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Development of Improved Institutional Distribution Network System for Seamless Energy Integration in Federal University of Technology Owerri, Nigeria

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Abstract: In recent years, Federal University of Technology Owerri (FUTO) Nigeria has seen a quantum increase in number of schools with the establishment of SLIT, SCIT, SESET and Medical school. This has resulted in construction of new buildings with consequential increase in electricity demand which cannot be adequately provided for by existing distribution network of FUTO. The school management in its effort to increase power generation has gotten the support of Rural Electrification Agency of Nigeria and its Alumni Association to provide large scale solar – based renewable energy and new 132/33kV substation respectively. With this expected increased generation, there is dire – need to provide improved distribution network that will accommodate the new energy intake. In this work, a new network is designed. Presently, FUTO has an 11/33kV substation at Bakassi from where power is distributed to various departments and units. The designed systems power flow equations were modelled using modified Gauss – Seidal method and thereafter simulated using ETAP software. Result showed that the peak load period in the University is between 1400 – 1600 hours. During rainy season, hydro from Otamiri river inside FUTO serving as a micro – dam proves to be preferred source. The hostel which accounts for over 22.5% of the load is recommended for the use of diesel generator at night if the utility is not available. This ensures that the battery storage system recommended for security lights around the university lasts longer.

Keywords: *Electricity, Distribution network, Utility, Battery storage, Integration.*

INTRODUCTION

Modern power system should be flexible to allow more energy sources to be integrated into the system. The use of electricity directly or indirectly affects the socio-economic growth of any society. This is because a reliable and available electricity brings many businesses and organization into an area thereby increasing the numbers of labours, capital and population.

This makes energy particularly electricity the most important inputs for industrial, service, and commercial sectors of any economic system (Kabeyi and Olanrewaju, 2021). The integration of energy into an existing network in an educational environment plays a major practical role in advancing both the research output of the community and economic transformation of both the school and neighbouring communities. Electricity not only attracts students and enhances their learning experience; it can also enhance staff retention and lead to better teacher training (Electricity and education, 2014). The integration of more energy sources to a power system boosts the availability of power and gives the consumers the options in their choice of the type of electricity consumed. Numerous sources of power that can be integrated to the Power system includes solar photovoltaic, fuel cells, wind turbines, power electronic and interfaces, information and communication, and supervisory and control (NRE). This integration of more energy sources is known as Distributed Generation (DG). DG is a small-scale power generation that is usually interconnected with the electric power system near to the load centers (Mohammadi and Faramarzi 2012; Mahajan and Vadhera, 2016; Onlam *et al.*, 2019). The inclusion of both renewable and non-renewable energy sources into a power system is to eliminate intermittent power supply. Satisfaction of energy demand call for uninterrupted integration of renewable energy resources in the power production system (Shahid, 2018).

Distributed generations fed into the electricity network could potentially pose some challenges to the power system operators due to the quality of the power (Gersema G., and Wozaba, 2019). These challenges include, downward flexibility of reducing the generation to match demand during situations of low demand, voltage fluctuation and stability issues. The need for a constant and reliable power supply to educational institutions is highly commendable. A reliable power supply is hard to be achieved in Nigeria due to lack of enough generation to match the demand in the country. The challenges facing adequate power supply in the country includes; weak grid network, insufficient distribution transformers, faulty switch gears, inconsistent government policies, poor payment of tariffs by the consumers etc. Before now, institutions were operating on either public power supply or stand by generator, not minding its abundance and dispersed renewable energy resources within their localities. Recently, many institutions have realized that these scattered resources can be put to use, but were hampered by lack of unified local energy network model and scattered/uncoordinated unit generators. Institutional based community are dense with several faculties, units, and sections that requires optimal energy access for its daily operations, but lack of institutional distribution Network system deprive the schools from harnessing available potentials. Renewable energy within academic communities varies, random, and uncertain, considering some environmental factors. Some institutions have considerable intensity of sun, which could permit solar energy production, some have a running micro-river within their environment, which would have encouraged hydro energy generation. Institutions in coastal and desert areas have wind energy potentials, but lacks energy integration model to manage these resources effect synchronization. Different faculties, units and sections have varying energy demand. These inadequacies may pose instability to the modelled distribution network, as well as imbalances to load supply (Bayer and Marian, 2020). In view of the aforementioned problem, there is a need to develop an institutional based power system with seamless energy integration model.

MATERIALS AND METHODS

2.1 FUTO Distribution Network

The FUTO network architecture is designed to manage the energy available for the university community. The network consists of 14 different buses with respective loads attached as in Fig. 1.

i. The supply from EEDC (utility) goes to Bakasi Bus (1) as Slack bus, with the loads from FUTO Consult, Gender Center, Health Center, Okiro Building and Hall of Mercy.
ii. Bus 2 is the Church bus, with the loads from St. Thomas Church, Anglican Church and All Saints Church.

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iii. Bus 3 is the Hostel bus, with the loads from hostel A, B, C and D, and special student hostel.
iv. Bus 4 is the staff school, with its loads from Primary School, Child Development Center, Secondary School, Stadium and Guest House.
v. Bus 5 fed the SEET Complex, with loads from SEET complex, Mechanical, Chemical and Petrochemical Engineering building, ICT building and lecture office complex.
vi. Bus 6 fed the Old SEET Complex, with loads from Old SEET, and New Biological building.
vii. Bus 7 fed the Old Registry, with loads from old registry, Estate and Works departments, Lecture Hall, and business centers.
viii. Bus 8 fed the Workshop, with loads from Workshop II & III, Micro Community Bank, PG lecture hall, FUTO Cooperative building.
ix. Bus 9 fed the RGS & FUTO Library, with loads from P.H.S building, FUT HB, and Fast-food centers.
x. Bus 10 feds the SAAT, with loads from old SAAT, new SAAT, center for nuclear energy, and SAAT auditorium.
xi. Bus 11 feeds the SOPS, with loads from SOPS building, SLTP building, Physics department building, and Computer Science building.
xii. Bus 12 feeds the School of Health Building (SOHS), with its loads from school of health, old SMAT, SOES building and SOGS.
xiii. Bus 13 feeds the SMAT, with its loads from SMAT building, SICT, Entrepreneurship center.
xiv. Bus 14 feeds the Senate building, with its loads from senate building, research center, FUTO water and convocation arena.

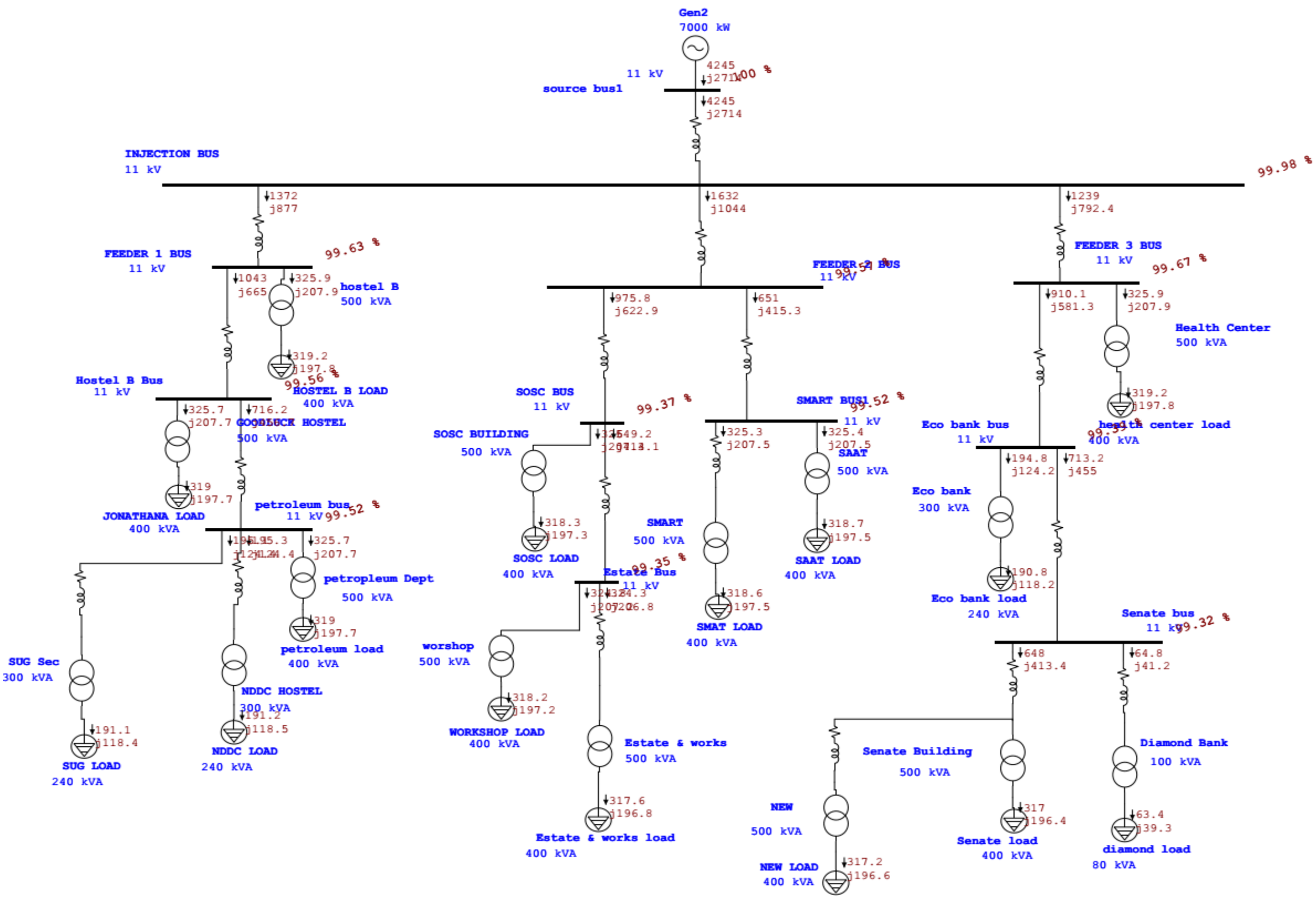

Fig. 1 One-line diagram of the 12-bus FUTO distribution network

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The Load Estimation for the FUTO network obtained from load audit carried on each building and units in the community to obtain the load for each buses was forecasted to be 3189.2 kW peak Load demand. This is distributed to daily energy demanded from various buildings in the school community, thus giving a total average load of 42550 kWh/day; average of 3320 kW Load, with a factor of 0.56 as shown in Table-1.

Table-1 Load Profile of Futo Distribution Network Model

S/N	Bus	Load Demand (kW)	Load Consumption (kWh/day)
1	Bakasi (Slack)	200	2563.25
2	Church	150	1922.44
3	Hostel	750	9612.20
4	Staff School	300	3844.88
5	SEET Complex	180	2306.93
6	Old SEET	200	2563.25
7	Old Registry	180	2306.93
8	Workshop	200	2563.25
9	RGS & FUTO Library Bus	180	2306.93
10	SAAT	200	2563.25
11	SOPS	200	2563.25
12	SOHT	200	2563.25
13	SMAT	180	2306.93
14	Senate Building	200	2563.25
Total		3320	42,550

2.2 System Architecture

The proposed system configuration architecture for the Estimated Load Profile of FUTO is shown in the Fig. 2. Due to scarcity of energy in the institution, renewable energy sources are optimized to obtain the power generated from these energy sources, and then their contribution to the energy needs of the institution are evaluated. The power supplied by each of the renewable energy sources are evaluated as in the following:

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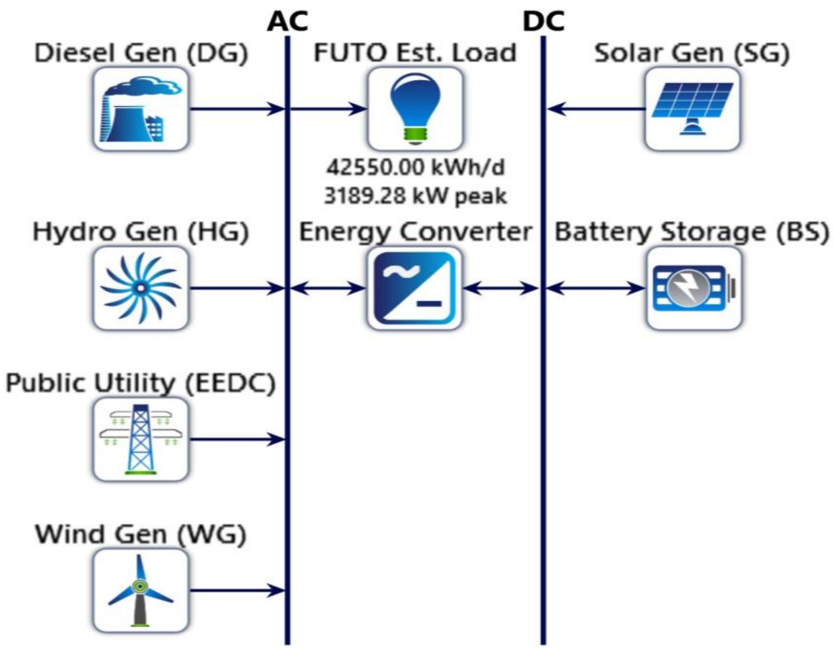

Fig. 2 Proposed system architecture

A. Solar

A solar PV installation is made up of four different solar configurations; stand-alone or off-grid, grid tie, grid tie with power backup and grid fallback (Haruna and Nasiru, 2014). The main components of a grid-tied solar PV systems with backups include the PV array, battery storage unit, energy converter unit and the local utility grid (Koko, 2022). The configuration used here is the grid tie with backup. The components of a solar PV system for a grid tie scenario includes; solar panels, battery systems and the inverter. The sizing of the above components is shown in equations (1-3) for inverter, battery systems and solar panels respectively.

Inverter size = 1.30 x total wattage of appliance (1)

Where the total wattage of the appliance here refers to the energy need of FUTO.

$$\text{The battery capacity for a solar system} = \frac{total\ Watt-hour \times days\ of\ autonomy}{Inverter\ efficiency \times discharge\ rate \times battery\ voltage} \quad (2)$$

$$\text{Number of PV panels} = \frac{W_P}{rating\ of\ each\ panel\ (Watts)} \quad (3)$$

Where W_p = Total daily Watt-hour peak required from the PV modules.

B. Hydro

The source of hydropower for the institution is the Otanmiri river. The hydropower potential of Otanmiri river based on the basic information concerning the river flow, discharge rate and depth cross-section are adequate for power generation (Okorafor *et al.,* 2013). The power generated from a hydropower is given in equation (4) (Sule *et al.,* 2011).

$$P = Q * \rho * g * H * \eta \quad (4)$$

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Where, P = Power generated in, kVA
g = acceleration due to gravity, ms^{-1}
Q = flow rate in the pipe (m3/s)
H = waterfall height (m),
η = global efficiency ratio (usually between 0.7 and 0.9)
ρ = density (kg/m3),

RESULTS AND DISCUSSION

The results from the institutional distribution architecture as designed in Fig. 2 is presented in this section. The hourly load consumption profile and Load demand per building are as shown in Fig. 3-Fig. 4 respectively.

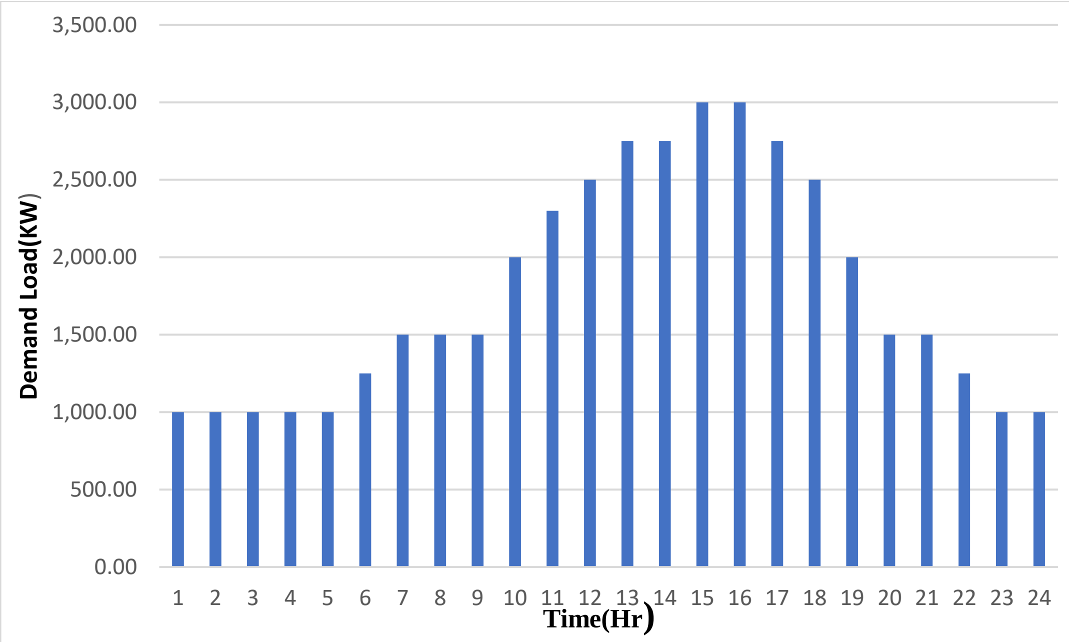

Fig. 3 Hourly Load Consumption Profile.

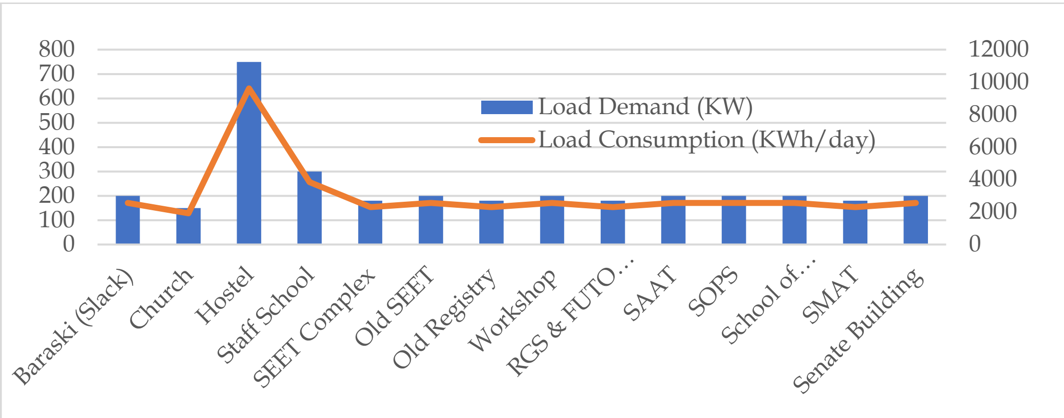

Fig. 4 Energy Requirement and daily load Consumption per Building.

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From the hourly consumption profile in Fig. 3, it showed that more energy is consumed within 1500 and 1600 hours corresponding to the periods when lectures are winding up and many students have gone to the hostel while majority of the staff are still in the office. The hostel accounts for the highest amount of energy consumed with over 22.5% of the total energy consumption in the institution while the church with over 4.5% accounts for the least energy consumed as it is not a regular arena. The sizing and units of the system parameters of each generating source are shown in Table-5.

Table-5 General Sizing Parameters for Designed System Model

Component	Name	Size	Unit
Generator	Diesel Gen (500 KW)	500	kW
PV	Solar Gen (PV modules)	9,991	kW
Storage	Battery Storage (2100Ah)	207	Strings
Grid	Public Utility (EEDC)	1,700	kW
Wind turbine	Wind Gen (WG)	271	ea.
Hydroelectric	Hydro 100kW	98.1	kW

The university community pooling model proposed in this research allots the energy demand to various energy sources, integrating both renewable energy and non-renewable sources alongside the public utility supply, as shown for the proposed system architecture is illustrated in Table-6.

Table-6 Percentage Power allocations for Energy Resources

Energy Sources	Percentage Allotment	Power Rating (KW)
Grid (EEDC)	50	1660
Solar Gen	19	631
Diesel Gen	15	498
Wind Gen	13	432
Hydro Gen	3	100
	100	3320

CONTRIBUTION TO KNOWLEDGE

An improved institutional distribution network/architecture was developed with an integrating model for seamless renewable system for Federal University of Technology, Owerri. It can equally be implemented in other Universities or similar institutions to improve their power supply conditions.

CONCLUSION

As the cost of generating energy is increasing, various steps towards exploring various cheaper means of power generation especially to an academic/research institution becomes sacrosanct. The utility grid system which is the popular means of energy supply has been proven not to be enough for a reliable power supply. However, each of the other means of power generation have its own challenges hence the development of development of institutional distribution network system for seamless energy integration in FUTO which ensured that each generating source has allocation that suits its availability. During the night, diesel powered generator is recommended for the hostel if the utility is not available while the battery storage system is used for security lights around other areas of the university.

CONFLICT OF INTEREST

There is no conflict of interest for this research work.

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