: Initialize the population size of GA and the parameters of UPFC device.
Step 2: Run the program of power flow (Newton Raphson).
Step 3: For all the individual's objective values are calculated.
Step 4: Based on the objective values, select a new population from the old population based on the calculation function.
Step 5: GA operators, crossover and mutation are applied to the population that has been selected to create new solutions.
Step 6: For new chromosomes the objective values are calculated and using it into the population.
Step 7: If the time done, stop GA program and print the best individual, while if not go to step 4.
The optimization strategy is summarized in Figure 5 [6].

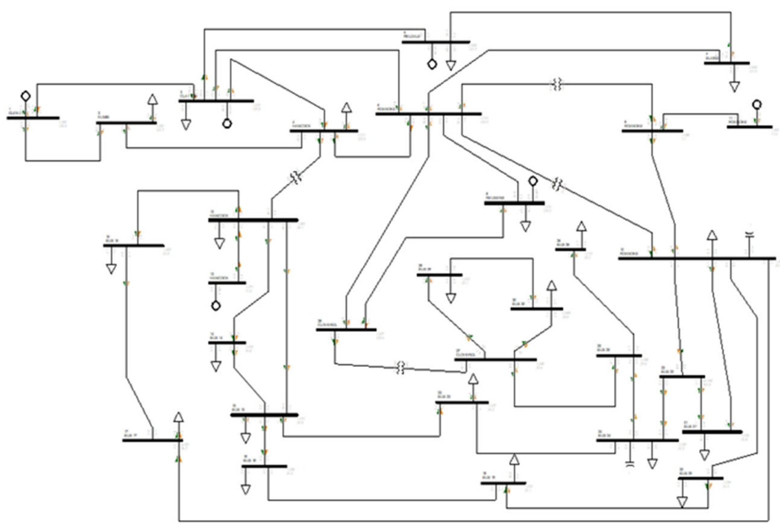

Figure 3. The configuration IEEE 30 buses electrical network

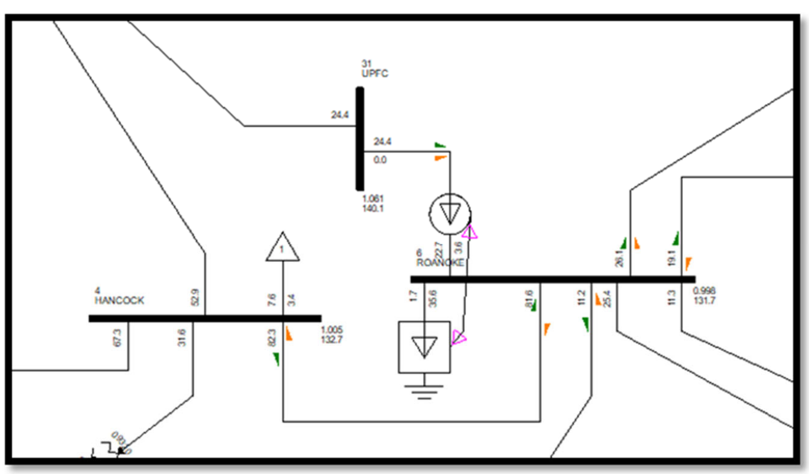

Figure 4. Represent the UPFC in PSS/E programs

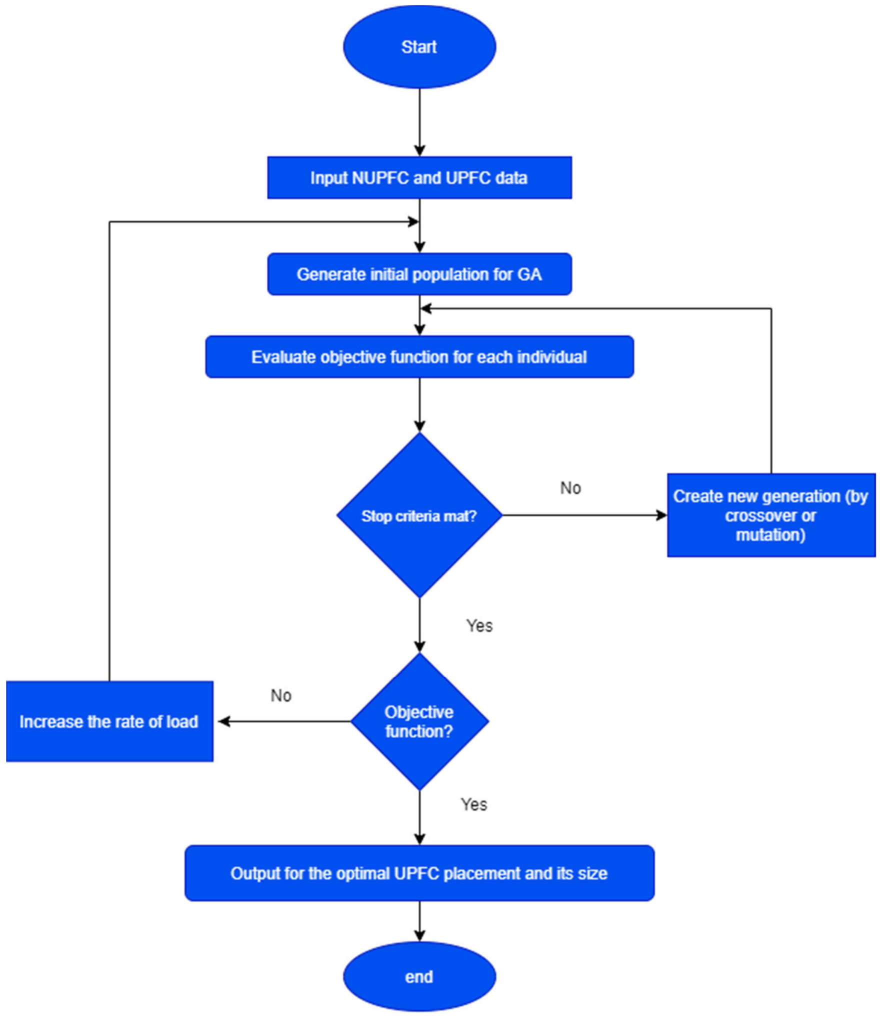

Figure 5. Optimization process flowchart of UPFC placement based on GA

5. RESULTS AND DISCUSSION:

As previously explained, the proposed genetic algorithm (GA) and the maximum number of FACTS devices are applied to the 30-bus power test system in order to find the optimal number, size and location of UPFC devices to reach all targets: increasing line tolerance and balanced power distribution and reducing total losses in Five different cases (normal case and increase overall load in (MVA) at (5%,10%,15% and 20%). In Table 1, it has been included the overall system loss rate and the number of transmission lines exposed to overload are included in all cases without adding UPFC to the system. Can noted that the system at the normal case (283.4 MW) which is represent the total rate loading of the system, the active and reactive total losses to the network equal to (17.5 MW and 67.6 Mvar) with one overload line. These results are consistent with the practical results taken from the program. The rate of these total losses will be increase and the loadability of the transmissions line will be decreases when the system is exposed to increase in the rate of demand. This is observed when the total load increases by (5%,10%,15%,20%). However, when added the UPFC to the system with optimal position selection and size by selecting optimal values by using genetic algorithms as shown in Table 2 and Table 3.

The overload line in 30-Bus system has been reduced, it is possible to observe the extent of the effect of the UPFC in Figure 6 and Figure 7.the Application in the PSS / E programs by using contours observed that when take the five case as example (at 20% increase in load) the four lines are up to the maximum degrees of the overloading more than 100%. While Figure 7. shows the loading of the same lines after the addition of UPFC device.

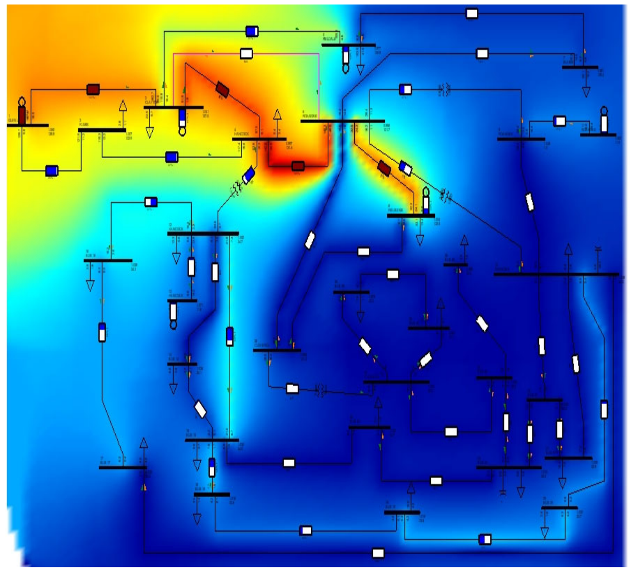

Figure 6. The loading in IEEE 30bus transmission line without UPFC device

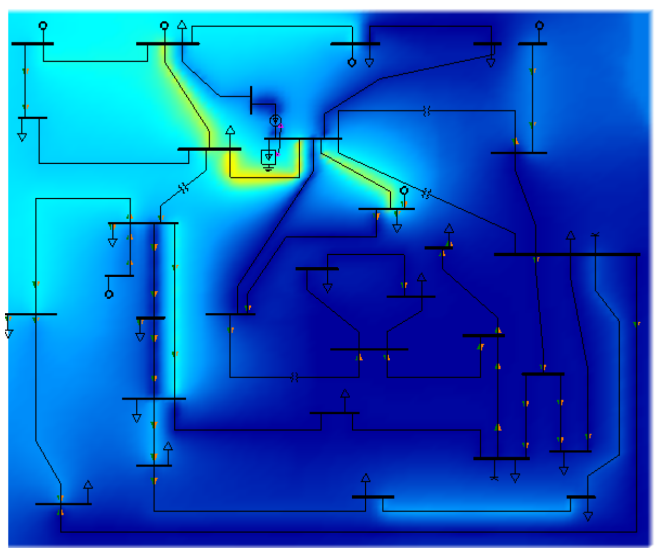

Figure 7. the loading in ieee 30bus transmission line with upfc device

2.minimining total losses with minimum number of upfc .as shown in figure 8 and figure 9. the total active and reactive power losses have been reduced after adding upfc to the system. where it is reduced the active power losses from (17.5 mw) to (5.312 mw) also the reactive power losses it is reduced from (67.6 mvar) to (16.573 mvar) after add the upfc to the system. as well as the remainder cases.

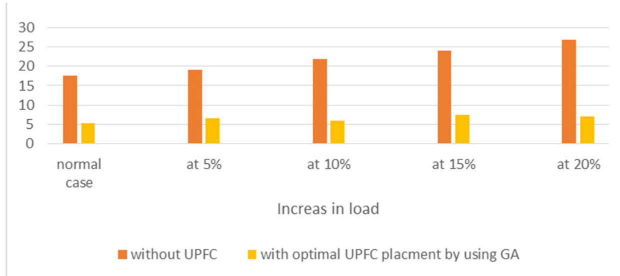

Figure 8. Effect adding UPFC on the active power losses at five cases with using GA

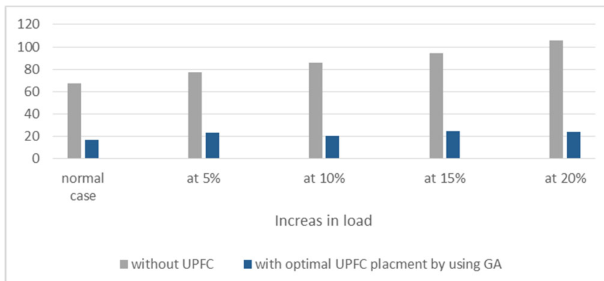

Figure 9. Effect add UPFC on the total reactive power losses at five cases with using GA

As shown in Figure. 10 and figure. 11 the buses voltage is kept within the normal limit and not deviations from original values.

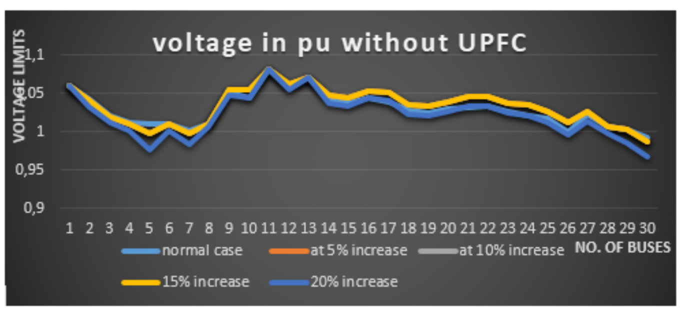

Figure 10. Voltages in per unit (p.u) for five loading cases without UPFC

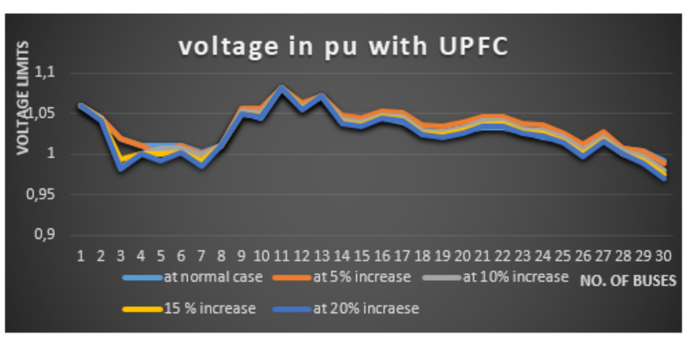

Figure 11. Voltages in per unit (p.u) for five loading cases with UPFC

Table 1. MATLAB and PSS\E result without UPFC

NO.OF CASES	LOADING IN (MW)	MATLAB result TOTAL LINE LOSSES		PSS\E result TOTAL LINE LOSSES		OVERLOAD LINE
		MW	Mvar	MW	Mvar	
Normal case	283.4	17.5	67.6	17.5	67.6	(1-2)
Increase (5%)	297.6	19	77	19	75	(1-2), (6-8)
Increase (10%)	311.74	21.855	85.978	21.8	83.9	(1-2), (6-8)
Increase (15%)	325.91	24.1	94.6	24.2	92.9	(1-2), (6-8)(2-6)
Increase (20%)	340	26.86	105.6	26.7	102	(1-2), (2-6) (4-6), (6-8)

Table 2. MATLAB and PSS\E result with UPFC with GA

NO. OF CASES	NUPFC\ LOCATION	UPFC SIZE	MATLAB result TOTAL LINE LOSSES		PSS\E result TOTAL LINE LOSSES		OVERLOAD LINE
			MW	Mvar	MW	Mvar	
Normal Case	NUPFC=1branch (4)between bus 3-4	Vcr =0.9947, δcr =-0.0985, Vvr =1.0987, δvr =-0.00887	5.312	16.573	5.5	18.6	NONE
Increase (5%)	NUPFC=1branch (6) between bus(6-2)	Vcr =0.245, δcr =-0.00842 Vvr =0.001, δvr =-0.00021,	6.6	23.076	6.0	24.1	NONE
Increase (10%)	NUPFC=1Branch (5)Between bus(5-2)	Vcr=0.893, δcr=-0.000913 Vvr=0.984, δvr=-0.0177	5.87	20.032	5.9	20.5	NONE
Increase (15%)	NUPFC=1branch (5)between bus(5-2)	Vcr=0.0068, δcr1=-0.00588 Vvr1=0.8958, δvr1=-0.00338	7.364	24.467	7	24.6	NONE
Increase (20%)	NUPFC=21.branch (5) Between bus (5-2) 2.branch 28 between bus 10-21)	Vcr1=0.0117, δcr1=-0.0015 Vvr1=0.077, δvr1=0.0046 Vcr2=0.1345, δcr2=-0.0664 vr2=0.0799, δvr2=0.006	7.039	23.763	7.2	23.5	NONE

Table 3. Appropriate Parameters Used in GA code

Parameters	Value
Number of generations	100
population size	50
Crossover fraction	0.8
Fitness limit	$1e^{-12}$
Time limit	∞

6. CONCLUSIONS:

In this work, examine the effect of UPFC in enhancing power system performance using in the IEEE-30 bus system as a case study. after inserting the UPFC device the total active power loss of the system is reduced by 69.594% and power transfer capability of the system is improved by making all power transfer over the transmission lines with in the normal rating.so this will make use the same line for transferring more power without any extra cost. Simultaneously the voltage profile of the system is kept with normal limit. Also due to the complexity of power systems and high cost that the installation of the UPFC device depended on the genetic algorithm (GA) it was gives better results (control the voltage magnitude, voltage phase angle, and impedance) and can get the best location and the right size with the least time this will achieved decreases overload lines and minimizes systemic power losses.

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