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Integration of the Baltic States into the EU electricity system: A technical and economic analysis

Final report (Executive Summary)

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Abstract

The present report describes and evaluates scenarios fostering the full integration of the Baltic electricity system within the EU power and market framework. Towards this goal, the de-synchronisation of the Baltic electricity grids from the Russia/Belarus system crucially represents a key-necessary requirement. In this sense, three de-synchronisation scenarios are assessed, looking in particular at alternative conditions of the Baltic power grid in terms of: (i) no synchronisation with any of neighbouring systems, (ii) synchronisation with the Nordic system, and (iii) synchronisation with the Continental European Network (CEN). The options diverge due to costs of additional fuel and infrastructure. The third option, Baltic-CEN synchronisation, emerges as the most techno-economically cost-effective. The highlights of the report are listed below.

- Three Baltic-Russia/Belarus power system de-synchronisation scenarios
- These scenarios include synchronisation of the Baltic grids with the Nordic system and with the CEN
- The three scenarios are compared over the 2025 and 2030 horizons
- Scenarios mainly differ in terms of generation cost and required power system investment
- Baltic power system synchronisation with the CEN emerges as the most cost-effective option

Executive Summary

Introduction and scenarios

Deeper integration of the Baltic States and their power grids within the electricity system of the rest of European Union (EU), including their synchronous operation, is a strategic priority of the EU energy policy. The Baltic Transmission System Operators (TSOs) reached an agreement on a "Roadmap towards the Baltic States power system synchronisation with the Continental European Network" in December 2014, and the Baltic Energy Ministers signed a joint "Declaration on Energy Security of Supply of the Baltic States" in January 2015.

These initiatives led to the inclusion of some of the necessary infrastructure reinforcements into the list of Projects of Common Interest[1], and the European Commission (EC) committed to assist the Baltic States in the development of an action plan on the basis of cost-effective technical solutions[2]. The current report supports this priority by assessing the cost effectiveness of various options of de-synchronisation of the Baltic power systems from the Belarus-Russia-Estonia-Lithuania-Latvia (BRELL) ring to which they are currently associated from an operational point of view.

The assessed scenarios, as defined by the BEMIP Working Group[3], are highlighted in the following:

1. *The Baltic States' electricity grid is NOT synchronised with any of the neighbouring countries*, but it remains asynchronously interconnected through Direct Current (DC) links with the Nordic countries and Poland. Two subcases have been considered:
   a) The Baltics do not exchange Frequency Containment Reserves (FCRs[4]) with their neighbouring countries;
   b) The Baltics have the possibility of FCR exchange with the Nordic countries via the existing Voltage Source Converter (VSC) - based DC undersea cables: Estlink 1 (Estonia-Finland), and NordBalt (Lithuania-Sweden).

2. *The Baltic States' electricity grid is synchronised with the Nordic system* through new Alternating Current (AC) undersea cables between Estonia and Finland.

3. *The Baltic States' electricity grid is synchronised with the Continental European Network (CEN)* via Poland (the existing Back-to-Back DC power converter station, which currently ensures asynchronous connection between Lithuania and Poland, will be used in this case to connect Lithuania and Belarus asynchronously)
   a) Through the existing double-circuit AC line: LitPol Link 1;
   b) Through the existing LitPol Link 1 and new double-circuit AC line: LitPol Link 2.

[1] European Commission. C(2015) 8052 final, Annex 1, amending Regulation (EU) No 347/2013 of the European Parliament and of the Council as regards the Union list of projects of common interest. https://ec.europa.eu/energy/sites/ener/files/documents/5_2%20PCI%20annex.pdf
[2] https://ec.europa.eu/energy/en/news/joint-press-statement-european-commission-and-energy-ministers-estonia-latvia-and-lithuania
[3] The BEMIP Working Group on "Various aspects of the integration of the Baltic States' electricity network into the continental European network, including their synchronous operation"
[4] also known as primary reserves

In all investigated scenarios, the Kaliningrad region receives the necessary emergency power reserves through Lithuania.

In order to cover all possibilities with respect to the sufficiency of one double-circuit line for synchronisation in 2025, Scenario 3b with an extra AC line between Lithuania and Poland (LitPol Link 2) has been added. LitPol Link 2 is a challenging project as the planned line route is crossing populated and protected areas (e.g. nature reserves or cultural heritage sites)[5].

De-synchronisation scenarios are assessed against the counterfactual of an unvaried (Reference) scenario, whereby the Baltics are still synchronised with BRELL. All scenarios are evaluated for the 2025 and 2030 time horizons.

Another key element of the prospective Baltic power system is the possibility of building a new Nuclear Power Plant (NPP) in Visaginas, Lithuania. If constructed, this plant would determine large differences in the required emergency power reserves. Both the Reference and the three de-synchronised scenarios are therefore also alternatively assessed with inclusion of the Visaginas NPP. Due to the long NPP construction period, these alternative scenarios are only estimated for the 2030 horizon: in other words, all estimates for 2030 are considered as unvaried with or without the NPP.

Methodology

The study is based on the simulation of the various scenarios with models of the power system of the Baltic States, and of the European power system. Crucial inputs to those simulations are the fuel and CO_2 price forecasts related to energy generation. The estimates of those values were adapted to the Baltic context through a methodology based on general forecasts from international agencies and insights from the relevant scientific literature.

The simulation of the scenarios is carried out in two steps. First, a zonal model of the whole European power system, encompassing 33 countries, has been constructed using the PLEXOS software tool[6]. This is an economic generation dispatch model, which minimises the objective function of running costs of the electricity system necessary to provide the power needed to cover the load, while keeping the loading of the cross-border transmission exchange capacity within an acceptable range. For each scenario, the economic dispatch is performed for a one-year period at an hourly time step. The price formation mechanism assumed is the standard one for electricity markets (uniform auction, marginal cost pricing). Demand is assumed to be completely inelastic and deterministic; also, generation uncertainty from Renewable Energy Sources (RES) and unplanned power grid outages are disregarded at this stage.

This simulation of the European power system provides, among others, hourly outcomes of cross-border flows, generation from wind, solar and hydro sources, and country loads. These outputs are then fed into a more specific grid-detailed model of the Baltic power system, elaborated in PowerWorld[7]. This Baltic model includes a detailed description of the power systems of Estonia, Latvia, and Lithuania, and a reference representation of the high-voltage power systems of Finland and Poland. The Baltic model is employed to carry out the n-1 contingency analysis: i.e. simulations of failures of key power system components, so to assess the system's ability to satisfy the load in situations of stress. Contingency analyses, such as the n-1 analysis, provide indications on required reinforcements in the power grid infrastructure. These reinforcements are then calculated as investments that are added to respective scenario costs.

[5] LitPol Link news. http://www.litpol-link.com/news/preparations-for-the-second-link-with-poland-have-started-Ndx2A0
[6] http://energyexemplar.com/software/plexos-desktop-edition/
[7] http://www.powerworld.com/

Two specific peak-load scenarios are simulated with the Baltic model: (i) residual winter peak-load, and (ii) residual summer peak-load.

Note that, due to the above assumptions of deterministic demand and RES generation, this study does not provide a thorough analysis of system randomness: as a consequence, it is not able to provide estimates of variations in Loss of Load Expectation (LOLE)[8].

Moreover, due to limitations in the reliability of price dynamics simulations, the costs for each scenario are simply assessed as differences with respect to the relevant Reference scenario in variable costs and infrastructure building costs.

A fitting real Weighted Average Cost of Capital (WACC) is imputed to the end of sketchily modelling project financing by means of a capital recovery factor over the regulatory assumed project lifetime. Discounting is carried out by a suitably adopted real Social Discount Rate (SDR). Based on a review of the available literature, in the baseline case both the WACC and the SDR are assumed to be equal to 5%.

Results

The key outcomes of the analysis are summarised in Figure 1, derived for the baseline real WACC = 5%, real SDR = 5% case. Figure 1 depicts scenario cost differences in the Baltic States with respect to the reference scenario (respectively with or without NPP).

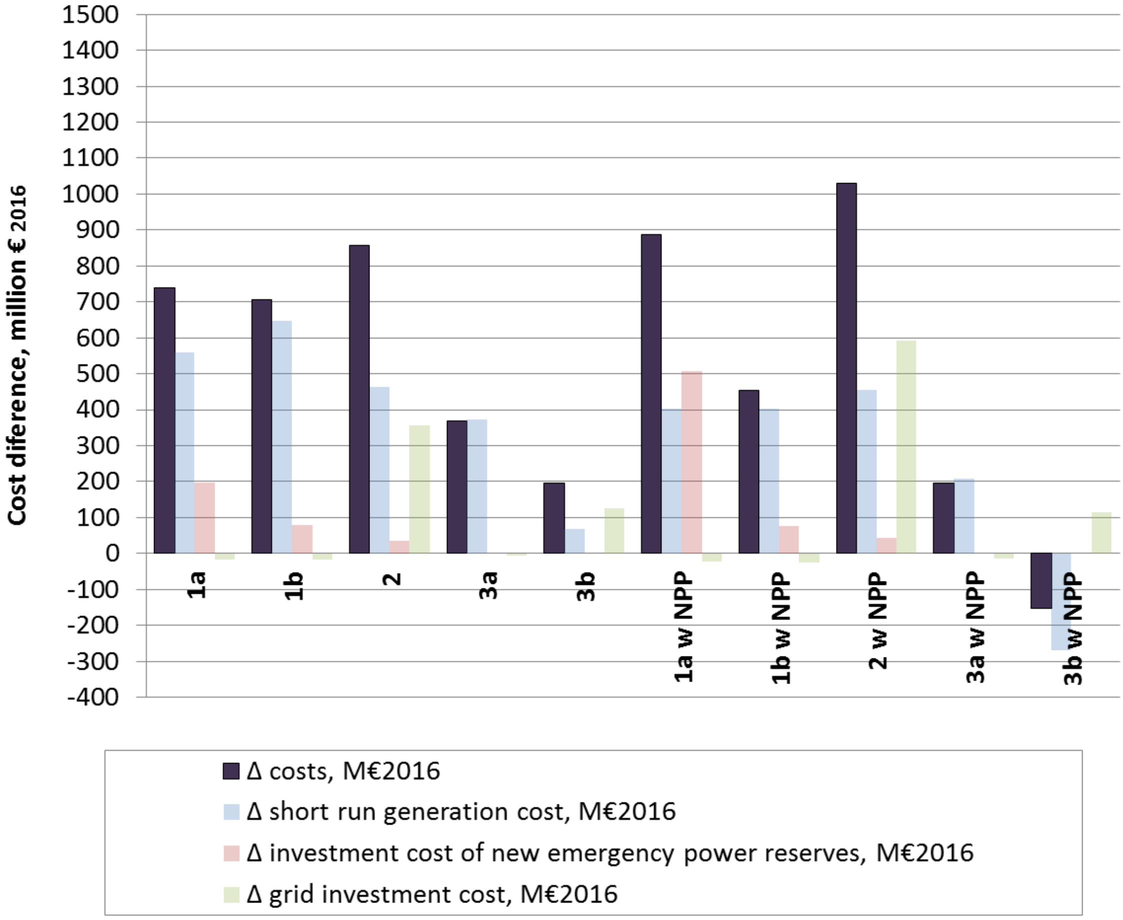

Figure 1 Differential aggregated scenario costs in the Baltic States with respect to the relevant Reference scenario 2025-2064; SDR = WACC = 5% (Base line)

[8] LOLE is the measure of how long, on average, the available generation capacity is likely to fall short of the load (demand). LOLE is used to study Generation (Resource) Adequacy.

It can be seen that de-synchronisation-related costs are minimised in Scenario 3, which considers Baltic grid synchronisation with the CEN. The main driver of this result is divergence in newly built FCRs generation capacity, transmission grid infrastructure in the Baltics, and overall variable generation, whose costs turn out to be substantially greater in Scenarios 1 and 2. Differences in variable generation costs turn out to be relatively marginal among the different scenarios in the overall computation.

Furthermore, the scenarios 1, 2a and 2b require high capacities of the FCRs within the Baltic States. This adds constraints on generation flexibility – in order to provide FCRs all or most of the available fossil-fired power plants should be spinning. And even then, in the most of the cases FCRs deficit do occur. The highest amount of required emergency power reserves is in Scenario 1a, due to the fact that the Baltics do not FCRs reserves with their neighbours.

Scenarios 3a and 3b have lower FCRs demand within the Baltics as most of it is provided from other CEN countries. This, in turn, adds high constraints on trading capacity between Lithuania and Poland.

A further expected result is that the construction of the Visaginas NPP drives down variable generation costs, so that these are generally lower in NPP scenarios, and 3b with NPP appears to be the cost-minimising case. However, the presence of the Visaginas NPP in all scenarios requires higher capacities of the emergency power reserves in Lithuania adding high constraints on local generators and on Lithuania-Poland/Sweden trading capacity.

The overall scenario related investment costs are summarised in Table 1. These costs amount only investment costs in emergency power reserves and in grid infrastructure in the Baltic States (including cross-border power connections with Finland and Poland).

Table 1 Overall aggregated scenario specific investment costs in the Baltic States

Scenario	**Overall investment costs, M€$_{2016}$**
Reference	27.7
1a	264.0
1b	103.4
2	601.6
3a	18.0
3b	215.2
Reference w NPP	42.9
1a w NPP	815.9
1b w NPP	102.6
2 w NPP	974.1
3a w NPP	18.0
3b w NPP	209.0

Limitations

Let it be noted that not all electricity system investment costs relevant to the de-synchronisation of the Baltics from IPS/UPS are included in the results. Regarding n-1 contingency analysis, the required reinforcements are estimated only for the 330 kV grid in the Baltic States. Not all n-1 contingency related cost is applied for the 2025/30 scenarios, as some unsolved n-1 contingency cases occur. *Potentially necessary reinforcement costs in the Nordic and CEN grids are also lacking*.

According to the previous studies[9] increased cross-border capacity between Lithuania and Poland (in scenarios 3a and 3b) may also require additional grid reinforcement cost in the Polish grid: the cost may go as high as 300 M€ for Scenario 3b. In Scenario 2, as reported by the Nordic TSOs[10] additional 50-100 M€ investments related to securing the dynamic and voltage stability may be needed.

In addition, as mentioned when describing the methodological approach applied in this study, no cost is considered for expanding the VSC-based DC links – NordBalt (Lithuania-Sweden) Estlink1 (Estonia-Finland) – needed for FCR exchange. All fossil-fired power plants are considered capable to contribute to the provision of the FCRs without any additional investment. However, when necessary, additional investment costs can simply be added following the aforementioned methodology.

Foreseen de-synchronisation expenses for the IPS/UPS (150 M€ for BtB converter on Kaliningrad–Lithuania border, and additional 62 M€ for new transmission lines as reported by Gothia Power) are not included in the final cost estimations as they appear in all considered scenarios.

Other assumptions are worth to be recalled: the marginal electricity generation cost for imports from IPS/UPS (including Kaliningrad) is assumed at 40 $€_{2013}$/MWh in all scenarios; no exports to IPS/UPS are modelled; and provision of the FCRs from Russia is assumed to be free of charge in the Reference scenarios.

[9] Gothia Power. Feasibility study on the interconnection variants for the integration of the Baltic States in the EU internal electricity market. 2013. CONFIDENTIAL (Executive Summary: http://www.ast.lv/files/ast_files/files/documents/Executive%20summary%20of%20FIS-BIS%20project.pdf)
[10] Fingrid, Statnett, Svenska Kraftnät, Energinet.dk. Impact of Baltic Synchronization on the Nordic Power System Stability. 2016. http://www.svk.se/siteassets/om-oss/rapporter/impact-of-baltic-synchronization-on-the-nordic-power-system-stability.pdf

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