

Optimasi Penempatan *Thyristor Controlled Series Capacitor* (TCSC) Menggunakan Algoritma *League Championship Algorithm* (LCA)

Optimization of Thyristor Controlled Series Capacitor (TCSC) Placement Using the League Championship Algorithm (LCA) Algorithm

Bagus Fatkhurrozi¹, Hery Teguh Setiawan*², Mokhammad Nurkholis Abdillah³

^{1,2} *Department Electrical, Mechatronic, and Information Engineering, Universitas Tidar
Jl. Kapten Suparman No. 39 Magelang*

*²Corresponding author: hery.teguh.s@untidar.ac.id
¹bagusf@untidar.ac.id, ³mnurkholisabdillah@untidar.ac.id

Received on 13-06-2025, accepted on 04-12-2025, published on 31-01-2026

Abstrak

Meningkatnya kebutuhan energi listrik di Indonesia menyebabkan operasional jaringan transmisi mengalami stress hingga pada batas stabilitas yang diperbolehkan. Perubahan konfigurasi saluran transmisi dapat dijadikan sebagai solusi permasalahan tersebut. Perubahan konfigurasi saluran transmisi menyebabkan permasalahan stabilitas tegangan pada saluran transmisi. Faktor utama yang menyebabkan permasalahan stabilitas tegangan adalah batasan daya reaktif generator, karakteristik beban, serta karakteristik kompensator yang terpasang pada saluran transmisi. Peningkatan profil tegangan pada saluran transmisi dapat dilakukan dengan menambahkan perangkat *Flexible Alternating Current Transmission System* (FACTS). Penentuan lokasi dan kapasitas FACTS merupakan hal yang sangat penting untuk diperhitungkan mengingat biaya investasi peralatan tersebut yang relatif mahal. TCSC merupakan salah satu perangkat FACTS yang lebih sederhana, serta dapat dikendalikan dengan mudah dibandingkan dengan peralatan FACTS lainnya. Penempatan FACTS didasarkan pada nilai VSI tertinggi, yaitu jika VSI bernilai 1 pu. Hasil perhitungan menunjukkan terdapat 3 lokasi kandidat penempatan FACTS, yaitu bus 9, 10, dan 14. Implementasi algoritma *League Championship Algorithm* (LCA) dalam menentukan lokasi optimal peletakan perangkat FACTS telah mampu mengurangi rugi-rugi daya. Rugi-rugi daya terkecil ada pada beban normal dan kehilangan terbesar ada pada beban 150%. Pembebanan dilakukan pada kondisi normal, beban 125%, 140%, dan 150%. Beberapa kondisi pembebanan pada sistem IEEE 14 BUS telah menunjukkan tegangan yang lebih stabil setelah pemasangan FACTS.

Kata kunci: FACTS, LCA, stabilitas tegangan, transmisi

Abstract

The increasing demand for electrical energy in Indonesia has caused transmission network operations to experience stress to the point of exceeding the permissible stability limits. Changes in transmission line configurations can be used as a solution to this problem. Changes in transmission line configurations cause voltage stability problems in transmission lines. The main factors causing voltage stability problems are: generator reactive power limitations, load characteristics, and the characteristics of compensators installed on the transmission line. Improving the voltage profile in transmission lines can be done by adding Flexible Alternating Current Transmission System (FACTS) devices. Determining the location and capacity of FACTS is very important to consider considering the relatively high investment costs of this equipment. TCSC is one of the simpler FACTS devices, and can be

controlled easily compared to other FACTS devices. FACTS placement is based on the highest VSI value, namely if the VSI is 1 pu. The calculation results show that there are 3 candidate locations for FACTS placement, namely buses 9, 10, and 14. The implementation of the League Championship Algorithm (LCA) algorithm in determining the optimal location for FACTS device placement has been able to reduce power losses. The smallest power losses occur at normal load and the largest losses occur at 150% load. Loading was carried out at normal conditions, 125% load, 140% load, and 150%. Several loading conditions on the IEEE 14 BUS system have shown more stable voltages after the installation of FACTS.

Keywords: FACTS, LCA, transmission, voltage stability

I. INTRODUCTION

The need for electrical energy in Indonesia increases every year. This causes the transmission line to be forced to operate at its stability limit, so that the transmission line experiences considerable stress. Changing the configuration of transmission lines is one method of reducing stress on the transmission network. Changes in transmission network configuration cause problems due to voltage instability on transmission lines. Voltage stability is the ability of an electric power transmission system to maintain the voltage on each bus in accordance with established standards[1], [2], [3].

The main factors that influence voltage stability in the transmission system are the generator's reactive power limitations, the characteristics of the connected load, and the characteristics of the reactive power compensator equipment. To improve the voltage profile and voltage stability of the system, this can be done by installing a Flexible Alternating Current Transmissions System (FACTS) on the transmission line[4], [5], [6]. FACTS is a very important device on the transmission line. FACTS placement must be calculated as well as possible considering the very expensive FACTS investment costs. In this regard, studies are needed to optimize the location and size of the FACTS device to obtain optimal investment costs.

Thyristor Controlled Series Capacitor (TCSC) is a FACTS device that can be used to reduce the power flow produced on transmission lines which results in increased loadability, reduced system losses, congestion management and increased stability[7], [8]. TCSC is a FACTS device that is easy to control compared to other devices[9], [10], [11].

In determining the most optimal position and size of Thyristors Controlled Series Capacitors (TCSC) in the transmission system, metaheuristic techniques are used[12], [13]. The metaheuristic method is to use the League Championship Algorithm (LCA) algorithm. League Championship Algorithm (LCA) is a recently proposed stochastic population-based algorithm for continuous global optimization that attempts to emulate a championship environment where artificial teams play in an artificial league over several weeks (iterations)[14], [15], [16]. By applying the LCA algorithm, it is hoped that the installation of the Flexible Alternating Current Transmissions System (FACTS) on the transmission line will be more optimal.

II. LITERATURE REVIEW

The TCSC placement problem is a complex nonlinear optimization problem and requires an intelligent algorithmic approach. One of the new approaches that has developed is the League Championship Algorithm (LCA), which is inspired by the sports competition league system[17]. TCSC is one of the FACTS components that functions to regulate the series impedance on the transmission line through thyristor control of the series capacitor[18]. Thus, TCSC is able to increase power transfer capacity, reduce system losses, and increase dynamic stability[19].

Sub-optimal TCSC placement can cause increased losses and even system instability. Therefore, a reliable and efficient optimization technique is needed. LCA is a population-based metaheuristic algorithm developed by Kashan [20]. This algorithm models the process of competition between teams in a league. Each individual (solution) is considered as a team, and the algorithm iteration takes place in the form of a match between teams to improve the quality of the solution. LCA has several advantages, such as balanced exploration and exploitation capabilities and resistance to premature convergence that often occurs in algorithms such as GA and PSO[21].

The proposed research is different because it offers a new and more efficient approach in solving the TCSC placement problem. By utilizing the advantages of LCA in terms of convergence speed and robustness to local optimum, this research has the potential to make significant contributions to real

applications in modern power systems, especially in the context of the need for adaptive and responsive systems to dynamic changes.

III. RESEARCH METHOD

The research stages carried out were determining and creating a bus system using ETAP software. The bus system created is then analyzed using MATLAB software to obtain an objective function. The objective function obtained is then optimized using the league championship algorithm metaheuristic method. After the optimization results obtained have been verified, the data is collected and a report is prepared.

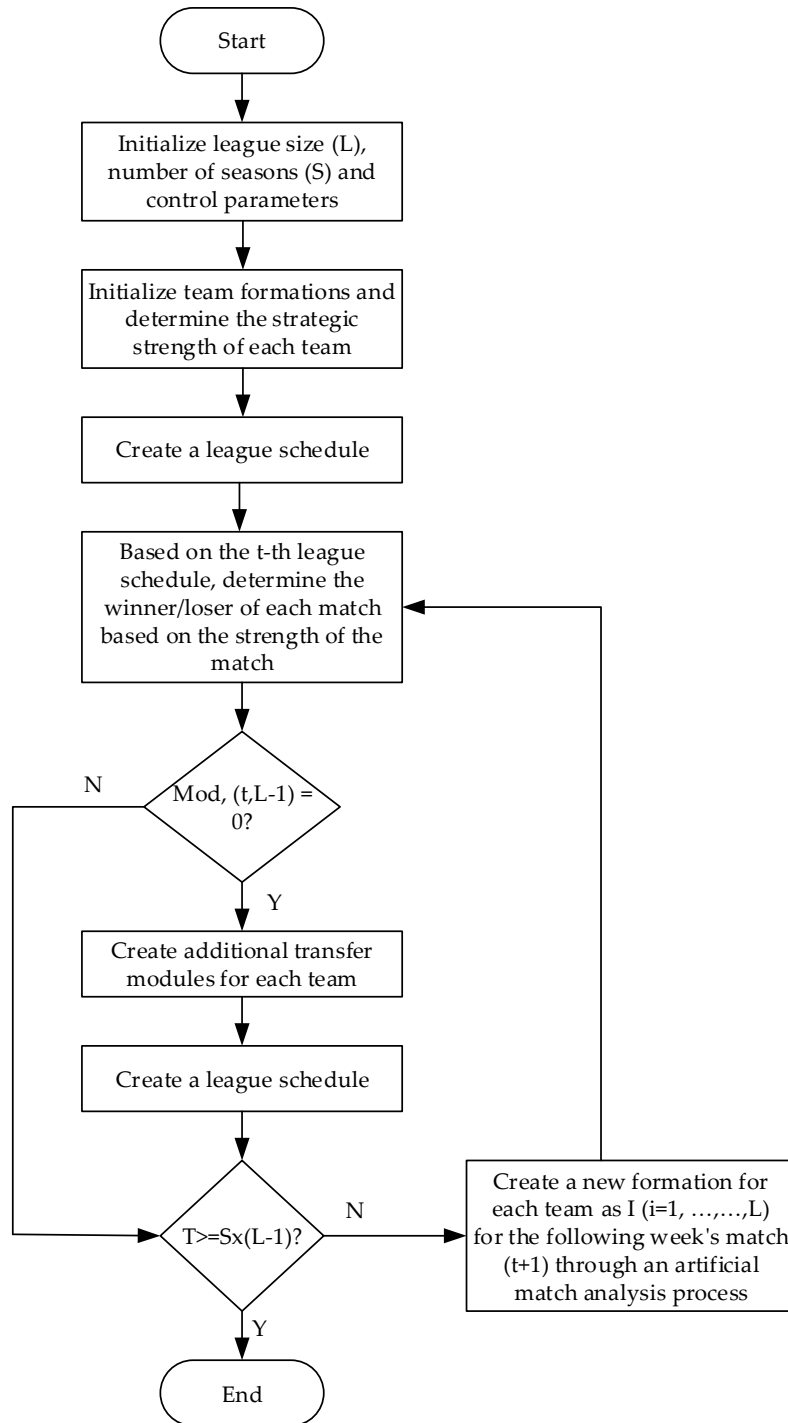


Fig. 1 Flowchart of League Championship Algorithm

The League Championship Algorithm (LCA) method used goes through several stages, namely initializing the league size, number of seasons (S), and control parameters. Then initialize the team formation randomly and determine the strength of each team. The formation of the league schedule is carried out using a single round-robin method so that each team will compete with other teams for each season. For a league consisting of L teams, the single round-robin method requires $L(L-1)/2$ matches. Based on the league schedule for week t, the team that wins/loses in each match is produced based on the playing strength of each team. then verify that in week t of a season there are no more matches, then a transfer module is added to each team. Then create a new league schedule for the next season's matches. Then the final optimization result is obtained when the stop criterion is met, namely $t \geq S(1-1)$ [22], [23], [24]. Flow diagram League Championship Algorithm (LCA) shown Fig.1.

IV. RESULTS AND DISCUSSION

A. Result

This section discusses IEEE 14 bus system modelling, Voltage Stability Index, and testing system..

1. IEEE 14 Bus system modeling

IEEE 14 Bus system modeling is carried out using Matlab software with standard parameters that have been determined in accordance with IE-EE14 BUS which consists of BUS data and channel data. Data using the IEEE 14 bus data-system line is shown in Table 1 and the IEEE 14 bus data-system bus in Table 1.

Table 1. Line data - sistem IEEE 14 bus[25]

Line Number	From bus	To bus	Line impedance (p.u.)		Half line charging susceptance (p.u.)	MVA rating
			Resistance	Reactance		
1	1	2	0,01938	0,05917	0,0264	120
2	1	5	0,05403	0,22304	0,0219	65
3	2	3	0,04699	0,19797	0,0187	36
4	2	4	0,05811	0,17632	0,0246	65
5	2	5	0,05695	0,17388	0,017	50
6	3	4	0,06701	0,17103	0,0173	65
7	4	5	0,01335	0,04211	0,0064	45
8	4	7	0	0,20912	0	55
9	4	9	0	0,55618	0	32
10	5	6	0	0,25202	0	45
11	6	11	0,09498	0,1989	0	18
12	6	12	0,12291	0,25581	0	32
13	6	13	0,06615	0,13027	0	32
14	7	8	0	0,17615	0	32
15	7	9	0	0,11001	0	32
16	9	10	0,03181	0,0845	0	32
17	9	14	0,12711	0,27038	0	32
18	10	11	0,08205	0,19207	0	12
19	12	13	0,22092	0,19988	0	12
20	13	14	0,17093	0,34802	0	12

Tabel 2. Bus data - IEEE 14 bus system[25]

Bus number	Bus voltage		Generation		Load		Reactive	
	Magnitude (p.u.)	Phase angle (degree)	Real power (MW)	Reactive power (MVAR)	Real power (MW)	Reactive power (MVAR)	Q_{min} (MVAR)	Q_{max} (MVAR.)
1	1.060	0	114,17	-16,9	0	0	0	10
2	1.045	0	40	0	21,7	12,7	-42	50
3	1.010	0	0	0	94,2	19,1	23,4	40
4	1	0	0	0	47,8	-3,9	-	-
5	1	0	0	0	7,6	1,6	-	-
6	1	0	0	0	11,2	7,5	-	-
7	1	0	0	0	0	0	-	-
8	1	0	0	0	0	0	-	-
9	1	0	0	0	29,5	16,6	-	-
10	1	0	0	0	9	5,8	-	-
11	1	0	0	0	3,5	1,8	-	-
12	1	0	0	0	6,1	1,6	-	-
13	1	0	0	0	13,8	5,8	-	-
14	1	0	0	0	14,9	5	-	-

Based on Table 1 and Table 2, a series of simulations for optimizing FACTS placement can be prepared optimally. The simulation series was created with Matlab Simulink software. The simulation circuit is shown in Fig.3.

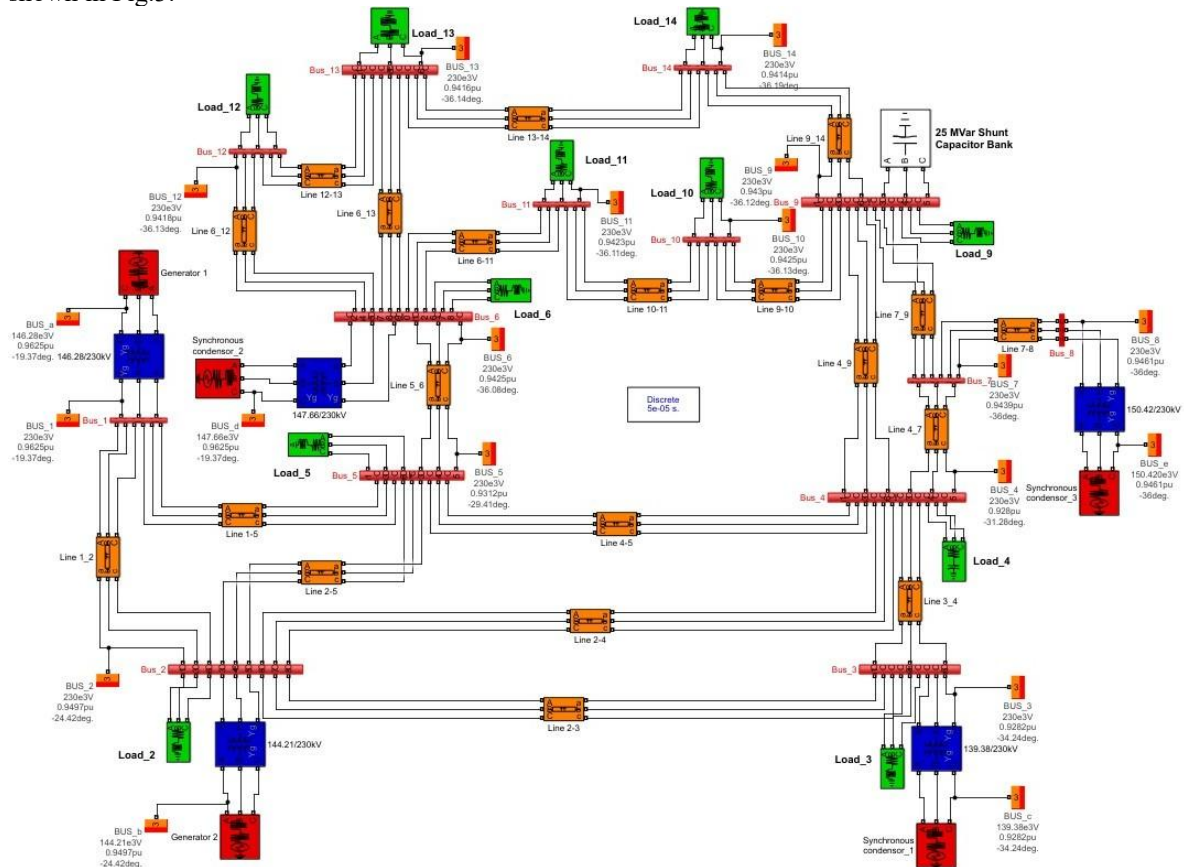


Fig. 3 Simulation of FACTS placement with Matlab Simulink

2. Voltage Stability Index (VSI)

Determining the optimal location for FACTS is a crucial step due to the high investment costs. In this study, the criteria for determining the most optimal FACTS location are based on the highest Voltage Stability Index (VSI) value. Determining the optimal position for FACTS placement requires calculating the voltage stability index (VSI) on the IEEE14 BUS system using the equation (1)[26], [27]:

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

In the context of this study, the VSI is calculated for each bus that is not a slack bus or generator (load bus). The bus with the highest VSI value (closest to the unstable value) is considered the most critical location and requires FACTS intervention.

- a. The FACTS placement criteria are: The bus with the highest VSI.
- b. The ideal (perfectly stable) VSI value is 1 pu.

The further a bus's VSI value is from 1, the more stable it is. Conversely, the lower a bus's VSI value (closer to 0 or negative in some formulations), the closer it is to the voltage collapse limit, making it the weakest bus. In this study, the bus with the highest (weakest) value was selected for FACTS installation.

Based on the calculations performed, the LCA algorithm (which uses VSI as part of its objective function) identifies the buses with the most critical VSI. The VSI calculation results for the IEEE 14 BUS system indicate that there are three prime candidate locations for FACTS placement: bus 9, bus 10, and bus 14

Placing FACTS at these locations aims to achieve better voltage profiles and stability, which are then verified through testing under various load conditions (normal, 125%, 140%, 150%).

Table 3. VSI calculation results for the IEEE 14 Bus system

Bus	VSI normal	Load 125%	Load 140%	Load 150%
4	0,676	0,714	0,714	0,722
5	0,806	0,695	0,705	0,705
7	0,700	0,687	0,695	0,695
9	1,000	1,000	1,000	1,000
10	1,000	1,000	1,000	1,000
11	0,512	0,509	0,497	0,495
12	0,48	0,507	0,465	0,464
13	0,435	0,431	0,439	0,437
14	1,000	1,000	1,000	1,000

3. Testing System

One of the advantages of installing FACTS is to reduce power losses and improve the system voltage profile. Table 4 shows the results of reducing power losses before and after installing FACTS on Buses 9, 10 and 14.

Table 4. Reduction of power losses after installing FACTS

Conditions	Power Loss Before Installation of FACTS (MW)	Power Loss After Installation of FACTS (MW)	Power Loss Reduction (MW)
Normal	13,5766	13,3741	0,2025
Load 125%	23,0880	22,2621	0,8259
Load 140%	30,3052	29,0668	1,2384
Load 150%	36,0280	34,5264	1,5016

From Table 4 it can be seen that the smallest power loss is at normal load and the largest loss is at 150% load. The condition of the line voltage profile before and after FACTS installation for several loading conditions can be seen in Table 5.

Test results show better stress stability after installing FACTS, both under normal conditions, loading 125%, 140% and 150%. Based on these circumstances, it can be concluded that the implementation of the League Championship Algorithm (LCA) algorithm in determining the optimal location for placing FACTS devices has been able to reduce power losses and increase voltage stability in several loading conditions on the IEEE 14 BUS system.

Table 5. Voltage profile before and after FACTS installation

Bus No	Normal Load		Load 125%		Load 140%		Load 150%	
	Before FACTS	After FACTS	Before FACTS	After FACTS	Before FACTS	After FACTS	Before FACTS	After FACTS
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

B. Discussion

1. FACTS vs. Traditional Transmission Control Techniques

FACTS devices are a relatively new technology that provides fast and flexible control of transmission system parameters such as line impedance, phase angle, and voltage. FACTS, compared to traditional transmission control techniques (such as the addition of new transmission lines, shunt capacitors, or mechanically operated reactors), has several key advantages:

- a. **Faster Response:** FACTS devices (such as the TCSC discussed in this study) use thyristors (power semiconductor components) that enable control of series impedance or reactive power at very high speeds, typically within a single cycle. Traditional techniques often involve slower switching mechanisms or permanent physical changes.
- b. **Better Asset Utilization:** FACTS can increase the power transfer capacity of existing transmission lines, reducing the need for expensive and difficult-to-permit new lines.
- c. **Improved Stability:** FACTS can improve the dynamic stability of the power system, including voltage stability. Traditional techniques may focus on only one aspect (e.g., power factor correction) without offering comprehensive stability improvements.
- d. **Loss Reduction:** With better control over power flow, FACTS can reduce power losses on transmission lines.

The Thyristor Controlled Series Capacitor (TCSC) is a simpler and easier-to-control FACTS device compared to other FACTS devices. Its primary function is to regulate the series impedance on the transmission line by controlling the thyristor in the series capacitor.

2. LCA Algorithm Factors for FACTS Optimization

The League Championship Algorithm (LCA) is a population-based metaheuristic method inspired by sports league systems. The application of LCA in this study aims to optimize the location and size of FACTS (TCSC). The main factors (parameters) in the LCA algorithm that significantly support the use and optimization of FACTS placement are:

a. Solution Representation (Team)

In LCA, each individual/solution (in this context, the combination of FACTS placement location and capacity) is represented as a team. Support for FACTS: The FACTS location and capacity determination problem is a complex nonlinear optimization problem because it involves both discrete variables (bus/channel locations) and continuous variables (device capacity). The team-based structure of LCA allows for a flexible representation of this multi-variable solution, where the "strength" of a team can be measured based on an objective function (e.g., minimizing power losses and improving voltage stability).

- b. **Competition and Solution Improvement Mechanism (Match)**
The algorithm operates through seasons or iterations, where teams compete in matches using a single round-robin method. Support for FACTS: Matches and win/loss outcomes effectively encourage exploration (search for new solutions) and exploitation (improvement of the current best solution) within the search space. This is crucial for FACTS because suboptimal TCSC placement can lead to increased losses and even system instability. The LCA mechanism ensures a reliable and efficient search to find the most optimal position and size.
- c. **Transfer Module**
After a week's matches are completed, a transfer module is added to each team. Support for FACTS: This transfer module is a mechanism for refining or modifying the current solution (FACTS position and capacity). This helps the algorithm avoid premature convergence to a local optimum, which often occurs in other metaheuristic algorithms such as GA and PSO. The advantages of LCA in terms of convergence speed and robustness to local optimum are crucial for finding a truly optimal FACTS configuration, given the very high investment costs of FACTS equipment.

This study uses LCA to optimize FACTS placement, demonstrating the following evidence:

- a. **Improved Voltage Stability:** Test results demonstrate improved voltage stability after FACTS (TCSC) installation, even under increased load conditions (125%, 140%, and 150%).
- b. **Reduced Power Losses:** Implementing LCA to determine the optimal location for FACTS placement has significantly reduced power losses.
- c. **Optimal Location Determination:** LCA determines the location of FACTS based on the highest Voltage Stability Index (VSI), identifying buses 9, 10, and 14 as candidate locations.

Overall, the LCA algorithm provides a metaheuristic framework that balances exploration and exploitation to efficiently solve complex FACTS placement problems, aiming to reduce power losses and improve voltage stability.

V. CONCLUSION

The implementation of the League Championship Algorithm (LCA) algorithm in determining the optimal location for placing FACTS devices has been able to reduce power losses. Loading is carried out under normal conditions, loads of 125%, 140% and 150%. Several loading conditions on the IEEE 14 BUS system have shown voltage stability in conditions after FACTS installation. Next, other algorithms can be added so that the results can be more optimal.

ACKNOWLEDGMENT

The author would like to thank Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) Universitas Tidar for funding the research of madya in 2023.

AUTHOR CONTRIBUTION

BFZ constructed the study design and prepared the manuscript. HTS and MNA performed and analyzed the data. MNA revised the final version of the paper. BFZ and HTS have read the final manuscript and approved the submission. BFZ, HTS, and MNA are the abbreviation of First, Second, and Third Author respectively.

REFERENCES

- [1] R. Gadal, A. Oukennou, F. El Mariami, A. Belfqih, and N. Agouzoul, "Voltage Stability Assessment and Control Using Indices and FACTS: A Comparative Review," *Journal of Electrical and Computer Engineering*, vol. 2023, pp. 1–18, Aug. 2023, doi: 10.1155/2023/5419372.
- [2] S. Mokred, Y. Wang, and T. Chen, "Modern voltage stability index for prediction of voltage collapse and estimation of maximum load-ability for weak buses and critical lines identification," *International Journal of Electrical Power & Energy Systems*, vol. 145, p. 108596, Feb. 2023, doi: 10.1016/j.ijepes.2022.108596.
- [3] H. S. Salama and I. Vokony, "Voltage stability indices—A comparison and a review," *Computers & Electrical Engineering*, vol. 98, p. 107743, Mar. 2022, doi: 10.1016/j.compeleceng.2022.107743.
- [4] A. Carbonara, S. Dambone Sessa, A. L'Abbate, F. Sanniti, and R. Chiumeo, "Comparison of Advanced Flexible Alternating Current Transmission System (FACTS) Devices with Conventional Technologies for Power System Stability Enhancement: An Updated Review," *Electronics*, vol. 13, no. 21, p. 4262, Oct. 2024, doi: 10.3390/electronics13214262.

- [5] E. Mohamed, A. Hellal, A. Souli, and R. D. Mohammedi, "The Impact Study of Flexible Alternating Current Transmission System on Transient Stability of Power Systems Using MATLAB CODE and Power World Simulator," *ITEGAM*, vol. 10, no. 50, 2024, doi: 10.5935/jetia.v10i50.1300.
- [6] M. Tarafdar Hagh, M. A. Jabbar Borhany, K. Taghizad-Tavana, and M. Z. Oskouei, "A Comprehensive Review of Flexible Alternating Current Transmission System (FACTS): Topologies, Applications and Innovative Models," *Heliyon*, p. e41001, Dec. 2024, doi: 10.1016/j.heliyon.2024.e41001.
- [7] Y. Feng, W. Huang, Z. Jin, Y. Li, Z. J. Shen, and Z. Shuai, "Voltage Support Strategy for Improving Power Transfer Capability of Grid-Connected Converter Under Unbalanced Conditions," *IEEE Trans. Power Electron.*, vol. 39, no. 7, pp. 7863–7875, Jul. 2024, doi: 10.1109/TPEL.2024.3380626.
- [8] D. M. Teferra and L. Ngoo, "Improving the voltage quality and power transfer capability of transmission system using FACTS controller," *International Journal of Energy and Power Engineering*, vol. 10, no. 1, pp. 10–19, 2021.
- [9] S. Alshehri et al., "Impact of Advanced Thyristor Controlled Series Capacitor on Load Frequency Control and Automatic Voltage Regulator Dual Area System with Interval Type-2 Fuzzy Sets-PID Usage," *Processes*, vol. 12, no. 12, p. 2647, Nov. 2024, doi: 10.3390/pr12122647.
- [10] F. Cao, L. Hu, J. Zhang, R. A. Almenweer, J. Alnasseir, and F. Almaghout, "Study on Power Flow Improvement Using Static Compensators and Thyristor Controlled Series Capacitor in Transmission Network," in *2023 5th International Conference on Electrical Engineering and Control Technologies (CEECT)*, Chengdu, China: IEEE, Dec. 2023, pp. 354–359. doi: 10.1109/CEECS59667.2023.10420634.
- [11] H.-K. Ku, H.-I. Kwon, J.-Y. Song, S.-C. Oh, and J.-H. Shin, "Analysis of the System Impact upon Thyristor Controlled Series Capacitor Relocation Due to Changes in the Power System Environment," *Energies*, vol. 16, no. 2, p. 722, Jan. 2023, doi: 10.3390/en16020722.
- [12] S. Kaur, Y. Kumar, A. Koul, and S. Kumar Kamboj, "A Systematic Review on Metaheuristic Optimization Techniques for Feature Selections in Disease Diagnosis: Open Issues and Challenges," *Arch Computat Methods Eng*, vol. 30, no. 3, pp. 1863–1895, Apr. 2023, doi: 10.1007/s11831-022-09853-1.
- [13] V. Kumar and S. M. Yadav, "A state-of-the-Art review of heuristic and metaheuristic optimization techniques for the management of water resources," *Water Supply*, vol. 22, no. 4, pp. 3702–3728, Apr. 2022, doi: 10.2166/ws.2022.010.
- [14] S. Akhemi, A. Husseinzadeh Kashan, and B. Ostadi, "Effective league championship algorithm and lower bound procedure for scheduling a single batch-processing machine with non-identical job sizes and job rejection," *RAIRO-Oper. Res.*, vol. 57, no. 3, pp. 1453–1479, May 2023, doi: 10.1051/ro/2023050.
- [15] D. Benkhetta, A. Rouina, and A. Necira, "The League Championship Algorithm (LCA) for optimal placement and sizing of shunt capacitors," *SEES*, vol. 5, no. 2, p. e6975, Aug. 2024, doi: 10.54021/seesv5n2-124.
- [16] M. Hosseinzadeh et al., "A secure routing approach based on league championship algorithm for wireless body sensor networks in healthcare," *PLoS ONE*, vol. 18, no. 10, p. e0290119, Oct. 2023, doi: 10.1371/journal.pone.0290119.
- [17] A. H. Kashan, "League Championship Algorithm: A New Algorithm for Numerical Function Optimization," in *2009 International Conference of Soft Computing and Pattern Recognition*, Malacca, Malaysia: IEEE, 2009, pp. 43–48. doi: 10.1109/SoCPaR.2009.21.
- [18] J. J. Shea, "Understanding FACTS-concepts and technology of flexible AC transmission systems [Book Review]," *IEEE Electr. Insul. Mag.*, vol. 18, no. 1, pp. 46–46, Jan. 2002, doi: 10.1109/MEI.2002.981326.
- [19] K. R. Padiyar, *FACTS Controllers In Power Transmission And Distribution*. y New Age International, 2007.
- [20] M. Huang, Q. Dong, F. Ni, and L. Wang, "LCA and LCCA based multi-objective optimization of pavement maintenance," *Journal of Cleaner Production*, vol. 283, p. 124583, Feb. 2021, doi: 10.1016/j.jclepro.2020.124583.
- [21] M. Basu, "Optimal power flow with FACTS devices using differential evolution," *International Journal of Electrical Power & Energy Systems*, vol. 30, no. 2, pp. 150–156, Feb. 2008, doi: 10.1016/j.ijepes.2007.06.011.
- [22] S. S. Das, G. Koneti, and R. Narayanan, "Hybrid Modified League Championship Algorithm and its Applications in Compartmental Pharmacokinetic-Pharmacodynamic Data Analysis," in *2022 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*, Las Vegas, NV, USA: IEEE, Dec. 2022, pp. 3248–3251. doi: 10.1109/BIBM55620.2022.9995090.
- [23] T. Shojarazavi, H. Barati, and A. Barati, "A wrapper method based on a modified two-step league championship algorithm for detecting botnets in IoT environments," *Computing*, vol. 104, no. 8, pp. 1753–1774, Aug. 2022, doi: 10.1007/s00607-022-01070-9.
- [24] M. Farhadi Sartangi, A. Husseinzadeh Kashan, H. Haleh, and A. Kazemi, "A Mixed Integer Linear Formulation and a Grouping League Championship Algorithm for a Multiperiod-Multitrip Order Picking System with Product Replenishment to Minimize Total Tardiness," *Complexity*, vol. 2022, no. 1, p. 1382558, Jan. 2022, doi: 10.1155/2022/1382558.
- [25] "DATA SHEETS FOR IEEE 14 BUS SYSTEM."
- [26] H.-Y. Kim, G.-S. Shin, J. Mahseredjian, and C.-H. Kim, "Voltage Stability Index(VSI)-Based Optimal Vehicle-to-Grid(V2G) Charging/Discharging Strategy in Radial Distribution System," *J. Electr. Eng. Technol.*, vol. 19, no. 7, pp. 3885–3890, Sep. 2024, doi: 10.1007/s42835-024-01818-7.
- [27] S. Sivakumar, S. B. Ramasamy Gunaseelan, M. V. Reddy Krishnakumar, N. Krishnan, A. Sharma, and A. Aguila Téllez, "Analysis of distribution systems in the presence of electric vehicles and optimal allocation of distributed generations considering power loss and voltage stability index," *IET Generation Trans & Dist*, vol. 18, no. 6, pp. 1114–1132, Mar. 2024, doi: 10.1049/gtd2.12968.