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PATHFNDR

Energy System

Flexibility-aware planning of distribution network reinforcements

Work package 2

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1 MOTIVATION

Growing Demand & New Challenges: With the increased penetration of distributed energy resources (DERs), and electrification of demand for heating and mobility, distribution networks face unprecedented challenges. Many of the existing networks face the risk of thermal overloads of cabling and voltage violations.

Importance of Proactive Planning: Traditional reinforcements are effective but expensive, take time to implement, and highly depend on uncertain customer behavior. By integrating flexibility options into planning, utilities can optimize their investment decision making, coupling traditional upgrades with customer-provided flexibility.

The Role of Flexibility: Rather than replacing upgrades, flexibility solutions allow utilities to delay or reduce the scale of network investments, enhancing both network performance and investment efficiency.

2 CONTRIBUTION TO PATHFDNR

This work was performed as part of **T2.3.2**, having reached project milestone **M2.3.2** and was documented in project deliverable **D.2.3.2a**.

- **Link to WP1**: In addition to the Mantelerlass targets, this work also considers future national scenarios (on PV, EV, HP proliferation) from WP1.
- **Link to WP4**: The results of the planning analysis are input to WP4 for the design of appropriate dynamic tariffs that motivate end-user flexibility.
- **Link to WP7**: The results of the electricity distribution planning analysis are input to WP7 for the design of appropriate policies and regulations.

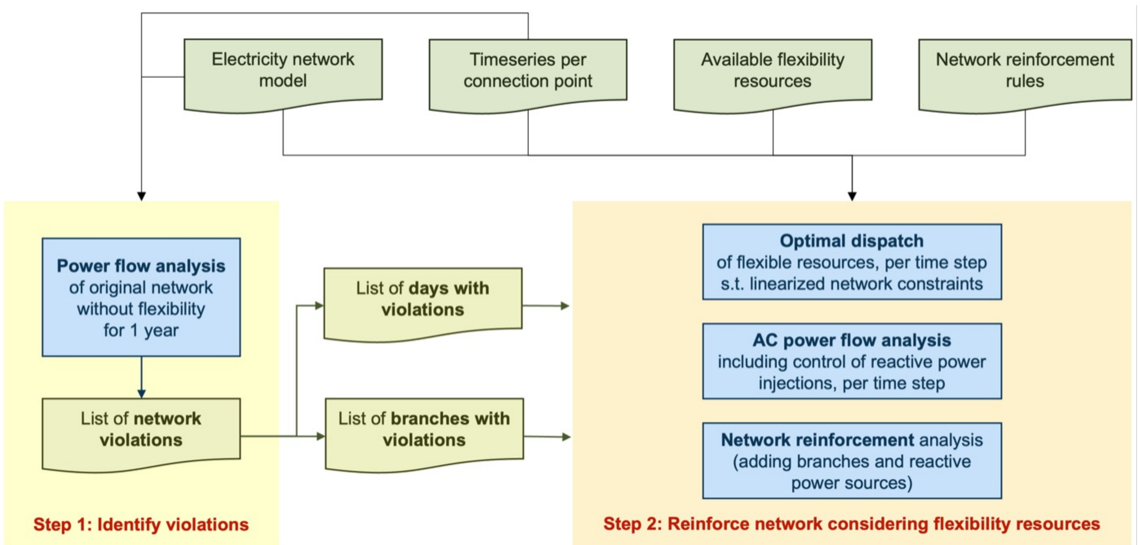
2 METHODOLOGY

The proposed approach includes two steps:

Step 1: **Identification of Network Violations**: Assess the needs for network upgrades assuming no availability of customer/prosumer flexibility

Step 2: **Network Reinforcement with Flexibility Resources:** Utilize available flexibility to manage thermal overloads, reducing or delaying network upgrades.

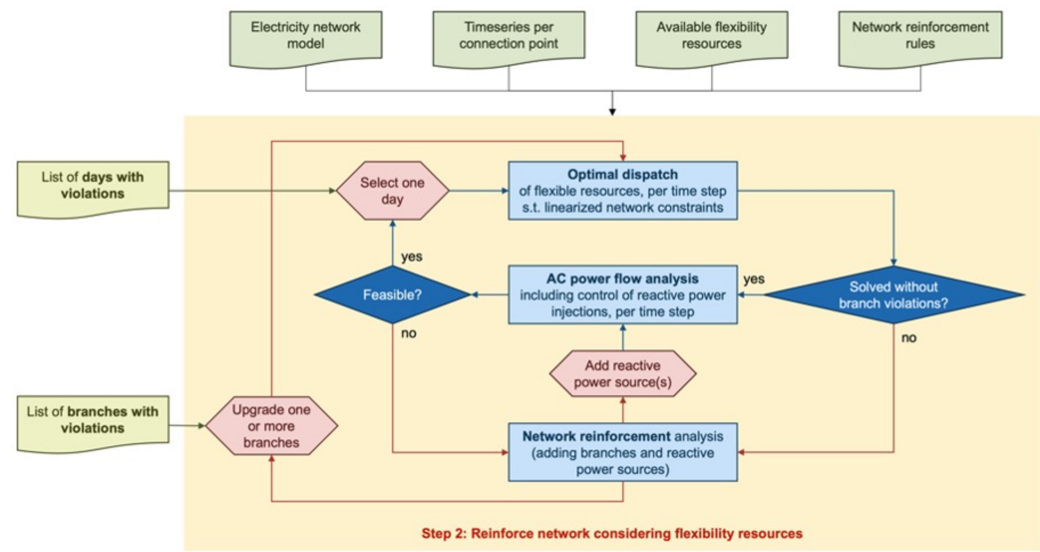
Tools Utilized: ETHZ-FEN in-house tools, FlexDyn and FlexECO, are used for grid power flow analysis and optimal dispatch, though alternative tools can be applied as well.



Step 2 consists of three core analysis Blocks:

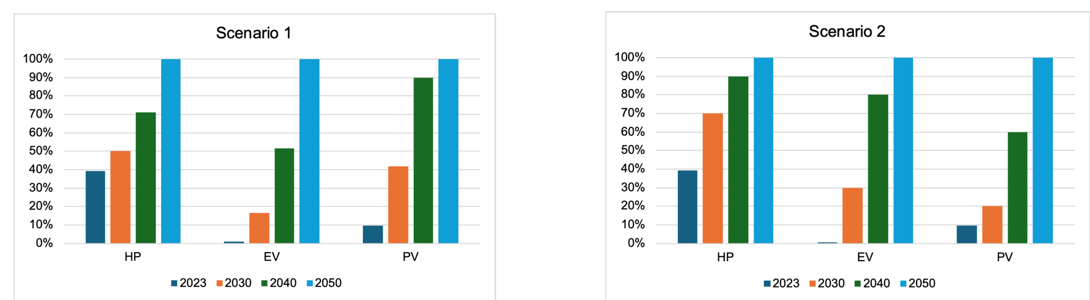
- **Optimal Dispatch**: Run a multi-period optimization (DC model) for selected days to identify if flexibility can mitigate overloads.
- **AC Power Flow Analysis**: Verify the feasibility of dispatch schedules with an AC network model, ensuring "AC" feasibility (i.e., no voltage violations and cable overloads)
- **Network Reinforcement Analysis**: Suggest network upgrades based on the results of previous analyses and utility-provided reinforcement rules.

Iterative Process: Step 2 analysis repeats until no further violations is found, forming an iterative loop.

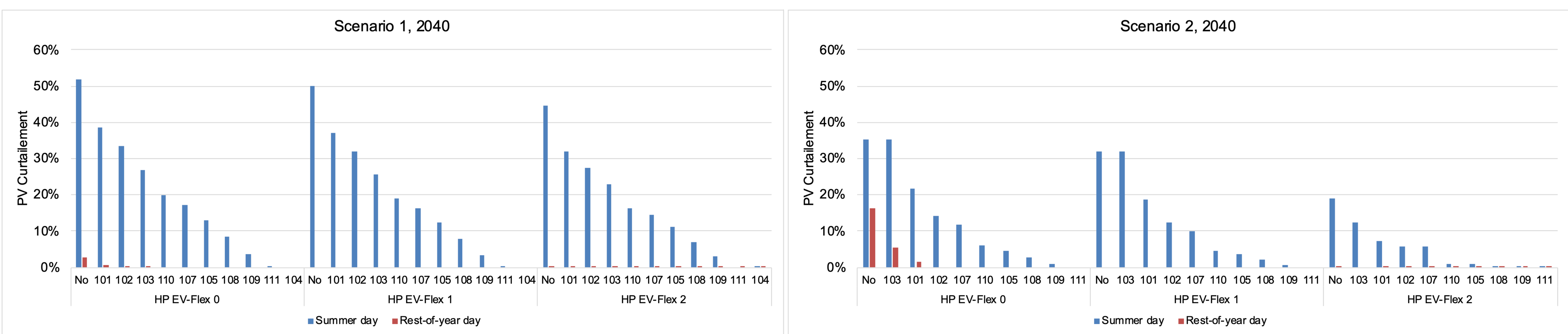


3 RESULTS

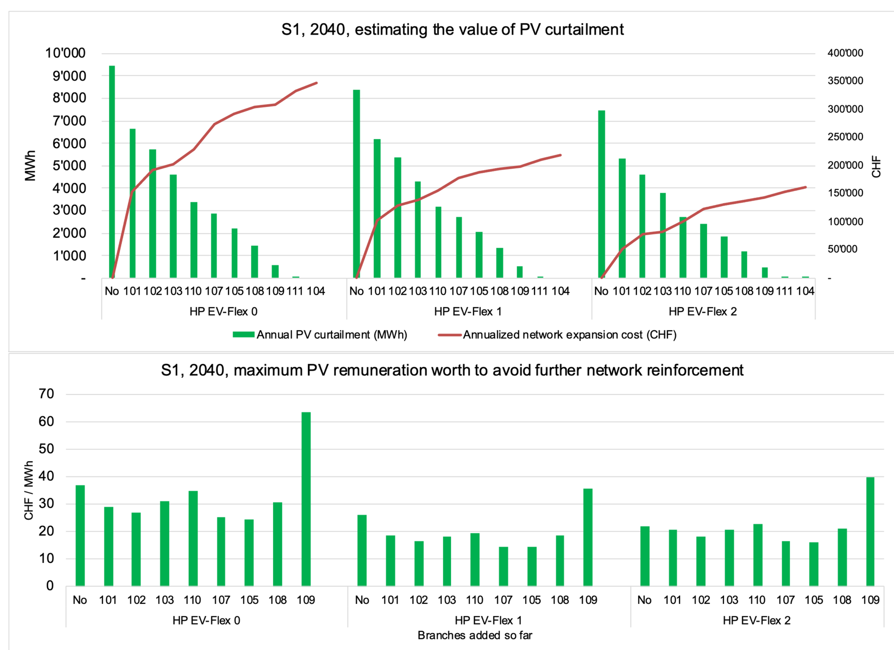
- **Test case overview:** Low-voltage (LV) distribution networks from a Swiss utility and 2 future scenarios are considered:
  - **Scenario 1:** Aligned with Swiss Energy Strategy targets through 2050.
  - **Scenario 2:** Faster penetration of HP and EVs but slower adoption of PV compared to Scenario 1.
- **Integration to MV network:** 15 LV networks are assigned to a 15-bus IEEE MV network.
- **Flexibility Options:**
  - **Demand-side flexibility:** HP EV-Flex 0: *No flexibility* | HP EV-Flex 1: *HP shifts (09:00-24:00), EV shifts (18:00-24:00)* | HP EV-Flex 2: *Full daily flexibility for HP and EV*.
  - **PV flexibility:** PV-Flex 0: *No flexibility (all excess power injected)* | PV-Flex 1: *Curtailment as a last resort, prioritizing demand-side flexibility.*
  - **Customer-level batteries:** Residential PV owners may install a battery that can store half of the maximum PV daily production.



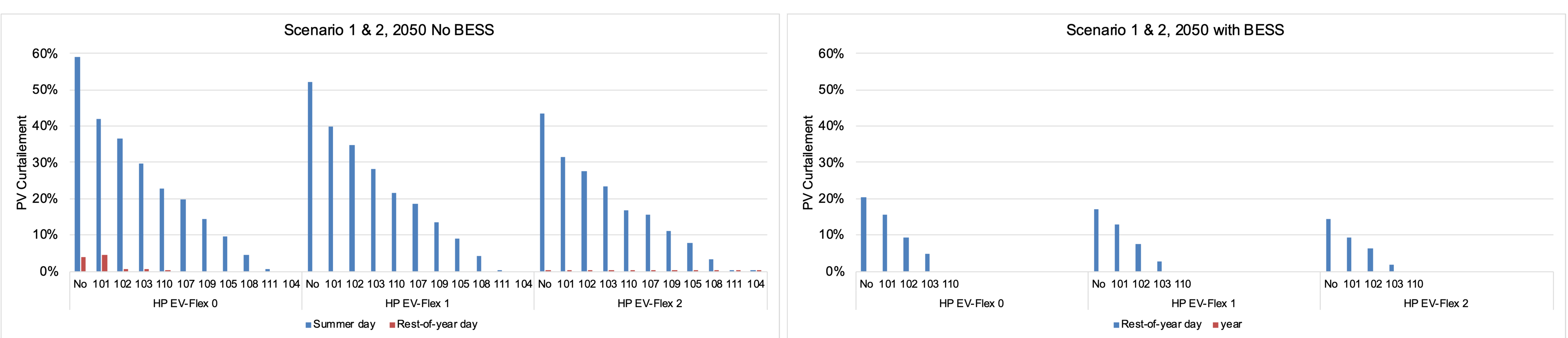
Trade-Off between flexibility and network reinforcements (PV curtailment as percentage of its daily available energy)



Investment cost analysis: "budget" for flexibility remuneration



Impact of customer-level batteries to network reinforcements



4 CONCLUSIONS

- The PV, EV & HP proliferation targets will result in **loading** of distribution networks **beyond their current capacities**.
- **PV** proliferation is the **primary factor** that drives grid upgrades, followed by EVs and, to a lesser extent, HPs.
- Limiting **peak PV power injections** considerably reduces the need for network upgrade requirements.
- Whenever PVs are installed together with a **battery**, acting in a "**grid-friendly**" manner (i.e., reducing the peak PV injections) has a significant benefit, reducing the need for grid investments.
- Engaging **demand-side flexibility** (demand shifting) can help defer some network investments. This is especially true in case where the electrification of demand happens faster than anticipated.

REFERENCES

[1] N. Savvopoulos, A. Marinakis, C.Y. Evrenosoglu, T. Demiray, "*Flexibility-aware planning of distribution network reinforcements*", Technical report, 2024.

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