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Impact of Reconfiguration of an electrical Distribution Network on On-ine Losses

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Abstract— The reduction of on-line losses constitutes one of major concerns of the managers of the electrical distribution networks today, because these losses take part in the large financial losses recorded by those and several solutions are considered within this framework for their minimization. The authors of this article choose the reconfiguration of the distribution network of the Beninese Company of Electrical energy (SBEE) by moving the switches open on the network. The method exploited by the authors is the topological optimization which requires the topological model of all the elements of the network. Their electric model made it possible to the authors progressively to calculate the load flow in the network. The use of software NEPLAN made it possible to the authors to appreciate the measurement of the impact of this reconfiguration on the network of SBEE.

Index Terms— electrical network, electrical energy, reconfiguration, topological optimisation, load flow

1 Introduction

The reduction of on-line losses constitutes one of major concerns of the managers of electrical distribution networks. Indeed, on-line losses cause large financial losses and several solutions can be under consideration for their minimization. Among these solutions, we can note enter others: reinforcement of the cables, the installation of the capacitor batteries, the conversion of certain networks LV into HV by bringing additional transformers, then especially optimal reconfiguration. This last solution is the subject of research of the authors of this article, since the starting investment is significantly negligible compared to the other solutions. This reconfiguration of the distribution networks should not especially impact their radial configuration which ensures an effective coordination of their protective gears [1]. The advantages obtained from optimal reconfiguration of a network are for example, the reduction of the active power, the balancing of the loads, the improvement of the profile of tension in the nodes, the increase in the safety and the reliability of the system, and the improvement of the quality of power [2-3]. The majority of the algorithms proposed in the literature for the reconfiguration of the networks are heuristic techniques of research based on the analytical methods. As for Shirmohammadi, he describes a technique for the reconfiguration of the distribution networks to reduce the on-line resistive losses [6]. In this article, the authors make a real application of optimal reconfiguration on a portion of the network of the SBEE by using primarily as software NEPLAN.

2 THEORETICAL ANALYSIS

2.1 Formulation of the problem

The objective of this problem of optimal reconfiguration is to minimize the total active losses:

$$P = \sum_{t}^{Nt} \sum_{k=1}^{l} R_k . I_k^2 \quad (1)$$

where P : is the total lost power

l : the number of feeders

R_k : the resistance of the branch K;

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

N_t: the number of level of voltage

The objective function is prone to the following constraints:

2.2. Equations of load flow

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$$P_i = \sum_{j=1}^{Nn} |Y_{ij} V_i V_j| \cos(\theta_{ij} + \delta_j - \delta_i) \quad (2)$$

$$Q_i = -\sum_{j=1}^{Nn} |Y_{ij} V_i V_j| \sin(\theta_{ij} + \delta_j - \delta_i) \quad (3)$$

where P_i et Q_i : active power and reactive power to node i;

Nn : number of nodes;

Y_{ij} : element (i, j) in the matrix of admittance of the nodes;

V_i , V_j: voltage to node i, and to node j;

θ_{ij}: angle of Y_{ij} ;

δ_i , δ_j: dephasing in tension of node I and the node J

2.3. Limits in voltage of the nodes

$$V^{\min} \leq V_i \leq V^{\max} \quad (4)$$

2.4. Thermal limits of feeders

$$|I_k| \leq I^{\max}, k \in \{1, 2, ...l\} \quad (5)$$

2.5. Format of the radial configuration

No isolated nodes

with V^{min} : minimal voltage

V^{max} : maximum voltage

I_k^{max} : maximum capacity in current in the branch K;

2.6. Algorithm

The goal of the procedure is to eliminate all the meshs from the network, by changing the topology of the network. Usually, there are a great possible number of topologies of the network. This procedure chooses a topology which minimizes the losses of the network, by taking account of all the constraints and without creating isolated subsystems.

The meshed configuration being that which minimizes more on-line losses of the network, at the beginning of the procedure, all the commutable elements of the level of tension considered are closed, and the network is meshed. After that, a process of iterations intervenes and comprises the following principal stages:

- calculation of the load flow;
- determination of the element with the lowest apparent power of all the commutable elements and the elements which were not marked as visited.

The iteration continues until there is no more commutable element or not yet visited elements.

3. EXPERIMENTAL WORK

3.1. Study of the network “Cotonou Est”

The portion of the network “Cotonou Est” of the SBEE is studied using software NEPLAN. This network is composed of 230 transformers, 620 nodes and of 9 feeders. Each feeder is represented in a color different from the others. This enabled us to see the limits of each feeder before and after reconfiguration. On figure 1, the authors made a zoom on the feeder D1 for example in the current configuration of the network. This feeder is currently limited by 3 open switches.

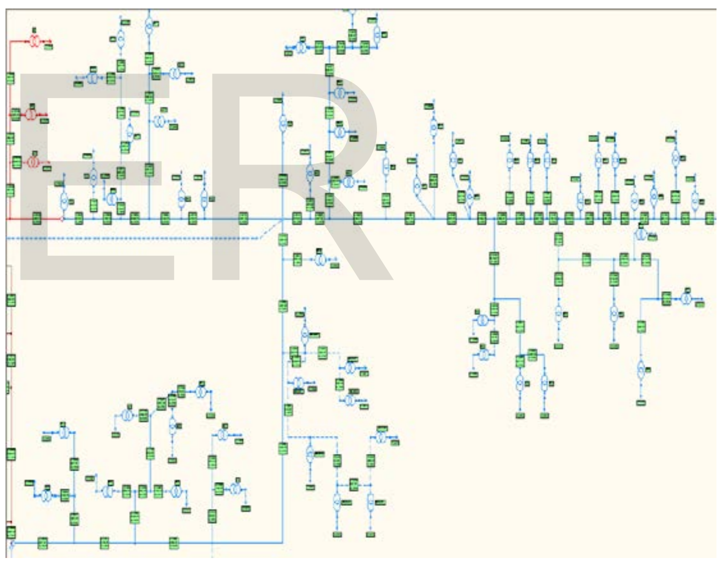

Figure 1: Current configuration of the feeder D1 of the network “Cotonou Est” of SBEE

3.2. Load flow and losses sum in the network “Cotonou Est” before optimal reconfiguration of the network

The first simulation of the network studied “Cotonou Est” in its actual state with NEPLAN, enabled us to obtain the power sum summarized in table 1.

Table 1: Load flow in the network “Cotonou Is” in its actual state

		TOTAL POWER SUM					
		P losse	Q losse	P imp	Q imp	P load	Q load
		MW	MVar	MW	MVar	MW	MVar
Network « Cotonou Est »		**1.062**	**5.273**	**25.573**	**15.721**	**24.511**	**10.448**
		POWER SUM BY FEEDER					
Node	Feeder	P losse	Q losse	P imp	Q imp	P load	Q load
Rame 1	COTONOU1	0.086	0.296	3.603	1.795	3.517	1.498
Rame 1	COTONOU4	0.057	0.284	2.615	1.666	2.558	1.382
Rame 1	ST MICHEL	0.04	0.126	1.656	0.999	1.616	0.872
Rame 2	COTONOU3	0.008	0.049	0.458	0.14	0.45	0.091
Rame 2	COTONOU5	0.046	0.139	2.144	0.665	2.098	0.526
Rame 2	COTONOU6	0.06	0.198	2.463	1.362	2.403	1.164
Rame 2	SONACI	0.022	0.078	1.193	0.244	1.171	0.167
Rame 3	**D1**	**0.346**	**0.637**	**5.621**	**2.722**	**5.275**	**2.085**
Rame 3	D2	0.293	0.43	5.716	3.094	5.423	2.664
		POWER SUM BY LEVEL OF VOLTAGE					
Un (kV)	P_online_losses (MW)	Q_ online_losses (MVar)		P_transfo_losses (MW)		Q_transfo_losses (MVar)	
15	0.54	0.214		0.42		2.025	
63	0	0		0.102		3.034	

This table present:

- the active and reactive losses of the network and by feeder (P loss and Q loss),
- the active and reactive imported powers (P imported and Q imported),
- the active and reactive powers of loads,
- losses by level of voltage.

Thus, the total active losses of the network rise to 1.062 MW, for a load of 24.51 MW, while the total power of the network is of 25.573 MW. D1 is the feeder which has more losses, that is to say 346 kW.

4. RESULTS

4.1. Reconfigurated network

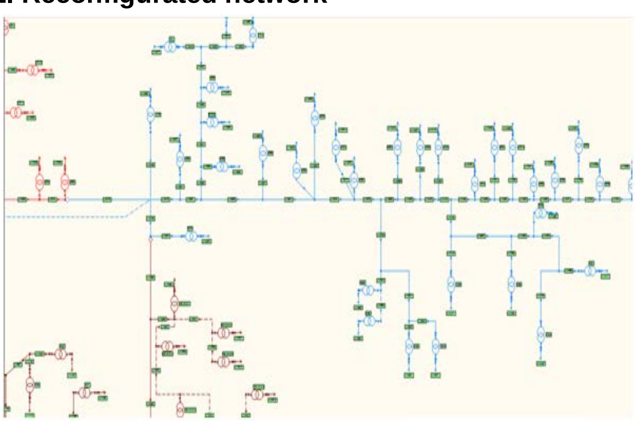

Figure 2: Reconfigured feeder D1

4.2. Load flow and losses sum after optimal reconfiguration of the network "Cotonou Est"

The results obtained after the reconfiguration of the network "Cotonou Est" are consigned in tables 2 and 3. Table 2 summarizes the load flow generated by the software NEPLAN before and after optimal reconfiguration with the variations obtained.

Table 2: Distribution of power in the network "Cotonou Is" before and after reconfiguration

	Before	After	Error %
$P_{imported}$ MW	25.573	25.435	0.54
$Q_{imported}$ MW	15.721	15.613	0.7
P_{loads} MW	24.511	24.511	0
Q_{loads} MVAr	10.448	10.448	0
P_{losses} MW	1.062	0.924	13
Q_{losses} MVAr	5.273	5.164	2

As for table 3, it gives the load flow generated by NEPLAN at the end of the optimal reconfiguration of the network according to the level of voltage.

Table 3: Load flow in the network "Cotonou Is" before and after reconfiguration according to the level of voltage

	Un=15 kV		Un=63 kV	
	Before	After	Before	After
$P_{on\text{-}line\ losses}$	0.54 MW	0.402 MW	0 MW	0 MW
$Q_{on\text{-}line\ losses}$	0.214 MVAr	0.158 MVAr	0 MVAr	0 MVAr
$P_{Transfo\text{-}losses}$	0.42 MW	0.421 MW	0.102 MW	0.101 MW
$Q_{transfo\text{-}losses}$	2.025 MVAr	2.037 MVAr	3.034 MVAr	2.969 MVAr

5. DISCUSSION

We can notice on figure 2, by comparison with figure 1, that the feeder D1 is now limited by two open switches. The three switches open in the initial state were moved, and the size of feeder D1 was considerably reduced. In the same way, each other feeder saw its size increased or reduced, according to the new position of the open switches which delimit it. The feeder which was impacted the most after optimization of the opened switchs is the feeder D1 which had the strongest rate of losses: from 346 kW to 136 kW, that is to say a reduction by 210 kW. The losses of certain feeders on the contrary increased. The network was thus meshed at the beginning of the process, for a total of 9 meshs. At the end of the iterations, the final configuration is the same one as initial i.e. the only one mesh. The losses passed from 1062 kW to 924 kW, that is to say a reduction of 13%, which is equivalent to an power saving of 138 kW. Being the losses calculated according to the level of voltage 15 kV, we obtained drop variations of 25% for the active losses and 26% for the reactive losses.

6. CONCLUSION

The authors have through this article, optimized the opened switchs of the network "Cotonou Est", by defining as objective the minimization of on-line losses of the network. With this intention, the authors presented the algorithm followed for the iterations which consists in a general way meshing the networks initially, then successively to open the commutable elements of kind to make the system radial. NEPLAN was the software by excellence for the practice. By these concrete results, the authors come from shown the possibility to the managers of the networks the possibility of reducing on-line losses and rebound to increase on the one hand, their energy deposit rate and on the other hand, to reduce their rate of dependence currently very high for certain States of West Africa of which the Benin and Togo in particular.

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