Internal Validation of the Mathematical Model vs= EVr + FIr as Applied to a Three-Phase Medium Transmission Lines Characterized by Unbalance Shunt Circuit

Engr. Ramon P. Velasco, *Member*, *IACSIT*

***Abstract*—In the previous research, the researcher showed the derivation of mathematical models expressing sending voltage and sending current in terms of receiving voltage and receiving current. Hence, two mathematical models for a three phase medium transmission lines which includes V_s=EV_r+FI_r and I_s=GV_r+HI_r are developed. This research is now after for the internal validation of V_s=EV_r+FI_r using t-test for independent sample means at 1% level of significance.**

***Index Terms*—Internal validity, mathematical model, power system, transmission lines.**

I. Introduction

Understanding of mathematical models for electricity is important. The future electrical engineers can use his knowledge on the model to explain and understand electrical phenomenon. Knowledge on the mathematical models is a valuable tool in solving work related problem work and many practical situations related to electricity.

The mathematical models for three-phase medium transmission lines characterized by unbalanced shunt admittance are derived using Kirchhoff's law and algebraic manipulation. The circuit diagram and the mathematical model are shown below [1]

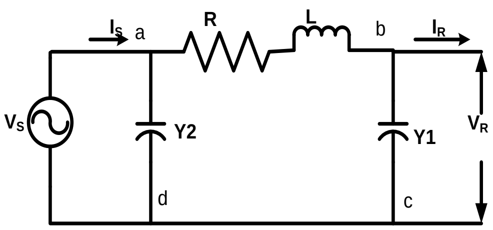

Fig. 1. Circuit diagram of short transmission line per phase.

$$V_s = EV_r + FI_r \quad (1)$$

$$I_s = GV_r + HI_r \quad (2)$$

where:

$$E = (1 + ZY_1) \quad (3)$$

$$F = Z \quad (4)$$

$$H = ZY_2 + 1 \quad (5)$$

$$G = EY_2 + Y_1 \quad (6)$$

The three electrical parameters of a three phase medium transmission lines are resistance, inductance and capacitance. The mathematical models of the three electrical parameters are given below [2]-[6]

$$R = \frac{\rho l}{A} \quad (7)$$

$$X_L = 2\pi fL \quad (8)$$

$$Xc = \frac{1}{2\pi fC} \quad (9)$$

$$Y = \frac{1}{X_c} \quad (10)$$

The main objective of the study is the internal validation of the first mathematical models expressing the source voltage in terms of the receiving voltage and receiving current (V_s=EV_r+FI_r**)**. The specific objectives are the following:

1) to design a simple experiment and measure sending voltage using NI Multi-Sim
2) to calculate the sending voltage using V_s=EV_r+FI_r
3) to validate the mathematical model which express source voltage in terms of receiving voltage and receiving current using t-test for independent sample means.

For the scope and limitation, the study covers internal validation of the model. The model is validated by comparing the calculated and measured sending voltage using t test for independent sample means at 1% level of significance and sample size of 10.

For the significance of the study, the internal validation on the research is another material that can be used in the laboratory by the engineering educators as a laboratory experiment for transmission line.

II. Discussion and Results

Internal validity in research means that the change in the dependent variable (output variable) is due to the changes in the independent variable. The block diagram below showed the independent variables, input variables and output variables.

Manuscript received November 18, 2013; revised January 18, 2014. This paper is part of the author thesis for Master of Science in Mathematics (Pamantasan ng Cabuyao). The registration of paper is supported by Malayan Colleges Laguna.

R. P. Velasco is with Colleges of Arts and Science, Malayan Colleges Laguna, Cabuyao, Laguna Philippines (e-mail: bseerv@yahoo.com, rpvelasco@mcl.edu.ph).

DOI: 10.7763/IJAPM.2014.V4.268

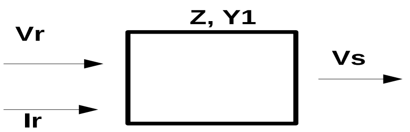

Fig. 2. Block diagram for the mathematical model *Vs= EVr + Fir*.

$Y_1$and *Z* are independent variables.
V_r and I_r are the input variables
V_s is the output variables.

A. Design a Simple Experiment Using NI Multi-Sim for the Mathematical Models V_s=EV_r+FI_r

1) Set the electrical parameters such as Resistor (*R*), Inductor (*L*) and Capacitor (*C*) for a 50 miles transmission lines.

$$R= 4.705\ \Omega$$
$$L= 50.35\text{ mH}$$
$$C1= .163\text{ uF}$$
$$C2= 1.6291\text{ uF}$$

2) Construct the circuit diagram below using Ni MultiSIM. Please refer to Fig. 1.

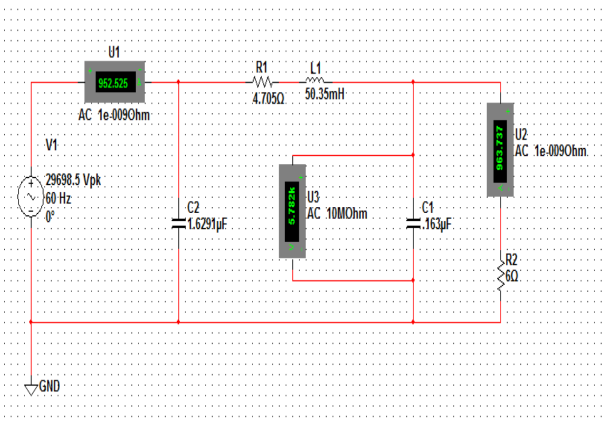

Fig. 3. Circuit diagram of short transmission line per phase for the first mathematical model using NI multisim.

3) Set the value of sending voltage to $\sqrt{2}$ (V1) from Table I and frequency to 60 Hz.

TABLE I: DIFFERENT VALUES OF SENDING VOLTAGE FOR PROCEDURE C

TRIALS	*Vs*	*Vr (V)*	*Ir (A)*
1	21000		
2	22000		
3	23000		
4	24000		
5	25000		
6	26000		
7	27000		
8	28000		
9	29000		
10	30000		

4) Press Simulate.
5) Measure the receiving current (*Vr*) and receiving current (*Ir*). Repeat procedure A to D for the 2nd to 10th trial.
6) Supply the data needed in the Table II.

TABLE II: EXPECTED MEASURED SENDING VOLTAGE AND RECEIVING CURRENT USING NI MULTI SIM. MEASUREMENT OF VR AND IR CAN BE VERIFIED USING NI MULTISIM

TRIALS	*Vs*	*Vr*	*Ir*
1	21000	5782	963.737
2	22000	6058	1010
3	23000	6333	1056
4	24000	6608	1101
5	25000	6884	1147
6	26000	7159	1193
7	27000	7435	1239
8	28000	7710	1285
9	29000	7985	1331
10	30000	8261	1377

B. Solve for the Sending Voltage Using the First Model

1) Set the value of *R*, *L* and *C*

$$R= 4.705\text{ mi}$$
$$L= 50.35\text{ mH}$$
$$C_T=1.792\ \mu\text{F}$$

2) *C*1 and *C*2 are divided so that combined reactance will result to 1.792 µF

$$C1= (\frac{1}{11})(1.792\,\mu F)$$

$$C1= \quad 0.163\mu F$$

$$C2= CT - C1$$

$$C2= 1.792\mu F - 0.163\mu F$$

$$C2= 1.6291\mu F$$

solve for X_{c1} and X_{c2}

$$Xc_1= \frac{1}{2\pi fC}$$

$$Xc_1= \frac{1}{(2\pi)(60)(.163\,\mu F)}$$

$$Xc_1= -16273.51184j$$

$$Xc2= -16273.51184j$$

solve for *Y1*

$$Y_1 = \frac{1}{X_c}$$

$$Y_1 = \frac{1}{-16273.511i}$$

3) Solve for the calculated value of the sending voltage using the measured value of receiving voltage and receiving current from Table III. The theoretical value of phase angle -60.598 is also used.

$$V_r = 5782 \angle -60.598$$

$$I_r = 963.737 \angle -60.598$$

Solution

$$V_s = EV_r + FI_r$$

solve for E

$$E = (1 + ZY_1)$$

$$E = 1 + (4.705 + 18.982i)\left(\frac{1}{-16273.511i}\right)$$

$$E = .999 \angle 0.0165$$

solve for F

$$F = Z$$

$$F = 4.705 + 18.982i$$

substitute A and B to $V_s = EV_r + FI_r$

$$V_s = (.999 \angle .0165)(5782 \angle -60.598) + (19.556 \angle 76.0679)(963.72 \angle -60.598)$$

$$V_s = 20968.427$$

4) Following the same procedures for different source voltage of Table III.

TABLE III: EXPECTED MEASURED VERSUS CALCULATED SENDING VOLTAGE

TRIALS	Calculated Vs	Measured Vs
1	20968.427	21000
2	22007.6	22000
3	23009.5	23000
4	23992.5	24000
5	24994.86	25000
6	25996.74	26000
7	26999.108	27000
8	28001	28000
9	29016.89	29000
10	30000.41	30000

C. Internal Validation of the Mathematical Model $V_s = EV_r + FI_r$ at 1% Level of Significance

1) Using Microsoft Excel Data analysis calculates the variance of the two independent samples.

TABLE IV: F TEST OF TWO SAMPLE FOR VARIANCES

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	25500	25498.7
Variance	9166667	9203732
Observations	10	10
df	9	9
F	0.995973	
P(F<=f) one-tail	0.497651	
F Critical one-tail	0.186876	

Table IV shows the variances of the calculated and measured sending voltage are different at 1 % level of significance.

2) State the hypotheses and identify the claim based on Table III.

H_0: The mean of calculated sending voltage is equal to the mean of measured sending voltage (claim)

H_1: The mean of calculated voltage is not equal to the mean of measured voltage

3) Apply Microsoft excel analysis in the data of Table III

TABLE V: T-TEST: TWO-SAMPLE WITH UNEQUAL VARIANCES

	Variable 1	*Variable 2*
Mean	25500	25498.704
Variance	9166667	9203732.2
Observations	10	10
Hypothesized Mean Difference	0	
df	18	
t Stat	0.000957	
P(T<=t) one-tail	0.499624	
t Critical one-tail	2.55238	
P(T<=t) two-tail	0.999247	
t Critical two-tail	2.87844	

4) Make the decision. Accept the null hypothesis since .000957 falls on non-critical region.
5) Summarize the results. There is enough evidence to support the researcher's claim that the calculated value is equal to the measured value at 1% level of significance.

III. CONCLUSIONS AND DIRECTIONS FOR FUTURE USE

The model $V_s = EV_r + FI_r$ is internally valid at 1% level of significance using the t test for two independent samples which means that the calculated values are equal to the measured values. Hence the mathematical model is effective in predicting the value of the source voltage and source current given the receiving electrical parameters *Ir* and *Vr*.

The researcher recommends the internal validation in the research as an equivalent experiment to compare the theoretical and actual value.

ACKNOWLEDGMENT

This research is not possible without the help of many individual. I would like to thank Dr. Florencio Reyes (my thesis adviser), Dr. Ricardo Bobadilla, Dr. Luisito Hagos and Dr. Vicente Castillo for sharing their expertise in this study

This research is not possible without the endorsement, good leadership and trust of Dr. Joy G. Hofileña (Dean of College of Arts and Science). I would also like to acknowledge the endorsement of Engr. Corazon C. Vergara (SHK Cluster) and Engr. Ria Grace Abdon (MMD).

The registration and presentation of the paper is supported by Malayan Colleges Laguna through the Office of Research and Promotion. The research is endorsed by ORPC under the leadership of Dr. Liza Patacsil and approved by the OVPAA under the leadership of Engr. Dennis H. Tablante.

I would like to thank my colleagues in MCL more especially to Anthony Jefferson Atienza for consultation in the statistical test and Hjalmar P. Hernandez for editing the paper.

This work is dedicated to my wife Leizle, my daughter Lira Samantha and son Edward James for all the inspiration and motivation.

REFERENCES

[1] R. P. Velasco, "Development of Mathematical Models for Three Phase Medium Transmission Lines," *International Journal on Applied Physics and Mathematics*, vol. 3, no. 4, pp. 260-263, 2013.

[2] M. E. Hawaray, *Introduction to Electrical Power Systems*, 1st Edition., New Jersey, U.S.A.: John Wiley and Sons, 2008, ch. 5, pp 176-182.

[3] B. M. Weedy and B. Cory, *Electric Power System*, 4th Edition., England: John Wiley and Sons, 1998, ch. 3, pp. 122-128.

[4] D. P. Kothari and I.J. Nagrath, *Power System Engineering*, 2nd Edition., New Delhi: Tata Mc Graw-Hill Publishing Company, 2008, ch. 5, pp. 176-186.

[5] S. A. Nasar, *Schaum's Outline for Electric Power System*, 1st Edition., U.S.A.: McGrawHill, 1990, ch. 3, pp. 26-29.

[6] W. Stevenson, "Elements of power system analysis,"4th edition., McGraw-Hill Book Company, 1984, ch 5, pp. 88-93.

Engr. Ramon P. Velasco obtained bachelor of science in electrical engineering from Colegio de San Juan de Letran Calamba(2005) and Master of Science Major in Mathematics from University of Cabuyao (Pamantasan ng Cabuyao-2013).

He worked as manufacturing engineer in Samsung Electronics (2006) and Cirtek Electronics (2007) before decided to join the academe in 2009. He joined Malayan Colleges Laguna (subsidiary of Mapua Institute of Technology)and taught professional courses in the Electrical engineering under Mapua Institute of Technology at Laguna.

The author is a member of Institute of Electrical Engineer (IIEE), Mathematical Society of the Philippines Calabarzon and International Association of Computer Science and Information technology (Singapore).