Improving the Power Quality of Distribution Network in Eastern Nigeria by Micro Grid Integration.

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Abstract: *Every Nigerian is concerned about the unstable power supply in the nation. High energy losses caused by deteriorated transmission and distribution networks, coupled with low access rates and unfeasible tariffs, lead to subpar operational and financial results. Research on renewable energy has been prompted by endemic problems; this project examines the integration of generation based on wind power renewable energy source to the distribution network and how it stabilizes the network by bringing the fluctuating voltage at the distribution end of the power system to a normal level. In order to determine the voltage status at the buses and the size and type of distributed generation that will be adequate to stabilise power on the network, analysis was first performed on a radial distribution network of electricity. Through the use of load flow analysis, power system steady state analysis was carried out. Genetic algorithm (GA) technology was used to create a model for the integration of distributed generation into the network. Last but not least, an optimization algorithm based on the principle of natural selection was used to implement the impact of the distributed generation on the system. This was done to address issues like the location, level of generation, or control of the connected generation's power factor.*

Keywords- *Distributed Generation, power system stability, intelligent distributed generation scheme, Genetic Algorithm*

I. INTRODUCTION

A reliable technology will be necessary for developing nations like ours to integrate micro grid sources into the national grid; consequently, significant distributed generation will necessitate fundamental changes to the way the electricity network operates. An intelligent system must be integrated into the traditional methods of power generation to prevent costly extensions of the grid's capacity. This refers to the creation and management of intelligently designed electrical distribution grids.

This work is aimed at Improving the Stability of Power system Distribution Network using renewable energy sources. The Concerns about frequent power outages and incessant tripping of gas turbine generators are shared by power system engineers in the electricity generation sector. The purpose of this research is to collect data from the described Enugu Electricity Distribution Company (EEDC) for Enugu only. To achieve this goal, the objectives of this work are stated in behavioural terms sequentially as follows**:** To

- Perform a load flow analysis of the radial distribution network to determine the voltage status at the buses and the size and type of distributed generation that will be sufficient to stabilise power on the network.
- run the developed model through the system.
- create a model incorporating distributed generation into the network using genetic algorithm (GA) technology.
- observe a natural selection-based optimization algorithm.
- simulate the effects of the DG,
- validate the design by performing

- Comparison of faulty voltage and corrected voltage.

II. PAST RELATED WORKS

The idea of utilising energy storage devices to improve distributed generation's (DG) intermittent output is currently being stressed [1]. Typically, standalone generators, which are typically owned by people living in remote locations, are referred to as distributed generators. They are described as the connection of small kW-rated generating plants between several kW and a few MW. The primary energy sources for these generators are typically fossil fuels, non-renewable sources like gas, or renewable sources like wind, solar, hydropower, and biomass [2]. These types of generating plants are typically synchronised to the load centres using devices called synchroscopes. Either the low voltage or medium voltage portions of the national grid are connected to them. Connecting through the nearest load centres or low voltage networks is standard procedure for safety reasons. When using renewable energy sources, such as photovoltaic solar panels and wind turbines, the output power will depend on the supply of those resources and may therefore change depending on the strength of the sun or the wind. When that happens, storage devices are used to supplement the DGs during unfavourable conditions [3]. The clean and efficient sources of wind and solar energy can be combined with other energy sources like biomass to improve or smooth the power in rural areas. In addition to storage batteries, we also have superconducting magnetic energy storage (SMES), flywheels, fuel cells, and ultracapacitors [4]–[7]. During periods of high demand, the storage devices may also aid in preserving the overall stability of the entire system by facilitating the performance of these generating sources. The smart grid method is used to connect these energy storage devices to the national grid. Reliable power conversion technologies would be used to connect it to the electric grid [8]–[10]. Even though providing electricity where there is no national grid is their main goal. When energy production exceeds local demand, DGs can be connected to the national grid to distribute the extra electricity. Although these distributed resources can be divided into various categories, the behaviour of a distributed resource (DR) primarily depends on the type of converter that is connected to it for it to communicate with the distribution end of the electrical power system. Depending on the type of DR with which they are connected, such as synchronous generators, asynchronous (or induction) generators, and static (or electronic) inverters, these electrical converters are divided into three main categories. To evaluate the effect, dynamic modeling and simulation are required. [11], [12]. Researchers have discussed the modeling of micro turbines and the effects of DGs and power management using STATCOM [13], [14]. In [15], the impact of nonlinear loads on the electric grid with DG was investigated. The stabilisation of the system is the primary technical impact of the DG penetration [16], [17]. The system's transient and steady-state stability are both impacted when a distributed unit or energy storage device is connected to the national grid [18]. An interface and storage model, along with a dynamic model of DG and power system grid/distribution system, need to be designed to study the effects of energy storage devices on the electric grid. Models for batteries and ultra capacitors, along with their control, are covered in [19] through [24]. The majority of the research discussed in the literature looks at how DG affects the grid, but very few have concentrated on how an intelligent distributed generation scheme can increase power system stability in distribution networks. Effects of DG/energy storage on the grid. The research project described here focuses on the analysis of an electrical distribution network's radial distribution system to determine the voltage status at the buses and to choose the size and type of distributed generation that will be sufficient to maintain power on the network. In the era of computers, the significance of energy systems cannot be overstated[25]. The network power fluctuations brought on by the rise in electricity demand are stabilised to some extent by distributed generation. Components of modern power systems have been used and stressed beyond their design limits. [26]. To ensure that the transmission system can withstand sudden disturbances when under load, power system stability is a crucial component of the transmission system security assessment[27].

The integration of renewable energy into the national grid could make up for the unstable power supply brought on by the slowly rotating hydro-turbine generators[28]. A hybrid configuration, which is used to feed microgrid sources into the grid, has the potential to provide improved performance and better financial values for a particular electrification situation[29]. A consistent power supply is a problem in Nigeria due to harmonics, short circuits, and power losses in the transmission network. The introduction of renewable energy sources may help solve this issue. [30]

III. MATERIALS IN THE SUBSTATION

Enugu Electricity Distribution Network consist of HV/MV substation equipped with an onload Tap changer and Shunt Capacitor banks whose power can be discretely controlledThe transformer has a rated voltage ratio of 33/11 kV and a rated average power of 7.5 MVA. The capacitor banks at the substation have a rated power of 1000 kvarwith steps of 200 kvar. The total feeder load is about 45 kVA at a power factor of 0.875. Being balanced, all the system loads are constant PQ. There are 32 loads in the network totaling roughly 16 MW and 9 Mvar.The Methodology used is the collection and tabulation of network operating parameters and performing load flow analysis to determinethe system operating parameters from the radial distribution network. This would determinethe voltage status at the buses and to determine the size and the type of Distributed Generation that will be adequate to stabilize power on the network.

3.1 Characterization of the distribution network of study.

The Enugu Electricity Distribution Company (EEDC) distribution network, which serves only the Enugu zone, was used in this thesis. The test system, a three-wire delta feeder running at a nominal voltage of 11 kV, is situated in the Nigerian state of Enugu. A combination of constant PQ, constant current, and constant impedance make up the system loads. The single line diagram of the distribution system used in this thesis is shown in Figure 3.1.The system resembles a medium voltage distribution network for suburbs. The HV/MV substation in this radial distribution network is outfitted with shunt capacitor banks with discretely controllable power and a on load tap changer.

3.2 Network Description:

When it comes to simplification, the per unit values serve as the foundation for power system analysis.Typically, transformers are used to connect various voltage levels in power systems. The per-unit system selects a standard set of base parameters in terms of which all system quantities are defined in order to streamline the analysis of these. The system consequently becomes reduced to a set of impedances and the different voltage levels disappear.

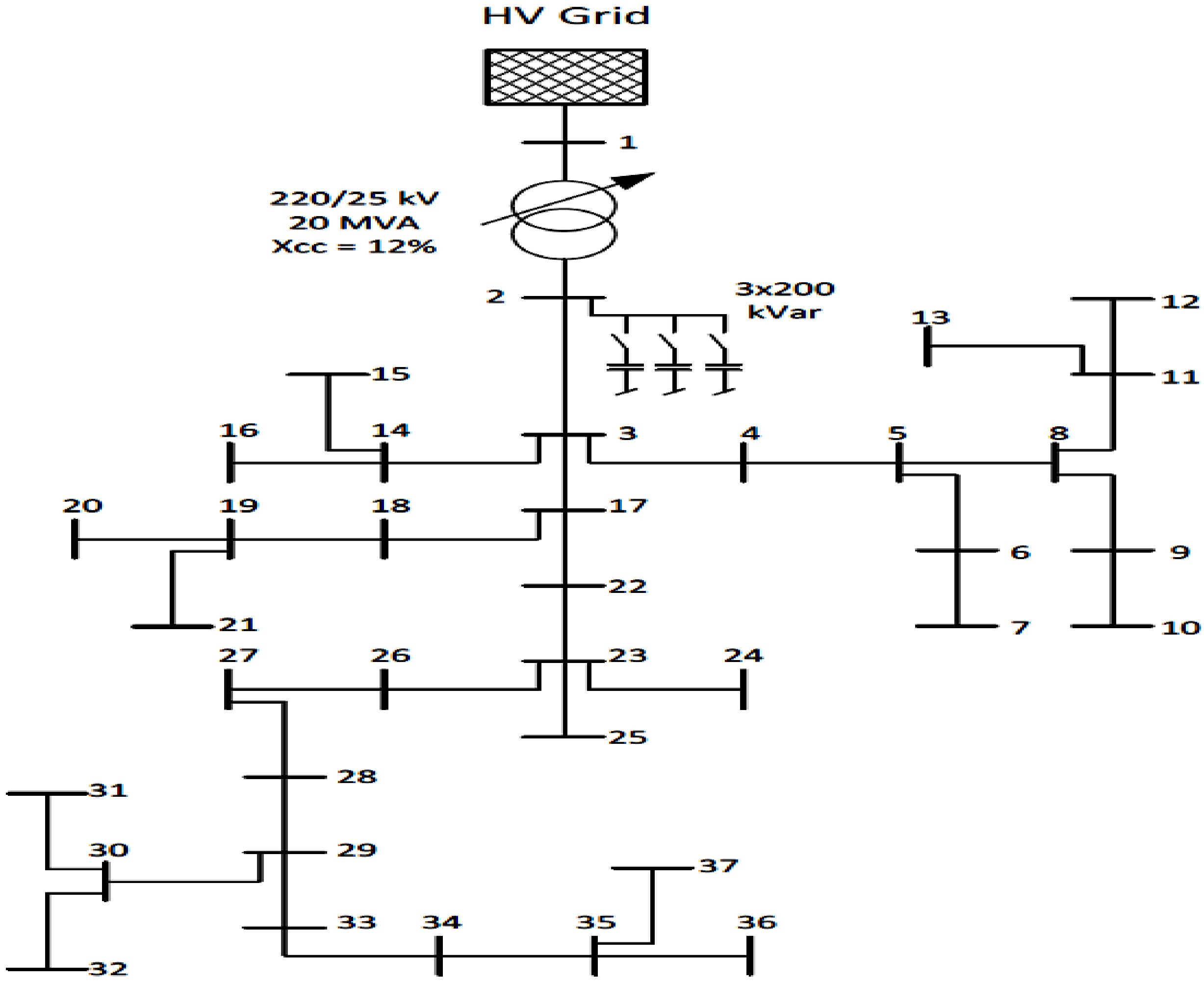

Fig.1. Single line diagram of the distribution network

Through this simplification, the per-unit values for transformer impedance, current and voltage are identical when referred to the primary and secondary side. According to the Equation 3.1the definition of any quantity in the per-unit systems:

$$Quantity\ (per\ unit) = \frac{Quantity\ (normal\ units)}{Base\ value\ of\ quantity\ (normal\ units)} \quad (3.1)$$

In order to characterize a per-unit system, the values of voltage, current, power and impedance must be defined. Given the four base values, the per-unit quantities are as follow:

$$V_{pu} = \frac{V}{V_{base}}\ ;\ I_{pu} = \frac{I}{I_{base}}\ ; S_{pu} = \frac{S}{S_{base}}\ ;\ Z_{pu} = \frac{Z}{Z_{base}} \quad (3.2)$$

Once any two of the four base values, namely $V_{base}, I_{base}, S_{base}, and Z_{base}$ are defined, the remaining two base values can be determined according their fundamental circuit relationships. Given the base value of power as S_{base} and the base value of voltage as V_{base}, the base values of impedance and current are determined according to:

$$I_{base} = \frac{S_{base}}{V_{base}} \quad (3.3)$$

$$Z_{base} = \frac{{V_{base}}^2}{S_{base}} \quad (3.4)$$

Assuming constant the value of S_{base} for all points in the system and the ratio of voltage bases on either side of a transformer equal to the ratio of the transformer voltage ratings, the per-unit impedance of the transformer remains unchanged when referred from one side of a transformer to the other. The base values of power and voltage for the analyzed system are:

$S_{base} = 100MVA; V_{base\,1} = 33kV; V_{base\,2} = 11kV$

Where $V_{base\,1}$ is referred to the high voltage side of the transformer and $V_{base\,2}$ to the voltage at the low side.

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```
clear
basemva = 100;  accuracy = 0.001; maxiter = 10;

%         30-BUS TEST SYSTEM FOR EEDC ENUGU
%         Bus Bus  Voltage Angle   ---Load----  -------Generator----- Injected
%         No  code Mag.    Degree  MW     Mvar  MW   Mvar Qmin Qmax     Mvar
busdata=[1    1    1.06    0.0     0.0    0.0   0.0  0.0   0    0        0
         2    2    1.043   0.0    21.70  12.7  40.0  0.0 -40   50        0
         3    0    1.0     0.0     2.4    1.2   0.0  0.0   0    0        0
         4    0    1.06    0.0     7.6    1.6   0.0  0.0   0    0        0
         5    2    1.01    0.0    94.2   19.0   0.0  0.0 -40   40        0
         6    0    1.0     0.0     0.0    0.0   0.0  0.0   0    0        0
         7    0    1.0     0.0    22.8   10.9   0.0  0.0   0    0        0
         8    2    1.01    0.0    30.0   30.0   0.0  0.0 -10   60        0
         9    0    1.0     0.0     0.0    0.0   0.0  0.0   0    0        0
        10    0    1.0     0.0     5.8    2.0   0.0  0.0  -6   24       19
        11    2    1.082   0.0     0.0    0.0   0.0  0.0   0    0        0
        12    0    1.0     0      11.2    7.5   0    0     0    0        0
        13    2    1.071   0       0      0.0   0    0    -6   24        0
        14    0    1       0       6.2    1.6   0    0     0    0        0
        15    0    1       0       8.2    2.5   0    0     0    0        0
        16    0    1       0       3.5    1.8   0    0     0    0        0
        17    0    1       0       9.0    5.8   0    0     0    0        0
        18    0    1       0       3.2    0.9   0    0     0    0        0
        19    0    1       0       9.5    3.4   0    0     0    0        0
        20    0    1       0       2.2    0.7   0    0     0    0        0
        21    0    1       0      17.5   11.2   0    0     0    0        0
        22    0    1       0       0      0.0   0    0     0    0        0
        23    0    1       0       3.2    1.6   0    0     0    0        0
        24    0    1       0       8.7    6.7   0    0     0    0      4.3
        25    0    1       0       0      0.0   0    0     0    0        0
```

```
        11    2    1.082   0.0     0.0    0.0   0.0  0.0   0    0        0
        12    0    1.0     0      11.2    7.5   0    0     0    0        0
        13    2    1.071   0       0      0.0   0    0    -6   24        0
        14    0    1       0       6.2    1.6   0    0     0    0        0
        15    0    1       0       8.2    2.5   0    0     0    0        0
        16    0    1       0       3.5    1.8   0    0     0    0        0
        17    0    1       0       9.0    5.8   0    0     0    0        0
        18    0    1       0       3.2    0.9   0    0     0    0        0
        19    0    1       0       9.5    3.4   0    0     0    0        0
        20    0    1       0       2.2    0.7   0    0     0    0        0
        21    0    1       0      17.5   11.2   0    0     0    0        0
        22    0    1       0       0      0.0   0    0     0    0        0
        23    0    1       0       3.2    1.6   0    0     0    0        0
        24    0    1       0       8.7    6.7   0    0     0    0      4.3
        25    0    1       0       0      0.0   0    0     0    0        0
        26    0    1       0       3.5    2.3   0    0     0    0        0
        27    0    1       0       0      0.0   0    0     0    0        0
        28    0    1       0       0      0.0   0    0     0    0        0
        29    0    1       0       2.4    0.9   0    0     0    0        0
        30    0    1       0      10.6    1.9   0    0     0    0        0];

%                                                 Line code
%            Bus bus   R       X       1/2 B      = 1 for lines
%            nl  nr   p.u.    p.u.    p.u.        > 1 or < 1 tr. tap at bus nl
linedata=[1   2   0.0192  0.0575  0.02640     1
          1   3   0.0452  0.1852  0.02040     1
          2   4   0.0570  0.1737  0.01840     1
          3   4   0.0132  0.0379  0.00420     1
          2   5   0.0472  0.1983  0.02090     1
          2   6   0.0581  0.1763  0.01870     1
          4   6   0.0119  0.0414  0.00450     1
```

Fig.2. Evaluation of the voltage profile of the network without a distribution generation using per-unit system.

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 7.54898e-007
No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.060	0.000	0.000	0.000	260.998	-17.021	0.000
2	1.043	-5.497	21.700	12.700	40.000	48.822	0.000
3	1.022	-8.004	2.400	1.200	0.000	0.000	0.000
4	1.013	-9.661	7.600	1.600	0.000	0.000	0.000
5	1.010	-14.381	94.200	19.000	0.000	35.975	0.000
6	1.012	-11.398	0.000	0.000	0.000	0.000	0.000
7	1.003	-13.150	22.800	10.900	0.000	0.000	0.000
8	1.010	-12.115	30.000	30.000	0.000	30.826	0.000
9	1.051	-14.434	0.000	0.000	0.000	0.000	0.000
10	1.044	-16.024	5.800	2.000	0.000	0.000	19.000
11	1.082	-14.434	0.000	0.000	0.000	16.119	0.000
12	1.057	-15.302	11.200	7.500	0.000	0.000	0.000
13	1.071	-15.302	0.000	0.000	0.000	10.423	0.000
14	1.042	-16.191	6.200	1.600	0.000	0.000	0.000
15	1.038	-16.278	8.200	2.500	0.000	0.000	0.000
16	1.045	-15.880	3.500	1.800	0.000	0.000	0.000
17	1.039	-16.188	9.000	5.800	0.000	0.000	0.000
18	1.028	-16.884	3.200	0.900	0.000	0.000	0.000
19	1.025	-17.052	9.500	3.400	0.000	0.000	0.000
20	1.029	-16.852	2.200	0.700	0.000	0.000	0.000
21	1.032	-16.468	17.500	11.200	0.000	0.000	0.000
22	1.033	-16.455	0.000	0.000	0.000	0.000	0.000

5	1.010	-14.381	94.200	19.000	0.000	35.975	0.000
6	1.012	-11.398	0.000	0.000	0.000	0.000	0.000
7	1.003	-13.150	22.800	10.900	0.000	0.000	0.000
8	1.010	-12.115	30.000	30.000	0.000	30.826	0.000
9	1.051	-14.434	0.000	0.000	0.000	0.000	0.000
10	1.044	-16.024	5.800	2.000	0.000	0.000	19.000
11	1.082	-14.434	0.000	0.000	0.000	16.119	0.000
12	1.057	-15.302	11.200	7.500	0.000	0.000	0.000
13	1.071	-15.302	0.000	0.000	0.000	10.423	0.000
14	1.042	-16.191	6.200	1.600	0.000	0.000	0.000
15	1.038	-16.278	8.200	2.500	0.000	0.000	0.000
16	1.045	-15.880	3.500	1.800	0.000	0.000	0.000
17	1.039	-16.188	9.000	5.800	0.000	0.000	0.000
18	1.028	-16.884	3.200	0.900	0.000	0.000	0.000
19	1.025	-17.052	9.500	3.400	0.000	0.000	0.000
20	1.029	-16.852	2.200	0.700	0.000	0.000	0.000
21	1.032	-16.468	17.500	11.200	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	3.200	1.600	0.000	0.000	0.000
24	1.022	-16.830	8.700	6.700	0.000	0.000	4.300
25	1.019	-16.424	0.000	0.000	0.000	0.000	0.000
26	1.001	-16.842	3.500	2.300	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	2.400	0.900	0.000	0.000	0.000
30	0.995	-18.015	10.600	1.900	0.000	0.000	0.000
Total			283.400	126.200	300.998	125.144	23.300

Fig.3 Power flow result of evaluation of the voltage profile of the network withot a distribution generation.

The modeling of the components discussed in this section is based on the assumption that the three phase system is balanced under steady state conditions. Using this assumption, per phase analysis can be done.

3.3. Load

The system loads are modelled as constant power. Constant power loads describe real and reactive power absorbed by the system so that these are modelled as positive power injections at the buses. In order to keep a constant power injection, these loads are characterized by reacting to changes in the voltage or current. Loads at PQ buses are modelled as constant active P_{Lk} and reactive power Q_{Lk} provided that voltage at bus k is within acceptable limits as:

$$P_k = -P_{Lk} \qquad (3.5)$$

$$Q_k = -Q_{Lk} \qquad (3.6)$$

In the case that voltage limits are violated, PQ loads are modified for as:

$$P_k = \frac{-P_{Lk} V^2{}_k}{(V^{lim}{}_k)^2} \qquad (3.7)$$

$$Q_k = \frac{-Q_{Lk} V^2{}_k}{(V^{lim}{}_k)^2} \qquad (3.8)$$

Where $V_L{}^{lim}$ is depending on the case $V_L{}^{max}$ or $V_L{}^{min}$.

3.4. Shunt Capacitor

In order to provide reactive power and raise the voltage magnitude at the secondary side of the transformer, the bank of capacitors is connected to bus 2 of the system.

The main purpose of shunt compensation is to regulate the amount of reactive power that flows through the power system. Benefits of shunt capacitors' reactive power support include improved voltage control and power factor as well as a decrease in the amount of reactive power needed at the generators. These capacitors are sized and placed at transmission and distribution substations to supply reactive power near the loads. As a result, power losses are decreased and voltage regulation at the load terminals is improved while the line current is kept to a minimum.

3.5 Methodology

The method and case studies used in this thesis' analysis of the system are presented in this section.

3.5.2 On-load tap switch (OLTC)

Programming in MATLAB/Simulink was used to create the power flow technique and the optimization method used in this paper.

3.5.1. Choosing the right DG to use based on the findings of the aforementioned study is the key to the solution.

The Newton Raphson power flow method has been selected to study the system. The choice of appropriate initial values for each of the state variables included in the study will determine how well the Newton Raphson method works to arrive at workable iterative solutions. Normal starting voltages for the power flow solution are 1pu at all PQ buses. If no generator reactive power limits are exceeded during the iterative solution, the specified values for the slack, PV, and PVT buses are used. At all buses, the initial voltage phase angles are set to 0.

The initial tapping position of LTCs should be at their nominal value in order to initialise the nodal voltage magnitudes and phase angles of the power flow solution. At each iterative step, the condition of the OLTC taps is examined to determine whether the OLTC is still operating within bounds and capable of controlling voltage magnitude.

For tap switching, a voltage magnitude tolerance of 0.01pu has been selected. Given that the OLTC taps are discrete variables, the variable has been limited using a first power flow analysis.

However, any voltage below or above it indicates that it is defective, which will undoubtedly cause it to experience any of the following power losses: short circuit, overcurrent, and harmonic distortion that has developed as a result of ripples. Meanwhile, it is known that voltage ranges between 0.95 and 1.05 are the normal range. As shown in figure 2 and figure 3; the faulty buses after the load flow results that need to be normalised by genetic optimization and injected into a suitable direct generator (DG) are buses 9, 11, 12, and 13. These buses have voltage profiles of 1.051p.u, 1.082p.u, 1.057 p.u, and 1.071p.u, respectively.

3.5.3 shunt capacitor

A shunt capacitor bank added to a load bus corresponds to the addition of a negative reactive load from the perspective of power flow. The susceptance is used to model the additional load. The susceptance B can be calculated from Q=V2 B given a required reactive power injection of Q cal, where V is the voltage of the bus where the shunt capacitor must be installed. The required reactive power has been calculated as a result of a first run of power flow. The susceptance is thus measured and discretized.

3.5.4 optimization

The four defective buses—9, 11, 12, and 13—were genetically modified to eliminate or reduce power losses, including overcurrent, overvoltage, and short circuits, to name a few, that were discovered in these buses. These buses fall above the typical voltage ranges of 0.95 through 1.05 for stable power supply.

Genetic algorithms were used as the optimization method in this thesis (GA). This algorithm is simple to use, produces consistently good results, and is computationally straightforward. A set of potential solutions that were randomly selected from a search space and represented in an appropriate coding constitute the initial population, or starting point, of a GA system. Each solution is unique and functions similarly to a chromosome. Chromosomes in GA are made up of a series of genes, each of which is represented by a binary value of 0 or 1.

GA are used to maximise or minimise a particular objective function, J obj, so that given a particular J obj, each individual I goes through an assessment of its fitness, with J i being a measure of each individual's performance.

Following the assignment of each person's fitness, the population is subjected to three fundamental operations: selection, crossover, and mutation.

The operator who determines convergence is selection, and premature convergence to a load optimum can be avoided by using an appropriate selection method. Several techniques can be used to choose individuals who will be permitted to reproduce based on their fitness assessment. These include elitist selection, scaling selection, roulette wheel selection, fitness proportionate selection, tournament selection, and fitness proportionate selection.

Two individuals are chosen to reproduce following the selection phase, and crossover and mutation are used to produce new offspring. Low performers are now eliminated, and as a result, the improvement happens as a result.

In the case of a crossover with a crossing site, a cross position k is chosen at random from the range [1, l-1], where l is the length of the individual's string as shown in Figure 4.

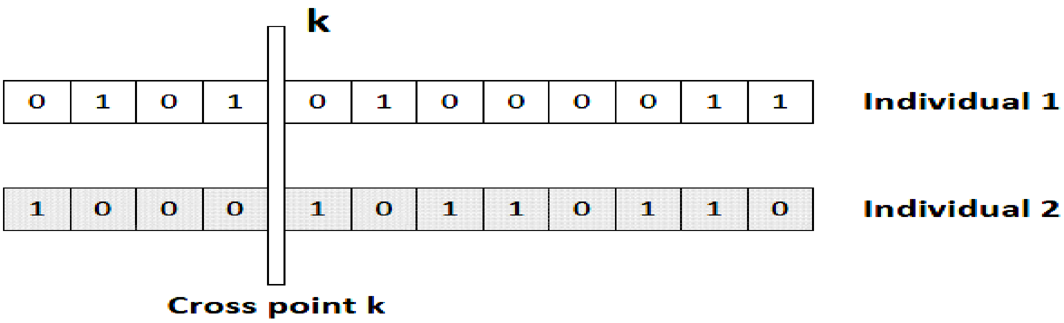

Fig.4. Representation of two individuals and the cross position k.

Two new strings are therefore created by swapping all characters between $k+1$and l as shown in Figure 5.

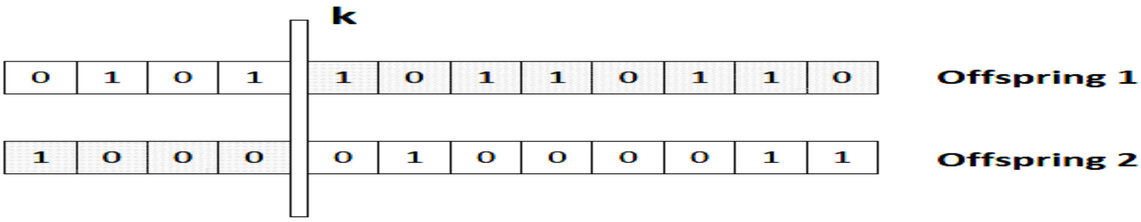

Fig.5. Representation of two individuals after mating the progenitors.

The strings of both parents are exchanged from the first position of crossover to the second one. The mutation operator is then applied with a probability, p mut, to each member of the current offspring in order to ensure genetic diversity. Best probability values change based on the circumstances. Any of an individual's genes can change, and

for binary genes, this is done by changing a 0 to a 1 or a 1 to a 0, as shown in Figure 3.5.

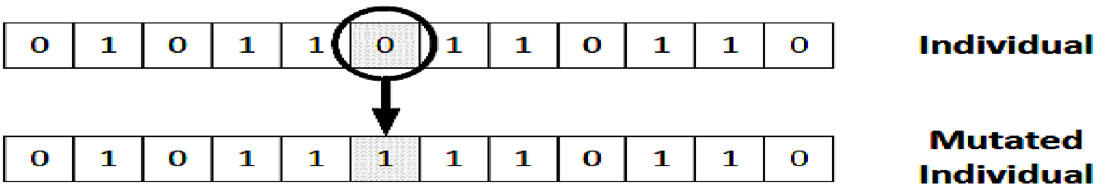

Figure 6. A person's representation of a gene mutation

The three operators result in the creation of a new population. In order to determine the best individual, both the initial population and the new generation are assessed. If the progenitor fitness function value is better than the offspring value, the individual from the initial population replaces the individual from the first generation. The obtained population goes through the same processes as the previous one after the first generation is finished: evaluation, selection, and mutation. A maximum generation or a specific value of the objective function evaluation can serve as the stop criterion.

The general steps involved in using a genetic algorithm is performed below:.

A. Objective functions

Finding the ideal values of the reactive power control variables that minimise the objective function is the fundamental goal of reactive power and voltage control.

The following goals are taken into consideration in this strategy.

1. Minimizing system power losses: The goal is to reduce all real power losses in the system to a minimum. This can be computed using the formula

:

$$F_1 = P_{loss} = \sum_{k=1}^{nb} p_{loss_i} \quad (3.9)$$

$$P_{loss} = \sum_{k=1}^{nb} G_k \left[{V_k}^2 + {V_m}^2 - 2V_k V_m cos(\theta_k - \theta_m)\right] \quad (3.10)$$

Where

nb:the number of branches

P_{loss_i}:the power loss in branch i

G_k:the conductance of the $k$line

V_k & V_m: the voltage magnitude at the end buses k & m

θ_k &θ_m: the voltage phase angle at the end buses k & m

i) Minimization of voltage deviation**:** Bus voltage is one of the important security and service quality indices. To improve the voltage profile the load bus voltage deviation should be minimized. This can be calculated as follows:

$$\boldsymbol{F}_2 = \sum_{h=1}^{\boldsymbol{nh}} \left[\overline{\boldsymbol{V}_h} - \boldsymbol{V}_{ref}\right] \quad (\mathbf{3.11})$$

Where

nh:the number of 10-minutes period

$\overline{\boldsymbol{V}_h}$:average value of voltage magnitude of the system for time h

V_{ref} : voltage reference generally valued as1

B. Problem Constraints

i) Equality Constraints: The equality constraints are the real and reactive power balance equations at all the bus bars. The equality constraints can be formulated as:

$$P_{Gk} - P_{Lk} = \sum_{k=1}^{n} |V_k||V_m||Y_{km}|cos(\theta_k - \theta_m - \theta_{km}) \quad (3.12)$$

$$Q_{Gk} - Q_{Lk} = \sum_{k=1}^{n} |V_k||V_m||Y_{km}|sin(\theta_k - \theta_m - \theta_{km}) \quad (3.13)$$

Where

n:the number of buses

Y_{km}:the mutual admittance between node k and m

θ_k, θ_m:the bus voltage angle of bus k and m respectively.

P_{Gk}, Q_{Gk}:the real and reactive power generation at bus k

θ_{km}:the admittance angle of line between buses k and m

P_{Lk}, Q_{Lk}:the real and reactive power demand at bus k

ii) Inequality Constraints

Transformer constraints

$$\boldsymbol{T}_{\boldsymbol{k}_{min}} \leq \boldsymbol{T}_k \leq \boldsymbol{T}_{\boldsymbol{k_{max}}} \quad (3.14)$$

Where

$T_{k_{min}}$ and $T_{\boldsymbol{k_{max}}}$ are the minimum and maximum range of ratio of tap changing transformer at bus k.

Switchable VAr constraints

$$Q_{Ck_{min}} \leq Q_{\boldsymbol{C}_k} \leq Q_{Ck_{max}} \quad (3.15)$$

Where

$Q_{Ck_{\boldsymbol{min}}}$ and $Q_{Ck_{max}}$ are the minimum and maximum allowable output of reactive power compensation equipment at bus k.

3.4 Development of a model for the integration of the Microgid to the network using genetic algorithm (GA) technology.

In this Section the different study cases are presented.

3.4.1 Case 0

In case 0, the model system depicted is analyzed without adding distributed generation nor operating shunt capacitors bank. Power losses, voltage profile, voltage deviation and OLTC number of operations are the results.

3.4.2 Case 1

In case 1, the system used in case 0 is analyzed adding distributed generation.

While wind power generation is injected at load buses. Location of distributed generation has been done by a simple visual analysis, using the assumption that power generation is most needed at the distribution end.

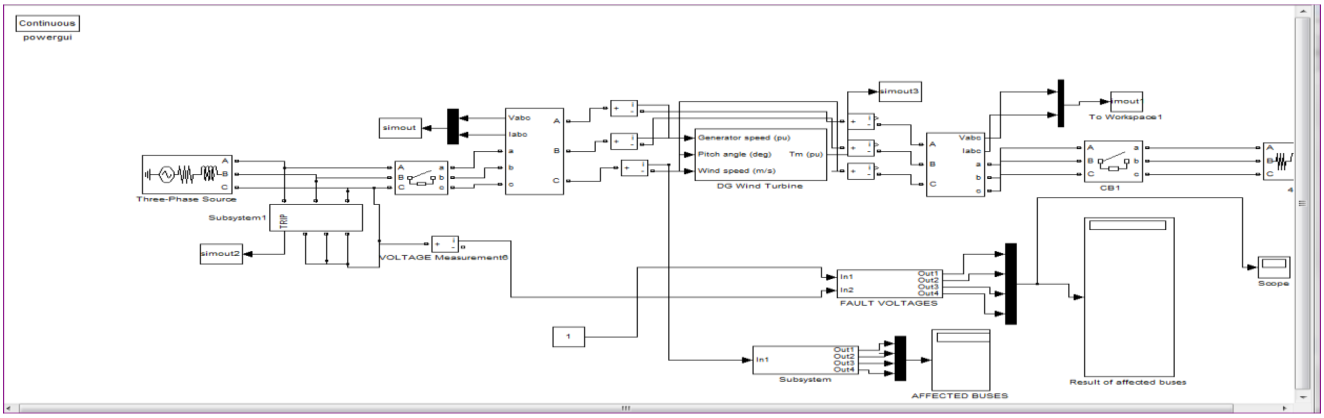

Fig.7. Model for the integration of the DG to the network using genetic algorithm (GA) technology

3.4.3 Case 2

In case 2, the system used in case 0 is analyzed operating shunt capacitors bank. Power losses, voltage profile, voltage deviation, OLTC number of operations and shunt capacitors switching are the results.

3.4.4 Case 3

In case 3, the model system is analyzed by adding distributed generation as in case 1 and operating shunt capacitors bank. Power losses, voltage profile, voltage deviation, OLTC number of operations and shunt capacitors switching are the results.

3.4.5 Case 4

Using the system analyzed on case 3, in case 4 a genetic algorithm is implemented in order to find the best location for DG.

3.5.6 Case 5

Using the best location obtained in case 4, in case 5 another genetic algorithm is implemented so that proper generation size for distributed generation is achieved.

Evaluation of the impact of the DG by simulating the developed model in the system.

3.5.7 Case 6

In case 6, results of case 5 are used and a genetic algorithm is performed in order to find the appropriate reactive power dispatching for DG.

Results so obtained graphically are displayed in chapter 4 after the optimization tool has been used in MATLAB to generate the Genetic Algorithm solver for analysis.

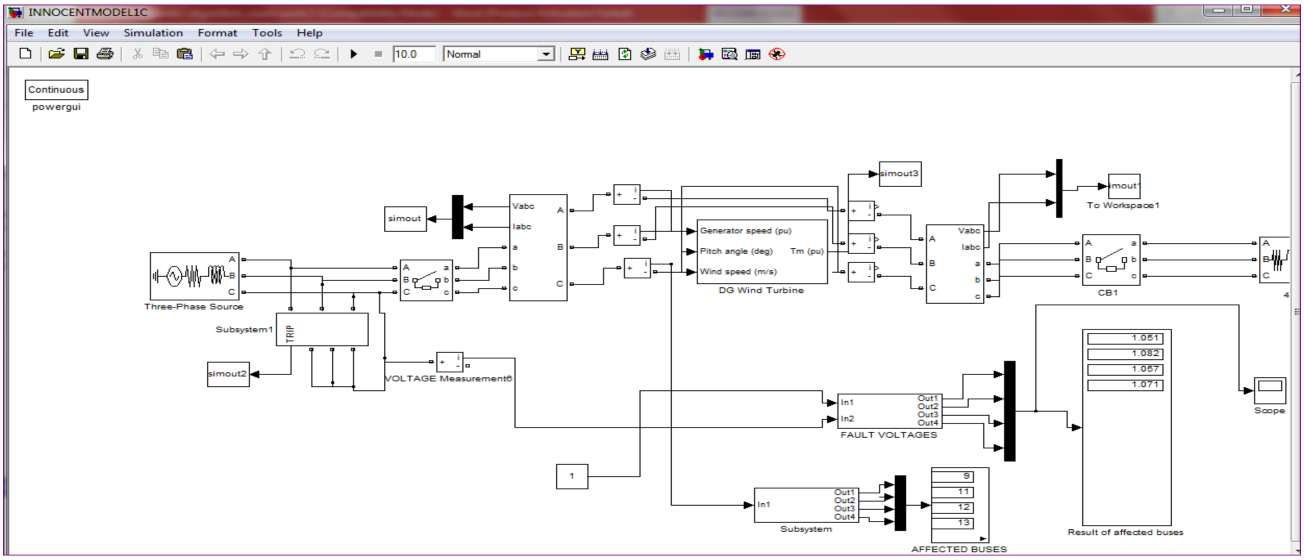

Fig.8. Simulated result when DG is added to the network

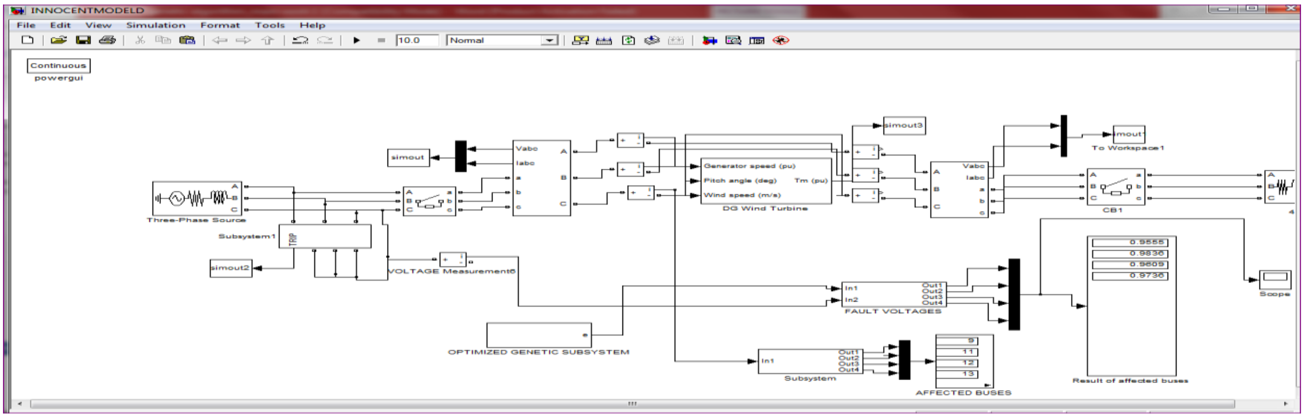

Fig.9. Simulated result when DG is added to the network optimized genetic algorithm technology

Fig.9. shows the corrected fault buses voltage result. The comprehensive analysis is shown in

IV. RESULTS AND DISCUSSION

The single line diagram of the distribution network is shown in Figure 1; the voltage profile of the network without a distribution generation is evaluated in Figure 2; the power flow that results from the evaluation of the voltage profile of the network without a distribution generation is shown in Figure 3; and the representation of two people and the cross position k is shown in Figure 4.

As shown in Fig. 5, two new strings are produced by switching every character between k+1 and l. A representation of two individuals after mating is shown in Fig. 5, a representation of a gene mutation in an individual is shown in Fig. 6, and a model for integrating the DG into the network using genetic algorithm (GA) technology is shown in Fig. 7.

Distributed Generators are added to the network in Fig. 8 and DG are added to the network using genetic algorithm technology that has been optimised in Fig. 9, respectively.

The corrected fault buses voltage result is shown in Fig. 9. The thorough analysis is displayed in Fig.10, where all four defective buses are contrasted for verification. Figure 10 compares the four faulty buses in the load flow with the corrected voltage buses that were added to the distribution network after a distributed generation model was implemented.

The power is stable now that it has been corrected, as shown in Fig. 11. As a result, consumers receive high-quality power supplies with little load loss. The impact of the DG on the developed model is depicted in Fig.12

Figure 12 depicts the DG analysis performed on the created model. The red graph displays high voltage, which causes high power loss, overvoltage, and ongoing system instability. The blue graph, on the other hand, displays a constant voltage.

A straightforward analysis of the power flow has been done in case 0. In this study case, Shunt Capacitors and Distributed Generation are not taken into account. As a result, in this instance, the substation is responsible for all active and reactive power generation.

Bus 30's load flow is shown in Figure 3; Fig.12 displays defective buses that did not fall within the Minimum voltage magnitude.

Table I: Comparison of Four Faulty Buses in the Load Flow

FAULTY VOLTAGE(P.U) AT BUS 9	FAULTY VOLTAGE(PU) AT BUS 11	FAULTY VOLTAGE(PU) AT BUS 12	FAULTY VOLTAGE(PU) AT BUS 13	TIME(S)
0	0	0	0	0
1.4	1.5	1.52	1.54	1
0.8	0.9	0.92	0.94	2
1.2	1.22	1.24	1.26	3
1.051	1.082	1.057	1.071	4
1.051	1.082	1.057	1.071	5
1.051	1.082	1.057	1.071	6
1.051	1.082	1.057	1.071	7
1.051	1.082	1.057	1.071	8
1.051	1.082	1.057	1.071	9
1.051	1.082	1.057	1.071	10

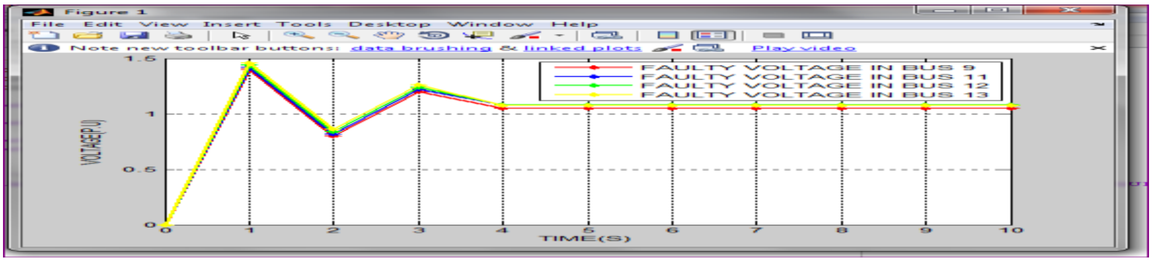

Fig .10. Comparison of Four Faulty Busses in the load flow

The analysis of the four defective buses in the load flow is shown in Fig. 10. The faulty buses, which have abnormal voltages, are buses 9, 11, 12, and 13, as shown in Figs. 2 and 3. These buses' abnormal voltages result in low power factor, over current conditions, and power losses, all of which contribute to ongoing power system instability. This contributed to the consumers receiving low-quality power supply.

Table 2: Corrected Voltages in buses 9 to 13

CORRECTED VOLTAGE IN BUS 9	CORRECTED VOLTAGE IN BUS 11	CORRECTED VOLTAGE IN BUS 12	CORRECTED VOLTAGE IN BUS 13	TIME (S)
0	0	0	0	0
1.3	1.4	1.6	1.8	1
0.7	0.8	0.9	0.93	2
1	1.1	1.2	1.23	3
0.9555	0.9836	0.9609	0.9736	4
0.9555	0.9836	0.9609	0.9736	5
0.9555	0.9836	0.9609	0.9736	6
0.9555	0.9836	0.9609	0.9736	7
0.9555	0.9836	0.9609	0.9736	8
0.9555	0.9836	0.9609	0.9736	9
0.9555	0.9836	0.9609	0.9736	10

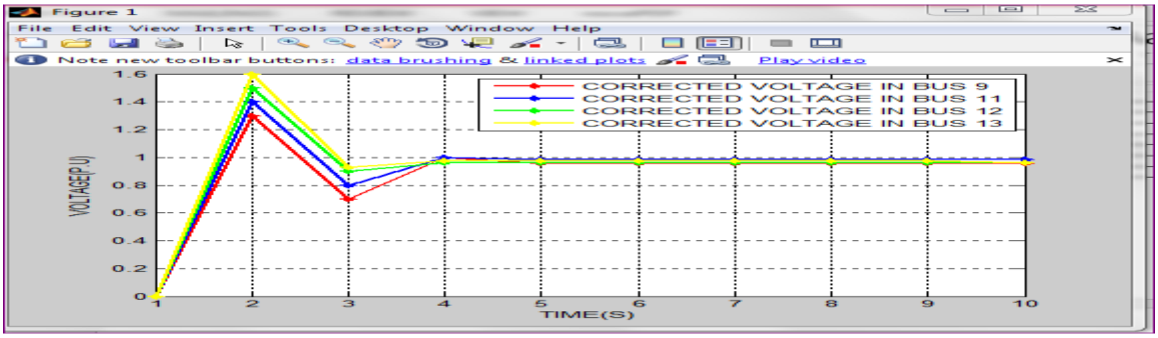

Fig.11 Corrected Voltage buses when a model of distributed generation was integrated in the distribution network.

Table3: Comparison of faulty voltage and corrected voltage.

FAULTY VOLTAGE AT BUS 9	CORRECTED VOLTAGE AT BUS 9	TIME(S)
0	0	0
1.4	1.3	1
0.8	0.7	2
1.2	1	3
1.051	0.9555	4
1.051	0.9555	5
1.051	0.9555	6
1.051	0.9555	7
1.051	0.9555	8
1.051	0.9555	9
1.051	0.9555	10

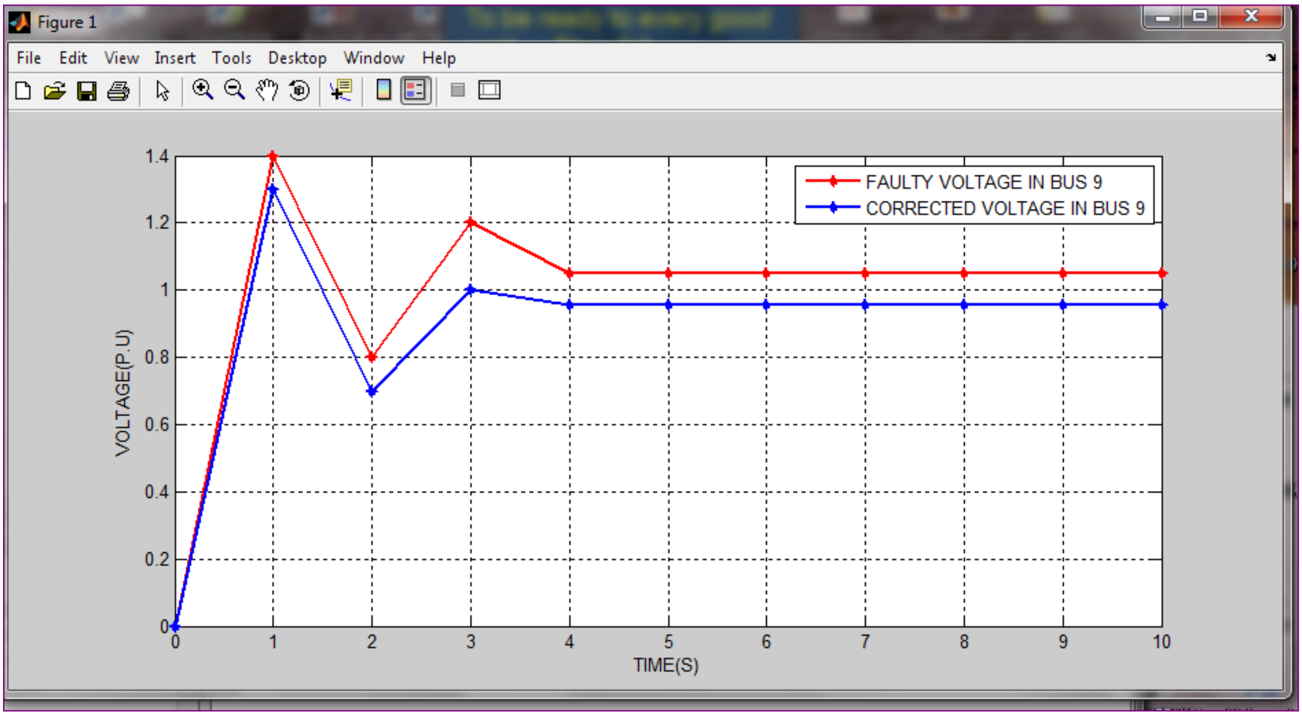

Fig.12. Result of the impact of the DG on the developed model

Fig.12 shows the analysis of DG on the developed model.
The red graph shows high voltage that leads to, high power loss, over voltage and constant instability in the system.
On the other hand, the blue graph shows a stable voltage.

V. CONCLUSION

The genetic algorithmic integration of renewable energy generation on the distribution network and how it affects voltage regulation and reactive power distribution network operation are the main topics of this paper.
Analysis has been done on the integration of distributed generation into the power systems.
Energy sources have been researched, technologies have been updated, and then distributed generation has been integrated into the grid in order to model a generation based on renewable energy.
One of the main issues in power systems is voltage drop up to the distribution network, so voltage regulation and reactive power control are crucial to the stability of the power system. As a result, equipment for power reactive control and voltage regulation have been examined.
In order to model the study test system, power flow analysis has been programmed using the main equations of electrical circuits in MATLAB.
There are some considerations to be made when mathematically modelling the power system. Problems with optimization are based on factors like energy efficiency and control requirements. When an objective function that is also subject to constraints has an acceptable value, optimization problems can be solved.
A standard system has been modelled in this study using load flow analysis for various scenarios. The effects of distributed generation on the system have been studied.
To address problems like location, level of generation, or control of the power factor of the connected generators, a number of optimization algorithms have been implemented based on the natural selection theory.
The MATLAB/Simulink programme was used to carry out all mathematical formulations and

optimization algorithms.

It follows that the distribution network's energy efficiency has increased as a result of the optimization technique's implementation .

VI. Acknowledgements

I wish to express my gratitude to my colleagues in the department for their contributions ;I would like to thank the members of the utility company for providing useful information for load flow analysis.

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