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Method for Calculating Load Rates and Phase Current Unbalance Rates in the M/Bt Network of the Lemba Sales and Service Center in Kinshasa.

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

Key words: Calculation method, Current unbalance, Phase, Distribution network, MT/BT

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I. INTRODUCTION

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. The low-voltage network largely supplies single-phase loads. Even if the distributor tries to distribute them evenly over the three phases, the variability of consumption generates a phenomenon of imbalance. Any voltage imbalance greater than 2% leads to overheating of the equipment, which requires oversizing to avoid premature degradation. Proper load distribution, a static compensator and a judicious setting of protections against current imbalances allow optimal use of the electrical network by subscribers. These phase imbalances are resolved by mathematical equations and simulated by Matlab software.

II. ELECTRICAL NETWORK EQUATIONS

II.1 Electrical parameters

II.1.1 Load rate equation

The phase currents, average currents, rated current and load rate are calculated using the formulas below:

$$Imoy = \frac{I_1 + I_2 + I_3}{3} = \qquad (2.1)$$

$$Tx\% = \frac{I_{moy}}{I_n} x100 = \qquad (2.2)$$

$$Tx\% = \frac{I_{pointe}}{I_n} x100 = \qquad (2.3)$$

II.1.2 Current imbalance equation

$$\text{Déséq} = \% = \frac{I_{max} - Iécart\ x\ 100}{I_{moy}} \quad (2.4)$$

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

$$\text{Imoy} = \frac{I_R + I_S + I_T}{3} (2.5)$$

$I_R + I_S + I_T$: phase currents.

The unbalance rate must be greater than or equal to 15% Ku utilization coefficient

$$\text{Ku} = \frac{\text{Imoy}}{\text{In}} \quad (2.6)$$

Coefficient d'utilisation actualisé

$$\text{K}'\text{u} = \text{Ku} + \left(\left(\frac{20 \text{ x Ku}}{100}\right)\right) \quad (2.7)$$

Considering that the maximum admissible temperature in the windings is 120°C, which corresponds to operation at 1.25 In in a balanced regime, let us study the overload capacity of a transformer as a function of the unbalance factor.

II.1.3 Procedure for cleaning up an electrical network

An electrical network which includes within it a given number of electrical transformers of apparent power (Sn1), load rate (Tx1), Sn2, Tx2,…, Snn, Txn must be reinforced for a given horizon, which is to limit the operating cost while maintaining the high level of reliability with constraints related to the environment.

$$S_{nt} = S_{n1} + S_{n2} + S_{n3} + \cdots + S_{nn} \quad (2.8)$$

II.1.4 Determine the average charge rate

The formula below makes it possible to determine the average load rate of the electrical network to be sanitized by:

$$T_{xmoy} = \frac{T_{x1} + T_{x2} + T_{x3} + \cdots + T_{xn}}{n} \quad (2.9)$$

II.1.5 Sanitation station equation

Determine discharge transformer by the formula below:

$$S_c = \frac{T_{xmoy} \text{ x } S_{nt}}{kTx} - Snt \qquad (2.10)$$

II.1.6 Power equation of the sewer network

Determine the number of transformers to be installed in the network to be cleaned up using the formula below:

$$N_{tfo} = \frac{S_c}{XxS_u} \qquad (2.11)$$

II.1.7 Sanitation Transformer Power Equation

Calculation of the discharge transformer elements to be installed in the network to be cleaned up, which is:

$$N_{bre\ de\ départ} = \frac{I_{n_{tfo}}}{I_{n_{cond}} \text{ x } k_{T_x}} \quad (2.12)$$

The total apparent power to the network to be cleaned up by formula below-:

$$S_{T_{xmoy}} = \frac{T_{x\,moy} \text{ x } Sn_t}{100} \quad (2.13)$$

II.1.8 Calculation of total active power

The total active power to the network to be cleaned up by formula below:

$$P_t = S_{T_{xmoy}} \cos ö \quad (2.14)$$

II.2 Technical data of CVS LEMBA

Cabine	I1 (A)	I2 (A)	I3 (A)	Imoy (A)	Tx(%)
Aruwimi	736	721	726	727,66	80,02
Basanga	610	680	660	650	71,48
Echangeur	730	658	698	695,33	76,46
Fwa	754	742	764	753,33	82,84
Kasumu	989	1010	990	996,33	43,14
Kimafiki	893	892	880	888,33	61,55
Kiyimbi 1	710	717	718	715	78,63
kiyimbi 2	725	730	705	720	79,18
Lemba mix	495	515	481	497	54,65
Loange	596	608	590	598	65,76
Lubefu	230	246	238	238	26,17
Luenda	590	610	585	595	65,43
Lufuku	775	794	786	785	86,33
Lulonga	744	760	758	754	82,92
Mohiya	600	625	635	620	68,18
Mondobwe	615	605	640	620	68,18
Mpukulu	633	640	656	643	70,71
Ngaba 1	610	645	635	630	69,28
Ndongala	716	681	686	694,33	76,35
Paka 1	615	631	630	625,33	86,65
Paka 2	654	661	625	646,66	71,11
Ruzizi	505	510	625	546,66	60,11
Saint Augustin	607	610	625	614	67,52
Somida	1052	1098	1025	1058,33	91,63
Tshangala	610	621	625	618,66	68,03
Tokwaulu	605	612	625	614	67,52
Tuana 11	433	425	625	494,33	54,36
Tuana 12	156	145	125	142	15,61
Tuana 2	376	390	625	463,66	32,12
Tuana 3	604	605	625	611,33	67,23
Katanga	321	322	625	422,6	46,48
Lonzo	583	550	625	586	64,44

III. PHASE CURRENT IMBALANCE

III.1 Analysis of phase current deviations in MT/BT substations

It should be noted that during a fault, load shedding or overload of a feeder or a zone, subscribers can connect in a disorderly fashion to one of the phases. And often, it creates overloads, burnt cables or strips in a cabin. In our case, Lemba has more or less 33 cabins which are supplied with 6.6 kV and 20 kV with different powers, 630 kVA, 800 kVA or 1,000 kVA.

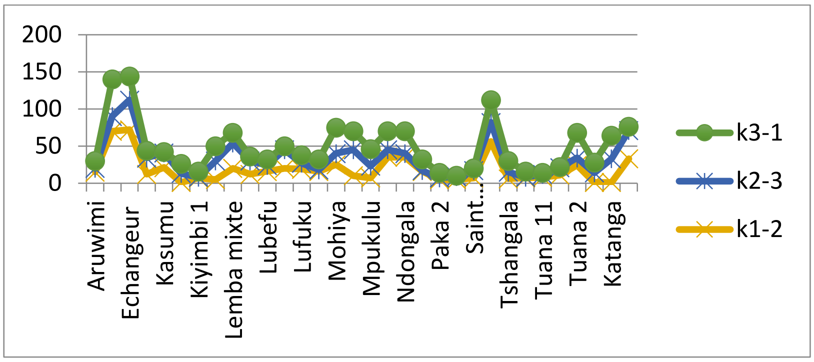

Figure III.1: Analysis of phase current deviations in MT/BT substations

The yellow curve shows the current difference between phase one and phase two, which varies from 1A (Kimafiki substation and Tuana3 cabin and Katanga cabin) to 72 A (Echangeur substation). The curve in blue shows the current difference between phase two and phase three, which varies between 1A (Kiyimbi 1 substation Paka1) to 303 A (Katanga substation). The green curve shows the current difference between phase three and phase one, which varies between 5A (Luenda substation) to 304 A (Katanga substation).

III.2 Phase current unbalance analysis in MT/BT substations

It should be noted that during a fault or load shedding of a feeder or a zone, subscribers can connect to one of the phases. And often, this creates overloads, burnt cables or strips which can create imbalances in the currents of the phases in a cabin. In our case, Lemba has more than 33 substations which are supplied with 6.6 kV and 20 kV with different powers, 630 kVA, 800 kVA or 1,000 kVA. Then, 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 starting value supplied by the current 1 and 2 for the 32 cabins of CVS Lemba. Ditto for current 2 and 3 and 3 and 1, the result of which was simulated by the MatLab software and the result will be expressed as a percentage (Tx%) Cfr result below:

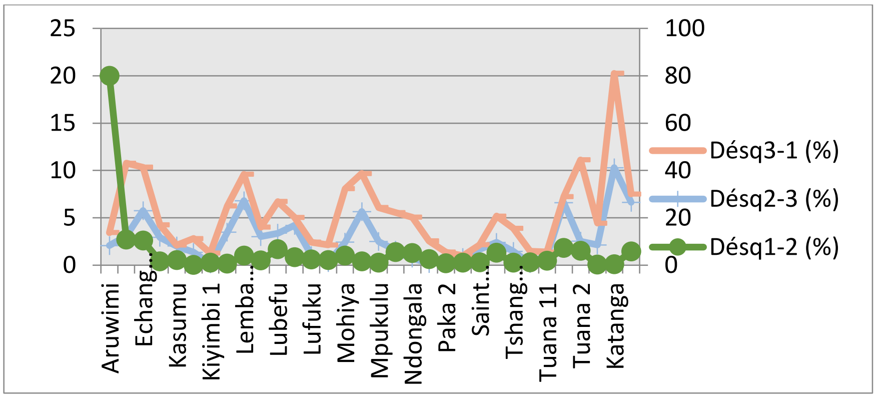

Figure III.2 : Phase current unbalance analysis in MT/BT substations

The purple curve shows the rate of current unbalance, between phase one and phase two, which varies from 0.1126% (Kimafiki substation) to 10.769% (Basanga substation). The blue curve shows the rate of current unbalance, between phase two and phase three, which varies between 0.13986% (Kiyimbi 1 substation) to 97.427% (Katanga substation). The curve in purple color gives the appearance of the current imbalance, between phase three and phase one, which varies between 0.01% (Kiyimbi1 substation) to 79.349% (Katanga substation).

III.3 Analysis of phase current deviations in MT/BT substations at 630 kVA

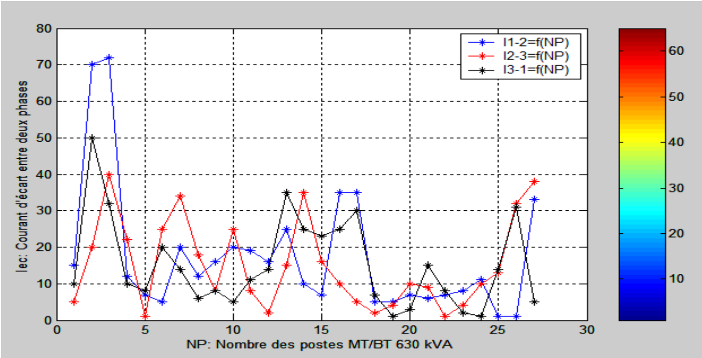

Figure III.3: Analysis of phase current deviations in MT/BT substations at 630 kVA

The blue curve shows the current difference between phase one and phase two, which varies from 1A (Tuana3 substation, Katanga substation) to 72 A (c Echangeur substation). The curve in red shows the current difference between phase two and phase three, which varies between 1A (Kiyimbi 1 substation) to 303 A (Katanga substation). The curve in black gives the appearance of the current difference between phase three and phase one, which varies between 5A (Luenda substation) to 304A (Katanga substation).

III.4 Phase current deviations in MT/BT substations not at 630 kVA

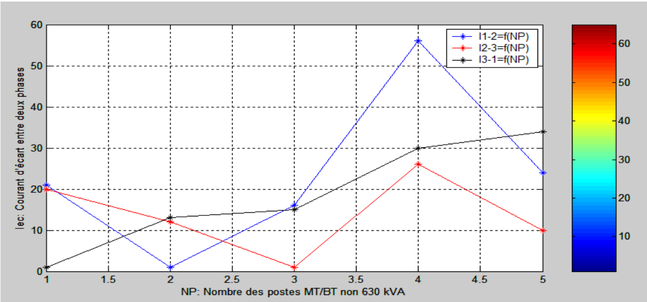

Figure III.4: Phase current deviations in MT/BT substations not at 630 kVA

The curve in blue gives the current difference between phase one and phase two, which varies from 1A (Kimafiki substation to 46A (Somida substation). The red curve gives the current difference , between phase two and phase three which varies between 1A (Paka1 substation) to 73 A (Somida substation).The curve in black gives the current difference between phase three and phase one which varies between 1A (Kasumu station) at 27 A (Somida station).

III.5. Analysis of phase current deviations in MT/BT substations at 6.6 kV

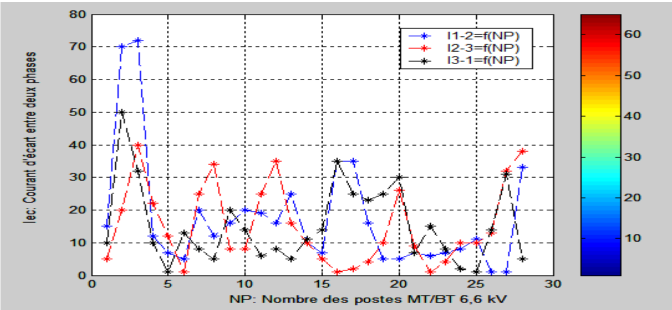

Figure III.5: Analysis of phase current deviations in MT/BT substations at 6.6 kV

The blue curve shows the current difference between phase one and phase two, which varies from 1A (Kimafiki, Tuana3 and Katanga substations) to 72 A (Echangeur substation). The curve in red shows the current difference between phase two and phase three, which varies between 1A (Kiyimbi 1, Paka1 substations) to 303 A (Katanga substation). The curve in black gives the appearance of the current difference between phase three and phase one, which varies between 5A (Luenda substation) to 304 A (Katanga substation).

III.6 Analysis of phase current deviations in MT/BT substations at 20 kV

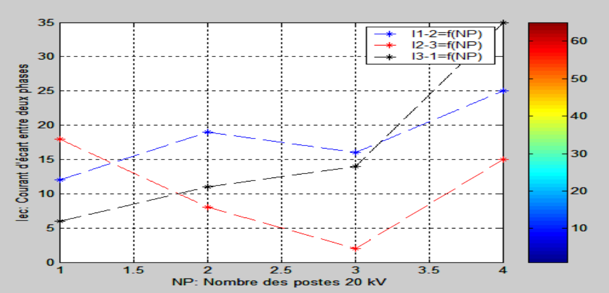

Figure III.6: Analysis of phase current deviations in MT/BT substations at 20 kV

The blue curve shows the current difference between phase one and phase two, which varies from 12A (Loange substation) to 25A (Mohiya substation). The red curve shows the current difference between phase two and phase three, which varies between 2A (Lulonga cabin) to 18 A (Loange substation). The black curve shows the current difference between phase three and phase one, which varies between 6A (Loange substation) to 35 A (Mohiya substation).

III.7 Phase current imbalance in MT/BT substations at 630 kVA

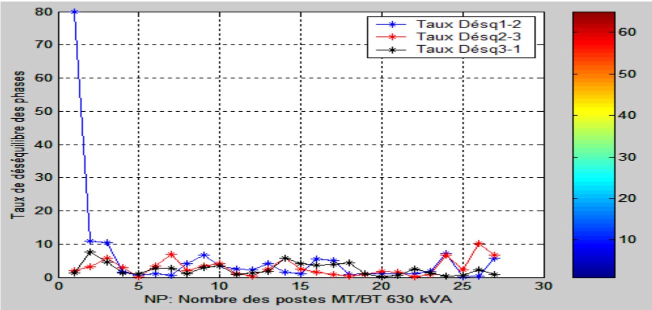

Figure III.7: Phase current imbalance in MV/LV substations at 630 kVA

The blue curve shows the current unbalance rate, between phase one and phase two, which varies from 0.16% (Tuana3 substation) to 10.769% (Basanga substation). The curve in red color gives the appearance of the current unbalance rate, between phase two and phase three, which varies between 0.13986% (Kiyimbi 1 substation) to 97.4276% (Katanga substation). The black curve shows the current imbalance between phase three and phase one, which varies between 0.01% (Kiyimbi1 substation) to 97.74% (Katanga substation).

III.8 Phase current imbalance in MT/BT substations not at 630 kVA

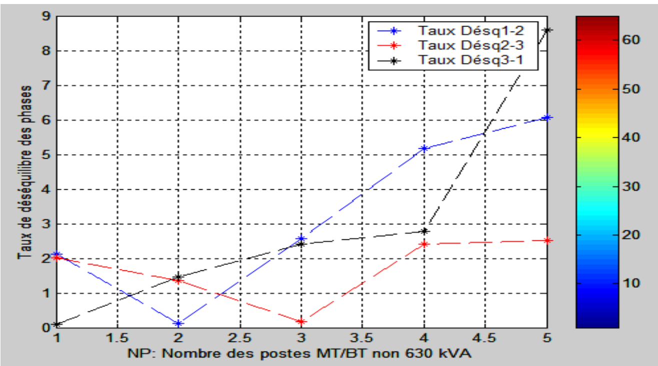

Figure III.8: Phase current imbalance in MT/BT substations not at 630 kVA

The blue curve shows the current unbalance rate, between phase one and phase two, which varies from 0.1126% (Kimafiki substation) to 4.251% (Somida cabin). The red curve shows the current unbalance rate, between phase two and phase three, which varies between 0.16% (Paka 1 substation) to 59.343% (Tuana2 substation). The curve in black color gives the appearance of current imbalance, between phase three and phase one, which varies between 0.1% (Kasumu substation) to 62.9% (Tuana2 substation).

III.8 Phase current unbalance in MT/BT substations not at 6.6 kV

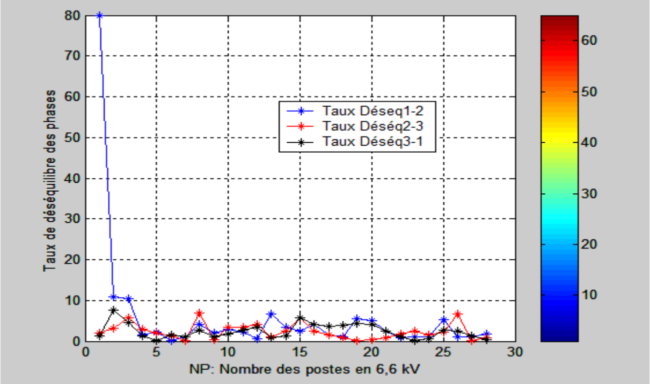

Figure III.9: Phase current unbalance in MT/BT substations not at 6.6 kV

The blue curve shows the current unbalance rate, between phase one and phase two, which varies from 2.06% (Loange substation) to 4.03% (Mohiya substation). The red curve shows the current unbalance rate, between phase two and phase three, which varies between 0.26% (Lulonga substation) to 3.01% (Loange substation). The black curve shows the current unbalance between phase three and phase one, which varies between 1.03% (Loange substation) to 5.64% (Mohiya substation).

III.10 Phase current imbalance in MT/BT substations at 20 kV

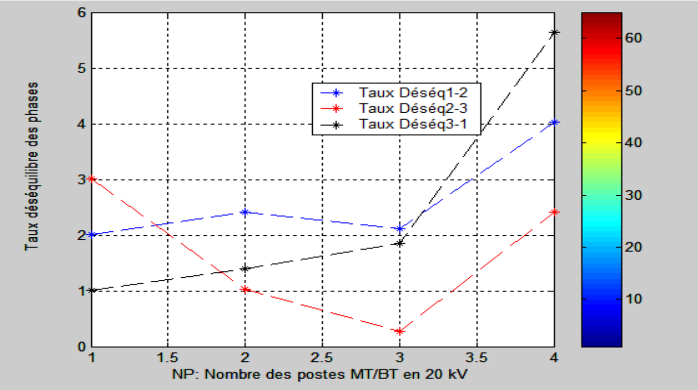

Figure III.10: Phase current imbalance in MT/BT substations at 20 kV

The blue curve shows the rate of current unbalance, between phase one and phase two, which varies from 2.006% (Loange substation) to 4.032% (Mohiya substation). The red curve shows the current unbalance rate, between phase two and phase three, which varies between 0.265% (Lulonga substation) to 3.01% (Loange substation). The curve in black color gives the appearance of the current imbalance, between phase three and phase one, which varies between 1.003% (Loange substation) to 5.65% (Mohiya substation).

IV. CONCLUSION

We have seen that this article consisted of 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 operating mode of the various MV/LV substations. We applied these equations to the positions of the sales and service center of the municipality of Lemba, resulting from the simulation with Excel software for the rates of charges for each position.

This article presents the numerical results used to determine the deviations between the phase current and the phase current unbalance rates on low voltage lines. The developed equations allowed us to evaluate the operating system of the electrical power distribution network through the use of Matlab software for the simulation and interpretation of the results.

In general, our results call into question the three-phase distribution system in the MV/LV distribution network in force insofar as the subscribers cling to the available phase, during the cut or absence of a phase of the network electric.

However, the implementation of a new electrical energy distribution system will also involve improving the quality of energy. The prepayment meter distribution system is an alternative to balancing the MV/LV distribution network.

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