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Influence choice of the injection nodes of energy source on on-line losses of a distribution network

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ABSTRACT: *One of the problems which contribute today to the energy dependence of Benin to more (90%) in 2012 of its own production constitutes the losses, of which on-line losses. Certain more remarkable consequences of this situation constitute the energy low level of cover, the large financial losses for the Distribution firm of Benin (SBEE). The object continued by the authors is to determine with precision, the points of injection of the photovoltaic power stations to connect to the distribution network of the SBEE in order to minimize on-line losses. With this intention, the authors have with the premium on board modeled with software NEPLAN, the network "COTONOU-EST" of the SBEE. They have according to the results obtained with NEPLAN, dimensioned with the software PVsyst the photovoltaic power stations. The behavior of the power stations was studied using Matlab/Simulink. Lastly, the authors determined by simulation with software NEPLAN the points of injection minimizing on-line losses.*

Keywords: *Electrical network, Electrical energy, On-line losses, photovoltaic Energy, Node of injection.*

I. Introduction

The liberalization of the energy sector, but especially the energy problem of deficit very accentuated in certain countries in the process of development like Benin, makes that the managers of the electrical networks connect energy sources dispersed on their distribution network. The form of the sources of production decentralized more in vogue nowadays is that of renewable energies. Indeed, one attends the connection of the photovoltaic and wind power stations more and more on the distribution networks electric, especially in the developed countries. This operation contributes in what relates to them, not only to solve the environmental problems by limiting the gas emissions to greenhouse effect in the respect of conventions of the protocol of Kyoto, but still to reduce the technical losses. Research is made indeed more and more to help the managers of network to reduce on-line losses. There were many studies on the reconfiguration of the distribution networks for the reduction of the losses. An exchange algorithm of switch was proposed in [1]. In [2], an approximate technique of flow of power was developed to analyze the reduction of the losses by the reconfiguration of the network. In [3], Fan and Zhang formulated the problem of reconfiguration like linear problem of programming and applied a method of optimization to only one loop to solve the reconfiguration of network. Other techniques such as the genetic algorithm, and the algorithm of research by colony of ants (ACS) were used for purposes of the reconfiguration of the network to reduce the losses. For the optimal site of condenser "a well-known gold rule," or "rule 2/3" for the reduction of the losses is presented in [4]. This method would bring back good solutions in the system where the loads are uniformly distributed. In distribution systems, the Autonomous Source (AS) can provide part of power active and/or reactive so that the current in the wire is reduced and the profile of tension can be improved with the reduction of the losses. However, the studies indicate that the bad choice of the place and the size would lead to losses higher than the losses without sources of decentralized production [4] and [5]. A technique for the site of AS using the rule "2/3" was presented in [4]. Although the rule of 2/3 is simple and easy to apply, this technique cannot be effective in distribution with the loads not uniformly distributed. It is strong of that it was published useful for the authors of this article to study the influence of the connection of AS in the case of a real distribution network where the loads are not distributed uniformly. Does the geographical location of the point of coupling to a real distribution network of these power stations, have an influence on the losses of the network? To give an exact answer to this question, the authors of this article analyzed the evolution of the losses by connecting a source of autonomous production of 3 MW on the portion of network "Cotonou Est" of SBEE. Software NEPLAN was used as basic tool to evaluate before and after the operations of injection of energy.

II. Material and methodology

2.1. 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 here is the minimization of the Joules losses. The authors expressed this objective by mathematical expressions which are integrated in the algorithms of optimization.

2.2. The losses Joules

The reduction of the Joules losses becomes a priority for the operators of distribution networks, especially in a deregulated and competing context. A minimization of the losses allows a reduction of the costs of energy distribution and involves an increase in the margins of transit on the electric lines as well as an improvement of the profile of voltage. To express this objective in an algorithm of optimization, the authors used the following expression:

$$f_{objectif} = \sum_k R_k . I_k^2 \qquad (1)$$

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.

2.3. 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.

2.3.1. Amplitude of the voltage

Concerning the amplitude of the voltage, each company of electricity is held to respect an interval in which the voltage can vary during the exploitation by taking account of the regulations of the international standards. It is necessary thus, when one seeks a network configuration, that the voltage in each node is included/understood between $V_{nominal} = \pm 5\ \%$ for HV distribution network and $U_{nominal} = +6$ and $-10\ \%$ for LV network (according to the European standards and French in particular). This constraint is expressed in the following way:

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

where : V_{in} : nominal voltage to node i
V_i : module of voltage to node i
$\varepsilon_{i\ max}$: variation of maximum voltage acceptable

In general, in the distribution networks, the loads are inductive. We thus observe voltage drops rather than of rises. However, the connection of the independent producers leads to local rises in voltage which could exceed the acceptable limits.

2.3.2. Acceptable currents

Another 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. We express this constraint in the form:

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

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

2.4. Representation of the network “Cotonou Est”

The network “Cotonou Est” of SBEE is the electrical network of the city “Cotonou”, which feed the feeders of the source station of Akpakpa. It now comprises 230 transformers HV/LV) and 620 nodes.

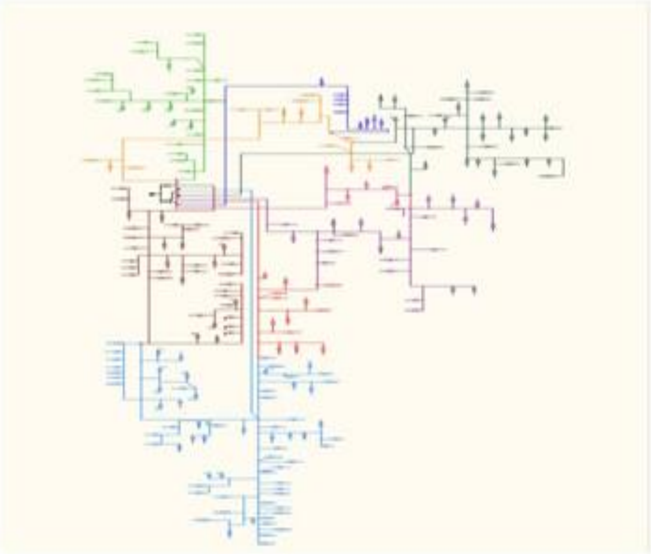

Figure 1: Network “Cotonou Est” SBEE

2.5. Modeling of the source station of Akpakpa with software NEPLAN

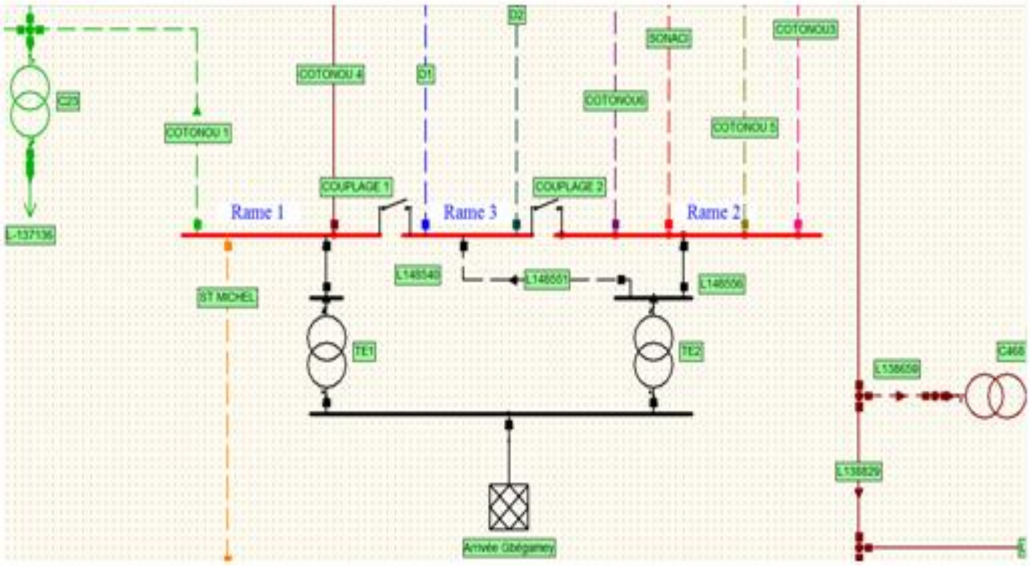

Figure 2: Source station of Akpakpa

The source station of Akpakpa have three (03) main nodes (Rame1, Rame2, Rame3), supplied with two named transformers HV/LV TE1 of power 20 MVA and TE2 of power 31,5 MVA. In normal circumstances of exploitation, when no coupling is closed, TE1 feeds Rame1, while TE2 feeds Rame2 and Rame3. There is a possibility of coupling Rame1 and Rame3 by closing the switch of coupling 1, Rame2 and Rame3 by closing the switch of coupling 2.

The source station of Akpakpa has 9 feeders which are: Cotonou1, Cotonou3, Cotonou4, Cotonou5, Cotonou6, St Michel, D1, D2 and Sonaci

Simulation and validation of the model with software NEPLAN

To validate the model, the authors have:

- compared the total load simulated by feeder, with the series of measurement of the loads by transformers on each feeder;
- compared the simulated value of the total power factor by feeder with the power factor measured during the series of measurement

Table 1, presents the comparison between the simulated values and the actual values:

Table 1: Comparison between real consumption and that simulated by feeder

	Real consumption			Simulated consumption			|Ecart| en %		
	P (MW)	Q (MVAR)	Cos Φ	P (MW)	Q (MVAR)	Cos Φ	P	Q	Cos Φ
Total	24.18	13	0.887	24.6	13.728	0.88	1.7	5.3	0.8
St Michel	2.0	1.3	0.85	1.81	1.074	0.86	9.5	17.4	1.2
Cotonou 1	3.1	1.6	0.90	3.632	1.861	0.89	14.6	14	1.1
Cotonou 4	2.1	1.4	0.84	4.011	2.38	0.86	47.6	41.2	2.3
Cotonou 5	2.5	0.8	0.95	2.169	0.857	0.93	13.2	6.7	2.1
Cotonou 6	1.6	0.9	0.84	2.335	1.508	0.84	31.5	40.3	0
SONACI	0.9	0.1	0.96	2.296	0.575	0.97	60.8	82	1
D1	5.3	2.5	0.90	3.227	1.375	0.92	39.1	45	2.2
D2	6.6	3.6	0.86	5.4	3.06	0.87	18.2	15	1.1
Cotonou 3				0.685	0.271	0.93			
TE 1	7.5	4.6	0.85	9.425	6.334	0.83	20	22.6	2.3
TE 2	17.1	8.2	0.90	16.036	4.973	0.89	6.2	39.3	1.1

It is thus noted that the difference between the simulated model and the real model is very weak overall when one carries out an analysis of the 'Total' line `' of table 1. The few strong variations noted on certain feeders are prone state of the switches on the network. We can validate our model from these results. Then, the authors carried out the calculation of load flow in the network studied before the connection of the autonomous source of production.

2.6. Power sum

The Power sum before the connection of the autonomous power station of production of 3 MW is presented in the table the 2 as well as losses per level of voltage.

The total active losses of the network rise to 1062 kW, for a load of 24.51 MW, while the total power in the network is evaluated to 25.573 MW.

Table 2: Load flow in the network "Cotonou Est" in its actual position (before injection energy of autonomous source)

<table>
<tr><th colspan="7">TOTAL POWER SUM</th></tr>
<tr><td></td><td>P losse
MW</td><td>Q losse
MVar</td><td>P imp
MW</td><td>Q imp
MVar</td><td>P load
MW</td><td>Q load
MVar</td></tr>
<tr><td>**Network« Cotonou Est »**</td><td>**1.062**</td><td>**5.273**</td><td>**25.573**</td><td>**15.721**</td><td>**24.511**</td><td>**10.448**</td></tr>
<tr><th colspan="7">POWER SUM BY LEVEL OF VOLTAGE</th></tr>
<tr><td>Un (kV)</td><td>P_online_losses (MW)</td><td colspan="2">Q_ online_losses (MVar)</td><td>P_transfo_losses (MW)</td><td colspan="2">Q_transfo_losses (MVar)</td></tr>
<tr><td>15</td><td>0.54</td><td colspan="2">0.214</td><td>0.42</td><td colspan="2">2.025</td></tr>
<tr><td>63</td><td>0</td><td colspan="2">0</td><td>0.102</td><td colspan="2">3.034</td></tr>
</table>

The Power sum by feeder is in table 3. The active losses of the feeder D1 on which we connected the autonomous source raise to 346 kW.

Table 3: Power sum by feeder

<table>
<tr><th colspan="8">POWER SUM BY FEEDER</th></tr>
<tr><td>Node</td><td>Feeder</td><td>P losse</td><td>Q losse</td><td>P imp</td><td>Q imp</td><td>P load</td><td>Q load</td></tr>
<tr><td>Rame 1</td><td>COTONOU1</td><td>0.086</td><td>0.296</td><td>3.603</td><td>1.795</td><td>3.517</td><td>1.498</td></tr>
<tr><td>Rame 1</td><td>COTONOU4</td><td>0.057</td><td>0.284</td><td>2.615</td><td>1.666</td><td>2.558</td><td>1.382</td></tr>
<tr><td>Rame 1</td><td>ST MICHEL</td><td>0.04</td><td>0.126</td><td>1.656</td><td>0.999</td><td>1.616</td><td>0.872</td></tr>
<tr><td>Rame 2</td><td>COTONOU3</td><td>0.008</td><td>0.049</td><td>0.458</td><td>0.14</td><td>0.45</td><td>0.091</td></tr>
<tr><td>Rame 2</td><td>COTONOU5</td><td>0.046</td><td>0.139</td><td>2.144</td><td>0.665</td><td>2.098</td><td>0.526</td></tr>
<tr><td>Rame 2</td><td>COTONOU6</td><td>0.06</td><td>0.198</td><td>2.463</td><td>1.362</td><td>2.403</td><td>1.164</td></tr>
<tr><td>Rame 2</td><td>SONACI</td><td>0.022</td><td>0.078</td><td>1.193</td><td>0.244</td><td>1.171</td><td>0.167</td></tr>
<tr><td>**Rame 3**</td><td>**D1**</td><td>**0.346**</td><td>**0.637**</td><td>**5.621**</td><td>**2.722**</td><td>**5.275**</td><td>**2.085**</td></tr>
<tr><td>Rame 3</td><td>D2</td><td>0.293</td><td>0.43</td><td>5.716</td><td>3.094</td><td>5.423</td><td>2.664</td></tr>
</table>

III. Results

3.1. Evolution of the losses by simulation of the injection point on the feeder D1

By varying the node of connection of a Dispersed Energy Source (DES) of 3 MW, we obtain the evolution of losses on the nodes of the longest line of the feeder D1. According to the power sum recapitulated in table 2, the power imported on the feeder D1 is of 5.621 kW.

Figure 3 gives the profile of losses according to the distances compared to the source station of Akpakpa.

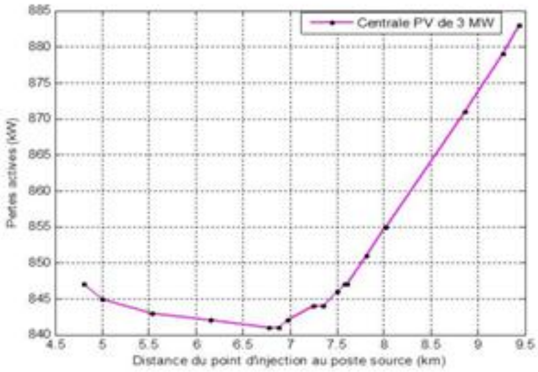

Figure 3: Evolution of the losses with the change of the point of injection on D1

For better appreciating the influence of the choice of the point of injection on on-line losses, the authors, not only chose various nodes of connection, but also varying the power of the DES. The results of simulation are related to figure 4:

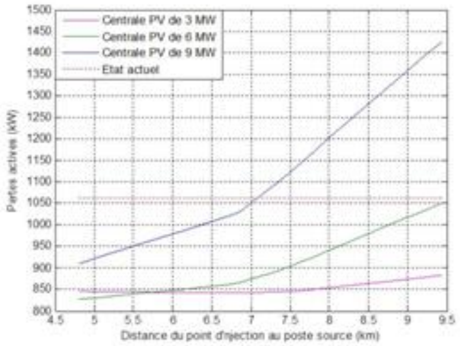

Figure 4: Evolution of the losses with the change of the point of injection on D1 for various powers of DES

IV. Discussion

The losses thus evolve from 841 to 883 kW on figure 3 for a total loss of 1.062 MW on the whole of the network, that is to say a maximum profit in power of 42 kW in HTA. Thus, we can reduce the power forwarded up to 42 kW by judiciously choosing the point of connection for an injection of 3 MW on the feeder D1, value which is lower than the power imported on this departure (5.621 kW) in the actual position of the network. The losses were minimized when we made connection with a node located at approximately 6.8 km of the source station of Akpakpa (figure 3).

An interpretation of this figure leads us to affirm with certainty that an electrical network admits a “center of load” which is function of the load-distribution in the network. When an injection of power is made with the node center, the losses are then minimized.

The analysis of the compared evolution of on-line losses (figure 4) according to the node of connection shows that on-line losses evolve proportionally with the power of the additional source, when this one is higher than the power imported on the feeder concerned. In this case, the center of the loads moves at the head of feeder. Thus, when the power of the autonomous source is higher than the imported power of the feeder on which it will be connected, connection must be made with the nodes at the head of feeder to minimize on-line losses. But when the connected power is lower than the imported power, it is important to seek the center of the loads which is not any more at the head of feeder. Figure 4 also shows us that the losses can become much more important than they are it in the actual position of the network, when the power injected is higher than the power imported on the feeder in the initial state of the network. It comes out the importance from it to decentralize the autonomous sources of production, by distributing the total power to inject in several small powers not to increase the rate of losses on the feeders.

V. Conclusion

We analyzed in this article, the influence of the choice of the injection nodes of the autonomous sources on the losses of the network “Cotonou Est” while using the simulation software NEPLAN with various values of powers from 3 to 9 MW exits of our photovoltaic power stations. The feeder D1 was retained on the network for our simulation, thus, it was determined the suitable node of connection for which the losses are minimized on the network “Cotonou Est”, i.e. to 6.8 km of the source station.

Apart from the minimization of on-line losses, the injection of the DES will make it possible to make up the energy deficit of Benin which currently knows a dependence of more than 90% of its energy need.

For a number of seven inhabitants per hearth on average, requiring according to a publication of UNDP of 0.99 kW energy per hearth, this recovery of loss of electrical energy of 42 kW can be used for supplying approximately 42 additional hearths and thus contributing the policy of reduction of poverty to the Benin.

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