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# Optimal Deployment of Distribution Static Synchronous Compensator on 15 Bus Lafia Feeder, Using Artificial Bee Colony

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***Abstract:*** ***To ensure that the radial distribution system operates as efficiently as possible, the distribution static synchronous compensator DSTATCOM must be properly deployed. This study use Artificial Bee Colony ABC to discover the optimal position and size for a Distribution STATCOM in order to reduce total line loss while improving voltage quality within acceptable bounds. ABC was tried on fifteen buses in Lafia, Nasarawa State, Nigeria. The ABC's performance was tested with and without DSTATCOM installed. MATLAB was used to develop and simulate the radial distribution system (RDS). According to the IEEE 33 Bus data, reactive power loss decreased by 26.7% from 134.99kVar to 98.93kVar, while real power loss decreased by 26.6% from 201.77kw to 148.05kW. The number of bus voltage violations dropped from 21 to 13, and the Lafia feeder's true power loss fell by 63.9%, from 171.65kw to 61.87kw. The reactive power loss decreased by 64.01%, from 195.47 to 70.35 kvar. There was only one bus voltage violation, not twelve. The study's findings showed that ABC outperformed the other findings in the literature. The DSTATCOM increased calculation speed, active power loss, and voltage profile. ABC improved the voltage profile and reduced active and reactive power loss in the industry-standard IEEE 33-bus and 15-bus Lafia RDS.***

***Keywords: Radial Distribution System, Artificial Bee Colony, Parameters, Improvement, Losses and Minimization.***

## I. INTRODUCTION

Technological advances in power semiconductors have enabled devices that act more like an ideal switch, are fully programmable, and have high frequencies of commutation at large amounts of tension and power [1]. Another factor to consider while developing and implementing an electrical system is the advancement of renewable energy sources such as solar, wind, and fuel cells, which have been related to the notion of flexible AC transmission system (FACTS) devices. FACTS devices require electronic equipment based on power converters to combine these energy sources while maintaining the reception quality of customers connected to the electrical network [2]. The FACTS controllers offer numerous options for regulating alternating current (AC) flow, boosting or reducing power in specific lines, and responding very instantaneously to stability difficulties. This technology's potential stems from its capacity to connect under-coupled networks and manage the flow of power, allowing agents to exchange energy [3]. FACTS devices can be classified as series, shunt, or a hybrid of the two based on how they are connected to the network. The FACTS devices consist of thyristor control series compensators (TCSC), series capacitor synchronous compensators (SCSC), unified power flow controllers (UPFC), generalized unified power flow controllers (GUPFC), and static compensators (STATCOM). UPFC, maybe the most adaptive of the FACTS controllers, provides variable power system regulation with a novel combination of shunt and series compensation. [4]. According to [5], there are three steady-state models of UPFC: decoupled injection and complete Newton-Raphson (NR). Electronic power converters provide high dynamic and adjustable power flow. Power converters based on completely regulated switches, such as Gate Turn Off Thyristors (GTO) and the more widely available high-power Insulated Gate Bipolar Transistor (IGBT), are especially helpful since they can handle greater switching frequencies [5][6]. This study examines the dynamic stability enhancement of the Abuja Electricity Distribution Company's Lafia feeder using DSTATCOM.

## II. OPTIMAL DEPLOYMENT TECHNIQUES

In order to improve voltage profiles and reduce power loss, researchers have created and implemented a variety of strategies for the proper placement and sizing of FACTS Controllers in electric power networks. Here are a few of the methods.

2.1 Analytical Techniques

This strategy is based on reduced network assumptions. The approaches are used to perform a variety of sensitivity evaluations with the purpose of enhancing power network dynamic stability. Power network controllers use a range of analytical methodologies to select and size FACTS sites as efficiently as feasible, including [7], [8], and [9]. The Sensitivity Based Method (SBM), Index Method (IM), Residual Based Method (RBM), Eigen Value Analysis (EVA), Modal Analysis (M.A.), and so on.

2.2 Optimal Allocation of DSTATCOM

DSTATCOM is used by the distribution system to analyze load flow. This study combines the backward sweep and the deconstructed forward sweep to create a load flow algorithm for radial distribution systems [10] [11]. Based on the sophistication and number of busses in an RDS, an optimization procedure was applied to identify the location and size of the DSTATCOM. Several optimization-based solutions have been developed to solve the optimal placement and sizing concerns of custom power devices (CPDs) [12] [13]. Radial distribution systems' ultimate goal is to find the optimal DSTATCOM position and size in order to improve power quality while lowering overall costs. The known techniques for the optimal D-STATCOM allocation in distribution systems are broadly classified into five categories: sensitivity approaches, metaheuristic approaches, artificial neural network-based approaches, hybrid approaches, and metaheuristics [14, 15].

## III. METHODOLOGY

The objective function problem formulation can be written as seen in equation (1)

$$Min(J) = (P_{total\ losses} + V_D) \quad \dots (1)$$

$$P_T = \sum_{i=1}^{ND} P_{Di} + P_L \quad \dots (2)$$

$$Q_T = \sum_{i=1}^{ND} Q_{Di} + Q_L \quad \dots. (3)$$

$$V_D = \sum_{i}^{NB} \left(\frac{V_{ref} - V_i}{V_{ref}}\right)^2 \quad \dots (4)$$

. The constraints are given in equations (5), (6), and (7).

$$V_{min} \leq V_i \leq V_{max} \quad \dots (5)$$

$$Q_{min} \leq Q_i \leq Q_{max} \quad \dots. (6)$$

$$P_{min} \leq P_i \leq P_{max} \quad \dots (7)$$

3.1 Flow Chart for Implementation of Optimal DSTATCOM Deployment

Figure 2 displays the flow chart for the suggested ideal DSTATCOM deployment in the distribution network.

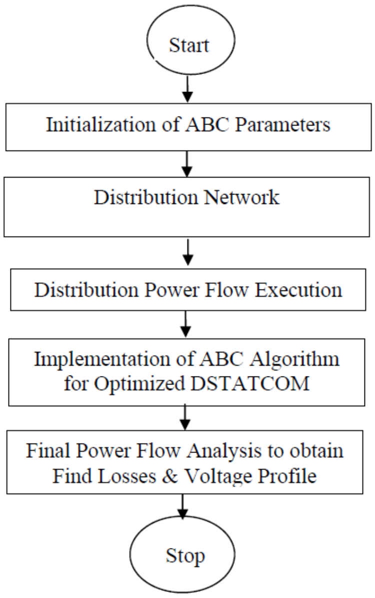


*Figure 2: Flow Chart of purposed ABC Algorithm*

## IV. OUTCOMES OF INSTALLING A 15-BUS LAFIA FEEDER WITH DSTATCOM

3.1 Location and sizing

Bus 4 appears to be the best location for DSTATCOM placement, according to the results of the artificial bee colony algorithm simulation for optimal DSTATCOM sizing and placement on the 15 Bus Lafia Feeders. According to the artificial bee colony algorithm, the optimal size of the DSTATCOM was 629.5 kVar. This can be seen in the 15-bus Lafia radial distribution system's enhanced voltage profile and reduced power losses.

3.2 Installing DSTATCOM Improves the Voltage Profile

Figure 2 displays a graphic for comparison with and without DSTATCOM loaded, along with the voltage profile acquired from 15 Bus Lafia RDS with DSTATCOM installed. According to the chart, bus 1 had the highest value of 1 pu, while bus 7 had the lowest value of 0.9488 pu. Additionally, it is clear that only one bus violated the restrictions.

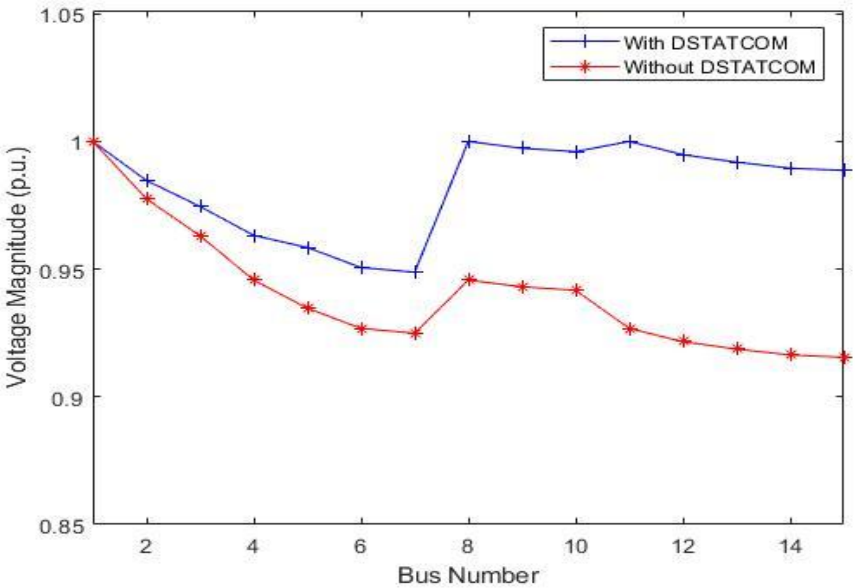


Figure 2: *Voltage Profile Comparison for 15 Bus Lafia feeder with DSTATCOM installed*

3.3 *Power Loses Reduction with DSTATCOM Installed*

With DSTATCOM installed, the load flow simulation for the 15 Bus Lafia feeder produced reactive losses of 70.35 kVar and real losses of 61.87 kw. The real and reactive losses at each bus with and without DSTATCOM implemented are contrasted in Figures 3 and 4.

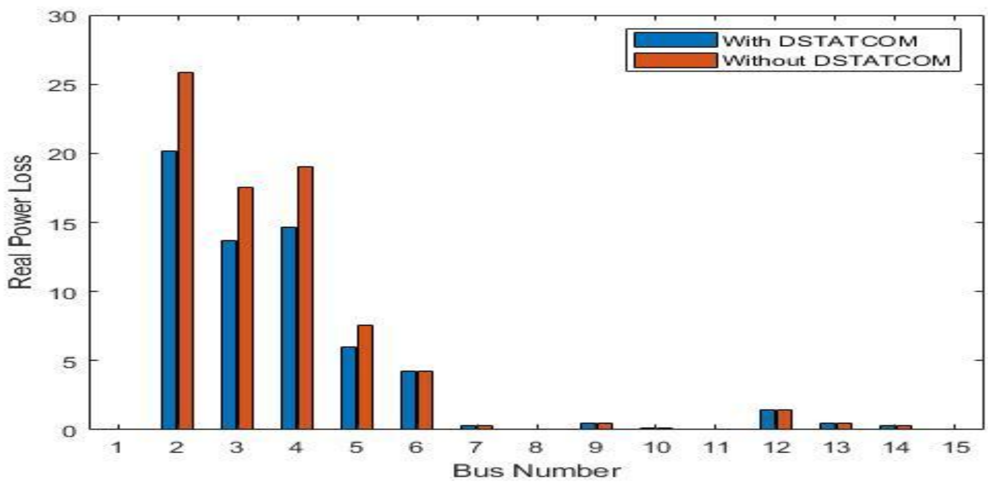


Figure 3: *Real Power Loss Comparison for 15 Bus Lafia feeder with and without DSTATCOM installed.*

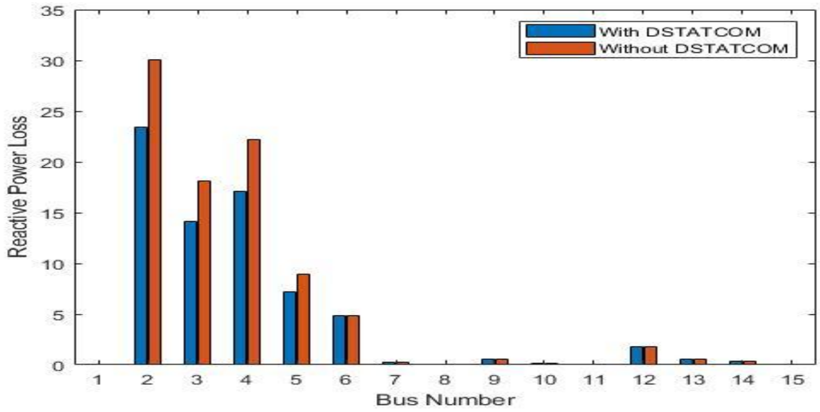


Figure 4: *Reactive Power Loss Comparison for 15 Bus Lafia feeder with and without DSTATCOM installed*

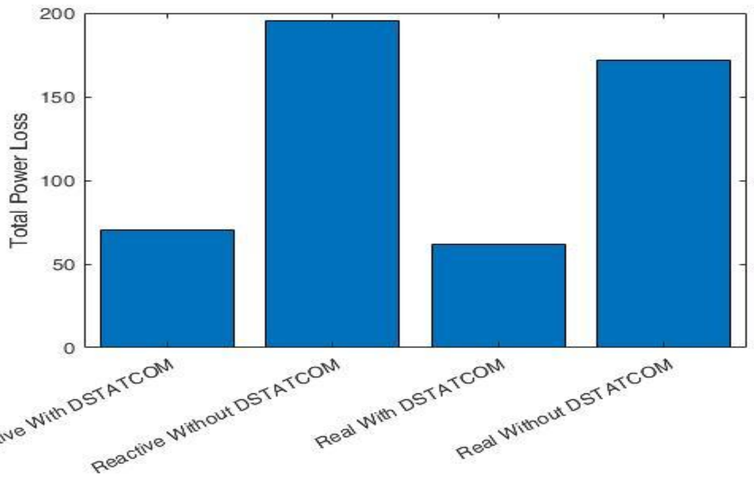


*Figure 5: Total Power Comparison for 15 Bus Lafia feeder with DSTATCOM installed*

Before DSTATCOM was installed, 15 Bus Lafia experienced a real power loss of 171.65 kW. The installation of DSTATCOM caused a 61.87 kW loss. This suggests a significant improvement of 63.9% in power loss throughout the RDS. Similarly, 195.47 kVar was the reactive power loss measured before DSTATCOM was installed. The reactive power loss decreased to 70.35 kVar after DSTATCOM was installed. Additionally, the RDS's overall reactive power loss has decreased by 64.01%. The DSTATCOM's ideal placement and dimensions on the RDS allowed for this loss reduction.

Table 1: Comparison of Results of the 15 bus Lafia Feeder with and without DSTATCOM

| Parameter | Base Case Without DSTATCOM | With DSTATCOM |
|---|---|---|
| Actual Power Loss | 171.65 kw | 61.87 kw |
| Loss of Reactive Power | 195.47 kvar | 70.35 kvar |
| Bus Max Vpu | 1@ Bus1 | 1@ Bus1 |
| Bus Min Vpu | 0.9155 @ Bus 15 | 0.9411@ Bus 7 |
| The quantity of bus infractions | 12 | 1 |
| Location of DSTATCOM | -- | Bus 4 |
| % decrease in the real power | -- | 63.9% |
| % decrease in Reactive Power Loss | -- | 64.01% |
| Ideal DSTATCOM | -- | 629.05 kvar |

## V. CONCLUSION

This research describes methods to optimize DSTATCOM siting and sizing in Radial Distribution Systems (RDS) using Artificial Bee Colony (ABC) to reduce power loss and improve voltage profile. Matlab was used to model the Abuja power distribution network's 15-bus feeder, Lafia. The models were simulated both with and without the DSTATCOM. Artificial Bee Colony (ABC) Optimization techniques were utilized to establish the optimal DSTACOM position and dimensions. The ABC technique used a multi-objective function to model the active power loss and bus voltage volatility of the radial distribution. Before being implemented to the Abuja electricity distribution network's 15-bus feeder Lafia, the approach was tested on a Standard IEEE 33-bus Radial Distribution System to establish its effectiveness. When ABC is used in conjunction with suitable DSTATCOM placement and sizing, the system voltage profile improves and power losses decrease. The findings show that DSTATCOM can successfully alter the voltage profile of a radial distribution system while lowering loss. DSTATCOM can lower both active and reactive losses simultaneously, as seen in the loss comparison table. The ABC method was also used to evaluate the optimal position and dimensions of the 15-bus, 11 kV feeder RDS in Lafia, Nigeria. Using ABC, the DSTATCOM was best positioned on bus 4, with a maximum DTSATCOM size of 629.05 kVar. ABC decreased system total real and reactive power losses by 63.9% and 64.01%, respectively, by boosting overall voltage. By enhancing the voltage profile and minimizing power loss, the findings presented in the lectures, tables, and figures demonstrate the utility and superiority of the suggested ABC algorithm in improving power quality

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