# ASPECTS REGARDING THE QUALITY OF THE ELECTRIC ENERGY IN PUBLIC DISTRIBUTION SYSTEMS

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***Abstract* - The development of the public distribution networks and the restructure of those which already exist gain more and more importance in the ensemble of the electric energy public distribution systems. The importance of the economic and social aspects and the multiplication of the decisions that must be adopted concerning the rational operation of these networks require a rigorous and coherent design under the aspect of the development and restructure of the electric energy distribution systems. In the paper there are presented mathematical models, methods and computing algorithms that allow the determination of the optimal sectioning branches and the installation of the compensation meanings in public distribution networks..**

***Keywords – optimal sectioning branches, compensation, genetic algorithms***

## 1. INTRODUCTION

The development of the public distribution networks and the restructure of those that already exist gain more and more importance in the ensemble of the electric energy public distribution systems. The necessary investments for the development of these public distribution systems are considerable. The importance of the economic and social aspects and the multiplication of the decisions that must be adopted concerning the rational operation of these networks require a rigorous and coherent design under the aspect of the development and restructure of the electric energy distribution systems. In this way, the assurance of a proper quality of the electric energy supplied to the consumers is desired.

The analysis of the parameters or indexes of quality, as obligation of the supplier, must be realized in strict correlation with the perturbations that might be introduced in the electric energy supply network during the operation of the consumers, [2], [4], [6].

Having as goal the improvement of the quality of the electric energy supplied to the consumers, it is necessary to be adopted both constructive and technologic measures, as well as running ones, such as: the establishment of the optimal unloop of these networks, the optimal configuration for normal operating states of the public distribution networks, the establishment of the optimal plots for the operation of the transformers from the transformation stations, the installation of the equipments that assure the compensation of the reactive charges and the introduction of the means of their adjustment, the limitation of the distorting state introducing harmonic filters in different points of the network, the optimal reconfiguration of the public distribution networks after faulty states, a.s.o.

## 2. THE RECONFIGURATION OF THE PUBLIC NETWORKS OPERATING SCHEMES

The public distribution networks of low and medium voltage are built in a looped configuration and work, most often, in unlooped, tree-shaped schemes, because of the requirements for simplification of the operating conditions and for reducing the investments in switching and protecting devices and in automations. The reconfiguration operations of the operating schemes for the public distribution networks are carried out, usually, as suite of the seasonal modifications in the consumption, or for avoiding malfunctions, [4], [5].

In the following lines, it is presented a method based on artificial intelligence, for assessing the unlooped operating schemes of the distribution networks, by diminishing the damages caused to the consumers by the improper quality of the supply voltage for a given period of time, period during which the configuration of the scheme remains unchanged. In this context, the mathematical model for the optimizing problem can be formulated as follows:

The objective function:

$$F = \sum_{k\in K}\sum_{i\in ND}\sum_{j\in NT}\left(\Delta P_{jik} t_k \beta + D_{jik}\right) \quad (1)$$

Restrictions:

$$\sum_{j \in NN} I_{jik} \le I_{adm.i} \;,\; k \in K \;,\; i \in ND \quad (2)$$

$$\sum_{i \in ND} \theta_{ij} = 1 \quad (3)$$

Where: $K$: the number of the charge curves levels ($k$ is one of the levels, $k \in K$); $ND$: the number of the distributors in the network ($i$ is one of the distributors, $i \in ND$); $NT$: the number of network branches ($j$ is one of the network branches, $j \in NT$); $\Delta P_{jik}$: the active power losses on the $j$ branch of the $i$ distributor, related to the $k$ level; $D_{jik}$: the damages caused to the consumer connected in the $j$ node of the $i$ distributor by the improper quality of the supply voltage; $\beta$: the price of electricity; $I_{jik}$: the current on the $j$ branch of the $i$ distributor, on the $k$ charge level; $I_{adm.i}$: the maximum admissible current associated to the distributor; $\theta_{ij}$: an element from the matrix that describes the incidence of the branches with the distributors ($\theta_{ij} = 1$, if the $j$ branch belongs to the $i$ distributor, and $\theta_{ij} = 0$, if it doesn't).

The public distribution networks supply a wide range of consumers that involve different operating states. The active and reactive charge curves, for each consumption point in the network, during the analysed period (a day, a month, a season or even a year), represented by a number of levels, are modelled by means of a database that contains the standard charge curves for different types of consumers, the consumption structure in the respective point and a small number of direct measurements performed in the network [1], [3], [7], [8].

To establish the unlooped operating schemes for the public distribution networks, one can use a classical method or a method based on genetic algorithms (GA). The classical method analysis, in a sequential way, all the possible variants of looping the distributors. To establish the optimal sectioning parts, which assure the minimization of the objective function (1) and fulfil the restrictions, (2), (3), the following steps are followed.

*Step 1.* The establishment of the feeders closed - looping possibilities set: $V=\{v_i\}$, $i=1, 2, ...$; one possibility is the set of the pairs of feeders which may be looped: $v_i = \{ b_{kj} \}$, $k, j = 1, ..., ND$; $k \neq j$ ($ND$ – the number of feeders from the analysed network );

*Step 2.* Each possibility is considered $v_i$ ( $i=1, 2, ...$), the following steps being covered:

*Step 2.1.* A pair of feeders $b_{kj} \in v_i$ is choosen for which the closed-loop is made by activating the reserve branch;

*Step 2.2.* The computation of the characteristic regimes for the closed - loop running of the $b_{kj}$ pair;

*Step 2.3.* For the $b_{kj}$ pair the optimal sectionalizing branch is established after minimum energy losses criterion and these losses are memorised $\Delta W_{kj}$;

*Step 2.4.* Step 2.1 is again actualised until all the $b_{kj} \in v_i$ pairs are computed;

*Step 2.5.* The total network energy losses $\Delta W$ corresponding to the optimal open-loop is calculated;

*Step 3.* The alternative $v^*$ corresponding to the minimum energy losses $\Delta W^* = \min \{ \Delta W_i \}$, $i=1, 2, ...$ is selected.

The usage of the parallel computational techniques (GA) shows as being a viable alternative, replacing the sequentially search with a parallel one, [4], [5]. For a given network configuration and a given number of supply points, the number of breaking points that ensures the unloop of the network and the supply of all consumers is a constant like:

$$N_{unl} = NS + NC - 1 \quad (4)$$

Where: $N_{unl}$: the number of breaking points; $NS$: the number of supply plugs; $NC$: the number of independent cycles in the network diagram.

The representation of the admissible solutions in the GA frame uses a double chromosome chain $2xN_{unl}$ in length. The first $N_{unl}$ elements indicate the distributors that are to carry the breaks, and the last $N_{unl}$ elements indicate the branches on each of these distributors on which the actual break is to take place. Considering the specific way in which the structure of a chromosome has been defined, the crossover of the "parental" chromosomes must take place in two points, corresponding to the distributor, and to the branch to be sectioned respectively. If the "descendent" chromosomes do not represent valid solutions of the problem, one of the restrictions being broken, the "parental" chromosomes shall pass to the next generation. The dominant chromosome is the one that is found most frequently in a generation's population, and the optimal chromosome is the one to which corresponds a minimal value of the objective function (1), being at the same time the solution of the optimal sectioning problem for the distribution network. No matter what method was chosen (the classical or the one based on GA), at the end of the computation, a list with the optimal branches to be sectioned, the branches that are to be disconnected, and the energy loss reduction is indicated for the analysed network.

## 3. INSTALLATION OF THE COMPENSATION MEANS FOR THE REACTIVE CHARGES IN THE PUBLIC DISTRIBUTION NETWORKS

The installation of the compensation means for the reactive charges in the public distribution networks is an efficient method to improve the level of the supply voltage, in both normal and faulty states, to reduce the distorted state, to reduce the power and active energy losses that occur in networks, as well as to increase the actual transport capacity of the network. According to the regulations in force in our country and to the UCPTE (Union for the Co-ordination of Production and Transmission of Electricity) regulations, in the public distribution networks one uses fixed or variable medium and low voltage capacitors as sources of reactive power. These may be placed on the medium voltage bars of the step-down substations, on the medium and low voltage bars of the substations, as well as along the distributors.

The optimal compensation of the reactive charges in view of reducing the damages caused to the consumers by the improper quality of the supply voltage, as well as for reducing the active power losses, may be computed either by means of simulation methods, or by using a combination between the principles of the genetic algorithms and the evolutional strategies. In this context, the mathematical model of the optimisation problem can be formulated as follows:

The objective function:

$$\begin{aligned} TUE = I &+ \sum_{k=1}^{T} D_k (1+a)^{-k} + \sum_{k=1}^{T} C_k (1+a)^{-k} + \\ &+ K_e \sum_{k=1}^{T} \Delta P_{\max.k} (1+a)^{-k} + \\ &+ \sum_{k=1}^{T} \beta_k \cdot \Delta W_k (1+a)^{-k} - V_{rem} (1+a)^{-T} \end{aligned} \quad (5)$$

Restrictions:

The voltages in the $N$ nodes of the network in which the compensation source is to be set-up must be maintained within the admissible ranges:

$$U_i^{\min} \le U_i \le U_i^{\max}, \quad i \in N \quad (6)$$

In the nodes where the compensation source is placed, one does not allow the outcome of reactive power to the supply outlet, under no operating state, all through the year:

$$\min_{l=1,12} \left( \min_{j=1,2} \left( \min_{t=1,24} Q_{i.ljt} \right) \right) \ge q_0 \cdot N_i, \quad i \in N \quad (7)$$

Where: $TUE$: total updated expenses; $T$: the study period, in years; $I$: the cost of the investment in capacitors and switching equipment; $a$: the yearly updated repayment; $D_k$: the damage caused to the consumers by the improper quality of the supply voltage, during the $k$ year of the determined period; $C_k$: the maintenance cost for the equipment at the level of the $k$ year of the study period; $K_e$: the price for an installed kW in the equivalent power station; $\Delta P_{max.k}$: the losses of active power in peak charge, during the $k$ year of the study period; $\Delta W_k$: the annual energy losses, during the $k$ year of the study period; $V_{rem}$: the remaining value of the investment at the end of the study period; $q_0$: the reactive power of a standardised compensation unit; $N_i$: the total number of standardised compensation units placed in the $I$ node of the network; $Q_{i.ljt}$: the reactive power corresponding to the $I$ node of the month $l$ and characteristic day $j$, at the $t$ hour.

To establish the optimal placement of the compensation sources in the public distribution networks, there can be used either methods of simulation, or methods based on GA and evolutional strategies (ES), [4], [5], [7].

The simulative methods are successive methods of searching, consisting of two steps. In the first one, a maximum number of capacitors, in all the nodes of the analyzed network, are allocated. In the second one, an iterative process, to eliminate a number of capacitors, is performed, until a global minimum of the objective function, (4), is achieved.

After passing the first step, the reference value, corresponding to the maximum number of capacitors possible to be connected in the nodes of the network, $TUE_{ref}$, is established. To decide, in a node, which capacitor is to be eliminated in the iterative process from the second step it is realized a simulation of operation. For every capacitor that is eliminated, $TUE$ is calculated. The optimal solution is that which correspond to the minimum value.

To establish the optimal compensation there can be used methods that are based on a combination between GA and ES. Following steps must be performed:

*Step 1* – GENERATION = 1

*Step 2.* Evaluation of solutions: $m$ chromosomes are randomly generated (admissible solutions) and the values of the adaptation function are computed for this generation:

$$f_I = 1/TUE, \ i=1, m. \quad (8)$$

*Step 3.* Selection: the parental chromosomes are selected by the principle of the roulette, in view of performing the crossing-over.

*Step 4.* Crossing-over of the chromosomes: the parental chromosomes are crossed-over with a certain probability given by the operand "cross-over rate", having children chromosomes as heirs.

*Step 5.* Mutations: the alteration of a randomly chosen gene from a child chromosome, alteration that is produced with a certain probability given by the operand “mutation rate”.

*Step 6.* Competition: each fellow of the extended population (*2m* chromosomes – the old generation and the children that resulted after crossing-over and mutation) take part in a competition with all other fellows to survive and get transmitted to the next generation. All chromosomes are arranged in descending order respective to their adaptation function, and the first *m* chromosomes are transmitted to the next generation, together with their corresponding adaptation function, thus forming a new generation.

*Step 7.* Elitism: the best chromosome replaces the chromosome with the minimal adaptation function.

*Step 8.* GENERATION = GENERATION + 1

*Step 9.* Check for the stop condition (reaching the maximal admitted number of generations): if it is not fulfilled, take over from step 3 to step 8; if it is, the (sub)-optimal solution is found in the chromosome with the maximal adaptation function from the last generation.

The obtained results, no matter the method that is used, are displayed under the total reactive power that is to be installed in every node of the analyzed network, the diminishment of the energy losses and the mean value of the supplied voltage non-regularity in the whole network.

## 4. CONCLUSIONS

Electrical energy is seen, in present, as a good as any other, wich must fulfil certain quality criteria to safisfy the expectations of the consumers. The mathematical models and classical methods of computation or those based on genetic algorithms and evolutional strategies allow the establishment of the functioning unlooped schemes of the public distribution networks, depending on the variation of the electric energy consumption, together with the optimal placement of the capacitors for improving the power factor.

The adoptation, in the exploatation process, of these kinds of solutions, leads to an improvement of the voltage quality, to the diminishment of the losses caused by the improper quality of it and to a diminishment of the energy losses with 15-16% in a year, which represents 0.17-0.19% of the energy that flows in the network.

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