International Journal of Engineering and Applied Technology (IJEAT)
Vol. 1 | November 2018
ISSN: 2620-9632

INVESTIGATIONS OF TRANSMISSION LOSSES AND EFFICIENCY

Osahenvenwen O.A.[1]*, Enoma O.C.[2], Aitanke H.[2]
Electrical and Electronic Department, Faculty of Engineering and Technology, Ambrose Alli University, Nigeria
Electrical and Electronic Department, National Institute of Construction Technology, Nigeria
*Email: Osahenvenwen.OA@gmail.com

Abstract

This study presents Evaluation of transmission losses and efficiency, aim at to determine the losses associated with power transmission line and provide solution to improve power transmission line. This study was carried out at Benin regional power transmission station on 330 KV / 132 KV power network, Sapele Road, Benin City. The Data collected were hourly reading recorded by various system operators on duty on a twenty-four hour basis, for duration of one year, from July 2009 to June 2010. Data collected were transmission parameters such has the sending voltage, Current and Power from Delta 330KV power station to Benin 330 KV received power station with voltage, current and power. In addition, 132KV transmission line parameters were also considered. The average voltage loss per month from 132 KV transmission line from Benin to Irrua is 2.67 KV, while the current is 16.25 Amp. The average voltage loss per month on 330 KV transmission line from delta to Benin power regional centre is 4.725 KV. While the current obtained is 22.5 Amp. It observed that the higher power transmitted the higher the losses associated with the power system. In addition, size of cable and the distance covered are major factor that lead to loss on the power transmission line.

Keywords: cable, losses, efficiency, transmission line and voltage

1 Introduction

Often time, all human activities are in one way or the other relies on electricity power supply to carry out their daily functions with shortest possible means and time. The power supply has become a live wire of any developing countries, which implies that stable power supply is proportional to economical development. The electric power supply industry consists of generation, transmission, distribution and utilization. It is described as "The greatest machine ever created by man" it is the inevitable integral part of the infrastructure. Bulk powers supply are generated from different power station of different capacities and fed into a common bus bar system called grid (Theraja & Theraja, 2004) Where it is transmitted and distributed to different substation and load centers. The transmission of power supply from various stages (from generation, transmission and distribution to customers) witnessed various degrees of losses which are major drawback in power distribution network. In general, losses are estimated as the discrepancy between power produced and power sold to end customers; the difference between what is produced and what is consumed constitute transmission and distribution losses, assuming no theft of utility occurs occurs. Power losses are been generated along over-aged transmission and distribution lines, unequal phase load inadequate reactive compensation and energy theft and not using appropriate conductors on the lines contributed to the high-energy losses transmission lines (Chimalawong, 2011; Cotton & Barber, 1970). Transmission and distribution of electrical energy require cables and power transformer which create three types of energy loss;

1. The joule effect where energy is lost as heat in the conductor (a copper wire for example).
2. Magnetic losses where energy dissipate into a magnetic field Thedielectric effect where energy is absorbed in the insulating material (Lionel, 2013; Singh & Manga, 2012).

The joule effect in a transmission cables accounts for losses of about 2.5% while the losses in transformer rangy between 1% and 2% depending on the type and rating of the transformer. These voltages losses are associated with conductors, used in transmission line and step-down transformers. But, the huge losses are associated with transformer. The total losses in a transformer are presented in Figure 1 (Arifujjaman, Iqbal, & Quaicoe, 2011; Okpeki & Efenedo, 2013).

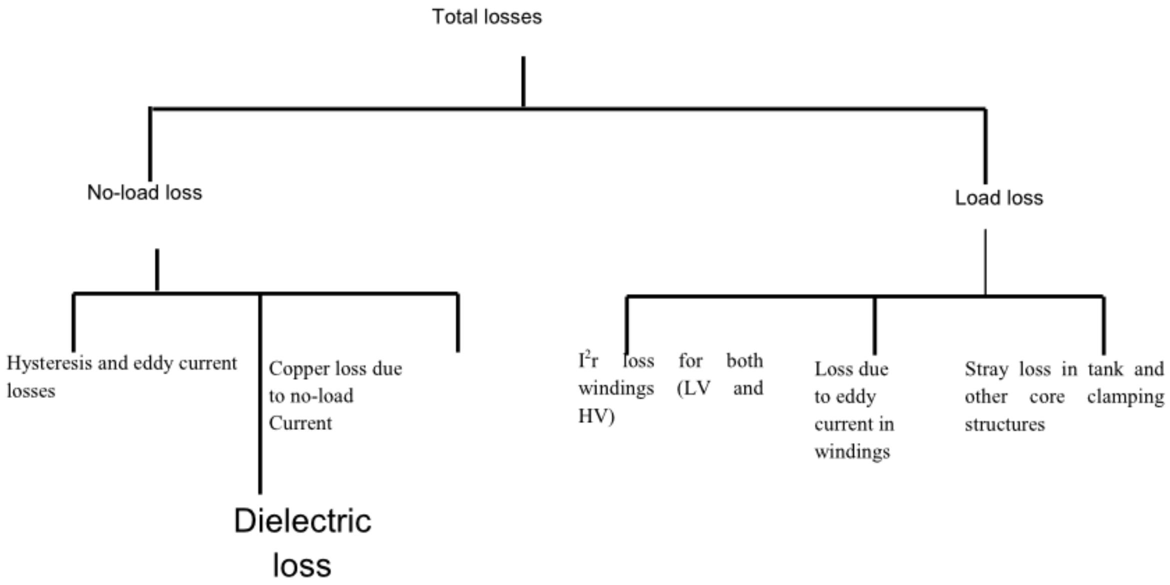

Figure 1. Total losses in a Transformer

2 Transformer Losses

An ideal transformer would have no energy losses, and would be 100% efficient. In practical transformers, energy is dissipated in the windings, core, and surrounding structures. Larger transformers are generally more efficient, and those rated for electricity distribution usually perform better than 98% (Chinwuko, Mgbemena, Aguh, & Ebhota, 2011; Evbogbai, Okonigene, & Obiorue, 2004; Osahenvemwem & Omorogiuwa, 2008). Experimental transformers using superconducting windings achieve efficiencies of 99.85%. The increase in efficiency can save considerable energy, and hence money, in a large heavily loaded transformer; the trade-off is in the additional initial and running cost of the superconducting design. The transformer losses vary with load, which are expressed in losses in terms of no-load loss, full-load loss, half-load loss, and so on (Akinwale, 2010; Samuel, Katende, & Ibikunle, 2012). Hysteresis and eddy current losses are constant at all loads and dominate overwhelmingly at no-load, variable winding joule losses dominating increasingly as load increases. The no-load loss can be significant, so that even an idle transformer constitutes a drain on the electrical supply and a running cost. Designing transformers for lower loss requires a larger core, good-quality silicon steel, or even amorphous steel for the core and thicker wire, increasing initial cost so that there is a trade-off between initial costs and running cost (Odior, Oyawale, & Ovuworie, 2010). Winding joule losses occur when current flowing through winding conductors causes joule heating. As frequency increases, skin effect and proximity effect causes winding resistance and, hence, losses to increase.

2.1 Core Losses

Hysteresis losses are generated any time the magnetic field is reversed, a small amount of energy is lost due to hysteresis within the core (Arifujjaman et al., 2011; Nunoo, Attachie, & Duah, 2012; Stevenson Jr & Grainger, 1994).

2.2 Eddy Current Losses

Ferromagnetic materials are also good conductors and a core made from such a material also constitutes a single short-circuited turn throughout its entire length. Eddy currents therefore circulate within the core in a plane normal to the flux, and are responsible for resistive heating of the core material. The eddy current loss is a complex function of the square of supply frequency and Inverse Square of the material thickness. Eddy current losses can be reduced by making the core of a stack of plates electrically insulated from each other, rather than a solid block; all transformers operating at low frequencies use laminated or similar cores (Theraja & Theraja, 2004).

2.3 Magnetostriction Related Transformer Hum

Magnetic flux in a ferromagnetic material, such as the core, causes it to physically expand and contract slightly with each cycle of the magnetic field, an effect known as magnetostriction, the frictional energy of which produces an audible noise known as mains hum or transformer hum cores (Okpeki & Efenedo, 2013; Theraja & Theraja, 2004).

2.4 Stray Losses

Leakage inductance is by itself largely lossless, since energy supplied to its magnetic fields is returned to the supply with the next half-cycle. However, any leakage flux that intercepts nearby conductive materials such as the transformer's support structure will give rise to eddy currents and be converted to heat. There are also radiation losses due to the oscillating magnetic field but these are usually small (Adoghe, Odigwe, & Igbinovia, 2009; Akinwale, 2010; Evbogbai et al., 2004).

A Corona loss is another important area of losses which the high voltage at which transmission line operates produces electric field strengths of sufficient intensity to ionize the air near the phase conductions. This effect is called corona which produces losses over the entire length of the transmission line network. The Corona effect is detectable audibly on a buzzing and hissing sound and usually as a faint bluish area surrounding the conductors (Adoghe et al., 2009).

2.5 Losses Associated with Voltage Transmission

Transmitting electricity at high voltage reduces the fraction of energy lost to resistance, which varies depending on the voltage and length of the transmission element. For example, a 100 mile 765 kV line carrying 1000 MW of energy can have losses of 1.1% to 0.5%. A 345 kV line carrying the same load across the same distance has losses of 4.2%. For a given amount of power, a higher voltage reduces the current and thus the resistive losses in the conductor. For example, raising the voltage by a factor of 10 reduces the current by a corresponding factor of 10 and therefore the I2R losses by a factor of 100, provided the same sized conductors are used in both cases. Even if the conductor size (cross-sectional area) is reduced 10-fold to match the lower current the I2R losses are still reduced 10-fold. Long distance transmission is typically done with overhead lines at voltages of 115 KV to 1,200 kV. At extremely high voltages, more than 2,000 kV between conductor and ground, corona discharge losses are so large that they can offset the lower resistive losses in the line conductors. Measures to reduce corona losses include conductors having large diameter; often hollow to save weight, or bundles of two or more conductors. In an alternating current circuit, the inductance and capacitance of the phase conductors can be significant. The currents that flow in these components of the circuit impedance constitute reactive power, which transmits no energy to the load. Reactive current causes extra losses in the transmission circuit. The ratio of real power (transmitted to the load) to apparent power is the power factor. As reactive current increases, the reactive power increases and the power factor decreases. For systems with low power factors, losses are higher than for systems with high power factors. Utilities add capacitor banks, rectors and other components such as phase-shifting transformers; static VAR compensators; physical transposition of the phase conductors; and Flexible Ac Transmission Systems (FACTS) throughout the system to control reactive power flow for reduction of losses and stabilization of system voltage (Hanreich, Nicolics, & Musiejovsky, 2000; Rao, Prasad, & Das, 2010).

3 Methodology

This study is on evaluation of transformer losses and efficiency, using Benin power regional substation as case study. Data were collected from Benin regional power transmission station 330KV/132KV network along Sapele Road, Benin City. The data were hourly reading recorded by various system operators on duty on a twenty-four hour basis, for duration of one year, from July 2009 to June 2010. Data obtained were the sending Voltage, Current and Power from Delta power station, also the received Voltage, Current and Power from Benin power station. In addition the 132KV transmission line parameters were also considered. The 330KV transmission line from Delta to Benin power station is 120.6 km distance covered in kilometers was obtained. Base on the obtained parameters, transmission line losses were determined and possible means of increasing efficiency are highlighted. The data obtained were evaluated based on sending and received ends of the power transmission parameters at both 330 KV and 132 KV lines.

4 Results and Discussion

Both ends of 330 kV transmission line from delta to Benin power region were obtained and the variation of voltage, current and power were analyzed and presented in Fig 2.While, both ends of 132 kV transmission line from Benin to

Irrua power station were obtained and the variation of voltage, current and power were analysis and presented in Figure 3 to Figure 4.

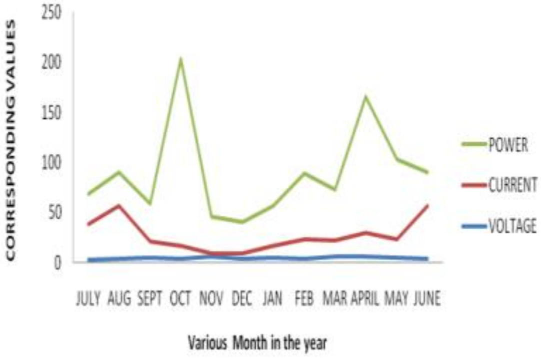

Figure 2. the various month of the year with corresponding values from 330KV

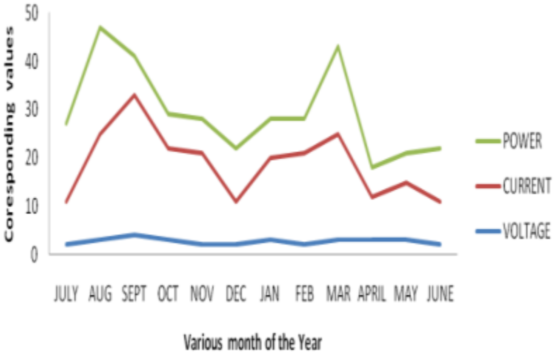

Figure 3. the various month of the year with corresponding values from 132KV

It is observed that the three basic parameters that affect transmission losses are voltage, current and power level. It is observed that these three parameters are not linear in power system transmission line.

The 132 KV transmission losses are depended on power, voltage and current. It is observed that voltages along this transmission line are in variance throughout the year shown in Figure 4, for effective power transmission, the voltage should be constant from one end to another. The 132 KV transmission line was used to validate the transmission line parameters characteristic of 330 KV transmission line. It is observed that both 330 kV and 132 kV has similar characteristics. Also, it is observed that as the transmission voltage increases, the losses witnessed along the transmission line increases. In addition, it is observed that transmitted voltage is not linear in nature throughout the year, shown in Figure 4.

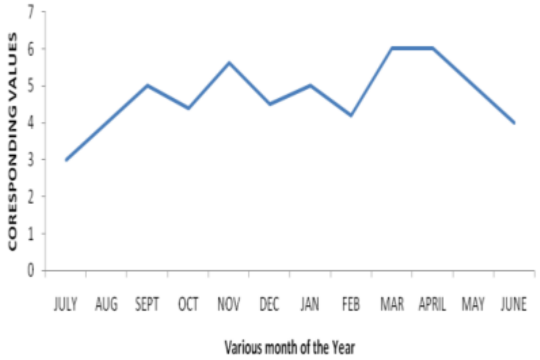

Figure 4. The various month of the year with corresponding values from 132 KV

The losses experienced from Current and Voltage from 330 KV and 132 KV transmission line for a period of one year are presented in Figure 5, with respective percentage.

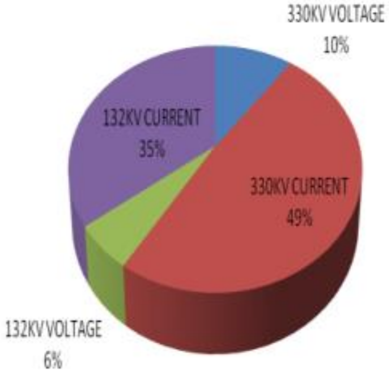

Figure 5. The various month of the year with corresponding values from 132 KV

The average voltage loss per month from 132 KV transmission line from Benin to Irrua is 2.67 KV, while the current is 16.25 Amp. The average voltage loss per month on 330KV transmission line from delta to Benin power station regional centre is 4.725 KV. While the current obtained is 22.5Amp. It observed that the higher the power supply transmitted, the higher the losses witnessed on the power system. Also, the major losses experienced in the transmission line are materials of cable used and the distance covered by the transmission line. The initial design values were done with bare Aluminum Conductors Steel Reinforced (ACSR) with a cross section area of 250mm2 all through the stretch of the line.

It is worthy of note that today more than 65% of the line is now carrying between 100 – 250 mm^2 bare Aluminum Conductor steel Reinforced (ACSR). The reason for this is due to vandalism as the majority of the vandalized portion have been replaced with lesser or lower conductor size due to poor management resulting from sanctions and high inflation, corruption and other social vices e.g. dishonesty on the part of the contractor as his (contractor) ultimate goal is to maximize profit. Most conductors have some degree of resistance which prevents electricity from flowing effortlessly.

Superconductors are materials that have no resistance to the flow of electricity and mostly this occurs at extremely temperatures. We are all used to seeing copper and aluminum electrical wires and cable which conduit electricity at ambient temperature but lose energy due to the joule effect. With superconductors, a loss due to the joule effect becomes essentially zero, thereby creating the potential for dramatic reduction in overall losses. Superconducting cable offer the advantage of lower loss, lighter weight, and more compact dimensions, as compared to conventional cables. In addition to better energy efficiency of the utility grid, this can lead to easier and faster installation of the cable system. Other factors as enumerated above could also be responsible for the loss and this can be remedied as follows;

1. Replacing all undersized conductors with the actual size or high sizes which earlier resulted from vandalism of the line.
2. Proper maintenance of the line by cleaning of the insulators to improve the mechanical strength against flash over and generally making the line to be high efficient. Result from proper jointing.
3. Proper tap-setting of interconnecting transformers to improve voltage and hence increase efficiency.
4. All over loaded transformers must be augmented either by adding to existing one to enable the shearing of the load or putting a transformer with higher capacity to be able to accommodate all the loads conveniently.

5. High level of vigilance must be regularly carried out to check pilferage of energy and other unauthorized use of electricity.
6. Proper security surveillance to eliminate vandalism of equipment.
7. Effective control of reactive power in the system to avoid Ferranti effect.
8. Using steel having a low reluctance (Silicon steel) in transformer iron core.
9. Proper redistribution of lines, feeder and load to balance it and hence minimize stress on a particular phase or line and hence reduce the losses.
10. Replacement of bad cables, meters, VT's, CVT's transducers and rewinding of burnt meter coil.
11. Adequate cooling methods must be adopted in the transformers to improve its efficiency and all transformers should not be overloaded if they must carry the actual load they are designed for so as to minimize stress due to overload, which can cause dielectric breakdown of the insulation.

4.1 Losses Associated with Transformer

Transformer failure can be as a result of either internal or external source, such as Failure of insulation of winding lamination, resulting in interturn or earth faults, which can leads to eddy current causing heat in the core. Also, major's parameters that can affect the efficiency of the transforms were oil deterioration which could be caused by poor quality oil penetration of by moisture, decomposition because of overheating. Loss of oil due to leakage cooling system faults. Based on the losses associated with transformer can be minimum based on deploying effective cooling system.

These higher losses may not only be due to the line parameters as enumerated earlier, greater part of it is due to:

1. Faulty (CVT) capacitor voltage transformer; if the CVT is faulty, there is bound to be false readings and also it serves as an avenue for loss.
2. Faulty transducer: if the transducer in the measuring meter is faulty, there is bound to be false readings and losses occur due to the meter being faulty.

3. Faulty connector cable: The cable connecting the lines to the meter when faulty or deteriorated gives false values and faulty cable also leads to great losses.
4. If the coil of the meter is bad or deteriorated, leakage occurs and losses arise and meter also gives false readings.
5. Poor power factor deterioration in the line or equipment causes a reduction in the power factor and hence losses also arise.
6. Vandalism, stealing of power materials like conductors, insulators and channel iron, leads to great loss as replacement is always highly expensive. In the last military era, sanctions were imposed on the country and vandalized materials were replaced with substandard ones and these lead to great losses on the conductor I2R if it is undersized and low rated or deteriorating insulators lead to leakage along the line.
7. Environmental Factors: The shinning phase of the insulators serves as mechanical strength for the voltage and current on the line but due to dustiness and heavy down poor, there is bound to be leakage due to deterioration of the mechanical strength. Rusting of the tower can also cause collapse and may lead to damage of materials.
8. Illegal connection and pilfering: most of the illegal connection are done with undersized cables or conductors and hence causes great loss. It also leads to over loading and there is no avenue to estimate the actual load consumption hence the illegal load that cannot be accounted for and therefore forms part of the losses.
9. Over loading: Overloading of lines and transformers causes heating effect and damages to the equipment. If not checked on time, it causes deterioration and in transformers, it causes a reduction in efficiency and power factor thus reducing the capacity of the transformers.
10. Improper construction and maintenance of lines and transformers: If a line is poorly constructed, there is bound to be great loss from all the parts in the constructed line and when poorly maintained, it causes a reduction in capacity and efficiency for both line and transformers.

11. Uneconomic conductor size: due to sanction as earlier mentioned, conductors of low size were used to improvise in the lines and hence losses occur greatly.
12. Aging in transformer due to prolonged usage without replacement, transformers power factor and efficiency tend to reduce and this
13. Affects their capacity and thus losses and the temperature is always increasing with load and ambient temperature. These enumerated reason account for the losses in the lines and transformers.

5 Conclusion

This study is aim at to determine transmission parameters and losses associated with high voltage transmission line in Nigeria, using Benin regional power station as case study. The study was carried out at Benin regional power transmission station 330KV/132KV network, Sapele Road, Benin City. The Data collected were hourly reading recorded by various system operators on duty on a twenty-four hour basis, for duration of one year, from July 2009 to June 2010.

Data were transmission parameters from both sending voltage, current and power from delta 1 power station, also the received voltage, current and power from 330kv benin power station. In addition, 132KV transmission line parameters were also considered. The transmission line power parameters were identified and were analyses know as current (Amp), voltage (KV) and power (MW). It was observed as any of the parameter increases the others parameters will increase in a proportional rate.

The average voltage loss per month from 132KV transmission line from Benin to Irrua is 2.67KV, while the current is 16.25Amp. The average voltage loss per month on 330KV transmission line from delta to Benin power regional centre is 4.725KV. While the current obtained is 22.5 Amp. It observed that the higher power supply transmitted the higher the losses associated with the power system. In addition, size of cable and the distance covered are major factor that lead to loss on the power transmission line.

References

Adoghe, A., Odigwe, I., & Igbinovia, S. (2009). Power sector reforms-effects on electric power supply reliability and stability in Nigeria. *International Journal of Electrical and Power Engineering, 3*(1), 36-42.

Akinwale, A. A. (2010). The menace of inadequate infrastructure in Nigeria. *African journal of science, technology, innovation and development, 2*(3), 207-228.

Arifujjaman, M., Iqbal, M., & Quaicoe, J. (2011). Power electronics reliability comparison of grid connected small wind energy conversion systems. *Wind Engineering, 35*(1), 93-110.

Chimalawong, P. (2011). A Feasibility Study on Compensating Voltage Drop by a Grid Connected Photovoltaic System at Chachreng Sau Wild Life Research Station.

Chinwuko, E., Mgbemena, C., Aguh, P., & Ebhota, W. (2011). Electricity Generation and Distribution in Nigeria: Technical issues and solutions. *International Journal of Engineering Science and Technology, 3*(11), 7934-7941.

Cotton, H., & Barber, H. (1970). *The transmission and distribution of electrical energy*: English Universities Press.

Evbogbai, M., Okonigene, R., & Obiorue, O. (2004). Reliability Study of Electric Power Supply in Ekpoma Distribution Area of National Electricity Power Authority (NEPA). *Journal of Science, Engineering and Technology, 1*(3), 5692-5570.

Hanreich, G., Nicolics, J., & Musiejovsky, L. (2000). High resolution thermal simulation of electronic components. *Microelectronics Reliability, 40*(12), 2069-2076.

Lionel, E. (2013). The dynamic analysis of electricity supply and economic development: Lessons from Nigeria. *Journal of sustainable society, 2*(1), 1-11.

Nunoo, S., Attachie, J. C., & Duah, F. N. (2012). An investigation into the causes and effects of voltage drops on an 11 kV feeder. *Canadian Journal on Electrical and Electronics Engineering, 3*(1), 40-47.

Odior, A. O., Oyawale, F., & Ovuworie, G. (2010). Some operations of electric power supply system in Benin City area of Nigeria.

Okpeki, U., & Efenedo, G. (2013). Stability and Sustainability Analysis of Power in a Deregulated System. *International Journal of Science and Technology, 2*(3).

Osahenvemwem, A., & Omorogiuwa, O. (2008). Electric transmission line faults in Nigeria: A cause study of Benin-Irrua 132kV transmission line. *International Journal of Electrical and Power Engineering, 2*(6), 384-388.

Rao, J. M., Prasad, P., & Das, G. T. R. (2010). Customer outage cost evaluation in electric power systems. *ARPN Journal of Engineering and Applied Sciences, 5*(8), 88-96.

Samuel, I., Katende, J., & Ibikunle, F. (2012). *Voltage Collapse and the Nigerian National Grid.* Paper presented at the EIE's 2nd International Conference on Computer Energy Networks Robotics and Telecommunication.

Singh, H., & Manga, H. S. (2012). *Impact of Unreliable Power on a Paper Mill: A Case Study of Paper Industry of Punjab, India.* Paper presented at the Proceeding of the International Multi Conference of Engineers and Computer Scientist. Retrieved.

Stevenson Jr, W., & Grainger, J. (1994). *Power system analysis*: McGraw-Hill Education.

Theraja, B., & Theraja, A. (2004). Electrical Technology, publication division of nirja construction and Development co. *Ltd New Delhi.*