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TOPIC: A FUZZY LOGIC BASED ALGORITHM FOR ELECTRIC POWER NETWORK MANAGEMENT.

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ABSTRACT

This project work is aimed at developing an efficient Algorithm for the management of Electric Power network using fuzzy logic. The fuzzy logic model functions as a system operator in making decision for load shedding and transfer switching. The new developed algorithm will solve the problem of inefficiencies associated with the conventional methods for the management of the system. The new technique uses the system data frequency variation, load variation and voltage variation and the experience of the system operators to formulate fuzzy rules, which are then simulated using fuzzy logic toolbox in MATLAB.

The fuzzy controller for the load shedding management of power system, was modeled and developed. Data collected from the New Haven Nigerian switch gear was used to formulate the fuzzy logic interference rules. Simulation results indicates a remarkable improvement in the performance of the load shedding management at the power plants. Using the fuzzy controller the delay in load shedding transfer switching was reduced from 600 s to 0.02316 s, representing 99.99% reduction in load shedding transfer switching. The fuzzy logic controller achieved a load shedding energy efficiency of 90.57% as indicated in table 4.2 of this research work

INTRODUCTION

The MATLAB simulink fuzzy logic controller tool box is used to model the load shedding power logic management fuzzy logic controller. The fuzzy logic membership function editor is used to create fuzzy linguistic variables as specified in This Paper. The layout of the input/output of the controller as illustrated within the simulink fuzzy logic FIS editor is shown in figure 4.1b

Literature review

Fuzzy logic was a controversial subject before 1960s, before then; there have been comments on the issue. According to Plato said that there is region of answers existing between true and false [3]. However, for many years prior to 1960, many scholars at various universities gave many concepts of fuzzy logic; even though their contributions were fuzzy.

The concept of fuzzy logic (FL) was conceived by Professor Lotfi Zadeh in 1960 as a way of processing data by allowing partial membership. In conventional logic, a statement is either true or false, was formulated by Aristotle some years ago as the law of “the excluded middle” .i.e. two valued logic rather than crisp set membership or non-membership.

Dr. Zadeh Lofti of university of California has since then given many works, papers and tutorial on the subject [3-5].

Along the various developments on the fuzzy logic, developing countries especially Asian countries have also modeled many hardware for fuzzy computations.

In fact the word fuzzy means vgueness or unclearness, fuzzy logic hence is used to solve problems whose answers and requirements are more than simple Yes or No, true or False, on or off. Fuzzy logic also takes care of the forbidden state of digital circuits (0.8V-2V) which is the main stream of information technology.

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Its applications are numerous; namely in chemical process control, electrically controlled machines, frequency converters manufacturing industries, video machines, automobiles expert systems and even in power system for heuristic optimization.

It resembles human reasoning in its approximation of information and uncertainty to generate decisions. It was specially designed to mathematically generate decisions. It was specifically designed to mathematically represent uncertainty and vagueness and provide formalizing tools for dealing with the imprecision to many problems. By contract, traditional computing, demands precision down to each bit. People do not require precise numerical information input, and be capable of highly adaptive control [6]. If feedback controllers could be programmed to accept noisy, imprecise input, they would be much more effective and perhaps easier to implement. Since knowledge can be expressed in a more natural way by using fuzzy sets, many engineering and decision problems can be greatly simplified.

Fuzzy logic offers a better way of representing reality or grading of thing in fuzzy logic a statement is true to various degrees ranging from completely true- through half-truth to completely false. The idea of multi-valued logic gives a new approach to the mathematics of thinking; it is a change of paradigm to Aristotelian logic.

The computer tool used in expert system development is “FLOPS” which means Fuzzy Logic Production System. FLOPS is based on fuzzy system theory. Fuzzy sets, fuzzy logic and fuzzy numbers [4]. The use of fuzzy mathematics gives FLOPS the advantage to reason in terms of words such a small, medium, fast slow and so on, rather than in terms of numbers. Hence ambiguities and contradictions can be easily handled and uncertainties pose no problems.

Fuzzy set theory implement classes or groupings of data with boundaries that are not sharply defined (i.e. fuzzy) any theory implementing “crisp” definitions such as classical set theory, arithmetic, and programming may be “fuzzified” by generating the concept of a crisp set to a fuzzy graph theory and fuzzy data analysis, though the term fuzzy logic is often used to describe them.

Truth of a statement is defined, as is correct. Truth is measured numerically in most fuzzy systems literatures, as ranging from zero (false) to one (true). A typical fuzzy system consists of a rule-base, membership functions and inference procedure. Today fuzzy logic is found in a variety of control applications including chemical process control, manufacturing and in some consumer products like washing machine, video cameras and automobiles.

Fuzzy Logic Based power Management:

Below is a series of steps showing the solution procedure followed in designing our scheme.

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Step I: Choose appropriate input conditions: Frequency, voltage and load in this case

Step II: Determine the fuzzy knowledge base and draw the membership functions (for our design, MATLAB codes are used).

Step III: Convert the input condition variables to fuzzy sets (fuzzification)

Step IV: Design the fuzzy inference-decision making (Rule base) and simulate with appropriate program, (like MATLAB).

Step V: Devise an appropriate transformation of fuzzy logic management action (defuzzifications)

Step VI: Model the power management controller using the MATLAB SIMULINK fuzzy Logic toolbox.

Step VII: Integrate the fuzzy logic power management controller with the MATLAB SIMULINK model of the case study power system.

Step VIII: Carry out simulation and evaluate the controller performance.

However, these steps were diligently applied here as shown in the flowchart of figure 1.1

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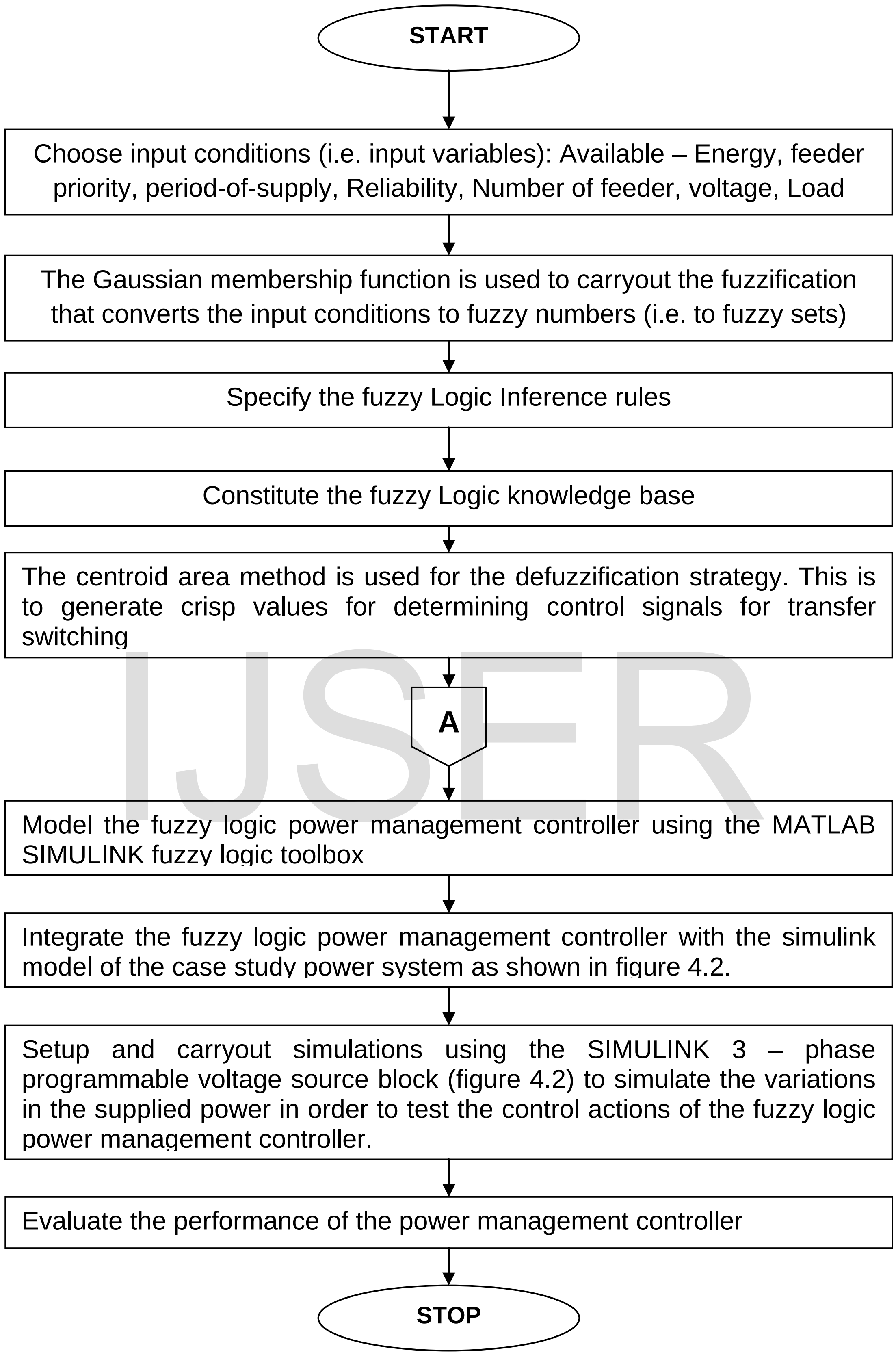

Flowchart for the fuzzy logic scheme

Modeling the Power Management fuzzy logic controller inference rules

Table 1.0 shows data obtained from power engineers at New Haven Nigerian. Power switch is used for formulating the fuzzy inference system. The fuzzy logic controller linguistic variables are;

1. Available –energy
2. Feederpriority
3. Period-of-supply
4. Reliability
5. Number-of-feeders

The available energy is the total energy available from the supply source as measured by simulink V-I measurement block. The feed-priority is the priority value (or weighting) assigned to feeders based on power management policy of the power system management. Period of supply is power sharing supply duration allotted to different load centers in situation of load shedding. Reliability is the numerical rating assigned to different load centers by power management decision to indicate feeders that are likely to waste energy as a result of non-usage resulting from high likelihood of fault. Number of feeders, based on power management decision, determines load centers likely or not likely to be supplied power on rotation basis, as a result of load shedding decision.

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The fuzzy sets are specified as HIGH and LOW.

Based on power management policy currently being implemented at the case study power system switchyard, the following fuzzy inference rules are formulated for the power management fuzzy controller.

1.0 Parameters for carrying out load shedding by power engineers of the New Haven Nigerian power switch yard

Feeders	**Priority**	**No ofFeeders**	**Reliability**	**Load**
Kingsway II	High	6	70%	17.50 MW
Kingsway I	Low	5	70%	19.50 MW
Amechi road	Low	1	30% because long distance tension down on (low)	13.6MW
Ituku-Ozalla	High	3	80%	15.10MW
Government house	High	1	90%	8.0MW
Independence layout	High	4	90%	10.6MW
New NNPC	Low	2	30%	19.0MW
Thinkers Corner	Low	4	90%	19.5MW
Emene	Low	1	60%	8 MW

Source: Enugu Electricity Distribution Company [EEDC]

Fuzzy Inference rules

- If available-Energy is LOW and Feeder-priority is HIGH and period-of-supply is LOW THEN supply is ON.

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- If available-Energy is LOW AND Feeder-priority is HIGH AND PERIOD-OF-Supply is HIGH then Supply is OFF.
- If available-energy is LOW AND Feeder-priority is LOW AND Number-of-Feeders is HIGH AND Reliability is HIGH AND Period-of-supply is low THEN supply is ON.
- If available-Energy is LOW AND Feeder-priority is LOW AND Number-of-Feeders is HIGH AND Reliability is HIGH AND Period of-supply is LOW THEN Supply is ON.
- If Available-Energy is LOW and Feeder-priority is LOW And Number-of-feeders is LOW AND Reliability is HIGH AND period-of-supply is LOW THEN supply is OFF.
- If available-Energy is LOW AND Feeder-priority is LOW and Number-of-feeders LOW AND Reliability is LOW AND period-of-supply is LOW THEN Supply is OFF.
- If available-Energy is LOW AND Feeder-priority is LOW AND Number-of-feeder is HIGH AND Reliability is HIGH AND period-of-supply is HIGH THEN Supply is OFF.
- If Available-Energy is LOW and Feeder-priority is LOW AND Number-of-feeders HIGH AND Reliability is HIGH and period-of-supply is HIGH THEN Supply is OFF.

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- If available-Energy is LOW AND feeder-priority is LOW AND Number-of-feeders is LOW AND Reliability is HIGH and period of Supply is HIGH THEN supply is ON.
- If Available-Energy is LOW AND Feeder-priority is LOW and Number-of-feeders is LOW AND Reliability is LOW AND period of supply is HIGH THEN supply is ON.
- If Available-Energy is HIGH Supply is ON

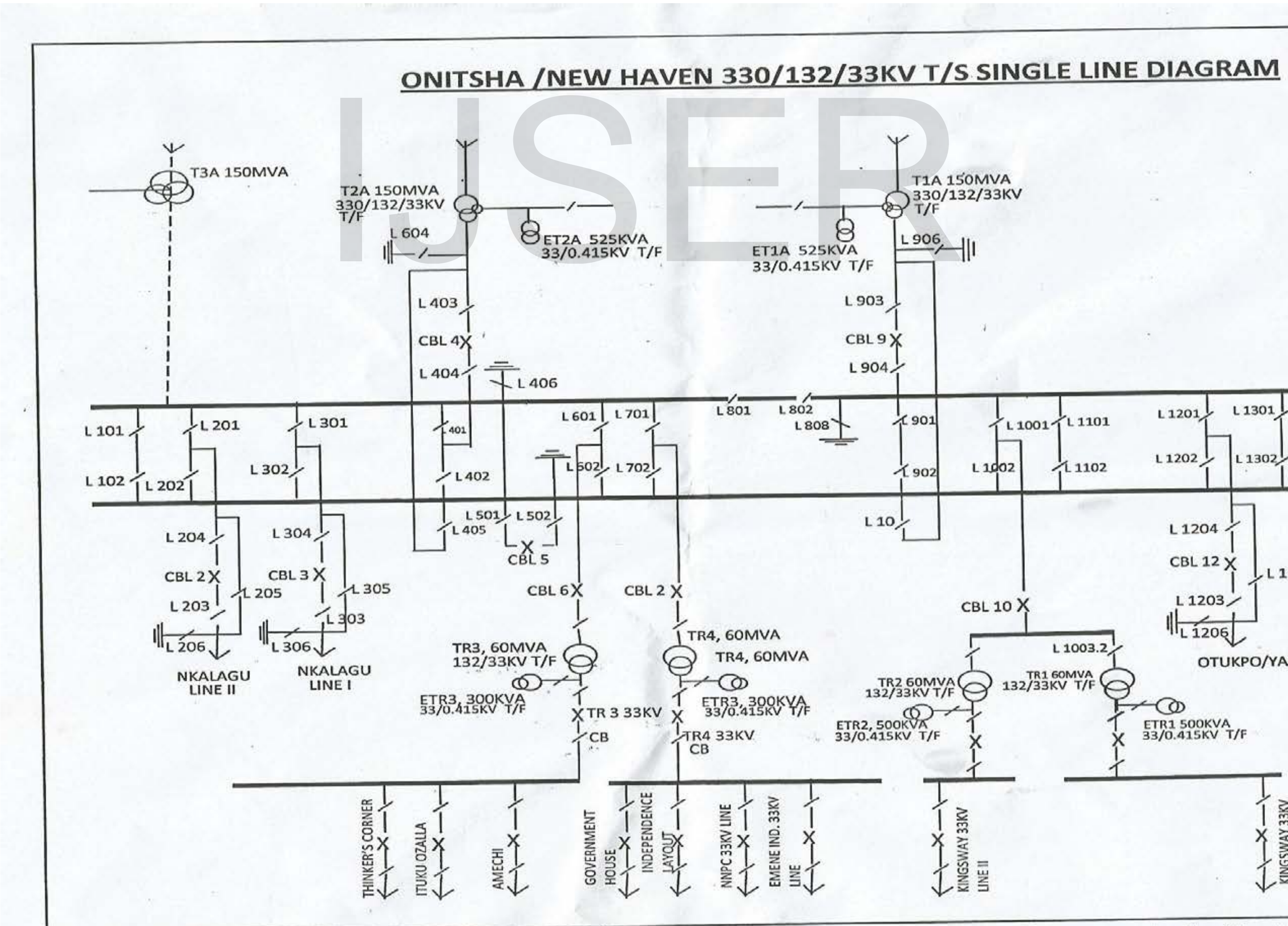

Fig. 4.1: Onitsha/New Haven 330/132/33KV single line diagram to indicat stations.

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The MATLAB simulink model of the test case power system with the power management fuzzy logic controllers integrated is depicted figure 1.0.

As the source is set to be 145MW part of power management load shedding is done to prevent the power system from total collapse.

The power management fuzzy controller systematically sheds loads in the system in order to systematically rotate power among the load center.

For the simulation set up, the load shedding is simulated automatic fuzzy logic controlled transfer switchgear operation.

The setup is to trip and reclose circuit breakers for connecting and dropping loads on the feeders.

The fuzzy controller uses its inference rules as modeled in chapter three to control the feeders whose loads are dropped (OFF) or connected. The fuzzy logic control is based on available power, the specified priorities of the number of feeders, the reliability rating of the feeders and the duration of having being supplied (period-of-supply).

Simulating Power Supply Variation and Evaluating the Load Shedding Fuzzy Controller

To be able to simulate variation in a case where a demand would exceed generation, the simulink 3 phase programmable voltage source block is used. Referring to figure 1.0, the simulink 3-phase programmable voltage source block is used as the variable energy source energizing the power system.

This block property in the simulink 3-phase programmable voltage is used to set the variation timing. The block is set to amplitude variation timing, the variation type is step and the time variation is set at intervals of 0.3 seconds. At step times indicated, the 3-phase programmable power source, based on the step function, varies the MVA (MW) and MVAR of the power source downwards at intervals. This simulates the drop in available energy. As indicated in figure 1.0, the generator (variable power source) is connected to the feeder network through the simulink three-phase V-I measurement block. This block provides the instrumentation feeds (inputs) required by the discrete 3-phase PLL and the discrete 3-phase PLL-Driven positive sequence Active of Reactive power block to dynamically measure.

Evaluation is carried out to estimate average reduction in load shedding transfer switching delay as compared to the current manual method. Furthermore the energy distribution is also evaluated.

At the set interval, the programmable power source varies its power downwards by 25% descent i.e following the trend 100%, 75%, 50% and 25% corresponding to 145MW, 108.75MW, 72.5MW and 36.25MW the active (i.e in mega watts MW) and reactive power supplied (available) to the network.

As indicated this measurement is fed as input (available-energy) to the power management fuzzy logic controller. The fuzzy logic controller uses this value in its inference rule to determine the feeders to drop or connected during the load shedding operation. As indicated the required fuzzy linguistic variables: feeder-priority, Number of-Feeders, Period-of-Supply are input into the fuzzy logic controllers through the simulink cost and blocks.

Based on these variables, the fuzzy logic controllers send trip signals to the circuit breakers to trip loads (turn off) on the appropriate feeders.

At initialization of the programmable power source at 145MW, the profile of the active power excitation of the generator is shown in figure 1.1

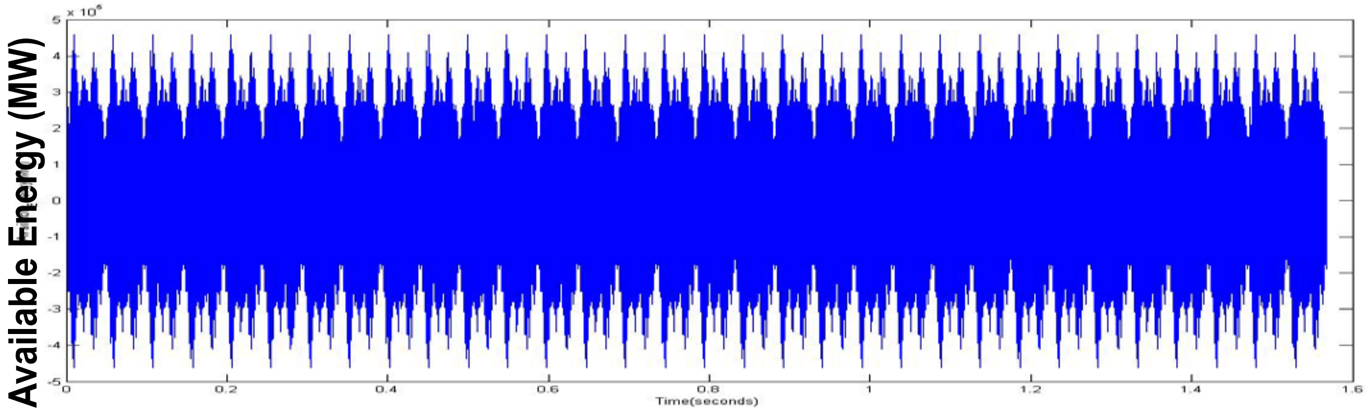

Figure 1.1: Power profile of the 145 MW generators used in the simulationstudy

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Time(s)

While the sample signal profiles at the feeders is shown in

Figure 1.2

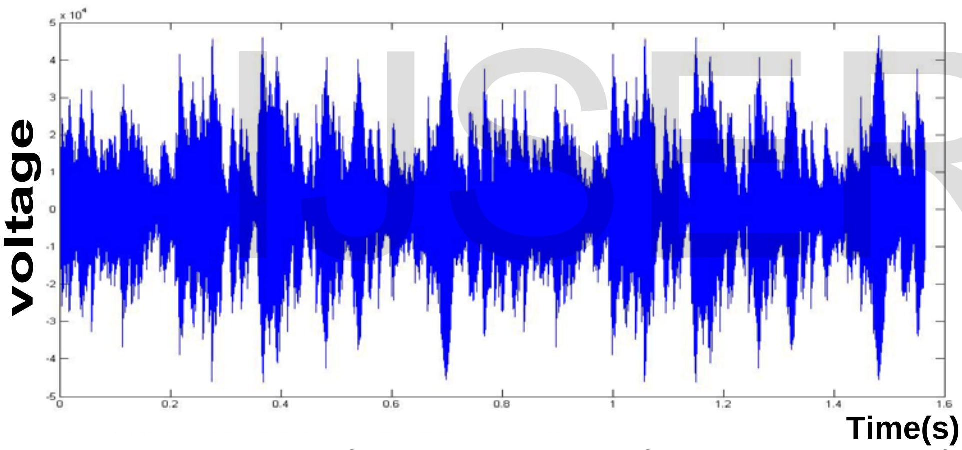
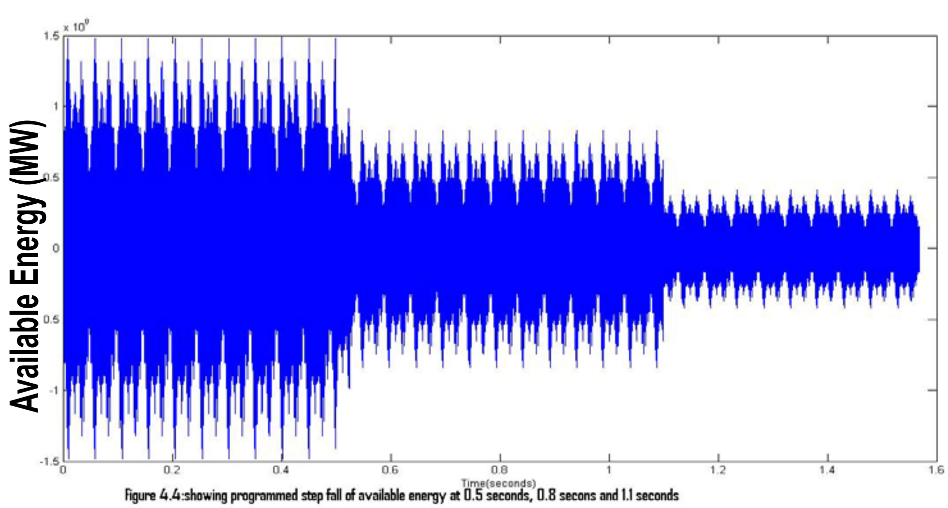


Figure 1.2: Signal profile at the load centre feeders at excitation of the 145 MW

`The step descent of the active power output of the programmable source at set intervals of 0.3 sec. is shown in figure 1.3



Time(s)

Figure 1.3: Showing a programmed step fall of available energy at 0.5 seconds, 0.8 seconds, and 1.1 seconds.

The diagram shows stepwise descent of the available power. This step fall in available energy causes the fuzzy controller, using the inference rules to systematically drop loads.

AT programmable source transmission at 0.5sec (carries providing to a 25% drop of main power supply which is a fall from around 145MW to 108), the signal and profile of the feeders: Emene and Amechi road and New NNPC as shown in figure 1.4. The graph shows that these feeders have been switched off by the fuzzy controller.

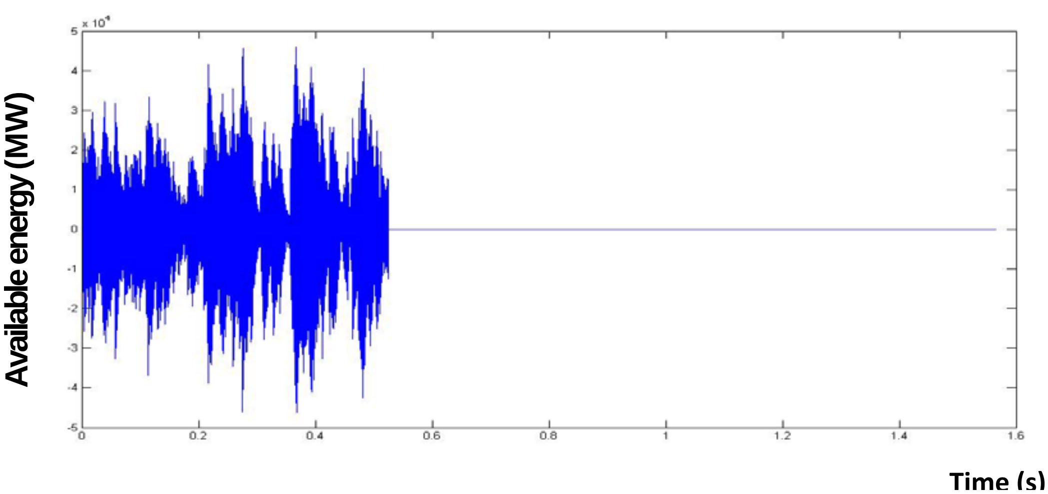


Figure 1.4: showing signal from load disconnected at 0.5254 for 25% fall in main energy supply at 0.5sec.

The decision to shed loads on these feeders is based on the fuzzy logic controller inference rule as specified in chapter three. The other loads on the other remaining six feeders are still connected.

At source energy change (descent) at 0.8sec (corresponding to a 50% drop of supplied energy, which is a fall approximately around 145MW to 72.5MW), the supply at the feeders, Thinkers Corner, New NNPC, Emene and Amechi Road Collapsed at around 0.8243 second as shown in fig 4.7. This represents a transfer switching delay of 0.243 second as against the 10minute delay using the current manual load shedding procedure.

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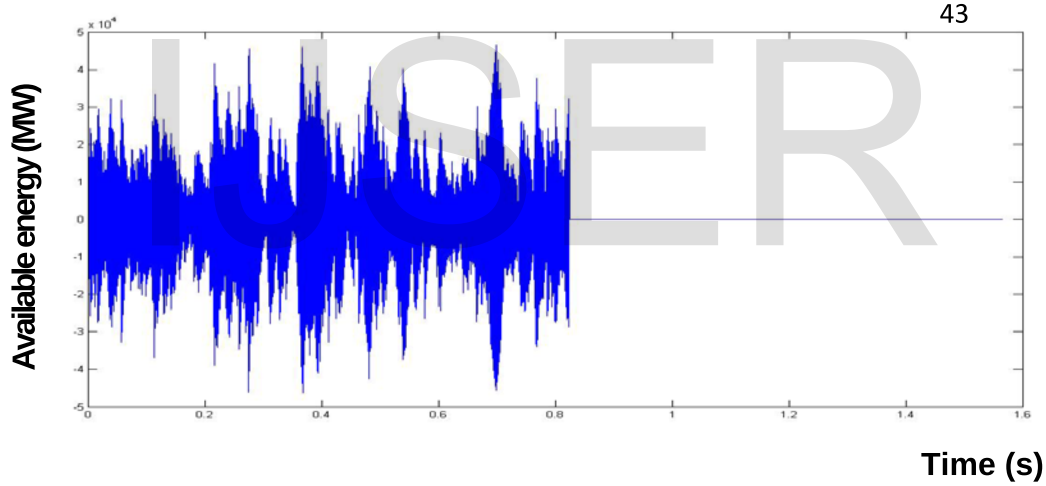

Figure 1.5: Signal for load disconnect at 0.8243 for 50% fell In Main Power Supply At 0.8sec.

It takes on average of 10 minutes (data as given by PHCN control unit engineers at the New Haven Nigerian switchyard).

The remaining five other feeders:

Kingsway 11, Kingsway 1, Ituku-Ozalla, Government house and independence layout remained energized.

At source drop step change at 1.1sec (corresponding to a 75% drop of supply, which is a full of approximately around 145MW to 36.25MW), the supply at the feeders: Kingsway1, Amechi Road, Ituku-Ozalla, New NNPC, Thinkers Corner, Emene were disconnected by the fuzzy controller at around 1.1198seconds. Fig 1.6.This represents a transfer switching delay of 0.1198 seconds. The 3-phase programmable source step transition time, the load drop time, and the transfer switching delay is given in table 1.1.

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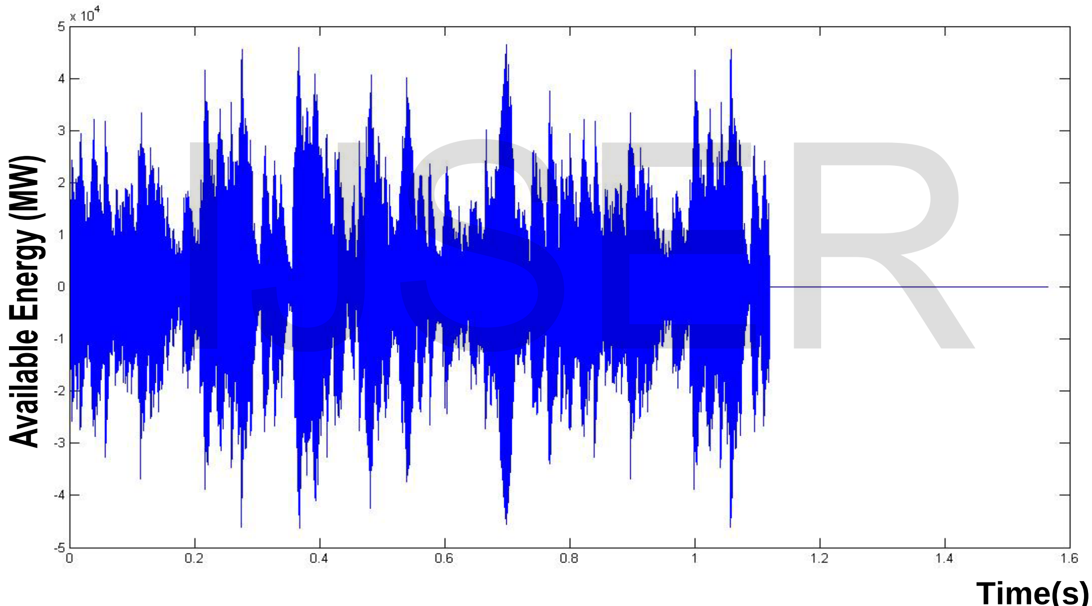

Figure 1.6: Showing signal for disconnect at about 1.1198sec for 75% power drop at 1.1sec.

The feeders connected, the available power and demanded power at connected feeders at various switching transfer time are given in table 1.2. For table 1.2.

Table 1.1: Reduction in load shedding transfer switching delay by the fuzzy logic controller

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Source supply Step Transition time (seconds)	**Load drop Time (secs)**	**Transfer switching (delay)time**
0.5	0.5254	0.0254
0.8	0.8243	0.0243
1.1	1.1198	0.0198

$$Average\ delay = \frac{0.0254 + 0.0243 + 0.0198}{3}$$

$$Average\ delay = \frac{0.0695}{3}$$

$$= 0.02316 sec$$

Based on the current manually load shedding transfer switching at the New Haven switch yard, it takes (according to one of the staff) an average of 10minutes to carry out the operation.

This means reduction in load shedding transfer switching delay from 600sec to 0.02316sec. This represents a 99.99% reduction in transfer switching delay.

Table 1.2 using parameter values for the estimation of the controller load shedding energy efficiency

Supply fall transition time (sec)	**Connected feeders**	**Demanded power (MW)**	**available power (supplied MW)**	**losses (MW)**
0.5	Kingsway II Kingsway I	90.2	108.75	18.55

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	ItukuOzalla Government house Independence layout Thinkers Corner			
0.8	Kingsway II Kingsway I ItukuOzalla Government house Independence layout	70.7	72.5	1.8
1.1	Kingsway II Government house Independence layout	36.1	36.25	0.15
	TOTAL	**197**	**217.5**	**20.5**

Some amount of energy would be wasted as a result of supply offer over shoot. This depends of the controllers computation of available energy at any time as against demanded energy on the connected feeders (i.e. connect load centers, that is the load centers that were not disconnected by the fuzzy controller). Hence evaluating the power management efficiency is in order.

$$\text{Efficiency} = \frac{\text{WorkOutput}}{\text{Workinput}} \times 100\%$$

$$= \frac{\text{EnergyUsed}}{\text{EnergySupplied}} \times 100\%$$

In this power management control case,

$$\text{Efficiency} = \frac{\text{Energy used by connected feeder}}{\text{Energy supplied}} \times \quad 100\%$$

Referring to table 1.2

$$\text{Efficiency} \quad = \quad \frac{\text{Energy demanded by Connected feeders x 100\%}}{\text{Energy supplied}}$$

$$\frac{197}{217.5} \times 100\%$$

$$= \qquad 90.57\%$$

The power management fuzzy controllers achieved a load shedding efficiency of 90.57%.

Conclusion

Fuzzy Logic based method was used in the development of power management Algorithm. The approach was effective in implementing a simple fuzzy procedure to solve a problem that required rigorous methods when the conventional approach is used. Only the system or network frequency or voltage is sufficient to implement this technique. The system simulation shows that the proposed approach is able to make decision and serve as logic for system stability, which acts to protect or save the network.

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