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Article

Optimal Location of Facts Devices in IEEE 14 Bus System Using Ga and Deiwo

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Abstract: FACTS devices provide significance to enhance the functioning of both static and dynamic power systems. The type, size, and location of FACTS devices determine how well they achieve the goals of enhancing voltage stability, loadability, and loss minimization simultaneously. The aim of the function in this study includes voltage stability, line loadings, and loss minimization, which are expected to obtain the most benefits from their installation and other weights allocated to them. It has been determined how installing TCSC, and SVC will improve loadability under situations of continuously increasing load. In this study, a novel optimization technique known as differential evolution invasive weed optimization (DEIWO) is utilized to locate the optimal location for FACTS devices within the IEEE 14 bus system by considering valve point effects. DEIWO was a recently developed, dominant, and simple metaheuristic algorithm for genuine parameter optimization. DEIWO was inspired by the natural process of weed colonization and dissemination, and it is highly effective at addressing broad multi-dimensional, linear and nonlinear optimization problems. The proposed method was implemented in the IEEE 14 bus testing system. Different methods from the research papers have been used to compare and analyze the results. The results demonstrate the DEIWO algorithm's capability and show how it may be used in practice to locate FACTS devices in deregulated electricity networks in the most advantageous place. A comparison of the proposed process to existing algorithms found in the literature and implemented using traditional techniques reveals that it performs better in terms of precision and convergence

Keywords: genetic algorithm; voltage sensitivity indices; loss sensitivity indices; voltage profiles; reactive power; active power; differential evolution invasive weed optimization

1. Introduction

Facts controllers can control transmission system parameters like series impedance, shunt impedance, current, voltage, phase angle, and oscillation damping at frequencies below the rated frequency, creating these opportunities. These limits cannot be solved mechanically while retaining the requisite system dependability without reducing usable transmission capacity. By adding flexibility, Facts controllers make it possible for a line to carry power closer to its thermal value. Automatic switching must be augmented with rapid-response power electronics. It's important to note that Facts is a supporting technology, not a direct replacement for mechanical. The Facts technology consists of several high-performance controllers that can be employed independently to control system characteristics [1]. The specific restrictions of a given transmission line or corridor can be overcome by a well-designed Facts controller.

All Facts Controllers are implementations of the same fundamental technology, allowing their products to eventually benefit from scale technologies. The thyristor or high-power transistor is a key component for numerous high-power electronic Controllers, just as the transistor is necessary for various microelectronic chips The Power Electronics Controllers that are now a part of the Facts framework were developed long before the framework's release to the technical community. The

Static Var Compensator (SVC) is one of the most used methods for regulating voltage because of its shunt connection [2]. The first series-connected controller uses a capacitor impedance control strategy and is low-power. It showed that series capacitor correction has no limits when an active controller is used. Before SVCs, there were powerful gapless metal oxide arrestors for limiting dynamic overvoltage and two variations of static saturable reactors for limiting overvoltage [3]. Phase shifters and solid-state tap changers have both been the subject of research. But what makes Facts technology special is that the umbrella concept showed how power electronics technology could be used to greatly improve the value of power systems. This opened the door for a lot of new and advanced ideas to make this a reality. Future power systems around the world will be rethought and re-engineered thanks to Facts technology, which has also given new generations of engineers a boost and excitement [4].

1.1. Voltage stability

Problems with voltage control and stability are not new to the electric utility industry, but they are now receiving special consideration from all power system analysts and researchers. Power system networks are becoming more vulnerable to voltage instability due to their growth and economic and environmental constraints. In the past few years, unstable power has caused major network failures in New York, Florida, France, Belgium, Sweden, Japan, and India. Understanding, assessing, and creating ever-newer techniques to deal with the threat of voltage instability/collapse is the responsibility of research If the voltages near the loads in a power system return to their pre-disturbance equilibrium values after being perturbed to a certain level, then the system is said to be voltage stable at that condition of operation. When electrical grids are overloaded or their transmission capacity is diminished as a result of disruptions, voltage instability becomes a serious issue in systems without sufficient reactive power support. The problem of maintaining a consistent voltage affects the entire power system, even though it typically has a greater impact on just one of the power system's most essential components [5].

1.2. Voltage collapse

After voltage instability, a power system will fail if the post-disturbance equilibrium voltages near loads are lower than the permitted limits. The breakdown of electricity might be blackout or incomplete [6]. Security of voltage refers to a system's capacity to continue functioning normally in the face of credible emergencies or increases in load. Voltage stability is a dynamic process, yet static analysis methods based on power flow are commonly used since they are fast and approximative.

1.3. Reasons for voltage instability

The following factors contribute to voltage instability, which may also cause voltage collapse.

1. Transmission line congestion has increased.
2. Reactive power limitations
3. Sudden failure in generating units
4. Dynamic operation of the on-load tap changer (OLTC)
5. Characteristics of load.

2. Countermeasures for instability of voltage

There are numerous consequences associated with voltage instability, including dynamic loads, reactive power production, load tap changer transformers, and transmission system power transfer capability[7]. The majority of these variables have a considerable impact on the generation, use, and transmission of reactive electricity.

1. Synchronous Condensers
2. Transformer tap changing settings
3. Phase shifters
4. Under voltage load shedding

5. Incorporation of FACTS devices in the network

These are the countermeasures for voltage instability/collapse. In this, some have their disadvantages.

2.1. Transformers tap change setting

Frequently, power applications in power systems call for the need to control the transformer's voltage. It might be needed in an application.

1. To provide a specific voltage to the Load
2. To compensate for the decreases in voltage caused by the Load

Transformers are necessary components of a power system because of their extra role in the regulation of active and reactive power flows. The voltage is controlled by adjusting the turn ratio. The winding has been designed with taps in it so that this can be performed. Because the volts per turn available in large transformers is extremely considerable, even one turn on the LV side produces a significant percentage change in voltage [8]. In addition, the LV currents are frequently too big to remove the tapping from the windings. The inner winding, known as LV winding, in core-type transformers makes it more challenging to remove the taps. Therefore, the HV winding is equipped with fixtures for any intended application of tapping. Tap changing refers to the process of providing taps to control voltage. Sometimes, a different voltage is injected in series with the line to raise or lower the voltage in a power system. This combination is sometimes referred to as buck-boost. In addition to that, the magnitude phase of the injected voltage might shift as it comes from different sources in power systems.

2.2. Synchronous condensers

By compensating for reactive power and adding to the network's short-circuit power capacity, synchronous condensers are an essential component in maintaining stable network voltage. Synchronous condensers are essentially synchronous generators that do not require an external prime mover to function. Power factor correction is accomplished by controlling the excitation current, which allows for reactive power generation and consumption. One of the most significant advantages of a synchronous condenser is the contribution it makes to the total short circuit capacity of the network node in which it is positioned. This increases the possibility that network-connected devices will be able to "ride through" network breakdown situations. The operation of a synchronous condenser is also ideally suited to take place during times of overload duty that are either shorter or longer in duration. By boosting the network's inertia, synchronous condensers help keep the power system's voltage stable during long-term voltage dips[9]. Consequently, they can be used as VAR compensating devices in situations where voltage instability must be avoided at all costs. The drawbacks of synchronous condensers are that they are expensive to run, need upkeep on rotating machinery, and have a slow reaction speed when something goes poorly.

2.3. Phase shifter

The transmission line can change the phase of an electromagnetic wave of a specific frequency with the help of a device called a phase shifter. The disadvantages of the two strategies described above are listed below.

1. These consequences are not responding quickly and have several constraints.
2. These are not providing proper results for voltage profile management.

2.4. Under voltage load shedding

Voltage load-shedding strategies may be required in unanticipated or exceptional circumstances. This is comparable to under-frequency load shedding, a procedure used frequently to handle extreme conditions brought on by inadequate generation capacity. The least expensive method of avoiding widespread power collapse is strategic load shedding[10]. Distinguishing between failures, transient voltage dips, and low voltage circumstances causing voltage collapse should be a goal of load-shedding programs.

2.5. Incorporation of facts devices in the network

FACTS devices are offered for quick reaction and for studying voltage stability in power systems. In addition, FACTS devices utilize sophisticated power electronic devices that provide flexibility and controllability for regulating active and reactive power [11]. Several studies have been conducted to examine how FACTS controllers affect the system's ability to improve static performance. System dependability, improved system stability, control over power flow, and decreased losses are all advantages of FACTS. For the FACTS devices to provide the benefits listed above, network installation must be done correctly. The following elements need to be taken into account when determining the best location and working range for various FACTS controllers[12,15]. They are active power loss reduction, improved stability, and taking the price of FACTS devices into account.

3. Line stability analysis

The Voltage Stability margins in a power system can be increased by using these FACTS devices in addition to compensating reactive power. Evaluation of stability for TCSC and SVC installation. Line stability is utilized to place TCSC, while voltage stability analysis is used to place SVC.

This analysis indicates that the line of test systems is prone to instability. The lines are judged based on the stability index. When this index of a particular sequence approaches the unity value, it is regarded as instability or has a chance of system collapse shortly[13]. A zero value of the line stability index indicates a stable system

where

$$L_{ij} = \frac{4XQ_j}{V_i^2 \sin(\theta - \delta)^2} \tag{1}$$

Table 1. Parameters definitions.

L_{ij}	Line stability index
$\theta - \delta$	The angle between sending and receiving end voltages
Q_j	Reactive power injection at receiving node j
V_i	The voltage at sending node 'i'
X	Reactance value between line i and j

3.1. Voltage stability index

In power systems, the stability indices are used to determine the overall level of stability of each bus as well as the bus that has the lowest level of stability. In an IEEE 14-bus network, utilize the Voltage Stability Index to calculate the stability indices of all load buses [14]. ThNewton-RaphsonRaphson load flow findings are used to calculate the voltage stability index (V index) for load buses under specific system operating conditions.

$$V_j = \left|1 - \sum_{i=1}^{g} F_{ij} \frac{V_i}{V_j}\right| \tag{2}$$

where
'j': Indicates load buses
'i': indicates generator buses

$$F_{ij} = [Y_{LL}]^{-1}[Y_{LG}] \tag{3}$$

4. Differential evolution invasive weed optimization (deiwo) algorithm

The beginning value and higher accuracy of errors can affect the classic numerical approach for solving nonlinear equations. This study introduces the differential evolution (DE) algorithm, a heuristic global search technique, and applies it to the problem of optimizing the spread of invasive weeds DEIWO[16]. In the iterative process, the invasive weed optimization algorithm's global exploration capability offers a useful search area for differential evolution, and at the same time, the differential evolution algorithm's heuristic searchability provides a solid direction for invasive weed optimization[17,18]. The differential evolution invasive weed optimization (DEIWO) algorithm was tested on a variety of common nonlinear equations and a circle packing problem; the results demonstrate that it is accurate and converges quickly, making it a practical and effective tool for addressing nonlinear systems of equations[19].In terms of convergence speed and ratio, nonconvex nonlinear equations are particularly difficult for nonlinear equations algorithms to solve efficiently. The Newton-Raphson, Quasi-Newton, and homotopy methods have traditionally been used to solve nonlinear equations.

The present work introduces a novel hybrid algorithm based on the population diversity of IWO. To deal with nonlinear systems of equations, consider the differential evolution (DE) algorithm. The combined approach achieves a greater level of optimization accuracy and a faster rate of convergence as a result of the population diversity, which improves the algorithm's capacity for global searching which increases its capacity for local extractive activities. [20,21] Both of these factors contribute to the hybrid algorithm. The suggested approach's performance has been evaluated for several recognized standard problems in kinematics, chemistry, combustion, and medicine. Mathematical observations show that the suggested method is efficient and flexible to solve large-scale equation solutions[22].

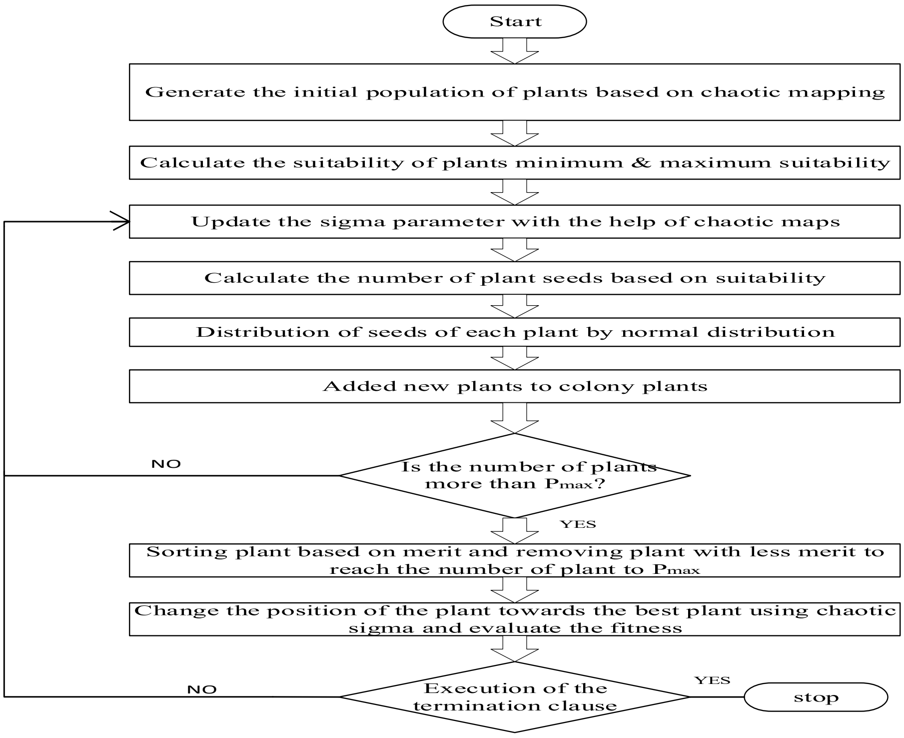

Figure 1. Flow chart for DEIWO.

Step 1 (Create a population). A set of potential starting points is randomly dispersed across the search space of dimension.

Step 2 (Reproduction). When a weed's fitness level is high, it will generate a greater number of seeds. The formulation for seeds that grow weeds is

$$Weed_n=(f-f_{min})/(f_{max}-f_{min})(s_{max}-s_{min})+s_{min} \tag{4}$$

Step 3 (spatial dispersion). Traditional random number distributions use zero-mean, variable-variance random numbers to scatter the generated seeds across the search space's dimensions. As a result, seeds are guaranteed to be distributed at random to stay close to the parent plant. However, over the course of each generation, the random function's standard deviation (σ) will be brought down from an initial value(σ) that was established in advance to a final value(σ) that will be used thereafter. A nonlinear alteration has demonstrated good performance in simulations when applied as follows:

$$\sigma_{cur}=(iter_{max}-iter)^n/(iter_{max})^n(\sigma_{init}-\sigma_{final})+\sigma_{final} \tag{5}$$

Step 4 (Competitive exclusion). Weed colonies will quickly reproduce to their maximum number (max) within a few repetitions. Each weed is now permitted to start producing seeds. When the seeds are placed, they are allowed to grow throughout the entire search area. After all of the sources have been located in the search region, they are ranked with their forebears (like a family of weeds). Next, the lowest-fitness weeds are eliminated to attain the maximum population density permitted for a colony. Together, seeds and weeds are ranked in this way, and only the ones that have a higher fitness level can continue existing and producing offspring. The method for controlling the population is also used on their offspring until the end of a given run. This is called competitive exclusion.

5. Results And Discussions

5.1. IEEE-14 Bus case study

For this case study, the IEEE-14 bus test system is being utilized. It is made up of 9 load buses and 5 generator buses, with this one bus serving as the slack bus in the arrangement. The bus information is given below.

Slack bus: 1st bus
Generator bus: 2nd, 3rd, 6th, 8th buses
Load buses: 4th, 5th, 7th, 9-14th buses
It consists of 20 Transmission lines
Base MVA = 100MVA
Maximum number of iterations = 100.

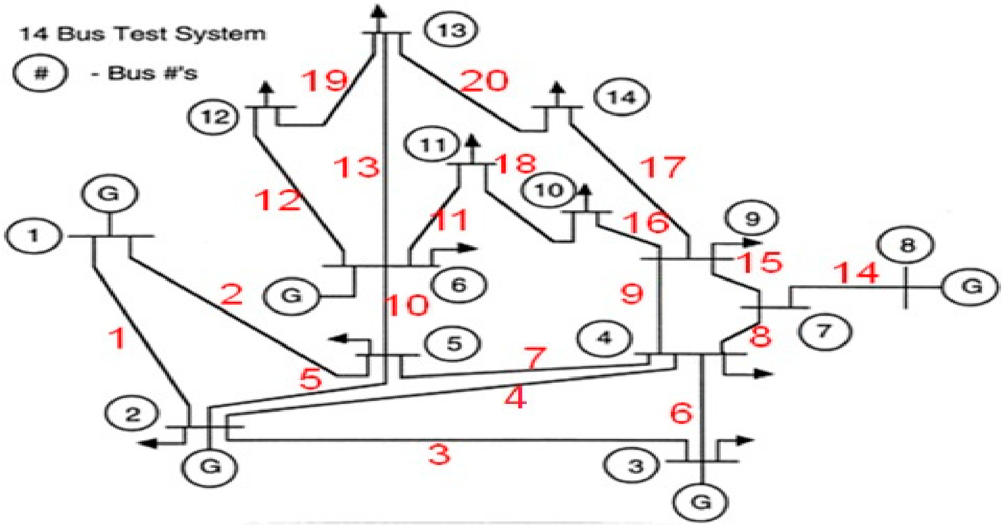

Figure 2. Test configuration for the IEEE-14 bus system.

5.2. Results of stability indices

Here the results of the Line Stability Index (LSI) and Voltage Stability Index (VSI) are given, which are obtained based on load flow results from equations 3 and 4. Table 1 represents the VSI for different load conditions as shown in Figure 3.

Table 1. Voltage stability Index for different load conditions.

Load bus	VSI Normal Load	VSI 125% Load	VSI 140% Load	VSI 150% Load
4	0.726	0.724	0.724	0.722
5	0.726	0.725	0.723	0.723
7	0.700	0.697	0.695	0.695
9	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000
11	0.502	0.499	0.497	0.495
12	0.470	0.467	0.465	0.464
13	0.445	0.441	0.439	0.437
14	1.000	1.000	1.000	1.000

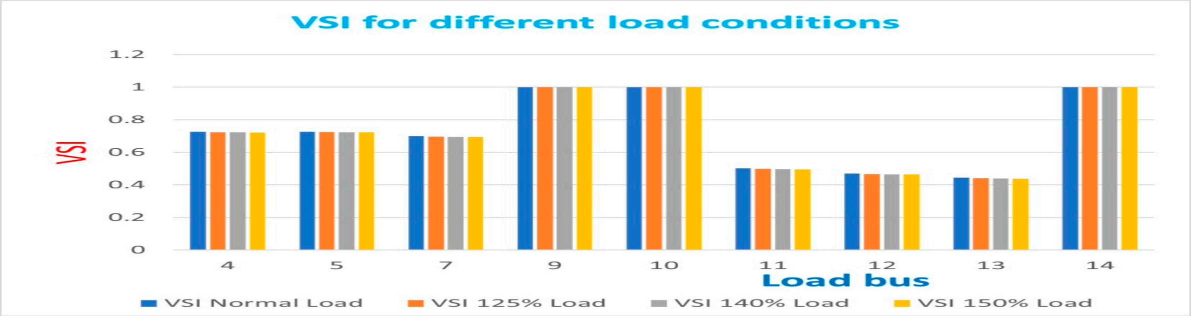

Figure 3. Voltage stability index for different load conditions.

5.2.1. Vsi results for different load conditions

VSI's purpose is to find the location of TCSC. Where the VSI is nearer to one, only TCSC is placed there. From the results of VSI shown in Table 1, VSI is one at the 9th, 10th and 14th load buses, so at that location, only TCSC is placed.

5.2.2. Lsi for different load conditions

LSI's purpose is to find the location of SVC. Where the LSI is Maximum, only SVC is placed at that location as shown in Figure 4.

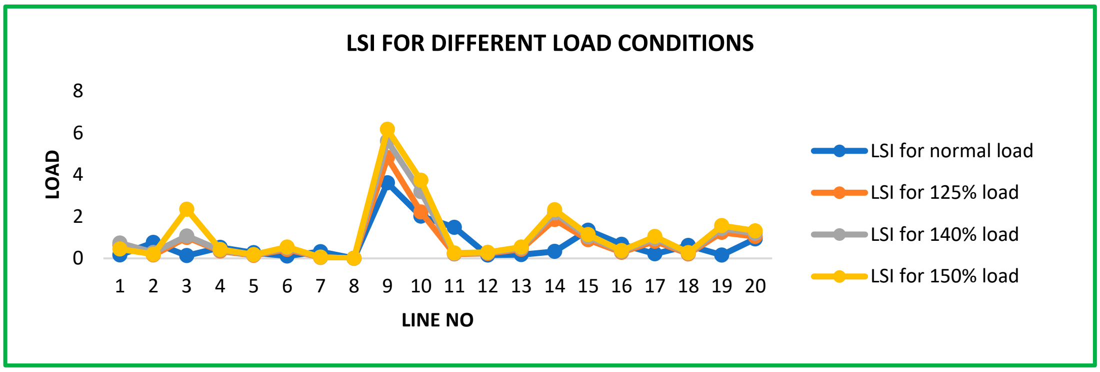

Figure 4. LSI For different load conditions.

From Table 2, at the 9th line, LSI is Maximum. So at the 9th line, SVC is placed. The following result shows the case study to fix the location of TCSC and SVC.

Table 2. LSI for average Load.

Bus no	LSI for normal Load	LSI for 125% load	LSI for 140% load	LSI for 150% load
1	0.1590	0.6274	0.7306	0.4416
2	0.7568	0.1590	0.2779	0.1906
3	0.1280	0.9969	1.0649	2.3437
4	0.5183	0.3405	0.3862	0.4201
5	0.2653	0.1397	0.1587	0.1727
6	0.1086	0.4211	0.4958	0.5359
7	0.3128	0.0392	0.0456	0.0501
8	0.0000	0.0000	0.000	0.0000
9	3.6137	4.8228	5.6146	6.1722
10	2.0189	2.2173	3.1881	3.7308
11	1.4794	0.2030	0.2296	0.2506
12	0.1526	0.2286	0.2603	0.2835
13	0.1736	0.4304	0.4900	0.5342
14	0.3270	1.8534	2.1655	2.3203
15	1.3372	0.8876	1.0274	1.1300
16	0.6680	0.2824	0.3287	0.3631
17	0.2100	0.8145	0.9447	1.0409
18	0.6090	0.2086	0.2430	0.2688
19	0.1545	1.2385	1.4234	1.5622
20	0.9274	1.0395	1.1956	1.3123

From the case study results shown in Table 3, we recognized that the 9th line and 9th bus loss reduction is more when compared to the remaining locations.

Table 3. Case study results after placing FACTS devices.

Location		GA		DEIWO	
Line	Bus	PLoss (MW)	Loss reduction (MW)	PLoss (MW)	Loss reduction (MW)
9	9	29.065	1.2392	29.0653	1.2399
9	10	29.650	1.0989	29.1749	1.1303
9	14	29.303	1.0036	29.2947	1.0105

5.3. GA Results

The following are the results of the Genetic Algorithm (GA) for Real power in different load conditions as shown in Table 4 and graphically represented in Figure 5. Voltage profiles can be shown in Table 6 with different load conditions and it is represented in Figures 7–10.

Table 4. Real power losses of GA.

Particulars.	Before Placing FACTS Loss (MW)	After Placing FACTS Loss (MW)	Loss Reduction (MW)
Normal case	13.5766	13.3741	0.2026
125% load	23.088	22.2621	0.7467
140% load	30.3052	29.0668	1.2384
150% load	36.0280	34.5264	1.5016

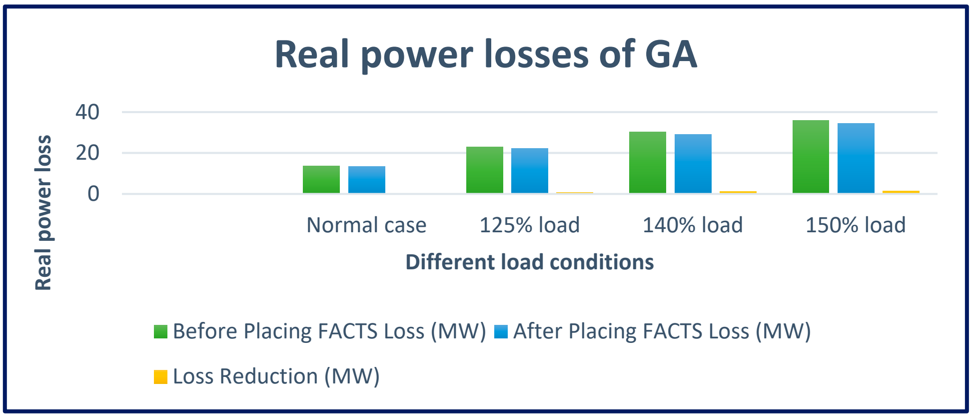

Figure 5. Real power losses of GA.

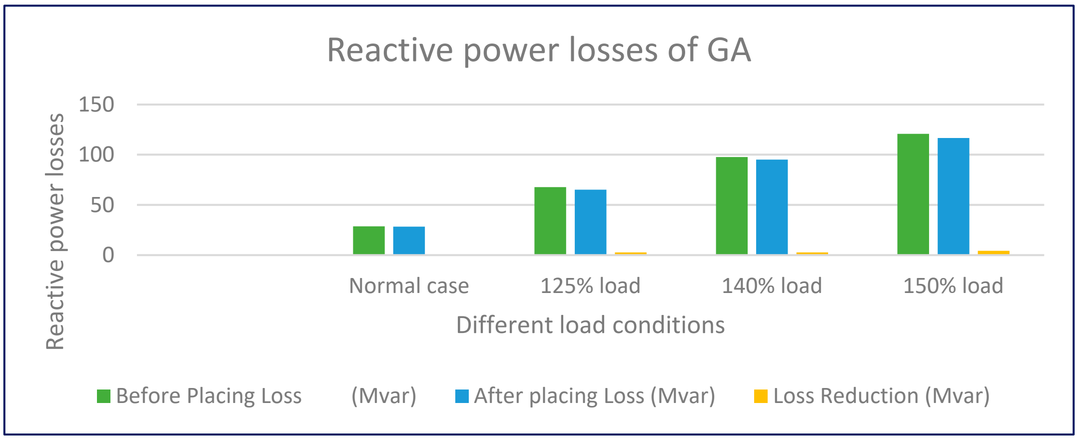

Figure 6. Reactive power loss.

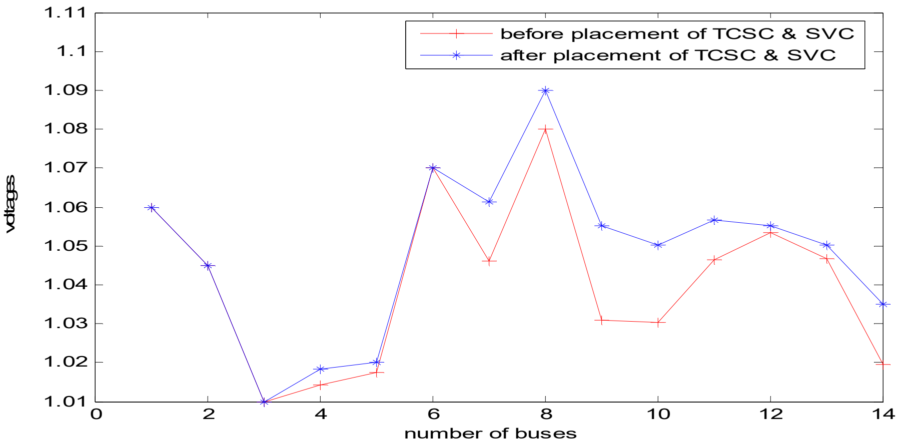

Figure 7. Voltage profile for normal cases in GA.

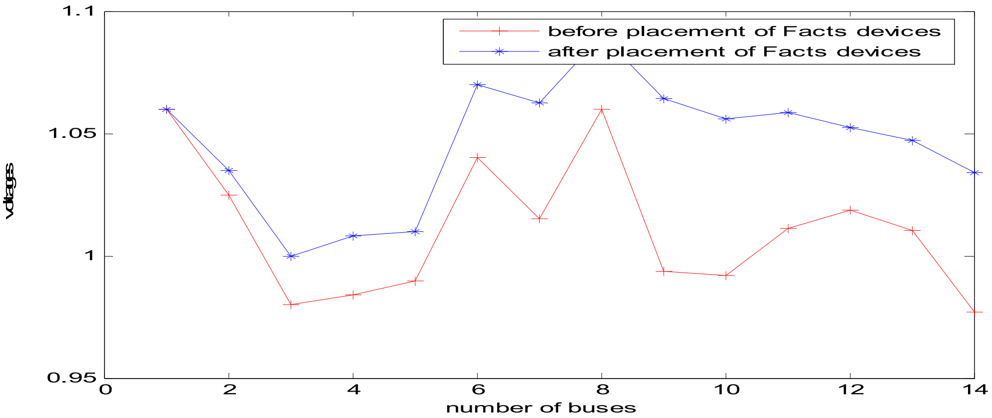

Figure 8. Voltage profile for 125% of cases in GA.

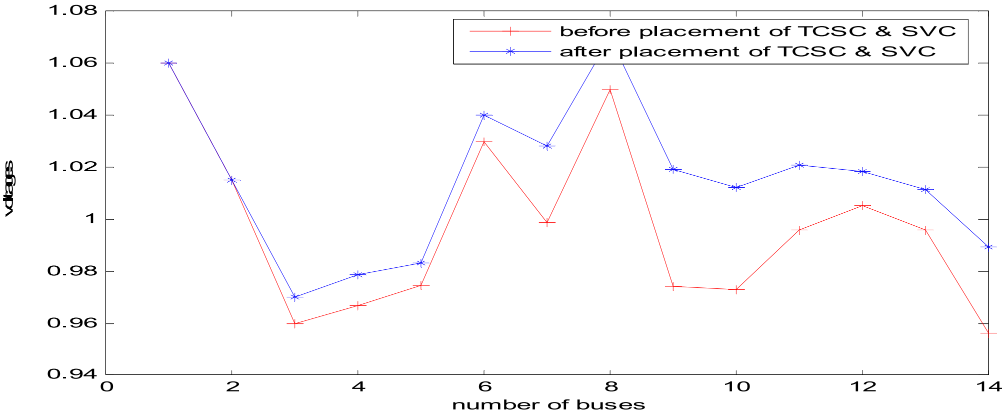

Figure 9. Voltage profile for 140% load in GA.

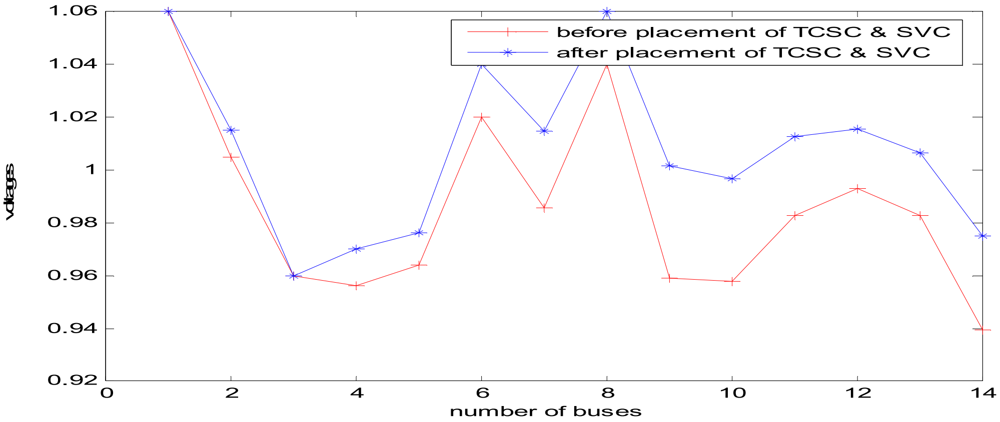

Figure 10. Voltage profile for 150% load in GA.

For Reactive power loss the different load conditions as shown in Table 5, and graphically represented in Figure 6.

Table 5. Reactive power losses of GA.

Particulars	Before Placing Loss (Mvar)	After placing Loss (Mvar)	Loss Reduction (Mvar)
Normal case	28.553	28.328	0.225
125% load	67.640	65.075	2.565
140% load	97.705	95.073	2.632
150% load	120.800	116.580	4.220

Table 6. Voltage profile of GA for a Normal load,125%load,140%load and 150% condition.

	Normal case		125% load condition		140 % load condition		150% load condition	
Line no	Before placing Facts devices	After placing Facts devices	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	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600
2	1.0450	1.0450	1.0250	1.0350	1.0150	1.0150	1.0050	1.0150
3	1.0100	1.0100	0.9800	1.0000	0.9600	`0.9700	0.9600	`0.9600
4	1.0141	1.0185	0.9840	1.0075	0.9670	0.9830	0.9562	0.9733
5	1.0173	1.0201	0.9897	1.0094	0.9746	0.9871	0.9638	0.9784
6	1.0700	1.0700	1.0400	1.0700	1.0300	1.0501	1.0200	1.0400
7	1.0461	1.0617	1.0150	1.0610	0.9986	1.0409	0.9858	1.0276
8	1.0800	1.0900	1.0600	1.0900	1.0500	1.0800	1.0400	1.0700
9	1.0309	1.0561	0.9935	1.0610	0.9742	1.0377	0.9593	1.0217
10	1.0303	1.0511	0.9919	1.0533	0.9729	1.0293	0.9578	1.0133
11	1.0463	1.0569	1.0110	1.0572	0.9958	1.0345	0.9828	1.0210
12	1.0533	1.0552	1.0186	1.0520	1.0054	1.0292	0.9933	1.0171
13	1.0467	1.0504	1.0103	1.0466	0.9957	1.0228	0.9827	1.0096
14	1.0195	1.0356	0.9769	1.0321	0.9562	1.0052	0.9395	0.9880

5.4. Voltage Profiles of GA

5.5. Deiwo Results

The following are the results obtained by performing Differential evolution Invasive weed Optimization. The real power losses for different load conditions with the help of the DEIWO Algorithm can be shown in Table 7 and graphically represented in Figure 11. Reactive power losses can be shown in Table 8 and graphically represented in Figure 12. Voltage profiles can be shown with the help of different load conditions in Table 9 with graphically shown in Figures 13–16.

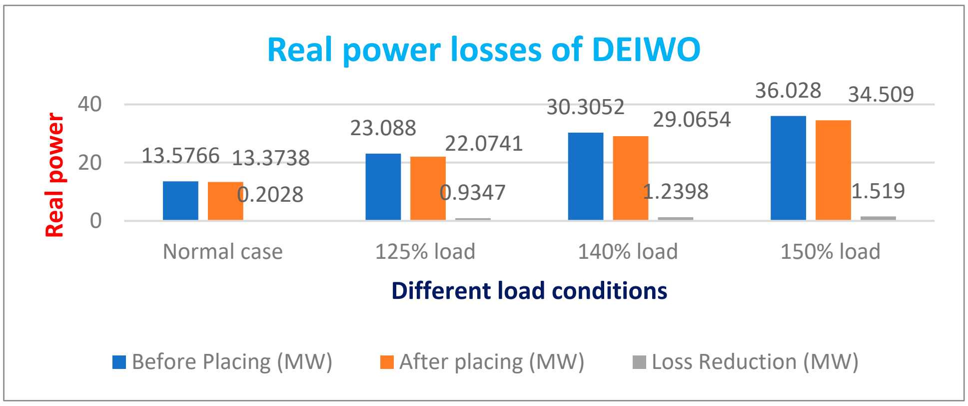

Figure 11. Real power loss.

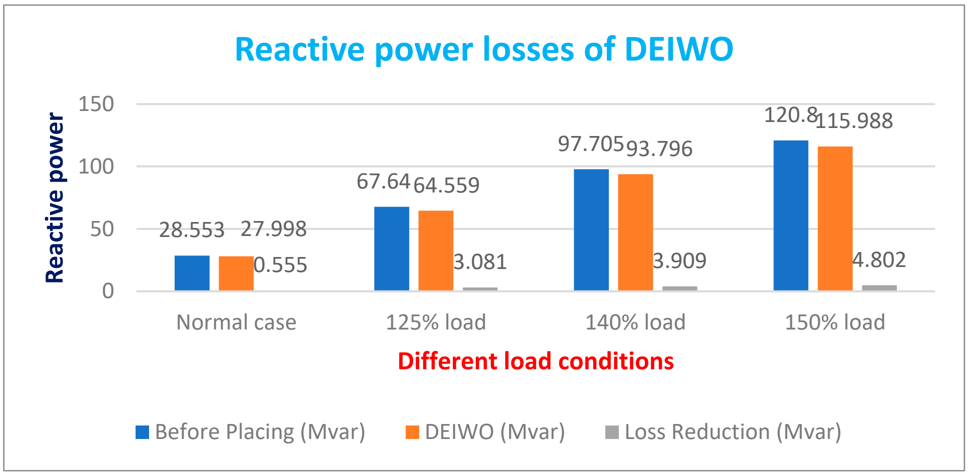

Figure 12. Reactive power loss.

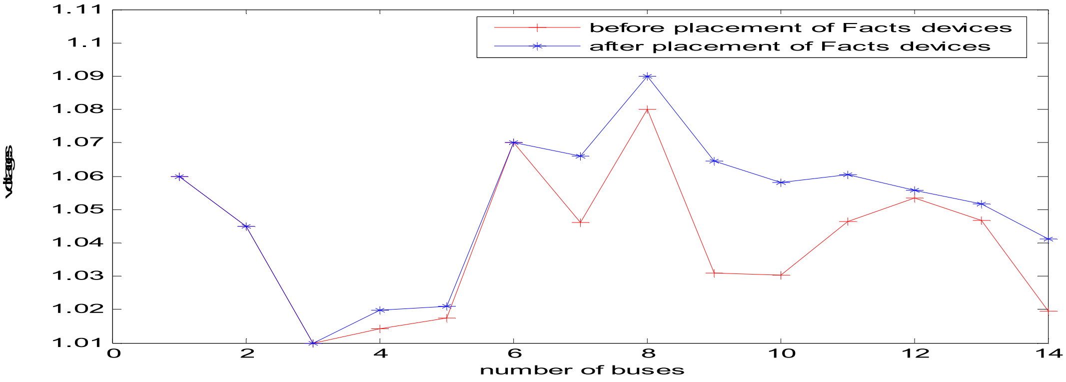

Figure 13. Voltage profile for normal Load in DEIWO.

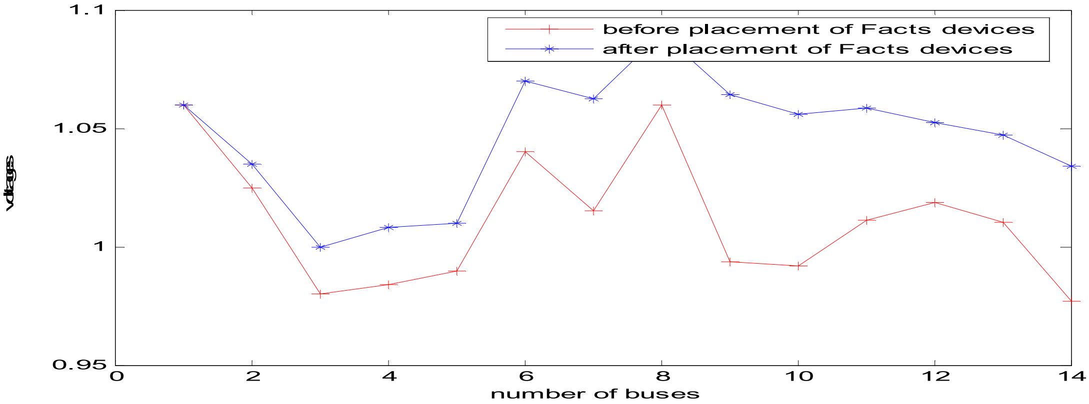

Figure 14. Voltage profile for 125% load in DEIWO.

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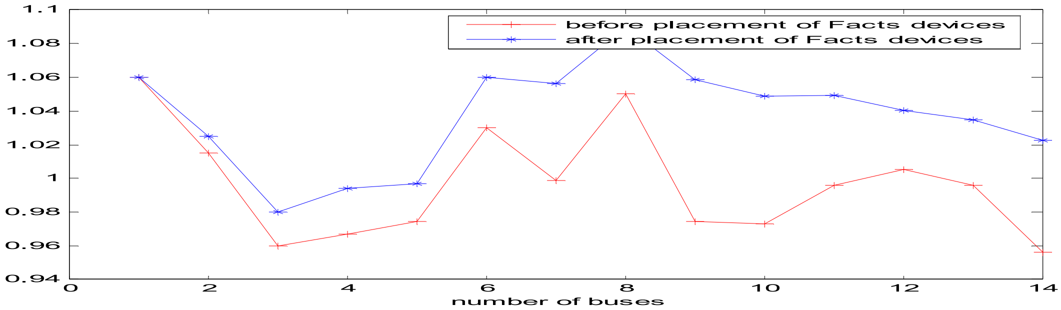

Figure 15. Voltage profile for 140% load in DEIWO.

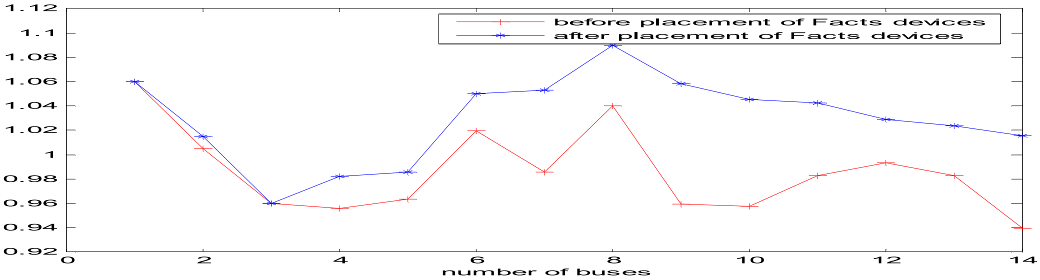

Figure 16. Voltage profile for 150% load in DEIWO.

Table 7. Real power losses of DEIWO.

Particulars	Before Placing (MW)	After placing (MW)	Loss Reduction (MW)
Normal case	13.5766	13.3738	0.2028
125% load	23.088	22.0741	0.9347
140% load	30.3052	29.0654	1.2398
150% load	36.0280	34.5090	1.5190

Table 8. Reactive power losses of DEIWO.

Particulars	Before Placing (Mvar)	DEIWO (Mvar)	Loss Reduction (Mvar)
Normal case	28.553	27.998	0.555
125% load	67.640	64.559	3.081
140% load	97.705	93.796	3.909
150% load	120.800	115.988	4.802

Table 9. Voltage profile of DEIWO for Different load conditions.

	Normal case		125% load condition		140 % load condition		150% load condition	
Line no	Before placing Facts devices	After placing Facts devices	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	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600
2	1.0450	1.0450	1.0250	1.0350	1.0150	1.0250	1.0050	1.0150
3	1.0100	1.0100	0.9800	1.0000	0.9600	0.9800	0.9600	0.9600
4	1.0141	1.0199	0.9840	1.0081	0.9670	0.9969	0.9562	0.9831
5	1.0173	1.0211	0.9897	1.0098	0.9746	0.9996	0.9638	0.9870
6	1.0700	1.0700	1.0400	1.0700	1.0300	1.0700	1.0200	1.0600
7	1.0461	1.0661	1.0150	1.0626	0.9986	1.0643	0.9858	1.0550
8	1.0800	1.0900	1.0600	1.0900	1.0500	1.0900	1.0400	1.0900
9	1.0309	1.0646	0.9935	1.0642	0.9742	1.0746	0.9593	1.0624

10	1.0303	1.0582	0.9919	1.0560	0.9729	1.0634	0.9578	1.0507
11	1.0463	1.0606	1.0110	1.0586	0.9958	1.0618	0.9828	1.0501
12	1.0533	1.0558	1.0186	1.0523	1.0054	1.0509	0.9933	1.0391
13	1.0467	1.0517	1.0103	1.0470	0.9957	1.0458	0.9827	1.0333
14	1.0195	1.0411	0.9769	1.0342	0.9562	1.0367	0.9395	1.0222

5.5.1. Voltage profiles for DEIWO

5.6. Comparison of GA and DEIWO

The real power losses, Reactive power losses and voltage profiles comparison for different load conditions with the help of GA& DEIWO.

Case 1: Real power losses can be computed as demonstrated in Table 11 and graphically illustrated in Figure 17.

Case 2: Reactive power losses can be calculated according to Table 12 and represented graphically in Figure 18.

Case 3: For different load conditions the voltage profiles can be evaluated in Table 13 and graphs shown in Figures 19–23.

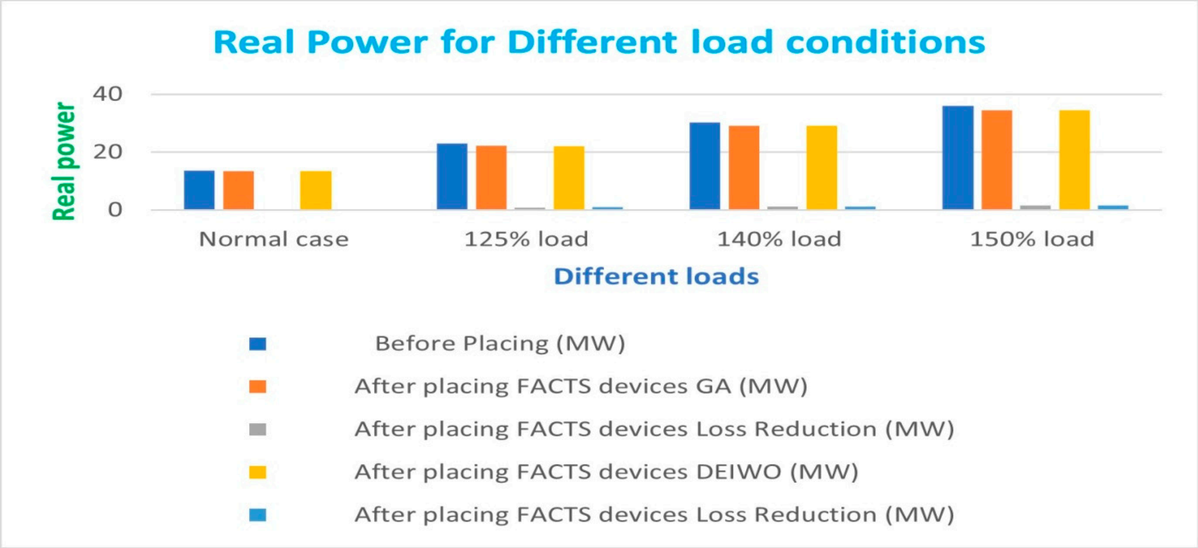

Figure 17. Real power for different load conditions.

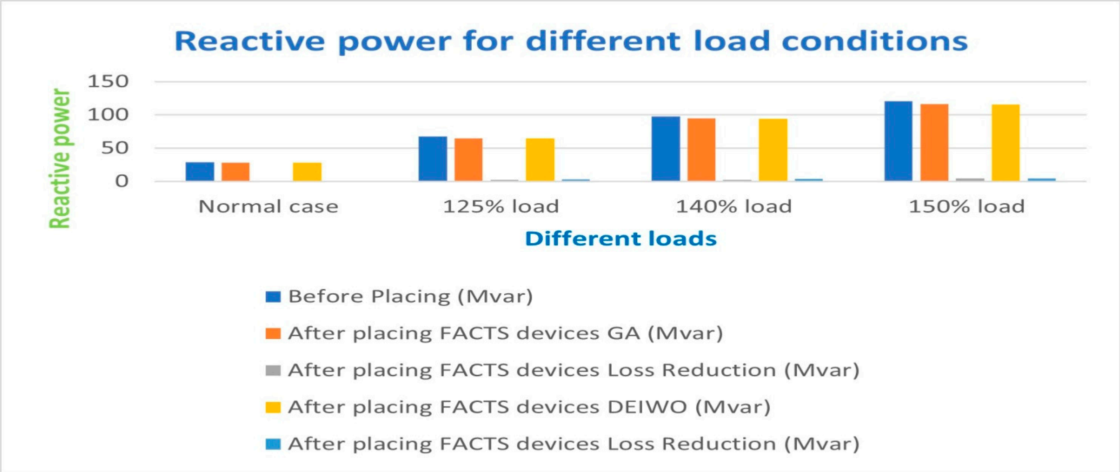

Figure 18. Reactive power for different load conditions.

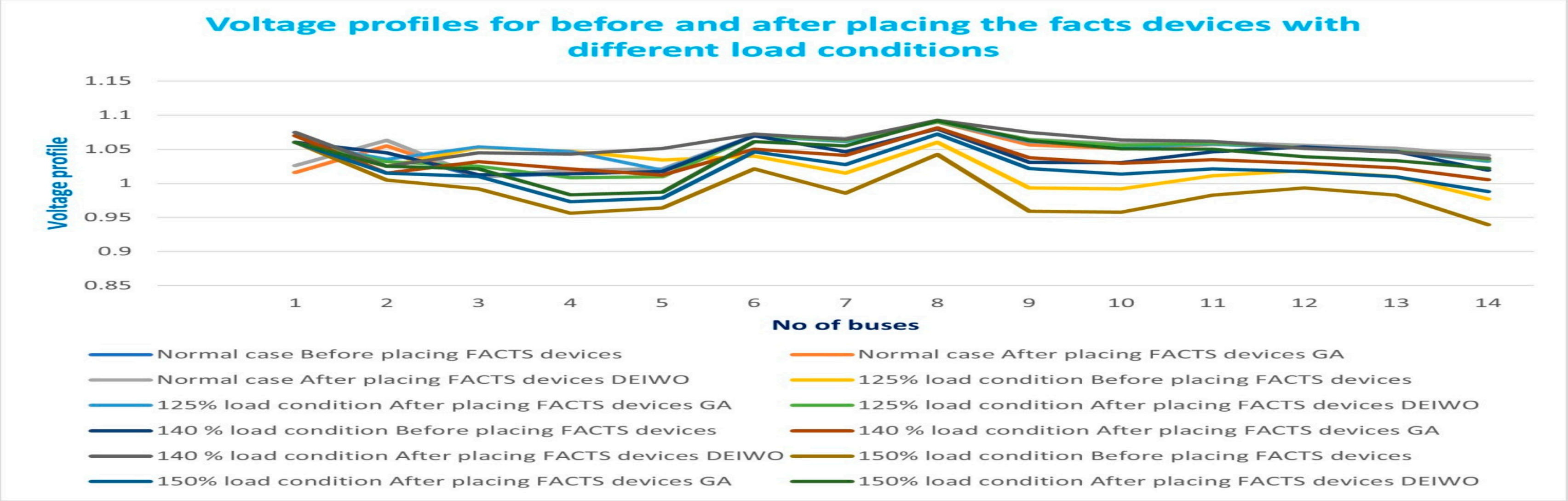

Figure 19. Voltage profiles before and after placing the facts devices in different load conditions.

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Figure 20. Voltage profile comparison of GA and DEIWO for normal load.

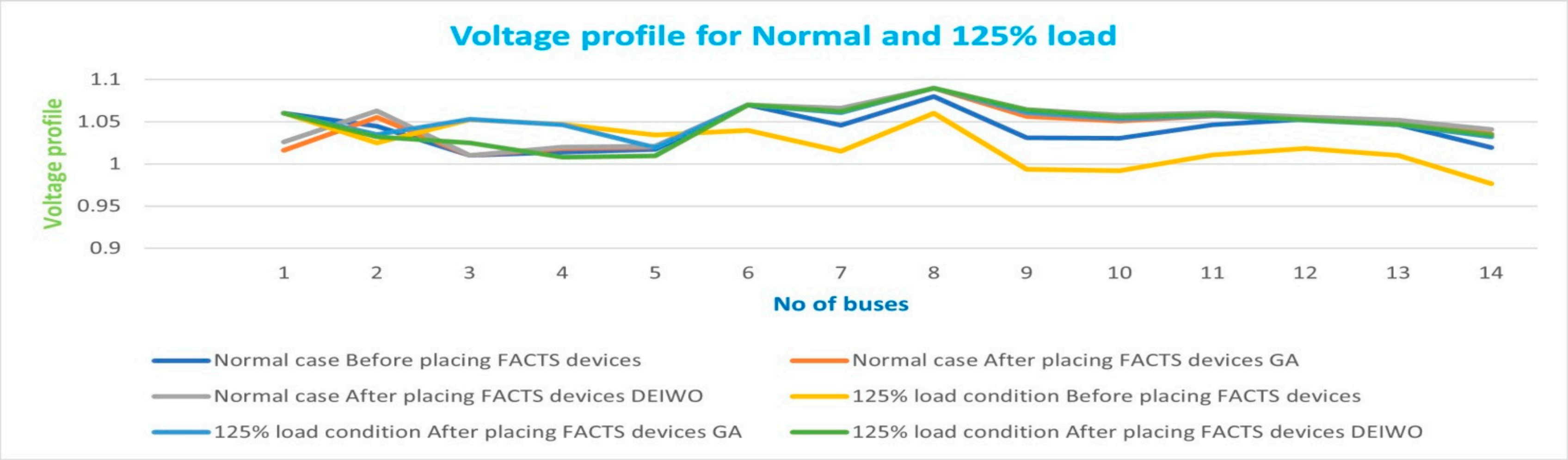

Figure 21. Voltage profile comparison of GA and DEIWO for 125% load.

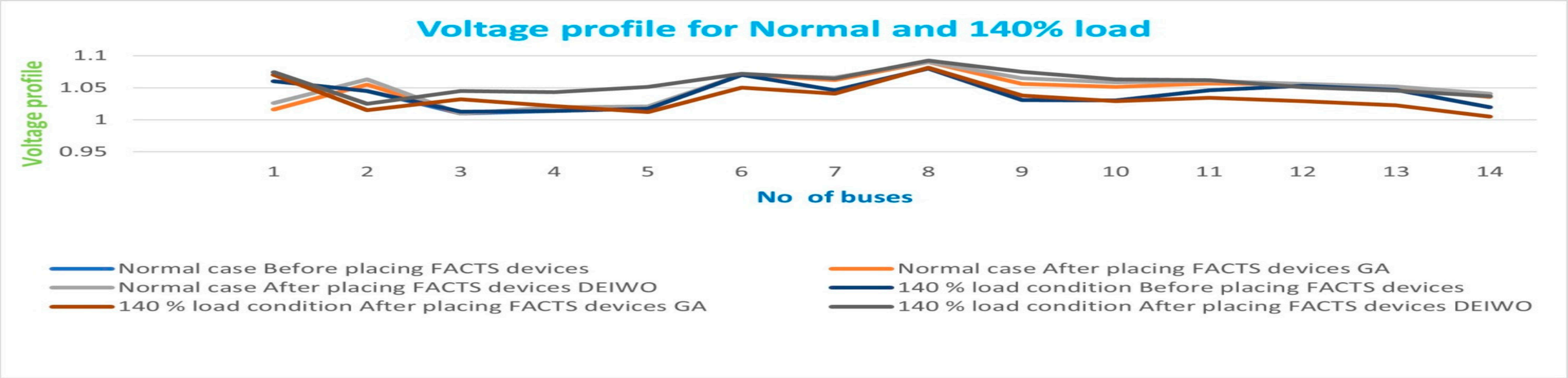

Figure 22. Voltage profile comparison of GA and DEIWO for 140% load.

doi:10.20944/preprints202305.2040.v1

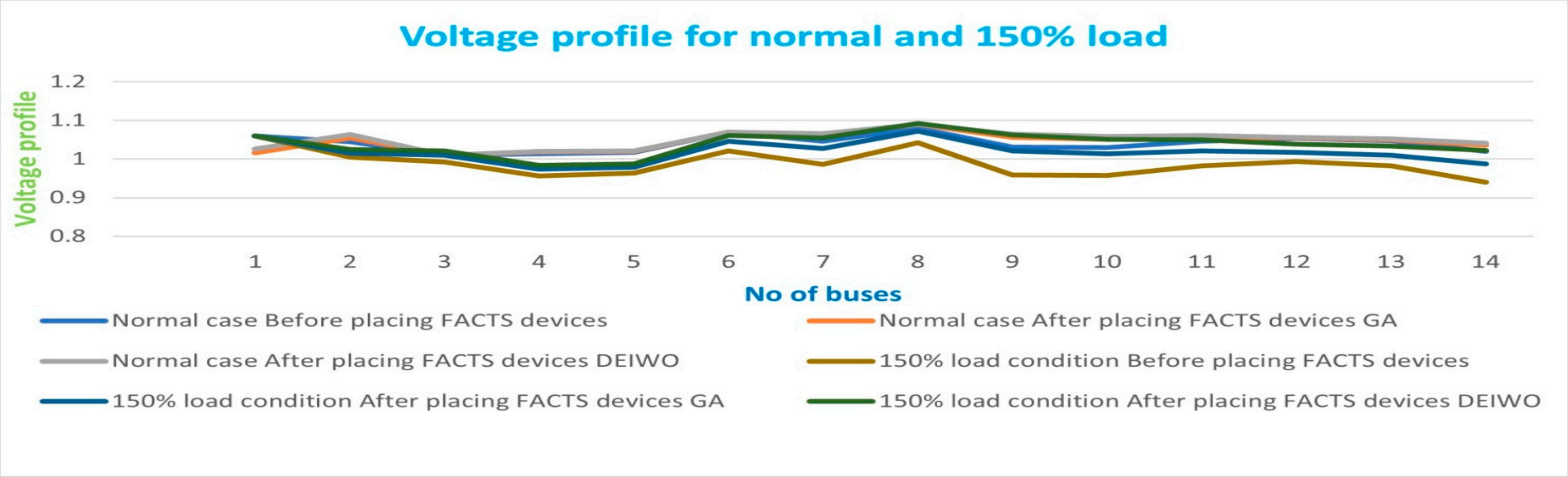

Figure 23. Voltage profile comparison of GA and DEIWO for 150% load.

doi:10.20944/preprints202305.2040.v1

Table 11. Real power loss comparison for different load conditions.

	After placing FACTS devices				
Particulars	**Before Placing (MW)**	**GA (MW)**	**Loss Reduction (MW)**	**DEIWO (MW)**	**LOSS REDUCTION (MW)**
Normal case	13.5766	13.3741	0.2026	13.3738	0.2028
125% load	23.088	22.2621	0.7467	22.0741	0.9347
140% load	30.3052	29.0668	1.2384	29.0654	1.2398
150% load	36.0280	34.5264	1.5016	34.5090	1.5190

Table 12. Reactive power loss comparison for different load conditions.

	After placing FACTS devices				
Particulars	**Before Placing (Mvar)**	**GA (Mvar)**	**Loss Reduction (Mvar)**	**DEIWO (Mvar)**	**Loss Reduction (Mvar)**
Normal case	28.553	28.328	0.225	27.998	0.555
125% load	67.640	65.075	2.565	64.559	3.081
140% load	97.705	95.073	2.632	93.796	3.909
150% load	120.800	116.580	4.220	115.988	4.802

Table 13. Voltage profile before and after placing FACTS devices for Different load conditions.

	Normal case			**125% load condition**			**140 % load condition**			**150% load condition**		
Line no	**Before placing FACTS devices**	**After placing FACTS devices**		**Before placing FACTS devices**	**After placing FACTS devices**		**Before placing FACTS devices**	**After placing FACTS devices**		**Before placing FACTS devices**	**After placing FACTS devices**	
		GA	**DEIWO**		**GA**	**DEIWO**		**GA**	**DEIWO**		**GA**	**DEIWO**
1	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1.0600	1..600	1.0600	1.0600
2	1.0450	1.0450	1.0450	1.0250	1.0350	1.0350	1.0150	1.0150	1.0250	1.0050	1.0150	1.0150
3	1.0100	1.0100	1.0100	0.9800	1.0000	1.0000	0.9600	0.9700	0.9800	0.9600	0.9600	0.9600
4	1.0141	1.0185	1.0199	0.9840	1.0075	1.0081	0.9670	0.9830	0.9969	0.9562	0.9733	0.9831
5	1.0173	1.0201	1.0211	0.9897	1.0094	1.0098	0.9746	0.9871	0.9996	0.9638	0.9784	0.9870
6	1.0700	1.0700	1.0700	1.0400	1.0700	1.0700	1.0300	1.0501	1.0700	1.0200	1.0400	1.0600
7	1.0461	1.0617	1.0661	1.0150	1.0610	1.0626	0.9986	1.0409	1.0643	0.9858	1.0276	1.0550
8	1.0800	1.0810	1.0900	1.0600	1.0876	1.0900	1.0500	1.0800	1.0900	1.0400	1.0700	1.0900
9	1.0309	1.0561	1.0646	0.9935	1.0610	1.0642	0.9742	1.0377	1.0746	0.9593	1.0217	1.0624
10	1.0303	1.0511	1.0582	0.9919	1.0533	1.0560	0.9729	1.0293	1.0634	0.9578	1.0133	1.0507
11	1.0463	1.0569	1.0606	1.0110	1.0572	1.0586	0.9958	1.0345	1.0618	0.9828	1.0210	1.0501
12	1.0533	1.0552	1.0558	1.0186	1.0520	1.0523	1.0054	1.0292	1.0509	0.9933	1.0171	1.0391
13	1.0467	1.0504	1.0517	1.0103	1.0466	1.0470	0.9957	1.0228	1.0458	0.9827	1.0096	1.0333
14	1.0195	1.0356	1.0411	0.9769	1.0321	1.0342	0.9562	1.0052	1.0367	0.9395	0.9880	1.0222

Table 14. TCSC ratings in % of XL.

	Normal	**125% load**	**140% load**	**150% load**
GA	4.6143	6.2615	11.2625	21.8451
DEIWO	3.3357	5.9665	9.1575	16.5474

Table 15. SVC ratings in % QL.

	Normal	**125% load**	**140% load**	**150% load**
GA	25.2501	31.0195	43.5568	45.6973
DEIWO	29.3052	33.0261	43.6937	50.0000

Table 16. TCSC ratings.

	Normal	**125% load**	**140% load**	**150% load**
GA (mF)	0.7104	0.5235	0.291	0.15
DEIWO **(mF)**	0.9765	0.5494	0.3579	0.1981

Table 17. SVC ratings.

	Normal	**125% load**	**140% load**	**150% load**
GA (Mvar)	5.8681	7.2089	10.1226	10.6183
DEIWO (Mvar)	6.8093	7.6752	10.1544	11.6200

Table 18. Time taken for execution.

	Normal Load (sec)	**125% load (sec)**	**140% load (sec)**	**150% load (sec)**
GA	1.6980	2.3770	3.2470	3.7468
DEIWO	5.2800	9.2580	10.4910	11.4370

6. Conclusion

Voltage regulation and stability are given significant consideration in a practical power system. The power sector is increasingly worried about the issue of voltage instability in power networks. The power system network may experience a collapse in voltage or a total blackout as a result. For increasing voltage stability, many conventional controllers are used, including synchronous condensers, adjusting transformer tap settings, phase shifters, and under voltage load shedding, among others. Because all of these have drawbacks, FACTS devices are being studied for voltage stability augmentation and lowering transmission line losses in the power system network. The proposed algorithms were evaluated using an IEEE-14 bus test system as a reference power system network.

The SVC and TCSC are two FACTS devices that achieve these goals by reducing transmission line losses and improving voltage stability. Benefits will be maximized by choosing the best location and FACTS device rating. The Genetic Algorithm and DEIWO are the optimization techniques that can be used to obtain the optimal FACTS device ratings. Stability indices are utilized so that the best possible site can be determined. Two such indices are the Voltage Stability Index (VSI) and the Line Stability Index (LSI), both of which are highlighted as follows. SVC's location is determined using VSI, and TCSC's position is determined using LSI.

After determining locations FACTS devices are connected to an IEEE-14 bus power system network. Now that both optimization strategies have been applied independently, their results have been shown for conditions with an average load, 125% load, 140% load, and 150% load. By examining the outcomes of all load circumstances, the ensuing observations are made. Comparing the DEIWO approach to the GA method, the DEIWO method has a better voltage profile. Additionally, the reduction of actual and reactive power loss is much better than the conventional method. However, when compared to the GA approach, the DEIWO method has superior TCSC and SVC evaluations. However, the GA approach takes less time to compute than the DEIWO method. Another important observation is that the GA method converges to the local optimum, i.e., the ratings of FACTS devices obtained from GA vary every time the program run, whereas the DEIWO converges to the global optimum.

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