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Reduction of the losses on the electric distribution network Low tension of the Beninese Company of Electrical energy (SBEE)

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ABSTRACT: *The authors approached in this article, the problems of the losses on the distribution network of electrical energy of the Beninese Company of Electrical energy more precisely in district NVENOUMEDE and various approaches for their minimization.*

According to the international standards in force, the maximum voltage drop of a network should not exceed 10% of the nominal voltage. At the conclusion of measurements taken by the authors, the voltage drop is about 79,52% between phase and neutral and of 68,42 between phases. Thus, the network causes enormous nuisances to the subscribers and maintains a permanent conflict between supplier and consumers.

The various approaches simulated by the authors made passed the voltage drop fall of phase from 79,52% to 10,75% and the losses active from 243 kW to 33 kW respectively variations of 86,5% and 92,12%.

KEYWORDS: *Dispersed PV Generation, Distribution network, Energy losses, Network reconfiguration, Voltage drop*

I. INTRODUCTION

The voltage drop and the active losses of an electrical distribution network are very important factors of appreciation of the quality of energy provided by a distributer. In the cities of the commune of Abomey Calavi, the quality of distributed energy is strongly threatened. Inadmissible voltage drops are regularly recorded. The measuring devices give 60 V for the measurements taken between phase and neutral instead of 220 V while for measurements between phases, we often read 120 V instead of 380 V.

Taking into account the dearness of electrical energy, the distributer is held to at least limit the losses of energy on its network. According to [1], [2], [3], [4] and [5], the reconfiguration of the network is a good alternative for the distributer, because it makes it possible to reduce the active power, to balance the loads of the system, to improve the profile of voltage in the nodes, to increase the safety and the reliability of the system, just as the improvement of the quality of power. Several forms of reconfiguration can be considered, in particular the displacement of the separation points, the adjustment of the taps.

In this document, the authors proposed the reconfiguration of low voltage (LV) distribution network, mainly by building new high voltage (HV) lines and also identifying the node of the center of gravity of the loads where the transformer must be connected; then, the authors suggested the connection of photovoltaic mini-power stations to the network studied to precise nodes [6].

The undertaken study and the results obtained are based on the real problems encountered on the LV electric line which feeds zone Pk 14 of district NVENOUMEDE of the commune of Abomey-Calavi.

II. Material and methodology

II.1 Characteristics of the studied network: The characteristics of the studied network are summarized in table 1:

Table 1: General characteristics of LV network of Nvènoumèdé and of transformer HV/LV

	Parameters	**Value**
Nodes	Nodes number	132
Line	LV customers number	2632
	Current called at the peak	391 A
	Developed length of feeder	6864 m
	Length of the most distant point	2022 m
	Section of lines	50 mm²
Transformer	Primary voltage (kV)	15
	Secondary voltage (V)	400
	Nominal power (kVA)	400
	Voltage of short-circuit	4%
	No-load Losses (W)	460
	No-load current (nominal In)	2,3%

II.2 Mathematical formulation of the objective to be optimized: The problem of optimization is related to one or more objectives which one tries to minimize (or to maximize). The main objective that the authors considered is: the minimization of the losses Joules. They expressed this objective by mathematical expressions which are integrated in the algorithms of optimization.

II.2.1 The losses Joules: To express this objective in an algorithm of optimization, the authors used the expression:

$$f_{objectif} = \sum_{k} R_k . I_k^2 \quad (1)$$

where: R_k : the resistance of the branch K;

I_k: the module of the complex current in the branch K;

To minimize the expression (1) led to a reduction of one of the costs of exploitation.

II.2.2 Formulation of the constraints of safety: *The constraints of safety* are the constraints related to the voltage on the level of each node of the network and with the currents on each branch of the network.

II.2.3 Amplitude of the voltage: It is necessary thus, when we seek a network configuration, that the voltage in each node lies between $V_{nominal} = \pm 5\ \%$ for HV distribution network and $U_{nominal} = +6$ and $-10\ \%$ for LV distribution network (according to the European and French standard in particular). This constraint is expressed by the expression:

$$\frac{V_{in} - V_i}{V_{in}} < \varepsilon_{i\ max} \quad (2)$$

where : V_{in} : nominal voltage to node i

V_i : module of voltage to node i

$\varepsilon_{i\ max}$: variation of maximum voltage acceptable

II.2.4 Acceptable currents: The constraint of safety is related to the currents on the branches which should not exceed the acceptable maximum currents in permanent mode, guaranteed by the manufacturers. It is expressed by the relation:

$$\frac{|I_j|}{I_{j\max\ adm}} < 1 \quad (3)$$

where I_j: the current on the branch j

$I_{j\max\ adm}$: the acceptable maximum current in the branch j

II.3 Modeling of the network: Fig.1 presents the studied network, which was entirely modeled under NEPLAN. The course of LV network to its various nodes was raised with a GPS. Fig.2, always result obtained under software Neplan shows the level of voltage drop of the network in its actual position. This voltage drop varies from 10,12 to 79,52%. The more we move away from the transformer, the more the value of the voltage drop moves away from the value fixed by the standard.

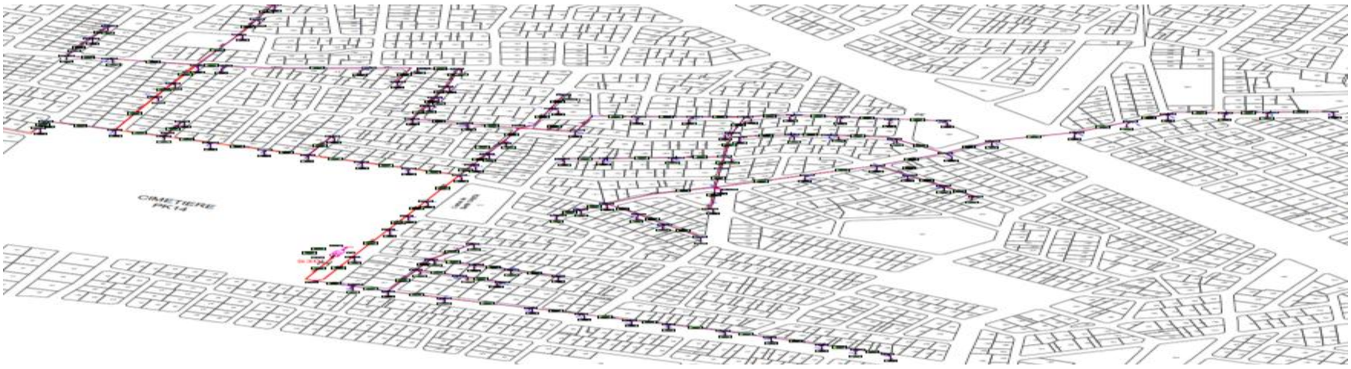

Figure 1: Model of the configuration of LV network of Nvènoumèdé PK 14 obtained under NEPLAN

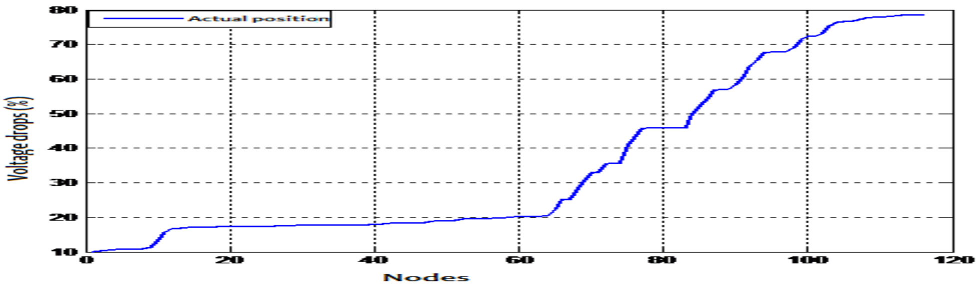

Figure 2: Actual position of LV network in three-phase current

With the analysis of these two figures we note the influence of two factors on the technical performances of the distribution network:

II.3.1 Structural factor: The structure and the characteristics of the low voltage network studied presents an irregular distribution over a length of network of approximately 6 km which outdistance the consumers of more than $2\,km$ of the transformer for wires whose section is of $3 \times 50\ mm^2$. That leads to inadmissible voltage drops.

The voltage drop in a line is evaluated by the vectorial representation of Fig.3.

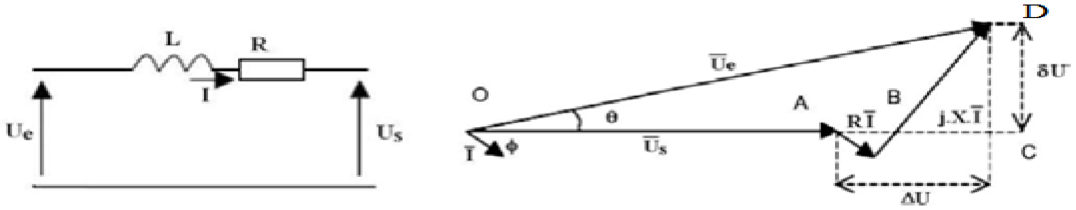

Figure 3: Vectorial representation of the voltage drop

In practice, we can admit that the voltage OC = OD and voltage drop in the wires are represented by AC. Thus, we can write: $AB = RI \times \cos\Phi$ (4)

$$BC = L\omega I \times \sin\Phi \quad (5)$$

$$AC = AB + BC = I \times (R\cos\Phi + L\omega\sin\Phi)$$

Thus, the voltage drop in the wire Δu is expressed by the following equation: (6)

$$\Delta u = I \times (R\cos\Phi + L\omega\sin\Phi) \quad (7)$$

Where, R is the resistance of wire (Ω), $L\omega$ the inductive reactance of the wire (Ω), I the current (A) and Φ dephasing. The relation of the voltage drop depends on type of line to knowing single-phase or three-phase. Then, for a single-phase line, the equation is given by:

$$\Delta u = 2I \times (R\cos\Phi + L\omega\sin\Phi) \quad (8)$$

For a balanced three-phase line, the equation is given by:

$$\Delta u = 3I \times (R\cos\Phi + L\omega\sin\Phi) \quad (9)$$

In these case, the line of distribution is three-phase and the expression of the current can be given by:

$$I = \frac{P}{U\sqrt{3}\cos\emptyset} \quad (10)$$

where, P is the power (W) and U the voltage (V).
Thus, the equation (10) can be represented by the following equation:

$$\Delta u = \frac{P}{U}\sqrt{3}(R + L\omega\tan\emptyset) \quad (11)$$

From this equation, we deduce the following equation:

$$\frac{\Delta u}{u} \times 100 = 100\frac{P}{U^2}\sqrt{3}(R + L\omega\tan\emptyset) \quad (12)$$

However $R = r \times l$ and $L = x \times l$
The expression (12) becomes:

$$\frac{\Delta u}{u} \times 100 = 100\frac{P}{U^2}\sqrt{3}(r + x\omega\tan\emptyset) \times l \quad (13)$$

With, P is the power in Watts, U the voltage in volts, R and $L\omega$ in Ω.
While expressing R and $L\omega$ in Ω/km and the length of the line by l, the preceding equation becomes:

$$\frac{\Delta u}{u} \times 100 = 100\frac{P \times l}{U^2}(R + L\omega\tan\emptyset) \quad (14)$$

II.3.2 Demographic factor : The district Nvènoumèdé PK14, there is still that a few years, was tiny room to a population installed in the perimeters of cemetery PK14 close to the inter-states road Cotonou-Lome. But today it largely extended with a strong population which does not cease increasing. This situation contributes to the continuous degradation of the functional parameters of the network and influences negatively the quality of the electrical energy provided to the consumers exposed thus to frequent disturbances.

II.3.3 Influence of photovoltaic voltage injected on the voltage of the network: The contribution of the voltage provided by the photovoltaic system is the difference between the voltage drop (ΔV) in the line with and without a photovoltaic generator. The relation of the voltage drop at the end of a balanced three-phase line having length l is given as follows:

$$\Delta V = \int_0^x I(l)Z(l)\,dl \quad (15)$$

with, the current (I) and impedance (Z) function of the length (l) of the line.

A photovoltaic generator reduced the voltage drop by reducing the current which forwards by the line. The contribution of the voltage by the photovoltaic system in a given point, example of the point (B) of Fig.4, is the difference in voltage drop with and without photovoltaic system:

$$\Delta V_B = \int_0^A [I(l) - I_{pv}]Z(l)dl + \int_A^B I(l)Z(l)\,dl \quad (16)$$

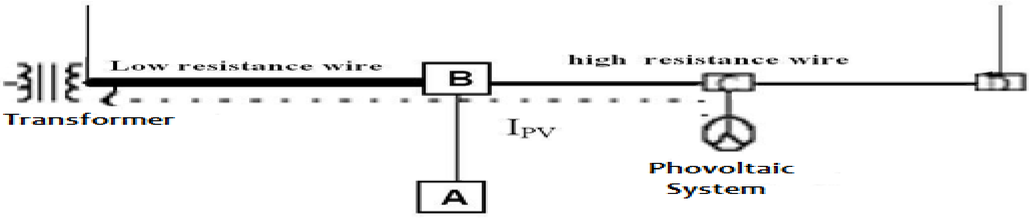

Figure 4: Photovoltaic voltage injected in the electrical line

As the current provided by the photovoltaic generator is constant, the equation (13) can be written as follows:

$$\Delta V_B = \int_0^B I(l)Z(l)dl - I_{pv}Z_A \quad (17)$$

where Z_A is the total impedance of the line of transformer up to point A.

The contribution of the voltage of the photovoltaic generator is given by the following relation:

$$VS_B = I_{pv}Z_A \quad (18)$$

Thus, the contribution of the photovoltaic tension at any point of the line is equal to the product of the photovoltaic current and the impedance of the line between the transformer and the photovoltaic generator.

III. RESULTS

III.1 Simulation with displacement of the transformer: With an aim of reducing the associated costs to the creation of a new transformer we analyzed the option of a simple optimal displacement of the existing transformer named Pk14 and calculated the level of improvement that could bring.

The curve of Fig.5 shows that for this option, the voltage drop expressed in % is reduced meadows of half, but still not meeting the standards in force.

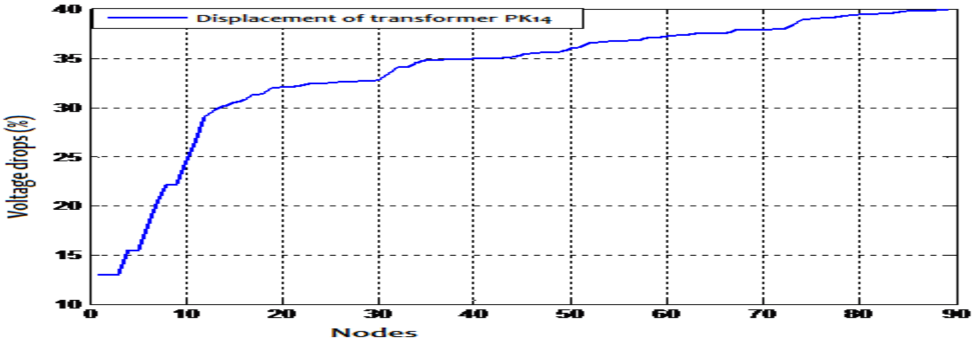

Figure 5: Variation of the voltage drop according to the nodes (case of reconfiguration by displacement of the initial station)

III.2 Simulation with displacement of transformer plus injection of an autonomous source:

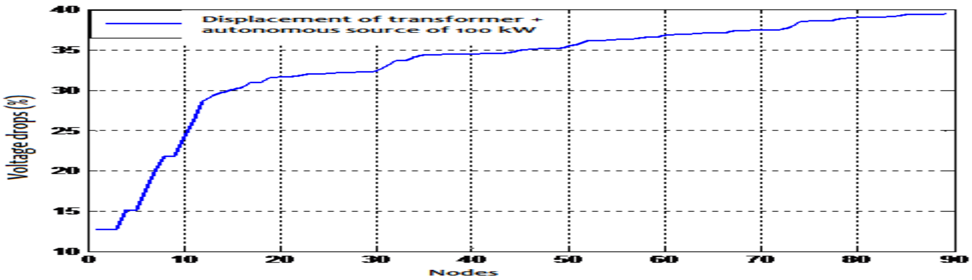

Figure 6: Variation of the voltage drop according to the nodes (case of reconfiguration by displacement of the initial transformer plus injection of an autonomous source)

The shape of the curve of Fig.5 and the level of the voltage drops show that the situation remains unchanged and the voltage drop to the node more degraded remains important, that is to say approximately 40%.

III.3 Simulation of the actual position plus creation of new transformer : While maintaining the initial transformer to its current location, we sought the most optimal position of the new transformer which would improve the tension with all the nodes and which would discharge the current transformer and the derivation low tension lines affected as shown in the Fig.7. The latter indicates the choice of the position of the new transformer.

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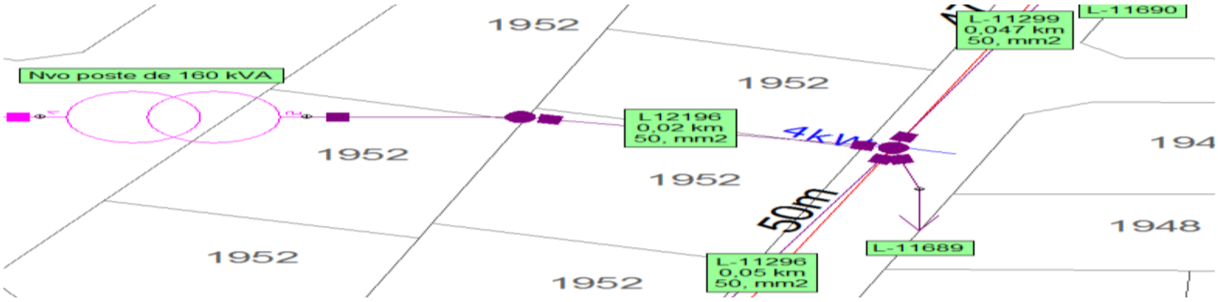

Figure 7: Choice of the position of the new transformer

With this position chosen, we successively connected the transformers of 50 kVA, 100 kVA and of 160 kVA and each time we compared the load circulating with the normal load which the initial transformer of 400 kVA can support. Results obtained, only the transformer of 160 kVA enables us to satisfy this condition and to reduce the voltage drops to the node more degraded to 10.75%. The results obtained of this simulation made it possible to plot the curve of Fig.8 which is variation of the voltage drop according to the nodes (case of reconfiguration with transformer).

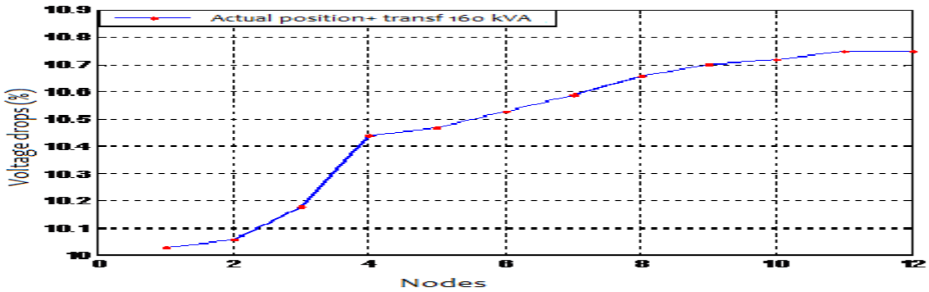

Figure 8: Variation of the voltage drop according to the nodes (case of reconfiguration with transformer)

However this option would suffer in the event of degradation from the voltage source coming from the Electric Community of BENIN (CEB) and which drops sometimes in lower part of 20%. Thus, the authors have proposed the autonomous addition of source for better appreciating the profile of the voltage drop.

III.4 Simulation of the actual position plus an additional autonomous PV source: Consequently we sought to replace the transformer by an autonomous additional source and to carry out a new simulation. This time we successively injected powers of 50.75 and 100 kW. Fig.9 shows the evolution of the voltage drop for these various powers.

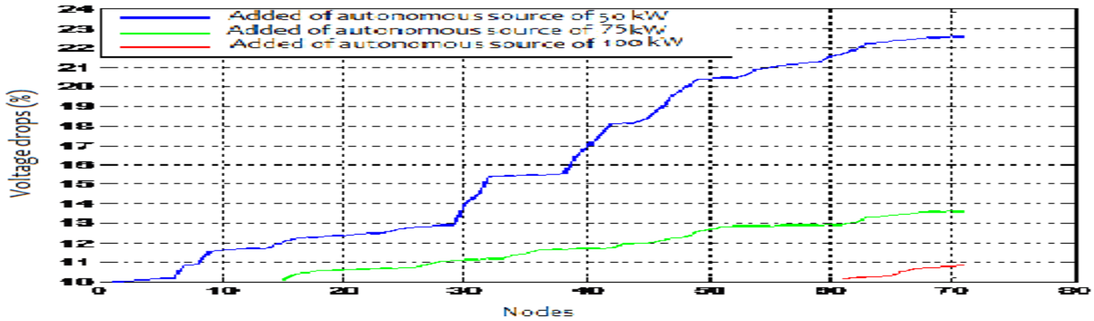

Figure 9: Evolution of the voltage drop with variation of the power of the autonomous source

III.5 Synthesis of the analyzes of simulation: To carry out the best alternative of solution to be applied to give satisfaction to the zone Pk14, we established the layout of Fig.10 which gathers the results of all simulations carried out (variation of the voltage drop according to the nodes) as well as the impact of improvement that they bring.

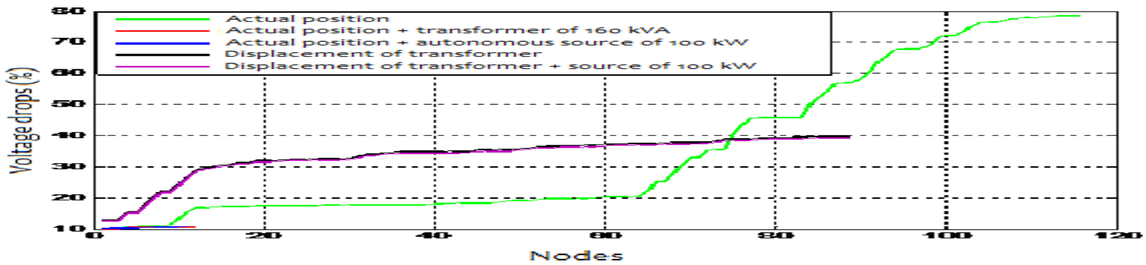

Figure 10: Variation of the voltage drop according to the nodes (case of all simulations carried out**)**

The levels of satisfaction justifying our choice and which also reduces the level of the active losses in the network are consigned in table 2.

Table 2: Important results of various simulations

	Actual position	Actual position + station of 160 kVA	actual position + autonomous source of 100 kW	Displacement of the station	Displacement of the station + autonomous source of 100 kW
Number affected nodes	116	12	11	89	89
Number overloaded elements	32	0	0	12	12
Level of load of the principal station	113 % 485.9 kW	68.37% (294 kW)	86.27% (371 kW)	107.67% (463 kW)	87.9% (378 kW)
Active losses	243 kW	33 kW	37 kW	57 kW	49 kW
Minimal voltage drop	10.01	10.03	10.12	13.01	12.72
Maximum voltage drop	79.52	10.75	10.82	39.04	39.39

IV. DISCUSSION

Analysis of the summary graph of Fig.10, it arises that only the solutions of creation of new transformer of 160 kVA or injection of autonomous additional source of power 100 kW make it possible to improve quality of the voltage and the energy distributed in the zone of Nvènoumèdé Pk14.

Because of quality sometimes degrading (although rare) of source from CEB, the solution which consist to inject additional autonomous source of 100 kW appears the best satisfactory to us.

It appears, when the length l of the dipole or the resistance of cable, or the power called increase, the drop voltage increases proportionally. But it decreases proportionally with the square of the tension. It is what explains the voltage drops on the network studied of Nvènoumèdé and which vary from 10 to 79,56% as we move away from the transformer; this also explains the nuisances related to the bad quality of the power provided to the customers.

V. CONCLUSION

The results obtained for the two types of possible solutions are very satisfactory. The insertion of the photovoltaic systems in the electrical distribution network improves the voltage in end of network and decreases the current forwarded by the line.

Thus, it is shown by various simulations which as well the insertion of the photovoltaic renewable energy sources as the creation of a new station can have the same technical repercussions on BT network.

The choice between the two solutions will take place only after the economic evaluation of the two systems. The economic evaluation will have the aim of determining the costs of each approach.

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