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Method of Calculation the Load Rates and the Unbalance Rates of the Current of the Phases in the MV/LV Network of the Sales and Service Center Lemba in Kinshasa

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ABSTRACT: In this article, we discuss the calculation of load and current imbalance rates, which is a steady-state study of the distribution network that consists of determining, for each subscriber station, the operating rate of the installed power transformer and the current difference between two phases of the MV/LV distribution station. Knowing the allowable currents of each low-voltage phase of the subscriber substations from the busbars as well as the rated current of the substations transformer, we can calculate, secondly, the average currents and load factors of the substations including the differences between the currents and their unbalance factors in the low-voltage distribution power lines. The mathematical equations of the electrical quantities of the power system facilitate the evaluation of the performance of the power transformer. These equations confirm that the variation in load ratio and current imbalance of three phases are closely related to the current draw of the allowable loads at each phase.

KEYWORDS: Load rate, Lemba in Kinshasa, MV/LV network, Unbalance of the phase current.

I. INTRODUCTION

Electrical energy is a very relevant factor for the development of society, its operation requires monitoring of current and voltage of phases in the distribution network [1][2]. However, an electrical network, even if it is installed according to the standards, is always subject to various disturbances in operation, such as unbalance of current and voltage of phases.

Phase voltage unbalance refers to the capacity of a power system and the radius of the low voltage lines, for a given initial operating condition [3][4]. On the other hand, the phase current imbalance is said to be related to the way subscribers are connected to the different phases of the distribution network.

We have observed several scenarios on the MV/LV electrical substations that supply an intolerable number distribution subscribers in the city of Kinshasa. Many of the substations operate with phase imbalances, which even influence the quality of electrical energy. These imbalances are due to the way subscribers are connected to the phases of the distribution network in the LEMBA area of KINSHASA. There is a voltage drop beyond the tolerable limit and the burning of low voltage cables.

The operation of a three-phase network ideally requires that the voltage and current amplitudes are respectively equal on each of the three phases with an angle of 120 degrees [5][6]. The low-voltage network supplies mostly single-phase loads. Even if the distributor tries to distribute them evenly over the three phases, the variability of the consumption generates an unbalance phenomenon.

Any voltage imbalance greater than 2% will cause equipment to overheat, making it necessary to oversize to avoid premature degradation [5][6] [7]. A good load distribution, a static compensator and a judicious setting of the protections against current imbalance allow an optimal exploitation of the electrical network by the subscribers.

These phase imbalances are solved by mathematical equations and simulated by Matlab software.

This article consists in calculating the power transformer load rates and the phase current imbalance rates in the MV/LV distribution network of the LEMBA center in Kinshasa.

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I.1 Load rate equation

The phase currents, average currents, rated current and load ratio are calculated by formulas (1), (2) and (3) :

$$Imoy = \frac{I_1 + I_2 + I_3}{3} \quad (1)$$

$$Tx(\%) = \frac{I_{moy}}{I_n} \times 100 \quad (2)$$

$$Tx(\%) = \frac{I_{pointe}}{I_n} \times 100 = \quad (3)$$

I.2 Current imbalance equation

$$\text{Déséq}(\%) = \frac{I_{max} - Iécart}{I_{moy}} \times 100 \quad (4)$$

Imax-écart=MAX (Imoy-I_R, Imoy-I_S, Imoy-I_T)

$$\text{Imoy} = \frac{I_R + I_S + I_T}{3} \quad (5)$$

$I_R + I_S + I_T$: phase currents.

The imbalance rate must be greater than or equal to 15% Utilization coefficient Ku

$$\text{Ku} = \frac{\text{Imoy}}{\text{In}} \quad (6)$$

Discounted Utilization Coefficient

$$\text{K'u} = \text{Ku} + \left(\left(\frac{20 \times \text{Ku}}{100}\right)\right) \quad (7)$$

I.3 Procedure for remediation of an electrical network

An electrical network which has within it a given number of electrical transformers of apparent power (S_{n1}), load rate (T_{x1}), S_{n2}, T_{x2}, ..., S_{nn}, T_{xn} must be reinforced for a given horizon, which is to limit the operating cost by maintaining the high level of reliability with constraints related to the environment. The total installed apparent power of the network to be remediated by the formula (8):

$$S_{nt} = S_{n1} + S_{n2} + S_{n3} + \cdots + S_{nn} \quad (8)$$

Formula (9) is used to determine the average load of the power system to be sanitized.

$$T_{xmoy} = \frac{T_{x1} + T_{x2} + T_{x3} + \cdots + T_{xn}}{n} \quad (9)$$

discharge transformer is determined by the formula (10) :

$$S_c = \frac{T_{xmoy} \times S_{nt}}{k \times T_x} - Snt \quad (10)$$

The number of transformers to be installed on the network to be repaired is determined by formula (11) :

$$N_{tfo} = \frac{S_c}{X_x \times S_u} \quad (11)$$

The calculation of the total apparent power to the network to be remediated is determined by the formula (12).

$$S_{T_{xmoy}} = \frac{T_{x\,moy} \times Sn_t}{100} \quad (12)$$

II. DATA OF CVS LEMBA

II.1 nominal characteristics of MV/LV substations

Poste MT/BT	S (kVA)	U (kV)	In (A)	I_1 (A)	I_2 (A)	I_3 (A)	Imoy (A)	Tx(%)
Aruwimi	630	6.6/0.4	909.3	736	721	726	727.66	80.02
Basanga	630	6.6/0.4	909.3	610	680	660	650	71.48

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Echangeur	630	6.6/0.4	909.3	730	658	698	695.33	76.46
Fwa	630	6.6/0.4	909.3	754	742	764	753.33	82.84
Kasumu	1600	6.6/0.4	2309.3	989	1010	990	996.33	43.14
Kimafiki	1000	6.6/0.4	1443.2	893	892	880	888.33	61.55
Kiyimbi 1	630	6.6/0.4	909.3	710	717	718	715	78.63
kiyimbi 2	630	6.6/0.4	909.3	725	730	705	720	79.18
Lemba mixte	630	6.6/0.4	909.3	495	515	481	497	54.65
Loange	630	20/0.4	909.3	596	608	590	598	65.76
Lubefu	630	6.6/0.4	909.3	230	246	238	238	26.17
Luenda	630	6.6/0.4	909.3	590	610	585	595	65.43
Lufuku	630	20/0.4	909.3	775	794	786	785	86.33
Lulonga	630	20/0.4	909.3	744	760	758	754	82.92
Mohiya	630	20/0.4	909.3	600	625	635	620	68.18
Mondobwe	630	6.6/0.4	909.3	615	605	640	620	68.18
Mpukulu	630	6.6/0.4	909.3	633	640	656	643	70.71
Ngaba 1	630	6.6/0.4	909.3	610	645	635	630	69.28
Ndongala	630	6.6/0.4	909.3	716	681	686	694.33	76.35
Paka 1	500	6.6/0.4	721.6	615	631	630	625.33	86.65
Paka 2	630	6.6/0.4	909.3	654	661	625	646.66	71.11
Ruzizi	630	6.6/0.4	909.3	505	510	625	546.66	60.11
Saint Augustin	630	6.6/0.4	909.3	607	610	625	614	67.52
Somida	800	6.6/0.4	1155	1052	1098	1025	1058.33	91,63
Tshangala	630	6.6/0.4	909.3	610	621	625	618.66	68.03
Tokwaulu	630	6.6/0.4	909.3	605	612	625	614	67,52
Tuana 11	630	6.6/0.4	909.3	433	425	625	494.33	54.36
Tuana 12	630	6.6/0.4	909.3	156	145	125	142	15.61
Tuana 2	1000	6.6/0.4	1443.2	376	390	625	463.66	32.12
Tuana 3	630	6.6/0.4	909.3	604	605	625	611.33	67.23
Katanga	630	6.6/0.4	909.3	321	322	625	422.6	46.48
Lonzo	630	6.6/0.4	909.3	583	550	625	586	64.44

II.2 Analysis of MV/LV substations

II.2.1 Analysis of the current in MV/LV substations

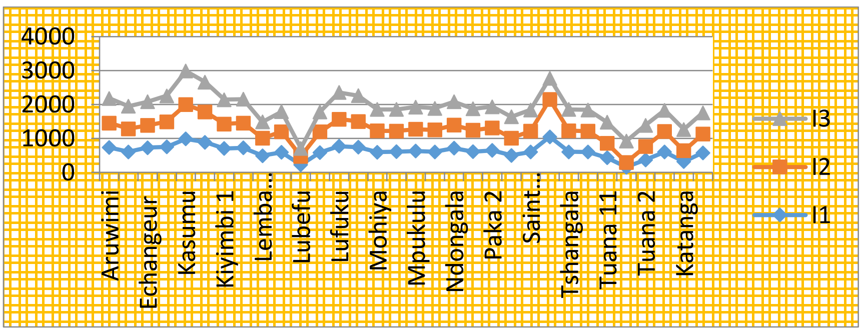

Figure 1 : Analysis of the current in MV/LV substations

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Figure (1) shows the analysis of the phase current in MV/LV substations. The blue curve shows the current of the first phase which varies between 156 A (Tuana12 substation) and 1052 A (Somida substation). The red curve shows the current of the second phase which varies from 145 A (Tuana12 substation) to 1098A. (Somida substation) The green curve shows the current of the third phase which varies from 125 A (Tuana12 substation) to 1025.(Somida substation).

II.3.2 Analysis of the average current of MV/LV substations

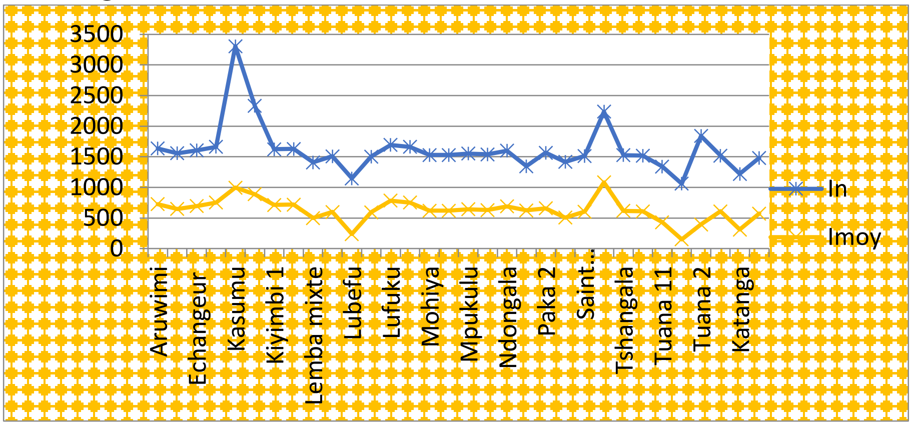

Figure 2 : Analysis of the average current of the phases in MV/LV substations

Figure (2) shows the variations in the behavior of the average current of the phases in the MV/LV substations. The blue curve shows the nominal current of all the substations, which varies between 721.6 A (Paka1 substation) and 2309.3 A (Kasumu substation). The purple curve shows the average current of all the substations, which varies between 142 A (Tuana12 substation) and 1058 A (Somida substation).

II.2.3 Analysis of transformer loading rates in MV/LV substations

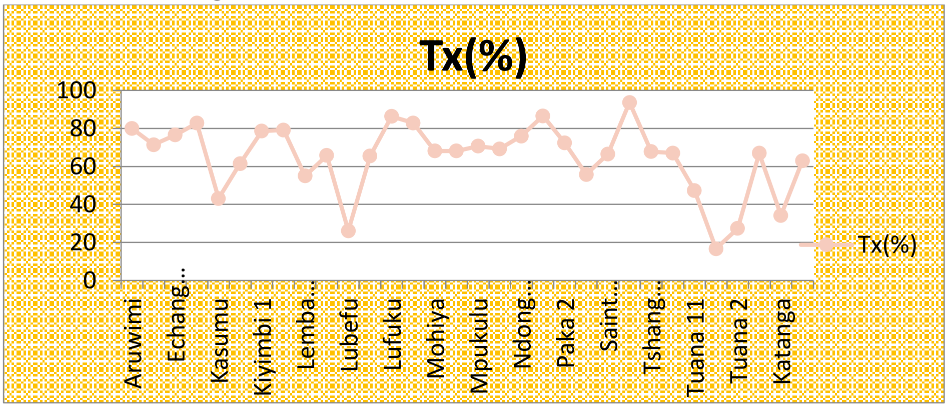

Figure 3 : Analysis of phase current behavior in MV/LV substations

Figure (3) illustrates the transformer loading rate in the MV/LV substations. We see that the load rate varies from 15.61% (Tuana12 substation) to 91.63% (Somida substation).

III. UNBALANCE OF PHASE CURRENT

III.1 Analysis of phase current gaps in MV/LV substations

It should be noted that during a fault, load shedding or overload of a feeder or a zone, subscribers can connect in a disordered way on one of the phases. And often, this creates overloads, burns cables or strips in a cabin. In our case, Lemba has at least 33 cabins that are supplied at 6.6 kV and 20 kV with different powers, 630 kVA, 800 kVA or 1,000 kVA.

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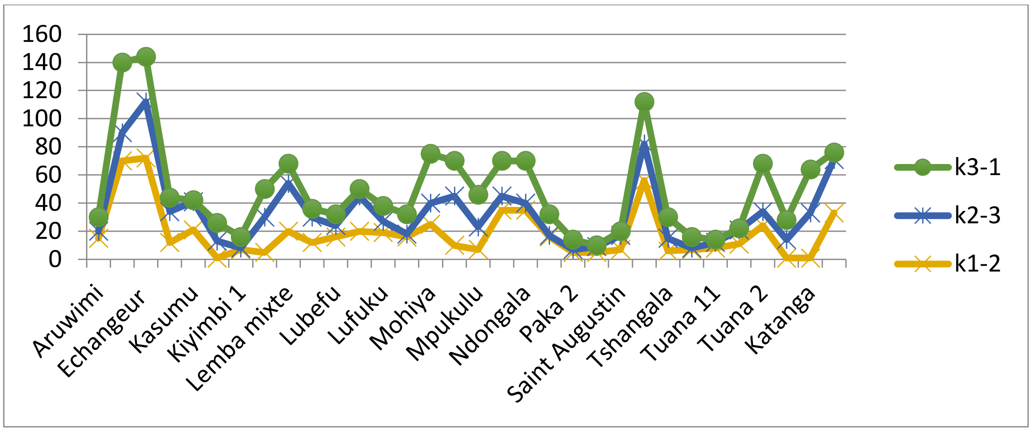

Figure 4 : Analysis of phase current behavior in MV/LV substations

Figure (4) shows the phase current deviations in the MV/LV substations. The yellow curve shows the current deviation between phase one (1) and phase two (2), which varies from 1A (Kimafiki substation and Tuana3 cabin and Katanga cabin) to 72 A (Echangeur substation). The blue curve shows the current difference between phase two and phase three, which varies from 1A (Kiyimbi substation 1, Paka1 substation) to 303 A (Katanga substation). The green curve shows the current difference between phase three (3) and phase one (1), which varies from 5A (Luenda substation) to 304A (Katanga substation).

III.2 Analysis of phase current imbalance in MV/LV substations

So, during a load shedding we can calculate the behavior of the current in one of the phases and we will take the smallest and the largest value of the departure fed by the current 1 and 2 for the 32 cabins of CVS Lemba. The same for the current 2 and 3, and 3 and 1 whose result was the object of the simulation of the software MatLab and the result will be expressed in percentage (Tx%) as illustrated on the figure (5).

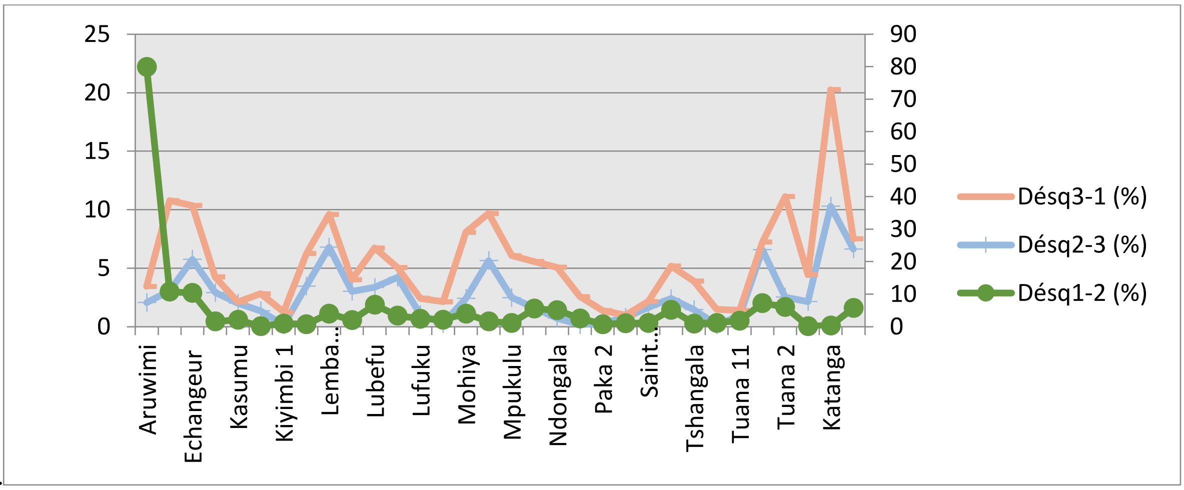

Figure 5 : Analysis of phase current behavior in MV/LV substations

The purple graph shows the current imbalance rate between phase one and phase two, which varies from 0.1126% (Kimafiki substation) to 10.769% (Basanga substation). The blue curve shows the current imbalance rate between phase two and phase three, which varies from 0.13986% (Kiyimbi 1 substation) to 97.427% (Katanga substation). The purple curve shows the current imbalance between phase three and phase one, which varies between 0.01% (Kiyimbi 1 substation) and 79.349% (Katanga substation).

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III.3 Analysis of phase current gaps in MV/LV substations at 630 kVA

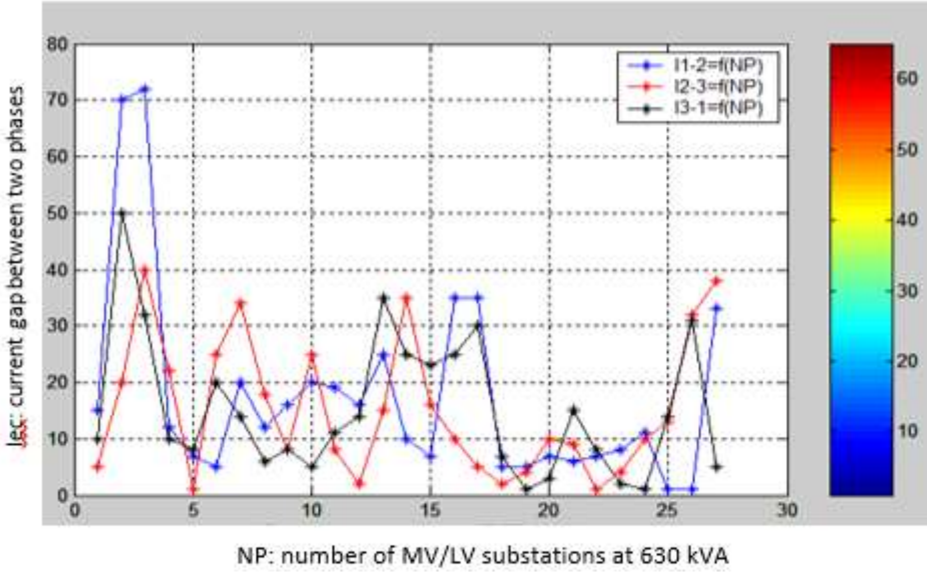

Figure 6 : Analysis of phase current behavior in MV/LV substations

Figure (6) shows the phase current deviations in the 630kVA MV/LV substations. The blue curve shows the current gap between phase one (1) and phase two (2), which varies from 1A (Tuana3 substation, Katanga substation) to 72 A (Echangeur substation). The red curve shows the current deviation between phase two (2) and phase three (3), which varies from 1A (Kiyimbi 1 substation) to 303 A (Katanga substation). The black curve shows the current difference between phase three and phase one, which varies from 5A (Luenda substation) to 304A (Katanga substation).

III.4 Phase current gaps in MV/LV substations not at 630 kVA

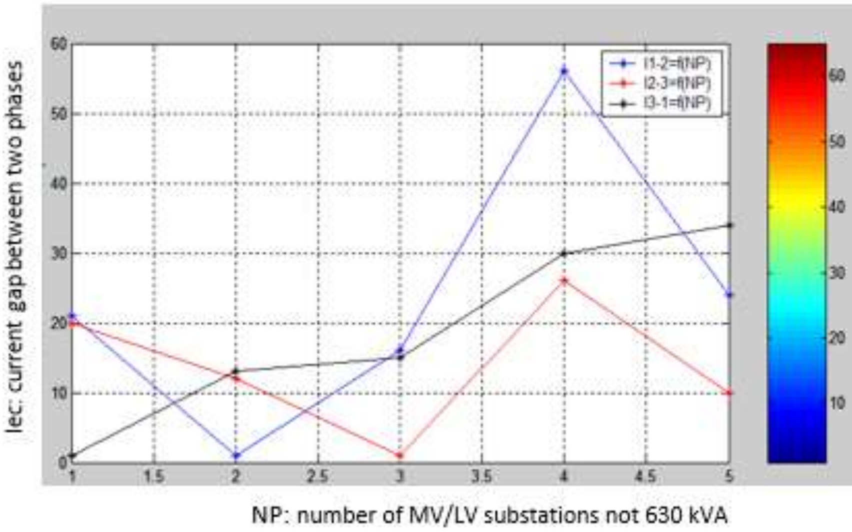

Figure 7: Analysis of phase current behavior in MV/LV substations

Figure (7) shows the curves of the phase current gaps in the MV/LV substations (Kimafiki, Somida, Pakal 1 and Kasumu) not at 630kVA. The blue curve shows the current difference between phase one (1) and phase two (2), which varies from 1A (Kimafiki substation) to 46A (Somida substation). The red curve shows the current gap between phase two (2) and phase three (3), which

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varies from 1A (Paka1 substation) to 73A (Somida substation). The black curve shows the current gap between phase three and phase one, which varies between 1A (Kasumu substation) and 27 A (Somida substation).

III.5. Analysis of phase current differences in MV/LV substations at 6.6 kV

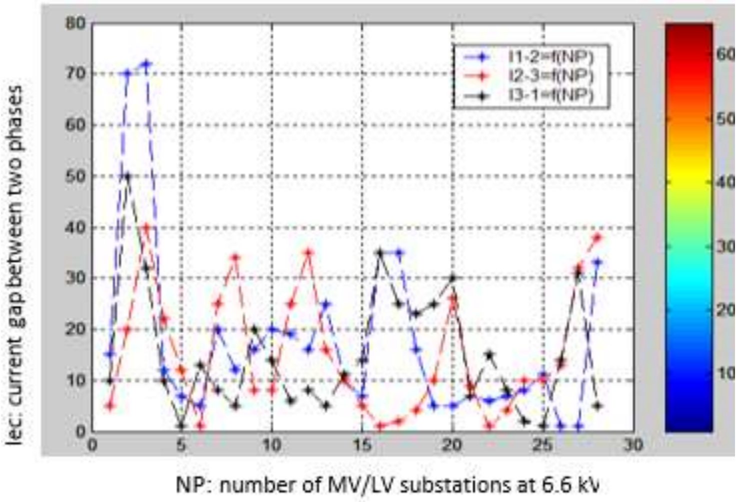

Figure 8 : Analysis of phase current behavior in MV/LV substations

In figure (8), the phase current deviations in MV/LV substations at 6.6kV are shown. The blue curve shows the current gap between phase one (1) and phase two (2), which varies from 1A (Kimafiki, Tuana3 and Katanga substations) to 72 A (Echangeur substation). The red curve shows the current gap between phase two (2) and phase three (3), which varies from 1A (Kiyimbi 1, Paka1 substations) to 303 A (Katanga substation). The black curve shows the current difference between phase three (3) and phase one (1), which varies between 5A (Luenda substation) and 304A (Katanga substation).

III.6 Analysis of phase current gaps in MV/LV substations at 20 kV

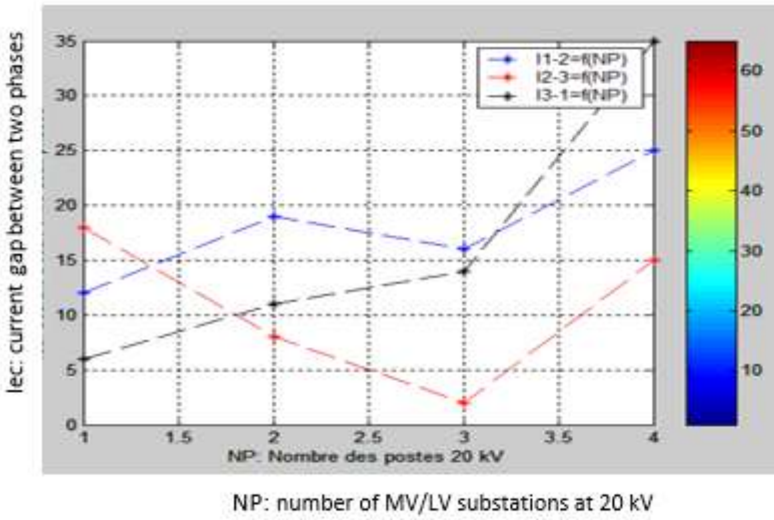

Figure 9 : Analysis of phase current behavior in MV/LV substations

We have analyzed on figure (9), the gaps of the current of the phases in the MV/LV substations at 20kV. The blue curve shows the current difference between phase one and phase two (2), which varies from 12A (Loange substation) to 25A (Mohiya substation). The red curve shows the current gap between phase two (2) and phase three (3), which varies from 2A (Lulonga cabin) to 18A

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(Loange station). The curve in black, the current difference between phase three (3) and phase one (1) varies between 6A (Loange substation) to 35A (Mohiya substation).

III.7 Phase current unbalance in MV/LV substations at 630 kVA

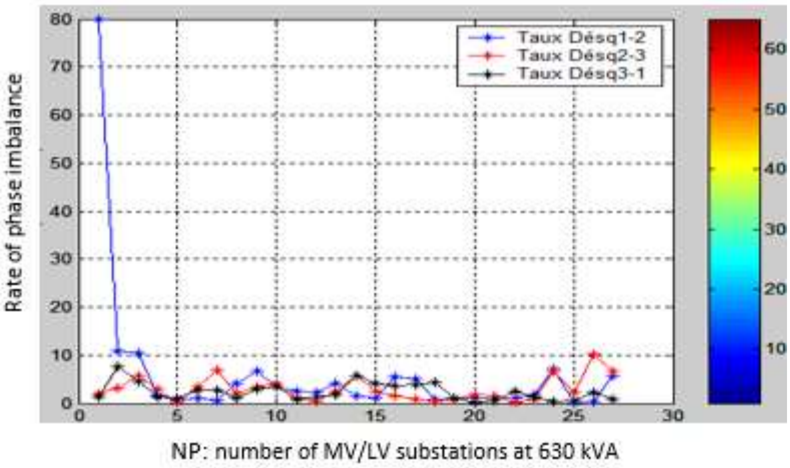

Figure 10 : Analysis of phase current behavior in MV/LV substations

In figure (10), we have represented the variation of the current unbalance of the phases in the MV/LV substations at 330kVA. The blue curve shows the rate of current unbalance between phase one (1) and phase two (2), which varies from 0.16% (Tuana3 substation) to 10.769% (Basanga substation). On the red curve, the rate of current imbalance between phase two (2) and phase three (3) varies from 0.13986% (substation Kiyimbi 1) to 97.4276% (substation Katanga). The curve in black shows the current imbalance between phase three (3) and phase one (1) varies between 0.01% (substation Kiyimbi 1) and 97.74% (substation Katanga).

III.8 Phase current unbalance in MV/LV substations below 630 kVA

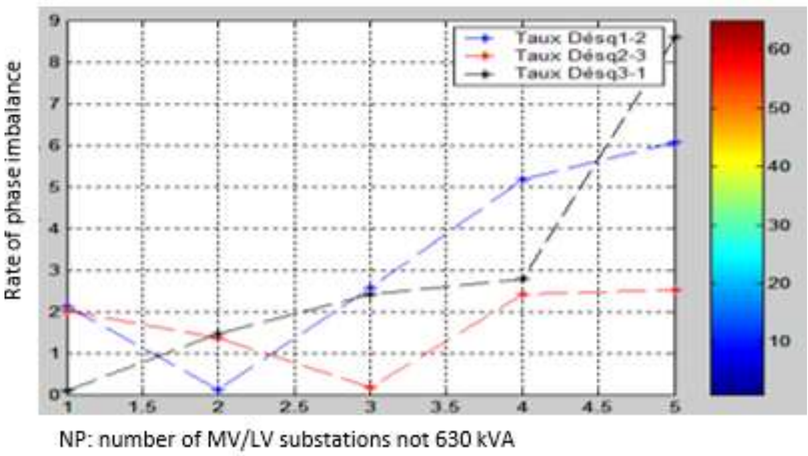

Figure 11 : Analysis of phase current behavior in MV/LV substations

In figure (11), we have plotted the rate of unbalance of the current of the phases in the MV/LV substations as a function the number of substations not at 630kVA. The blue curve shows the unbalance rate between phase one (1) and phase two (2), which varies from 0.1126% (Kimafiki substation) to 4.251% (Somida cabin). On the red curve, the rate of current imbalance, between phase two (2) and phase three (3) varies between 0.16% (Paka 1 substation) to 59.343% (Tuana2 substation). The curve in black, the current imbalance between phase three (3) and phase one (1) varies between 0.1% (Kasumu substation) to 62.9% (Tuana2 substation).

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III.8 Phase current imbalance in MV/LV substations not at 6.6 kV

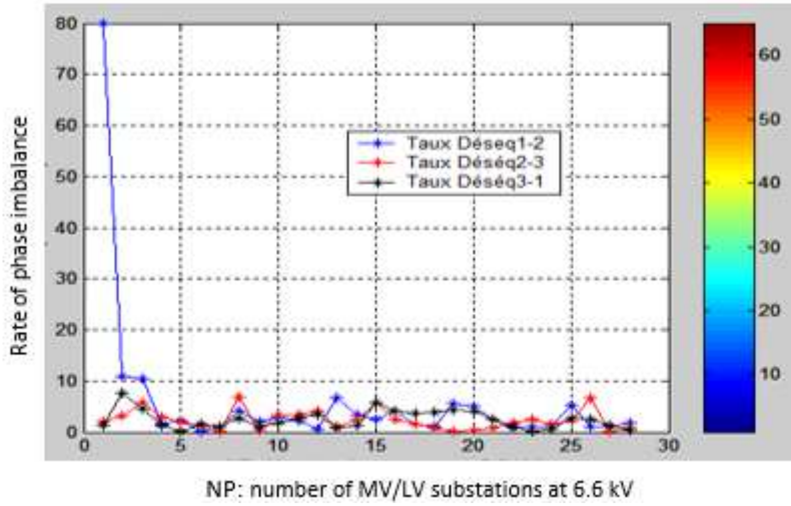

Figure 12 : Analysis of phase current behavior in MV/LV substations

Figure 12 represents the rate of phase current unbalance in the substations (Mohiya, Lulonga and Loange) as a function of the number of 6.6 kV substations. The blue curve shows the current unbalance rate between phase one (1) and phase two (2), which varies from 2.06% (Loange substation) to 4.03% (Mohiya substation). On the red curve, the rate of current imbalance between phase two (2) and phase three (3) varies between 0.26% (Lulonga substation) and 3.01% (Loange substation). The curve in black, the current unbalance rate, between phase three (3) and phase one (1) varies between 1.03% (Loange substation) to 5.64% (Mohiya substation).

III.10 Phase current unbalance in MV/LV substations at 20 kV

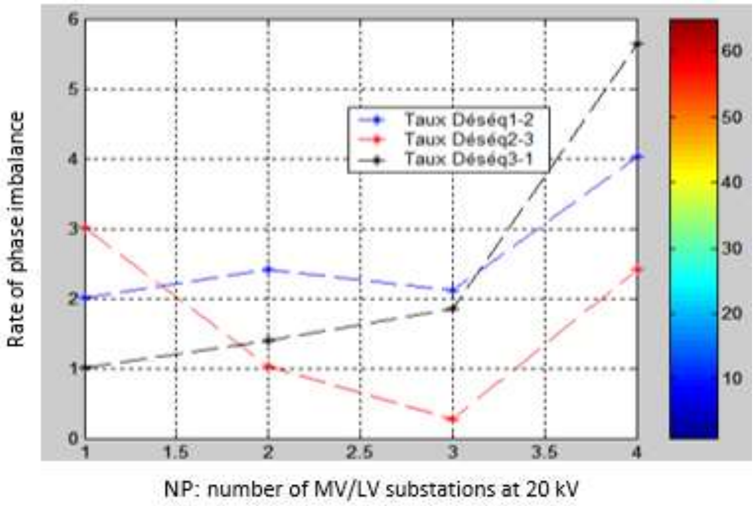

Figure **13 :** Analysis of the behaviour of the phase imbalance rate of MV/LV substations

We have plotted in Figure 13 the rate of unbalance of the phase current in the substations (Mohiya, Lulonga and Loange) as a function the number of substations at 20 kV. On the blue curve, the rate of current unbalance between phase one (1) and phase two (2) varies from 2.006% (Loange substation) to 4.032% (Mohiya substation). The curve in red color, current imbalance rate pattern, between phase two (2) and phase three (3) varies between 0.265% (Lulonga substation) to 3.01% (Loange substation). On the black curve, the rate of imbalance between phase three (3) and phase one (1) varies between 1.003% (Loange substation) to 5.65% (Mohiya substation).

CONCLUSION

We have seen that this article consisted in calculating the power transformer load rates and the phase current unbalance rates in the MV/LV distribution network. The mathematical equations used for each method reflect the operation of the different MV/LV substations. We applied these equations on the substations of the sales and service center of the municipality of Lemba, from the simulation with Excel software for the rates of loads of each substation. This paper presented the numerical results to determine the differences between the phase current and the unbalance rates of the phase current on the low voltage lines. The developed equations allowed us to evaluate the operating system of the power distribution network by using the Matlab software to simulate the results. In general, our results question the three-phase distribution system in the MV/LV distribution network in force insofar as the subscribers hang on the available phase, during the cut or absence of a phase of the electrical network. However, the implementation of a new power distribution system will also involve the improvement of power quality. The prepaid meter distribution system is an alternative to balancing the MV/LV distribution network.

REFERENCES

1. ALIDOU KOUTOU, 2015 : Étude des déséquilibres d'amplitude et de phase des tensions d'un réseau a câbles de garde isolés de lignes de transport d'énergie électrique, thèse de l'université du Québec à trois-rivières.
2. Chompoo-inwai, W.Lee, P.Fuangfoo, M.Williams, R.Liao, 2005 : «System impact study for the interconnection of wind generation and utility system», IEEE Trans. Industry Applications, vo141, pp. 163-168, Jan-Feb.
3. Gatta F. M., lliceto F., Life F., Lauria S., Masato P, 2005 : Balancing methods of the "3-phase" shield wire schemes ". Power Tech, IEEE Russia, Digital Object Identifier: 1 0.11 09/PTC.
4. I.S.Brahami, 20016 : Etude d'un poste de transformation HTA/BT de distribution d'énergie électrique, Laboratoire Intelligent Control and Power Electrical Systems
5. M. Bollen, 1999 : Understanding Power Quality Problems. Voltage Sags and Interruptions, Wiley-IEEE Press.
6. I1iceto F, Gatta F. M, S. Lauria, G. Dokyi, "Three-Phase and Single- Phase Electrification in Developing Countries Using the Insulated Shield Wires of HV Lines Energized at MV, /1 in Proc. CI RED 1999, Nice (France), Paper N° 5/pl0.
7. Cinieri E, «A New Lossless Circuit Balancing the MV Distribution Systems From lnsulated Shield Wires ofHV Lines," in Proc. IEEE T&D Conf 1999.

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