



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 12, December 2021

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

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# Minimization of Power Loss Using Hybrid Optimization Technique for Optimal Placement of Capacitor in Electrical Distributed System

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**ABSTRACT:** The continuous improvement in CAPICATOR technology helps in providing electricity to its consumers in a very cost effective nature. In case of competitive (wholesale) deregulated environment, the users owing their CAPICATOR's responds to very high price swings in order to decrease the price volatility. The CAPICATOR's operated on utility are considered as the most suitable option for the process of planning. In emergency conditions, some part of the whole load is shifted on an isolated type of generator which provides some relief to the burden faced by utility. If a small unit of CAPICATOR fails, it does not affect the reliability of the working operation. Placement of Distributed generation (CAPICATOR) controls the real power flow of the system and minimizes the system real power loss while connecting the shunt capacitor system reactive power flow is optimized and system voltage will be within the specified limit. CAPICATOR is the electricity generation from renewable energy resources that are located near to the consumer side Power system consists of generation, transmission and distribution system. The components of the power systems are generators, transformers, transmission lines, distribution lines, loads and compensating devices like shunt, series, and static VAR compensators. Electrical power is transmitted by high voltage transmission lines from sending end substation to receiving end substation [1,24]. Transmission network supplying power to a region may consist of 400kv, 230kv, 132kv and 45kv. The distribution system provides a link between transmission system and customer and provides the power to local use. The distribution network consists of 33kv and 15kv middle voltage distribution line by step down transformer rated 132/33kv, 132/15kv and 45/15kv. Most of distribution network is operated by 15kv; however, regions with low demand density in rural areas are operated by 33kv because the distribution lines in rural area tend to be longer than urban area. The voltage is then further reduced by distribution transformers to the utilization voltages of 380 volts three-phase or 220 volts single-phase supply required by most users

## I. INTRODUCTION

Transmission and distribution loss is an unwanted phenomenon in the power system. Generation Company generates power in the power plant but the utility sector or the receiving end does not exact amount of generated power. Some of the power generated is usually lost. This loss actually includes transmission loss, distribution loss and loss due to power theft. Due to low voltage level and in consequence high flowing current in the distribution system, the most power loss portion is the distribution section in comparison to the transmission section. Power loss in distribution system occurs in distribution lines and distribution transformers. The loss in distribution lines is copper loss and can be determined as  $I^2R$ , where "I" is the current through the line and "R" is the resistance of line. This copper loss is dependent on the load profile of system and material used to construct the line usually aluminium or copper. The loss in distribution transformers is combination of copper loss and core loss, while the copper loss of transformers occurs in the primary and secondary windings and dependable on the loading profile, the core loss occurs in the core and not dependable on loading profile. The core loss, which is made up of eddy current loss and hysteresis loss, accounts for majority of loss at low power levels. The magnitude of core loss is greatly affected by its physical construction. While core loss due to eddy current can be reduced by use of thin steel laminations, hysteresis loss can be minimized by a proper composition of iron and by proper annealing. It has been found that the addition of small percentage of silicon to iron reduces the iron loss. The causes for large power loss and poor voltage quality in distribution systems are long & overloaded distribution lines, low power factor of consumer loads, absence of shunt compensation in distribution lines, installation of distribution transformers away from load centers and load unbalancing. Development of electrical power distribution system performance requires proper plans for increasing utilities efficiency, for instance, loss reduction. Various methods of the loss minimization for distribution system are available in the literature but the basic methods are reconfiguration and capacitor placement.



Capacitors have been very commonly employed to provide reactive power compensation in distribution networks [1,21]. Capacitors are attractive because they are economical and easy to maintain. Not only that, they have no moving parts, unlike some other devices used for power loss reduction. They are used to reduce power losses, power factor improvement and to maintain a voltage profile within acceptable limits. The benefits of the compensation depend greatly on how the capacitors are placed on the system, namely, on the location and size of the added capacitor [14,27,65]. Capacitors, when they are optimally allocated, reduce power losses, correct the power factor, improve the voltage profile, and release system capacity [1,8,5,11,15]. These units also supply reactive powers locally at their connection points, and so, they strengthen the system against reactive power shortages [6]. These sources of reactive power also reduce the operational stress on the traditional voltage control devices, e.g., on-load tap changer transformers (OLTC) and step voltage regulators (SVR), in which their managing systems are mechanical based [7]. Furthermore, they can also release the spare capacity of the interfacing inverter of particular renewable energy sources, thereby reducing their active power curtailments [1,8]. Besides, capacitors require lower initial and operational costs compared with other effective voltage control devices. It is a fact that allocating several capacitors at improper locations with erroneous sizes could worsen the performance of distribution systems. Indeed, the problem of capacitor allocation means determining the best combination of locations for installing capacitors with their optimal capacities so that their benefits are maximized. In addition, the number of capacitors is a critical variable that needs to be optimally calculated. This optimization problem has combinatorial nature where several continuous and discrete variables are required to be solved. For such nature, exhaustive search methods are not helpful considering their computational burden, especially with a high number of capacitors to be allocated.

## II. RELATED WORK

**Mahmoud Karar and Matti Lehtonen [1].** This study proposes a novel and efficient analytical closed-form expressions for the optimal allocation of multiple capacitors in distribution systems to maximize the total cost reduction (CR) while considering power losses. The proposed expressions are novel since they can directly solve the allocation problem without requiring iterative processes or optimization algorithms. Specifically, two analytical closed-form expressions are introduced to determine the optimal number, locations, and sizes of multiple capacitors. The first analytical expression computes directly the optimal sizes of multiple capacitors where it is employed for the optimal sizing of capacitors for all possible combinations of locations. In turn, the best combination is then assigned by using a second analytical expression which directly evaluates all the combinations in terms of their contribution in CR.

**Sk. Md. Golam Mostafa et al. [2].** In this research study, the first section provides an extensive literature review of optimal SCBs placement and sizing. Later on, a new technique called Combinatorial Method has been developed for sizing and sitting of optimal Shunt Capacitors to reduce the distribution loss significantly. The developed method was tested for different case studies using Indian practical 22-bus and IEEE-69-bus network. The results were compared with DSA, Fuzzy GA, and TLBO method and found better distribution feeder loss minimization and voltage profile improvement.

**Markos Kassaw [3].** The purpose of this study is to explore combination of optimal capacitor placement and network reconfiguration for power loss reduction in Geferssa distribution system. In this thesis, Loss Sensitivity Factor (LSF) and minimum line current reduction (MLCR) method is used to solve capacitor placement and network reconfiguration problem respectively. To achieve this objective, the existing distribution system of Geferssa 132/15 KV distribution system is modeled by using DigSilent power factor software and simulation is carried out for balanced operation conditions.

**M. Dehghani et al. [4].** This study offers a newly developed metaheuristic technique, named dice game optimizer to determine optimal size and location of capacitors in a distribution network. Dice game optimizer is a game-based optimization technique that is based on the rules of the dice game. In the simulation results, it is looked that the results are more precise than the results reported in the current literature. The convergence rate of the dice game optimizer is good and it solves the problem in less computational time than the other investigated techniques.

**J. M. Home-Ortiz et al. [5].** This paper presents a study about operation planning for radial distribution systems using a mixed-integer second-order cone programming formulation. The proposal consists of a complete model for solving the problems of the reconfiguration of feeders and allocation of capacitor banks simultaneously, with the objective of achieving a minimum overall investment, in both fixed and switchable capacitor banks, and operational costs, related to the cost of energy losses. The approach includes a voltage-dependent load representation, as well as a precise representation of the operation of capacitor banks, which is also voltage dependent. The use of a mixed-integer second-





order cone programming model guarantees convergence to optimality using existing optimization software. Several tests are performed using the 69-node distribution system and a real 2313-node distribution system, demonstrating the effectiveness of the proposal. The results indicate that better solutions can be obtained by performing the simultaneous optimization of the reconfiguration and allocation of capacitor banks than by solving the two problems sequentially, which may even lead to infeasible solutions.

**M. Ghaljehei et al. [6].** This paper also contributes to the relevant literature by formulating a model which determines the RPR of modern WFs to be included in the management of total RPR of the power system. Also, a coordinated RPR (CRPR) scheme is proposed by using this model. The proposed model benefits from a detailed reactive power output model of the DFIG wind turbines in order to handle real-world power system operation. Two studies are considered in the proposed SMO-OD problem: (i) SMO-OD with uncoordinated RPR provision (SMO-OD-URPR), and (ii) SMO-OD with the CRPR provision (SMO-OD-CRPR). The proposed SMO-OD problem is applied to the IEEE 30-bus test system. Simulation results show that using the proposed model, a proper trade-off is made between technical and economic aspects of power system operation, and considerable LM and RPR are provided. In the proposed SMO-OD-CRPR problem, the value of expected RPR increases compared to SMO-OD-URPR problem, and the DFIG-based WF has more expected RPR to inject to grid under contingency or sudden increased load.

**Mahmoud and Lehtonen [8].** This paper proposes a method for determining the optimal sites and sizes of multi-type distributed generations (DG) and capacitors for minimizing reactive power losses (RPL) in distribution systems. The proposed method is developed based on generic closed-form analytical expressions for calculating optimal sizes of DG units and capacitors at their candidate sites. The reduction in RPL with DG and capacitors is evaluated using another analytical expression that relates power injections of DG and capacitors with RPL. An optimal power flow algorithm (OPF) is incorporated in the proposed method to consider the constraints of the distribution systems, DG, and capacitors. Various types of DG are considered, and their optimal power factors can be accurately computed while optimizing the sizes of capacitors in a simultaneous manner to reduce RPL. The 69-bus distribution system is used to test the proposed method. An exact search method is employed to verify the accuracy of the proposed method. The effectiveness of the proposed method is demonstrated for solving the optimal allocation problem with different combinations of multi-type DG units and capacitors.

**Srinivasa Rao Gampa and Debapriya Das [10].** This paper presents a combination of fuzzy and genetic algorithm (GA)-based methodology for simultaneous optimum allocation and sizing of distributed generations (DGs) and shunt capacitors (SCs) together in distribution systems. The objectives of reduction of active power and reactive power supply, reduction of real power loss and improvement of branch current capacity, voltage profile and voltage stability are considered. The combination of shunt capacitors with both unity power factor DGs and lagging power factor DGs also considered for analysing the performance of the distribution systems. Simulation results are demonstrated to show the advantage of proposed fuzzy genetic algorithm-based technique over conventional multi-objective approach and loss sensitivity-based optimization techniques reported in the literature.

**Leandro Ramos de Araujo et al. [8].** This paper describes an allocation methodology for capacitor placement in unbalanced distribution systems to achieve loss minimization with an adequate voltage profile. Switched capacitor banks and/or fixed banks can be allocated on a per-phase or multi-phase, discrete basis, and this allows consideration of the actual unbalanced characteristics of distribution systems. While most methods available in the literature address some specific network loading conditions, e.g., average, light-load or heavy-load, the proposed algorithm is based on the daily load variation curve. The method consists of two main steps: (i) reactive power demand calculation to achieve loss minimization; (ii) discrete capacitor placement. The method is applied on the IEEE 4-bus, IEEE 123-bus and IEEE NEV Test Feeders as well as on an 85-bus feeder.

**V. Tamilselvan et al. [12].** In this paper, a new metaheuristic algorithm that mimics the pollination process of flowers and is known as the flower pollination algorithm (FPA) has been proposed for the solution of the optimal capacitor placement (OCP) problem in a radial distribution system (RDS). The objective of this problem is to minimize the total power loss and cost of capacitor installation by optimal location and sizing of the capacitors. OCP also improves the voltage profile. In this work, the power flow and losses in the network are obtained with the help of load flow analysis using data structures. The proposed FPA approach has been applied to solve 33-, 34-, 69- and 85 bus RDSs. The results obtained are compared with those of the analytical method, fuzzy real coded genetic algorithm, two stage fuzzy approach and teaching learning-based optimization algorithms. The comparison shows that FPA is a highly suitable optimization approach for solving capacitor placement problems.



### III. PROPOSED WORK

In the proposed work Tabu search and Water cycle algorithm is used for the better optimization results. A genetic algorithm is a meta-heuristic algorithm which is based on the gene and their operation. In the Tabu search, all the process is based on the selection, cross-over and mutation operation for the optimal results. The optimization is based on the fitness value of the genes. This algorithm supports the local optimization process which is not enough to get the effective results. To overcome this issue the hybrid approach is proposed in the present work. The Water cycle algorithm is a meta-heuristic algorithm which is based on the behavior of swarms. This algorithm is used to solve the complex problem to get the optimal results. Water cycle algorithm supports the Global optimization feature and gives the solution of the problem which is globally best. In the present work, Water cycle algorithm and Tabu search work parallel for better and optimal solution because both have the different feature of optimization. In the below-given section, we explain the Tabu search and Water cycle algorithm with the algorithm and their flow chart. The flow chart of explains the step by step working an algorithm represents the technical implementation of the algorithms.

Steps for the proposed methodology are illustrated as follows:

**Step 1:** Initialize the Load/Power.

**Step 2:** Initialize the generator Load Power.

**Step 3:** Allocate the Capacitors and calculate the cost.

**Step 4:** Apply the Water cycle for optimization.

**Step 5:** If the output of Water cycle is optimized then check the convergence otherwise Tabu search starts it working with the following steps.

- a. Initialize the chromosomes.
- b. Crossover between chromosomes.
- c. Apply Roulette Selection.

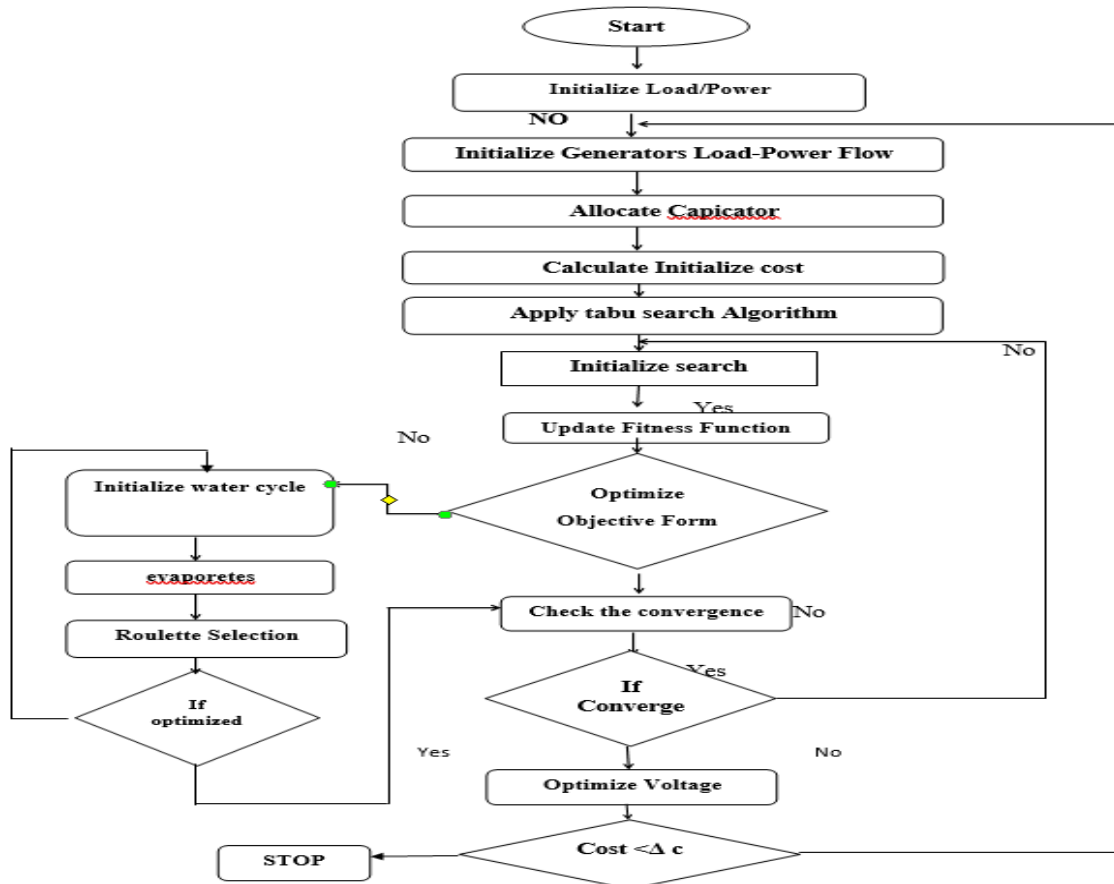


Figure 1: Proposed Flowchart



Results Analysis

Number of Capacitor	Error (FPA)	Error (BFO)
0	0.5	0.5
2	0.23	0.33
4	0.12	0.14
6	0.1	0.12
8	0.08	0.1
10	0.06	0.09
12	0.044	0.05

Table 1: Comparison of error of proposed and existing approach on 14 bus system

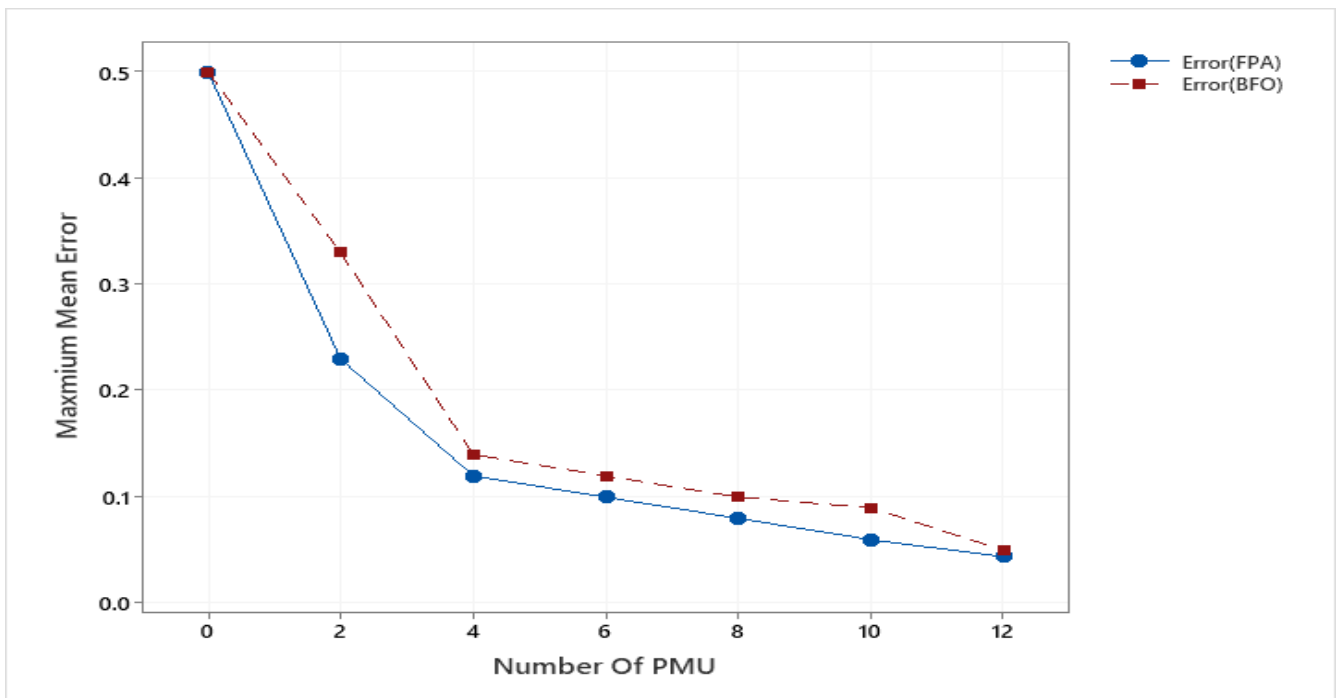


Figure 2: Comparison of error of proposed and existing approach on 14 bus system

Configuration	Capacitor Allocation	Error
1	2,3,5,6	0.14
2	5,6,7,8	0.12
3	6,8,9,10	0.16
4	1,5,3,4	0.15
5	1,7,8,9	0.13

Table2: Comparison of error of proposed and existing approach on 14 bus system

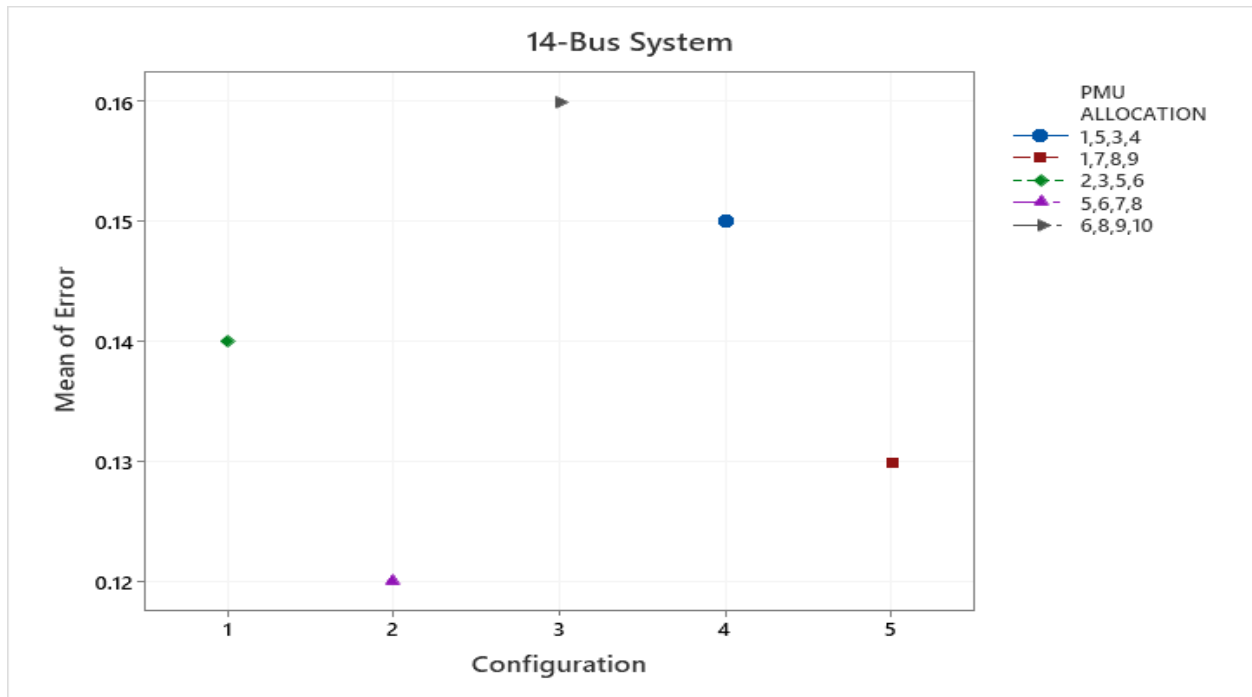


Figure 3: Comparison of error of proposed and existing approach on 14 bus system

Number Of Capacitor	Error (FPA)	Error (BFO)
0	0.8	0.8
2	0.34	0.45
4	0.3	0.4
6	0.23	0.35
8	0.1	0.23
10	0.08	0.2
12	0.06	0.09

Table3: Comparison of error of proposed and existing approach on 30 bus system

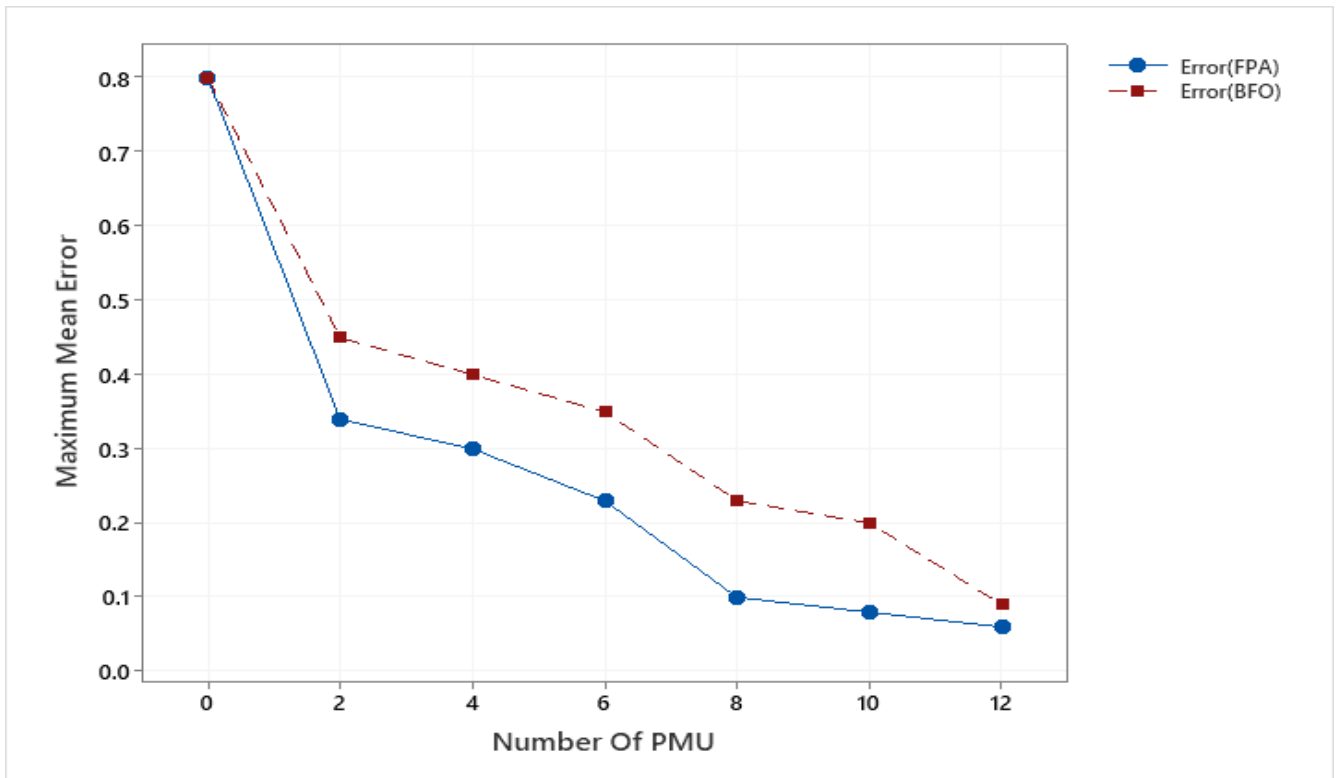


Figure 4: Comparison of error of proposed and existing approach on 30 bus system

Configuration	Capacitor Allocation	Error
1	1,3,12,15,16,20	0.34
2	3,4,20,22,23,24	0.44
3	7,8,10,11,22,29	0.3
4	2,23,24,26,27,29	0.45
5	2,5,6,23,24,26	0.54

Table4: Error of proposed approach on different CAPACITOR allocation configuration 30 bus system

#### IV. CONCLUSION

This synopsis proposed a new approach for the FPA algorithm which integrates a new mutation strategy and V-shaped sigmoid for solving the OPP hassle considering ZIB, unmarried CAPACITOR loss, and CAPACITOR’s channel restrict, which turned into in no way considered earlier than within the FPA set of rules. In addition, this paper also proposed a new health characteristic for the case of unmarried CAPACITOR loss. The consequences display that the proposed technique can produce a exquisite solution in terms of size redundancy in comparison to prior studies. The proposed approach additionally controlled to lessen the number of CAPACITORS needed for the -bus system. The demand of power network increasing and it enhances the requirement of control system and protection requirement and make it complex to manage. In current years,. To prevent events inclusive of lack of energy, electricity community providers must comprehend the high-quality and balance of diverse parts of the electricity transmission network via





monitoring and measuring equipment. Based at the GPS synchronized clock, the phasor dimension unit can degree a giant quantity of important energy community records, which incorporates bus voltage, bus current, generator velocity, and power attitude.

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