NEW TECHNOLOGIES FOR POWER SYSTEM LONG-TERM MANAGEMENTS

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Basic concepts. All over the world and particularly in Latvia, Estonia and Lithuania it is very essential for electrical engineers to take optimal decisions on utilisation of investments under conditions of changeable market economy. Specifying the mentioned the following is to be provided as:

1) all the investments are to be economically efficient,

2) production cost of electrical energy is to be continuously reduced.

In order to realise the mentioned objectives the management of Energy Company is to guide by diversified and operative technical economical analysis, applying sophisticated computer hardware and mathematical modelling methods.

At present the most urgent problems in Latvia are related to reconstruction of network. The reconstruction and refurbishment is to be continued as well energy losses in network are to be reduced. Energy losses in Latvia network are more substantial than in other European countries. Unfortunately the methods (technology) on such problems solutions are not sufficiently elaborated. To great extent a big scale of network, dynamics and uncertainty of information could motivate this.

Besides there are specific conditions in Latvia that considerably differ from the conditions of other countries and therefore direct application of foreign used software systems is not suitable in Latvia.

The network was built mainly in the 60s-70s. The useful *life time* for electrical equipment is usually 20-30 years, which means, that a lot of equipment is obsolete or is worn out and must be replaced in the near future.

Economical analyses agreeably to the methods make for objects economical life cycle (in networks –20-25 years). Efficiency function calculates to all estimation periods T. Under the information uncertainty to try makes decision only in the nearest future (approx. 5 years forward). This time interval call as decision-making period $t_d<T$ (see fig.1.)

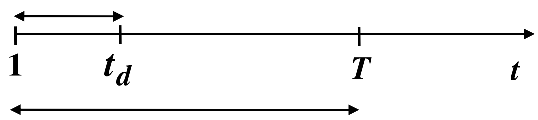

Figure1. Calculation and decision-making period.

Information about development period is uncertainty, therefore for decision-making is necessary the regular decision adaptation.

The planning process of development occur step by step:

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.

Review dynamic planning process, to take life cycle cost is 20 years, which determine divided in four 5 years stages (see fig.2.). Moreover, in stage “0” occur analyse, decision-making and designing. Decision makes only for I stages. For technical and economical analyse in first approximate option new objects for stages II, III and IV.

Final decision about these objects makes in next design stages (after 5,10 and 15 years).

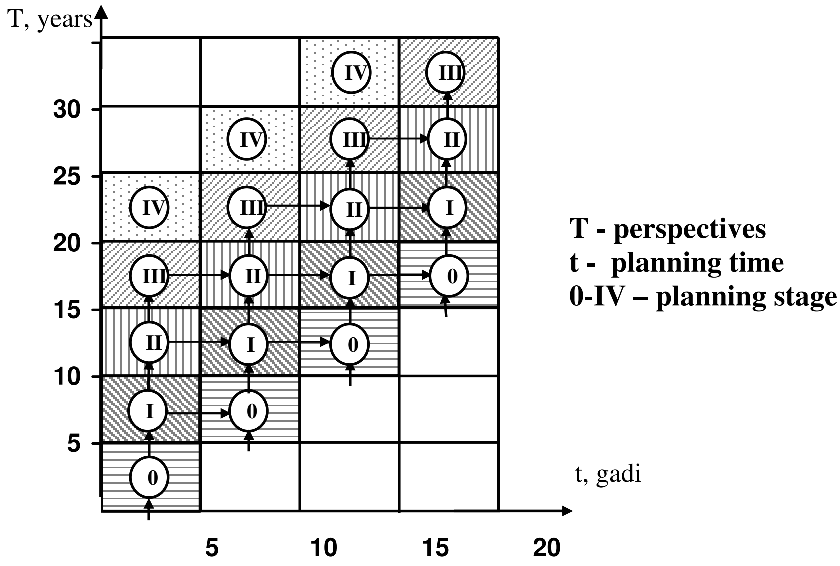

Figure 2. Dynamic process of power system long-term managements.

Laboratory of Electric Power System Simulation (EMML)

The reserch area of EMML is illustrated by fig.3.

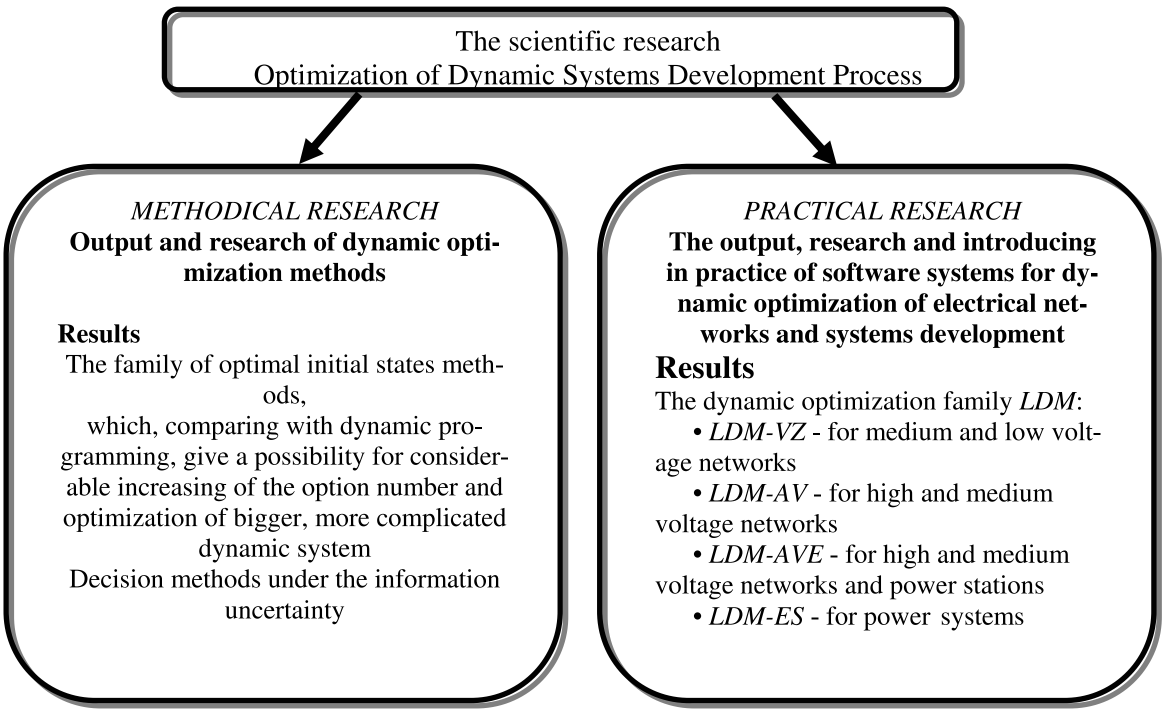

Figure 3. The research area of EMML.

Optimal Initial States methods

The methods based on dynamic programming (DP) seem to be very attractive since they naturally allow representing the dynamic nature of the development process. Another advantage of the method is that there is no need for linearization of the objective function used in the optimization process.

This also means that the objective function can contain present values of costs, witch reduces influence of investments made far in the future.

Thus the decisions made for the nearest future will be correct, but the decisions for the distant future can be corrected when more accurate forecasts are available.

The only challenge which makes DP not applicable to the real-size network planning problem is the so called "curse of dimensionality"; the method demands very big computational effort. On the other hand, when talking about network planning, in many cases it means reinforcement of existing network. These are the types of tasks where DP could be applied efficiently.

The idea behind DP is that the decision at the t^{th} stage is obtained from the decision made at stage (t-1) minimizing the transfer cost of moving from the starting point to this stage, which mathematically can be expressed as follows:

$$F(t,e) = \min_{\{G(t,e)\}} [g(0,e(0) + g(1,e(1)) + ... + g(t,e(t))] \,, \tag{1}$$

where

{G(t,e)} - is the set of acceptable strategies during the time t and until e is reached,

g (t, e (t)) - is the component of the objective function at t^{th} stage for the state e(t).

Furthermore, it can be shown, that Equation (1) can be reduced to the following recursive equation of DP:

$$F(t,e) = g(t,e) + \min_{\{e(t-1) \subseteq e\}} F(t-1, e(t-1)), \tag{2}$$

where $\{e(t\text{-}1) \subseteq e\}$ stands for the set of states e(t-1) from which the transition to state e is feasible. (fig. 4).

Then the optimization process can be accomplished by decision of some set of equations according to Equation (2) minimizing the objective function for the period from the initial to the final stage.

In order to overcome the difficulties connected with high dimensions, there are attempts to reduce computational capacities needed for realization of the DP method.

A number of researches have applied DP to the distribution network reinforcement problem, attracted by its advantageous features. However, the problem of the "green-field" network planning (planning of a new network) is likely to be addressed by some other optimization techniques.

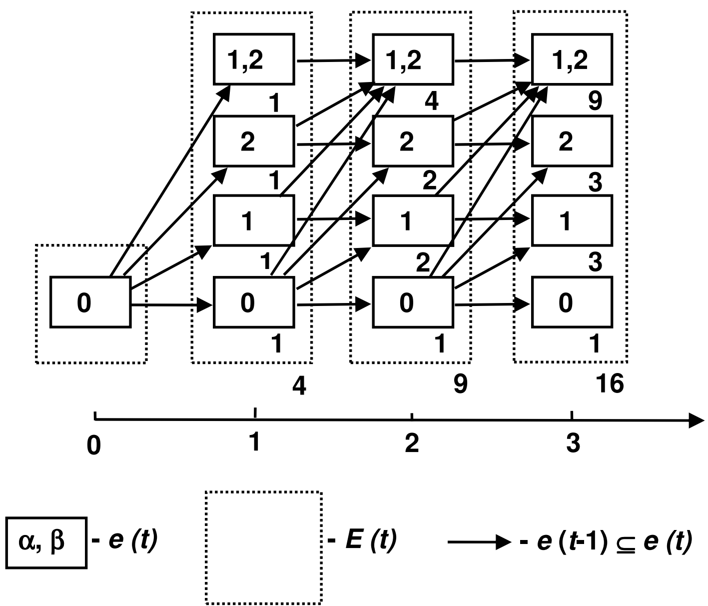

Figure 4. Dynamic development of electric power system object.

Considerable limitation of the algorithm of the DP is that with the number of variables n exponentially increases the number of states, which is 2^n (n=30 – milliard states). The method *Optimal Initial States* considerably reduces the number of states for examination compared to pure *DP*. The idea behind this algorithm is that as the dynamic optimization proceeds at each stage only some states could lead to the optimal solution. These states called optimal initial states should be kept for further consideration. It gives great savings in computer time and memory.

The method optimal initial states location for the stage *t+1* without calculation of the objective function can be obtained taking into account features listed above. The method contains subsequent minimization tasks according to the following algorithm:

- Find $\omega(t)_1$ which is the global optimum among all the states according to:

$$f(t,\omega(t)_1) = \min_{e\in\{e(t)\}_1} f(t,e)\,, \tag{3}$$

- The next optimal initial state $\omega(t)_2$ can be detected as a local minimum

$$f(t,\omega(t)_2) = \min_{e\in\{e(t)\}_2} f(t,e)\,, \tag{4}$$

where $\{e(t)\}_1$ is the set of the states to which transition from $\omega(t)_1$ is impossible.

- The algorithm proceeds by subsequently finding of local optimums according to:

$$f(t,\omega(t)_i) = \min_{e\in\{e(t)\}_i} f(t,e)\,, \tag{5}$$

where $\{e(t)\}_i$ is the set of states to which transition from $\omega(t)_1$, $\omega(t)_2$,…, $\omega(t)_{i-1}$ is impossible

- the algorithm proceeds until $\{e(t)\}_i = \varnothing$, which means that all the optimal initial states are detected.

The number of optimal initial states depends on several factors and is different for every particular task.

Traditionally for *O.I.S.* selected in real task we use:

1) Character economics curves of network (fig.5),
2) States graph (fig.6).

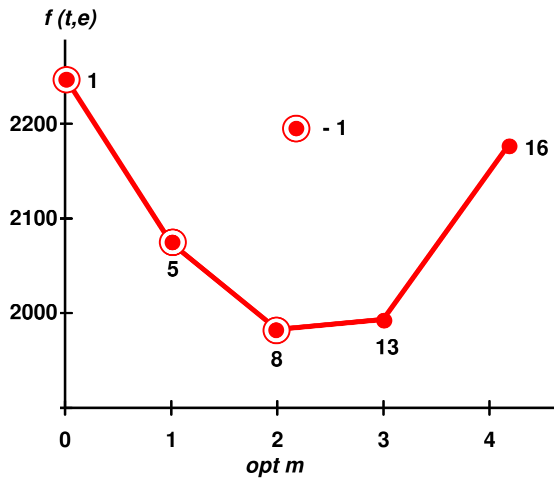

Figure 5. Character economics curves of network.

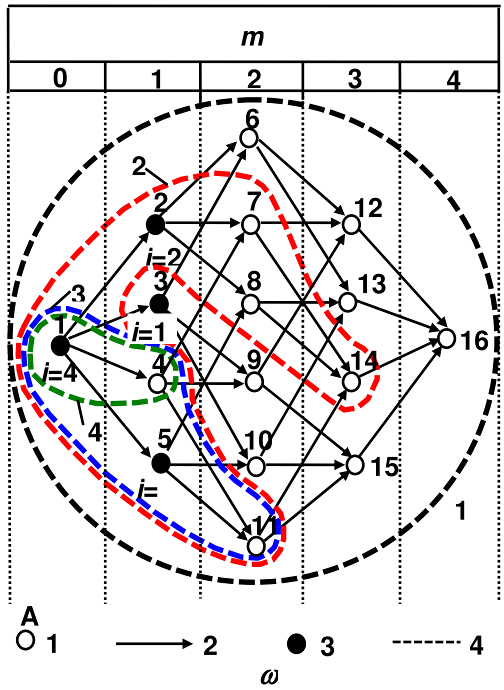

Figure 6. States graph.

The value of the objective function to optimal number of measures *opt m* is increase but, its go up then *m>opt m.*

The planning task could be represented as a graph where the nodes represent particular states of the network and the branches represent certain investments made to reinforce the network (realized actions) when moving from one state to another. Each column depicts a certain time stage and each line one possible action (Figure 6.). For a particular task some of the graph branches can be absent corresponding to the logical (or others) constraints. On the other hand, some investments can be made simultaneously, in which case the graphical problem representation would not be so obvious.

Latvian Dynamic Model

The main assignment of system which determines the principles of its formation - to ensure a possibility for different level managers to make decisions which base themselves on objective facts not on experts' opinions or suppositions. It's necessary to take into consideration the general principles of system formation for realization of this assignment:

- less information systems and interfaces;
- an united information architecture;
- an operative preparation and reiteration of optimization;
- simple, comfortable and quick input of scheme;
- simple, comfortable and quick correction of parameters;
- a review of life cycle; a review of many alternatives;
- an automation and integration of processes;
- a choice of the vital information and presentation to different level managers.

All life cycle must review into optimization process. The criterion of choice is the net present value (NPV) for life cycle. The many different alternatives must review into course of optimization process and must realize electrical calculations for all variants. Some competitive availability variants must obtain as a result of optimization. It's means that must use the dynamic optimization methods.

An optimization system must be friendly to consumer. In case of investment efficiency analysis, it must ensure a possibility for different level managers to take decisions which base oneself on maximally objective calculations not on experts' opinions or suppositions only. Solving the development assignments must ensure a possibility to prepare a calculated object quickly and also, more exact information making, operatively reiterate the optimization and correct farther decisions.

At 2001 year, Laboratory of Electric Power System Simulation worked out new software of Latvian Dynamic Model (LDM) family.

The software *LDM-VZ.* The software *LDM-VZ* realizes investment efficiency analysis of reconstructing and new constructing low voltage network objects and also of transformer substations (20/0.4 or 10/0.4 kV) under uncertainty, using a criterion of net present value (NPV) and dynamic optimization of network. *LDM-VZ* is suitable for using at the level of distribution network enterprises.

The software *LDM-AVE.* The software *LDM-AVE* realizes investment efficiency analysis of reconstructing and new constructing 330-11-20-10-6 kV network objects including local power stations, using technical economical calculation methods and dynamic optimization of network.

Both of the software base themselves on the above-mentioned principles and have the same structure. The software is programmed in *Delphi* language, using all advantages of the operative system *Windows*. Both of the software systems ensure possibilities: 1) to eliminate investments, which increase prime cost, 2) to arrange the required investments by their efficiency. Those are envisaged for *Pentium III* type computers for operative system *Windows*.

The databases *LDM* are formed by joining gradually network objects. In comparison with previous software systems of *LDM* family, the new systems have considerably simplified input and this considerably diminishes a possibility to make mistakes.

The software *LDM-AVE* makes analysis and optimization employ:

1. Database of Latvenergo STDRS (distribution network working state systems).
2. All Latvian high and medium voltage networks data archive.

The software operational flow is presented in fig.7.

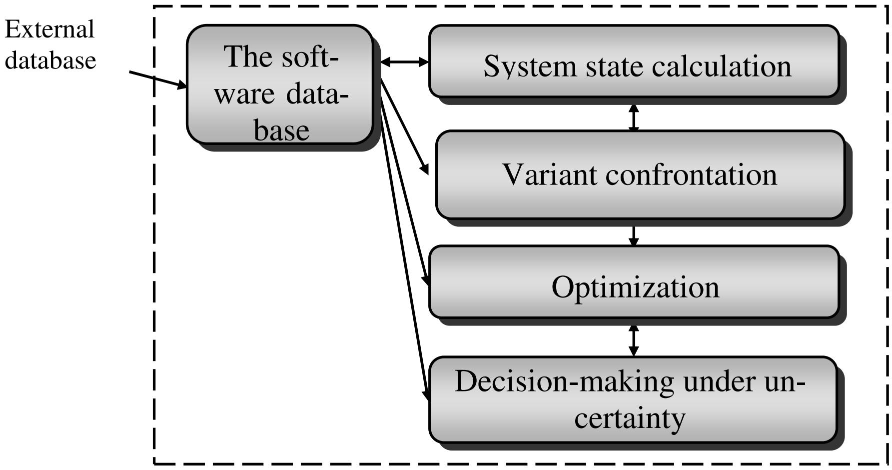

Fig.7. Flow of operation in the software LDM calculation.

The program LDM is foreseen for reinforcement planning of MV and LV distribution network under information uncertainty.

The program has the following main function:

- Technical and economic estimation of the present state of the network;
- Define economically appropriate actions from the given set of alternative actions (constructions, reconstruction or elimination of network elements) and terms of their realization;
- Estimate power supply quality and define the most effective actions to improve it;
- Provide risk analysis as a decision-making tool under information uncertainty.

Moreover, calculations such as load flow, voltage drops, fault current, energy and power losses, reliability estimates, annual and total costs for the particular network as well as investments pay-back times are also provided.

There are two main options in the program: dynamic optimization and analysis. Dynamic optimization and analysis Dynamic optimization uses as an input data base data together with development conditions and alternative actions. NPV of total network costs (investments, cost of losses, cost of energy not supplied) is used as an optimization criterion.

As a result of optimization except for the optimal strategy, one gets the set of “good” strategies. The final decision can be made taking into account uncertainties according to the minimal risk criterion.

In real life users are mostly interested in actions, which should be realized in the nearest future (2-5 years forward). Therefore the concept “decision-making period” is used. It means that providing analysis under uncertainty the actions suggested for realization during decision-making period are considered to be performed and at every new future scenario adaptation of strategies to the new development conditions is carried out.

Both of the software can be used in other Latvenergo database. The software *LDM-VZ* use with software *ZUDUMI (LOSSES)* - that is designed for the calculation of technical losses in low voltage network. Both software databases are related. The link principle is shown in fig.8.

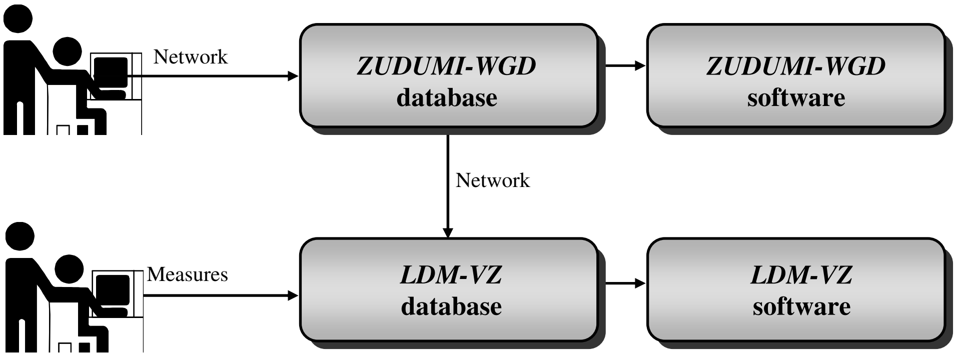

Figure 8. Structure of software system (low voltage network).

With the software *ZUDUMI-WGD* and *LDM-VZ* several measures could be analysed, for instance:

• The replacement of the existing transformers by respective power transformers and such a way to reduce idle losses;

• The replacement of the existing wires by bigger cross-section wires;

• The construction of new MV transformer substations (transformer nodes).

The database structure of *ZUDUMI-WGD* is the following:

1. The database of network area is divided into calculated objects. Apart of low voltage network corresponds to the calculated objects that is supplied from one MV transformer substation;

2. In order to identify network calculated objects, their names (designation) should reflect the site (note) and operative number of MV transformer substation;

3. The database should comprise the latest standard objects.

All this software is already applied in Latvia, Latvenergo network enterprises. Also the EMML organised special training courses for users of software family LDM. Experience of software family LDM applied is successful.

Об авторах.

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