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Optimal Location and Parameter Setting of FACTS Devices based on WIPSO and ITLBO for Power System Security Enhancement under Single Contingency

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Abstract: ***In electric power system, finding optimal location and setting of Flexible AC Transmission System (FACTS) devices have been proved to be complex system and it's under single contingency. This paper presents a new approach which is based on Improved Teaching Learning Based Optimization (ITLBO) and Weight Improved Partial Swarm Optimization (WIPSO) to find the optimal location and parameter setting of Unified Power Flow Controller (UPFC) and Static Var Compensator (SVC) to achieve optimal performance of power system network. The effectiveness of the proposed method is tested on IEEE 14-bus system .The results show that, based on ITLBO and WIPSO can significantly minimizing the Over Load Index and the Voltage Violations Index that can successfully achieve that proper setting and placement of FACTS devices.***

Index Terms: Improved Teaching Learning Based Optimization (ITLBO); Weight Improvement of Particle Swarm Optimization (WIPSO); Static Var Compensator (SVC); Unified Power Flow Controller (UPFC); Line Overload Sensitivity Index (LOSI); Over Load Index (OLI), Voltage Violation Index (VVI).

I. INTRODUCTION

The working of power system becomes more complex due to the continuous increase in load demand which leads to an enlarged stress of the transmission lines. So, power system can be operated in less protected state following unexpected line congestions voltages. To overcome this problem we can construct new transmission lines. However it takes more time due to administrative and environmental reasons. Static security of the power system can be enhanced by generation rescheduling and load shedding as the primary corrective strategies for alleviating overloads on transmission lines. The rescheduling of generation and load shedding may not be acceptable by both power providers and customers, due to their significant effect on the existing power transaction contracts. An alternate solution can be devised through the use of FACTS technology.

Flexible Alternating Current Transmission Systems (FACTS) is a concept proposed by N.G. Hingorani [1] which is designed to remove various limitations of transmission lines and meet operator's goals without having to undertake major system additions. To achieve a certain objectives of a new methodology to analyze the system security.

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Therefore in order to achieve a certain objectives of a new methodology to analyze the system security under transmission line(s) and/or generator(s) outage conditions has been presented [2] a new optimization algorithm ITLBO has been proposed.

Here, [3] deals with the novel approach based on NSPSO has been present and applied to optimal location and setting of SVC and TCSC to enhance dynamic voltage stability.

SVC is a shunt FACTS device that can be used for improvement of voltage profile in a power system. Since the investment cost of this device is high, the paper [4] deals with the optimal placement of SVC in a power system using Voltage Performance Index. To analyzed [5] the system security under contingency OPF problem solved while satisfying system equality and in equality constraints, in this method is proven its effectiveness by starting iterative process with good initial value and reaches final best compare to existing method. The single objective OPF problem was solved using some of the advanced optimization techniques repeated in [6-9] while satisfying system constraints.

Now, a day's hybrid algorithms reported in [10-12] are used to solve OPF problem. Because of this implementation, the convergence has been improved rapidly and global optimal solution is obtained in less time. In this same way multi objective optimal power flow problem was solved in the presence of flexible AC transmission system (FACTS) controllers using some of the latest optimization methodologies reported in [13-15]. To identify an optimal location to install one of the advanced multiline FACTS controllers, namely, generalized UPFC and SVC. In this location, system security can be enhanced by minimizing the severity of the system. From the over view of literature survey, it is clear that the optimal location of FACTS devices provides to improves the system performance and to identify that system can be operated under contingency conditions to analyses the system security.

This paper presents a heuristic based ITLBO and WIPSO techniques is applied to find out the optimal location and parameter setting of FACTS devices for enhancing system security under single line contingencies through minimizing the overloaded lines and the bus voltage limit violations.

II. PROBLEM FORMULATION

Now day increasing demands on large and complex power system,

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it has become a critical issue to operate the power system with enhanced security limits. Hence, it to determine the optimal parameter setting of the UPFC & SVC installed in the power network to minimize the over loaded lines and the bus voltage violations at various single lines contingency. The strategy consists of the objective function in two linked stages one for the load voltage deviations and other for line loading there by making it a comprehensive one, whose minimization is carried under single line contingency which leads to security oriented solution. Here the variables to be optimized are number, type, location, parameter setting.

A. Cost $(C_{UPFC})\&(C_{SVC})$

The objective function C_{UPFC} presents the installation cost of UPFC device and C_{SVC} is the installation cost of SVC in the network, which are given by the following equations.

$$C_{UPFC} = 0.0003\, s^2 - 0.2691 s + 188.22 \quad \text{US \$/ KVar} \quad (1)$$

$$C_{SVC} = 0.0003 s^2 - 0.3051 s + 127.38 \quad \text{US\$/KVar} \quad (2)$$

B. Line Loading $[LL]$

FACTS devices are located in order to remove the overloads and to distribute the load flows uniformly. To achieve this, line loading is considered as first term in the objective function

$$LL = \sum_{l=1}^{nl} \left(\frac{S_i}{S_i^{\max}} \right)^{2n} \quad (3)$$

S_l is the apparent power in the line l.

$S_{l\max}$ is the apparent power rating of line l.

C. Line Voltage Deviations [LVD]

To determine the best location of FACTS devices and to improve voltage profile and avoiding voltage collapse in the power system. Several methods have been proposed to assess the static security of power system in load voltage deviations at network buses. When there is excessive high or low voltages can lead to an unacceptable service quality and create voltage instability problems formula used to explain below,

$$LVD = \sum_{m=1}^{nb} \left(\frac{V_{mref} - V_m}{V_{mref}} \right)^{2n} \quad (4)$$

V_m is the voltage magnitude at bus m

V_{mref} is the nominal voltage at bus m and is considered as 1.0 pu. m refers to the load buses, where V_m is less than V_{mref}.

D. Contingency Analysis

A contingency is considered to be the outage of a generator, transformer or transmission line. The system may become unstable and enters an insecure state when contingency event is occurred. Contingency analysis is one of the most important functions performed in power system to establish appropriate preventive and/or corrective actions for each contingency. In this work, it is focussed only on the single line outage contingency (N-1 contingency). For each simulated line outage contingency, the overall line loading and the load bus voltage deviation are determined. Also the critical severity index of the system is calculated using the formula,

$$LOSI = \sum_{m=1}^{nl} \left(\frac{P_{lm}}{P_{lm}^{max}} \right)^{2n} \quad (5)$$

The LOSI value calculated reflects the level of contingency. The optimal location and parameter setting of the UPFC & SVC under single line contingencies is carried out using optimization techniques. Installing UPFC & SVC in the optimized location with the optimized parameter setting will minimize the overloaded lines and bus voltage violations under contingency.

The objective function is formulated as

$$Min\, F = W_1[(C_{UPFC} * s) + (C_{SVC} * s)] + W_2[LVD] + W_3[LL] \quad (6)$$

F is the objective function;

C_{UPFC} is the cost of UPFC device in US \$/KVar;

C_{SVC} is the cost of SVC device in US \$/KVar;

S is the operating range of the FACTS device;

LVD is the Load voltage deviation;

LL is the Line loading;

W_1,W_2 & W_3 are the weight factors

$W_1 = 0.5$, $W_2 = 0.25$, $W_3 = 0.25$.

The optimal placement of UPFC and SVC is chosen in such a way that, it can easily its controlled operation under variable load conditions.

III. OVERVIEW OF ITLBO TECHNIQUE

The conventional Teaching Learning Based Optimization (TLBO) algorithm is one of the nature inspired algorithms and developed based on the effect of influence of teacher on students in a class. In general teacher is rich in knowledge and tries to influence the students to learn the subject/ concepts. In general, after completion of teachers lecture, students prepare the concepts through discussions among themselves. Due to this, the outcome of the students does not reflect the teacher knowledge completely. To overcome this difficulty, a new improved teaching learning based optimization (ITLBO) algorithm is proposed in this work. Before explaining the implementations of the proposed algorithm the important phases in the existing TLBO algorithm are explained as follows.

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A. Teacher Phase (Existing)

The teacher always tries to bring the knowledge of his/her students up to his/her knowledge. But in real time, this process may not yield good result; this is because of the different parameters such as learners knowledge, concentration, aptitude and commitment to learn the concepts, and also some times because of the improper lecture delivered by the teacher. From this, it can be consolidated that, a teacher can able to increase the mean level of the learner's knowledge rather the individual learner's knowledge.

B. B. Learner Phase (Existing)

Each of the students always tries to improve his/her knowledge by participating in discussions with his/her friends. For example, a student wants to interact with one of his/her friends to share the knowledge. At this stage there are two possibilities. One is that, student gains the knowledge, provided his friend has more than his knowledge. Second is that, no knowledge is gained, provided his friend has less knowledge than his knowledge. Due to which, learners will take more time to gain full knowledge. The proposed ITLBO algorithm overcomes the difficulties in teaching and learning phases of conventional TLBO algorithm. The details regarding the modified teaching and learning phases are explained as follows.

C. Teaching Phase (Proposed)

The existing teaching phase consists one teacher for learners, but the proposed teaching phase consists more number of teachers for learners. Because of this, the student who has poor knowledge gets improvement rapidly than the student of the conventional teaching phase. In fact, the real time problem needs to evaluate many nonlinear functions, with the conventional teaching phase, getting an optimal solution in less number of iterations which is difficult and sometime leads to poor convergence. To overcome this, more number of teachers is defined and all students are divided into several groups based on their knowledge levels. After this, for each of these groups, a teacher is assigned to teach the students. With this implementation, a teacher can concentrate more on their students to improve the knowledge by delivering the lecture according to the student understanding.

D. Learning Phase (Proposed)

In existing learning phase, student gains the knowledge through discussions with his/her friends, but in the proposed learning phase, student participates in discussion not only with his/her friends but also with his/her teacher. Due to which, one can gain the knowledge in less time. In real time, the modification of control parameters in next stage reflects the best set of control parameters in earlier stage. With this, the convergence is enhanced with good optimum result.

Implementation procedure for the proposed ITLBO for power system optimization problem is summarized as follows.

The system control parameters such as active Power Generation (PG) and Voltage magnitudes (VG) at Generator buses, tap settings of Tap-changing transformers (T) and Shunt Compensators (Qsh) are generated randomly between their limits for initial number of population (N).

Each of the population is updated in line and bus data and the power flow problem is solved using Newton Raphson load flow solution. The formulated objective function values and the respective fitness values are evaluated for each of the populations using equ (6)

$$fit_i = Min\ F \qquad i = 1,2,3 \ldots\ldots, N \qquad (7)$$

The evaluated objective functions and respective fitness values given in the form of vectors can be expressed as where $J_1; J_2; \ldots; J_N$ and $fit_1, fit_2, \ldots, fit_N$ are the respective objective function and fitness values of each of the population. Select the (T) population as the initial number of teachers randomly and treat the remaining population as the learners provided T < N.

$$J_1; J_2; \ldots; J_{T-1}; J_T; J_L; J_{L+1}; J_{L+2}; \ldots; JN \qquad (8)$$

To assign the learners to each of the teachers, a criteria based on their fitness values is formulated and this can be expressed as

$$fit_m \geq fit_n \geq fit_{m+1} m = 1,2, \ldots\ldots. T \& n = L, L + 1 \ldots\ldots\ldots, N \qquad (9)$$

If this condition is satisfied then assign the learner to teacher 'm' else not assign this learner to teacher 'm + 1' and repeat the same process for all learners to form 'D' number of groups (i.e. Teachers group).After this, calculate the mean value of all control variables in each of the groups (Mean $_D$) and using this, the teaching factor (TF) in i_{th} iteration can be calculated as

$$TF_i = \frac{Mean_{Di}}{Mbest_{,Di}} \qquad (10)$$

where, $M_{best; Di}$ is the position of the teacher in group 'D'. Using this teaching factor, the updated control variables in iterative process are calculated as

$$X_{new,j} = X_i + rand(X_{teacher,Di} - (TF \times Mean_{Di})) \qquad (11)$$

In each group, learner interacts randomly with other learners and teacher to enhance his/her knowledge. Learner increases knowledge through discussions with other learners and teacher. The mathematical expressions used to update the knowledge of a learner can be given as

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$$X_{new,i} = X_i + rand1(X_i - X_j) + rand2.(X_i - X_{teacher}) \quad if\ f(X_i) < f(X_i) \qquad (12)$$

$$X_{new,i} = X_i + rand1(X_j - X_i) + rand2(X_{teacher} - Xi if f Xi > f Xi \qquad (13)$$

At last, using these updated control parameters, evaluate the objective function and fitness values. Repeat this process for a predefined number of iteration or termination criteria is reached.

IV. MODELLING OF FACTS DEVICES

A schematic representation of UPFC is shown in Figure.1. The output voltage of the series converter is added to the AC terminal voltage V_0 via the series connected coupling transformer. The injected voltage V_{CR} acts as a series voltage source, changing the effective sending-end voltage as seen from node m. The products of the transmission line current I_m and the series voltage source V_{CR} determines the active and reactive power exchanged between the series converter and the AC system.

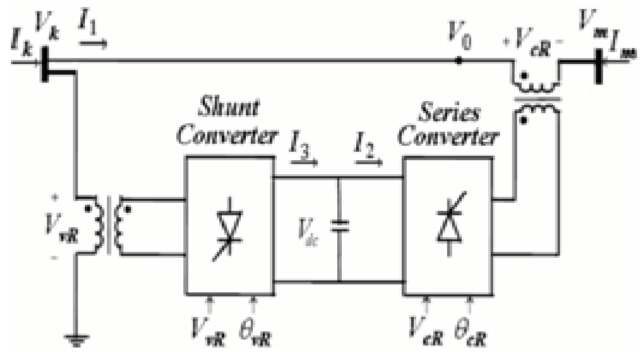

Figure 1: Structure of UPFC

A. 1. Mathematical Modelling of UPFC Devices

The model of UPFC is shown in Figure.2. A controllable series voltage source V_{CR} placed between the nodes K and M and in series with the line reactance. The two voltage source converter of the UPFC connected through a DC link can be modelled as two ideal voltage source, one controlled in series and other in shunt between the two buses K and M.

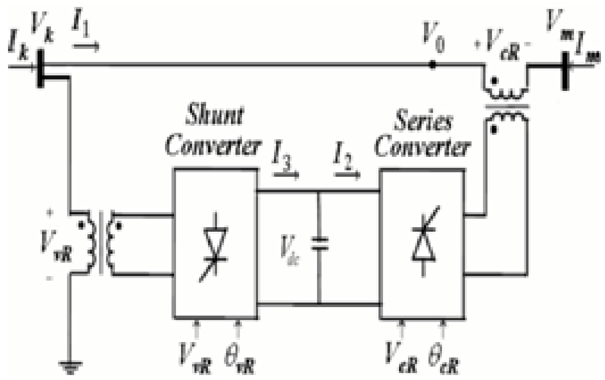

Figure 2: Voltage Source Model of UPFC

The output of the series voltage source V_{CR} and δ_{CR} are controllable magnitude and angle between the limits $V_{CR}min \leq V_{CR} \leq V_{CR}max$ and $0 \leq \delta_{CR} \leq 2\pi$ respectively and the shunt voltage source is V_{VR} and δ_{VR} are controllable between the limits $V_{vR}min \leq V_{vR} \leq V_{vR}max$ and $0 \leq \delta_{vR} \leq 2\pi$ are the impedance of the two coupling transformer connected in series and other in shunt between the line and UPFC.

It is generally represented by two coordinated synchronous voltage source and it is represented by,

$$V_{vR} = v_{vR}(cos\delta_{vR} + jsin\delta_{vR}) \qquad (14)$$

$$V_{cR} = v_{cR}(cos\delta_{cR} + jsin\delta_{cR}) \qquad (15)$$

A. 2. Advantages of UPFC

The UPFC is an advantageous power system device capable of providing simultaneous control of voltage magnitude, active and reactive power flows .Also it has

- Instantaneous speed of response
- Extended functionality
- Capability to control voltage, line impedance and phase angle in the power system network
- Enhanced power transfer capability
- Ability to decrease generation cost
- Ability to improve security and stability

B. Modelling of SVC Devices

The SVC is a general term for a TCR (thyristor controlled reactor), a TSC thyristor switched capacitor) .In fact, according to the Figure.3 SVC is a capacitor in parallel with a TCR which is connected in parallel with the network and can be used as compensating reactive power, hence it can be modelled as a variable reactive power source.

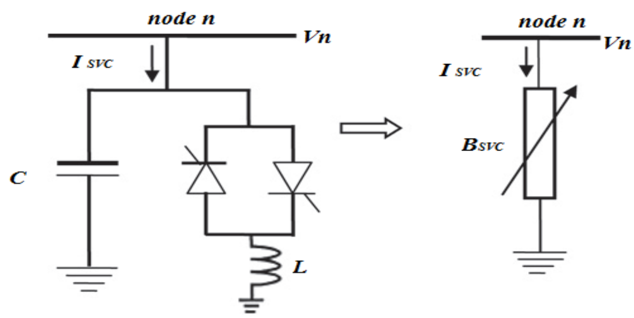

Figure 3: Basic structure of SVC Figure 4: Model of SVC

The function of SVC is to maintain a bus voltage at a desired value during load variations. Automatically, it injects or absorbs its reactive power, Qsvc at a chosen bus.

The working range of SVC is $Q_{SVC}^{min} \leq Q_{SVC} \leq Q_{SVC}^{max}$ (0MVar until +100MVar).

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The principle of shunt reactive power (var) compensation as illustrated in SVC is placed any load bus in Figure. 4.

B. 1 Advantage of Static Var Compensator

- It increased the power transmission capability of the transmission lines.
- It improved the transient stability of the system.
- It controlled the steady state and temporary over voltages.
- It improved the load power factor, and therefore, reduced line losses and improved system capability.

V. IMPLEMENTATIONS OF ALGORITHM

A. WIPSO Algorithm

WIPSO is based on the improved weight parameter function. For getting the better global solution, the traditional PSO algorithm is improved by adjusting the inertia weight, cognitive and social factors. WIPSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. The applied the concept of interaction to problem solving. Each particle tries to modify its position using the following steps.

STEP: 1

Read the line data, bus data &tolerance of convergence.

STEP: 2

WIPSO parameters such as the size of swarm m, the number of variables to be optimized, limits of each variable in the particle, C_1&C_2, C_{1min} ,C_{2min} & C_{1max} ,$C_{2max,}$ $iter_{max}$, W_{min} & W_{max}, D, velocity limits, P_{best} and G_{best} & maximum number of iterations are initialized.

STEP: 3

Run Newton –Raphson load flow and obtain bus voltages and line flows.

STEP: 4

Simulate contingency in K^{th} line, where K=1 to nl and calculate the line loading and load voltage deviations.

STEP: 5

Calculate Line Over Severity Index - LOSI value of the system using the equation (5).

STEP: 6

An initial population is randomly generated considering the variables to be optimized. [the number of FACTS devices, type, location, rating of the device]

STEP: 7

For each particle i[i =1,2,…..m] in the population, the objective function is evaluated.

STEP: 8

The objective function value of each particle is compared with the corresponding P_{best} of previous iteration and P_{best} of each particle is updated.

STEP: 9

G_{best} is identified, then compared with the G_{best} in the previous iteration and it is updated.

STEP: 10

A new population is created by updating the velocity and position of the particle.

STEP: 11

If stopping criteria is satisfied then optimum is reached otherwise go to (step7) for the next iteration.

STEP: 12

Run the load flow after optimally placing the FACTS devices as per the WIPSO algorithm to determine the line loading and load voltage deviations.

STEP: 13

The same procedure is repeated from (step 4) for different line contingencies.

B. ITLBO Algorithm

Optimization speaks about feasible solutions which correspond to extreme values of our objectives functions. The main optimization of problems mostly need for minimum possible values. Because of such extreme characteristics of optimal solutions, optimization processes are of high consideration in practice. Mostly real world problems naturally involved multiple objectives function.
The stepwise procedure for the implementation of TLBO algorithm in solving the optimization of ITLBO is given by following steps and it shows in Figure.5

VI. SIMULATION AND RESULTS

A. Simulation in power system

Matlab codes for WIPSO and ITLBO, a modified power flow algorithm to include UPFC and SVC were developed and incorporated together for the simulation purposed. To installation the validation of the applied techniques, both WIPSO and ITLBO algorithms have been tested on the IEEE 14 bus systems.

B. Observed Results

The effectiveness of the proposed algorithm has been tested on IEEE 14 bus system. (N-1) contingencies are simulated and for each contingency line the optimal device location and ratings are identified.

In this paper comparison between two different combination of WIPSO and ITLBO algorithm are done under single line contingency and critical contingency condition through FACTS devices to minimizing an objective function consisting of Line Over load Sensitivity Index, Over Load Index and Voltage Violation Index.

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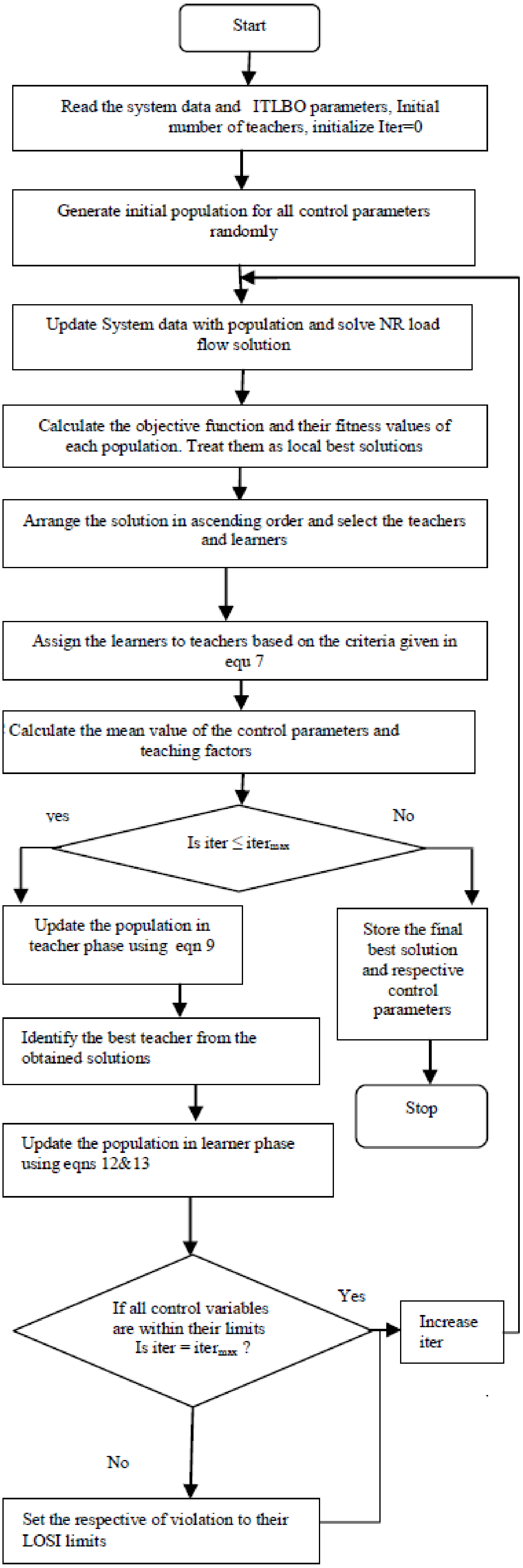

Figure 5: Flowchart of the proposed ITLBO algorithm

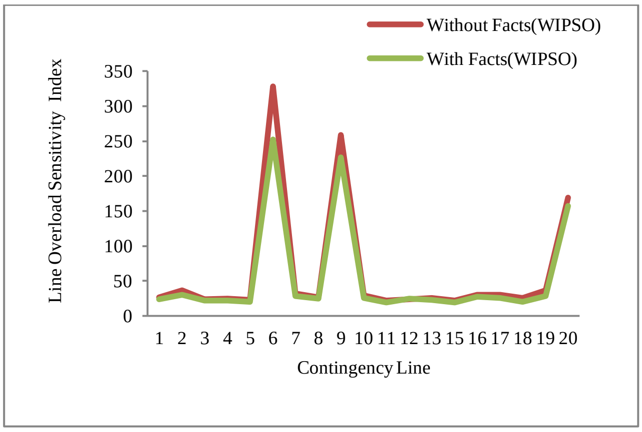

Figure 6: Minimization of the Line over load Sensitivity Index by WIPSO technique for IEEE 14 bus system under contingency line outage

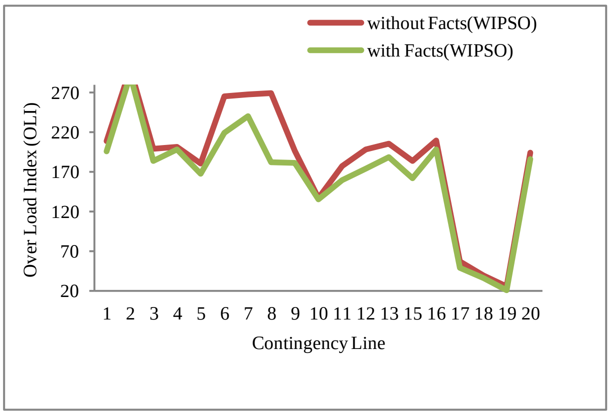

Figure7: Minimization of the Over Load Index by WIPSO technique for IEEE 14 bus system under contingency line outage

Figure.6 and 7 shows the Line Over load Sensitivity Index (LOSI) and Over Load Index (OLI) for IEEE 14- bus system under contingencies line outage. With and without placing Facts devices in this system to minimizing LOSI and OLI to achieved by applying WIPSO technique.

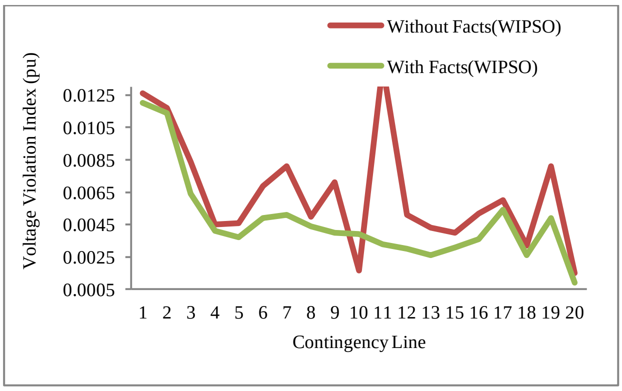

Figure 8: Improvement of the Voltage Violation Index by WIPSO technique for IEEE 14 bus system under contingency line outage

Figure. 8 shows the improvement of the Voltage Violation Index for sample system, with and without Facts devices under contingencies lines outage using WIPSO technique.

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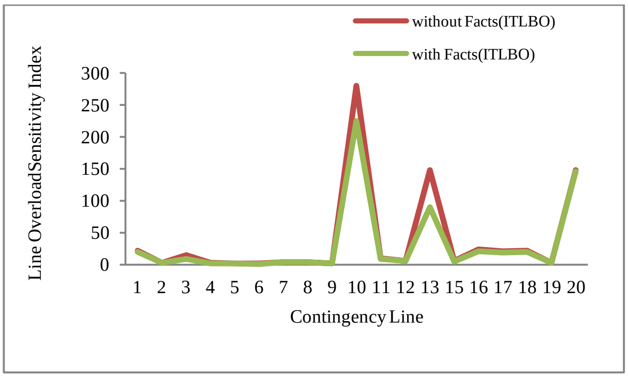

Figure 9: Minimization of the Line over load Sensitivity Index by ITLBO technique for IEEE 14 bus system under contingency line Outage

Figure.9 and 10 shows the Line Over load Sensitivity Index (LOSI) and Over Load Index (OLI) for IEEE 14- bus system under contingencies line outage. Without and with placing Facts devices to minimizing LOSI and OLI to achieved by applying ITLBO technique. Hence this enhances the security of the system

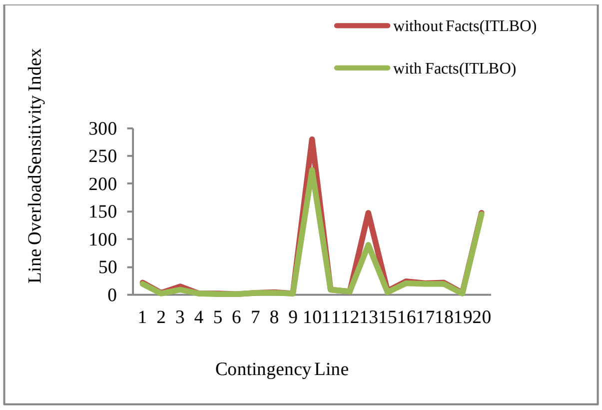

Figure 10: Minimization of the Over Load Index by ITLBO technique for IEEE 14 bus system under contingency line outage

Table 1: Line Overload Sensitivity Index, Over Load Index and Voltage Violation Index before and after using UPFC and SVC in the optimal locations obtained by WIPSO

Contingencies	Line overload sensitivity Index(LOSI)		Over Load Index (OLI)		Voltage Violation Index(VVI)(p.u)	
Branch	Before Placing FACTS Devices	After Placing FACTS Devices	Before Placing FACTS Devices	After Placing FACTS Devices	Before Placing FACTS Devices	After Placing FACTS Devices
1-2	26.46	24.16	209.31	195.71	0.0126	0.0120
1-5	36.48	30.19	299.82	291.89	0.0117	0.0114
2-3	23.89	22.09	199.14	184.21	0.0084	0.0064
2-4	24.87	22.30	201.96	198.22	0.0045	0.0041
2-5	23.18	19.72	180.57	167.74	0.0046	0.0037
3-4	328.13	252.46	265.06	219.70	0.0069	0.0049
4-5	31.86	28.57	267.47	240.19	0.0081	0.0051
4-7	26.89	24.31	209.40	181.93	0.0050	0.0044
4-9	258.68	226.49	197.16	181.31	0.0071	0.0040
5-6	29.68	25.57	137.42	135.08	0.0016	0.0039
6-11	21.95	19.65	177.59	159.24	0.0143	0.0033
6-12	23.59	245.51	198.73	174.02	0.0051	0.0030
6-13	25.23	23.31	205.85	188.87	0.0043	0.0026
7-9	21.78	19.03	184.22	162.26	0.0040	0.0031
9-10	29.85	27.17	209.97	198.67	0.0052	0.0036
9-14	30.55	25.42	56.782	49.095	0.0060	0.0054
10-11	25.32	19.78	39.457	35.883	0.0032	0.0026
12-13	36.97	28.56	25.876	20.372	0.0081	0.0049
13-14	168.89	157.68	194.20	186.63	0.0015	0.0009

It has been observed that there is a considerable reduction in line loadings and improvement in bus voltage profile after the placement of FACTS devices using WIPSO and ITLBO technique. To obtained results for IEEE 14 bus system are presented in table.1 shows the contingencies lines are indicate the 6, 9&20 and table.2 shows 10, 13 and 20 are identified as critical contingencies with very high LOSI values are carried out on IEEE 14 bus system. Even in the critical contingency condition, by placing the FACTS devices optimally, both overload index and voltage violation index are minimized.

Table 2: Line Overload Sensitivity Index, Over Load Index and Voltage Violation Index before and after using UPFC and SVC in the optimal location obtained by ITLBO

Contingencies	Line overload sensitivity Index(LOSI)		Over Load Index (OLI)		Voltage Violation Index(VVI)(p.u)	
Branch	Before Placing FACTS Devices	After Placing FACTS Devices	Before Placing FACTS Devices	After Placing FACTS Devices	Before Placing FACTS Devices	After Placing FACTS Devices
1-2	21.58	19.89	197.71	188.317	0.0095	0.0090
1-5	2.89	2.69	291.82	241.54	0.0084	0.0064
2-3	14.97	9.20	191.14	176.71	0.0045	0.0031
2-4	2.47	2.14	198.96	178.42	0.0040	0.0020
2-5	1.71	1.49	185.45	157.79	0.0039	0.0022
3-4	1.56	1.29	125.06	109.70	0.0061	0.0047
4-5	3.71	3.61	254.84	228.59	0.0068	0.0038
4-7	4.20	3.63	215.11	194.44	0.0041	0.0035
4-9	2.26	1.84	169.41	150.93	0.0077	0.0034
5-6	279.82	224.89	237.42	208.54	0.0008	0.0035
6-11	9.65	9.01	175.59	157.23	0.0012	0.0028
6-12	6.16	6.06	188.73	164.09	0.0084	0.0025
6-13	147.83	90.10	201.85	178.48	0.0045	0.0021
7-9	6.23	4.62	174.22	152.26	0.0037	0.0028
9-10	24.25	21.11	193.97	168.88	0.0043	0.0031
9-14	20.80	19.09	37.239	34.732	0.0051	0.0046
10-11	21.58	19.89	29.895	26.649	0.0063	0.0021
12-13	2.89	2.69	10.738	10.063	0.0043	0.0013
13-14	147.79	145.74	182.30	165.91	0.0013	0.0004

Table 3: SVC device placement and their rating for WIPSO and ITLBO

Contingencies	SVC placement (Mvar)			
	WIPSO		ITLBO	
	Base	Qsvc	Base	Qsvc
1-2	12	1.04	12	0.582
1-5	7	5.94	12	4.049
2-3	7	0.09	14	0.040
2-4	14	0.17	13	0.14
2-5	12	0.07	4	0.058
3-4	14	0.12	14	0.02
4-5	11	0.84	7	0.054
4-7	14	5.08	9	3.845
4-9	7	0.68	7	0.158

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5-6	12	0.27	10	0.160
6-11	7	0.25	13	0.19
6-12	14	7.05	4	6.283
6-13	4	0.28	12	0.20
7-9	5	8.74	5	6.741
9-10	4	0.09	4	0.001
9-14	8	5.94	7	2.07
10-11	14	4.58	7	1.074
12-13	16	3.68	12	2.94
13-14	10	3.87	18	2.548

From the Table.3 show the SVC placement and then the rating for both WIPSO and ITLBO techniques. On such a basis, the SVC usually installation the appropriate capacity to the selected bus bars of power system

Figure.11 shows the Voltage Violation Index of this system for contingencies line outage. With and Without Facts devices is to improve VVI simulations are carried out on IEEE 14 bus systems to apply ITLBO technique.

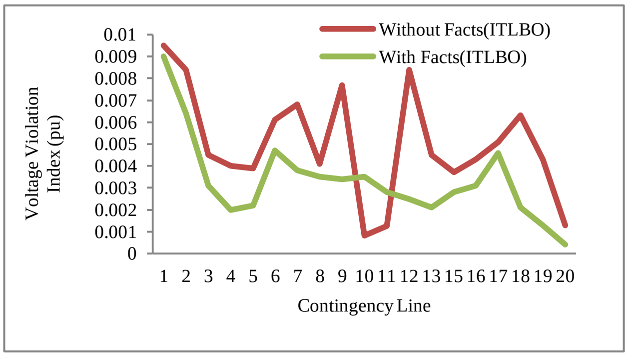

Figure 11: Improvement of the Voltage Violation Index by ITLBO technique for IEEE 14 bus system under contingency line outage

Table 4: WIPSO based on UPFC Placement and their rating

Contingencies	UPFC Placement					
Branch	Series voltage source(p.u)			Shunt voltage source(p.u)		
	Line No	V_{series}	V_{angle}	Bus No	V_{shunt}	V_{angle}
1-2	16	0.009	0.021	10	1.050	50.75
1-5	17	0.030	0.035	9	1.040	52.08
2-3	12	0.008	0.073	7	1.087	50.12
2-4	6	0.043	0.082	4	1.119	41.93
2-5	12	0.021	0.090	7	1.061	48.73
3-4	8	0.027	0.185	4	1.144	44.25
4-5	7	0.009	0.059	4	1.136	42.53
4-7	8	0.018	0.077	5	1.130	42.31
4-9	9	0.020	0.109	10	1.149	36.88
5-6	16	0.012	0.038	4	1.052	54.82
6-11	7	0.030	0.048	10	1.128	42.20
6-12	16	0.019	0.014	4	1.051	51.26
6-13	13	0.007	0.056	9	1.133	42.40
7-9	16	0.028	0.014	7	1.056	48.62
9-10	7	0.018	0.010	9	1.070	48.43
9-14	9	0.036	0.015	13	1.011	19.37
10-11	13	0.034	0.027	4	1.035	20.80
12-13	16	0.012	0.052	7	1.090	12.06
13-14	11	0.015	0.028	9	1.030	17.04

From Table.4 and 5 shows the optimal location and parameters setting of UPFC using WIPSO and ITLBO techniques respectively.

Table 5: ITLBO based on UPFC Placement and their rating

Contingencies	UPFC Placement					
Branch	Series voltage source (p.u)			Shunt voltage source (p.u)		
	Line No	V_{series}	V_{angle}	Bus No	V_{shunt}	V_{angle}
1-2	15	0.001	0.016	9	1.059	49.13
1-5	14	0.024	0.033	7	1.038	21.82
2-3	7	0.004	0.053	7	1.033	17.82
2-4	14	0.024	0.030	4	1.110	16.59
2-5	8	0.017	0.089	4	1.088	14.05
3-4	18	0.019	0.009	12	1.012	17.25
4-5	19	0.042	0.034	13	1.019	18.05
4-7	7	0.014	0.028	4	1.069	12.28
4-9	8	0.013	0.077	4	1.078	12.44
5-6	19	0.036	0.028	13	1.025	32.96
6-11	14	0.028	0.035	7	1.034	15.70
6-12	10	0.010	0.104	5	1.075	10.77
6-13	17	0.001	0.016	10	1.029	18.11
7-9	15	0.007	0.005	9	1.040	21.26
9-10	17	0.001	0.020	10	1.010	18.93
9-14	19	0.046	0.045	13	1.011	18.37
10-11	17	0.024	0.017	9	1.031	16.86
12-13	7	0.010	0.032	4	1.085	11.96
13-14	15	0.025	0.034	7	1.025	15.00

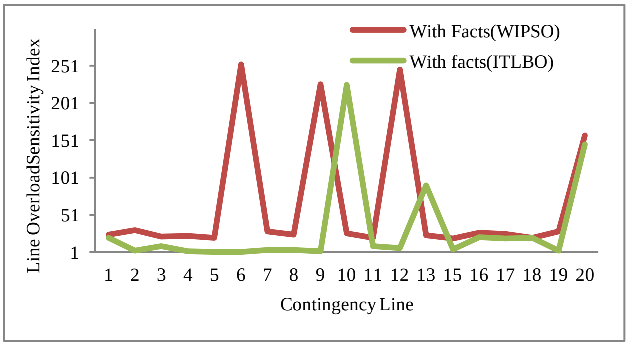

Figure 12: Line Over load Sensitivity Index using WIPSO and ITLBO algorithms of IEEE 14 bus system with FACTS devices

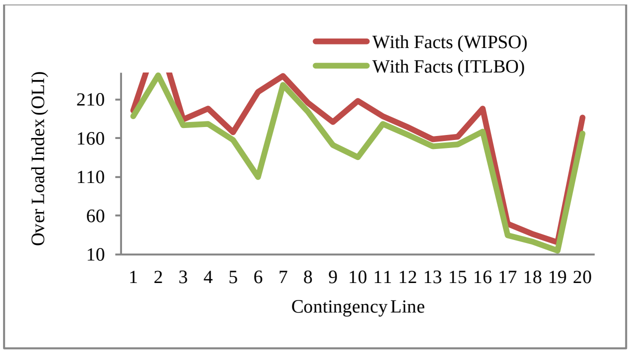

Figure 13: Over Load Index using WIPSO and ITLBO algorithms of IEEE 14 bus system with FACTS devices

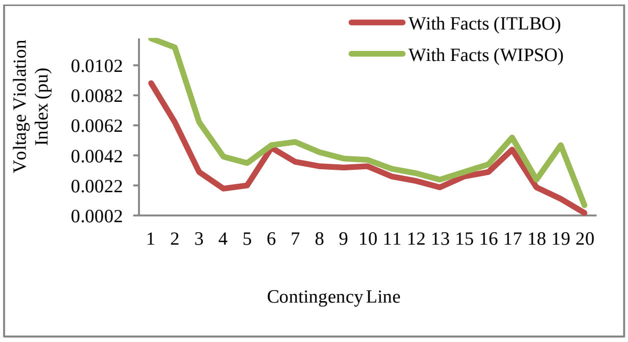

Figure 14: Voltage Violation Index using WIPSO and ITLBO algorithms of IEEE 14 bus system with FACTS devices

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The comparison of contingency line outage to minimizing of LOSI, OLI and VVI are shown in Figure.12,13 &14 respectively. From the Figures it is clearly shows the proposed method give better result.

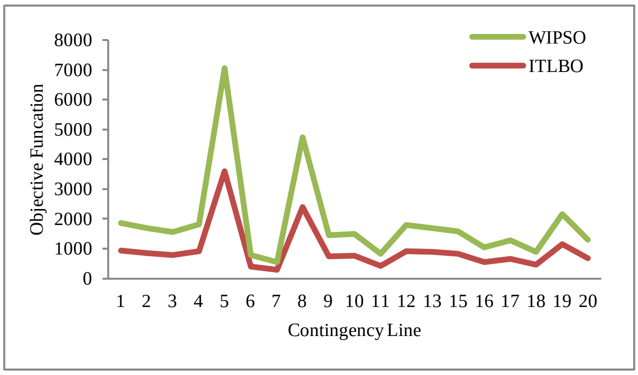

Figure 15: Objective function values after Placement of FACTS devices using WIPSO and ITLBO techniques

The comparison of minimizing the objective function values are achieved by both WIPSO and ITLBO techniques under single contingency and graphical represent are shown in Figure.15

VII. CONCLUSION

This paper present the application of WIPSO and ITLBO techniques to find the optimal location of UPFC and SVC devices for getting enhancing the security of power systems under single contingency. In voltage source based power injection model of FACTS devices, NR load flow incorporation procedures is to determination of the most severe contingency were performed based on the Line Over load Sensitivity Index (LOSI) selection and ranking process. When compared to ITLBO had better accuracy than WIPSO. ITLBO has been successfully applied to the over load index and voltage violation index to the minimization of the power system security is considered as the optimization criterion. The proposed ITLBO algorithm has been tested on standard IEEE 14 bus system through the FACTS devices. The result shows that improving the security of power systems under single line contingency.

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