Ilkogretim Online - Elementary Education Online, 2021; Vol 20 (Issue 1): pp. 7700-7715
http://ilkogretim-online.org
doi: 10.17051/ilkonline.2021.01.793

Optimal Statcom Location Identification Framework Based On Gravitation Search To Minimize Power Loss

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ABSTRACT

Due to the rising demand for power, power loss in transmission lines is becoming a bigger problem that needs to be addressed. One of the actual devices that can control power loss by being fixed to transmission lines is the static synchronous compensator. However, the placement of STATCOM devices, which must be done in the best possible area, is crucial to improving the voltage profile. Various research methods have already been introduced for the best location prediction for STATCOM devices. These research methodologies, however, frequently suffer from convergence problems and erroneous prediction. By introducing the Gravitation Search based Optimal STATCOM Location Identification method, this research effort addresses the issue (GS-STATCOM-LI). On this study, the gravitational search method is used to forecast where STATCOM devices should be placed in the IEEE bus lines in order to optimise voltage profiles effectively. By using the installation cost and power loss as fitness characteristics, the best placement is predicted. It has been established through the implementation of the full study project in the Matlab simulation environment that the suggested strategy ensures effective voltage power loss reduction.

Keywords: Location prediction, optimal, algorithm, IEEE-14, Gravitation, power loss, installation cost

I. INTRODUCTION

As technology and population rose, so did the demand for power, which must be safeguarded against loss in order to satisfy the people's needs without fail. Most of the time, environmental or physical losses can be blamed for this power loss. Quasi fluctuations in the load current and energy sources are the main causes of power loss. The availability of longer transmission lines or the changing conditions of the environment may both contribute to this.The FACTS family member compensator (STATCOM) is a promising technology that is widely utilised as the modern dynamic shunt compensator for distribution and transmission systems to manage reactive power [1].

By installing external devices inside longer transmission lines that can manage voltage variation, the power system's regular operation can be maintained [7]. Different researchers use different equipment, such as reactors, generators, and so on, to lessen the power loss. However, it appears that the presence of high-power flow significantly reduces this device's performance.The three parameters—the locations, the types, and the sizes of DGs—are optimised simultaneously. To guarantee that the ideal point is attained, a genetic algorithm (GA) is used. The radial distribution systems in Kaliasin, East Java, are used to test the proposed strategy [2]. The FACT technology is used by various researchers to resolve this [9]. By more precisely controlling the power flow, this technique offers researchers an easier and more adaptable solution to address the problem of power loss. Additionally, the damping capacity can be improved by these technologies [3].

By limiting the voltage supply and managing the power flow, this STATCOM can significantly reduce power loss. However, depending on where it is integrated, STATCOM device performance may be impacted. To correct the STATCOM and ensure proper and unambiguous network flow, the appropriate bus must be chosen. The focus of current research is most heavily on where to place STATCOM devices.The best bus number for STATCOM to be on is that one. The gravitational search method is used in this study work to discover the most advantageous site where STATCOM devices can be integrated. The installation costs and power loss are taken into consideration when doing this.

The overall organization of this study is as follows: The entire picture of the necessity of power-controlled devices and their contribution to the reduction of power loss is provided in this section. In section 2, many current research projects are discussed in an effort to anticipate the best position for the devices. Section 3 provides a full explanation of the intended work along with pertinent diagrams. Discussion of the simulation findings is provided with more simulation outcome in section 4.

II. RELATED WORKS

Karthikeyan et al .'s efforts to improve the power system architecture's rotor angle and voltage stability were unsuccessful. The optimal decision is made in this instance thanks to the application of the particle swarm optimization approach, whose main goal is to predict the ideal spot of STATCOM devices. As a result, the voltage stability can be significantly improved. The Power System Study Tool Box Software is used to perform a comprehensive analysis of this research project.

This attempt to introduce the particle swarm optimization algorithm in order to improve voltage stability. Predicting the appropriate location of the STATCOM devices within the power system controller is the main goal of this approach. The results of this research project's evaluation process demonstrated that a system for decreasing power loss can operate more efficiently with a higher damping capacity. The subsystems of a small spacecraft are modularized and created such that any number of each module can be joined at once to accomplish the goals of the proposed power system [3]

The cuckoo search technique was used by Abd-Elazim et al. to anticipate STATCOM device locations most accurately. By visualising the objectives as PV curves, this is achieved. Utilizing genetic algorithms and loophole procedures, the research's effectiveness is evaluated, and the recommended cuckoo search will be contrasted [5].Network properties and the point of common coupling have no bearing on this profile. However, increased reactive power demand results in increased reactive power imbalances in the networks that must be made up for by the transmission grid that is overlay [4].Chemical reaction optimization was used by Dutta et al. to determine the best site for STATCOM devices. The performance assessment was carried out using the IEEE 30 bus system and IEEE 57 bus system. The performance evaluation has been carried out in the Matlab simulation environment.

We attempted to predict the optimal location for mounting the STATCM devices in the distributed system in order to provide greater voltage control. Another factor driving this trend is the increase of consumer electronics. DC power distribution technologies have returned in this situation and continue to see noteworthy growth in research attention and industry uses. [6]. The major objective of this research project is to improve voltage stability while reducing energy consumption with increased loss. The UK 38 bus system was used for the entire evaluation of this research project.

Singh et algenetic .'s algorithm was used to determine the best position for various FACTS devices. The IEEE 37 bus distribution scheme is used to do the performance study. Finding the ideal position to reduce power loss is the major goal of this study project.A fundamental model is also altered in this work to assist in determining the optimum hazy solution [8]. The performance evaluation, which makes use of the IEEE 24 bus system, shows how the suggested technique can enhance outcomes by encouraging wise decision-making and reducing power loss.

III. Location Identification Using Optimal Statcom Search Based on Gravitation

The higher danger found in the power design that would be brought on by fluctuating voltage violations is power flow maintenance. The transmission lines would experience power loss as a result. Longer transmissions, in particular, would result in more power loss, which requires greater care to prevent [7]. One of the widely used and developing technologies that can guarantee a significant reduction in power loss is FACTS devices. For the purpose of reducing power loss, one of the fact devices, STATCOM, is used in this study. Predicting the ideal spot for the STATCOM to be put, or the ideal transmission bus line, is trickier.On this study, the gravitational search method is used to forecast where STATCOM devices should be placed in the IEEE bus lines in order to optimise voltage profiles effectively [10]. By using the installation cost and power loss as fitness characteristics, the best placement is predicted. Take solar photovoltaic systems, which are used to generate power throughout the day, as an example. During the night, these PV solar cells will be inactive. Figure 1 in the accompanying text shows a schematic of STATCOM equipment. A recently created metaheuristic method dubbed the crow search algorithm is used to determine the best position for capacitors in a distribution network. [9].

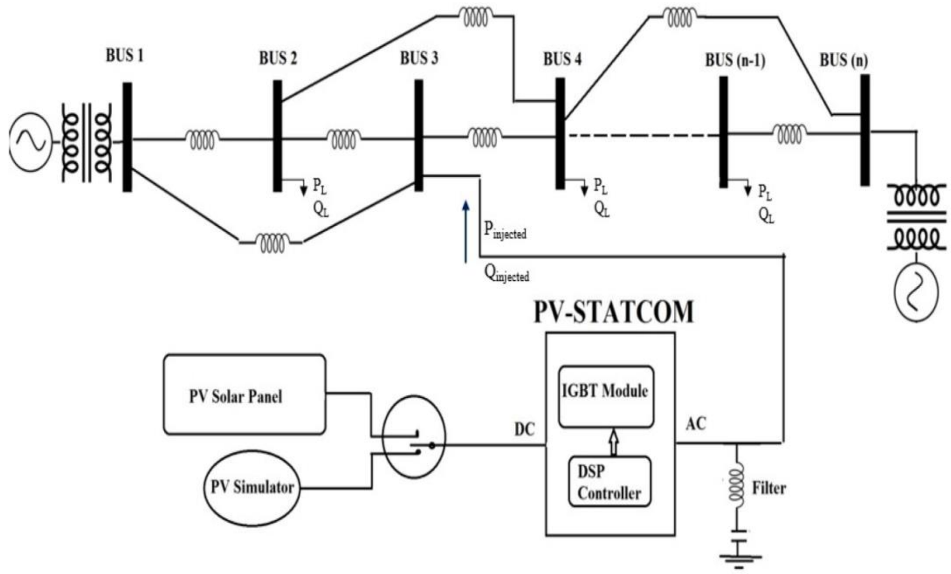

Figure 1. STATCOM device

3.1. PROBLEM FORMULATION

A second-generation FACT device called the STATCOM is employed in numerous areas to regulate voltage variation and lower energy consumption. On the other hand, the converter absorbs slack current from the AC framework if the yield voltage of the convertible is not precisely the corresponding AC structure transit level. The accompanying figure 2 shows the STATCOM schematic diagram.

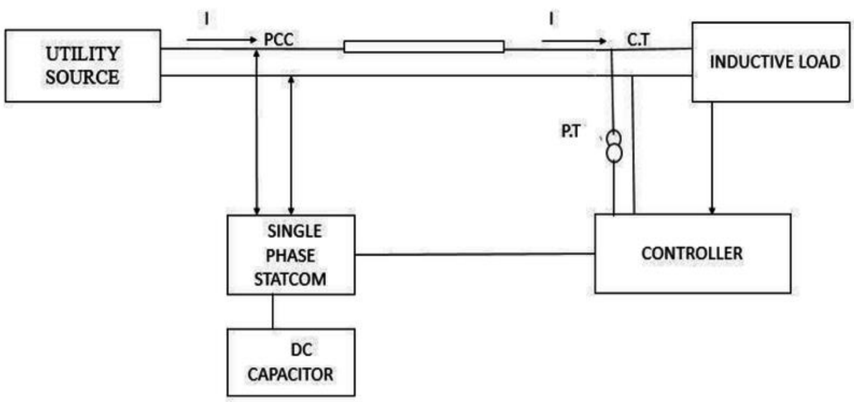

Fig. 2. Figure 1: STATCOM device block diagram

It is desirable to keep voltage variations inside state at or below 5% of their base case size in order to maintain the safe operation of an intensity framework. Improved voltage profiles, fewer power losses, lower energy loss costs, better voltage stability margin, lower energy loss costs, lower D-STATCOM installation costs, and total savings are gained for UK 38 [11]. The excessive requirement to boost the voltage at the comparing transport will typically result in a STATCOM providing an additional voltage boost if it drops below 0.89p.u. The appropriate location of STATCOM in this study will be determined by using GSA to maintain load transport voltages inside of 5% of each base case value individually [15]. The major objective of this research project is to improve power system architecture performance while minimising power loss.To do this, the STATCOM devices are strategically placed to minimise power loss and installation costs.

3.1.1. POWER LOSS

We can calculated the power loss with the given formula

$$\mathrm{Power_{loss}} = \sum_{i=1}^{b} R_i I_i^2 = \sum_{i=1}^{b} \sum_{j=1, i\neq j}^{b} \left[V_i^2 + V_j^2 - 2V_iV_j\cos(\theta_i - \theta_j)\, Y_{ij}\cos\Phi_{ij}\right]$$

Where

b ➔ number of buses

R_i ➔ Resistance

I_i ➔ current through line i

V_i ➔ Voltage magnitude at bus i

θ_i ➔ Angle at bus i

Y_{ij} ➔ magnitude of line intersection

Φ_{ij} ➔ Angle of line intersection

3.1.2. Cost of Installation

The cost function must be taken into consideration during installation because, as was already indicated, STATCOM devices are among the most expensive. This is done to provide consumers with a cost-free environment. The following is a list of the steps for cost computation:

$$\mathrm{InstallationCost_{Yearly}} = K_e . E_{loss} + \sum_{j=1}^{N} B_j(K_b + K_a(S_{STATCOM}))$$

Where

E_{loss} ➔ Total energy loss

K_e ➔ average cost of unsold energy

K_a ➔ deprivation of installation

K_b ➔ Maintenance cost

B_j ➔ binary variable

$S_{STATCOM}$ ➔ Size

3.2. Gravitational Search Algorithm for Optimal Location Prediction

The gravitational search technique is used in this study to forecast the STATCOM devices' ideal locations. Operators are taken into account as a transport number in the suggested computation, and their display is calculated using their capacity misfortune. The force of gravity pulls each of these items toward the others, and as a result, all of these objects move collectively in the direction of the objects with heavier masses. Because of this, masses can directly communicate with one another through the effects of gravity. The heavier masses travel faster than the heavier ones, which assures that the computation will not be used improperly [12]. Significant masses associated with huge arrangements move more slowly. A wellness work is used to resolve its gravity and inertial masses, and the problem's answer is correlated with the mass's situation. Each mass appears to have a solution, so to speak, and the calculation is checked by appropriately changing the gravity and inactive masses. We believe that the largest mass will pull in smaller masses over time. This mass will display an optimal configuration in the search area. The GSA could be viewed as a disjointed collection of masses. It resembles a miniature fake cosmos where the masses move and attract according to Newton's rules. More conclusively, people adhere to the laws that go with them:

According to the law of gravity, every molecule attracts every other molecule, and the gravitational force between two particles is inversely proportional to their distance from one another, or R. We choose R over R2 because, according to the findings of our investigation, R produces better results than R2 in every trial case [14].

The law of motion states that every mass's current speed is equal to the sum of its past speed divided by the speed variations.The theoretical maximum capacitor voltage ripple limit is determined, as well as the lowest allowable dc capacitance values for the converter. The suggested low-capacitance StatCom enables efficient operation of large capacitor voltage ripples that are very close to the estimated theoretical maximum voltage ripple [16]. Any mass's ability to move at a different speed or accelerate is equivalent to the force exerted on a framework that is isolated by a mass in dormancy.

$$X_i = (x_i^1, \ldots, x_i^d, \ldots, x_i^n) \text{ for } i = 1,2, \ldots, N$$

Where x_i^d ➔ Position of agent

$$F_{ij}^d = G(t)\frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t) + \varepsilon}(x_j^d(t) - x_i^d(t))$$

Where

M_{aj} ➔ active gravitational mass

M_{pi} ➔ passive gravitational mass

$G(t)$ ➔ gravitational constant

ε ➔ small constant

$R_{ij}(t)$ ➔ Euclidean distance

$$R_{ij}(t) = \|X_i(t).X_j(t)\|_2$$

$$F_i^d(t) = \sum_{j=1, j\neq i}^{N} \text{rand}_j F_{ij}^d(t)$$

Where rand_i ➔ random number with [0,1] interval

$$a_i^d(t) = \frac{F_i^d(t)}{M_{ij}(t)}$$

Where M_{ij} ➔ inertial mass

$$v_i^d(t+1) = rand_i \times v_i^d(t) + a_i^d(t)$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1)$$

Where $rand_i$ ➔ uniform random variable

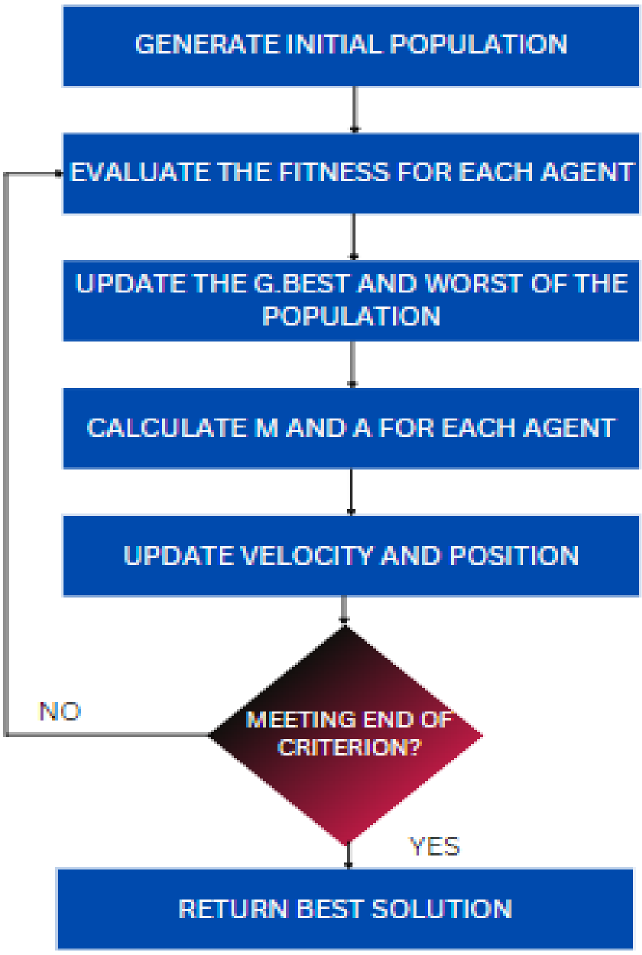

Figure 3. GSA algorithm

The following are the different calculations steps of the suggested calculation:

Search space ID (a).

Introduction through randomization (b).

(c) A specialist's fitness evaluation.

For I = 1, 2,..., N, update G(t), best(t), worst(t), and Mi(t).

(e) Various methods of calculating the total power

(f) Calculation of speed and acceleration.

(g) Changing the position of operators.

(h) Continue performing steps c through g until the stop criteria is reached. (I) End.

IV. RESULTS AND DISCUSSION

In the IEEE 30-Bus framework, the GSA computation is actualized to determine the STATCOM's optimal location. There are 41 lines, 5 PV transports, 24 PQ transports, and 1 leeway transport in this framework. In the base situation, voltage is slightly above 1 p.u. at all transports with the exception of transport no. 40 (0.8853 p.u), proving the validity of the framework. However, during single line blackouts there is a chance that particular transports could abuse the voltage point of confinement state, as shown by VPI.For 37 of 41 lines, the Newton-Raphson Load Flow Program merged. Table 1 and Table 2 show the results of a potential study into the Voltage Performance Index and BUS blackouts, respectively. The synchronism of the generators can be maintained by the FACTS devices notwithstanding any type of disturbance. The dynamic stability of the power system can be greatly enhanced by STATCOM, a FACTS component [13]. The lines in the execution file that are typically cut off are 36, 4, and 5. The optimal area has been determined using GSA calculation. The optimal reactive power dispatch (ORPD) problem has a substantial impact on the optimal functioning of power systems. However, it is challenging for the researchers to find the optimum solution to the ORPD problem. The introduction of flexible AC transmission system (FACTS) components in the power system network to address the ORPD issue adds to its complexity [17]. There are 24 specialists (or the number of burden shipments) who are taken into account while determining the STATCOM's best location, each with a different estimate of the location.200 of the largest cycles are used for the GSA computation. The operator with STATCOM area at transport 26 and 30 has acquired the global ideal arrangement in this way, which has a global best value of 801.8436. Line 36's VPI is increased to 0.0359. In table 4, values of 0.0157 from 0.6304 for line 4 and 0.8773 from 0.8773 are shown.

Table 1. Contingency Ranking

LINE NO	VPI	RANKING	LINE NO	VPI	RANKING
1	1.1008	5	22	1.1223	27
2	1.107	6	23	1.1221	28
3	1.1151	50	24	1.1221	29
4	1.7414	2	25	1.1221	44
5	1.6147	3	26	1.1221	45
6	A	49	27	1.1222	46
7	1.1505	7	28	1.1222	35
8	1.125	10	29	1.1223	36
9	1.1303	9	30	1.1223	30
10	1.1451	33	31	1.1222	31
12	1.122	47	32	1.1223	37
13	1.1222	34	33	1.1222	32
14	1.1218	48	34	1.1395	38
15	1.1244	20	35	1.1222	8
16	1.1128	51	36	1.9883	39
17	1.1223	25	37	1.1222	1
18	1.1242	22	38	1.4222	40
19	1.1224	23	39	1.1222	4
20	1.1223	24	40	1.1222	41
21	1.1223	26	41	1.1222	42

Table 2- Bus Voltages

BUS NO	VOLTAGE	BUS NO	VOLTAGE
1	2.17	16	2.1461
2	2.1531	17	2.14
3	2.1304	18	2.1284
4	2.1181	19	2.135
5	2.12	20	2.1305
6	2.2228	21	2.1295
7	2.116	22	2.1283
8	2.12	23	2.1156
9	2.154	24	1.0945
10	2.1465	25	1.0366
11	2.193	26	1.0268
12	2.1547	27	1.0129
13	2.182	28	2.1225
14	2.1461	29	1.9005
15	2.1462	30	1.9755

After locating the STATCOM, the transport voltages are enlarged by keeping an eye on tables 2 and 3. Additionally, thanks to STATCOM, the presentation record is increased from tables 1 and 4 and the seriousness of the transmission lines is reduced.

Table 3. Bus voltages following the STATCOM position

BUS NO	VOLTAGE	BUS NO	VOLTAGE
1	2.16	16	2.1581
2	2.153	17	2.1525
3	2.1364	18	2.1414
4	2.1281	19	2.1387
5	2.12	20	2.1427
6	2.1258	21	2.1455
7	2.116	22	2.146
8	2.12	23	2.1406
9	2.164	24	2.1347
10	2.1577	25	2.1313
11	2.193	26	2.1137
12	2.1709	27	2.1379
13	2.182	28	2.1238
14	2.156	29	2.1181
15	2.1512	30	1.0067

Table 4. VPI for lines 36, 4 and 5 improved after STATCOM was placed.

LINE NO	VPI
47	1.1469
5	1.1169
6	1.138

The next figure 4 displays the actual power that was attained throughout our simulation.

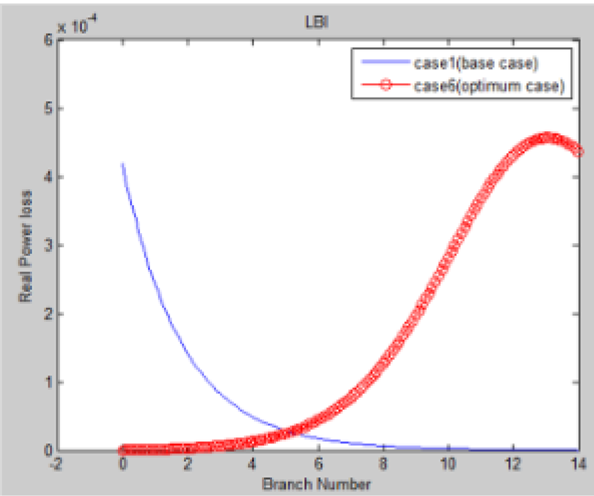

Figure 4. Comparison of the actual power loss before and after putting STATCOM

Table 5. Voltage enhancement and values for the angles

VOLTAGE IMPROVEMENT	ANGLE DEGREE	BUS NO	VOLTAGE IMPROVEMENT	ANGLE DEGREE
2.17	1.1111	16	2.1426	-26.7078
2.1541	-6.4636	17	2.1313	-26.9533
2.1311	-8.6429	18	2.1239	-27.6892
2.1219	-10.3959	19	2.1191	-27.8482
2.1211	25.2803	20	2.1221	-27.6334
2.1212	-22.1738	21	2.1213	-27.3063
2.1134	-23.9766	22	2.1248	26.0766
2.1211	-22.9279	23	2.1217	-27.3195
2.1513	-25.1619	24	2.1144	-27.4177
2.1342	-26.7566	25	2.1236	-27.2716
2.1931	-25.1619	26	2.1111	-27.8905
2.1614	-26.2046	27	2.1351	-26.8223
2.1821	-26.2046	28	2.1202	-22.8545
2.1441	-26.0802	29	2.1187	-28.147
2.1374	26.092	30	2.1111	-29.1316

4.1. NUMERICAL ASSESSMENT

In order to demonstrate the improvement in the planned research study's performance, comparison assessment is used in this work. The comparison is made using three popular research methodologies: the chemical reaction approach (CRA), PSO, and CSA [15]. These previous studies are contrasted with the GS-STATCOM-LI approach that has been suggested. In this study, the comparison evaluation takes into account both the transmission loss and the voltage stability index. The comparison evaluation of the current and suggested research approaches is shown in figures 5, 6, 7, and 8 below. In this instance, two situations are compared. With STATCOM and without STATCOM, respectively.

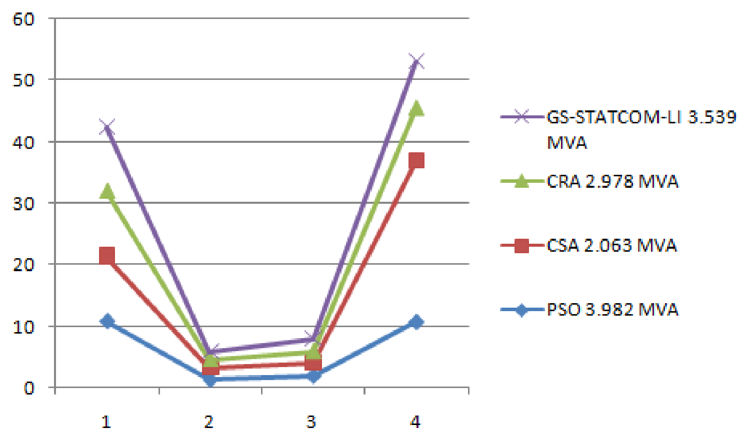

Figure 5. Transmission Loss comparison without STATCOM

Figure 5 depicts the proposed research technique's convergence feature. This comparison demonstrates that the suggested approach typically has lower transmission loss than the other study methodologies. According to this analysis, the proposed GS-STATCOM-LI exhibits transmission losses that are 4.30% lower than those of the CRA, 13.17% lower than those of the CSA, and 16.82% lower than those of the PSO.

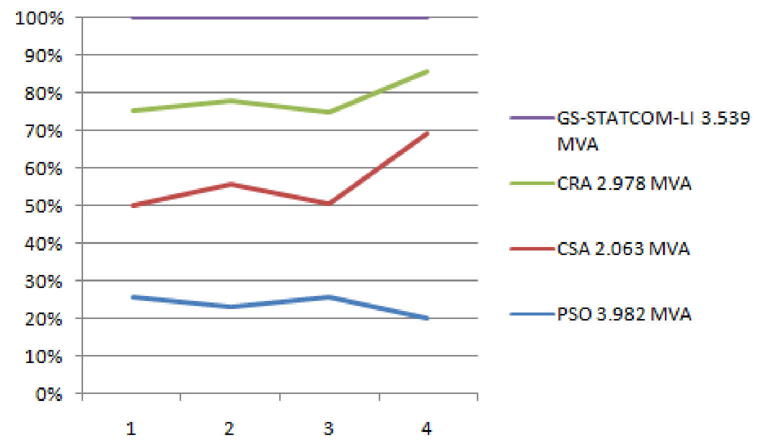

Figure 6. Transmission Loss vs STATCOM Comparison

Figure 6 displays the proposed research technique's convergence feature. This comparison demonstrates that the suggested approach typically has lower transmission loss than the other study methodologies. According to this analysis, the proposed GS-STATCOM-LI exhibits transmission losses that are 6.06% lower than those of the CRA, 17.88% lower than those of the CSA, and 22.5% lower than those of the PSO.

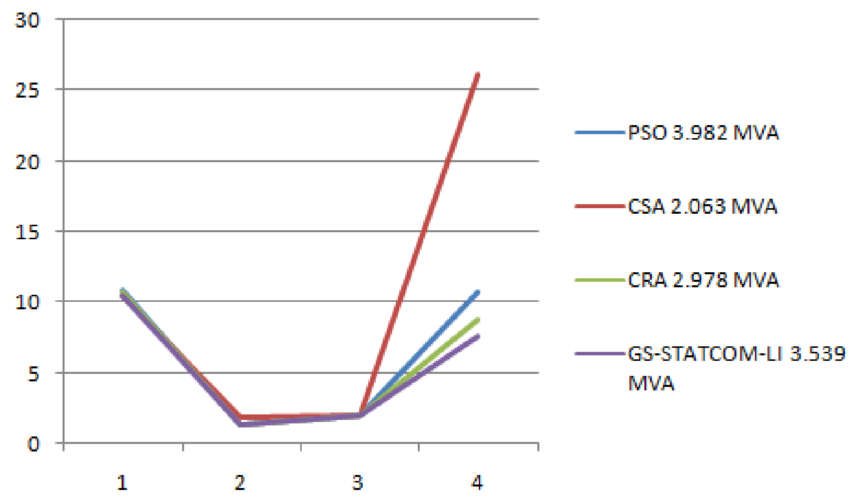

Figure 7. Comparison of the Voltage Stability Index without STATCOM

Figure 7 displays the voltage stability index of the suggested study method without STATCOM. This analysis confirms that the proposed GS-STATCOM-LI exhibits stability index loss that is 3.27% lower than that of the CRA, 5.92% lower than that of the CSA, and 10.37% lower than that of the PSO.

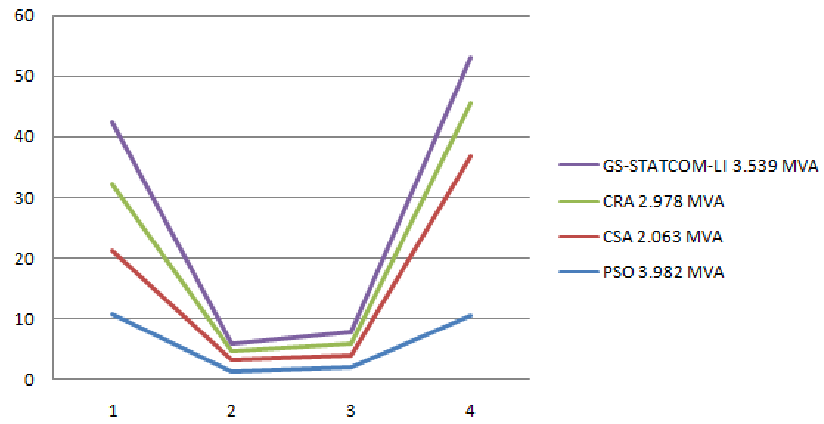

Figure 8. Comparison of the Voltage Stability Index with STATCOM

Figure 8 displays the voltage stability index of the suggested study method with STATCOM. This comparison demonstrates that the suggested approach typically has a lower stability index than the other research methodologies. This analysis confirms that the proposed GS-STATCOM-LI displays a stability index loss of 5.04% less than the CRA, 8.43% less than the CSA, and 14.75% less than the PSO.

Table 6. Comparison results of different methods

Objective Functions	PSO	CSA	CRA	GS-STATCOM-LI
Size	2.871 MVA	1.952 MVA	1.867 MVA	2.428 MVA
Total Power Loss (MW)	9.74	9.38	9.56	9.3
Voltage Deviation	0.248	0.1897	0.207	0.164
Fitness Function Value	0.99	0.8654	0.8962	0.841
Computational Time (S)	9.61	13.9	7.56	6.43

V. CONCLUSION

On this study, the gravitational search method is used to forecast where STATCOM devices should be placed in the IEEE bus lines in order to optimise voltage profiles effectively. By using the installation cost and power loss as fitness characteristics, the best placement is predicted.he system power factor is used to represent how the power system performs in various scenarios, including those with and without distributed generation (DG), DGs of various types, STATCOM integration, and DG, STATCOM, and PHEV integration in distribution systems with DSLMs [18]. It has been established through the implementation of the full study project in the Matlab simulation environment that the suggested strategy ensures effective voltage power loss reduction. The outcome shows a considerable power loss decrease.

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