Estimation of Line Parameters of an IEEE 14 Bus System

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***Abstract*-The feeder parameters are usually considered constant, but they are not constant. Feeder parameters keeps on varying due to sag ,temperature rise, anomalous resistivity of earth, etc. The estimation of parameters becomes necessary when a new parallel line is constructed between two substations due to load growth or if an underground cable replaces an overhead line and overall parameters of the paralleled lines or cable are desired to be determined. This paper describes the method of estimating the transmission line parameters from voltage, current & power measurements at the two ends of the line.The parameters of the equivalent pi network of the line are obtained from the measurements of at the line ends by using Newton- Raphson method to solve the non linear equations .The proposed method then gives the resistance, inductance and capacitance considering the distributed nature of transmission line. The technique to determine the conductance parameter is also presented.**

I. INTRODUCTION

Accurate transmission line impedance parameters are of great importance in power system operations for all types of system simulations, such as transient stability, state estimation, etc., and are used as the basis for protective relay settingsTransmission line parameters in the past have been estimated by engineers based on the tower geometries, conductor dimensions, estimates of actual line length, conductor sag, and other factors The usual problem in transmission line studies assumes that the line parameters and either the input or output variables are known, and it is desired to calculate the corresponding output or input variables. The inverse problem focuses on the determining the line parameters when measured values of input& output variables are known.

Several methods have been proposed in the past to identify TL parameters using PMU measurements.One two-port ABCD parameter based method is proposed in Ref. [4]. This method utilizes two samples of synchronized measurementsfrom each terminal of the TL to identify the ABCD parameters; from these chain parameters the impedance parameters can be calculated. Another simpler method proposed in Ref. [5] requires only one sample from the two terminals of a transmission line to calculate its impedances directly; this method is henceforth referred to as the ‘‘single measurement method’’. These methods are based on the positive sequence TL model which is suitable only for fully transposed lines; when the lines areuntransposed or not fully transposed, applying these methods will lead to considerable errors in the calculated parameters.This paper provides an example of obtaining the transmission line parameters from input-output measurements only. The paper assumes that simultaneous measurements of voltage, current, power & power factor at the two ends of transmission line are available and determines the resistance, reactance and susceptance of equivalent pi network .This method considers the distributed nature of line parameters and determines per metre line parameters from the equivalent pi network .This method determines the line parameters using non linear equations & avoids the disadvantage of using linear equations. A change in operating conditions and corresponding input& output measurements does not lead to different line parameters when non linear equations are used. The obtained line parameters will however depend on time of input-output measurements and corresponding weather conditions. The input-output measurements can be carried out using synchronised phasor measurement units.

II. TRANSMISSION LINE MODEL

Though the feeder impedances are routinely assumed to be known, the accuracy of the impedance parameters cannot always be guaranteed. Therefore, it would be preferable if the
feeder impedances are regularly calculated and updated fromthe measured power/current flow in the feeder.Thelong transmission line equations are

$$Vs=\cosh\Upsilon l.Vr+Zo.\sinh\Upsilon l.Ir \qquad (1)$$

$$Is=.\sinh\Upsilon l/Zo.Vr+\cosh\Upsilon l.Ir \qquad (2)$$

Where

l=line length
ϒ=propagation constant
Zo=characteristic impedance
Vs=sending end voltage
Vr=receiving end voltage
Is=sending end current
Ir=receiving end current

The equivalent pi network of the long line is

$$V_s=(1+ZY).Vr+Z.Ir \qquad (3)$$

$$I_s=(2Y+ZY^2)V_r+(ZY+1).I_r \qquad (4)$$

$$Z=R+jX \qquad (5)$$

$$Y=G+jB \qquad (6)$$

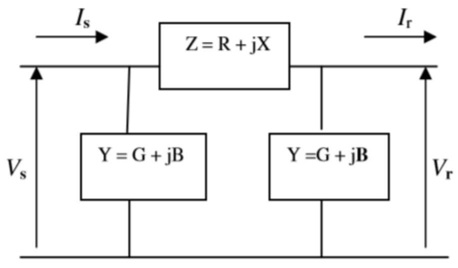


Fig. 1. Equivalent pi network.

Comparing the above equations we get

$Z=Z_0.\sinh \Upsilon l$ (7)

$Y=1/Z_o.\tanh(\Upsilon l/2)$ (8)

III.BASIC EQUATIONS

The problem formulation uses the measured values of the voltage and current magnitudes and the real and reactive powers at the two ends of the transmission line to findthe load angle d and the three unknown line parameters R, X and B shown in the equivalent pi network of the longline in Fig.1.Since the power lost in the insulation resistance in comparison with other line losses, the value of line conductance parameter is usually low. If in usual circumstance the value of actual insulation resistance is much lower, perhaps due to wet dirty line separators or supports ,the insulation resistance can have smaller than normal value.In this case the loss can represented by small conductance G, in shunt with the capacitance C. From the above phasor diagram given in Fig. 2, the following equations are obtained.

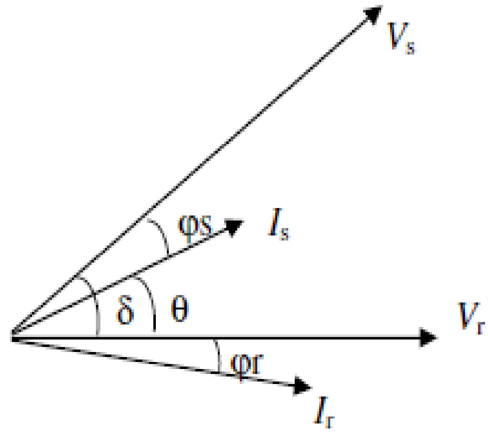
$V_s\cos\delta=V_r+RGV_r-BXV_r+RI_r\cos\phi_r+XI_r\sin\phi_r$
$=a$ (9)

$V_s\sin\delta=XGV_r+BRV_r+XI_r\cos\phi_r-RI_r\sin\phi_r$
$=b$ (10)

$I_s\cos(\delta-\phi_s)$ $=2GV_r+RG^2V_r–RB^2Vr - 2XGBVr+IrCos\phi_r–XBIrcos\phi r+RGIrcos\phi r+RBI_r\sin\phi_r+ XGI_r\sin\phi_r=c$ (11)

$I_s(\sinh(\delta-\phi_s))=2BV_r+XG^2V_r -XB^2V_r+2RGBVr-I_r\sin\phi_r-RGI_r\sin\phi_r+XBI_r\sin\phi_r+ RBI_r\cos\phi_r+ XGI_r\cos\phi_r=d$ (12)

Note that the values of power factors $\cos\phi_r$ & $\cos\phi_s$ are available from the measured real and reactive powers at the two ends of the line.



Using the Newton-Raphson method ,the following four nonlinear equations are solved for the unknowns X,R,B &G.

$F_1(x)=-V_s^2+a^2+b^2=0$ (13)

$F_2(x)=-\tan\delta+b/a=0$ (14)

$F_3(x)=-I_s^2+c^2+d^2=0$ (15)

$F_4(x)=-\tan(\delta-\phi_s)+d/c=0$ (16)

For nonlinear equations F(x)=0
$\Delta x = - J(0)^{-1}F(0)$ (17)

The value of x at next iteration is
$X=x(0)+\Delta x$ (18)

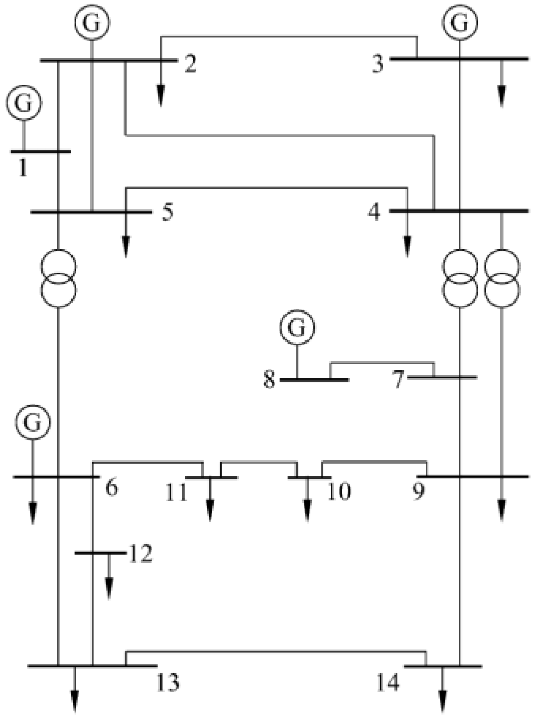
IV. NUMERICAL RESULTS

A 220 kV, 300 km long 60Hz transmission line is considered.The per phase per metre line parameters X,R,B & G are146.4ohm, 26.4 ohm, 000511 & $5.99e10^{-11}$. The line is operated at receiving end power of 135MW and Qr=5.7MVAr.The following quantities are calculated in usual way,
$Ir=0.44A,\phi_r=2.4^o,\delta=30.98^o,Vs=127kV,I_s=0.416kA, \theta=12.39^o$.

Parameters	Actual	Calculated
X	146.4	146.6
R	26.4	26.64
B	.000511	.000511
G	5.99e-11	5.99e-11

The above relation was applied to standard IEEE 14 bus system & following results were obtained. The IEEE14 bus sytem was choosen as test system as it is considered for large scale simulations having non linear characteristics. The test systemhas 5 generator busesin which bus 1 is slack bus, buses2,3,6,& 8 are PV buses while the rest are PQ buses.

Buses 9 and 14 have shunt compensation VARs.



It can be seen in Table.1, that the values varies upto maximum 7%

Lines	Actual impedance	Corrected impedance	%change
1-2	0.0194+0.0592j	0.0202+0.057j	1.85
1-5	0.0540+0.2203j	0.0551+0.213j	3.656
2-3	0.04699+0.1979j	0.0581+0.199j	1.65
2-4	0.0581+0.1763j	0.0590+0.172j	1.8370
2-5	0.0561+0.1964j	0.0568+0.198j	3.613
3-4	0.0670+0.1701j	0.0604+0.167j	2.945
4-5	0.0134+0.421j	0.0150+0.417j	2.26
9-10	0.03181+0.845j	0.0307+0.077j	6.3
9-14	0,12711+0.2731j	0.1263+0.250j	3.85
7-8	0.176115j	0.0006+0.167j	5
7-9	0.11001j	-.0002+0.102j	6.9
12-13	0.0820+0.1921j	0.0801+0.184j	6.25
13-14	0.127+0.270j	0.1295+0.272j	0.977
4-7	0.20912j	-0.0005+0.209j	4.35
5-6	0.2520j	0.2913j	4.246
6-11	0.1229+0.2559j	0.1522+0.323j	2.3
6-12	0.1343+0.6152j	0.1342+0.642j	1.3
6-13	0.06615+0.1302j	0.0681+0.133j	2.365
9-14	0.12711+0.270j	0.1367+0.211j	1.01
10-11	0.1271+0.270j	0.1292+0.271j	3.493

V. CONCLUSION

Measurement errors would affect the values of estimated parameters. Many factors can reduce the precision of results like errors in CTs& CVTs.The errors also happens because of variation of temperature, anomalous resistivity of earth, skin effect, proximity effect, sag, etc.Thus the proper parameters of the line can be estimated with this technique. The importance of technique becomes evident especially with the construction of new parallel transmission line between two substations due to load growth or when underground cable replaces overhead line.

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