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Cost Of Resilient Power System With High Penetration Of Renewable Energy Source

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The European Green Deal goals of climate-neutral economy by 2050 sets the path for future energy sector. According to the "Fit-for-55" package Europe's net greenhouse gas emissions should be reduced by at least 55% by 2030, compared to 1990 levels. The agreement on the revised Renewable Energy Directive sets the EU's binding renewable energy target for 2030 at a minimum of 42.5%. Installed more than 400 GW of wind and solar energy production capacity in 2022, and an increase of over 25% compared to 2020 indicates the inertia of EU energy sector transformation. According to the National Energy Independence Strategy (NEIS, 2018), 45% of Lithuania's total electricity consumption is expected to be produced by RES in 2030 and RES production is projected to increase to 80% of total national load in 2050 making it the main source of electricity. In 2021, 48% of the country's electricity was generated by RES, in 2022 – 60 % and in 2023 – 70 %. Considering such green electricity production tendencies, a significant RES capacity growth can be foreseen in the near future.

High penetration of RES impacts on power system resilience by enhancing or deteriorating it (Bhusal et al., 2020). Specifically, RES deteriorates the ability of bulk power systems to 'withstand' disturbances but improve the ability of power systems to 'recover' from disturbances and blackouts, which requires to take appropriate strategies derived from the comprehensive evaluations (Bhusal et al., 2020). Various optimization methods and modelling approaches are applied to evaluate power system resilience. In accordance to Bhusal et al. (2020), cost-benefit analysis has not attained significant attention yet. In agreement with scientists, at current stage of research, the paper estimates and analyze the cost of resilient power system subject to high volumes of RES.

Plexos Integrated Energy Model was applied to forecast electricity prices. This is a bottom-up model, which is mainly used for the purpose of investment and operation decision making (Ringkjøb et al., 2018). Plexos solves the optimization task for the power system over a variety of times scales from to short-term (less than 1 year) to long-term (1-40 years) (Chiodia et al., 2023). Alternatively, it minimizes an objective function subject to the expected cost of electricity dispatch given a number of constraints including load, availability and operational characteristics of generating plants, fuel costs, network constraints and market information (Chiodia et al., 2023) (Figure 1). In this research, Plexos solves one optimization problem for each time slot and determines the lowest market price for the zone, including the decision for which generator to start up, when to start up, where the flows go, etc. Basically, it simulates a separate merit order curve for each hour.

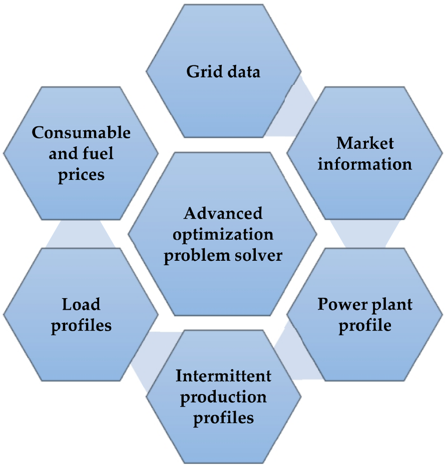

Fig. 1. Structure of Plexos model.

The five different scenarios were analyzed considering High, Mid and Low values of RES capacity and load based on national targets for 2030. The modelling results show that the average electricity market price in Lithuania has a downward trend as RES capacity increases (Figure 2).

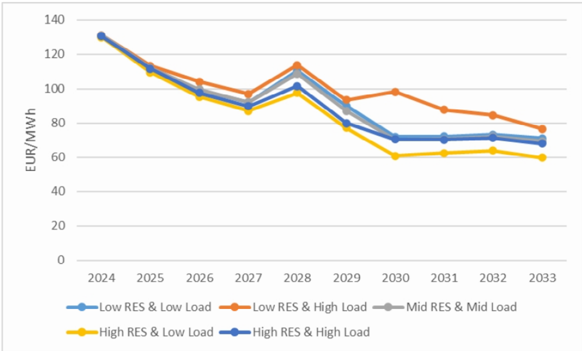

Fig. 2. Electricity market forecast in Lithuania.

In Low RES and Mid RES scenarios the average electricity market price is estimated to be around 130 EUR/MWh in 2024 and 70–98 EUR/MWh in 2030. In High RES scenarios, the average electricity market price is projected to decrease to 60 EUR/MWh in 2030. In 2028, a price increase by 12–20% is estimated due to expected introduction of the Harmony Link, which will provide electricity export opportunities and create additional electricity demand.

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Uncertainty analysis