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Improving Power System Stability in Distribution Network with Intelligent Distributed Generation Scheme

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ABSTRACT: *The concern of every Nigerian is the unreliable power supply in the country. Dilapidated transmissions lines and distribution networks cause high energy losses, which together with low rate of access and uneconomic tariffs, result in poor operational and financial outcomes. The endemic challenge has led to the research on renewable energy; this project analyses the integration of generation based on wind power renewable energy source to the Distribution network and how it stabilizes the network by normalizing the fluctuating voltage at the distribution end of power system. Firstly, Analysis was made on a radial distribution network of Electricity distribution network to find out the 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. The steady state analysis of power systems was performed through load flow analysis. A model for the integration of the Distributed generation to the network using genetic Algorithm (GA) technology was produced. Finally, the impact of the distributed generation on the system was implemented using optimization Algorithm based on the principle of natural selection; this was used to solve issues such as the location, level of generation or control of the power factor of the connected generation.*

KEY WORDS: *Distributed Generation, power system stability, intelligent distributed generation scheme, Genetic Algorithm*

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I. INTRODUCTION

Developing countries like ours, to integrate distributed generators into the national grid will require a reliable technology;hence,a high amount of distributed generation fundamental changes in electricity network operation are required. To avoid expensive extension of grid capacity an intelligent system has to be embedded into the conventional means of power generation. That means to develop and operate electrical distribution grids with intelligent techniques.

1.1 Aim of the Study

This study is aimed at Improving Power System Stability in Distribution Network using Intelligent Distributed Generation Scheme

1.2 Objectives of Study

Incessant power failures and frequent tripping of Gas turbine generators is a concern for power system engineers in our electricity generation sector. The objectives of this work in behavioural terms are stated sequentially to achieve the purpose of this study; therefore, the objective of this research work is to

- Collect data from the characterized Enugu Electricity Distribution Company (EEDC) distribution network for Enugu only.
- Perform load flow analysis of the radial distribution network to determine the 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.
- Design a model for the integration of the Distributed generation to the network using genetic Algorithm (GA) technology.
- Introduce optimization Algorithm based on the principle of natural selection to.
- Evaluate the impact of the DG by simulating the developed model in the system.

- Validate the design by performing Comparison of faulty voltage and corrected voltage.

II. EXTENT OF PAST RELATED WORKS

There is emphasis now on the concept of improving intermittent output of distributed generation (DG) using energy storage Devices [1]. Distributed Generators are usually referred to as standalone generators normally owned by persons in the remote locations. They are defined as the connection of generating plants of small kW rating between several kW to a few MW. The main source of this energy for these generators are usually fossil fuels or sources that are not renewable in nature like gas or the renewable sources such as wind, solar, hydro, and biomass [2]. The generating plants of this nature are usuall synchronized to the load centers though synchronizing machines called synchroscope. They are either tied to the medium voltage or low voltage sections of the national grid. The common practice for safety reasons is to connect through nearest the load centers or the low voltage networks. In some case where renewable energy source is required, such as wind turbines and photo voltaic solar panels, the output power depends on availability of renewable resource and therefore may vary according to the sun or the wind velocity. When that occurs, in order to augment the DG's during the unfavorable conditions, storage devices come to into play [3]. The wind and solar are very useful and clean source; storage can help in Improving or smoothing the power in conjunction with other sources like biomass especially for rural locations. We have other storage devices apart from storage batteries; these are, ultra-capacitors, flywheels, fuel cells and superconducting magnetic energy storage (SMES) [4]-[7]. To facilitate out performance of these generating sources, during peak demand, the storage devices may also help in maintaining the overall stability of the whole system. These energy storage devices are tied to the national grid using the technique referred to as smart grid. It would be connected to the electric grid by means of reliable power conversion devices [8]-[10]. Though the primary objective of Distributed Generators is to supply electric power where there is no national grid. In cases where energy generated is more than the local demand, DG's can be connected to the national grid thereby giving out the excess electric power. Despite the different categories of these distributed resources, the behaviour of a Distributed Resources (DR) mainly depends upon the type of the converter that is connected with these DR in order to interact with the Electrical power system at the distribution end. These electrical converters are classified into three major types, depending on the type of DR with which are connected like synchronous generators, asynchronous (or induction) generators, and static (or electronic) inverters.

. Dynamic modeling and simulation are needed to assess the impact [11], [12]. Researchers have presented the micro turbine modeling and impact of DG's and power management through control strategy using STATCOM [13], [14]. Effect of nonlinear loads on electric grid with DG was studied in [15]. The major technical impact of the DG penetration is on stabilizing the system [16], [17]. Interconnecting a Distributed units or energy storage device to the national grid usually affects the transient as well as steady state stability of the entire system [18]. To study the impact of energy storage device on the electric grid, an interface and storage model needs to be designed in conjunction with a dynamic model of DG and power system grid/distribution system. Batteries and ultra-capacitors models including their control have been discussed in [19]-[24]. Most of the work presented in the literature examines effects of DG on the grid, but very few have focused on improving Power System Stability in Distribution Network with Intelligent Distributed Generation Scheme .DG/energy storage effects on grid. The research work presented here aims on the Analysis of a radial distribution network of Electricity distribution network to find out the 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

III. MATERIALS AND METHODS

Materials in Enugu Electricity Distribution Network

Enugu Electricity Distribution Network consist of HV/MV substation equipped with an on-load Tap changer and Shunt Capacitor banks whose power can be discretely controlled The 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 kVar with 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 determine the system operating parameters from the radial distribution network. This would determine the 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 system used in this thesis is the Enugu Electricity Distribution Company (EEDC) distribution network covering Enugu zone only. Located in Enugu State of Nigeria, the test system is a three-wire delta feeder operating at a nominal voltage of 11 kV. The system loads consist of a mix of constant PQ, constant

current and constant impedance. Figure 3.1depicts the single line diagram of the distribution system used in this thesis.
The system corresponds to a suburban Medium Voltage distribution network. In this radial distribution network, the HV/MV substation is equipped with an on load tap changer and shunt capacitors banks whose power can be discretely controlled.

3.1.1 Network Description

The per unit values form the basis of power system analysis when it comes to simplification**.**
Typically, the power systems consist of different voltage levels interconnected by mean of transformers. In order to simplify the analysis of these, the per-unit system chooses a common set of base parameters in terms of which, all systems quantities are defined. As a result, the system reduces to a set of impedances and the different voltage levels disappear.

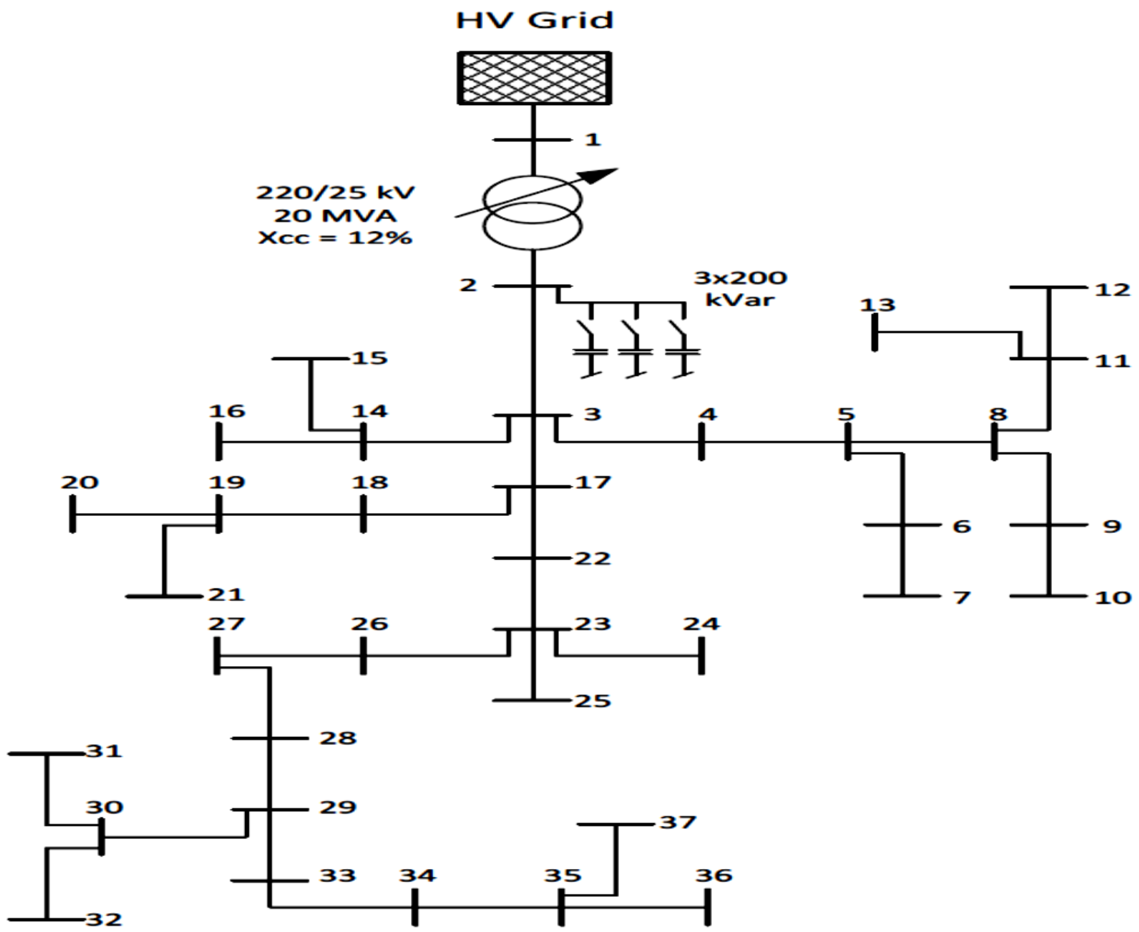

Fig.1. Single line diagram of the distribution network

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:

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

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:

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

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:

$$I_{base} = \frac{S_{base}}{V_{base}} \tag{3.3}$$

$$Z_{base} = \frac{{V_{base}}^2}{S_{base}} \tag{3.4}$$

Assuming constant the value of S_{base} for all points in the system and the ratio ofvoltage 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:

$$S_{base} = 100MVA; V_{base1} = 33kV; V_{base2} = 11kV$$

WhereV_{base1} is referred to the high voltage side of the transformer and V_{base2} to the voltage at the low side.

Editor - C:\Users\personal\Documents\MATLAB\INNOCENTPOWERFLOW.m

```
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.

3.2. 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:

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

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

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

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

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

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

3.3. Shunt Capacitor

The bank of capacitors is connected at bus 2 of the system in order to deliver reactive power and increase the voltage magnitude at the secondary side of the transformer.

Shunt compensation is used basically to control the amount of reactive power that flows through the power system. Benefits of the reactive power support by shunt capacitors comprise an improvement of the voltage control and power factor, as well as a reduction of reactive power requirements at the generators. Sized and located at transmission and distribution substations, such capacitors supply reactive power close to the loads. As a result, the line current is minimized, reducing power losses and improving voltage regulation at the load terminals.

3.4 Methodology

In this section, the methodology and case studies used in this thesis for analyzing the system are presented. Both the power flow technique and the optimization method used in this thesis have been programmed in MATLAB/Simulink.

3.4.1. Determination of the appropriate DG to be used based on the result of the above study (2)

In order to study the system, the power flow method chosen has been the Newton Raphson. The effectiveness of the Newton Raphson method to achieve feasible iterative solutions is dependent upon the selection of suitable initial values for all the state variables involved in the study. The power flow solution is normally started with voltage magnitudes of 1pu at all PQ buses. The slack and PV and PVT buses are given their specified values, which remain constant throughout the iterative solution if no generator reactive power limits are violated. The initial voltage phase angles are selected to be 0 at all buses.

3.4.2 On Load Tap Changer (OLTC)

For initializing the nodal voltage magnitudes and phase angles of power flow solution, the initial tapping position of LTCs to be at their nominal value. The status of OLTC taps is checked at each iterative step to assess whether or not the OLTC is still operating within limits and capable of regulating voltage magnitude.

Voltage magnitude tolerance of 0.01pu has been chosen for the tap switching. Given that the OLTC taps are discrete variables a first power flow analysis has been run in order to limit the variable.

Meanwhile it is known that voltage ranges from 0.95 to 1.05 is the normal range but any one below or above it shows that it is faulty which will definitely make it to experience any of the following power losses, short circuit, over current, harmonic distortion that has arisen as a result of ripples. The faulty buses after the load flow results which has to be normalized by genetic optimization and inject in an appropriate direct generator (DG) are buses 9, 11, 12 and 13 that have voltage profile of 1.051p.u,1.082p.u, 1.057 p.u. and 1.071 p.u. as shown in figures 3.2.5 and 3.2.6.

3.4.3 Shunt capacitor

From the point of view of power flow, the addition of a shunt capacitor bank to a load bus corresponds to the addition of a negative reactive load. The additional load is modelled with the susceptance. Given a required reactive power injection of Q_{cal}, the susceptance B can be calculated from $Q = V^2B$. V is the voltage of the bus where the shunt capacitor needs to be installed. A first run of power flow has been performed so that the required reactive power has been calculated. As a result, the susceptance is obtained and discretized.

3.4.4 Optimization

The faulty four buses are 9,11, 12 and 13 that fall above the normal voltage ranges of 0.95 through 1.05 for stable power supply were genetically optimized to erase or minimize power losses, over current, over voltage, short circuit to mention a few that were found in these buses.

The optimization technique used in this thesis has been Genetic Algorithm (GA). This algorithm is easy to implement, computationally simple and always producing high quality solutions. Called initial population, the starting point of GA is a set of potential solutions obtained randomly in a search space and represented in a suitable coding. Each solution is an individual which represents analogously to a chromosome. Composed of genes, chromosomes in GA consist of a string of genes, each represented by binary values of 0's and 1's.

GA are applied to maximize or minimize a certain objective function, J_{obj}, so that given a specific J_{obj}, each individual i undergoes through the evaluation of its fitness, J_i considered as a measure of the performance of each individual.

Once the fitness has been assigned to each individual, three basic operators are applied to the population, including selection, crossover and mutation.

Selection is the operator responsible for determining convergence and premature convergence to a load optimum can be avoided applying a suitable selection method. To select individuals that will be allowed to reproduce, based on their fitness evaluation, several methods are available to be employed. These are tournament selection, fitness proportionate selection, roulette wheel selection, scaling selection, ranking selection and elitist selection.

After the selection step, two individuals are chosen to reproduce, so that crossover and mutation are applied to generate a new offspring. It is at this point that low performers are eliminated and therefore the improvement arises as a consequence.
Considering a crossover with a crossing site, a cross position k, is selected at random in the interval [1, l-1], being l the individual's string length as depicted in Figure 3.3

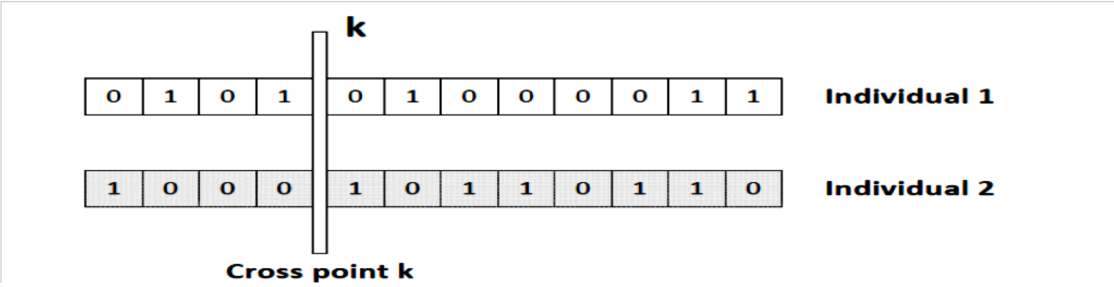

Fig.4. Representation of two individuals and the cross position k.

Two new strings are therefore created by swapping all characters between $k+1$and l as shown in Figure 3.3.2.

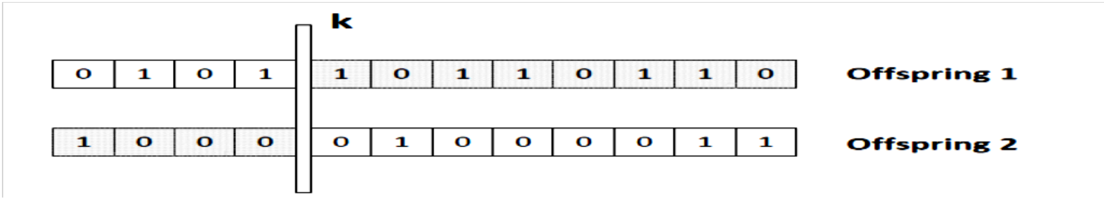

Fig.5. Representation of two individuals after mating the progenitors.

From the first position of crossover to the second one, elements of the strings of both parents are exchanged. Finally, to guarantee genetic diversity, the mutation operator is applied with a probability, p_{mut}, to each individual of the currentoffspring. Best probability value varies depending on the case. Any of the genes of the individuals can be mutated and for binary genes, this is obtained changing 0 to 1 or a 1 to 0, represented in Figure 3.5.

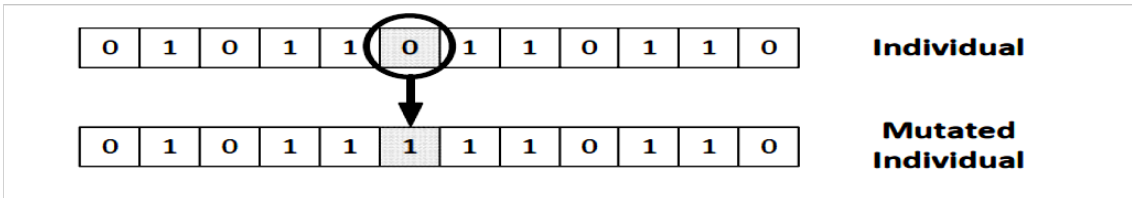

Fig.6. Representation of the mutation of a gene in an individual

As a result of applying the three operators, a new population is created. Both the initial population and the new generation are evaluated in order to find best individual, so that if progenitor fitness function value is more suitable than the offspring value, individual from the initial population replaces the individual from the first generation. After the first generation is completed, the obtained population undergoes the same steps as the previous one: evaluation, selection and mutation. The stop criterion can be a maximum generation or a certain value of the objective function evaluation.
A general procedure for the implementation of Genetic Algorithm is depicted in Figure 2.15.

A. Objective functions
The basic objective of reactive power and voltage control is to identify the optimal values of reactive power control variables which minimize the objective function.
In this approach the following objectives are considered.
i) **Minimization of system power losses**: The objective is to minimize the total real power losses in the system. This can be calculated as follows:

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

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

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

ii) 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:

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

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

iii) Inequality Constraints

Transformer constraints

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

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

Switchable var constraints

$$Q_{Ck_{\boldsymbol{min}}} \le Q_{C_k} \le Q_{Ck_{max}} \quad (3.15)$$

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

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

In this Section the different study cases are presented.

3.5.1 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 operationsare the results.

3.5.2 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.

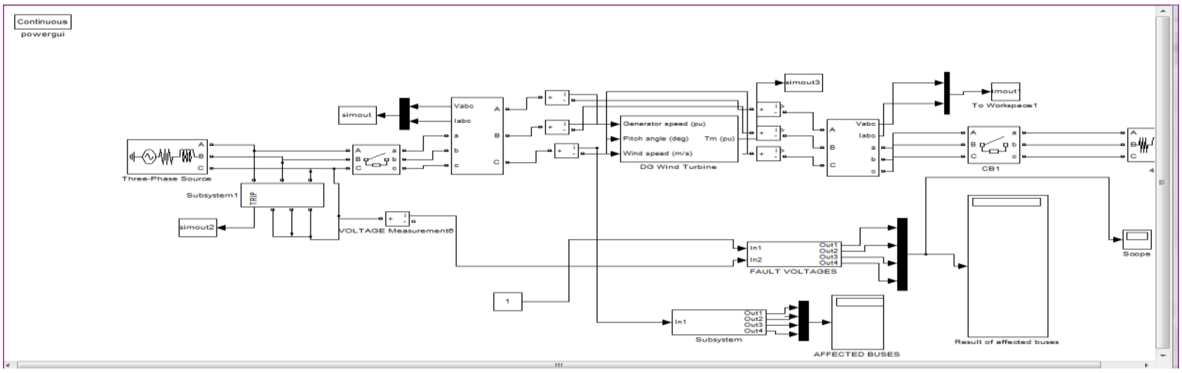

Fig.7. Model for the integration of the DG to the network using genetic algorithm (GA) technology

3.5.3 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.

3.5.4 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.

3.5.5 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.

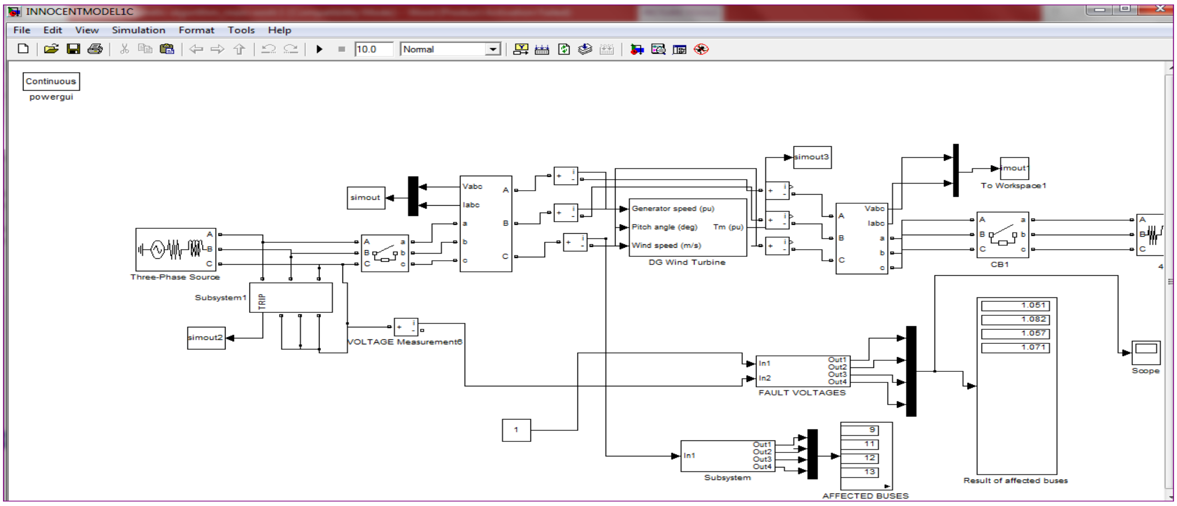

Fig.8. Simulated result when DG is added to the network

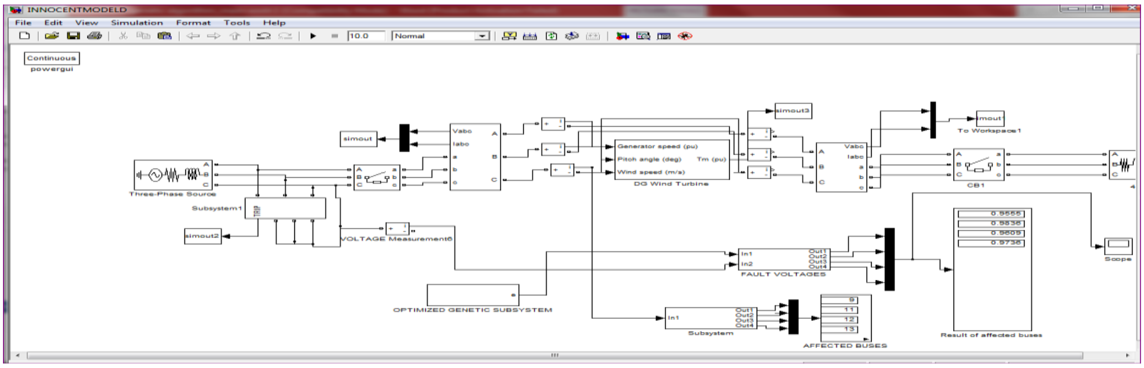

Fig.9. Simulated result when DG is added to the network optimized genetic algorithm technology

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

IV. RESULTS AND DISCUSSION

Fig.1.shows the Single line diagram of the distribution network; Fig.2 is the Evaluation of the voltage profile of the network without a distribution generation, Fig.3.is the Power flow result of evaluation of the voltage profile of the network without a distribution generation, Fig.4.is the 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 Fig.5. Fig.5 is the Representation of two individuals after mating the progenitors, while Fig.6 is a Representation of the mutation of a gene in an individual, Fig.7 displays the Model for the integration of the DG to the network using genetic algorithm (GA) technology.

Fig.8 is the simulated result when Distributed Generators are added to the network; Fig.9 Simulated result when DG is added to the network with optimized genetic algorithm technology.

Fig.9 shows the corrected fault buses voltage result. The comprehensive analysis is shown in Fig.10 where all the four faulty buses are compared for validation. Fig .10 is a Comparison of the Four Faulty Busses in the load flow,

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

Fig.11 shows that the power is stable since it has been corrected. Therefore high quality power supply is distributed to the consumers with minimal load loss. Fig.12.shows the 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.

In case 0 a simple power flow analysis has been performed. Both Shunt Capacitors and Distributed Generation are not considered in this study case. Therefore, in this case the whole active and reactive power generation comes from the substation.

Fig. 12 shows faulty buses that did not fall within the Minimum voltage magnitude; in bus 30, load flow shown in Fig.3 .

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

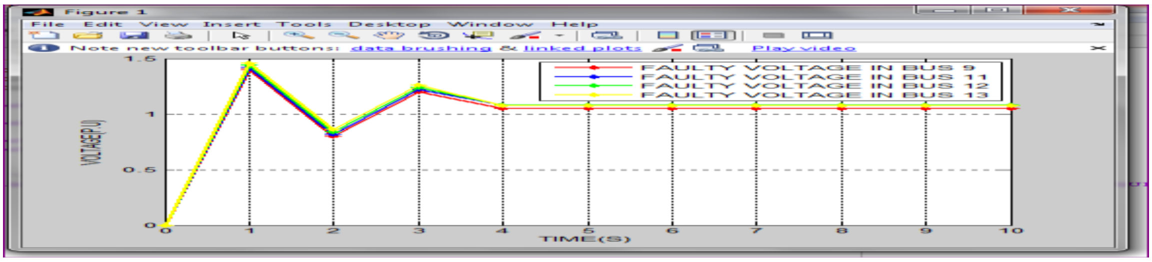

Fig .10. Comparison of Four Faulty Busses in the load flow

Fig.10 shows the analysis of the four faulty buses in the load flow. The faulty buses are buses 9, 11, 12 and 13 as shown in Fig.2 and Fig.3 having abnormal voltages. This abnormal voltages observed in these buses causes, low power factor, over current and power losses thereby resulting in constant power system instability. This of cause lead to poor quality power supply to the consumers.

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

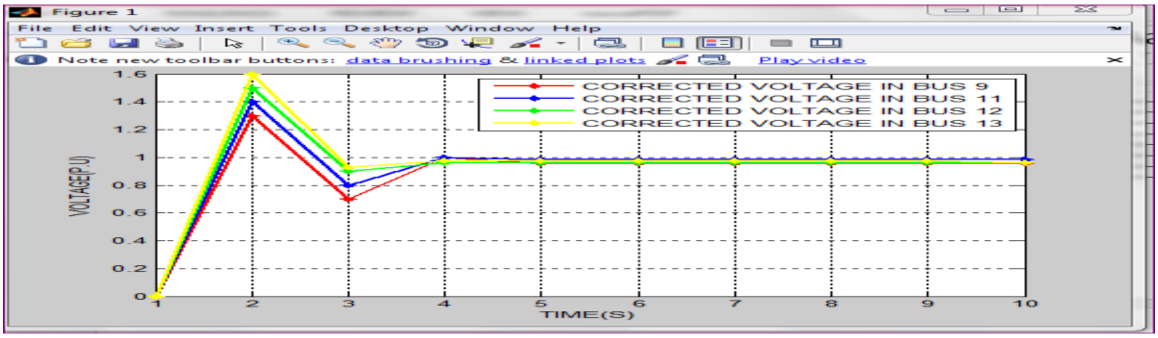

Fig.11 Corrected Voltage buses when a model of distributed generation was integrated in the distribution network.

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

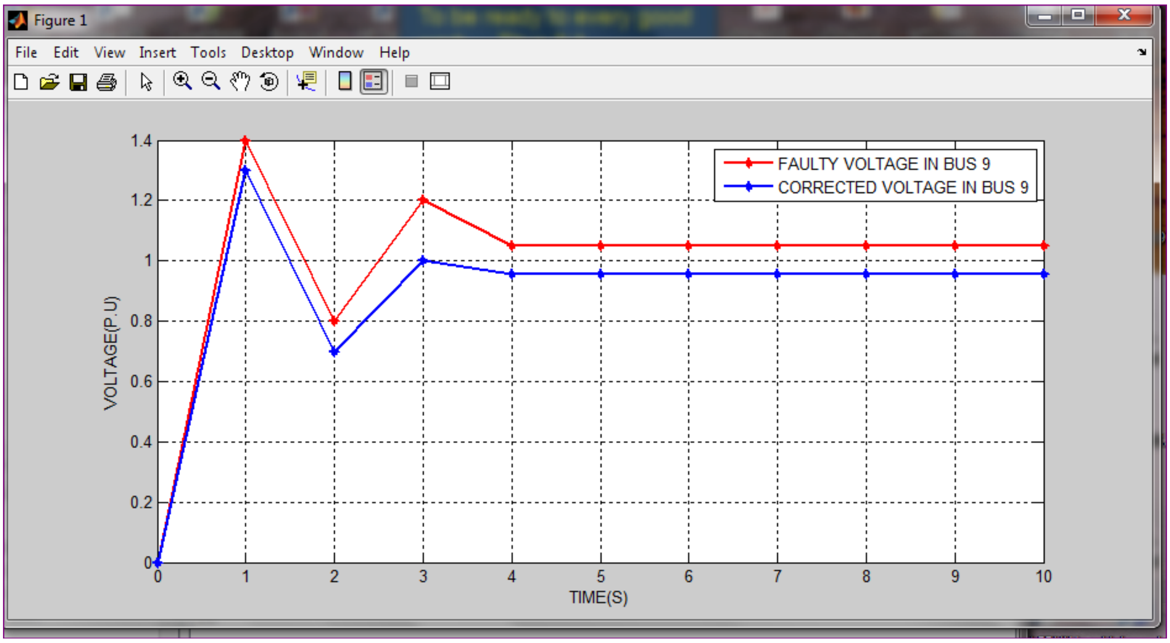

Fig.12. Result of the impact of the DG on the developed model

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

This paper thesis deals with the genetic algorithmic integration of renewable energy generation on the distribution network and how it affects the operation of the voltage regulation and reactive power distribution network.

The integration of distributed generation into the power systems has been analysed.

In order to model a generation based on renewable energy, firstly energy sources have been studied; secondly, the technologies have been revised and finally the integration of distributed generation into the grid it has been carried out.

Voltage drop up to the distribution network is one of the most important concerns in power systems, therefore, voltage regulation and the reactive power control has an important role to play in power system stability. Consequently, an analysis of voltage regulating devices and power reactive control equipment has been done.

Power flow analysis has been programmed, by formulating main equations of electrical circuits in MATLAB enabling the study test system to be modelled.

When modeling the power system mathematically, there are some issues that have to be taken into account. Issues such as control requirements and energy efficiency provide the basis for optimization problems. Solving optimization problems is achieved when there is an acceptable value for an objective function that is also subject to limitations.

In this study, a standard system has been modelled based on load flow analysis for different scenarios. Study has been carried out on the impact of distributed generation on the system.

Various optimisation algorithms has been implemented based on the principle of natural selection to solve issues such as the location, the level of generation or control of the power factor of the connected generators.

All mathematical formulations and optimization algorithms was performed using the MATLAB/Simulink program.

It is therefore obvious that the implementation of the optimisation technique has improved the energy efficiency of the distribution network.

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