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TRANSMISSION NETWORK LOSS MINIMIZATION USING ARTIFICIAL NEURAL NETWORK AND FACTS DEVICES

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Abstract: **Due to the increase in voltage instability problem and power losses in Nigeria grid are a serious operational challenger facing electricity supply utilities. The Nigeria 330Kv power grid was used as a case study for the evaluation of the proposed power loss reduction system a simulink model of the Nigeria 330Kv transmission system with the proposed neural network controlled TCSC integrated was created in the MATLAB/SIMULINK programming environment. Genetic algorithm was used for optimal placement of the FACTS device in the MATLAB/SIMULINK model of the Nigeria 330Kv transmission system .The proposed approach has been implemented on IEEE 67 bus system, 39 load points, 111 transmission lines and 14 generators. The simulation and evaluation were carried out with TCSC installed with each variation of the load at the bus; load flow is run to determine total system losses. Findings showed that the proposed neural network controlled TCSC to Achieved an average active power loss reduction of 13.11378 (p.u) and average reactive power loss reduction of 78.16378 (p.u). This shows that TCSC reduced both active and reactive power loss in the system.**

Keywords: **TCSC, FACTS Devices, Neural Network, GA, Modeling and training, Transmission Grid, Classification of FACTS Devices.**

I. INTRODUCTION

From the physical principles of electric power transmission, when a conductor is subjected to electric power, electric current flows in the medium. Resistance to the flow produces heat (thermal energy) which is dissipated to the surroundings. This power loss is referred to as Ohmic loss (Wang, C. and M.H. Nehrir, 2004). Ohmic loss otherwise known as line loss on power transmission occurs as a result of resistance of conductors against current flow. The effective resistance of the transmission line is a function of the current on the line. This is because of the heat produced in the conductor resulting from current flow, and this leads to a temperature rise in the conductor. This rise in temperature increases the resistance of the conductor and consequently the losses on the line. The power losses could take off a sizeable portion of the transmitted power since transmission lines usually span a long distance, sometimes several hundred kilometers (Wang, C. and M.H. Nehrir, 2004).

The resistance R of a line conductor having resistivity ρ (Ω/m), length l (m) and an area of cross section (m^2) is given by:

$$R = \rho l/a \quad (1)$$

One way to reduce power losses is to reduce the current carried in transmission lines, but this way is limited due to the high cost of HV transformers. However, another way is by use of FACTS devices.

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Artificial Neural Network (ANN) initiates the biological nervous system to perform the tasks on the input data. To solve highly complex tasks such network are widely used. It consists of input, one or two hidden and output layers (Mahammad A Hannan et al, 2018). ANN has a lot advantages that makes very suitable and of huge advantage in the design of controllers. In this regard its consideration as universal approximations of functions for structured or unstructured multivariate data sets makes its use in controllers very easy to realize (Haykin, S.S., 2009). Its massively parallel processing capability makes it very much capable than conventional controller such as PL controller for real time control mission. ANN has found many applications in power systems (Vidya Sagar et al., 1993). Once trained the neural network is able to provide sufficiently accurater commendations in a very short time suitable for on line applications in power system.

II. FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

Flexible Alternating Current Transmission Systems (FACTS), according to IEEE definition are "Alternating current transmission systems incorporating power electronic based and other static controllers to enhance controllability and increase power transfer capability (V. Azbe et. al., 2005). Most of the publications on FACTS stress the point that FACTS are used to improve a power system performance by modifying the transmission line parameters.

Literature survey indicates that what is most interesting for power transmission planners is that FACTS technology opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines (A. Zangeneh et. al., 2008). The possibility that current through a line can be controlled enables a large potential of increasing the capacity of existing line with larger conductors, and use of one of the FACTS controllers to enable corresponding power to flow through such lines under normal and contingency conditions.

It is reported in the literature (Fang, W. L. and H. W. Ngan, 1999), (Onyemaechi, A.B. and O.O. Isaac, 2017) that these opportunities arise through the ability of FACTS controllers to control the interrelated parameters that govern the operation of transmission systems such as series impedance, shunt impedance, current, voltage, phase angle, and the damping of oscillations at various frequencies below the rated frequency. These constraints cannot be overcome, while maintaining the required system reliability, by mechanical means without lowering the useable transmission capacity. The argument advanced by researchers(V. Azbe et. al, 2005),(Fang, W. L. and H. W. Ngan, 1999) is that by providing added flexibility, FACTS controllers can enable a line to carry power closer to its thermal rating. Mechanical switching needs to be supplemented by rapid-response power electronics. Gonen, 2014 emphasized that FACTS is an enabling technology, and not a one-on-one substitute for mechanical switches.

The FACTS technology is not a single high-power controller, but rather a collection of controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system parameters mentioned above (Gonen, 2014). Well-chosen FACTS controllers can overcome the specific limitations of a designated transmission line or corridor. It is said that because all FACTS controllers represent applications of the same basic technology, their production can eventually take advantage of technologies scale. It is noted in the reference (Wang, C. and M.H. Nehrir, 2004) that just as the transistor is the basic element for a whole variety of microelectronic chips and circuits, the thyristor or high-power transistor is the basic element for a variety of high-power electronic controllers.

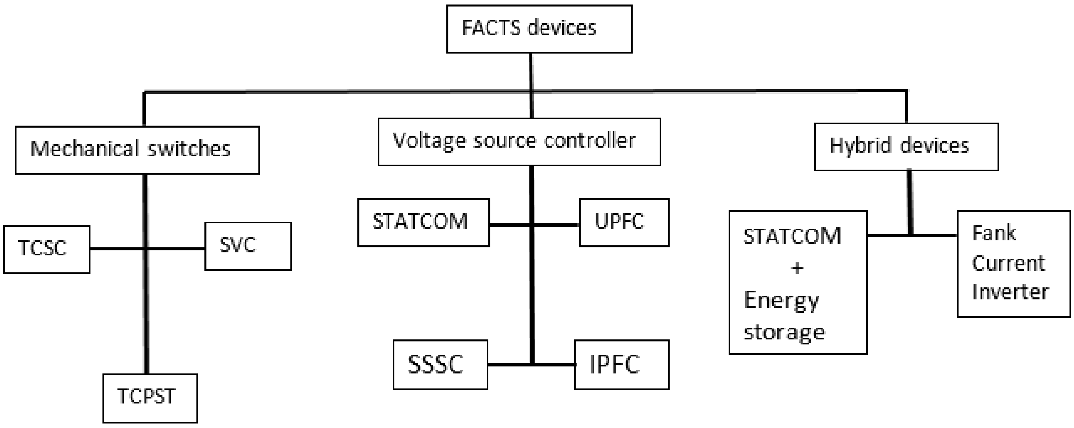

Figure 1.0: Classification of FACTS Devices

III. MATHEMATICAL MODEL FOR THE POWER LOSS

The main reason for losses in transmission and sub-transmission lines is the resistance of conductors against the flow of current. The production of heat in the conductor as a result of the flow of current increases its temperature. This rise in the conductor's temperature further increases the resistance of the conductor and this will consequently increase the losses. This implies that ohmic power loss is the main component of losses in transmission and sub-transmission lines, Mehta and Mehta (2008) and Gupta (2008). The value of the ohmic power loss, Wadhwa (2009), is given as

$$L_{ohmic} = I^2 R \qquad (2)$$

I Denotes current along the conductor and

R Represents resistance of the conductor.

The formation of corona on transmission line is associated with a loss of power, which will have some effect on the efficiency of the transmission line. The corona power loss for a fair weather condition, Mehta and Mehta (2008), Wadhwa (2009), Gupta (2008) and James (2005), has the value

$$L_{corona} = 242\,\frac{(f+25)}{\delta}.\sqrt{\left(\frac{r}{d}\right)}.(V - V_0)^2.10^{-5} \qquad (3)$$

Where

f Represents the frequency of transmission,

δ Denotes the air density factor,

r Is radius of the conductor?

d Represents the space between the transmission lines,

V Is the operating voltage and

V_0 Denotes the disruptive voltage.

Taking the total power loss on transmission lines to be the summation of ohmic and corona loss,

$$T_{loss} = L_{ohmic} + L_{corona} \qquad (4)$$

i.e

$$T_{loss} = I^2 R + 242\,\frac{(f+25)}{\delta}.\sqrt{\left(\frac{r}{ds}\right)}.(V - V_0)^2.10^{-5} \qquad (5)$$

The general form of equation (5) is given by

$$T_{loss} = I^2 \frac{\rho l}{A} + 242\,\frac{(f+25)}{\delta}.\sqrt{\left(\frac{r}{d}\right)}.(V - V_0)^2.10^{-5} \qquad (6)$$

Where

ρ Is the resistivity of the conductor?

l Denotes the length of the conductor and

A Is the cross-sectional area of the conductor?

In this paper, FACTS device (TCSC) under the control of neural network is used for the minimization of power losses. Referring to equation (5), if the current I is kept low and the operating voltage V is kept very close to the critical disruptive voltage V_0(so that the difference $V - V_0$ is low) , then T_{loss} will be minimized. Hence, the transmission current I, the operating voltage V and the critical disruptive voltage V_0 are used as part of the inputs to the neural network for the control of the FACTS device.

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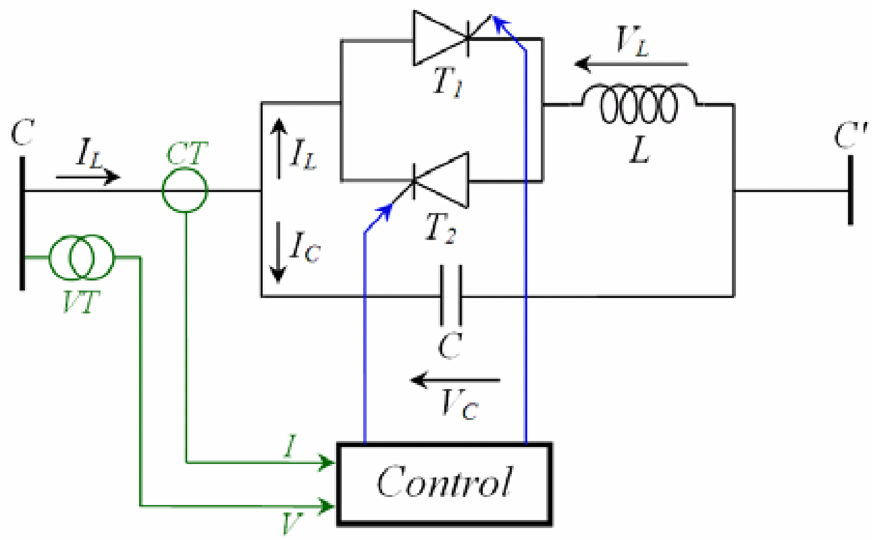
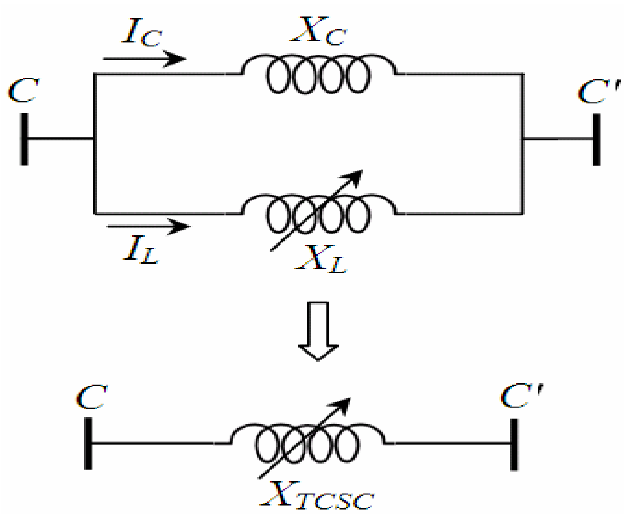
IV. THYRISTOR CONTROLLED SERIES CAPACITOR

TCSC (Thyristor Controlled Series Capacitor) shown mounted on transmission line on Figure 1.1 is a type of series FACTS Controllers (or Compensators). It consists of capacitor (C) connected in parallel with an inductance (L) controlled by a valve mounted in anti-parallel conventional thyristors (T_1 and T_2) and controlled by an angle of extinction ($\propto$) varied between 90^0 and 180^0.



(a) System configuration



(b) Apparent reactance.

Figure 1.1: Transmission line with TCSC system.

From Figure 1.1 (b), the compensator TCSC injects in the transmission line a variable capacitive reactance (X_{TCSC}). The expression of X_{TCSC} is directly related to the controlled thyristors, angle ($\propto$) which is varied between 90^0 and 180^0 and expressed by following equation (S. Khanchi and V.K Garg, 2013),(P.S Georgilakis and P.G Vernados, 2011):

$$X_{TCSC}(\propto) = X_d // X_L(\propto) = \frac{X_C . X_L(\propto)}{X_C + X_L(\propto)} \qquad (7)$$

$$\underset{n_L}{X}(\propto) = X_{LMax}\left[\frac{\pi}{\pi - 2\propto - \sin(2\propto)}\right] \qquad (8)$$

Where

$$X_{LMax} = L.\omega \tag{9}$$

And,

$$X_C = {}^{-1}/_{j.C.\omega} \tag{10}$$

From the equation (7), (8) and (9) the equation (10) becomes:

$$X_{TCSC\,(\propto)} = \frac{X_C.X_{LMax}\left[\frac{\pi}{\pi - 2\propto - \sin(2\propto)}\right]}{X_C + X_{LMax}\left[\frac{\pi}{\pi - 2\propto - \sin(2\propto)}\right]} \tag{11}$$

V. MATERIAL AND METHOD

The material used is artificial neural networks and genetic algorithm to be used for the control and placement of the FACTS Devices respectively for optimal active power loss reduction so as to reduce ohmic and corona in the power system. Neural network controller is used to control the injection and adsorption of active and reactive power by the TCSC so that current and voltage are actively controlled .Genetic algorithm was used in this paper to compute optimal location for the placement of the FACTS Device.

The Nigeria 330Kv power grid was used as case study for the evaluation of the proposed power losses reducing system the digital model of the case study power system with the proposed neural network controlled TCSC integrated was created in the MATLAB/ SIMULINK programming environment.

VI. SIMULATING THE EFFECT OF LOADING PATTERN IN SYSTEM LOSS.

Loss in the power system results from power flow. The nature of the power flow is primarily due to the load conditions the power system is subjected to at various buses in the system. Hence, in this work, load variations will be used to evaluate the transmission loss reduction due to the installations of the neural network controlled FACTS devices. The simulations is carried out in MATLAB and a particular selected bus is subjected to load variations in order to effectively determine the effect of the neural network controlled FACTS devices on active and reactive power loss reduction.

In order to keep the effect of system instability to a minimum as much as possible, the buses subjected to load variation are buses that are stable. To ensure this, the bus selected is a bus having eigenvalue that lie on the left side of the S-plane and having a high value of damping ratio.

The eigenvalue program is loaded into the MATLAB workspace to carry out eigenvalue analysis on the digital model of the power system. The output from the eigenvalue analysis is extracted and tabulated on table10.

Table 1: Extracted output from eigenvalue analysis

Bus Name	Eigen value	Damping ratio(G)	Participation factor(%}
AFAM GS		0.4762	0.0102
ALAOJI 330KV	-2.325±j8.0321	0.2781	2.0018
EGBIN GS		0.4810	0.2146
SAPELLE		0.2233	10.1575
AKANGBA	-0.4087±j0.8293	0.4421	0.0625
ALAGBON	0.8922±j3.013	0.2842	3.1174
LEKKI	-5.3063±j10.3295	0.4569	0.0625
OMOTOSO TS	-5.1617±j11.2755	0.4162	12.4678
SAKETE	-0.4759±j0.5616	0.6465	0.0933
AJA	-04164±j0.6618	0.5325	0.0536
GBARAIN		0.2562	2.0341
JEBBA TS	-1.1731±j4.1051	0.2751	4.3210

KADUNA	-0.8042±j2.9632	0.2623	0.7326
OKEARO TS	-1.1843±j3.845	0.2942	3.0072
OMOKU		0.3283	0.4136
OWERRI	-0.9499±j3.5917	0.2552	2.0018
RIVERS 132KV		0.5716	1.4172
YENEGOA	5.5160±j5.22030	0.7108	8.3066
ABA 132KV	-3.7688±j6.0058	0.5315	3.4172
ADIABOR	-3.2505±j82795	0.36543	0.9847
AFAM	-2.8394±j7.8648	0.3396	2.6731
AFAM 132KV	2.6431±j8.0318	0.3126	0.9874
AHOADA	-2.9202±j7.7275	0.3536	0.0378
AJAOKUTA	3.5157±j6.3330	0.4762	0.0102
ALADJA	-2.325±j8.0321	0.3781	1.0018
ALAOJI GS		0.2810	0.2146
ALAOJI 132KV	-2.4892±j10.8650	0.2233	10.1575
ASABA	-2.4087±j0.8293	0.5421	0.0625
AYEDE	-0.8922±j3.013	0.2842	5.1174
BENIN	3.3063±j12.3295	0.3569	0.0625
DAMATURU	-5.1617±j11.2755	0.4162	12.4678
DELTA		0.3465	2.0933
EGBIN TS	-04164±j0.6618	0.5325	0.0536
EKET 132KV	-2.0922±j7.914	0.2562	2.0341
GANMO	-1.1731±j4.1051	0.2751	4.3210
GERGU GS		0.2623	0.7326
GOMBE	1.1343±j3.345	0.2942	1.0072
GWAGWA	-1.1012±j3.1752	0.3283	0.4136
IBOM 132KV		0.2552	2.0018
IHOVBOR TS	-3.0428±j5.80451	0.5716	1.4172
IKEJA WEST	5.5160±j5.22030	0.3108	5.3066
IKORODU	-3.7688±j6.0058	0.5315	3.4172
IKOT EKPENE	-2.2505±j82795	0.36543	1.9847
ITU 132KV	-2.8394±j7.8648	0.3396	2.6731
JEBBA GS		0.3126	2.9874
JOS	-2.9202±j7.7275	0.2536	1.0378
KAINJI GS		0.3762	0.0102
KANO	-2.325±j8.0321	0.2781	3.0018
KATAMPE	-5.6837±j10.3601	0.8810	2.2146
KEBBI	-2.4892±j10.8650	0.2233	4.1575
LOKOJA	-3.4087±j0.8293	0.4421	0.0625
MAIDUGURI	-0.8922±j3.013	0.2842	3.1174
MAKURDI	-5.3063±j4.3295	0.4569	0.0625
NHAVEN	-3.1617±j1.2755	0.4162	6.4678
ODUKPANI G.S		0.6465	0.0933
OKPAI GS		0.5325	0.0536
OLORUNSOGO GS		0.2562	2.0341
OLORUNSOGO TS	-6.1731±j4.1051	0.2751	4.3210
OMOTOSO GS		0.2623	0.7326
ONITSHA	-8.1843±j3.845	0.2942	3.0072
OSHOBO	-1.1012±j3.1752	0.3283	0.4136
PH MAINS		0.2552	2.0018
SAGAMU		0.5716	7.4172
SHIRORO	-3.5160±j5.22030	0.7108	8.3066
SHIRORO GS		0.5315	3.4172
UGWUAJI	-3.2505±j82795	0.36543	0.9847
YOLA	-2.8394±j7.8648	0.3396	2.6731

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From the tabulation, it can be seen that the base system (i.e the system without any compensation installed, in this case without any FACTS device installed) is not stable. This is due to the fact that all the eigenvalues are not located on the left side of the S-plane.

The eigen value analysis program is applied to the case study power system modeled in MATLAB. The MATLAB m-file code of the eigenvalue program interfaces with the MATLAB/SIMULINK model of the case study power system via the MATLAB program Workspace.

VII. MODELING ANN CONTROLLER BASED TCSC

The key focus of the paper in terms of TCSC is the performance evaluation of transmission network loss minimization using ANN based FACTS devices. The core strategy is the optimal placement and controls of the FACTS device in order to synchronizing for the minimization of power losses. This would ensure the minimization of ohmic and corona losses.

For the TCSC to control power flow to minimize losses on the transmission line, it has to be appropriately controlled to inject variable capactive reactance X_{TCSC} into the transmission line. The NN has to be trained to use appropriate inputs to output the appropriate angle of extinction required to control the switching of the anti-parallel thyristors (T_1 and T_2) of the TCSC.

The functional model of the TCSC with the neural network controller is shown in figure 1.2. As can be seen, the TCSC is connected between bus K and L on the transmission line.

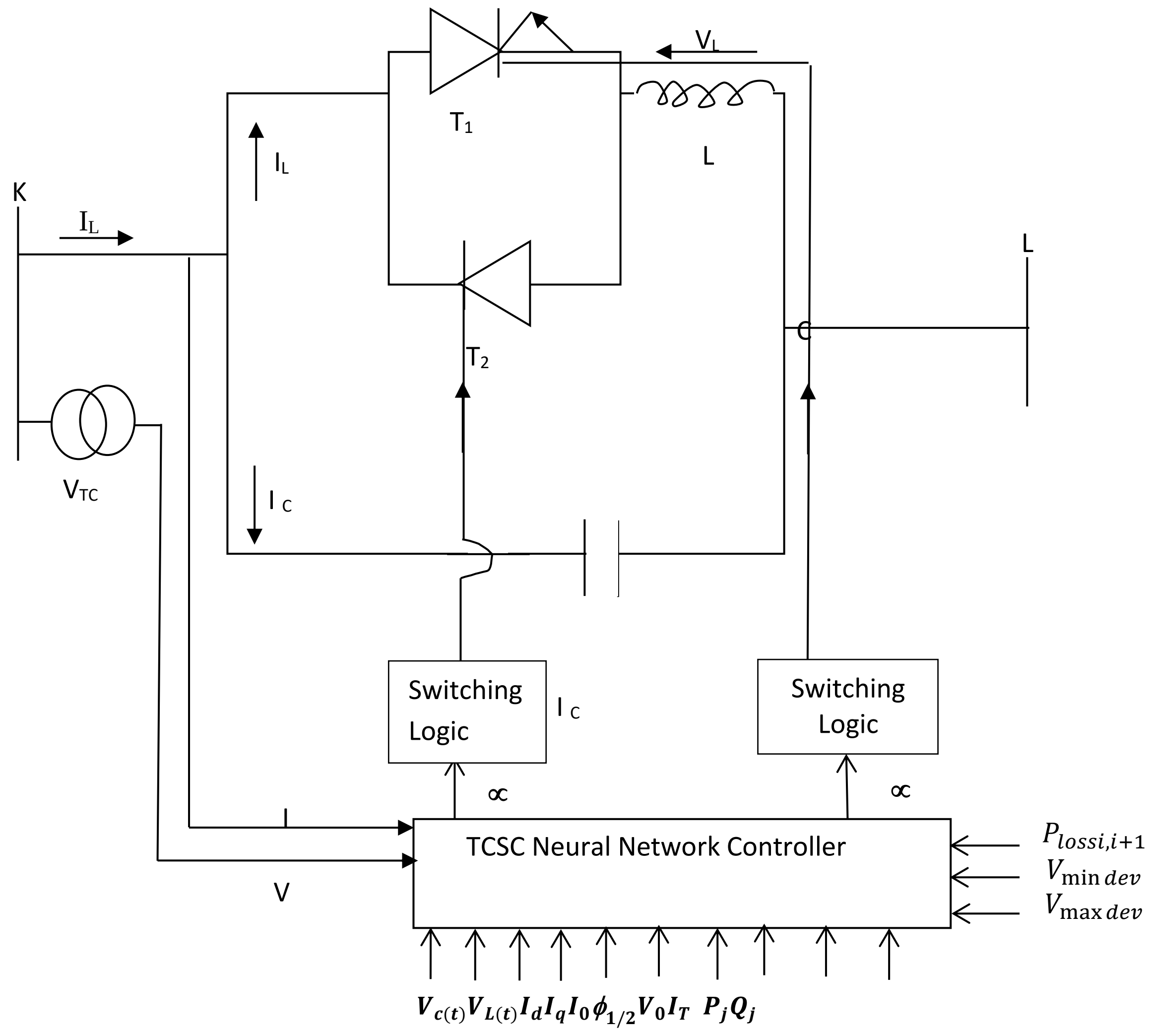

Figure 1.2: Model of TCSC with Neural Network Controller

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The main components of the TCSC circuit are the capacitor (C), the inductor (L) in parallel with the capacitor and the two anti-parallel thyristors (T_1 and T_2). Parameters that relate with each of these components are part of the input to the neural network. The operation of the TCSC involves discrete actions and is periodic in nature whereby on the anti-parallel thyristors of the TCSC conducts during a portion of a half-cycle of the power frequency and is turned-off during the remainder of the cycle. The other anti-parallel thyristor repeats the conduction/non-conduction during the next half-cycle and vice-versa. The duration and timing of the thyristor conduction is based on the triggering or switching logic and is controlled by the neural network controller.

During the conduction interval of a thyristor, the TCSC is modeled as a parallel LC circuit as given in equation (12) and (13) (Hisham Othman, 1996)

$$C\frac{dv}{dt} = (I_d coswt - I_q sinwt + I_0) - I_T \quad (12)$$

$$\frac{L\, dI_T}{dt} = V_L \quad (13)$$

Or in state space form

$$\dot{x} = Ax + B\, I_{dqo} \quad (14)$$

Where

$$x = \begin{bmatrix} V \\ I_T \end{bmatrix},\; A = \begin{bmatrix} \frac{Coswt}{C} & -\frac{sinwt}{C} & \frac{1}{C} \\ 0 & 0 & 0 \end{bmatrix}, I_{dq0} = \begin{bmatrix} I_d \\ I_q \\ I_0 \end{bmatrix}$$

A and B are the system and input matrix respectively. I_{dqo} are the d, q and 0 components of the curents (i.e based on the d_{qo} cordinate frame).

I_T is the total current injected into the terminal of the TCSC.

During the turn-off period of the thyristor, the TCSC is modeled as a series capacitor as given in equation (15) (Hisham Othman, 1996).

$$C\, \frac{dv}{dt} = I_d\, coswt - I_q sinwt\, I_0 \quad (15)$$

Inputs to the TCSC Neural Network Controller

From the structure and analysis of the dynamics of the TCSC, the variable relating to the capacitor, indicator and two anti-parallel thyristors are among the inputs to the neural network controller.

- Capacitor voltage at the present instant: $V_{c(t).}$
- Indicator voltage at the present instant: $V_{L(t)}$.
- d component of the line current: I_d.
- q Component of the line current: I_q.
- O (i.e zero crossing) component of the line crossing: I_0.
- $\phi_{1/2}$ Change in thyristor triggering instant during half cycle.
- Total current injected at the terminal of the TCSC: I_T
- Critical disruptive voltage: V_0
- Active power injected at node j: P_j
- Reactive power injected at node j: Q_j
- Active loss at the ith and (i + 1)th bus: $P_{lossi,i+1}$
- Power balance deviation: P_{dev}
- Minimum voltage constant deviation: $V_{\min dev}$
- Maximum voltage constant deviation: $V_{\max dev}$

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Output of the TCSC neural network controller:

- The extinction angle (∝)

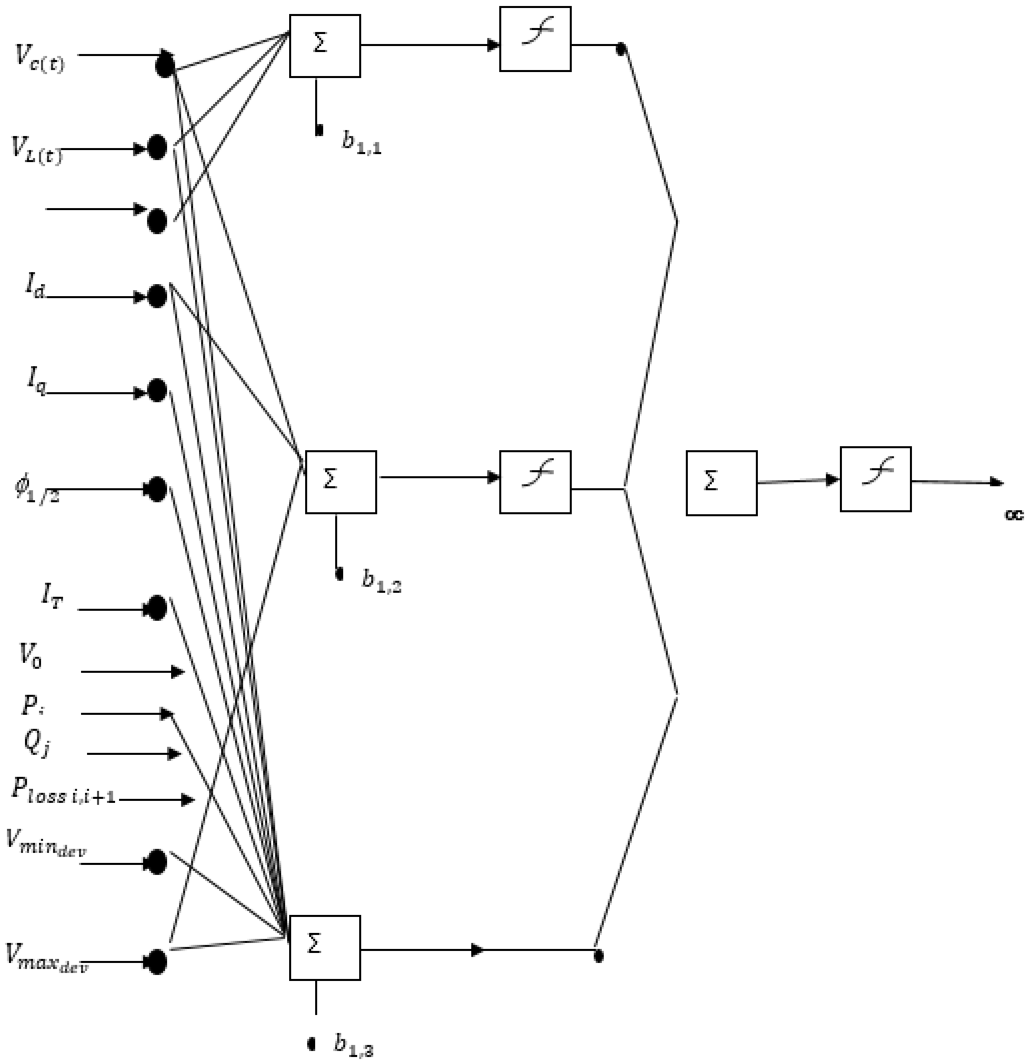

Fig 1.3: the Model of the Neural Network for the Control of TCSC

VIII. TRAINING THE NEURAL NETWORK MODEL FOR THE CONTROL OF TCSC

For the training of the neural network valves for input and output parameters have to be determined, from which the training dataset is obtained which will be used as examples for NN. For this, simulations is carried out to obtain the set of X_{TCSC} corresponding to varying the angle of extinction (∝) from 90^0-180^0 (at steps of and X_{TCSC} that reduces power loss corresponding to various system values of currents, voltages, impedances and the critical voltage are extracted from simulation workspace as examples for training the TCSC neural network..

IX. PLACEMENT OF THE TCSC USING GENETIC ALGORITHM

Optimal placement of FACTS devices in a transmission network of greater importance for the effective utilization of transmission network .Genetic algorithm is used this paper for the placement of the TCSC on the transmission network .The basic concept in GA is from the D arwin principle survival of the fittest, which implies only the best individuals will be selected based on defined fitness level to participate with their genetic parameters in next generation, so the worse individuals is eliminated.GA only works with individuals are coded to chromosomes that contain variables of the problem .The configuration of chromosome to reach the optimal installation of the TCSC location has two parameter setting (VcR and VvR) as coherent model parameters for TCSC.

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Therefore the fitness function can be expressed as:

$Ft = min(T_{loss})$

The population on-line performance *P(n)* is defined as

$$P(n) = \frac{1}{P}\sum_{p=1}^{N} F_t^n(p) \qquad n = 0,\ 1,\ \ldots\ldots\ldots,\quad T-1 \tag{16}$$

Where

N = Total population size;

T = total generations;

Ft p = the fitness function of the pth chromosome in the nth generation.

To maintain diversity in the population, the variable distance *dij* between two solutions *X(i)* and *X(j)* is considered.

$$d_{ij} = \sqrt{\sum_{k=1}^{S}\left(\frac{X_k^{(i)} - X_k^{(j)}}{X_k^{max} - X_k^{min}}\right)^2} \tag{17}$$

Where

S: the number of the variables included in the optimizes X_k^{max} and X_k^{min}respectively the upper and the lower bounds of variables of K_k respectively

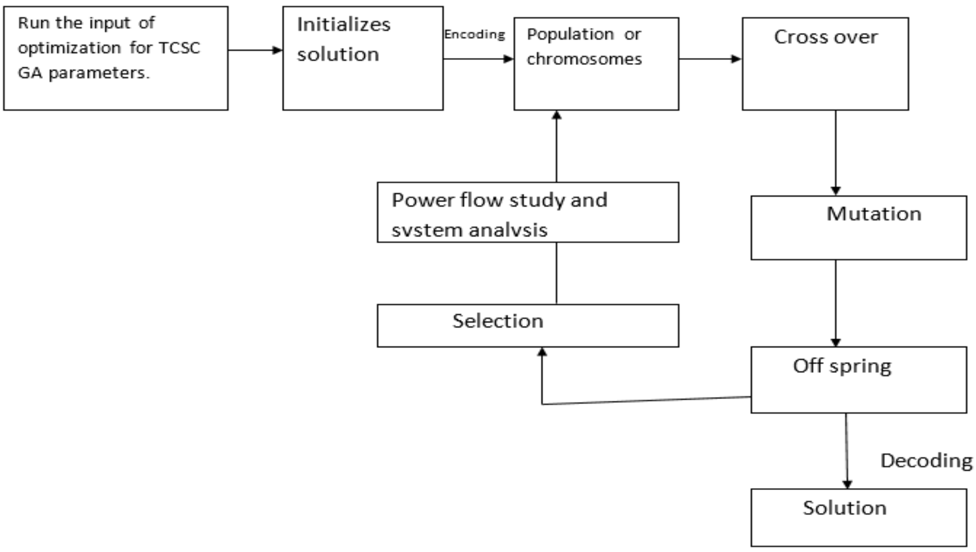

Figure 1.4: The block diagram showing the General structure of GA- Evolution of TCSC.

The process of the implementing the GA technique is described in the following steps:

Step 1: initialize a population (randomly done) and set the generation counter to zero.

Step 2: calculate the fitness of each member of the population;

Step 3: select individuals fitness insider the population is calculate using the (objective function).

Step 4: crossover the parents to create new offspring;

Step 5: mutate will desired to achieving the individuals for the new offspring

Step 6: replace the less fit members with the offspring.

Step 7: done when desired generation counter reached, else

Step 8: increment the generations counter and go to step 2.

X. TRANSMISSION LOSS REDUCTION FOR LOAD VARIATION AT BUS 49 WITH TCSC INSTALLED

In the simulation carried out, load flows are carried out to evaluate the loss reduction for load variation at 49(the most stable bus in the base case of the power system).The simulation and evaluations are carried out with the TCSC installed.

The three phase SIMULINK R-L-C load blocks installed at the load buses are configurable. The load values in the blocks can be reconfigured in MATLAB.

With each variation of load at the bus, load flow is run to determine total system loss either with the UPFC installed or without the UPFC installed.

The variation of load on the bus starts at 198MW (which is about 2% of the total Nigerian load demand of 9895MW, not including export demand) . Then an increment of 50% (i.e. 99MW) of the initial load is added to obtain further load variations at the bus. Hence, the variations of loading conditions at the bus are: 198MW, 297MW, 396MW, 495MW, and 594MW. With 198MW drawn at bus1, the line values output from the load flow of the active and reactive power loss profiles are plotted as shown in Figures 1.5 and 1.6 respectively.

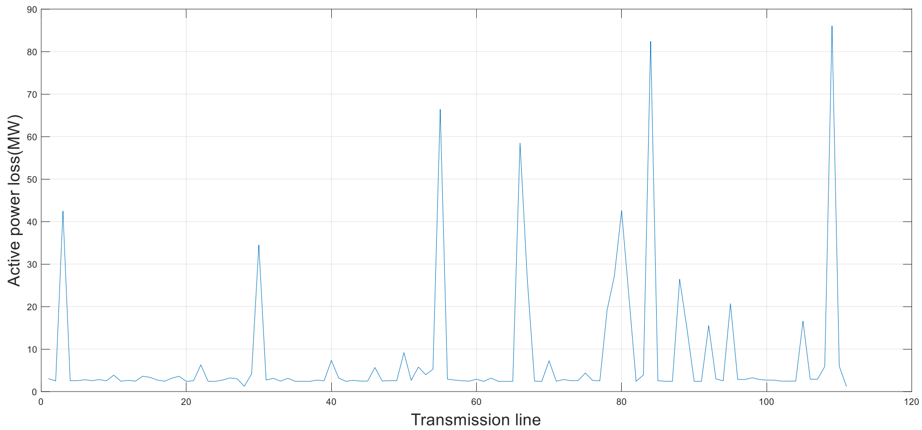

Figure 1.5: Active power loss distribution in the power system with TCSC installed for the 198MW load drawn at bus 49.

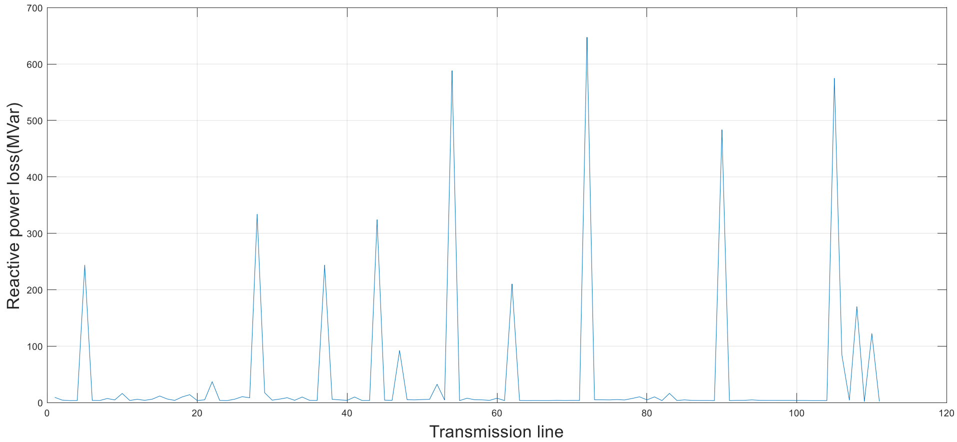

Figure 1.6: Reactive power loss distribution in the power system with TCSC installed for the 198MW load drawn at bus 49.

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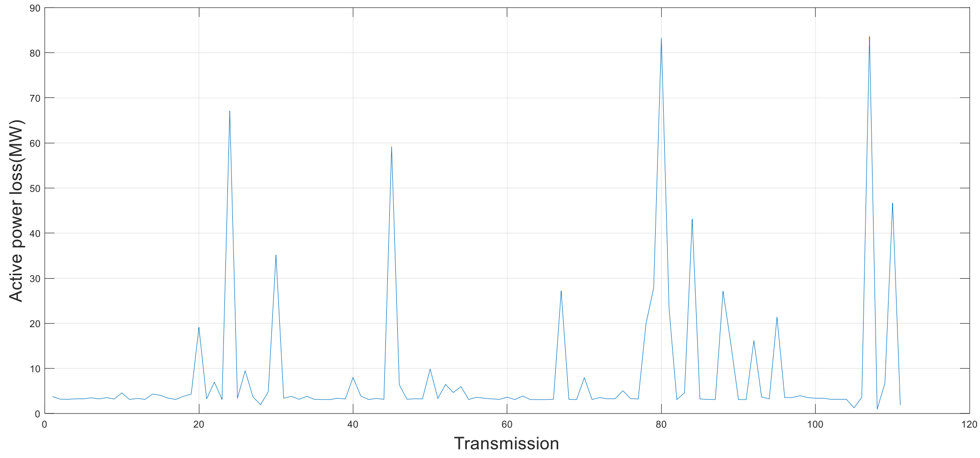

Figure 1.7: Active power loss distribution in the power system with TCSC installed for the 297MW load drawn at bus 49.

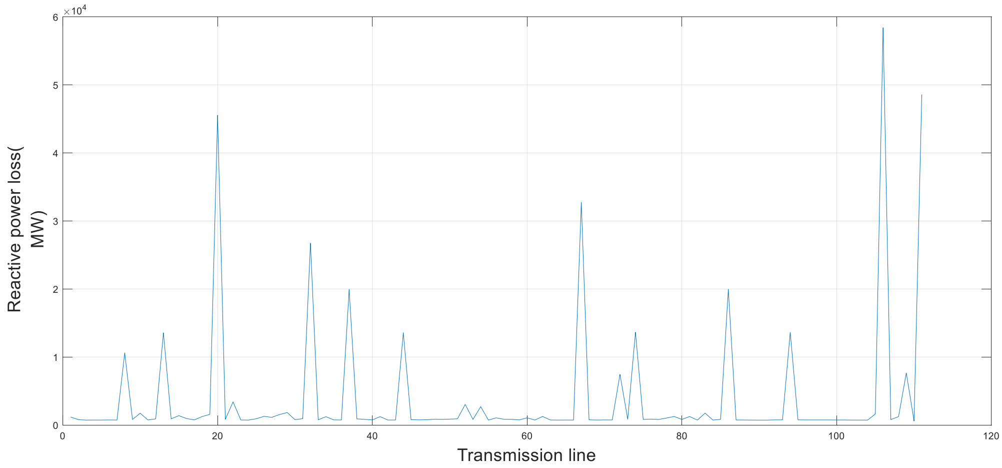

Figure 1.8: Reactive power loss distribution in the power system with TCSC installed for the 297MW load drawn at bus 49

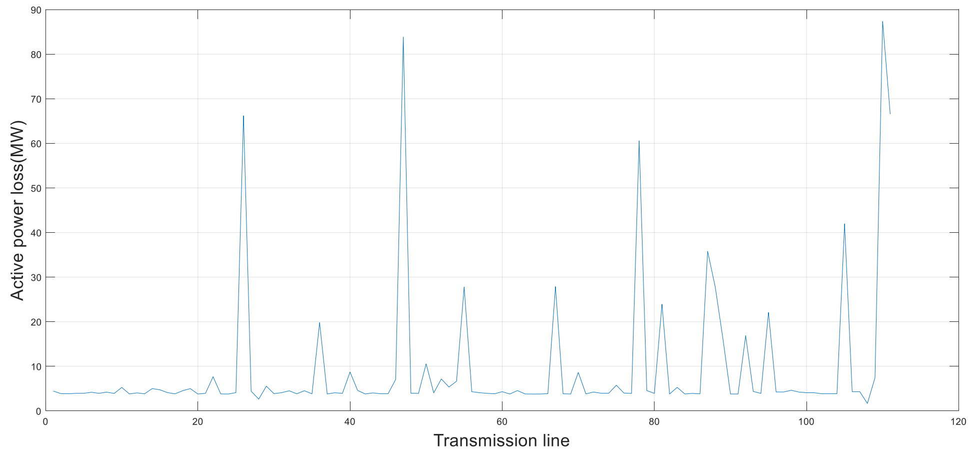

Figure 2.0: Active power loss distribution in the power system with TCSC installed for the 396MW load drawn at bus 49.

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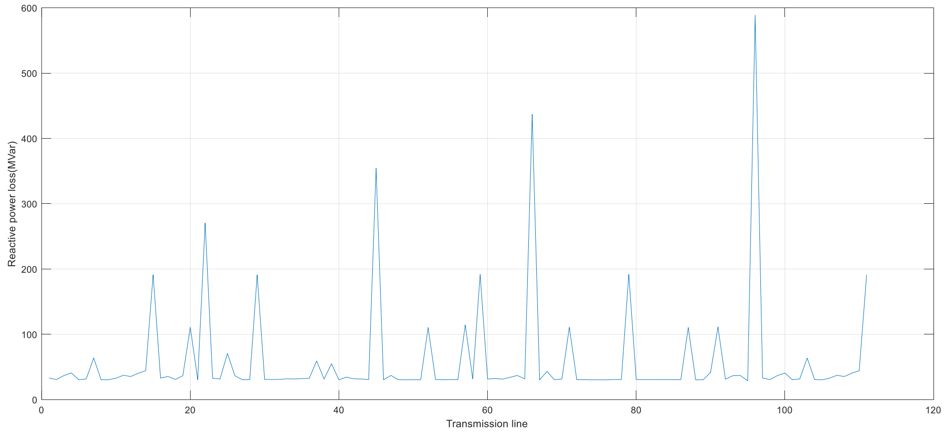

Figure 2.1: Reactive power loss distribution in the power system with TCSC installed for the 396MW load drawn at bus 49.

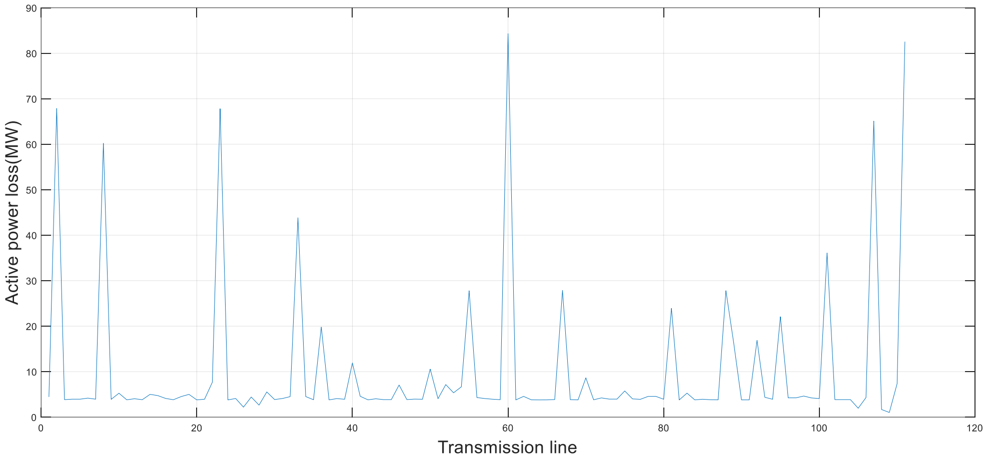

Figure 2.2: Active power loss distribution in the power system with TCSC installed for the 495MW load drawn at bus 49.

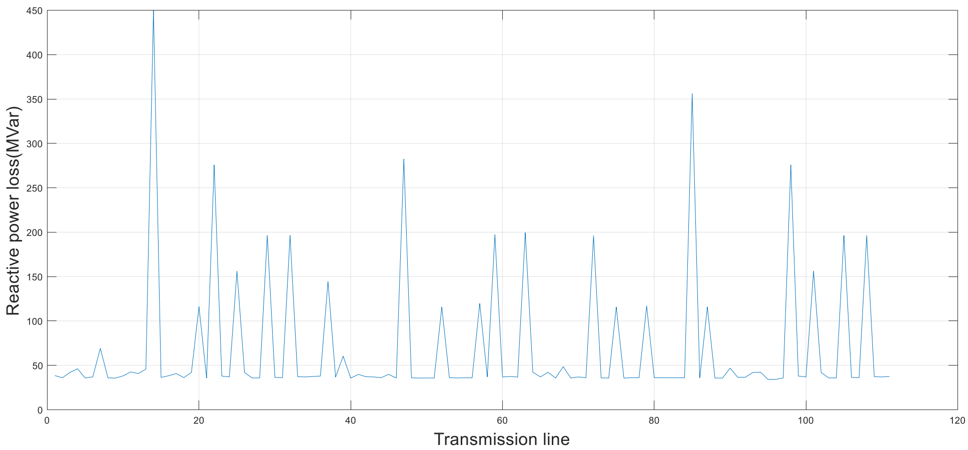

Figure 2.3: Reactive power loss distribution in the power system with TCSC installed for the 495MW load drawn at bus 49.

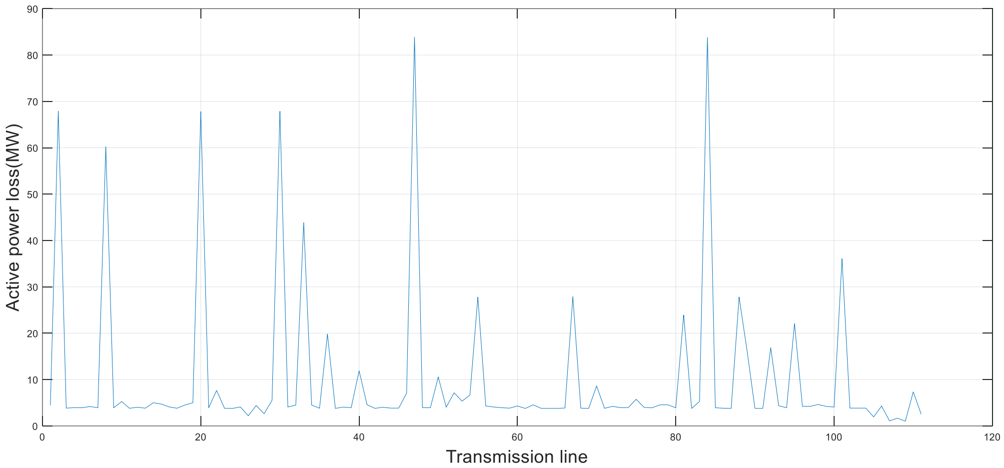

Figure 2.4: Active power loss distribution in the power system with TCSC installed for the 594MW load drawn at bus 49.

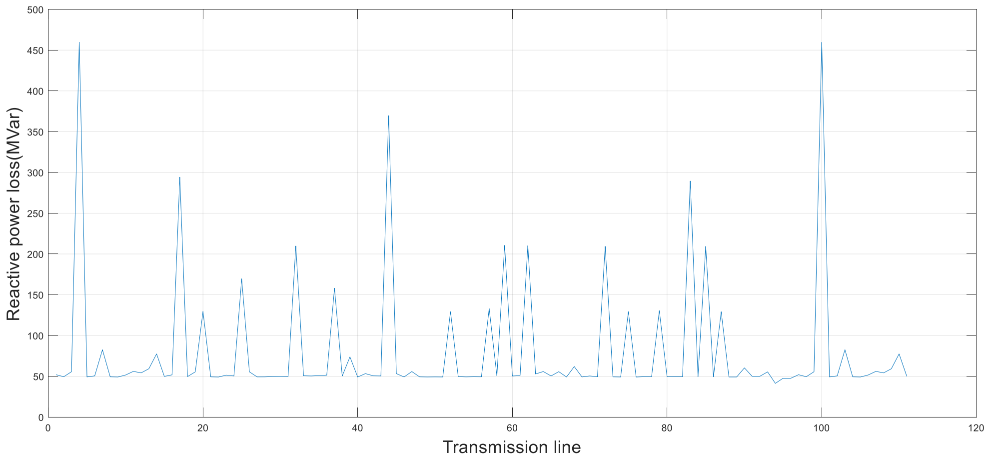

Figure 2.5: Reactive power loss distribution in the power system with TCSC installed for the 594MW load drawn at bus 49.

With the installation of the TCSC, to obtain the variation of active and reactive power loss with load, the total active and reactive losses from are collected and tabulated as shown in Table 1.1

Table 1.1 Variation of power losses with load in the power system with TCSC installed

Load variation(MW)	Total active power loss(p.u)	Total Reactive power loss(p.u)
198	10.6191	59.9223
297	12.273	65.994
396	13.3386	78.9341
495	14.4138	86.6993
594	14.9244	99.2942
Average	**13.11378**	**78.16878**

The trend that can be observed from Table 1.0.Result obtained showed that the proposed system achieved an average active power loss reduction of 13.11378(p.u) and average reactive power loss reduction of 78.16878(p.u) This shows that the TCSC reduced both the active and reactive powers loss in the system.

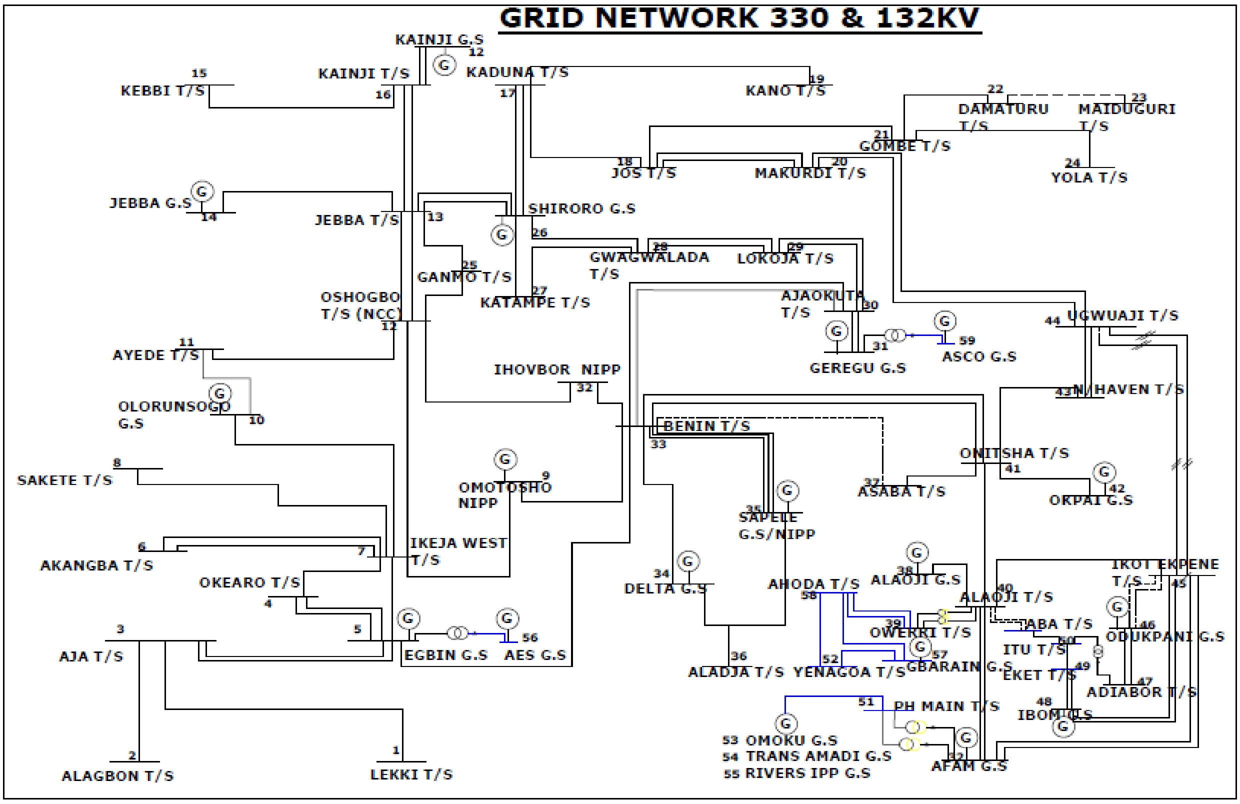

Figure 2.6: Single Line Diagram Of The Nigerian 330/132kv Power System

GENERATOR DATA

There are 14 synchronous generations in the system. The base voltage is 330kv and 100mva.

The following table gives the initial load flow conditions of the 14generators buses.

The following table gives the parameters of the generators

Generator Station	Generation	Rated voltage	Voltage pv
Kainji	292mw	332kv	1.0060
Jebba	404mw	312kv	0.9455
Shiroro	450mw	320kv	0.9697
Egbini	611mw	335kv	1.0151
Sapele	68mw	332kv	1.0060
Delta	470mw	318kv	0.9636
Geregu	144mw	319kv	0.9677
Omotosho	187.5mw	305kv	0.9242
Olominsogo gas	163.6mw	300kv	0.9090
Geregu NIpp	150mw	331kv	1.0030
Sapele NIpp	113.1mw	320kv	0.9692
Olorunsogo NIpp	130.9mw	316kv	09576
Omotosho NIpp	228mw	347kv	1.05151
Okapia	363mw	331kv	1.0030

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LINE DATA

Line #	Buse Code p-q	Line positive sequence Resistance p.u	Line positive sequence Reactance p.u	Length km	Status
1		0.0612	0.0801	3.14	
2		0.0312	0.0452	2.78	
3		0.043	0.0713	1.98	
4		0.0612	0.0801	3.14	
5		0.0612	0.0801	3.14	
6		0.0312	0.0452	2.78	
7		0.0573	0.1013	5.0	
8		0.0614	0.0994	4.50	
9		0.0614	0.0994	4.50	
10		0.03342	0.0784	4.80	
11		0.043	0.0713	1.98	
12		0.043	0.0713	1.98	
13		0.0312	0.0452	2.78	
14		0.0612	0.0801	3.14	
15		0.0612	0.0801	3.14	
16		0.0278	0.0407	1.20	
17		0.0278	0.0407	1.20	
18		0.0614	0.0994	4.50	
19		0.0573	0.1013	5.0	
20		0.0312	0.0452	2.78	
21		0.043	0.0713	1.98	
22		0.0278	0.0407	1.20	
23		0.0603	0.1034	3.60	
24		0.0389	0.0813	2.50	
25		0.043	0.0713	1.98	
26		0.03342	0.0784	4.80	
27		0.0612	0.0801	3.14	
28		0.0278	0.0407	1.20	
29		0.043	0.0713	1.98	
30		0.0278	0.0407	1.20	
31		0.043	0.0713	1.98	
32		0.0573	0.1013	5.0	
33		0.0614	0.0994	4.50	
34		0.03342	0.0784	4.80	
35		0.0603	0.1034	3.60	
36		0.0603	0.1034	3.60	
37		0.0612	0.0801	3.14	
38		0.0278	0.0407	1.20	
39		0.043	0.0713	1.98	
40		0.0603	0.1034	3.60	
41		0.0389	0.0813	2.50	
42		0.0603	0.1034	3.60	
43		0.0389	0.0813	2.50	
44		0.043	0.0713	1.98	
45		0.0612	0.0801	3.14	
46		0.03342	0.0784	4.80	
47		0.0614	0.0994	4.50	
48		0.0573	0.1013	5.0	

49		0.043	0.0713	1.98	
50		0.0278	0.0407	1.20	
51		0.0278	0.0407	1.20	
52		0.043	0.0713	1.98	
53		0.0278	0.0407	1.20	
54		0.0312	0.0452	2.78	
55		0.0573	0.1013	5.0	
56		0.0612	0.0801	3.14	
57		0.0614	0.0994	4.50	
58		0.0614	0.0994	4.50	
59		0.0614	0.0994	4.50	
60		0.0573	0.1013	5.0	
61		0.03342	0.0784	4.80	
62		0.0612	0.0801	3.14	
63		0.043	0.0713	1.98	
64		0.043	0.0713	1.98	
65		0.0278	0.0407	1.20	
66		0.0612	0.0801	3.14	
67		0.0573	0.1013	5.0	
68		0.03342	0.0784	4.80	
69		0.043	0.0713	1.98	
70		0.043	0.0713	1.98	
71		0.0603	0.1034	3.60	
72		0.043	0.0713	1.98	
73		0.0603	0.1034	3.60	
74		0.0278	0.0407	1.20	
75		0.0278	0.0407	1.20	
76		0.0612	0.0801	3.14	
77		0.0573	0.1013	5.0	
78		0.03342	0.0784	4.80	
79		0.0612	0.0801	3.14	
80		0.0389	0.0813	2.50	
81		0.0278	0.0407	1.20	
82		0.0614	0.0994	4.50	
83		0.03342	0.0784	4.80	
84		0.0312	0.0452	2.78	
85		0.0389	0.0813	2.50	
86		0.043	0.0713	1.98	
87		0.0312	0.0452	2.78	
88		0.0612	0.0801	3.14	
89		0.03342	0.0784	4.80	
90		0.0278	0.0407	1.20	
91		0.0312	0.0452	2.78	
92		0.0612	0.0801	3.14	
93		0.0312	0.0452	2.78	
94		0.0573	0.1013	5.0	
95		0.043	0.0713	1.98	
96		0.0603	0.1034	3.60	
97		0.0573	0.1013	5.0	
98		0.0612	0.0801	3.14	
99		0.0312	0.0452	2.78	

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100		0.043	0.0713	1.98	
101		0.0612	0.0801	3.14	
102		0.0612	0.0801	3.14	
103		0.0312	0.0452	2.78	
104		0.0573	0.1013	5.0	
105		0.0614	0.0994	4.50	
106		0.0614	0.0994	4.50	
107		0.03342	0.0784	4.80	
108		0.043	0.0713	1.98	
109		0.043	0.0713	1.98	
110		0.0312	0.0452	2.78	
111		0.0612	0.0801	3.14	

XI. CONCLUSION

In this paper neural network controlled TCSC was used for the reduction of losses in power transmission network. Result obtained showed that the proposed system achieved an average active power loss reduction of 13.11378 and average reactive power loss reduction of 78.16878.

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