Feasibility Study and Analysis of a Micro-Grid Scheme for Federal University of Technology, Owerri, Imo State, Nigeria

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ABSTRACT

The need for reliable, robust, clean and secure electrical energy has led to developments in distributed off-grid solutions. This work considers various distributed generation sources such as; hydro, solar and wind, within the specified environment. Its aim is to ascertain the most feasible micro-grid solution for the specified campus environment. The work evaluates various micro-grid models to ascertain the most suitable model for the campus environment. HOMER micro-grid optimization software was used to aid the analysis. The micro hydropower plant at Otamiri River was found to be a good source with the power output of 586kW, and cost of energy per kWh of $0.284. Consequently, the model of the micro-grid was further analyzed in MATLAB/Simulink to determine the behavior of the system. The effect of load variation and short circuit fault was observed, and it shows the performance of the system to be stable.

Key Words: Micro-grid, Distributed Generation, Wind, Power, Solar, Micro-hydro.

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1. INTRODUCTION

Around the world, conventional power system is facing the problems of gradual depletion of fossil fuel resources, poor energy efficiency, and high vulnerability to natural disaster, cyber-attacks and environmental pollution. Various steps are being taken to address these problems and equally improve the system for cost effective supply of reliable electrical energy. This has led to a new trend in power generation at the distribution voltage level by using non-conventional/renewable energy sources like natural gas, biogas, wind power, solar photovoltaic cells, fuel cells, combined heat and power (CHP) systems, and micro-turbines and their integration into the utility distribution network [1].

This type of power generation is termed as distributed generation (DG) and the energy sources are termed as distributed energy resources (DERs). The term 'Distributed Generation' has been devised to distinguish this concept of generation from centralized conventional generation (traditional power generation) systems.

In order to realize the emerging potential of DG, the Distributed Resources (DR) and the associated loads are interconnected as a small power system that is called a micro-grid. A Micro-grid system is an aggregation of electrical/heat loads and small capacity on-site micro-sources operating as a single-controllable unit at the distribution voltage level [1]. By allowing multiple generation assets to provide power for a common load, a micro-grid has the potential to greatly increase both the reliability of power and the efficiency of generation [2].

Consequently, the power reliability need of the Federal University of Technology, Owerri (FUTO) campus calls for the consideration of a campus micro-grid especially that which can supply power to the student's hostel, considering the reliability issues associated with utility power supply and high cost of running diesel generators. Distributed generation can help deal with the power instability issues, but its success depends largely on a good feasibility study, to ascertain that its deployment will deliver its promises, without any loss in revenue, time and energy.

2. LITERATURE REVIEW

2.1 History Of Distributed Generation and Microgrid

The early power systems served just a few blocks of the city, produced DC power, and had a total generating capacity of initially less than 1 MW [3]. By today's standards, this is right in the size range of distributed generation, and given to the limited area served, they can certainly be classified as a micro-grid. As late as 1918 about half of the customers in most towns and small cities were still receiving their power from small-scale isolated power systems with generation plants sized well under 10 MW in capacity [4]-[8]. Therefore, each town operated as an independent island— micro-grid. In addition to the small-town and city systems, smaller micro-grids composed of individual businesses such as hotels, industrial plants, and commercial offices often operate their own power systems, combining heat and power. However, the early micro-grids were not particularly reliable because only one power plant supplied all of the energy needed. If that plant fails, then the whole system will collapse. Early power system engineers considered interconnecting some of the systems to improve reliability. These concepts began to make people consider that isolated micro-grids should be interconnected into a larger system [5]. In the past, there was little standardization of frequency, and so many systems were not inter-connectable. Some systems are Direct Current (DC) systems, while others are Alternating Current (AC) systems supplied at various frequencies between about 25 Hz and 100 Hz. Methods of synchronization, protection, and control of remote plants were also still in their infancy then, so this was a barrier to interconnection as well.

Between 1910 and 1920, various technological innovations and other development emerged which set in motion the movement away from the early micro-grids and toward a system based upon increasingly large-scale central-station plants interconnected via transmission lines. Isolated micro-grids offered by competing utilities, gave way to a monopoly system featuring centralized power plants owned by utilities.

3. MATERIAL AND METHODOLOGY

3.1 DESCRIPTION OF STUDY AREA

The feasibility of micro-grid scheme for Federal University of Technology, Owerri is studied. This area is located at latitude of 5°, 2' 60N and longitude of 7°, 22' 60E at an altitude of about 156 meters (511 feet) above sea level [6]. The mean annual maximum and minimum temperatures are 33.5°C and 22.5°C respectively and the relative humidity is 80%. The mean annual rainfall of the study area is 789mm [7].

3.2 FEASIBILITY, OPTIMIZATION, AND SENSITIVITY ANALYSIS

To analyze a suitable distributed generation design, first, ascertain the most feasible option. By collecting the various data of available distribution energy resources and analyzing the data with HOMER, the most feasible option can be determined. Once determined, a design of the most optimal option is done in order to analyze the response of the system to various changes.

3.3 OVERVIEW OF HOMER

HOMER (Hybrid Optimization Model for Electric Renewable) is a software application that models hybrid power systems (or micro-grid) to determine if a micro-power system can provide for a particular load and how much the system will cost to install and maintain for the life of the project. It is a modeling application that works in three parts:

- simulation,
- optimization, and
- Sensitivity analysis.

When conducting a simulation, HOMER will analyze a system each hour of a year to determine its technical feasibility. It then generates life cycle cost estimates for that system. When optimizing a system, HOMER seeks to determine the most cost effective system arrangement by scaling the various components in the system. The third process is sensitivity analysis, in which HOMER determines the robustness of the optimized system in response to changing variables that are external to the system [8].

3.2 LOAD

The load applied for the study is the student hostels of the federal university of technology Owerri. The hostel is empowered currently by diesel generator of 500KVA during peak load period (from 19:00-23:59). Using a power factor of 0.8 the real power is 500*0.8 = 400 kW. The electrical load is 3.2Mwh/day and 400kW peak load demand.

3.5 DISTRIBUTED GENERATION RESOURCES INVESTIGATED

In the design of hybrid power station (or micro-grid), both the feasibility of the design and the economic implication of each design arrangement is of great importance. In feasibility study using HOMER, the following DG sources are to use to design a micro-grid that will supply the load in the most efficient and cost effective combination. This DG sources were chosen because of their potential availability in the study area. By providing the environmental factors and the nature of cost, each to HOMER

during simulation, analysis could be done to determine both feasible design, most optimal design and how sensitivity factors external to the design affects the most optimal choice.

- Solar Energy
- Micro-hydro power
- Wind Turbine
- Diesel generator and
- Storage system.

SOLAR PV

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV) or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic which are our focus here convert light into electric current using the photovoltaic effect. A solar cell, or photovoltaic cell (PV), is a device that converts light into electric current using the photovoltaic effect. Solar cells produce direct current (DC) power which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages of alternating current (AC), through the use of inverters. Multiple solar cells are connected inside modules. Modules are wired together to form arrays, then tied to an inverter, which produces power at the desired voltage, and for AC, the desired frequency/phase. PV cells are robust, with an average lifespan of 25 years, require little maintenance and can be deployed at the household level; consequently, they stand as effective distributed energy resource for micro-grids.

The solar radiation of Owerri, the study area was obtained from [9] as shown in Table 1.

Table 1: Monthly solar radiation of Owerri and clearness index [9]

	Insolation, $kwh/m^2/day$	Clearness Index
January	5.78	0.61
February	5.87	0.59
March	5.43	0.52
April	5.09	0.49
May	4.74	0.47
June	4.36	0.44
July	3.89	0.39
August	3.79	0.37
September	3.96	0.39
October	4.27	0.43
November	4.89	0.51
December	5.41	0.59

The average solar radiation of the area is 4.79 $kWh/m^2/day$ and average clearness index of 0.4833.

3.6 ENERGY OF THE PV ARRAY

The power delivered by the PV array (Ep) can be calculated as:

$$E_p = p\eta P_A H_t \qquad\qquad 1.1$$

Where;

$p\eta$ = *Efficiency*

P_A = *Power per square meter per day*

H_t = *Area of PV module*

As stated above, the average data energy available for a tilted solar panel per square meter per day is 3.79kWh/m^2 by August while the available maximum power is 5.87kWh/m^2 by February.

The average energy that can be produced by a square meer solar panel for this area at 100% efficiency will be 4.79kWh/day.

With a PV module comprising an amorphous and microcrystalline silicon film with an established module efficiency of 15% and standard 2ft by 2ft (0.744m^2) panel, will produce from each panel:

Ep = 0.15x0.774x4.79 = 0.5346kWh per day.

This is equivalent to 22.275W.

Therefore, to generate 50kW, abut 50000/22.275 standard PV module is required. This is equal to 2245 module and will cover an area of about 2245x8 = 17960ft = 1,668,539m^2.

COST DETAIL OF SOLAR PV

The cost of PV array is taken as shown in table 2. The cost detail was obtained from [10].

Table 2: Solar PV cost detail

Installation cost ($/kW)	Replacement cost (($/kW)	O & M ($/kW)
5100	4800	10.0

While simulating, a de-rating factor of 80% is applied to account for the degrading factors by temperature, soiling, shading, etc. The daily radiation (in kWh/m^2/day) and the clearness index of Owerri are shown by figure 1.
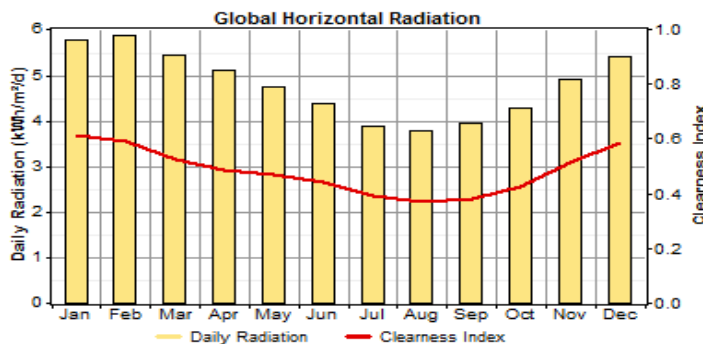

Figure1: Bar chart of Solar Radiation of Owerri

3.7 MICRO HYDRO TURBINE

Otamiri River located within the study area has the following hydrological data. This is from hydrological data collected from Imo River Basin for the 1986/87 and 1987/1988 hydrological year [9]. The river is located at LAT: 05° 26'N and LONG: 07° 02'E with a catchment area of 100 sq. Km. The summary of the data is shown table 3.

Table 3: Water Stage and Water Discharge of Otamiri 1987 [9]

Month	Water stage (m)		Water Discharge (m^3/s)		
	Minimum	Maximum	Minimum	Maximum	Average
JAN	0.96	1.00	8.86	9.10	9.08
FEB	0.96	1.00	8.54	9.08	8.65
MAR	1.29	0.95	8.40	8.96	8.96
APR	0.96	0.99	8.54	8.96	8.60
MAY	0.96	1.04	8.54	9.68	8.84
JUN	0.95	1.04	8.40	9.68	8.71
JUL	0.92	1.05	7.98	9.80	8.87
AUG	0.91	1.17	7.84	11.62	8.63
SEP	0.95	1.35	8.40	14.60	9.30
OCT	1.00	1.01	9.10	9.24	9.31
NOV	1.00	1.04	9.10	9.66	9.28
DEC	0.96	1.01	8.54	9.24	8.80

The capital cost for the installation of micro hydro is taken as $3,312,000 with replacement cost of$3,000,000 and operation/ maintenance (O&M) cost of $75,000 per year. The monthly average stream flow of the study stream is shown by figure 2.
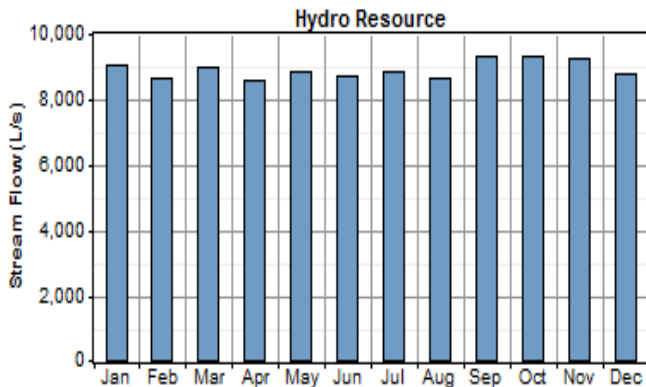
Figure 2: Bar chart of monthly average flow of Otamiri River

3.8 POWER OUTPUT OF THE HYDRO TURBINE

The river has a monthly average flow of 8919L/s taking account of possible change in discharge rate which is placed at 8500L/s (i.e. $8.5m^3/s$) and an average natural head of 0.9m. The power output (P) is calculated thus:

$$P = wQHg\rho \qquad\qquad 1.2$$

Where;

w = density of water (kg/m^3)

Q = discharge rate (m^3/s)

H = design head (Natural or Artificial head)

ρ = Efficiency of turbine (using 75% efficiency)

g = acceleration due to gravity (approx. $9.81m/s^2$)

With natural head of 0.9m, the output power is:

$P = 1000 \times 8.5 \times 0.9 \times 9.81 \times 0.75 \times 10^{-3} = 75.0465$kW.

Considering erection of dam to increase the head to about 8m, the same calculation can be done to observe the difference in power generated. That is with artificial head of 8m;

$P = 9.81 \times 8.5 \times 8 \times 0.75 = 500.31$kW.

3.9 WIND ENERGY DATA

Wind energy exists as a form of kinetic energy. The wind drives a wind turbine which is coupled to an electric generator. The electric generator consequently generates electricity. Electricity from wind energy is produced by using an aero generator, which is an electro-mechanical system.

Table 4: Monthly wind speed of Owerri [9]

Month	Wind Speed (m/s)
January	2.75
February	2.97
March	2.71
April	2.39
May	2,.23
June	2.81
July	3.21
August	3.37
September	2.96
October	2.35
November	2.25
December	2.40

The study area has a very poor wind speed. From data gotten from [9] (shown in Table 4), the average monthly wind speed is 2.7 m/s and monthly average is shown by figure 3.
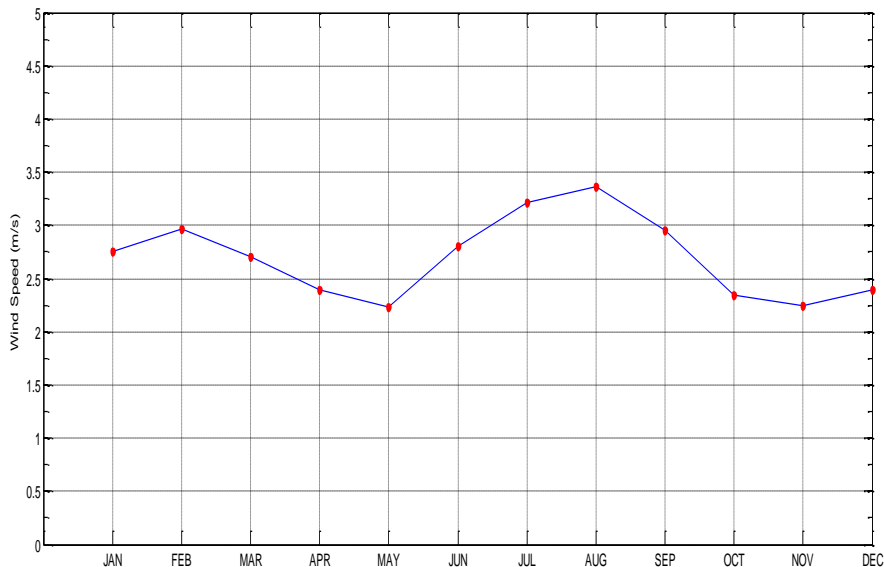
Figure 3: Mean Monthly wind speed of Owerri, Nigeria

POWER OUTPUT OF THE WIND TURBINE

The expression for power out put of a wind turbine is given as thus;

$$P = \frac{1}{2}\rho A c_p V_w^{\ 3} \text{ W} \qquad\qquad 1.3$$

Where;

ρ = density of air,

A = turbine swept area,

V_w = wind speed and

c_p = the coefficient of performance of turbine.

From the wind turbine performance curve, a typical value of c_p is 0.45.

Using a design rotor disc radius of 4m, the turbine swept area can be calculated as thus;

$A = \pi r^2$

A = 3.1416x4x4 = 50.3m^2

Air density = 1.225kg/m^3

The average wind speed of the area is 2.7m/s.

Therefore power output that can be generated is;

P = 0.5x50.3x0.45x2.7^3 = 222.76W.

In simulation of the Wind Energy Solution (WES) – 30 wind turbines with rated power of 250kW AC was selected.

DIESEL GENERATOR

A diesel generator consists of a diesel powered prime mover and an electric alternator for the generation of electricity. The diesel burns in inside the engine and the product of combustion is used as a 'working fluid' to produce mechanical energy which drives the alternator part of the machine.

Diesel generator is also another possible alternative source of energy supply for the area. It is generally used as a back-up power supply due to their flexibility and portability. Also they can serve as power supply for an isolated remote load. Consequently, it will be part of the feasibility analysis. The capital and replacement cost of 20kW of diesel generator is taken as $15,000 with operational, maintenance cost of $0.2/hr. and cost of fuel as $0.96/L. A carbon monoxide of 6.5g/L of fuel, unburned hydrocarbons of 0.72 g/L of fuel, particulate matter of 0.49 g/L of fuel, Proportion of fuel Sulphur converted to PM as 2.2% and Nitrogen oxides of 58g/L of fuel.

BATTERY

The energy storage component to be modeled is DC battery which is to store the energy and retain the energy during peak load periods. In the simulation, it is assumed that battery property of battery remains constant throughout its lifetime and is not affected by external factors. For the simulations Surrette 6CS25P battery is chosen. Surrette 6CS25P is a deep cycle, high capacity, lead acid battery and is most suitable for renewable energy application [11, 12]. The battery technical details are shown in table 5.

Table 5: Surrette 6CS25P battery technical details [12]

Battery Type	Surrette 6CS25P
Nominal Voltage	6V
Nominal Capacity	1.156Ah (6.94kWh
Lifetime Throughput	9.654kWh
Capital Cost	$1.250
Replacement Cost	$1.100
O&M Cost	$15/yr

CONVERTER

The sources being modeled like PV arrays and battery needs their direct current output to be converted to AC. This is achieved using bidirectional converter. This is a device that converts DC power to sinusoidal AC power in inversion process and from AC to DC power in rectification process. The bidirectional converter costs and replacement cost is taken as $800/kW, and O&M cost of $15/yr. for a lifetime of 25 years [19]. The inverter and rectifier efficiencies are assumed to be 85% and 90% respectively.

3.10 HOMER SIMULATION MODEL

The figure 4 shows the system implementation model in HOMER. The solar, wind, hydro and diesel data were used as input in HOMER and the simulation was done to obtain different design configuration and their cost details which HOMER uses to do feasibility analysis of the system to provide the economic implication of each possible system configuration.
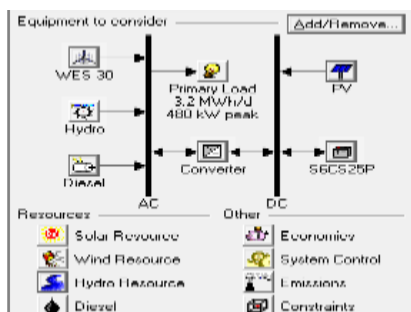

Figure 4: System implementation in Homer (WES 30 wind turbine, Hydro power, Diesel generator, Load, Converter, Solar PV and S6CS25P battery.

3.11 SIMULATION OF THE MOST OPTIMAL MICROGRID

Having determined from the previous section, that the most optimal micro-grid option to be a micro hydro power plant. In this section the proposed hydro turbine is modeled and its dynamic behavior studied.

The schematic diagram of the generation and distribution is shown below, showing the arrangement of key component.
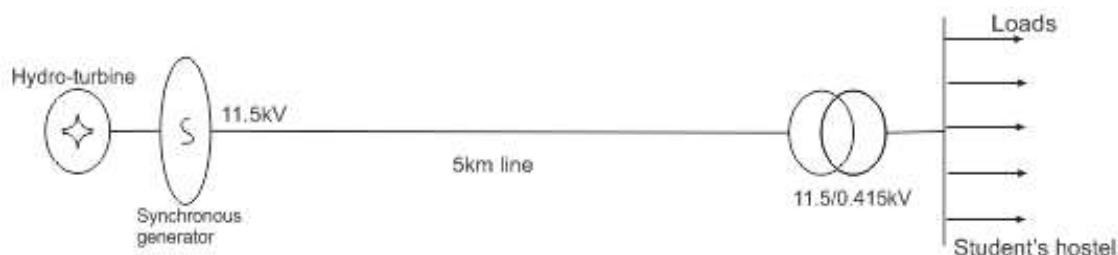

Figure 5: Schematic diagram of the micro-grid (DG is Micro-hydro turbine)

To calculate the rating of each component;

With load power of 450kw, and allowing 80% loading for 33kV/0.415kV transformer should be rated; 450*100/80 = 560 kw

And using 0.8 power factor; the transformer should be rated 700 kVA

And generator rating will equally be 700 kVA

Taking the plant auxiliaries power requirement as 50kw and average steady load of 350 kW, the system was developed in MATLAB Simulink as shown by figure 10.

According to [9], the generator employed in hydro-electric power plants is three phase alternating current synchronous generator.

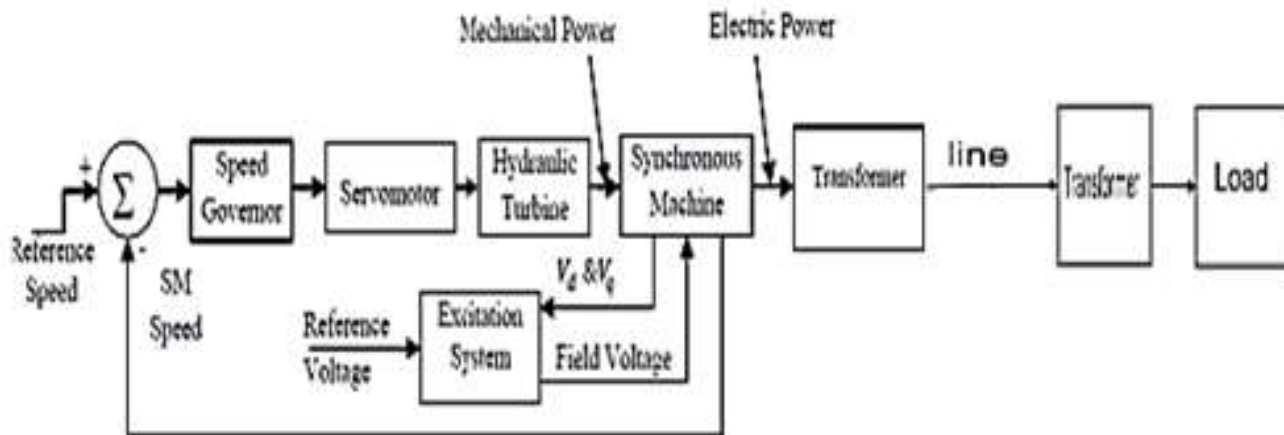The block diagram of entire system is as shown in figure 6.

Figure 6: Block diagram of a hydro turbine micro-grid

3.12 MODELLING THE TURBINE GOVERNOR AND SERVOMOTOR SYSTEM

A governor regulates the speed and power output of a prime mover as a control system. The governor includes mainly a controller function, and one or more control actuators [14].

Nowadays, speed governors for hydraulic turbines uses electro hydraulic systems. The Electro-Hydraulic governor uses the three-term controllers with proportional-integral derivative action, PID-controller, to perform the low-power functions [15].

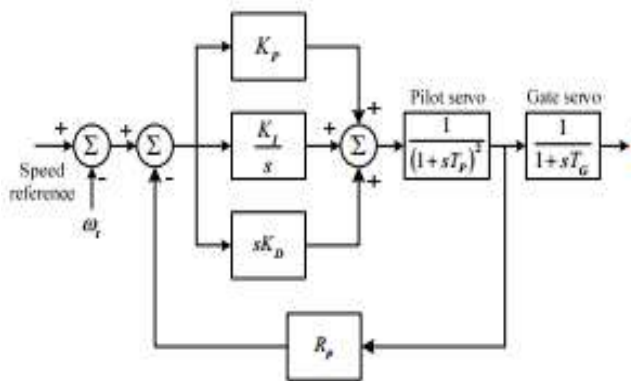The block diagram of a PID controller is shown by Figure 7.

Figure 7: Typical PID Governor Controller, [16]

Where,

K_p= Proportional gain

K_i = Integral gain

K_d = Derivative gain

e = Error

t = Time or instantaneous time (the present)

Tp = Pilot servo motor time constant

T_G = Gate servo motor time constant.

R_p = Permanent speed droop, [pu]

The **permanent speed droop** R_p determines the amount of change in output a unit produces in response to a change in unit speed.

3.13 MODELLING OF TURBINE

Figure 8 shows the block diagram of the general form of nonlinear hydraulic turbine-penstock model as presented by [17].
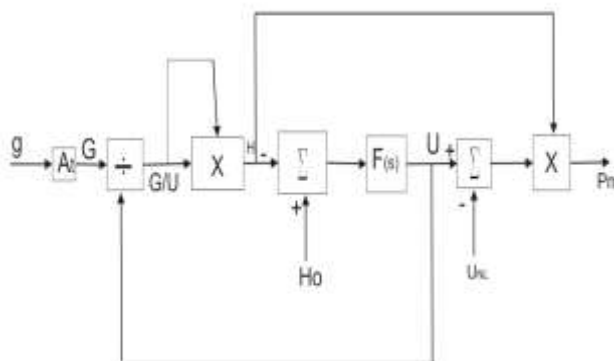

Figure 8: General form of nonlinear hydraulic turbine-penstock model

where,

g = gate opening

At = turbine gain

H = normalized head

UNL = normalized velocity of water.

Ho = head at steady state.

Using simplified nonlinear model which neglects the traveling pressure wave and water compressibility is neglected. Then, F(s) is described as:

$$F(s) = - \frac{1}{sTw} \qquad\qquad 1.4$$

$$Tw = \text{Water starting time (s)}$$

Pm = mechanical power developed.

$$At = \frac{1}{Gmax - Gmin} \qquad\qquad 1.5$$

Gmax = Full load maximum per unit gate opening (taken as 0.01)

Gmin = No load per unit gate opening (taken as 0.975)

Therefore, At = 1.03627

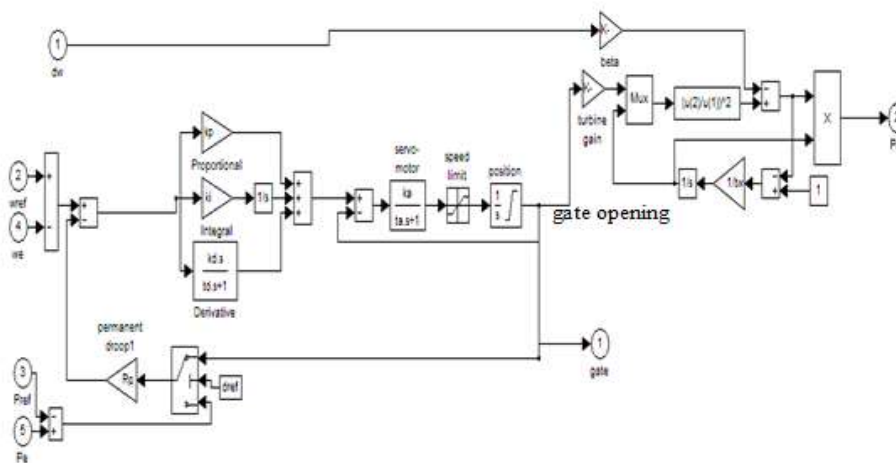The complete model in MATLAB Simulink is shown by figure 9.

Figure 9: Hydro turbine model in MATLAB Simulink.

Where,

Wref = Reference speed, in pu.

Pref = Reference mechanical power in pu. This input can be left unconnected   if you want to use the gate position as input to the feedback loop instead of the power deviation.

We   = Machine actual speed, in pu.

Pe0   = Machine actual electrical power in pu.

Dw = Speed deviation, in pu.

Pm   = Mechanical power Pm for the Synchronous Machine block, in pu.

The values of the parameters for the turbine and governor system used for the simulation are shown in table 6.

Table 6: Turbine and Governor Parameters

Parameter	Name	Value
Ta(s)	Servo motor time constant	0.07
Rp	Permanent speed droop	0.05
Kp	PID proportional constant	1.163
Ki	PID integral constant	0.105
Kd	PID derivative constant	0.00
Tw	Turbine time constant	2.67

The parameters of the turbine are modeled in per unit so that it can always fit to the specification of the synchronous generator to be connected.

Connecting the turbine model to Simulink synchronous generator module and excitation system, the line, transformer and load, the complete system was developed in MATLAB Simulink as shown by figure 10.
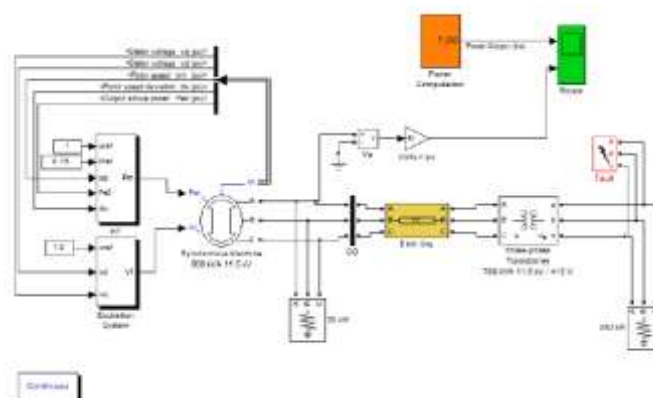

Figure 10: Isolated micro-grid of hydro turbine in MATLAB Simulink

4.   RESULTS AND DISCUSSION

Analysis of distribution generation resources within FUTO community was done and simulations carried out to:

1. Determine and demonstrate the most feasible option (economically and otherwise) for powering the students' hostel using distributed generation. (HOMER simulation utilized)
2. To analyze the dynamic nature of the most optimal system and its response to changes in load and short circuit fault at the load end.

4.1 POSSIBLE FEASIBLE CONFIGURATIONS

From the analysis done with HOMER, below is the possible micro-grid design configurations arranged in a tabular form starting with the most economical design. The result equally shows the Net Present Cost, Initial Capital, electrical power developed and Cost of Energy (COE)of feasible options. This result is shown in Table 7. All cost is in USD.

Table 7: Feasible Configurations (HOMER result)

PV (kW)	WES30	Hydro (kW)	Dsl (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Dsl (hrs)
		589				$ 3,312,000	60,444	$ 4,049,294	0.284	1.00	0.00		
		589		4	20	$ 3,333,000	61,085	$ 4,078,107	0.286	1.00	0.00		
		589	350			$ 3,574,500	56,098	$ 4,258,780	0.299	1.00	0.00		0
		589	350	4	20	$ 3,595,500	56,739	$ 4,287,592	0.301	1.00	0.00		0
50		589			20	$ 3,583,000	61,344	$ 4,331,272	0.304	1.00	0.00		
50		589		4	20	$ 3,588,000	61,585	$ 4,339,206	0.305	1.00	0.00		
50		589	350		20	$ 3,845,500	56,998	$ 4,540,757	0.319	1.00	0.00		0
50		589	350	4	20	$ 3,850,500	57,239	$ 4,548,691	0.319	1.00	0.00		0
	1	589				$ 4,312,000	70,368	$ 5,170,346	0.363	1.00	0.00		
	1	589		4	20	$ 4,333,000	71,009	$ 5,199,158	0.365	1.00	0.00		
	1	589	350			$ 4,574,500	66,022	$ 5,379,831	0.378	1.00	0.00		0
	1	589	350	4	20	$ 4,595,500	66,663	$ 5,408,644	0.380	1.00	0.00		0
50	1	589			20	$ 4,583,000	71,268	$ 5,452,324	0.383	1.00	0.00		
50	1	589		4	20	$ 4,588,000	71,509	$ 5,460,257	0.383	1.00	0.00		
50	1	589	350		20	$ 4,845,500	66,922	$ 5,661,809	0.397	1.00	0.00		0
50	1	589	350	4	20	$ 4,850,500	67,163	$ 5,669,743	0.398	1.00	0.00		0
	1		350	60	80	$ 1,401,500	540,544	$ 7,994,991	0.561	0.23	0.00	395,423	6,080
50	1		350	60	120	$ 1,688,500	526,680	$ 8,112,879	0.569	0.26	0.00	382,415	5,907
	1		350			$ 1,262,500	643,219	$ 9,108,408	0.640	0.12	0.01	468,407	7,532
			350	60	80	$ 401,500	715,280	$ 9,126,403	0.641	0.00	0.00	535,201	7,962
100			350	60	120	$ 943,500	678,349	$ 9,217,913	0.647	0.00	0.00	503,429	7,549
50	1		350		20	$ 1,533,500	635,437	$ 9,284,480	0.653	0.14	0.01	461,092	7,468
			350			$ 262,500	760,239	$ 9,535,795	0.671	0.00	0.01	567,314	8,760
50			350		20	$ 533,500	756,173	$ 9,757,204	0.687	0.00	0.01	562,142	8,760

= Solar PV module, = Wind turbine, = Hydro turbine, = Diesel generator
= Battery, = Converter.

From table 7, it can be seen that micro hydro power is the most optimal. It has power output of 586 kW with Initial capital cost of $3,312,000, operating cost $60,444, total net present cost of $4,049,294 and cost of energy per kWh of $0.284.

4.2 STREAM FLOW EFFECT ON OPTIMAL SYSTEM TYPE
The result depicted by figure 11 shows how optimality of the systems are affected by changes in flow rate and wind speed. It can be seen that as far as the stream flow exceeds 5500m^3/s, hydro turbine is the optimal system type.
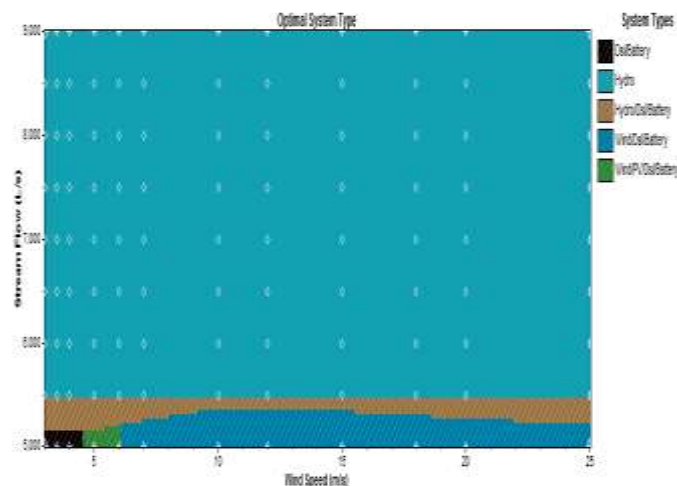

Figure 11: Optimal system type

With the flow rate below 5500m^3/s, other options are more feasible, such as hydro, diesel and battery combination. With a higher wind speed above 5m/s, systems incorporating wind turbine are also feasible.

4.3 CHANGES IN HYDRO PRODUCTION TO STREAM FLOW RATE
The result shown in figure 12 shows the amount of power that can be generated from hydro at different flow rates within the range of 4m^3/s and 7m^3/s.
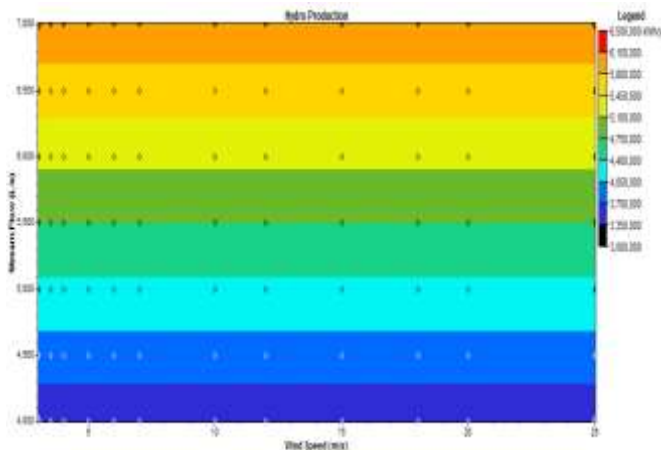

Figure 12: Variation of Energy to charges in flow rate.

4.4 POWER CURVES AND VOLTAGE WAVEFORMS OF MODELED HYDRO PLANT MICROGRID
As seen in previous section, micro hydro power plant is the most optimal DG, and consequently, the model of the system was developed. Figure 13 shows the graph of the system power and voltage waveforms during start-up and steady state operation, plotted against time, t.
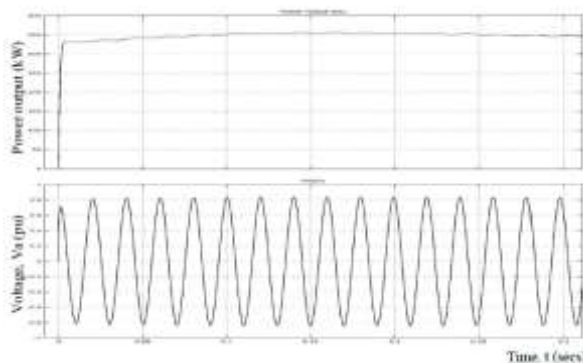

Figure 13: Power and voltage waveform during start up and steady state operation.

The simulation was run from time, t = 0 to t = 2 secs.
Figure 14 shows the same plot of power and voltage waveforms with sudden rise in load by 50kW at time, t = 1secs. This shows that such increase within the capacity of the system have minimal effect on the voltage waveform.
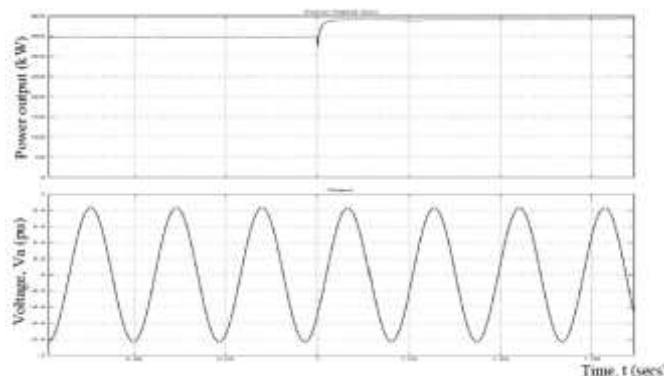

Figure 14: Power and voltage waveform during load variation.

Short circuit fault that occurs at time, t = 1 secs and cleared after 0.1 secs was equally simulated as shown by figure 15. Both power and voltage waveform experienced serious distortion which made the voltage waveform tends to zero.
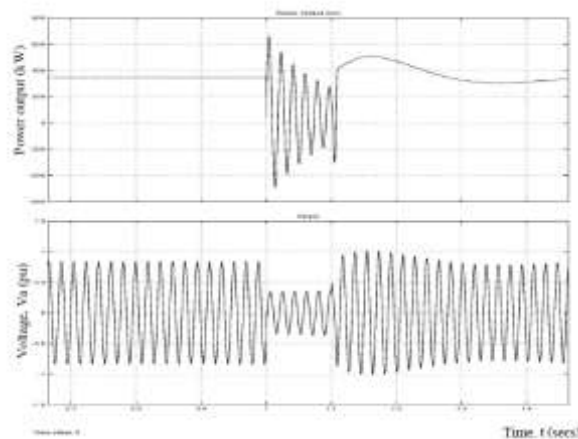

Figure 15 Power and voltage waveform during short circuit fault.

As an island micro-grid, system design should take account of this response and fast response protection systems installed to enable quick fault clearing to avoid instability of the system and to protect the synchronous generator.

5. CONCLUSION

Nigeria and indeed FUTO community is endowed with many distributed generation potentials which can be utilized in microgrid design and consequently help to increase reliability and stability of power supply. Fromthe analysisofthe various distributed generation resources, this paper hasshown that the most feasible option for providing power to the students' hostel is microhydro power plant from Otamiri. This was shown to be both economically and technically viable and being a clean source of electrical power will pose no environmental challenge and will equally save the cost of diesel currently used as a back-up power to utility supply. Further analysis hasalso shown that such asystem can operate in a stable mode. With good understanding of micro-grid systems, as this paper unveils, we can prepare for its most optimal and feasible deployment.

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