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OPTIMAL SVC ALLOCATION IN POWER SYSTEMS USING TEACHING LEARNING BASED OPTIMIZATION

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ABSTRACT:
Electrical power losses are considered as important factor for the operation of power system. There are various methods which are used for reducing real power losses in transmission system. These methods help to reduce real power losses and improve the voltage profile of the system.
The proposed method is used for the optimal location and sizing of FACTS device such as SVC using Teaching and Learning Based algorithm. The main objective is to minimize real power losses while keeping the voltage profiles in the network within specified limits. The proposed technique is tested to IEEE 14 bus and 30 bus systems.
KEYWORDS: --- SVC, TLBO,

1. Introduction

Power generation, transmission, and use are all part of the electric power system. To meet the increasing demand for electrical energy, the power system sector is constantly confronted with significant problems related to the design of future power systems. An increasing demand for energy is putting a strain on technology that is decades old [2]. Fast and reliable optimization strategies that can simultaneously handle both security and economic challenges are needed to power system operation and control [2].
Operation and planning of power systems face a major challenge in solving the Optimal Power Flow (OPF) problem, which was suggested by Carpentier in the early 1960s. It can be separated into two sub problems: real power dispatch (RPD) and optimal reactive power dispatch (ORPD). There has been a lot of interest in ORPD due to improvements in power system efficiency and security [8]. Control variables that minimize a particular objective function while meeting specific physical and operational restrictions are a primary goal of optimal reactive power dispatch in the power system.
Automatically generated reactive power has a low impact on total generation costs because it ensures voltage control within specified limits and maintains the power system in operation and balanced condition, thus reducing transmission losses as much as possible. Reactive power is generated at a very low cost to the power industry. Complex, nonlinear, highly constrained non convex optimization issue due to continuous and integer/discrete control variables in ORPD. Switching shunt capacitor banks and transformer tap settings are examples of integer control variables.
The optimal reactive power dispatch problem has been solved using a variety of standard optimization techniques. The gradient method, interior point method, quadratic programming, linear programming, and non-linear programming are all examples of these techniques. It is impossible to solve the ORPD problem using typical approaches since it is non-linear and non-convex. These methods may not be able to find the global optimum, as they use derivatives and gradients. In addition, the tap altering transformer's discrete variables cannot be directly incorporated into the algorithm. Large computations, long execution times, and a lack of adaptability in real-world systems are all drawbacks of these approaches. There are numerous shortcomings of conventional optimization approaches that must be overcome in order for new algorithms to be developed.
The use of nature-inspired optimization methods such as genetic algorithm, particle swarm optimization, simulation annealing, Ant colony optimization, bacterial foraging methodology and differential evolution to solve ORPD problems has recently been the focus of numerous studies.

An optimization technique that has recently been developed is the teaching-learning-based optimization TLBO, which is a population-based optimization technique inspired by the way students learn in a classroom.

1.2 Research Motivation

Deregulation of the electricity market has made it imperative for the power system to keep the voltages on the load bus within the acceptable range for customer satisfaction. If this is not done correctly, the active power transmission line losses can be enormous. Voltage collapses and power outages result from these transmission losses. Power transmission losses must be minimised to ensure dependable and cost-effective functioning of the power grid. Active power transmission losses must be minimized and the voltage profile of the overall power system maintained by modeling it as an ORPD issue with the active power transmission loss as the goal function.

1.3 Objective

The following are the paper's primary goals:

- To investigate the formulation of ORPD, its equality and inequality requirements, and the control and state variables.
- To acquaint yourself with the TLBO method.
- Implementation and comparison of the suggested algorithm with a population-based algorithm on the IEEE 30-bus test case.
- The proposed TLBO algorithm's optimal values should be implemented in a real-world context.

2. STATIC VAR COMPENSATOR:

Static Var compensator (SVC) is a type of FACTS(flexible AC transmission system) device, used for shunt compensation to maintain bus voltage magnitude. SVC regulates bus voltage to compensate continuously the change of reactive power loading. The most popular configuration of this type of shunt-connected device is a combination of fixed capacitor C and a thyristor-controlled reactor (TCR) as shown in Figure 1. The thyristor valves are fired symmetrically in an angle α, ranging from 90° to 180°.

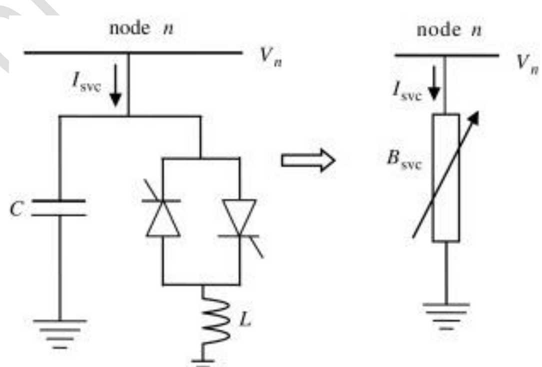

Figure2.1: SVC circuit diagram

2.1 SVC device structure:

SVC is a variable impedance device consisting of several components: thyristor-controlled reactor (TCR) and thyristor switched capacitor (TSC). Besides, there are variants with fixed capacitors (FC—fixed capacitor), which are characterized by step regulation. Thyristor-controlled reactors serve to absorb reactive

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power if excess occurs, while thyristor-controlled capacitors or fixed capacitors produce reactive power when the need arises. The control of SVC is based on silicon-controlled rectifier thyristors. The basic structure of an SVC device consisting of TCR and TSC is shown in Fig.1.2

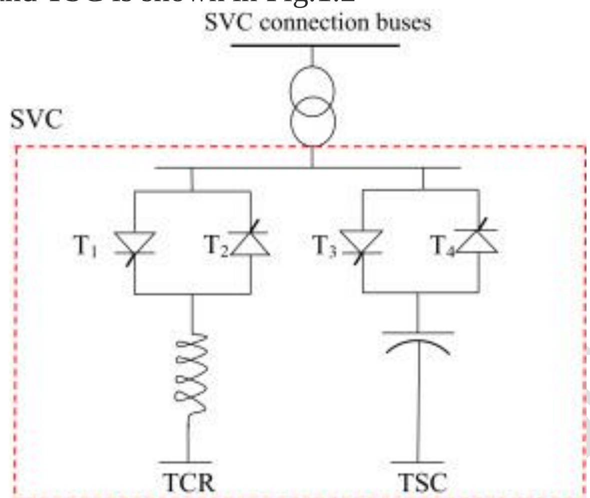

Figure 2.2: view of SVC structure

The existence of a connection transformer is very important because SVC contains sensitive semiconductor components. To meet the requirement to inject basic frequency reactive power into the system, a filter must be added. The structure of such a system is shown in Fig. 1.3 The installation of filters prevents the 'penetration' of higher harmonics into the power system. SVCs generally contain filters to remove the third, fifth, and seventh harmonics, while other higher-order harmonics are neglected due to the very small influence on the voltage waveform or current at the hub to which SVCs are connected.

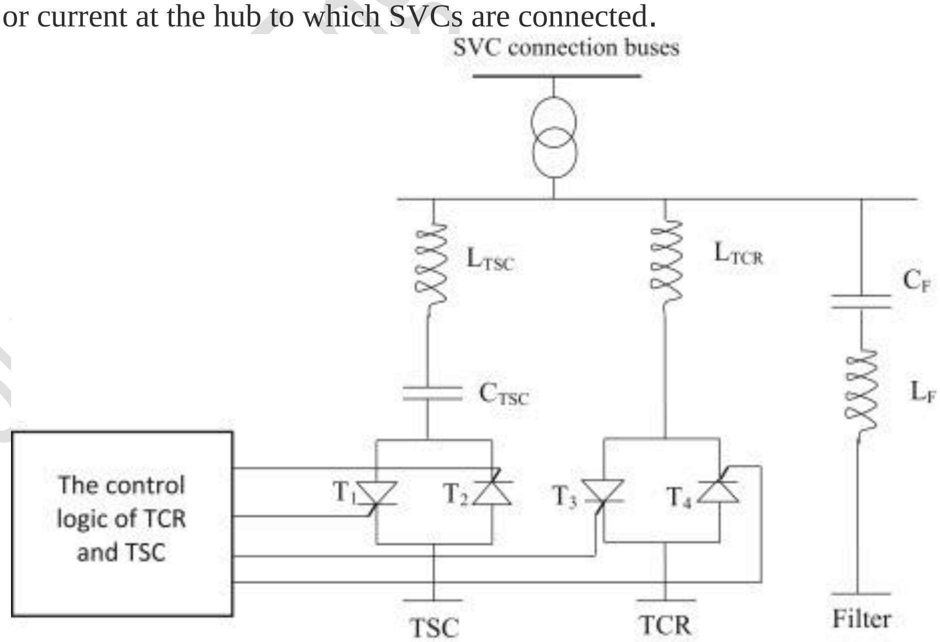

Fig 2.3 view of SVC structure with filter

3. TEACHING LEARNING BEST OPTIMIZATION ALGORITHM

The Teaching Learning Best Optimization (TLBO) algorithm is a new population-based algorithm invented by Rao et al. The algorithm illustrates the teaching abilities of teachers and learners in the classroom. In this method population is a number of students (learners) in a classroom and design variables are the topics present to the students (learners). The results of students (learners) can be compared with fitness values, and the rate of the objective function constitute the knowledge of a specific student. Teacher is observed as highly learned person, so the best solution is parallel to teacher in the TLBO. There are 2 parts of process for TLBO, 1st part consist of 'Teacher phase' and the second part consist of the 'Learner phase' means learning through the interaction between learners.

We are used MATLAB for simulation and analyzed the result using TLBO algorithm. The TLBO algorithm explained here is shown in the flow chart of figure 1

Step 1 : Number of students in the initial class (N), number of generations (G), number of topics provided, the number and the number of units placed in the distribution system (D) and the limits of design variables The optimization complication is defined as: Minimize , is a function of objective, X design variable.

Step 2 : create a random population accordant to the number of students in the class (N) and number of subjects provided (D). the mathematical expression for this population is

$$V = \begin{bmatrix} X_{1,1} & X_{1,2} & . & . & X_{1,D} \\ X_{2,1} & X_{2,2} & . & . & X_{2,D} \\ . & . & . & . & . \\ . & . & . & . & . \\ X_{N,1} & X_{N,2} & . & . & X_{N,D} \end{bmatrix}$$

Where $X_{i,j}$ is the initial grade of the j^{th} subject of the i^{th} student

Step 3: Assess the mean grade of each course given in the class. the average grade of the j^{th} subject at generation g is explained as

$$M_g = \text{mean}\,(X_{1,j}, X_{2,j}, \ldots\ldots, X_{i,j}) \qquad (2)$$

Step 4 : From the grade value generated classify the students from finest to worst. The best answer is observed as teacher and it is given as:

FACTS equipment are power electronic based devices and these devices is installed in the AC transmission line. The important features of these devices are they provide increase in power transfercapabi lity, stability terminated series or shunt compensation. Here we are using SVC and STATCOM. The main intension of using SVC is to manage the voltage level at a particular bus. Same as another device STATCOM is used during fault condition STATCOM own the capability to supply high capacitive reactive power.

$$X_{teacher} = X|_{f(X)=min} \quad (3)$$

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Step 5 : Alter the grade point of each course of each student. Altered grade point of the j^{th}course of the i^{th}student is given as:

$$X_{new^g(i)} = X_i^g + rand \times (X^g_{Teacher} (4) T_F M^g)$$

Where r_1 , r_2 are random numbers between[0,1].

Step6: Each learner enhance grade point of every topic by the mutual interaction beside the

$$X_{new^g(i)} = X_i^g + r1 \times \left[X^g_{Teacher} - (round\,(1 + r_2) \times M^g)\right]$$

learner, The grade point of thej^{th}learner is changed by

$$X_{new^g\,(i)} = \begin{Bmatrix} X_i^g + rand \times (X_i^g - X_r^g)\ if\ (X_i^g < X_r^g) \\ X_i^g + rand \times (X_r^g - X_i^g) \qquad otherwise \end{Bmatrix}$$

3.1 TLBO ALGORITHM:

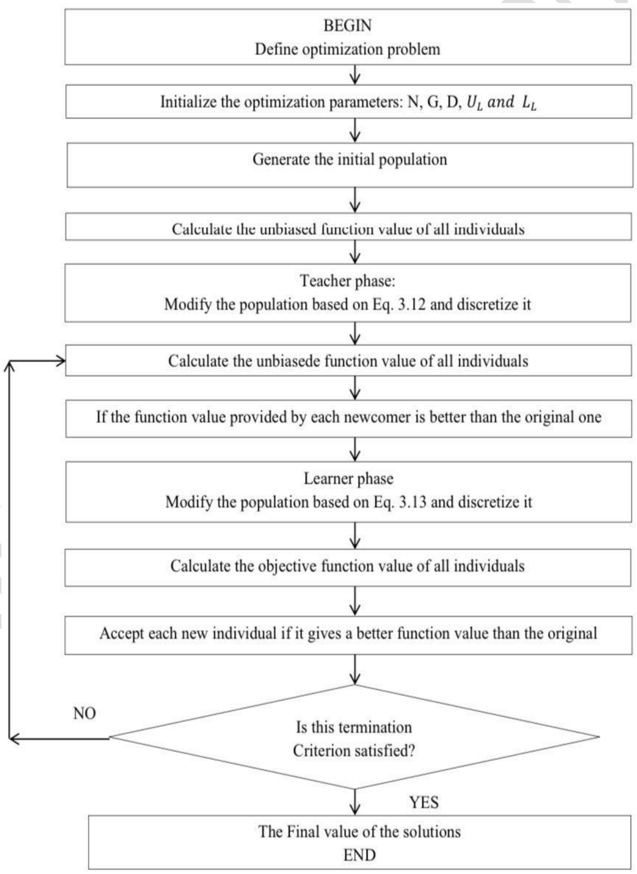

Figure.3.1**:** Flowchart diagram of TLBO algorithm

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4. SIMULATION RESULTS AND ANALYSIS:

4.1 IEEE-30 BUS SYSTEM:

The proposed TLBO technique was validated using an IEEE 30-bus test system. Figure 3 depicts the single-line diagram for the IEEE 30-bus test case. All of the IEEE 30-bus test system's components can be found here: 6 generator buses, 21 load buses, 41 transmission lines, 4 transformers with off-nominal tap ratios at the branches (6-9, 11-13). buses 6-10, 4-12, 27-28) are equipped with two shunt VAR compensators (10 and 24). A total of 12 optimal control variables are utilised for this ORPD(optimal reactive power dispatch)problem.

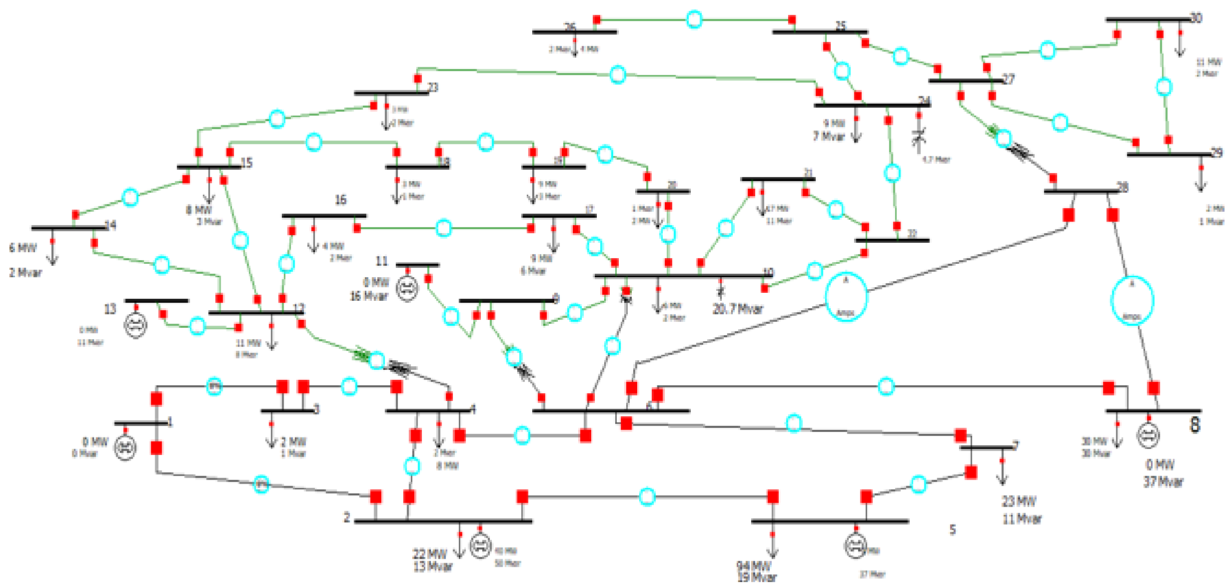

Fig 4.1 single line diagram of IEEE 30-bus test system

The variable limits given in table. 1 were used as a system constraints to solve active power transmission loss objective function .

Control variables	**quantity**	**maximum**	**minimum**
GEN voltage	6	**0.95**	**1.10**
Transformer tap Ratio T	**4**	**0.90**	**1.10**
Shunt VAR compensator Qc	**2**	**0.00**	**0.20**

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Table.1 IEEE 30-bus system control variable limits

The average convergence curve for the 30 bus test system TLBO algorithm power loss is shown in figure4.2 The TLBO algorithm converged from 20-25iterations.

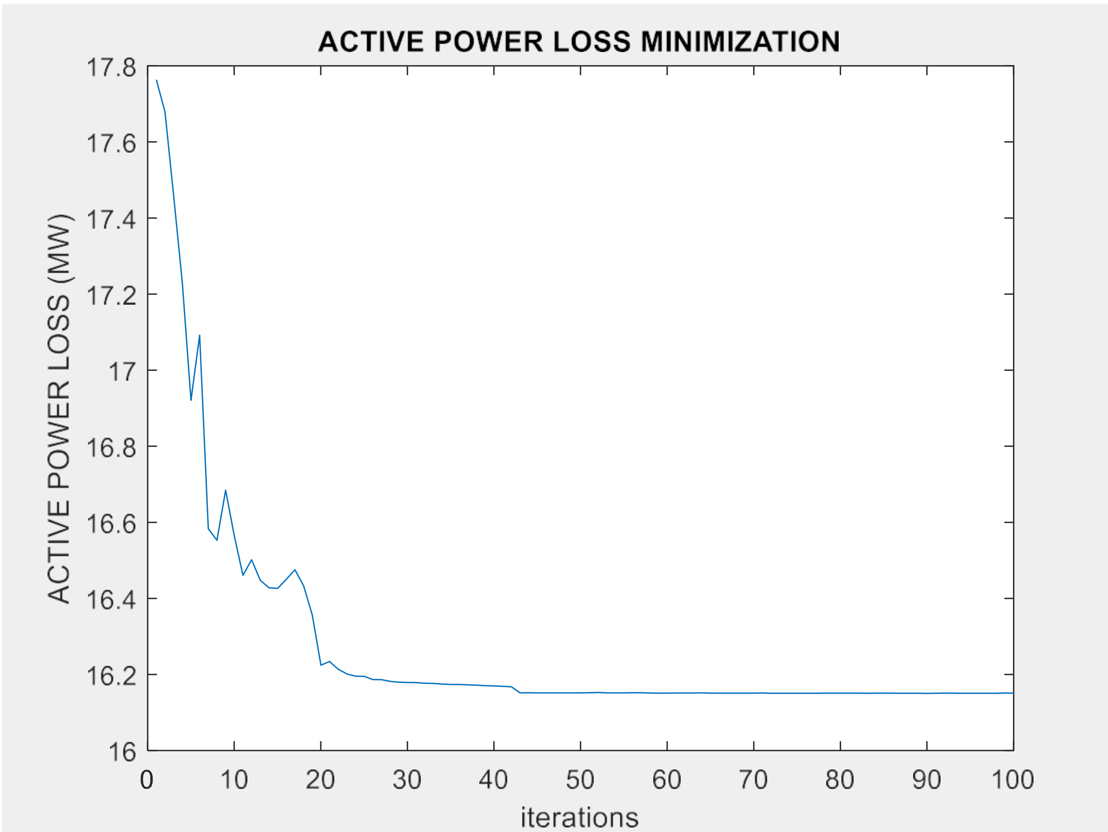

Figure 4.2: Convergence curve for 30 bus test system using TLBO

Control variables	**Base case**	**TLBO (First phase)**	**TLBO (Final phase)**
V_{G1}	1.060	1.091	1.100
V_{G2}	1.045	1.074	1.0848
V_{G5}	1.010	1.010	1.0538

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V_{G8}	1.010	1.035	1.059
V_{G11}	1.082	0.971	1.100
V_{G13}	1.071	1.099	1.100
T_{6-9}	0.980	0.9960	1.0699
T_{6-10}	0.970	1.0437	0.90
T_{4-12}	0.930	1.0460	1.0495
T_{27-28}	0.970	0.9435	0.9784
Q_{C10}	0.19	0.1816	0.0277
Q_{C24}	0.043	0.0200	0.20
P_loss	**17.557**	**17.207**	**16.1504**

Table 2: Control variables for various phases of optimization for IEEE 30-bus test system

4.1 Power flow in SVC with TLBO

Line		Line flow		Line		Line flow		Line losses	
From	To	MW	Mvar	From	To	MW	Mvar	MW	Mvar
1	2	118.1446	−15.7977	2	1	−115.9046	16.1876	2.2401	0.3899
1	3	58.9123	−1.3724	3	1	−57.6153	1.8452	1.2969	0.4728
2	4	34.116	−3.0655	4	2	−33.555	0.4798	0.561	−2.5856
2	5	63.4673	0.1879	5	2	−61.8579	1.7447	1.6094	1.9326
2	6	45.3184	−3.837	6	2	−44.3088	2.5511	1.0096	−1.2859
3	4	55.2153	−3.0452	4	3	−54.8686	3.0689	0.3467	0.0237
4	6	49.7658	−4.1591	6	4	−49.5083	4.0228	0.2574	−0.1363
4	12	30.6313	−7.2253	12	4	−30.6313	9.4285	0	2.2032
5	7	−11.0378	6.0844	7	5	11.1089	−8.198	0.0711	−2.1135
6	7	34.1836	1.6218	7	6	−33.9089	−2.702	0.2747	−1.0802
6	8	11.3603	−5.088	8	6	−11.3445	4.1144	0.0158	−0.9736
6	9	18.6798	−2.2759	9	6	−18.6798	2.9206	0	0.6447
6	10	12.9337	−3.2421	10	6	−12.9337	4.1073	0	0.8652
6	28	16.0227	−0.213	28	6	−15.9847	−1.1336	0.038	−1.3466
8	28	2.425	−1.4359	28	8	−2.4211	−3.4315	0.0038	−4.8674
9	11	−11.8844	−13.3475	11	9	11.8844	13.9235	0	0.576
9	10	29.7656	−13.1558	10	9	−29.7656	14.166	0	1.0101
10	20	9.3463	−0.2655	20	10	−9.2771	0.4199	0.0692	0.1544
10	17	5.7452	1.9148	17	10	−5.7351	−1.8886	0.01	0.0262
10	21	15.7107	4.4805	21	10	−15.6322	−4.3115	0.0785	0.1689
10	22	7.5314	1.7869	22	10	−7.4945	−1.711	0.0368	0.0759
12	13	−12	−5.7784	13	12	12	5.9865	0	0.2081
12	14	7.4429	0.4532	14	12	−7.3856	−0.334	0.0573	0.1192
12	15	17.6056	−1.0625	15	12	−17.4331	1.4024	0.1725	0.3399
12	16	6.8101	0.8088	16	12	−6.7728	−0.7305	0.0372	0.0783
14	15	1.1211	−1.3069	15	14	−1.1155	1.3119	0.0056	0.005
15	18	5.6764	0.5257	18	15	−5.6468	−0.4652	0.0296	0.0605
15	23	4.7414	−0.6974	23	15	−4.7218	0.7369	0.0196	0.0395
16	17	3.2731	−1.0693	17	16	−3.2648	1.0886	0.0083	0.0194
18	19	2.4463	−0.4349	19	18	−2.4429	0.4418	0.0034	0.0069
19	20	−7.0575	−3.8419	20	19	7.0765	3.8799	0.019	0.0379
21	22	−1.8682	−1.8886	22	21	1.8689	1.89	0.0007	0.0014
22	24	5.6237	−0.181	24	22	−5.5925	0.2295	0.0312	0.0486
23	24	1.5212	1.4817	24	23	−1.5161	−1.4713	0.0051	0.0104
24	25	−1.589	−0.4559	25	24	1.5935	0.4637	0.0045	0.0078
25	26	3.5401	2.3564	26	25	−3.5006	−2.2973	0.0395	0.059
25	27	−5.1334	−2.8229	27	25	5.1656	2.8844	0.0322	0.0615
27	28	−17.7746	7.009	28	27	17.7746	−5.7913	0	1.2177
27	29	6.185	−0.3413	29	27	−6.1139	0.4755	0.071	0.1342
27	30	7.0548	0.8528	30	27	−6.9186	−0.5965	0.1362	0.2564
29	30	3.7139	1.3646	30	29	−3.6816	−1.3036	0.0323	0.061

Table.3: power flow in SVC with TLBO

5 . CONCLUSION:

An evaluation and testing of the TLBO algorithm on IEEE 30-bus test systems was performed in order to resolve the ORPD. When compared to existing metaheuristic algorithms and evaluated with Power World, simulation results show that the technique is robust and efficient. As shown by the simulations, the active power transmission line losses were reduced using TLBO approach from 17.557MW to 16.1504MW (about 8.01 percent loss reduction). It is clear from the simulation results that using TLBO in the context of ORPD is an effective way to predict optimal values, but the Power World solution offers a more realistic approach to solving the ORPD problem by highlighting areas for improvement and transmission lines that require overload correction while keeping control variables within their constraint limits. For the identical input parameters as in the TLBO method, the Power World simulation reveals a reduction in active power transmission loss from 18.13MW to 16.27MW (approximately 10.26% loss reduction). Correcting the ORPD problem yielded a better result: a true power loss of 7.30MW.

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