Selection of Partition Nodes In Medium Voltage Power Distribution Networks

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ABSTRACT *The following article presents a procedure and algorithms for selection of a partition node of two-way powered branches and one-contour electric power distribution networks constructed with overhead power lines. The presented procedure, algorithm and program support allow one to select the partition node following three criteria: minimum discounted costs, minimum power loss and minimum quantity of undelivered electricity. Actual results of the application of methods for different configuration distribution networks are shown.*

Introduction

In accordance with the European Union definition, intelligent electric power networks or Smart Grids (SG) are energy efficient and economical functioning electric power circuits with coordinated management and two-way connection between the generating sources and the customers. SG construction involves the introduction of automation, control and monitoring in the distribution network thus improving the electric power supply reliability and providing a two-way flow of electricity to the customers (Russell and Benner, 2010; Gellings, 2010). SG construction concept is based on the following decisions (Farhangi, 2010; Guimond,2010; Gharavi and Ghafurian, 2011):

- automation system realization and management in the distribution network;
- introduction of modern diagnostic tools;
- use of modern information and computer technology capabilities;
- integration of decentralized generators (wind farms, photoelectric systems, small hydropower plants with capacity up to 5MW, etc.) and the storage systems.

The construction of distribution networks as SG elements involves the following three stages:

- Restructuring of the distribution networks in two-way powered branches;
- Selection of the partition node (circuit interruption in normal mode) of two-way powered branches or contours;
- Introduction of automatic devices for distribution network partition.

This paper's purpose is to draw a procedure for selecting partition nodes of medium voltage (MV) distribution network branches constructed with overhead power lines.

The predetermined criteria and limitations in partition node selection are the following (Andonov and Bakardjieva, 2012):

- The discounted cost criterion is selected out of all cost-effective indicators for alternate testing during the electric power network reconstruction.
- The optimal distribution network partition point should be selected following two criteria:
  - minimum power loss;
  - minimum quantity of undelivered electricity.
- The normal and emergency mode parameters represent the technical limitations to be kept within the permissible margins during reconstruction and selection of partition point in the MV distribution network.
  When preparing the algorithms it is necessary to consider

the fact that partitioning should comply with the presence of decentralized generators (DG) attached to a specific branch. Their construction sites depend on the available natural resources while their accession is mainly to the distribution network.

In view of the above purpose the following tasks are solved:

- Drawing algorithms for selection of partition node of two-way powered branch of distribution network with overhead power lines.
- Drawing algorithms for selection of partition node of one-contour distribution network.

Procedure for selection of a partition node of two-way powered electric power distribution network branch
A partition node implementing the selected criteria should be found as a two-way powered circuit chart.

The actual configuration of branches powered by two sources is represented in Fig.1, where the circuit nodes are numbered from 1 to 38. The figures placed against each branch show the "weight functions" corresponding to the selected criteria quantification – discounted cost, power loss or quantity of undelivered electricity. In Fig. 1 the "weight functions" represent the discounted costs in relative value units $R_{D*} = R_D / R_{D\min}$ for each branch, where R_D is the calculated value of the specific branch discounted cost; $R_{D\min}$ - the minimal discounted cost out of all discounted costs for all distribution network branches (in this case for branch 10-11). Discounted costs R_D for each branch are defined with

$$R_D = \sum_{t=1}^{T_c} K_t\, \alpha^{t-1} + \sum_{t=1}^{T_c}\ \sum_{j=1}^{m} C_j\ \alpha^{t-1} \quad (1)$$

where K_t are the investments for year t; T_c – operational life; m – number of operational cost types; C_j – operating cost of type j for year t; α – discount rate (Andonov and Bakardjieva, 2012).

Branches I and II are powered by substation (SS) 1, while branches III and IV – by SS2. There is a coupling constructed between branches I and IV, as well as between II and III. The total capacity of the two new branches does not exceed 4,5MVA.

Fig.2 represents the algorithm flowchart for defining the partition node in the distribution network. The algorithm is as follows:

The chart topology, node power data and branch impedance

are imported in compliance with the selected actual circuit configuration; the numbers of the first and last main circuit node are set – Fig.2, DANNI block. The current indices are: i for nodes, j for branches, k for contours.
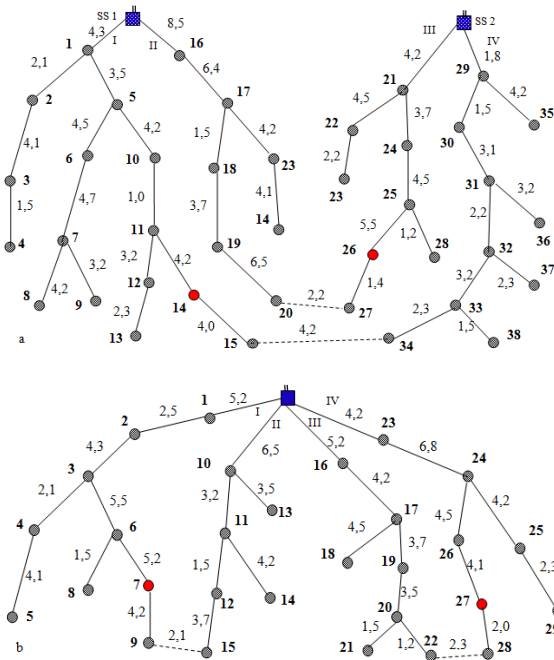

Fig.1.Distribution network chart

The magistral is found by running the procedure for tracking the peaks of the graph representing the electric power network (BSF block). The connection between the set first and last node numbers is searched for the set node and branch numbering is kept in new arrays NB and NK.

The magistral nodes and their respective branches are re-numbered as per the order of their finding as a result of which two arrays are derived with indices from 1 to NBM for the nodes and NMK branches along the main circuit.
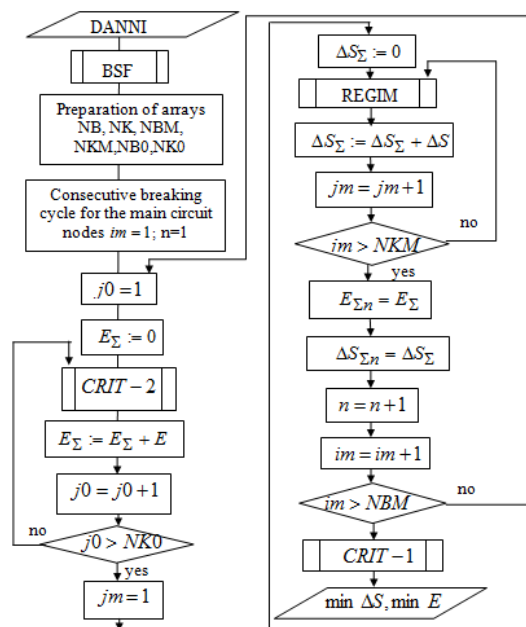

Fig.2.Algorithm flowchart for defining the partition node

in the distribution network

The deviations' nodes and branches are numbered with arrays NB0 and NK0, respectively. This separation of the deviations' nodes from branches is necessary as the calculations under the selected reliability criterion should be implemented only with regards to the deviations. The current indices are: im and jm for the main circuit nodes and branches; i0 and j0 – for the deviations' nodes and branches.

A consecutive breaking cycle is introduced for the main circuit branches from 1 to NBM.

It is found that as a result of the potential two-way electric power supply of customers along the main circuit a power supply break of a given tapping may occur in case of a failure of the power line connecting the tapping to the main circuit. The quantity of undelivered electricity $E_{\Sigma n}$ in case of main circuit connection breaking is calculated for all tappings $j0 \in K \quad 0$ (CRIT-2 block).

Post-emergency mode capacities are derived (REGIM block). Power losses are found and recorded as $\Delta S_{\Sigma n}$ for n-th breaking version of the circuit in node n.

The derived values for power losses and quantity of undelivered electricity are compared (CRIT-1 block) for each n-th circuit breaking version as a result of which the optimal version is derived.
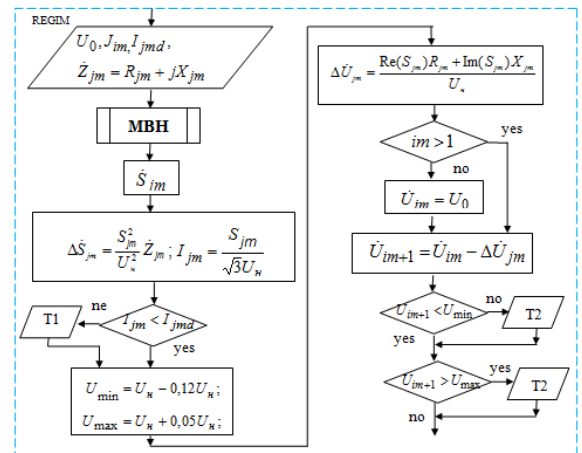

Fig.3.Structure chart of REGIM block

The calculation of current flows and the verification of their size against the maximum permissible values for the given conductor type are also made in the REGIM block apart from deriving the capacity distribution and power losses. Calculations are made for the voltage losses along the branches and voltages in the nodes which are verified to comply with the permissible values.

The derived discrepancies in fact represent failure to meet the technical limitations. Such can be: design current exceeding the permissible; voltage in the nodes outside the limits. Each limitation discrepancy is shown as a message.

The structure chart of REGIM block is presented in Fig.3 using the following indications: MBH – a subprogram for drawing and solving node equations (Notov and Nedeltcheva, 2009);

$$\dot{Z}_{jm} = R_{jm} + jX_{jm}$$

- the circuit branches impedances; U_0 - supply node voltage; U - nominal voltage; $\dot{S}_{im}$ - set capacities in the main circuit nodes; S_{jm} - capacities in the main circuit branches; T1 – text message: "jm branch current exceeds the permissible value"; T2 – text message: "im+1 node voltage is outside the

permissible limits".

The permissible voltage loss in post-emergency mode for MV distribution networks is 12 %. The permissible minimum voltage is set in the algorithm at 12% of the nominal voltage. The permissible maximum voltage may exceed the nominal with 5%.

Results of Fig.1a branch algorithm implementation:

Branches I and IV with a coupling:
- Total active power loss as a result of partitioning in end node 15,branch I - 618 kW;
- Total active power loss as a result of partitioning in end node 34, branch IV - 602 kW;
- Total active power loss as a result of partitioning in the optimally selected node 14 of branch I - 570 kW, thus achieving:
    - power losses reduction with 8% compared to par titioning in branch I end node;
    - IV power losses reduction with 5,4% compared to partitioning in branch IV end node.

- **Branches II and III with a coupling:**
- Total active power loss as a result of partitioning in end node 20, branch II - 570 kW;
- Total active power loss as a result of partitioning in end node 27, branch III - 582 kW;
- Total active power loss as a result of partitioning in the optimally selected node 26, branch III - 540 kW, thus achieving:
    - power losses reduction with 5,3% compared to partitioning in branch II end node;
    - power losses reduction with 7,3% compared to partitioning in branch III end node.

Selection of a partition node of one-contour electric power distribution network
When couplings are constructed on branches fed by a common source the main circuits are connected in a contour (Fig.1b). Supply power for both branches is the same.

Results of Fig.1b branch algorithm implementation:

Branches I and II with a coupling:
- Total active power loss as a result of partitioning in end node 9, branch I - 301 kW;
- Total active power loss as a result of partitioning in end node 15, branch II - 308 kW;
- Total active power loss as a result of partitioning in the optimally selected node 7 of branch I - 285 kW, thus achieving:
    - power losses reduction with 5,4% compared to partitioning in branch I end node;
    - power losses reduction with 7,5% compared to partitioning in branch II end node.

Branches III and IV with a coupling:
- Total active power loss as a result of partitioning in end node 22, branch III - 288 kW;
- Total active power loss as a result of partitioning in end node 28, branch IV - 295kW;
- Total active power loss as a result of partitioning in the optimally selected node 27, branch IV - 279 kW, thus achieving:
    - power losses reduction with 3,2% compared to partitioning in branch III end node 22;
    - power losses reduction with 5,5% compared to partitioning in branch IV end node 28.

Conclusions
The presented procedure, prepared algorithm and program support make it possible for the selection of a partition node to be implemented following two criteria: minimum power losses and minimum quantity of undelivered electricity

The optimal selection of a partition node results in power loss reduction as well as in reduction of electric power circuit operating costs, respectively. For the observed actual cases the loss reduction reaches 8% in case a partition node is selected under the accepted criteria.

Apart from minimum power losses the optimal selection of a partition node leads to a more even weight distribution along the branches.

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