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Analysis of 33/11KV RSU Injection Substation for Improved Performance with Distributed Generation (DG) Units

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ABSTRACT: *It is noted that substantial amount of power loss and low voltage profile is associated in power system network especially in the primary and secondary distribution system of power supply. Distribution networks are often time in a radial configuration having a very long distance of feeder line and several loads connected to it. Problems restraining distribution feeders' performance are poor power factor at load end, overloading of feeder transformers, inadequate sizing of conductors, inadequate power distribution from the grid, etc. In this research work: analysis of 33/11KV RSU Injection Substation for Improved performance using Distributed Generation (DG) Units to cushion the drawback related to power losses and low voltage profile. The analysis ensured that adequate placement of DG and optimum size is investigated and adopted, however, injection substation transformers' are also upgraded for adequate power flow without overloading the transformers. The approach utilized here is a load flow techniques where the distribution network under analysis is modeled in ETAP 7.0. It is a powerful graphical user interfaces power system simulation software capable of modeling and simulating power system network. The analysis is in four sections/ scenarios with results: load flow results from the base-case and formation of priority list for power loss and voltage profile without DG; integration of DGs at each bus and formation of priority list for power loss and voltage profile; comparison of the priority list and placement of DG at the appropriate location and optimal sizing of the DGs. From the results obtained for total branch power losses: the base-case without DG is 2824KW, 3575.3KVar; With DG at each bus is 4265.2KW, 5412.7KVar; With DG at optimal location recorded 195.8kW, 240.7KVar. The least bus terminal voltage recorded for the various scenarios base-case was 4.676KV; DG at each bus is 11KV while DGs at the optimal location recorded 10.8 KV. There was power loss minimization from 2824KW to 195KW and a voltage improvement from 4.676KV to 10.8KV.*

Keywords*: Distribution feeder, Distributed Generation, Load Flow Techniques, Optimal sizing and allocation, Power loss reduction, Voltage profile improvement.*

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I. INTRODUCTION

The distribution of bulk electricity from upstream to downstream and to the consumers is not an easy task; the daily needs of electrical energy in (MWh or KWh) by the power consuming equipment and devices from the industries, essential services, commercial services, residential homes, etc., and its configuration makes it more complex in nature. Consequently, powers being generated do not match power demanded and at such the primary and secondary distribution sections are suffering due to inadequate power supply leading to low voltage margin, load shedding syndrome at the sub-transmission sections (132KV), poor energy management systems, power rationing at the secondary distribution sections (11KV), political interest, the incessant action of vandalism, etc., are factors that mitigate against constant power supply.

In investigating the power generating stations in Nigeria, according to (Sule, 2010), there are two basic power generating stations such as Hydropower generating stations (located at Kainji, Shiroro, Jabba, etc.) and Thermal-power generating stations that uses fossil fuels such as natural gas, crude oil, coal, uranium, etc.,(in their numbers in Nigeria). These bulk electricity generation stations utilize three basic 'prime-mover-to-generator techniques' (conventional techniques) of electricity generation namely hydropower systems, Steam turbine power systems and Gas turbine power systems. Steam and Gas turbines are a function of fossil fuels. It is noted that hydropower stations constitute only 21.42%, gas turbine power stations are 64.29% and Steam power stations score 14.29% of the bulk power stations. The amount of power generated does not commensurate to the demand, hence, there is frequent power outage either forced or planned; since the national grid network is over stressed. The electricity generating stations in Nigeria are interconnected in radial configuration with a single National Control Centre (NCC) in Oshogbo. Currently, the Nigerian National grid score low-reliability index in power system analysis [1].

Note that, the application of renewable energy sources such as solar (sunlight) and the wind power are in their primary stages in Nigeria, therefore, generation, transmission and distribution of bulk electric power supply into the grid from renewable power generation had not being noticed. Few middle-class and high-class personality and some industries provide and install some considerable size of solar power generating system (using the photovoltaic array) to harness electrical energy from the sunlight. The harnessed energy from the sunlight is inverted into alternating current (AC) using inverter systems before use but not grid connected [1].

From the power loss point of view, according to Jignesh (2013), the difference between the power generated and distributed account for both technical and non-technical losses in power system network. The weakest connection is the distribution networks in the entire power sector. Transmission losses are estimated 17% while distribution network losses account for 50% approximately. Technical losses are normally 22.5%, and directly dependent on the network characteristics and the mode of operation [2].

The primary and secondary distribution networks suffer heavy amount of power losses; therefore, it must be properly planned to ensure that the losses are within limits. Most distribution networks are in radial configuration having very long distance of feeder line which may result in heavy I^2R losses on the line; also the distribution networks are prone to low voltage profiling, poor power factor at load end, overloading of feeder transformers, sudden faults, inadequate real and reactive power distribution from the grid to end users, etc. Distribution networks are the key link between generated powers and the end users [2].

The increasing nature of power systems infrastructures without corresponding upgrade and maintenance system some overhead conductors, mechanical supports, insulators, transformers, generators, switchboard systems, etc., are affected by ageing. There is need to upgrade the electrical infrastructures periodically to meet the demand for electrical power, safely as generated, transmitted and distributed. In terms of upgrading, we could install new infrastructure or revamp existing infrastructure. The new infrastructure may encompass the integration of new transmission lines, line compensators, transformers, distributed generation, protection systems and perhaps new injection substations. These new assets could be located nearness to the residential area, that is, at load's centers [3].In spite of the above-mentioned limitations of the distribution network and the urgent needs to restructure the distribution network safely with adequate power supply to avoid load rationing, poor voltage margin, etc., this research is geared to proffer solution to an existing feeder as a case study. In [4], it is mentioned that a successful operation of a power system depends largely on the capability to readily deliver safe, reliable, stable, clean and uninterrupted service distribution to the load's centers with almost constant voltage and frequency at all times [4].

1.1 The aim of this Research Work

The aim of this research work is to analyse the 33/11KV RSU injection Substation for improved performance with Distributed Generation (DG) units.

1.2 Objective of this Research Work

The objectives of this research work in regards to the aim are as follows:

i. *Optimally integrate distributed generation (DGs) unit(s) either micro, small or medium size into the 11kV secondary distribution network (feeders) at strategic location;*
ii. *Improve the active and reactive power flow of the distribution feeder (Case study: Wokoma feeder)*;
iii. *Improve the bus voltage margin of the distribution feeder*;
iv. *Possibly resize/upgrade overloaded grid connected transformers, etc.*

1.3 Structure of Power System Network in Nigeria

1.3.1 Generation sections

Usually, Alternating Current (AC) generation voltage in the world using either thermal or hydropower generating system is between 10.5-28kV with operating frequency of 50Hz or 60Hz [5][6]. Nigeria is within the range above. Generators rated terminal voltage are 10.5, 11, 11.5, and 16KV with operating frequency of 50Hz.

1.3.2 Transmission sections

- The Nigeria Power Grid Network (NPGN) voltage is 330KV, primary transmission.
- Sub-transmission Network (STN) voltage is 132KV, secondary transmission.

1.3.3 Distribution sections

- Primary Distribution Feeders (PDF) voltage is 33KV (primary distribution voltage) to various injection substations for further distribution in Nigeria.
- Secondary Distribution Feeders (SDF) voltage is 11KV to various consumers on point load and consumers down the street and roads through overhead lines and underground cables.

1.3.4 Tertiary Distribution sections

This section comprises of 11/0.415KV transformers that received power from the secondary distribution network on (11KV) and distribute power to consumers on the tertiary distribution network (4-wire network).

1.3.5 Load section

Here a service wire is used to connect from the 4-wire network to feed the load (domestically) on 415V - three-phase voltage (L-L), and 220V single-phase voltage (L-N).

II. LITERATURE ASSESSMENT

The incessant power failure and inadequate power supply from the central generation down to the consumers suffer a lot of sets back; researchers, technologist, etc., have resort to others means of remedying the setback. In literature different approaches has been implemented to provide an effective solution in regards to reliable power generation and delivery. Presently, the impact of distributed generation linked to the distribution networks is on course. Distributed generation units have several benefits such as stability, reliability, and economy; but it suffers some critical problems that may disturb these benefits as seen in [7].

On daily basis, different technologies and power system utilities are increasing to enhance the distribution of power and to maintain the voltage stability using distributed generation (DG) units; network reconfiguration; line compensators; etc., to relieve the grid power supply and of course to boost the power delivery at the distribution sections. What are these distributed generation that is currently integrated into the distribution networks? *Distributed generation (DG) can be seen as the utilization and operation of small or medium size integrated power generating technologies that can be pooled with energy management and storage systems. It is connected close to load centers and mainly on distribution network or feeders to boost power supply.*

According to (Rao & Obulesh, 2013), the introduction of Distributed Generation (DG) will effectively improve the active power and loss reduction. They represented a technique by which power losses can be minimized in a distribution feeder by optimizing distributed generation (DG) model in terms of size, location and operating point of DG. A typical Distributed Generation size is of the ranges from less than a kilowatt to few megawatts of Power Generation. FACTs devices provide passive element except for DG units placement that provides an active element to improve the power system network. Installation of DG units in a given power system network will rapidly improve the voltage profile twice or thrice that of passive injection of reactive power through capacitors bank to reduce power losses. In their work, a sensitivity analysis was carried out to minimize the power losses, optimal sizing of the DG and its operating point. They proposed that sensitivity indices can indicate the changes in power losses with respect to DG current injection. However, the proposed technique was developed considering load characteristics and representing a constant current model. The usefulness of the proposed method was tested and verified using MATLAB software on long radial distribution system [8].

According to (Guneet et al, 2012), the flexible alternating current transmission systems (FACTS) are the useful system that provides very important benefits in the fields of power transmission system. One of such system/device is the static VAR compensator (SVC) usually of power electronics for switching and control. In their research work, low-rated static VAR compensators were installed at the load ends on 33/11 kV distribution network. Software called Electrical Transient Analyzer Program (ETAP) was used to model and simulates the network using load flow analysis to investigate the performance of the network. Thereafter, Genetic Algorithm (GA) was used for the optimum location of the two SVCs. With the integration of SVCs in the distribution substation, the various bus voltages were enhanced and a drastic reduction in the branch power losses set in for adequate power flow in [9].

Again, *the effect of distributed generation on distribution systems* was mentioned in (Balamurugan et al, 2011). In their paper, they modelled and applied the IEEE 34 bus distribution system as the test feeder using a commercial software package called DIgSILENT power factory version 14. They noticed that optimum size and allocation of DG in the network changes the characteristics of the distribution network due to the penetration of the generating sources with a positive effect on the various parameters. They integrated solar photovoltaic generators at the various buses and observed the effects on the real and reactive power loss, fault level, voltage margin, etc., on the distribution system by varying the penetration ratio and as well changing the placement of DGs at various buses. Load flow and short circuit analysis were applied during the simulation and results achieved were presented in [10].

The researchers (Heydari et al, 2016), in their work, presented *distributed generation (DG) and capacitor banks installation*, a combined technique to reduce the active and reactive power loss, and to improve the voltage margin of the total distribution network. Different objectives may be pursuit in the integration of DGs units in the distribution systems. Sensitivity analysis was used to optimise the DGs placement directly on the candidate buses to reduce the search space and provide more effect on the voltage profile improvement. Plant growth simulation algorithm (PGSA) was used for the optimal sizing (magnitude) of the DGs while ETAP software was also used to optimally incorporate the capacitor banks into the network to enhance the voltage margins and reduce branch power losses. The results obtained on the 33-bus IEEE test network during assessment shows the effectiveness of the proposed technique [11].

In (Suyono & Hasanah, 2016), the impact of power losses and the penetration level in the application of distributed generation on a distribution system was investigated. It was aimed to examine the levels of power losses on the distribution network with different DGs penetration. A steady-state power flow analysis was applied to investigate the different voltage profile and power losses during the variation of the DGs penetration. The different DGs technologies applied are wind power turbine, photovoltaic power system and micro-hydro power plants. Four different cases were analyzed beginning from the original grid in the first case, followed by addition of photovoltaic plant, the second case using wind power plant, the third and fourth cases were the addition of micro-hydro power plant to the grid. From the analyzed results, the introduction of (case 4) micro-hydro power plant and its size indicates the best impact as compared to the three other cases. The micro-hydro power plant potential was greater than that of wind power plant and photovoltaic plant as they noted. The integration of renewable power plants in the study was their priority despite it was the least favourable but in general; it improves the voltage margins and reduces the power losses in the system [12].

According to (Sun et al, 2016), to optimise distribution network with a distributed generation more fully: the network loss, the DG investment, and reliability of power supply should be contained in the objective function. However, a new planning model for the distribution system, which not only contains capital investment but also considered the factor of a distribution system reliability to optimises distribution network by taking minimum equipment investment costs, system power losses, interruption costs and power purchasing costs as objective function [13].

In (Nibedita et al, 2012), optimum allocation of distributed generation units in a distribution system for voltage enhancement and loss reduction was carried out using a load flow based method. In their work, DG was stated as “a small-scale power generation unit connected directly to the distribution network or near customer load center”. The system may or may not be electric grid connected. DG is integrated into distribution network to minimize losses, improve the voltage profile and to provide reliable power flow. Optimum DG allocation provides a series of benefits. However, inadequate and improper allocation of DG can introduce over-voltage or low-voltage in the network. A load flow based method using Electrical Transient Analyzer Program (ETAP) software was used to fix the optimum position and rating of the DG in a 33-bus distribution network for voltage profile improvement and loss reduction [14].

According to (Afzalan & Taghikhani, 2012), optimal sizing and integration of DG in the distribution network is an optimisation problem with continuous and discrete variables. Afzalan & Taghikhani in their paper recommended a hybrid algorithm (PSO&HBMO) for optimal incorporation and sizing of distributed generation (DG) in a radial distribution system to improve the voltage profile and reduces the total power losses of the network. ‘A 13-bus radial distribution system was used as the test system; however, MATLAB software was used for the simulation and the results obtained indicate that (PSO&HBMO) technique can offer better results than the simple heuristic search technique and PSO algorithm’, they said. ‘The technique has the capacity to be a tool for identifying the best location and rating of a DG to be integrated for enhancing the voltage condition and line loss reduction in an electrical power network’[15].

III. MATERIALS AND METHODS

3.1. Description of the 33/11kV RSU injection Substation and the Test Feeder

The 33/11KV RSU injection substation is one of the injection substations linked from the Port Harcourt town (zone 4, sub-transmission network). The injection substation under analysis is located at the Rivers State University, Port-Harcourt Campus. It comprises of two 15MVA, 33/11KV transformers, four outgoing feeders from the indoor switchboard that provides power to four (4) major areas. The feeders are named according to the areas: Wokoma feeder, Federal feeder, Ojoto feeder and RSUST feeders. Among this active distribution feeder mentioned above ‘***Wokoma feeder’*** is the longest, having more load connection than other feeders. Table 1.1 shows the transformers connected to Wokoma feeder with a total transformer capacity of 20800kVA (i.e. 20.8MVA). This total capacity is equal to 70% of the installed 2 X 15MVA transformers (30MVA) at the injection substation. Federal feeder unit is estimated to have 6.1MVA; RSUST feeder is 4.3MVA, and Ojoto feeder is estimated to have 5.3MVA. If we add the entire load estimated under operation, we have 36.7 MVA plus 20% of the total estimated transformers capacity as losses. Hence, we expect a total transformer capacity of 44.04MVA minimum.

3.2 Materials Considerations

Base-case model of the feeder network; Cross section area of conductor = 182mm^2, ACSR/GZ. (Aluminium conductor steel reinforced with galvanised) Overhead Horizontal formation; Distribution Transformers Voltage rating (injection substation 33/11KV, and along the streets 11/0.415KV); Distributed Generation (DG) Units propose range is 2MW≤DG (MW) ≤50MW; using Electrical Transient Analyzer Program (ETAP) software for simulation, etc. [17].Table1.1 is the total transformers connected on Wokoma feeder and Table 1.2 is the input load data on Wokoma network/feeder [16].

3.3 Method Applied

The injection substation feeder (*Wokoma network*) under consideration is a large distribution network (See Figure 1.1) model using [17]. The purple coloured composite network is the (Wokoma network) with 74 buses. The methods of analysis applied here is a **Load Flow-Based Technique** using Newton-Raphson load flow techniques for the simulation in ETAP environment with the following *basic heuristic processes*: (a) model the feeder (network)configuration; (b) run load flow for the base-case; (c) readjust if any, for necessary error of transformer rating and tap setting for possible simulation;(d) identify the bus voltage margins, branch power flow and losses; (e) integrate sizable DGs into the feeder buses; (f) make priority lists for voltage margins and the power losses from the results obtained, etc.

The **Operational Algorithms** utilised for the placement and sizing of DG Units constitutes four sections/scenarios: examining the base-case load flow simulation results; examining and ranking of the voltage profile and power loss level without DGs; examining and ranking of the voltage profile and power loss with DG unit at each bus; and with sizable DG units at the optimal location. The procedural steps are:

First Section: Scenario I (Base-case)

1) Model the network, run the base -case load flow.
2) Record the sensitive buses to voltage (i.e. buses whose bus voltage limit are unacceptable); buses with low voltage in magnitude are considered and ranked **without** DG integration.
3) Plot graph of % voltage versus Bus Nos.
4) Plot graph of branch line power losses between buses or lines
5) Make a priority list for % voltage without DG unit and ranked from the minimum to maximum value.
6) Make a priority list for line power losses without DG unit and ranked from the minimum loss value to maximum loss value.

Second Section: Scenario II (Integration of DG at each Bus - Wokoma Feeder)

7) Placement of DGs at each bus (at least 2MW≤DG(MW)≤50MW)
8) Run load flow again
9) Plot graph of branch line power losses between buses **with** DGs integration
10) Make a priority list for % voltage with DGs unit and ranked from the minimum to maximum value.
11) Make a priority list for new line power losses with DGs unit placement and ranked from minimum to maximum value.

Third Section: Scenario III (Integration of DGs into the Feeder at the Optimal Searched Buses Only)

12) Compare step (5) and (10), and then make another list.
13) Compare step (6) and (11) to make another list.
14) Choose the best place(s) to integrate DG unit(s) using the last power loss priority list and voltage profile priority list accordingly then move on to scenario IV.

Fourth Section: Scenario IV (Optimal sizing and placement of DG Unit)

In consideration of the size/ ratings of DGs, placement for the power enhancement, we shall adopt this constraint $2MW \leq DG(MW) \leq 50MW$ to see the impacts on the distribution network heuristically.

15) Choose different sizes of DGs into the appropriate location, run load flow again, find at least the optimal size for minimum loss reduction and voltage profile improvement.
16) Plot graphs of relevant parameters as required, etc. and discuss.

Table 1.1: Transformers Connected on Wokoma Feeder (Active)

S/No.	No. of Transformer	Transformer Rating
1	1	700KVA
2	1	600KVA
3	29	500KVA
4	9	300KVA
5	8	200KVA
6	7	100KVA
	Total = 56	Total= 20,800KVA

Source: (PHEDC, 2014) Unpublished

IV. RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Results of Scenario I: Base-Case

Note that, all the results of various scenarios conducted may not be added here due to the limited number of pages for a journal paper. The feeder (Wokoma Network) under investigation is the lengthiest among the four feeders; consists of 21.1MVA loads and it is associated with undesirable low voltage profile. After applying the algorithms of scenario I, the results of the base-case voltage profile of the 74 Bus(from Bus9-Bus82) is shown in Table 1.3while Table 1.4shows the results of the base-case load flow *branch power losses* at the buses **without DG integration**. Also, Table 1.5 presents the base-case load flow results of the load power demanded, net load power received, and the voltage magnitude at each bus. Figures 1.2(a) and 1.2(b) are split of one graph/figure for *% voltage profile of the base-case load flow without DG integration*. Figures 1.3(a) and 1.3(b) are also a one-split graphs of branch power losses (in KW) without integration of DG unit(s).Figure 1.4 is one of the pages of the simulation results (screenshot) of the base-case load flow (from Bus 10 – Bus 36) without DG integration, indicating all bus voltages in the critical state (i.e., buses in red colours presentation are undesirable voltage limit).According to IEE standard, the voltage drop at the consumer terminal end should not be more than 5% of the normal sending end voltage. The acceptable voltage limit for the11KV network should be between 10.5KV – 11.5KV.

4.1.2 Results of Scenario II: Integration of DG at each Bus (Wokoma Feeder)

Table 1.6is the results of **branch power losses** due to the integration of distributed generation (DGs) at each bus to actually identify the candidates' buses for optimal placement. We noticed that the total losses increased as compared to the base-case scenario from (2824KW + j3575.3KVar) to (4265.2KW + j5412.7KVar). It was also observed that there were no injections of active power into the network rather more reactive power was injected during the simulation. In this scenario, DG placement was not optimised. Figure 1.5 (a) and Figure 1.5(b) are split one graph. From the branch power loss recorded ranking is done by considering the least or minimum power losses first as rank 1, second least as rank 2 and vice versa. The most sensitive buses indicated by the integration of Distributed Generation (DG) at each bus falls within rank1 and rank 2 as seen.

4.1.3 Results of Scenario III& IV: Integration of DGs into the Feeder at the Optimal Buses (Only)

From the ranking algorithm stated above the sensitive buses are in rank 1 with (Bus15, Bus 18, Bus 19, Bus34, Bus 36, Bus 42, Bus 56, Bus 61, Bus 63, Bus 78 and Bus 81). Of course, installing DG into these 11 buses found may not be economical, therefore, during integration, % Voltages, and power losses are again compared after the load flow simulation. Thus, four (4) optimal locations were found: **Bus 8 or 15, Bus 34, Bus56, and Bus78**. Note, due to the capacity of the loads and power losses associated with the entire power system network, transformer T1B (30MVA) at Amadi junction receiving power from grid supply was upgraded to 60MVA (See Figure 1.1 below).

To effectively distribute power and reduce the stress on the power grid, DG allotted to Bus 15 is move to **Bus 8** with an installed capacity of 26MW and distributing power at 18MW. Hence, **Bus 8, Bus 34, Bus 56, and Bus 78** are incorporated with DGs.Table1.7 shows the improved voltage profile at each bus after optimal integration of DG and the minimum bus voltage recorded was 98.191 % of the nominal voltage while the maximum is 100% of the nominal voltage. Figure 1.6(a) and (b) are a one-split graphs of the improved %voltage profile with the optimal integration of DG units (Bus 9 - Bus 82). Also, Figure 1.7 (a) and (b) shows the net power received ***without*** DG versus ***with*** DG integration (Bus 9-Bus 82).

Table 1.8 presents the results of the improved load power demanded, the net load received and the bus voltage magnitude of the feeder. Table 1.9 is the summary results of the branch power losses. Having applied the fourth section/scenario IV with the constraint adopted, the various DG sizes and transformers proposed are given in Table 1.10, the recommended distributed generators to improved RSU 33/11KV Injection substation.

4.2 Discussions

From the results of Scenario I (Base-case load flow), it was seen that all the load buses and nodes connected on Wokoma feeder have extreme low voltage (i.e. the steady state voltage at each bus is undesirable). The minimum percentage bus voltage recorded was 42.51% at bus 82 (Ojukaye Amachree street by Eliopranwo Road) while at bus 9 (RSU injection substation switchboard) recorded 73.76% of the nominal voltage (11KV). All the buses were sensitive to voltage violation. On simulation, ETAP indicates marginal alert for 95% and critical alert for 105% of the nominal voltage. The branch power losses recorded from Bus 9 through Bus 82 under simulation was (2824KW +j3575.3KVar). See Table 1.3, Table 1.4 and Table 1.5 below, the results of the base-case simulation without DG.

The bus voltage profile from Scenario II with DGs connected at each bus indicates 100% of the bus voltage (i.e. 11KV) while the total sum of power loss from bus 10 through bus 82 indicates (4265.2KW +j5412.7KVar). There was no real power injected into the feeder rather more reactive power was injected as observed during the simulation. Thus, there was an increase in the power loss by 51.03% of the base-case power loss. Table 1.6 indicates the results of branch power losses and Figure 1.5(a) and (b) shows the graphical relationship between the losses in kW and bus no due to DG integration at each bus. Some bus terminal indicates zero power loss been sensitive. Note that, it is uneconomical and unfeasible to incorporate DGs in all buses; it will cause a negative impact on the system.

Examining the voltage profile of the feeder due to Scenario III & IV with the integration of DG at the optimal buses selected (Bus 8 or Bus 15, Bus 34, Bus 56 and Bus 78). On Table 1.7 the minimum bus voltage recorded is 98.191 % of the nominal voltage while the maximum voltage is 100% of the nominal voltage and the % voltage drop is acceptable. On Table 1.8 the net load power received is almost equal to the load power demanded. Figure 1.6(a) and (b) is single column chart that indicates the improved voltage profile with the optimal integration of DG units. Note the column chart is split into two due to space. Figure 1.7 (a) and (b) is a single figure showing the net load power received (blue coloured) without DG versus net load power received (red coloured) with DG integration. Figure 1.8 shows the simulation result (screenshot) of the improved Wokoma Feeder showing (Bus 10-Bus 36) with DG integration. Table 1.9 is the summary results of the branch power losses with a total reduction of 93.07% of the base-case branch power losses from **(2824kW+j3575.3kVar)** to **(195.8kW+ j240.7kVar).**

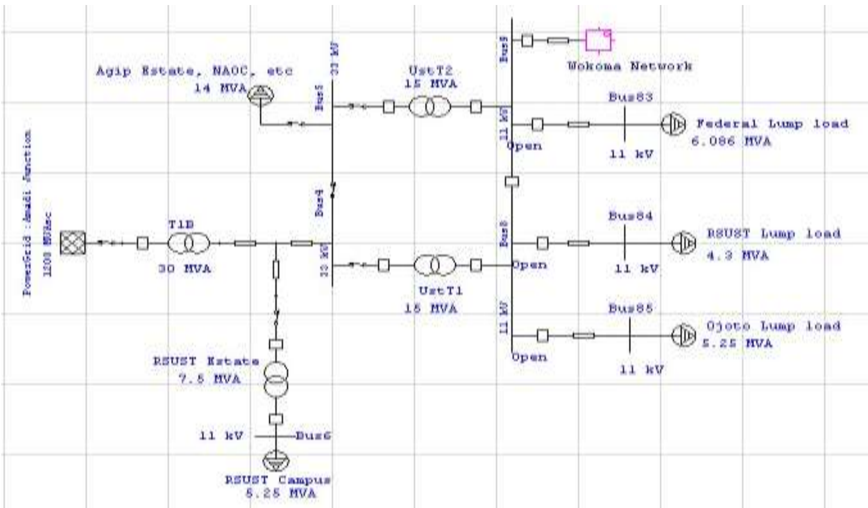

Figure 1.1: The Base-case Network Diagram of the RSU 33/11kV Injection Substation without DG Integration

Table 1.2: Input Load Data for Wokoma Feeder

Load Parameters		*Line Parameter*			*Load Parameters*		*Line Parameter*		
Bus No.	***Transformer Connected (kVA)***	***From***	***To***	***Length (m)***	***Bus No.***	***Transformer Connected (kVA)***	***From***	***To***	***Length (m)***
Bus9	-	Bus9	Bus10	350	Bus10	500	Bus10	Bus11	100
Bus 11	100	Bus11	Bus12	150	Bus12	-	Bus12	Bus13	150
Bus13	500	Bus12	Bus14	400	Bus14	-	Bus14	Bus15	250
Bus15	300	Bus14	Bus16	150	Bus16	200	Bus16	Bus17	250
Bus17	-	Bus17	Bus18	200	Bus18	200	Bus17	Bus19	100
Bus19	300	Bus16	Bus20	300	Bus20	500	Bus20	Bus21	100
Bus21	100	Bus21	Bus22	100	Bus22	100	Bus22	Bus23	50
Bus23	500	Bus23	Bus24	900	Bus24	500	Bus22	Bus25	150
Bus25	500	Bus25	Bus26	100	Bus26	700	Bus25	Bus27	150
Bus27	500	Bus27	Bus28	50	Bus28	300	Bus28	Bus29	50
Bus29	-	Bus29	Bus30	350	Bus30	300	Bus29	Bus31	150
Bus31	200	Bus31	Bus32	100	Bus32	300 & 500	Bus32	Bus33	1000
Bus33	-	Bus33	Bus34	350	Bus34	200	Bus33	Bus35	150
Bus35	-	Bus35	Bus36	750	Bus36	100	Bus35	Bus37	200
Bus37	500	Bus37	Bus38	350	Bus38	300	Bus37	Bus39	650
Bus39	-	Bus39	Bus40	200	Bus40	500	Bus39	Bus41	50
Bus41	-	Bus41	Bus42	350	Bus42	100	Bus41	Bus43	100
Bus43	500	Bus43	Bus44	350	Bus44	-	Bus44	Bus45	300

Bus45	500	Bus44	Bus46	350	Bus46	500	Bus46	Bus47	50
Bus47	-	Bus47	Bus48	200	Bus48	500	Bus48	Bus49	350
Bus49	500	Bus49	Bus50	400	Bus50	200	Bus50	Bus51	50
Bus51	-	Bus51	Bus52	250	Bus52	500	Bus51	Bus53	600
Bus53	600	Bus47	Bus54	100	Bus54	300	Bus54	Bus55	300
Bus55	-	Bus55	Bus56	200	Bus56	200	Bus55	Bus57	50
Bus57	500	Bus57	Bus58	400	Bus58	300	Bus58	Bus59	150
Bus59	100	Bus59	Bus60	100	Bus60	-	Bus60	Bus61	250
Bus61	200	Bus60	Bus62	250	Bus62	-	Bus62	Bus63	250
Bus63	200	Bus62	Bus64	50	Bus64	500	Bus64	Bus65	200
Bus65	100	Bus65	Bus66	150	Bus66	-	Bus66	Bus67	300
Bus67	500	Bus67	Bus68	450	Bus68	500	Bus66	Bus70	250
Bus69	300	Bus70	Bus71	500	Bus70	500	Bus66	Bus69	250
Bus71	500	Bus69	Bus72	250	Bus72	-	Bus72	Bus73	250
Bus73	500	Bus73	Bus74	200	Bus74	500	Bus72	Bus75	200
Bus75	500	Bus75	Bus76	450	Bus76	-	Bus76	Bus77	450
Bus77	500	Bus76	Bus78	50	Bus78	500	Bus 76	Bus79	400
Bus79	500	Bus79	Bus80	350	Bus80	-	Bus80	Bus81	300
Bus81	100	Bus80	Bus82	200	Bus82	500	18.95km ≈ **19km**		

Table 1.3: Results of Base-Case Load Flow **Voltage Profile** at each Bus (**without** DG integration)

Base-case load flow Voltage profile at each Bus (From Scenario I)								
Bus No.	***% Voltage***	***Angle (Deg.)***	***Bus No.***	***% Voltage***	***Angle (Deg.)***	***Bus No.***	***% Voltage***	***Angle (Deg.)***
Bus9	**73.76**	-9.9	Bus10	71.41	-10.27	Bus11	70.76	-10.38
Bus12	69.78	-10.54	Bus13	69.76	-10.55	Bus14	67.24	-10.98
Bus15	67.22	-10.99	Bus16	66.3	-11.16	Bus17	66.26	-11.16
Bus18	66.25	-11.17	Bus19	66.25	-11.17	Bus20	64.48	-11.5
Bus21	63.89	-11.61	Bus22	63.31	-11.73	Bus23	63.29	-11.73
Bus24	63.15	-11.77	Bus25	62.48	-11.9	Bus26	62.46	-11.9
Bus27	61.71	-12.05	Bus28	61.46	-12.1	Bus29	61.21	-12.15
Bus30	61.18	-12.16	Bus31	60.49	-12.3	Bus32	60.02	-12.4
Bus33	55.54	-13.42	Bus34	55.52	-13.43	Bus35	54.88	-13.59
Bus36	54.85	-13.6	Bus37	54.01	-13.81	Bus38	53.98	-13.82
Bus39	51.33	-14.53	Bus40	51.18	-14.54	Bus41	51.14	-14.58
Bus42	51.12	-14.59	Bus43	50.74	-14.69	Bus44	49.43	-15.06
Bus45	49.39	-15.08	Bus46	48.17	-15.44	Bus47	48	-15.49
Bus48	47.86	-15.54	Bus49	47.66	-15.6	Bus50	47.5	-15.65
Bus51	47.49	-15.66	Bus52	47.45	-15.67	Bus53	47.37	-15.67
Bus54	47.73	-15.58	Bus55	46.94	-15.82	Bus56	46.93	-15.83
Bus57	46.82	-15.87	Bus58	45.86	-16.18	Bus59	45.51	-16.3
Bus60	45.29	-16.38	Bus61	45.27	-16.38	Bus62	44.74	-16.57
Bus63	44.72	-16.57	Bus64	44.63	-16.61	Bus65	44.23	-16.75
Bus66	43.94	-16.85	Bus67	43.85	-16.88	Bus68	43.78	-16.94
Bus69	43.61	-16.96	Bus70	43.86	-16.89	Bus71	43.79	-16.92
Bus72	43.3	-17.07	Bus73	43.22	-17.1	Bus74	43.18	-17.11
Bus75	43.11	-17.13	Bus76	42.77	-17.25	Bus77	42.7	-17.28
Bus78	42.76	-17.26	Bus79	42.61	-17.31	Bus80	42.54	-17.33
Bus81	42.53	-17.34	Bus82	**42.51**	-17.35			

Table 1.4: Results of Base-case Load Flow **Branch Power Loss** at the Buses (**without** DG integration)

Base-case Load Flow (Branch Power loss at the Buses)								
Bus No.	***kW***	***kVar***	***Bus No.***	***kW***	***kVar***	***Bus No.***	***kW***	***kVar***
Bus9	-	-	Bus10	304	386	Bus11	82.9	105.3
Bus12	123.3	156	Bus13	0.1	0	Bus14	314	398.8
Bus15	0	0	Bus16	114.4	145.4	Bus17	0.1	0.1
Bus18	0	0	Bus19	0	0	Bus20	213.8	271.6
Bus21	67.8	86.1	Bus22	67.1	85.2	Bus23	0.1	0.1
Bus24	0.4	0.4	Bus25	88.9	113	Bus26	0.1	0.1
Bus27	77.4	98.3	Bus28	24.3	30.8	Bus29	23.3	29.6
Bus30	0.1	0	Bus31	67.4	85.5	Bus32	43.7	55.5
Bus33	392.5	498.6	Bus34	0	0	Bus35	57.2	72.6
Bus36	0	0.1	Bus37	75	95.3	Bus38	0.1	0
Bus39	216.8	275.4	Bus40	0.1	0.1	Bus41	15.4	19.5
Bus42	0	0	Bus43	30.3	28.4	Bus44	97.8	124.2
Bus45	0.2	0.2	Bus46	89.3	113.5	Bus47	11.6	14.7
Bus48	2.0	2.5	Bus49	2.1	2.7	Bus50	1.3	1.6
Bus51	0.1	0.1	Bus52	0.1	0.1	Bus53	0.4	0.5

Bus54	14.6	18.5	Bus55	40.8	51.7	Bus56	0	0
Bus57	6.5	8.2	Bus58	45.7	58	Bus59	15.8	20.1
Bus60	10.3	13	Bus61	0	0	Bus62	24.2	30.8
Bus63	0	0	Bus64	4.6	5.8	Bus65	15.7	20
Bus66	11.4	14.5	Bus67	0.6	0.7	Bus68	0.2	0.2
Bus69	8.8	11.2	Bus70	0.5	0.6	Bus71	0.3	0.8
Bus72	7.6	9.6	Bus73	0.5	0.6	Bus74	0.1	0.1
Bus75	3.3	4.2	Bus76	5.1	6.4	Bus77	0.2	0.3
Bus78	0	0	Bus79	1.3	1.6	Bus80	0.3	0.4
Bus81	0	0	Bus82	0.1	0.1			
Total Power Loss: **2824kW, 3575.3kVar**								

Table 1.5: Result of Base-case Load Flow (Power Demanded, Net Power Received, and Voltage Magnitude at each Bus)

Results of Base-case Load Flow (Power Demanded, Net Power Received at each Bus) without DG (From Scenario I)													
	Load Power Demanded		***Net Load Power Received***		***Bus Voltage***	***Bus Voltage***		***Load Power Demanded***		***Net Load Power Received***		***Bus Voltage***	***Bus Voltage***
Bus No.	***P_D (kW)***	***Q_D (kVar)***	***P_L (kW)***	***Q_L (kVar)***	***V (p.u)***	***V (mag.) kV***	***Bus No.***	***P_D (kW)***	***Q_D (kVar)***	***P_L (kW)***	***Q_L (kVar)***	***V (p.u)***	***V(mag.) kV***
Bus 9	0	0	0	0	0.7376	**8.114**	Bus10	400	300	263	197	0.7141	**7.855**
Bus11	80	60	52	39	0.7076	**7.784**	Bus12	0	0	0	0	0.6978	**7.676**
Bus13	400	300	270	167	0.6976	**7.674**	Bus14	0	0	0	0	0.6724	**7.396**
Bus15	240	180	148	111	0.6722	**7.394**	Bus16	160	120	102	76	0.6629	**7.293**
Bus17	0	0	0	0	0.6626	**7.289**	Bus18	160	120	94	71	0.6625	**7.288**
Bus19	240	180	146	109	0.6625	**7.288**	Bus20	400	300	236	177	0.6448	**7.093**
Bus21	80	60	50	37	0.6389	**7.028**	Bus22	80	60	51	32	0.6331	**6.964**
Bus23	400	300	256	192	0.6329	**6.962**	Bus24	400	300	244	183	0.6315	**6.947**
Bus25	400	300	241	181	0.6248	**6.873**	Bus26	560	420	328	246	0.6246	**6.87**
Bus27	400	300	239	179	0.6171	**6.788**	Bus28	240	180	143	107	0.6145	**6.761**
Bus29	0	0	0	0	0.6121	**6.733**	Bus30	240	180	142	107	0.6118	**6.729**
Bus31	160	120	94	71	0.6049	**6.654**	Bus32	640	480	368	275	0.6002	**6.602**
Bus33	0	0	0	0	0.5554	**6.109**	Bus34	160	120	88	66	0.5552	**6.107**
Bus35	0	0	0	0	0.5488	**6.037**	Bus36	80	60	46	35	0.5486	**6.034**
Bus37	400	300	226	140	0.5401	**5.941**	Bus38	240	180	129	80	0.5397	**5.937**
Bus39	0	0	0	0	0.5133	**5.646**	Bus40	400	300	221	137	0.513	**5.643**
Bus41	0	0	0	0	0.5114	**5.625**	Bus42	80	60	44	27	0.5112	**5.624**
Bus43	400	300	204	126	0.5074	**5.582**	Bus44	0	0	0	0	0.4943	**5.437**
Bus45	400	300	203	152	0.4937	**5.432**	Bus46	400	300	200	150	0.4817	**5.298**
Bus47	0	0	0	0	0.4799	**5.279**	Bus48	400	300	184	138	0.4785	**5.264**
Bus49	400	300	184	138	0.4766	**5.243**	Bus50	160	120	72	54	0.475	**5.225**
Bus51	0	0	0	0	0.4748	**5.223**	Bus52	400	300	182	137	0.4744	**5.219**
Bus53	480	360	219	165	0.4737	**5.211**	Bus54	240	180	110	83	0.4772	**5.251**
Bus55	0	0	0	0	0.4694	**5.164**	Bus56	160	120	72	55	0.4693	**5.162**
Bus57	400	300	182	136	0.4682	**5.149**	Bus58	240	180	107	80	0.4585	**5.044**
Bus59	80	60	36	27	0.4551	**5.006**	Bus60	0	0	0	0	0.4528	**4.981**
Bus61	160	120	71	53	0.4527	**4.979**	Bus62	0	0	0	0	0.4474	**4.921**
Bus63	160	120	70	53	0.4472	**4.919**	Bus64	400	300	187	116	0.4463	**4.909**
Bus65	80	60	36	23	0.4423	**4.866**	Bus66	0	0	0	0	0.4393	**4.833**
Bus67	400	300	171	128	0.4384	**4.823**	Bus68	400	300	170	128	0.4377	**4.815**
Bus69	240	180	104	78	0.4361	**4.797**	Bus70	400	300	185	114	0.4386	**4.825**
Bus71	400	300	185	114	0.4378	**4.816**	Bus72	0	0	0	0	0.4329	**4.763**
Bus73	400	300	172	129	0.4322	**4.754**	Bus74	400	300	175	132	0.4318	**4.751**
Bus75	400	300	175	131	0.4311	**4.742**	Bus76	0	0	0	0	0.4277	**4.705**
Bus77	400	300	174	131	0.4271	**4.697**	Bus78	400	300	204	153	0.4276	**4.704**
Bus79	400	300	204	153	0.4261	**4.688**	Bus80	0	0	0	0	0.4254	**4.679**
Bus81	80	60	37	28	0.4253	**4.678**	Bus82	400	300	187	140	0.4251	**4.676**
	P_{D1}	Q_{D1}	P_{L1}	Q_{L1}				P_{D2}	Q_{D2}	P_{L2}	Q_{L2}		
	8080	**6060**	**4149**	**2991**				**8640**	**6480**	**4534**	**3296**		
(P_{D1} + P_{D2}=16720kW, Q_{D1}+Q_{D2}=12540kVar)=**21MVA** - Load Power Demanded (P_{L1}+P_{L2} = 8683kW, Q_{L1}+Q_{L2} =6287kVar) =**10.720MVA –** Net Load power Received													

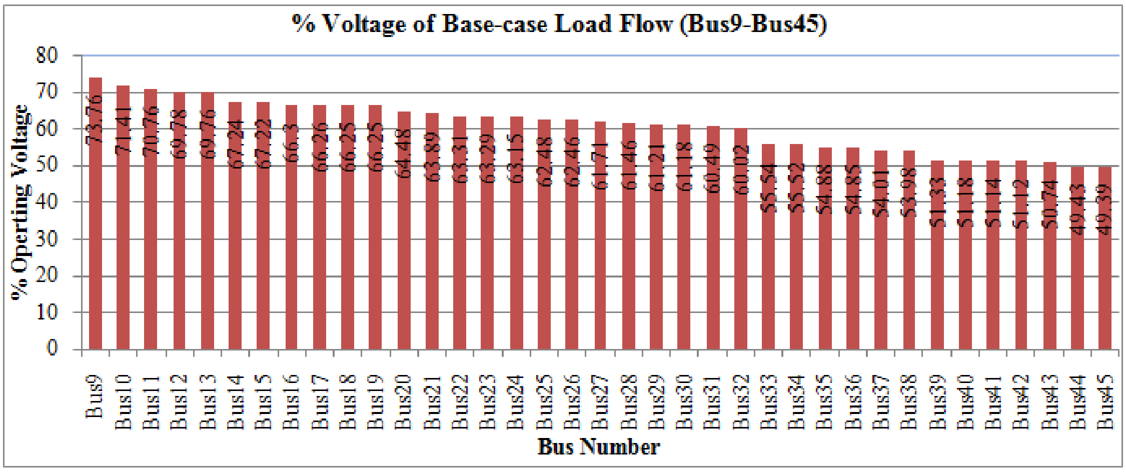

Figure 1.2(a): % Voltage Base-case Load Flow (Bus9-Bus45) **without** integration of DG units

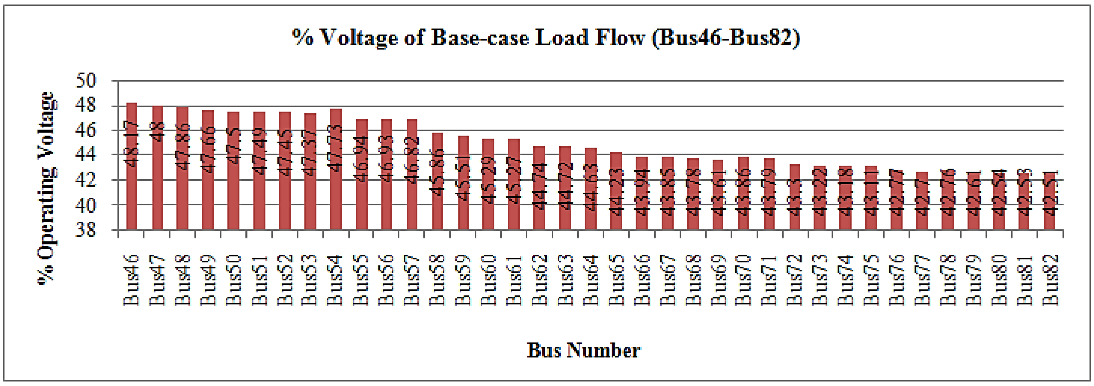

Figure 1.2(b): %Voltage of Base-case Load Flow (Bus46-Bus82) **without** integration of DG units

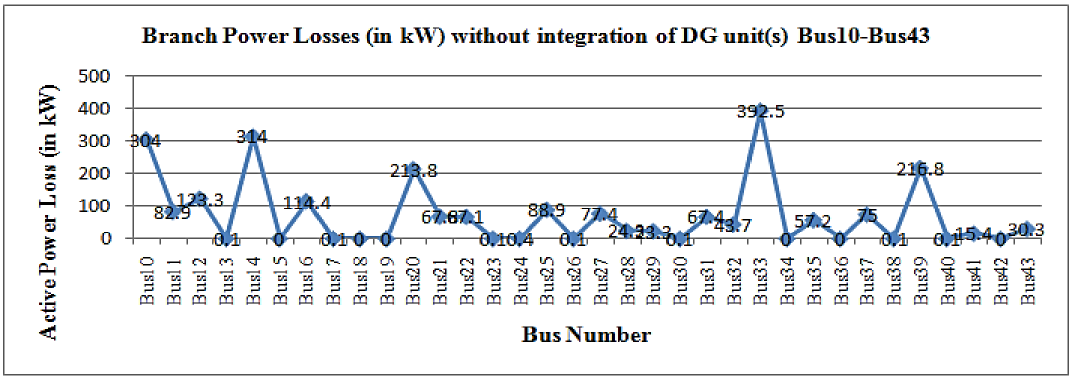

Figure 1.3(a): Branch Power Losses (in kW) **without** Integration of DG units (Bus10-Bus43)

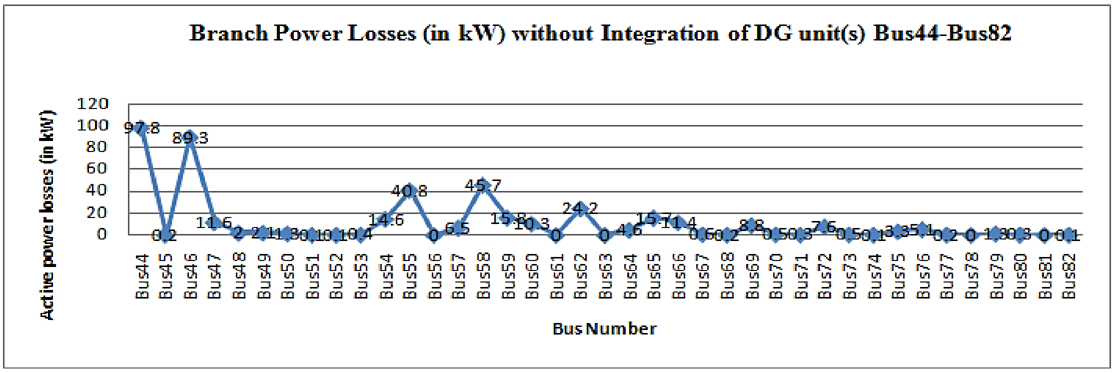

Figure 1.3(b): Branch Power Losses (in kW) **without** Integration of DG units (Bus44-Bus82)

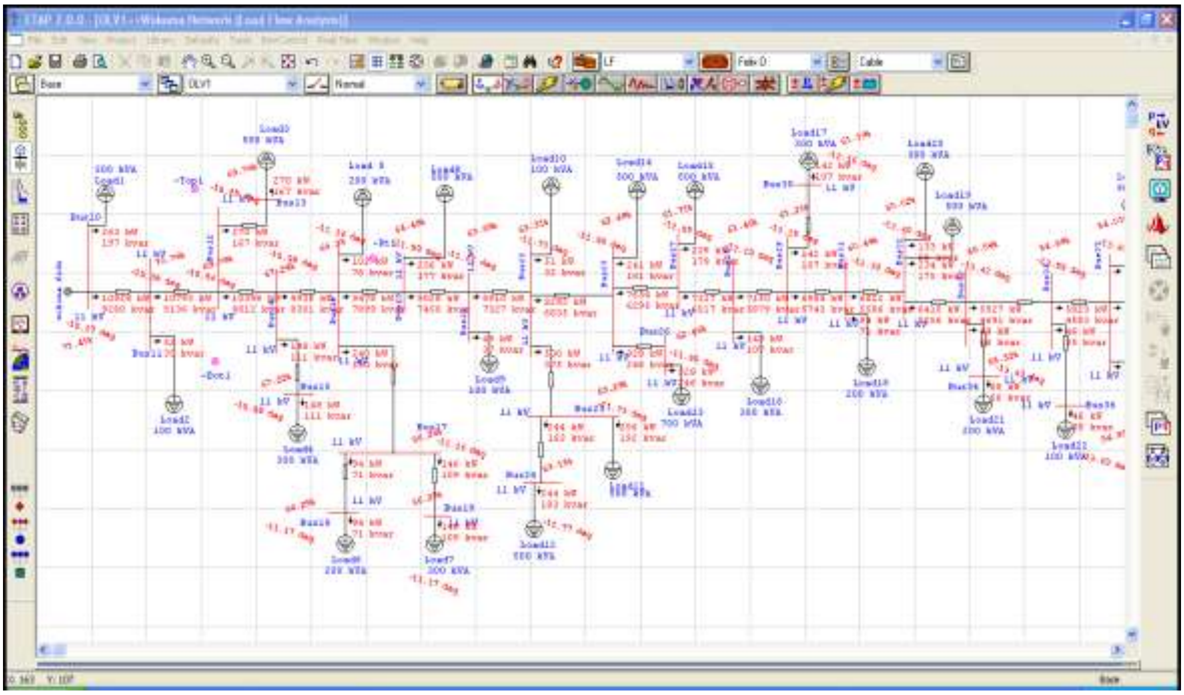

Figure 1.4: Simulation Result (Screenshot) of the Base-case Load Flow showing (Bus 10 –Bus 36) (**without** DG integration)

Table 1.6: Results of **Branch Power Losses** due to DG Integration at each Bus (From Scenario II)

Results of Scenario II (Branch Power loss at the Buses)											
Line ID	***Bus No.***	***kW***	***kVar***	***Line ID***	***Bus No.***	***kW***	***kVar***	***Line ID***	***Bus No.***	***kW***	***kVar***
Wok fedr	Bus10	865.6	1099.5	Line1	Bus11	201.4	255.9	Line2	Bus12	243.6	309.4
Line3	Bus13	0.7	0.9	Line4	Bus14	470.4	597.4	Line5	Bus15	0	0
Line6	Bus16	162	205.8	Line7	Bus17	0.1	0.1	Line8	Bus18	0	0.1
Line9	Bus19	0	0	Line10	Bus20	296.3	376.3	Line11	Bus21	92.1	116.9
Line12	Bus22	90.2	114.5	Line13	Bus23	0.1	0.1	Line14	Bus24	0.5	0.2
Line15	Bus25	119.5	151.8	Line16	Bus26	0.1	0.1	Line17	Bus27	103.5	131.5
Line18	Bus28	32.3	41	Line19	Bus29	31.1	39.4	Line20	Bus30	0.1	0.1
Line21	Bus31	89.1	113.1	Line22	Bus32	57.4	72.8	Line23	Bus33	496.5	630.3
Line24	Bus34	0	0.1	Line25	Bus35	69.1	87.7	Line26	Bus36	0	0.3
Line27	Bus37	89.7	113.8	Line28	Bus38	0.1	0.1	Line29	Bus39	252.2	320.1
Line30	Bus40	0.1	0	Line31	Bus41	17.5	22.2	Line32	Bus42	0	0.1
Line33	Bus43	34.3	43.5	Line34	Bus44	109.2	138.6	Line35	Bus45	0.2	0.1
Line36	Bus46	98.1	124.5	Line37	Bus47	12.7	16.1	Line38	Bus48	2.3	2.8
Line39	Bus54	15.7	19.9	Line40	Bus49	2.4	2.9	Line41	Bus50	1.4	1.7
Line42	Bus51	0.1	0.1	Line43	Bus52	0.1	0.1	Line44	Bus53	0.5	0.3
Line45	Bus55	43.4	55	Line46	Bus56	0	0.1	Line47	Bus57	6.8	8.7
Line48	Bus58	47.6	60.2	Line49	Bus59	16.2	20.6	Line50	Bus60	10.5	13.3
Line51	Bus61	0	0.1	Line52	Bus62	24.6	31.1	Line53	Bus63	0	0.1
Line54	Bus64	4.6	5.8	Line55	Bus65	15.7	19.8	Line56	Bus66	11.3	14.3
Line57	Bus67	0.6	0.7	Line58	Bus68	0.2	0.1	Line59	Bus69	7.8	9.7
Line60	Bus70	0.5	0.6	Line61	Bus71	0.3	0.1	Line62	Bus72	7.4	9.3
Line63	Bus75	2.9	3.6	Line64	Bus73	0.5	0.6	Line65	Bus74	0.1	0
Line66	Bus76	4.3	5.2	Line67	Bus78	0	0	Line68	Bus79	1	1.1
Line69	Bus77	0.2	0.1	Line70	Bus80	0.3	0.2	Line71	Bus82	0.1	0
Line72	Bus81	0	0.1								
	Total Power Loss: **4265.2kW,5412.7kVar**										

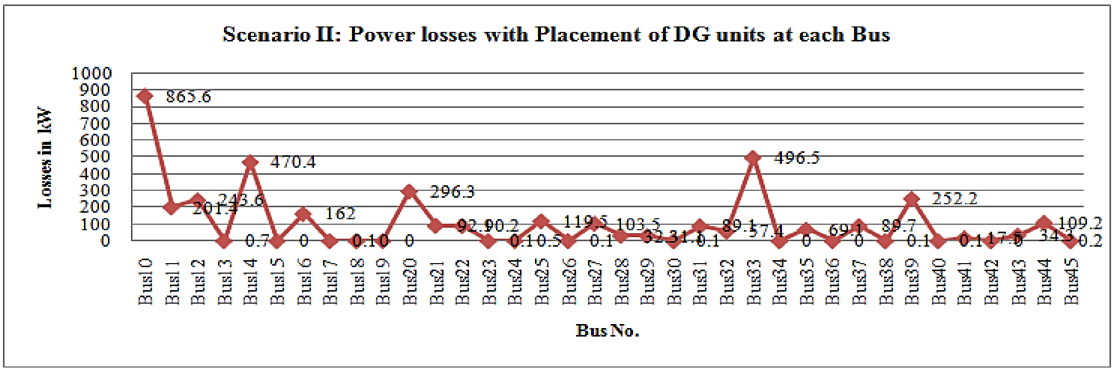

Figure 1.5(a): Branch Power Losses (in kW) **with** Integration of DG unit(s) at each Bus(Bus10-Bus45)

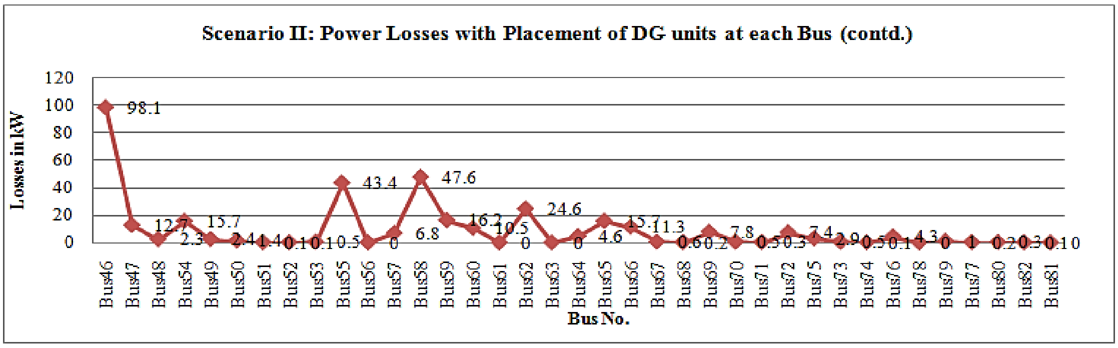

Figure 1.5(b): Branch Power Losses (in kW) **with** Integration of DG unit(s) at each Bus (Bus46-Bus82)

Table 1.7: Improved Voltage Profile **with** Integration of DG Units (from Scenario III & IV)

Results of Scenario III & IV (Improved Voltage Profile at each Bus after Optimal DG integration)											
Bus No.	***% Voltage***	***%Vd Drop***	***Bus No.***	***% Voltage***	***%Vd Drop***	***Bus No.***	***% Voltage***	***%Vd Drop***	***Bus No.***	***% Voltage***	***%Vd Drop***
Bus 9	**100**	0	Bus10	**99.517**	0.48	Bus11	**99.395**	0.12	Bus12	**99.217**	0.18
Bus13	**99.193**	0.02	Bus14	**98.807**	0.41	Bus15	**98.783**	0.02	Bus16	**98.668**	0.14
Bus17	**98.628**	0.04	Bus18	**98.615**	0.01	Bus19	**98.618**	0.01	Bus20	**98.457**	0.21
Bus21	**98.403**	0.05	Bus22	**98.352**	0.05	Bus23	**98.336**	0.02	Bus24	**98.191**	0.14
Bus25	**98.328**	0.02	Bus26	**98.306**	0.02	Bus27	**98.362**	0.03	Bus28	**98.382**	0.02
Bus29	**98.406**	0.02	Bus30	**98.372**	0.03	Bus31	**98.493**	0.09	Bus32	**98.558**	0.06
Bus33	**99.467**	0.91	Bus34	**100**	0.53	Bus35	**99.376**	0.09	Bus36	**99.352**	0.02
Bus37	**99.261**	0.12	Bus38	**99.227**	0.03	Bus39	**99.054**	0.21	Bus40	**99.022**	0.03
Bus41	**99.046**	0.01	Bus42	**99.035**	0.01	Bus43	**99.034**	0.01	Bus44	**99.047**	0.01
Bus45	**98.999**	0.05	Bus46	**99.117**	0.07	Bus47	**99.135**	0.02	Bus48	**98.988**	0.15
Bus49	**98.786**	0.2	Bus50	**98.619**	0.17	Bus51	**98.601**	0.02	Bus52	**98.561**	0.04
Bus53	**98.486**	0.12	Bus54	**99.245**	0.11	Bus55	**99.605**	0.36	Bus56	**100**	0.4
Bus57	**99.566**	0.04	Bus58	**99.32**	0.25	Bus59	**99.242**	0.08	Bus60	**99.193**	0.05
Bus61	**99.177**	0.02	Bus62	**99.088**	0.11	Bus63	**99.072**	0.02	Bus64	**99.07**	0.02
Bus65	**99.03**	0.04	Bus66	**99.005**	0.02	Bus67	**98.909**	0.1	Bus68	**98.837**	0.07
Bus69	**99.124**	0.12	Bus70	**98.925**	0.08	Bus71	**98.845**	0.08	Bus72	**99.268**	0.14
Bus73	**99.187**	0.08	Bus74	**99.155**	0.03	Bus75	**99.446**	0.18	Bus76	**99.921**	0.48
Bus77	**99.849**	0.07	Bus78	**100**	0.08	Bus79	**99.78**	0.14	Bus80	**99.713**	0.07
Bus81	**99.703**	0.01	Bus82	**99.681**	0.03						
	Improved Voltage profile range:98.191% min, 100% max, of the normal voltage										

Table 1.8: Improved Load Flow (Power Demanded, Net Power Received, and Voltage Magnitude at each Bus)

Results of Load Flow (Power Demanded, Net Power Received at each Bus) with DGs Integration											
	Load Power Demanded		***Net Load Power Received***		***Bus Voltage***		***Load Power Demanded***		***Net Load Power Received***		***Bus Voltage***
Bus No.	***P_D (kW)***	***Q_D (kVar)***	***P_L (kW)***	***Q_L (kVar)***	***V (Mag.)kV***	***Bus No.***	***P_D (kW)***	***Q_D (kVar)***	***P_L (kW)***	***Q_L (kVar)***	***V (Mag.)kV***
Bus 9	0	0	0	0	**11**	Bus46	400	300	396	297	**10.90287**
Bus10	400	300	398	298	**10.94687**	Bus47	0	0	0	0	**10.90485**
Bus11	80	60	79	60	**10.93345**	Bus48	400	300	395	296	**10.88868**
Bus12	0	0	0	0	**10.91387**	Bus49	400	300	394	296	**10.86646**
Bus13	400	300	396	297	**10.91123**	Bus50	160	120	157	118	**10.84809**
Bus14	0	0	0	0	**10.86877**	Bus51	0	0	0	0	**10.84611**
Bus15	240	180	237	177	**10.86613**	Bus52	400	300	393	295	**10.84171**

Bus16	160	120	157	118	**10.85348**	Bus53	480	360	471	354	**10.83346**
Bus17	0	0	0	0	**10.84908**	Bus54	240	180	238	178	**10.91695**
Bus18	160	120	157	118	**10.84765**	Bus55	0	0	0	0	**10.95655**
Bus19	240	180	236	177	**10.84798**	Bus56	160	120	160	120	**11**
Bus20	400	300	393	294	**10.83027**	Bus57	400	300	398	298	**10.95226**
Bus21	80	60	78	59	**10.82433**	Bus58	240	180	238	179	**10.9252**
Bus22	80	60	78	59	**10.81872**	Bus59	80	60	79	59	**10.91662**
Bus23	400	300	392	294	**10.81696**	Bus60	0	0	0	0	**10.91123**
Bus24	400	300	391	294	**10.80101**	Bus61	160	120	158	119	**10.90947**
Bus25	400	300	392	294	**10.81608**	Bus62	0	0	0	0	**10.89968**
Bus26	560	420	549	412	**10.81366**	Bus63	160	120	158	119	**10.89792**
Bus27	400	300	392	294	**10.81982**	Bus64	400	300	396	297	**10.8977**
Bus28	240	180	235	177	**10.82202**	Bus65	80	60	79	59	**10.8933**
Bus29	0	0	0	0	**10.82466**	Bus66	0	0	0	0	**10.89055**
Bus30	240	180	235	177	**10.82092**	Bus67	400	300	395	296	**10.87999**
Bus31	160	120	157	118	**10.83423**	Bus68	400	300	394	296	**10.87207**
Bus32	640	480	629	472	**10.84138**	Bus69	240	180	237	178	**10.90364**
Bus33	0	0	0	0	**10.94137**	Bus70	400	300	395	296	**10.88175**
Bus34	160	120	160	120	**11**	Bus71	400	300	394	296	**10.87295**
Bus35	0	0	0	0	**10.93136**	Bus72	0	0	0	0	**10.91948**
Bus36	80	60	79	60	**10.92872**	Bus73	400	300	396	297	**10.91057**
Bus37	400	300	396	297	**10.91871**	Bus74	400	300	396	297	**10.90705**
Bus38	240	180	238	178	**10.91497**	Bus75	400	300	397	298	**10.93906**
Bus39	0	0	0	0	**10.89594**	Bus76	0	0	0	0	**10.99131**
Bus40	400	300	395	296	**10.89242**	Bus77	400	300	399	299	**10.98339**
Bus41	0	0	0	0	**10.89506**	Bus78	400	300	400	300	**11**
Bus42	80	60	79	59	**10.89385**	Bus79	400	300	399	299	**10.9758**
Bus43	400	300	395	297	**10.89374**	Bus80	0	0	0	0	**10.96843**
Bus44	0	0	0	0	**10.89517**	Bus81	80	60	80	60	**10.96733**
Bus45	400	300	395	296	**10.88989**	Bus82	400	300	398	299	**10.96491**
	P_{D1}	Q_{D1}	P_{L1}	Q_{L1}			P_{D2}	Q_{D2}	P_{L2}	Q_{L2}	
	7840	**5880**	**7718**	**5792**			**8880**	**6660**	**8790**	**6595**	
($P_{D1}+P_{D2}$=16720kW, $Q_{D1}+Q_{D2}$=12540kVar)=**21MVA**- Load Power Demanded ($P_{L1}+P_{L2}$ = 16508kW, $Q_{L1}+Q_{L2}$ =12387kVar) =**20.64MVA** – Net Load power Received											

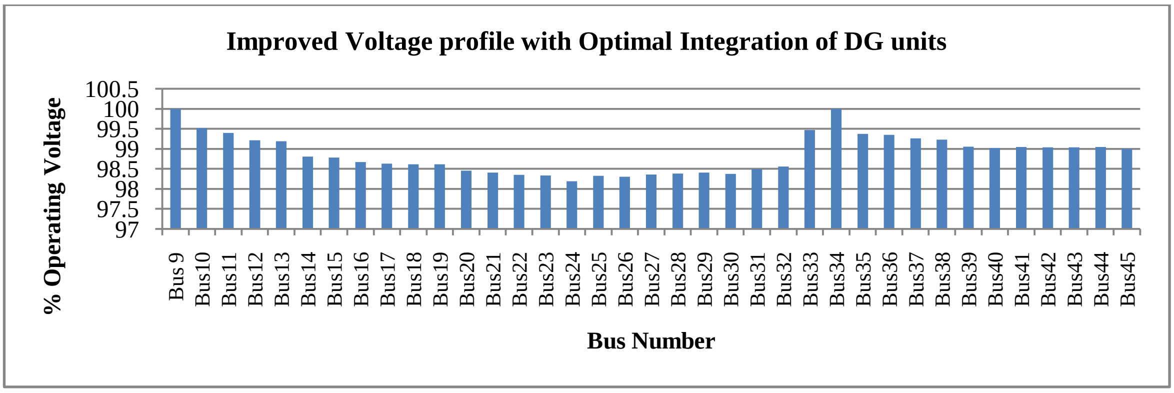

Figure 1.6(a): Improved %Voltage Profile **with** Optimal Integration of DG Units (Bus 9-Bus45)

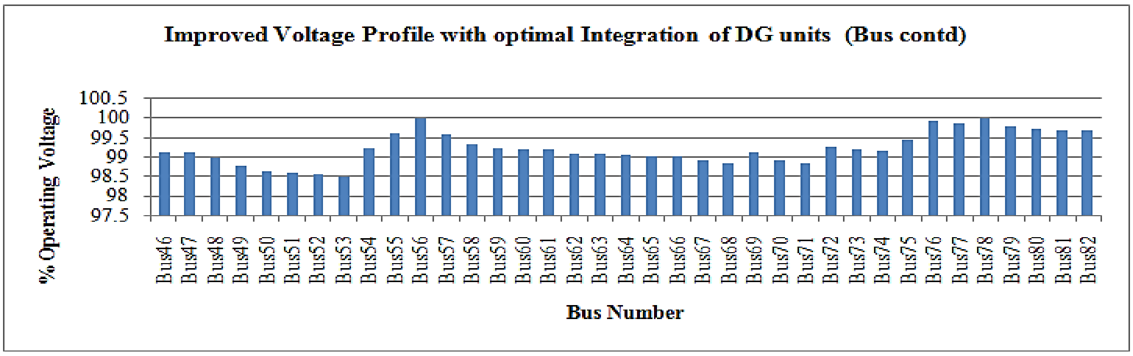

Figure 1.6(b): Improved %Voltage Profile **with** Optimal Integration of DG Units (Bus46 –Bus 82)

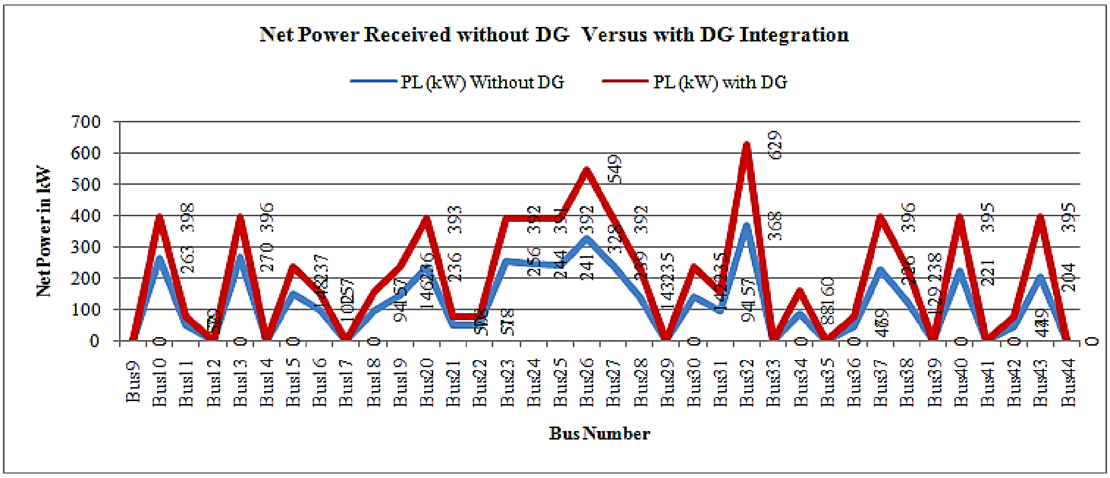

Figure 1.7 (a): Net Power Received without DG versus with DG Integration (Bus 9-Bus44)

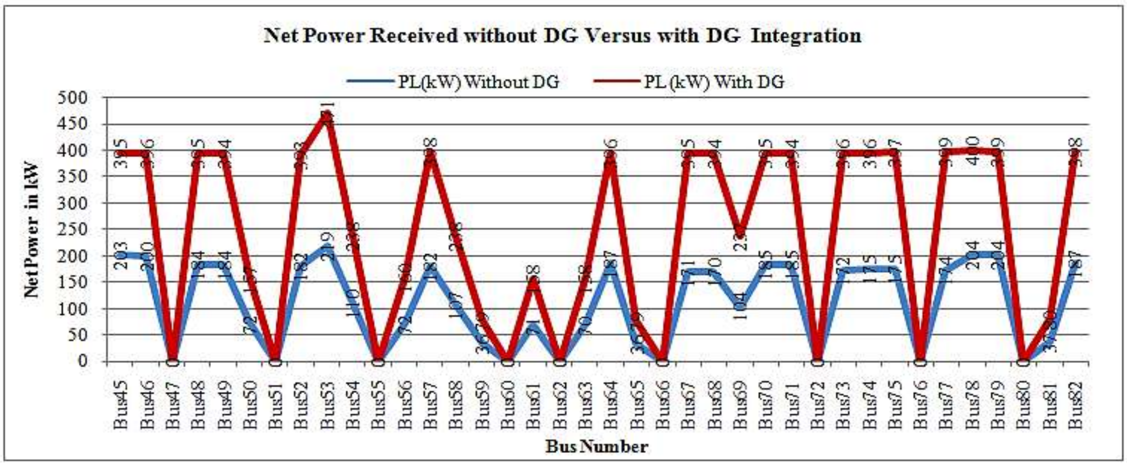

Figure 1.7 (b): Net Power Received without DG versus with DG Integration (Bus 45-Bus82)

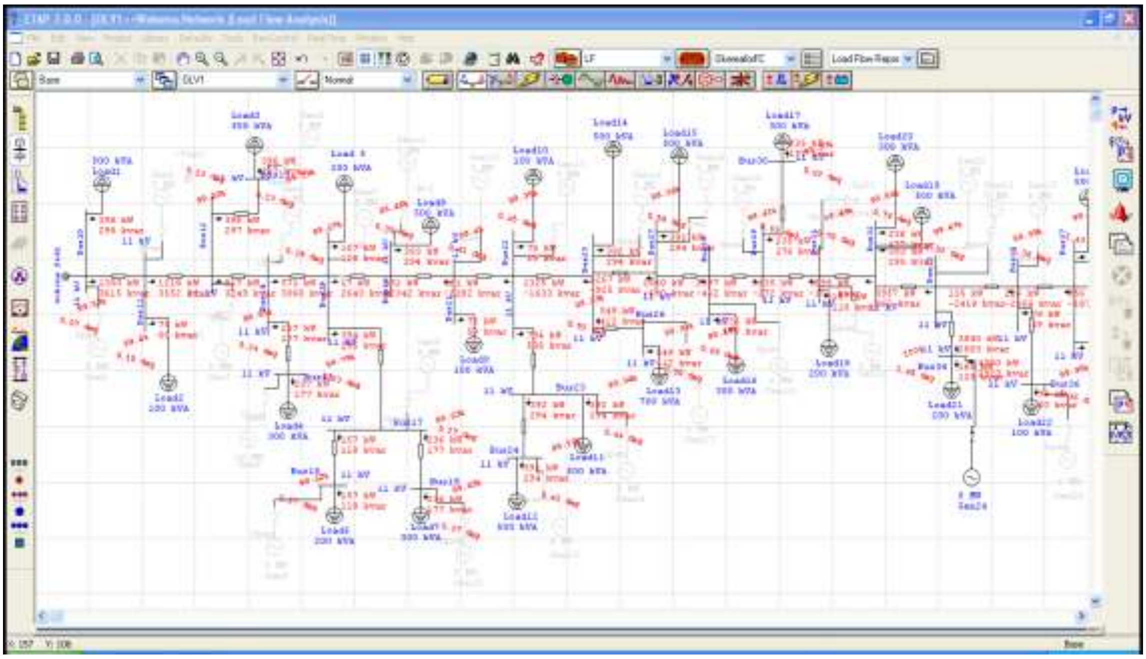

Figure 1.8: Simulation Result (Screenshot) of the Improved Wokoma Feeder showing (Bus 10 –Bus 36) (**with** DG integration)

Table 1.9: Summary Results of Branch Power Losses **without** and **with** DG integration

Summary Results of Branch Power Losses without and with DG integration		
Scenario I	***Scenario II***	***Scenario III & IV***
Base Case Without DG	***With DG at each Bus***	***With DG at Optimal Location only***
2824kW, 3575.3kVar	4265.2kW, 5412.7kVar	195.8kW, 240.7kVar
Least Voltage at a Bus	**Least Voltage at a Bus**	**Least Voltage at a Bus**
4.676kV	11kV	10.8kV

Table 1.10: Recommended Distributed Generators to Improved RSU 33/11kVInjection Substation on Wokoma Feeder

Bus No.	*Proposed DG Allocation &Name*	*Proposed DG Installed Capacity*	*DG Operating Capacity*	*Operating Voltage*
Bus 8	At the RSU Injection Substation	26MW	18MW	11kV
Bus 34	NSPRI at TF200kVA	5MW	4MW	11kV
Bus56	AA Place along Rumuepirikom at TF200kVA	8MW	6MW	11kV
Bus78	Eliopranwo/Mgbuakara at TF500kVA	6MW	5MW	11kV
Proposed Transformers for Upgrade				
Location of Transformer		*Old Rating*	*New Rating*	
Amadi Junction (Port Harcourt Town, zone 4)		T1B: 30 MVA	60MVA	132/33kV
RSU Injection. Substation		-	30MVA (addition)	33/11kV

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In literature different approaches has been utilised to improve positively on the distribution network. The task takes stringent steps in achieving the aim as in this research work. The materials and methods employed here are technically direct, using a load flow approach as the simulation tool to investigate the different scenarios/ sections of the principal algorithms regarding the objectives of the research work. The Wokoma feeder has been the longest feeder with a load capacity of 21MVA and was not effective in its operational capability due to very low voltage experienced at the end of the feeder.

From the analytical finding, drastic improvement was made on the RSU 33/11kV injection substation with the integration of distributed generation (DGs) on the case feeder (Wokoma feeder) as seen in Table 1.8 and Table 1.9. There was a reduction in the branch power losses which causes an increase in the net power received at the consumers' end. The impact of optimal integration of DG into Wokoma feeder reduces the branch power losses by 93.07% of the base-case branch power loss and the minimum bus voltage now sustain is 10.8kV. Note that, the full results pages of the simulated improved Wokoma feeder with DG integration are not attached here to avoid excessive numbers of pages of article.

5.2 Recommendations

The continual increase in electric power demands without corresponding increase in generation will persistently cause a drawback in a technologically driven economy. The consequence by which a country is under developing is the issues of incessant power interruption, inadequacy, unreliability and unclean power supply. Developed countries are associated with continual research for improvement in the power sector as it affects all sectors of life. To relieve the central generation and control of electric power, and its transmission pressures, we recommend that: (i) Continual planning and execution for expansion with intention to upgrade old or/and under-rated transformers at the primary power distribution substation (132/33kV injection substations) to effectively take care of the power demand; (ii) Upgrade transformer T1B 30MVA to 60MVA at the Amadi junction (Port Harcourt town Zone 4, operating at 132/33 kV); (iii) Make additional new dedicated 30MVA, 33/11kV transformer at the RSU 33/11kV injection substation for Wokoma Feeder; (iv) Utilise the appropriate location for the integration of distributed generators as in Table 1.10 for improvement of the RSU 33/11 injection substation. (v) Distributed Generator (DG) model is an industrial turbines single lift package.

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