Estonia-Latvia fourth electricity interconnection technical research service

June, 2026

SUMMARY

GLOSSARY

BESS	Battery Energy Storage System
CAPEX	Capital Expenditures
CBRA	Cable Burial Risk Assessment
EE	Estonia
EIA	Environmental Impact Assessment
EMT	Electromagnetic Transient
GIS	Geographic Information Systems
HVAC	High Voltage Alternative Current
HVDC	High Voltage Direct Current
IBR	Inverter-Based Resource
ms	milliseconds
LT	Lithuania
LV	Latvia
PV	Photovoltaic
RMS	Root Mean Square
SPS	Special Protection Scheme
TSO	Transmission System Operator
TTC	Total Transfer Capability

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Introduction

The operation of interconnected power systems is essential to guarantee a reliable, secure and efficient electricity supply, while also enabling the development of integrated regional markets. In the Baltic region, Latvia and Estonia are currently linked through three existing 330 kV overhead interconnections. However, the increasing penetration of renewable energy sources and the growing need for cross-border exchanges are progressively putting pressure on the existing transmission capacity.

In this context, the development of a fourth interconnection between Latvia and Estonia has emerged as a strategic priority to enhance system flexibility, improve security of supply, and support the large-scale integration of renewable energy sources, particularly offshore wind projects in the Baltic Sea. The geographical configuration of the region, combined with the expected growth in variable renewable generation and the ongoing synchronization of the Baltic power systems with the Continental European network, further reinforces the need for additional transmission infrastructure.

To address these challenges, Augstsprieguma tīkls (AST) and Elering, the Latvian and Estonian Transmission System Operators (TSOs), prepared a technical study aimed at assessing the feasibility and optimal configuration of a new HVAC interconnection between the two countries. The proposed solution is based on an innovative routing combining offshore and onshore sections, connecting the Western part of Latvia (Ventspils area) with Saaremaa Island in Estonia.

The objective of the study is to define the most suitable technical solution for the interconnection, including routing, technology, and main design parameters, as well as to evaluate its impact on the Baltic power system. The analysis covers multiple aspects, including network performance under different future scenarios (2035, 2040, and 2050), environmental constraints, system stability, transfer capacity, and preliminary cost estimation.

Context and objectives of the study

The Estonia-Latvia fourth interconnection project consists in the development of a new cross-border transmission infrastructure aimed at strengthening the existing connection between the two countries. As anticipated, Latvia and Estonia are currently interconnected through three onshore 330 kV lines (Kilingi-Nõmme – Riga CHP2, Tartu – Valmiera and Tsirguliina – Valmiera). The proposed project is based on a new interconnection concept characterized by a different routing compared to the existing infrastructure. More specifically, the solution foresees the connection of the Western part of Latvia (Ventspils area) with Saaremaa Island in Estonia through HVAC submarine cables, complemented by internal network reinforcements in both countries (Ventspils-Broceni in Latvia and Saaremaa-mainland Estonia towards the Lihula area). A conceptual scheme of the fourth Estonia-Latvia interconnection is shown in Figure 1:

Figure 1: *Preliminary routing of the fourth interconnection between Latvia and Estonia*

The development of the fourth interconnection is driven by several technical and strategic needs:

- Increase the cross-border transfer capacity between Latvia and Estonia and reduce existing congestion on the transmission network;
- Enable the integration of additional renewable energy sources, particularly offshore wind generation in the western areas of both countries;
- Improve the overall security of supply and operational reliability of the Baltic power system;
- Support the evolving regional power flows in the context of Baltic synchronization with the Continental European network and future interconnections (e.g. next Estlink developments).

In order to assess the feasibility and define the most suitable technical solution for the project, the study carried out for AST and Elering includes the following main activities:

1. **Identification** and **evaluation** of alternative **routing options**, including offshore and onshore sections, and selection of the preferred interconnection corridor;
2. **Definition** of the **optimal interconnection scheme** and **development** of representative **power system models**;
3. Network performance analyses, including **load flow**, **short-circuit** and **dynamic simulations**, under different **future scenarios** (2035, 2040 and 2050);
4. **Preliminary environmental analysis** and **identification** of potential **constraints** and **impacts**;
5. **Definition** of the main **technical characteristics** of the **interconnection** (cables, substations, compensation equipment);
6. **Estimation** of project **costs** (**CAPEX**) and **preliminary implementation timeline**.

Adopted methodologies

Preliminary environmental and routing analysis

The first step of the study consisted in the identification of a feasible corridor for the new interconnection between Latvia and Estonia.

The analysis focused on the evaluation of alternative routing options connecting the candidate nodes in Latvia (Ventspils, Ziras) and Estonia (Kotlandi, Lomala), considering both offshore and onshore sections.

The routing activity was based on the definition of a broad study area and the subsequent identification of alternative corridor options through a GIS-based approach. The analysis integrated multiple layers of spatial information, including environmental constraints (e.g. protected areas, Natura 2000 sites, marine habitats), physical characteristics (bathymetry and orography), existing infrastructure, and socio-economic factors such as population density and land use.

Specific routing criteria were applied to guide the selection process, including:

- minimization of environmental and social impacts;
- avoidance of critical constraints (e.g. protected areas, densely populated zones);
- preference for direct routes and reduced total length, particularly relevant for HVAC submarine cables;
- exploitation of synergies with existing infrastructure and corridors.

Based on these criteria, several alternative corridors were identified and subsequently compared using environmental and technical indicators. The comparative assessment allowed the identification of routing options that provide the best balance between technical feasibility and environmental compatibility.

The main outcomes of this activity are:

- definition of a set of feasible offshore and onshore corridor options;
- integrated evaluation of environmental, territorial and technical constraints;
- preliminary identification of the preferred routing solution for the interconnection.

Network analyses

Network analyses represent a central component of the study and aim at assessing the impact of the proposed fourth interconnection on the Baltic transmission system under a wide range of future operating conditions.

The analyses were carried out using detailed network models of the Baltic countries and were structured into the following sub-tasks, each addressing a specific aspect of system performance:

1. **Load flow analyses (N and N-1 conditions[1])** were performed using detailed network models developed for three horizon years (2035, 2040 and 2050).
   For each target year, a comprehensive set of operating scenarios was defined to capture the variability of system conditions and to isolate the impact of the new interconnection and offshore wind integration. The analysis considered different load conditions, levels of renewable generation and alternative network configurations, including cases without the interconnection, with the interconnection in service, and with both the interconnection and offshore wind generation connected to the system.

   The analyses were performed by verifying compliance with the main operational constraints of the transmission system, including admissible voltage ranges for the Baltic synchronous area, thermal loading limits of lines and transformers, and generator operating capabilities. To ensure realistic operating conditions, the 330 kV network in Latvia and Estonia was assumed to operate at voltage levels close to 350 kV under normal (N) conditions.

   Particular attention was given to identifying critical network elements prone to congestion and to assessing the redistribution of power flows resulting from the introduction of the new interconnection. Overall, the load flow results provide a comprehensive evaluation of the network's capability to accommodate the project, highlighting potential needs for additional reinforcements, especially at lower voltage levels.

2. **Short-circuit current evaluation** was performed in accordance with the IEC 60909 standard to assess the evolution of fault levels associated with the integration of the new interconnection. The objective of this activity is to verify that the short-circuit currents remain within acceptable limits for existing equipment and to evaluate the effect of network reinforcement and increased generation capacity on system strength. The results provide indications on the adequacy of existing equipment ratings, the identification of potential critical nodes approaching short-circuit limits, and the need for further detailed assessment or mitigation measures in subsequent stages.

[1] N condition means that load flow analysis is performed considering all lines and transformers in service. Instead, N-1 condition is when the load flow analysis is performed considering one element (line or transformer) out of service. The N-1 analysis is applied to all network elements, one at the time.

3. **Dynamic analyses** were carried out to assess the stability of the system under severe disturbances and contingency events. The analyses include scenarios such as three-phase short circuits, loss of major generation units and tripping of key network elements, including existing and proposed interconnections.

   The objective is to evaluate system response in terms of:
   - voltage behavior during and after disturbances
   - frequency deviations and recovery during and after disturbances
   - transient angle stability and damping of oscillations after disturbances

   These analyses allow verifying that the system maintains acceptable stability margins and that the new interconnection is properly integrated from a dynamic perspective without introducing adverse effects.

The network analyses were performed considering different target years, reflecting the progressive evolution of the Baltic power system. For each horizon year, different operating conditions were assessed, including winter peak and summer off-peak scenarios combined with high and low levels of renewable generation.

In addition, alternative network configurations were considered (with and without the new interconnection and with different levels of offshore generation), in order to isolate the impact of the project and assess its contribution to system performance.

Total Transfer Capacity assessment

The Total Transfer Capacity (TTC) assessment was carried out in order to identify the operational transfer limits of the Estonia-Latvia corridor under representative system conditions. The analysis was based on load flow simulations performed under both N and N-1 conditions, progressively increasing the power exchange between the two areas until the first operational limit was reached (thermal overloads or voltage constraints).

Power transfers were evaluated in both directions (from Latvia to Estonia and from Estonia to Latvia), considering different seasonal conditions (summer off-peak and winter peak) and varying levels of renewable generation. To isolate the impact of the project, simulations were performed for different network configurations, including cases with and without the proposed new interconnection, while maintaining consistent assumptions on offshore wind generation.

The methodology ensures that the resulting TTC values reflect realistic operational limits of the transmission system and allows identifying the network elements constraining cross-border exchanges.

Technical design of the interconnection

A preliminary definition of the technical configuration of the fourth EE-LV interconnection was carried out to identify a feasible solution in terms of technology, voltage level and main components.

The technical assessment was based on a set of design assumptions, including different voltage levels, cable configurations and required transmission capacity, considering the overall length of the connection and the constraints associated with HVAC submarine cable systems, particularly in terms of reactive power generation and compensation requirements.

From a technical and technological perspective, the analysis highlighted the limitations associated with higher voltage levels for long HVAC submarine connections, mainly due to increased reactive power generation and more complex installation requirements. Based on these considerations, the 330 kV option was excluded, while both 220 kV and 275 kV solutions were initially assessed.

The comparison of the candidate solutions led to the selection of the 275 kV HVAC configuration as the most suitable compromise between transmission capacity, technical feasibility and overall system complexity. The selected solution is based on a three-core submarine cable system, combined with onshore cable sections and appropriate reactive compensation equipment.

Cost estimation (CAPEX)

The methodology adopted for the CAPEX estimation is based on a combined approach, integrating internal expertise and external reference data.
For the interconnection cable, the cost assessment relies on CESI's experience and internal data derived from similar projects and engineering activities. For the remaining components, such as substations, reactors and other electrical equipment, publicly available benchmark values were used.
In particular, cost references were derived from recent international sources, ensuring consistency and alignment with current market conditions.

For components whose cost data were available in foreign currencies, appropriate conversion factors were applied to express all values in euros.
The outcome of this activity is a preliminary estimation of the investment cost associated with the project.

Scenarios and main assumptions for network analyses

As described in the previous section, the network models have been developed to represent the evolution of the Baltic power system over the considered time horizons (2035, 2040 and 2050).
In this context, a set of representative scenarios has been defined to capture the expected variability of operating conditions and to assess the impact of the proposed interconnection under different system configurations. The scenarios are built based on consistent assumptions regarding demand levels, generation mix, cross-border exchanges and operational behavior of flexible resources such as BESS and electrolysers.
In particular, Table 1 presents the projected installed capacity in the Baltic countries for 2035, 2040, and 2050, consistent with the scenario framework.

Table 1: *Expected generation fleet in Baltic countries for years 2035, 2040 and 2050, [MW]*

[MW]	LATVIA			LITHUANIA			ESTONIA		
TYPE	2035	2040	2050	2035	2040	2050	2035	2040	2050
THERMAL	1000[2]	150	150	505	505	505	842	1206	1522
HYDRO	1558[3]	1558[4]	1558[5]	1136[6]	1136	1136	0	0	0
BIOMASS	150	150	150	212	212	212	155	155	155
PV	2296	2296	4826	5000	5100	5100	900	900	1500
WIND ONSHORE	790	790	1913	3060	3060	3060	844	880	1600
WIND OFFSHORE	1000	1500	7500	1200	1200	1200	1000	2080	4500
BESS STORAGE	90	650	650	749	749	749	200	314	1260
ELECTROLYSER	800	800	1500	2000	2000	2000	0	0	1000

The projections highlight substantial investments in renewable generation across all Baltic countries, particularly in solar and wind technologies, along with the development of electrolysers and BESS, contributing to increased system flexibility. By 2050, thermal capacity

[2] https://latvenergo.lv/lv/par-mums/razosana
[3] Available capacity in summer period: 354MW
[4] Available capacity in summer period: 354MW
[5] Available capacity in summer period: 354MW
[6] Hydro pump included

declines in Latvia while increasing in Estonia, with emerging flexible demand such as data centers helping absorb excess renewable generation.

Main Results

Environmental analysis and route selection

The **environmental pre-feasibility analysis** assessed alternative corridors for the fourth interconnection between Latvia and Estonia, considering the **candidate landing points** in Latvia (**Ventspils and Ziras**) and Estonia (**Kotlandi and Lomala**), together with the main offshore and onshore environmental and territorial constraints.

More in detail:

- **Four route options** were **assessed** between the candidate nodes in Latvia and Estonia, considering both **territorial waters (TWs)** and **exclusive economic zones (EEZs)**.

- EEZ routes may offer some environmental advantages, but they are longer, increase the project footprint and may interfere with planned offshore wind developments.

- TW routes show better technical performance due to their shorter length and greater project sovereignty, particularly in the case of Ventspils, which is closer to Estonia than Ziras. The TW route will have better ability to provide physical protection of such infrastructure, taking into account current geopolitical situation in Baltic Sea.

- The option **Ventspils – Kotlandi/Lomala via neutral corridors** (**Option 1.1**) is preliminarily identified as the **preferred route**, representing the most balanced solution from technical, environmental and strategic perspectives.

- Within Option 1.1, **two** preliminary **variants,** presented in Figure 2**,** were considered: **Route 1.1A** is slightly longer (approx. **109 km**) and **minimizes interference** with **Natura 2000 areas**, while **Route 1.1B** is shorter (approx. **100 km**) but entails **greater interaction** with **protected areas**.
  This reflects the main trade-off between route length, environmental constraints and permitting risk (Figure 2).

Route 1.1A

Route 1.1B

Figure 2: *Preliminary variants of the preferred Route 1.1 corridor: Route 1.1A vs Route 1.1B*

Technical design of the interconnection

The preliminary design of the proposed interconnection is based on **HVAC technology**, combining submarine cables with onshore transmission elements. Among the voltage levels assessed, the 330 kV option was excluded due to the lack of commercially available three-core submarine cables and the technical and economic disadvantages associated with single-core solutions, including higher installation complexity and more demanding reactive power compensation.

More specifically:

- After evaluation of project different voltage technical solutions, the project ultimately converged on the **275 kV solution**, identified as the best compromise between transmission performance, technical feasibility and overall system complexity.
- The **selected** configuration consists of **two 275 kV three-core HVAC submarine cable circuits** with XLPE insulation and 2500 mm^2 conductor cross-section, each rated at about **520 MVA**, with a main submarine section of approximately 94 km, **enabling** the achievement of the target **interconnection capacity** of at least **700 MW**.
- Compared with 220 kV, the 275 kV option provides higher transfer capability with a limited impact on the main cable cost drivers.

The single line diagram below shows the selected 275 kV HVAC configuration, consisting of two submarine cable circuits and the main associated substation equipment, identified as the minimum arrangement capable of meeting the target transfer capacity and the relevant security requirements (Figure 3).

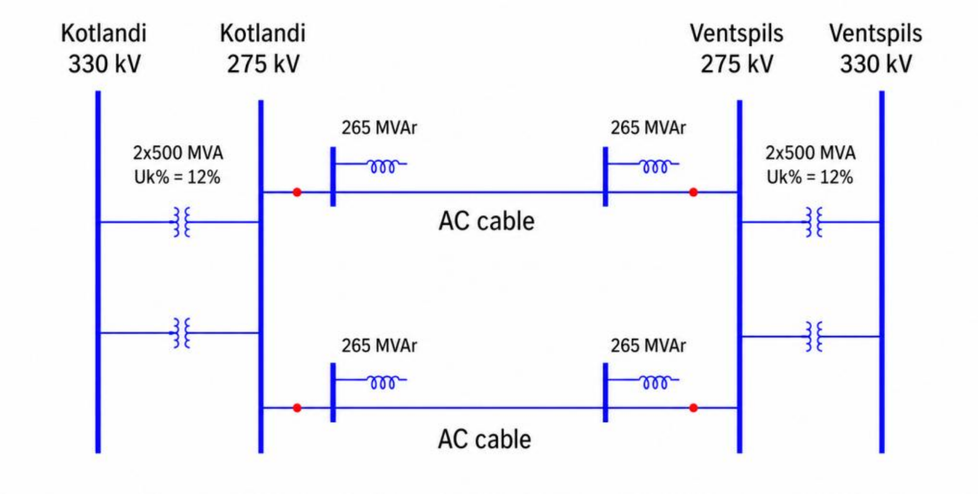

Figure 3: *Single line diagram of the interconnection*

Network Analyses

The network analyses, including steady-state, TTC, short-circuit and dynamic simulations, confirm the overall technical feasibility of the proposed fourth interconnection between Estonia and Latvia.

Across all analyzed time horizons, the 330 kV network remains generally robust, while the main constraints are observed in the 110 kV Latvian network.

More in detail:

- From a **steady-state perspective**, the system becomes progressively more stressed over time, although the **330 kV transmission backbone** remains generally **adequate**.
- In **2035**, the main **issues,** due to RES generation integration, are limited to a few **Latvian 110 kV corridors**, while the 330 kV network does not exhibit significant constraints.
- In **2040**, the **increasing** integration of **RES** leads to higher stress on the 110 kV network, with **overloads** in some cases **exceeding 200% under N-1 conditions**, whereas the 330 kV grid continues to perform adequately.
- In **2050**, the most critical conditions are observed, with widespread overloads and **undervoltages** in the **110 kV network**, including **voltage drops** down to around 0.8 p.u. Despite this, the 330 kV system remains robust overall.

The results confirm that the integration of the fourth EE-LV interconnection does not compromise the security of operation of the Baltic transmission system, as the main limitations remain confined to localized 110 kV conditions while the 330 kV transmission backbone preserves adequate operating margins.

- The **TTC assessment** (Table 2) shows that the new interconnection significantly **increases** transfer capacity between the two countries under all analyzed 2035 operating conditions. In the **LV → EE** direction, the TTC is particularly high, ranging between 2592 MW and 2869 MW. Regarding the TTC increase the range is between 719 MW and 972 MW under worst N-1 conditions.

Table 2: *TTC for the direction LV → EE and EE → LV, [MW]*

Direction	TTC in the worst N-1 conditions with IV interconnection	**ΔTTC increase in the worst N-1 conditions**
Latvia → Estonia	2592 – 2869 MW	719 – 972 MW
Estonia → Latvia	2187 – 2442 MW (2472 – 2557 MW*)	320 – 542 MW (561 – 659 MW*)

** Values calculated with limiting offshore wind production in Kotandi area*

In the opposite direction (**EE → LV**), the **TTC increase** is **lower** and more sensitive to network topology and offshore wind generation in the Kotlandi area. **Without limiting Kotlandi** offshore wind production, the **TTC increase** ranges between **320 MW** and **542 MW** under worst **N-1** conditions (while the total transfer capacity is between 2187 MW and 2442 MW).
If **Kotlandi** offshore wind output is **limited**, the attainable **TTC** improves, reaching at least **561 MW** and **659 MW** in **N-1 conditions,** while the TTC is between **2472 MW** and **2557 MW**.

- This behavior is mainly due to the fact that, under **high offshore wind** output, the combined **flows** from **Kotlandi** and **mainland Estonia** may **saturate** the **Kotlandi-Ventspils corridor** under contingency conditions. Overall, the TTC limits are driven by thermal loading constraints rather than voltage stability issues (Figure 4).

Figure 4: *Illustrative N-1 contingency scenario showing the impact of high offshore wind generation from Kotlandi and additional power flows from mainland Estonia.*

- **Short-circuit analyses** indicate a progressive **increase** in **fault levels** from 2035 to 2050, driven by the growth in installed generation capacity and the **strengthening** of **network** interconnections. In Estonia, the highest increase at 330 kV is observed in 2050, reaching about 6.3 kA. Overall, short-circuit levels remain within acceptable limits at transmission level, although in the longer term some locations, particularly in Latvia, may approach equipment ratings and therefore require further monitoring and detailed verification.

- **Dynamic simulations** confirm **stable system behavior** under all investigated contingencies, including severe three-phase faults, disconnection of key network elements and loss of major generating units. The results show adequate damping of oscillations, satisfactory recovery of voltage and frequency, and compliance with CFCT requirements, confirming that the new interconnection is well integrated into the Baltic power system from a dynamic perspective.

CAPEX evaluation

The CAPEX evaluation combines CESI's internal cost assessment for the cable system with benchmark costs for the remaining project components.

More in detail:

- The estimated cost of the cable system is about 408 M€ per cable, including supply, installation, protection, spare parts, engineering, project management and surveys.
- The estimated CAPEX of the other main equipment is about 132 M€ in the base configuration and 144 M€ in the configuration including two additional 100 MVAr shunt reactors for enhanced voltage control.
- Overall, the **total project CAPEX** is estimated at about **948-960 M€,** depending on the selected compensation scheme. In all cases, the **cable system** represents by far the dominant cost component, accounting for about **85% of the total investment**.
- Considering the current feasibility stage of the project, a **35% contingency margin** was applied in line with the AACE Class 4 approach[7], resulting in a **total estimated CAPEX** in the range of about **1280-1296 M€**.

Table 3: *Summary of CAPEX evaluation [M€]*

Item	Without additional shunt reactors [M€]	With additional shunt reactors [M€]
Cable CAPEX	816	816
Other equipment CAPEX	132	144
Total	***948***	***960***
Contingency margin (35%)	*332*	*336*
Total	***1280***	***1296***

As shown in Table 3, the inclusion of two additional shunt reactors has only a limited impact on total CAPEX, while the application of the contingency margin significantly increases the overall investment estimate.

Conclusions

The analyses carried out in this study demonstrate that:

- The proposed **fourth Estonia-Latvia interconnection** is a **viable technical option** and a strategically relevant project for the long-term evolution of the Baltic power system. The

[7] https://aheinc.ca/wp-content/uploads/2018/12/AACE-Cost-Estimate-Classification-System.pdf

project is expected to strengthen regional security of supply and system stability, while enabling the integration of large-scale offshore renewable generation, including **Elwind** project in **Latvia** and **Estonian offshore** wind **projects above 1 GW**, while also expanding cross-border exchange capability.

- The environmental screening compared **four routing alternatives** between the candidate landing points in Latvia (**Ventspils**, **Ziras**) and Estonia (**Kotlandi**, **Lomala**), considering both **territorial waters** (**TWs**) and **exclusive economic zones** (**EEZs**). The results point to a clear trade-off: routes in EEZs may reduce interaction with sensitive coastal habitats, but they are longer, imply a larger footprint and may overlap with planned offshore wind activities; routes in TWs are technically preferable because they are shorter and easier to control from a project governance perspective.

- The corridor **Ventspils – Kotlandi/Lomala via neutral zones** (**Option 1.1**) emerges as the most suitable preliminary solution. Within this preferred corridor, two alternative alignments are considered: **Route 1.1A**, about **109 km** long, **minimizes interference** with Natura 2000 areas, whereas **Route 1.1B**, about **100 km** long, entails **greater interaction** with protected areas. Therefore, the final alignment should be confirmed in the next project phases, taking into account route length, environmental constraints, permitting risk, cost implications and possible mitigation measures.

- Based on the preferred routing, preliminary engineering confirms that an **HVAC solution at 275 kV** is appropriate for the project scope. The selected configuration relies on **two 275 kV AC cable circuits**, **each** with a rating of about **520 MVA**, and includes a main submarine section of approximately **94 km**, sufficient to deliver a transfer capacity of at least **700 MW**. By contrast, the 330 kV alternative was discarded because of the absence of commercially available three-core submarine cables and the greater technical and economic complexity associated with single-core arrangements.

- The preliminary cost assessment indicates a project CAPEX of around **948-960 M€**, depending on whether additional shunt reactors are included in the final configuration. When a **35% contingency allowance** is applied, in line with a feasibility-level estimate, the overall investment rises to approximately **1280-1296 M€**. In both cases, the cable system remains the main cost driver, representing roughly 85% of the total. These amounts relate to the interconnection project itself and do not cover possible internal reinforcements in the Latvian and Estonian grids.

- From the network point of view, the analyses confirm that the **330 kV transmission backbone remains** broadly **adequate** in all assessed horizon years (2035, 2040 and 2050), assuming that the already planned reinforcements in Latvia and Estonia (Ventspils – Broceni – Varduva (LT) project in Latvia/Lithuania and Kotlandi – Lihula corridor in Estonia) are implemented. Both under normal operation and under contingency conditions, the high-voltage network can accommodate the expected additional flows without major voltage or thermal problems at transmission level.

- The key network **constraints** are instead found at the **110 kV** level, especially in Latvia. In **2035**, overloads in some Latvian 110 kV corridors may already reach **130-140%**; in **2040**, some N-1 cases exceed **200%**; and by **2050** the system shows its highest stress, with widespread overloads and undervoltages down to around **0.8 p.u.** in some areas.
This confirms that the bulk transmission grid is not the main bottleneck, whereas **local** reinforcements in the **lower-voltage network** will be **necessary** to maintain secure operation over time and have a safe RES integration.

- The **TTC analysis** highlights a strong contribution of the new interconnection to cross-border transfer capability. The most pronounced effect is observed in the **LV → EE** direction, where the increase in TTC is always above **700 MW** and can approach **970 MW** under specific contingencies. This indicates that the new asset would materially strengthen the export capability from Latvia towards Estonia under the analyzed 2035 system conditions.

- In the opposite **EE → LV** direction, the **gain** is **lower** and **depends** more strongly on network topology and on offshore **wind production** in the **Kotlandi** area.
Without curtailing Kotlandi offshore generation, the TTC ranges between 320 MW and 542 MW in N-1 conditions. If offshore wind output is limited, the attainable TTC improves to at least 531 MW in N conditions and 561-697 MW in N-1 conditions. These results also show that the limiting mechanism is linked mainly to thermal congestion, rather than voltage stability.

- The **short-circuit assessment** confirms that both **Estonia** and **Latvia** remain within **acceptable** operating **bounds** in **2035**, while **fault** levels **rise** progressively in **2040** and **2050** as generation increases and the system becomes more extensively interconnected. In **Estonia**, the **largest increase** observed at 330 kV reaches about **6.3 kA** in **2050**. In

Latvia, the growth is more critical at some locations, where fault levels may draw closer to equipment ratings in the longer term, making additional verification and targeted mitigation measures advisable.

- The dynamic simulations indicate that the **Baltic system** retains **satisfactory stability margins** under severe events, including 250 ms three-phase faults, disconnection of major transmission elements and loss of large generating units. Across all the investigated cases, oscillations remain well damped, voltage and frequency return to acceptable ranges, and the new interconnection does not create negative dynamic interactions. On the contrary, it appears to be well integrated into the system and beneficial in terms of operational flexibility and power exchange capability.

In overall terms, the project can be regarded as a credible and strategically valuable reinforcement for the Baltic grid: it offers clear benefits in terms of renewable integration and transfer capability.

Recommendations

Strategic recommendations for interconnection development

Based on the results of the study, the following recommendations are proposed for the further development and implementation of the fourth interconnection between Estonia and Latvia.

- The preferred technical solution for the project is the implementation of **two 275 kV three-core HVAC submarine cable circuits** with **2500 mm^2 conductor cross-section**, as this configuration is able to provide a transfer capacity of about **700 MW** while remaining technically feasible within the current market framework.

- At the same time, this solution is already close to the **practical technological limit** of HVAC three-core submarine cable systems. Voltage levels above **275 kV** and conductor cross-sections above **2500 mm^2** are not currently standard commercial solutions, meaning that the selected design leaves only limited room for future capacity expansion within the same technology family.

- If future offshore wind development in the Baltic Sea, especially in the Kotlandi / Saaremaa area, is expected to grow significantly beyond the levels considered in this study, higher-capacity transmission alternatives should be assessed at a later stage. In particular, HVDC-based solutions exceeding 1000 MW could be investigated as long-term planning options, in order to provide additional transfer margin and greater operational flexibility for future system development.

- From a broader planning perspective, attention should also be paid to the different role played by the interconnection in supporting offshore wind integration in Estonia and Latvia. Offshore generation connected in the Kotlandi area is more dependent on the fourth interconnection, whereas generation connected directly to the Latvian grid benefits from a stronger and more diversified generation evacuation structure. For this reason, it may be appropriate to assess a more balanced allocation of future offshore wind capacity between the two systems.

Recommendations for network integration and Baltic system planning

The study results highlight several planning priorities related to internal grid development, local network constraints and the future evolution of the Baltic power system.

- The secure integration of the interconnection is conditional on the implementation of the already planned 330 kV reinforcements, in particular the Ventspils-Broceni-Varduva(LT) reinforcement in Latvia/Lithuania and the Kotlandi / Saaremaa-Lihula corridor in Estonia. These projects should therefore be considered enabling conditions for the interconnection.

- The analyses also show that the most relevant network constraints are concentrated in the 110 kV grid, especially in Latvia. For this reason, targeted reinforcements of the lower-voltage network should be planned in parallel with the interconnection project, particularly in areas where overloads and undervoltages become more critical in the 2040 and 2050 scenarios.

- In addition to conventional reinforcements, TSOs should consider operational and planning measures such as **Dynamic Line Rating (DLR)** and advanced forecasting tools capable of correlating weather conditions, RES output and expected network stress. These measures may help mitigate local overload risks under high renewable generation conditions.

- Looking ahead, the increasing penetration of **inverter-based resources (IBRs)**, such as wind, PV, BESS and HVDC converters, suggests that future system studies should progressively complement RMS-based simulations with EMT analyses, in order to better capture fast control interactions and converter-driven stability phenomena.

Recommendations for project implementation and operation

Beyond the planning aspects, several implementation and operational measures should be considered to reduce project risks and ensure reliable operation during the lifetime of the interconnection.

- The next stages of the project should include a full **Environmental Impact Assessment (EIA)** and a detailed **marine survey**, in order to refine the preferred route, verify installation conditions and confirm the most suitable landfall and offshore corridor solutions.

- A dedicated **Cable Burial Risk Assessment (CBRA)** should be carried out to define the most appropriate cable protection strategy and reduce the risk of future failures caused by external human activities.

- Since submarine cable repairs can be costly and time-consuming, it is strongly **recommended** to **procure** and **store spare cable sections** and **joints** from the outset, to minimize restoration time in the event of damage.

- From an operational point of view, the **introduction** of a **long HVAC cable** may **alter local voltage behavior** in a system currently operated close to 350 kV. For this reason, it is **recommended** to evaluate either a **reduction** of the operating **voltage** of the **Ventspils-Kotlandi section** (for example to around 340 kV) or the **installation** of **additional reactive compensation**, such as the two 100 MVAr shunt reactors already considered in the CAPEX assessment.

- In addition, the implementation of a **Special Protection Scheme (SPS)** should be considered to **manage power exchanges** and maintain **compliance** with **admissible operating limits**, particularly in relation to exchanges involving Latvia-Lithuania, Lithuania-Poland and potentially also the Saaremaa area.