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Impact of High Voltage Transmission on I^2r Losses Using A Simplified ETAP Model

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ABSTRACT: This paper is aimed at the analysis of the impact of high voltage transmission on I^2R losses using a simplified ETAP model. The work considers a simple power system model which comprises of a synchronous generator interconnected through a busbar to a 2-windings transformer and a lumped load at the receiving end, this was being modelled and simulated in three separate cases in ETAP Software Environment. The simulation results obtained show a current of 176.5A flowing through the conductor with a corresponding computed power loss of 28597.74kW at a transmitting Voltage of 330kV, similarly, a current of 1769A flows through the line with a corresponding computed power loss of 2872753.38 kW at a transmitting voltage of 33kV. The simulation and computed results indicated that at a high transmitting voltage a low power loss occurred, while at low transmitting voltage a high-power loss occurred on the transmission line, that is to say, the transmission of electrical power at very high voltage reduces power losses along the line. Which illustrates the impact of high voltage transmission on I^2R losses. This work proved that ETAP software is a reliable and sophisticated software for electrical power system simulation and analysis.

KEYWORD: Transmission Line, AC Transmission Techniques, I^2R Losses, ETAP Software

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I. INTRODUCTION

A Transmission line conveyed bulk electrical power from the generating station to consumers through the distribution lines. This is done at a high voltage to reduce losses along transmission lines, it is important to put into consideration voltage drop, line losses and efficiency when designing the line, which values are seriously influenced by Resistance R, Inductance L, and Capacitance C of the lines [1, 2].

The international electromechanical commission defines high voltage as above 1000V for Alternating Current and at least 1500V for Direct Current [3]. To reinstate professional safety and caution in the practice of high voltage engineering, the power system engineers is advised to always review the condition for high voltage transmission. During the transmission of power over a long distance, natural energy losses occur, when power is being transmitted at high voltage their losses are minimized as the power flows from one location to another [4].

However, the higher the voltage, the lower the current, and the lesser the resistant losses along the conductor, which result in reduced energy losses. It is based on this knowledge that electrical power system engineers have to put into consideration, factors such as the amount of power to be transmitted, the distance of transmission, while recommending the optimal transmission voltage. Taking about the economic importance of high voltage transmission, if the lower the current that flows during the process results in lesser resistance in the conductors, in such situation, conductors with lighter weight can be used in long-distance transmission, which the support towers load will reduce, this is a typical economic value of high voltage transmission.

Electrical Transient Analyzer Program (ETAP) is a full spectrum analytical engineering software company specializing in the analysis, simulation, monitoring control, optimization and automation of electrical power systems [5]. This paper presents an ETAP Model of three separate transmission networks (330kV,132kV, and 33kV) which demonstrate a typical power system network, with various levels of load flow in a different component of three separate networks, considering I^2R losses in the conductor.

II. AC TRANSMISSION TECHNIQUES

High voltage transmission can be done using the overhead system or underground transmission techniques. Before choosing this transmission, techniques there are factors to be considered as these techniques has their various criteria's, such considerations are the weight of conductors, environmental conditions to which the conductors are to be subjected to also cost of installation. One of the conventional techniques of transmitting electrical power is by 3-phase,3-wire overhead lines, overhead power lines are structures used in electrical power transmission to convey electrical energy from one location to another. These structures consist of multiples of uninsulated conductors supported by towers erected across large distances [3, 6]. Another system of AC power transmission is the underground transmission technique, in this technique the cables are laid beneath the earth thereby having low visibility, the weather is not a constrain to this type of power transmission technique though it is expensive and time-consuming with regards to large cables process [1].

CAUSES OF HIGH VOLTAGE AC POWER TRANSMISSION LOSSES

Losses that occur in a transmission line network can be caused due to technical and non-technical factors such as;

i. Losses Due to Conductor Resistance: this occurs due to the flow of high current along conductors used for the transmission of electrical power. When alternating current flows along the conductors, heat is generated thereby increasing the temperature of the conductor, when the temperature of the conductor is being increased, the resistance increases and this cause an increase in power losses along the line [7, 8, 9].

The three-phase line losses is mathematically expressed as;

$$P_{Loss} = 3I^2 R \text{ (kW)} \quad (1)$$

Where I, is the amount of current flowing in the conductor, and R is the resistance offered by the conductor.

When the length of the line increases, the resistance along also increases, which increase power losses along the line

$$R = \frac{\rho l}{A} \; (\Omega) \quad (2)$$

$$A = \pi r^2 \; (\text{mm}^2) \quad (3)$$

Where ρ is the resistivity, l is the length of the conductor, and A is the cross-sectional area of the conductor.

ii. LOSSES DUE TO CORONA: Corona is the phenomenon of voltage glow, hissing noise and production of ozone gas in an overhead transmission line [1]. When ionized charges are set up across the conductor surface, these ionized charges take energy from the supply system, thereby causing some loss of energy due to the formation of corona and these losses are seen as resistance loss [8]. From studies, it has been specified that when disruptive voltage is exceeded, the power loss due to corona is expressed as [1],

$$P = 242.2 \left(\frac{f+25}{\delta}\right) \sqrt{\frac{r}{d}} (V - V_c)^2 \times 10^{-5} \quad \text{(kW/kM/phase)} \quad (4)$$

Where;

F = Supply Frequency in Hz

V = Phase-Neutral Voltage (r.m.s)

V_c = Disruptive Voltage Per Phase (r.m.s)

TECHNICAL MEASURES FOR REDUCING HIGH VOLTAGE TRANSMISSION LOSSES

High voltage AC transmission losses cannot be absolutely mitigated but can be reduced to a reasonable percentage. Some of the technical strategies for reducing high voltage AC transmission line losses are suggested as follows;

a. By utilizing higher transmission voltages.
b. Improving power factor of the system.
c. By reducing the skin effect of conductors.
d. Installation of capacitor banks along transmission lines as this will increase the availability of reactive power.
e. Proper connection of conductors.

III. METHOD AND MATERIALS

A single line power system model which comprises a 575MW synchronous generator is interconnected to a step-up transformer, the transformer is terminated at a lumped load through a busbar, the lumped load is rated 100MVA. This single line power system network is modelled in ETAP software Environment in three separate cases of voltages (330kV,132kV, and 33kV). ETAP simulation is done using the load flow tools, the various power system component parameter is shown in figure 2, 3, 4 and 5.

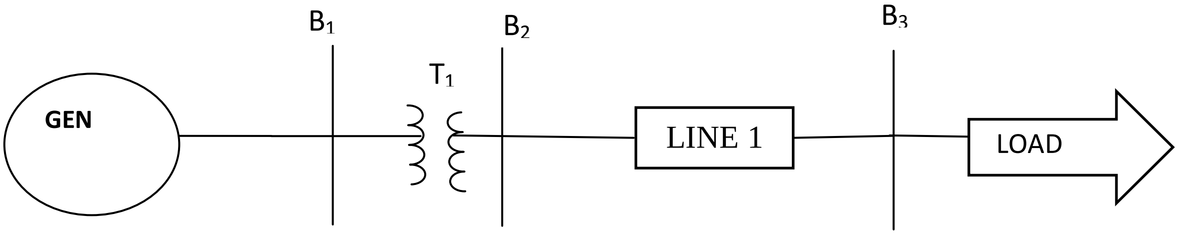

Figure 1: Single Line Diagram of the Model

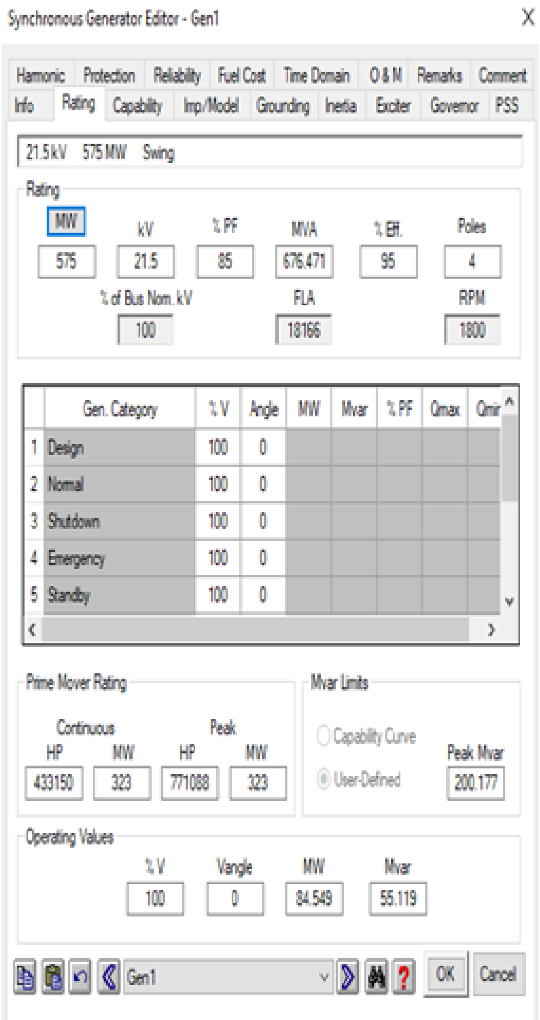

Figure 2: Synchronous Generator Parameter Details

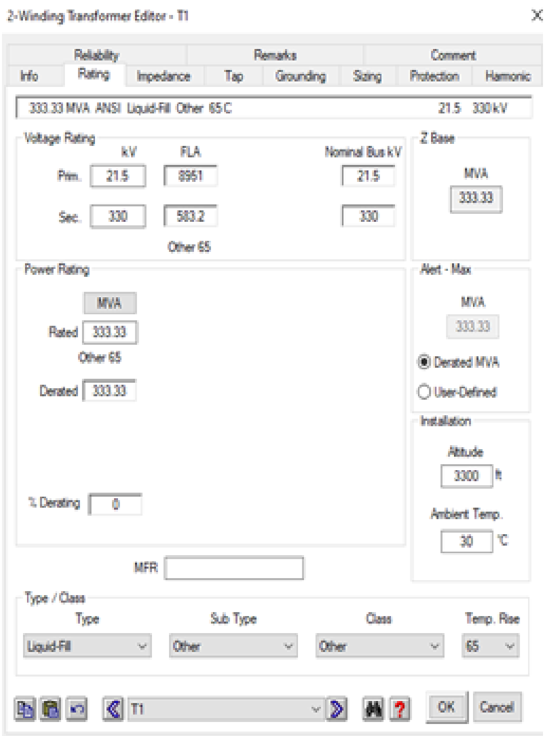

Figure 3: Transformer Parameter Details

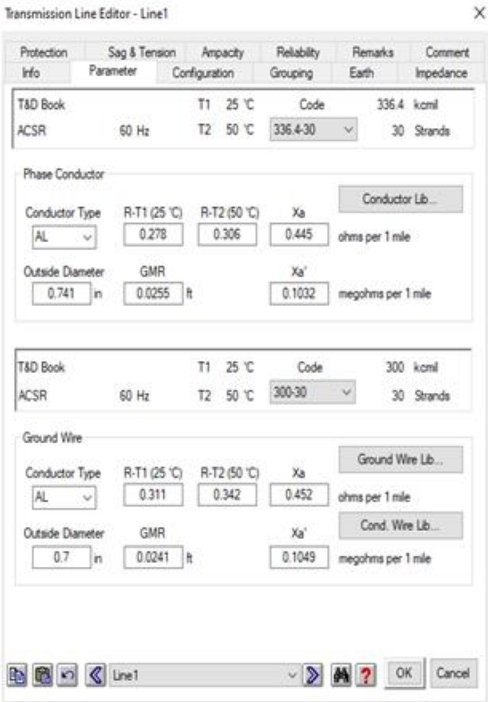

Figure 4: Transmission line parameter details

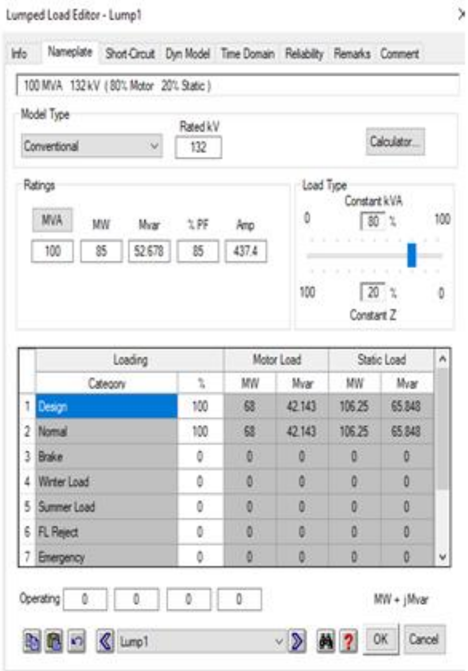

Figure 5. Lumped Load parameter details.

IV. RESULT AND DISCUSSION

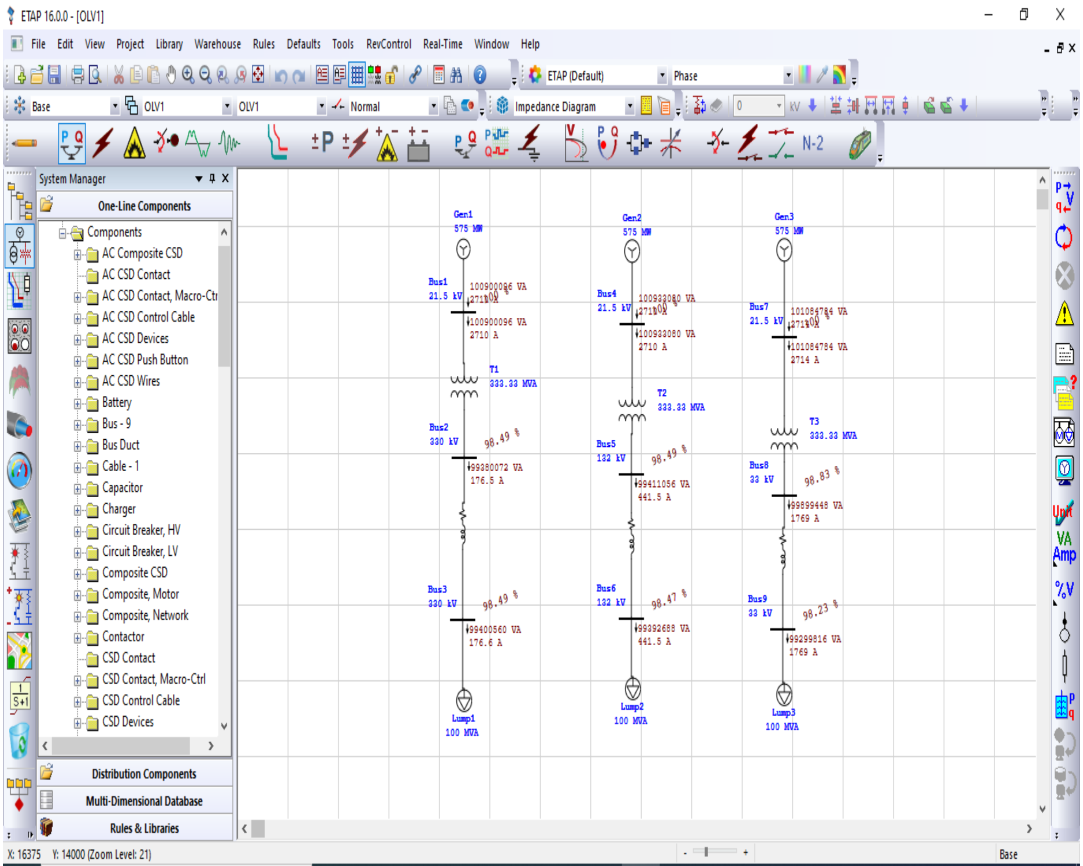

Figure 6: Simulation Model in ETAP Environment

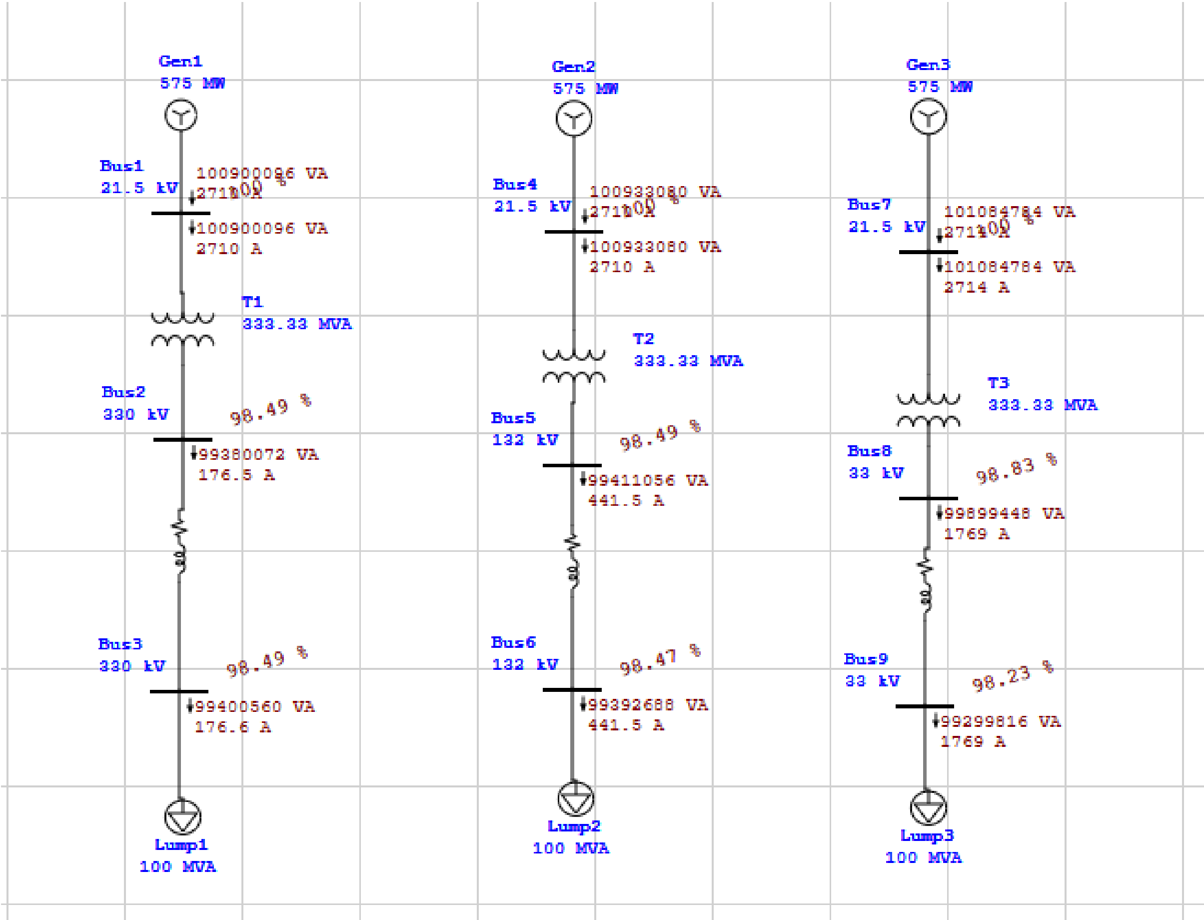

Figure 7: Extracted Simulated Model from ETAP Environment.

Computation of I^2R Line Losses

The three-phase I^2R line losses are computed using the formula expressed in equation (1) [9].

$P_{loss} = 3I^2 R$ (kW)

Where R = 0.306 Ω

CASE I:

When voltage is 330kV, the current along the Line is 176.5 A

Power loss here is named P_1, therefore;

$P_1 = 3 \times (176.5)^2 \times 0.306 = 28597.74$kW

CASE II:

When voltage is 132kV, the current along the line is 441.5 A

Power loss here is named P_2, therefore;

$P_2 = 3 \times (441.5)^2 \times 0.306 = 178938.63$ kW

CASE III:

When voltage is 33kV, the current along the line is 1769 A

Power loss here is named P_3, therefore;

$P_2 = (1769)^2 \times 0.306 = 2872753.38$ kW

V. DISCUSSION

From Figure 7, and the computed power losses in each case of consideration, it can be verified that at high voltage transmission (330kV) a current of 176.5 A flows through the conductor which results in a corresponding computed power loss to be 28597.74kW, but at low voltage transmission (33kV) a current of 1769 flows through the conductor which also results to a corresponding computed power loss along the line to be 2872753.38 kW. The result shows that when high voltage is adopted for power transmission small amount of power loss is observed, and when a low voltage is adopted, a high amount of power loss is observed along the line.

VI. CONCLUSION

The impact of high voltage transmission on I^2R power losses is that when electrical power is transmitted at a high voltage the observed power loss along the line is reduced as compared to when a low voltage is adopted for the same amount of power transmission. This was confirmed from the simulation analysis and the computation of I^2 R losses simple analysis. This work proved that ETAP software is a reliable and sophisticated software for electrical power system simulation and analysis. The model in this work can be used by electrical power system instructors in the academic field to demonstrate transmission line power losses studies.

REFERENCES

[1]. V. K. Mehta and Rohit Mehta, "Principle of Power System", International Edition, S. CHAND and Company PVT. Ltd. 2008.

[2]. Naenwi Yaabari, Odu Patrick O. and Ojobe Obasi-Sam O., "Analysis of Three-Phase Transmission Line Fault Using Matlab/Simulink, "International Journal of Advances in Engineering and Management, Volume 3, issue 7, pp 1820-1827, 2021.

[3]. Electrical Installation Rules Standard, August 2020, Achieved from the original on 22, August 2010, Retrieved 18 July 2020. www.en.m.wikipdia.org.

[4]. www.betaengineering.com

[5]. Aung Zaw Latt, "Three-Phase Induction motor stating Analyzing using ETAP", International Journal of Latest Technology in Engineering Management and Applied Science, Volume 8, Issue 4. 2009.

[6]. www.electrical-engineering-portal.com/total-losses-in-power-distribution-and- transmission-lines by Jiguparmar, August 2013.

[7]. O. M. Bamigbola, M. M.Ali and K. O. Awodele, "Predictive Models of Current, Voltage and Power losses on Electric Transmission Lines", Journal of Applied Mathematics, Article ID, 146937 page 5, Volume 2014.

[8]. Kittipong Tonmiti and Tharin Ratanabuntha, "Comparison of Power Loss due to Corona Phenomena model with Peeks Formula in High Voltage 115 kV and 230kV system", International Electrical engineering Congress, IEECON2016, Chang Mai Thailand, March 2016.

[9]. M. C. Anumaka "Analysis of Technical Losses in Electrical Power System (Nigerian 330kv Network as A Case Study)", IJRRAS, Volume 12, Issue 2, 2012.

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