



## Optimal Placement of DSTATCOM into the Government Feeder Lafia of Abuja Electricity Distribution Network Using Artificial Bee Colony

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### ABSTRACT

Flexible AC transmission system (FACTS) devices provide significant opportunities for regulating the transmission of alternating current (AC) and bus voltages. These devices have the capability to increase or decrease power flow in specific lines, offering nearly instantaneous response to stability issues. The potential of FACTS technology lies in its ability to control the route of power flow and connect networks that are not adequately interconnected, facilitating energy trading between agents. There are several types of FACTS devices, each connected in different ways within the network. These include series devices, shunt devices, and combinations of the two. Examples of FACTS devices encompass the static compensator (STATCOM), Thyristor control series compensator (TCSC), series capacitor synchronous compensator (SCSC), Unified power flow controller (UPFC), and Generalized unified power flow controller (GUPFC), among others. In the context of the Abuja electricity distribution network, particularly at the government feeder Lafia, there is a significant need to address the higher reactive power. To mitigate this issue, it is essential to insert a Unified Power Flow Controller (UPFC) into the feeder. By doing so, the adverse effects of higher reactive power can be minimized. To optimize the performance of the network and achieve power loss minimization and voltage profile improvement, the optimal location of a Dynamic Static Synchronous Compensator (DSTATCOM) needs to be determined. This can be achieved by employing the Artificial Bee Colony (ABC) algorithm, which aids in identifying the most suitable location for the DSTATCOM within the network. The proposed methodology involves implementing the ABC algorithm to determine the optimal placement of the DSTATCOM. Power flow analysis of the network is then performed using MATLAB, comparing scenarios with and without the DSTATCOM. The simulation results obtained are analyzed to assess the impact on power loss reduction and voltage profile enhancement, enabling the derivation of necessary recommendations. In conclusion, FACTS devices play a vital role in regulating AC transmission and bus voltages. By employing the appropriate FACTS technology, such as the UPFC, the adverse effects of higher reactive power in the Abuja electricity distribution network can be mitigated. Furthermore, through the optimal placement of the DSTATCOM using the ABC algorithm, power loss can be minimized, and voltage profiles can be improved. These measures contribute to the overall stability and efficiency of the power system.

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### INTRODUCTION

The technological advances in power semiconductors permit the development of

devices that react more like an ideal switch, totally controllable, admitting high frequencies of commutation to major levels of tension and

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power (Shahgholian *et. al.*, 2018). The concept of flexible AC transmission system (FACTS) device was associated with the development of the renewable energy sources such as fuel cells, wind energy and solar cells, another factor to keep in mind in the development and configuration of the electrical system.

FACTS devices require electronic equipment based on power converters that facilitate the integration of these sources of energy, without damaging over the reception quality of the users connected to the electricity network (Luburic and Pandzic, 2019). The FACTS controllers offer great opportunities to regulate the transmission of alternating current (AC), increasing or decreasing the power flow in specific lines and responding almost instantaneously to the stability problems. The potential of this technology is based on the possibility of controlling the route of the power flow and the ability of connecting networks that are not adequately interconnected, giving the possibility of trading energy between agents (Bhukya and Mahajan, 2019).

There are many types of FACTS devices depending on the way are connected in the network such as; series, shunt and the combination of the two. There are many types of FACTS devices depending on the way they are connected in the network such as; series, shunt and the combination of the two. Examples of FACTS devices include; static compensator (STATCOM), Thyristor control series compensator (TCSC), series capacitor synchronous compensator (SCSC), Unified power flow controller (UPFC), generalized unified power flow controller (GUPFC) etc. UPFC is perhaps the most versatile of the FACTS controllers, offering a unique combination of shunt and series compensation which guarantee flexible power system control (Fazeli-Nejad *et. al.*, 2019). The three steady state models of UPFC according to (Dawn *et al.*, 2019) are; decoupled, injection and comprehensive newton raphson (NR) models.

The flexible power flow control and high dynamics can be successfully achieved by applying electronic power converters. It is particularly beneficial to use power converters based on full controlled switches, such as Gate Turn Off thyristors (GTO) and the more recently available high-power Insulated Gate Bipolar Transistor (IGBT), which are suitable to

handle higher switching frequencies (Golshannavaz *et. al.*, 2019). The work investigates the dynamic stability enhancement of the Government feeder, Lafia in the Abuja distribution company using DSTATCOM.

## LITERATURE REVIEW

### *Review of Fundamental Concepts*

DSTATCOM is a member of FACTS devices consists of two solid state synchronous voltage source converters coupled through a common DC link. The DC link provides a path to exchange active power between converters. The series converter injects a voltage in series with the system voltage through a series of transformer. The power flow through the line can be regulated by controlling voltage magnitude and the angle of series injected voltage (Hareesh *et. al.*, 2019). The injected voltage and line current determine the active and reactive power injected by the series converter.

The converter has a capability of electrically generating or absorbing the reactive power. The shunt converter has a capability of independently supplying or absorbing reactive power to regulate the voltage of the AC system (Yu *et. al.*, 2012). The DSTATCOM is a device placed between two buses referred to the DSTATCOM sending bus (B1) and the DSTATCOM receiving bus (B2), It consists of two voltage-sourced converters (VSCs) with a common DC-link. For the fundamental frequency model, the VSCs are replaced by two controlled voltage sources (Kaliaperumal *et. al.*, 2020).

DSTATCOM are the most versatile and complex power electronic equipment applied to control and for the power flow optimization in electrical power transmission systems. It offers major potential advantages for the static and dynamic operation of transmission lines. The DSTATCOM combines the functions of several FACTS devices and is capable of implementing voltage regulation, series compensation, and phase angle regulation at the same time. Thus, realizing the separate control of the active power and reactive power transmitted simultaneously over the line. The DSTATCOM thus provides effective means for controlling the power flow and improving the transient stability in a power network. According to (Yu *et. al.*, 2012),

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DSTATCOM is the most effective Flexible Alternating Current Distribution System (FACTS) device which is able to optimize the power transfer capability of interconnected power systems (Amin *et al.*, 2018).

The DSTATCOM can be used to control the line power flow and voltage bus individually or simultaneously. Now, the implantation of FACTS devices in load flow algorithms is considered as a fundamental requirement in planning, operation, and the control. Generally, the existing load flow programs need to be modified to incorporate these devices. The required modifications due to many reasons such as; addition reference buses related to the number of FACTS have to be added in the network, the impedances of FACTS have to be incorporated into original admittance matrix, and the powers contributed by FACTS have to be included into power mismatches vector. Some of excellent research works have been done to reduce the complexity of load flow programs with the DSTATCOM device (Padmarathi and Rama, 2019).

The DSTATCOM is the most powerful and versatile FACTS equipment used to control the power flow and stability of the power system. The DSTATCOM uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor-controlled systems (Yu *et al.*, 2012). The DSTATCOM is a combination of a static compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The DC terminal of the two converters is connected together with a DC capacitor.

According to IEEE definition and standard DSTATCOM is combination of both static compensator (STATCOM) and static synchronous series compensator (SSSC). Those devices are coupled via common dc power link to allow bidirectional flow of real power between the series output terminal of SSSC and the shunt output terminal of STATCOM (Hamed and Ahmet, 2018).

### Computation of Load Current

Considering the  $k^{th}$  bus of a distribution power network, the load current at

bus  $k$  is expressed as (Sidhartha and Ramnarayan, 2006):

$$I_{L(k)} = \frac{P_k - jQ_k}{V_k^*} \quad (2.1)$$

for  $k=1,2,3,\dots,N_{Bus}$

Where,  $N_{Bus}$  is the total number of buses,

$P_k$  and  $Q_k$  are the real and reactive power demand at bus  $k$  respectively,

$V_k^*$  is the voltage conjugate at bus  $k$

### BIBC Matrix Formation

The relationship between load currents ( $I_L$ ) and branch currents ( $I_B$ ) can be established by applying the Kirchhoff's current law (KCL) to the distribution network. The network branch currents are expressed as (Tolabi *et al.*, 2015):

$$I_{B1} = I_{L2} + I_{L3} + I_{L4} + I_{L5} + I_{L6} \quad (2.2)$$

$$I_{B2} = I_{L3} + I_{L4} + I_{L5} + I_{L6} \quad (2.3)$$

$$I_{B3} = I_{L4} + I_{L5} + I_{L6} \quad (2.4)$$

$$I_{B4} = I_{L5} \quad (2.5)$$

$$I_{B5} = I_{L6} \quad (2.6)$$

Equations (2.2) to (2.6) can be expressed in a matrix form as follows Tolabi *et al.*, 2015):

$$\begin{bmatrix} I_{B1} \\ I_{B2} \\ I_{B3} \\ I_{B4} \\ I_{B5} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_{L2} \\ I_{L3} \\ I_{L4} \\ I_{L5} \\ I_{L6} \end{bmatrix} \quad (2.7)$$

The above matrix can be written in a more compact form as Tolabi *et al.*, 2015):

$$[I_B] = [BIBC][I_L] \quad (2.8)$$

Where,  $BIBC$  is the Bus Injection to Branch Current matrix and contains values of 0 and 1.

### Forward Sweep

Since voltage values of source buses are known, the receiving end bus voltages can be determined by deducting the corresponding branch voltage drop from values of the sending end voltages. The voltage at bus  $k$  is given by Taher and Afsari, 2014):

$$V_k = V_i - I_{B(ik)} * Z_{ik} \quad (2.9)$$

for  $ik = 1, 2, 3, \dots, N_{Branch}$

Where,  $N_{Branch}$  is the total number of branches,

$V_k$  and  $V_i$  are the receiving and sending end voltages of branch  $ik$  respectively,

$I_{B(ik)}$  is the current flowing in branch  $ik$ ,

$Z_{ik}$  is the impedance of branch  $ik$ .

### Power Losses

The active and reactive power losses of branch  $ik$  are calculated using Tolabi *et al.*, (2015):

$$P_{ik(loss)} = |I_{B(ik)}|^2 * \Re(Z_{ik}) \quad (2.10)$$

$$Q_{ik(loss)} = |I_{B(ik)}|^2 * \Im(Z_{ik}) \quad (2.11)$$

Total active and reactive power losses of a radial distribution system can be determined by taking the summation of individual active and reactive power losses using Eqns. (2.10) and (2.11) respectively.

### FACTS and FACTS Controllers

The word FACTS is an acronym for Flexible AC Transmission System. According to the IEEE PES Task Force of the FACTS working Group, the general and standard definitions for FACTS and FACTS Controllers respectively are stated as (Rajiv *et al.*, (2016)): "Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability" and "a power electronic-based system and other static equipment that provides control of one or more AC transmission system parameters". Basically, FACTS controllers are classified into (Vireshkumar and Jangmsheti, 2013):

- i. Thyristor controlled based FACTS controllers such as Thyristor Controlled Reactor (TCR), Thyristor Controlled Series Compensator (TCSC), Static Var Compensator (SVC), etc.
- ii. Voltage source inverter (VSI) based FACTS controllers such as Static Synchronous Series Compensator (SSSC), Distribution Static

Compensator (D-STATCOM), Unified Power Flow Controller (UPFC) etc.

Generally, FACTS controllers are categorised based on the nature of their connection in electric power systems. The four basic categories of FACTS controllers are as follows (Porate and Kumar, (2014)): i) Series connected; ii) Shunt connected; iii) Combined series-series connected; and iv) Combined series-shunt connected.

### Optimal Siting and Sizing FACTS device

Researchers have developed and applied several techniques for optimal siting and sizing of FACTS Controllers in electric power networks in order to enhance the network performance by reducing power loss and improving voltage profile. Some of the techniques are as follows

### Analytical Techniques for FACTS device location

This approach is on the basis of simplified network assumptions. The techniques are employed for various sensitivity analysis for improving the dynamic stability in power networks. Some of the analytical techniques used for optimal siting and sizing of FACTS Controllers in power networks include Porate and Kumar, (2014): Eigen Value Analysis (EVA), Modal Analysis (MA), Residual Based Method (RBM), Index Method (IM), Sensitivity Based Method (SBM), etc.

### Optimal Allocation of DSTATCOM

The DSTATCOM was employed in the distribution system by performing load flow analysis. This paper presents backward /forward sweep load flow algorithm for radial distribution systems which includes the backward sweep and the decomposed forward sweep (Augugliaro *et al.*, 2010). Based on the technical and economic feasibility, the location and size of the DSTATCOM should be determined by using the process of optimisation. To solve the optimal placement and sizing problems of CPDs, several optimisation-based techniques have been proposed. The ultimate goal in radial distribution system is to determine the optimal location and size of the DSTATCOM to improve the power quality while minimising the total cost. The existing methods for optimal

allocation of D-STATCOM's in distribution systems can be divided mainly into five categories: analytical methods, artificial neural network-based methods, metaheuristic methods, sensitivity approaches, and a hybrid approaches and metaheuristics.

#### Analytical methods for DSTATCOM location

The analytical methods consisting simple algorithms that have been proposed in privation of powerful computing resources. The aim of proposing analytical methods in optimal allocation of D-STATCOM, is to identify the optimum solutions without considering nonlinearity and complexity in the problem. For reducing the computational procedure, some approximations should also be applied to these algorithms. (Oloulade *et. al.*, 2018) used an analytical method developed for determining the optimum position of DSATATCOM in a distribution network. Power losses and the voltage profile of the system are considered as the objectives in optimization process. The proposed method was tested in a 33-bus radial distribution system. In the results, voltage regulation and the number of buses that have an under/over voltage problem were examined and compared. D-STATCOM cost and other related advantages were also considered. This method was compared to the well-established genetic algorithm (GA).

Muthubalaji *et. al.*, (2018), developed analytical technique for optimal placement and sizing of DG and DSTATCOM in radial distribution systems. They proposed an analytical technique to determine the optimal allocation of Distributed generation (DG) and Distribution static compensator (DSTATCOM) in radial distribution systems. Minimizing the power loss and improving the voltage profile were used as the main objective functions. Power stability index (PSI) was used to determine the optimal locations of DG and DSTATCOM that identifies the candidate buses which are more suitable for connecting these devices. Sensitivity analysis was used to determine the optimal size of DGs, while the size of DSATCOM is increase gradually by step size until reach to lowest losses. The developed algorithm was tested on the 15 bus Government feeder Lafiya of Abuja Distribution Company..

#### Metaheuristic methods

Metaheuristics are the most commonly used methodologies for solving D-STATCOM allocation problems. They are stochastic, population-based optimization algorithms which are generally efficient in handling multimodal, multi-objective, discrete and constrained environments.

Padmavathi and Sudha (2019), used a single-phase Distribution Static Compensator (DSTATCOM) with reduced dc-link voltage for power quality improvement in a distribution system. The dc-link voltage of DSTATCOM was maintained twice the peak of Point of Common Coupling (PCC) voltage by voltage regulation loop. But, the dc-link voltage was maintained itself without voltage regulation loop in the proposed method. They discovered that required dc-link voltage magnitude is less when compared to conventional method. Under predefined load conditions such as industrial set loads, this less voltage is sufficient to give satisfactory performance. Therefore, the rating of DSTATCOM is reduced and thereby the cost of system is reduced. The proposed method enables compensation of reactive power and mitigation of source current harmonics in a distribution system for low power applications. The advantages of the proposed method are elimination of dc voltage sensing elements, minimization of switching loss of Voltage Source Inverter (VSI) and cost effective.

Padmavathi & Rama (2019), implemented an optimal placement and sizing of DSTATCOM using firefly algorithm in the distribution system. Minimisation of power loss and minimisation of installation cost of DSTATCOM were considered as the objective function (OF), where the voltage and current limits of the buses are chosen as the optimization constraints. The performance of the proposed methodology using FA was demonstrated on IEEE 33-bus and 69-bus radial distribution systems using MATLAB software. Backward/forward sweep algorithm was used for load flow analysis of radial distribution system. The efficacy of the proposed methodology using FA was compared with the results obtained by using immune algorithm (IA) and results were found to be excellent.



Kaliaperumal *et. al.*, (2020), implemented new approach to optimal location and sizing of DSTATCOM in radial distribution networks using bio-inspired cuckoo search algorithm. They proposed a new approach based on a bio-inspired Cuckoo Search Algorithm (CSA) that can significantly envisage with several issues for optimal allocation of distribution static compensator (DSTATCOM) in Radial Distribution System (RDS). In the proposed method, optimal locations of the DSTATCOM are calculated by using the Loss Sensitivity Factor (LSF). The optimal size of the DSTATCOM were simulated by using the newly developed CSA. Load flow calculations are performed was using a fast and efficient backward/forward sweep algorithm. Here, the mathematically formed objective function of the proposed method was to reduce the total system power losses. Standard 33-bus and 69-bus systems where been used to show the effectiveness of the proposed CSA-based optimization method in the RDS with different load models. The simulated results confirmed that the optimal allocation of DSTATCOM plays a significant role in power loss minimization and enhanced voltage profile. The proposed method encourages one to use renewable-based resources, which results in affordable and clean energy.

## METHODOLOGY

### Modelling and Simulation

Consider a multi-objective problem with  $m$  decision variables (parameters) and  $n$  objectives:

$$\text{Minimize } y = \{f_1(x), f_2(x), \dots, f_n(x)\} \quad (3.1)$$

$$X = [x_1, x_2, \dots, x_m]$$

(3.2)

Where,  $x$  and  $y$  are the decision and objective vectors respectively.

### Problem Formulation

Here, the objective is to accomplish two goals:

- i. Minimize total active power loss,  $P_{T(loss)}$
- ii. Minimize voltage deviation,  $V_D$

The network total active power loss function as modelled in equation (2.11) is given by:

$$P_{T(loss)} = \sum_{ik=1}^{N_{Branch}} |I_{B(ik)}|^2 * \Re(Z_{ik}) \quad (3.3)$$

The voltage deviation function is expressed by:

$$V_D = \sum_{k=1}^{N_{Bus}} (V_k - V_k^{ref})^2 \quad (3.4)$$

Where,  $V_k$  and  $V_k^{ref}$  are the per-unit (p.u) voltage values at bus  $k$  and the reference bus respectively. The multi-objective function ( $J$ ) can be formulated mathematically using the weighted sum of equation (3.3) and (3.4) to give:

$$\text{min}(J) = \text{min}(\omega_1 P_{T(loss)} + \omega_2 V_D) \quad (3.5)$$

Where,  $\omega_1$  and  $\omega_2$  are the weighting metrics used for adjusting the network total active power loss and voltage deviation functions respectively. Due to the equal importance attached to both objectives in equation (3.5), a unit weighting metric was assigned to both objective functions. Thus,  $\omega_1 = \omega_2 = 1$ .

The optimal siting and sizing of DSTATCOM is considered as a constrained optimization problem that deals with the equality and inequality constraints.

#### a) Equality Constraints

The equality constraints represent the power flow equations expressed as:

$$\sum_{k=1}^{N_{Bus}} P_{Gk} - P_{Dk} = P_L \quad (3.6)$$

$$\sum_{k=1}^{N_{Bus}} Q_{Gk} - Q_{Dk} = Q_L \quad (3.7)$$

Where,  $P_{Gk}$  and  $Q_{Gk}$  are the total active and reactive power generation at bus  $k$  respectively,

$P_{Dk}$  and  $Q_{Dk}$  are the total active and reactive power demand at bus  $k$  respectively,

$P_L$  and  $Q_L$  are the total active and reactive power losses.

#### b) Inequality Constraints

The inequality constraints represent the network load bus, bus voltage and DSTATCOM size limits respectively given by:

$$\lambda_n^{\min} \leq \lambda_n \leq \lambda_n^{\max} \quad (3.8)$$

$$V_k^{\min} \leq V_k \leq V_k^{\max} \quad (3.9)$$

$$Q_n^{\min} \leq Q_n \leq Q_n^{\max} \quad (3.10)$$

The initial parameter settings for DSTATCOM and ABC algorithm are furnished in Table 1.

Table 1: Parameter settings for DSTATCOM and ABC algorithm

ABC Parameter	Value
Population of Bees	30
Population of Onlooker Bees	30
Maximum Iteration	100
Acceleration Coefficient	1

## RESULTS AND DISUSSIONS

Results obtained during the simulation of the optimal placement of distributed Static Synchronous Compensator (DSTATCOM) for the 15-bus Government distribution feeder is presented.

### Results for Govt-House 15 Bus Feeder without DSTATCOM

#### Voltage Profile

Figure 9 shows the voltage profile obtained for the 15 Bus Government Feeder without the DSTATCOM installed. It can be seen from the figure that the highest value of 1 pu was obtained at bus 1 while the lowest

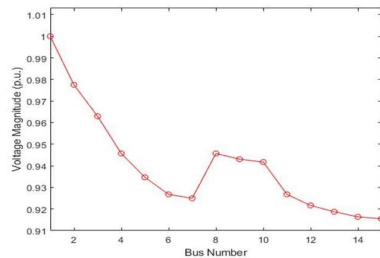


Figure 2: Voltage Profile for Govt-House Feeder without DSTATCOM

value of 0.9155 pu was obtained at bus 15. It can also be seen that 12 buses violated the allowed voltage range because they are outside the allowed range of  $\pm 0.95$  pu. It took about 0.5 seconds to run the simulation.

### Power Losses Without DSTATCOM

After running the load flow simulation for the 15 Bus Government Feeder without DSTATCOM, the real and reactive losses obtained is 171.66 kW and 195.47 kVar respectively. Figure 3 shows the real and reactive losses obtained on same plot. The real and reactive losses are highest on bus 2 and lowest at bus 9.

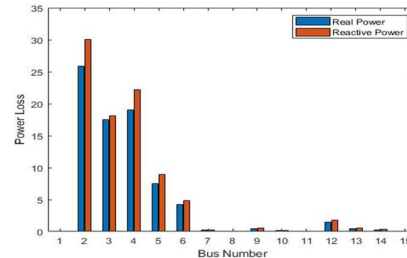


Figure 3: Real and Reactive Losses at Govt-House Feeder without DSTATCOM

### Results for the 15 Bus Government Feeder with DSTATCOM

#### Location and Sizing of DSTATCOM

The results obtained after running the artificial bee colony algorithm simulation for the optimal sizing and placement of DSTATCOM on the 15 bus Government feeder shows that, the best location for placement of DSTATCOM is at Bus 4. The artificial bee colony algorithm arrived at an optimal size of 629.5 kVar for the DSTATCOM. This can be seen in the voltage profile improvement and

reduction in the loss along the Govt-House 15 bus radial distribution system.

Figure 4 shows the plot of the voltage profile obtained for Govt-House 15 Bus RDS with DSTATCOM installed. It can be seen from the figure, the highest value of 1 pu was obtained at bus while the minimum value of 0.9488 pu was obtained at bus 7. It can also be seen that there was only one bus that violated the constraints. ( $\pm 0.95$ pu). Figure 5 shows the plot for comparison of both with and without DSTATCOM installed.

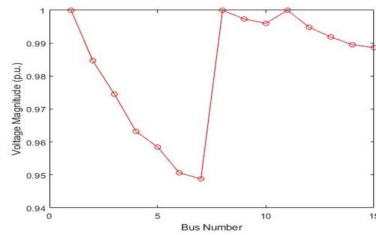


Figure 4: Voltage Profile for Govt-House 15 Bus feeder with DSTATCOM

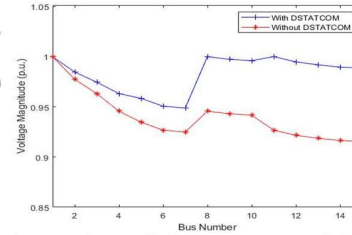


Figure 5: Voltage Profile for Govt-House 15 Bus feeder with and Without DSTATCOM

Table 2 shows the performance indices for the proposed approach. The total voltage deviation, mean average error and sum of square of errors obtained for the GRA 15 bus RDS is 0.8979, 0.0599 and 0.0619 respectively. With DSTATCOM, installed the total voltage deviation, mean average error and sum of square of errors obtained for the GRA 15 bus RDS is 0.2616, 0.01744 and 0.0094 respectively. The values obtained for the RDS with DSTATCOM installed is much lower than without the DSTATCOM installed. This indicates that there is an overall significant improvement in the quality of voltage which is as a result of the installation of the DSTATCOM.

From results shown in Table 2 and Figure 5, it can be clearly seen that the DSTATCOM improved the power quality of the whole Govt-House 15 Bus feeder system. There was only one bus voltages violation after the DSTATCOM was installed as compared to 12 bus violations when the DSTATCOM was not installed. The lowest voltage at the bus without the DSTATCOM was at bus 7 at 0.9155 pu. After optimal DSTATCOM installation the bus voltages improved and the new minimum voltage was at bus 0. 0.9488 pu at bus 7. All the bus voltage except bus 7 fall within the allowable range of  $\pm 1.05$ pu. The highest voltage for both cases was 1pu @ bus 1.

Table 2: ABC Performance Indices

Performance Indices	Govt feeder	Govt feeder+ DSTAT
Total Voltage Deviation	0.8979	0.2616
MAE	0.0599	0.0174
SSE	0.0619	0.0094

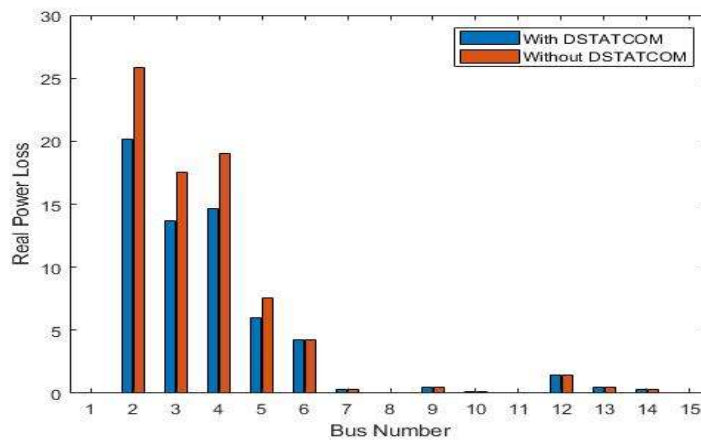


Figure 6: Real Power Loss for Govt-House 15 Bus feeder with and Without DSTATCOM

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### Power Losses Reduction with DSTATCOM

After running the load flow simulation for the Govt-House 15 Bus feeder with DSTATCOM installed the real and reactive losses obtained is 61.87 kW and 70.35 kVar respectively. Figures 6 and 7 show the real and

reactive power losses obtained. Figure 8 shows the comparison between the total real and reactive power losses obtained for all the branches with and without optimal allocation of DSTATCOM. losses at each bus with and without DSTATCOM installed.

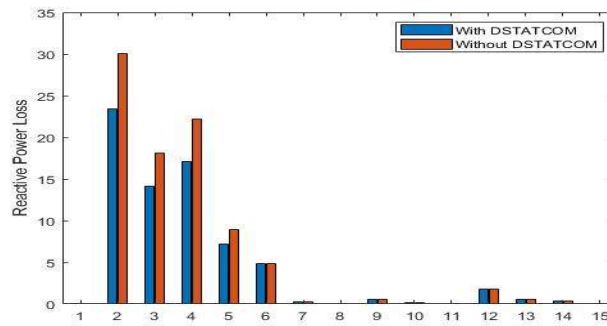


Figure 7: Reactive Power Loss for Govt-House 15 Bus feeder With and Without DSTATCOM

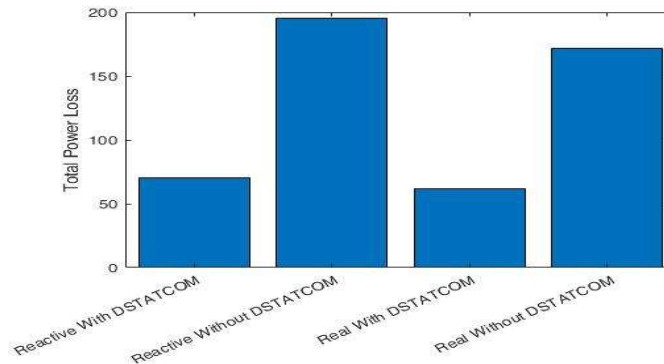


Figure 8: Total Power for Govt-House 15 Bus feeder with and Without DSTATCOM

At the Govt. feeder 15 Bus, the real power loss obtained before DSTATCOM installation is 171.65 kW. After DSTATCOM installation a loss of 61.87 kW was obtained. This represent 63.9% reduction in power loss across the RDS, which is a significant improvement. Similarly, the reactive power loss obtained before DSTATCOM installation is 195.47 kVar. With DSTATCOM installation the

reactive power loss dropped to 70.35 kVar. This also represents 64.01% reduction in reactive power loss across the RDS. This loss reduction achieved because of the optimal placement and sizing of the DSTATCOM on the RDS. Table 3 presents the summary of the results obtained with and without the optimal allocation of STATCOM.

**Table 3:** Comparison of Results for Govt-House Feeder with and without DSTATCOM

Parameter	Base Case: Without DSTATCOM	With DSTATCOM
Real Power Loss	171.65 kw	61.87 kw
Reactive Power loss	195.47 kvar	70.35 kvar

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Parameter	Base Case: Without DSTATCOM	With DSTATCOM
Bus Max Vpu	1@ Bus1	1@ Bus1
Bus Min Vpu	0.9155 @ Bus 15	0.9411@ Bus 7
Number of Bus Violations	12	1
DSTATCOM Location	--	Bus 4
% Reduction in Real Power Loss	--	63.9%
% Reduction in Reactive Power Loss	--	64.01%
Optimal size of DSTATCOM	--	629.05 kvar
Convergence Time	0.4s	101s

## CONCLUSION

This paper presents the application of Artificial Bee Colony (ABC) for the optimal DSTATCOM siting and sizing in Radial Distribution Systems (RDS) for power loss minimization and voltage profile improvement. The 15 bus Government feeder Lafia of the Abuja electricity distribution network has been modelled in Matlab environment. The RDS power flow analysis was carried out using the Bus Injection to Bus Current matrix (BIBC). The models have been simulated with and without DSTATCOM. The optimal location and sizing of the DSTATCOM was done using Artificial Bee Colony (ABC) Optimization techniques.

The ABC algorithm was also used to determine the optimal location and size for the 15-bus, 11 kV Govt. feeder RDS in Lafia, Nigeria. The DSTATCOM was optimally sited using ABC between at 4 with a maximum DSTATCOM size of 629.05 kVar. There was an overall voltage improvement with ABC and this caused a system total real and reactive power loss reduction of 63.9% and 64.01% for real and reactive power respectively. Result presented clearly show the effectiveness and superiority of the proposed approach by improving voltage profile and reducing power loss.

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