# Planning of Urban Medium Voltage Network

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*Abstract:* - Under the conditions of liberalized market development the role of networks optimization is not diminishing but is being even enhanced. The given algorithm has been developed having applied software LDM-SG'07 for dynamic planning of medium voltage distribution network in urban and rural areas. Software allows making comparison in multistep development up to 10 variants applying periodic regular year criteria with possibility calculating reliability and other criteria in each variant in each step. Model structure of optimization system under market conditions is being discussed in a paper; as well as certain experience of LEPSS is described.

*Keywords:* Power System Planning, Power Distribution, Power System Simulation, Development Optimization, Liberalized Electricity Market, Uncertainty, Risk Analysis

## 1 Introduction

The current situation of Riga's urban distribution network is critical from the point of view of new loads connection to power network – effective legislation and available financial resources represent insufficient basis to allow all perspective loads (up to and higher 1 MW) be connected to the grid. In Riga city there are ~300 MW perspective loads, which are not connected to the grid due to the above-mentioned reasons. In existent 330-110/20-10 kV substations in middle voltage side available number of bays (cells) or available bays (cells) are insufficient. New connections to grid are eliminated by unavailable loads of power transformers too - mostly transformers in substations are fully loaded. As the result large perspective loads (~10 MW) connection to grid without transformers replacement by more capacious and/or additional bays (cells) installation in substations medium voltage sections is not possible. Actually connection of predictable prospective loads may be anticipated by construction of 4-6 new substations (110/20-10 kV) during coming 3 years; that would be solution only for current situation without considerable perspective loads reserve. For example newly (built within the latest 3 years) feeding centers (there are-110/20-10 kV substations), after relatively short time are fully loaded.

At present two new substations are in the process of construction, but all possible loads are reserved (during the project phase approximately half of possible perspective transformers loads are matched for allocation.

Medium voltage electric lines division of different types and age groups is represented in Fig.1. and Fig.2.

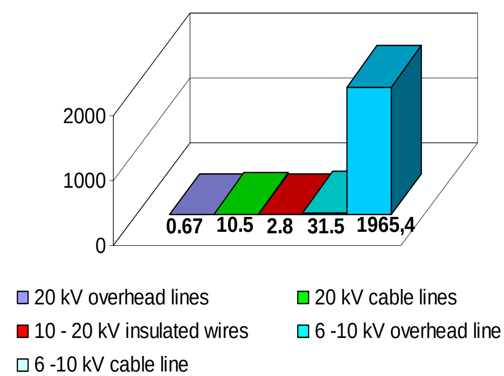



Fig.1. Electrical lines division by types

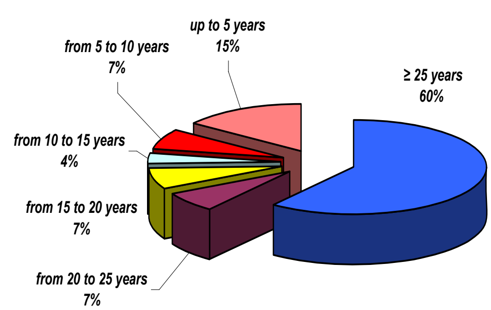



Fig.2. Electrical lines division by age

Distribution transformers division by age illustrated in Fig.3, switchgears division - in Fig.4.

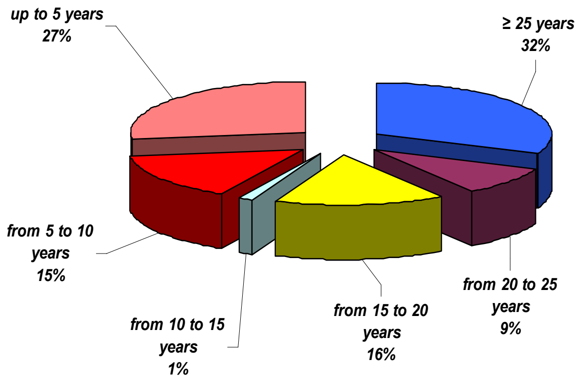



Fig.3. Distribution transformers division by age

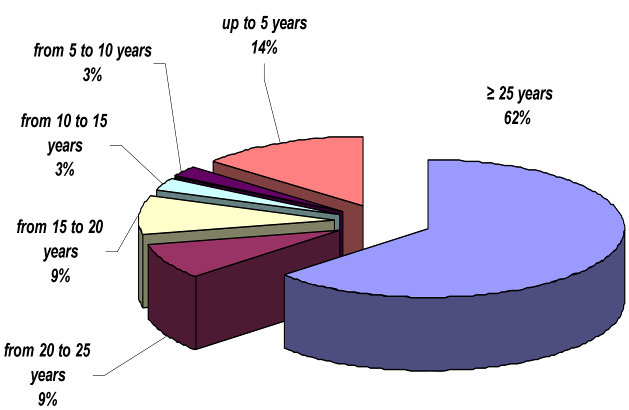



Fig.4. Switchgears division by age

One of fundamental problems in distribution network development in Rigs city is insufficient long term development planning for local grid regions (for example, perspective location of 10/0,4 kV substations), development based on overall visions about how distribution network in next 12 years would be arranged. In year 2002 perspective development plan for distribution network was updated for next 18 years which was executed by *SC Siltumelektroprojekts* in 1998, but in updates confirmation process updated plan was usable only partly, because new perspective load and feeding centers developed very rapidly and planned substations had been built earlier than provided in perspective development plan, some of measures still have not been done, as not required , new load centers are developed which have not been envisaged in perspective development plan. In year 2006 new perspective development plan was developed with perspective feeding centers location. New substations are envisaged according to the principle to cover loads that there are of primary solution, grid reliability and loads reservations are of secondary.

To improve the existing situation detailed problems analysis should be done, distribution network development and reconstruction planning should be done under information uncertainty conditions. At the same time perspective loads connection to grid, load reservation, grid reliability and optimal network configuration problems would be solved [1, 2, 3, 4].

## 2 Decision Making Principles

Economic analyses determine objects economic life cycle, in networks – estimated as 20-25 years. Efficiency function calculation is applied to all estimation periods $T$. under the information uncertainty conditions on making decision only for the nearest future (approx. 5 years forward). These time intervals are called as decision-making period $td < T$ (see Fig.2.)

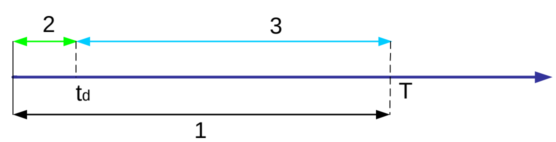



Fig.5. Development process: 1 - estimation period; 2 - decision-making (planning) period; 3 - adaptation period

Information about development period is uncertain; therefore the regular decision is necessary for decision-making adaptation

The planning process of development is envisaged gradually - step by step [3]:

1) To keep up external information adaptation.
2) To use decision-making for advance stage (horizontal information flow).
3) To use adapting information about advance development of the system (vertical information flow).

Reviewing dynamic planning process, life cycle cost is taken as 20 years, which is determined by dividing in four 5 years stages (see Fig.6). Moreover, in stage "0" analysis, decision-making and designing occur only for I stages. For technical and economic analysis in first approximate option there are new objects for stages II, III and IV.

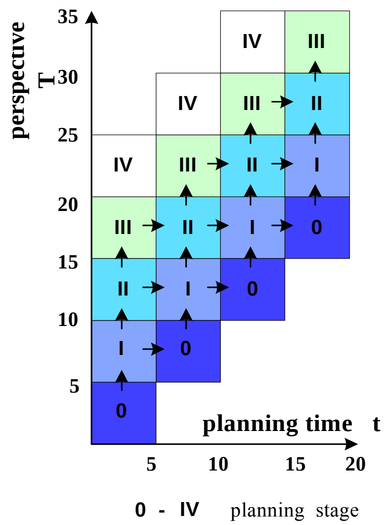



Fig.6. Dynamic process

Final decisions about these objects are made in next design stages (after 5, 10 and 15 years).

## 3 Model Structure of Optimization System

The structure of major models is represented in Fig.7.

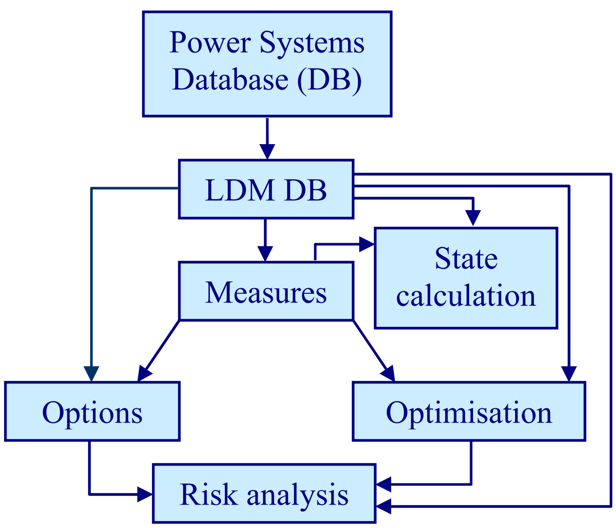



Fig.7. Scheme of major models (LDM software's)

***Measures*** forming model of development events. The modeled events are used searching for the optimal option with simulation method (*Options*), as well utilizing optimal output state method (OIS) [4,5,6].

***State calculation:*** 1) load flow; 2) reliability of switchyards 3) reliability of network; 4) reliability of node.

***Options*** can be used for simple optimization assignment direct solution or for complex assignment on optimization range reduction. By this model applying development measures, the user forms development options and performs its technical economic analysis.

***Optimization*** selects the competitive options group (up to 10 options). ***Optimization consists*** of two sub-blocks: 1) set up of alternative actions and 2) dynamic optimization. Optimization takes place under the determined information - average forecast.

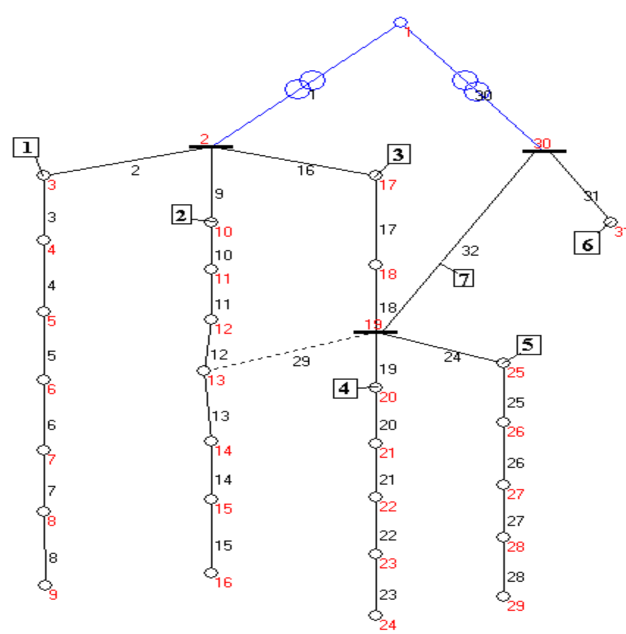
In order to observe uncertainty after Optimization - ***Risk analysis shall be applied.*** Optimization is performed by the optimal initial state method (OIS).

## 4 Network Model

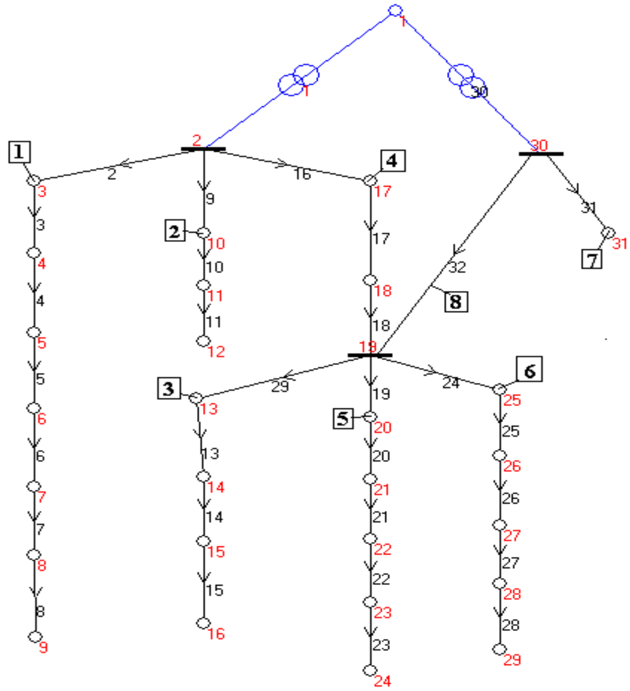
Configuration of models is described by graph, with nodes and links. In calculations process graph is partitioned in sections - sets of connected nodes and links ($Mm$ and $Ms$). Sections are very important elements in electrical supply reliability criteria calculations. Nodes are classified: 1) feeding node; 2) generator node; 3) load node; 4) key node. Key node characteristics are: a) switchgear is in node; b) no loads are in node; 3) node separate sections but not belonging to any section.

Model structure and elements showed in Fig.8. Node 1 is 110 kV switchgear, nodes 2 and 31 are medium voltage switchgears. All outgoing lines have circuit breakers. Node 19 is medium voltage distribution point. In example state **a** is an initial state and have 7 network sections, but state b is a state after reconstruction and have 8 sections.

Sets of section nodes and links:



**a)**




**b)**

Fig.8. Network model: **a)** initial state, **b)** network after reconstruction;
[1] - section number

## 5 Criteria for Reliability Estimation

In Table 1 reliability estimation criteria are given [2, 3, and 5].

Table 1

| No. | Name |
|---|---|
| 1. | Undelivered electrical energy $W$ [MWh/year] |
| 2. | Undelivered energy costs $C$ [th.Ls/year] |
| 3. | Electrical energy supply interruption time (asymptotic unavailability parameter) $U$ [h/year] |
| 4. | Unavailability possibility for network sections [h/year] |

Criteria for reliability estimation calculated by following equations:

- network section $i$ unavailability possibility:

$$\chi_i = \sum_{L \in Ms} \frac{\lambda_L \cdot K_{avar} \cdot DL_L \cdot r_L}{100 \cdot 8760}; \quad (1)$$

where $Ms$ - links set that form a section;
$\lambda_L$ - links $L$ specific failure number at 100 km per year;
$DL_L$ - links $L$ length, km;
$r_L$ - removal time for link $L$;
$K_{avar}$ - correction coefficient for failure number;

- electrical energy supply interruption time (asymptotic unavailability parameter) [h/year]:

$$U_i = \sum_{re=1}^{15} \chi_i \cdot T_{re_{re}} \cdot a; \quad (2)$$

- summary electrical energy supply interruption time for one section (asymptotic unavailability parameter) [h/year]:

$$U_{S_i} = \sum_{n \in Mn} U_i; \quad (3)$$

where $Mn$ - nodes set that form a section $i$;

- summary electrical energy supply interruption time for all network [h/year]:

$$T_{nep} = \sum_{i=1}^{scsk} U_{S_i}; \quad (4)$$

where $scsk$ - number of sections;
$T_{nep}$ - electrical energy supply interruption time;

- undelivered energy [MWh/year]:

$$W_{np} = \sum_{i=1}^{scsk} W_{SC_i} \cdot \chi_i; \quad (5)$$

where $W_{SC_i}$ - consumption of electrical energy in section $i$ [MWh/year];

$$W_{SC_i} = \sum_{re=1}^{15} T_{re_{re}} \cdot a_{re} \cdot \sum_{n \in M_{n_i}} P_{n,t,re}; \quad (6)$$

- penalty for undelivered energy [th. Ls/year]:

$$C_{np} = \sum_{re=1}^{15} \sum_{sc=1}^{scsk} \chi_i \cdot T_{re_{re}} \cdot a_{re} \cdot \left( \sum_{n \in N_{SC}} P_n \cdot c_k \right); \quad (7)$$

where $re$ - regime index number;
$i$ - network section index number;
$k$ - undelivered energy specific penalty group index number in load node $n$.

## 6 Algorithm for Reliability Criteria Calculations

Algorithm was developed for dynamic design of urban and rural area medium voltage distribution network with software LDM-SG'07. Software envisages multi step development (perspective up to 25 years), comparing up to 10 variants with every year criteria with possibility calculate reliability and other criteria in each variant in each step $t$ [5, 6].

Algorithm of reliability calculations in Fig.9 is shown.

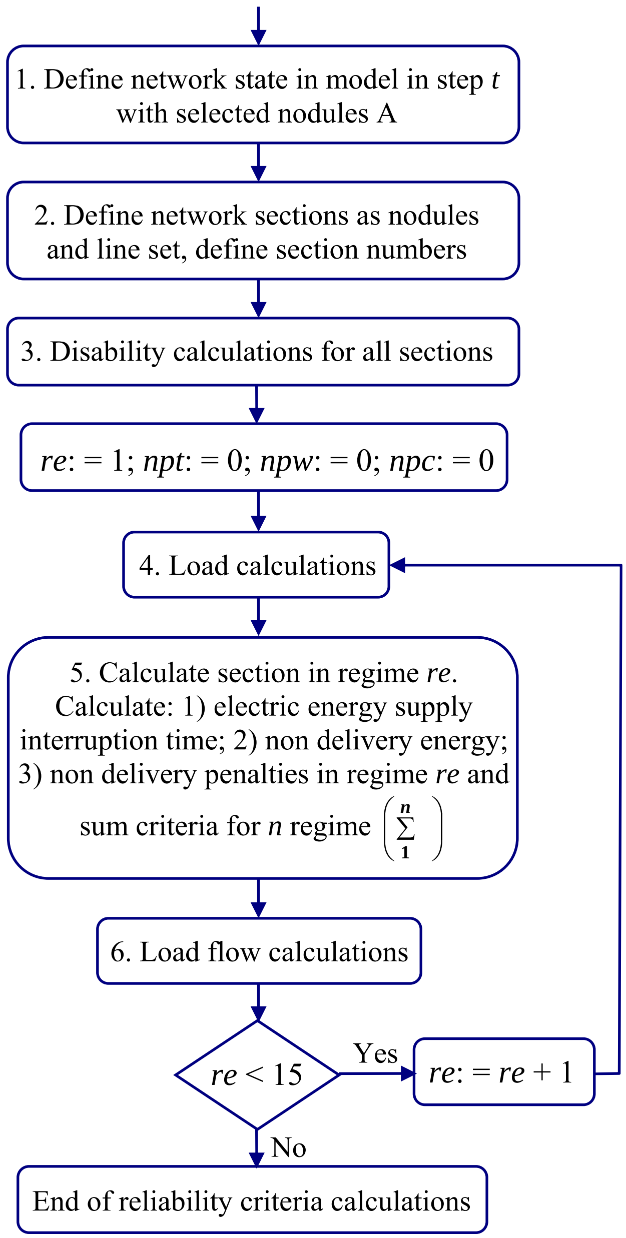



Fig.9. Algorithm of reliability estimation; *npt* - electrical energy supply interruption time; *npw* - undelivered electrical energy; *npc* - costs of undelivered energy

In first block network calculations model is formed considering realized measures before development step $t$. In second block network sections are formed considering to network model. Results are used in third block in unavailability possibility calculations. Unavailability possibility does not depend on load and is the same in all regimes. In software LDM-SG`07 second and third blocks are united in one procedure. Future calculations will be done in cycle by regimes $re = 1 \ldots 15$. At the beginning of cycle purifying of criteria *npt*, *npw* and *npc* will be done, then regime re=1 will be formed. In fourth block loads in nodes and sections will be calculated. In fifth block undelivered energy and undelivered energy costs will be calculated with unavailability possibility calculated in the third block and loads calculated in the fourth block. Results are used for *npt*, *npw* and *npc* formation. At the end of cycle by regimes $(re = 15)$ *npt* is total interruption time of electrical energy supply in nodes, *npw* - undelivered energy per year, *npc* - costs of undelivered energy per year. Reliability criteria would be calculated by formulas given above.

The Sixth block (flux calculations) is not used in reliability criteria calculations. The variants comparisons are done, calculating losses of power and energy in regime, overloads in links, voltage drop in nodes and other technical and economical criteria.

## 7 Conclusions

1) New method for medium voltage network (6, 10, 20 kV) optimization calculations were developed.
2) Method allows calculating medium voltage network development under conditions of the instant time period.
3) Main problems to be solved by new method are:
    a. connection of new loads;
    b. reconstruction and modernization of network in conditions of existing load growth;
    c. local power station connection to network;
4) Application of method in practice is positive.

Situation in Riga's urban electrical distribution network is such that it is not possible to connect to the grid new perspective loads. Actually there are more than 300 MVA unconnected perspective loads. Targeted and extensive distribution network reconstruction and development forms feasible and vital basis for detailed network analysis. In Laboratory of Electric Power System Simulation software LDM-SG'07 was developed for analysis of medium voltage distribution network development and reliability. After testing process the conclusion is as follows: the new method and software are needed which are based on real network structure for reliability estimation with possibility to include in optimization process all local reconstructions.

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