**Load Flow Evaluation of Nigerian Transmission System for Improved Stability/Performance Using Global-best Artificial Bee Colony (GABC) Algorithm; A Case Study of the Calabar 132/33kV Transmission/Distribution Network**

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**Abstract*:***

*The Nigerian power sector has witnessed an increasing load demands in recent times, it is essential to plan, manage, and expand the power system in order to meet up with the energy demand in order to avoid transmission system collapse due to over bearing demand. This thesis uses the Global Best Artificial Bee Colony (GABC) method in order to assess the 132/33kV Calabar transmission network (which includes a 35-bus network) and simulate it in a MATLAB environment to determine the current status of its load flow. Data used was sourced from the Transmission Company of Nigeria (TCN) and its results revealed that GABC fared better than the other known techniques giving the least or best cost (power mismatch) and improved voltage profile.This occurred after a little over 14,000 max-cycles.* *Due to overloading, distance, and line ageing, the transmission line connecting buses 20 and 21 experienced losses. Since lines with the greatest real and reactive loss are those linked to buses with the lowest voltage angle magnitude, respectively, both the real and reactive power flow can be impacted by changes in bus voltage angles and magnitude.*

*Additionally, the bus voltage began on bus number 1 within the tolerance level of about 1 p.u and continued to do so in bus 2, before fluctuating down towards 0.99 p.u at bus 3, even though it exceeded 1 p.u in bus 15. This indicates that the voltage overstepped its boundaries in the response pattern within the normal tolerance limit. The load flow findings show that the transmission lines from 1 to 2, 10 to 6, 3 to 18, and 20 to 21 recorded the biggest power losses. This could be due to distance, line overloading, or line ageing, thus improvements in the networks' ability to provide power should be addressed.*

*The following reactive power optimization (RPO) results were obtained for the real Calabar 132kV 35-bus, and IEEE 57-bus standard test bus systems, respectively, to check the efficacy and robustness of the GABC algorithm: 3.01424603and 11.488.Proving that GABC is a better strategy for reducing power loss when compared to the literature that is currently accessible (networks of comparable size/capacity). Finally, the Wilcoxon rank sum test was used to statistically analyze the results of this study for the genuine Calabar 132kV 35-bus system and the IEEE 57-bus standard test bus system. The given results are as follows: 0.850216995 and 0.850359749 (i.e., This test is run at a significance level of 0.05. If the statistical value is greater than the significance threshold (i.e.,) in the instance of the Wilcoxon rank sum test, the hypothesis will be kept by (or vice versa). 1.983971519 is the determined critical value. Finally, the designed network for the improvement of voltage and stability of the network was sproposed, utilizing the incorporating of the distributed generation (DG) to the central generation in the network for optimum performance.*

***Keywords:*** *Artificial Intelligence, Artificial Bee Colony, Load Flow Analysis, Global Best Artificial Bee Colony (GABC), Employed Bee, distributed Generation (DG), Central Generation (CG)*

1. **INTRODUCTION**

The Calabar 132kV sub-transmission infrastructure is carefully examined, and it becomes clear that the transmission companies are unable to adequately control the reactive electrical power flow of the network, which results in voltage losses and load shedding. These networks are linked to insufficient electricity distribution and insufficient generation capacity. Inadequate or non-existent reserves and insufficient control infrastructure are other significant factors impacting stability. Therefore, to ensure effective performance, a thorough network analysis, planning, optimisation, operation, and control must be made as soon as possible to prevent a complete system failure. Similar to how the most recent collapse of the national power grid was witnessed [1].

This study aims to assess and enhance the existing 132/33kV Calabar transmission system's load flow performance for the stability of the network and overall efficiency, thus providing the network with a framework for medium-term operation. With the following specific objective; To create a standard swarm intelligence model based on GABC to calculate the voltage magnitudes, phase angle of load buses, actual and reactive power flows, and other parameters of the transmission line, Using the algorithm known as the Global Best Artificial Bee Colony (GABC) Algorithm, model, modify, and simulate the network, To make better use of the base-case simulation's findings in order to reduce loss of power across the 132kV Sub-transmission system and to improve the overall actual and reactive power flow.

The significance of this research study lies in the solutions it will provide for efficiently reducing real and reactive power losses and appropriately injecting reactive and active electrical power into the networks in an effort to boost performance and provide better service. Once more, the evaluation's findings will offer helpful data for future growth.

Modelling and simulating unique Gbest ABC algorithms for the 132kV Calabar zonal transmission system is the goal of this research project. This is necessary in order to increase the quality of the power being transmitted and distributed throughout the metropolis of Calabar and its surroundings. The model being proposed is an accurate technological approach that is extremely effective, efficient, and high convergence for studying a transmission network that is under a lot of stress, such as the Calabar network.

Due to its high rate of convergence, the Newton Raphson (NR) approach is still widely used today to solve load flow equations, but it has some drawbacks as well. For instance, the method's efficiency is dependent on the network's initial values, it is challenging to identify the normal operating solutions, and it cannot be used to solve large, complex power systems [2].

In this study, the 132kV 35-bus network, which makes up the Calabar transmission network, has a load flow problem that is being solved using the Global Best Guided Artificial Bee colonies (GABC) method, which is based on swarm intelligence. Through simulation on a 35-bus real (stressed/ill-conditioned) Calabar network to further validate the uniqueness of our model, it is demonstrated that the GABC algorithm performs better than the standard ABC, the traditional Newton-Raphson (NR method), Gause-Seidel (GS methods) [1]

The supply of efficient, reliable and affordable electric power is a panacea to foster development in any country. Development of electricity infrastructure is undoubtedly a capital intensive project that must be carefully and holistically planned especially when future expansion frame work is taken into consideration. For Nigeria to keep pace with other developed countries which have exhibited a substantial growth in economic developm

, the existing gap between the electric power demand and supply of the country must be bridged. Till now, Nigeria is still entrenched in constricted opportunity for development due to frequent outages resulting from shortage in generation, as well as inadequate transmission and distribution infrastructure. Within the ambient of socio-economic development and increase in human population electric load demand is on the increase over the years. This research studies a load demand forecasting for residential section of the power sector using time series as a tool for analysis. The outcome shows there is need to constantly improve power generating, transmission and distribution network to deliver at least 20,000mw of power to its residents in other to meets the estimated or forecasted power of 19576.05 MW in the year 2030 [3]

1. **LITERATURE REVIEW**

An important role for load flow analysis is played in the design, management, and control of power system networks. In the recent few decades, a number of optimization algorithms have been introduced, including the evolutionary algorithm, particle swarm optimization, harmony search, artificial bee colony, and ant colony optimization. Its performance was evaluated using the benchmark optimization function, and its development was inspired by modelling the intelligent foraging behaviour of honey bees in their colony. The following are only a few of ABC’s key advantages over other optimization algorithms: Robustness, adaptability, and simplicity of modelling, use of few control parameters are used, Hybridization with additional optimisation methods is simple, Capacity to manage the stochastic character of the objective cost, Simplicity in application using fundamental logical and mathematical operations and Reliability, robust convergence, and accuracy.

In the Nigerian Power Sector (Lagos Zone), the deregulation exercise and constant rise in Load demand has led to the need for planning, controlling and expanding of the power system network which is important and it’s done with power flow studies on existing network to determine some unknown network parameters with the assumptions that the system is in steady state. In this work, ABC simulates the intelligent foraging behaviour, of a honeybee swarm and it is used for optimizing a large set of numerical test functions and the results produced by the three variants of the ABC namely, ABC\_normal, ABC\_global best and ABC\_matlab fitness evaluation controlled. They are investigated to ascertain which is best or which of these technique are potential candidates used for load flow analysis of power system network? Simulations were conducted using the MATLAB programming language considering primarily the bus voltage, line losses and phase angle for the 35bus, 132kV Nigerian sub-transmission power system network, Lagos Zone. The results of simulations revealed that the voltages and angles solved by the ABC\_normal and ABC\_gbest techniques are closely correlated i.e. not significantly different from zero, with a p-value of about 0.3033 and 0.2029 respectively with the Pearson T-test; and on the other hand, there exists no correlation between the ABC\_normal and ABC\_mfe\_controlled technique corresponding to a significant distance from zero. The ABC\_gbest also fared better giving the least cost or power mismatch after 15,000 iterations of the load flow simulation [4].

In the past, load flow issues were examined using the Newton-Rahpson (NR) approach. However, NR has certain intrinsic flaws such the inability to handle heavily loaded networks, the need for starting value assumptions, and anomalous operating situations. The load flow problem for the 35-bus real Calabar 132kV transmission network, IEEE 57-bus, and IEEE 118-bus is solved using the Global Best Artificial Bee Colony algorithm (GABC), a recently invented swarm intelligence-based technique, to get around the limitations of the existing NR method.

Take for instance if the design of transmission system are not properly design to accommodate future needs or other associated complexities, then that project is bound to fail because if a power system network like that of Nigeria is not design taking into consideration the population growth, then future expansion becomes difficult. That is why traditional systems' handling of the strategic issues of project management has various flaws that have been exposed by the rising complexity of projects and the environment, as well as the rapid rate of change to which organizations are subjected. The system dynamics model is a useful tool for more effectively organizing the management of key strategic concerns. In an ever-evolving world of technology and innovations, the client's behaviour on a project has led to many complexities, including schedule constraints on accomplishments, high demand for progress reports, delays in the approval of progress recorded, as well as changes to agreed work templates over the course of the project. Project managers have learned how crucial it is to take these effects into account in order to connect with their clients. However, keeping in mind that the conventional approaches to project planning and management have failed to deliver accurate and timely information. System Dynamics offers a different perspective in which these significant variables are taken into account and explicitly measured [4].

The provision of sufficient, reasonably priced, and reliable electric power is a vital prerequisite to nurture or drive this necessary desired transformation for Nigeria to make significant progress in terms of growth in its key sectors such as infrastructure, economics, and security. Additionally, the nation's electric power consumption and supply must be comprehensively planned and achieved as a matter of urgent necessity if it is to keep pace with developed countries around the world that have demonstrated phenomenal growth in economic development and transformed into industrialized nations. Epileptic power supply issues have recently gotten worse at an alarming rate. In particular, low power output and the national grid breakdown brought on by unrest brought on by bandit attacks on the facilities housing the transmission lines. The strength of any healthy economy is directly correlated to the expansion of the industrial sector, which is made possible by the accessibility of a reliable power supply. Today's industries in Nigeria produce their own power, largely as a result of the discontent with the available supply. Additionally, the cost of manufacturing is high due to the spike in petrol, diesel, and petroleum prices, which raises market prices for other goods and drives up inflation. If the demand and supply for electric energy can be balanced, other problems in Nigeria will be significantly less difficult to tackle. Therefore, the purpose of this study is to project the load demand for the industrial sector using a time series model. The results show that, by the year 2030 or earlier, it would be necessary to create a projected 20,000MW of electric power in order to effectively and affordably power her industry [5][6].

In contemporary load flow calculations, it is still the approach of preference. The load flow calculation approach has seen numerous developments since the 1970s. The fastest of them, also known as the PQ decoupling approach, has proven to be the most effective. This method is more widely used in many situations since it is algorithmically simpler and more effective than the Newton method. In the last 20 years, there has been a lot of research done on load flow analysis. Numerous studies have targeted the objective of enhancing the Newton methods along with the PQ decouple method's convergence properties [16][7][17][18][19][20]. The genetic algorithm, the artificial neural network approach, and fuzzy algorithm have all been applied to load flow evaluation along with the advancement of artificial intelligence theory [11]; [22];[13] [14].

1. **METHODOLOGY**

**3.1 Mathematical Model and Fundamental Equations of Load Flow Analysis on an N-bus System**.

The mathematical Formulation for Reactive Power optimization entails obtaining the stated objective function for the given problem while abiding by the boundary conditions. The optimization problem's mathematical model is typically expressed as follows:

Maximize / Minimize f (x, u)

With constraint h (x, u) = 0 (3.1)

Lower limit ≤ g (x, u)

≥ Upper limit

Here, f is the defined problem's formulated objective function, h is the equation or equality constraint, g is the inequality constraint, x is the defined problem's state variable, the lower limit is the defined problem's lower limit, and the upper limit is the defined problem's upper limit.

Reactive power optimization is the process of reducing active power loss while maintaining grid security requirements. The objective function for the problem of reactive power optimization is provided below in the mathematical form:

Minimize F(x,u) = Minimize PLoss

Nb

= Ʃ Transmission Loss k (3.2)

k=1

where Nb is the total number of branches or lines in the network, PLoss is the objective function for optimising the reactive power problem, and Transmission Lossk is the active power loss in the kth branch or line. The active power loss:

Nb

PLoss = Ʃ G(k) (Vm(FB(k))2 + Vm(TB(k))2 - 2Vm(FB(k)) Vm(TB(k))cos (Vaa(FB(k)) –

k=1

Vaa(TB(k))) (3.3)

where G(k) is the conductance of the kth line, Vaa represents the voltage angle of the corresponding bus voltage, Vm is the magnitude of the corresponding bus voltage, and FB(k) and TB(k) are the notations for the respective buses, from and to, respectively. It is specified by FB(k) and TB(k) how the buses are connected.

**3.2 Application of G-Best Guided ABC Algorithm for Optimization Of Reactive Power Problem**

**A. Initialization phase**

Set the hive's population to zero. Choose half of the population to be workers, and the other half to be observers. Set up the maximum trail counter and the most cycles. Set the upper and lower bounds for the vectors of the control variables, i.e.

P upper\_limit ≥Pgk ≥ Plower\_limit

gk

gk

V upper\_limit ≥Vgk ≥ Vlower\_limit

gk

generator k

Tupper\_limit ≥ Tk ≥ Tlower\_limit

k

k

Q upper\_limit ≥Qshk ≥ Qlower\_limit

shk

shk

Randomly generate initial food source or solutions by generating control variables in between upper and lower limit by equation (3.17) i.e.

UT = [ Pg1, … …, PNg, Vg1, … …, VNg, Qsh1 … …, QNq, T1, … …,TNt]

But except generator connected at slack bus. Use control variables and run Newton Raphson power flow. Check whether constraints satisfy the upper and lower limit or not i.e.

V upper\_limit ≥ VLk ≥ Vlower\_limit ,

Lk

Lk

Q upper\_limit ≥Qgk ≥ Qlower\_limit ,

gk

gk

S upper\_limit ≥SLk

Lk

Apply penalty weight method to differentiate violated and unviolated solutions. Memorize the least power loss solution from set of solutions.

**Cycle = 1;**

**While (Cycle >= maximum number of cycle)**

## For employed bee = 1: number of employed bees

### **B. Employed bee phase**

Exploit initial food source by equation (3.21) by randomly selecting any control variable from particular initial solution. Use control variables and run Newton Raphson power flow. Check whether constraints satisfy their upper and lower limit or not i.e. V upper\_limit ≥ VLk ≥ Vlower\_limit , Q upper\_limit ≥ Qgk ≥ Qlower\_limit and S upper\_limit ≥ SLk . Apply penalty weight method to differentiate violated and unviolated solutions. Memorize the least power loss solution from set of solutions.

Lk

gk

gk

Lk

Lk

**End**

**For onlooker bee = 1: number of onlooker bees**

**Unemployed or Onlooker Bee Phase**

Exploit initial food source or solution again by equation (3.21) by randomly selecting any control variable from particular initial solution. Use control variables and run Newton Raphson power flow. Check whether constraints satisfy their upper and lower limit or not i.e. V upper\_limit ≥ VLk ≥ Vlower\_limit , Q upper\_limit ≥ Qgk ≥ Qlower\_limit and S upper\_limit ≥ SLk. Apply penalty weight method to differentiate violated and unviolated solutions. Memorize the least power loss solution from set of solutions.

Lk

gk

gk

Lk

Lk

**End**

### **Scout Bee Phase**

Investigate the incremental trail counter. If the number of trails counter exceeded the predetermined maximum number of trails counter, the first solution in question was rejected, and the new solution set was created by randomly generating control variables between higher and lower bounds.

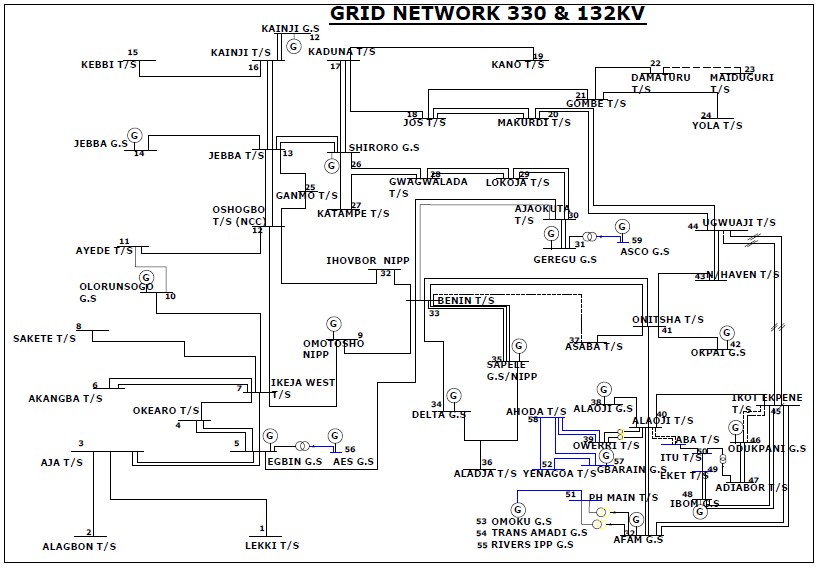
**Cycle = Cycle + 1;**

1. **Termination criteria** If cycle number is equal to the maximum number of cycles, then stop the exploitation. **End.**

**3.3 Cross-Section of Nigerian 132kV Power Transmission Network (Calabar Zone)**

In this research, the Calabar 132kV transmission network was investigated and a special attention was paid to the NIPP Odukpani Power Plant (since it delivers the highest quantum of power to the station). The Calabar 132kV transmission station is considered strategic and unique to the Nigerian national grid. The station has two (2) incoming 132kV lines, and 35-bus 132kV outgoing lines to step down transmission stations in the network. The transmission station consists of four (4) 150MVA step-down transformer (resulting in a total station capacity of 600MVA or 480MW) for stepping the incoming 330kV to 132kV.

The transformer has nomenclatures given as; T1A, T1B, T2A and T2B. Two (2) 75MX reactors R1 and R2 are connected to the 330kV bus-bar for voltage stability. Two earthing transformers (GT1A and GT2A) are attached to the transformers, and GT1A is connected to the tertiary of T1A while GT2A is connected to the tertiary of T2A. The generators are assumed to be operating at 80% of their maximum installed capacity with the highest being the EGBIN thermal station which will be assumed as the power swing bus for the Load Flow Analysis [1].

 The information for the accurate representation of this test system was obtained through an authorized data gathering from the Transmission Company of Nigeria Substation. In this research effort, typical values of machine parameters, such as steady state and dynamic data,

**Figure 3.1: Single Line Diagram of Nigerian 330kV/132kV Power System.**

were incorporated for simulation. These values could not be obtained from TCN (Transmission Company of Nigeria). Lagos is home to one of Nigeria's largest 132kV transmission networks. From the Transmission Company of Nigeria Substation, the Calabar metropolitan transmission network has the following line voltage levels: 330kV, 132kV, 33kV, 11kV, and 240V. The single line diagram of the 330kV/132kV Nigerian Transmission networks is shown in Figure 3.1 above.

**Table 3.1: Sub-transmission Network of the Calabar Sub-RegionSubstation**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Calabar 132kVSub-region** | | | | | | |
|  | | | | | | |
| **S/N** | **Transmissionsubstation** | **TransmissionSubstation**  **Location** | **AreasConnected** | **Load(MW)** | **TransformerLocationName** | **TransformerSize(MVA)** |
|  |  |  | Akamkpa | 8 |  |  |
|  |  |  | Creek Town | 8 | T1A | 60 |
| 1 | Feeder 1 | Akampa | Uyanga | 22 | T1B | 30 |
|  |  |  | Federal Housing | 13 | T2A | 30 |
|  |  |  |  | 22 | T2B | 45 |
|  |  |  |  | 22 |  |  |
|  |  |  |  | 8.2 |  |  |
|  |  |  | Ameka | 8.5 |  |  |
|  |  |  | Unical | 17.6 |  |  |
|  |  |  | Eta Agbor | 1.8 |  |  |
|  |  |  | Atimbo | 14.3 | T1A | 60 |
| 2 | Feeder 9 | Ameka | Airport Road | 12.1 | T2A | 60 |
|  |  |  | IBB | 5.8 | T3A | 60 |
|  |  |  | Atimbo | 17.8 |  |  |
|  |  |  | Ekpo-Abasi | 13.8 |  |  |
|  |  |  | Crutech-Calabar | 16.4 |  |  |
|  |  |  | Diamond | 15 |  |  |
|  |  |  | Diam.Essien Town | 15 | T1 | 40 |
| 3 | Feeder 8 | Diamond | Ekorinum | 3 | T2 | 40 |
|  |  |  | Calabar Road | 2.5 |  |  |
|  |  |  | Target Road  Marian Hill | 4.5 |  |  |
|  | Feeder 7 | Water Board | Water Board | 19 | T1 | 40 |
| 4 |  |  | Parliamentary | 20 | T2 | 40 |
|  |  |  | Parliamentary village | 8 |  |  |
|  |  |  | Flour Mill Road 2 | Nil |  |  |
| 5 | Feeder 5 | Flour Mill Road 2 | Ikorishi | 4 | T1 | 40 |
|  |  |  | Essien Town | 10 | T2 | 40 |
|  |  |  | Ikot Ansa  Marian | 13 |  |  |
|  |  |  | Flour Mill Road 1 | 16 |  |  |
|  |  |  | State Housing | 17.6 | T01 | 60 |
| 6 | Feeder 6 | Flour Mill Road 1 | Essien Town | 7.5 | T02 | 60 |
| 7 | Feeder 3 | Flour mill Industry | Flour Mill Industry | 6.8 | T01 | 60 |
| 8 | Feeder 10 | Olam | Olam | 7.5 | T01 | 60 |
| 9  10  11  12 | UNICEM  EPZ 1  EPZ 2 | EPZ  EPZ Complex 1  EPZ Complex 2 | EPZ  EPZ Complex 1  Esukutan  EPZ Complex 1 | 8.4  5  5  10 | T01  T01  T01  T02 | 60  60  60  60 |
| (**Source:**TransmissionCompanyofNigeria,Calabar) | | | | | | |

**Table 3.2: Load Legend for 132kV Sub-Transmission Network for Sub-region and their Load Capacity**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **LoadLegendfor132kV Calabar Sub-transmission Networks** | | | | | |
| **Legend** | **Name** | **Power(MW)** | **Legend** | **Name** | **Power(MW)** |
| L1 | Akamkpa | 16 | L2 | Water Board | 17.6 |
| L3 | Creek Town | 7.5 | L4 | Parliamentary | 6.8 |
| L5 | Uyangha | 7.5 | L6 | Parliamentary Extension | 8.4 |
| L7 | Federal Housing | 8 | L8 | Diamond | 8 |
| L9 | EPZ Complex 1 | 22 | L10 | Diamond By Essien Town | 13 |
| L11 | Esukutan | 22 | L12 | Ekorinum | 22 |
| L13 | EPZ Complex 2 | 17.8 | L14 | Calabar Road | 13.8 |
| L15 | Flour Mill Road 1 | 16.4 | L16 | Target Road | 14.3 |
| L17 | State Housing | 12.1 | L18 | Marian Hill | 5.8 |
| L19 | Essien Town | 8.2 | L20 | Ameka | 8.5 |
| L21 | Olam | 17.6 | L22 | Eta Agbor | 18 |
| L23 | Flour Mill Industry | 15 | L24 | Atimbo | 15 |
| L25 | Flour Mill Road 2 | 3 | L26 | Airport Road | 2.5 |
| L27 | Ikoreshi | 4.5 | L28 | IBB | 19 |
| L29 | Essien Town Extension | 20 | L30 | Ekpo Abasi | 8 |
| L31 | Ikot Ansa | Nil | L32 | UNICAL/UCTH | 4 |
| L33  L35 | Marian  UNICEM | 10  1.6 | L34 | CRUTECH Calabar | 13 |

*(****Source:*** *Transmission Company of Nigeria, Calabar)*

**IV. SIMULATION RESULTS, PLOTS AND DISCUSSION**

**4.0 SIMULATION PARAMETER SETTING**

With the following simulation parameter settings, the GABC method is being applied to the IEEE 57-bus, IEEE 118-bus, and the real time 35-bus Calabar 132kV transmission networks: In this thesis, the gbest guided ABC algorithm is used to solve a reactive power optimization issue. This approach is used to tackle the optimization of reactive power problems on three test systems, including the genuine 35-bus Calabar 132kV network, IEEE 57-bus, and 118-bus bus system. The advantage of utilizing the GABC algorithm is demonstrated by the comparative study of the results produced for each test system.

## Real 35-bus Calabar 132kV System

## Table 4.1: Bus Codes, Labels, Bus Types, Bus Power Injection (Smva), Real and Reactive Power.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Bus Code** | **Label** | **Type of Bus** | **SMVA** | **P (MW)** | **Q (MVAR)** |
| 1 | Akamkpa | PQ | 120.0000 | 96.0 | 72.0 |
| 2 | Creek Town | PQ | 132.0000 | 105.6 | 79.2 |
| 3 | Uyangha | PQ | 600.0000 | 480.0 | 360.0 |
| 4 | Federal Housing | PQ | 90.0000 | 72.0 | 54.0 |
| 5 | EPZ Complex 1 | PQ | 85.0000 | 68.0 | 51.0 |
| 6 | Esukutan | PQ | 660.0000 | 144.0 | 108.0 |
| 7 | EPZ Complex 2 | PQ | 130.0000 | 104.0 | 78.0 |
| 8 | Flour Mill Road 1 | PQ | 150.0000 | 120.0 | 90.0 |
| 9 | State Housing | PQ | 75.0000 | 60.0 | 45.0 |
| 10 | Essien Town | PQ | 135.0000 | 108.0 | 81.0 |
| 11 | Olam | PQ | 150.0000 | 120.0 | 90.0 |
| 12 | Flour Mill Industry | PQ | 60.0000 | 48.0 | 36.0 |
| 13 | Flour Mill Road 2 | PQ | 60.0000 | 48.0 | 36.0 |
| 14 | Ikoreshi | PQ | 135.0000 | 108.0 | 81.0 |
| 15 | Essien Town | PQ | 60.0000 | 48.0 | 36.0 |
| 16 | Ikot Ansa | PQ | 150.0000 | 120.0 | 90.0 |
| 17 | Marian | PQ | 120.0000 | 96.0 | 72.0 |
| 18 | UNICEM | PQ | 90.0000 | 72.0 | 54.0 |
| 19 | Water Board | PQ | 165.0000 | 132.0 | 99.0 |
| 20 | Parliamentary | Slack | 337.5000 | 270.0 | 202.5 |
| 21 | Parliamentary Ext. | PQ | 180.0000 | 144.0 | 108.0 |
| 22 | Diamond | PQ | 70.0000 | 56.0 | 42.0 |
| 23 | Diamond By Essien | PQ | 115.0000 | 92.0 | 69.0 |
| 24 | Ekorinum | PQ | 105.0000 | 84.0 | 63.0 |
| 25 | Calabar Road | PQ | 120.0000 | 96.0 | 72.0 |
| 26 | Target Road | PQ | 90.0000 | 72.0 | 54.0 |
| 27 | Marian Hill | PQ | 85.0000 | 68.0 | 51.0 |
| 28 | Ameka | PQ | 135.0000 | 108.0 | 81.0 |
| 29 | Eta Agbor | PQ | 522.0000 | 417.6 | 313.2 |
| 30 | Atimbo | PQ | 105.0000 | 84.0 | 63.0 |
| 31 | Airport Road | PQ | 60.0000 | 48.0 | 36.0 |
| 32 | IBB | PQ | 60.0000 | 48.0 | 36.0 |
| 33 | Ekpo-Abasi | PQ | 60.0000 | 48.0 | 36.0 |
| 34 | Unical | PQ | 80.0000 | 64.0 | 48.0 |
| 35 | CRUTECH Campus | PQ | 120.0000 | 96.0 | 72.0 |

**4.1 RESULTS**

Figures 4.1 to 4.3 illustrate the bus voltages at ABC\_gbest, the matching best fitness, and line losses as well as the results of the suggested approach. These values were acquired using a 15000 iteration maximum cycle.

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**Figure 4.1: ABC\_Gbest Bus Voltage Magnitude Profile Chart.**

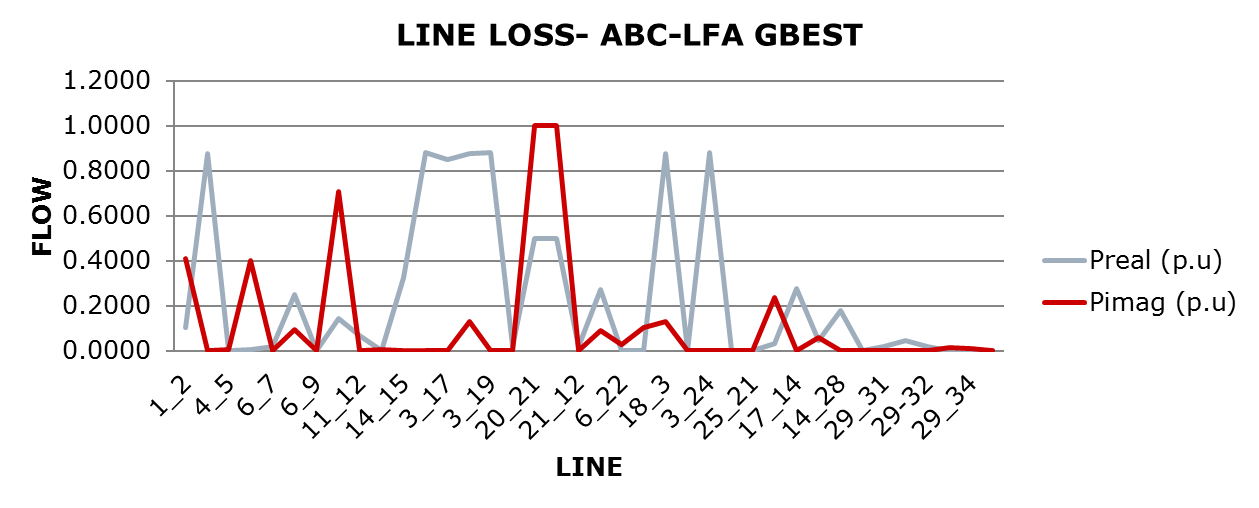
In Figure 4.1, the bus voltage began at a tolerance level of approximately 1 p.u for bus number 1, continued to do so in bus 2, and then fluctuated down towards 0.99 p.u at bus 3. However, it exceeded 1 p.u in bus 15, indicating that voltage overstepped the limits in the pattern of responses within the normal tolerance limit. Below is a graphic representation of the most effective cost/iteration for the related ABC-Gbest.

**Figure 4.2: ABC\_GbestBestcost (fitness) and Iteration Graph.**

In

Figure 4.2, a total of 2000 cycles or iterations is adequate to determine the load flow analysis program's early stability or convergence. which means that any number of cycles above 2000 has little to no impact on the LFA's convergence or stability until around 14000 cycles. At 14000 iterations, this later experienced a less-than-ideal convergence. Care must be taken when handling it.

**The result of the Line Losses for the corresponding ABC-Gbestis presented graphically below.**



**Figure 4.3: Graph Showing ABC\_Gbest Line Losses**

The transmission lines ranging from 1 to 2, 10 to 6, 3 to 18, and 20 to 21 recorded the biggest power losses, according to Figure 4.3's load flow results. This could be due to distance, overloading the lines, or aging of the lines.

**Table 4.2: ABC\_gbest load flow Bus Code, Label, Voltage (V), Bus Angle (d), Load Bus Real Power (Pd), Load bus Reactive Power (Qd), Generator bus Real Power (Pg) and Generator Bus Reactive Power (Qg)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus Code** | **Label** | **V (p.u.)** | **d (p.u.)** | **Pd(p.u.)** | **Qd(p.u.)** | **Pg(p.u.)** | **Qg(p.u.)** |
| 1 | Akampka | 0.8500 | 0.2461 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 2 | Creek Town | 0.8500 | 0.2290 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 3 | Uyangha | 0.9673 | 0.3139 | 0.7523 | -0.3142 | 0.0000 | 0.0000 |
| 4 | Fed. Housing | 0.9275 | 0.2597 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 5 | EPZ Complex 1 | 0.8971 | 0.2365 | 0.5000 | -0.7507 | 0.0000 | 0.0000 |
| 6 | Esukutan | 1.0120 | 0.3175 | 0.5001 | -1.0000 | 0.0000 | 0.0000 |
| 7 | EPZ Complex 2 | 0.9793 | 0.3082 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 8 | Flour Mill Road1 | 0.9477 | 0.2980 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 9 | State Housing | 1.0063 | 0.3200 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 10 | Essien Town | 1.0158 | 0.3182 | 0.6474 | -1.0000 | 0.0000 | 0.0000 |
| 11 | Olam | 0.9629 | 0.2514 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 12 | Flour Mill Indust. | 0.9789 | 0.2954 | 0.4800 | -1.0000 | 0.0000 | 0.0000 |
| 13 | Flour Mill Road 2 | 0.9856 | 0.3246 | 0.4800 | -1.0000 | 0.0000 | 0.0000 |
| 14 | Ikoreshi | 0.9517 | 0.3529 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 15 | Essien Town | 0.9512 | 0.3944 | 0.4800 | -0.7453 | 0.0000 | 0.0000 |
| 16 | Ikot Ansa | 0.9637 | 0.3161 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 17 | Marian | 0.9612 | 0.3346 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 18 | UNICEM | 0.9765 | 0.3102 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 19 | Water Board | 0.9599 | 0.3661 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 20 | Parliamentary | 1.0000 | 0.3448 | 0.0000 | 0.0000 | 2.7000 | 2.0250 |
| 21 | Parliamentary Ext. | 0.9952 | 0.3402 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 22 | Diamond | 0.9890 | 0.3094 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 23 | Diamond Ext. | 1.0160 | 0.3221 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 24 | Ekorinum | 0.9644 | 0.3204 | 0.5215 | -1.0000 | 0.0000 | 0.0000 |
| 25 | Calabar Road | 0.9801 | 0.3410 | 0.5766 | -0.9185 | 0.0000 | 0.0000 |
| 26 | Target Road | 0.9511 | 0.3871 | 0.5242 | -1.0000 | 0.0000 | 0.0000 |
| 27 | Marian Hill | 0.9498 | 0.1410 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 28 | Ameka | 0.9393 | 0.3468 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 29 | Eta-Agbor | 0.9735 | 0.2848 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 30 | Atimbo | 0.9649 | 0.2928 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 31 | Airport Road | 0.9657 | 0.2857 | 0.4800 | -1.0000 | 0.0000 | 0.0000 |
| 32 | IBB | 1.0020 | 0.2697 | 0.4800 | -1.0000 | 0.0000 | 0.0000 |
| 33 | Ekpo-Abasi | 1.0339 | 0.2568 | 0.4800 | -0.8279 | 0.0000 | 0.0000 |
| 34 | UNICAL | 0.9744 | 0.2852 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |
| 35 | CRUTECH Cal. | 0.9687 | 0.2908 | 0.5000 | -1.0000 | 0.0000 | 0.0000 |

**4.2 Results and Discussions/Analysis**

In this study, a swarm-based method that can be helpful in load flow analysis (LFA) of a power system was proposed. The ABC\_gbest method performed better than other well-known methods, providing the least or best cost (power mismatch), and it was discovered that the Voltage profile had improved. The least fitness or best cost (i.e., power mismatch) was obtained using the ABC\_gbest LFA simulations. After a bit more than 14,000 max-cycles, this happened. Due to overcrowding, the line's length, and its age, the transmission line connecting bus 20 and bus 21 had losses in each of the three ABC variations. Since lines with the highest real and reactive loss are connected to buses with the lowest voltage angle magnitude, respectively, both the real and reactive power flow may be impacted by changes in bus voltage angles and voltage magnitude.

It is advised that the old lines be replaced with new lines whose conductors have large cross-sectional areas, that the old lines be conductor bunched, and that unified power flow controllers (upfc) be used. This will reduce losses and increase performance and efficiency. Since it is well known that line length impacts line performance, it is advised that the line length be properly specified in the system to aid in analysis and adjust for lines with significant power losses in order to lower losses.

Data is gathered through the Transmission Company of Nigeria (TCN) Calabar work center for the 35-bus actual Calabar 132kV system. There are six thermal generators, nine compensators for reactive power, and four transformer taps here. The reactive power load is 126.2 MVAR, while the total active power load is 283.4 MW. There are six generators attached to buses 1, 2, 5, 8, 11, and 13. Bus 1 is regarded as the standard bus. Buses 10, 12, 15, 17, 20, 21, 23, 24, and 29 are where the compensators are attached, accordingly. The branches of the transformer are, in order, (6-9), (6-10), (4-12), and (28-27). There are 41 transmission lines in the test system. Table I below lists the variables' upper and lower bounds. 100 MVA has been chosen as the base MVA.

Figure 4.4 depicts the convergence characteristic for the 35-bus real Calabar 132kV system. This graph makes it quite evident that the guided ABC algorithm converges after 28 iterations. Table 4.3 contains the results that were obtained. Additionally, listed in Table 4.3 are the control variables for the discovered solution. Table 4.5 provides a comparison with the literature that is currently in existence. The provided result is the best of all the material that is currently accessible. 100 trial runs are conducted in order to assess the guided ABC's reliability. Figure 4.5 displays the plotted outcome of 100 trial runs. In comparison to results acquired above the mean line, more results obtained on average throughout 100 trials fall below the mean line. This proves GABC is good in tracking global best solution. The standard deviation for this 100-trial run is given in Table 4.6

0

10

20

30

40

50

60

70

80

90

100

0

3

6

9

12

15

18

Iterations

Cost ($/h)

**Figure 4.4: Convergence characteristics of the real Calabar 132kV 35 bus system**

**Table 4.3: Limits of the variables for Calabar 132kV 35-bus System**

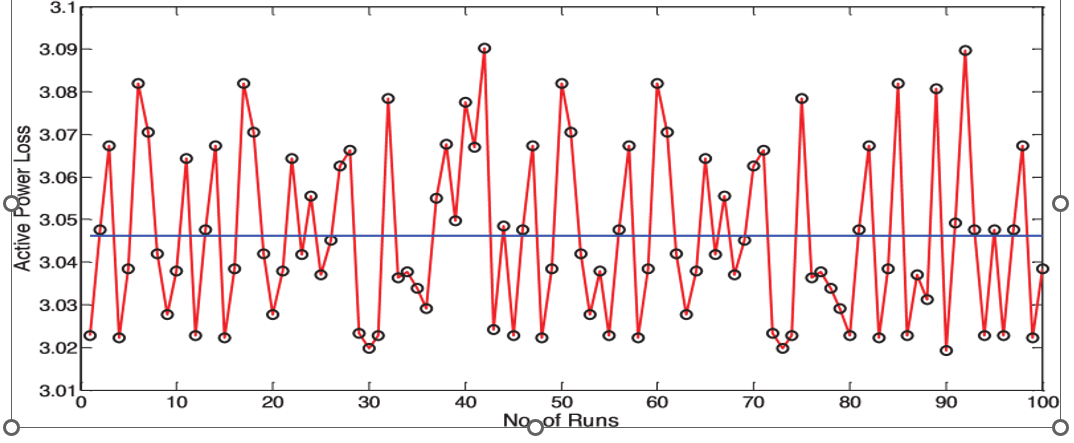
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable** | **Upper limit** | **Lower limit** | **Variable** | **Upper limit** | **Lower limit** |
| *PG1 (p.u.)* | 0.50 | 2.00 | *T6 - 10 (p.u.)* | 0.90 | 1.10 |
| *PG2 (p.u.)* | 0.20 | 0.80 | *T4 - 12 (p.u.)* | 0.90 | 1.10 |
| *PG5 (p.u.)* | 0.15 | 0.50 | *T28 - 27 (p.u.)* | 0.90 | 1.10 |
| *PG8 (p.u.)* | 0.10 | 0.35 | *QC10 (MVAR)* | 0.00 | 0.05 |
| *PG11 (p.u.)* | 0.10 | 0.30 | *QC12 (MVAR)* | 0.00 | 0.05 |
| *PG13 (p.u.)* | 0.12 | 0.40 | *QC15 (MVAR)* | 0.00 | 0.05 |
| *VG1 (p.u.)* | 1.00 | 1.10 | *QC17 (MVAR)* | 0.00 | 0.05 |
| *VG2 (p.u.)* | 1.00 | 1.10 | *QC20 (MVAR)* | 0.00 | 0.05 |
| *VG5 (p.u.)* | 1.00 | 1.10 | *QC21 (MVAR)* | 0.00 | 0.05 |
| *VG8 (p.u.)* | 1.00 | 1.10 | *QC23 (MVAR)* | 0.00 | 0.05 |
| *VG11 (p.u.)* | 1.00 | 1.10 | *QC24 (MVAR)* | 0.00 | 0.05 |
| *VG13 (p.u.)* | 1.00 | 1.10 | *QC29 (MVAR)* | 0.00 | 0.05 |
| *T6 - 9 (p.u.)* | 0.90 | 1.10 |  |  |  |
|  |  |  |  |  |  |

**Table 4.4: Control variables for Calabar 132kV 35-bus System**

|  |  |  |  |
| --- | --- | --- | --- |
| **Control Variable** | **GABC** | **Control Variable** | **GABC** |
| *PG2 (MW)* | 80 | *QC12 (MVAR)* | 5 |
| *PG5 (MW)* | 50 | *QC15 (MVAR)* | 4.858283 |
| *PG8 (MW)* | 35 | *QC17 (MVAR)* | 5 |
| *PG11 (MW)* | 30 | *QC20 (MVAR)* | 4.153956 |
| *PG13 (MW)* | 31.98754 | *QC21 (MVAR)* | 5 |
| *VG1 (p.u.)* | 1.097944 | *QC23 (MVAR)* | 2.604547 |
| *VG2 (p.u.)* | 1.0900352 | *QC24 (MVAR)* | 5 |
| *VG5 (p.u.)* | 1.071557 | *QC29 (MVAR)* | 2.067431 |
| *VG8 (p.u.)* | 1.076513 | *T6 - 9 (p.u.)* | 1.03117 |
| *VG11 (p.u.)* | 1.1 | *T6 - 10 (p.u.)* | 0.918068 |
| *VG13 (p.u.)* | 1.1 | *T4 - 12 (p.u.)* | 0.980552 |
| *QC10 (MVAR)* | 5 | *T28 - 27 (p.u.)* | 0.965991 |
| **Power loss (MW)** | | **3.01424603** | |
|  |  |  |  |

**Table 4.5: Comparison table for Calabar 132kV 35-bus System**

|  |  |
| --- | --- |
| Algorithm | Power loss (MW) |
| **GABC** | **3.01424603** |
| ABC [23]. | 3.09 |
| SARGA [12] | 4.57401 |
| GS [12] | 5.10120 |
| CLPSO [10] | 4.5615 |
| PSO [10] | 4.6282 |
| EGA-DQLF [8][9] | **3.2008** |



**Figure 4.5: Results of reactive power optimization for hundred trial runs**

**Table 4.6: Statistical data for Calabar 132kV 35-bus System**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Algorithm | Fuel Cost ($/h) | | | | Standard Deviation |
| Minimum Value | Average Value | Maximum Value | Median |
| GAB | **3.0142** | 3.0461 | 3.0901 | 3.0419 | 0.01994 |
| C | **4603** | 38854 | 93904 | 18205 | 88 |

# **4.3 STATISTICAL ANALYSIS**

Student t-tests and Wilcoxon rank sum tests are used to confirm the outcomes of the Gbest guided ABC algorithm, according to [21]. These tests are conducted exclusively using the best guided ABC algorithm because other researchers do not provide the results for hypothetical tests. Statistical analysis is a helpful tool for selecting whether to accept or reject the results. This test is run with a significance level of 0.05. If the statistical value is greater than the significance threshold, or, in the case of the Wilcoxon rank sum test, the hypothesis will be preserved or vice versa. Table 4.12 contains the Wilcoxon rank sum test findings. If the statistical value for a student t-test is larger than the tcritical value, the result will be accepted; otherwise, it will be rejected. For this analysis, tcritical was calculated to be **1.983971519**.

**Table 4.12: Statistical analysis for RPO problem**

|  |  |  |  |
| --- | --- | --- | --- |
| StandardIEEE Systems | Standard Deviation | Paired t-test tcritical = 1.9839715 | Wilcoxon rank sum test |
| 35 Bus Real Calabar System | 0.0199488 | 35.46778 | 0.850216995 |

**4.4 Voltage improvement and control for the Calabar 132/33kV Distribution System Network with Distributed Energy Resources**

The Central Generation system (CG) has been in large use for many years, serving large consumptions of power but with a variety of problems. These problems include its cost, sustainability, reliability, and stability in the long run. However, the Distributed Generation system (DG) is simple in design and the power generation models are primarily designed for Renewable Energy Resources (RER). Some examples are: wind, biomass, and solar energy resources. The optimal sizing and location of distributed generators (DG) remains crucial factors in their application .

The purpose of this research is to propose activities and design concepts that facilitate the national roadmap for developing the future flexible grid by improving voltage control for distribution system network with distributed energy resources as well as analyzing simulated results for the combination of both DG and CG power distribution system as a sustainable means in solving the problem of power failure in the Calabar metropolis.

The Newton-Raphson methods with the help of ETAP application were used to reveal the loading, reliability, and transient stability conditions of the Amika Utuk feeder line located in Calabar, Cross River State of Nigeria, as a case study with real time power rating data from the Programme to attain Reliability Analysis and Load flow study to discover the rate at which Distributed Generation Energy Resources can be used to improve voltage control of Central generation in the distribution system network.

A centralized system of power generation (CG) cannot meet the quest for providing quality and sustainable power supply due to its unitary system of power distribution. Hence, the combination of both the CG and DG systems of power generation will provide consistent electricity with proper DG lowest cost technology as well as providing better resilience than a CG system. This research work is based on real time data from the PHED monthly feeder lines data report on electricity consumption and consumers feedbacks.

## In spite of the many advantages of the DG system, there are still some limitations, which include: the cost of electricity is higher than that of CG, dispatched cannot be possible except biomass, and CG’s distributed system network may require restructuring of the electricity supply centres to meet up with increasing demands.

## 

**Figure 4.6 a: Voltage improvement and control for the Calabar 132/33kV distribution system network with distributed energy resources.**

## 

**Figure 4.6 b: Voltage improvement and control for the Calabar 132/33kV distribution system network with distributed energy resources.**

## 

**Figure 4.6 c: Voltage improvement and control for the Calabar 132/33Kv distribution system network with distributed energy resources.**

## 4.5 SUMMARY

In this study, the use of the gbest guided artificial bee colony method to address reactive power optimization is described. The IEEE 57 and IEEE 118 test bus systems, as well as the actual Calabar 132kV 35-bus network, are the systems used for the study. The outcomes of these case studies show that the GABC algorithm is more effective than other existing optimization techniques at tracking the best solution for the optimization of the reactive power problem. The guided gbest ABC algorithm can be a useful tool for nonlinear complicated engineering optimization problems in addition to reactive power optimization problems.

In order to determine the state of power flow, the base-case networks were simulated. It was discovered that the transmission line connecting buses 20 and 21 had losses because of overloading, distance, and line ageing. Since lines with the highest real and reactive loss are connected to buses with the lowest voltage angle magnitude, respectively, both the real and reactive power flow can be impacted by changes in bus voltage angles and voltage magnitude. 84.3% was the crucial threshold at which 2 buses were functioning, while 96.9% was the marginal point at which 5 buses were working. Although the marginal bus voltage areas were within acceptable bounds, any change in load demand will push these buses to a breaking point, so efforts should be made to enhance the networks' ability to supply electricity.

The Calabar sub-region transmission network's actual 132kV 35-bus systems are used to test the suggested method. The outcomes of the simulations showed that the voltages and angles solved by ABC\_ gbest approaches performed better than the other well-known strategies in terms of cost (power mismatch) and voltage profile improvement. The least fitness or best cost (i.e., power mismatch) was obtained using the ABC\_gbest LFA simulations. After a bit more than 14,000 max-cycles, this happened. The real Calabar 132kV 35-bus systems, the IEEE 57-bus, and the IEEE 118-bus standard test bus system were used to assess the efficiency and robustness of the gbest-guided ABC algorithm. The results were **3.01424603 and 11.488** respectively.

The results of the gbest - guided ABC algorithm for the application of the reactive power optimization problem is validated by comparison with data from the body of existing literature. Additionally, the Wilcoxon rank sum test was used to statistically analyze the gbest guided ABC algorithm for the real Calabar 132kV 35-bus systemIEEE 57-busstandard test bus system in order to further validate the results of GABC. The results of this test were **0.850216995 and 0.850359749** (i.e., this test was conducted at a significance level of 0.05). If the statistical value is greater than the significance threshold (i.e.,) in the instance of the Wilcoxon rank sum test, the hypothesis will be kept by (or vice versa).

1. **CONCLUSION & RECOMMENDATION**

**5.0 CONCLUSION**

The Global Best Artificial Bee Colony (GABC) algorithm, one of the best swarm intelligence approaches employed in load flow analysis/optimization in recent years, is presented in this thesis as an effective load flow calculation method. This algorithm is used to model the 35-bus 132kV real Calabar transmission system as well as the IEEE 57-bus networks. When the results are compared to those of other methods that have been studied before, it is found that the performance of the new algorithm is superior in terms of reduced transmission line voltage loss, least or best cost power mismatch, and voltage profile. The proposed technique could also be employed in numerous power system researches, such as optimal power flow, state estimation and stability studies.

**REFERENCE**

[1] Okachi, S. E., Akpama, J. E. (2024) “Load flow Analysis of 132kv Calabar transmission system for improved performance using Global Best Artificial Bee Colony (GABC) Algorithms. Nigerian journal of Engineering Research NJER, Volume 1, Issue 1, page 62 – 74, (<http://www.journal.njerunicross.com>)

[2] Huang,Y.M. & Lin, J.C. (2011) “A New Bee Colony Optimization Algorithm with Idle time based Filtering Scheme for Open Shop-scheduling Problems”, Expert Systems with Applications, Vol. 38, No. 5, pp.5438–5447.

[3] Okachi, S. E., Akpama, E. J. & Ogar, V. N. (2019) “Times Series Analysis of Residential Energy Demanded Forecast in Nigeria” IJRDO – Journal of Electrical and Electronics Engineering Volume 5, Issue 6, ISSN: 2456-6055, page 1 – 12.

DOI: <http://doi.org/10.53555/.eee.v5ie.2899>

[4] Okachi, S. E., Akpama, E. J., Pepple, E. C., Acha, G. O. (2022) “Load Flow Analysis of 132kv Transmission System Using Artificial Computers, Volume 7, ISSN: 2367-8895, page 31 – 37 <http://www.iaras.org/iaras/journals/ijc>

[5] Okachi, S. E., Akpama, J. E., Obojor, L. O., Ene, E. I. & Orok, M. E. (2023) “Energy Demanded forecast for the Industrialization of Nigeria using Time – Series Analysis model. Journal of Emerging Technologies and Innovative Research (JETIR). Volume 10, Issue 8, ISSN: 2349.5162, page 760 – 767

[6] Okachi, S. E., Ekum, A. E., Osundina, E. M., Orok, M. E., Anyin, P. B. & Ene, E. I., (2023) “Nigerian Commercial Energy Demand Estimate Using Time – Series Model (A panacea to Foster Rapid Growth and Development), International Journal of Modernization in Engineering Technology and Science, Volume 5, Issue 8, e-ISSN: 2582-5208, page 1295 – 1305, DOI: <http://www.doi.org/10.56726/irjmets43838>

[7] Wang HC, Wang YC, Tsai MS (2010a) Performance comparisons of genetic algorithm and artificial bee colony algorithm applications for localization in wireless sensor networks. In: 2010 international conference on system science and engineering (ICSSE), pp 469–474.

[8] Kumari M.S., & Maheswarapu, S. (2010). “Enhanced Genetic Algorithm-based Computation.Technique for Multi-objective Optimal Power Flow Solution”, International Journal of Electrical Power Energy System 32 (6):736–742.

[9] Kumari M.S., & Maheswarapu, S. (2010). “Enhanced Genetic Algorithm-based Computation.Technique for Multi-objective Optimal Power Flow Solution”, International Journal of Electrical Power Energy System 32 (6):736–742

[10] Mahadevan K. & Kannan, P.S. (2010). “Comprehensive Learning Particle Swarm

Optimization for Reactive Power Dispatch”, Applied Soft Computing10 (2):641–652.

[11] Salomon C. P., Lambert-Torres, G., Martins, H. G., Ferreira, C., & Costa, C. I. (2010).

"LoadFlow Computation via Particle Swarm Optimization”, Proceeding of International

Conference on Industry Applications (INDUSCON), Sao Paulo.

[12] Subbaraj P., & Rajnarayanan, P.N. (2009). “Optimal Reactive Power Dispatch using Self-adaptive Real-coded Genetic Algorithm”, International Journal on Electric Power Systems Research79 (2):374– 381.

[13] Subrahmanyam B. V. (2009). “Load Flow Solution of Unbalanced Radial Distribution

Systems”, Journal of Theoretical and Applied Information Technology, Jatit.

[14] Zhu G. & Kwong, S. (2010) “Gbest-guided Artificial Bee Colony Algorithm for Numerical Function Optimization”, Applied Mathematics and Computation, Vol. 217, No. 7, pp.3166–3173.

[15] Ahmed, F. J., McFadden S., & Rayudu, R. (2019). "Weather-Dependent Power Flow Algorithmfor Accurate Power System Analysis Under Variable Weather Conditions," *IEEE Transactions on Power Systems*, vol. 34, no. 4, pp. 2719-2729, doi: 10.1109/TPWRS.2019.2892402.

[16] Wang C., Feng, C., Zeng, Y., & Zhang, F. (2020). "Improved Correction Strategy for Power FlowControl Based on Multi-Machine Sensitivity Analysis, "IEEE Access, vol. 8, pp. 82391-82403, Doi: 10.1109/ACCESS.2020.2989927.

[17] Wang H., Yan, Z., Xu, X., & He, K. (2018). "Evaluating Influence of Variable Renewable Energy Generation on Islanded Micro-grid Power Flow," IEEE Access, vol. 6, pp. 71339-71349, Doi: 10.1109/ACCESS.2018.2881189.

[18] Wang H.C., Wang, Y.C. & Tsai, M.S. (2010a) ‘‘Performance Comparisons of Genetic Algorithm andArtificial Bee Colony Algorithm Applications for Localization in Wireless Sensor Networks’’, IEEE International Conference on System Science and Engineering (ICSSE), 2010, pp.469–474.

[19] Wang J., Li, T. & Ren, R. (2010b) “A Real-time IDSS-based on Artificial Bee Colony-support Vector Machine Algorithm”, IEEE Third International Workshop on Advanced Computational Intelligence (IWACI), 2010, pp.91–96.

[20] Wang X., Xie, X.& Cheng, T.C.E. (2012) “A Modified Artificial Bee Colony Algorithm for Order Acceptance in Two-machine Flow Shops”, International Journal of Production Economics, January, Vol. 141, No. 1, pp.14–23.

[21] Salvador G., Daniel M., Manuel L., & Francisco H., (2009). “A Study on the use of

Nonparametric Tests for Analyzing the Evolutionary Algorithms Behavior: A Case Study on

the CEC2005 Special Session on Real Parameter Optimization” Journal of Heuristics,

15:617–644.

[22] Karaboga D. (2005). "An Idea-based on Honey Bee Swarm for Numerical Optimization”, Technical report TR06. Computer Engineering Department, Erciyes University, Turkey.

[23]Kursat A., & UlaSKılıc, (2012). “Artificial Bee Colony Algorithm Solution for Optimal

Reactive Power Flow” Applied Soft Computing, 12:1477– 1482.