

*Full Length Research Paper*

# Ferranti effects in Algerian Network\_Adrar, Simulation Model using Matlab

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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 2005). 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 2002). It is potentially very destructive for network equipments 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 (using the MATLAB to give the locus of sending end voltage with line length which shows that receiving end voltage is greater than sending end voltage) 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.

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

## Introduction

There are many factors affecting temporary over voltages that may be considered in insulation. The 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 (Hung 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 19<sup>th</sup> 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 2002)

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).

## Materials and Method

### The ferranti effect

#### 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

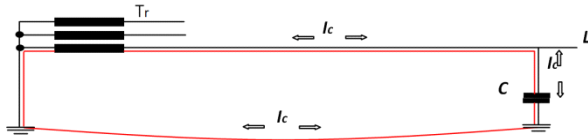


Figure 1. Cause of ferranti effect.

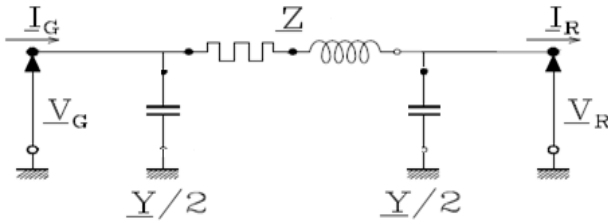


Figure 2. Quadropole π of the electrical line.

Table 1. Calculation of quadropole parameters π: (ABB 2009a)

Line parameters	Quadropole Parameters
$r=0.06[\Omega/Km]$	$R=r*L=0.06*192=11.52 [\Omega]$
$\ell=0.60[mH/Km]$	$X=X_L*L=(2*\pi*50*0.60e3)*192=j36.17 [\Omega]$
$c=0.14[\mu F/Km]$	$Y=Y_C*L=(2*\pi*50*0.14e-6)*192= j84.40e-4 [\Omega]$
$L=192[Km]$	$Z=R+jX=11.52+j36.17=37.96 [\Omega] \angle 72.33^\circ$

plant, or the resulting voltage increases with the increase of the length of line (Hung et al., 2006).

**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 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).

The value of the current  $I_c$  generated by the capacitive effect is a function of the voltage with respect to earth, that is to say the phase voltage  $U_{ph}$  of the line capacitance  $C$  and the frequency  $f$  of the current source.

The formula to calculate the capacitive current is:

$$I_c = U_{ph} \cdot 2 \cdot \pi \cdot f \cdot C \tag{1}$$

$$C = (\pi \cdot \epsilon \cdot L) / \log(2D/d) \tag{2}$$

D: distance Phase / ground [m].  
L: length of the line [m].

$\epsilon$ : Air permittivity [F / m].  
 $d$ : diameter of the line in [mm].  
 $C$ : capacity [Farad].

**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 Km and powered by  $V_G = 220 Kv$  with a 50Hz frequency (Figure 2, Table 1).

The equations of quadropole π are given by:

$$V_G = A \cdot V_R + \sqrt{3} \cdot B \cdot I_R \quad (\text{Phase\_Phase}).$$

$$I_G = C \cdot V_R + D \cdot I_R \quad (\text{Neutral\_Phase}).$$

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

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

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

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

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

$$V_R = \underline{258.82 Kv} > (V_G=220 Kv),$$

So there is really a ferranti effect in this network.

%voltage setting =

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

**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

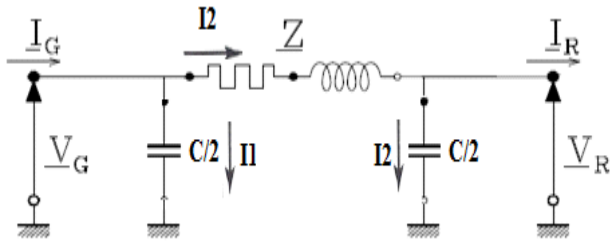


Figure 3. π model for the transmission line.

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 2000). To show the behavior of this network using the model in π as shown in Figure 3.

**Electrical equations**

$$V_G = \frac{1}{C/2} \int i_1 dt \tag{3}$$

$$U_1 = R \cdot i_2 + L \cdot \frac{di_2}{dt} + \int \frac{1}{C/2} \cdot i_2 dt \tag{4}$$

$$i_1 = \frac{C}{2} \cdot \frac{dV_G}{dt} \tag{5}$$

We can also calculate the current value  $i_2$  using the equation (4) as follows:

$$I_2 = \frac{1}{L} \cdot (\int V_G dt - R \int i_2 dt - \frac{2}{C} \int \int i_2 dt) \tag{6}$$

The voltage value at the end is:

$$V_R = i_2 \cdot \frac{1}{\omega \cdot C/2} \tag{7}$$

**Calculation of parameters**

- $\omega = 2 \cdot \pi \cdot f = 2 \cdot \pi \cdot 50 = 314$  (rad/s).
- $R = 6e-2 \cdot L$ . Resistance of the power line ( $\Omega$ ).
- $L = 0.60e-3 \cdot L$ . Inductance of the power line (H).
- $C = 0.14e-6 \cdot L$ . Capacity of the power line (F).
- $L = 192 \text{ \& } 409$  Km. Length of the power line (Km).

**Construction of the simulation block (Figure 4)**

**Line ADRAR Timimoune 192 km**

**Discussion of results**

When a transmission line is unloaded, ferranti effect

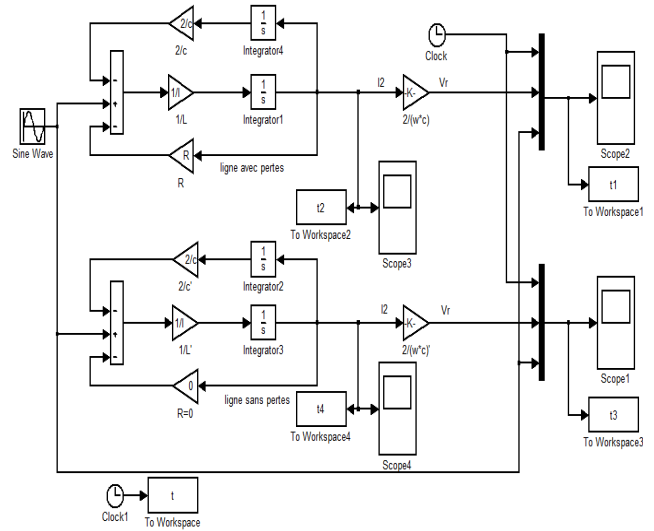


Figure 4. Simulation block with MATLAB, using electrical equations.

causes an increase in voltage from sending end to end of line ( $V_R = 258.8 \cdot 10^3$  for our network) as indicated at (Figure. 5d).

Some disturbances are on the voltage and current signals at the end of the line which can be up at  $352.6 \cdot 10^3$  Volts and 1489 Amps for current (Figures 5a, 5b and 5c), 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 (Figure 5d) at (Figure 5e).

**Line ADRAR Ain SALAH 409 km**

**Simulation results**

**Discussion of results**

The capacitive effect increases proportionally to the length of the line. For this transmission line, receiving voltage ( $V_R = 580.73 \cdot 10^3$  Volts) as indicated (Figures 6a and 6b) So the voltage rise value caused by Ferranti effect  $\Delta V = V_R - V_G = 580.73 \cdot 10^3 - 220.00 \cdot 10^3$  Volts =  $350.73 \cdot 10^3$  Volts, that is means here we have a very dangerous surge, and the voltage setting value:

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

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

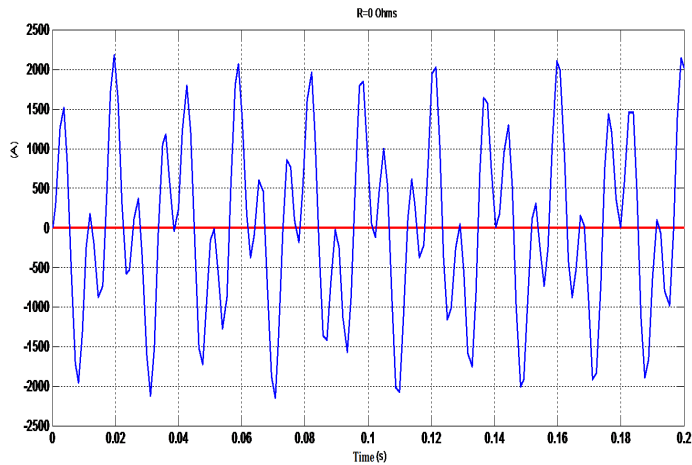


Figure 5a. Sending end and receiving end voltage.

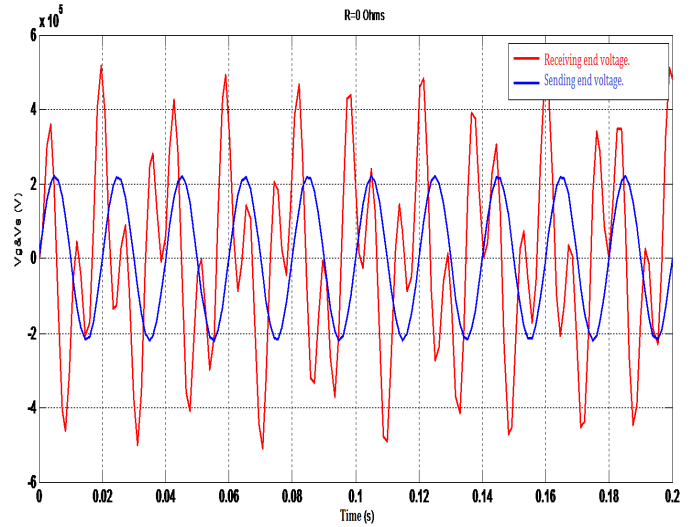


Figure 5d. Sending end and receiving end voltage.

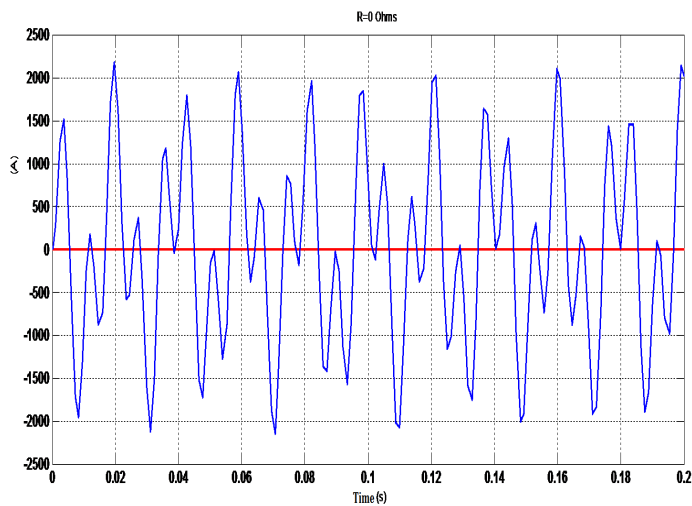


Figure 5b. Receiving end current.

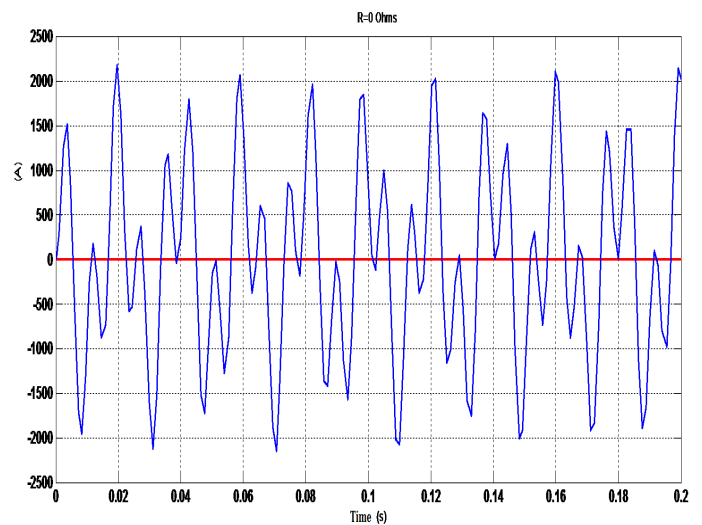


Figure 5e. Receiving end current.

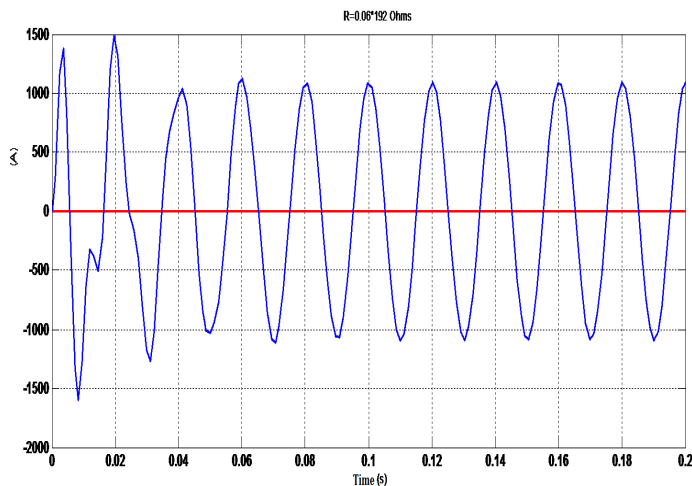


Figure 5c. Receiving end current.

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.

**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

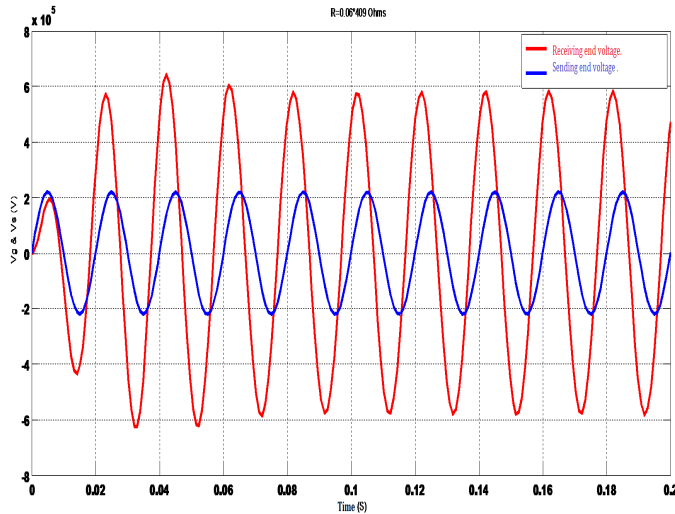


Figure 6a. Sending end and receiving end voltage of line.

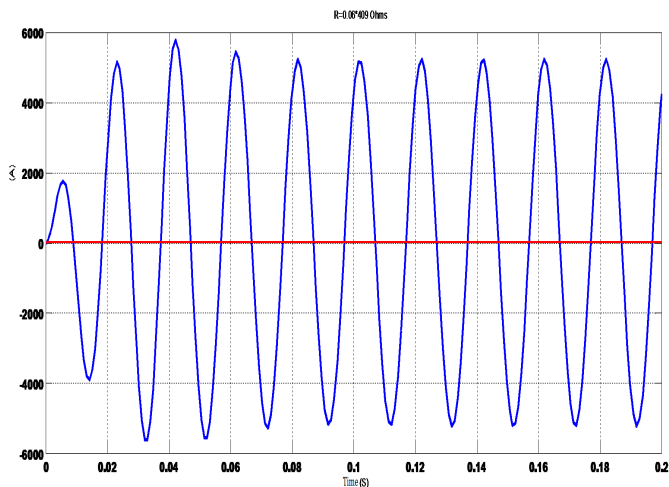


Figure 6b. Sending end current.

the line is powered from a low (short-circuit poor capacity) (ABB 2009b). 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 1 second. These reactors also serve to limit the excitement of the surge (transient switching) (ABB 2009c) (Figure 7).

**Electrical equations**

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

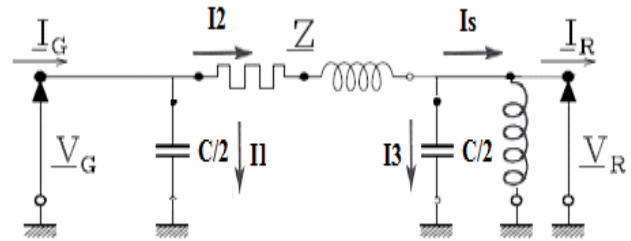


Figure 7. π model of the transmission line connected to the Self.

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

$$i_1 = \frac{C}{2} \cdot \frac{dV_G}{dt} \tag{10}$$

We can also calculate the current value  $i_2$  using the equation (9) as follows:

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

With :

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

The voltage value at the end is:

$$V_R = i_s \cdot (\omega \cdot L_{SELF}) \tag{13}$$

With :

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

**Construction of the simulation block (Figure 8)**

**Application on the line ADRAR\_INSALAH409 km**

**Simulation results (Figure 9a and b)**

**DISCUSSION OF RESULTS**

The capacitive effect is almost completely eliminated on the transmission line (Figure.9a) or receiving voltage ( $V_R$

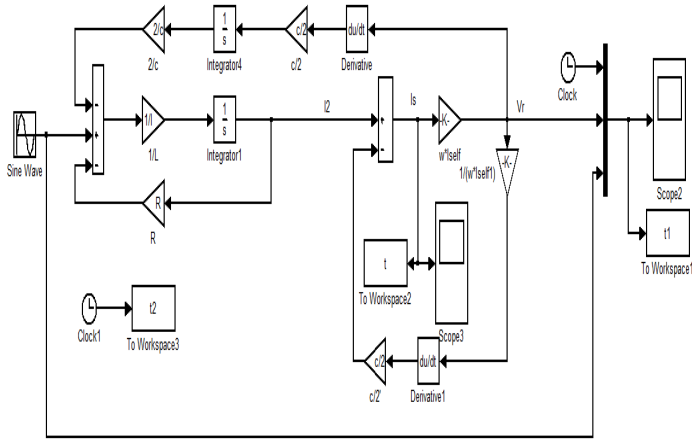


Figure 8. Simulation block with MATLAB, transmission line connected to the Self using electrical equations.

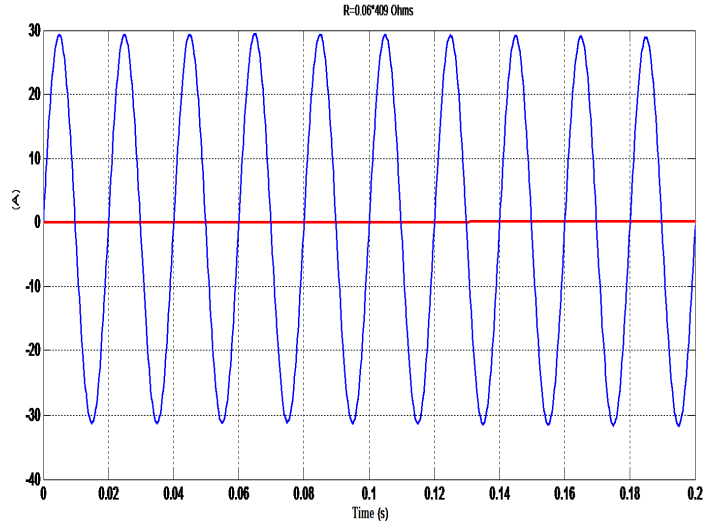


Figure 9b. Current of mobile Self span.

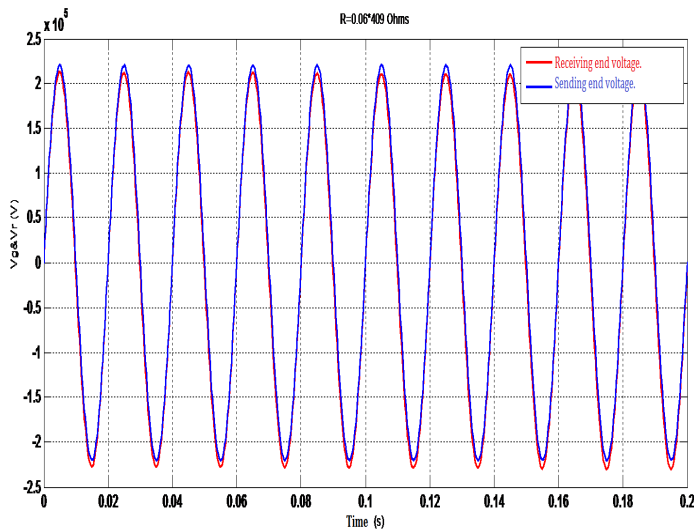


Figure 9a. Sending end and receiving end voltage of line.

= 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. The Ferranti effect is potentially very destructive to the

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.

**CONCLUSION**

network equipments; it is more dangerous with the introduction of 400 Kv lines in particular in the night hollow, especially as the insulation level of equipment 400 Kv 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**

ABB S (2009a). Basic on reactive compensation, Shielded Heads line 220Kv., GRTE-PAT: 001-2009.  
 ABB S (2009b). Concept of reactive compensation and principles techniques of operating self span 220Kv., GRTE-PAT: 001-2009.  
 ABB S (2009c). Technicals and functionals characteristics of the self span 220Kv., GRTE-PAT: 001-2009.  
 Ashfaq H (2000). Electrical Power Systems CBS Publishers & Distributors. 4<sup>th</sup> Revised.,pp: 226-22.  
 Hung SP, Bong HL, Young SC, Sang OH (2006). Calculation of Shunt Reactor Capacity in 400 Kv Power

- System Using EMTP. Korea I. Conf. Elec. Eng., ICEE2006: 9-13-2006.
- Ibrahim AD (2005). A Knowledge Base for Switching Surge Transients. Canada I. Conf. Pow. Sys., IPSY05: 19-23-2005.
- Walling J (2002), The ferranti Effect in Data Grade Cables and Channels. Canada. 56<sup>th</sup> I. Wire & Cable Symp., pp: 274-283.