

Effective Power Restoration in the National Grid, Using Interconnected System (Neural Network Intelligence): A Review of the Nigerian Grid System

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Abstract: Power demand is increasing with recent developments in technology to improve and facilitate the smooth running of daily lives around the country. In order to realize the purpose of basic and daily use of energy and safer environment; researchers and fields of specialists have actualized methods of maximizing the advantages provided through artificial Neural community Intelligence techniques. This article affords an outline of this network and its application in the strength sector, basically the Nigerian national Grid, studies progress of energy recuperation, such as power failure and load recovery. There may be a great job to obtain automatic restoration in huge effective electricity restoration. The studies makes a specialty of healing of electricity failure in Nigeria with the aid of the usage of artificial neural network. There are many reasons of energy failures in Nigeria power community. Nigerian 330kV network was modeled. The network was modeled in PSAT and the south eastern part was mapped out and modeled with electricity library in SIMULINK. The contemporary side of the network without fault prevalence was provided. The contemporary side for each region after switching of each of the place's circuit breaker was received and applied in producing the ANN model. ANN model version was applied to the power device version in SIMULINK and used to predict the effect switching places or location of the circuit. A great result was achieved thereafter.

Keywords: Power Failure, Power Restoration, National Grid System, Artificial Neural Network, Artificial Intelligence

1. Introduction

Energy system is a system which includes generation, distribution and transmission chain. It makes use of energy (such as coal, solar, diesel, steam, wind and so forth.) and change it into power energy. The power system consists of the devices linked to the system such as motor, synchronous generator, transformer, conductor, circuit breaker, and so forth. The energy plant generates the power that's step-up or step-down thru the transformer for transmission. The network transmission line transfers the energy to the diverse transformer units. through substations, the energy is moved to the distribution transformer which step-down the electricity to the right value which is good for the end users. **The** factors include climate conditions which including snow, lightning, ice, rain, dust, and even, wind. One of the maximum crucial factors that hinder the non-stop supply of

power and energy is a fault in the electricity gadget [1]. Any anomalous float of power in a electricity system additives can lead to a fault inside the power device. These faults cannot be absolutely prevented for the reason that a component of those faults additionally occur because of technical reasons which can be always beyond the manage of mankind. consequently, it's far very essential to have a nicely-coordinated safety device that detects any kind of peculiar flow of energy in the power system, identifies the sort of fault after which appropriately locates the placement of the fault within the power machine. The faults are commonly sorted by using devices that come across the occurrence of a fault and ultimately isolate the faulted phase from the relaxation of the energy gadget.

Consequently a number of the vital demanding situations for the incessant supply of energy are detection, type and location of faults. Faults may be of diverse kinds [2] specifically brief, persistent, symmetric or asymmetric faults and the fault detection procedure for every of those faults is tremendously precise inside the experience, there is nobody well-known fault region approach for these kinds of types of faults. Synthetic Neural network Intelligence are computational strategies the mastering procedure in which the connections among processing devices are numerous via weight adjustments. ANN an effective opportunity for hassle answers where it's far records. [3, 4]

2. Overview

Power Transmission

Over 170 million people call Nigeria home, with a 6% annual growth rate. Nigeria is without a doubt the largest country in Africa. The country is made up of 36 states, split into six Geo-Political Zones, and the Federal Capital Territory (FCT). A country with such a vast population needs a robust electricity sector to thrive. This research's primary goal is to x-ray Effective solutions for power restoration in Nigeria's national grid [5, 6]. Therefore, understanding the sector's history is crucial and cannot be overstated. In Nigeria, electricity production began in 1896 with the installation of two (2) small generating units to supply the Lagos colony of the time. The generator's total output back then was 60kW. Even less than the 60kW generated at its peak was the demand. It had been fifteen years since England had arrived in Nigeria. In order to assume control of the energy supply in Lagos State, the Public Works Department (PWD) of Nigeria formed the Nigerian government electrical undertaking in 1946. The Electricity Corporation of Nigeria (ECN) was created by an Act of Parliament in 1951, and the Niger Dams Authority (NDA) was also established for the production of hydroelectric power in 1962. But in 1972, the two (2) organizations were combined to become the National Electric Power Authority (NEPA). The fundamental reasons for merging the organizations were that ECN was primarily in charge of distribution and sales and NDA was founded to build and operate producing stations and transmission lines. Prior to 1999, the power sector did not experience a significant investment in infrastructure expansion. The power industry was in a terrible shape during that time because neither new plants were built nor were the existing ones properly maintained [7, 8]. When compared to a load requirement of 6,000MW in 2001, generation decreased from an installed capacity of roughly 5,600MW to an average of roughly 1,750MW. Additionally, just 19 of the installed generating units' 79 total were running. The Nigerian power industry was run by the National Electric Power Authority, a vertically integrated utility. Additionally, NEPA added new thermal and hydropower producing capacity between the 1970s and 1980s. Up until 2005, NEPA was entirely in charge of the production, transmission, and distribution of energy. However, during President Olusegun Obasanjo's

administration, the organization's name was changed to Power Holding Company of Nigeria (PHCN). The Power Sector Reform Bill was passed into law in March 2005 by President Olusegun Obasanjo, opening up the energy generation, transmission, and distribution industries to private corporations. Eleven distribution firms (DISCOS), six generating companies (GENCOS), and one transmission company (TRANSCOS) were to make up the deregulated PHCN. The federal government was supposed to oversee TRANSCO. It should be mentioned that PHCN was established to address NEPA's shortcomings and to enhance Nigeria's electricity grid. Out of the 4000 MW of possible generation, the highest generation on August 8, 2005, was 3774 MW. This improvement was attributed to the involvement of private investors and the repair of generating facilities. [9] For a population of more than 150 million, the largest on the African continent, in 2010, five years after the most recent reform, however, very little restructuring had been done, and the available generation capacity was less than 4,000 MW (a figure that had essentially remained unaltered since the 2005 changes). Due of the nation's urgent electricity needs and the chance for private investors to invest in the industry, Independent electricity Producers (IPPs) have their roots in these situations. The Lagos State Government, the Federal Ministry of Power & Steel, and NEPA founded Nigeria's first IPP in 1999. Approximately 25% of Nigeria's electricity is produced by three large-scale IPPs as of 2012, with the remaining 75% coming from the Power Holding Company of Nigeria (PHCN) and the State governments, or about 1,000 MW (IPPs) and 3,000 MW (non-IPP), respectively. Despite the 'Road Map', the private power components will more than treble in less than five years, including through the sale of the nation's generating assets. IPPs have been gradually introduced (beginning in 1999). Knowing the history of IPPs is crucial given the tremendous change that is about to occur. The PHCN is unbundled into 18 successor firms, as was first indicated.

On a strategic level, the reform's goals comprise;

- (i) The outsourcing of the management and funding of the activities of succeeding firms to the organized private sector;
- (ii) The creation of a regulatory body that is impartial and effective and that oversees and tracks the sector;
- (iii) Concentrating the FGN's efforts on industry development and policy creation.

This will result in:

- (i) Broader availability of power services;
- (ii) Enhanced service dependability, price, efficiency, and quality;
- (iii) Increased investment in the industry to promote economic expansion.

3. Methods

Characterization of the National Grid Transmission System

Voltage instability (voltage profile violation), long line

transmissions, nature station lines, and high-power generating and distribution systems are some of the main issues with the Nigerian 330KV Grid system. Nigeria's transmission network consists of 132 KV and 330 KV circuits and substations. While the hydro generation is located further north at Jebba, Kainji, and Shiroro, the thermal generation is generally close to the country's gas reserves in the south. Distribution is divided into 11 zones, with 33 KV, 11 KV, and low voltage circuits making up the distribution networks. 50Hz is the system's nominal frequency. The Nigerian power grid is made up of generating stations, the majority of which are situated in outlying areas close to sources of unprocessed fuel. These stations are often connected to the load centers by extensive transmission lines. The National Electric Power Authority (NEPA), now known as the Power Holding Company of Nigeria (PHCN), is legally responsible for the generation, transmission, distribution, and marketing of power [10] in Nigeria. The national power grid now consists of nine producing units, with a total installed generating capacity of 6500MW,

including three hydro and six thermal. The majority of the country's thermal stations are in the south, in the cities of Afam, Okpai, Delta (Ughelli), Egbin, and Sapele. The hydroelectric power plants are situated in Kainji, Jebba, and Shiroro in the north central region of the nation. The 5000km of 330KV lines, the 6000km of 132KV lines, the 23km of 330/132KV sub-stations, and the 91km of 132/33KV sub-stations make up the transmission network. The distribution sector consists of 679 33/11 KV sub-stations, 19,226 km of 11 KV lines, and 23,753 km of 33 KV lines. There are also 680 injection substations and 1790 distribution transformers. Although existing power plants have an installed capacity of 6500MW, the highest load ever recorded was 4,000MW. Due to a lack of resources to perform the necessary maintenance, the majority of generating units have currently broken down. The radial transmission lines are overcrowded. [11] Power transformers haven't been maintained in a while, and switchgear are out of date. With a population of over 160 million, the installed generating capacity is currently around 6000MW, and the highest generation is 4000MW.

Table 1. The Operating generating stations within the country Nigeria.

S/No	Location of the Station	State	Status (mw)
1	Shiroro power plant	Niger	Working 600
2	Thermal power plant	Lagos	Working 350
3	Hydro power station in kainji	Niger	Working at 760
4	Thermal power Station	State of delta	Working at 912
5	Apham power at alaoji	Rivers State	Operating at 9700
6	Thermal Powr station at Egbin	State of Lagos	Working at 1350
7	Thermal Power sapele	Delta State	Working at 1020
8	Thermal power Ijora	State of Lagos	Operating at 40
9	Total		13820

The Nigeria 330-kV transmission system used as the main study of this research which includes eleven (11) turbines, thirty six, (36) transmission line, twenty one (21), load buses, which reduce throughout the six (6) Geopolitical zone

(South-West, South-South, South-East, North Central, North-West and North-East place) of the country Nigeria with long radial interconnected transmission network line.

Procedure of the Research work

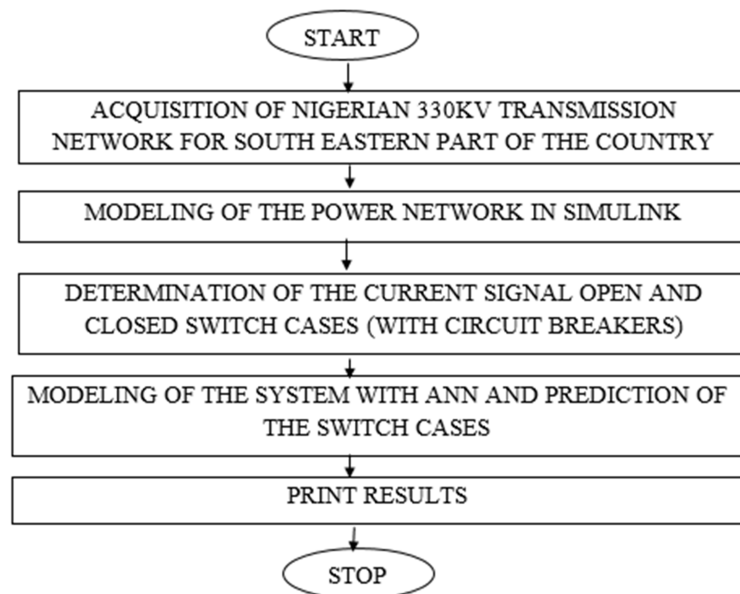


Figure 1. Summary procedure of the work.

For the aim of this work, south eastern part of the Nigerian 330KV Transmission Line was mapped out. The data used were collected from the Distribution company Power Holding of Nigeria (PHCN). Study, its assessment of the generation and distribution stations was carried out and analysis where made on the causes of power failure around the areas on their existing data and consequently techniques for effective power restoration was carried out. The collapsed of the grid twice in March 2022 just at a space of forty eight hours. There are a range of things to give an explanation for this example and for that reason inform what wishes to be finished about it. They encompass insufficiently skilled personnel, poor in local manufacturing, bad utility performance, theft of grid device, weather, gasoline deliver, inadequate investment and the age of grid infrastructure. The causes of energy failure the national grid is designed to feature below managed limits to make sure stable grid operations. [12, 13] Exceeding the bounds leads to instability

– and regularly leads to crumble. The transmission employer is meant to allocate the load to the distribution organizations based on demand information obtained from the countrywide manage Centre. This ensures that there may be no mismatch between electricity supply and demand to keep away from national grid device crumble. In some conditions, the quantity of strength provided to the grid is decrease than the strength demand. While this happens, an automated load losing plan is activated. But if this fails, the mills switch off one after any other till there is a whole disintegrate of the country wide grid. [14, 15].

South eastern part of the network modeled with SIMULINK was shown in figure 2 to analyze the flow of power. The Stations with generating stations are the outlined part in circle with the stations marked with a triangle is the stations with the load.

For effective clarity and analysis, the system in figure 2 was re-modeled with SIMULINK and shown in figure 3.

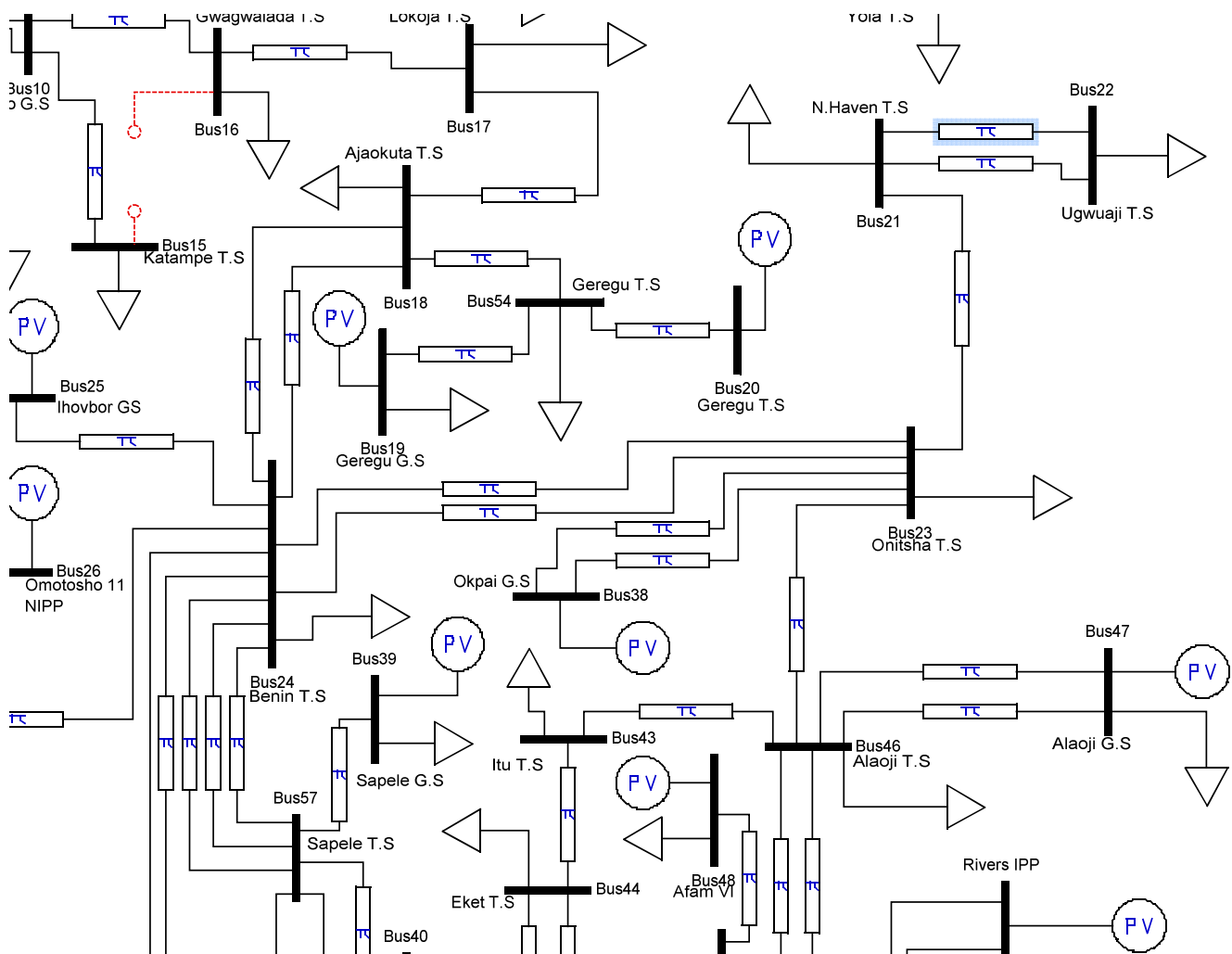


Figure 2. South Eastern part of the power system network.

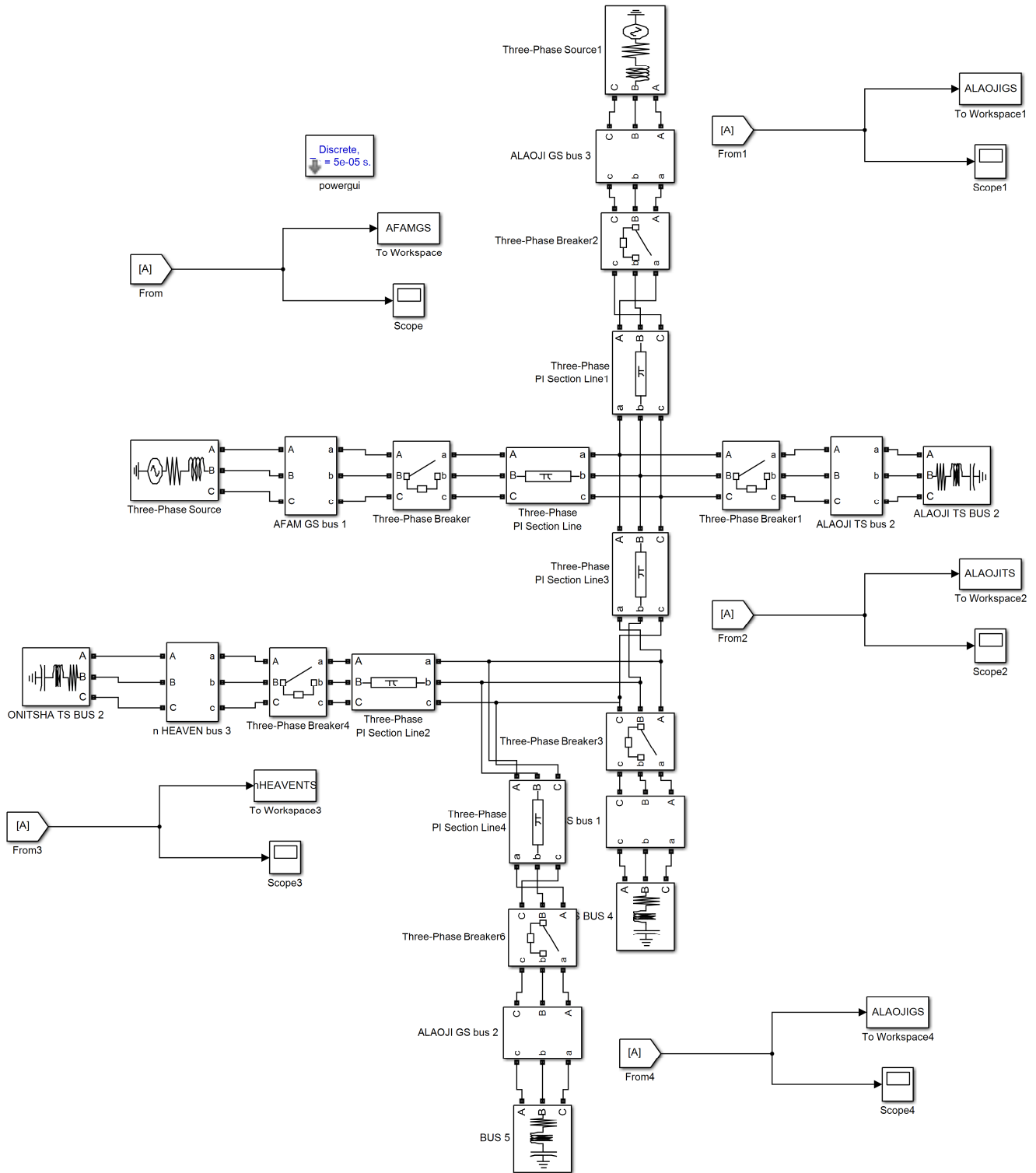


Figure 3. South eastern power network modeled in SIMULINK.

4. Modeling of ANN

For An effective power planning that minimizes power outages requires early detection and identification of fault occurrence within a power system network, cutting of the fault and restoring power areas that are not affected at shortest time. Currently, faults are been diagnosed base on

the control monitor without an effective faster way of identifying the fault which leads to cascade and damage to other equipment. Hence, for this study, ANN model was utilized in circuit breaker switching to ensure effective power restoration whenever power outages occur. This would be used on the Nigeria south eastern transmission network.

Artificial Neural network with feed forward topology are called feed forward ANN. The situation in feed forward is

the unidirectional of the neural N/W record float both in output and input record in absence of back loop. The record is transferred to the next layer of the Neuron while the corresponding input is recorded in the intermediate layer. When the activation characteristics alerts signal all the neurons sends signal alert. The indicator of the Neuron which is generated through the next layer or intermediate are weighed within the output hidden Neuron. Thereafter, it moved to output layer of the Neuron,. However, alert signal that measures what is needed accordingly, is produced by output Neuron. All required information coming from neuron is simultaneously proceed by the Neuron. A steady time period is observed which is known as higher layer. The signal perception helps to add flexibility to the output and intermediate response of the Neuron.

The feed ahead network deals with pattern statistics despite that the pattern records have transient despite on the previous signal. Some other first rate functions of feed forward Artificial Neural Network is the inability to recollect or memorize information due to lack of feedback loop return.

5. Intake to the Advanced Neural Network-Based Fault Segment Selector

Phase currents and energy factor at the relay function alternate considerably if there is a fault on the line maintenance/detector fault section makes use of those changes. The precept of fluctuation of present day signal either after or before repetition of the used fault. This is quick with ANN in detection of the problem. The entry edge wave forms are placed at 20 per cycle within each sample in each phase current in individual time that are examined in uniform samples section taken half of the cycle concurrently. The indicator are generated according to the mixture of the present sample as shown in equ. 1 to 3, A_{NN1} , A_{NN2} , and A_{NN3} which corresponds to the power factor correction, turbine speed correction for generation stations and phase switch for distribution stations.

The resulting 3 superimposed alerts are taken into consideration the primary three inputs to the constructed neural community errors detection/segment selector module as shown in figure 4.

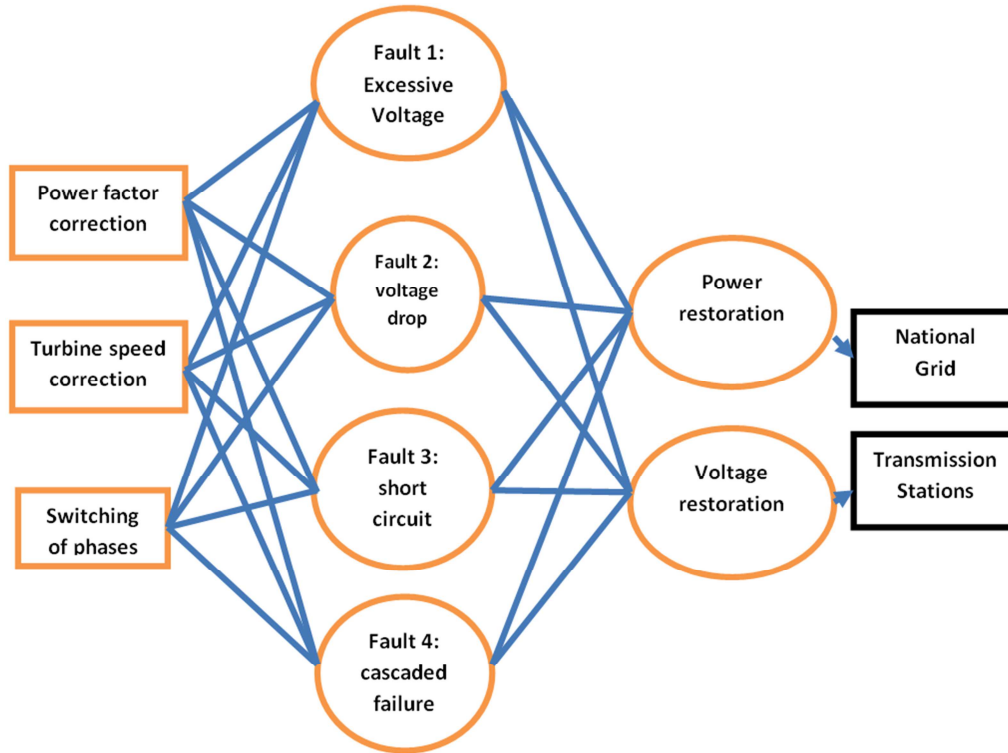


Figure 4. The ANN block in SIMULINK.

$$A_{NN1} = i_{N1}(n) + 2i_{N1}(n - N/2) + i_{N1}(n - N) + i_{N1}(n - 2N) \quad (1)$$

$$A_{NN2} = i_{N2}(n) + 2i_{N2}(n - N/2) + i_{N2}(n - N) + i_{N2}(n - 2N) \quad (2)$$

$$A_{NN3} = i_{N3}(n) + 2i_{N3}(n - N/2) + i_{N3}(n - N) + i_{N3}(n - 2N) \quad (3)$$

In sample number in equation 1, 2, and 3, N sample is the range within the cycle line there was a consideration of minus and zeros in the components within the input of 4 and 5 of neural N/W. In the utilization of the resources of the input records to the Network, we discovered that there is a

mistake detector set of regulations is likewise capable of hit upon errors sorts and behaves successfully even for evolving sequential errors.

The activation potential A_i of an ANN is equal to

$$Ai = (x + a)^n = \sum_{j=1}^N w_{ij}x_j - b_j \quad (4)$$

wherein N is the variety of things inside the input vector x_i , w_i are the interconnection weights, b_i is the 'bias' for the neuron; the bias is a coefficient that maintains the activation of the sign treated by means of manner of the Artificial Network. The neuron output based upon handiest on records this is regionally available on the neuron, both stored

internally or arrived through the weighted coefficients.

The SIMULINK implementation of the ANN block in figure 4 describes the power factor control, phase switch and turbine speed control in order to restore power to the national grid. The ANN simulink was then implemented as shown in figure 5.

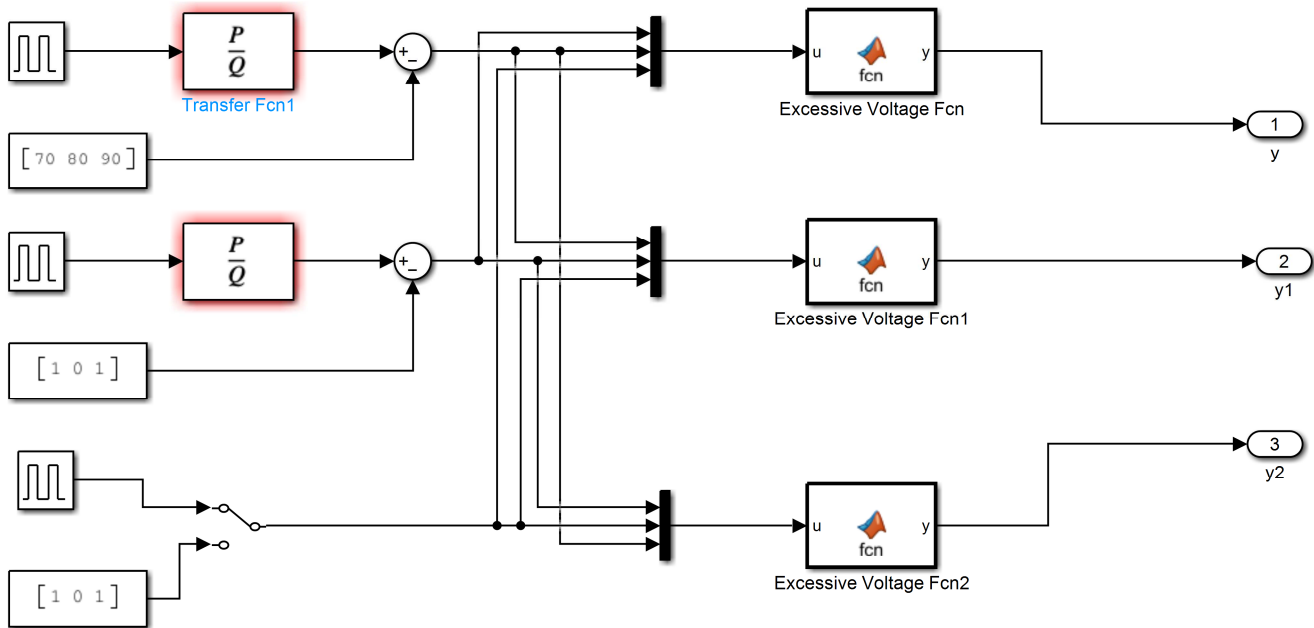


Figure 5. SIMULINK implementation of the ANN control.

After the simulation, the resulting ANN model block in SIMULINK.

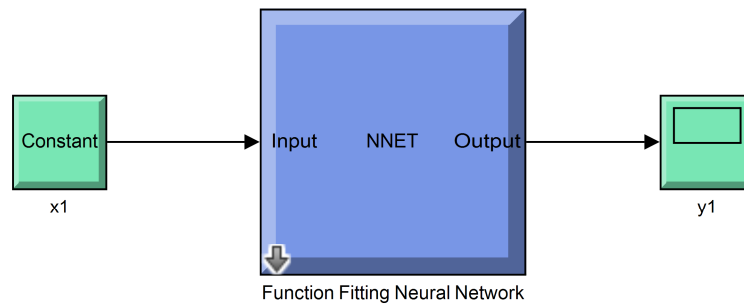


Figure 6. ANN model block in SIMULINK.

To generate the ANN model, the input to the model was the summary of the current when the circuit breaker for the Alaoji transmission station was switched on indicating the presence of fault for power to be restored at other stations.

The output (target) variable is the predicted location of the fault (to predict the location of the station that fault occurred). The data utilized for the ANN model was shown in table 2.

Table 2. Data for ANN model.

Current signals during CB of AlaojiTs was switched on (AMPS)	Bus locations/numbers
244.4171	1
271.7376	2
38.0960	3
274.0128	4
189.7078	5
29.2621	6

The SIMULINK model with the ANN block is displayed in the figure 7 below.

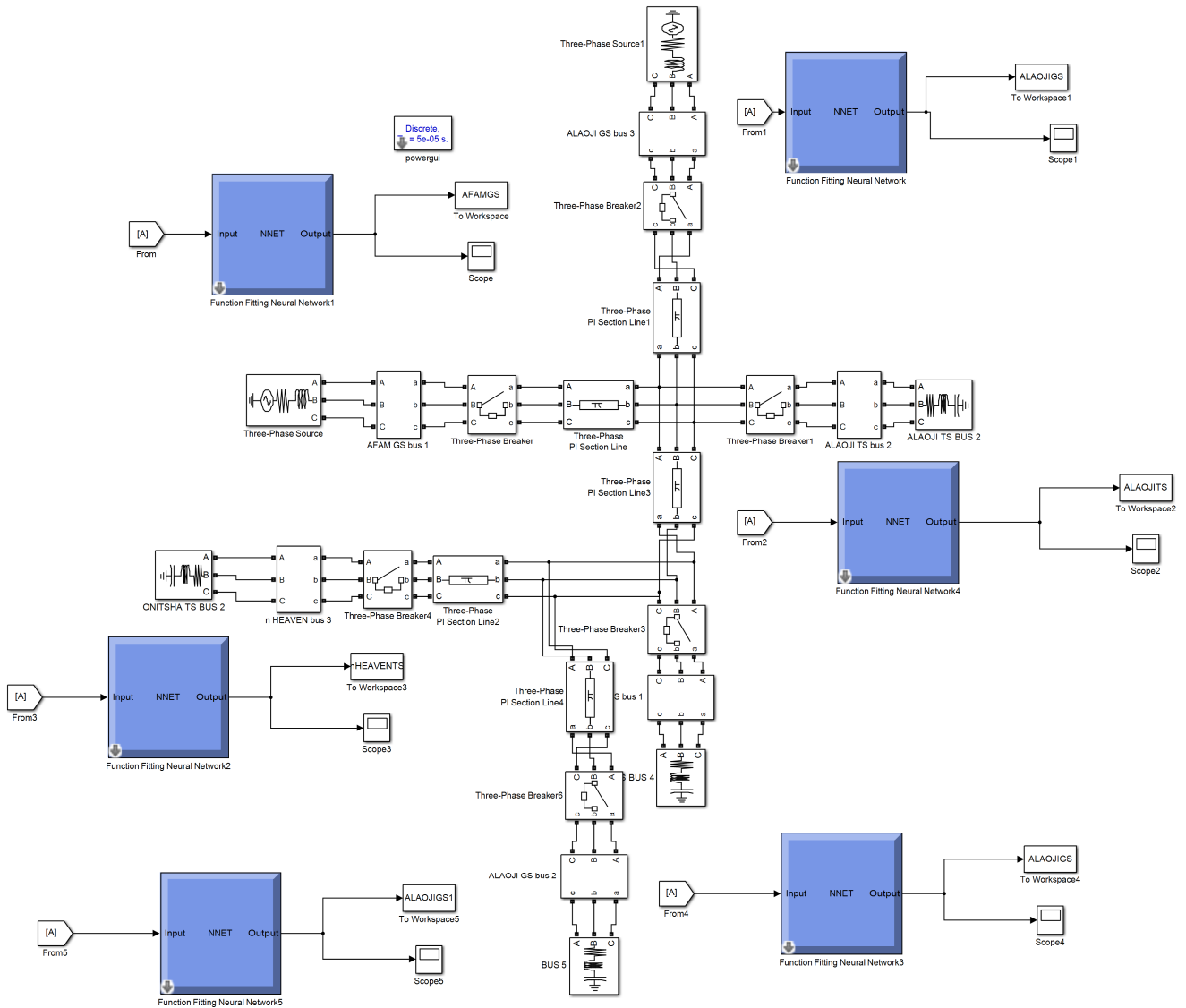


Figure 7. Power system model in SIMULINK with ANN block.

Artificial neural community is an instance of low-degree natural fashions, observed in body shape or genetics. much like the useful conduct of the mind, the network receives indicators and inner processing takes location thru the activation of neurons to yield output signs. in the strength gadget packages, the ANN design is cascaded to in structure the popular problems. ANN is an effective opportunity for problem solutions where it is viable to collect records describing the trouble behavior but a mathematical description of the system is not possible. ANNs have numerous appealing characteristics. The capacity of version to tool facts and the power to perform new obligations are some of the upgrades of these techniques. ANNs are parallel systems that normally require some little quantities of reminiscence and processing time. ANNs can collect and keep records in a dispensed fashion and still have a great fault tolerance. The utility of ANN on this research paintings extra applicable power and facilitated effective strength stability in the country wide grid. [16] The reimpose

device generated through the PSR scheme has a terrific way to permit for sufficiently massive load and technology without encountering undesirable and uncontrollable conduct that could bring about instability and a re-occurrence of the failurer. in order to check the stableness of the progressed energy device, brief stability studies need to be executed. the firmness of a multimachine system is decided with the resource of stability assessment application programs [17, 18].

6. Result and Discussion

Power restoration in 4 generation companies in Nigeria, [19] since the simulation models contains generators, the generation companies implementing the use of mostly hydro has been used during the simulation for power factor restoration. The capacity and type are tabulated in table 1 below.

Table 3. Power factor restoration.

Set of Generation station units	Type	Capacity (MW)	Transmission line length (km)
Jebbi and kinji	Hydro	1330MW	350
SHIRORO	Hydro	600MW	450
Afam	Hydro + gas	987.2MW	300
Egbin	Hydro + gas	1020MW	300

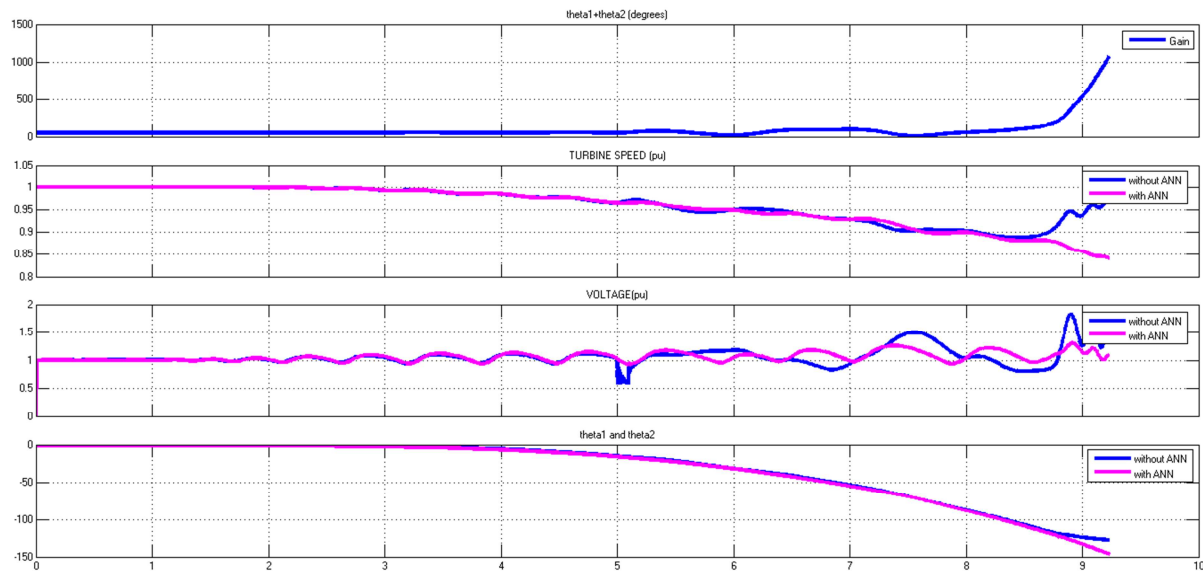
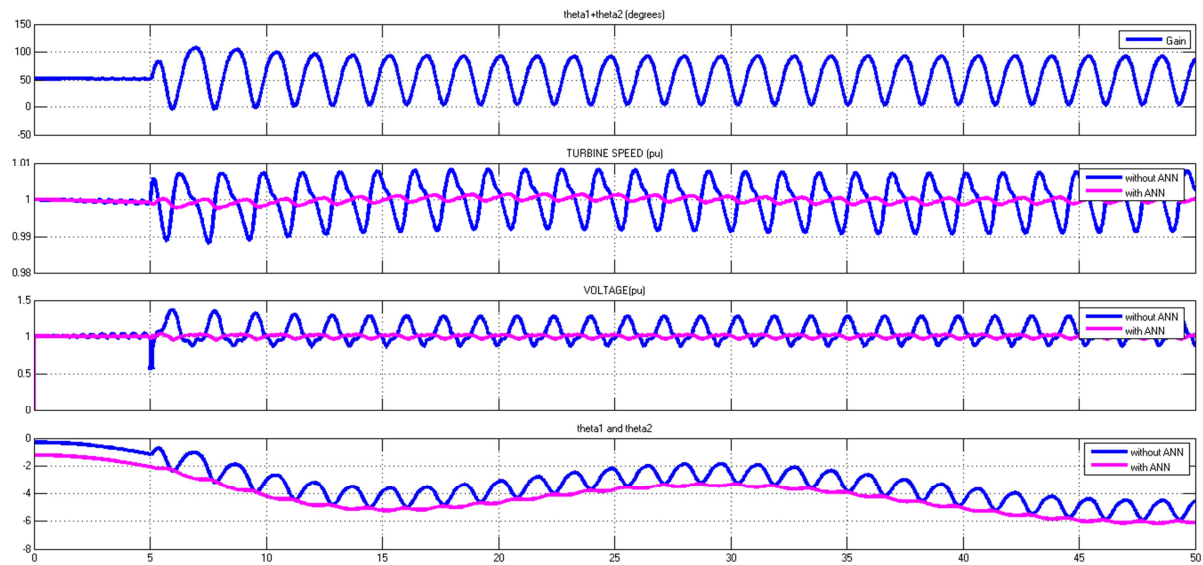
The artificial network (ANN) scheme was tried out on transmission bus machine of 162 in comparison. Effects of using energy recuperation in ANN gives possible outcome if implemented in real time. [20, 21]

7. Power Restoration in Shiroro Power PLC

To analyze the performance of the ANN restoration scheme, the scheme was also tested on the Shiroro power station, in a

similar manner like the Kainji power station, the ANN scheme has restored the power in the generation station to some extent, the plot also depicts a drop in the turbine speed at effective restoration of power in the station, this is due to the ANN automatically reducing the power factor generated by the turbines [22, 23] in the system as simulation runs.

The plot when compared with figure 8 shows that the reason for the poor restoration was as a result of the transmission line length in the Shiroro power station.

**Figure 8.** Graph showing comparison of ANN restoration scheme and conventional restoration scheme in Shiroro power station.**Figure 9.** Plot showing comparison of ANN restoration scheme and conventional restoration scheme in Egbin power station.

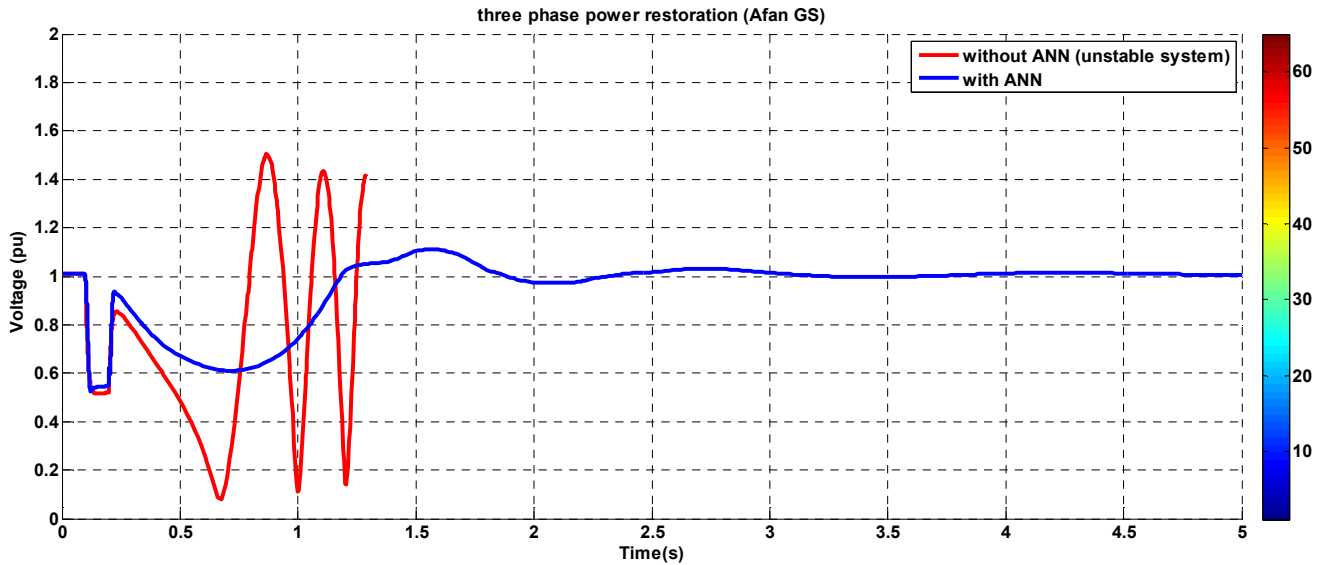


Figure 10. Power outages in unaffected areas.

8. Power Restoration in Egbin Power PLC

Figure 8 shows the simulation results of power restoration using the Egbin generation station data, the station implements more of gas than hydro and constitutes lots of transmission line resulting in more line resistance and capacitance, the results shows that large distortion are experience in power restoration using the conventional scheme to restore power plan speed and generated voltage, but the application of the ANN scheme shows a better result when compared, reducing all ripples from start to the end of the process. The outcome describes the implementation scheme of ANN on generation station.

The scheme performs power factor correction alongside restoration of turbine speed and generated voltage.

9. Conclusion

Nigerian 330kV network was modeled for the south easter part of the country. The complete network was modeled in PSAT and the south easter area was mapped out and modeled with strength library in SIMULINK. The cutting-edge signal of the system network without fault occurrence was provided. The modern-day signal for every location after switching of each of the place's circuit breaker was acquired and applied in generating the ANN model. ANN version model was applied to the strength machine version in SIMULINK and used to forecast the effect switching locations of the circuit whose predictions were almost similar to the circuit breaker region used as target. The essence is ANN can embark on activate fault location and initiate the switching manner if you want to lessen.

10. Recommendation

Based on the efficiency of ANN to ensure switching of the

circuit breaker and predict the fault location, it is recommended that ANN should be applied in the planning of any country energy system machine to maintain the extent of energy failure in un-affected locations.

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