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Model Transmission Line Parameters Evaluation Using Matlab: A Case Study of Short-Line and Nominal-Pi Methods

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ABSTRACT

The accurate modeling of transmission lines is essential for analyzing their performance, optimizing design, and ensuring stability. Several studies have contributed to the development of transmission line models, providing analytical, numerical, and computational frameworks for their analysis, this work focuses on the realization of digital tool for effective evaluation of transmission line models parameters. The methods considered here includes, the Pi-line model and short-line model methods, where typical line data were sampled and implemented in a develop Matlab Scripts of the models. Without human efforts the various Line parameters (such as the sending-end voltage (Vs), current (Is), Line power (Ps) and power factor (PFs),) were obtain via graphical plots with minimal time consideration. The results obtained confers accurately with existing analytical calculation method. the study proves the sophistication of Matlab in power system modelling and analysis.

Keywords: Transmission line parameters, Short-line and Nominal-Pi line Models, Matlab

INTRODUCTION

Transmission lines are critical components of electrical power system, responsible for transmitting energy over vast distances with minimal losses. Proper evaluation of transmission line model parameters plays a crucial role in ensuring efficient operation, reliability, and performance optimization [1]. These parameters influence power losses, voltage regulation, and overall system performance. They are made up of conductors that are evenly spaced to permit the flow of electric current and are held aloft by towers or poles. Because of their high conductivity [2]. By avoiding direct touch, towers keep the conductors well above the ground, minimizing losses and guaranteeing safety. Performance of transmission Lines assessment involves evaluating key considerations like losses, voltage regulation, power transfer capability, and efficiency under different operating conditions [3]. Transmission line models are mathematical representations used to analyze the behavior of power system networks, each model is characterized by fundamental parameters: resistance (R), inductance (L), capacitance (C), and conductance (G), which influence the power flow, voltage regulation, stability. This research work considers further parameters which are vital for the computation of the various fundamental line constants, such as the sending-end voltage, current, power and power factor, the study embraces the sophistication of Matlab for the digital implementation of the evaluation prompt realization.

REVIEW OF RELATED LITERATURES

Transmission lines are modeled using mathematical representations based on their length and electrical characteristics. Transmission lines are categorized based on the applicability of lumped or distributed parameters. Lumped Parameter Model: Suitable for short transmission lines (<80 km) where capacitance is negligible [4]. Distributed Parameter Model: Consider transmission lines as continuous systems where voltage and current vary along their length and are used for medium (80–250 km) and long (>250 km) transmission lines.

[5] Provided a comprehensive analysis of multiconductor transmission lines, establishing fundamental equations for modeling, Glover et al. (2012) Discussed power system analysis with transmission line modeling for energy distribution, [6] Applied the finite element method (FEM) for solving Maxwell's equations in transmission line

behavior, [7] Developed finite difference time domain (FDTD) methods for time-domain simulation of transmission lines, [8] Introduced hybrid transmission line models that integrate analytical and numerical methods, [9] Studied the suitability of different transmission line models in power systems, [10] Applied artificial intelligence (AI) for parameter estimation and optimization in transmission line models, [11] Modeled transmission lines for integrating renewable energy sources. There is need for digital tools application for suitable evaluation of the parameters of transmission line models, which this work applicably presented.

Importance of Parameter Evaluation

The relevance of transmission line models parameters evaluation can be appreciated in the following areas:

i. Power System Efficiency and Reliability: Accurate evaluation of transmission line parameters improves efficiency by minimizing losses and enhancing power transfer capability [12].
ii. Fault Analysis and Protection: Precise parameter determination aids in fault localization and protection system design, improving grid resilience [13].
iii. Electromagnetic Compatibility (EMC) and Signal Integrity: In communication systems, transmission line models help mitigate attenuation, reflection, and crosstalk [14].
iv. Load Flow and Stability Studies: Power flow analysis and transient stability studies rely on accurate parameter values to maintain system reliability [15].

METHODOLOGY

Short Transmission line Model

In short transmission line both shunt conductance and shunt capacitance are normally neglected, the considerable parameters are resistance and inductance of the line are also called series parameters of the line, as shown in Figure 1., so the current flowing through the line remains same all through the length of the line [16].

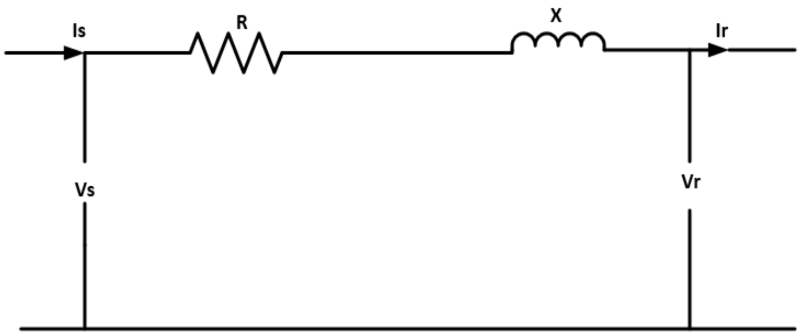

Figure 1: Short Transmision Line Model

Where V and I represent voltage and current, whereas subscripts 's' and 'r' represent sending end and receiving end quantities, respectively. The line resistance is represented by R and inductive reactance of the line is represented by X.

Receiving end voltage is taken as reference phasor and can be represented as

$$V_r = V_r \angle 0^0 = V_r + j0 \quad (1)$$

For a lagging power factor, the line current can be represented as

$$I_s = I_r = I \angle \emptyset_r = \mathrm{I}(\cos\emptyset_r - \mathrm{j}\sin\emptyset_r) \quad (2)$$

The line impedance Z is represented as

$$\mathrm{Z} = R + jX \quad (3)$$

From figure 1., the sending end voltage is expressed as

$$V_s = V_r + IZ \quad (4)$$

Using equation (2) and equation (3), then equation (4) can be expressed as

$$V_s = V_r + I(\cos\emptyset_r - \sin\emptyset_r)(R + jX) \quad (5)$$

Simplifying equation (5), we have,

$$V_s = (V_r + IR\cos\emptyset_r + j\sin\emptyset_r) + j(\mathrm{IX}\cos\emptyset_r - IR\ \sin\emptyset_r) \quad (6)$$

Equation (6) represents the short transmission line sending and voltage in terms of receiving end voltage, line current and receiving end power factor and the line parameters X and R.

Pi Transmission Line Model

In this method, capacitance of each conductor (line to neutral) is divided into two halves; one half being lumped at the sending end and the other half at the receiving end. Also, its charging current must be added to line current in order to obtain the total sending end current [17].

Taking the receiving end voltage as the reference as seen in figure 2., we have,

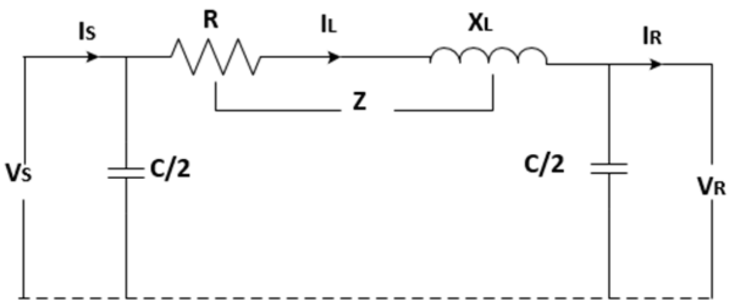

Figure 2: Nominal Pi Model for Medium Transmission Line.

$$V_R = V_R + j0 \quad (7)$$

The load current can be expressed as

$$I_R = I_R(\cos\emptyset_R - j\sin\emptyset_R) \quad (8)$$

Charging current at the load is

$$I_{C1} = j_\omega\left(\frac{C}{2}\right)V_R = j\pi fC\,V_R \quad (9)$$

Line Current,

$$I_L = I_R + I_{C1} \quad (10)$$

Sending end voltage

$$V_S = V_R + I_L Z \quad (11)$$

Sending end current

$$I_S = I_L + I_{C2} \quad (12)$$

Sending power becomes

$PFs = \sqrt{3}\,V_s I_s \cos\emptyset_s$

Both the short-line and Pi-line model of the transmission line parameters are been implemented in Matlab environment using the various Matlab syntax and build-in functions.

SIMULATION RESULTS AND DISCUSSION

The details of the adopted transmission line data are presented in table 1.

Table 1: Model Transmission Line Data

Frequency (Hz)	50
Length of Line (Km)	100
Shunt Admittance (Mho)	10^{-3}
Series Admittance (Ohm)	33+j132
Receiving end load (Mw)	50
Line Voltage (KV)	220
Power factor	0.9 lagging

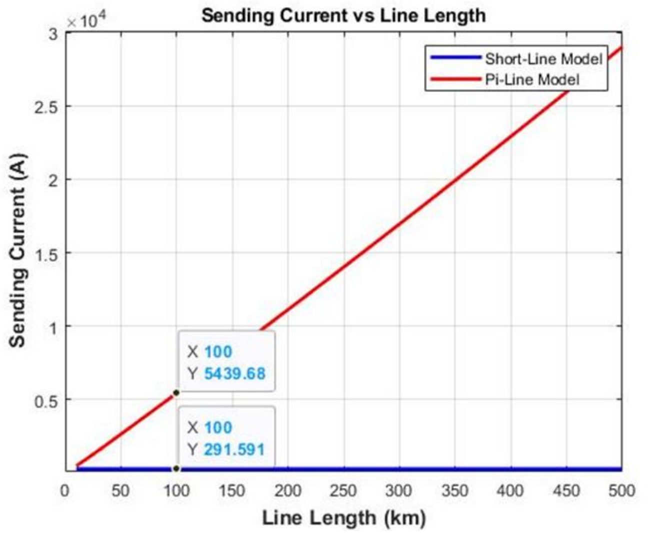

Figure 3: Sending End Current Magnitude Using Shortline and Nominal Pi Methods

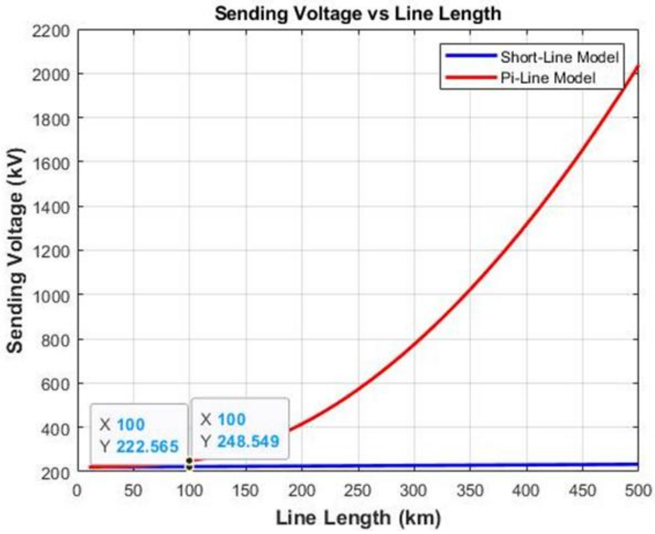

Figure 4: Sending End Voltage Magnitude Using Shortline and Nominal Pi Methods

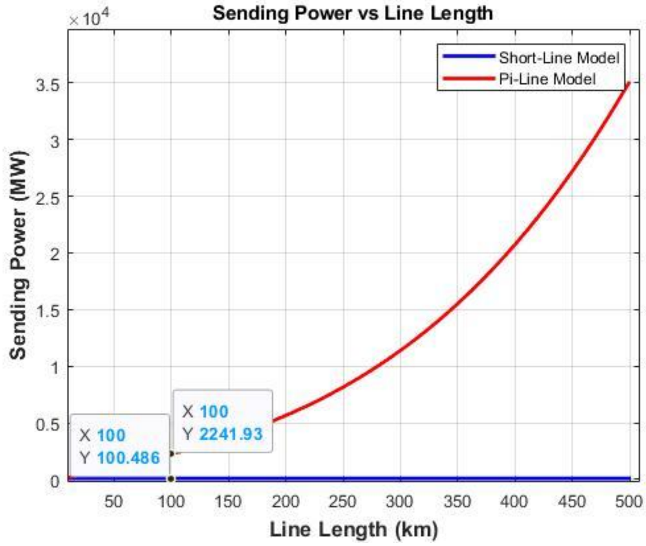

Figure 5: Sending End Real Power Magnitude Using Shortline and Nominal Pi Methods

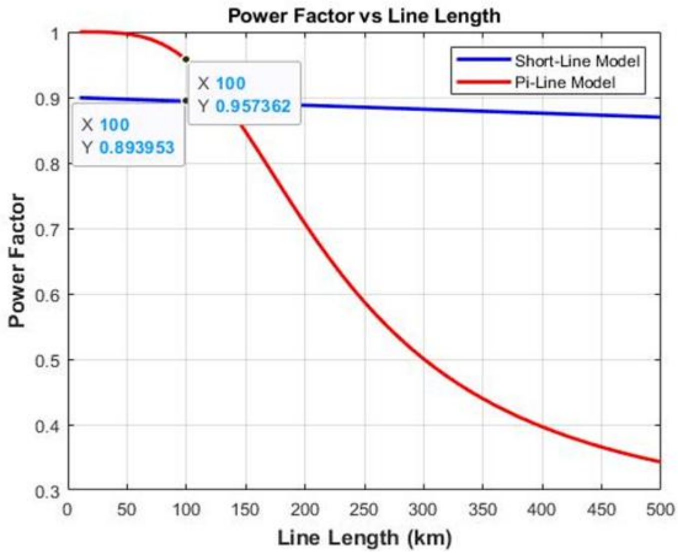

Figure 6: Sneding End Power factor Suing short line and Nominal Pi Methods

DISCUSSION

From figure 3. The Pi-line model account for capacitance, resulting in a slightly higher sending voltage but in short-line model, its higher than receiving voltage due to only series impedance. The pi-model includes charging current, making sending ending current higher than short-line because shunt capacitance draws additional charging current with reference to figure 4., the short-line model shows slightly higher power loss, since it does not account for capacitance compensation as could be seen in figure 5., the pi-line model improves power factor due to capacitive effect compensating inductive reactance as could be seen in figure 6.

CONCLUSION

Short-Line Model is simpler and suitable for short distances, but it does not account for line charging effects. Pi-Line Model is more accurate for longer lines as it considers capacitance, which improves the power factor slightly but increases the sending voltage and current. In real applications, for long distances, the π-model provides better approximations and is often used in power system analysis. The results of the evaluation show clearly the effect of various transmission line parameters on its dynamic performance. The Matlab scripts realized can be used as a digital tool for easy and accurately transmission line models parameters evaluation.

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