Artificial Neural Network (Ann) Based Economic Generation Scheduling in Nigeria Power Network

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Abstract

Economic generation scheduling determines the most efficient and economic means of dispatch of generated energy to meet the continuously varying load demand at the most appropriate minimum cost, while meeting all the units equality and inequality constraints in power network. This is currently not applicable in Nigeria power network. The network under study consists of seventeen (17) generating stations (Existing Network, National Integrated Power Projects and the Independent Power Producers). This work investigates economic generation and scheduling in Nigeria 330KV integrated power network at minimum operating cost using the classical kirmayer's method and Artificial Neural Network (ANN) for its optimization in Matlab environment. ANN is trained to adopt its pattern at different load demands and acquires the ability to give load demand as soon as the set target and goal tends to equality. Cost function for each generating unit as well as a model for economic generation scheduling was developed.

Keywords: Ann, Nigeria, Cost Function, Phcn

1. Introduction

Economic generation scheduling involves optimization of certain equality and inequality constraints in power network, while satisfying load demand at minimum operating cost. It determines the most efficient, low-cost and reliable operation of power system by dispatching the available electricity generation resources to supply load to the system [1]. Generally, generation scheduling has become necessary because of rapid increase of energy requirements.

Researchers reviewed economic load dispatch and generation scheduling and applied it to power network [1-5].Considering the conventional approaches of schedule [6-10] and the use of intelligent methods for optimal scheduling such as Simulated Annealing (SA), Artificial Neural Network (ANN), Genetic Algorithm (GA), [11-17], it was found that accurate results were obtained even in very large and complex power networks compared to the conventional methods. Intelligent methods are computer-based problem solving systems which are computational models of evolutionary processes as key elements in their design and implementation [18]. It is un-economical to operate all available units in generating stations during peak and off peak period, hence the problem of unit commitment of each generator in the network. Unit commitment problem is solved by ensuring that there is a plan of units to be selected from generating facilities to meet predicted demand in a reliable and economic manner [19]. In solving this problem, ANN was used to generate pre-scheduling by adjusting their output according to priority of fuel cost per unit output [20, 21]. This work aims at using ANN based optimization technique for economic generation and scheduling in Nigeria 330kV power network and minimize overall cost of generation and power losses. It also involves modelling the network such that it can easily be adjusted to suit daily requirement and changes such as addition and removal of generating units.

1.1 Nigeria Power Network

In an attempt to meet the increasing power demand, the country's electricity industry is undergoing changes in terms of building more generating stations, transmission lines and distribution lines/stations through National Independent Power Projects (NIPP) and Independent Power producers (IPP). NIPP and IPP have increased the numbers of generating stations from nine (9) to seventeen (17), transmission lines from thirty (30) to sixty-four (64) and buses from twenty-eight (28) to thirty-two (52) for the 330kV transmission grid. Presently, of the seventeen (17) active power generating stations, eight of these are owned by Federal Government (existing) with installed capacity of 6,256MW and 2,484MW is available. The remaining nine (9) are from both National Independent Power Project (NIPP) and the Independent Power Producers (IPP) with total designed capacity of 2,809MW, of which 1,336.5MW is available [23]. Table 1.0 shows maximum and available generating capacities, their location and type of turbine. Table 2.0 shows bus names.

Table 1.0 Nigeria Power Network Showing Their Maximum and Available Generating Capacities [23]

S/N	POWER STATION	LOCATION	TURBINE TYPE	INSTALLED UNIT	AVAILABLE UNIT	Maximum Capacity (MW)	Available Capacity (MW)
1	Kainji	Niger	Hydro	8	6	760	259
2	Jebba	Niger	Hydro	6	5	540	402
3	Shiroro	Niger	Hydro	4	3	600	408
4	Egbin	Lagos	Steam	6	4	1320	900
5	Trans-Amadi	Rivers	Gas	4	1	100	7.3
5	A.E.S (Egbin)	Lagos	Gas	9	8	250	233.8
6	Sapele	Delta	Gas	10	2	1020	170
7	Ibom	Akwa-Ibom	Gas	4	1	155	25.3
8	Okpai	Delta	Gas	3	2	900	223
9	Afam I-V	Rivers	Gas	20	3	726	60
10	AfamVI(Shell)	Rivers	Gas	6	5	650	550
11	Delta	Delta	Gas	18	12	912	281
12	Geregu	Kogi	Gas	3	3	414	120
13	Omoku	Rivers	Gas	6	4	150	28
14	Omotosho	Ondo	Gas	8	2	304	88.3
15	Okpai (Agip)	Delta	Gas	6	6	480	480
16	Olorunshogo phase I	Ogun	Gas	8	2	200	114.5
17	Olorunshogo phase II	Ogun	Gas	8	2	200	200
Total Power						9545	4404

Table 2.0 Bus Names [23]

S/NO	BUSES	S/NO	BUSES	S/NO	BUSES
1	Shiroro	21	New haven south	41	Yola
2	Afam	22	Makurdi	42	Gwagwalada
3	Ikot-Ekpene	23	B-kebbi	43	Sakete
4	Port-Harcourt	24	Kainji	44	Ikot-Abasi
5	Aiyede	25	Oshogbo	45	Jalingo
6	Ikeja west	26	Onitsha	46	Kaduna
7	Papalanto	27	Benin north	47	Jebba GS
8	Aja	28	Omotosho	48	Kano
9	Egbin PS	29	Eyaen	49	Katampe
10	Ajaokuta	30	Calabar	50	Okpai
11	Benin	31	Alagbon	51	Jebba
12	Geregu	32	Damaturu	52	AES
13	Lokoja	33	Gombe		
14	Akangba	34	Maiduguri		
15	Sapele	35	Egbema		
16	Aladja	36	Omoku		
17	Delta PS	37	Owerri		
18	Alaoji	38	Erunkan		

19	Aliade	39	Ganmo		
20	New haven	40	Jos		

Nigeria as a nation is yet to meet the increasing energy requirements fully because of its limited power systems for generation and transmission, so it is important not to waste the limited energy generated and this can be achieved effectively by optimal generation and scheduling.

1.2 Economic Generation and Scheduling Methods

In power systems engineering, economic generation and scheduling have been used to plan over a given time horizon in order to obtain the most economical schedule of committing and dispatching generating units. The essence is to meet forecasted demand levels and spinning reserve requirements while all the generating unit constraints are satisfied. For inter connected power systems which contain multiple areas and tie lines, capacity constraints are also needed to be considered in the multi-area ELD. The generating unit schedule that yields minimum total production cost which consists of the following cost: fuel, operating crew members, maintenance, starting up and shutting down of generating units, which is the optimal solution of economic generation and scheduling (EGS are considered. The cost of power generation is solely dependent on the type of fuel used, the energy requirement of consumers and on power losses experienced in the power system. The ELD problem minimizes the total cost of generation while honoring the operational constraints of the available generation resources. EGS utilizes the use of every power generated thereby saving cost, losses and enabling an effective power plant. It will help countries like Nigeria struggling with the high demand of electricity to avoid wastage of its limited power generated.

Economic generation and scheduling (EGS) involves solution of two different problems. These are the unit commitment (UC) and the on-line economic dispatch (EP). Unit Commitment (UC) or pre-dispatch problem involves optimal selection of available generating sources, to operate and meet the expected load demand at minimum cost for a specified period of time. The on-line economic load dispatch is required to distribute load among generating units to minimize total cost of supplying the minute to minute requirements of the system and expected losses. Various methods have been used to tackle EGS. Mathematical formulations include conventional methods like Exhaustive Enumeration, Priority List, Lagrangian Relaxation, Sequential Method, Mixed Integer Programming, Decommitment Method, Dynamic Programming, Branch and Bound technique, Lambda Iterative Method, Gradient Method, Newton's Linear Programming. These methods are usually time consuming and usually prone to errors. With the advancement in technology, easier and more accurate methods have been adopted. These methods involve the use of computer programs. Though they may require special training and skills, they have proven to be the best in solving such problems. These methods include Genetic Algorithm (GA), Fuzzy Logic(FL), Tabu Search(TS), Artificial Neural Network(ANN), Particle Swarm Optimization(PSO) e.t.c. ANN has proven to be robust, easy to modify, not limited to a specific number of input and output, and it controls non-linear systems that would be difficult or impossible to model mathematically [13,14,21,22].

2. Methodology

Classical Kirchmayer's method is used in this research work with ANN based optimization technique because of its robust, easy to adjust and its inability to be limited which are its advantages. The achieving the set objective, the following procedures is adopted for the work:

- Define the control objectives, criteria and constraints.
- Determine the number of generating stations to be studied and their capacity.
- Create ANN and define the values of input/output terms.
- Create the necessary pre and post processing ANN routines.
- Set up and test the 330KV Network using the load flow results obtained from Power Word Simulator environment.
- Evaluate the results.

2.1 Mathematical Modeling of Economic Load Dispatch (Eld) Problem

Mathematically, the conventional ELD can be represented as;

$$minF = \sum_{i=1}^{N} 1\, F_i(P_i) \tag{1}$$

$$F_i(P_i) = a_i + (b_i P_i) + c_i P_i^2) \tag{2}$$

With $P_{i\,min} \le P_i \le P_{imax}$

Transmission loss is given as

$$P_i = P_j B_j \tag{3}$$

Subject to:

$$P_D + P_L - \sum_{n=1}^{N} P_n = 0 \tag{4}$$

Using the lagrangian multiplier λ, the auxiliary function is given by:

$$A = A_T + \lambda \left(P_D + P_L - \sum_{n=1}^{N} P_n \right) \tag{5}$$

Partial differential of this expression when equated to zero gives the condition for the economic load dispatch, i.e.:

$$\frac{\partial A}{\partial P_n} = \frac{\partial A_T}{\partial P_n} + \lambda \left[\frac{\partial P_L}{\partial P_n} - 1 \right] = 0 \tag{6}$$

or

$$\frac{\partial A_T}{dP_n} + \lambda \frac{\partial P_L}{\partial P_n} = \lambda \tag{7}$$

The term $\frac{\partial P_L}{\partial P_n}$ is known as the incremental transmission loss at a plant n and λ is known as the incremental cost of the received power.

The equations 4 and 5 are a set of n equations with (n+1) unknowns. These equations control both the incremental transmission losses and production cost.

To solve these equations, the loss formula is expressed in terms of generations and is approximately expressed as:

$$P_L = \sum_{i=1}^{N} \sum_{i=1}^{N} 1\, P_i P_{ij} P_j + \sum_{i=1}^{N} 1\, B_{0i} P_i + BB_{00} \tag{8}$$

With $P_{i,\,min} \le P_i \le P_{i,\,max}$

Where:

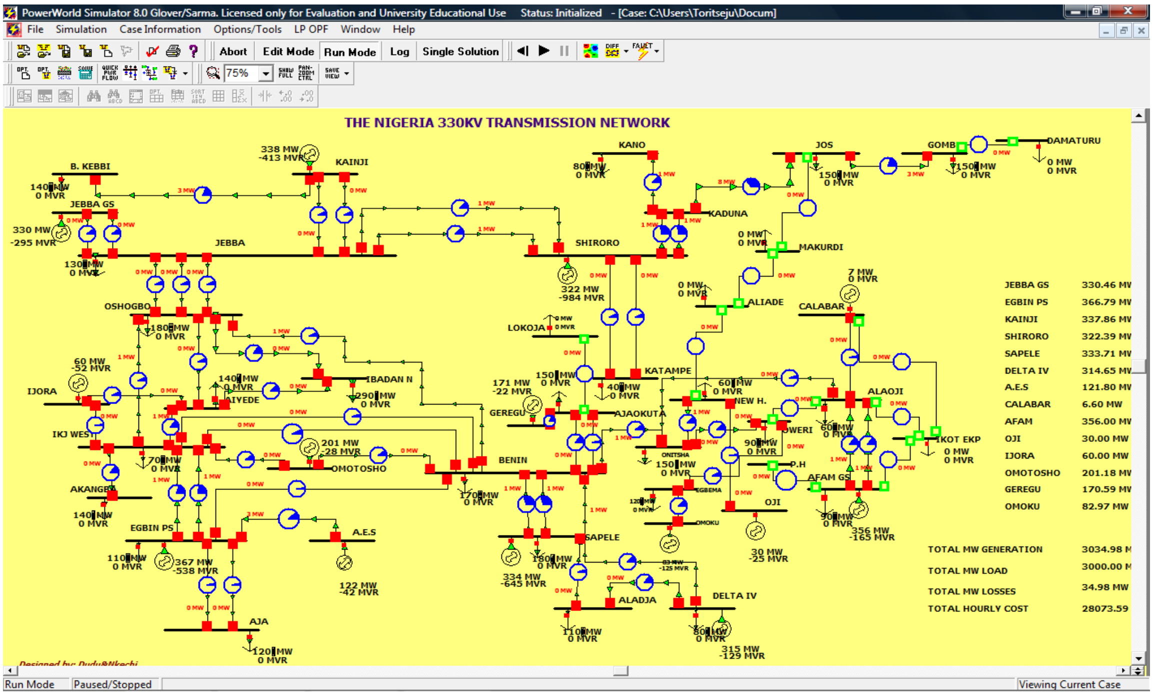
F is the system overall cost function; *N*= the number of generators in the system

C_i, b_i and a_i are cost constants which include the following: c_i is a measure of losses in the system, b_i is the fuel cost and a_i is the salary/wages, interest and depreciation of the machines.

P_D=the total power system demand; P_L=the total system transmission losses

P_i=the active power generation of generator number *I;* B_{ij}, B_{0i}, B_{00}= Transmission loss coefficients.

Figure 1.0 shows the modelling of Nigeria 330kV power network in power world simulator environment. This model is achieved by obtaining data such as transmission line parameters, bus data, load data, reactors sizes ,transformers sizes and generators power limit (active and reactive).Table 3.0 shows the result obtained for the various This give the power flow and losses in the network as shown. The result obtained from this model is now used for the training of the network using artificial neural network.



2.2 *Training the Network Using Ann.*

The algorithm to train the neural network is typed on the editor window of Matlab. This program calls up the neural network tool and analyses the total area load demand as the input to the neural network. The electric power generation of the seventeen power stations, are taken as the output of the neural network. For the purpose of training the neural network, data were obtained from the simulated results from Power World Simulator at fourteen different total area load demand to ensure a fast learning rate and ability to produce correct output when fed with a different input. These data are shown in appendix A.After preparing adequate data for training and test of neural networks, now the important key is selecting the number of neurons in the hidden layer of the networks such that the exactness of network is maximum. For this reason, the neural network is trained with five neurons in the hidden layer and a neuron in the output layer. A number of 200 epochs is considered. The Tan-Sigmoid Transfer Function was used in the hidden layer while the Linear Transfer Function was used in the output layer. Also, the default Levenberg-Marquardt algorithm (trainlm) was adopted to achieve a better training speed.The figures of the Training Pattern of the Neural Network and the Linear Regression for the Generation Output (MW) of the trained system are obtained after the program has been run for analysis by clicking on the run icon. Figure 2 shows the training of the data obtained from PHCN. This gives a Regression (R). It measures the correlation between outputs and targets. An R value of 1 means a close relationship, 0 a random relationship. The next step then involves setting a goal so as to know when the training will end considering all the constraints. Figure 3 shows that the performance goal of the network was met after 61 epochs.

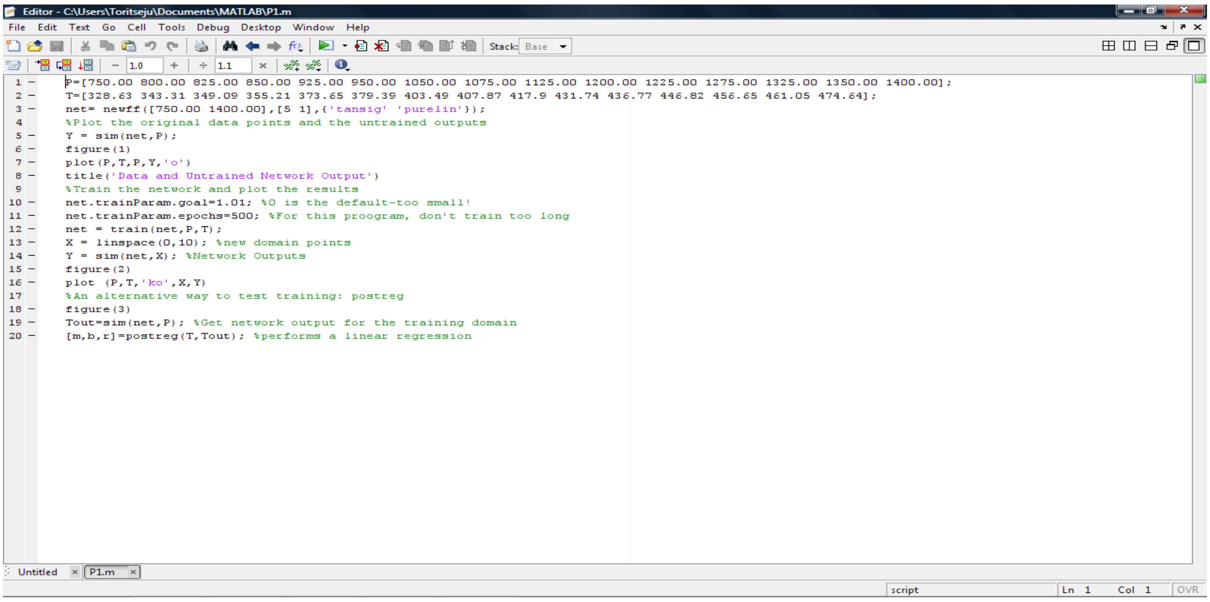


Figure 2. Training the data using artificial neural network

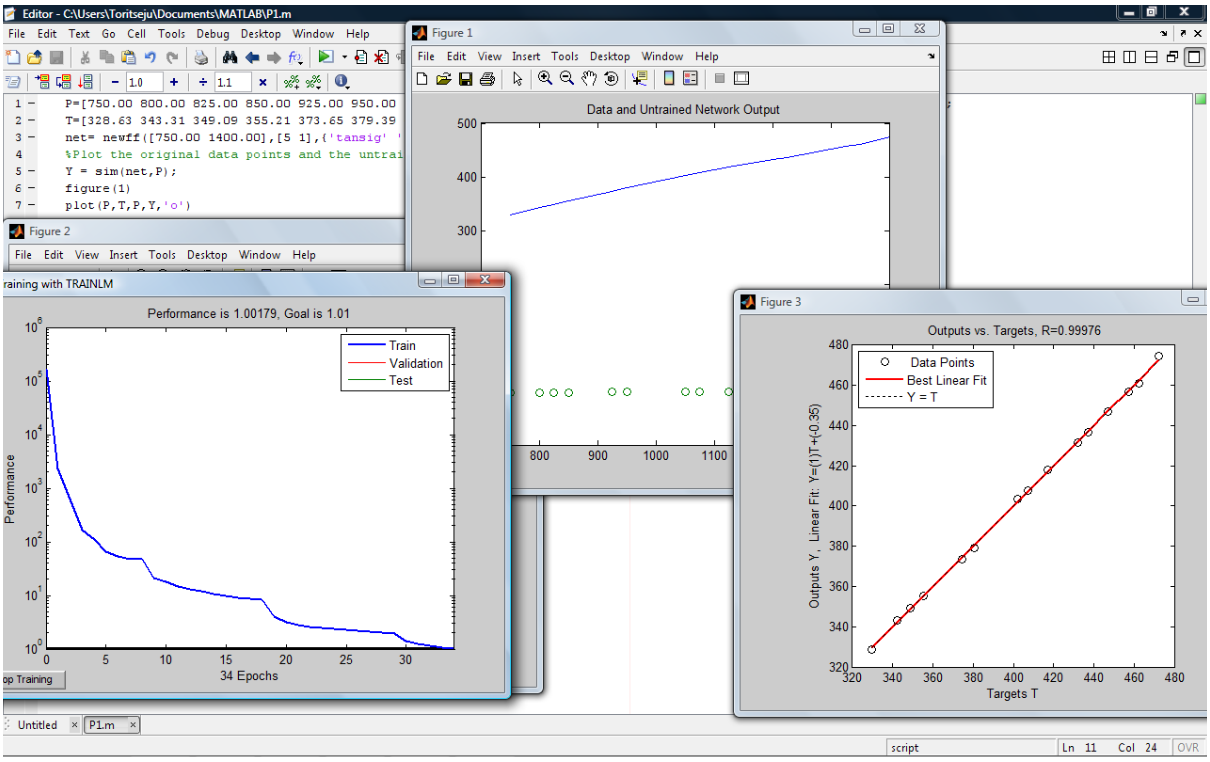


Figure 3 Shows that the performance goal of the network was met after 61 epochs.

Tables 3.0 and 4.0 respectively showed the generation scheduling using power world simulator and then applying ANN for the power generation scheduling respectively. The generating stations are shown also for range of power between 1500MW and 6000MW.

Table 3.0: Simulated Results of Nigeria 330kV Economic Generation Scheduling

Calabar (MW)	Afam(MW)	Oji (MW)	Ijora(MW)	Omotosho (MW)	Geregu (MW)	Omoku(MW)	TotalArea Load(MW)	Jebba (MW)	Egbin (MW)	Kainji(MW)	Shiroro(MW)	Sapele(MW)	Delta IV (MW)	A.E.S (MW)
0.00	152.31	9.52	0.00	92.58	61.86	36.38	1500.00	206.66	195.06	206.07	176.04	165.59	170.69	44.70
0.00	180.80	15.29	13.32	110.15	79.74	42.74	1750.00	228.29	223.14	229.20	202.18	192.14	193.70	57.63
1.13	222.21	22.61	28.30	126.96	93.96	50.86	2000.00	247.89	253.16	249.90	224.75	215.47	212.16	71.30
6.60	250.12	28.42	43.33	144.83	111.59	57.27	2250.00	266.97	281.52	270.14	246.17	243.81	236.89	84.09
6.60	275.83	30.00	59.20	163.79	129.67	63.61	2500.00	287.61	312.64	292.01	270.16	272.40	260.94	97.97
6.60	320.22	30.00	60.00	176.30	145.06	73.77	2700.00	304.00	327.59	310.12	293.23	295.08	283.90	104.60
6.60	357.44	30.00	60.00	201.42	167.50	82.18	3000.00	327.52	370.77	334.85	317.02	332.48	315.75	123.52
6.60	503.97	30.00	60.00	253.06	223.68	100.00	3700.00	381.07	448.02	391.74	383.50	415.95	387.92	156.69
6.60	550.53	30.00	60.00	278.75	247.71	100.00	4000.00	407.07	488.41	419.68	406.44	455.67	420.61	173.67
6.60	590.77	30.00	60.00	298.20	265.85	100.00	4250.00	431.46	520.08	445.81	436.54	484.15	445.31	186.84
6.60	669.88	30.00	60.00	335.00	300.00	100.00	4750.00	475.70	588.20	493.07	485.28	550.46	502.88	214.66
6.60	813.60	30.00	60.00	335.00	300.00	100.00	5500.00	540.00	703.10	582.27	590.88	663.83	598.97	260.08
6.60	903.72	30.00	60.00	335.00	300.00	100.00	5750.00	540.00	756.83	614.14	600.00	721.43	600.00	270.00
6.60	958.86	30.00	60.00	335.00	300.00	100.00	6000.00	540.00	833.23	687.26	600.00	791.80	599.68	270.00

Table 4.0: ANN's Response to Simulated Generation Output

For Ijora Power Station

Total Area Load(MW)	Simulated Gen. (MW)	ANN's Response (MW)	% Error
1750.00	13.32	13.40	0.60
2000.00	28.30	28.41	0.39
2250.00	43.33	43.24	0.21
2500.00	59.20	58.99	0.35
2700.00	60.00	59.97	0.05
3000.00	60.00	59.94	0.10
4000.00	60.00	60.00	0.00
4250.00	60.00	60.00	0.00

5500.00	60.00	60.00	0.00
6000.00	60.00	60.00	0.00

For Calabar Power Station

Total Area Load(MW)	Simulated Gen. (MW)	ANN's Response (MW)	%Error
1750.00	0.00	0.00	0.00
2000.00	1.13	1.10	2.65
2250.00	6.60	6.61	0.15
2500.00	6.60	6.60	0.00
2700.00	6.60	6.00	9.11
3000.00	6.60	5.99	9.24
4000.00	6.60	5.98	9.39
4250.00	6.60	6.61	0.15
5500.00	6.60	6.60	0.00
6000.00	6.60	6.60	0.00

For Shiroro Power Station

Total Area Load (MW)	Simulated Gen. (MW)	ANN's Response (MW)	%Error
1750.00	202.18	201.85	0.16
2000.00	224.75	225.02	0.12
2250.00	246.17	247.26	0.44
2500.00	270.16	267.98	0.81
2700.00	293.23	295.26	0.69
3000.00	317.02	316.22	0.25
4000.00	406.44	405.67	0.19
4250.00	436.54	435.73	0.19
5500.00	590.88	590.16	0.12
6000.00	600.00	600.22	0.04

For Omoku Power Station

Total Area Load(MW)	Simulated. Gen. (MW)	ANN's Response (MW)	%Error
1750.00	42.74	42.72	0.05
2000.00	50.86	50.87	0.02
2250.00	57.27	57.30	0.05
2500.00	63.61	63.63	0.03
2700.00	73.77	73.77	0.00
3000.00	82.18	82.20	0.02
4000.00	100.00	100.00	0.00
4250.00	100.00	100.03	0.03
5500.00	100.00	100.04	0.04
6000.00	100.00	100.04	0.04

For Afam Power Station

Total Area Load(MW)	Simulated Gen. (MW)	ANN's Response (MW)	%Error

1750.00	180.80	180.56	0.13
2000.00	222.21	222.10	0.05
2250.00	250.12	249.11	0.40
2500.00	275.83	275.46	0.13
2700.00	320.22	321.51	0.40
3000.00	357.44	356.98	0.13
4000.00	550.53	551.45	0.17
4250.00	590.77	591.16	0.07
5500.00	813.60	812.71	0.11

For Kainji Hydro Power Station

Total Area Load (MW)	Simulated Gen. (MW)	ANN's Response (MW)	%Error
1750.00	229.20	229.25	0.02
2000.00	249.90	249.10	0.32
2250.00	270.14	269.98	0.06
2500.00	292.01	292.10	0.03
2700.00	310.12	312.22	0.68
3000.00	334.85	333.99	0.26
4000.00	419.68	420.22	0.13
4250.00	445.81	446.18	0.08
5500.00	582.27	583.62	0.23
6000.00	687.26	686.79	0.07

For Orji Power Station

Total Area Load (MW)	Simulated Gen. (MW)	ANN's Response (MW)	%Error
1750.00	15.29	15.40	0.72
2000.00	22.61	22.55	0.27
2250.00	28.42	28.44	0.07
2500.00	30.00	29.97	0.10
2700.00	30.00	29.99	0.03
3000.00	30.00	29.99	0.03
4000.00	30.00	29.99	0.03
4250.00	30.00	29.99	0.03
5500.00	30.00	29.99	0.03
6000.00	30.00	29.99	0.03

3. Discussion

In other to economically dispatch power generated, it must be as economical as possible. In large interconnected systems, it is humanly impossible to calculate and adjust each generation and hence the help of digital computer system is being used and the whole process is carried out automatically.The most economic generation scheduling of power in the Nigeria 330KV network is determined for each station as shown both in table 3.0 and 4.0 respectively. The first stage is to model the Nigeria 330KV network in power world simulator environment in order to obtain the best schedule if a certain quantity of generation is required assume a range of (1500MW-6000MW) as shown in table 3.0. The next stage is then to further optimize these generations scheduling using ANN approach and then make comparison between the simulated scheduling with and without optimization as shown in table 4.0. In the course of this work, PWS (power system modelling software) is used to determine economic generation scheduling considering transmission losses of power plants very efficiently and accurately. Different generation scheduling values ranging from 1500MW-6000MW were used. This schedule ensures that the systems are always not stressed beyond their thermal limit and the losses of each power station and their constraints are put into consideration. A case of load schedule of 1500MW shows contribution of individual generators as economical as possible considering generating power within the acceptable loss range and power limits (active and reactive) .Take also an instance of the Nigeria power network generating 2500MW, for optimal scheduling, the various stations are required to generate various quantity of power as shown in table 3.0.However considering the same quantity of power generation using ANN approach, and then comparing the same result without the ANN, the results obtained is shown in table 4.0.Percentage errors were computed to show the best approach and it was found that adopting ANN for generation scheduling is best as its very economical.

4. Conclusion/Recommendation

Economic load dispatch in electric power sector is an important task, as it is required to distribute the load among the generating units actually paralleled with the system in such a manner as to minimise the cost of supplying the minute to minute requirement of the system which aids in profit-making. In a large interconnected system, it is humanly impossible to calculate and adjust each generation and hence the help of digital computer system is being used and the whole process is carried out automatically. Currently the practice of ELD is not obtainable in Nigeria. It is therefore recommended that the Nigeria government should adopt the approach of economically scheduling power generation.

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Appendix A

S/N	TRANSMISSION LINE		LENGTH (KM)	CIRCUIT TYPE	LINE IMPEDANCE (PU)		
	From	**To**			**Z**	**B**	**ADMITTANCE**
1	Katampe	Shiroro	144	Double	0.0029 + j 0.0205	0.308	8-j4.808
2	Afam GS	Alaoji	25	Double	0.009 + j0.007	0.104	9.615-j16.129
3	Afam GS	Ikot-Ekpene	90	Double	0.0155 + j0.0172	0.104	9.615-j16.129
4	Afam GS	Port-Harcourt	45	Double	0.006 + j0.007	0.104	9.615-j16.129
5	Aiyede	Oshogbo	115	Single	0.0291 + j0.0349	0.437	3.205-j2.288
6	Aiyede	Ikeja west	137	Single	0.0341 + j0.0416	0.521	2.695-j19.919
7	Aiyede	Papalanto	60	Single	0.0291 + j0.0349	0.437	3.205-j2.288
8	Aja	Egbin PS	14	Double	0.0155 + j0.0172	0.257	16.129-j9.615
9	Aja	Alagbon	26	Double	0.006+j0.007	0.257	6.494-j3.891
10	Ajaokuta	Benin	195	Single	0.0126+j0.0139	0.208	1.429-j12.180
11	Ajaokuta	Geregu	5	Double	0.0155+j0.0172	0.257	6.494-j3.891
12	Ajaokuta	Lokoja	38	Double	0.0155+j0.0172	0.257	8-j4.808
13	Akangba	Ikeja west	18	Single	0.0155+j0.0172	0.065	32+j19.32
14	Aladja	Sapele	63	Single	0.016+j0.019	0.239	5.284-j51.913
15	Alaoji	Owerri	60	Double	0.006+j0.007	0.308	6.494-j3.891
16	Aladja	Delta PS	32	Single	0.016+j0.019	0.239	5.848-j4.184
17	Alaoji	Onitsha	138	Single	0.035+j0.0419	0.524	2.754-j33.553
18	Alaoji	Ikot-Ekpene	38	Double	0.0155+j0.0172	0.257	6.494-j3.891

19	Aliade	New Haven South	150	Double	0.006+j0.007	0.308	16.129-j9.615
20	Aliade	Makurdi	50	Double	0.0205+j0.0246	0.308	4.545-j3.247
21	B-kebbi	Kainji	310	Single	0.0786+j0.0942	1.178	1.235-j0.478
22	Benin	Ikeja west	280	Double	0.0705+j0.0779	1.162	1.637-j12.626
23	Benin	Sapele	50	Double	0.0126+j0.0139	0.208	3.194-j17.555
24	Benin	Delta PS	107	Single	0.016+j0.019	0.239	5.848-j4.184
25	Benin	Oshogbo	251	Single	0.0636+j0.0763	0.954	1.508-j12.932
26	Benin	Onitsha	137	Single	0.0347+j0.0416	0.521	2.8-j33.771
27	Benin	Benin north	20	Single	0.049+j0.056	0.208	8-j4.808
28	Benin	Egbin PS	218	Single	0.016+j0.019	0.239	5.848-j4.184
29	Benin	Omotosho	120	Single	0.016+j0.019	0.365	3.846-j2.739
30	Benin North	Eyaen	5	Double	0.0126+j0.0139	0.208	8-j4.808
31	Calabar	Ikot-Ekpene	72	Double	0.0126+j0.0139	0.208	6.494-j3.891
32	Damaturu	Gombe	135	Single	0.0786+j0.0942	1.178	1.19-j0.848
33	Damaturu	Maiduguri	140	Single	0.0786+j0.0942	1.178	1.19-j0.848
34	Egbema	Omoku	30	Double	0.0126+j0.0139	0.208	8-j4.808
35	Egbema	Owerri	30	Double	0.0126+j0.0139	0.208	8-j4.808
36	Egbin PS	Ikeja west	62	Single	0.0155+j0.0172	0.257	7.308+j57.14
37	Egbin PS	Erunkan	30	Single	0.016+j0.019	0.239	5.848-j4.184
38	Erunkan	Ikeja west	32	Single	0.016+j0.019	0.239	5.848-j4.184
39	Ganmo	Oshogbo	87	Single	0.016+j0.019	0.239	5.848-j4.184
40	Ganmo	Jebba	70	Single	0.0341+j0.0416	0.239	2.615-j1.919
41	Gombe	Jos	265	Single	0.067+j0.081	1.01	1.923-j16.456
42	Gombe	Yola	217	Single	0.0245+j0.0292	1.01	1.391-j2.999
43	Gwagwalada	Lokoja	140	Double	0.0156+j0.0172	0.257	6.494-j3.891
44	Gwagwalada	Shiroro	114	Double	0.0155+j0.0172	0.257	6.494-j3.891
45	Ikeja west	Oshogbo	252	Single	0.0341+j0.0416	0.521	2.695-j1.919
46	Ikeja west	Omotosho	160	Single	0.024+j0.0292	0.365	2.695-j1.919
47	Ikeja west	Papalanto	30	Single	0.0398+0.0477	0.597	2.695-j1.919
48	Ikeja west	Sakete	70	Single	0.0398+j0.0477	0.521	2.695-j1.919
49	Ikot-Abasi	Ikot Ekpene	75	Double	0.0155+j0.0172	0.257	6.494-j3.891
50	Jebba	Oshogbo	157	Single	0.0398+j0.0477	0.597	0.246-j3.092
51	Jalingo	Yola	132	Single	0.0126+j0.0139	0.208	8-j4.808
52	Jebba	Jebba GS	8	Double	0.002+j0.0022	0.033	3.174-j1.594
53	Jebba	Kainji	81	Double	0.0205+j0.0246	0.308	3.607-j40.328
54	Jebba	Shiroro	244	Single	0.062+j0.0702	0.927	1.559-j13.297
55	Jos	Kaduna	197	Single	0.049+j0.0599	0.927	1.873-J1.337
56	Jos	Makurdi	230	Double	0.002+j0.0022	0.308	4.545-J3.247
57	Kaduna	Kano	230	Single	0.058+j0.0699	0.874	1.657-j14.12
58	Kaduna	Shiroro	96	Single	0.0249+j0.0292	0.364	3.935-j3.379
59	Katampe	Shiroro	144	Double	0.0205+j0.0246	0.308	8-j4.808
60	New Haven	Onitsha	96	Single	0.024+j0.0292	0.365	3.935-j33.79
61	New Haven	New Haven South	5	Double	0.0205+j0.0246	0.308	4.545-J3.247
62	okpai	Onitsha	80	Double	0.006+j0.007	0.104	16.13-J9.615
63	Onitsha	Owerri	137	Double	0.006+j0.007	0.104	16.13-J9.615
64	Ikot Ekpene	New Haven South	143	Double	0.0205+j0.0246	0.257	6.494-j3.891