Integrated Energy Marketing and Load Shedding Scheduling in Trans Amadi Port Harcourt Using Fuzzy Logic

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Abstract- This study investigated the integrated energy marketing and load shedding scheduling at Trans-Amadi, Port Harcourt city, using fuzzy logic. This work presented an improved load shedding scheduling strategy based on the Fuzzy Logic. With the use of the Fuzzy Logic, there are no changes that need to be made to the power plants' output. The system evaluates the regions with their maximum load if any region requires additional electricity to meet the load requirement. Four objectives were made up for the aim of this study to guide it. Real load statistics from the Trans-Amadi transmission station were collected to highlight the impact of the load shedding effect. The data (conditions) analysis is accomplished with computer simulations, using the fuzzy logic toolbox in MATLAB. The single line diagram was implemented in simulink with fuzzy logic controller integrated, while the ETAB version 12.6 was used to simulate the Trans-Amadi 33kV Network distributed generation for the integrated energy marketing and load shedding. The study's findings show that the fuzzy logic controller performs better than a basic neural network model in predicting loads. According to the study, Nigerian energy management businesses should establish a plan for managing the electric power network utilizing artificial intelligence approaches such as the usage of fuzzy logic controllers for load shedding power management.

Indexed Terms- Fuzzy logic, Matlab, Load, Load Shadding, Etap\B

I. INTRODUCTION

1.1 Background to the Study

The quantity of current provided to a dynamo or producing station at any given moment is referred to as load, and "shedding" refers to reducing the load or amount of power. The word "load shedding" is used in this project to describe the intentional shut-down of energy in a portion or portions of an electricity distribution system Liu, et al(2016). Load shedding results in significant financial loss, discomfort, and inconvenience. Small businesses suffer a lot in the industry. Agriculture output is also harmed since pumps supplying water from river canals to irrigate agricultural land are unable to function. Because the lights and fans are turned off, office work suffers greatly. This load shedding costs the country a lot of money. It is known in electrical power engineering that a generator can only take less than 100% of its load at once since it would cause too much drop in frequency and voltage of the generator Verayiah *et al*, (2014). Power plants have rated values of power frequency and tolerance which implies to maintain overload you can either oversize the generator to be able to comfortably accommodate the initial site load, depending on some significant factors which can be expensive

With the continuous improvement of technology in the industry, there is an increasing demand for appropriate power supply. It is necessary to expand an electrical generation's capacity to meet the required number of active loads. The existing smart grid technology is capable of detecting such faults to some extent. However, not all countries have the same situation when it comes to the trade-off between electricity demand and power supply. The following elements influence the availability of electricity: i) geographical location, ii) availability of conventional and non-conventional power sources, iii) country economic state, and iv) amount of urbanization. (Ernst 2021) has mentioned that in India, renewable power plants account for 38% of total capacity in the year 2020, while non-renewable power plants account for 62%. Coal, hydroelectricity, and nuclear power are the primary sources of energy.

However, to maintain the frequency within prescribed limits, power supply has to be discontinued Firmansyah *et al*, (2012). This discontinuity in electrical power supply is known as "load-shedding" which procedure in simple term involves putting a "delay" on some of the electrical lines making up the circuit within an area to avoid the initial load on the generator exceeding acceptable limits or range of operation. During this systematic "cut off" the power is shifted so that each affected area suffers minimum possible blackout time. At the moment Nigeria's electrical grid is undergoing significant changes. And there is a need for models for effective and efficient load scheduling in response to the obviours shortage in power (Makwe et al, 2012).

Load shedding is the process of tripping a certain amount of load with a lesser priority in order to maintain the system's consistency. To maintain the electricity system's stability, a successful load shedding program is essential. Lack of load shedding will result in substantial frequency decay and a stability issue for the system. In contrast, excessive load shedding will generate an unnecessarily large load trip, resulting in a power outage. When the frequency falls below predefined settings, utility companies commonly do load shedding by using under-frequency relays to trip the planned load with many shedding stages. To achieve an efficient load shedding strategy, transient stability investigations for all probable failure scenarios of the external utility power system must be carried out. As a result, one of the optimization issues that is estimated is the critical load margin.

The establishment of an integrated energy market opens up new possibilities for integrated energy trading liberalization and flexibility. The energy demands of both private residences and industrial users are included in integrated energy. Combining power, heat, and mobility with industrial operations is what this means in the industrial sector. The goal of it all is to cut CO_2 emissions. Integrated energy is seen as a critical technology in the energy transition. It integrates the different energy sectors of electricity, heat, and mobility to guarantee that renewable energy is used efficiently. This is the only method to accomplish worldwide economic decarbonization. A improved load shedding forecast procedure can bring certain value-added methods to the restoration process. When a grid transports a large quantity of electricity, the transmission channels are used to their maximum capacity. At the same time, the limited availability of generating reserves and the inability of reactive power to meet load needs are clear.

The city of Port Harcourt has been dealing with a high energy deficit as a result of its inability to satisfy the huge rise in electrical consumption brought on by population expansion. As a result, power interruptions among electricity users are unavoidable, causing them inconvenience. Rolling blackouts of 2 to 3 hours, and maybe 6 hours per day, have been implemented as a result of the energy shortfall difficulties. Blackouts may happen at any time and for any length of time, which makes things much more uncomfortable. Because of the unexpected outages, domestic customers had trouble planning their daily routines. This will disrupt industrial users' everyday operations, forcing them to install their own generators, raising their running costs.

This paper proposes the use of fuzzy logic algorithms as one of several approaches for addressing the city of Port Harcourt's energy shortfall. While some approaches are inexpensive, their efficacy is restricted. There are more effective techniques, such as using renewable energy technologies, but they demand a significant investment and a longer period to see results. The use of load shedding scheduling or rolling blackouts is a quick and effective solution to the energy shortfall problem.

To lower power demand, this approach will rotate the supply of electricity to clients. Because it lowers the demand for power, this strategy is beneficial in reducing the deficit. It must, however, be carefully timed so that the blackout rotation is done fairly. For a power system like Nigeria's, this is a huge difficulty since there is a considerable energy shortage for 24 hours, especially during peak hours (7pm-10pm), the system needs are intricate, and the electrical demand is constantly changing. As a result, blackouts are occasionally irregular; they are not on time, the timeframe is too lengthy, and so on. To provide equitable and methodical rolling blackouts, this study presents an enhanced load shedding scheduling mechanism based on fuzzy logic.

II. LITERATURE REVIEW

2.1 Extent of Previous Work

Energy challenges (and energy experts) arose everywhere, with some focused on specific "new" technologies—photovoltaics, wind, synthetic fuels—while others took a sectoral approach—the role of energy in agriculture, forest resource exploitation, and dozens more Makwe et al, (2012). Because of a lack of natural and financial resources, energy concerns were frequently exaggerated in developing nations, and many of these innovative concepts found their way to the Third World. Today's electric grid was built around century-old concepts and technologies, not the needs and opportunities of tomorrow's emerging system.

Energy technologies have evolved in multiple sectors, leading to diversity in how and where energy is generated. This diversity has not only turned one-way power flow on its head, but it also has opened the door to unprecedented energy resilience and efficiency as well as advanced mobility. Through integration of energy systems, we can capture the unique value of new technologies and methods and discover the beneficial pathways at their intersection. An integrated energy system will call on creative solutions to energy storage, connections between renewable and conventional resources, and advanced controls that create greater grid security and flexibility.

Previous reviews on integrated energy marketing and load shedding scheduling, failed to address extensively key issues on proper scheduling program which is necessary due to the high electricity demand in Nigeria. The electricity generation system in Nigeria fails owing to instability during high demand times. The suggested scheduling method in this study would have a defined periodic schedule, specified outage hours, will be equitably distributed and rotated among users, and will, most significantly, manage Nigeria's energy shortfall problem optimally. This work aims to bridge the gap by enhancing an intelligent load shedding technique via the use of fuzzy control algorithms. This technique is based on a real-time estimation of the load quantity to shed. Calculation algorithms with fuzzy controllers provide command vectors that ensure the load shedding of a certain proportion of loads in order to restore power balance and lead the electrical network to a new stable state. This efficient load scheduling algorithm makes advantage of fuzzy logic. The output of this study will confirm the relevance and efficiency of neural networks in load shedding scheduling and load forecasting in general and in the energy management of Electrical Distribution Company in particular.

III. MATERIALS & METHODS

3.1 Material Used

The material used for this research will consider:

i. Integrated energy marketing history in the study.
ii. Energy and load requirement.
iii. Application of MATLAB (fuzzy logic) for the analysis.
iv. Presentation of a single line diagram for the study using ETAB.

3.2 Method Used

This method will adopt the application of load shedding technic which will be based on fuzzy logic.

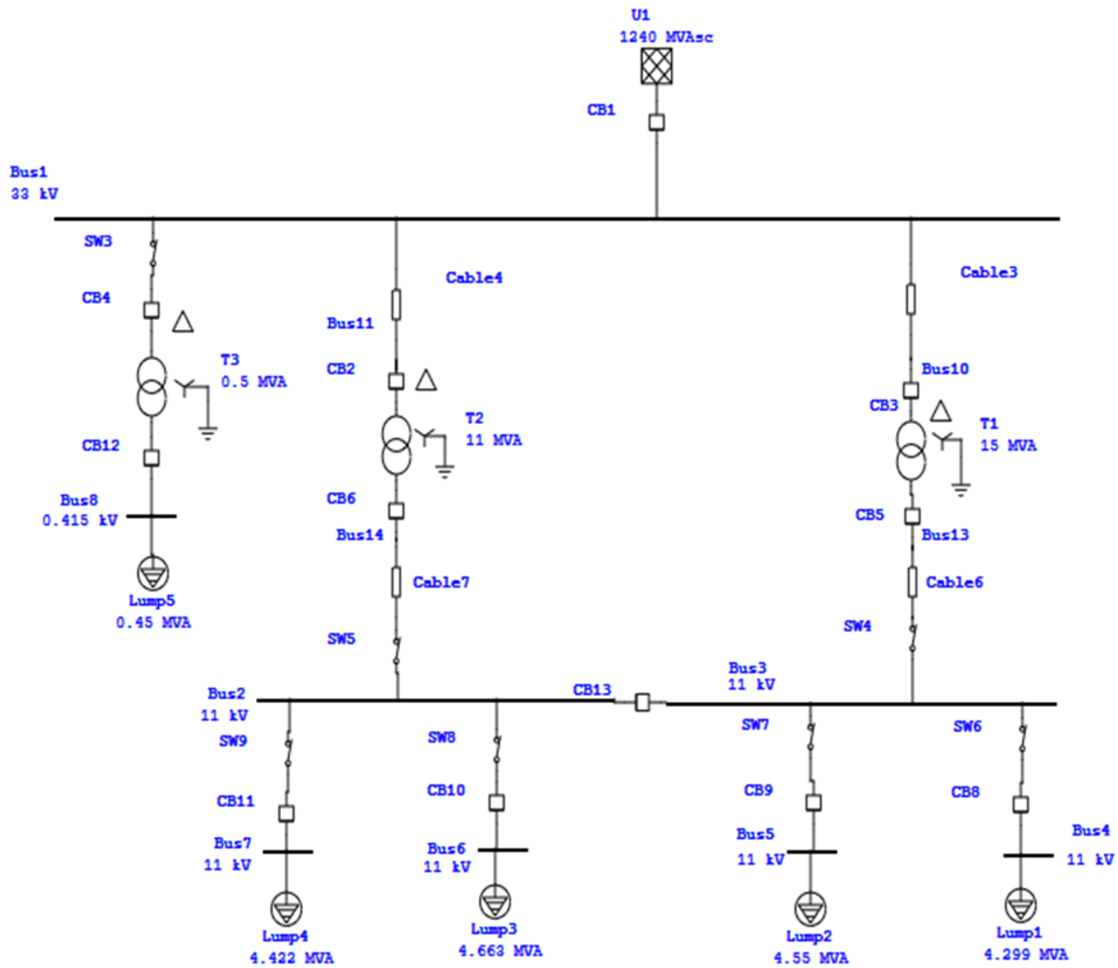


Fig. 3.1: Single line diagram of the study under investigation

3.3 Sources of Data

Real-world load statistics are obtained to highlight the significance of the load shedding impact in Trans Amadi transmission station. Engineers with expert knowledge were interviewed to obtain relevant operational data and information.

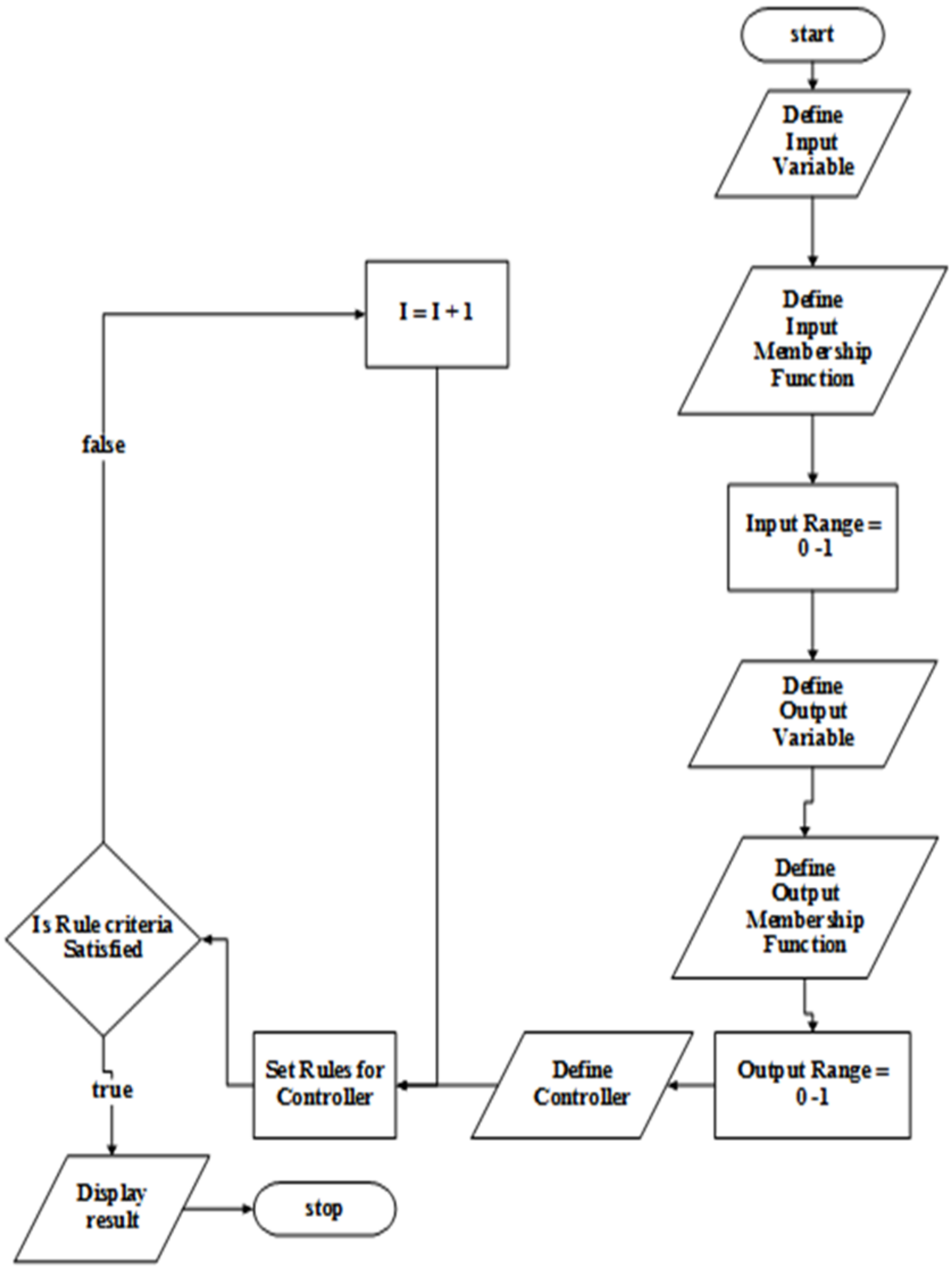
3.4 Design Strategy

Generally, the most common advantage of fuzzy logic system in power management, in comparison with other conventional methods is that their designs are carried out by human linguistic knowledge. Fuzzy logic power management can be assumed as the emulation of a skilled human operator. There are different methods to design fuzzy logic management.

i. Formulate the rule base by an expert interview
ii. Model directly the management actions of the operator by means of numerical data and system performance.
iii. Estimate a fuzzy model (FM) of the process and design a fuzzy manager by simulation studies.
iv. Generate the rules by a self-organizing mechanism.

3.5 Theory of Fuzzy Logic

Prior to the 1960s, fuzzy logic was a contentious topic; there have been remarks on the subject. According to Plato, there is a range of possible solutions between truth and false (Arief,2014). However, numerous researchers at many colleges contributed many principles of fuzzy logic, despite the fact that their contributions were hazy. Professor Lotfi Zadeh developed the notion of fuzzy logic (FL) as a method of processing data that allows for partial membership. Aristotle's concept of "the excluded middle," which states that a proposition is either true or untrue, was articulated some years ago. i.e. two valued logics rather than sharp set membership or non-membership. Fuzzy logic is used to handle issues whose responses and needs are more than basic Yes or No, true or False, on or off. Fuzzy logic also handles the prohibited state of digital circuits (0.8V-2V), which is the main stream of information technology. Its applications are vast, including chemical process control, electrically operated machines, frequency converter manufacturing sectors, video machines etc (Club et al,2013).



The flowchart of Figure 3.2 graphically depicts the flow (the steps) for the design and testing of the proposed fuzzy logic power management controller. As indicated, the system input variables used for the modeling of the fuzzy inference system have to be first specified. The variables are chosen partly as load shedding policy variables at Borikiri transmission station which was used as a case study. These variables are used for the specification of the fuzzy inference rules as reported below. Since the input variables are entered as numbers (numeric values), fuzzification is required to translate these values to fuzzy linguistic variables (fuzzy sets). To carry out this, the Gaussian membership function is given as:

$$guassian(x, \partial, c) = e^{-\frac{(x-c)}{\partial}} \quad (3.1)$$

From the equation (3.1), it can be seen that the Gaussian membership function is defind by (∂, c) where c depict membership function and ∂ sets the breadth of the function. A control decision making structure is required for the power management control, hence the inference rules for the fuzzy logic controller is specified as carried out in section 3.6. The inference rules are organized systematically within a storage data structure. This systematic organization and storage of the inference rules constitutes the fuzzy logic knowledge base. The MATLAB SIMULINK toolbox's rule editor is used to create this knowledge base. Since the system output variables will be in fuzzy linguistic terms, it is necessary to convert these fuzzy values to numeric (crisp) values in order to carry out power management actions (such as sending control signal to effect transfer switching for load shedding). To achieve this step, a defuzzification method is used. The defuzzification method used in the design is the centroid area method given as:

$$Z_{COA} = \frac{\int_Z^1 \mu C^1(Z) z dz}{\int_Z^1 \mu C^1(Z) dz} \quad (3.2)$$

Where $\mu C^1(Z)$ is the aggregated output membership function, Z is the fuzzy set output of the rule processing and ZCOA is the representative crisp value obtained via the centroid of area defuzzification strategy. The MATLAB SIMULINK fuzzy logic toolbox is used to model the power management controller. The toolbox has the facility for specifying the fuzzy logic membership function, it has the tool for constructing and editing the inference rules, for the specification of the centroid area defuzzification method. These actions automatically generate the power management controller program code. The integration of the controller with the simulink model of the case study power system and the carrying out of the simulation is discussed in chapter four.

3.6 Simulation Analysis

The data (conditions) analysis is accomplished with computer simulations, using the fuzzy logic toolbox in MATLAB, the fuzzy logic controller linguistic variables are; (1) Energy available, (2) Priority feeder (3) Time-of-supply (4) Reliability (5) Amount of feeders

The entire energy available from the supply source, as measured by the simulink V-I measuring block, is referred to as the available energy. The feed-priority is the priority value (or weighting) applied to feeders in accordance with the power management policy of the power system management. In the event of load shedding, the period of supply is the amount of time that electricity is shared among multiple load centers. Reliability is a numerical grade applied to distinct load centers by power management decisions to highlight feeders that are likely to waste energy due to non-use due to a high chance of fault.

IV. RESULTS AND DISCUSSIONS

4.1 Results

The circuit diagram employed in this research work are presented in figure 4.1. For the purpose of this study, the Trans-Amadi 33kV Network will be used as a case study. The single line diagram which is implemented in simulink with fuzzy logic controller integrated as shown in figure 4.1. ETAP version 12.6 was used to simulate the Trans-Amadi 33kV Network distributed generation for the integrated energy marketing and load shedding

Table 4.1: Station Identification showing the Reactance, Impedance and Admittance (Trans Amadi Transmission Station)

Identification Station	R	X	Y
First Aluminum	0.236536	0.143000	0.0000637
Sunflower	0.236536	0.143000	0.0000637
Stallion Commodity	0.236536	0.127000	0.0000660
Rivot Company	0.236536	0.143000	0.0000637
Admiralty	0.327145	0.151000	0.0000581
Bonded	0.236536	0.143000	0.0000637
Stallion Commodity 1	0.236536	0.143000	0.0000637
Trans-Amadi	0.637122	0.150000	0.0000498
Morgul fishery	0.236536	0.143000	0.0000637
Sea-Food	0.637122	0.150000	0.0000498
Stallion fish	0.236536	0.143000	0.0000637
Cinfores	0.236536	0.143000	0.0000637
Zitudel	0.236536	0.143000	0.0000637
OIS	0.236536	0.143000	0.0000637
SGS Golba	0.236536	0.143000	0.0000637
ETS Golba2	0.236536	0.143000	0.0000637
ETS Golba	0.236536	0.127000	0.0000660
Lasien	0.236536	0.143000	0.0000637
Lubricks	0.236536	0.143000	0.0000637
Sea-Food 1	0.236536	0.143000	0.0000637
AOS-Orwell	0.236536	0.143000	0.0000637
Trident	0.327145	0.151000	0.0000581
Lotus	0.236536	0.143000	0.0000637
Ordinance injs	0.236536	0.143000	0.0000637
Ordinance Aux	0.236536	0.143000	0.0000637
Baker Hughes	0.236536	0.143000	0.0000637
LNG	0.236536	0.127000	0.0000660
Sasun Hotel	0.236536	0.143000	0.0000637
Ordinance 2	0.236536	0.143000	0.0000637
Ordinance 1	0.236536	0.143000	0.0000637
Swiss Hotel	0.236536	0.143000	0.0000637
Greater P.H.	0.236536	0.127000	0.0000660
Wheelb 1	0.236536	0.143000	0.0000637
Wheelb 2	0.236536	0.143000	0.0000637
N Hotel	0.236536	0.143000	0.0000637
V. Hotel	0.236536	0.143000	0.0000637
Rockline	0.236536	0.143000	0.0000637

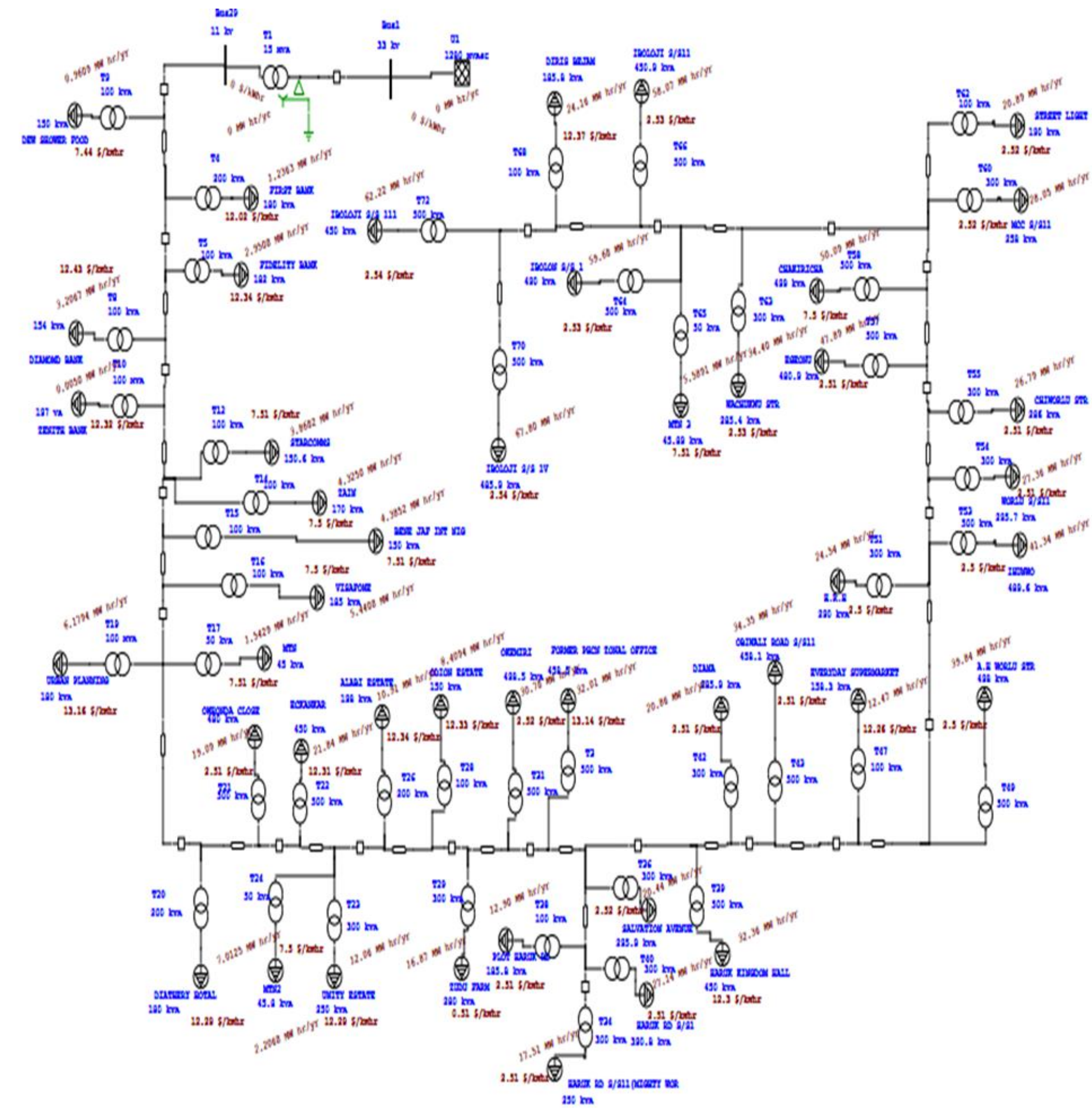


Figure 4.1: Simulated Network diagram of Trans-Amadi Injection Substation Using ETAB

4.2 Load Shedding of Trans Amadi network using the Fuzzy Controller

The simulink 3 phase programmable voltage source block is intended to mimic variation in cases where demand exceeds generation. The variable energy source fueling the power system is a simulink 3-phase programmable voltage source block. This block attribute of the simulink 3-phase programmable voltage is used to control the variation time. The block is set to amplitude variation timing, the variation type is step, and the time variation is set at 0.3 second intervals. Based on the step function, the 3-phase programmable power source adjusts the MVA (MW) and MVAR of the power source downwards at intervals at the step timings given. This replicates the decrease in available energy.

The simulink three-phase V-I measuring block connects the generator (variable power source) to the feeder network. This block supplies the instrumentation feeds (inputs) necessary for dynamically measuring the discrete 3-phase PLL and the discrete 3-phase PLL-Driven positive sequence Active of Reactive power block. The evaluation is conducted to assess the average reduction in load shedding transfer switching latency when compared to the existing manual approach. In addition, the energy distribution is examined. At the predetermined interval, the programmable power source decreases its power by 25%, equating to 150MW, 110MW, 75MW, and 40MW of active (i.e. in Mega Watts) and reactive power delivered (available) to the network. This measurement, as shown, is given as input (available-energy) to the power management fuzzy logic controller. This number is used by the fuzzy logic controller's inference algorithm to identify which feeders to drop or connect during the load shedding process. The needed fuzzy linguistic variables: feeder-priority, Number-of-Feeders, and Period-of-Supply are fed into the fuzzy logic controllers via the simulink cost and blocks, as specified. Based on these factors, the fuzzy logic controllers transmit trip signals to the circuit breakers, causing loads on the relevant feeders to trip (turn off). Figure 4.2 depicts the profile of the active power excitation of the generator during the startup of the programmable power source at 150MW.

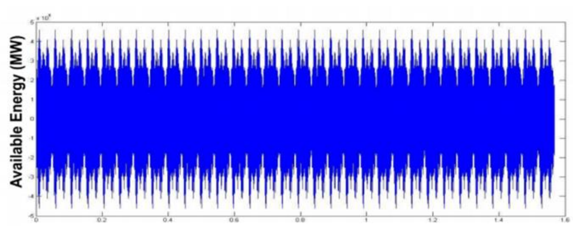


Figure 4.2: Time(s) of the power profile of the 150 MW generators employed in the simulation research

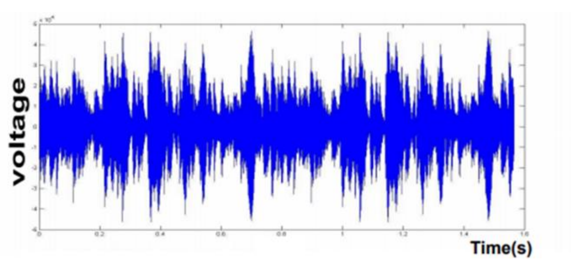


Figure 4.3: Signal profile at the load center feeders during the 145 MW excitation

The step descent of the active power output of the programmable source set at intervals of 0.3 sec. is shown in figure 4.5

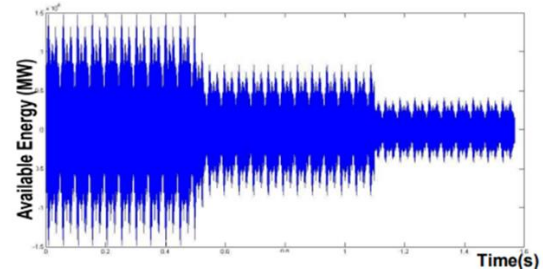


Figure 4.4: A planned step decline in available energy is shown at 0.5, 0.8, and 1.1 seconds.

The figure depicts the progressive reduction of available power. This step decrease in available energy causes the fuzzy controller to lower loads consistently utilizing the inference rules. The signal and profile of the feeders: E Baker Hughes, Rockline, and N Hotel are illustrated in figure 4.6 at programmed source transmission at 0.5sec (carries giving a 25% decline in main power supply, which is a drop from roughly 150 MW to 110 MW). The graph illustrates that the fuzzy controller has turned off these feeds.

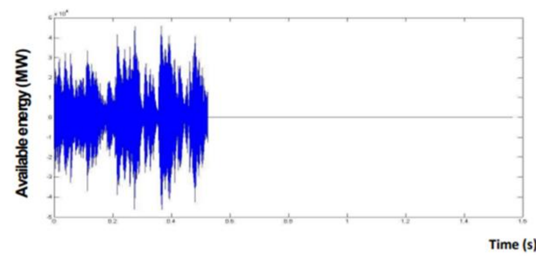


Figure 4.5: displaying a signal from a load unplugged at 0.5254 for a 25% drop in main energy supply at 0.5sec

Choice to shed loads on these feeders is based on the fuzzy logic controller inference rule provided in chapter three. The other loads on the remaining six feeds are still connected. At 0.8sec (equivalent to a 50% loss in delivered energy, which is a drop from about 145MW to 72.5MW), the supply at the feeders, Thinkers Corner, New NNPC, Emene, and Amechi Road dropped, as illustrated in Figure 4.6. This indicates a transfer switching latency of 0.243 second as opposed to the existing manual load shedding procedure's delay of 10 minutes.

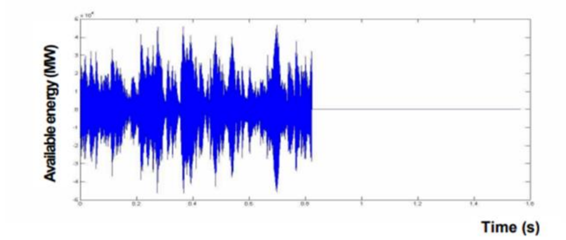


Figure 4.6: At 0.8sec, signal for load disconnect at 0.8243 for 50% reduction in Main Power Supply.

It Requires around ten minutes on average (statistics provided by PHCN control unit engineers at the Trans-Amadi substation). Feeders such as First Aluminium, Wheelb 1, Ordinance 2, Greater P.H, and Admiralty were kept running. The supply at the feeders drops by 75% at 1.1sec (equivalent to a reduction of roughly 150MW to 40MW). As shown in Fig 4.8, the fuzzy controller disconnected SGS Golba, ETS Golba2, Sea Food 1, Ordinance Aux, Thinkers Corner, and Lotus at around 1.1198 seconds. This translates to a 0.1198-second transfer switching delay. Table 4.1 shows the transition times for the three-phase programmable source steps, the load drop time, and the transfer switching delay.

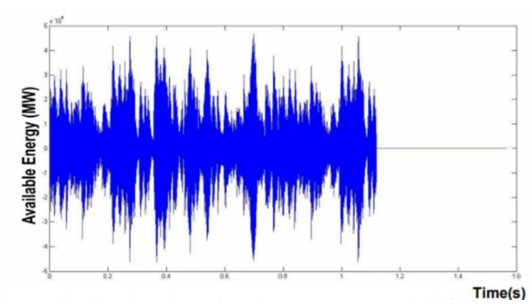


Figure 4.7: Displaying a disconnect indication at about 1.1198sec for a 75 percent power decrease at 1.1sec.

Table 4.2: The fuzzy logic controller reduces the load shedding transfer switching latency.

Source supply step transition time (seconds)	Load drop Time(secs)	Transferring switching(delay)time
0.51	0.5254	0.0254
0.8	0.8243	0.0243
1.1	1.1198	0.0198

CONCLUSION

Life without electricity is meaningless as basically, all aspect of life requires electricity in this modern time. Load-shedding of electricity imposes costs and economic lost on consumers and therefore affects operational performance of any firm or industry. The known issues with electricity shortages is the load shedding programs that have been implemented to compensate for the lack of power. The regular shedding program has an influence on the form and size of the load curve. A unique fuzzy strategy with three steps is suggested in this paper to address the load shedding effect in load forecasting. This approach outperforms the standard neural network model in forecasting loads. The suggested model provides a view of load dynamics in the absence of a shedding scheme. If there is no lack of electrical power, this vision assists personnel in the electric sector in determining the true requirement for electricity. This research work provides a better strategy that can replace or complement the conventional methods of Power System Management. This was borne as a result liberalization of the electrical market, the introduction of new technologies, and the expansion of local generation in order to decrease capital expenditure and power losses while improving reliability and power quality delivery The optimum power management development challenge in power networks is a multi-criteria, dynamic task with a high number of state and decision factors. This assignment must be designed with the potential effect of random and unpredictable factors that change on a regular basis in mind. Solving such an issue entails significant mathematical computation and informational challenges. The following primary factors and parameters were used to characterize the evolution of power management: There are deterministic, probabilistic, fuzzy, and really uncertain approaches. The power management Algorithm was created using a Fuzzy Logic-based technique. When compared to the conventional methodology, the strategy proved effective in constructing a simple fuzzy process to tackle an issue that needed rigorous procedures. This approach may be implemented using only the system frequency or voltage. The system simulation demonstrates that the suggested technique may make decisions and serve as logic for system stability, so protecting or saving the network. The following are the two primary findings that can be derived from the work:

i. Modern mathematical and computational techniques enable the solution of large-scale power network management issues in its general formulation, while accounting for - Uncertain and random components. - Several criteria - Dynamic development procedure.
ii. Practical use of the proposed approaches and algorithms would need significant effort to produce sophisticated, powerful, and user-friendly software suitable for data collecting and processing.

In summary, in as much as integrated energy marketing and load-shedding is of importance as it helps prevent damages in the power station, its effect on the consumers cannot be over-emphasized. The affected consumers, especially those who need power supply for commercial purposes, spend more money in buying and maintaining a generating set. Therefore, it is obvious that the disadvantages of load shedding are far greater than its advantages of protecting the system. Government should replace old power equipment with modern ones and more transformers installed to meet up with present realities.

RECOMMENDATIONS

i. It is recommended that the energy management companies in Nigeria should implement a strategy for the management of the electric power network using artificial intelligence techniques such as use of fuzzy logic controller for the load shedding power management.
ii. The government of Nigeria should make electricity available at all the times to the citizenry and load shedding should be eradicated totally and stopped in Nigeria as this affects social life, commercial and industrial activities.
iii. Regular monitoring of the existing state in order to enhance future prediction of load demand and power generation.

ACKNOWLEDGEMENTS

My sincere thanks goes to God for his immense help all through the period of this programme.

I also wish to appreciate my supervisors, Engr. Prof. D.C. Idoniboyeobu and Engr. Dr. S.L. Braide, who have been very kind and helpful to me in this research. I wish to specially thank Engr. Prof. C. O Ahiakwo, Dean of Engineering, for his continual encouragement and scrutiny throughout the period of the dissertation. I also want to appreciate my lecturers in the Department for their advice, guidance, assistance and co-operation in bringing this research to reality.

I will not forget my friends Mr. Frank Temisa, Mr. Ama Ibe Ama and Mr. Alaso Zion Diboye Suku for their encouragements. May God bless you all.

Finally, I would like to thank my beloved wife NNADI, Divine Immaculate, who stood behind my success in this program, my children NNADI Conciliare, NNADI Tamunomiebaka, NNADI Royal and NNADI Omasirichi for their continued support.

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