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Modeling of a Microgrid

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Abstract: *To address the trend of power failure, there is need to develop a model capable of efficiently managing the power supply system. In this study a microgrid was modeled and simulated for the Federal University of Agriculture Abeokuta (FUNAAB), Ogun State to manage the power supply challenge. Facilities audits were carried out within the University campus. Matlab/simulink was used to model a microgrid for (FUNAAB). Facilities audit revealed that FUNAAB had a total power generator rating of 6130kVA. From the load audit the generator capacity could be aggregated into three power houses of 2 x 2000kVA and 1 x 1950kVA. The remaining 3 x 60kVA generators were left unaggregated to serve as auxiliary/back up. The total power from PHCN was 2100kVA and 2 x 2000kVA for the proposed power houses 1 and 2 when synchronized. However, there would be need to upgrade the power transformer of rating 2000kVA (11/0.415kV) to 2 x 2500kVA (11/ 0.415kV) for this purpose and for future expansion. The proposed power house 3 could then serve as a backup. The modeled microgrid could be used in the development of supply infrastructure for estates, communities, organizations and establishments.*

Keyword: *Communities, organization, development, infrastructure, supply*

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I. Microgrid

Microgrid is an aggregation of loads and micro sources operating in as a single system providing both power and heat. The majority of the micro sources must be power electronics based to provide the required flexibility to insure operation as a single aggregated system. This control flexibility allows the microgrid to present itself as a single controlled unit which meets local needs for reliability and security. In addition microgrids have the capability to isolate themselves from the utility power grid in case of faults in the grid, in order to protect the micro sources and loads within the microgrid. This operation is called the islanded mode, in which the microgrid operates independently until stability is restored in the utility grid. Microgrid contains an energy manager within them which is responsible for maintaining balance between energy demand and supply within the microgrid by the use of energy management strategy, while making sure certain criteria such as minimizing operating cost, fuel consumptions, emissions etc are met. A microgrid is a collection of distributed power generators and loads acting together, (Lasseter *et al.*, 2002).

Micro grid is a power supply network in which a cluster of small on-site generators provide power for a small community such as homes, parks, and office buildings. The increasing interest in micro grid is changing the dependency on the conventional centralized power system. In a centralized power system, power is transmitted from a large source to several utilities through a transmission line and a centralized control and hence can create shortcomings in the efficiency power supply. During disturbances, the generation and the loads of a micro grid can be separated from the main distribution system to isolate the loads from the disturbance and thereby maintaining the continuity and reliability of the service without harming the main transmission grid, (Robert and Paolo, 2004).

Modern micro grids are regarded as small power systems that confine electric energy generating facilities, from both renewable energy sources and conventional synchronous generators, and customer loads with respect to produced electric energy (Smallwood, 2002). They can be connected to the main grids or operated as isolated power systems (Katiraci *et al., 2005*). In the micro grids, alternative energy sources such as renewable can be integrated with local consumptions (Katiraci et al., 2005) and are more efficient and initiate less environmental issues. This, in turn, enables performance optimization and enhances the supply reliability (Moldernik et al., 2010). Furthermore, since micro grids are to be on or near the site which they are to supply, losses due to transmitting electricity is relatively minimized, which makes micro-grids even more useful (Marshal, 2004). Finally, micro grids can be modified according to the needs of the site it will be servicing. For example, it can be used only for lighting purpose or for working on big machinery.

As discussed earlier, micro grid encourages the use of renewable energy sources. Although renewable energy resources, such as wind and solar, enhance the generation capability of a micro grid and address the environmental concerns (Leite da Sila, 2010 et al.,), they impose economic operation and stability challenges to the micro grid due to their unpredictable nature. Power fluctuations caused by intermittent nature of the renewable should be smoothed to serve the demand more appropriately and competently.

II. Methodology

This explained the methodology adopted in this research. It explains the study designs, materials and methods that were adopted from collecting data from the field and modeling of the microgrid.

2.1 Materials

The data used in this study were from works and services of this university; data were collected from logbooks and were analyzed with Matlab. The materials used were: Utility grid, Monthly electric loads consumption, transformers ratings and generators ratings in the university Matlab / Simulink package allows for the following:

Simulation and management of data**.** Firstly, a micro grid model was developed, which comprise of a utility grid, generators, transformers, loads, and the simulation was performed by matlab/simulink version R2012a..

III. Load Audit Calculation

The power demand for electrical components is given by equation (3.5)

$$S = IV \qquad (3.3)$$

$$S = P + JQ \qquad (3.4)$$

$$Where\ P = S\ Cos\ \emptyset = IVcos\ \emptyset \qquad (3.5)$$

$$Q = S\ Sin\ \emptyset = IV\ Sin\ \emptyset \qquad (3.6)$$

$$Where\ P = Real\ power\ (watts), Q = Reactive\ power,$$

$$S = Complex\ power\ or\ apparent\ power, I = Measured\ Current\ (Amperes)$$

$$V = Voltage\ supplied\ (volts)$$

The conversion of power in horse power (hp) to watt is given below:
1hp =746 watts.

IV. Microgrid Model

The following conditions have been met by generators in the university: The source (generator or sub-network) must have equal line voltage, frequency, phase sequence, phase angle, and waveform to that of the system to which it is being synchronized .So from the existing power facilities in the campus, microgrid model was developed and simulated.The generators in the university campus was synchronized. Since we are modeled from existing power facilities and the generators available were low voltage generators, and it is not possible to feed low voltage generators to 11 kV transmission lines. As a result of this, the generators in each proposed power house were aggregated and fed into 2000 kVA transformer to step up the output of the synchronized generators to 11 kV.

It was discovered that there are many generators in the power house and other locations that are not fully utilized and some of these are disadvantages associated with unnecessary dumping of generators across the campus:

i. Environmental pollution and hazard to human health and surroundings e.g. emission of carbon monoxide
ii. Maintenance costs and operating costs are very high since, each generator site has at least a technician
iii. Smoke and heat from generators across the campus is also a factor
iv. Two or three power house schemes will contribute to effective, improved management of energy resources and full utilization of power resources in the campus by all colleges and units of the university.

5.1.0 Advantages of Aggregating Generators

i. It is easy to maintain
ii. It requires lesser operators. Only the proposed power houses will need operators as compared to the system presently running by the university.
iii. The emission of carbon monoxide will be reduced and easy to control
iv. Back up will be available, in case there is fault in one power house, auxiliary/back up power house will be switched on
v. Reliable and save to run
vi. The facilities could be well managed and controlled

vii. The cost of operation and running generators in each colleges and units will be reduced by monitoring the fuel consumption and other important records by each proposed power house
viii. Reduction of noise around the colleges and units

The generators scattered around the various colleges and units of the university with the following disadvantages stated above can be aggregated to form two or more power houses as shown in the Figure1.It showed the microgrid modeled for FUNAAB.

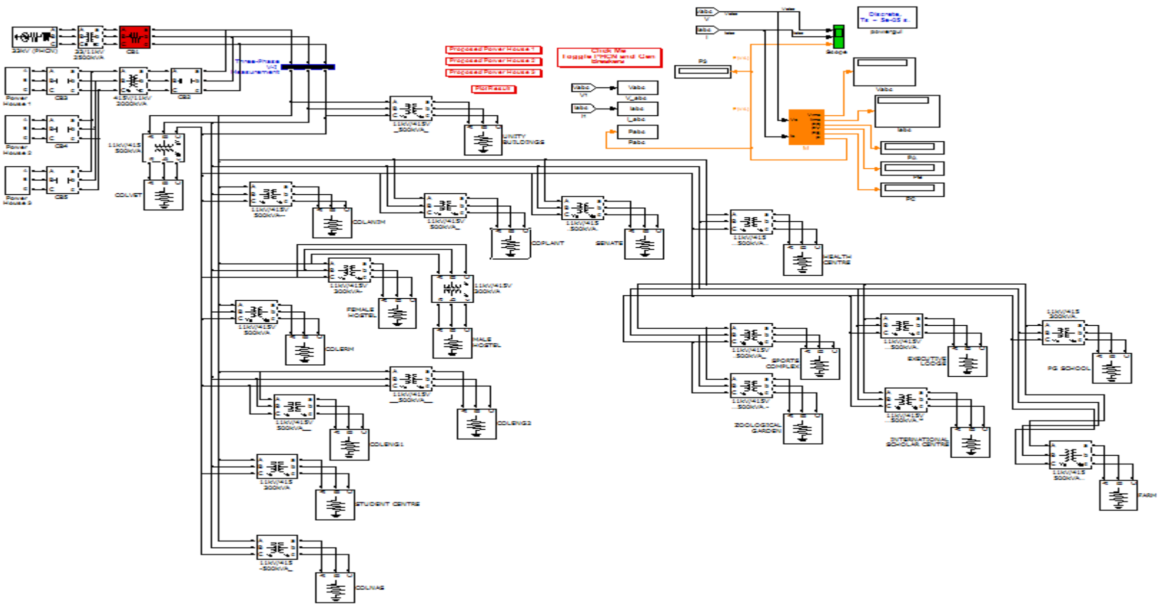

Figure 1: Microgrid developed for Federal University of Agriculture,Abeokuta.

The following generators were aggregated to form the proposed power house 1:1000 kVA generator in the existing power house, 500 kVA in the existing power house and 500 kVA presently in post graduate school and these were aggregated together to 2000 kVA.

Similarly, the following generators were aggregated to form the proposed power house 2 :800 kVA generator in the existing power house, 200 kVA presently in COLNAS, 500 kVA presently in International Scholar Centre, 500 kVA in the present power house and these were summed together to 2000 kVA.

Also, the following generators were aggregated to form proposed power 3: 250 kVA generator presently in Unity buildings, 250 kVA generator presently in Livestock complex, 250 kVA generator presently in executive lodge, 250 kVA generator presently in ICT REC,100 kVA generator in ICT REC,100kVA in Health centre,100 kVA generator presently in central laboratory,200 kVA generator in COLAMRUD, 250 kVA generator in COLANIM and 200 kVA generator in Senate. The remaining 3 x 60 kVA generators were left unaggregated to serve as auxiliary/back up.

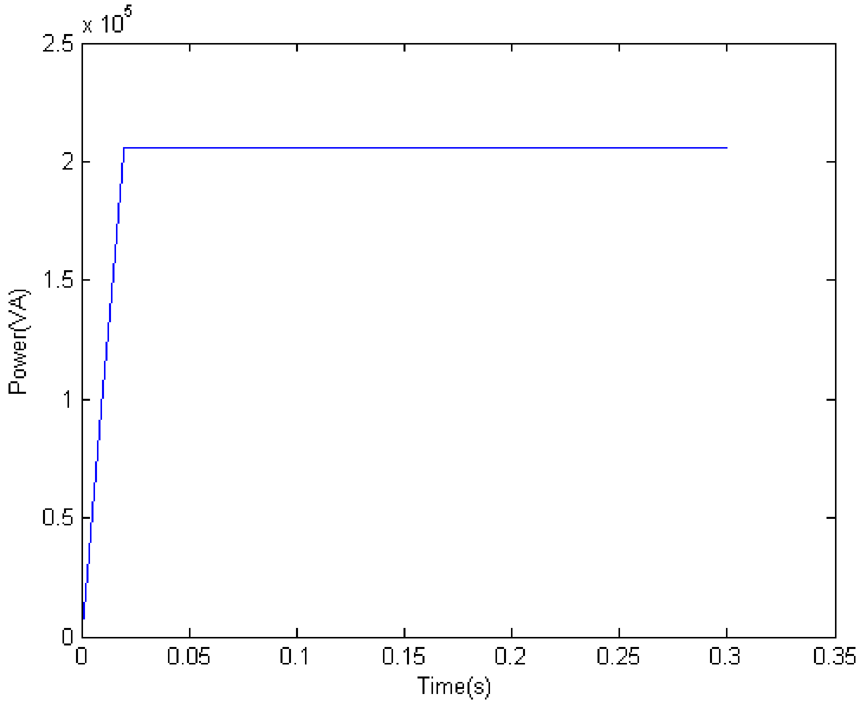

Figure 2: Waveform of supplied power from PHCN to the network

Table 3: List of transformers and generators in FUNAAB

S/N	Equipment	Rating (kVA)	Type	No
1	Transformer	2000	Power transformer	1
2	Transformer	2500	Power transformer	1
3	Transformer	500	Distribution transformer	16
4	Transformer	300	Distribution transformer	4
5	Generator	1000	Low voltage	1
6	Generator	800	Low voltage	1
7	Generator	500	Low voltage	4
8	Generator	250	Low voltage	5
9	Generator	200	Low voltage	3
10	Generator	100	Low voltage	3
11	Generator	60	Low voltage	3

V. Modeling of Microgrid for Federal University of Agriculture,

Abeokuta using MATLAB/Simulink

Simulink is an environment for multi-domain simulation and Model-Based Design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing. In this project, the sympower systems block set was utilized for modeling the power system. Sim PowerSystems provides component libraries for modeling and simulating electrical power system.

The simulation was done with the following parameters setting for the Simulink environment:

I. ode14x fixed step solver (solver for the ordinary differential equation solution of the model)
II. Simulation step size of 50μs
III. Simulation time of 0.3s

The solution was model based on the fact that the model was represented internally in this form:

$$V(t) = R_{eq}y(t) + L_{eq}\frac{dy(t)}{dt} \quad (4.4)$$

Rewritten as

$$v = R_{eq}y + L_{eq}y' \quad (4.5)$$

This integration is done using the ode14x fixed step solver over the simulation time range, where y(t) represents the equivalent load current in the system, V represents the supply voltage, R_{eq} is the total total sum of all the impedance of simulated load and L_{eq} represents the total equivalent of the inductance of the simulated load.

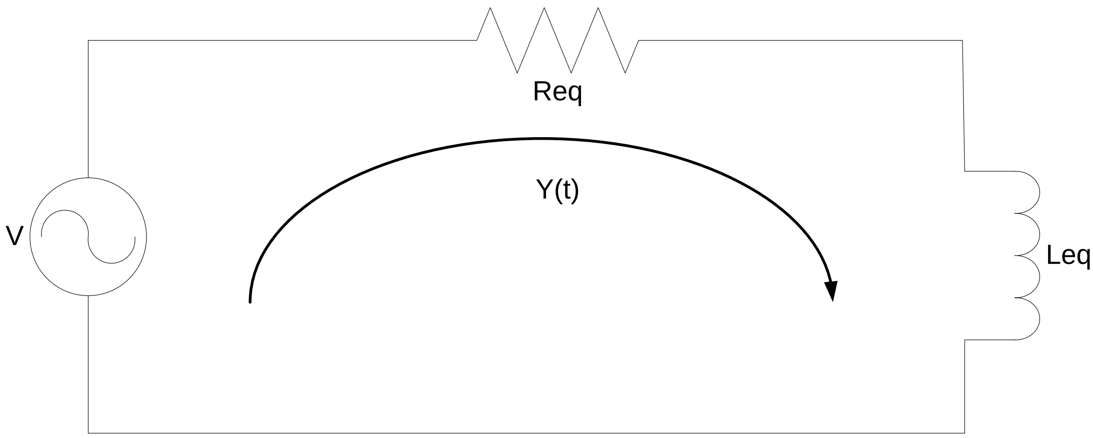

Figure 3: Equivalent circuit diagram of the model

This ode14x solver is an implicit, extrapolating fixed-step solver whose extrapolation order and number of Newton's method iterations can be specified via Simulink configuration parameters. The ode14x solver is faster than Simulink explicit fixed-step solvers for certain types of stiff systems that require a very small step size to avoid unstable solutions.

The power supply from PHCN was 2500kVA (2000kw) and this always cater for the whole power network. When compared this with the total ratings of 20 functional generators, it was observed that the University generators (total ratings of 6130kVA) are under-utilized. Whereas, 2500kVA – 4000kVA aggregated ratings of these generators would provide sufficient energy for the University with the power waveform of PHCN as the standard and the modeling equations above. Also, it showed that The Federal University of Agriculture Abeokuta, Ogun State has a total number of 22 functional transformers, one step-down transformer, one step-up transformer and 20 distribution transformers and 20 functional low voltage generators.

To improve the supply power to the network, two of the three proposed power houses can be synchronized together; this will effectively cater for the whole power network. When proposed power houses 1 and 2 were synchronized and proposed power house 3 can serve as auxiliary/back up. At night/during weekend that the power demand may be very low (hostels, classes and street lights) one/two of the generators aggregated in the any of the proposed power houses can be switched on. The supply to the power network can be increasing gradually by switch on more generators from the aggregated generators as the load demand is increasing and switch off some of the generators if the load demand is reducing.

VI. Conclusion

Loads and facilities audit was carried out with the visitations to the available facilities locations and measurements were taken with the help of Clamp meter, some parameters such as frequency, ratings and phase were observed and consumption loads for the period of three days morning and afternoon consecutively, it was discovered that there are 20 functional low voltage generators (6130kVA) that are under-utilized and 20 distributing transformers (8200kVA) ,1 step-up power transformer (2000kVA) and 1 step-down transformer (2500kVA) .Microgrid was modeled for the Federal University of Agriculture, Abeokuta, Ogun State, from the load audit and the generator capacity were aggregated into three proposed power houses of 2 x 2000kVA and 1 x 1950kVA. For effective maintenance and the various environmental impacts of running generators across the campus will be controlled. Energy efficiency, reliability, availability, conservation and optimization can be guaranteed by aggregating the generators in three proposed power houses. The remaining 3 x 60kVA generators were left unaggregated to serve as auxiliary/back up and each of this could be moved to some places that need cogent power supply but at lower rating and where there is no need to connect the microgrid.

VII. Recommendation

For the implementation 2 X 2500KVA step- up power transformer that will step-up the output voltage of the low voltage to 11kV should be used to give room for expansion and clearance and when compared with the stepped down transformer that steps down 33kV to 11 kV from PHCN which is 2500kVA that is able to cater for the system so something higher than that of PHCN should be used if two of the proposed power houses are to be synchronized for sufficient output, since power input =power output + losses.

Microgrid is an alternative idea to support the grid, it can be applied in a street, estates, community or a locality (towns and villages),organizations and establishments.Load forecasting can be further extended to Organisations, Local Government, State and country to determine the energy consumption.

Energy storage should be incorporated to the power network to cater for sudden energy demand increase.

The three proposed power houses should be centrally controlled by a control panel so as to be able to switch on/off more generators from the aggregated generators when the needs arise and to be able to monitor what is going in the network. The loads on the phases should be balanced because there were critical unbalanced loads on the phases following the readings obtained from the substations.

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