DEVELOPMENT OF A MODIFIED DOPEZO TRANSMISSION LOSS MODEL FOR ANALYSIS OF TECHNICAL LOSSES IN ELECTRICAL POWER NETWORKS

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Abstract

Dopezo transmission loss is the loss of signal strength at the far end of a transmission line compared to the signal that was introduced into the line. This loss is due to the electrical impedance of the copper cable, the loss of energy though the cable insulation and the impedance caused by the connector. Transmission electricity at high voltage reduces the fraction of energy lost to resistance which varies depending on the conductors, the current flowing and the length of the transmission line. The Dopezo transmission loss model is not effective for the assessment of technical losses in electrical power network. This research paper develops a Modified Dopezo transmission loss model for analysis of technical losses in the electrical power network. The total injected bus power at specific buses on the transmission line network and the impedance matric of the transmission network are used on input parameters in the development of the Modified Dopezo transmission loss model using appropriate mathematical notations. The results of the Modified Dopezo transmission loss model developed shows that the voltage magnitude varies linearly as the injected currents in the transmission network. The current injected increases progressively to a peak value of 68 volts which corresponds to a voltage magnitude of 16 volts. This is due to the ohmic resistance of the transmission line. The phase angles also increase correspondingly as the voltage magnitudes with a voltage magnitude of 18 volts corresponding to a phase angle of 60 degrees. At least current of 1 ampere was injected in the transmission network with a corresponding least phase angle of 5 degrees indicating a direct relationship between the two quantities. The voltage magnitude asymptotically varies directly as the phase angle. At a phase angle of 75 degrees, a corresponding voltage magnitude of 200 volts was noticed. The network power varies sinusoidally as the voltage magnitude. During the first swing of the operation, the power increases progressively to voltage magnitude of 0 vott and 9.0 volts. The Modeified Dopezo transmission loss model is efficient in the analysis of technical losses in electrical power network.

Keyword: Modified Dopezo, Transmission Loss, Technical Losses, Power Networks, National Grid, Transmission Lines, Distribution Lines.

I. Introduction

One of the most important forms of energy is electrical energy which drives the economy of any society for the comfort of human kind. With the help of transmission and distribution lines, electricity generated from the power station gets to the consumers who are the end- users. In the process of such transmission, some losses are experienced. The national grid transmits electricity through 330 kV or 132 kV. Transmission grid is a network made of conductors carried on a steel towers in-between transformer stations, which converges generated power from power stations to major load centers, and interconnecting all power stations to form a solid network accessible to all load centers.

Technical Losses

Technical losses are losses that are occur naturally and is made up of power dissipation in electricity system components such as transmission and distribution lines, transformers and measurement systems.

The distance of transmission line is usually very long from the generating stations and also a very good distance to the distributing stations where energy is lost as heat in the conductor.

Causes of Technical Losses

The major reasons for high technical losses include the following:

(i) Inadequate investment on transmission and distribution, especially in sub-transmission and distribution. Low investment resulting in overloading of the distribution system without commensurate strengthening and augmentation.
(ii) Pour quality of equipment used in agricultural pumping in rural areas, cooler air-conditioners and industrial loads in urban areas.
(iii) Too much stage of transformations and improper load management
(iv) Large scale rural electrification trough long 11 kV and low tension lines.

Reduction of Technical Losses

The following measures can be taken to reduce technical losses:

(i) A comprehensive system improvement scheme has to be formulated with detailed investment program.
(ii) Financial requirements for implementation of the different phases o0f system improvement works must be estimated.
(iii) Improvement of the distribution systems along with associated transmission system must be prepared on long-term basis.
(iv) Data regarding existing loads, operating conditions and forecast of expected loads must be regularly computed.
(v) Shunt capacitors for power factor improvement should be installed.
(vi) Lower capacity distribution transformers at each consumer premises must be installed.

II. Materials and Method

Development of modified DOPEZO transmission los model:

Given that the total injected bus power at bus i is ‘S_i’.

Then:

$$P_L + jQ_L = \sum_{i=1}^{n} S_i = \sum_{i=1}^{n} V_i I_i^*$$

$$= V_{bus}^T I_{bus}^* \quad (1)$$

Where:

P_L and Q_L are the real and reactive power loss of the system.

V_{bus} and I_{bus} are the column vectors of voltages and currents of all the buses.

Then:

$$V_{bus} = Z_{bus} I_{bus} \quad (2)$$

Where Z_{bus} is the bus impedance matrix of the transmission network and is given by:

$$Z_{bus} = R + jX = \begin{bmatrix} r_{11} & r_{12} \cdots & r_{1n} \\ r_{21} & r_{22} \cdots & r_{2n} \\ r_{n1} & r_{n2} \cdots & r_{nn} \end{bmatrix} + j \begin{bmatrix} x_{11} & x_{12} \cdots & x_{1n} \\ x_{21} & x_{22} \cdots & x_{2n} \\ x_{n1} & x_{n2} \cdots & x_{nn} \end{bmatrix}$$

From equation 1 and 2,

$$P_L + jQ_L = I_{bus}^T Z_{bus}^T I_{bus}$$

$$= I_{bus}^T Z_{bus}^T I_{bus} \quad (3)$$

$$I_{bus} = I_p + jI_q = \begin{bmatrix} I_{p1} \\ I_{p2} \\ \vdots \\ I_{pn} \end{bmatrix} + j \begin{bmatrix} I_{q1} \\ I_{q2} \\ \vdots \\ I_{qn} \end{bmatrix}$$

The loss equation can be written as:

$$P_L + jQ_L = \left(I_p + jI_q\right)^T (R + jX)\left(I_p - jI_q\right) \quad (4)$$

Separating out the real part P_L from the above matrix product;

$$P_L = {I_p}^T R I_p + {I_p}^T \times I_q + {I_q}^T R I_q - {I_q}^T \times I_p \quad (5)$$

Note that X is a symmetric matrix.

$${I_p}^T \times I_q = {I_p}^T \times I_p \quad (6)$$

Hence:

$$P_L = {I_p}^T R I_p + {I_q}^T R I_q \quad (7)$$

Equation (7) is called the Dopezo transmission loss Model.

Using index notation; equation (7) becomes

$$P_L = \sum_{\substack{i=1 \\ k=1}}^{n} r_{jk} \left(I_{pj} I_{pk} + I_{qj} I_{qk}\right) \tag{8}$$

For bus powers at bus i,

$$P_i + jQ_i = V_i I^*$$

$$= V_i\left(I_{pi} - jI_{qi}\right)$$

$$= |V_i|(\cos\delta_i + j\sin\delta_i)\left(I_{pi} - jI_{qi}\right) \tag{9}$$

Where:

$\delta_i$is the phase angle of voltage V_i with respect to the reference voltage i.e. the slack bus voltage.

Separating real and imaginary parts,

$$P_i = |V_i|\cos\delta_i\, I_{pi} + |V_i| I_{qi} \sin\delta_i \tag{10}$$

$$Q_i = |V_i|\sin\delta_i\, I_{pi} + |V_i| I_{qi} \cos\delta_i \tag{11}$$

Solving for I_{pi} and I_{qi}

$$I_{pi} = \frac{1}{|V_i|}(P_i \cos\delta_i + Q_i \sin\delta_i) \tag{12}$$

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$$I_{qi} = \frac{1}{|V_i|}(P_i \sin\delta_i - Q_i \sin\delta_i) \tag{13}$$

Equations (12) and (13) express the real and imaginary components of bus currents in terms of bus power and bus voltages.

From equation (12),

$$I_{pi} = \frac{1}{|V_i|}(P_i \cos\delta_i + Q_i \sin\delta_i)$$

Let $Q_i \sin\delta_i = 0$

$$I_{pi} = \frac{P_i \cos\delta_i}{|V_i|} \tag{14}$$

$$P_i = \frac{I_{pi}|V_i|}{\cos\delta_i} \tag{15}$$

Also from equation (13)

$$I_{qi} = \frac{1}{|V_i|}(P_i \sin\delta_i - Q_i \sin\delta_i)$$

Let $Q_i \cos\delta_i = 0$

$$I_{qi} = \frac{P_i \sin\delta_i}{|V_i|}$$

$$P_i = \frac{I_{qi}|V_i|}{\sin \delta_i} \tag{16}$$

Adding equations (15) and (16)

$$2P_i = \frac{I_{pi}|V_i|}{\cos \delta_i} + \frac{I_{qi}|V_i|}{\sin \delta_i} \tag{17}$$

$$2P_i = |V_i| \left[\frac{I_{pi}}{\cos \delta_i} + \frac{I_{qi}}{\sin \delta_i}\right] \tag{18}$$

Let $I_{pi} = I_{qi} = I_i$

$$2P_i = |V_i| \left[\frac{I_i}{\cos \delta_i} + \frac{I_i}{\sin \delta_i}\right] \tag{19}$$

$$2P_i = |V_i|(I_i) \left[\frac{1}{\cos \delta_i} + \frac{1}{\sin \delta_i}\right] \tag{20}$$

$$P_i = \frac{|V_i|I_i}{2} \left[\frac{1}{\cos \delta_i} + \frac{1}{\sin \delta_i}\right] \tag{21}$$

A graph of power is plotted against the $\left(\frac{1}{\cos \delta_i} + \frac{1}{\sin \delta_i}\right)$ to obtain the modified DOPEZO transmission loss model for analysis of technical losses in electrical power networks.

Equation (21) is the Modified DOPEZO transmission loss formula for analysis of technical losses in electrical networks.

III. Discussion of Results

The relationship between the voltage magnitude and current injected in the power network is illustrated in Figure 1. When the voltage magnitude was 4 volts, a current of 18A was injected in the network. The voltage magnitude increases proportionately until a peak voltage magnitude of 18 volts which corresponds to an injected current of 67 Amperes. This is due to the fact that the ohmic resistance of the power network increases with time. Thus the voltage magnitude varies linearly with the injected current in the power network. At voltage magnitude of 6V, 8V, 10V and 18 volts, the corresponding current injected in the network are 28A, 36A, 44A and 68A respectively. This implies that the ohmic resistance of the power network increases progressively.

Figure 2 illustrates the variation of phase angle with the voltage magnitude. It is observed that the phase angle increases progressively as the magnitude of the voltage. A phase angle of 20 degrees corresponds to a voltage magnitude of *V. Voltage magnitude of 12V, 18V and 26V give rise to phase angles of 40 degrees, 60 degrees and 180 degrees, thus, there is direct relationship between the phase angle and the voltage magnitude.

A direct relationship is observed between the injected current in the power network and the phase angles as shown in Figure 3. The least current injected in the power network was 1A which corresponds to a least phase angle of 5 degrees. At an injected current of 10A, the phase angle suddenly increases to 25 degrees while a phase angle of 60 degree gives a corresponding injected current of 20A. The trend continues until a peak injected current of 60 Amperes leading to a corresponding peak phase angle of 100 degrees.

The trend observed in Figure 4 follow a different pattern entirely even though, the voltage magnitude asymptotically varies linearly as the phase angle after the voltage magnitude of 1 volt. A voltage magnitude of 200V gives a phase angle of 75 degrees. Phase angle of 100 degree, 125 degrees and 155 degrees give corresponding voltage magnitude of 400V, 500V and 800V respectively.

Figure 5 illustrates the relationship between the power and the voltage magnitude for the power network. The power in the network varies sinusoidally with the voltage magnitude. Within the first swing of the operation, the power increases progressively between o watt and 1000 watts which correspond to voltage magnitude of 0 volt and 9.0 volts. In the second swing of the operation, the power falls dramatically from 2000 watts to 10 watts. This is maintained constant for some times until it starts increasing again until it attains another peak value of 1500 watts. During this second swing, the power dropped sharply to -2500 watts and later starts increasing within the range. This is due to the fact that the injected current in the network varies linearly as the power and inversely as the applied voltage in the network.

Figure 6 discusses the relationship between the power and the current injected in the network. The power varies sinusoidally on the injected current in the network. Within the first swing of operation, the power varies linearly as the injected current in the network. A similar observation is noticed in the second half of the swing since the voltage of the power network varies linearly as the power and inversely as the injected current in the network.

Figure 7 illustrates relationship between the power in the network and the summation of the phase angle. Observation from the figure shows that the Modified Dopezo transmission loss varies linearly as the power injected in the power network and inversely proportional to the phase angles.

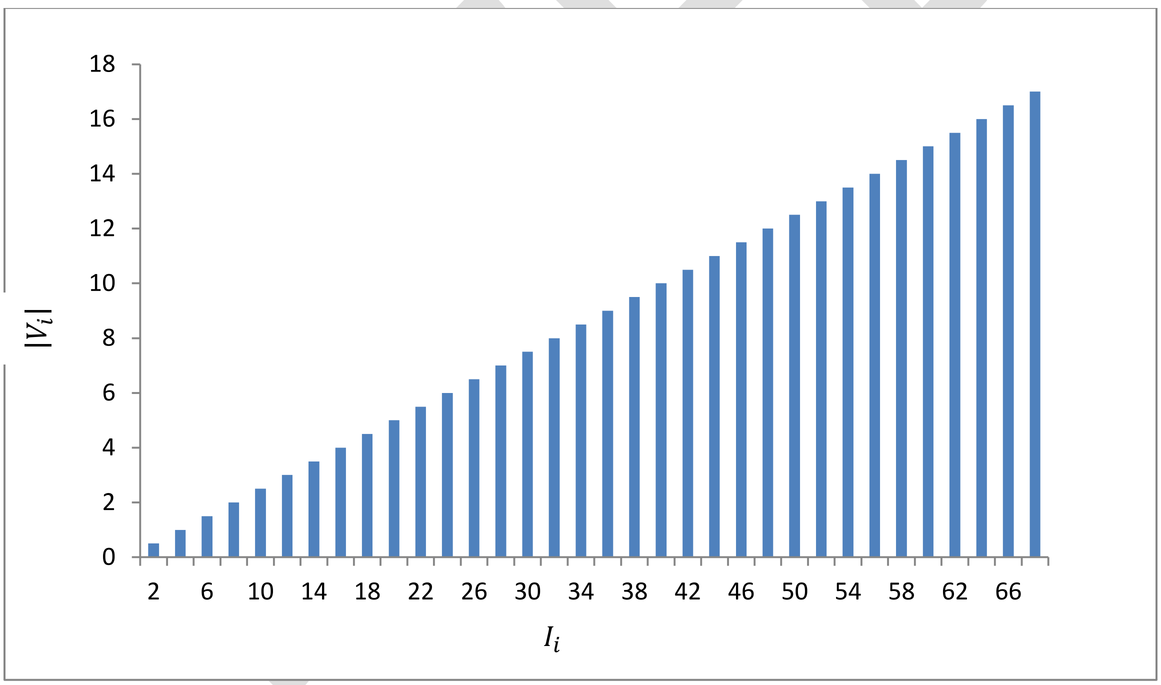

Figure 1: $|V_i|$ versus I_i

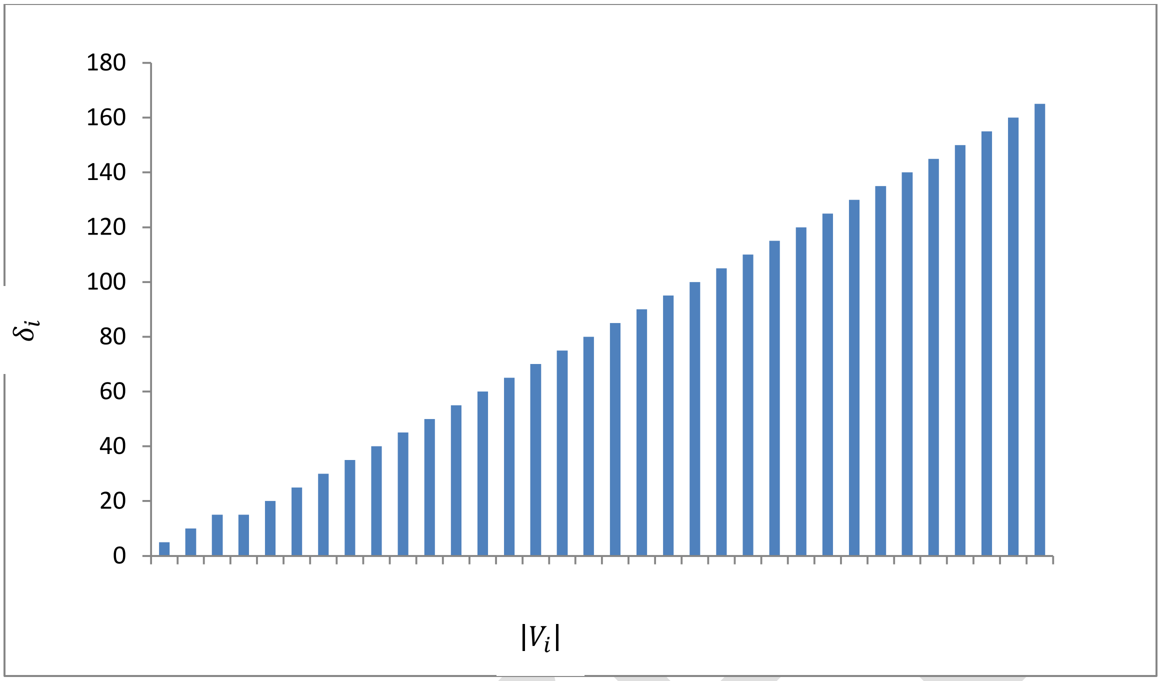

Figure 2: δ_i versus $|V_i|$

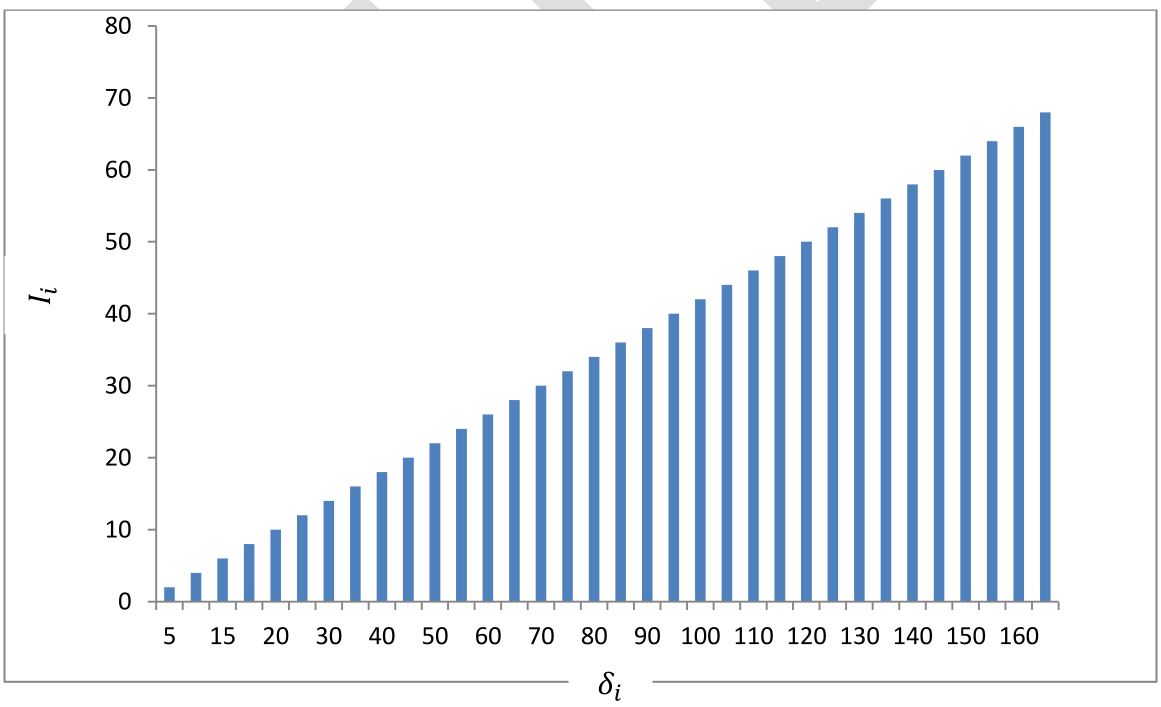

Figure 3: I_i versus δ_i

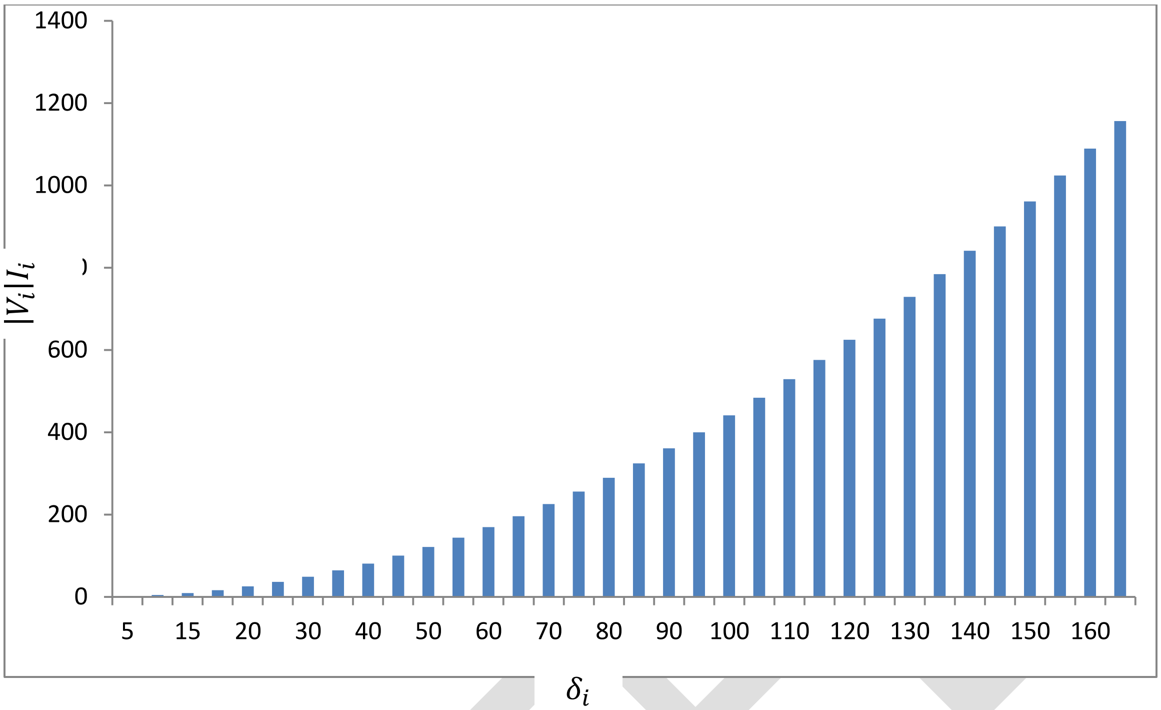

Figure 4: $|V_i|I_i$ versus δ_i

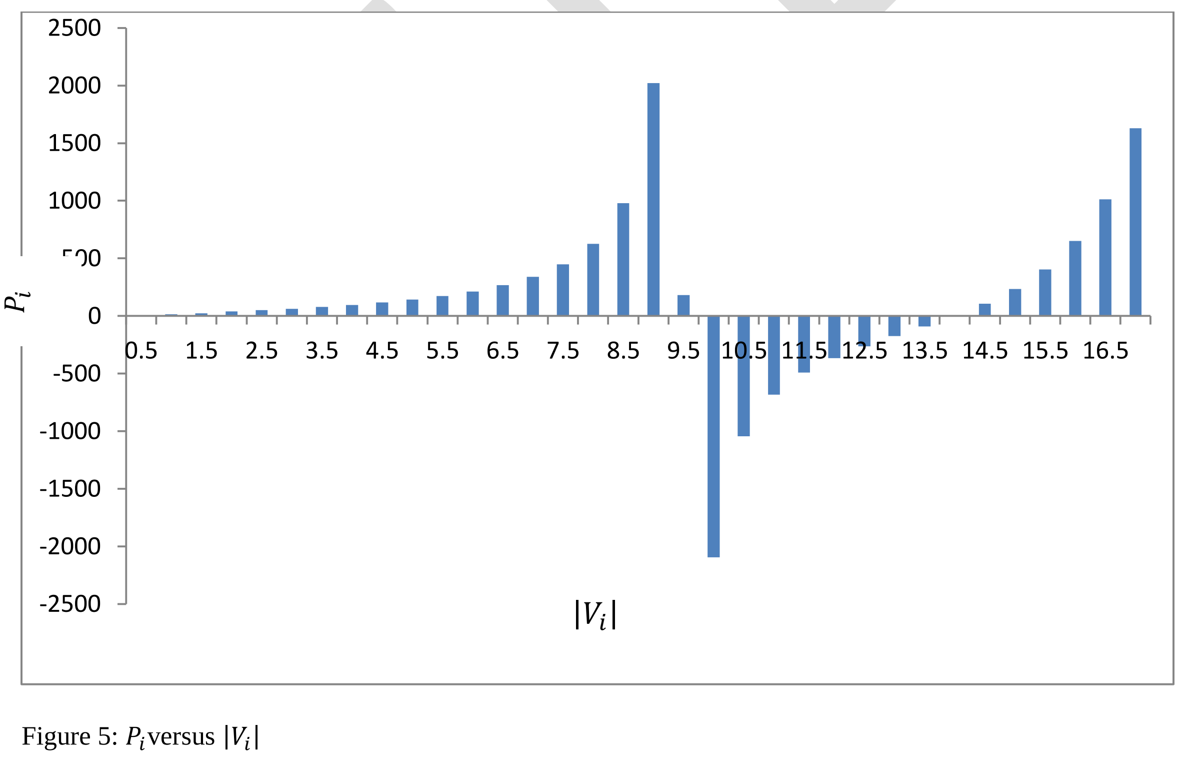

Figure 5: $P_i$versus $|V_i|$

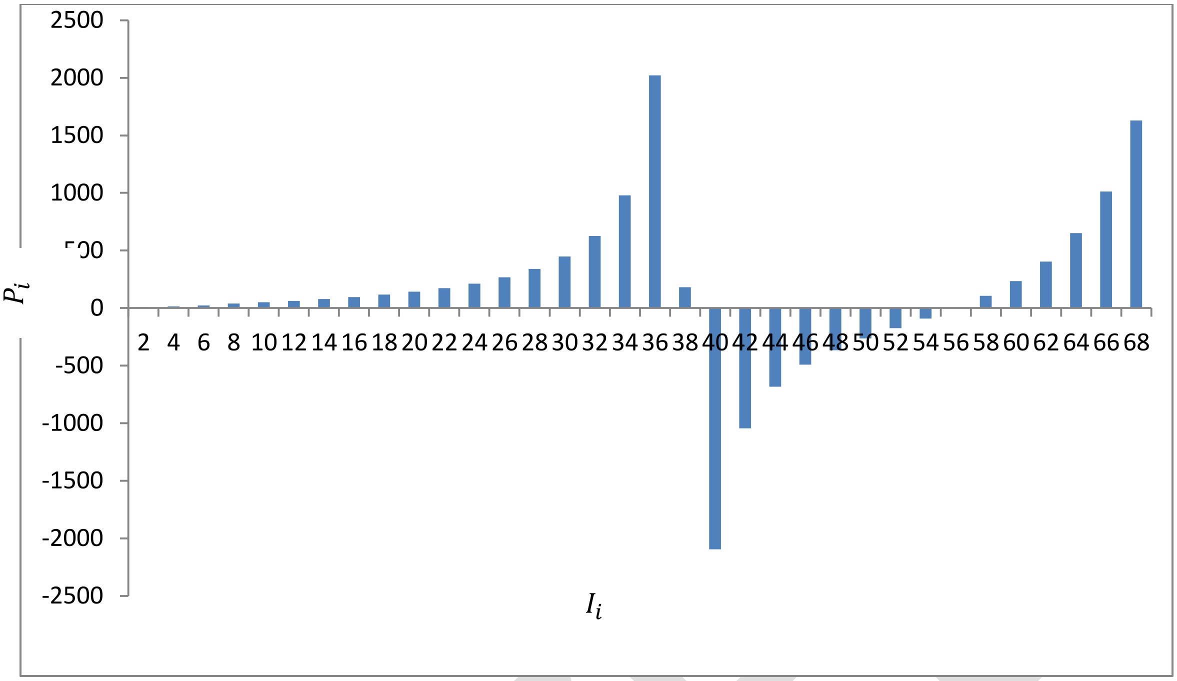

Figure 6: P_i versus

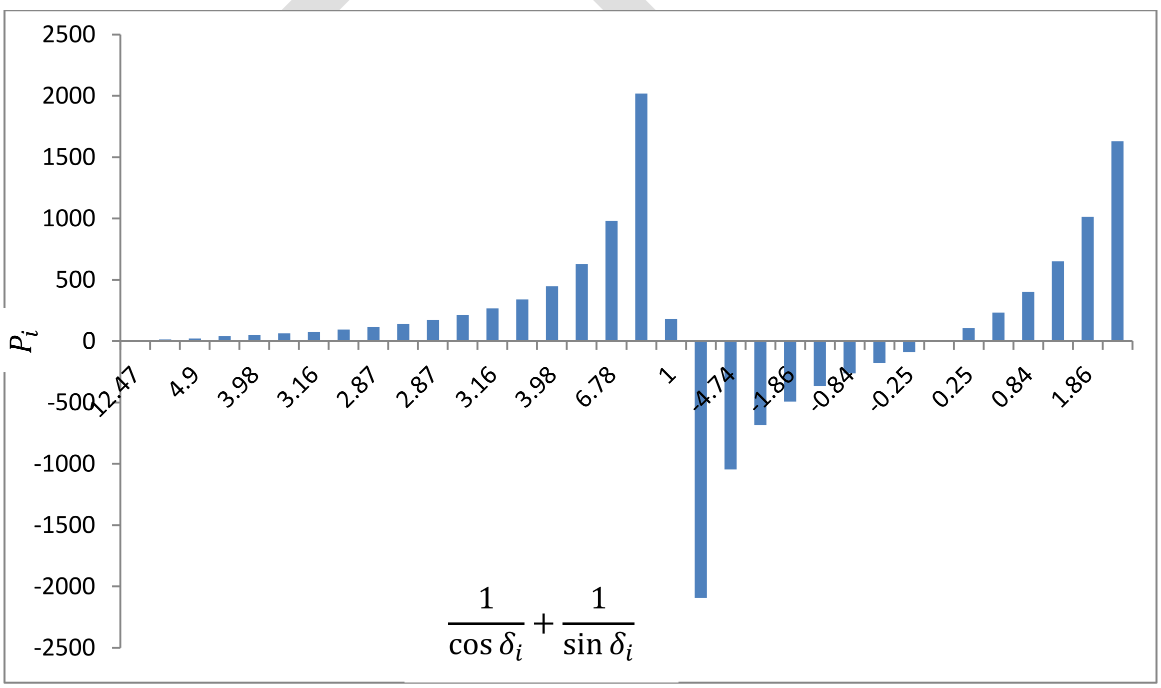

Figure 7: P_i versus $\frac{1}{\cos \delta_i} + \frac{1}{\sin \delta_i}$

IV. Conclusion

A Modified Dopezo transmission loss model for analysis of technical losses in electrical power network has been developed. The development of the model started with the use of total injected bus powers at specific buses on the transmission line network as the input parameters with the aid of appropriate mathematical notations.

The results of the modified model developed shows that the voltage magnitude and currents injected in the transmission network are linearly related due to the ohmic resistance of the line. The phase angle and the voltage magnitudes also increase correspondingly. Where is a sinusoidal relationship between the power in the network and the voltage magnitude. The power increases between o watt and 2000 watts, which corresponds to 0 volt and 9.0 volts during the first swing of the operation.

The Modified Dopezo transmission loss model offers a better and efficient approach in the analysis of technical losses of electrical power network.

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