DESIGN AND ANALYSIS OF FERRANTI EFFECT COMPENSATION OF SINGLE PHASE TRANSMISSION LINE

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ABSTRACT

Transmission lines comprises with series inductance and shunt capacitance along with resistance of the conductor. Series inductive phenomenon predominate among others owing to huge power transmit with power frequency. Shunt capacitance effects also there with larger voltage level. These parameters are distributed along the line. Receiving end voltage magnitude is higher than sending end voltage at no load and light loaded conditions pointed out by Ferranti so called Ferranti effects. Consequence of that an attempted to study these effect presented in this paper. A long transmission line of 400km considered and its parameters obtained from its equivalent circuit model. A malt lab based simulation and experimentation is conducted and test results are discussed and presented.

KEYWORDS: Transmission line model, Ferranti effect, MAT Lab.

I. INTRODUCTION

Over voltages causes the insulation failure of the electrical conductors. It may be caused by internal or external disturbances. Ferranti effect is a phenomenon where the steady voltage at the open end of an uncompensated transmission line is always higher than the voltage at the sending end. It occurs as a result of the capacitive charging current flowing through the inductance of the line and resulting over voltage increases according to the increase in line length [1].Traditionally the most accurate transmission line models have been based on a constant transformation matrix with frequency dependent modes. This type of model may give satisfactory results for situations involving high frequency transients, but the accuracy often deteriorates in the low frequency area due to frequency dependency of the transformation matrix [2].

In long transmission lines, the most important factors which affect the power frequency voltages on the line during normal operation and the increase in voltages during a fault are the length of the line and the degree of shunt compensation. Both parameters have a major indirect influence on the transient phenomena connected with the initiation or clearing of a fault, as well as with normal switching operations [3].

The Ferranti effect describes the strange phenomenon that under certain conditions of frequency and line length a voltage increase may be observed at an open ended transmission line relative to a sinusoidal input voltage. Reactive power is a very important quantity in electric power systems since it affects the efficiency of these systems [4].Also capacitive loads can produce over voltage in electric transformers by Ferranti effect which produces bad power quality, so it is necessary to measure the reactive power correctly [5].

Shunt inductive compensation is used either when charging the transmission line or when there is very lows load at the receiving end. Due to very low or no load, very low current flows through the transmission line. Shunt capacitance in the transmission line causes voltage amplification (Ferranti effect).The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines).To compensate in the case of no loss line, voltage magnitude at receiving end is the same as voltage magnitude at sending end($V_S=V_R=V$):.Transmission results in a phase lag δ that depends online reactance X. Shunt reactors are connected across the transmission lines [6].

This paper organised as Vi sections, back ground of the problems and its related issues are described in introduction I, followed by the modelling of transmission line section II, section III presented the insight of Ferranti effect on transmission line and its phasor representation. The proposed study verified with MAT Lab software version 16 presented in section IV, results and discussion over the results are presented in section V. section VI Concludes the present work and highlights the future scope of the present work.

II. MODEL OF TRANSMISSION LINE

Transmission lines are is modelled by using line parameters such as series resistance R, wire inductance and inductance caused by the current flow L, shunt capacitance C, and are measured per unit length of line. More over surge impedance Zo, propagation time constant of wave γ. Formerly, R, L, C and G are named as primary constant while Zo and γ are named as secondary constant, by using these parameters in lumped manner, representation of transmission line is shown in Fig.1.

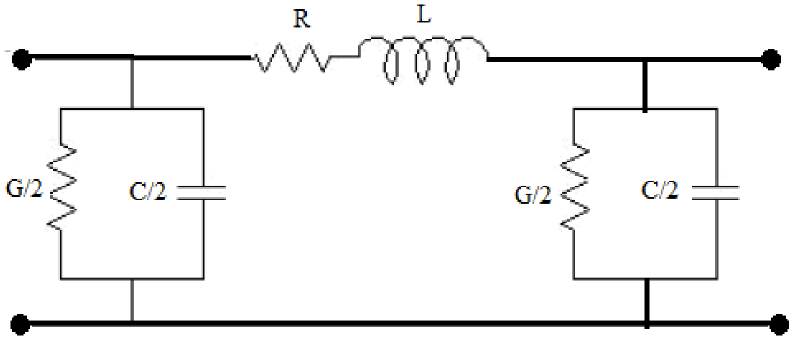

Figure 1: π model representation of Transmission line

Figure 1 consists of series impedance Z, shunt admittance Yare lumped to get proper concept involved in it, by using electrical relationship the surge impedance$Z_o$is written as

$$Z_o = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \ ohm\ per\ kilometer \qquad (1)$$

Where, $Z = R + j\omega L;$, $Y = G + j\omega C;$ and $\gamma = \sqrt{ZY} = \sqrt{(R + j\omega L)(G + j\omega C)}$, obviously the effects of resistance over a line is neglected therefore R and G is neglected, consequent of that the time constants are written as

$$\left.\begin{array}{l} Z_o = \sqrt{\frac{L}{C}}\ in\ ohm\ per\ kilometer\ and \\ \gamma = \sqrt{LC} \end{array}\right\} \qquad (2)$$

Here, Zo is called as the impedance of the transmission line. For lossless transmission line, it is also known as a surge impedance or characteristic impedance. It is a real quantity therefore considered as the natural impedance of the line. In general, huge power is transmitted by a balanced three phase system with power frequency. In order to perform better analysis of study per phase basis is good. Therefore the network should represented by two port network with ABCD parameters are

$$\left.\begin{array}{l} V_S = A\, V_R + B\, V_S \quad and \\ I_S = C\, V_R + D\, I_R \end{array}\right\} \qquad (3)$$

III. FERRANTI EFFECT

A substantial quantity of charging current is drawn by a long transmission line. In such a line, receiving end voltage may become greater than sending end voltage at open circuited or very lightly loaded by Ferranti Effect. The distributed line parameters such as inductance and shunt capacitance along with wave propagation causes this phenomenon invented by Ferranti so called Ferranti effect. Obviously the charging current of shunt capacitance is negligible in short line but significant effects in medium line and appreciable amount in long line should represented by equivalent π model. It is proportional to the square of length of lines ($\Delta V \propto k\, x^2$), where x is the length of line and k is a constant for all voltage levels [1].

In order to study the Ferranti Effect nominal π model of the line is shown in Fig.2 (a) is considered and its phasor representation illustrated in Fig.2 (b).

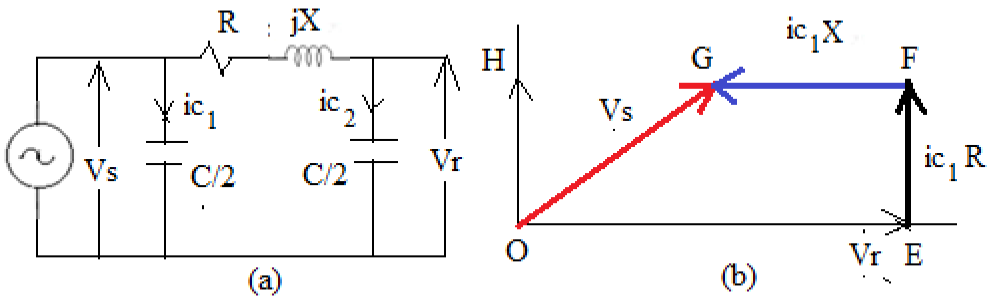

Figure 2 (a) Nominal π model of the line at no load (b) Phasor diagram

In Fig.2 (b), receiving end voltage V_r represented by segment $\overline{OE}$, sending end voltage V_s by $\overline{OG}$, voltage drop across the shunt capacitance and series reactance's are by $\overline{EF}$, $\overline{FG}$ respectively. The voltage drop across X is $IC_1\, X$ leads the phasor $IC_1\, R$ by $90°$.It is seen from the phasor diagram that $V_s < V_s$. In other words, the voltage at the receiving end is greater than the voltage at the sending end when the line is at no load. In practice, the capacitance of the line is not concentrated at definite point. It is distributed uniformly along the whole length of the line. Therefore the voltage will increase from sending end to receiving end at no load or light loaded conditions.

From Fig. 2(b), the following relationships are derived

$$V_S = \left(1 + \frac{ZY}{2}\right) V_R + Z I_R \qquad (4)$$

The receiving end current is zero at no load ($I_R = 0$)condition, therefore the equation (4) can be re written as

$$V_S = \left(1 + \frac{ZY}{2}\right) V_R \qquad (5)$$

$$V_S - V_R = \frac{ZY}{2} \qquad (6)$$

Where,$(Z = R + j\omega L)a$;, $Y = (j\omega C)a$; if R is neglected; $Z = (j\omega L)a$ and

$$\left.\begin{aligned} V_S - V_R &= \frac{1}{2}(2\pi f l a)(j\omega C a) \quad and \\ V_R &= -\frac{1}{2}(\omega^2 a^2)(LC\, V_s) \end{aligned}\right\} \qquad (7)$$

For overhead lines, $\frac{1}{\sqrt{LC}}$ is the velocity of propagation of electromagnetic waves on the line which is equal to 3×10^8 m/s. Where the difference of voltage between sending and receiving end is

$$V_S - V_R = -\frac{1}{2}(2\pi f)^2 a^2 \frac{1}{(3 \times 10^8)^2} V_R = -\left(\frac{4\pi^2}{18 \times 10^6}\right) f^2 a^2 V_R \qquad (8)$$

This equation shows that $(V_S - V_R)$is negative. That is,$V_R > V_S$. This equation also shows thatFerranti effect depends on frequency and electrical length of the line. The conductor diameter and spacing have no bearing on Ferranti effect.

In general, for any line

$$V_S = A\, V_R + B\, I_R \qquad (9)$$

At no load condition receiving end current is zero and voltage is nominal value, therefore the sending end voltage can be written as

$$V_S = A\, V_{nominal} \qquad (10)$$

$$|V_{nominal}| = \frac{|V_S|}{|A|} \quad (11)$$

For a long line A is less than unity and it decreases with the increase in length (a) of line. Hence $V_{nominal} > V_S$.As the line length increases the rise in the voltage at the receiving end at no load becomes more predominant [7]. The line parameters are designed by using the derived equations as shown in Table-1is tested with a single phase circuit of 230V, 50 Hz supply.

Table 1 DESIGN PARAMETERS OF THE TRANSMISSION LINE

Line resistance	4.5 ohm/km
Line inductance	110mh/km
Line capacitance	0.4 Micro farads /km
frequency	50Hz
Load power	10kW

IV. MATLAB BASED SIMULATION

In this paper we have consider the Ferranti effect in transmission line and the fault simulation by MATLAB software is shown in Fig.3.

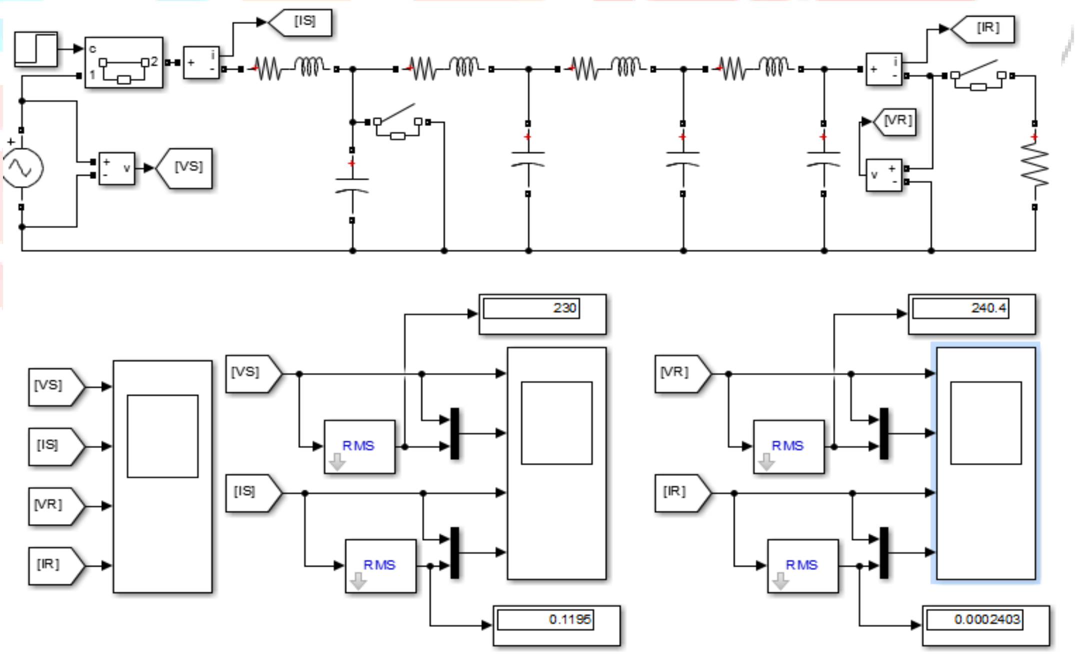

Figure 3 MATLAB /Simulink Model of a transmission line

It gives clear idea about the connections in the model line. It consists of four Pi-section of length of 100kms. In this MATLAB software there are two switches are provided. First for the study of Ferranti effect with load C.B, while second to create the short circuit fault along with fault C.B.

V. RESULTS

Ferranti effect is observed by closing the switch at load side. In this case output side is open circuited or light loaded to be assumed, hence resulting voltage at this remote terminals in more than sending end voltage. For the study of Ferranti effect in the long line load breaker at load side should be closed while the fault circuit breaker kept as opened.

Ferranti effect is observed for the time period at about 14 seconds out of 1 second time interval. That means for 0.3 sec this load breaker has been kept closed and after this interval it became as open circuited. Results are as shown below.

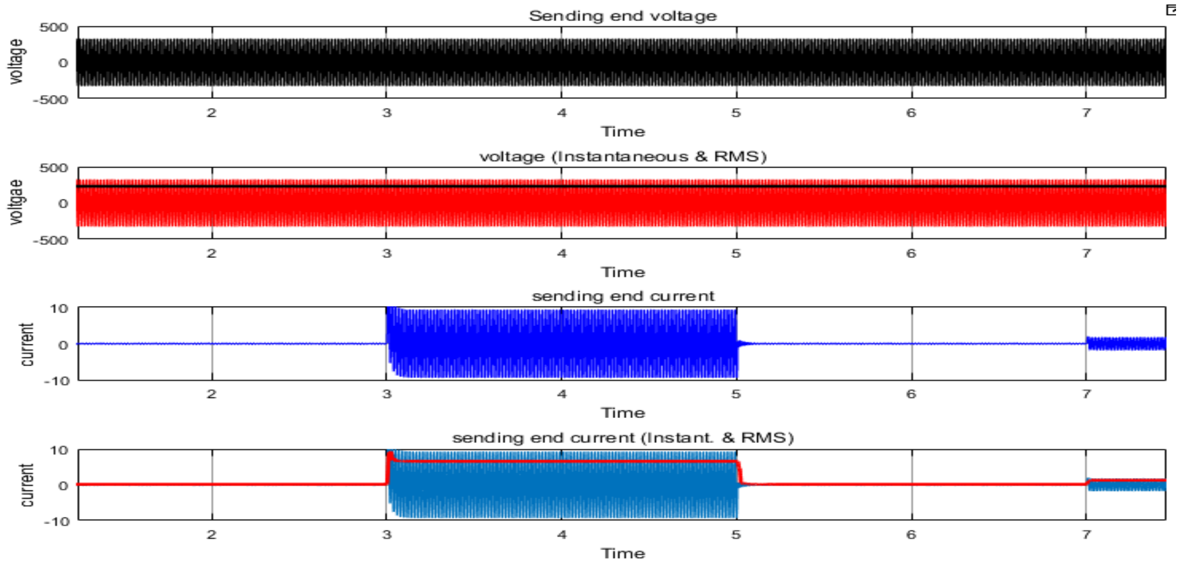

Figure 4 Simulated Wave Forms at Sending end

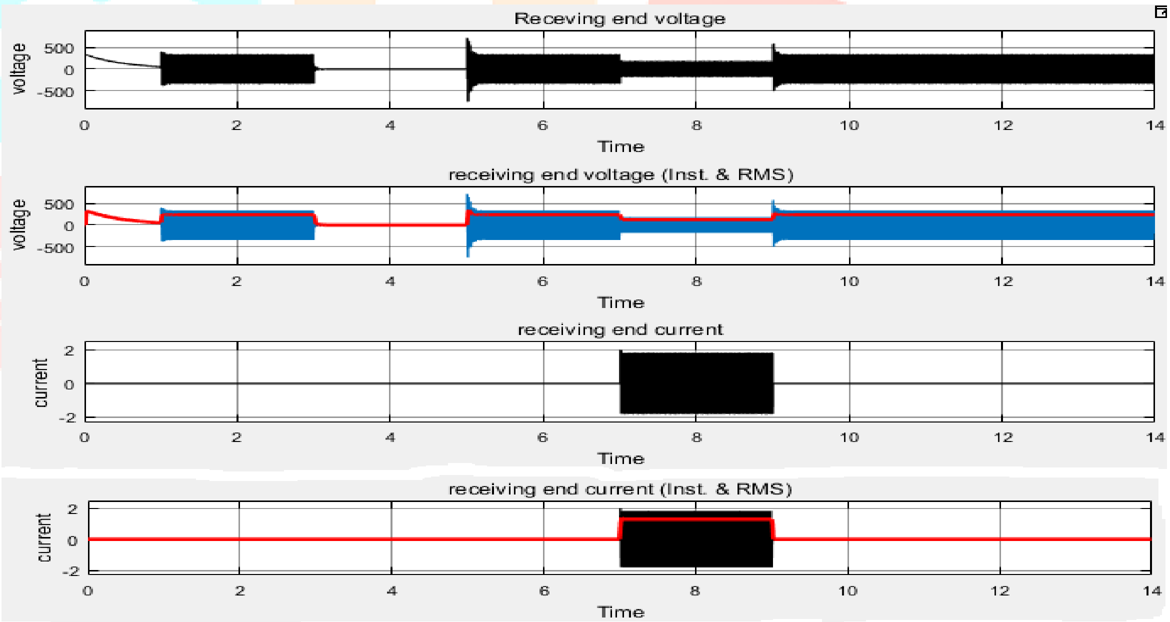

Figure5 Simulated Waveforms at Receiving end

VI. Conclusion

This paper on the "Performance study of the long transmission line, Ferranti effect and fault simulation using MATLAB" has successfully studied. This paper explains the performance of long transmission line with an experimental study on demo model. From this model, Ferranti effect been studied which gives result as receiving end voltage greater the sending end voltage in the long transmission line about 400 kilometres. It is observed from the voltage rise equation the Ferranti effect been increased as the length of line increased. Also fault clearing process has been performed by using fault breaker along with relay circuit both, MATLAB/Simulink as well as on hardware.

REFERENCES

[1]. Bjorn Gustavsen, Garth Irwin, Ragnar Mangelred, Dennis Brandt, Kelvin Kent, "Transmission Line Models for the Simulation of Interaction Phenomena between Parallel A.C and D.C Overhead Lines," *PST 99'-InternationalConference on Power Systems Transients, June 20-24, Budapest-Hungary.*

[2]. A.I. Ibrahim, H.W Dommel, "A Knowledge Base for Switching Surge Transients," *International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June 19-23, 2005.*

[3]. Jorg-Hein Walling, "On the Ferranti Effect in Data Grade Cables and Channels," *Proceedings of the 56thInternational Wire & Cable Symposium, Canada. pp. 274-283.*

[4]. L. Gyugyi, "Dynamic compensation of ac transmission lines by solid-state synchronous voltage sources," IEEE Trans. Power Del., vol. 9, no. 2, pp. 904-911, Apr. 1994.

[5]. Vicente Leon-Martinez, et all. , "Power Quality Effects on the Measurement of Reactive Power in Three-Phase Power Systems in the Light of the IEEE Standard 1459-2000,"9th International Conference, Electrical Power Quality and Utilisation, Barcelona, 9-11 October,2007.

[6]. Narain.G.Hingorani, Laszio Gyugi, "Understanding FACTS Concepts and Technology of Flexible A transmission system," IEEE Press, 2001.

[7]. MATLAB /Simulink software Version.16.0