OÜ Põhivõrk
AS Latvenergo
Lietuvos Energija AB

BALTIC GRID 2025

Tallinn-Riga-Vilnius
2005-2007

Introduction

Electricity market within Europe is integrating and expanding and will also enfold Baltic States into the system in the future. Considering this and many other aspects there is a need to evaluate readiness of power systems in Estonia, Latvia and Lithuania.

In 2003 was launched a study Baltic Grid 2012 for evaluating power transfer possibilities of three power systems of Estonia, Latvia and Lithuanian in cooperation with UPS and integration to UCTE and NORDEL which covers the period up to 2012. However, study showed necessity to evaluate the time horizon up to 2025 and therefore a new study BALTIC GRID 2025 was launched.

The study took into account the most like conditions, scenarios and stages for the development of power network in the Baltic States up to 2025.

The study is covering:

- Legal framework, including EU directives.
- Demand forecasts, based on future social and economical implications.
- The expansion and location of generating capacity in the long term.
- Scenarios and hypothesis of power exchange.
- Scenarios and assumptions for the long-term network structure, technical and economical evaluation of grid extension projects.
- Overview of UCTE and NORDEL.

The study consists of one volume

The study was performed by:

From OÜ Põhivõrk side:	Mart Landsberg Oleg Tsernobrovkin Andrus Reinson Raivo Attikas
From AS Latvenergo:	Maris Balodis Aleksandrs Babikovs Santa Kiene Arnis Staltmanis
From Lietuvos Energija AB:	Dalius Šulga Antanas Jankauskas Rimantas Rutkauskas

1. Executive Summary

1.1 Study goal

The main goal of the study was evaluation of power transfer possibilities of the three power systems of Estonia, Latvia and Lithuania (Baltic IPS / Baltic) on cooperation with UPS and integration to UCTE and NORDEL for the time period up to year 2025.

1.2 Scenarios

Five main power flow scenarios were created to meet study's goal - to identify boundary limits for maximum import, export and transit capacity for Baltic transmission network. The scenarios are based on the different assumptions, concerning internal energy system development (generation, demand, transmission network), also influences outside the Baltic, like the price level in UCTE and NORDEL or in UPS.

Generation and demand

Two generation scenarios were established:

- best estimated - renovation of many existing and development of new generating units according to development plans of each country incl. new Lithuanian NPP 3000 MW and other projects, that means power surplus in Baltics or export possibilities;
- conservative - at present clearly determined plans for existing and new generating capacities, that means decommissioning of Ignalina NPP and other out-of-date power plants and consequently power deficiency in Baltics or import need.

As demand scenario is used most likely demand projection according to GDP of each Baltic country.
According to established generation and demand scenarios, there appears power surplus or deficiency in Baltic countries, i.e., power export possibilities or import need, which is described as following power flow scenarios:

0. Base Case - generation balance in Baltic
1. Export from Baltic to UCTE and NORDEL
2. Export from Baltic to UPS
3. Import from UCTE and NORDEL to Baltic
4. Import from UPS to Baltic
5. Baltic in balance, New nuclear PP (Ignalina) works at 3000MW for internal Baltic market (No export/import outside Baltic)

Transmission network

Baltic 330 kV transmission network with developments up to year 2025 as well as new DC interconnections to Finland, Sweden and Poland is shown in Figure 1-1.
Estonian transmission network development plan considers building of new 330 kV power ring Tartu - Sindi - Harku.

Latvian transmission network development plan forecasts building of new 330 kV power ring in western part of Latvia: Riga (Imanta) - Tume - Ventspils - Grobina, and closing of 330 kV ring around Riga city by building power line Riga CHP-1 - Imanta. Lithuanian transmission network development plan intends building 330 kV power lines Klaipeda - Telsiai, Panevezys - Musa, and double circuit line Kruonio HPSPP - Alytus in case of Poland interconnection.

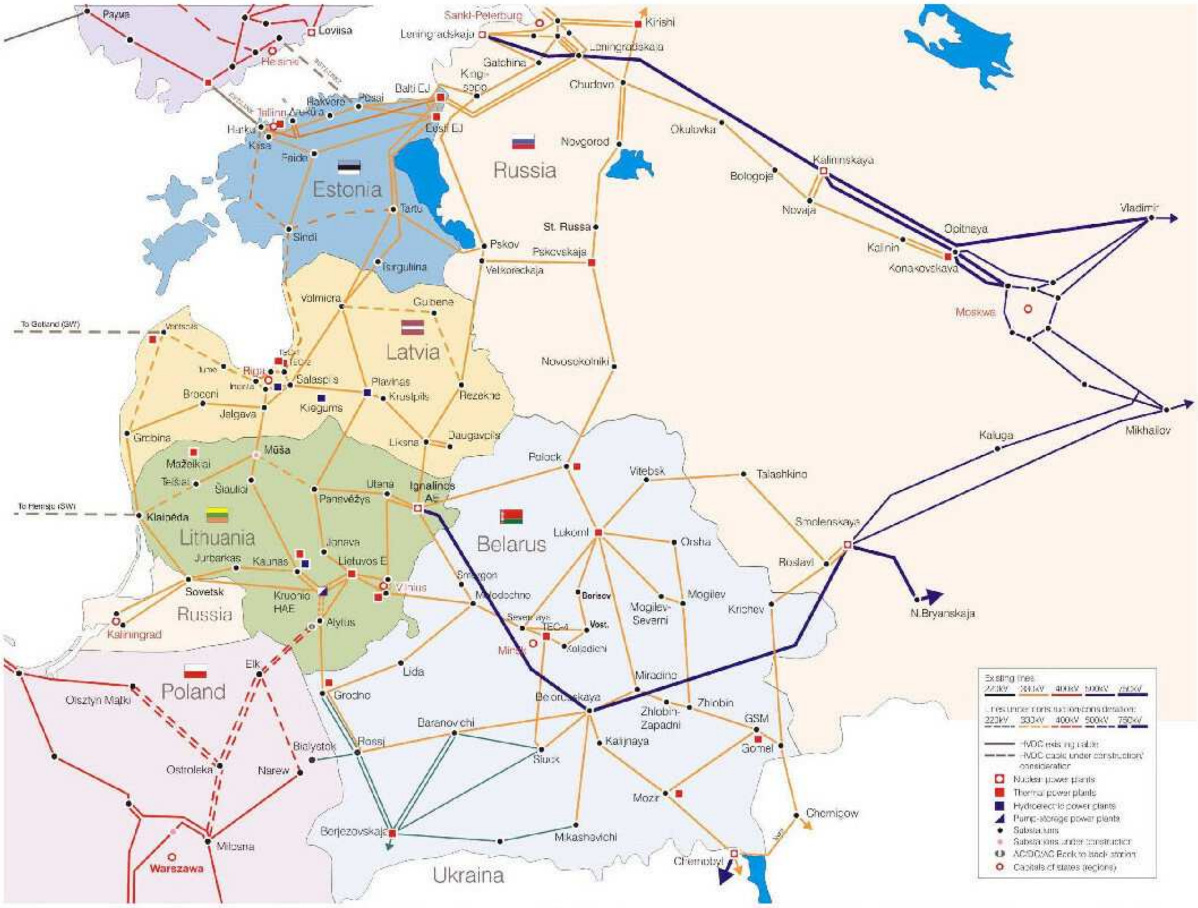

Figure 1-1 Baltic, Russian, Byelorussia interconnected 330 - 750 kV transmission network with developments for year 2025

1.3 Calculations

1.3.1 Calculation methodology

To evaluate the operation of the power system and its reliability considering different failures and faults within the system for maximum winter peak load hour a common power system model was used. Each scenario was investigated considering N-1 contingencies in 330 kV - 750 kV transmission network and controlling thermal limits of power lines (keeping 8% safety margin of line loading) and voltage levels on busbars.

Figure 1-2 briefly describes the methodology of power flow calculations.

In case of exceeding limiting factors, export/import in all scenarios was modelled mainly by changing generation in Baltic power system - for export scenarios capacity of new nuclear PP was decreased, for import cases generating capacities in each Baltic power system were increased to meet the stated limits.

In dynamic calculations are investigated some of the hardest faults in Baltic power system. The hardest case which was investigated in Baltic power system is when Ignalina NPP generator (~800MW) was switched off due to a heavy disturbance in power system of Baltics. Only export scenarios were investigated in dynamic studies and the load-flow situation for internal network is according to present situation, except the DC links which are added.

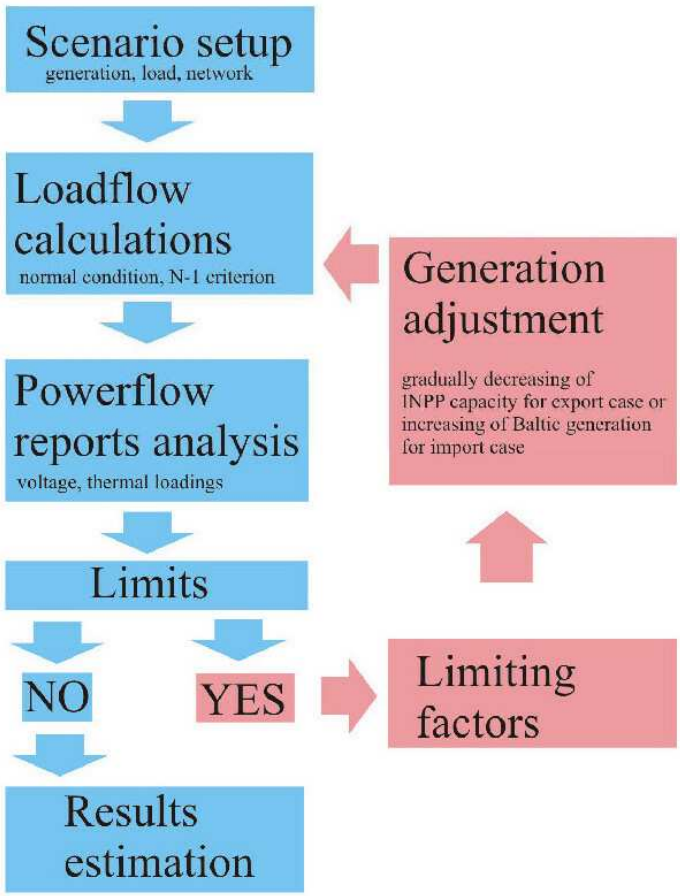

Figure 1-2 Calculation methodology

1.3.2 The model

1.3.2.1 Load flow model

<u>Baltic countries grid models contain:</u>

1) Base case model contains probable grid developments up to year 2025,
2) 110 – 330 kV grid model, without 110 kV transformers and load is modelled on the substation 110 kV busbars,
3) All shunt reactors and capacitor banks were modelled,
4) Wind power generators was modelled as aggregated model in the nearest 110 kV substation busbars,
5) Load demand used in model is winter peak load forecasted for year 2025 and is equal to 2263 MW for Estonia, 2576 MW for Latvia and 3454 MW for Lithuania.

Russian model base was get from DC Baltija, and original source is Russian CDU (Centralnoje Dispetšerskoje Upravlenije).

<u>Russian grid model contains:</u>

1) Base case model contains expected grid development up to year 2012,
2) 330 – 750 kV grid was modelled, in that case load was modelled on the 330 kV busbar,
3) Some part of 110 kV and 220 kV grid was modelled and in that case load was modelled on the substation 110 kV or 220 kV busbar (without 110 kV transformers),
4) Russian grid ties with Baltic countries; Ukraine and Belarusian grids were also modelled.
5) Swing bus was located in the Russian grid, near to Vladimir 500 kV substation.
6) 301 machines were modelled,
7) Load demand for Russia in model is 66.9 GW.

Belarusian model base is DC Baltija file, which was developed according to Belarusian grid development plans up to year 2020.

Belarusian grid models contain:

1) Base case model contains probable grid developments up to year 2020,
2) 330 kV and 750 kV grid was modelled, 220 kV grid was replaced by 330 kV or by 110 kV network (according to development plans). Usually load was modelled on the 330 kV busbars; in the case of 110 kV model existing load was modelled on the 110 kV busbar.
3) All plants bigger than 100 MW were modelled,
4) All grid ties were modelled (with Lithuania, with Russia and also with Ukraine)
5) Ukraine system was taken into account as well. The data source is same as Russian.
6) Load demand for Belorussia in model is 7810 MW.

Ukrainian grid model contains:

1) 330 – 750 kV grid was modelled, in that case load was modelled on the 330 kV busbar,
2) Some part of 110 kV and 220 kV grid was modelled and in that case load was modelled on the substation 110 kV or 220 kV busbar (without 110 kV transformers),
3) All grid ties with Russia and with Belarusian were modelled.
4) Totally 146 machine were modelled.
5) Load demand for Ukraine in model is 25.4 GW.

New interconnections
The following new interconnections were investigated:

- Estonia – Finland (ESTLINK-2) link, 650 MW;
- Lithuania (or Latvia) – Sweden link (700 MW);
- Lithuania – Poland link (1000 MW).

1.3.2.2 Dynamic model

Dynamic model is based on present power system configuration which consists:
1) Swing-bus Beshkaij, in Russian power system
2) 800 machines

3) Baltic and North-West Russia power-loop generators are detailed modelled and also simplified models of the main units are available of the rest of Russia, Belorussia and Ukraine.
4) Total generation capacity of the model is 88,8 GW
5) Load-flow conditions and network topology in Baltic states respond to the peak-load of year 2007

1.3.3 Load flow calculations

According to analysis of each scenario the following results were drawn up:

Scenario 0 (Generation balance in Baltic).

Network operation is reliable and stable at normal operation and at all N-1 contingencies as well. Power transit of 300 MW via Baltic transmission network could be reliably maintained in both north to south and south to north directions.

Scenario 1 (Export from Baltic to NORDEL/UCTE).

According to the stated generation cases total surplus power in Baltic is 2700 MW, which can't be exported to UCTE and NORDEL if there are export to Latvia and Estonia at the same time. Main limiting factor is overloading of power transmission line Ignalina NPP - Liksna and Ignalina NPP - Utena at most of N-1 contingencies. The maximum transfer capacity varies from 1835 – 2150 MW, depending on the transit case. Reinforcement of interconnection between Lithuania and Latvia allows larger export from Ignalina to other Baltic countries and to NORDEL through perspective links to Poland, Sweden and Finland. More calculations of that scenario are brought out at calculation part chapter 7.

Scenario 2 (Export from Baltic to UPS).

Maximal power export to UPS from Baltic is 2700 MW. There are limiting factors according to N-1 contingency analysis at 300 MW transit case to south. The problem occurs when Eesti - Kingisep OHL trips and the result is overloading of Eesti-Balti OHL.

Scenario 3 (Import from NORDEL/UCTE to Baltic).

Total power deficiency in Baltic could be about 4100 MW. Power import from UCTE/NORDEL to Baltic can be maintained at full DC links capacity that is 3400 MW in case of DC links to Sweden (700 MW through Latvia and 700 MW through Lithuania), 1000 MW link to Poland and 1000 MW link to Finland. Also the balancing of remain 700 MW deficiency could be maintained from UPS. If there is only one DC connection to Sweden, then full DC link capacity is 2700 MW, and remain 1400 MW deficiency could be covered from UPS.

Scenario 4 (Import from UPS to Baltic).

Baltic import need could be about 4100 MW, which can't be fully covered from UPS. Maximal allowed import from UPS to Baltic is 2700 MW. Remain capacity of 1400 MW has to be imported via DC links or new power plants have to be constructed in Baltic. The bottlenecks are Estonia - Russia cross-section lines that are overloaded at N-1 contingencies:

– Eesti-Kingisep (N-1 Balti-Kingisep);
– Balti-Kingisep (N-1 Eesti-Kingisep).

Scenario 5 (Power transfer from New nuclear PP to Baltic).

At standing assumptions Baltic transmission network is adequate to transmit capacity of only 2100 MW from Ignalina NPP to Baltic countries - 700 MW to each. The main limiting factor is hard grid congestion at Ignalina NPP region: overloading of power lines Ignalina NPP - Liksna, Ignalina NPP - Utena, Utena - Panevezys at normal and N-1 contingencies. When exporting from Lithuania to Baltic, export possibilities to UCTE and NORDEL from Ignalina NPP will be limited also. It is necessary to build additional line Ignalina-Liksna 2. If the capacity of new nuclear power plant will be 3000 MW, additional line Ignalina – Kruonis is needed.

1.3.4 Dynamic calculations

The studies were done to find out export (through DC links) influence to the dynamic stability. The influence of the next DC links was investigated:

- ESTLINK 1 (from Estonia to Finland) 350MW
- LT -> SWE (from Lithuania to Sweden) 700MW
- LT -> POL (from Lithuania to Poland 1000MW
- ESTLINK 2 (from Estonia to Finland) 650MW

To keep generation balance Ignalina NPP generation was increased. Switching on LT->SWE DC link additional 800MW generation in Ignalina was added. In case of switching on LT-> POL DC link another additional 800MW generation in Ignalina was added.

The dynamic simulation results showed that on 3ph Ignalina 330 kV busbar fault and following trip off 800MW generation in Ignalina NPP critical fault clearing time decreases from 0,23 seconds to 0,20 seconds depending on export by DC links.

Voltage stability was not a problem in these simulations if transmission system of Baltic remains connected with Russia. To have better understanding of the results a chart with different fault clearing times are given in appendixes 7.18-7.21.

One problem with dynamic simulations for such a long time horizon as in present study until year 2025 there is not enough information about details of the machines that will be connected to the grid. But in other hand it gives some cognition of what might be the bottlenecks in dynamics and some basics for future calculations.

Dynamic calculations might bring out limits that are lower than load-flow limits and therefore it is needed to continue dynamic simulation studies and investigate more conditions and disturbances.

1.4 Conclusions and recommendations

Existing transmission system allows to transfer only limited capacity of foreseen power import and export through planned interconnections from New nuclear power plant in Ignalina.
Integration to UCTE and NORDEL requires additional reinforcement of Baltic transmission network.
Also imported/exported capacity amount largely depends on future power transit situation in BRELL power loop.

Recommended interconnections with neighbouring systems:

- Interconnection of Baltic to UCTE (link Lithuania – Poland)
- Larger interconnection capacity to NORDEL (Estlink 2, Link to SWEDEN)
- With UPS no reinforcement of interconnections is needed

Recommended reinforcement of internal interconnection lines

- Reinforcement of interconnections between Lithuania - Latvia and Latvia – Estonia allows larger transfer from Ignalina or between UCTE, Baltic countries and NORDEL
- The following lines should be constructed:
    - Construction of additional 330 kV power line Lithuania – Latvia (eg. Ignalina-Liksna);
    - Construction of additional 330 kV power line between Estonia and Latvia (eg. Riga-Pärnu OHL);
    - Reinforcement of Lithuanian internal grid with construction of new 330 kV line new nuclear power plant (Ignalina) – Kruonis.

Planned links will improve security of supply in Baltic countries, develop Baltic Sea regional market (stronger interconnections between Baltic countries) and allow joining of Baltic to internal market of EU.

Figure 1-3 represents the reinforced interconnection between Estonia, Latvia and Lithuania or it can also be called as perspective power bridge NORDEL-Baltic-UCTE.

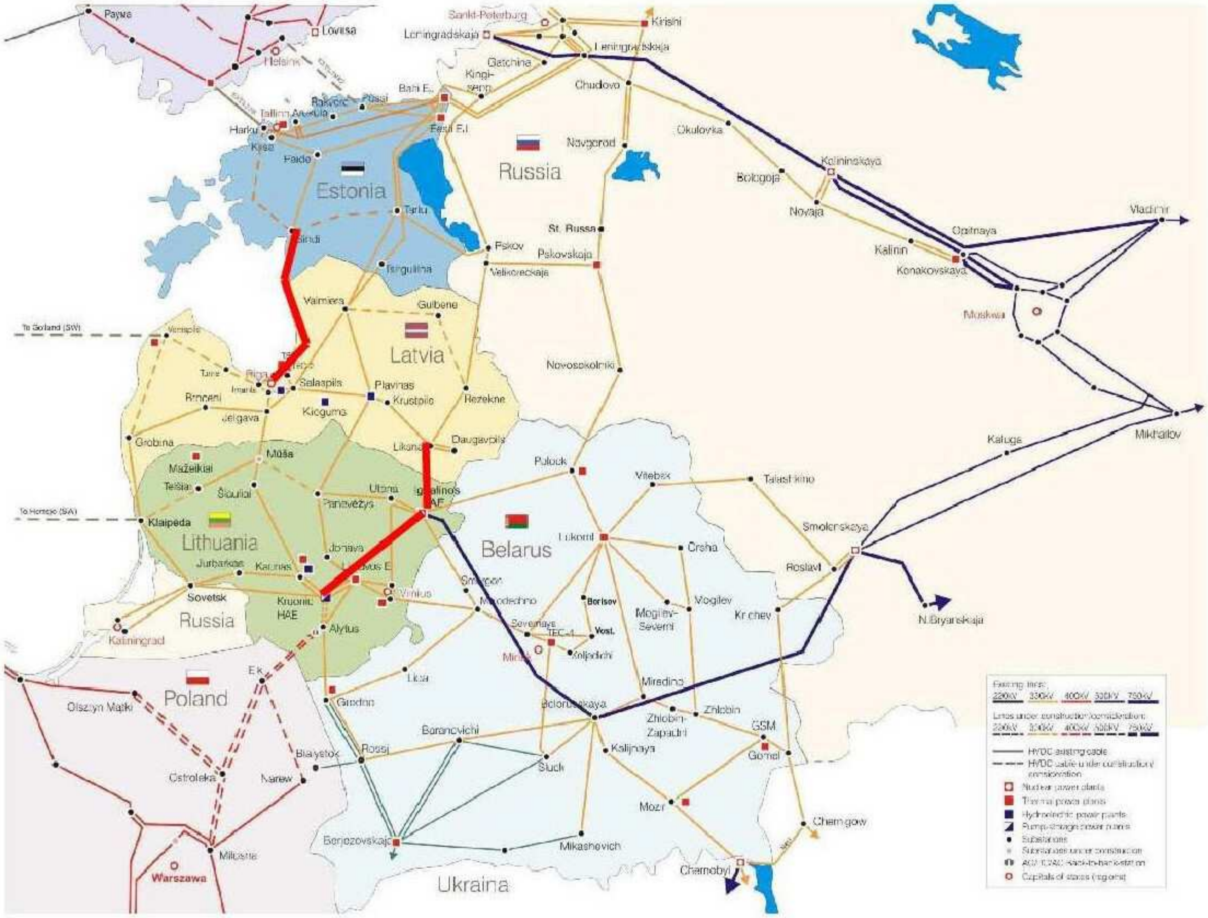

Figure 1-3 Recommended internal interconnection lines