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THE METHOD ELABORATION OF POWER SUPPLY RELIABILITY ASSESMENT

Summary of Doctoral Thesis

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Introduction

Reliability issues of high voltage transmission network are being solved in the promotion work.

There are many diversified factors that have impact on problem solution in energy industry, Comparing with other factors reliability is a special issue is to be observed always and everywhere. The electric power supply of consumers is influenced by unforeseen circumstances related to emergencies, disturbances or failures of equipment or systems in the power system objects. The electricity consumers as industrial group, agriculture etc. are dependable on electric power supply reliability. Its dependence is so considerable that electric power supply interruption would cause essential material losses that are of national scale. The losses caused by durable and considerable interruptions and outages of power supply are so significant that according to technical and national economic estimations it is required to achieve higher level of electric power supply reliability. The consequences of reliabihty shortage in power system are very serious and it is evident that the methods continuous improvement is required on power system design, construction, operation and maintenance. Therefore investigation and assessment of power systems reliability has been and will be the most significant issue in the power energy branch. The investigations and research performed and power network reliability issues approve that reliability issue of power systems and networks are the most urgent all over the world.

Today electricity market liberalisation is taking place in the whole Europe as well as in Latvia associated with new coming problems regarding power supply. Liberalisation of electricity market demands upgrading of production, transmission and distribution systems. It means that the unbundling process of production from transmission and distribution is taking place in many previously monopolised electricity markets segments. As far the public service utilities are under the influence of price escalation they are forced to reduce both investments and maintenance costs. But such undertaking generally would negatively influence quality of the rendered services.

The objectives and assignments of the study

The objectives of the promotion work:

1. To work out long-term methodology that provides research and analysis of issues and aspects of transmission network reliability.
2. To work out model algorithm examining network element interruption by one *(n-1)* and by two *(n-2)*.
3. To work out assessment methodology on 330kV and 110kV substations distribution units reliability factors.
4. To accommodate reliability calculation method for transmission networks in Latvia and Baltic region.

Research method and tools

The research methods as analysis and synthesis are applied in the study. The system customised principles are applied in the work - assignments, objectives and criteria selection unification, identification of the most essential assets of the system, and mathematical simulation methods. Besides, mathematical statistical methods are applied here too.

Scientific novelty

1. The algorithm original model on disconnection simulation has been worked out, that examines network disconnection elements by one *(n-1)* and by two *{n-2)*.

2. The original method on 330kV un 110kV substations distributions units reliability factors has been worked out that would be applicable in the optimisation process of transmission network.

Practical application of the research results

The results of the work form the programme *LDM-AD'04* that is envisaged for reliability analysis of high voltage transmission network. This programme is used by AS *Latvenergo Augstsprieguma Tīkls (AST),* that provides the opportunity to increase high voltage network reliability and economic efficiency.

Work approbation

The results of the work have been available in the respective informative sources and have been discussed during 11 international conferences:

1. RTU 44 international scientific conference;
2. 11 International Power Electronics and Motion Control Conference "EPE-PEMC 2004", Riga, Latvia;
3. 75 international scientific seminar „Power system reliability researches methodological questions", Minsk, Belorussia;
4. International scientific conference "Power System: control, quality, competition", Yekaterinburg, Russia;
5. International Scientific Conference 2005 IEEE St.Petersburg PowerTech'05, St.Petersburg, Russia;
6. 76 international scientific seminar „Power system reliability researches methodological questions", Pskov, Russia;
7. The 3rd international Scientific Symposium ELEKTROENERGETIKA 2005. Stara Lesna, Slovak Republic;
8. RTU 46 international scientific conference;
9. The 1st International Scientific Conference, Electro-Tech 2005, Budapest, Hungary;
10. The 7th International Scientific Conference EPE-2006, Brno, Czech Republic.
11. The 9th International Conference on Probabilistic Methods Applied to Power Systems PMAPS-2006, Stockholm, Sweden.

Author publications

In total 21 publications were issued in report journals:

1. Krišāns Z., Kutjuns A, Mutule A. *330 kV komutācijas shēmu drošuma novērtēšanas matemātiskais modelis* //Latvian journal of physics and technical scienes, 2002, Nr. 5, 16-26.lpp.

2. Krišāns Z., Oļeinikova I., Kutjuns A., Mutule A. *Latvijas 110-330 kV pārvades tīkla drošuma novērtēšanas metode* //Latvian journal of physics and technical scienes, 2002, Nr. 6, 30-38.lpp.

3. Krišāns Z., Oļeinikova I., Kutjuns A. *Network Reliability optimization under liberalizes electricity market* //Latvian journal of physics and technical sciences, 2003, Nr. 5, 3-10. lpp.

4. Krišāns Z., Oļeinikova I., Kutjuns A. *Elektriskā tīkla drošuma līmeņa izmaksu aprēķina principi brīvā elektroenerģijas tirgū* //Rīgas Tehniskās universitātes zinātniskie raksti. RTU-2003, 4.sērija, 9.sējums, 42-48.lpp.

5. A.Kutjuns, I.Oļeinikova. *Latvijas, Lietuvas un Igaunijas elektroenerģijas tirgus galvenie aspekti II* Rīgas Tehniskās universitātes zinātniskie raksti. RTU-2004, 4.sērija, 11.sējums, 55-62.lpp.

6. Z.Krišāns, I.Oļeiņikova, A.Kutjuns. *Augstākā sprieguma (330,110kV) tīkla un apakšstaciju sadalietaišu darba un elektroapgādes drošuma kritēriju un tehnisko aprēķinu programma LDM-AD '04//*LZA FEI, Rīga, 2004, 73 lpp.

7. A.Kutjuns, LOļeinikova. *Distribution system and transmission network power supply reliability's estimation software //*1th International Power Electronics and Motion Control Conference "EPE-PEMC 2004", Riga, Latvia, September 2-4, 2004. - Proceedings, Vol. 5, P. 139-142.

8. Кришанс З.П., Олейникова И.Н., Купон А.К. „*Программа LDM-AB'04 для выбора схем питающих сетей с учетом надежности электроснабжения " //* Методические вопросы исследования надежности больших систем энергетики, Иркутск - Минск - 2005, № 55,240-247с.

9. А.Кутюн, И.Олейникова, З.Кришанс. *Метод оценки надежности главных схем и электротехнического оборудования подстанций 110-750 кВ. II* УГТУ Вестник №12 (42). Энергосистема: Управление, Качество, Конкуренция. Екатеринбург - 2004, Россия, 303-307с.

10. Z.Krišāns, A.Kutjuns, I.Oļeiņikova. *Pārvades tīkla drošuma aprēķins, ievērojot divu tīkla elementu vienlaicīgus atslēgumus. II* Latvian Journal of Physics and Technical Sciences, 2005, No 2,43-49.lpp.

11. Z.Krishans, A.Mutule, A.Kutjuns. *Integration of distributed generation in the networks of Latvian power system. II* International Scientific Conference Sankt-Petersburg PowerTech'05. Russia, 2005. Conference Proceeding on CD.

12. K.Briņķis, A.Kutjuns. *Orkāna izraisītie bojājumi Baltijas valstu elektrotīklos un iespējama sistēmas sadalīšanas analīze. II* Latvian Journal of Physics and Technical Sciences, 2005, No 3,43-49 .lpp.

13. Купон А.К., Кришанс З.П., Олейникова И.Н. *Состояние, задачи и проблемы обеспечения надёжности энергосистем Балтийских государств, после вступления в ЕС и внедрения рынка электроэнергии. II* 76-й международный научный семинар Российской академии наук Сибирского отделения „ Методические вопросы исследования надёжности больших систем энергетики", Иркутск - Псков - 2005, Россия.

14.Z.Krishans, A.Kutjuns, LOleinikova. *Reliability problems in Baltic countries power networks under liberalized electricity market conditions. //* The 3 international scientific symposium ELEKTROENERGETIKA 2005. Stara Lesna, Slovak Republic, 2005, Conference Proceeding on CD.

15.Z.Krišāns, A.Kutjuns, I.Oļeinikova. *Reliability problems on Baltic countries power networks.* //Rīgas Tehniskās universitates zinātniskie raksti. RTU-2005, 4. sērija, 14 sējums, 123-128.1pp.

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17. Кришанс З.П., Купон А.К., Олейникова И.Н. *Расчет надежности передающей сети, при помощи критерия недоотпуска электроэнергии II* Вестник научной академии А.М.Прохорова, №15, Москва - Н.Новгород, Россия-2005, 264-267С.

18. Z.Krishans, A.Kutjuns. *Transmission network reliability calculation with conventional load non-supp1y criterion,* // Международная научно-техническая конференция „Перенапряжения и надежность эксплуатации оборудования" 4.издание Санкт-Петербург - 2006, 192-200 с.

19. Z.Krišans, A.Kutjuns, I.Oļeinikova. // *Baltic countries power networks reliability problems tender market conditions and methods of reliability improvement.* The 7th International Scientific Conference EPE-2006, Brno, Czech Republic, 2006, Conference Proceeding on CD.
20. Z.Krishans, A.Mutule, I.Oleinikova, A.Kutjuns. *Application of risk assessment method for Baltic States power system development optimization.* // The 9th International Conference on Probabilistic Methods Applied to Power Systems PMAPS-2006, Stockholm, Sweden. Conference Proceeding on CD.
21. Z.Krishans, I.Oleinikova, A.Mutule, A.Kutjuns. *Optimization method of power system development under uncertainty* // The 9 International Conference on Probabilistic Methods Applied to Power Systems PMAPS-2006, Stockholm, Sweden, June - 2006. Conference Proceeding on CD.

1. The reliability problems of transmission network in Latvia.

1.1. Transmission network of Latvian power system.

High voltage transmission network of the Republic of Latvia incorporates grid of 330 kV and 110 kV lines, which interconnect distribution switchgear units, substations and generation sources in the territory of Latvia as well as with neighbouring systems. The Transmission network of the Latvian power system incorporates many ties (see. fig. 1.1).

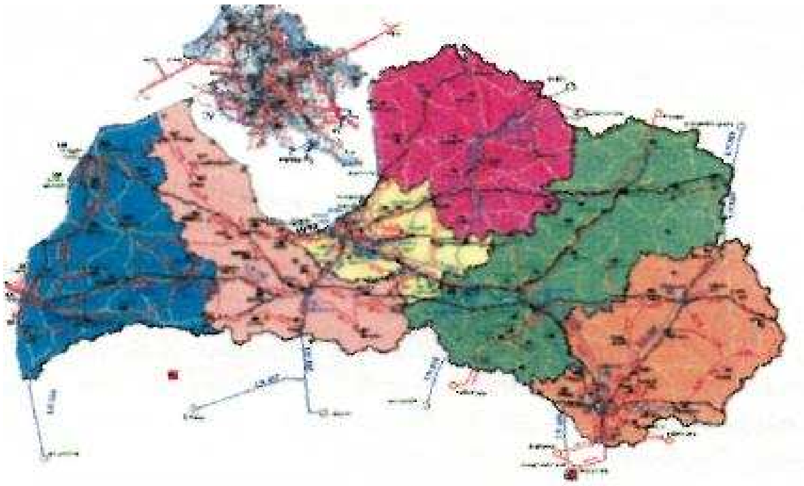


Fig. 1.1. Latvian power system transmission network.

The existing transmission network will be sufficient for ten years regarding forecasted electricity and power demand. Development of specific regions (such as cities: Riga, Liepaja, Ventspils, etc.), where the existing loads re-tailoring or reallocation is taking place and load increase is expected, the demand for construction of new substations, power plant and transmission line is evident.

To increase reliability of transmission grid the research for new projects on power plants and construction of transmission lines in Riga, Ventspils and other extensive Latvian cities are being performed.

Hurricane that happened in Latvia in January of 2005 evidently demonstrated that reliability issues and transmission network electrical schemes drawbacks and „bottle necks" of the entire Latvian power system are very actual and these shall be efficiently solved. The natural disaster resulted in huge scope of damage to the Latvian transmission network. Outages of many transmission lines caused partly blackout in many large cities and regions of Latvia

The scope of damages caused by hurricane demonstrated that the power system is not protected from the natural cataclysms and in many cases is unable to withstand it therefore consequently the power system reliability shall be improved to protect electric power supply.

1.2. Latvian power system operation in electric ring pool

Latvian power system operates in the frame of Baltic power systems pool. The power systems of Baltic States Estonia, Latvia and Lithuania are interconnected by 330 kV transmission electric power lines and simultaneously form one of components for electric rings which incorporate 330, 500 and 750 kV electric networks, belonging to neighbouring state power systems - Byelorussian and Russian.

330÷750 kV electric ring considerably increase reliability of power supply of each state as its development is coordinated in the frame of integrated power system pool.

Having acceded the European Union Latvian power system is to open liberalised electricity market and connect own electric networks to transmission networks of the European states. As far Lithuania and Estonia are the nearest European states to Latvia and there are no other connections to European networks the Latvian power system participates in the state joint project of the Baltic States on new lines construction with Western European states.

1.3. Introduction of liberalised electricity market in Latvia

After joining the European Union Latvia shall follow the requirements of the European Directives and open free electricity market. That is very complicated and labour capacious process that influences operation of transmission and distribution networks that's why Latvia takes its time in the process of electricity market liberalisation and definition procedure of eligible electricity customer.

Within the latest time the priority of free electricity market against power supply reliability is the reason of blackouts or outages. Under market liberalisation conditions when competition is fostered, the reliability requirements remain as the second priority and this is the reason of the energy faults occur [13], [14], [15]. As far the core business of power system is not focused just to guarantee maximal reliability, so it creates prerequisites for such emergency situation when collision interests come for the sake of maximal profit acquisition from the one side and from the other side assignment of network operator - to provide secure and reliable electricity supply.

1.4. The Latvian power system - as deficit system

At present Latvian power system is a deficit system in comparison with neighbouring systems of Lithuania and Estonia where electricity generation exceeds the demand. At present Latvia has to purchase approximately 40% of electricity from neighbouring power systems: Estonian, Lithuanian and Russian. Electricity generation in Latvia is provided by regeneration and hydro power plants.

The Baltic power systems from the previous historic times have inherited quite modern and efficient energy assets. But due to specific activities the capacity surplus has been rapidly reduced and further on (about the year's 2010.-2015.) introduction of new capacities will be needed for the power systems. The demand for the introduction of new capacities is mainly related to the major generation source of Lithuania - Ignalinas nuclear power plant closing. Operation termination of Ignalina NPP essentially influences not only the entire Lithuanian energy complex development but it will exert impact of close neighbouring systems including Latvia. The whole Baltic Region will lose the most capacious, efficient and cheapest electricity generation source and from neighbouring power systems power flow will increase to Lithuania that consequently will be reflected in transmission networks operation as Lithuania will have to purchase part of the demanded electricity from neighbouring power systems.

In order to increase generation capacity of Latvian power system reconstruction works of electric power plants are extensively initiated on replacement of deteriorated assets by new modern equipment. After electric power plants reconstruction and refurbishment and new power plants construction Latvian power system is to become self-balanced system that to a great extent will improve electric power supply reliability and security.

1.5. Reconstruction of Latvian transmission network

One of the most significant factors, which in combination with slow pace of electric networks development and complicated conditions of power system operation hampering electric power supply reliability - is aging of electric equipment of power plants and substations.

More than 30 years passed since first 330 and 110 kV lines and substations were constructed in Latvia, so now it is real time to renew these. Up to the 90-ies of the last century mainly new substations were built and constructed but old equipment was not renovated. Therefore modernisation and reconstruction of Latvian transmission power network meeting the European power system standards is very actual today. The replacement of old equipment by modern one and re-tailoring of network configuration is taking place now in the transmission network that consequently promote reliability of transmission network operation.

2. Methods summary on reliability assessment applied abroad. Reliability under conditions of free electricity market - from analysis to risk management.

2.1. Reliability analysis general idea

Methods for power system reliability evaluation have been developed over the past 30 years [1-4]. Although research still continues in search of better models and methods but in general there is substantial body of knowledge that can be used effectively for analysis and management of reliability related issues. The general idea of a reliability analysis is given in figure 2.1.

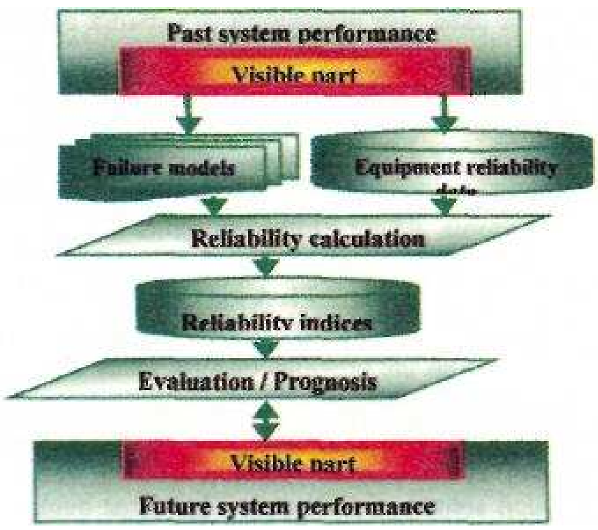


Fig.2.1. General sequence of reliability analysis.

From the observation of the past performance a set of outage models and corresponding input data are derived using appropriate outage statistics. In the calculation part, one or numerous possible scenarios are generated depending on the method used. From these scenarios, system performance indices are derived. In most cases these are indices of supply interruptions.

Depending on the scope, reliability analysis requires the simulation of the complete operational behaviour of the system to a certain extent including manual or automatic actions taken in response to component failures. Therefore reliability calculation is a much more sophisticated task compared to conventional *(n-1)* - power-flow analysis. Suitable models to represent the components and the system are needed. We also need tools and data for making calculations using these models and the indices and methods for incorporating the output of these models and methods for appropriate applications. These aspects of reliability analysis are portrayed in figure 2.2 [6].

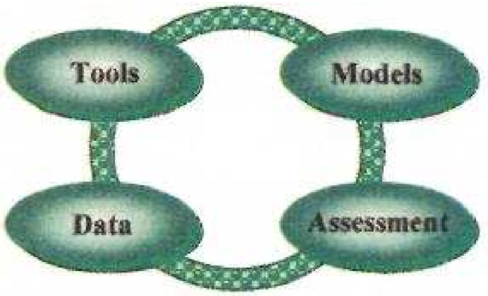


Fig.2.2. Aspects of power system reliability analysis.

Reliability assessment and research is performed in several levels: generation, transmission, distribution, etc., and by several models tools: generation model, transmission lines model, transformer model etc.

2.2. Reliability from the point of view of consumers

The major problem of reliability assessment is maintaining of quality level on electric power supply that consequently requires definite operation cost to the system's owner while lack of quality cause consumers expenses. Quality of electric power supply and price are the most significant electricity characteristics specifically in regard to industrial consumers.

From the point of view of consumers it would be preferable to create such structure where the customer could demand for supply quality and respective costs. For instance, in bibliography [4] offered for consumers could select corresponding individual reliability level, paying for connection and service as well as insurance costs for additional reliability. In figure 2.3 general principles of this approach are shown:

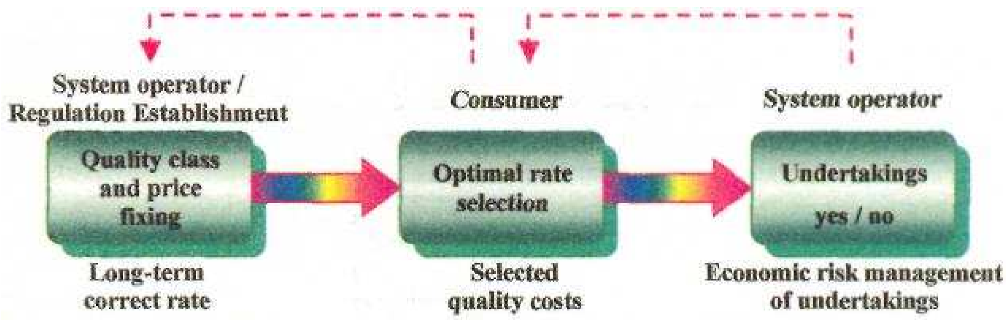


Fig.2.3. Quality structure oriented on customers/consumers

For all three steps it is required to calculate not only consumer's reliability indicators but to convert these into expenses. As reliability indicators are subject to forecast ambiguity so consequently the calculated reliability expenses will be also of probability breakdown. The expenses probability breakdown forms the basis for the respective risk assessment.

2.3. The conclusion

Rapid changes in energy domain create new approach to reliability issues. The interest on adequate reliability level creation in future is increased both from the users/customers side and from the Regulation Institutions. For reliability provision in many countries several companies have applied economic simulation methods. But still up to now there is no customised standardised applied structure yet.

Before historically many research and development studies were completed that resulted in softwares (as working tools) which consequently required for risk analysis performance. But still it is evident that incorporates a long process to create risk management software, which observes reliability for current decision making process.

3. Elaboration of transmission network reliability factor assessment method 3.1. The problem statement

The transmission and communication system infrastructure shall be developed. The integration of generation domain shall be performed being completely aware of expected benefits or advantages. The support of transmission system with generation domain can create bilateral benefit for electric power supply utilities and customers but negatively influence reliability. Where and how the generation shall be involved - this is determined by cost system. To make these costs visible it is required to transfer it into traditional reliability measures.

The methodological issues on reliability research and assessment are subdivided into two basic directives (see fig.3.1).

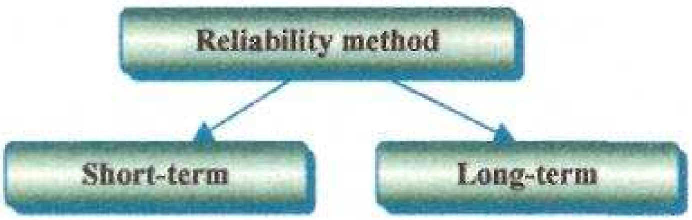


Fig.3.1. The structure of operation reliability method.

The short-term method is a method that does not require considerable capital investments. The short-term method is designed for power systems and local operator control in post-emergency modes in order to decrease the scope and duration of tripping and disconnection.

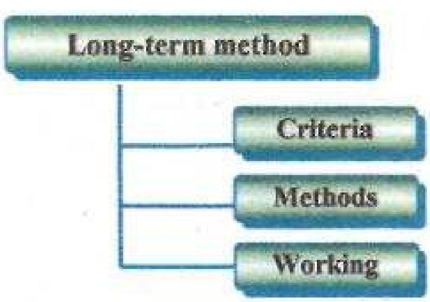


Fig.3.2. Structure of long term method.

The long-term method is designed for capital investments elevation to increase reliability level. The long-term method is envisaged for system and network development analysis, as well as for designing of networks and networks elements taking into consideration power supply reliability. The structure of long-term methodology on reliability assessment is shown in figure 3.2.

In the process of the promotion work great attention was paid to the currently urgent issues on power system reliability and security improvement both in Latvia and abroad and the following has been performed:

1. Long-term method on research and analysis of transmission network reliability analysis and that is an integrated component of dynamic optimisation development process;
2. Disconnection modelling algorithm, having reviewed network elements disconnections by one *{n-1)* and by two *(n-2).* Comparing with criterion *n-1,* reliability calculation is more complex assignment - that's why, that depending on situation reliability analysis requires entire simulation of operative work conditions to certain extent, including also manual and automatic operations responding to failures.
3. The reliability calculation method is adoptable for Latvian and Baltic region transmission networks. As far as there are specific characteristics in Latvian and Baltic transmission networks the reliability calculation method is created for the conditions prevailing in Latvia and Baltic region.

In the promotion work on transmission network reliability problems solution the following criteria have been applied: (see 3.1. tab.).

Tab.3.1.

Reliability criteria for 330,110 kV networks options comparing

Nr.	Title
1.	Non-delivered energy ***W*** [MWh/year]
2.	Non-delivery costs ***C*** [thous. Ls/year]
3.	Time of electric power supply interruption (asymptotical operation unavailability parameter) ***U*** [h/year]

1.**criterion.** It is significant and has been investigated because major assignment of the power system is customers supply with electricity in the demanded amount and quality. The consequences due to each undelivered MW could be very miserable specifically if that influence national economic important objects and customers.

2.criterion. The customers - industry, agriculture etc. are dependent on electric power supply reliability. This dependence is so considerable that, interruption of electricity supply causes considerable material losses of national scale. The most serious emergencies or blackouts in the world are: blackout in New York in 1965; Chernobyl accident in 1986; emergencies in USA un Canada in 2003 august [13]; energy crisis in Europe in 2003 [13]; hurricane ravages in Baltic States in 2005, on January 9, including in Latvia [14]; energy crisis in Moscow in 2005, May 25 [15], In each event the material losses due to undelivered electricity were huge therefore it always shall be calculated for each probable case to what extent and in what scope the costs of undelivered electricity can be expected.

3.criterion. In any emergency situation whether its scale may be, it is necessary to utmost provide electricity supply in areas of tripped consumers particularly if these are important objects. Therefore it is important and obligatory to calculate power supply interruption time and predict emergency development route and thus make a forecast for probable disconnections, its points and consequences.

3.2. Modelling principles of emergency disconnection

Electricity transmission from generation sources till distribution companies or customers is significant component in the entire process of electric power supply.

The transmission network of Baltic States is closed with many circuits and almost all load nodes are supplied from two or more ties (see fig.3.3). There are some exceptions in transmission network scheme: delta connection lines where tie is connected to the trunk line without circuit breaker. In Baltic 330 kV transmission network such line is between Latvia and Lithuania (LN305/457 Jelgava-Šauļi-Telši), from which branch goes to Telšiem. In transmission network of 110 kV such cases are more used: in Latvia 110 kV branches to Aizputi, Valdemārpili, Ilūksti etc.

If failure occurs in delta line (short circuit at least in one of three ends), relay protection system disconnects the whole line with circuit breakers. It means that the entire transmission network element is disconnected from the grid. Generally simulating disconnection it is necessary to use new definition in our methodology - ***failure element.***

Failures element - this is transmission line group which is limited by circuit breakers (in specific example with delta line 330 kV Jelgava-Siauliai-Telsiai, failure elements are switchgears at three substations: Jelgava, Siauliai and Telsiai). But if the system under analysis is transmission network, then object for analysis in 330 and 110 kV grid is transmission line.

Fig.3.3. Baltic power systems 330kv transmission network.

In figure 3.4 transmission network part is shown with elements (transmission lines). The lines are connected both in chain, in parallel and the objects (nodes) can be feeded both from one side, and from two and more sides.

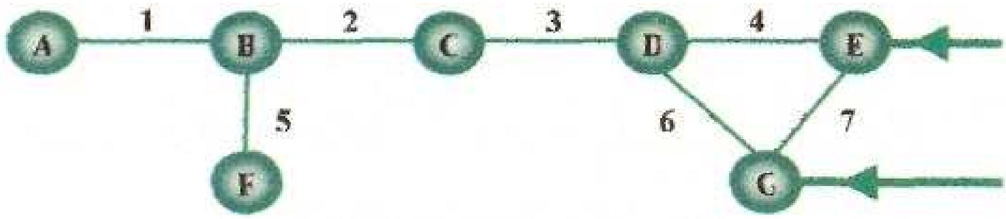


Fig.3.4. Network estimation scheme.

Where in nodes **A, C, D, E, F** and **G** are switchgear units with circuit breakers in all connected lines; in node **B** there no switchgear unit and circuit breaker; **1**,... ,**7** - transmission lines.

The network parts feeding nodes are G and E. Then in case of one element failure couplings and nodes appear that remain without electric power supply (see tab.3.2).

Table 3.2.

Failure element AE	Couplings total $M_{At.El.}$	Nodes without power supply
1	1, 2, 5	A, F
2	3	A, F, C
3	4	——
4	6	——

Modelling of disconnections. In calculation process disconnections is modelling as follow:

- disconnections by one element,
- disconnections by two elements.

This criterion reduces calculation time. Due to huge scope of calculation, essential calculation problems could appear, because, disconnecting lines by two, sizeable combination number presented. For example, Baltic 330kV transmission network have there 60 elements (transmission lines), then $C_n = \frac{n(n-1)}{1 \cdot 2} = \frac{60 \cdot 59}{1 \cdot 2} = 1770$ combination number for this mode. Combination numbers to Latvian 1 l0kV transmission network, disconnection elements by two is $C_n = \frac{n(n-1)}{1 \cdot 2} = \frac{150 \cdot 149}{1 \cdot 2} = 11175$

In the process of dynamic modelling in each calculation step at least 10 elements shall be (10 schemes for different calculation). It means that power flow distribution of transmission network is observed. For routine and qualitative reliability analysis it is required to calculate at least 100 network power flow distribution states resulted in the huge number of calculation operations. In order to reduce scope of calculations and calculation errors, in the promotion work it is suggested to calculate reliability with conventional load undelivery criterion.

3.3. Transmission network reliability calculation algorithm

In the calculation process of reliability criteria of transmission network interruptions or disconnections are reviewed by one and by two simultaneously. In the result of interruption:

- one or more nodes could be without electric supply,
- overload in other power lines could occur.

Network reliability calculation block diagram can see in figure 3.5.

For the modes calculations of transmission network consistent load duration curves are applied.

First of all in blocks 1 and 4 the nodes are identified which in the result of disconnection power supply is lost in all load modes and the following items are calculated:

1)Time of interruption,

2)Undelivered electric energy,

3)No supply costs.

If line tripping does not cause one or more nodes disconnection from the supply source it should be checked whether the line tripping causes congestion of ties of non disconnected line.

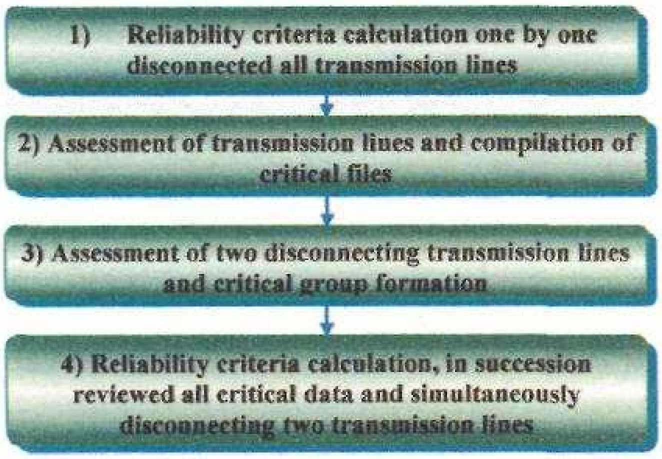


Fig.3.5. Network reliability calculation block diagram.

1st block. In the 1st block, disconnecting in succession all lines, first should be tested or checked whether load is disconnected. If load is disconnected, then calculated undelivered energy amount W_{Li}.:

$$W_{L_i} = \sum_{re=1}^{rem} \cdot U_{re,L_i} \cdot P_{re} [kWh], \tag{3.1}$$

where re - mode ordinal number;

rem - number of modes;

P_{re} - mode's *re* disconnected load;

L_t - disconnected transmission line;

$U_{re,Li}$ - line L_i fault prevention time in mode *re* (asymptotic unavailability

$$U_{re,L_i} = \frac{\lambda_{L_i} \cdot DL_{L_i} \cdot r_{L_i} \cdot Tre_{re}}{100 \cdot 8760} [h]; \tag{3.2}$$

where X_u - number of failure per year per 100 km line *Li* [failure/100 km per year];

DL_{Li} - transmission line *Li* length [km];

r_{L_i} - transmission line Li duration of repair [h];

Tre_{re} - mode *re* duration [h].

In such a case undelivered electric energy amount will be equal to undelivered electric energy amount in the specific line $W_{nep} = W_{Li}$.

If load is not disconnected from the network, it should test whether there is or not overload in other lines *Lt*, if there such - it defines:

$$\Delta P_L = P_{S_{L,re}} - P_{\max_L} [kW], \tag{3.3}$$

where $P_{S_{L,re}}$ - power flow in transmission line *L* mode *re;*

$P_{\max_L}$ - admissible load in line *L*.

It is assumed that to provide network normal operation overloaded lines L_i in interruption time load is reduced by ΔP_L.

The amount of electric energy undelivered in line L_i at disconnection time is calculated by the following formula:

$$W_{L_i} = \sum_{re=1}^{rem} \sum_{L \in M_{re,L_i}} \Delta P_L \cdot U_{re,L_i} [kWh], \quad (3.4)$$

where M_{re,L_i} - mode *re* line L_i at disconnection time overloaded electric lines totally.

The 1st block algorithm scheme is shown in figure 3.6.

To consumers undelivered electric energy is

$$W_{nep} = \sum_{L_i = M_i} W_{L_i}. \quad (3.5)$$

Costs of undersupply energy:

$$C_{nep} = c_{nep} \cdot W_{nep}, \quad (3.6)$$

where c_{nep} - undelivered electric energy specific costs [6/kWh].

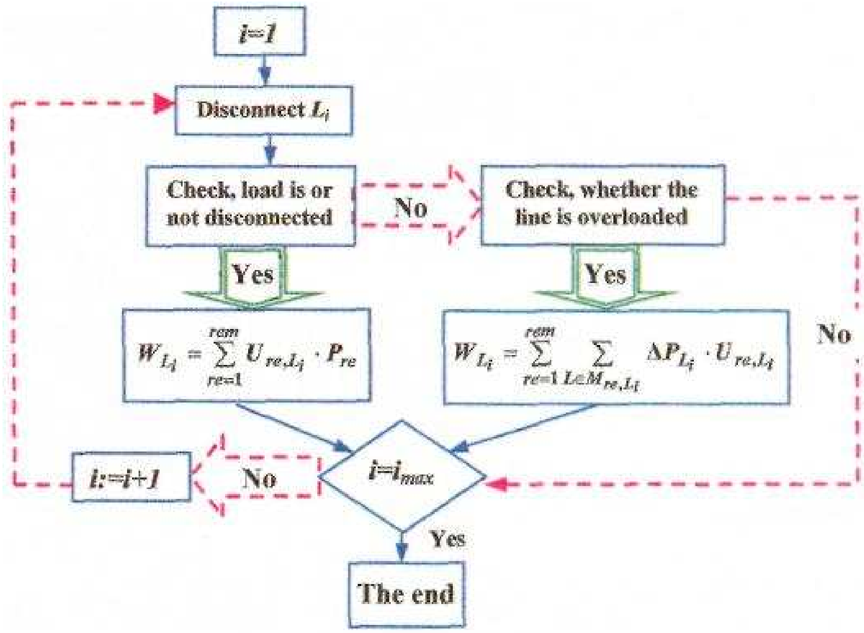


Fig.3.6. 1st block algorithm block scheme.

2nd block. In the 2nd block power lines are selected according to these criteria:

$$K^*_{L,re} = \sum_{L \in M} Tre_{re=1} \cdot \chi_L \cdot Ps_{L,re=1} [MWh], \quad (3.7)$$

where L - transmission line ordinal number, $L \in M$;

M - disconnected transmission lines group;

re - modes ordinal number $re=1$;

$Tre_{re=1}$ - mode $re=1$ (maximal loads, local power plants are not in operation) duration [h/year];

$Ps_{L.re=1}$ - transmission line L flow in mode $re=1$ [MW];

$\chi_L = \frac{\lambda_L \cdot DL_L \cdot r_L}{100 \cdot 8760}$ - interruption probability of transmission line L;

λ_L - specific number of failures per 100 km of lines per year;

DL_L - electric transmission lines/, length [km];

r_L - electric transmission line L fault prevention duration [h].

This criterion is to regard as conventional load non-supply.

3rd block. In the 3rd block two simultaneously interrupted electric transmission lines are reviewed. It is assumed, that in the reliability calculation we should observe only such electric transmission lines pairs, which have highest probability values of simultaneous interruption. In the 3rd block selection simultaneously interrupted electric transmission lines according the following criteria:

$$K^*_{L\{i,j\},re} = \sum_{L \in M} Tre_{re=1} \cdot \chi_{L\{i,j\}} \cdot Ps_{L\{i,j\},re=1} = \sum_{L \in M} Tre_{re=1} \cdot \chi_{L\{i\}} \cdot \chi_{L\{j\}} \cdot Ps_{L\{i,j\},re=1} [MWst], \quad (3.8)$$

where $\chi_{L\{i,j\}}$ - transmission lines simultaneous interruption probability.

The selected set is assumed as two elements interruption critical group.

4th block. In the 4th block is continued the 3rd block initiated network reliability criteria calculation. Reliability criteria are calculated by algorithm in succession simultaneously disconnecting two transmission lines. The 4th block scheme is same the 1st block scheme, only L_i equals $L_k = L_{i+j}$ - simultaneously interruptible transmission lines pair.

Conclusion

Calculating and estimating transmission network reliability by conventional load non-supply criterion K^*, we have to select the most significant and the most loaded lines, in order to decrease calculation scope and reduces calculation mistakes. This criterion is applied only to research power system with many transmission lines.

3.4. Methodological problems of reliability factor economic assessment

The system reliability can increase only attracting extra costs. Such reliability improvement is subject to reduction of customer supply interruption costs.

The electric power supply reliability is related to two types of costs: with power supply costs and direct losses for customers in power supply interruptions. Having introduced the additional equipment in power supply system, power supply costs will be elevated but customers losses will be decreased in power supply interruptions. Respectively, reducing the equipment units the power supply costs will be reduced, but customers losses due to power supply interruption will increase (see. fig.3,7).

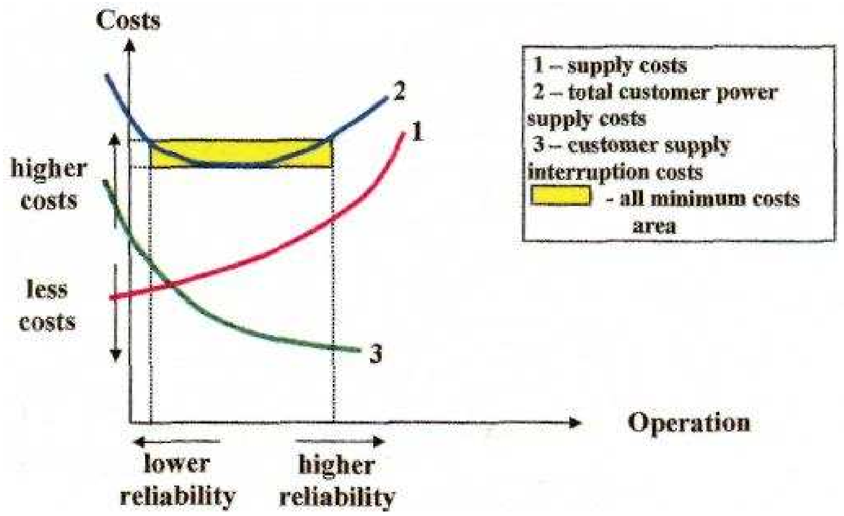


Fig.3.7. Costs of electric power supply reliability.

In order to calculate costs of undelivered electricity c_{nep}, in many countries specific costs **of undelivered electricity** c_{nep} are used of electric network supply interruption caused total costs proportion against to undelivered electricity in kWh. The specific expenses c_{nep} are framed in the result of perennial observations. Using the undelivered specific costs the information on interrupted load and interruption duration shall be available. These values can be easily calculated in distribution networks as in case of fault one or more load buses or nodes are tripped. The foreign researches state, that specific costs of undelivered energy c_{nep} depending on users comprise 0,5-100 $/kWh [7]. In Latvia such investigations and research have not been done yet, and at present Latvian conditions the specific costs of undelivered energy are not known.

3.5. The reliability's level economic criterion

As reliability's level in economic criterion investigation use the cost price of network operator. The criterion is determinate with networks annual cost price C_{et}, which consist of three basic components [10]:

$$C_{et} = C_{O\&M} + C_K + C_{zud}\,, \tag{3.9}$$

where $C_{O\&M}$ - annual operation and maintenance costs;
C_k - annual capital costs:

$$C_K = \sum_{n=1}^{n=m} \frac{(p_{am} + i)}{100} \cdot K_n; \tag{3.10}$$

K_n - capital in vestments of network's n-an element (power line or substation);
m - number of network elements;
p_{am} - amortization costs %:

$$p_{am} = \frac{100}{T_{LC_n}}\%; \tag{3.11}$$

T_{LC_n} - economic life time of n -an network element, years;
i - interest rate %;
C_{zud} - annual costs of energy and power loss.

Reliability level W_{mp} (energy not supplied) is depending from all three costs components.

Reducing *Com,* the network elements failure number and repair duration increase. To reduce C& usually refuse actions, which increase power supply reliability: substations and power lines building. Reducing *K,* usually increase energy not supplied and networks energy loss. Increasing *Tic* gives failure number and repair duration increase. So reliability level W_{mp} depends of network annual costs C_{tt}. On figure 3.8 is illustrating $W_{mp} = f(C_{e(})$ character.

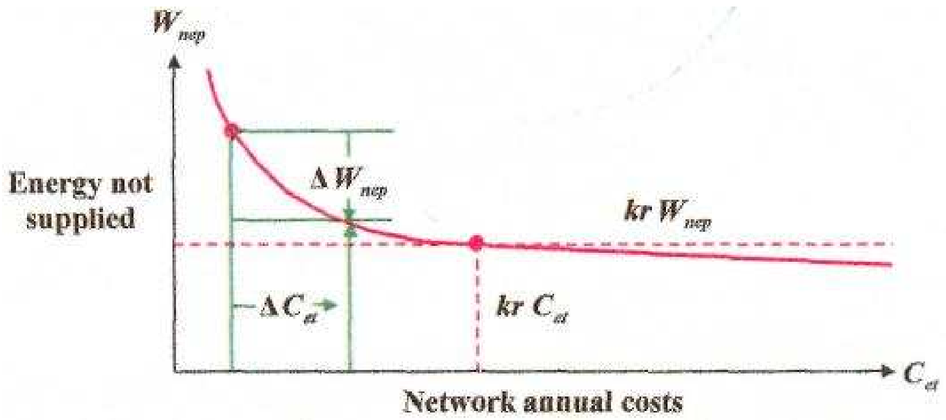


Fig.3.8. Reliability level W_{nep} changes to increase annual network costs C_{et}.

The X-axis C_{et} can split into two intervals: 1) $0 \div krC_{et}$ and 2) $krC_{et} - \infty$. At the first interval can find measures, which reduce W_{nep} and increase reliability. At C« > krC_a reliability level W_{nep} is minimal changes, if it have big changes.

4. Reliability factor assessment method elaboration for 330 un 110 kV substations and switchgear units.

4.1. The problem's statement

The issue of upgrading and reconstruction of Latvian power transmission networks in compliance with the requirements of the integrated power systems of the European Union states is very urgent, so such undertakings are performed as replacement of old deteriorated equipment by modern one including configuration alteration of transmission network structure. These undertakings are very capacious, demands a lot of time, schedule schemes for repairing in transmission networks but simultaneously increase electric power supply reliability.

One of the major assignments for solution in the promotion work is - 330 and 110 kV assessment method elaboration on reliability factor of substations switchgear units. The long-term reliability assessment methodology has been worked out that provides opportunity to select the optimal configuration of switchgear and apparatus in regard to the whole transmission network in general.

The results of the promotion work are available for *Latvenergo* high voltage and distribution network analysis, planning and design that provides opportunity to select the optimal option of 330 and 110 kV substations modernisation, reconstruction and new construction project, observing customers' electric power supply reliability and technical economic criteria. The selection is done under perspective information ambiguity conditions applying net present values (NPV) criteria and restrictions according to reliability criteria.

The assignment is very complex: it is determined by variety of switchgear equipment type and need to perform fast comparison of different types of switchgear.

4.2. The analysis of Latvian 330 and 110 kV substations

At present there are fourteen 330 kV substations in *Latvenergo* AST (High-Voltage network), 7 of these are older than 30 years and 125 of 110 kV substations, 60 of which are older than 30 years. For major part in (91) substations are two transformers , with three transformers 4 substations are operated ; with four - 2 substations; with one - 25 substations,

Switchyards schemes with varieties are used in Latvia.

4.3. The main parameters of substations schemes reliability.

The power plants and substations electric schemes are of great importance in the reliability provision of electric power supply. For substations the scheme shall be designed in such a way that in case of drop of any its element the power supply shall be maintained.

The main indicators identifying the scheme of distribution units in regard to reliability conditions are:

- probability of complete (100%) disconnection of substation;
- average frequency (50%) of disconnection of links (to transformers, lines);
- probability of disconnection of two lines (faulted and non-faulted lines).

4.4. Switchyards reliability estimation.

The most essential and element most subjected to damage is switchgear. The best insulation and arc extinguish medium is SF6 in comparison with air and oil and during the latest time in reconstruction and construction of new substations the advantage is given to SF6 switchgears. Let's define the reliability of substation applying the probability calculation method of switchgears interruption of the scheme.

It shall be mentioned that probability is expected if:

1) all switchgears are in operation mode;
2) only one switchgear is out of operation;
3) only two switchgears are out of operation etc.

Such calculation shall be performed applying binominal distribution. If *"n"* tests are calculated, the event A may occur or all *"n"* times or *"n-1"* time or *"n -"2"* times, ..., or once or no one time. This can be calculated as binominal distribution by Newton:

$$(p+q)^n = p^n + np^{n-1}q + C_n^{n-2} p^{n-2} q^2 + C_n^{n-3} p^{n-3} q_3 + ... + C_n^m p^m q^{n-m} + ... + q^n \qquad (4.1)$$

where p - probability that the event will occur in one scenario trial;
q - probability that the event will not occur in one scenario trial.

Probability that under *n* trials the event A will occur exactly *m* times can be determined as Newton general binomial component by formula Bernoulli:

$$P_{n(m)} = C_n^m p^m q^{n-m} = \frac{n!}{m!(n-m)!} p_{(A)}^m q_{(A)}^{n-m} \qquad (4.2)$$

where C_n^m - number of combination of *n* out of *m* elements. 0!=1

For air switchgears probability when switchgear is out of operation conditions - 0.05, but in operation - 0.95, respectively for SF6 switchgears - in out of operation conditions - 0.008, but in operation conditions - 0.992.

Binomial distribution is discreet event volume distribution from *0* to *n*. Binomial volume can write in table form (see table 4.1).

Tab. 4.1.

Binomial distribution

m	$P_{n\,(m)}$
n	p^n
$n-1$	$np^{n-1}q$
$n-2$	$C_n^{n-2}p^{n-2}q^2$
…	…
m	$C_n^m p^m q^{n-m}$
…	…
1	npq^{n-1}
0	q^n

Probability calculation example for quadruple scheme is shown in table 4.2.

Tab.4.2.

Nr.	Switchgear's mode	Probability	
		Air gas switchgear	SF_6 switchgear
1.	All in operation mode	0,815	0,968
2.	1 is out of operation	0,171	0,031
3.	2 is out of operation	0,014	0,0004
4.	3 is out of operation	0,00002	0,000002
5.	All is out of operation	0,000006	0,000000004

Probability, that all switchgears in operation mode:

Air gas switchgears: $P_4^{(0)} = p^n = 0{,}95^4 = 0{,}815$;

SF_6 switchgears: $P_4^{(0)} = p^n = 0{,}992^4 = 0{,}968$.

Probability, that 2 switchgears is out of operation by (4.2):

Air gas switchgears:

$$P_4^{(2)} = C_n^{n-2}p^{n-2}q^2 = \frac{n!}{m!(n-m)!}p^2q^2 = \frac{4!}{2!(4-2)!}0{,}95^2 \cdot 0{,}05^2 = 0{,}014;$$

SF_6 switchgears:

$$P_4^{(2)} = C_n^{n-2}p^{n-2}q^2 = \frac{n!}{m!(n-m)!}p^2q^2 = \frac{4!}{2!(4-2)!}0{,}992^2 \cdot 0{,}008^2 = 0{,}0004$$

etc.

According to the calculations, the conclusion from the point of view of power supply reliability; the SF6 switchgears are considerably advanced better that air switchgears and air switchgears replacement by SF6 switchgears will improve power supply.

4.5. Reliability criteria.

In many countries there are 3 types of reliability criteria in state power industry which are applied for undertaking selection focused on power system reliability increase. [3]:

1) Reliability criteria in normative pattern - ***determined reliability criteria*** (can be reviewed up to five elements simultaneous disconnection *n* - 5);
2) Reliability criteria that are determined by target ***function cost minimisation***. Costs are structured by the costs of power system reliability increasing together with undelivered electricity costs (taking into account lines and transformers real flow in different load modes);
3) Reliability ratio rating - ***probability reliability criteria*** .
   - Asymptotic operation unavailability parameter U [h./y.];

This criterion is calculated taking into account operation&maintenance conditions of substations and switching operation time of schemes.

- Probability of operation unavailability conditions % [a.u.].

In practise of the European Union the following electric power supply reliability criteria are applied [2-3]:

1. Probability of operation unavailability conditions ;
2. Probability of operation availability;
3. Non-delivered power;
4. Non-delivered energy ***W;***
5. Non-delivered electricity costs ;
6. Scheme adequacy assessment.

The conditions of power network operation unavailability are created by:

- Scheduled repairs (maintenance works);
- Failures due to damage result.

The conditions of operation unavailability in quantity is characterised by operation unavailability parameter U - duration of expected (predicted) operation unavailability conditions hours/year:

$$U=U_a+ U_{pr} \text{ [hours/year]}, \qquad (4.3)$$

where U_a - expected duration of fault, hours/year;
U_{pr} - duration of scheduled repair, hours /year.

The scheduled repairs and its duration are standardised. The expected fault duration is calculated using statistical data of failures:

1) Failures average expectancies number per year λ - assuming that failures are proportionally distributed in time;
2) Duration of repair *r (*hours /failure).

The operation unavailability parameter U_a *is calculated according the formula :*

$$U_a = \lambda \cdot r \text{ [hours/year]}, \qquad (4.4)$$

Probability of operation unavailability conditions is calculated by formula:

$$\chi = U_a/8760 \text{ [a.u.]}, \qquad (4.5)$$

Undelivered energy *W is* calculated as follows:

$$W = U_a \cdot P \text{ [MWh/year]}, \quad (4.6)$$

where P - disconnected load, MW.

Undelivered costs is calculated by formula:

$$C_{nep} = c_{nep} \cdot W \text{ [thous. Ls]}, \quad (4.7)$$

where c_{nep} - undelivery specific costs.

The duration of scheduled repairs U_{pr} and probability on operation unavailability conditions to scheduled repair χ_{pr} calculated by formula, which is analogous to formulas (4.5) and (4.6):

1) Failures parameters λ_{pr};
2) Time of repairing r_{pr}.

For scheme that incorporates many elements in integrated schemes characteristics values on failures are calculated using classical probability theory formulas.

The power system reliability numerically characterizes probability of emergent conditions q and probability of operation conditions p, sum of which equals 1:

$$p + q = 1. \quad (4.8)$$

Probability of operation conditions can be expressed as:

$$p = 1 - q. \quad (4.9)$$

Evidently that scheme or element reliability is higher if ***p*** value is higher and less ***q*** value. In evaluation process of reliability scheme is accepted that high reliability level has the scheme which $p \geq 0{,}9998$ (scheme admissibility criterion).

5. Calculation technology for 330 and 110 kV switchgear reliability criteria.

5.l. General description of long-term reliability assessment calculation stipulations.

The main assignment of long-term method is switchgear equipment and apparatus type selection according to reliability and economic criteria taking into consideration system operative and development process.

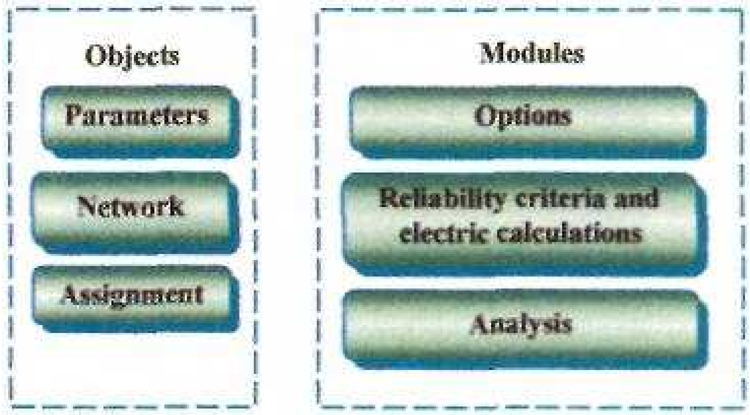
In order to realise these requirements reliability assessment is performed under the frame of software *LDM-AD.* The program *LDM-AD* is the first *LDM* group program, which reliability analysis can be performed on transmission network substations and switchgear operation and power supply, as well as technical and economic analysis of several dynamic development processes options, observing reliability economic ratios.

330 and 110 kV transmission network reliability assessment program is capable to:

1. assess reliability for transmission network;
2. calculate time of electric power supply interruption (in interim result eliminating expected interruption time of power supply (hours/year);

3. envisage the opportunity to estimate reliability in transmission line scheme when electric power supply is provided by two (more) lines, including also case when one line is under the scheduled maintenance and the second line unscheduled disconnection occurs;
4. in case of radial lines take into account the time of scheduled repair.

Software *LDM-AD* structure is shown in figure 5.1.



Mg.5.1. software *LDM-AD* structure.

High rigid requirements are set forth to reliability assessment criteria (see fig.5.2). For this criterion calculation the information is required that depends on calculation provisions, on switchgear equipment configuration type and apparatus type.

Fig.5.2 Switchyard reliability criterion

5.2. Definition *rated element.*

To create the program, which allows considering various variants of distribution system schemes, is necessary to use the specialized approach.

The considered types of switchyard are divided into **elements.**

Definition: **Rated element is a switchyard part, which is disconnected from power system as a fault clearance result.**

Properties:

- **Rated elements is a critical devices group, which is disconnected from power system, if only one device from this group has fault clearance;**

- **Switchyard power flows or short-circuit currents go through series or parallels elements.**

Asymptotic unavailability of element *i* calculated by formula:

$$U_i = N_{j,i} \cdot \lambda_j \cdot r_j + N_{k,i} \cdot \lambda_k \cdot r_k + N_{a,i} \cdot \lambda_a \cdot r_a + N_{pn,i} \cdot \lambda_{pn} \cdot r_{pn} + N_{st,i} \cdot \lambda_{st} \cdot r_{st} + $$
$$+ N_{LN,i} \cdot \lambda_{LN} \cdot r_{LN} + N_{AT,i} \cdot \lambda_{AT} \cdot r_{AT} + N_{LN(RA),i} \cdot \lambda_{LN(RA)} \cdot r_{LN(RA)} + \quad (5.1)$$
$$+ N_{LN(RA),i} \cdot \lambda_{LN(RA)} \cdot r_{LN(RA)} + N_{AT(RA),i} \cdot \lambda_{AT(RA)} [hours / year],$$

where $\lambda_j ... \lambda_{sp}$ - critical devices failure parameters [num./y];
$r_j \ldots r_{sp}$ - critical devices repair time [hj;
$N_{j,i}$ - number of switchgears in element *i;*
$N_{k,i}$ - number of busbar location in element *i;*
$N_{a,i}$ - number of disconnectors in element *i;*
$N_{pn,i}$ - number of surge arrester in element *i;*
$N_{sp,i}$ - number of voltage transformer in element *i;*
$N_{st,i}$ - number of current transformer in element *i;*
$N_{AT,i}$ - number of autotransformer in element *i;*
$N_{LN,i}$ - number of power lines in element *i*;
$N_{AT(AR),i}$ - number of autotransformer relay protection in element *i;*
$N_{LN(AR),i}$ - number ofpower line relay protection in element *i;*

Switchyard rated element example is showing in figure 5.3.

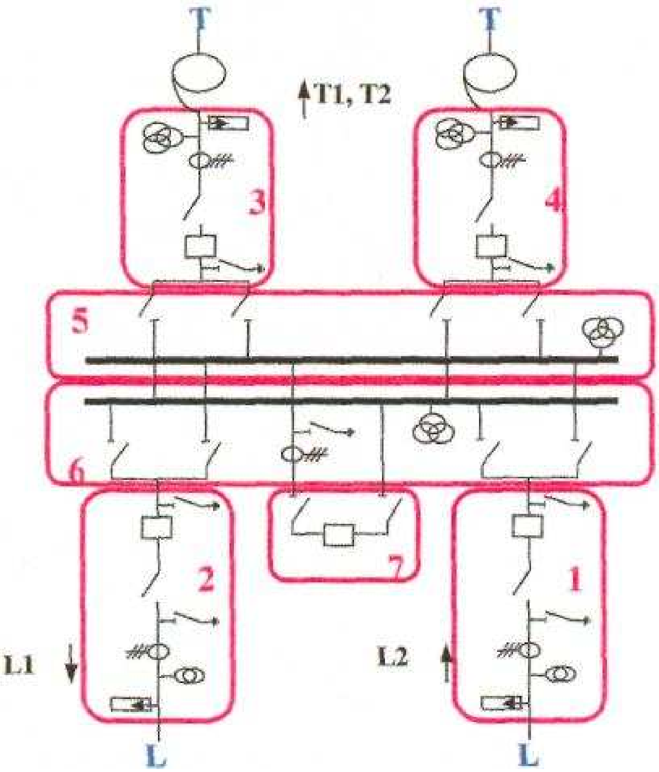


Fig. 5.3. 330 kV switchyard (double-busbar scheme configuration) division into *rated elements;*

Operating repair asymptotic unavailability U_{pr} is calculated by formula, which is similar to formula (5.1), where r and λ changed with:

1. failure parameter λ_{pr};
2. repair time r_{pr}.

Element i probability of disability:

$$\chi_i = \frac{U_i}{8760} \tag{5.2}$$

5.3. Power network reliability criteria estimation algorithm.

The formulas, developed earlier, are used for each switchyard type calculation from database and calculation of the parameters χ and U for element i. Block scheme of the algorithm is shown in figure 5.4.

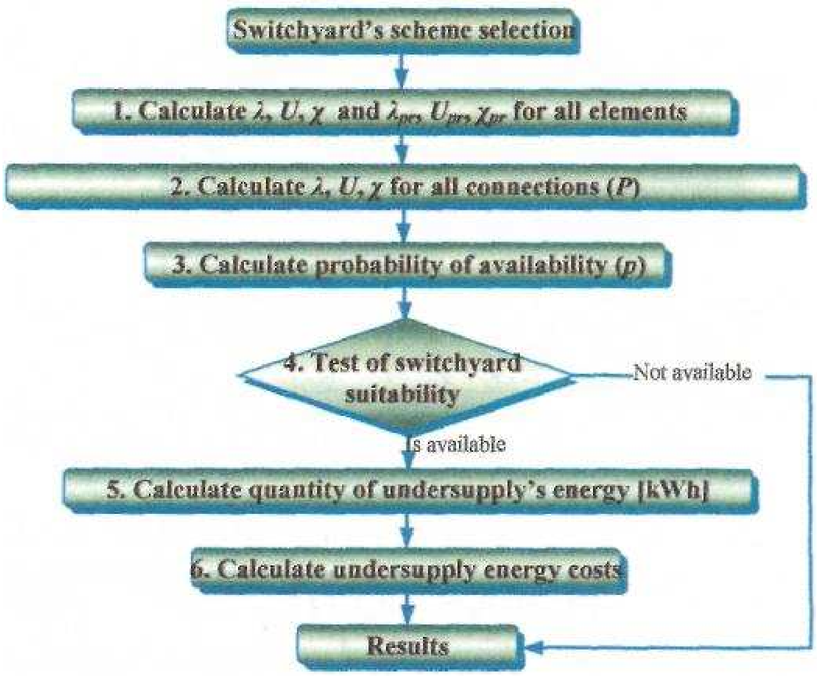


Fig. 5.4. Reliability criterion estimation algorithm block scheme;
λ- failure rate, χ- probability of unavailability position,
U- asymptotic unavailability parameter.

Tab. 5.1.

330 kV switchyard (double-bus bar scheme configuration) parameters of a rated element

i	$N_{f,i}$	$N_{a,i}$	$N_{st,i}$	$N_{sp,i}$	$N_{pm,i}$	$N_{k,i}$	λ, h/y	U, h/y	χ, a.u.
1	1	1	1	1	1	0	0,0126	0,141	0,000016
2	1	1	1	1	1	0	0,0126	0,141	0,000016
3	1	1	1	1	1	0	0,0126	0,141	0,000016
4	1	1	1	1	1	0	0,0126	0,141	0,000016

i	$N_{j,i}$	$N_{a,i}$	$N_{st,i}$	$N_{sp,i}$	$N_{pn,i}$	$N_{k,i}$	λ, h/y	U, h/y	χ, a.u.
[illegible]	0	5	0	1	0	5	0,0268	0,2346	0,000026
[illegible]	0	5	0	1	0	5	0,0268	0,2346	0,000026
[illegible]	1	2	1	0	0	0	0,0108	0,1316	0,000015

*1.**block.*** For all elements failure mathematical expectation λ, asymptotic unavailability U and probability of unavailability position χ are calculated. The calculation is made for the emergency failures and to maintenance position.

*2.**block.*** Calculate:

1. Connections *LI*, *L2*, ... probability of disability λ_{L1} , λ_{L2} , ... and asymptotic unavailability U_{L1}, U_{L2}, ...;
2. Transit probability of unavailability χ and asymptotic unavailability parmeter U.

The formulas, developed earlier, and the first block rated results are used for each switchyard type. Calculation results see in Table 5.2 and 5.3.

Tab. 5.2.

Example of 330 kV switchyard second block calculation(double-busbar system)

Connection Nr.	χ calculation formula, a.u.	U calculation formula, h/y
L1	$\chi_{L1} = \chi_1 + \chi_5$	$U_{L1} = \chi_{L1} \cdot 8760$
L2	$\chi_{L2} = \chi_2 + \chi_5$	$U_{L2} = \chi_{L2} \cdot 8760$
T1	$\chi_{T1} = \chi_3 + \chi_6$	$U_{T1} = \chi_{T1} \cdot 8760$
T2	$\chi_{T2} = \chi_4 + \chi_6$	$U_{T2} = \chi_{T2} \cdot 8760$
L1+L2*	$\chi_1 \cdot \chi_2 + \chi_5$	$\chi_{L1+L2} \cdot 8760$
T1+T2*	$\chi_3 \cdot \chi_4 + \chi_6$	$\chi_{T1+T2} \cdot 8760$

Comment: * think, that the 1 element is repairing, but the 2 element has a fault..

3. block. Calculation of availability's probability.

Tab. 5.3.

Example of 330 kV switchyard third block calculation

Nr.	Mode name	p formula, a.u.	U, h/y
1.	All connections synchronized disconnection	$p = 1 - \chi_{L1+L2}$	0,228
2.	Transit interruption	$p = 1 - \chi_{L2}$	0,367
1.	Load disconnection	$p = 1 - \chi_{T1+T2}$	0,228

4. block - suitability's test. As the suitability's criteriap= *0,9998* is used.
5*. block* - calculation of not supplied energy.
The undelivered energy calculated by formula:

$$W = P \cdot U_{T1+T2} \cdot k_{gr} \quad \text{[MWst]}, \qquad (5.3)$$

where k_{gr} - rated coefficient, which observes load graph, accepting, that failures can take place during a year.

P - to switchyard undelivered energy.

5. *block* - calculation of energy's undersupply costs:

$$C_{nep}=c_{nep}\cdot W \text{ [thous.Ls/y]}. \quad (5.4)$$

In the ultimate result having selected switchgear and equipment type with different options and having calculated for all these situations reliability with undelivered load criterion, the most acceptable option is selected and the rest options are considered as invalid and unacceptable.

Conclusions:

1. In promotion work the transmission networks functioning problems in Latvia have been analysed:
   - The existing transmission network in Latvia and Baltic region will ensure the flow for the installed capacity of the electric power plants and demand increment only within the nearest years period. The anticipated need for new substations, power plants and power transmission lines is expected with the development of separate regions where the load re-allocation and load elevation occurs.
   - Electricity market liberalisation that gradually is being introduced in Latvia too requires restructuring of generation, transmission and distribution sectors that negatively influence quality of the offered services and reliability of electric power supply.
   - At present the Latvian power system is a shortfall system and it imports electricity from the neighbouring countries that has impact on cross-section loading also of neighbouring power systems. The Latvian power system reliability and security will be influenced due to shutdown of Lithuanian Ignalinas NPP.
   - Construction of new generation sources is evidently required in Latvia as well as modernisation of the existing electric power plants in compliance with modern standards. After these undertakings been fulfilled Latvia shall become as self-balanced power system that to great extent will promote independence and reliability of power supply to Latvian customers.
   - As far the power plant and substations equipment aging and reduces power supply reliability, and is necessary to reconstruct and refurbish energy objects for power supply reliability and security improvement replacing equipment installed in 70-80-ies by new and modern assets.

2. In promotion work the bibliographic sources analysis done based on experience of foreign states regarding power supply reliability and security issues visibly confirms, that power supply issue is of vital importance for any country all over the world. The losses occurred due to capacious and durable power supply interruptions are so significant taking into account technical and national economic estimations and it is evidently urgent that electric power supply shall ensure higher reliability level.
3. In promotion work the long-term methodology is created on research of Latvian transmission network reliability issues. This long-term method is designed for systems and networks development analysis (development strategy elaboration) taking into account electric power supply reliability issues and is focused on capital investment increase for reliability level improvement.
4. Disconnections modelling algorithm is worked out that is capable to review disconnection elements by one *(n*-1*)* and by two (*n*-2). The algorithm is modelling elements failures and after all transmission network lines and failure elements have been analysed, just disconnections are modelled.

5. In promotion work assessment method on 330 and 110 kV substations switchgear reliability factor designed and applicable for power transmission networks in Latvia. The schemes and diversity of the existing transmission network switchgear hampering reliability calculation process have been analysed. The method estimates transmission network reliability with criterion of undelivered energy.
6. In the elaborated methods of the Promotion work dynamic optimisation software *LDM-AD'04* is applied created by Mathematical Modelling Laboratory (EMML) of the Academy of Science Physical Energy Institute of the Republic of Latvia according to the order-assignment of public utility AS *Latvenergo.* The program performs reliability analysis of transmission network substations and switchgear operation and electric power supply reliability and security analysis.

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