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Optimizing Power Loss on Nigerian Weak Transmission Line Using Facts Devices and Genetic Algorithm

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Abstract:*This research focuses on the optimization of power loss on Nigerian 330kV, 30-bus transmission line by installing high power electronics called FACTS device to improve the key parameters (line impedance, phase angle and voltage magnitude) and also increase the stability of the system. This was achieved through the use of Genetic Algorithm (GA) as it helps in finding an optimal location for the FACTS device. The load flow analysis for the 30bus transmission line was gotten through the use of power flow toolbox (PFATB).*
After optimization, it was observed that there was an improvement in the voltage profile(VPII) and also the line loss improvement index(LLII) which showed that the FACTS device used with genetic algorithm has helped to reduce the value of the losses from -13.85MVAR to -13.766MVAR.
The simulation results demonstrate the performance of the system for each of the FACTS devices in improving the power profile and thereby voltage stability of the same.
Keywords*- FACTS, real and reactive power, Static Compensator (STATCOM),voltage profile (VPII), loss improvement index(LLII) Static Synchronous Series Compensator (SSSC), Thyristor Controlled series compensator (TCSC), power profile.*

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I. Introduction

The Nigeria transmission network and distribution system, supply the vast needs of electrical power to its citizenry. Due to the tremendous power requirement, there is a concern of efficient operation of the power transmission network and the associated systems [1]. Power is an essential commodity, because it drives the economy of a nation and the reliability that sustains her developmental growth. There is therefore a correlation between the standard of living and the available power supplied in a nation. With the ever growing technological world, there is a deep dependence on the continuous availability of electricalpower [2]. Increase in electric usage is necessary and desirable since electrical services are essential for the nation's improved standards of living. In contrast, the Nigeria power system is faced with the problem of insufficient generation and overloaded transmission lines which results in the overloading and stressing of the network beyond their thermal limit, due to the increasing load demand. The resultant effect is having the transmission lines voltages operating outside the allowable limit of + or - 5%, insufficient and inadequate power flow, high line losses, and damping oscillation.

Some of the measures that can be put in place to curb the situation includes:

1. Installation of new transmission line
2. Changing the conductor of the Transmission Line/Terminal Equipment
3. increase the operating voltage of the transmission line, such as upgrading the voltage from 132 kV to 330 kV.
4. Addition of reactive power compensation devices (especially FACTS devices) in the form of series compensation, shunt compensation or the combination of the two.

Installation of new transmission line is usually the first option that comes to mind whenever a transmission line is limited in the amount of power it can transmit, so as to alleviate overloading by providing additional paths for power flow. It is beneficial by increasing the reliability of the transmission system. However, it has to pass through economic, political and environmental hurdles.

Also, changing the conductor of the Transmission Line/Terminal Equipment is another option. The conductor of a particular line can be changed with a larger conductor with more power-carrying capability if the original transmission line conductor is inadequate to carry expected power flows, provided that the transmission line towers do not need to be significantly altered to support the heavier conductor. In addition, some terminal equipment may need to be upgraded to match the desired rating**.**

Another option is to increase the operating voltage of the transmission line, such as upgrading the voltage from 132 kV to 330 kV. In this instance, for example, the nominal rating of the line maybe drastically increased while using the same conductor. This type of improvement may require upgrading the transmission towers to meet National Electric Safety Code (NESC) clearance levels. In addition, the switching stations and substations must also be upgraded with higher voltage circuit breakers, switches, transformers, and other related equipment**.**

Finally**,** addition of reactive power compensation devices (especially FACTS devices) in the form of series compensation, shunt compensation or the combination of the two, (depending on the nature of the line and its identified deficiency and need) to the transmission line is also another means of enhancing the performances of a transmission line. The addition of compensation modifies the electrical impedance of the line and therefore increases the power flows across the line. This can be an effective and economical means of increasing the transmission capability as a whole, by taking advantage of transmission lines that are not loaded to their thermal limits. This is the focus of the research. The rest of the paper is organized as follow: section two is on the literature review while section three is on the concept of FACTS devices. Section four is on methodology while section five is on research findings and discussion and section six is on the discussion.

II. Literature Review

Basedon the research conducted, in [14] FACTS devices can be broadly divided into two;

- conventional thyristor based FACTS devices
- voltage source converter based FACTS devices

Over the years, various researchers, both in Nigeria and abroad have said something about FACTS devices. Their work are still ongoing so as to find newer concept for minimizing the reason for voltage collapse by increasing the voltage stability(dynamic, transient, and steady state stability),voltage margin and voltage security in the system. Recently, it has been observed that;

- the improvement of electric power quality in Nigeria existing 330kV 28 bus electric power system can be done by using static Var compensator system[3]
- the efficiency improvement of 330kV network can be done by using the flexible alternating current transmission system devices[8]
- there is an impact of FACTS devices on transmission congestion charges in LMP – based market[11]
- the modeling , simulation and comparison of various FACTS Devices in power system can help improve the voltage stability of a power system[13]
- there is an adverse effects of FACTS on the performance of distance protection relays[9]
- the genetic algorithm can be applied on the optimal location of FACTS devices in the power system[15].

III. Concept of Facts Device

FACTS is defined by Institute of Electrical Electronic Engineers (IEEE) as “a power electronic based system and other static equipment that provides control of one or more Alternating Current (AC) transmission system parameters to enhance controllability and increase power transfer” [4]**.**In a power system, the transmission of power in a transmission line is mainly dependent on the sending and receiving end voltage levels, the transmission angle and the transmission line reactance. To increase the power flow through a transmission system, one or more of the above parameters must be changed.

For example, the transmission angle can be increased with the use of a phase shifting transformer but such an item of plant is costly to purchase and install, and the transformer losses must be accounted for. Increasing the transmission angle also pushes a power system closer to its stability limit, thereby increasing the likelihood of system instability. Also the transmission voltage level could be increased.

However, this would only be economically feasible if permitted by existing tower construction, and it would still be very costly to upgrade system insulation and switchgear. Where such an approach is envisaged in the future, transmission lines could be constructed taking into account future operation at higher voltage levels.

Hence, FACTS devices can be broadly applied to increase the power flow or even to change the power flow by having a higher degree of control of the three key parameters of line impedance, phase angle, and voltage magnitude. In addition, FACTS devices are used to increase the stability of the system and to regulate the system voltage.

FACTS controller or devices are broadly classified into four different categories based on the type of application [9]:

1. Series devices
2. Shunt devices
3. Combined series-series devices
4. Combined series-shunt devices

IV. Methodology

The optimization technique used for the purpose of this study is the genetic algorithm for optimal location of the FACTS device on the transmission line in the MATLAB 7.10 environment. The desired effect on the transmission line depends largely on the type of FACTS device, the capacity required and the location that will optimize the functioning of the device. Hence, genetic algorithm is the method used for solving both constrained and unconstrained optimization problems that is based on natural selection Unlike genetic algorithm, Newton –Raphson and its many relatives and variants are based on the use of local information [12]. The function value and the derivatives with respect to the parameters optimized are used to take a step in an appropriate direction towards a local maximum or minimum (i.e Newton –Raphson is only helpful in finding local extreme). The genetic algorithm repeatedly modifies the parameters in question(bus voltages, phase angles) by choosing the parameters to optimize, determining the chromosomal representation of parameters, generating the initial population of individual chromosomes, evaluating the fitness of each individual to reproduce and finally allowing the selection rules for next population.
However, it should be noted that the load flow analysis of the modeled network was done with the use of
Newton Raphson Load-flow Analysis**.**

The test system configuration is based on the Nigerian 330kV, 30-bus power system as shown in Fig 1. For the 330kV Nigeria power network simulation and analysis, some MATLAB algorithm programs were developed. The first algorithm used for the simulation and analysis of the case study was 'Power Flow Analysis Toolbox' **(PFATB).** PFATB is a collection of routines, written mostly in m-files which comprises of three main algorithm namely; gauss Seidel, Newton Raphson and P-Q decoupling method. The second algorithm used was the genetic algorithm for optimization. The input data for the power flow analysis include; the bus data for both the reactive and active power of the generator buses , the transmission line data, voltage and transformer / load data which were obtained from power holding company of Nigeria (downloaded online) are presented in the Table 1 and Table 2.

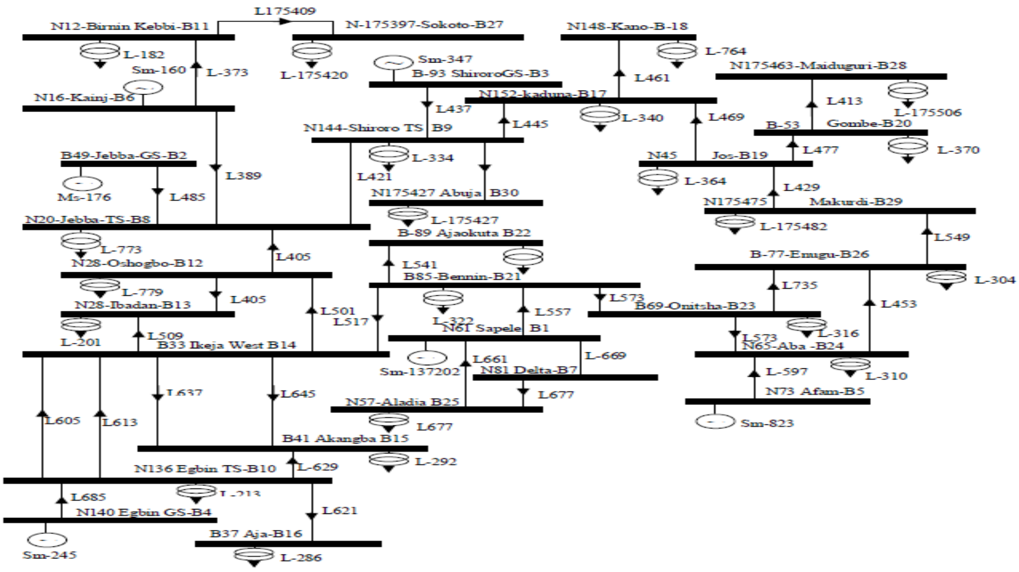


Fig 1: Modelled Network of 330kV 30Bus System in Matlab.

Table 1: Transmission Line Data (of Bison, two conductors per phase and 2x350 mm^2X-section Conductor)

S/N	Bus Name		Length (km)	$R_{1(p.u)}$	X_1(p.u)	Shunt
	From	To				$\frac{y}{2}(p.u)$
1.	Akamgbe	Ik-West	17	0.0006	0.0051	0.065
2.	Ayede	Oshogbo	115	0.0041	0.0349	0.437
3.	Ik-West	Egbin	62	0.0022	0.0172	0.257
4.	Ik-West	Benin	280	0.0101	0.0799	1.162
5.	Oshogbo	Jebba	249	0.0056	0.477	0.597
6.	Oshogbo	Benin	251	0.0089	0.0763	0.954
7.	JebbaTs	JebbaGs	8	0.003	0.0022	0.033
8.	Jebba TS	Shiroro	244	0.0087	0.0742	0.927
9.	Jebba TS	Kainji	81	0.0022	0.0246	0.308
10.	Kainji	B.Kebbi	310	0.0111	0.942	1.178
11.	Shiroro	Kaduna	96	0.0034	0.0292	0.364
12.	Kaduna	Kano	320	0.0082	0.0899	0.874
13.	Jos	Gombe	265	0.0095	0.081	1.01
14	Benin	Ajaokuta	195	0.007	0.056	0.745
15.	Benin	Sapele	50	0.0018	0.0139	0.208
16.	Benin	Onitsha	137	0.0049	0.0416	0.521
17.	Onitsa	N.Heaven	96	0.0034	0.0292	0.0355
18.	Onitsha	Alaoji	138	0.0049	0.0419	0.524
19.	Alaoji	Afam	25	0.009	0.007	0.104
20.	Sapele	Aladja	63	0.0023	0.019	0.239
21.	Delta	Aladja	30	0.0011	0.0088	0.171
22.	*Kainji GS	Jebba TS	81	0.0022	0.0246	0.308
23.	Ayede	Ik West	137	0.0049	0.0416	0.521
24.	Egbin TS	Aja	27.5	0.0022	0.0172	0.257
25	Egbin TS	Aja	27.5	0.0022	0.0172	0.257
26.	Kaduna	Jos	197	0.007	0.0599	0.748
27.	Jos	Makurdi	275	0.0029	0.0246	0
28.	Oshogbo	Ik West	252	0.0049	0.0341	0.521
29.	Benin	Delta	107	0.0022	0.019	0.239
30	Onitsha	Okpai	80	0.009	0.007	0.104

Table 2: Bus Data

B No	Bus Name	Generation		Load		V	Angle	Remarks
		P (MW)	Q(MVar)	P (MW)	Q (MVar)	(volts)	(degree)	
1.	Egbin	-	-	0,0000	0.0000	1.02	0.0000	Slack
2.	Delta Ps	55.000	28.160	-	-	1.0000	0,0000	PV Bus
3.	Okpai	220.000	112.700	-	-	1.0000	0.0000	PV Bus
4.	Sapele	75.000	38.420	-	-	1.0000	0.0000	PV Bus
5.	Afam	479.000	245.390	-	-	1.0000	0.0000	PV Bus
6.	Jebba	322,000	164.960	-	-	1.0000	0.0000	PV Bus
7.	Kainji	323.000	165.490	-	-	1.0000	0.0000	PV Bus
8.	Shiroro	280.000	143.440	-	-	1.0000	0.0000	PV Bus
9.	Geregu	200.000	102.440	-	-	1.0000	0.0000	PV Bus
10.	Oshogbo	-	-	120.370	61.650	1.0000	0.0000	Load Bus
11.	Benin	-	-	160.560	82.240	1.0000	0.0000	Load Bus
12.	Ikj-West	-	-	334.000	171.110	1.0000	0.0000	Load Bus
13.	Ayede	-	-	176.650	90.490	1.0000	0.0000	Load Bus
14.	Jos	-	-	82.230	42.129	1.0000	0.0000	Load Bus
15.	Onitsha	-	-	130.510	66.860	1.0000	0.0000	Load Bus
16.	Akamgbe	-	-	233.379	119.560	1.0000	0.0000	Load Bus
17.	Gomgbe	-	-	74.480	38.140	1.0000	0.0000	Load Bus
18.	Abuja(katampe)	-	-	200.000	102.440	1.0000	0.0000	Load Bus
19.	Maiduguri	-	-	10.000	5.110	1.0000	0.0000	Load Bus
20.	Egbin TS	-	-	0.000	0.000	1.0000	0.0000	Load Bus
21.	Aladja	-	-	47.997	24.589	1.0000	0.0000	Load Bus
22.	Kano	-	-	252.450	129.330	1.0000	0.0000	Load Bus
23.	Aja	-	-	119.990	61.477	1.0000	0.0000	Load Bus
24.	Ajaokuta	-	-	63.220	32.380	1.0000	0.0000	Load Bus
25.	N.Heaven	-	-	113.050	57.910	1.0000	0.0000	Load Bus
26.	Alaoji	-	-	163.950	83.980	1.0000	0.0000	Load Bus
27.	Jebba TS	-	-	7.440	3.790	1.0000	0.0000	Load Bus
28.	B.Kebbi	-	-	69.990	35.850	1.0000	0.0000	Load Bus
29.	Kaduna	-	-	149.77	76.720	1.0000	0.0000	Load Bus
30.	ShiroroTS	-	-	73.070	37.430	1.0000	0.0000	Load Bus

Value= 100MVA
Base voltage = 330KV
Per unit value = MVA/ Basevalue.

- Number of 330KV substations =19
- Total number of 330KV circuit= 49
- Length of 330KV lines(km)= 4800
- Number of control centres= 1
- Number of transmission lines = 40
- Number of buses= 30

Optimization through Genetic Algorithm

Genetic algorithm (GA) is widely considered in numerical optimization methods, which use the natural processes of evolution and genetic recombination. GAs are particularly useful when the goal is to find an approximate global minimum in a high-dimension, multi-modal function domain, in a near-optimal manner. Unlike the most optimization methods, they can easily handle discontinuous and non-differentiable functions. The process is analyzed as follow:

GA Iteration Process

- Initial population

Initial population provides the GA with a large sampling of search space, though not all population makes up the next iterative population.

- Reproduction

Though various methods are used in selecting the fittest individual in the reproduction process. These include: rank selection, tournament selection, Boltzmann selection and Roulette-wheel selection. In this work, the Roulette-wheel selection is utilized. The Roulette Wheel selection operates by the probability of the parenthood being proportional to the level of fitness. The Wheel is spun until the two parents that create one offspring is selected[12]. Random numbers are generated in the interval whose segment spans this selection.

- Cross Over

Cross over produces new strings by the exchange of information among the strings of mating pools. Probability of cross over rate varies from 0 to 1and range from 0.7-1 for population within the range of 50-300[8]

- Mutation

Mutation introduces some sort of artificial diversification in the population to avoid premature convergence to local optimum [8]. Non-uniform mutation,which has proved to be successful in a number of studies [21], is employed in this study.

For a given parent X=$x_1, x_2 ... x_k ... x_l$, if the gene x_k is selected for mutation and the range of x_k is $\left[U_{Min}^k, U_{Max}^k\right]$, then the result x_k is :

$$x_k = \begin{cases} x_k \Delta(t, U_{Max}^k - x_k) if random(0,1) = 0 \\ x_k - \Delta\left(t, x_k - U_{Min}^k\right) if random(0,1) = 0 \end{cases} \quad \ldots(1)$$

Where bullet operator

$$\Delta(t, y) = y \cdot \left[1 - r^{\left(1 - \frac{t}{T}\right)b}\right] \quad \ldots(2)$$

$\Delta(t, y)$ (y represents $x_k - U_{Min}^k$ and $U_{Max}^k - x_k$)returns a value in the range [0,y]. Its probability being close to 0 and increases as t increases (t is generation number).

Optimization with Facts Device and GA

With the same purpose in mind, genetic algorithm is used for the optimal placement of the FACTS device .there is an initialization of the initial population and selection of those initial population of the binary string from all possible locations. This process helps in catering for the need of FACTS device to be located on the transmission lines through the binary selection of one or else the binary selection value will be zero. The rated value of FACTS device is also selected after its location has been established.

Hence , the encoding of TCSC, UPFC and STATCOM was done.

Fitness Computation of Each Device

Fitness computation evaluates each individual population and then compares different solutions . It picks the best individuals and uses the ranking process to define the probability of selection (UPFC,TCSC and STATCOM).This applies to the three FACTS devices. Locating these devices optimally during normal and overload conditions is achieved using GA in order to improve the overall performance of the transmission grid. The criteria for optimal placement depends on some fitness function that involves voltage profile, bus network, line parameters, voltage violation reduction, line loading conditions/ratings, active and reactive power limits of generators, system configuration and current system operating points. Describing the fitness function mathematically gives:

- **Min fitness**$F_T(A, B)$

Subject to $E_T(A, B) = 0.0$; $I_T(A, B) \leq 0.0$;

where:

$\boldsymbol{F_T(A, B)}$ = Fitness function to be optimized:

$\boldsymbol{E_T}\ (\boldsymbol{A}, \boldsymbol{B})$= Equality constraints (active and reactive power);
$\boldsymbol{I_T}(\boldsymbol{A}, \boldsymbol{B})$= inequality constraints of the FACTS devices targeted at parameters ranges limits such as bus voltages , phase angles , active and reactive power generation.
A= voltage magnitude and phase angles state of the electrical work,
B= control variables to be optimized

- **Bus Voltage Violation Optimization**

$A_T(A, B) = \sum_{i=1}^{i=1N_B} F(V_B)$..(3)
$F(V_B)$= 0 if 0.95≤ $V_a \leq 1.05$ .... (4)
Otherwise:$F(V_B)$=$log\ \varphi F(V_B) abs\left(\frac{V_a(nominal\ )-V_a}{V_a}\right) * \left(\frac{1}{Iin}\right)$...(5)
Where :* is an asterisk operator
$F(V_B)$=violation function of bus voltage ;
V_a = voltage magnitude at bus a;
$\varphi F(V_B)$= index value for percentage of bus voltage against allowable limit;
Iin = integer coefficient to regulate voltage variations;
N_B= number of buses in the system

- **Overloaded Lines And Bus Voltages**

$A_T\ (A, B) = \sum_{i=1}^{N_T} F(L_O) + \sum_{i=1}^{N_B} F(V_B)$……………………………………………………………………….(6)

V. Research Findings and Discussion

As earlier discussed in the aforementioned chapters on the objectives of this research work, it is imperative to reiterate the effect of power losses and overloading of the power network lines beyond their voltage limits which comes as a result of excess reactive power on the lines.

Although, just like synchronous generators can absorb or generate reactive power depending on the excitation pattern(that is , if the system is overexcited, synchronous generators can supply reactive power and if under excited, synchronous generators can absorb reactive power), loads and transformers can also absorb reactive power.

However, the voltage variation as par imbalance in the generation and consumption of reactive power in the system can cause excessive heating of the distribution transformers thereby reducing the transformer capacity, when there is a wide variation between the power generated and that consumed.

Hence, this research was able to discover anomalies in the 330KV network and studied three different optimization techniques that could serve as a way out. This chapter is further divided into four sections viz: the result of the load flow analysis using the power flow analysis toolbox, the optimization technique of just incorporating FACTS device into the network without genetic algorithm, the optimization of the power network(330KV) using genetic algorithm alone without incorporating FACTS device and the optimization of the 330KV network using genetic algorithm with the incorporation of FACTS device

Load Flow Analysis By N-R Method With Polar Coordinate

From the load flow which shows the bus voltage, angle and the pu value of both the active and reactive power on load and genrator , it is observed that some buses (like bus 1,7,9,11,12,13,14) have exceeded the tolerable voltage limit of $\pm 5\%$ `and hence termed the weak buses on the transmission line as shown (in the screenshoted command window result of MATLAB SIMULINK) Table 3 below

Table 3: Load Flow Result

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.060	0.000	-0.000	-0.000	2.610	-0.170	0.000
2	1.043	-5.497	-0.217	-0.127	0.400	0.488	0.000
3	1.022	-8.004	-0.024	-0.012	0.000	0.000	0.000
4	1.013	-9.661	-0.076	-0.016	0.000	0.000	0.000
5	1.010	-14.381	-0.942	-0.190	0.000	0.360	0.000
6	1.012	-11.398	-0.000	-0.000	0.000	0.000	0.000
7	1.003	-13.150	-0.228	-0.109	0.000	0.000	0.000
8	1.010	-12.115	-0.300	-0.300	0.000	0.308	0.000
9	1.051	-14.434	-0.000	-0.000	0.000	0.000	0.000
10	1.044	-16.024	-0.058	-0.020	0.000	0.000	0.190
11	1.082	-14.434	-0.000	-0.000	0.000	0.161	0.000
12	1.057	-15.302	-0.112	-0.075	0.000	0.000	0.000
13	1.071	-15.302	-0.000	-0.000	0.000	0.104	0.000
14	1.042	-16.191	-0.062	-0.016	0.000	0.000	0.000
15	1.038	-16.278	-0.082	-0.025	0.000	0.000	0.000
16	1.045	-15.880	-0.035	-0.018	0.000	0.000	0.000
17	1.039	-16.188	-0.090	-0.058	0.000	0.000	0.000
18	1.028	-16.884	-0.032	-0.009	0.000	0.000	0.000
19	1.025	-17.052	-0.095	-0.034	0.000	0.000	0.000
20	1.029	-16.852	-0.022	-0.007	0.000	0.000	0.000
21	1.032	-16.468	-0.175	-0.112	0.000	0.000	0.000
22	1.033	-16.455	-0.000	-0.000	0.000	0.000	0.000
23	1.027	-16.662	-0.032	-0.016	0.000	0.000	0.000
24	1.022	-16.830	-0.087	-0.067	0.000	0.000	0.043
25	1.019	-16.424	-0.000	-0.000	0.000	0.000	0.000
26	1.001	-16.842	-0.035	-0.023	0.000	0.000	0.000
27	1.026	-15.912	-0.000	-0.000	0.000	0.000	0.000
28	1.011	-12.057	-0.000	-0.000	0.000	0.000	0.000
29	1.006	-17.136	-0.024	-0.009	0.000	0.000	0.000
30	0.995	-18.015	-0.106	-0.019	0.000	0.000	0.000

Optimization of The Load Flow Analysis

The optimization of the load flow result is categorized into three phases which will be expounded(i.e discussed extensively) in various sub- sections.

Case One :

Optimization by Incorporating Facts Devices Only

In this section, the impact of connecting a FACTS device to the 330KV Nigeria power network is presented and analyzed. The STATCOM is connected to all the buses. These results tabulated and plotted in this section are corresponding values for each program obtained from the simulation of the developed Matlab programs.

The comparative tabulated result and plot of voltage magnitude of the network for conventional Newton-Raphson Power Flow and STATCOM Newton-Raphson Power flow is shown in Fig2 below

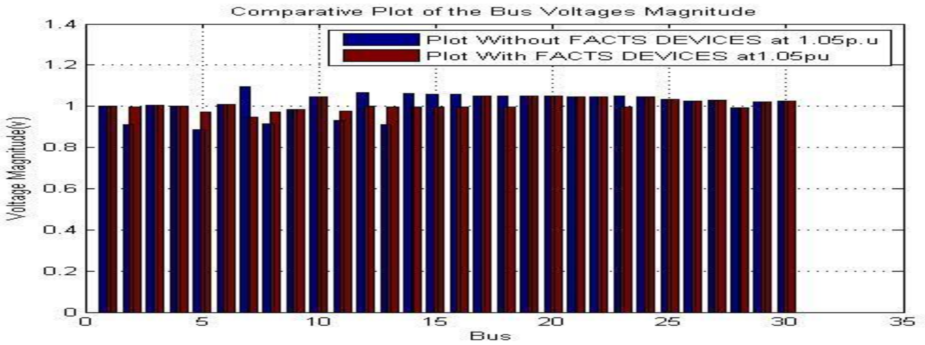


Fig2: Voltage Profiles before and after FACTS device incorporation

This mode of optimization is obtained by writing codes of Newton-Raphson algorithm for FACTS device incorporated into the power system and it is programmed in such a way that when any bus voltage is beyond ±5%, it regulates it back to its tolerable set limit while those buses with voltage within the tolerable limit are being maintained as shown in the figure above.

However the only limitation that comes with incorporating FACTS device through newton Raphson algorithm only as an optimatization technique for minizing power loss is that it is a conventional method of optimization. The conventional method of optimization is characterized with loops like slow processing of recurrent data for forecasting the future condition of the power network.

Case Two : **Optimization of Power Loss by Incorporating Genetic Algortihm Only**

This kind of optimization involves the use of genetic algorithm to optimize the power losses on the transmission line. This is one of the artificial intelligence techniques that is characterized with precision and speed in the processing of data with minimal error. When this was done, the major objective is to check the best fitness for the bus voltage improvement per generation. This objective is formulated as an optimization problem of minimizing the total fuel cost of all committed plant while meeting the network (power flow) constraints. The total generation was set to meet the total demand and transmission loss.

Hence, the result of the optimization of the the load flow analysis is shown in Fig 3 below:

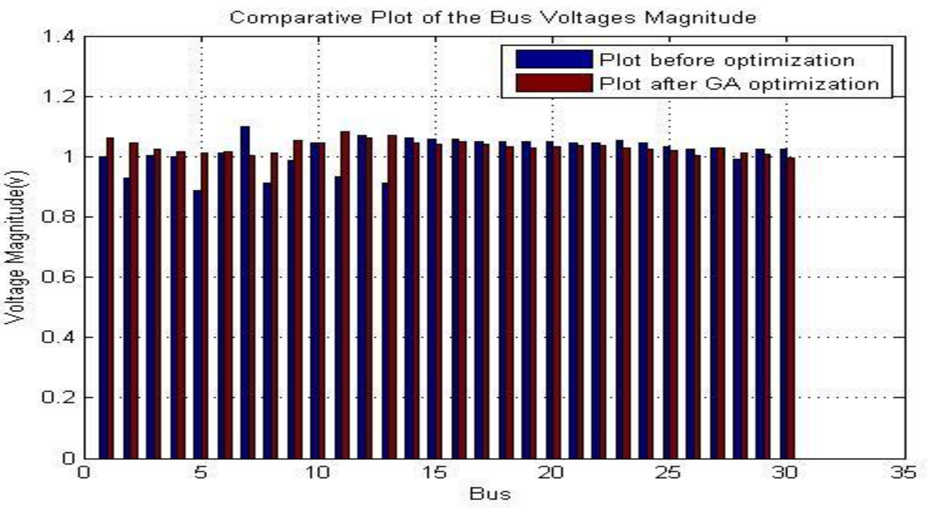


Fig3: Voltage Profile after Optimization with GA without FACTS

From the Fig3 above, it can be observed that optimization through genetic algorithm has a great effect on each of those bus voltages either by increasing the value to a tolerable voltage limit or by reducing the value of some bus voltage to a voltage that is within $\pm 5\%$.

Case Three: Optimization of the Power Network by Using Facts Device Incorporated into Genetic Algorithm

This optimization technique removes the limitation of the conventional method applied when FACTS device was incorporated alone with Newton Raphson's algorithm and setting a control to address the excesses provided with just the use of genetic algorithm.

First step to optimization optimally place the FACTS devices at locations where the bus voltages are out of the allowed tolerable voltage limit of $\pm 5\%$. After optimal location of where to fix the FACTS device, the load flow analysis is re-run to check for the reduction in line losses and improvement in the voltage profile of the 330KV Nigera power network. In doing this, the objective funtion was set to minimize the voltage at each bus, active and reactive power flow and the line losses. After simulation so as to optimally locate the FACTS device(which are eight in number) , it was discovered that bus 14, 19, 10, 22, 15, 8, 11, and 7 requires 50Mvar, 60Mvar, 70Mvar,160Mvar, 200Mvar, 250Mvar, 300Mvar and 400Mvar respectively. From these results of optimal placement, the injected Mvars are placed at each of those buses.

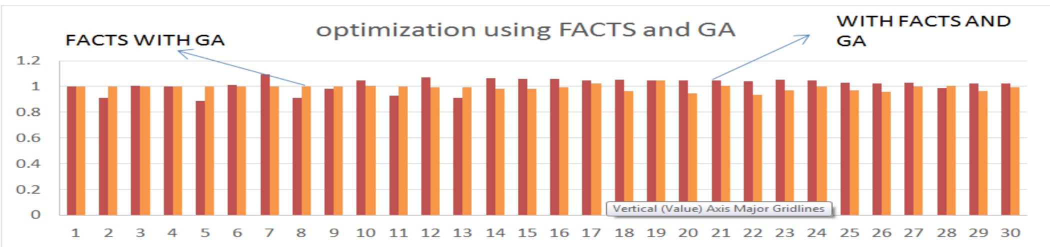


Fig4: Voltage Profile after Optimization with GA and FACT Devices

Discussion on the Various Optimization Approaches

In other to access each optimization approach that best improved the voltage profile of the 330kV , 30 bus Nigerian interconnected power system, the voltage profile improvement index(VPII) was determined for each of the optimization approach. VPII is the ratio of the sum of all the voltage at all buses when any of the optimization process is employed to the sum of all the voltages at all buses when no optimization approach was employed

Mathematically:VPII=$\frac{voltage\ profile\ with\ any\ optimization\ approach}{voltage\ profile\ without\ any\ optimization\ approach}$

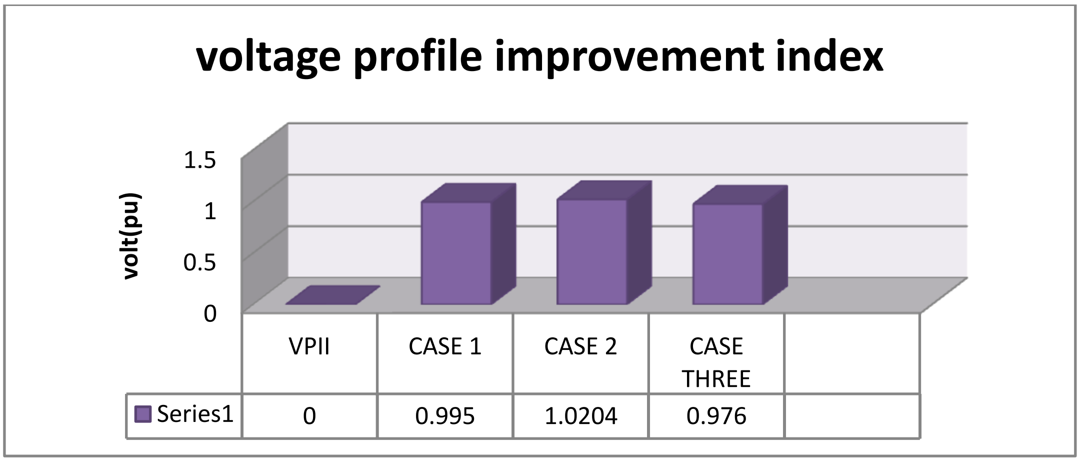
Under the following set conditions:
For VPII< 1 ; optimization approach has a negative effect on the network voltage.

.For VPII= 1: optimization approach does not have effect on the network voltage

For VPII>1: optimization approach has apositive effect on the network voltage

It should be noted that there is a set constrain for determining the best optimization approach. Hence , the voltage profile index with the lowest value is considered best.

VPII(case 1) = $\frac{30.296}{30.443}$ = 0.995
VPII(case 2) = $\frac{31.0661}{30.443}$ = 1.0204
VPII(case 3) = $\frac{29.7368}{30.443}$ = 0.976



Also the line loss improvement index was determined. In its evaluation, there is reduction in lin losses when :LLII < 1.

LLII= $\frac{LINE\ LOSS\ AFTER\ OPTIMIZATION}{LINE\ LOSS\ BEFORE\ OPTIMIZATION}$

VI. Conclusion

The study has proven that with appropriate placement of FACTS device(s) using Genetic algorithm, the voltage profile is being improved and the line losses are being minimized compared to when the network had no device. Although, other optimization approach produced a voltage improvement in some of the buses, yet, the improvement in line loses could not be ascertained through those processes.

Furthermore, case three optimization approach proves to be more productive when considering its effect on economic dispatch. It will be recalled that economic dispatch is the short term determination of the optimal output of a number of electricity generation facility to meet the system load at the lowest possible cost when subjected to transmission and other operational constraint.

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