Optimization of Harmonic Filtering Methods Produced by Single-Phase Non-Linear Charge (Case of Kinshasa Low-Voltage Power grid).

Mathangila Kimeya[1], Gogom Mathurin[2], Gomba Rodolphe[3], Lidinga Mobonda Flory[4], Okemba Rodrgue Armel Patrick[5], Haroun Abba Labana[6], Nsongo Timothée[7]

Electrical Engineering Research Laboratory, University of Brazzaville-Congo, Brazzaville

Abstract: In this article, we present different mathematical methods for harmonic filtering in the electrical energy distribution network. The equations developed address the harmonic problem in the electrical energy distribution station. In this part, we consider a set of stabilizers. The artery has a non-zero impedance (Rth and Xth). Similarly, each stabilizer is connected to the main artery by a line with a non-zero impedance (Rb and Xb). This configuration has the particularity of being more realistic and giving more precise results, but its approach remains more complex. The purpose of this article is to evaluate the effectiveness of different methods of harmonic filtering. As far as passive filtering is concerned, the configuration of parallel resonant and damped filters is studied theoretically and by simulation. Many active filter configurations can be encountered, but all are based on a stabilizer and plasma screen (with power transistors and diodes), a continuous source of voltage or filtering and coupling current.

Keywords: **Optimization of methods, Harmonic filtering, Grid, Distribution.**

1. INTRODUCTION

Stabilizers and plasma screens used in household appliances are considered to be single-phase non-linear receivers. These types of receivers have a relatively low harmonic output. But because of their ever increasing number in households, stabilizers and plasma screens are becoming important sources of harmonic currents. However, as their number increases, the cumulative harmonics produced could create significant harmonic distortions. Harmonics produced by so-called non-linear loads similar to stabilizers and plasma screens are usually characterized by normalized phasors where the fundamental component of the current; it varies proportionally with the power of the load. The analysis of the harmonics produced by a set of stabilizers or nonlinear loads must plasma display whose characteristic parameters are represented on an equivalent circuit that will be presented later. A description of this circuit will be presented. The mathematical equations governing its operation will be established. The amplitudes and phases of the harmonic currents will be determined. The simulation results are presented Matlab / Simulink Power System Blocks.

1.1 Harmonics present on the electrical networks

The waveforms of current and voltage found on distribution power grids are quite different from the pure ideal sinusoid. The deformation of the voltage results from the circulation on the network of non-sinusoidal currents. Since the elements of the network have a linear behavior, the effect on the voltage of all currents is the superposition of the effect that each current would have individually.

The harmonics present on the electrical networks come from the use of non linear loads which subjected to a sinusoidal tension, absorb a non-sinusoidal current. In many cases, these loads behave like sources of harmonic currents, the harmonic current being fixed by the load and not by the voltage or the impedance of the network. We can also define at any point of a network a harmonic impedance which depends on the harmonic rank h considered; it represents the paralleling of all the lines converging towards this point. We also speak of a harmonic voltage source to describe the state of a network disturbed by a high nonlinear load; the product of current harmonics by the harmonic impedance of the one-point network creates voltage harmonics according to Ohm's law.

1.1.1 Domestic users

The residential sector contributes to an important part of the harmonic pollution observed on the electrical networks because of the introduction of electronics in household electrical appliances, one of the main disruptive devices is the television set whose power is constituted a single-phase rectifier with capacitive filter.

1.1.2 Tertiary sector

The most disruptive activities are the offices, the administration and the shops, the educational institutions come to occupy the third place. Harmonic injector devices are essentially capacitive filter rectifiers (computer, office automation), food cold, air conditioning, elevators and fluorescent lamps.

1.1.3 Industrial sector

Strong harmonic injections are observed at the level of the installations belonging to the energy sectors as well as the transformations and the mechanics. Among harmonic injector devices: drives for AC motors that gradually replace drives for DC motors and which are three times more polluting. The harmonic injection also depends on the periods of the year and the time slots, a simultaneity factor can be applied for a number N of homogeneous users, according to a specified time slot.

1.2 Effects of harmonics

Instant effects: These are the immediate effects on the functioning of a material, they concern the devices producing an electronic image (computer screens, televisions), the devices producing a sound supposed to be of good quality (HI-FI chain, telephone) or the accuracy of measuring devices. Delayed effects: They occur after a long exposure to the phenomenon and result in a partial loss of functionality or a complete destruction of the device

1.3 Harmonic sensitivity in the different materials

- Asynchronous machines: The circulation of harmonic currents in the windings of the motor, creates additional heating as well as an alteration, generally weak, of the engine torque.
- Transformers: They undergo additional heating in the presence of harmonic currents and can also enter into mechanical resonance at harmonic frequencies, which causes besides the acoustic inconvenience, a mechanical fatigue.

- Power cables: Circulation of harmonic currents in the cables results in additional Joule losses.

Capacitors: In the presence of loads generating harmonics, it is necessary to over-size the capacitors. In case of resonance in a network, the capacitors can be subjected to strong harmonic voltages and deteriorate.

- Protection relay of the networks: The presence of harmonic currents is translated by untimely tripping or by a loss of precision of the threshold of triggering.
- Power meters: The accuracy of power measurements is influenced by the presence of voltage and current harmonics.
- Large-scale electronic equipment: They are likely to be disturbed in their DC power supply. On television screens and microcomputers, whitish lines appear when the rank of the applied harmonic and its amplitude are high.
- Telephone lines: Their juxtaposition with electrical lines where circulating harmonic currents, produced by induction, the appearance of unwanted harmonic voltages that disturb the sound signal. The signal is all the more disturbed as the frequency in question is close to the maximum sensitivity of the human ear in the frequency range used for telephone transmission.

2. MATHEMATICAL MODELING

2.1 Fourier Transform

Let a signal $S_g(t)$, which can represent a current or a voltage, periodic of period T, therefore of frequency:

$$f = \frac{1}{T} \qquad 2.1$$

And pulsation:

$$\omega = 2\pi f \qquad 2.2$$

This signal can be broken down into a Fourier series as follows:

$$S_g(t) = a_0 + \sum_{h=1}^{\infty}[ah.cos(\omega.h.t) + bh.sin(\omega.h.t)] \quad 2.3$$

With :

$$a_0 = \frac{1}{T} = \int_0^T S_g(t).dt \qquad 2.4$$

And for

$h \geq 1$:

$$a_h = \frac{2}{T} = \int_0^T S_g(t).cos(\omega.h.t).dt \qquad 2.5$$

$$b_h = \frac{2}{T} = \int_0^T S_g(t).sin(\omega.h.t).dt \qquad 2.6$$

Is:

$$S_g(t) = a_0 + \sum_{h=1}^{\infty}[Ch.sin(\omega.h.t + \Theta_h)] \quad 2.7$$

Where :

$$C_h = \sqrt{ah^2 + bh^2} \qquad 2.8$$

$$\Theta_h = arctan\left(\frac{ah}{bh}\right) \qquad 2.9$$

The harmonic frequencies f_h are defined as the multiple frequencies of the frequency f. their rank « h » is such that:

$$f_h = h\,x\,f \qquad 2.10$$

The term $[ah.cos(\omega.h.t) + bh.sin(\omega.h.t)]$ is the harmonic of rank h.

The magnitude $C_h = \sqrt{ah^2 + bh^2}$ is the amplitude of the harmonic of rank h.

A distorted signal generally has several harmonics. This signal is often represented in the form of a spectrum. At each harmonic frequency fh, we match the value of Ch. The interest of harmonic decomposition is to facilitate network computations, because the study is separated from the fundamental frequency of those relating to harmonic frequencies. This decomposition, called harmonic, is a very practical mathematical artifice, it is not a distinct physical phenomenon because, in reality, we observe only non-sinusoidal signals and not really harmonics.

2.2. Electrical quantities in deformed regime and harmonic indices

The instantaneous voltage and current expressions are given respectively by:

$$v(t) = \sum_{h=1}^{\infty} vh(t) = \sum_{h=1}^{\infty} \sqrt{2}\, V_h \sin(h.\omega.t + \theta_h) \quad 2.11$$

$$i(t) = \sum_{h=1}^{\infty} ih(t) = \sum_{h=1}^{\infty} \sqrt{2}\, I_h \sin(h.\omega.t + \theta_h) \quad 2.12$$

With:

V_h : RMS harmonic voltage value of rank h

I_h : RMS harmonic current value of rank h

2.2.1 Instantaneous power and average power (active)

$$p(t) = v(t).i(t) \quad 2.13$$

$$P = \frac{1}{T}\int_0^T v(t).i(t)dt \quad 2.14$$

$$P = \sum_{h=1}^{\infty} V_h x I_h x cos(\Theta_h - \Theta_h) = \sum_{h=1}^{\infty} P_h \quad 2.15$$

2.2.2 RMS values of current and voltage

$$V = \sqrt{\frac{1}{T}\int_0^T v^2(t)\, dt} = \sqrt{\sum_{h=1}^{\infty} {V_h}^2} \quad 2.16$$

$$I = \sqrt{\frac{1}{T}\int_0^T i^2(t)\, dt} = \sqrt{\sum_{h=1}^{\infty} {I_h}^2} \quad 2.17$$

2.2.3 Apparent power, reactive power and distortion power

The apparent power is given by the expression:

$$S = \sqrt{P^2 + Q^2 + D^2} \quad 2.18$$

In single-phase, the voltage and the instantaneous currents are given by the expressions:

$$v(t) = \sqrt{2}V.sin(\omega.t) \quad 2.19$$

$$i(t) = \sum_{h=1}^{\infty} \sqrt{2}\, I_h \sin(h.\omega.t + \theta_h) \quad 2.20$$

With :

$$P = VI_1 cos(\Theta_1) \quad 2.21$$

$$Q = VI_1 sin(\Theta_1) \quad 2.22$$

$$S = V.I \quad 2.23$$

$$\sqrt{{I_1}^2 + {I_2}^2 + {I_3}^2 + \cdots . {I_n}^2} \quad 2.24$$

When the harmonics are not present, S is equal to $V_1 . I_1$,, which is the classical definition of the apparent power at the fundamental frequency.

2.2.4 Harmonic indices

There are several indices that can be used to describe the effects of harmonics on the switchgear. The current and voltage harmonics are characterized by the following main indices:

$$\frac{I_h}{I_1} \text{ ou } \frac{V_h}{V_1}$$

The individual distortion rate is the ratio of the effective value of the harmonic of rank h to the effective value of the fundamental:

$$THD_V = \frac{\sqrt{\sum_{h=2}^{\infty} {V_h}^2}}{V_1} \qquad 2.25$$

$$THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} {I_h}^2}}{I_1} \qquad 2.26$$

3. SIZING METHOD OF A PARALLEL PASSIVE FILTER

3.1 Design of a simple resonant filter

A simple resonant filter is a series RLC tuned on the frequency of a single harmonic. Its impedance ZF is given by:

$$Z_F = R + j\left(L\omega - \frac{1}{C\omega}\right) \qquad 3.1$$

where:
R: is the filter resistance (Ω)
L: is the inductance of the filter (H)
C: is the filter capacity (H)
ω : is the angular velocity of the power grid. At resonance, its impedance is a resistance of relatively low value.

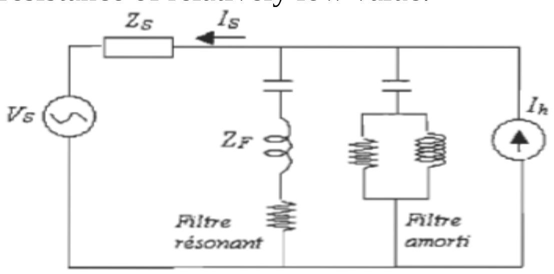

Figure 3.1 : Single-phase diagram of a network with a resonant and damped filter

From the following relationships:

- Angular frequency of tuning (rad/sec) :

$$\omega_n = \frac{1}{\sqrt{LC}} \qquad 3.2$$

- Frequency deviation compared to the resonant frequency :

$$\delta = \frac{\omega - \omega_n}{\omega_n} \qquad 3.3$$

- Reactance of inductance or capacitance at the tuning frequency :

$$X_n = L\omega_n = \frac{1}{C\omega_n} = \sqrt{\frac{L}{C}} \qquad 3.4$$

- Quality factor of the inductance or tuning of the filter :

$$F_q = \frac{X_0}{R} \qquad 3.5$$

We obtain :

$$\omega = \omega_n(1+\delta); \frac{1}{\omega_n X_0} = \frac{1}{\omega_n R.F_q}; L = \frac{X_0}{\omega_n} = \frac{R.F_q}{\omega_n}$$

Substituting these equations into equation (2.1) gives:

$$Z_F = R.\left(1 + jF_q.\delta\frac{2+\delta}{1+\delta}\right) \qquad 3.6$$

For small frequency deviations $(\delta \ll 1)$, the impedance is given very closely by :

$$Z_F = R.(1 + j2\delta.F_q) = X_0\left(\frac{1}{F_q} + 2j\delta\right) \qquad 3.7$$

$$|Z_F| = R\sqrt{1 + 4\delta^2 {F_q}^2} = X_0\sqrt{\frac{1}{{F_q}^2} + 4\delta^2} \qquad 3.8$$

Under such conditions, the admittance, conductance and susceptance of the filter are given by:

$$Y_F = \frac{1}{R(1 + j2\delta.F_q)} = \frac{1 - j2\delta.F_q}{R(1 + 4\delta^2.{F_q}^2)} = \frac{F_q - j2\delta.{F_q}^2}{X_0(1 + 4\delta^2.{F_q}^2)} \qquad 3.9$$

$$|Y_F| = \frac{1}{R\sqrt{1 + 4\delta^2.{F_q}^2}} = \frac{F_q}{X_0\sqrt{1 + 4\delta^2.{F_q}^2}} \qquad 3.10$$

$$\mathrm{G_F} = \frac{1}{R\left(1+4\delta^2.F_q{}^2\right)} = \frac{F_q}{X_0\left(1+4\delta^2.F_q{}^2\right)} \qquad 3.11$$

$$\mathrm{B_F} = \frac{2\delta.F_q}{Rx\left(1+4\delta^2.F_q{}^2\right)} = \frac{2\delta.F_q{}^2}{X_0 x\left(1+4.\delta^2.F_q{}^2\right)} \qquad 3.12$$

Frequency derivation: in practice, the filter is not always tuned exactly to the frequency of the harmonic to be removed. Network frequency (AC) may change ; which causes a proportional change in the harmonic frequency. Also, inductance and capacitance may change due to change in ambient temperature, etc. The 2% change in L and C causes the same attenuation as the 1% grid frequency change. The total disagreement or deviation from the equivalent frequency is given by the following equation :

$$\delta = \frac{\Delta f}{f_n} + \frac{1}{2}\left(\frac{\Delta L}{L_n} + \frac{\Delta C}{C_n}\right) \qquad 3.13$$

Minimization of the harmonic voltage V_h :

This is to minimize, not the impedance of the Z_{nF} filter alone, but the Z_h impedance resulting from the parallel combination of the Z_{nF} filter impedance and the Z_{hS} impedance of the network(ca) :

$$V_h = |Z_h| I_{hS} = \frac{|I_{hS}|}{|Y_h|} = \frac{|I_{hS}|}{|Y_{hF} + Y_{hS}|} \qquad 3.14$$

With :

I_{hS} : is the harmonic current of order h on the network source side;

Y_{hF} : is the admittance of the filter;

Y_{hS} : is the admittance of the network ;

Y_h : is the equivalent admittance of the paralleling of Y_{hF} and Y_{hS};

For the case of the infinite network impedance, the resulting impedance is simply that of the filter:

$$Z_h = Z_{hF} \qquad 3.15$$

With :

$$V_h = |Z_{hF}|.I_{hS} = X_0\left(F_q{}^{-2} + 4\delta_{max}{}^2\right)^{\frac{1}{2}}.I_{hS} \qquad 3.16$$

For X_0 and δ_{max} given, V_h is minimized by putting $F_q = F_{q0} = \infty$ Then the harmonic voltage is given by:

$$V_h = 2\delta_{max}.X_0.I_{hS} \qquad 3.17$$

In practice, there is a maximum value of Fq for which the coil can be constructed to operate at a given frequency. Conversely, the economy of cost imposes a value of Fq quite low. If the voltage harmonic exceeds the limits allowed for this value of Fq , it becomes necessary to decrease X_0.

3.2 Conception d'un filtre amorti (passe-haut) de second ordre

3.2.1 Second order filter impedance

The impedance of the second order filter is :

$$Z_{ph} = \frac{1}{jC\omega} + \left(\frac{1}{R} + \frac{1}{jL\omega}\right) - 1 \qquad 3.18$$

3.2.2 Variables

The following variables are introduced: :

$$\omega_n = \frac{1}{\sqrt{LC}};\ f' = \frac{\omega}{\omega_n} = \frac{f}{f_n};\ X_0 = \sqrt{\frac{L}{C}};\ F_q = \frac{R}{X_0};\ Z' = \frac{Z}{X_0}$$

$$\mathrm{Z'_{ph}} = \frac{1}{\mathrm{jf'}} + \left(\frac{1}{\mathrm{q}} + \frac{1}{\mathrm{jf'}}\right) - 1\ ;\ \mathrm{Z_{ph}} = X_0.\mathrm{Z'_{ph}};R = \sigma.X_0;\left(F_q = \sigma\right);$$

$$0.5 < \sigma < 2\ \ \text{et}\ \mathrm{h_0} \le \sqrt{2\mathrm{h_{min}}}$$

With :

h_{min} : est le rang harmonique le plus faible filtré par le filtre passe haut ;
h_0 : est le rang harmonique choisi le calcul de la fréquence de résonnance du filtre passe-haut.

3.2.3 Simplified diagram of a power grid

Consider the simplified diagram of a power grid with passive filters, shown in the figure below, on the basis of which the design steps of a passive filter are described.

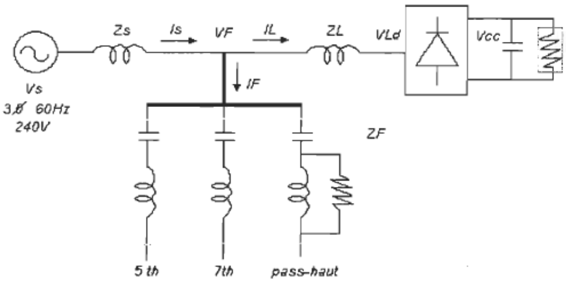

Figure 3.2 : Single-phase diagram of a network with passive filters for a diode rectifier

The passive filter to be designed consists of several low LCR shunt impedances, each branch of which is tuned in series at a given harmonic frequency. The table below shows the values of the parameters of the selected standard network.

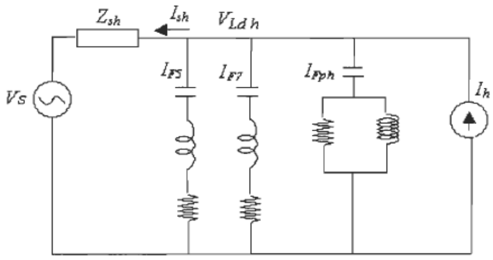

Figure 3.3 : Single-phase diagram of a simplified network with filters

Table 3.1 : Three-phase power grid parameters table, are as follows :

V_s	L_s	L_L	R_L
3θ-60Hz-240V	0.3mH	$76\mu H$	5Ω
$Z_h = \frac{{V_S}^2}{S_b} = \frac{240^2}{20e^3}$. $Z_S = 4\%\ et\ Z_L = 1\%$			

3.2.4 Application of the passive filter to Kinshasa's distribution network

A precise knowledge of the profile of the harmonics to be filtered and the required attenuations is necessary for the realization of the passive filter. After identifying the harmonic content of the current is (= iL) in the power grid. Le tableau ci-dessous, presente les caracteristiques du filtre utilise

Table 3.2 : parallel passive filter parameters

Fréquence du filtre	L (mH)	C (μF)	R (Ω)	Fq
5h	0.89	304.38	0.085	19.76
7h	2.55	56.22	0.34	
Passe-haut	0.11	537.12	0.46	

3.3 Simulation des résultats

This section presents the results of the simulations, composed by : the shapes and spectral analysis of the output signals at the source and the load, before and after the installation of the passive filter.

Source signals

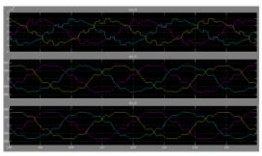

Figure 3.3: Degraded source voltage and current without using the filter

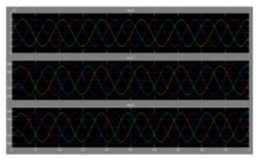

Figure 3.4: Improved source voltage and current using filter

The curves in Figure 3.5 show that, the output signals representing the currents and voltages of the source, before installation of the passive filter in the electrical network, are disturbed, degraded and lose their sinusoidal quality. We observe that, the use of the filter in the electrical network, improves the shape and quality of the currents and voltages at the source, as shown in figure 3.4.

Load signals

Figure 3.5 and figure 3.6 represent the variations of the current and the variations of the voltage as a function of time, at the load.

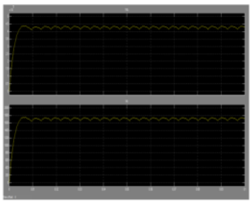

Figure 3.5: Degraded load voltage and current without using the filter

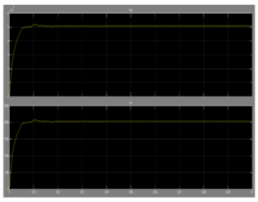

Figure 3.6: Improved charging voltage and current with use of the filter

Without using the filter in the electrical network, the curves of the currents and voltages at the level of the load, represented by figure 3.5, show very large ripples on the two signals, thus losing their rectilinear shape. As shown in Figure 3.6, the use of the filter in the power grid eliminates ripples in the signals and thus improves the shape and quality of the signals.

Spectral analysis signals power sources

Supply voltage wave

Figure 3.7 and figure 3.8, represent the harmonics rate variations as a function of frequency, of the voltages phase A power supply generator.

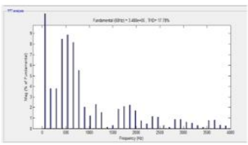

Figure 3.7: Source phase A voltage spectrum without using the filter

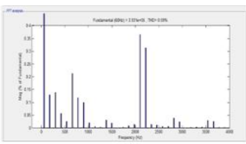

Figure 3.8: Source phase A voltage spectrum using the filter

The spectral analysis of the curve in figure 3.7, representing the waveform of the source voltage at phase A, before use of the filter in the electrical network, reveals the presence of a high level of harmonics of rank 2 and rank 4, with a harmonic distortion rate of THD = 17.78%. After the use of the passive filter in the electrical network, we observe, the spectral analysis of the curve in figure 3.8, presents a harmonic distortion rate THD = 0.59% with elimination of harmonics of frequencies between 500Hz and 2000Hz, and those whose frequency is higher than 2500Hz, thus improving the signal quality.

supply current wave

Figure 3.9 and figure 3.10, represent the harmonics rate variations as a function of frequency, of the current phase A power supply generator.

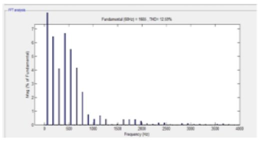

Figure 3.9: Source phase A current spectrum without using the filter

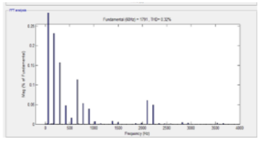

Figure 3.10: Source phase A current spectrum using the filter

As for the analysis of the source voltages, the spectral analysis of figure 3.9, representing the curve of the source currents at the level of phase A, before the use of the filter in the electrical network, shows that, the signal has a high level of harmonics from order 3 to order 7, with a harmonic distortion rate of THD = 12.59%. On the other hand, after the use of the passive filter in the electrical network, the spectral analysis of the curve in figure 3.10, shows a harmonic distortion rate THD = 0.32% with elimination of harmonics of frequencies between 1000Hz and 2000Hz, and those whose frequency is higher than 2250Hz, thus improving the signal quality.

CONCLUSION

In conclusion, the oscillations due to the generation of harmonics are eliminated by the resonant filters and the high-pass shunt filter which provide a low impedance for current harmonics and thus limit the harmonic voltages transferred to the network. However, these filters together with the supply impedance cause resonances at other frequencies.

The figure 3.6 shows that the impedance Zeq has low values at the frequencies of the 5th and 7th harmonics, however its value is important at the frequencies of the 6th and 5th harmonics, which can cause the amplification of these harmonics if they occur.

The resistors are inserted into the filters to dampen these resonances but the losses increase. Another solution is the application of sharp resonant filters able to follow the change in the conditions of the network to ensure dynamic characteristics of harmonic filtering or resonance damping.

BIBLIOGRAPHIE

[1] Hirofumi Akagi, « Control strategy and site selection of a shunt active filter for damping of harmonic propagation in power distribution systems», IEEE Transactions on Power Delivery, Vol. 12, No 1, pp.354-363, January 1997.

[2] Su Chen and Géza Joos « Analysis and comparison of passive and active harmonic suppression filters in distribution systems», Electrical and Computer Engineering, 2000 Canadian Conference,Vol. 2 , pp.615-619, 7-10 March 2000.

[3] M.J. Bridgeman, Norman MacLeod, S.B. Tennakoon, and R.E. Morrison, « The resonance damping effect associated with linear shunt loads and single-phase converters», Harmonies and Quality of Power, 2000. Proceedings. Ninth International Conference, Vol. 2, pp.535-540, 1-4 October 2000.

[4] Evan J. Currence, John E. Plizga, and Howard N. Nelson, « Harmonie resonance at medium-sized industrial plant», IEEE Transactions on Industry Applications, Vol. 31, No4, pp.682-690, July/August 1995.

[5] Fang Z. Peng, Gui-Jia Su, and George Farquharson « A series LC filter for harmonie compensation of ac drives», Power Electronics Specialists Conference, PESC 99. 30th annual IEEE, VoLl , pp. 213-218, 1999.

[6] H. Sasaki and T. Machida, « A new method to eliminate ac harmonic currents by magnetic compensation-consideration on basic design», IEEE Transactions on Power Appl. Syst.,Vol. 90, No 5, pp.2009-2019, 1971.

[7] Fang-Zhang Peng, Hirofumi Akagi, and Akira Nabae, Fellow, IEEE, «A study of active power filters using quad-series voltage-source PWM converters for harmonic compensation», IEEE Transactions on Power Electronics, Vol. 5, No 1, pp. 9-15, January 1990.

BIOGRAPHY

Mathangila Kimeya, diploma from Engineering 1978 UNIKIN in D.R of Congo, Master degree 2004 of Electrical Engineering KUL of (Belgum)- and PhD student in engineering sciences of the University of Brazzaville-Congo.

Dr. Gogom Mathurin, PhD In Engineering Sciences, Dept. Of Electricity.
ENSP-UMNG Electrical Engineering Research Laboratory

Dr. Gomba Rodolphe, PhD In Engineering Sciences, Dept. Of Electricity.
ENSP-UMNG Electrical Engineering Research Laboratory
Speciality : Energy and protection of the electrical network . He is General-Manager of the National Rural Electrification Agency (ANER).

Dr.Ir Lidinga Mobonda Flory, PhD In Engineering Sciences, Dept. Of Electricity.
ENSP-UMNG Electrical Engineering Research Laboratory
Speciality : Automatiques de systèmes énergétiques et méthode numérique des opérations industrielles
National President of the National Network of Engineers of Congo (RNIC).

Rodrigue Armel Patrick Okemba PhD in engineering sciences of The University of Brazzaville-Congo.
ENSP-UMNG Electrical Engineering Research Laboratory. He is expert of rural electrification (decentralized) using photovoltaic systems.

Haroun Abba Labana, PhD student in engineering sciences of The University of Brazzaville-Congo. ENSP-UMNG Electrical Engineering Research Laboratory

Prof. Dr NSONGO Timothée, Ph.D is presently lecturer at the University of Brazzaville-Congo, Dept.physics. Speciality: Physics/Materials science