

## Modeling And Simulation of Loads Into Existing Distribution Network System Using MATLAB/Simulink

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**Abstract:** This paper presents the detail model of load and other devices in distribution network systems (DNS). Simulation and modeling is done using MATLAB/Simulink software package. The proposed model is user friendly and can be used as a common platform for both applied physics and power system engineers. The proposed model is very simple, fast and accurate. A detailed modeling algorithm is presented. Ede distribution Business Hub of Ibadan Electricity Distribution Company (IBEDC) of Osun Region, South West, Nigeria is used for the modeling. This network comprises of two feeders namely: Ede Township feeder and Ede Cottage feeder. The designed model is used to verify the need to transform from existing conventional grid to smart distribution grid. The results of simulation indicates from the waveform display that numerous challenges facing centralized traditional distribution grid require modern technologies to shift to decentralized smart distribution grid for smooth distribution of power system to ensure an enhanced quality and reliability.

**Keywords:** DNS, MATLAB/Simulink, algorithm, IBEDC, smart distribution grid, traditional distribution grid, modern technology.

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### I. Introduction

An electric power distribution system is the last stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and step down the transmission voltage to medium voltage ranging between 2 kV and 33 kV with the use of transformers [1].

Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again step down the voltage to the utilization voltage of household appliances and typically feed many customers through secondary distribution lines at this voltage [1].

Commercial and residential customers are connected to the secondary distribution lines through service drops. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub transmission level.

Some challenges identified in the existing power distribution are, weak and inadequate network coverage, overloaded transformers and bad feeder pillars, substandard distribution lines, poor billing system, unwholesome practices by staff and very poor customer relations, inadequate logistic facilities such as tools, working vehicles, poor and obsolete communication equipment, low staff morale and lack of regular training, insufficient funds for maintenance activities and non-availability of research and development [2-4].

In addition to cost is the negative impact on people's time - this can mean the time spent accessing alternatives, or the time lost because reading is difficult in the evenings. The modern world is dependent on access to information, which in turn is only possible with a reliable and constant source of electricity.

The DNS of Ede Business Hub which comprises of two 11kV feeders; Ede Township and Ede Cottage feeders as shown in a line diagram of fig no. 1 is used to model on MATLAB/Simulink and the modeled circuit was depicted in fig no. 4 which simulation was carried out to give the waveforms as shown that is used to justify the results of appraisal in [5] which clearly indicates the need to transform the DNS from centralized traditional system to smart distribution system.

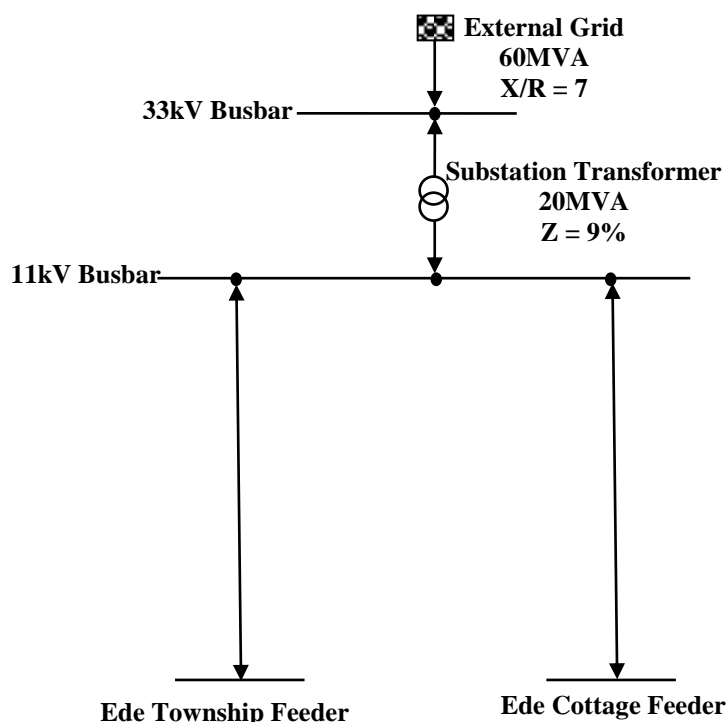


Fig no.11kV Ede Distribution Network System

### Distribution Substation

A distribution substation transfers power from the transmission system to the distribution system of an area. The input to a distribution substation is typically at least two transmissions or sub-transmission lines. Distribution voltages are typically medium voltage, between 2.4kV and 33kV depending on the size of the area served and the practice of the local utility [6].

Besides changing the voltage, the job of the distribution substation is to isolate faults in either the transmission or distribution systems. Distribution substations may also be the points of voltage regulation, although on the long distribution circuits (several km), voltage regulation equipment may also be installed along the line.

Complicated distribution substations can be found in the downtown areas of large cities, with high-voltage switching, and switch and backup systems on the low-voltage side [6].

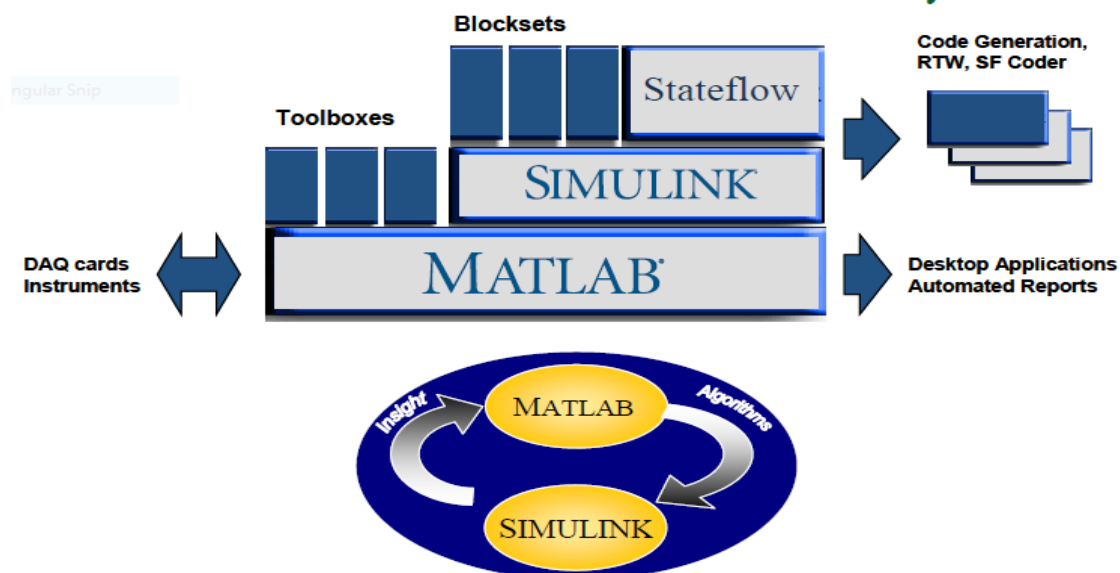
## II. MATLAB/Simulink Software Platform To Model The Distribution Network

The environment in which we build our simulation model was MATLAB. The name MATLAB stands for matrix laboratory. *MATLAB*, developed by MathWorks Inc., is a software package for high performance numerical computation and visualization. The combination of analysis capabilities, flexibility, reliability, and powerful graphics makes *MATLAB* the premier software package for scientific researchers. *MATLAB* provides an interactive environment with hundreds of reliable and accurate built-in mathematical functions. These functions provide solutions to a broad range of mathematical problems including matrix algebra, complex arithmetic, linear systems, differential equations, signal processing, optimization, nonlinear systems, and many other types of scientific computations. The most important feature of *MATLAB* is its programming capability, which is very easy to learn and to use, and which allows user-developed functions. It also allows access to FORTRAN algorithms and C codes by means of external interfaces. There are several optional toolboxes written for special applications such as signal processing, control systems design, system identification, statistics, neural networks, fuzzy logic, symbolic computations, and others. *MATLAB* has been enhanced by the very powerful Simulink program [7].

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multi-rate, i.e., have different parts that are sampled or updated at different rates. For modeling, Simulink provides a graphical user

interface (GUI) for building models as block diagrams, using click-and-drag mouse operations as shown in fig no. 2. With this interface, you can draw the models just as you would with pencil and paper (or as most textbooks depict them).

## The MathWorks Product Family



**Fig no. 2** The relationship text base programming and graphical base programming of MATLAB/Simulink application package

Simulink includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. You can also customize and create your own blocks. Models are hierarchical.

This approach provides insight into how a model is organized and how its parts interact. After you define a model, you can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. The menus are particularly convenient for interactive work, while the command-line approach is very useful for running a batch of simulations (for example, if you are doing Monte Carlo simulations or want to sweep a parameter across a range of values). Using scopes and other display blocks, you can see the simulation results while the simulation is running. In addition, you can change parameters and immediately see what happens, for "what if" exploration. The simulation results can be put in the MATLAB workspace for post processing and visualization. And because MATLAB and Simulink are integrated as shown in fig no. 2, you can simulate, analyze, and revise your models in either environment at any point. [7]. The main features of the MATLAB/Simulink desktop environment are located in a single directory as shown in fig no. 3. This Working Environment contains a set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files. MATLAB's applications [7].

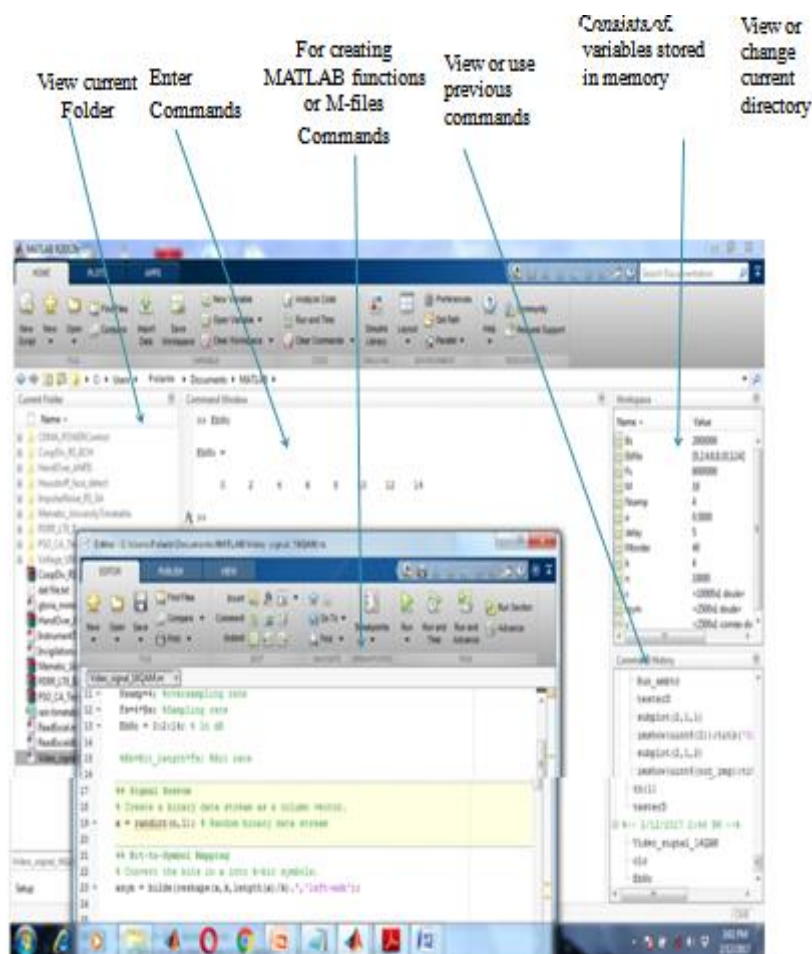


Fig no. 3 Main windows for the working environment features

### Modeling Approach

The simulation models were developed using MATLAB/Simulink with SimPowerSystems. It is then used to simulate various DNS and observe how these change the power system sinusoidal waveform. The models were developed with minimum number of blocks in mind and use their default settings whenever possible to reserve their easiness and reproducibility for the reader. The developed models present in the paper also serve as basic building blocks to a larger power system. The distribution voltage level used in the models is based on the Ede business hub of IBEDC grid code. Simulation models including Ede Township Feeder and Ede Cottage Feeder models used to simulate are described in procedure methodology with output results and waveform display in fig no. 5 to nos. 10.

### Procedure Methodology

- Step 1: Launch the Matlab.exe
- Step 2: GOTO the Simulink library
- Step 3: Proceed to Simpower system TOOL BOX
- Step 4: Select the appropriate Simulink block ELSE Create/Set the block parameters
- Step 5: Configure the block to Specification
- Step 6: Draw the lines appreciate for the Connection of each block
- Step 7: Complete all the Connections
- Step 8: RUN the Program
- Step 9: Extract the Result for further Analysis
- Step 10: END.

**Supporting Mathematical Expression**

$$L = \frac{V_{base}^2}{P_{sc}} \cdot \frac{1}{2\pi f} \cdot R = \frac{X}{X/R} = \frac{2\pi fL}{X/R} \tag{1}$$

$$V_{abc}(pu) = \frac{V_{phaseto\ ground} (V)}{V_{base} (V)} \tag{2}$$

Where

$$V_{base} = \frac{V_{nom} (V_{rms})}{\sqrt{3}} \cdot \sqrt{2} (V) \tag{3}$$

$$V_{abc} = \frac{V_{phasetop\ hase} (V)}{V_{base} (V)} \tag{4}$$

Hence

$$I_{abc} (pu) = \frac{I_{abc} (A)}{I_{base} (A)} \tag{5}$$

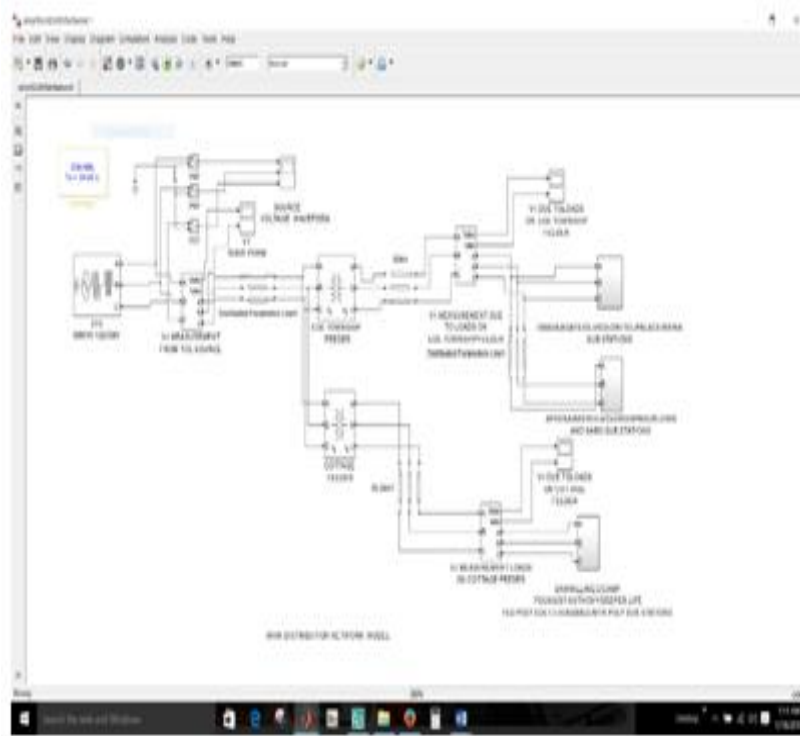
Thus,

$$I_{base} = \frac{P_{base}}{V_{nom}} \neq \frac{\sqrt{2}}{\sqrt{3}} \tag{6}$$

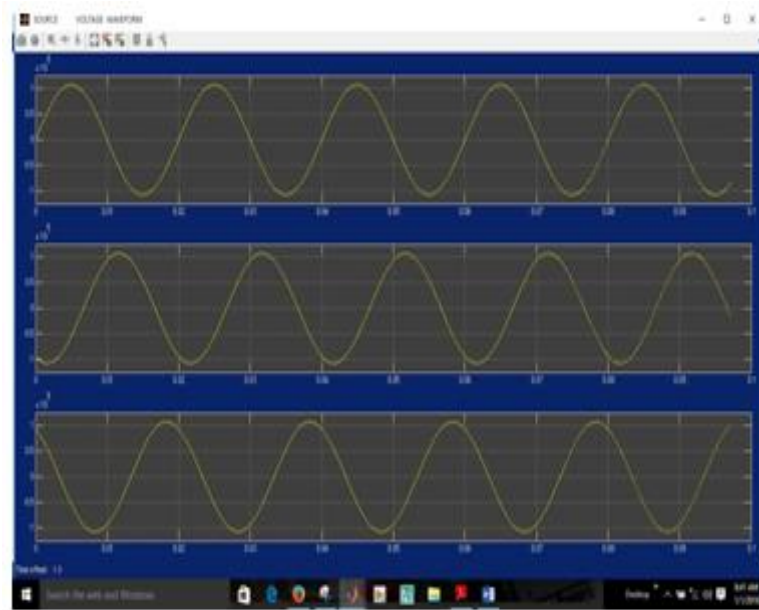
$V_{nom}$  and  $P_{base}$  are specified in the Three-Phase V-I Measurement block dialog box

**III. Results And Discussion**

The results of modeled distribution network is as shown in fig no. 4 while the associates transformer and loads model results are shown in fig nos. 5 to 10 respectively. This is the outcome of the modeled distribution network of Ede Business Hub with the procedure methodology above.



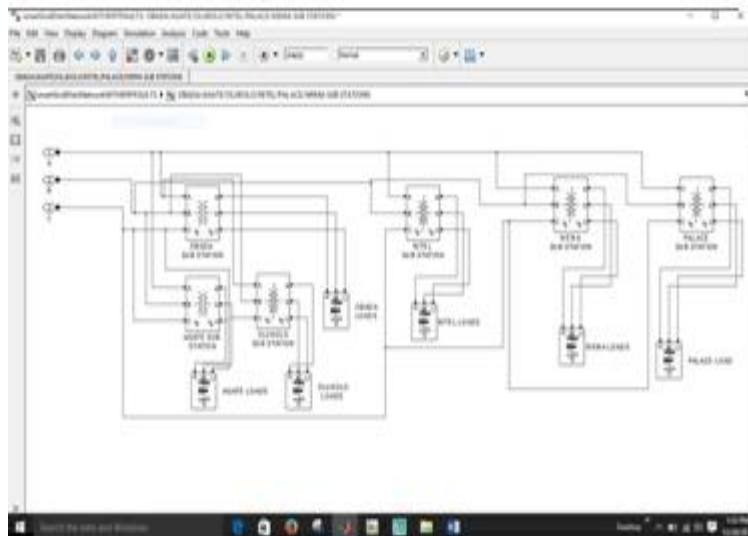
**Fig no. 4** Modeled Ede Business Hub distribution network system



**Fig Figno. 5** Waveform Voltage ( $V_{abc}$ ) result of modeled Ede Business Hub Distribution Network

Fig no. 5 is the source voltage waveform of modeled network from the National Control Centre (NCC), Osogbo. It contains three phase voltage  $V_a$ ,  $V_b$  and  $V_c$  as shown. This indicates a smooth and accurate waveform without any eruption. We observed phase shift of  $0^\circ$  for  $V_a$ ,  $-120^\circ$  and  $120^\circ$  phase shifts for  $V_b$  and  $V_c$  respectively as shown in fig no. 5. Given below are the data implication from simulation of V-I Measurement from the Source:

$V_a = 107664.92 \text{ V}$ ,  $-0.00^\circ$ ;  $I_a = 17.89 \text{ A}$ ,  $-77.54^\circ$   
 $V_b = 107664.92 \text{ V}$ ,  $-120.00^\circ$ ;  $I_b = 17.89 \text{ A}$ ,  $162.46^\circ$   
 $V_c = 107664.92 \text{ V}$ ,  $120.00^\circ$ ;  $I_c = 17.89 \text{ A}$ ,  $42.46^\circ$



**Fig no. 6** Modeled transformer and load on Ede township feeder1

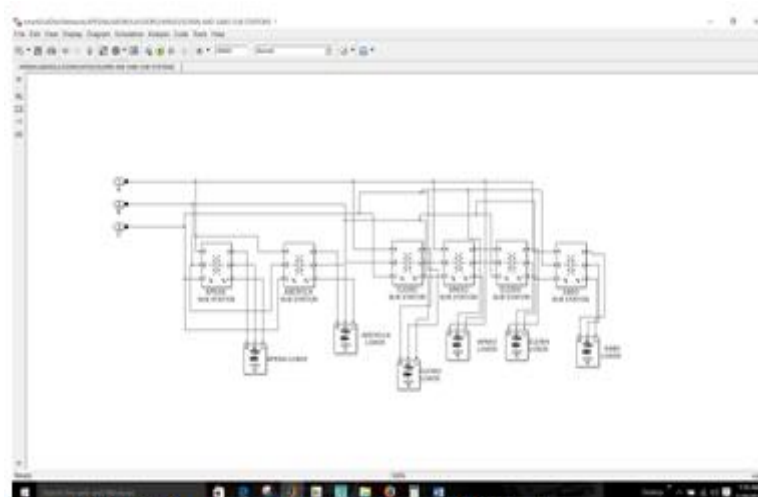


Fig no. 7 Modeled transformer and load on Ede township feeder 2

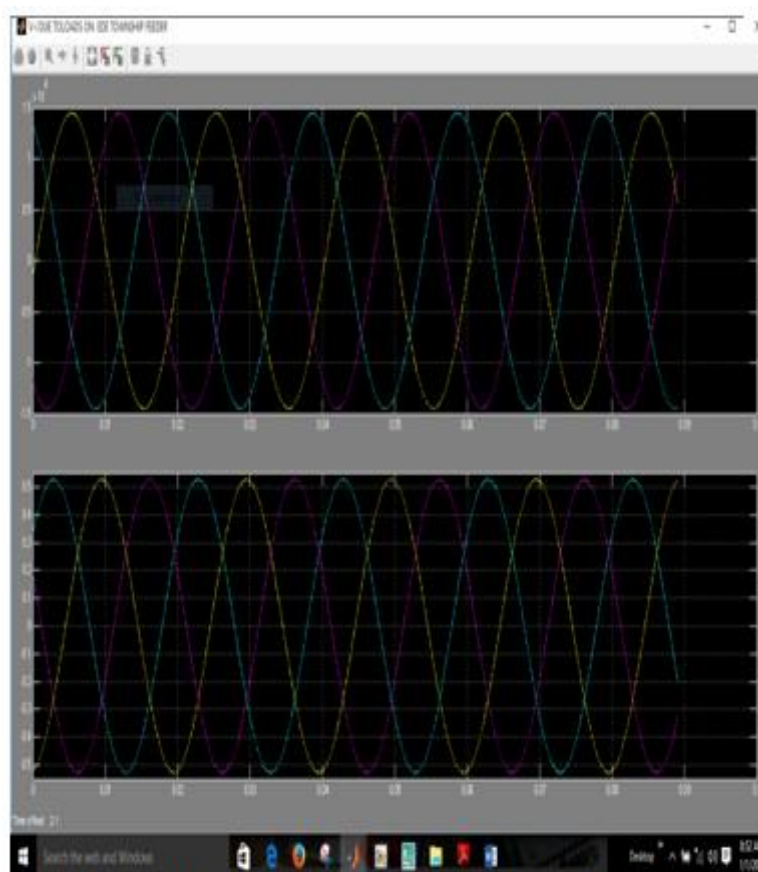
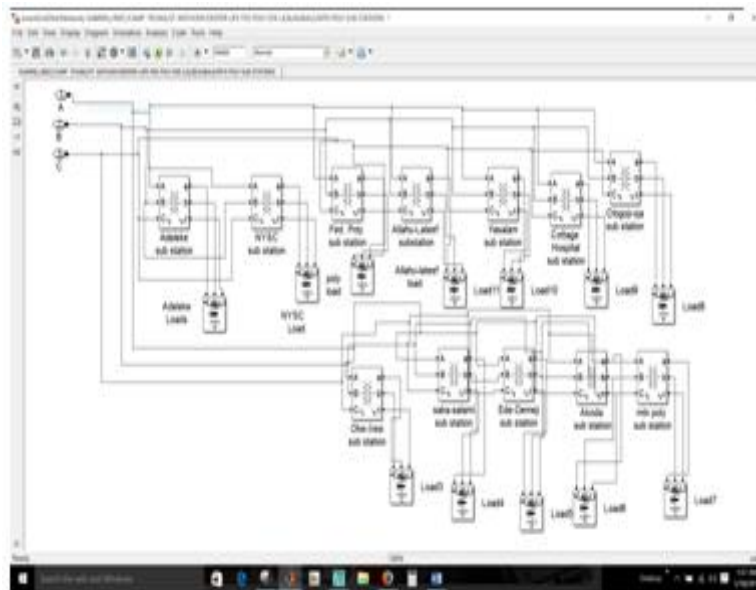


Fig no. 8 Results of  $V_{abc}$  and  $I_{abc}$  Due to Load on Ede Township network feeders

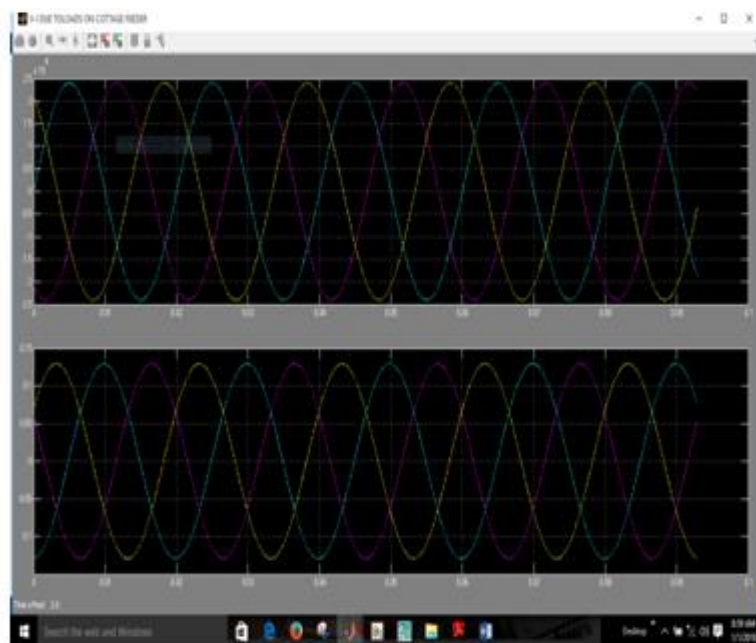
Fig no. 8 shows the waveform of Ede Township Feeder of V-I Waveform due to load on the feeder. We noticed distortion in the waveform. This interruption on waveform justify result of reliability appraisal in [5] which was obtained with data obtained from the utility station. This is as a result of inability of the utility to meet load demand of the consumers. Hence lead to load shedding of some area in order to meet the demand of their customers. Therefore the need of smart devices is very essential to avert this problem.

The data implication of this obtained from the simulation is given as V-I Measurement due to loads on Ede Township Feeder are:

$$\begin{aligned}
 U_a &= 14492.01 \text{ V}, -6.30^\circ; I_a = 85.99 \text{ A}, -81.30^\circ \\
 U_b &= 14492.01 \text{ V}, -126.30^\circ; I_b = 85.99 \text{ A}, 158.70^\circ \\
 U_c &= 14492.01 \text{ V}, 113.70^\circ; I_c = 85.99 \text{ A}, 38.70^\circ
 \end{aligned}$$



*Fig no. 9 Modeled transformer and load on Cottage feeder*



**Fig no. 10 Results of  $V_{abc}$  and  $I_{abc}$  Due to Load on Cottage network feeders**

Fig no. 10 shows Ede Cottage feeder waveform V-I due to load on the feeder. The waveform follows the same pattern with the previous and as well indicates justification of results obtained in [5] with data collected from the IBEDC, Osun region, South West Nigeria. This validates results of appraisal of reliability indices of the network on [5].

The voltage and current waveform of the load on the Ede Cottage feeder are observed to follow the same pattern. They are smooth with minimal or very low level of interruption. However in term of value they are quite distinct. As shown

$$U_a = 24017.47 \text{ V}, 119.80^\circ; I_a = 21.13 \text{ A}, 32.52^\circ$$

$$U_b = 24017.47 \text{ V}, -120.20^\circ; I_b = 21.13 \text{ A}, 152.52^\circ$$

$$U_c = 24017.47 \text{ V}, -0.20^\circ; I_c = 21.13 \text{ A}, -87.48^\circ$$

The above results from the waveforms are used to form the basis of our research to transform the DNS from centralized traditional to decentralized smart system in order to accommodate all the smart technologies



available to enhanced the reliability and quality of electrical power distribution in some of developing nations in Africa particularly Nigeria.

#### **IV. Conclusion**

In this paper, a new simulation procedure methodology load and associates devices incorporation into distribution networks was presented. MATLAB/Simulink was used as the tool to build the simulation environment. The strength of this simulation method falls in the ability to study the effect of different kind of eruptions on the system behavior. The other advantage of this method is its flexibility in building the different kind of loads on feeders and ability to appraise the gravity of effect on network systems. This simulation methodology could be used to build different loads types, validates the results of reliability in [5] and opens the doors to use the MATLAB in this new field.

#### **V. Acknowledgement**

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