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Analysis of Amplitude and Phase of Voltage on a SNEL MV / LV Network of Kinshasa

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ABSTRACT: In this article, we approach the power flow calculation which is a study in steady state of the complex network which consists in determining at each busbar, the amplitude and the phase of the voltage as well as the active powers and reactive injected. Knowing the voltages (amplitude and phase) at the busbars as well as the powers injected (active and reactive), we can calculate, secondly, the currents and powers in the electrical distribution lines. The mathematical model based on the linear equations of the electrical quantities of the network facilitate the determination of the voltage variation at medium voltage and at low voltage. These models confirm the variation of the network voltage as a function of the load and the load unbalance factor.

KEYWORDS: Analysis method, Amplitude imbalance, Voltage phase, Snel network

I. INTRODUCTION

The frequency of the electrical system is the indicator of the balance between the production and consumption of electricity. The frequency of the electrical system is shared by all users connected to the network and has the characteristics of a public good, its value must be constant 50 or 60 hertz (Hz) depending on the country. However, it is almost impossible to achieve balance between generation and demand in an electric power system. Amplitude is one of the ratings of electrical devices. These are manufactured to operate at a certain rated voltage to achieve their best performance and comply with safety standards.

Depending on the variation in amplitude, a distinction is made between voltage dips, overvoltages and cuts which result from a large variation and which originate from short circuits. These variations are caused by fluctuating loads or reconfiguration of thenetwork. Any electricity network is therefore legally obliged to supply electricity toconsumers at regulatory voltage levels.

I.1 METHOD OF REDUCTION BY CAPACITIVE REACTANCE AND SINGLE INDUCTANCES

I.1.1 Network resistance balancing

In the equivalent circuit, the voltages applied by the transformer supplying this network are represented by ideal generators with electromotive forces EA, EB, EC; the load is balanced on the three phases each with a ZL impedance. Rsw and RG being respectively the resistance of the guard conductor and of the return circuit by the earth. Now let's insert two resistors in series with RG.

$$R^{*} = R_{SW} - R_{G} \quad (1.1)$$

$$R' = -R^{*}$$

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S Following this modification, the circuit regime does not change and we obtain the insertion of resistors:

$R^{*} = R_{SW} - R_{G}, R' = -R^{*}$

I.1.2 Unbalanced star load is connected

This charge is formed by the presence of a negative resistance, the other two being zero. If in the branches of zero impedances we insert two reactances, the first inductive:

$$X_L = -\frac{R'}{\sqrt{3}} \quad (1.2)$$

$$X_C = \frac{R'}{\sqrt{3}} \quad (1.3)$$

I.1.3 Balancing circuit

The balancing circuit is highlighted in the square:

$$X_C = -\frac{JR'}{\sqrt{3}} \quad (1.4)$$

$$X_L = \frac{JR'}{\sqrt{3}} \quad (1.5)$$

The equivalent resistance of each phase of the circuit after balancing (protective conductor and the return circuit via earth) according to the literature is equal to:

$$R_{eq} = \frac{1}{3(2R_{WS} + R_G)} \quad (1.6)$$

I.2 Impedance reduction method

I.2.1. Impedances installed in the return to earth circuit

Ignoring all the capacitances and the magnetic coupling between the earth cables and the HV line conductors, the radius equivalent for the two earth cable conductors is:

$$\text{Rgesw} = \sqrt{\boldsymbol{rs}} \quad (1.7)$$

The inverse component of the voltages of the insulated earth wire, the voltage EWI and -Ew2 must have the same amplitude and must be offset by 120 °, namely:

$$E_{SW1} = e^{-j120^{\circ}}(-E_{SW2}) = e^{j60^{\circ}} E_{SW2} \quad (1.8)$$

Obtain the following equations:

$$E_{SW1} = E_1 - E_3 - Z_p l_{sw1} - Z_m l_{sw2} - Z_c(l_{sw1} + l_{sw2}) \quad (1.9)$$

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$$E_{SW2} = E_2 - E_3 - Z_p l_{sw2} - Z_m l_{sw1} - Z_c(l_{sw1} + l_{sw2}) \quad (1.10)$$

Taking into account that:

$$l_{SW2} = e^{-j120°}.l_{SW1} \quad (1.11)$$

AND

$$E_{SW1} = e^{-120°}(-E_{SW2}) = e^{-j60°}E_{SW2} \quad (1.12)$$

The impedance Zc can be calculated with the formulas following:

$$Z_C = R_C + JX_C = Z_P - 2Z_m \quad (1.13)$$

From where:

$$Z_c = R_{SW} - \pi^2 f.10^{-4} + j.0{,}1445 \log_{10}\left(\frac{D^2{}_{sw}}{r_{gesw} D_e}\right) \quad (1.14)$$

I.2.2 Winding directly to earth

In the case of MV/LV distribution transformers with a winding directly to earth:

$$E_r = e^{\pm j60°}E_S \quad (1.15)$$

I.2.3 Terminal connected to earth

In the case of an MV / LV distribution transformer with a terminal connected to earth by an impedance.

$$E_l - E_p = e^{\pm j60°}(E_m - E_p) \quad (1.16)$$

The concept is to take into account the change of the mutual admittance Yij of nodes i and j where the compensating admittance Ys is connected. The unknown auxiliary

$$A_i = Y_S(E_i - E_j) \quad (1.17).$$

In this case, removing the fixed voltage source nodes, and adding the condition: (1.17). The following equations are obtained:

$$\begin{bmatrix} I_4 \\ I_n \\ 0 \end{bmatrix} = \begin{bmatrix} Y_4 \\ Y_n \\ 0 \end{bmatrix}\begin{bmatrix} E_4 \\ E_n \\ 0 \end{bmatrix} \quad (1.18)$$

Where all the unknowns are load node voltages andet Ai= Ys(Ei - Ej) ; We therefore obtain the following equation for the calculation of Y_S:

$$Y_s = \frac{[Y_S(E_i - E_j)]}{E_i - E_j} \quad (1.19)$$

If the MV / LV distribution transformer has a terminal connected to earth by a ZCI impedance, equation (1.19) must be replaced by (1.20).

$$\begin{bmatrix} I_4 \\ I_n \\ 0 \end{bmatrix} = \begin{bmatrix} Y_4 \\ Y_n \\ 0 \end{bmatrix}\begin{bmatrix} E_4 \\ E_n \\ E_K/Z_C \end{bmatrix} \quad (1.20)$$

Z_C : can be easily calculated with the following formula:

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$$Z_C = \frac{E_k}{[E_K/Z_C]} \qquad (1.21)$$

II. IMBALANCE ON A MV / LV NETWORK DEPENDING ON LOAD

II.1 MV and LV voltage variation per phase depending on the load

Thus for an expected MV output voltage value of 34.5kV, the voltage Vac (red) varies from 34 kV to 31.5 kV; the voltage Vbc (green) from 34.43 kV to 33.25 kV and Vab (blue) from 35kV to 33.4kV. As for the LV voltage foran expected voltage value of 400V, the Vac (red) varies from 395 V to 355V; the voltage Vbc (green) from 398 V to 375 V and Vab (blue) from 405 V to 377 V.
Hence an amplitude imbalance of the compound voltage values felt more on this phase c.

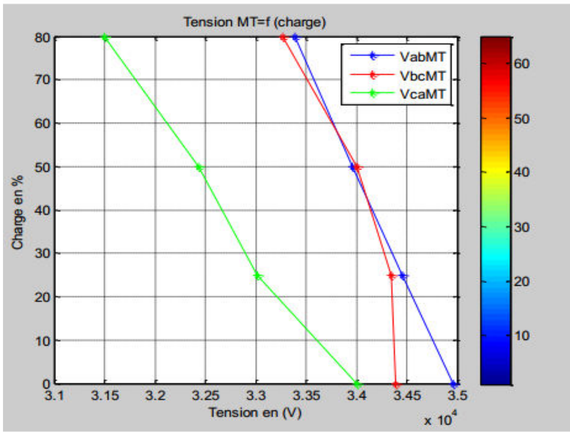

Fig II.1: Variation of MV voltage per phase as a function of the load

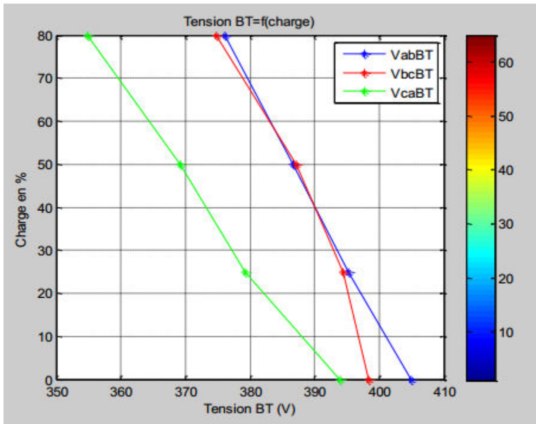

Figure II.2: LV voltage variation per phase as a function of the load.

II.2 variation of the MV and LV unbalance factor as a function of the load

This amplitude imbalance is perceptible on which the MV and LV unbalance factors represent.
It can be seen that these two unbalance factors have the same appearance and vary according to the load. For a load between 0 and 25%, the unbalance factor is between 2.5 and 4.25%.
From more than 25% load to 50% load the unbalance factor varies between 4.25 and 4.75%. And finally for a load of more than 50% to 80%, the unbalance factor is between 4.75 and 5.8%.

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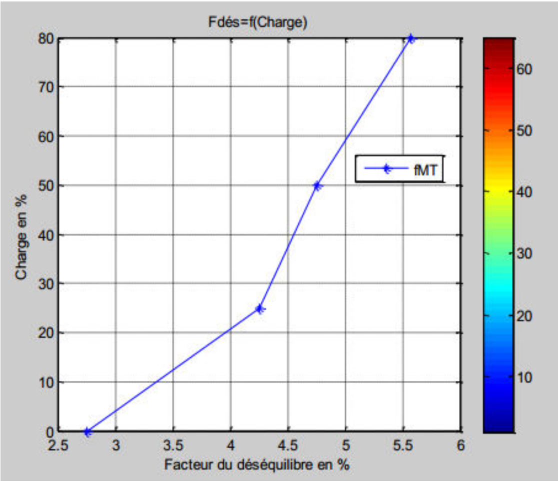

Fig II.3: Variation of the MV unbalance factor as a function of the load

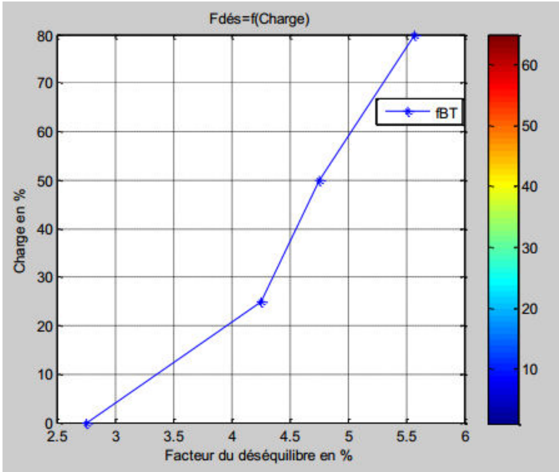

Fig II.4: Variation of the LV unbalance factor as a function of the load.

II.3 Illustration of the variation of MV and LV phasing as a function of the load

In the two figures the evolution of the phase shifts Vab (blue), Vbc (green) and Vac (red) are represented there as a function of the power of the load. It appears that whatever the level MV or LV voltage, there is a difference in phase shift on the three phases (Vab, Vbc and Vca) compared to a reference of -120°, 0° and 120° represented in blue triangle in the two figures, although the load is balanced.

There is therefore a phase imbalance. These results mean that an amplitude and phase imbalance is present. The connection of the third phase to the earth contributes to increasing these two imbalances. The more the transformer is loaded, the higher the amplitude and phase imbalances.

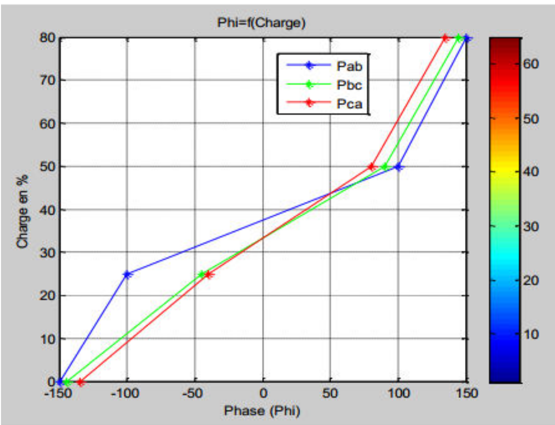

Fig II.5: Illustration of the variation of MV phasing asa function of the load

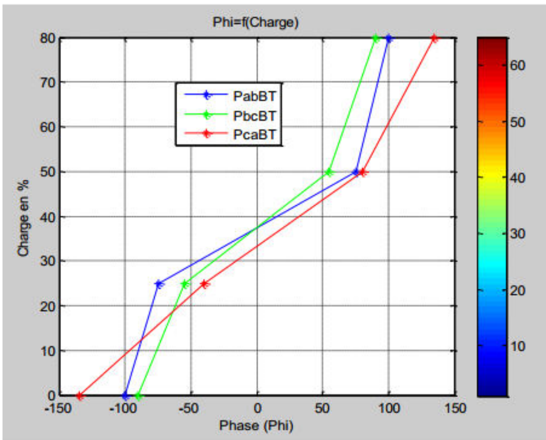

Fig II.6: Illustration of the variation of LV phasing asaa function of the load

III. AMPLITUDE AND PHASE IMBALANCE DEPENDING ON THE VALUE OF THE IMPEDANCE RESISTANCE

III.1 MV and LV voltage variation per phase as

a function of earth resistancein these two figures the shape of the voltages Vab (blue), Vbc (green) and Vca (red) are represented for each resistance value reached. It appears that whatever the level of voltage MV or LV, the variation differs on the three phase-to-phase voltages (Vab, Vbc and Vca).

This accentuated variation of the two line voltages Vca (red) and Vbc (green)is caused by the connection of phase c to earth, resulting in an amplitude imbalance of the compound voltage values Vac (red) and Vbc (green).

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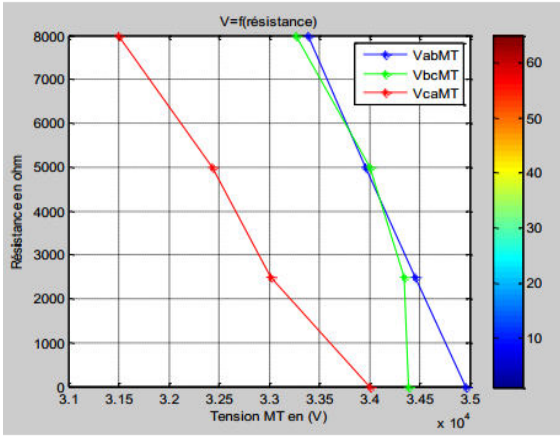

Fig III.1: variation of MV voltage per phase as a function of earth resistance.

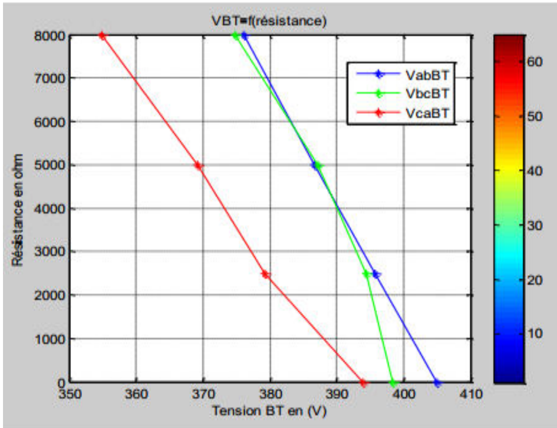

Fig III.2: LV voltage variation per phase as a function of earth resistance.

III.2 Variation of the MV and LV unbalance factor as a function of the resistance of Earth

This amplitude imbalance is perceptible in the figures which represent the MV and LV unbalance factors. We aknowledgethat these two unbalance factors have the same appearance and vary according to the value of the resistance.

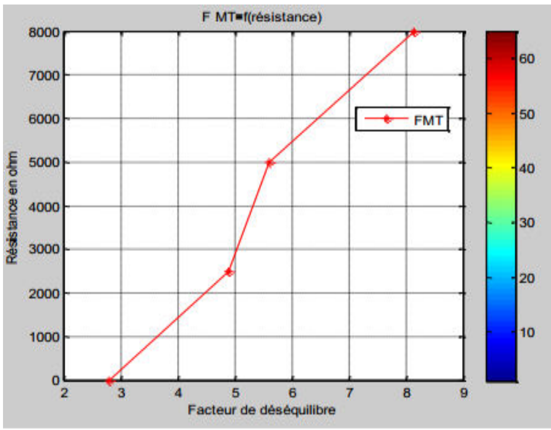

Fig III.3: variation of the MV unbalance factor as a function of the earth resistance

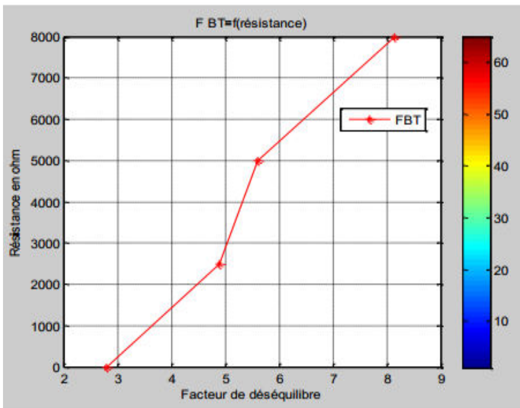

Fig III.4: Variation of the MV unbalance factor depending on earth resistance

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III.3 Variation of MI and BI phasing as a function ofearth resistanceangular angles

Vab (blue), Vbc (green) and Vac (red) are represented there for different resistance values. It appears that whatever the level of voltage MV or LV, one notices a difference of angle values on the three phases (Vab, Vbc and Vac) compared to a reference of -120°, 0 ° and 120 ° represented in blue triangle in both figures. These results mean that an increase in the value of the resistance in the circuit of the third phase connected to ground causes an imbalance of amplitude and phase. Unlike the variation in amplitude which takes on large proportions when the resistance increases, the angular difference varies little with the resistance.

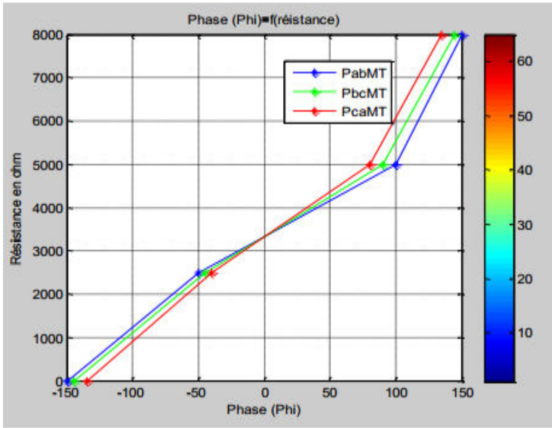

Fig III.5: variation of MV phasing as a function of earth resistance.

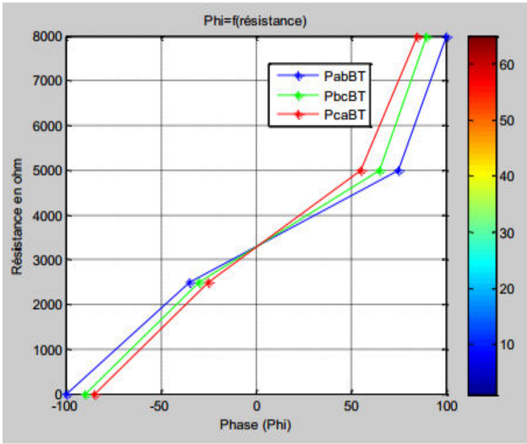

Fig III.6: Variation of LV phasing as a function of earth resistance

IV. ANALYSIS OF THE VOLTAGE QUALITY AS A FUNCTION OF THE VARIATION OF LAND INDUCTANCE

IV.1 MV and LV voltage variation per phase as a function of the earth inductance

The figures illustrate the variation of the amplitudes of the phase-to-phase voltages MV and LV as a function of the value of the inductance. In these two figures the shape of the voltages Vab (blue), Vbc(green) and Vca(red) are represented there for each value of the inductance.

It appears that whatever the MV or LV voltage level, this variation is different on the three phase-to-phase voltages (Vab, Vbc and Vca). Thus for an expected output MT voltage value of 34.5kV, the voltage Vac (red) varies from 33.7 kV to 26.4 kV; the voltage Vbc (green) of 34.3 kV to 32.3 kV and Vab (blue) remains substantially constant at 34.9 kV.

As for the LV voltage for a voltage value of 400V expected, the voltage Vac (red) varies from 390 V to 306 V; the voltage Vbc (green) from 397 V to 374 V and Vab (blue) substantially constant at 405.

The phase-to-phase voltages Vca(red)and Vbc (green) in MV and LV undergo more variation than the voltage Vab (blue), and that according to the size of the inductance. This variation is more accentuated on phase-to-phase voltages Vac (red) and Vbc (green) caused by the connection of phase c to earth, hence an amplitude imbalance of the phase-to-phase voltage values Vac (red) and Vbc (green).

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Compared to the increase in resistance, that of the inductance causes more amplitude imbalance of the phase-to-phase voltages of phase c (connected to earth) and any other of the phases (a or b).

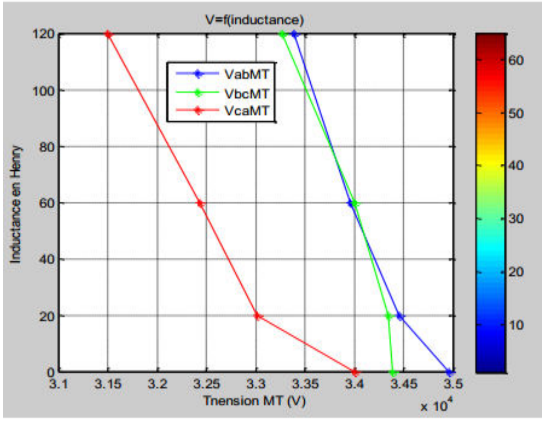

Fig IV.1: Variation of MV voltage per phase as a function of earth inductance

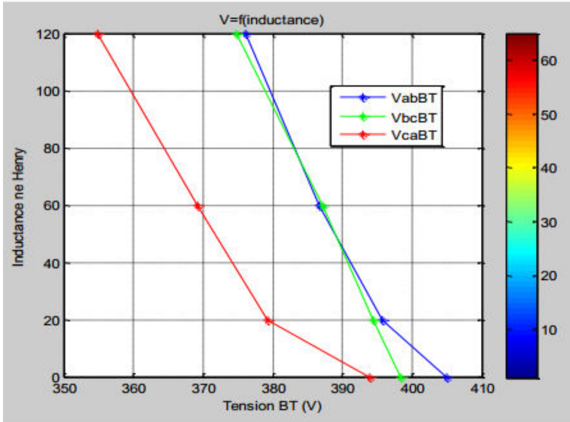

Fig IV.2: LV voltage variation by phase in function of earth inductance

IV.2 Variation of the MV and LV unbalance factordepending on the inductance ofearth

This amplitude imbalance is perceptible in the figures which represent the MV and LV unbalance factors. We aknowledge that these two unbalance factors have a linear variation and to very large proportions (3.56% to 27.31%) depending on the value of the inductance.

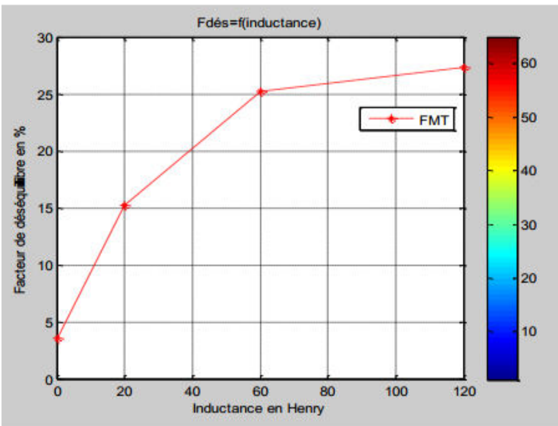

Fig IV.3: Variation of the MV unbalance factor as a function of the earth inductance.

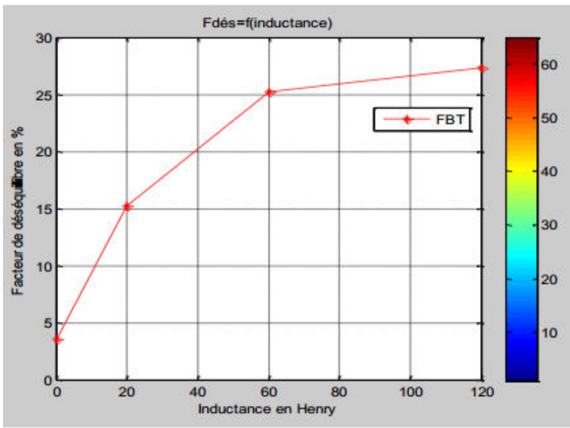

Fig IV.4: Variation of the LV unbalance factor as a function

IV.3 Variation of MV and LV phasing as a function of earth inductance

The figures illustrate the different phase shifts existing between two consecutive phases. In these two figures the shape of the angular values Vab (blue), Vbc (green) and Vca (red) are represented there for different inductance values. It appears that whatever the level of voltage MV or LV, one notices a difference of angle values on the three phase shifts (Vab, Vbc and Vac) compared to a reference of -120 °, 0 ° and 120° shown in blue triangle in both figures. Thus for the MV voltage, instead of an ideal phase shift of -120° for the phase.

Vac(red) the angle varies from IV.2 to -118 °; phase Vbc (green) from IV.3 to 134.2 ° instead of 120 ° and phase Vab (blue) substantially constant at 0.28 against 0°. As for the LV voltage, the phase shift variations are from-IV.4 to 117.9° for the Vac phase (red); 122 to 134.2° for phase Vbc (green) and 0.31 for phase Vab (blue). These differences indicate

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non-ideal phase shifts for the two voltage levels MV and LV. They are more sensitive for phase-to-phase voltages Vac (red) and Vbc (green) for which phase c is connected to earth.
JI therefore exists a phase imbalance. These results mean that an increase in the value of the inductance causes an imbalance of amplitude and phase. Unlike the variation in amplitude which takes on large proportions as the inductance increases, the phasing varies little with the inductance. These imbalances are much more accentuated compared to those obtained for increasing the value of the resistance. As the inductance takes on greater v alues, the amplitude and phase imbalances reach very considerable proportions.

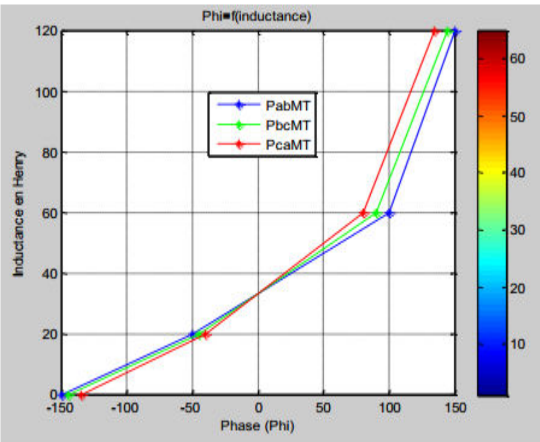

Fig IV.5: Variation of MV phasing as a function of earth inductance

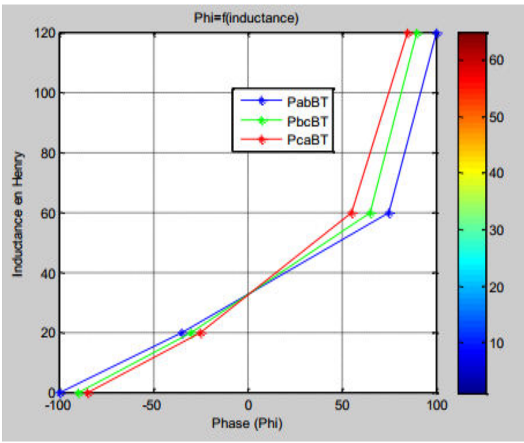

Fig IV.6: Variation of LV phasing as a function of earth inductance

V. CONCLUSION

We have seen that this article consisted of In this chapter we dealt in the first part of the characteristics contracts of an electrical network between the consumer and the distributor which are the combination of the quality of the voltage and the frequency. In a second part we have studied some of these characteristics, namely the amplitude and phase imbalance on the Kinshasa insulated ground wire network subject to load variations and the increase in the impedance value of the third phase connected to the earth. The results show that these two imbalances increase when the load increases at the terminals of the transformer, which causes a degradation in the quality of the voltage.
This degradation is accentuated when the earth impedance increases. The earth impedance being made up of a resistance and an inductance, the study shows that the increase in the value of the inductance generates more amplitude and phase imbalance than that of the resistance, we have applied these models on the network and simulate by Matlab software.

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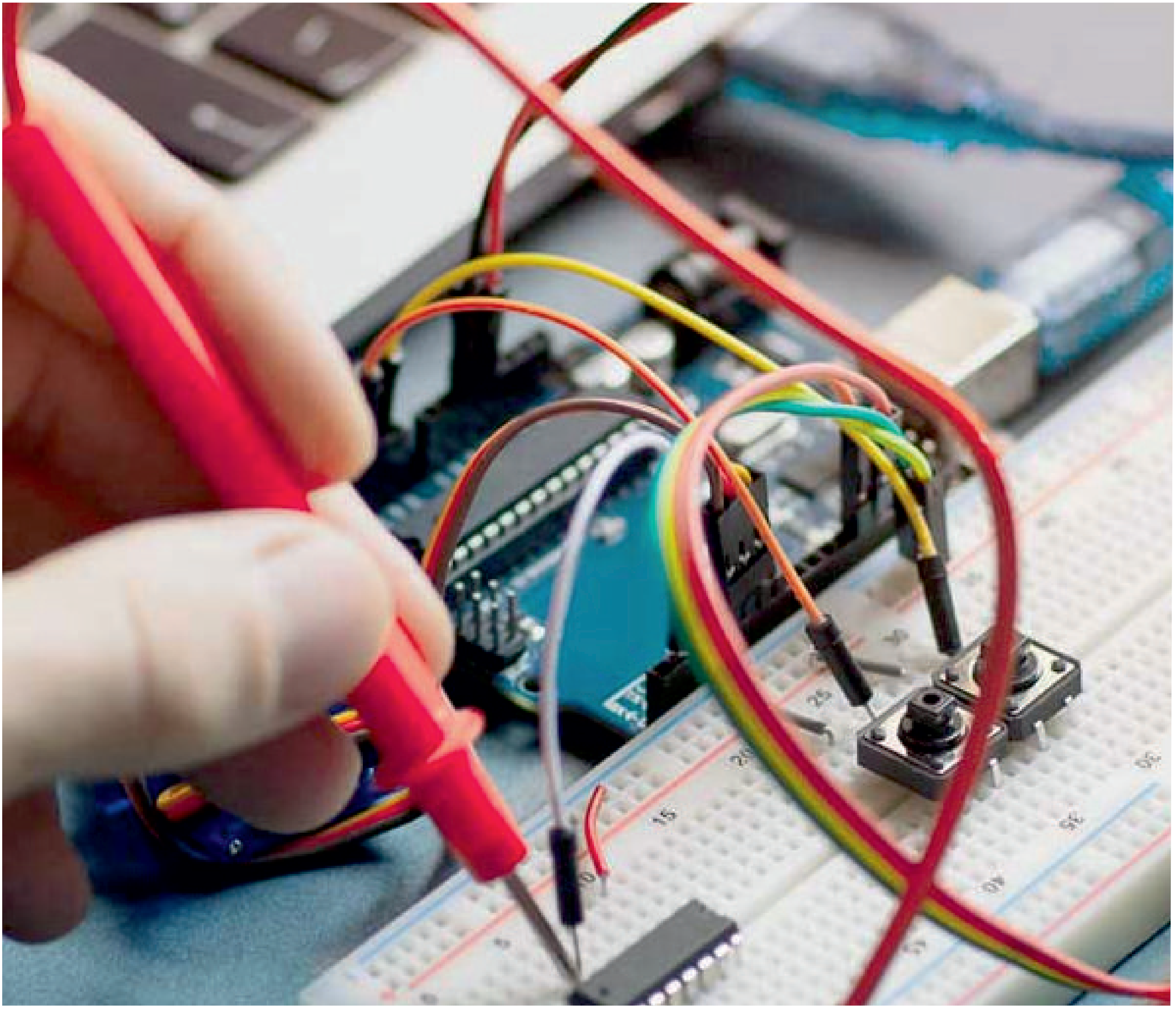

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