Ferranti Effects in Algerian Network Adrar, Simulation Model using Matlab

Nassim Guernoudj
Department of Science and Technology, University of Batna2, Batna, Algeria

Keywords: Voltage setting, transmission line, mobile self, MATLAB, Ferranti effect, capacitive effect, Algerian network.

Abstract: The work presented in this paper is conducted over the Ferranti effect (line capacitive effect). Ferranti effects are well known in the field of power transmission over long distances at relatively low frequencies (Ibrahim A et.al, 005). The voltage at the receiving end can become the twice of voltage at sending end (usually in the case of very long transmission lines) (Walling J). It is potentially very destructive for network equipment and especially for Insulators of lines and electric cables, so it is very necessary to seek a solution to eliminate this effect in our network. To validate this study, we conducted several tests of MATLAB simulations on the Algerian network _ADRAR and specifically electrical transmission lines (line ADRAR_TIMIMOUNE 192Km and line ADRAR_IN SALAH 409Km) with and without mobile self, knowing that This network is powered by a Gas Turbine plants of Adrar and In Salah, interconnected through a 220Kv network spreading from In Salah to Timimoun via Aoulef and Adrar. Finally, this simulation study refines the voltage setting in the grid. It highlights the advantage of using the mobile self 220Kv for stabilizing the voltage at the end of high voltage lines.

1 INTRODUCTION

There are many factors affecting temporary over voltages that may be considered in insulation. The ferranti effect is an 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 occours 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 (Hung Sok P et.al, 2006).

The Ferranti effect describes the strong phenomenon that certain conditions on length of line and frequency, a rise in voltage is found at an open ended transmission line as source voltage is relatively sinusoidal in nature. This effect of phenomenon was discovered at the end of 19th century in the Great Britain during the ac based distribution system. In the UK it was Sebastian Sinai de Ferranti, who as an ardent defender of an ac system which installed an ac system along with intermediate levels of different voltage and remote step-down transformers. Ferranti observed on one ac transmission system an altered by his installers that by increasing length of line i.e. by adding an extra section of distribution line, the rise in voltage various remote ends (Walling J).

The objective of this work is to give a simple idea on the Ferranti effect, which may cause rises in voltages in the transmission lines especially in the Algerian network (Adrar_network).

2 FERRANTI EFFECT

2.1 Definition

Ferranti effect is a phenomenon where the voltage at the open end of a transmission line without compensation is always greater than the voltage delivered by the power plant, or the resulting voltage increases with the increase of the length of line (Hung Sok P et.al, 2006).

2.2 Details

Ferranti effect is caused by the capacitive effect of the line; power lines have a certain capacitance relative to earth. A line capacitance can be represented by a capacitor between the phase

Guernoudj, N.
Ferranti Effects in Algerian Network Adrar, Simulation Model using Matlab.
DOI: 10.5220/0009770602310237
In *Proceedings of the 1st International Conference of Computer Science and Renewable Energies (ICCSRE 2018)*, pages 231-237
ISBN: 978-989-758-431-2

conductor and earth, if the phase conductor is connected to an alternating current source grounded, the capacitive effect would result by the flow of a reactive current in the line.

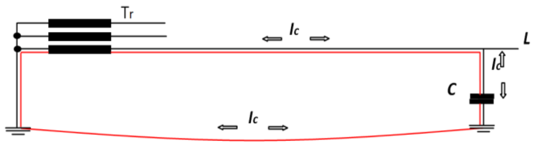


Figure 1: Cause of ferranti effect.

The value of the current *Ic* generated by the capacitive effect is a function of the voltage with respect to earth, that is to say the phase voltage *Uph*of the line capacitance *C* and the frequency *f* of the current source.

The formula to calculate the capacitive current is:

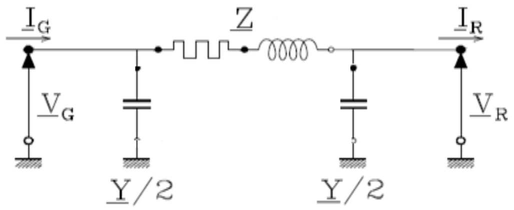
$$I_c = U_{ph}.2.\pi.f.C \quad (1)$$
$$C = (\pi.\varepsilon.L)/\log(2D/d) \quad (2)$$

D: distance Phase / ground [m].
L: length of the line [m].
ε: Air permittivity [F / m].
d: diameter of the line in [mm].
C: capacity [Farad].

2.3 Really Exists a Ferranti Effect at Algerian Network_ adrar?

Working with a model π, assuming that the voltage at the _Fin end of the line is set to a value equal to 220Kv, So here we look for the voltage value at the end of the Beginning line: If it is less than 220Kv implies that there is an overvoltage caused by the ferranti effect, else the network is perfect, or by calculating the value directly at the final end of the line: If it exceeds 220Kv implies that there is an overvoltage caused by ferranti effect, Else the network is perfect.

Take as an example the electrical transmission line Adrar_Timimoune which has a length of 192 Kmand powered by V_G = 220 Kv with a 50Hz frequency.



Figiure 2: Quadrupole π of the electrical line.

Table 1: Calculation of quadrupole parameters π: (ABB S, 2009)

Line parameters	QuadrupoleParameters
r=0.06[Ω/Km]	R=r*L=0.06*192=11.52 [Ω]
ℓ=0.60[mH/Km]	$X=X_L$*L=(2*pi*50*0.60e3)*192=j 36.17 [Ω]
c=0.14[µF/Km]	$Y=Y_C$*L=(2*pi*50*0.14e-6) *192= j84.40e-4 [Ω]
L=192[Km]	Z=R+jX=11.52+j36.17=37.96 [Ω] ∠72.33°

The equations of quadrupole π are given by:

$V_G = A.V_R + \sqrt{3}.B.I_R$ (Phase_Phase).
$I_G = C.V_R + D.I_R$ (Neutral _Phase).

$A = D = 1+\frac{1}{2}.Y.Z = 0.8474 + j0.0486 = 0.85\angle 3.28°$

$B = Z = 11.52+j36.17\ \Omega$

$C = Y.(1+\frac{1}{4}.Y.Z) = -0.0002 + j0.0078 = 0.78e-2\angle -88.53°$

no load $I_R=0$, $V_G = A.V_R$, $I_G = C.V_R$:

$$V_R = \frac{V_G}{A} = \frac{V_G}{1+\frac{1}{2}.Y.Z} = \frac{220\times 10^3}{0.85\angle 3.28} = \underline{258.82}$$

Kv> (V_G=220 Kv), So there is really a ferranti effect in this network.

%voltage setting =

$$\frac{V_G - V_R}{V_R} = \frac{220-258.82}{258.82} * 100 = -14.99\%$$

2.4 Simulation of Network Pole_ adrar

This part of the paper presents a study of the Ferranti effect in the electric transmission line. MATLAB gives rise to see the voltage at the end of the high voltage line which is very long, which shows that the voltage receiving end is greater than the voltage sent by the power plant (Ashfaq H, 2000). To show the behavior of this network using the model in π as shown in the figure below:

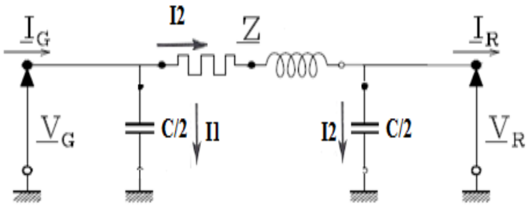


Figure 3: π model for the transmission line.

2.4.1 Electrical Equations

$$V_G = \frac{1}{C/2}\int i_1\,dt \quad (3)$$

$$U_1 = R.i_2 + l.\frac{di_2}{dt} + \int \frac{1}{C/2}.i_2dt \quad (4)$$

$$i_1 = \frac{C}{2}.\frac{dV_G}{dt} \quad (5)$$

We can also calculate the current value I_2 using the equation (4) as follows:

$$I_2 = \frac{1}{l}.(\int V_G\,dt - R\int i_2\,dt - \frac{2}{C}\int\int i_2\,dt) \quad (6)$$

The voltage value at the end is:

$$V_R = i_2.\frac{1}{\omega \cdot C/2} \quad (7)$$

2.4.2 Calculation of Parameters

ω=2*π*f=2*π*50=314(rad/s).
R=6e-2*L. Resistance of the power line(Ω).
l=0.60e-3*L. Inductance of the power line(H).
C=0.14e-6*L. Capacity of the power line(F).
L=192 & 409 Km. Length of the power line(Km).

2.4.3 Construction of the Simulation Block

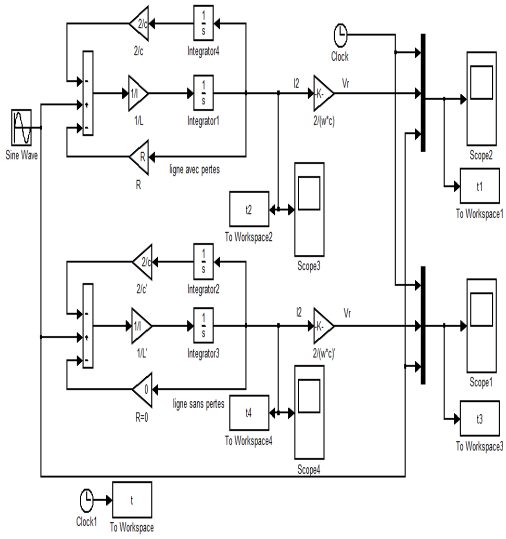


Figure 4: Simulation block with MATLAB, using electrical equations.

2.4.4 Line ADRAR Timimoune 192 km

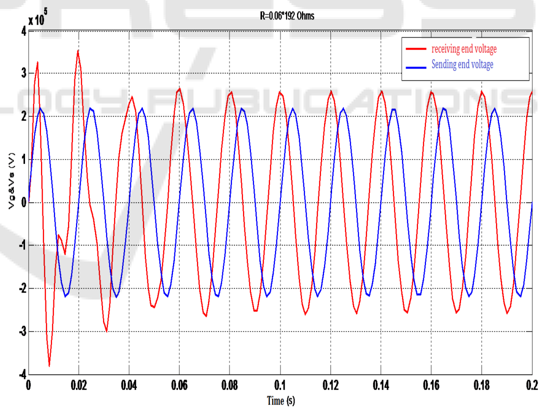


Figure 5_1: Sending end and receiving end voltage.

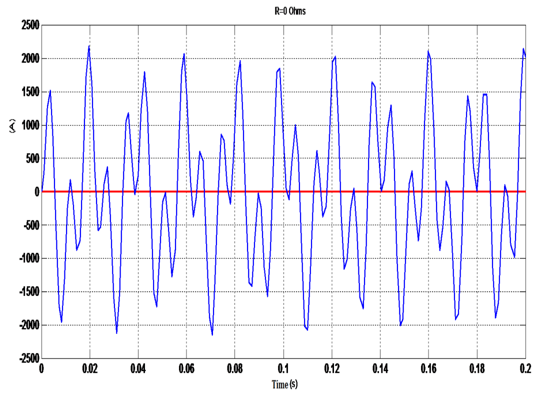


Figure 5_2: Receiving end current.

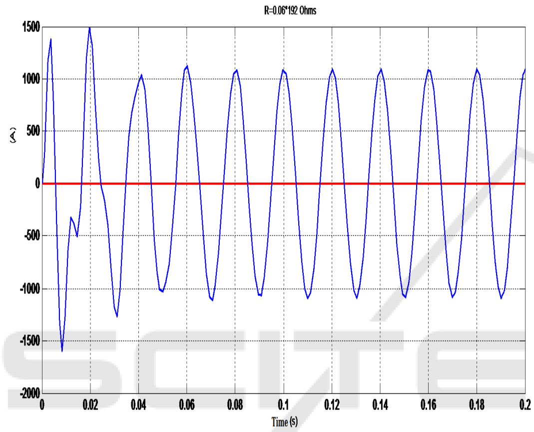


Figure 5_3: Receiving end current.

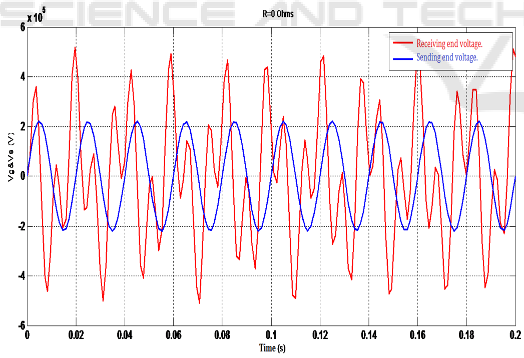


Figure 5_4: Sending end and receiving end voltage.

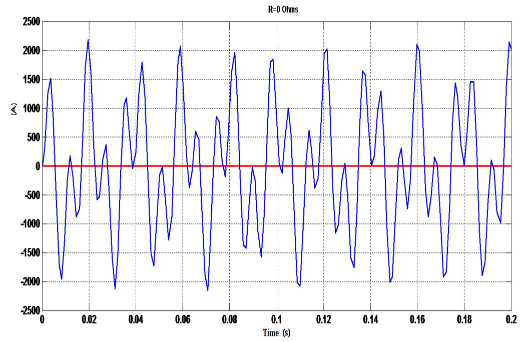


Figure 5_5: Receiving end current.

When a transmission line is unloaded, ferranti effect causes an increase in voltage from sending end to end of line (V_R=258.8*$10^3$for our network) as indicated at (Fig.5_4).

Some disturbances are on the voltage and current signals at the end of the line which can be up at 352.6*10^3 Volts and 1489 Ampsfor current, these disturbances caused by the closing of the different switches of the electrical network, both signals start taking perfect forms after t=0.0312 Seconds.

The Ferranti effect is maximal at the end of the transmission lines who have no losses Joule (R=0 Ohms) that is means no active power transported on the line (Fig.5_4) et (Fig.5_5).

2.4.5 Line ADRAR Ain SALAH 409 km

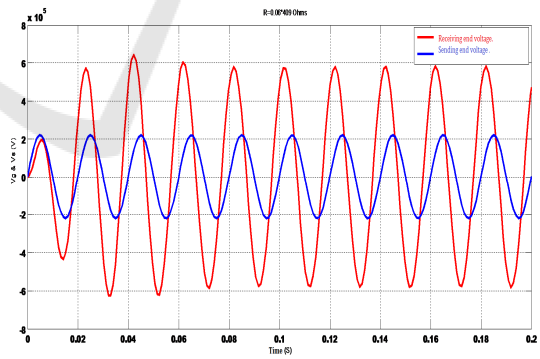


Figure 6_1: Sending end and receiving end voltage of line.

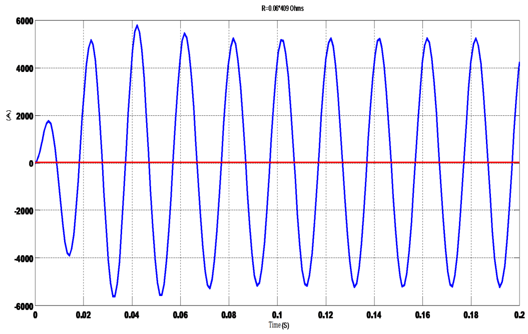


Figure 6_2: Sending end current.

The capacitive effect increases proportionally to the length of the line. For this transmission line, receiving voltage (V_R=580.73*10^3 Volts) as indicated (Fig.6.1) So the voltage rise value caused by Ferranti effect $\Delta V=V_R-V_G$=580.73*10^3-220.00*10^3Volts=350.73*10^3 Volts, that is means here we have a very dangerous surge, and the voltage setting value:

%voltage setting=

$$\frac{V_G - V_R}{V_R} = \frac{220-580.73}{580.73} * 100 = -62.12\%$$

When the network is not loaded, that is to say, the impedance of the load is very high, the voltage on the line tends to rise considerably, this voltage increase is all the more important than the network that is operated at high voltage and the lines are long. To reduce voltage in the end of the line, we must increase artificially the characteristic impedance of the line or decreasing the effect of the shunt capacity by installing self-span at the end of it.

2.5 Using the Mobile Self-span 20mvar

By specification using the shunt reactor for compensating the effects of the capacity of the line, in particular is to limit the rise in voltage at the opening circuit or at light load. It is generally necessary for airlines over than 200Km. Shorter airlines may also require shunt reactors if the line is powered from a low (short-circuit poor capacity) (ABB S, 2009). When the extreme _End of the line is open, the current flowing through the line will cause a rise in voltage (V_G) in sending end of line thus the effect "Ferranti" will cause further tension rising in receiving end (V_R).

The shunt reactor of sufficient size must be permanently connected to the line in order to limit the fundamental frequency temporary overvoltage approximately 1.5pu duration less than 1second. These reactors also serve to limit the excitement of the surge (transient switching) (ABB S, 2009).

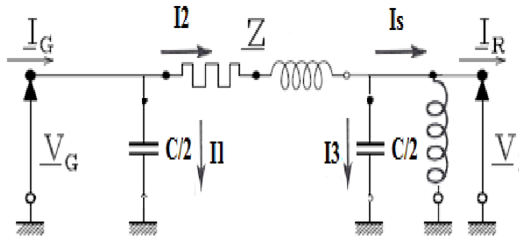


Figure 7: π model of the transmission line connected to the Self.

2.5.1 Electrical Equations

$$V_G = \frac{1}{C/2}.\int i_1\,dt \tag{8}$$

$$V_G = R.i_2 + L.\frac{di_2}{dt} + \int \frac{1}{C/2}.i_3 dt \tag{9}$$

$$i_1 = \frac{C}{2}.\frac{dV_g}{dt} \tag{10}$$

We can also calculate the current valueI_2using the equation(9) as follows:

$$I_2 = \frac{1}{l}.(\int V_G\,dt - R\int i_2\,dt - \frac{2}{C}\int\int i_3\,dt) \tag{11}$$

With :

$$i_3 = \frac{C}{2}.\frac{dV_R}{dt} \tag{12}$$

The voltage value at the end is:

$$V_R = i_s.(\omega.l_{SELF}) \tag{13}$$

With :

$$i_s = i_2 - i_3 \tag{14}$$

2.5.2 Construction of the Simulation Block

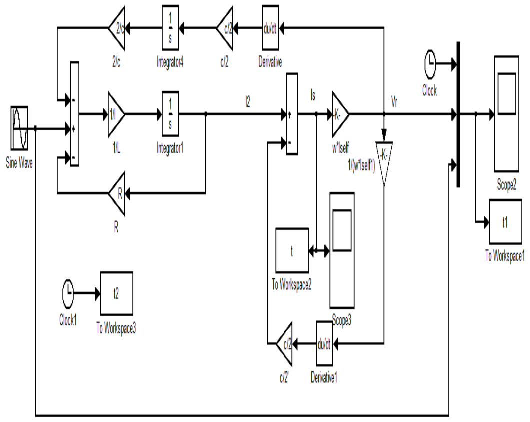


Figure 8: Simulation block with MATLAB, transmission line connected to the Self. using electrical equations.

2.5.3 Application on the Line ADRAR_INSALAH 409 km

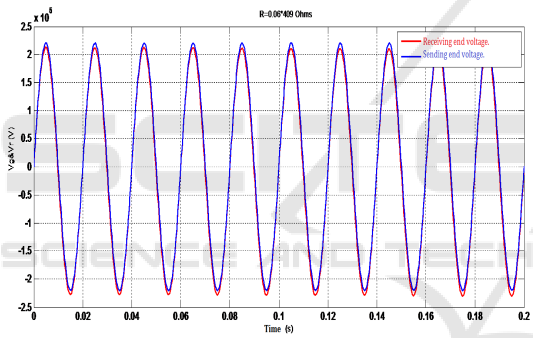


Figure 9_1: Sending end and receiving end voltage of line.

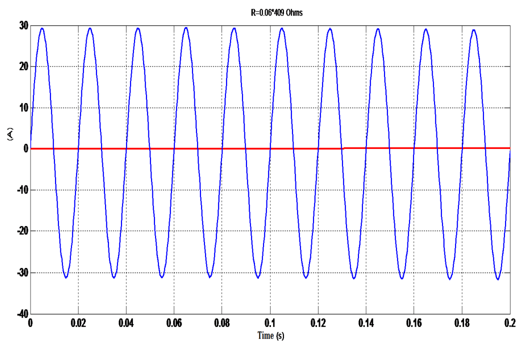


Figure 9_2: Current of mobile Self span.

The capacitive effect is almost completely eliminated on the transmission line (Fig.9.1). Or receiving voltage (V_R = 212.97 * 103 Volts) So the voltage setting value this time will be very suitable:

%voltage-setting=

$$\frac{V_G - V_R}{V_R} = \frac{220 - 212.97}{212.97} * 100 = 3.30\%$$

For a length of the line, more charge is more important the voltage ultimately decreases (Some capacitive loads or the voltage level rises with the active power). For loads with a rear power factor (inductive loads) which constitutes the vast majority of loads the level of voltage decreases rapidly with the call to active power. This is even true that the power factor is low.

This study shows very well that the voltage control at the end of line is very bad on uncompensated lines. We also note that:

- if the line is long, the control voltage at the end of this line is bad.
- if the load is not important on a network with long transmission lines, it is necessary to compensate to maintain the voltage at the end of line to a value close to the rated voltage.

3 CONCLUSION

The Ferranti effect is potentially very destructive to the network equipment; it is more dangerous with the introduction of 400Kv lines in particular in the night hollow, especially as the insulation level of equipment 400Kv is not far from the operating voltage.

In the long transmission lines, the most important factors affecting the increase in voltage during a fault are the length of the line and the degree of compensation parameters they have an indirect influence on transients connected to the opening or defect compensation, and the normal operations of switching.

REFERENCES

Ibrahim A, Dommel (2005). A Knowledge Base for Switching Surge Transients. Canada I. Conf. Pow. Sys., IPSY05: 19-23-2005.

Walling J, The ferranti Effect in Data Grade Cables and Channels. Canada. 56th I. Wire & Cable Symp., pp: 274-283.

Hung Sok P, Bong Hee L, Young Seon C, Sang Ok H (2006). Calculation of Shunt Reactor Capacity in 400 Kv Power System Using EMTP. Korea I. Conf. Elec. Eng., ICEE2006: 9-13-2006.

ABB S (2009). Basic on reactive compensation, Shielded Heads line 220Kv., GRTE-PAT: 001-2009.

Ashfaq H (2000). Electrical Power Systems CBS Publishers & Distributors. 4th Revised.,pp: 226-22.

ABB S (2009). Concept of reactive compensation and principles techniques of operating self span 220Kv., GRTE-PAT: 001-2009.

ABB S (2009). Technicals and functionals characteristics of the self span 220Kv., GRTE-PAT: 001-2009.