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Improvement of Total Transfer Capability of Nigerian South Eastern Transmission Network with Distributed Generation: A Comparative Study of Solar Energy and Wind Energy

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Abstract

The problem of total power transfer capability at slack buses within transmission network poses a problem to the supply of quality power at distributing stations. The project has carried out a performance analysis for the improvement of total power transfer capability in the South Eastern (SE) transmission network. The study has devised means for the integration of Distributed Generation (DG) at various stations to acquire the required power transfer capability at the various stations. Etap software has been used for the design SE transmission network connecting the following station, Afam GS, Alaoji GS, Egbema GS, IkotAbassi TS, IkotEkpene GS, Okpai GS, Onitsha TS And Owerri TS. Furthermore in the study 6 scenarios were considered of which the wind and solar unit DG were integrated at the station bus to analyze the performance of the DG at the selected stations, power flow was considered in this scenarios so as to obtain the best total power flow capability for each integration. The result presented shows that the power flow has its best performances when the overall power flow was designed to flow simultaneously into the main grid from Transmission stations like Owerri and Onitsha, the results also shows that at this integration the power flow at each station is on the average.

Keywords*: Transmission, Distributed Generation, Transfer Capability, Solar, Wind*

1. INTRODUCTION

Over the past 40 years, Nigeria has produced electricity using a variety of fuels, with gas and oil-fired power plants, hydroelectric power stations, and coal-fired power plants holding primacy. While Jebba, Kainji, and Shiroro are locations further north, and these are hydro power plants. The thermal generation is generally close to the country's gas reserves in the south. At the power plants, electricity is produced between 11.5 and 16 kilovolts and is then stepped up to 330 kilovolts by a step-up transformer (Braide, 2018). Since the generated electricity must be delivered over large distances, this is done to account for power losses (I^2R losses) along the line of transmission. The National Grid is used to transfer the electricity generated by the nation's numerous generating stations (Anumaka, 2012). Transmission is the next stage in the electricity delivery process to the consumer. Substations and circuits with voltages between 132 kV and 330 kV make up Nigeria's transmission network. Beginning with the movement of 330 kV of power along transmission lines (sometimes referred to as conductors), the transmission process is then stepped down to 132 kV at the transmission substation. Once at the injection substations, this voltage is further stepped down to 33 kV through transmission lines. The distribution of power starts at this point (Okoye, 2019). The voltage is reduced by a distribution transformer to 11 kV, then to 0. 415 kV, and lastly to 240V before it reaches our residences or places of business. It is a key factor in the operation and planning of the power system because it ensures that the transmission system is run within safe and dependable parameters. Total transfer capabilities (TTC) consider a number of variables, including the transmission line capacity, the system's voltage restrictions, and the capacity of the available generation (Alvarado et al., 2001; Ou & Singh, 2002). The power system is thoroughly analyzed in order to calculate TTC, and the effects of numerous contingencies including line outages, generator outages, and load changes are all taken into account. When used in practice, complex computer simulations of the behavior of the power system under various operating situations are used by power system operators to calculate TTC. In addition to accounting for the dynamic behavior of the loads and generators, these models also take into account the transmission system's physical properties.

TTC is a crucial component of power system planning because it ensures that the transmission network can handle the expected growth in demand for electricity. System operators can anticipate possible transmission system bottlenecks and make plans for the expansion or building of new transmission lines by calculating the TTC. TTC is a crucial factor in guaranteeing the safe and dependable operation of the power system and is essential for preserving the equilibrium between supply and demand for energy.

Several technologies, including solar panels and combined heat and power plants, that generate electricity at or close to the area where it will be utilized are referred to as "distributed generation".

- Wind
- Reciprocating combustion engines, such as backup generators, can burn either biomass or biofuels.

The reliability of Nigeria's electrical grid has recently been questioned especially in the south-eastern region of Nigeria, for instance, Alaoji transmission station. This congested or trapped flow of electricity limits the amount of power that should reach the loads. For instance, when 100MW is sent out, we find that 20% or 30% of it is lost due to congestion or losses, as appropriate. In light of the aforementioned, we must devise a way to ensure that a greater quantity of generated electricity reaches its destination in order to fix Nigeria's unstable power supply.

Therefore, this work intend to analyze improvement of the total transfer capability of the Nigerian southeastern transmission network with distributed generation of which a comparative study of solar energy and wind energy was used. And to achieve this, the following specific objectives were considered:

- Getting data on Nigeria's South East region's power network.
- Creating a model of the Nigerian power grid with the power system analysis program, Etap.

- Including distributed generation systems for solar and wind energy in the model.
- Comparing the power network's overall transfer capacity to that of dispersed generation systems.

2. LITERATURE REVIEW

In Nigeria, the main sources of energy have historically been coal, oil, and natural gas. From 1990 until 2000, there was a sharp drop. The consumption of coal increased from 2000 to 2015 until about 2018, when it began to decline gradually. In Enugu, eastern Nigeria, coal was discovered in 1909; the first coal was produced there in 1916. A 3 phase, four wire, fifty cycle structure was implemented in the year 1924 with the closure of the Marina site on November 28, 1923 (Edomah, Foulds & Jones, 2016).

Generation

Nigeria Electricity generation began in the year1896, however, the Nigerian Electricity Regulation Commission (NERC) states that the establishment of the first utility company, known as the Nigerian Electricity Supply company, did not occur until 1929. The first electrical power plant in Nigeria was built in 1896 and had a 30kilowatts, 1000volts, and 80cycle supply. By 1909, with the addition of a second unit and a recorded energy demand of 65 KW, the installed capacity had grown to 120 Kilowatts. In the year 1920, the Lagos Marina power plant had an installed capacity of 420 kilowatts. Several outrages led to the establishment of the Niger Dams Authority (NDA), whose plan called for the construction of three hydroelectric and three thermal generating facilities. The amount of power that was available in Nigeria did not expand along with the country's population expansion.

The National Electric Power Policy of 2001 and other reforms were put into effect as a result. To overcome the electricity shortfall, the National Integrated Electricity Projects (NIPP) and Independent Power Producers (IPPs) were created by 2001. The vertical unbundling of Nigeria's power industry, which led to the creation of six generating firms and independent power producers (IPPs) known as GenCos, was a defining feature of the country's energy reform (Ayamolowo, 2019).

Transmission

The country's energy transmission system is run by Transmission Company of Nigeria (TCN). One of the 18 companies that were cut loose in the year 2004 from the Power Holding Company of Nigeria (PHCN), which is no longer in existence. It was produced by merging the transmission and system operations sections of PHCN.

Transmission Company of Nigeria (TCN) oversees the nation's energy distribution network. It is one of the 18 companies that were cut loose in April 2004 from the now-defunct Power Holding Company of Nigeria (PHCN). It resulted from the merger of the transmission and system operations divisions of PHCN (TCN, 2022).

Distribution

The electrical power generated by the Generation Companies is supplied to the grid in Nigeria by the Transmission Company of Nigeria (TCN). Transmission of electric power from TCN to the main electrical substations of the distribution corporations, then to the additional distribution system, and finally to the end customers, is how electricity is distributed.

Distributed Generation

The term "distributed generation" (DG) describes a variety of tiny electrical plants, ranging in size from only a few kilowatts to 10 megawatts (MW), that are situated in proximity to the a lot and can operate independently or in conjunction with a grid at the transfer or sub-transmission level to produce power near to the point of use, maintaining homes, businesses, and institutions from unplanned power outages and lowering associated costs and losses (Mahmoud, Ali, Moeini-Aghtaie, and Muhammad, 2017).

Wind Energy

An example of renewable energy that employs airflow to produce electricity is wind energy (also known as wind power). Onshore and offshore wind farms are both viable sources of renewable energy. Wind turbines are used to capture wind energy and transform its kinetic energy into electrical or mechanical power. An apparatus that transforms part of the momentum of the breeze into useful mechanical power is a windmill on a transmission shaft and subsequently into electrical energy via a generator. To catch greater winds, wind turbines are usually 120 meters or so tall, with 45-meter-long blades.

Solar Energy

Sunlight is directly converted into power by solar energy, which is the energy generated by the light which is one of the most economically viable types of sustainable power. There are ways to turn solar energy into electrical energy: either by using the quantization of solar energy into photons is well known. When sunlight strikes solar panels, these photons are absorbed by conductive materials like silicon. A solar power network is made up of an inverter collector and an inverter storage device that gather light radiation. A collector takes the sunrays that beats it and turns a portion of it into different types of power. When just a very little amount of radiation will be received, the storage unit conserves for those situations.

Difficulties in Positive Execution of Distributed Generation in Nigeria

• At the moment, there aren't many incentives to promote dispense generation integration existing dispense system or post integration administration services.

• Voltage quality issues caused by DGs include transient voltage changes and harmonic distortion of the network voltage.

• Due to the reverse power flow that the DG's presence introduces into the network, connecting a DG to a distribution network makes it to raise, that results in power variances.

Determination of Total Transfer Capability

The highest amount of power that can be moved from one region to another without going beyond any operating parameters or resulting in instability is known as a power system's total transfer capability (TTC). TTC is calculated by taking into account a variety of variables, such as voltage restrictions, system stability, and heat constraints. Because they are most likely to be breached, thermal limits are the most important consideration in determining TTC. The hottest line in the power system is taken into account while determining thermal limitations. Here are some additional TTC notes:

- TTC is a dynamic statistic that may change over time as a result of adjustments in system variables like weather, load demand, and generator availability.

- TTC is sometimes represented as a percentage of the "n-1" rating, which represents the system's maximum capacity.

- TTC is a crucial factor to take into account while developing and running a system since it establishes the maximum quantity of power that may be exchanged across areas.

- Typically, software like ETAP is used to perform a thorough power system simulation of the behavior of power structure in many working state in order to calculate TTC value. These simulations account for the dynamic behavior of the loads and generators as well as the physical properties of the transmission system.

Review of Related work

Funso, Michael (2021) outlines the fundamental analysis done on the 330 kV electrical network in Nigeria. The survey cover harmonics, transient stability, modal/eigenvalue computation, short circuit, and load flow. The suggested network is an extension of the current network that includes minor hydro, solar, and wind energy sources. Energy Commission of Nigeria (ECN) has suggested a few areas for distributed generating. A calculating tool called Power Factory, created by DigSILENT, was used to mimic the traditional sources and distributed generation.

Umar (2014), According to the statement, numerous energy production resources are being introduced around the world to get the continuously improving need for electric energy in the modern era. However, since the existing power network was not built with the new integration of generation in mind, a difficulty occurs when the new generation is integrated with the power network and distribution.

Fasina et al (2022) The distribution system's handling of the growing number of DG connected to it was significantly impacted. In this report, examining the effects of grid-connected DG on it was provided. Without DG, the test system's bus voltage magnitudes occasionally exceeded the allowable voltage, according to the results. However, the voltage magnitudes were increased to acceptable levels once the DG was attached. The network active power loss decreased from 85.60MW to 75.30MW by 12.03%. The electricity system improves in security and efficiency as a result.

Ilo et al (2022), Using distributed generation systems, the behavior of the power structure dispensation in Enugu Nigeria, was improved. Power structure distribution's primary duty is to deliver electricity to customers while keeping a reliable voltage quality for each and every client.

They suggested building centralized power facilities to use Distributed Generation (DG) to distribute electricity throughout the state

Ezeakudo et al (2020), researched on the advantages of dispersed generation in the electricity grid of Nigeria's South West zone. The Software called NEPLAN was used to model the fitting of Distributed generation capacity in the power structure. Some benefits that were noted in the results included network loss reduction, transmission line loss and congestion reduction, as well as an improvement in the voltage profile for the network's nodes.

3. MATERIALS AND PROCEDURES

3.1 Materials

The following materials will be employed in this project,

i. Etap software
ii. South east transmission network data
iii. Matlab/simulink

3.2 Procedures

The data used was that of Nigerian transmission structure taken from Enugu Electrical Distribution Company EEDC, Enugu state Nigeria. Figure 3.1 shows the flow chart of the power transfer capability of the Nigeria SE Transmission Network (TN) using DG.

3.2.1 System operation and integration

The operation of the proposed power transfer capability system is as shown in figure 3.2, the integration of the solar/wing DG to the system is for the sake of improving power transfer capability of buses/feeder/networks/generators with poor power transfer capability. A poor power transfer capability will reflect on the voltage profile of the identified buses/feeder/networks/generators and improving of this power transfer capability will improve the overall voltage profile in the transmission grid.

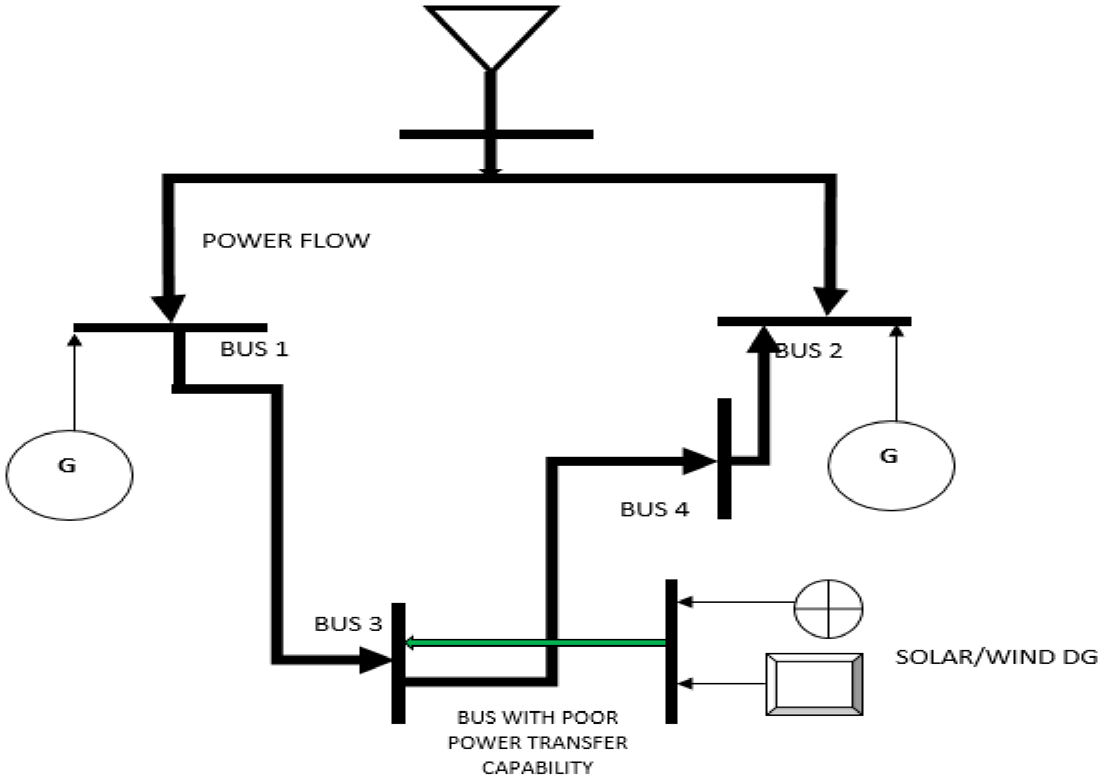


Figure 3.1: system block diagram

3.2.2 Design of the Nigerian south east transmission network

A simple structure of the south east transmission network consists of the 330kv network line with 4 generation station and transmission stations; the implementation of the network follows the collection of its line length and load variations. The structure is as shown in figure 3.3

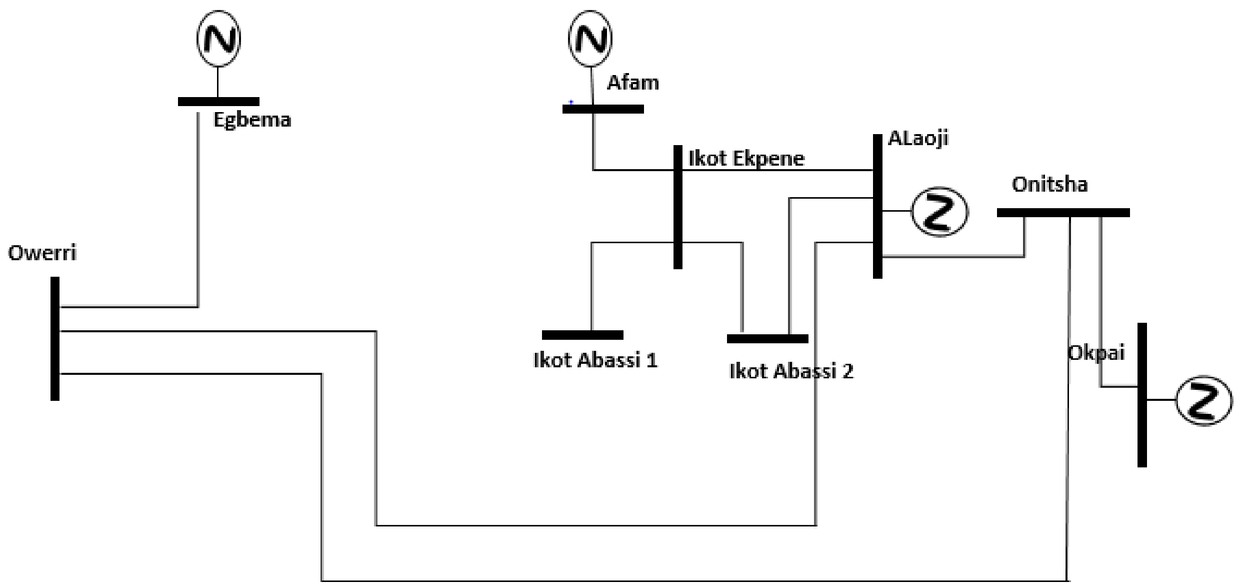


Figure 3.2: Schematic diagram of the SE 330/132 kv transmission network

The implementation of the network on Etap is as shown in figure 3.4, The voltage profile, line length and bus location within the TN of the structure in Table 4.1 to 4.3 in chapter 4.

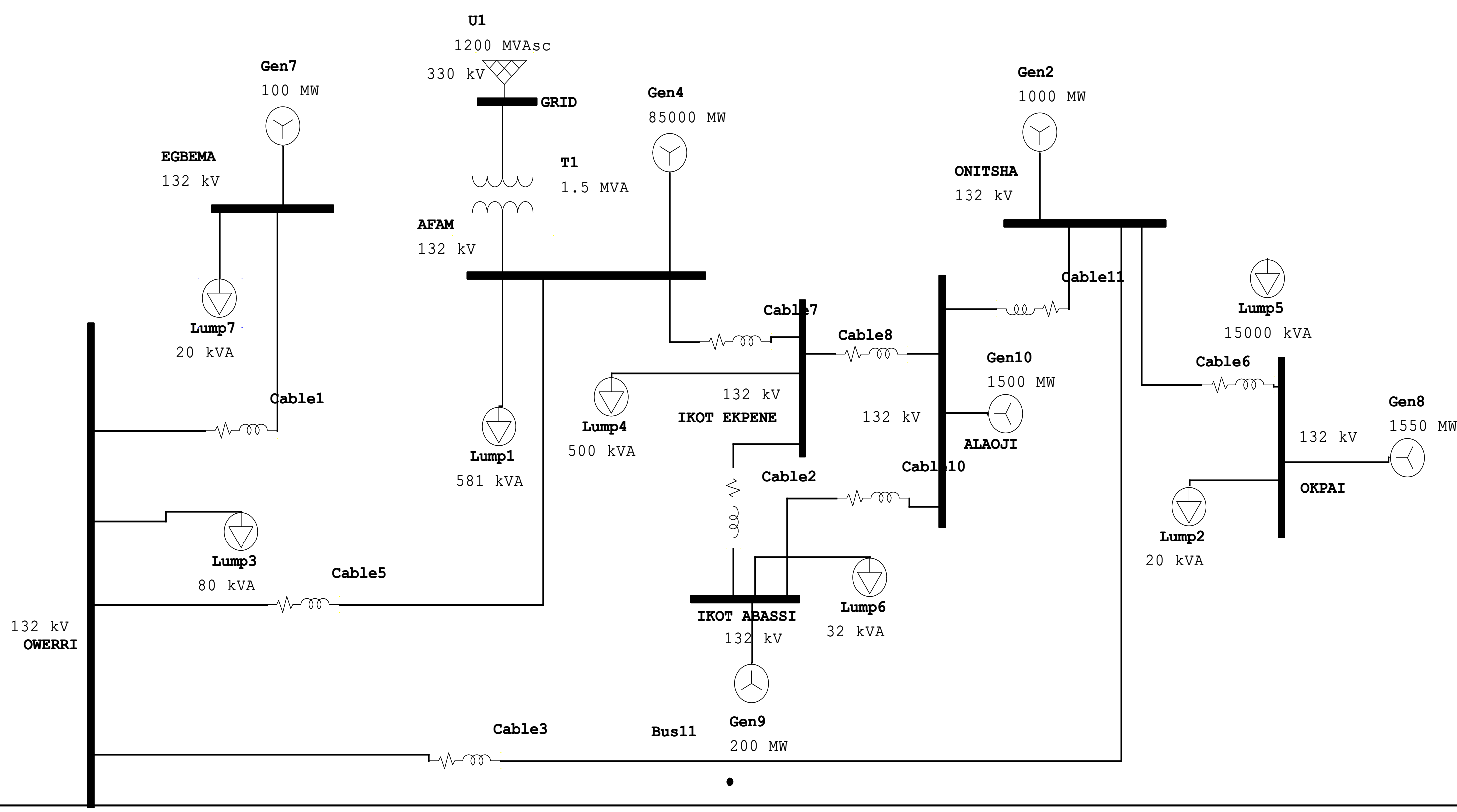


Figure 3.4: implementation of the SE Transmission network on Etap

4. RESULTS AND DISCUSSIONS

4.1 Design of the DS/TS grid system without DG

The design data for the SE 330/132 kv is as shown from table 4.1 to 4.3, the outcome for the structure shows that power transfer capability of each bus from another, the line length from each TS to another is also shown in table 4.3. Figure 4.1 show the transmission grid design on Etap software. Table 4.2 the outcome at the buses are at critical level as designed from Etap before the introduction of the DG, especially at Alaoji and Egbema. Table 4.1 present the parameters for the arrangement in solar Photovoltaic cells and windmill DG's.

Table 4.1: Solar Unit and Wind Unit DG design parameters

Solar Unit PV parameters	
Power	229.3 watt/panel
Number of Solar Unit PV	4
Temp.	25 degree C
Number of series panels	160
DC volts	1172.8 V
Watt (DC)	7.42
Watt (AC)	7.2
Voltage	11KV
Wind Unit Turbine parameters	
Power	50 kw
Wind Unit speed	30 m/s
Number Wind Unit turbines	2×10 *Aero leaf*
DC volts	15 KV
Watt (DC)	7.42
Watt (AC)	7.2
Voltage	132 KV

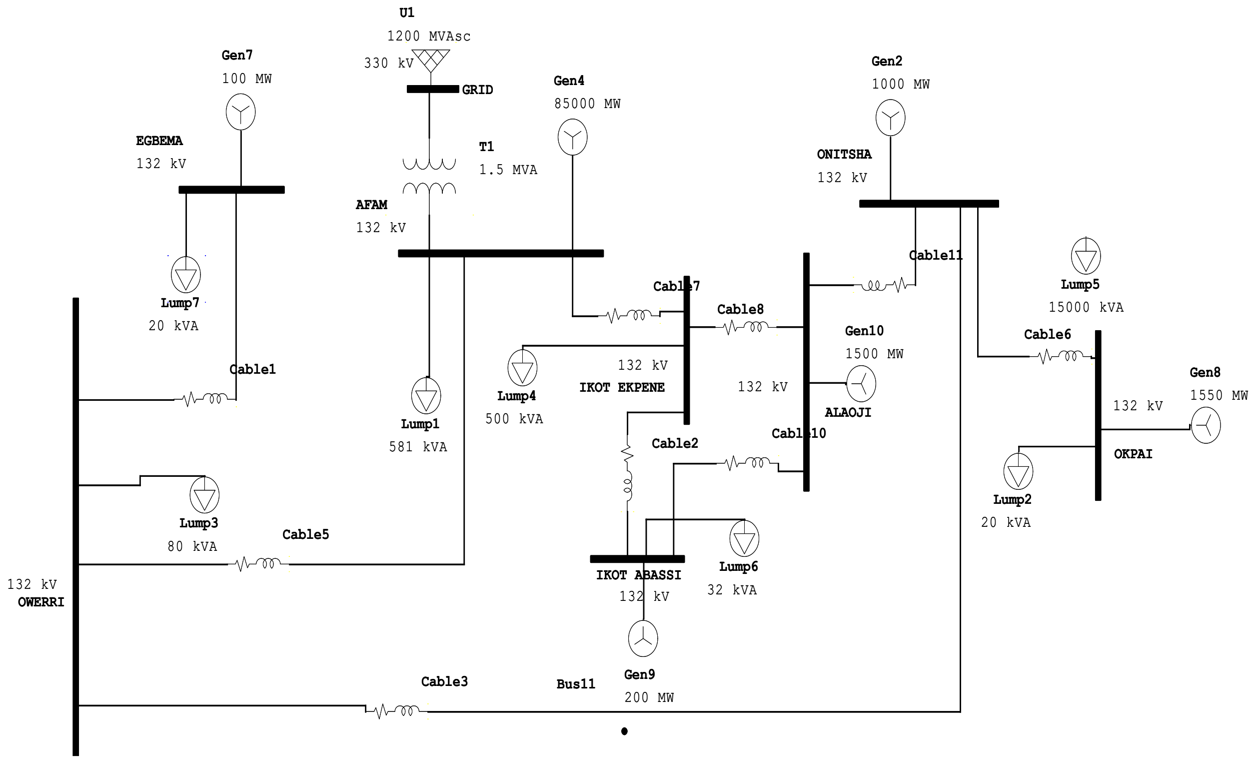


Figure 4.1: 1 line representation of grid system on Etap

Table 4.1: Bus voltage, amp loading and voltage profile at the buses

Bus ID	Nominal kV	Type	Voltage (kv)	V (%)	kW Loading	Amp Loading
AFAM	132	Gen.	120.605	91.36742424	1021.1	5.755
ALAOJI	132	Gen.	120.493	91.28257576	26.74	0.16
EGBEMA	132	Load	120.494	91.28333333	15.47	0.093
GRID	330	SWNG	330	100	1044.5	2.302
IKOT ABASSI	132	Gen.	120.489	91.27954545	26.29	0.148
IKOT EKPENE	132	Load	120.499	91.28712121	447.6	2.532
OKPAI	132	Gen.	120.464	91.26060606	16.43	0.093
ONITSHA	132	Gen.	120.483	91.275	24.65	0.139

OWERRI	132	Load	120.505	91.29166667	95.43	0.534

Table 4.2: transmission line length from 1 DS/TS to the other

S/N	From	To	Length (km)
1	Onitsha	Okpai	23
2	Onitsha	Alaoji	16
3	Onitsha	Owerri	23
4	Afam	Ikot-ekpene	30
5	Owerri	Egbema	20
6	Alaoji	Owerri	11
7	Alaoji	IkotAbasssi	18
8	Owerri	Alaoji	45

4.2 Performance analysis

To carry out a performance analysis, there is need to test by introduction of Wind Unit/Solar Unit PV DG systems at the buses with low power transfer capability to check the performance of the DG at the buses.

The testing comes in 6 different scenarios as shown below.

4.2.1 Scenario 1: 4 Solar point and 1 Wind point integration at Owerri

By the integration of 4 Solar source and 1 Wind source DG at the owerri TS, we can see the results from figure 4.2, table 4.4 and table 4.5

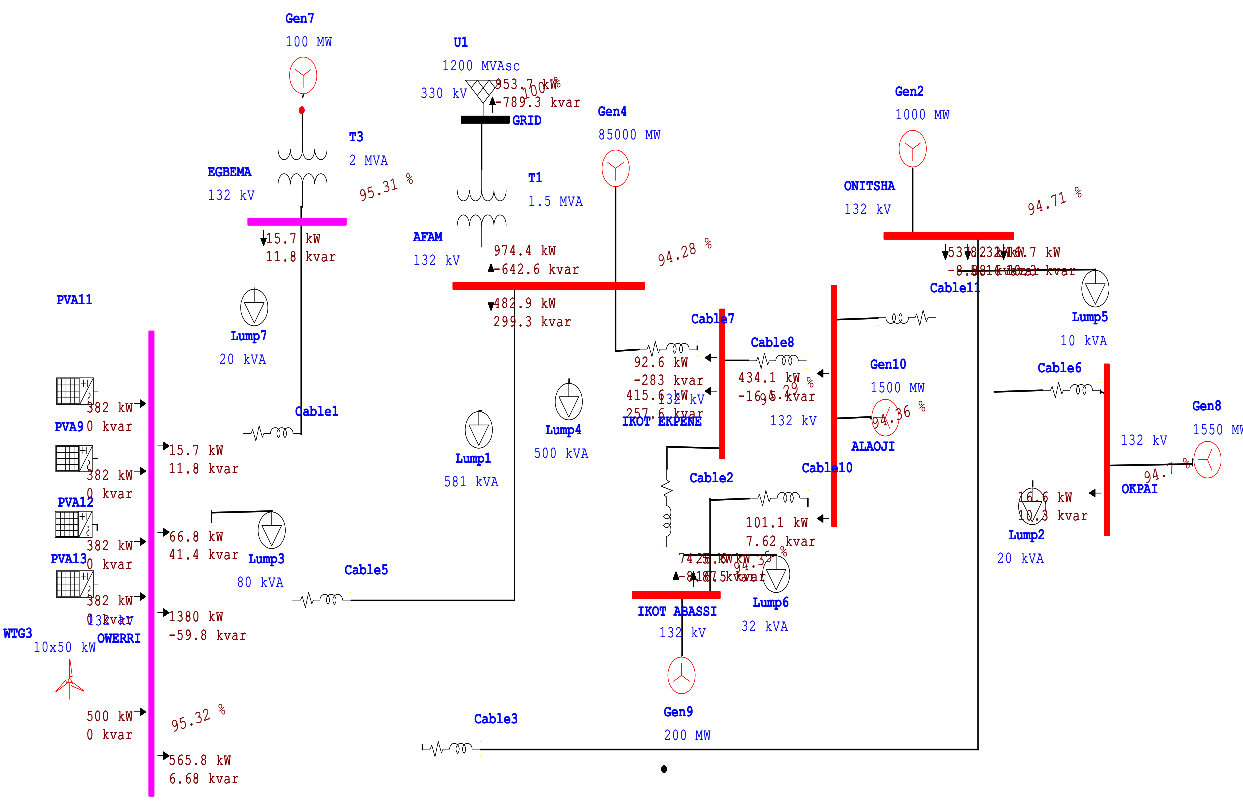


Figure 4.2: Etap (integration of 4 Solar Unit and 1 Wind Unit integration at Owerri)

Table 4.4: voltage profile for integration at 4 Solar Unit and 1 Wind Unit integration at Owerri

Bus Identity	Nominal(kV)	Class	Voltage(KV)	V(%)	kW Fill	Amp Fill
AFAM	132	Gen.	124.455	94.28409091	1457.3	7.388
ALAOJI	132	Gen.	124.56	94.36363636	535.2	2.482
Bus10	132	Gen.	122.742	92.98636364	0	0
EGBEMA	132	Load	125.811	95.31136364	15.71	0.09
GRID	330	SWNG	330	100	953.7	2.166
IKOT ABASSI	132	Gen.	124.538	94.3469697	101.1	0.475
IKOT EKPENE	132	Load	124.467	94.29318182	508.2	2.698
OKPAI	132	Gen.	125.001	94.69772727	16.65	0.09
ONITSHA	132	Gen.	125.019	94.71136364	562.2	2.597
OWERRI	132	Load	125.82	95.31818182	2028	9.31

- **PURPLE =MARGINAL**

- **RED = CRITICAL**

Table 4.5: MW Power transfer capability from one DS/TS to another

Identity	Class	Flow(MW)	MVar Flow	Amp flow	% fill
AFAM TO IKOT EKPENE	Cable	0.0926	-0.283	1.381	
EGBEME TO OWERRI	Cable	0.0157	0.0118	0.09	
IKOT EKPENE TO IKOT ABASS	Cable	0.0745	-0.0089	0.348	
ONITSHA TO OKPAI	Cable	0.0167	0.0103	0.09	0.7
OWERRI TO AFAM	Cable	1.38	-0.0598	6.337	
OWERRI TO ONITSHA	Cable	0.566	0.0067	2.596	18.9

4.2.2 Scenario 2: 2 Solar Unit and 1 Wind Unit integration at Owerri and Onitsha

By the integration of 2 Solar Unit and 1 Wind Unit DG at the owerri TS and Onitsha GS, we can see the results from figure 4.3, table 4.6 and table 4.7

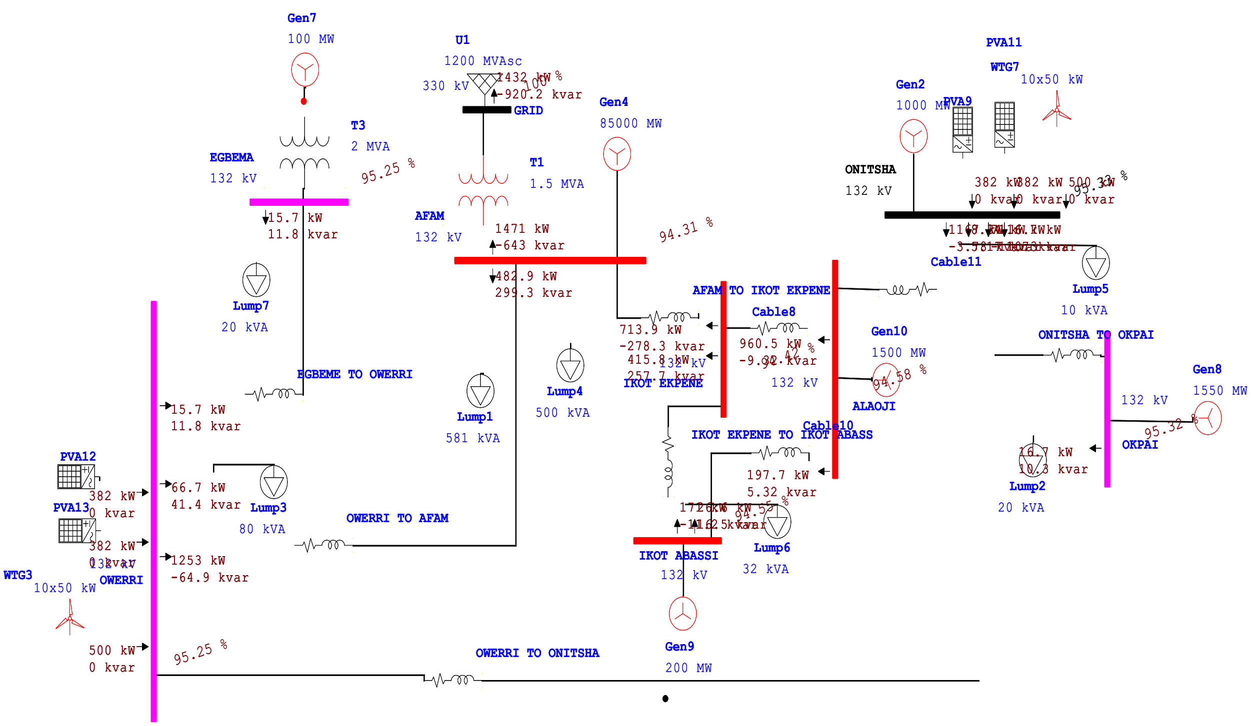


Figure 4.3: Etap (integration of 2 Solar Unit and 1 Wind Unit each at Owerri and Onitsha)

Table 4.6: voltage profile for integration of 2 Solar Unit and 1 Wind Unit each at Owerri and Onitsha

Bus Identity	Nominal (kilovolt)	class	Voltage (KV)	V(%)	KW Fill	Amp Fill
AFAM	132	Gen.	124.494	94.31363636	1953.6	9.538
ALAOJI	132	Gen.	124.844	94.57878788	1158.2	5.356
Bus10	132	Gen.	122.659	92.92348485	0	0
EGBEMA	132	Load	125.725	95.24621212	15.7	0.09
GRID	330	SWNG	330	100	1431.6	2.977
IKOT ABASSI	132	Gen.	124.802	94.5469697	197.7	0.918
IKOT EKPENE	132	Load	124.64	94.42424242	1129.7	5.389
OKPAI	132	Gen.	125.818	95.31666667	16.69	0.09
ONITSHA	132	Gen.	125.836	95.33030303	1264	5.8
OWERRI	132	Load	125.735	95.25378788	1335.6	6.14

- **PURPLE =MARGINAL**
- **RED = CRITICAL**

Table 4.7: MW Power transfer capability from one DS/TS to another

Identity	Class	Flow (MW)	MVar Flow	Amp Flow	% Fill
AFAM TO IKOT EKPENE	Cable	0.714	-0.278	3.549	
EGBEME TO OWERRI	Cable	0.0157	0.0118	0.09	
IKOT EKPENE TO IKOT ABASS	Cable	0.171	-0.0112	0.793	
ONITSHA TO OKPAI	Cable	0.0167	0.0103	0.09	0.7
OWERRI TO AFAM	Cable	1.253	-0.0649	5.762	
OWERRI TO ONITSHA	Cable	0.0716	-0.0117	0.333	2.4

4.2.3 Scenario 3: 2 Solar Unit at Afam and 1 Solar Unit, 1 Wind Unit each at Owerri and Onitsha

By the integration of 2 Solar Unit at Afam and 1 Solar Unit, 1 Wind Unit each at Owerri and Onitsha, we can see the results from figure 4.4, table 4.8 and table 4.9.

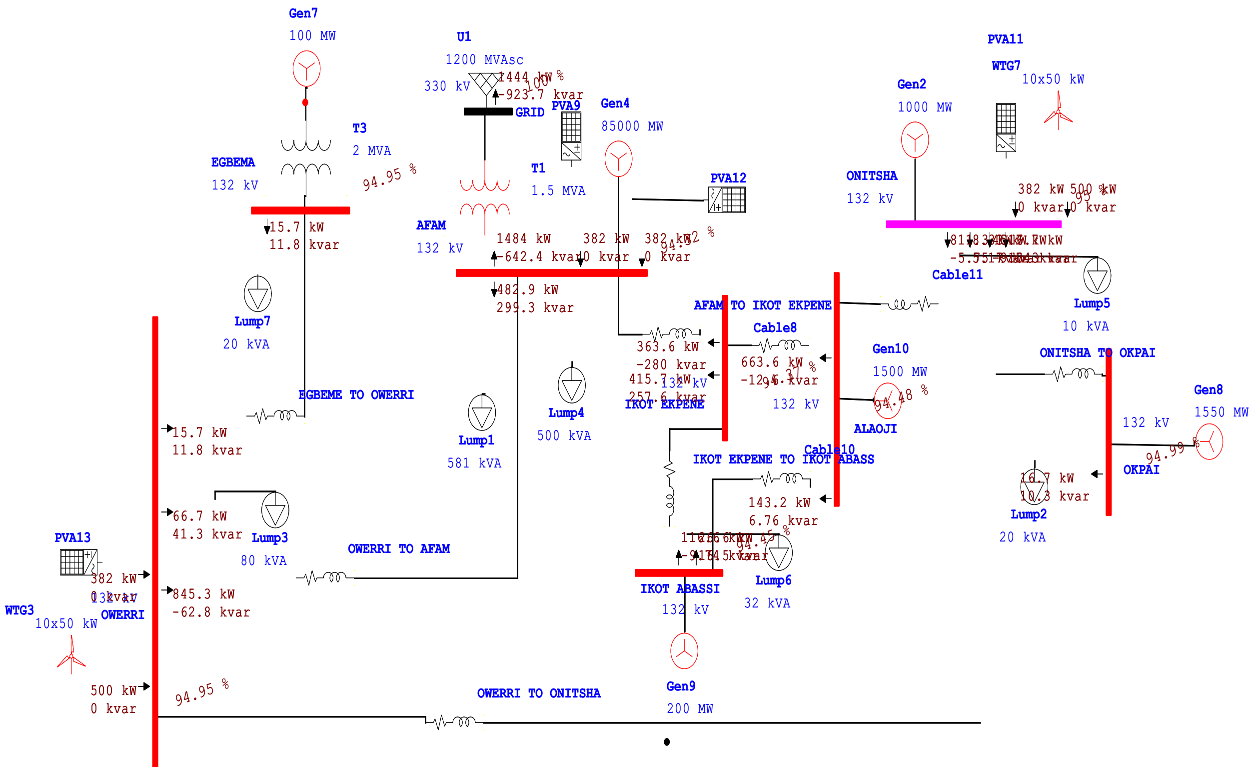


Figure 4.4: Etap (integration of 2 Solar Unit at Afam and 1 Solar Unit, 1 Wind Unit each at Owerri and Onitsha)

Table 4.8: voltage profile for integration of 2 Solar Unit at Afam and 1 Solar Unit, 1 Wind Unit each at Owerri and Onitsha

Bus Identity	Nominal kilovolt	Class	Voltage		kW fill	Amp fill
AFAM	132	Gen.	124.499	94.31742424	1966.9	9.596
ALAOJI	132	Gen.	124.711	94.4780303	806.8	3.736
Bus10	132	Gen.	122.271	92.62954545	0	0
EGBEMA	132	Load	125.328	94.94545455	15.68	0.09
GRID	330	SWNG	330	250	1444.3	3

IKOT ABASSI	132	Gen.	124.681	94.45530303	143.2	0.668
IKOT EKPENE	132	Load	124.57	94.37121212	779.3	3.838
OKPAI	132	Gen.	125.384	94.98787879	16.67	0.09
ONITSHA	132	Gen.	125.403	95.00227273	882	4.061
OWERRI	132	Load	125.338	94.9530303	927.7	4.283

- **PURPLE =MARGINAL**
- **RED = CRITICAL**

Table 4.9: MW Power transfer capability from one DS/TS to another

Identity	Class	Flow (MW)	MVar Flow	Amp Flow	% Fill
AFAM TO IKOT EKPENE	Cable	0.364	-0.28	2.127	
EGBEME TO OWERRI	Cable	0.0157	0.0118	0.09	
IKOT EKPENE TO IKOT ABASS	Cable	0.117	-0.0097	0.542	
ONITSHA TO OKPAI	Cable	0.0167	0.0103	0.09	0.7
OWERRI TO AFAM	Cable	0.845	-0.0628	3.905	
OWERRI TO ONITSHA	Cable	0.0457	-0.0097	0.215	1.6

4.2.4 Scenario 4: 3 Solar Unit, 1 Wind Unit at Afam and 1 Solar Unit, 1 Wind Unit at Owerri

By the integration of 3 Solar Unit, 1 Wind Unit at Afam and 1 Solar Unit, 1 Wind Unit at Owerri, we can see the results from figure 4.5, table 4.10 and table 4.11.

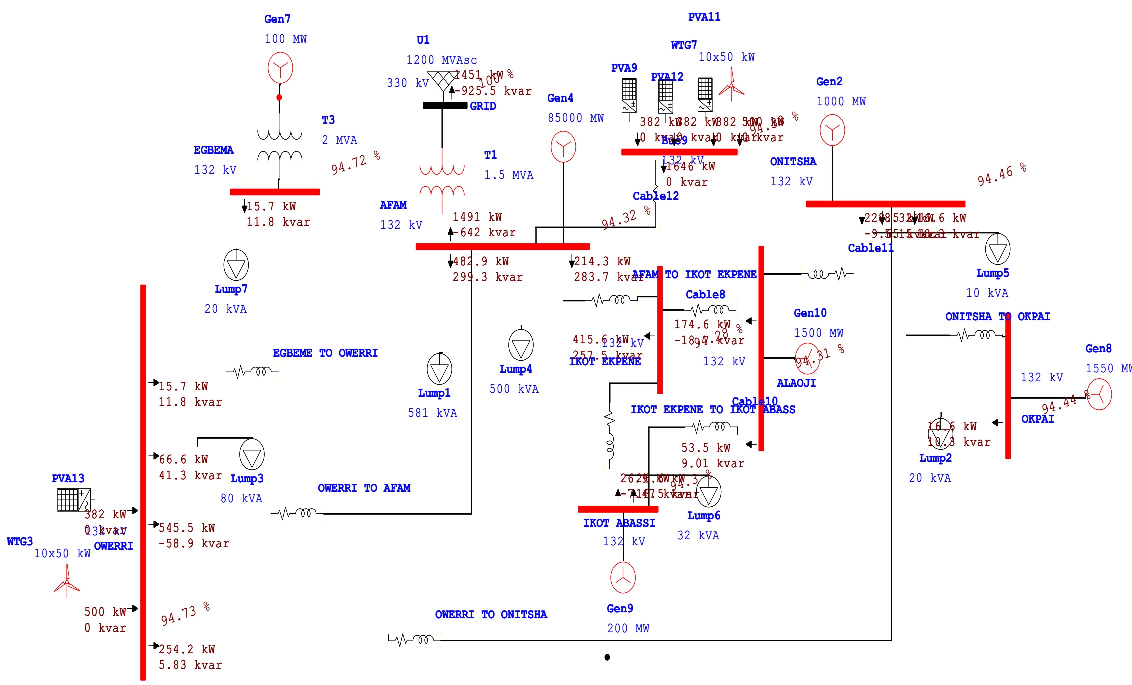


Figure 4.5: Etap (Integration of 3 Solar Unit, 1 Wind Unit at Afam and 1 Solar Unit, 1 Wind Unit at Owerri)

Table 4.10: voltage profile for integration of 3 Solar Unit, 1 Wind Unit at Afam and 1 Solar Unit, 1 Wind Unit at Owerri.

Bus Identity	Nominal kilovolt	Class	Voltage (KV)	V(%)	kW Fill	Amp fill
AFAM	132	Gen.	124.503	94.32045455	2188.1	10.57
ALAOJI	132	Gen.	124.487	94.30833333	228.1	1.062
EGBEMA	132	Load	125.035	94.72348485	15.67	0.09
GRID	330	SWNG	330	100	1451	3.011
IKOT ABASSI	132	Gen.	124.476	94.3	53.5	0.26
IKOT EKPENE	132	Load	124.45	94.28030303	415.6	2.334
OKPAI	132	Gen.	124.664	94.44242424	16.63	0.091

ONITSHA	132	Gen.	124.683	94.4568181 8	253.4	1.176
OWERRI	132	Load	125.045	94.7310606 1	882	4.081

- **PURPLE =MARGINAL**
- **RED = CRITICAL**

Table 4.11: MW Power transfer capability from one DS/TS to another

Identity	Class	Flow (MW)	MVar Flow	Amp Flow	% Fill
AFAM TO IKOT EKPENE	Cable	0.214	0.284	1.649	
EGBEME TO OWERRI	Cable	0.0157	0.0118	0.09	
IKOT EKPENE TO IKOT ABASS	Cable	0.0269	-0.0075	0.13	
ONITSHA TO OKPAI	Cable	0.0166	0.0103	0.091	0.7
OWERRI TO AFAM	Cable	0.046	-0.0589	2.533	
OWERRI TO ONITSHA	Cable	0.154	0.0058	1.174	8.5

4.2.5 Scenario 5: 1 Solar Unit, 1 Wind Unit at each Station

By the integration of 1 Solar Unit, 1 Wind Unit at each Station, we can see the results from figure figure 4.6, table 4.12 and table 4.13.

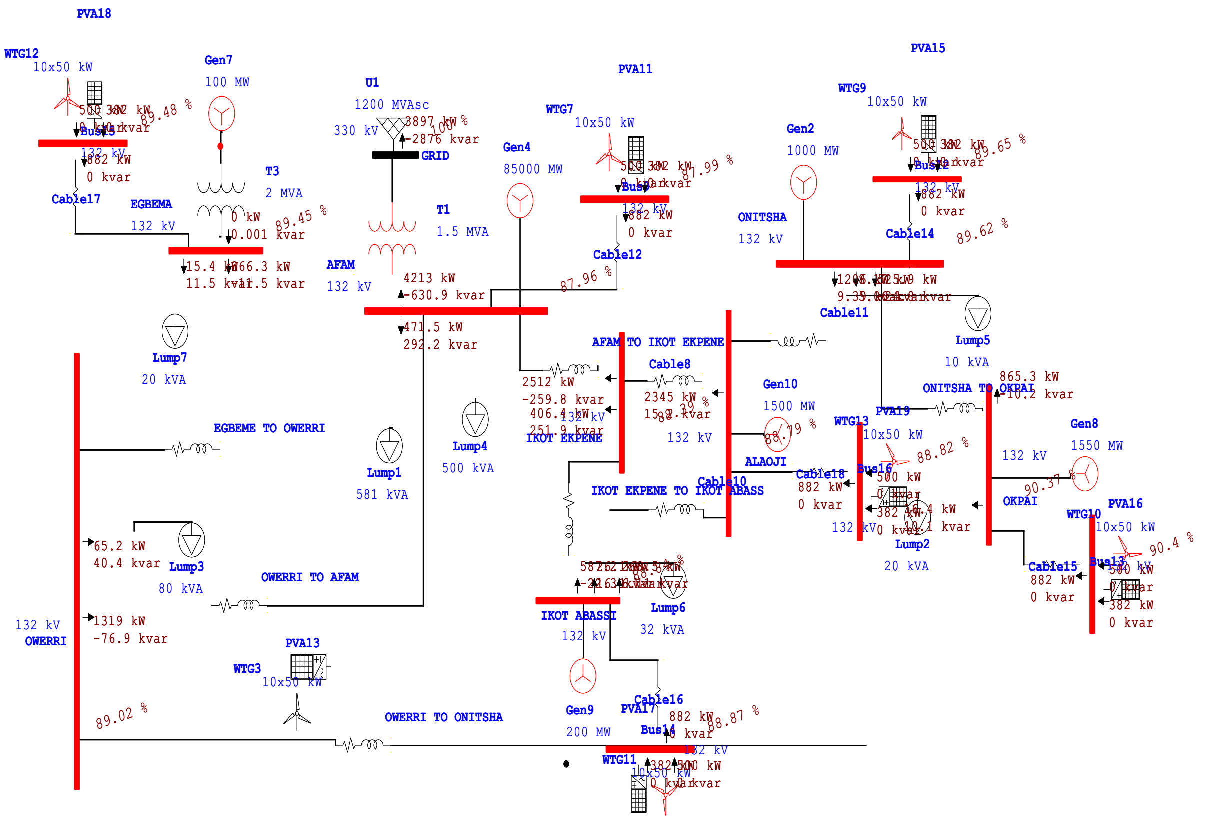


Figure 4.6: Etap (Integration of 1 Solar Unit, 1 Wind Unit at each Station)

Table 4.12: voltage profile for integration of 1 Solar Unit, 1 Wind Unit at each Station.

Bus Identity	Nominal kilovolt	Class	Voltage (KV)	V(%)	kW fill	Amp fill
AFAM	132	Gen.	116.105	87.9583333 3	4684.5	23.5
ALAOJI	132	Gen.	117.204	88.7909090 9	2344.6	11.55
EGBEMA	132	Load	118.069	89.4462121 2	881.7	4.312
GRID	330	SWN G	330	100	3896.7	8.473
IKOT ABASSI	132	Gen.	117.265	88.8371212 1	881.7	4.342

IKOT EKPENE	132	Load	116.671	88.38712121	2918.1	14.5
OKPAI	132	Gen.	119.284	90.36666667	881.7	4.268
ONITSHA	132	Gen.	118.294	89.61666667	1739.8	8.492
OWERRI	132	Load	117.503	89.01742424	1384.6	6.814

Table 4.13: MW Power transfer capability from one DS/TS to another

Identity	Class	Flow(MW)	MVar Flow	Amp Flow	% fill
AFAM TO IKOT EKPENE	Cable	2.512	-0.26	12.5	
EGBEME TO OWERRI	Cable	0.866	-0.0115	4.237	
IKOT EKPENE TO IKOT ABASS	Cable	0.587	-0.0223	2.893	
ONITSHA TO OKPAI	Cable	0.865	-0.0102	4.188	30.4
OWERRI TO AFAM	Cable	1.319	-0.0769	6.494	
OWERRI TO ONITSHA	Cable	0.526	-0.0248	2.57	18.7

4.2.6 Scenario 6: 4 Solar Unit at Onitsha Station and 2 Wind Unit at Owerri Station

By the integration of 4 Solar Unit at Onitsha Station and 2 Wind Unit at Owerri Station, we can see the results from figure 4.7, table 4.14 and table 4.15.

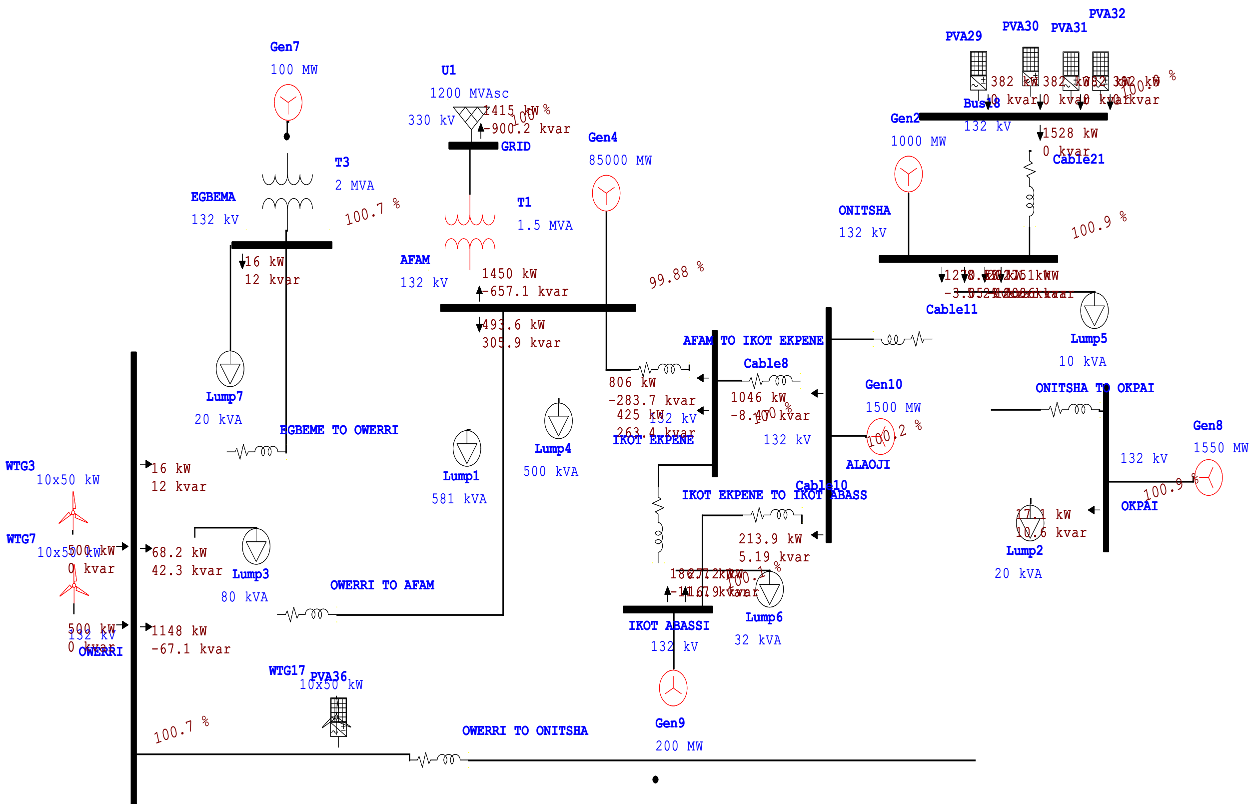


Figure 4.7: Etap (Integration of 4 Solar Unit at Onitsha Station and 2 Wind Unit at Owerri Station)

Table 4.14: voltage profile for integration of 4 Solar Unit at Onitsha Station and 2 Wind Unit at Owerri Station.

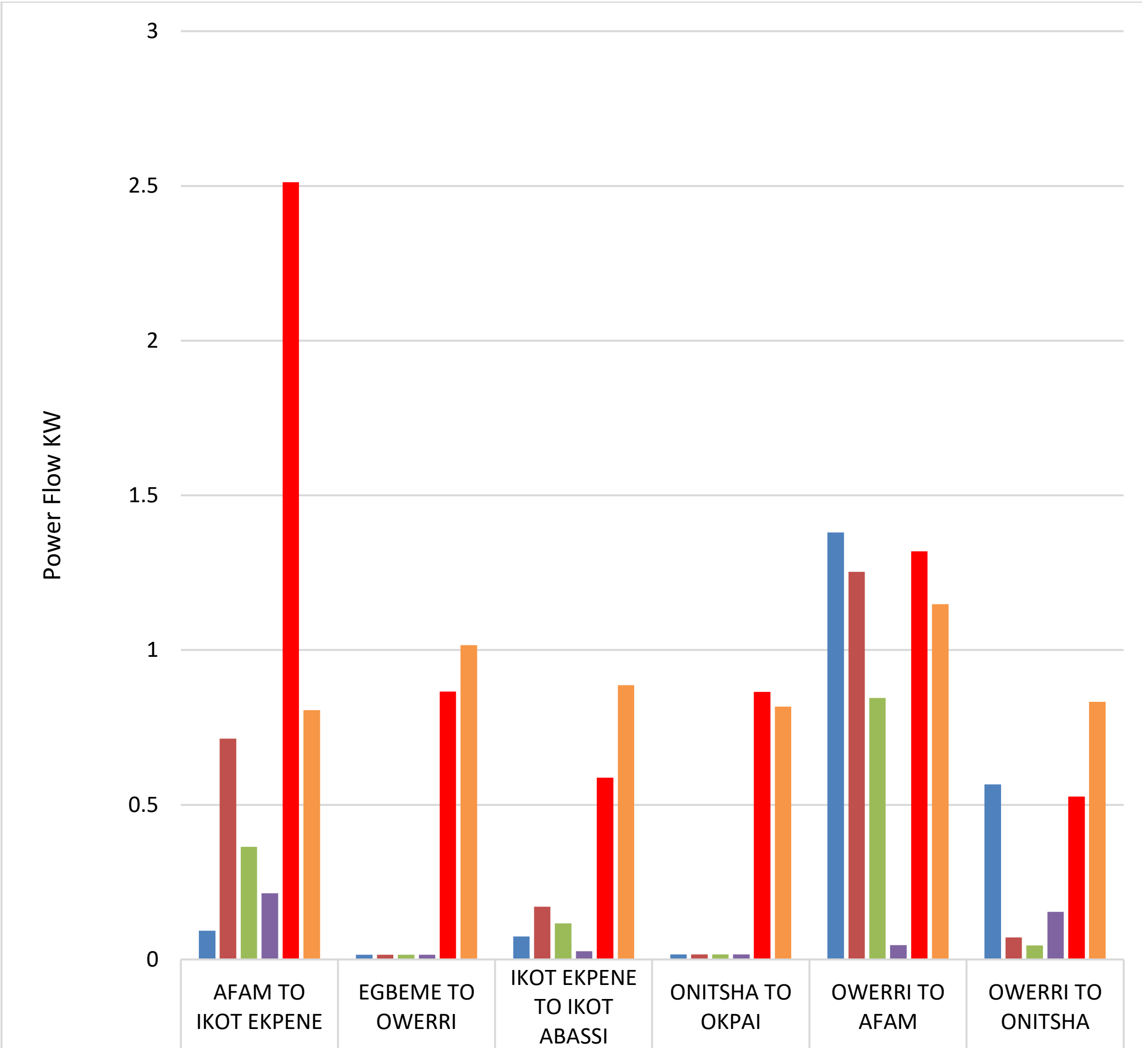
Bus Identity	Nominal kilowatt	Class	Voltage (KV)	V(%)	kW Fill	Amp fill
AFAM	132	Gen.	131.842	100	1943.3	8.983
ALAOJI	132	Gen.	132.208	100	1260.2	5.503
EGBEMA	132	Load	132.907	101	16.04	0.087
GRID	330	SWNG	330	100	1415.5	2.935
IKOT ABASSI	132	Gen.	132.165	100	213.9	0.937
IKOT EKPENE	132	Load	131.997	100	1231	5.526
OKPAI	132	Gen.	133.209	101	17.06	0.087
ONITSHA	132	Gen.	133.227	101	1528	6.622
OWERRI	132	Load	132.916	101	1232	5.359

Table 4.13: MW Power transfer capability from one DS/TS to another

Identity	Class	Flow(MW)	MVar Flow	Amp Flow	% fill
AFAM TO IKOT EKPENE	Cable	0.806	-0.284	3.738	
EGBEME TO OWERRI	Cable	1.016	0.012	0.087	
IKOT EKPENE TO IKOT ABASSI	Cable	0.887	0.0117	0.817	
ONITSHA TO OKPAI	Cable	0.8171	0.0106	0.087	0.6
OWERRI TO AFAM	Cable	1.148	-0.0671	4.994	
OWERRI TO ONITSHA	Cable	0.833	-0.0128	1.009	7.3

From the integration of 4 Solar Unit at Onitsha station and 2 Wind Unit turbine unit, there is seen to be a uniform power flow in figure 4.7, power is seen to flow from Onitsha to IkotEkpene and Okpai stations with high Kvar (Solar PV), power is also seen to flow from Owerri to Egbeme low KVar (Wind), Power is also seen to flow simultaneously into Afam station from both Owerri and Onitsha (1450 kw and 806 kw) respectively. The simultaneous power flow into the grid station (Afam) will help eliminate the issues of poor power transfer, hence improving the voltage profile at each station.

Figure 4.8 shows the power transfer capability chart for power flow from each station to another for the different scenarios, for scenario 1, the maximum Power transfer capability is at power transfer from Owerri to Afam with its lowest effect at Afam to IkotEkpene, scenario 5 has a maximum power flow from Afam to IkotEkpene and its lowest from Owerri to Onitsha. Scenario 5 has an average power flow at each flow from one station to another. Therefore integration of DG following scenario 5 will help improve the power flow capacity at the SE GS/TS network in Nigeria.



	AFAM TO IKOT EKPENE	EGBEME TO OWERRI	IKOT EKPENE TO IKOT ABASSI	ONITSHA TO OKPAI	OWERRI TO AFAM	OWERRI TO ONITSHA
scenario 1	0.0926	0.0157	0.0745	0.0167	1.38	0.566
scenario 2	0.714	0.0157	0.171	0.0167	1.253	0.0716
scenario 3	0.364	0.0157	0.117	0.0167	0.845	0.0457
scenario 4	0.214	0.0157	0.0269	0.0166	0.046	0.154
scenario 5	2.512	0.866	0.587	0.865	1.319	0.526
scenario 6	0.806	1.016	0.887	0.8171	1.148	0.833

Figure 4.8: Plot showing Power flow capability from one station to another

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The proposal has performed an analysis for the improvement total power transfer capability in the SE transmission network. The study has devised means for the integration of DG at various stations to acquire the required power transfer capability at the various stations. Etap software has been used for the design SE transmission network connecting the following station, Afam GS, Alaoji GS, Egbema GS, IkotAbassi TS, IkotEkpene GS, Okpai GS, Onitsha TS And Owerri TS. Furthermore in the study 6 scenarios were considered of which the wind and solar unit DG were integrated at the station bus to analyze the performance of the DG at the selected stations, power flow was considered in this scenarios so as to obtain the best total power flow capability for each integration. The result presented shows that the power flow has its best performances when the overall power flow was designed to flow simultaneously into the main grid from TS stations like Owerri and Onitsha, the results also shows that at this integration the power flow at each station is on the average.

5.2 Recommendation

The systems has incorporated the manual application of renewable energy DG to improve the total power flow capability, for subsequent study the application of AI enabled system should be encouraged so as to detect buses with low total power flow capability help improve power flow around the network.

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