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MAXIMIZING OPTIMAL PERFORMANCE OF DISTRIBUTION FEEDERS IN NIGERIA.

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Abstract

The rising demand for electricity particularly in developing economies like Nigeria need real-time visibility of energy supply and demand to optimize service availability, reliability and cost to the power consumers. This research covers the proposed technology to be implemented for the Nigerian distribution system, the proposed implementation technique to be used comparable to the conventional distribution network available, the closed loop operation of the proposed network, the conventional layout of consumer connections to a feeder network, the proposed model of the implementation process and the test result of the transfer operation of the proposed network. The optimum goal of this research is ensuring optimal performance of distribution feeders through the use of a proposed distribution implementation technique liable to delivering better service to power consumers. The network and feeder reconfiguration in the proposed distribution system is realized by changing switches, which is usually done during load balancing, voltage loss minimization and voltage profile correction. The essence of reconfiguration is to improve the voltage, avoid imbalances and reduce voltage drop on a specific feeder. Also, it is to minimize the system power losses. It also contributes a technology for online remote and automatic switching of consumers to reduce unbalance to a minimal level at the low voltage side of the distribution network.

Key words: Distribution feeders, electricity, optimal performance, switching, voltage

I. INTRODUCTION

Distribution feeders are the networks that transport electric power to the end users from the distribution substations. They are usually radially structured, closely connected so as to supply distributed customers across the network.

A typical distribution network comprises of the primary or medium voltage (MV) side and the secondary or low voltage (LV) side. This system is continually subjected to load variations, which affect its overall performance. Such performance is hindered due to overloading of transformers and cables, excessive technical power losses, incorrect load voltage, phase voltage and current imbalances, malfunctioning of protective relays and poor quality of power delivery to the consumers. To avoid this, advanced distribution network should be inbuilt in other to automatically ensure that its performance is optimal at all times, at the Medium Voltage and Low Voltage levels. This implies that cases of overloading of transformers and cables, phase voltage and current unbalances are automatically sensed and remedies are provided to curb the abnormalities, which are eventually eradicated or simply kept within minimal level. Achieving balanced transformer and feeder loads is an important goal in developing power system.

In Nigeria, since some distribution transformers and feeders are sometimes loaded close to their limits, which is usually due to the obvious load growth and the delay in response to the need for constructions of new automated substations and feeders within the power system.

II. Load Balancing

Load balancing is usually achieved by reconfiguring feeders and redistributing load currents among feeders and transformers, under normal condition (Baran and Wu, 1989). This is carried out by changing the state (open/close) of the switches on the distribution feeders to transfer some load currents from the heavily loaded feeders to the relatively less heavily loaded feeders (Baran and Wu, 1989). This network reconfiguration alone is however insufficient to attain optimal performance. It has to be complemented with techniques for phase rearrangement between distribution transformer banks and the specific primary feeder with a radial structure. Even then, this is insufficient; it needs to be complemented with some type of technique for ensuring continuous dynamic load balancing along a feeder with a radial structure and load reconfiguration on the secondary side. It contributes such a technique at the secondary side of the distribution network. (Siti, Jimoh and Nicolae, 2005).

The network reconfiguration problems for loss reduction and load balancing involve load transfer between the feeders or substations by changing the position of switches In achieving this, some predefined objectives has to be satisfied under different conditions. Consumer loads are mostly single phase and often times, the single phases are arranged or grouped to have a balanced three phase systems, however, unbalance still occurs due to the unequal load distribution among the phases of the feeder. Hence the need to minimize the unbalance by transferring loads from the heavily loaded to the less loaded phases so as to reduce power loss , voltage drop etc (Shirmohammadi and Hong, 1989).

III. THE PROPOSED TECHNOLOGY FOR THE DISTRIBUTION SYSTEM

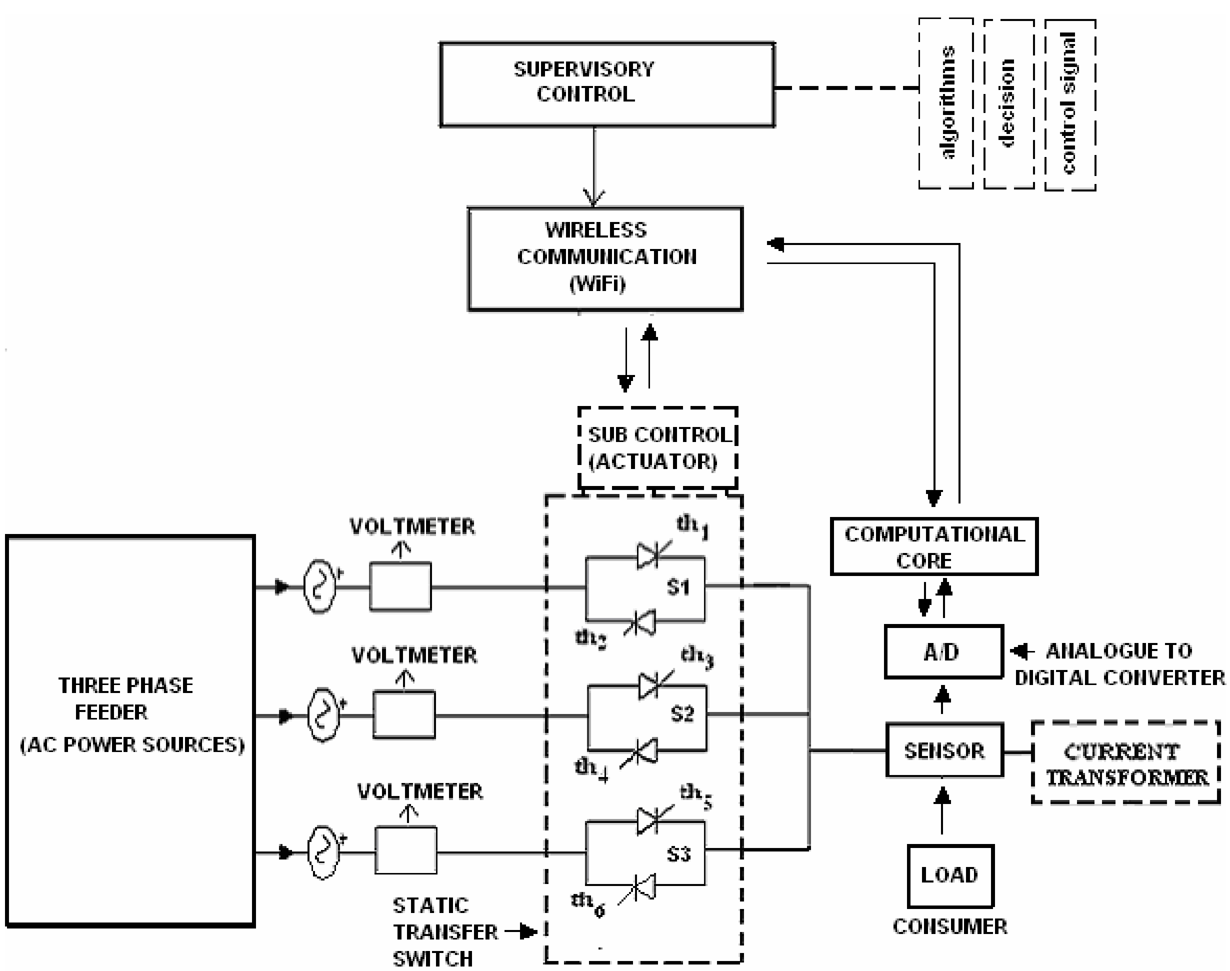

Figure 1:- Schematic diagram of the Proposed Technology for the Distribution Network. (Siti, Nicolae, Jimoh and Ukil, 2007).

Starting with the switching unit, which comprises mainly the static transfer switches (S_1, S_2 & S_3) and the sub control or actuator. The static transfer switch is made of two pair of thyristor connected in inverse parallel for each phase. During normal operation, one of the static transfer switches is in ON mode or close position (example S_1) allowing the conduction of current to the load (consumer) while the other two pair of static transfer switches (S_2 and S_3) are in the OFF mode or open. When the rearrangement (transfer) operation is required due to overload on the current phase (example S_1) being used, S_2 or S_3 is turned on to conduct the current to the load from the phase that can accommodate the existing consumer and balance (or minimize the unbalance) of the three phase feeder. Then, the current in S_1 is blocked at the first zero crossing. The control actions sent from the supervisory control is carried out through a logic switching circuit acting as the operating mechanism or better known as the actuator. The actuator is part of the sub control.

The sub control is interlinked with the supervisory control and located on the line. It is designed to acquire data, switching status and transfer same to the supervisory control through a communication interface (wireless link) and also perform switching action. The monitored information and the command (control) signal to switches S_1 or S_2 or S_3 to perform a transfer operation from Phase 1 (Red) to Phase 2 (Blue) or Phase 3 (Yellow) when the preferred source voltage or current deviates from the pre-set upper or lower limit is sent from the supervisory control via the sub control. The monitored information (real time data) is realized through the sensing unit design whose functional modules include: the sensing interface which is made of the sensor and analogue digital converter; computational core and communication medium for transfer of data to the supervisory control station.

IV. PROPOSED IMPLEMENTATION TECHNIQUE

A block diagram of the proposed implementation technique is shown in Figure 2. The block diagram consists of the following main components:-

1. Switching device: This is made of three phase ac static switch as well as operating mechanism (actuator control unit) that is capable of opening and closing the switching device remotely (complex digital signal processing), even during a load unbalance or system outage.

2. Sensing unit: This is dependent on the problem formulation solution technique or algorithm may be current or any other quantity at the consumer's connection node, is required to allow the monitoring of system conditions; collects input data; converting analogue sensor signal into digital data that can be recognized by microcontroller and communicating with the supervisory control station.
3. Supervisory Control unit: This consists of embedded microcontrollers for effective co- ordination, computational and control of other intelligent units.
4. Communication unit: This is a means of data communication between the switching unit, sensing unit and the supervisory control station.
5. Uninterruptible power supply (u.p.s.) unit capable of powering all components of the package may be required. The fundamental concept of the proposed technology is based on the open-transition switch that enables the transfer or re-arrangement of consumer loads in the three-phase feeder system within milliseconds. This is made possible through supervisory control system for effective co-ordination, computational and control of other intelligent units.

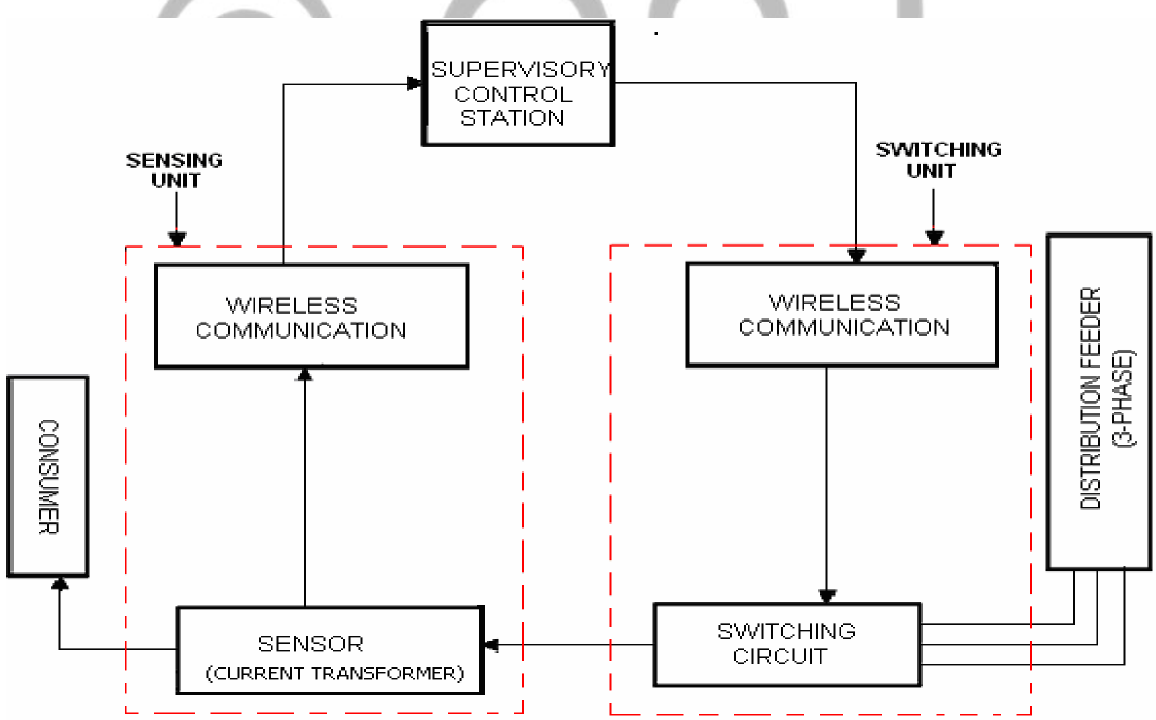

Figure 2:- The block diagram for a proposed implementation technique for the Distribution Network.
(Siti, Jimoh and Nicolae, 2005).

In figure 2, the proposed implementation technique for the distribution network works with Smart grid phenomenon by incorporating with a class of technology that people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. The entire systems are made of two-way communication technology and computer processing. It's usage on electricity networks, from the power plants and wind farms, all the way to the consumers of electricity in homes and businesses have paved way in network reliability. They offer many benefits to utilities and consumers as mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' at homes and offices. (United States Office of Electricity Delivery and Energy Reliability, 2015).

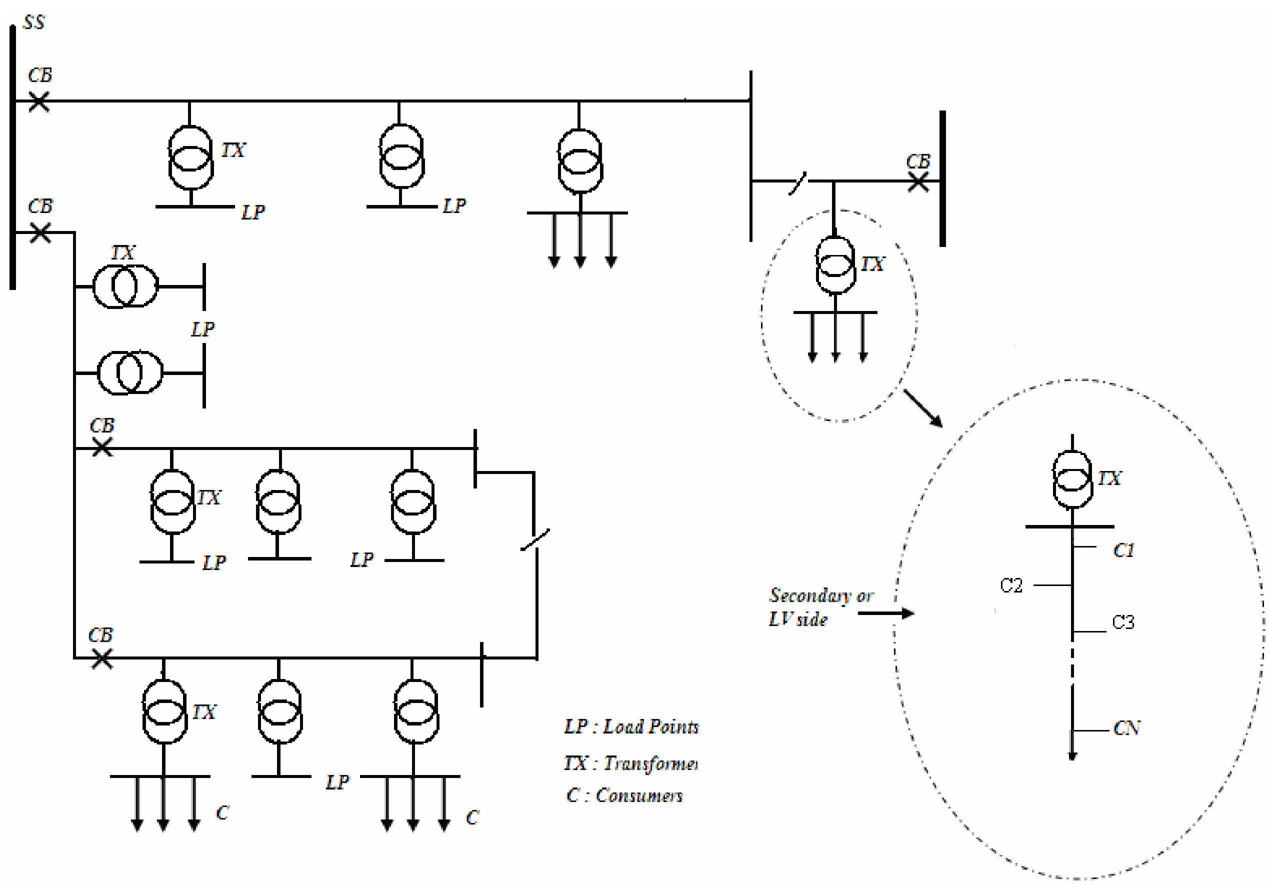

Figure 3:- The Conventional Distribution Network.
(Siti, Nicolae, Jimoh and Ukil, 2007).

The conventional distribution network consists of Circuit breakers, transformers, consumers, and load points at different bus bars of the entire distribution network.

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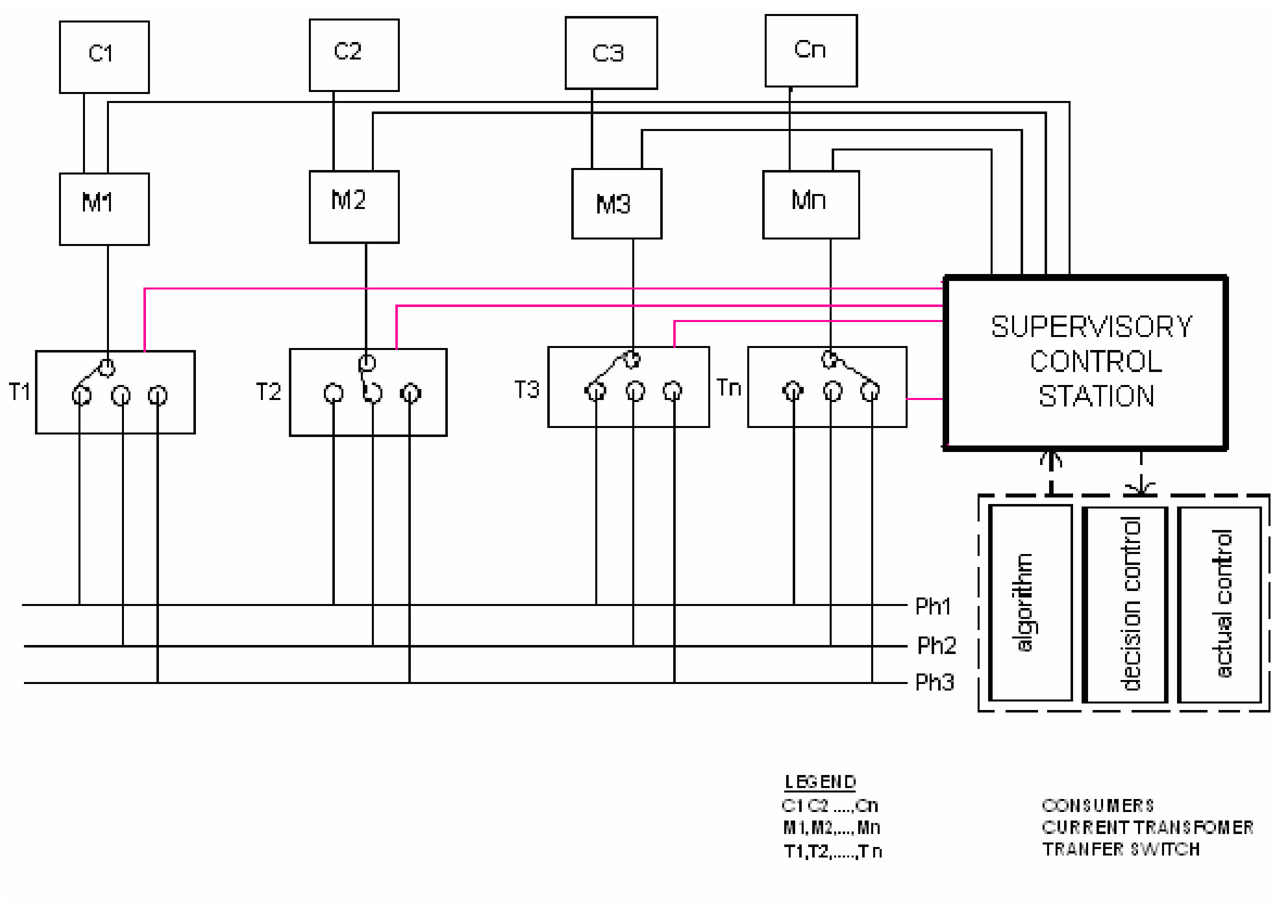

Figure 4:- The Conventional Layout of Consumer Connections to a Feeder System. (Jimoh, Siti and Davidson, 2004).

The three phases in figure 4 above shows the outlet connections to the consumer points, C1, C2, C3 to C_n as well as the respective transformers; T_1, T_2, T_3 to T_n alongside the motors; M_1, M_2, M_3 to M_n.

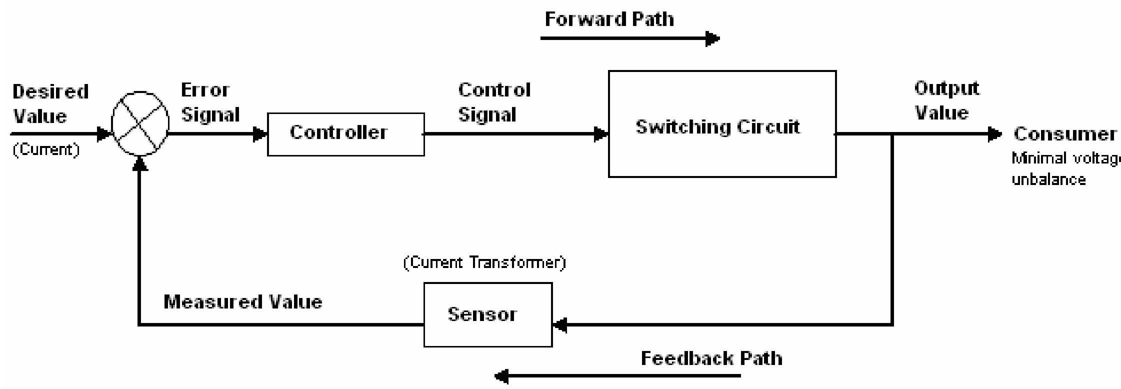

Figure 5: The Closed Loop Operation of the Proposed Network
(Siti, Jimoh and Nicolae, 2005).

The closed loop operation of the proposed network in figure 5 above is explains how the forward signal is sent and a feedback signal passes through the sensor or detector to ascertain the measured value of the signal processed. The controller (actuator) sends the command or control signal to the switching unit for the static transfer switch (S_1) via wireless communication to open, while within a micro second, a signal is sent to S_2 or S_3 to close when the prefer load current on phase 1 deviates from the pre-set upper or lower limit. It occurs during the following conditions:-

1. The phase-angle difference of the phases is within the pre-set value.
2. The voltage of the alternate source is within the limit.
3. The alternate phase or phases can accommodate the required load.

The status of the static transfer switches is also communicated back to the supervisory control station.

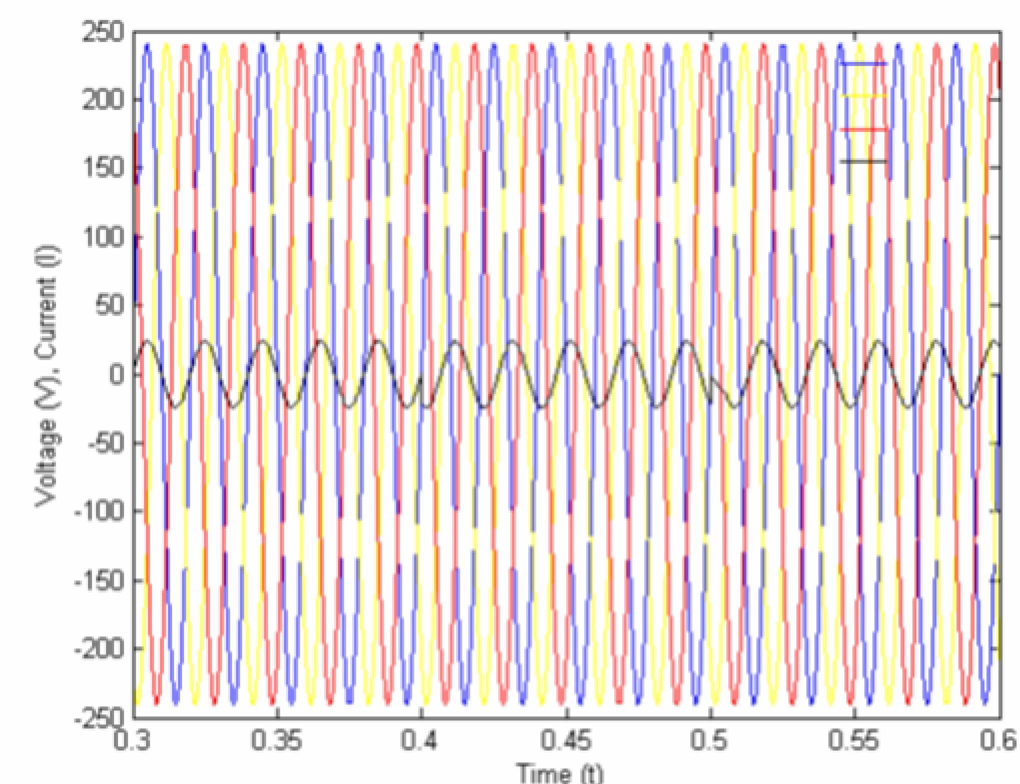

Figure 6: Proposed model for the implementation

The operating characteristic of the proposed model of implementation is between Power (Voltage x Current.) and time measured in seconds. The model actually explains the behaviour of the devices at some certain pre-determined values of power measured in watts and the time frame used to undergo the entire process of implementation.

Table 2: power in watts and time in seconds.

POWER (WATTS)	TIME (SECONDS)
250	0.3
200	0.35
150	0.4
100	0.45
50	0.52
0	0.55
-50	0.6
-100	Nil
-150	Nil
-180	Nil
-200	Nil

At 250 watts, the specific timing falls at 0.3 second. While, at 200 watts, the timing is 0.35 second; at 150 watts, the time for implementation is 0.4 second and so on. But at -50 watts, which is unrealistic in terms of the overall distributed voltage took a larger timing to implement. Finally, the negative powers are zero because the proposed implementation model transfers negligible signals, which will produce unreal voltage at the output end.

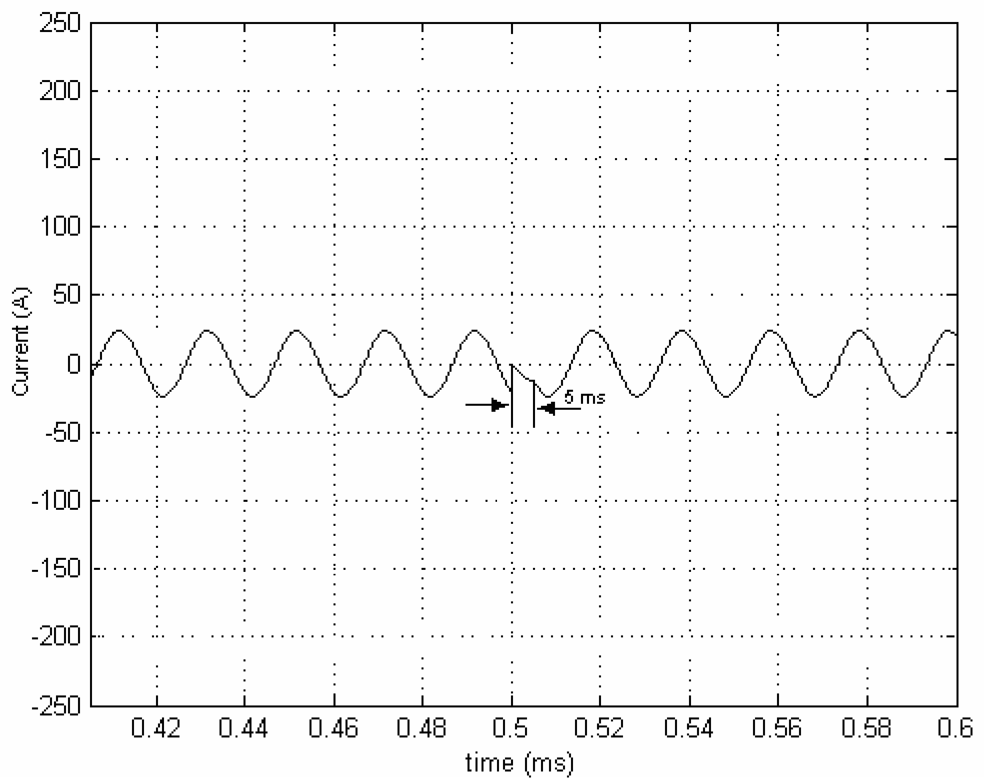

Figure 7: Test Result of transfer operation

Figure 7 shows a comparison between Current measured in amperes (A) and the time in milliseconds. At 250A, the timing for the transfer operation to occur while sending signal is 0.42 ms and it also happens simultaneously at various current values as well as at varying timings.

V. CONCLUSION

The proposed technology for distribution feeders will increasingly need to be based on a trans-sector concept and this digital technological development needs to tap into the economic and social multiplier effects. For this to become economically viable, open infrastructural outlets need to be available to these sectors on a utilities basis. It does not make economic sense for all of these sectors to develop and run their own communications infrastructure using this proposed smart technology. The feasibility of this technology will be realistic only if the government, power and telecommunication companies are collectively involved financially.

Thus, this technology promotes online remoting and automatic switching of consumers to reduce unbalanced loads to a minimal level at the low voltage distribution network. The proposed technology implementation addresses the problems of phase current and voltage imbalances due to irregular distribution of loads in a secondary distribution system feeder. The system utilizes static transfer power electronics switching devices, which has been proven as an effective tool in solving imbalances in the low voltage distribution network.

Finally, the implementation of the automation of the control of these switches using artificial intelligence, telecommunication and power electronic equipment as well as ensuring the prompt implementation of the proposed technology in the Nigerian power distribution network will offer an optimal solution to the power wastage. This will in turn be technically and economically advantageous to the utilities and consumers by boosting power availability. Revenue will be boosted at the utility end and the consumers will enjoy better service delivery at last.

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