Modeling of High Voltage Distribution System Using Simulink

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Abstract: In Nigeria, the average transmission and distribution losses have been officially indicated as 39% of the electricity generated. This is caused by the usage of existing distribution transformers (DTR). The distribution losses can be reduced by proper selection of distribution transformers, feeders, proper re-organization of distribution network, theft control, adoption of upgraded technology etc. In this paper, Modeling of High Voltage Distribution system using Simulink is presented. High Voltage Distribution (HVDs) helps in distributing the power safely without affecting the performance of a system. It is considered as the best move to enhance the performance of distribution system.

Keywords*: Distribution Transformer, High Voltage Distribution System, Voltage Profile.*

I. INTRODUCTION

Power distribution system in Nigeria is characterized by high power and voltage losses which consequently lead to poor quality of electric power reaching consumers. Too wide variation of voltage may cause erratic operation or even malfunctioning of consumer's appliances.

This distribution system begins as the primary circuit which leaves the sub-station and ends as the secondary service which enters the consumer's meter [1].
Electric power at 220 kV is transmitted by three phase, three-wire overhead system to the outskirts of the city and this power is then received by the primary sub-station which reduces the voltage level further to 66 kV. This voltage is further stepped down to 11 kV at secondary sub-station located at some strategic points in the city. In rural areas, loads are widely dispersed and low tension lines run for long distances to feed a small load. Two or three low tension spans are to be laid to fetch a load of one pump set of 4HP and such 10 to 20 pump sets are connected on each distribution transformer of 63 kVA or 100 kVA [2].

The main cause responsible for voltage variation is the variation in load on the supply system. Moreover, Losses in distribution system are also caused among others, by the following, uneven distribution of loads among various feeders and substations, inadequate layout of feeders, overloading of distribution transformers, poor power factor due to inadequate reactive compensation. Therefore, it became very imperative to implement an HVDS that can help mitigate the high level of losses.

In this paper, Modeling of High Voltage Distribution system using Simulink is implemented.

II. ENERGY FLOW FROM GENERATION TO CONSUMERS

The low voltage operations in the distribution are a major reason of higher technical losses due to inherent properties of the bulky networks. Figure1 shows the Energy flow from Generation to Consumers

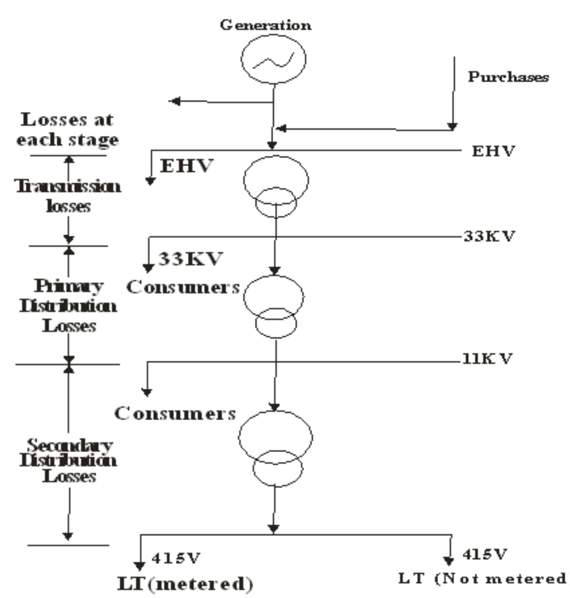

Figure 1: Energy flow from Generation to Consumers [3].

A. Losses in Distribution System

Figure 2 shows that losses occur due to technical and commercial reasons. Minimizing either Technical or

Commercial losses may not serve the purpose of any distribution utility and requires a simultaneous action on all of them.

System losses include transmission losses and distribution losses. The distribution losses make major contribution to the system losses and are about 70% of the total losses. Distribution losses being major share of the system losses needs special attention for achieving remarkable reduction in loss figure. The distribution losses contribute the major portion of the system losses. The losses occurring in the distribution system are divided into two main parts:

i. Technical Losses
ii. Non-Technical Losses

Technical losses result from the nature and type of load, design of electrical installation/equipment, layout of installation, poor maintenance of the system, under size and lengthy service lines, over- loading and sub-standard electrical equipment. Non-technical losses result from incorrect meter readings, and/or billing periods, human errors, and connection running at site but disconnected in record, non affection of meter change orders in time and pilferage of energy [4].

Non-technical losses of the distribution system are extremely high. It is estimated that these losses are more than 33% of the total distribution system losses. Although reduction of these losses may not lower the energy demand and requirement on the distribution system, however it will improve the financial base and provide for a non-equitable base for rate structuring.

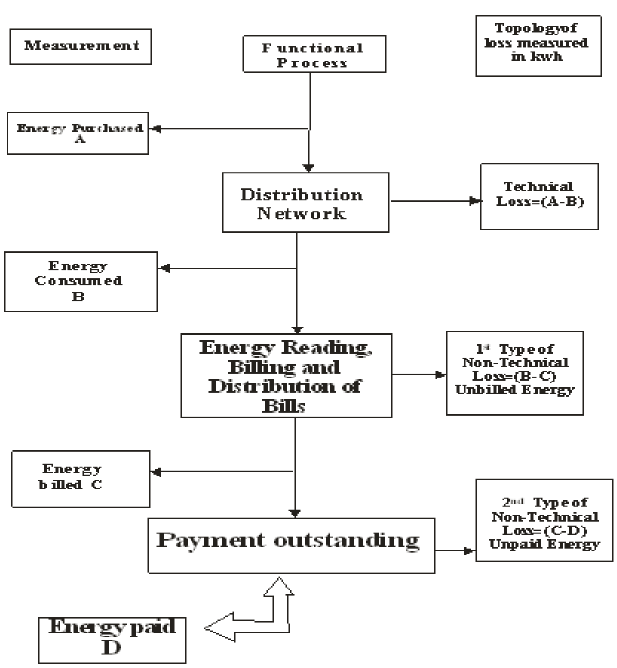

Figure 2: Flow of losses in Distribution System

B. Causes of Losses in Distribution System

1 Technical Losses

Technical loss of a network is as a result of the following causes:

i. No re-configuration of feeder lines and distribution transformers so as to reduce the length of LT lines,
ii. Non usage of smaller size energy efficient distribution transformers,
iii. Non usage of Aerial Bunched Cables for improved reliability and total elimination of faults on LT lines,
iv. Insufficient of reactive compensation, e.g. non-inclusion of appropriate capacitor banks at appropriate places.
v. Overloading of system elements like transformers, feeders, conductors, etc.
vi. Inadequate investments for infrastructure improvement.
vii. Ill maintained equipment and substation, ageing transformers etc.

2 Non-Technical (Commercial) Losses

The commercial losses in power distribution network involve mainly the following:

i. Theft and pilferage,
ii. Low metering efficiency,
iii. Non-reading of meters,
iv. Non application of Advanced Metering Infrastructure
v. Faulty meter reading,
vi. Inefficient billing,
vii. Under billing
viii. Faulty bill distribution,
ix. Software errors,
x. Prolonged disputers,
xi. Inadequate revenue collection,
xii. Revenue account not updated regularly,
xiii. Inefficient collection avenues etc.

3 Advantages of HVDS

i. Customer has sense of ownership
ii. Prevention of unauthorized loads.
iii. Minimal Failure because of on over loading and no meddling of LT lines.
iv. High quality of supply owing to practically no voltage drop.
v. Less burn outs of motors because of good voltage and less fluctuation
vi. Considerable reduction in line losses and consequent savings in power purchase cost
vii. No additional generation capacity needed for giving new loads due to reduction in power drawals.

viii. Accidents due to touching of snapped conductors reduce because the breaker trips at substation since the line is at 11KV potential.

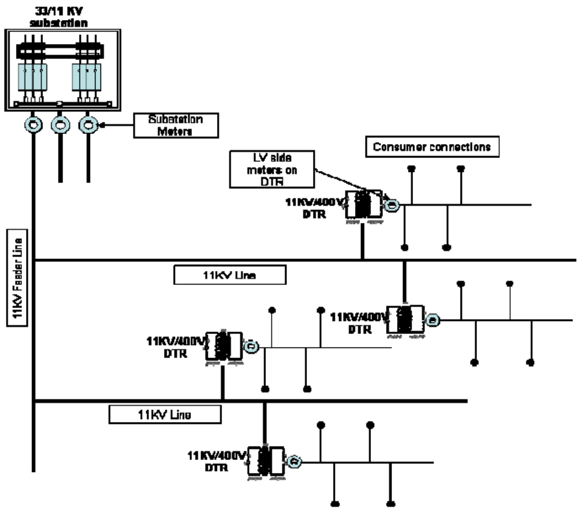

Figure 3: Connection Diagram of HVDS [5]

III. IMPLEMENTATION

The scheme envisages running 11KV lines right up to a cluster 3 or 4 different consumers by employing a small sized distribution transformer a 100KVA and extend supply to these 3 or 4 consumers with an Aerial Bunched Cable (ABC). A smart meter with two way communications module is finally installed at the customer's load point. The power factor is taken to be 0.85. All the poles are equidistant from each other. For the high tension lines, the distance between two consecutive poles is 50meters.

The voltage profile is determined by backward and forward sweep method [6].

Step1-Backward sweep: For every iteration, branch currents are determined from tail end loads to origin using:

$$I_i = \frac{p_i}{v_i * \cos\emptyset * \sqrt{3}} \qquad (1)$$

Step2-Voltage drop in every branch is determined from the corresponding branch current so obtained in step1 using:

$$V_{d_i} = I_i * R_i \qquad (2)$$

Step3-Forward sweep: The branch voltage near origin is obtained from the corresponding branch current obtained in step1 and by considering the total load acting on the system. By considering the voltage drops obtained in step2, the voltages in other branches are also determined from origin to tail end loads.

Step4- The above steps are repeated until we get constant branch voltages or with an at most difference of 10^{-10}.

In HV implementation, we considered 11 kV main distribution feeders with three-phase spur lines and multiple three-phase distribution transformers transforming 11 kV into 415V.

Figure 4 is simulink implementation of HV connections

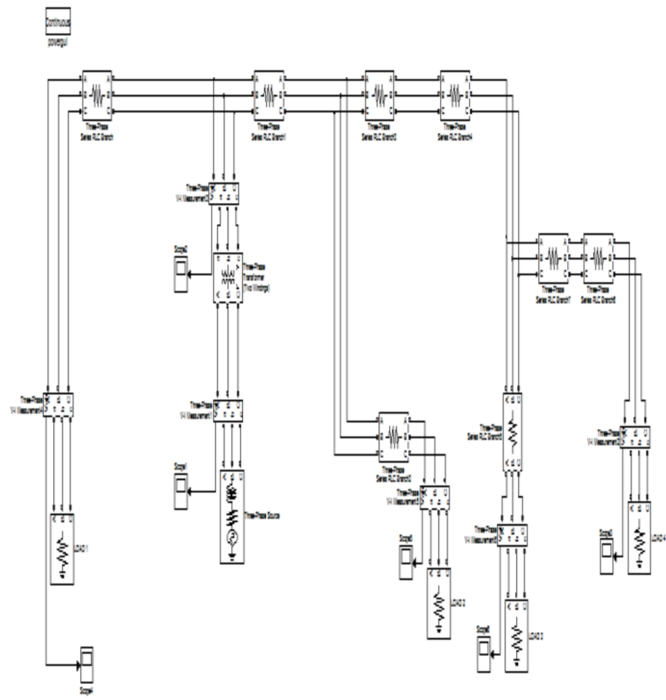

Figure 4: Simulink implementation of HV connection

IV. RESULTS AND DISCUSSION

A. Results

In the results, the extreme end loads are taken to differentiate the Voltage profiles. Three Phase VI Measurement blocks are used to measure the voltages and currents of the Lines. Scope is used to view the graphical results of the simulation model. The results for the Simulink model at different load points are as follows. Figures 5 to Figure 8 show the result of the simulink model of HVD systems.

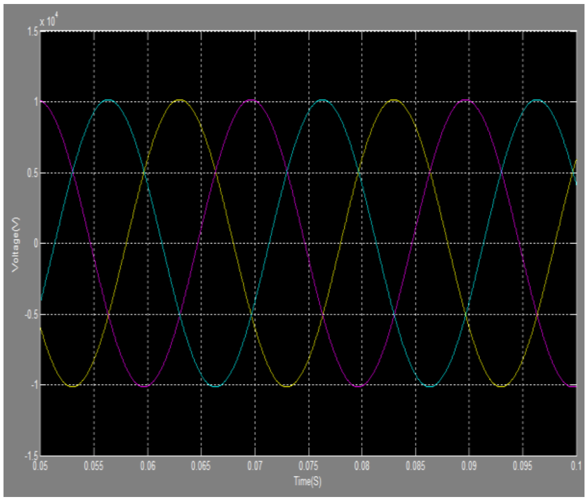

Figure 5: Scope 1

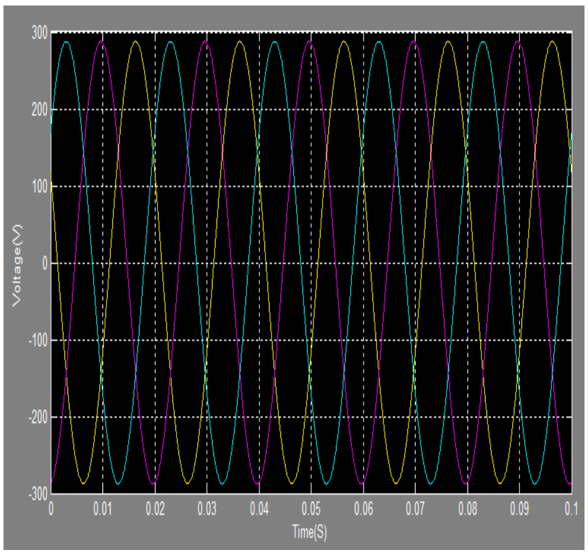

Figure 6: Scope 2

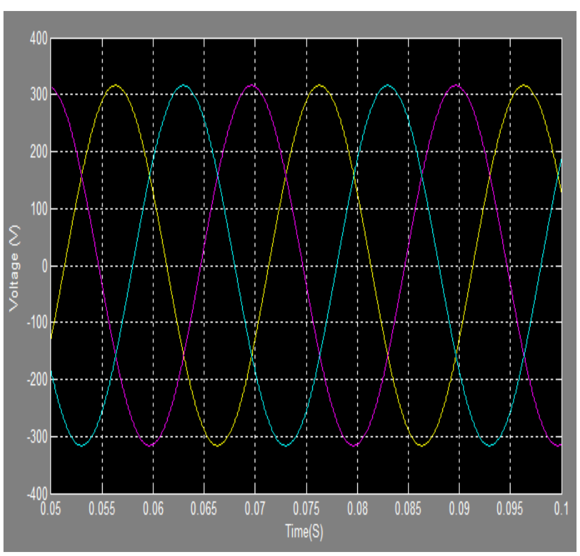

Figure 7: Scope 3

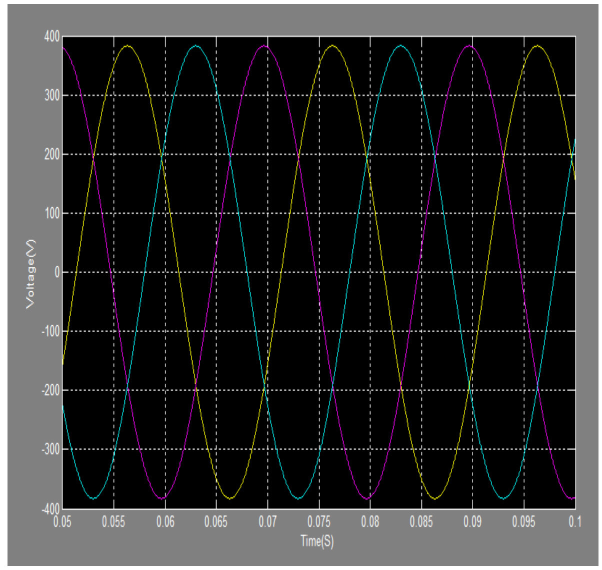

Figure 8: Scope 4

B. Discussion

In HVDS where multiple distribution transformers are employed, Voltage profile at all loads are very high, and hence there is a lot of improvement in voltage profiles and reduced power loss. As 11kV is extended up to load ends and AB cables are used for distributions, from DTR to loads, theft losses are avoided & voltage profiles are maintained. High quality of supply owing to practically no voltage drop was observed.

CONCLUSION

Based on the case study, it is observed that by the implementation of HVDS, there is an improvement of voltage profile, and hence there is an improvement in voltage indices too. HVDS scheme has led to the formulation of new strategy of energy conservation, minimization of transmission and distribution losses by reducing the power theft. The adoption of HVDS has been indicated as the necessary factor in efficient energy distribution thereby tackling the problems faced by the consumers. However, the capital cost will be marginally higher due to increase in the number of transformers and increase the total capacity. If the overall cost of the system is taken into account, the HT distribution system may be economical compared to LT distribution system. It is observed that the use of distribution transformer of small rating for two or three consumers has reduced the outages and power losses. Adoption of this innovative measure has been stated to have improved the commercial and technical performance in the particular state. The implementation of this HVDS opens the avenues for the work in many other related areas.

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