A PARADIGM SHIFT IN BUILDING DESIGN – TOWARDS ENERGY OPTIMIZED BUILDINGS THAT INTELLIGENTLY INTERACT WITH THE POWER GRIDS

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DFF POSTDOC

RESEARCH QUESTION:

How can operational bottlenecks in the interaction between Near Zero Energy Building and the power grid interaction be avoided and what performance indicators can optimize NearZEB design for an intelligent interaction with the power grid?

PARTICIPANTS:

AAU - Civil Engineering (Anna, Per), Energy Technology (Iker, Birgitte)

Uppsala University, Sweden – Joakim Widén

Insero Energy – Carolina Carmo

AffaldVarme Aarhus ?

DURATION:

January 2013 – July 2016 (1-year maternity leave)

OUTLINE OF THE PROJECT

1. Energy load and generation profiles
   Objective: development of high resolution household electricity load profiles

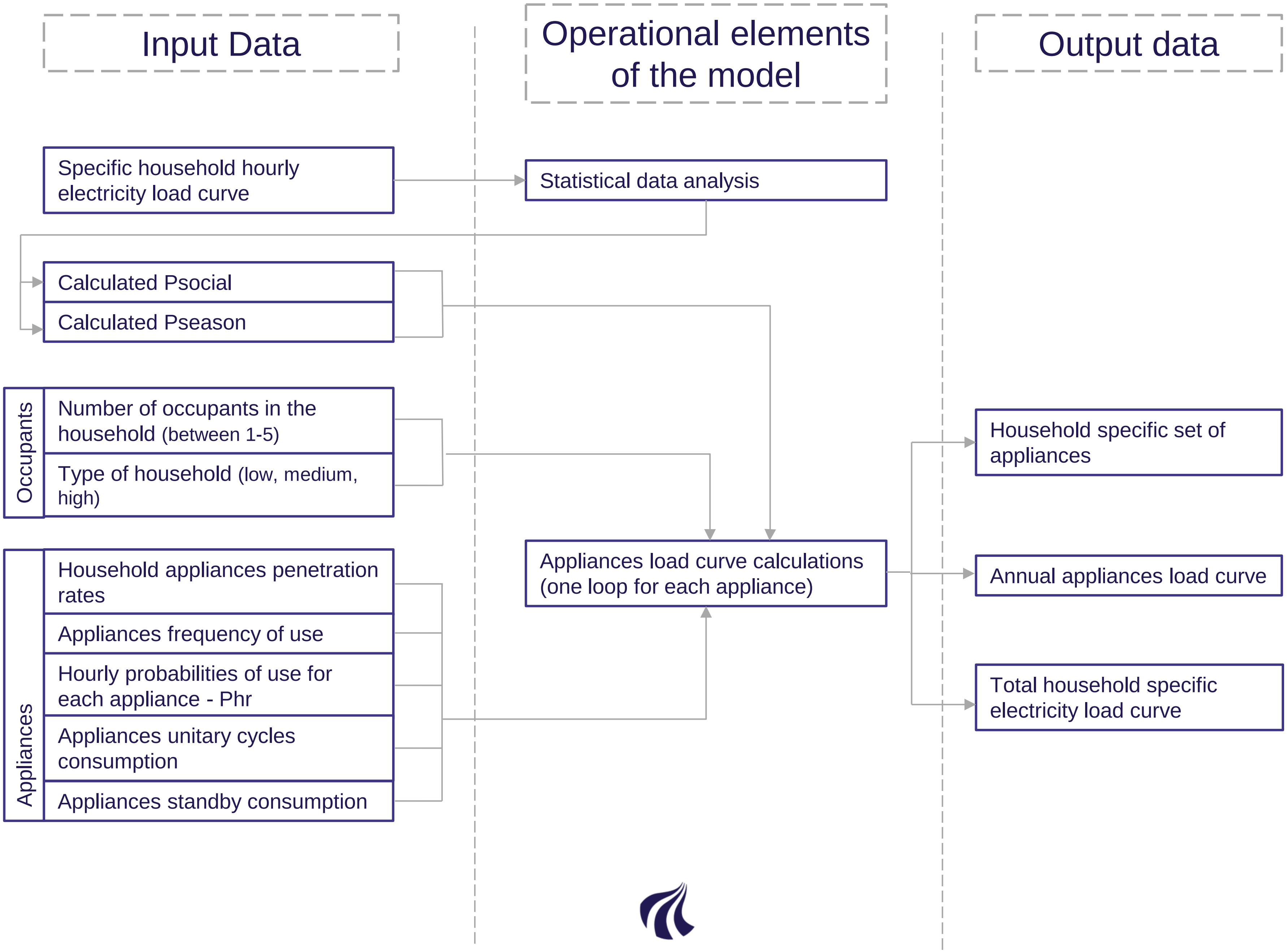
2. Transient simulations of NearZEBs and power grid
   Objective : create models of city-centre, suburban and rural grid configurations for Danish conditions.

3. Identification of critical challenges in building-grid interaction
   Objective: identify the critical challenges that need to be addressed to reach optimal energy exchange between the building and the power grid

4. Development of the theoretical framework and new design parameters.
   Objective: devise new set of design parameters that will be used as “interaction” performance indicators for NearZEBs

PHASE 1 – ENERGY LOAD MODEL

- Empirical-probabilistic bottom-up approach model
- Developed in Matlab environment
- Minimum resolution 1-min
- Annual simulations
- Electricity load profile for 35 household appliances (heavy electrical loads e.g. heat pumps not included)
- Applicable for DK single family houses with 1-5 occupants and 3 types of households (low, medium, high)



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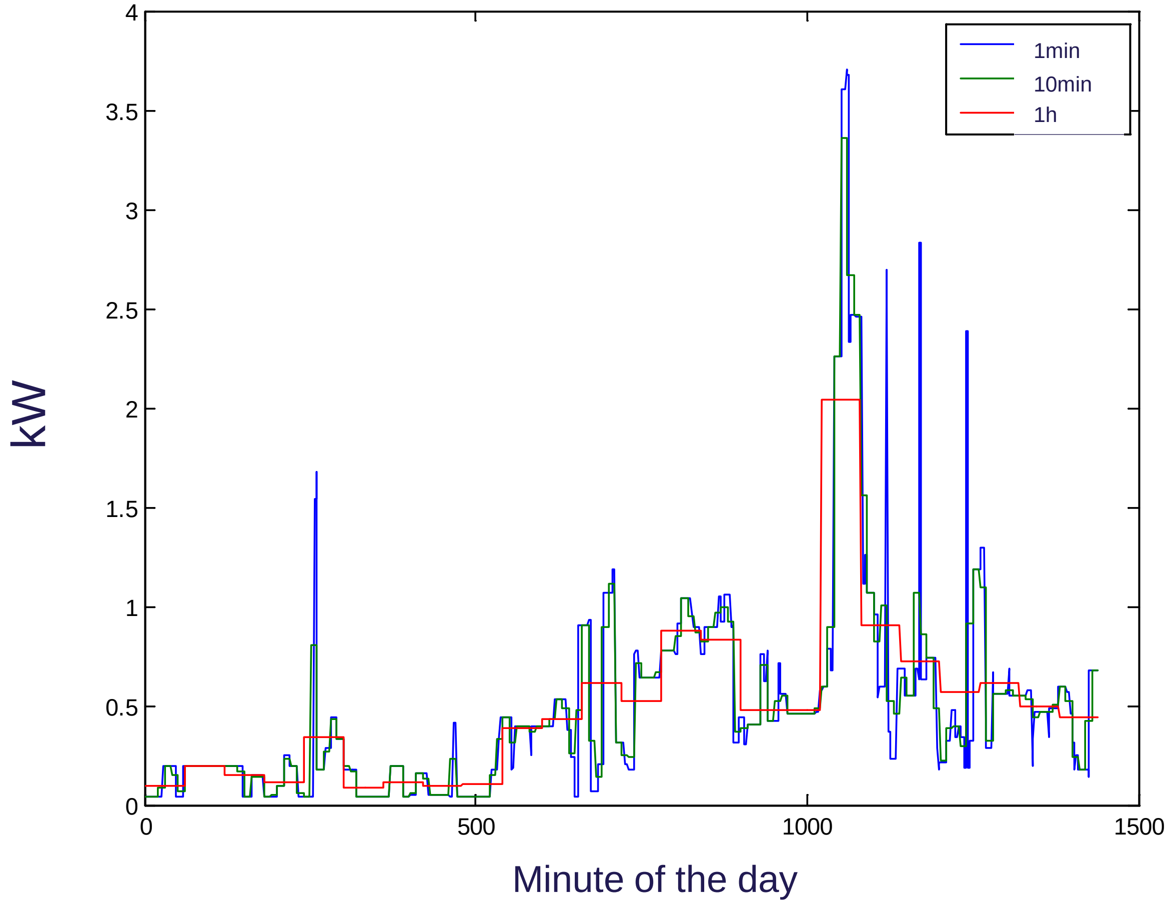
OUTPUT OF THE MODEL



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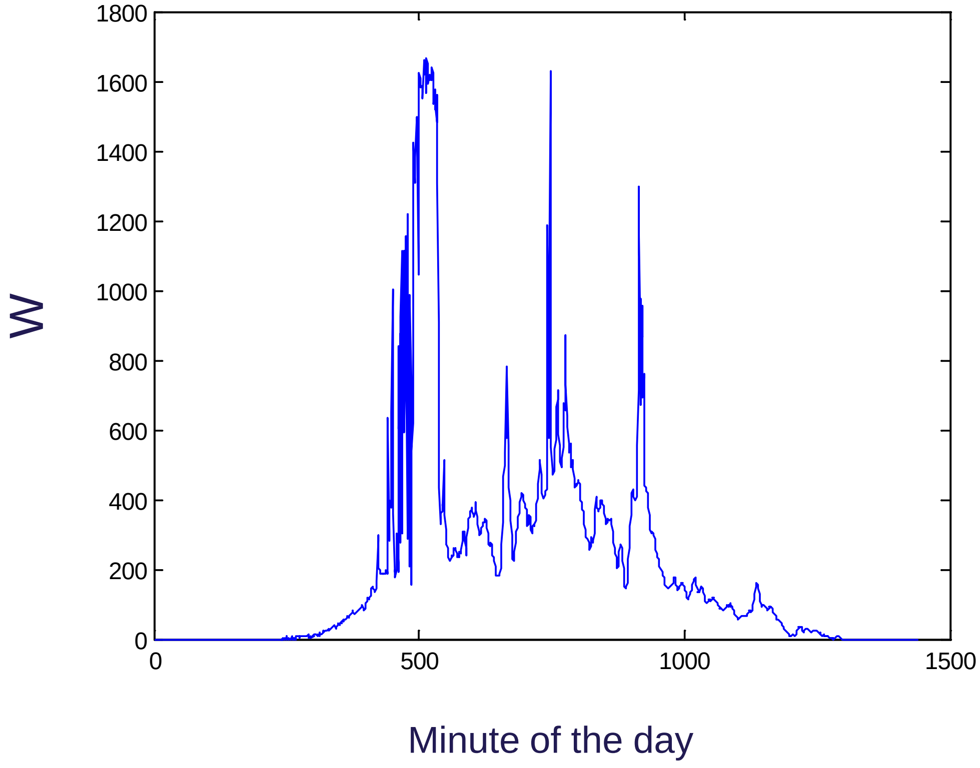
PHASE 1 – GENERATION PROFILES



PV power output:

$$P_g = A_c I \eta_{mp} \eta_a \text{ [W]}$$

Maximum power-point efficiency of PV

$$\eta_{mp} = \eta_{STC}[1 + \mu(T_a - T_{c,STC} + I \frac{T_{c,NOCT} - T_{a,NOCT}}{I_{NOCT}}(1 - \eta_{STC})]$$

Conversion efficiency at STC

$$\eta_{mp} = \frac{P_{STC}}{I_{STC} A_{ref}}$$

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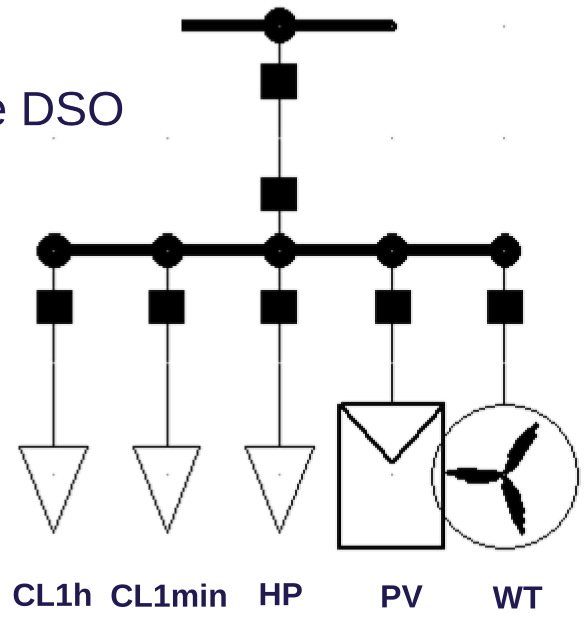
AIM OF THE MODEL - BASICS

- Aim of the Model
  - Represent the LV network performance as realistically as possible to understand its limitations and opportunities.
  - Not only at different time windows of the year but also at different penetration levels and ways of distributing the different assets.
  - Define the hosting capability of the network
  - Determine the what are the network constrains/bottlenecks and the potential locations to appear.
  - Define the amount of flexibility required to solve the given local problems.

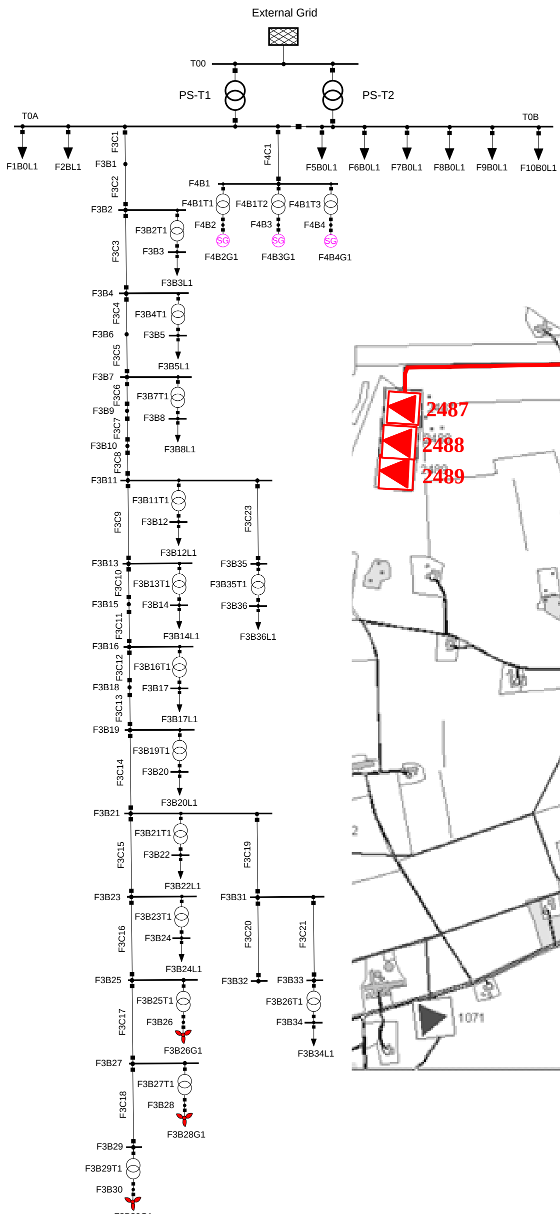
- Power Distribution Operation :
  - Power Lines and Transformers shout not be loaded more than 80 % at any time.
  - European Standart EN 50160: maximum voltage deviation ± 10 % at any bus of the MV and LV system. According to the DSO experience ± 6 %.

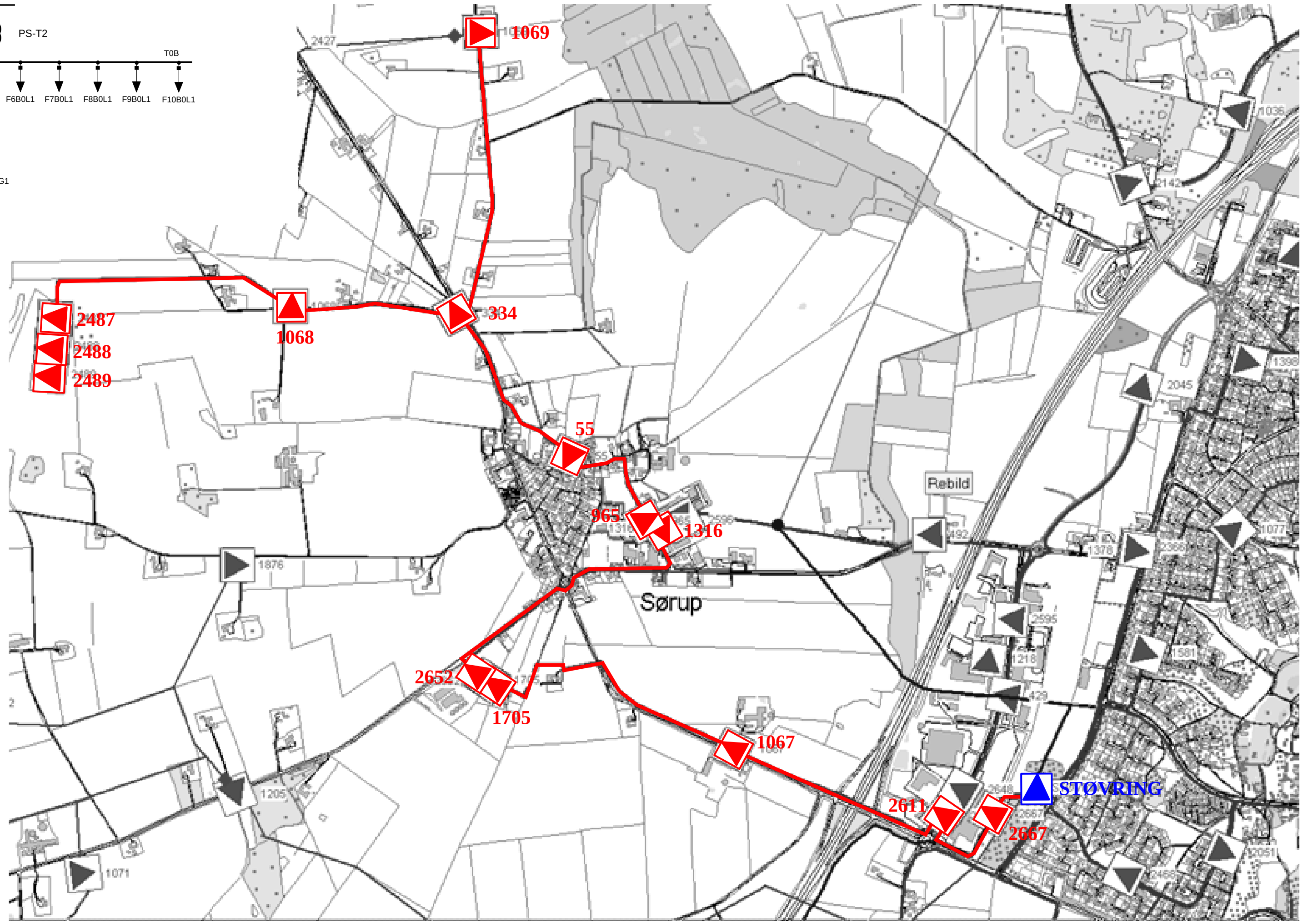
POWER GENERATION AND DEMAND MODEL

- The ZEB are only appointed at residential level
- From an electrical perspective, the users living in ZEB are represented by power consumption and generation profiles with 1 min resolutions:
  - Load:
    - CL (1 hour based) – Original provided by the DSO
    - CL (1 min based)
    - HP (1 min based) – No yet
  - Generation:
    - PV (1 min based)
    - WP (1 min based) –No yet



CASE STUDY - SØRUP 20 KV FEEDER





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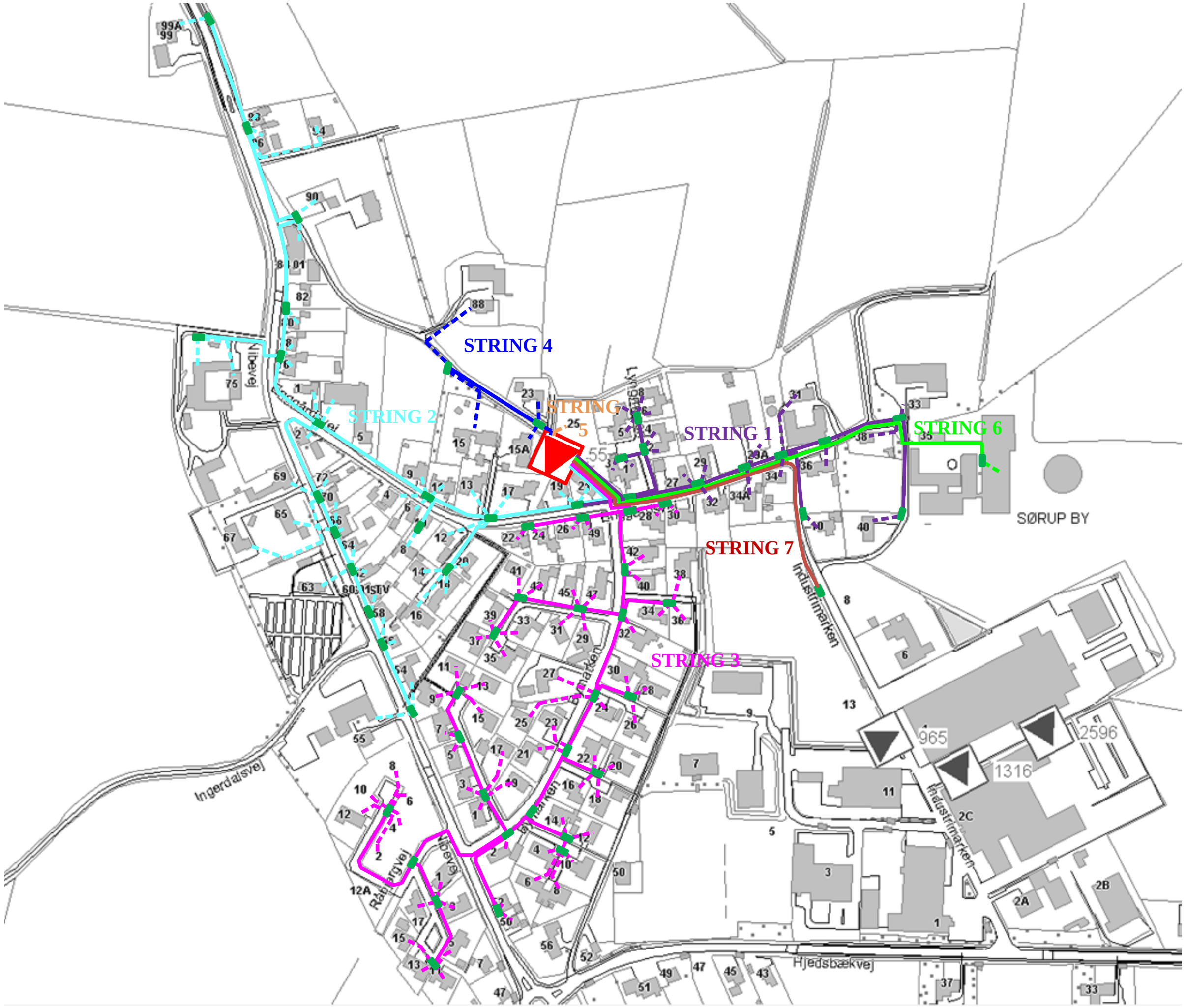
CASE STUDY – SØRUP ST



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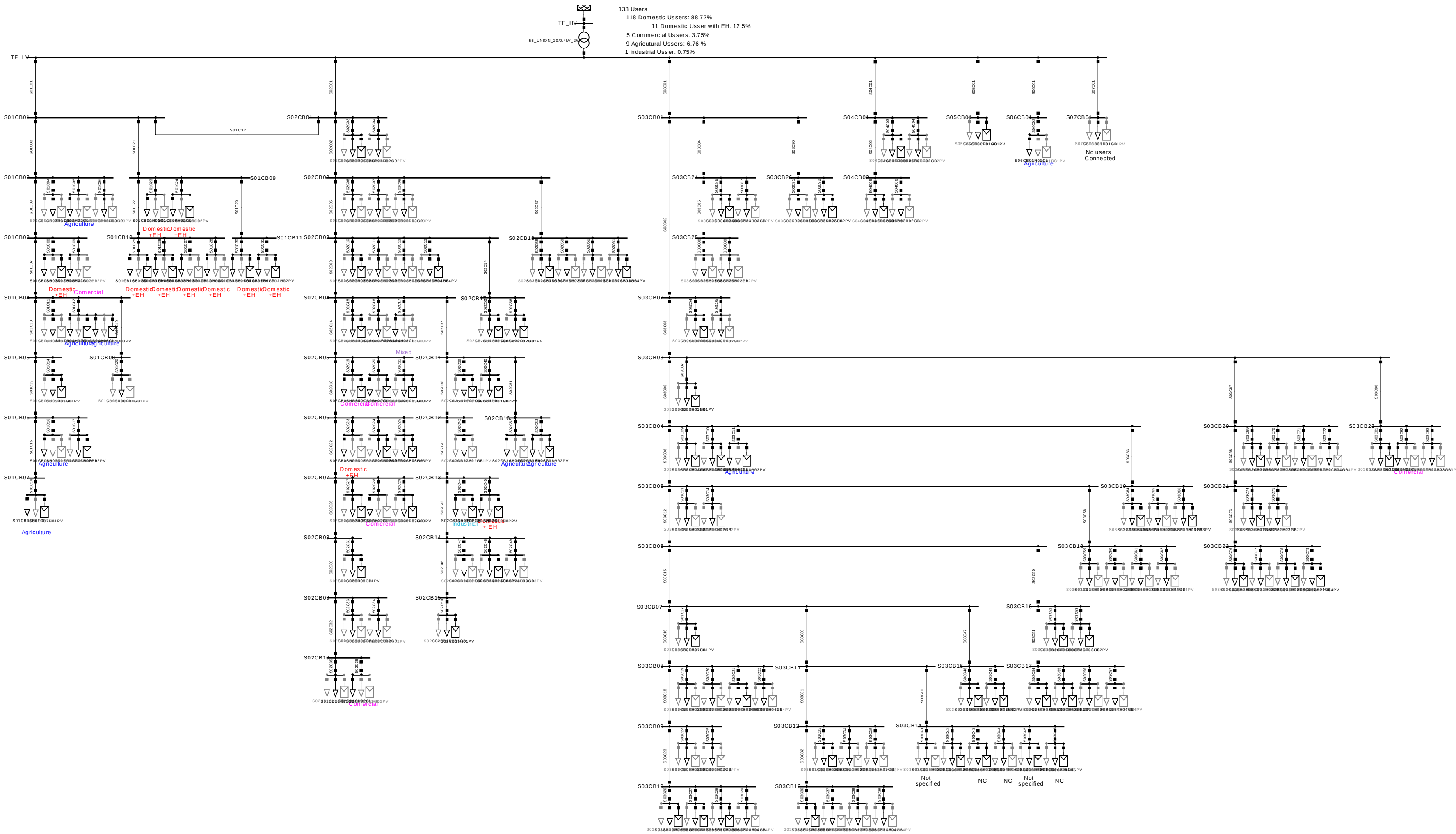
WHAT DO WE EXPECT TO GET FROM THIS MODEL?



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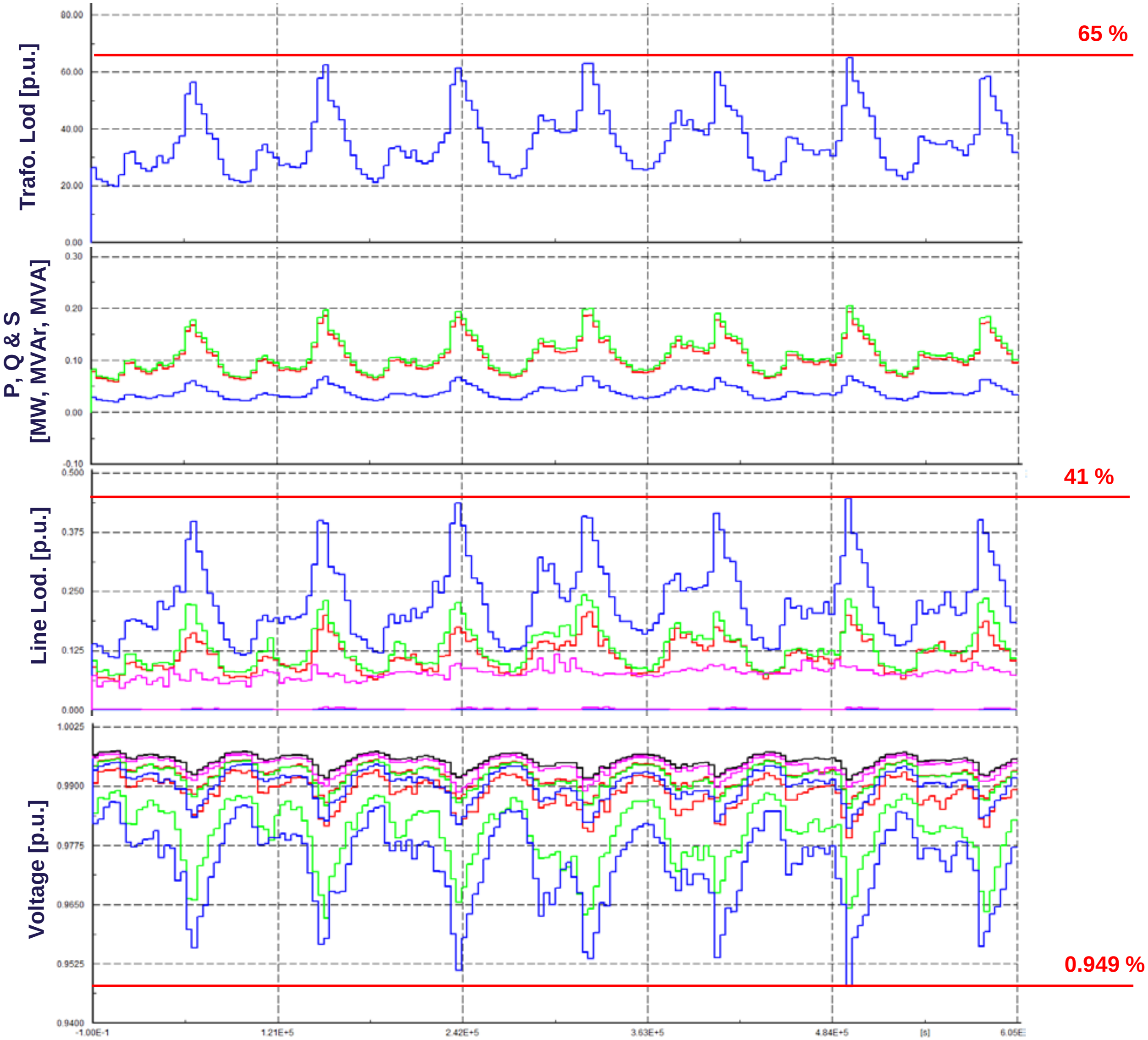
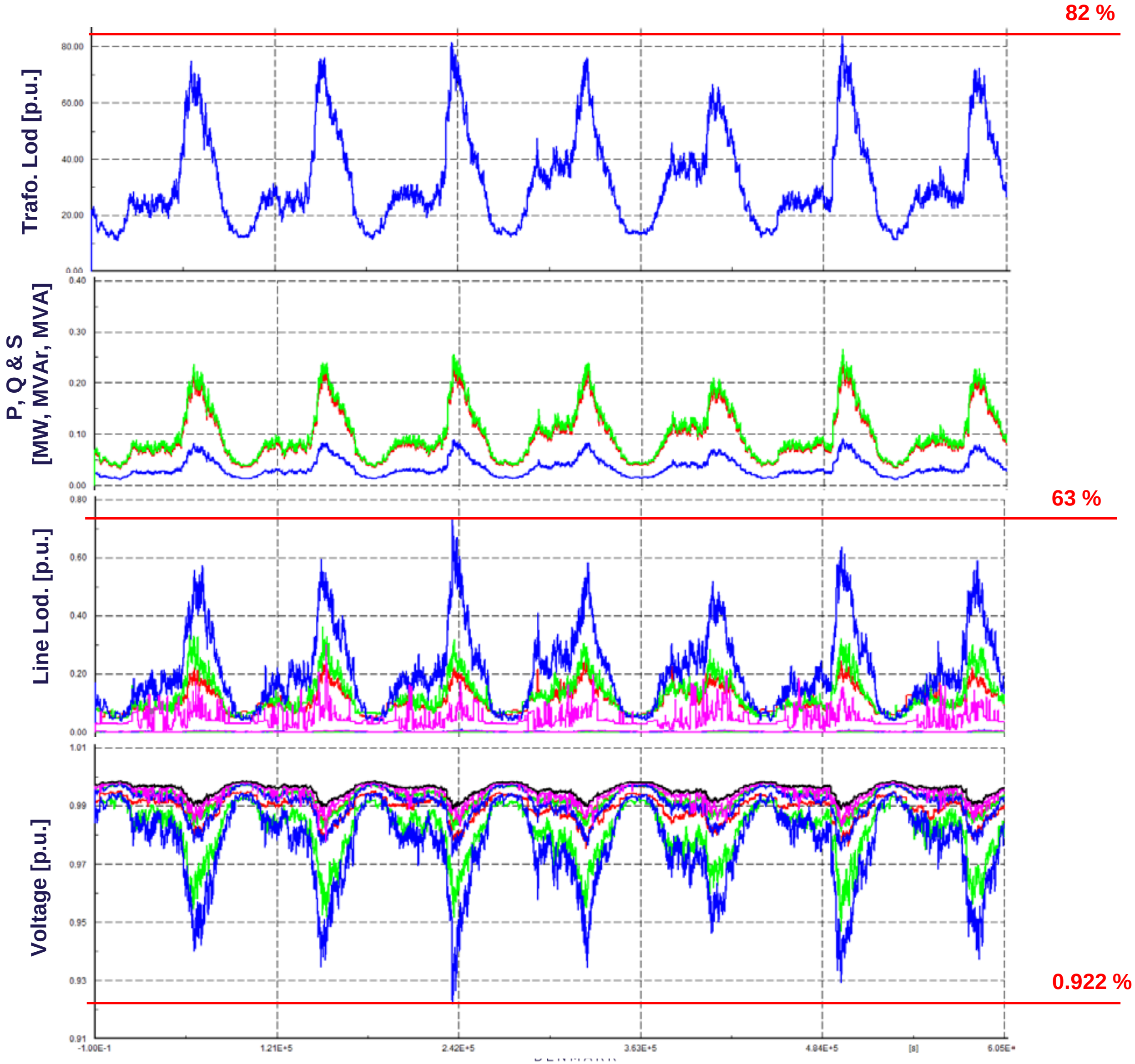
PRELIMINARY RESULTS

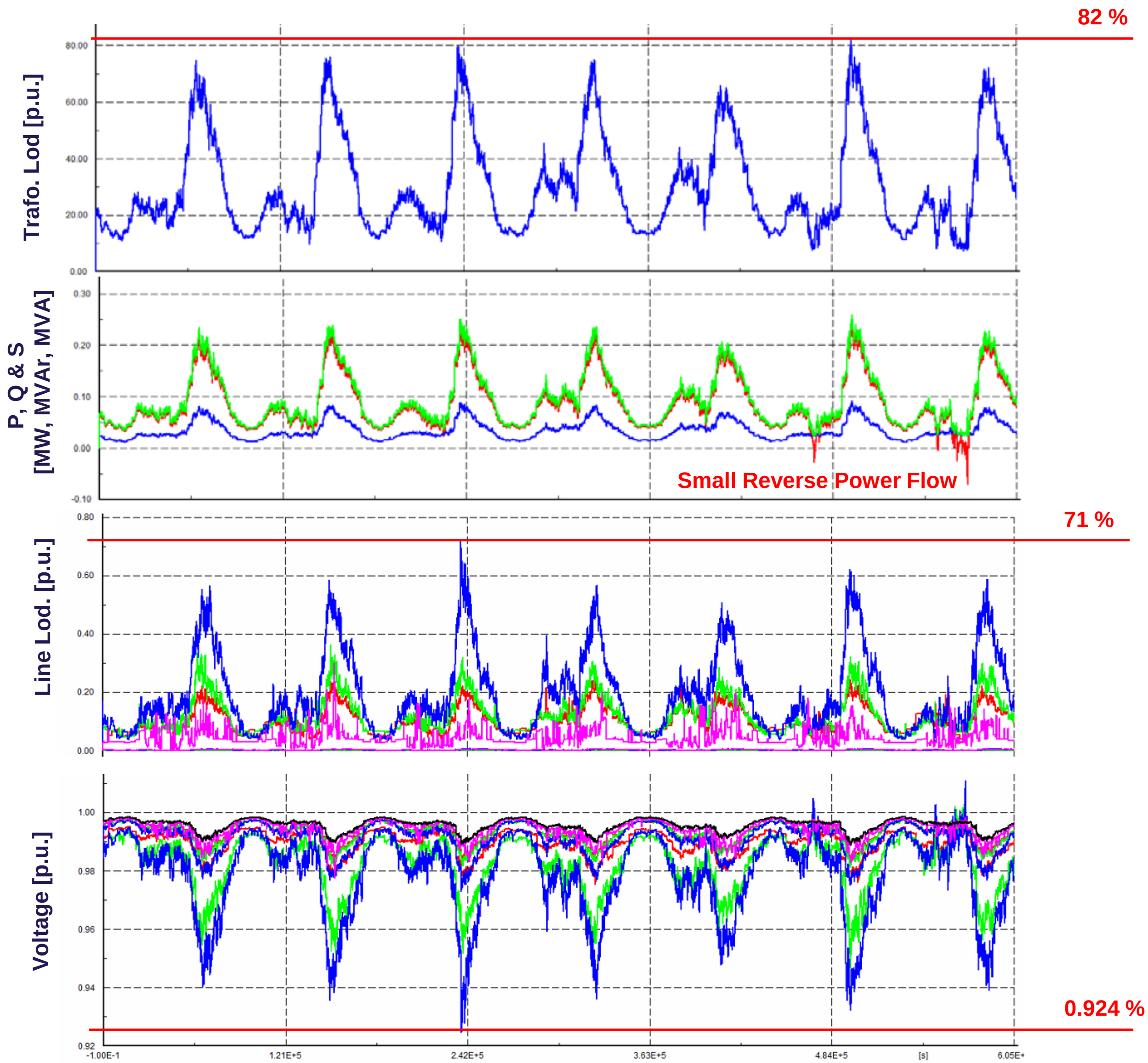
FIRST WEEK OF FEBRUARY – 1 HOUR BASED PROFILES



PRELIMINARY RESULTS
FIRST WEEK OF FEBRUARY – 1 MIN BASED PROFILES



PRELIMINARY RESULTS
FIRST WEEK OF FEBRUARY – 50% OF PV



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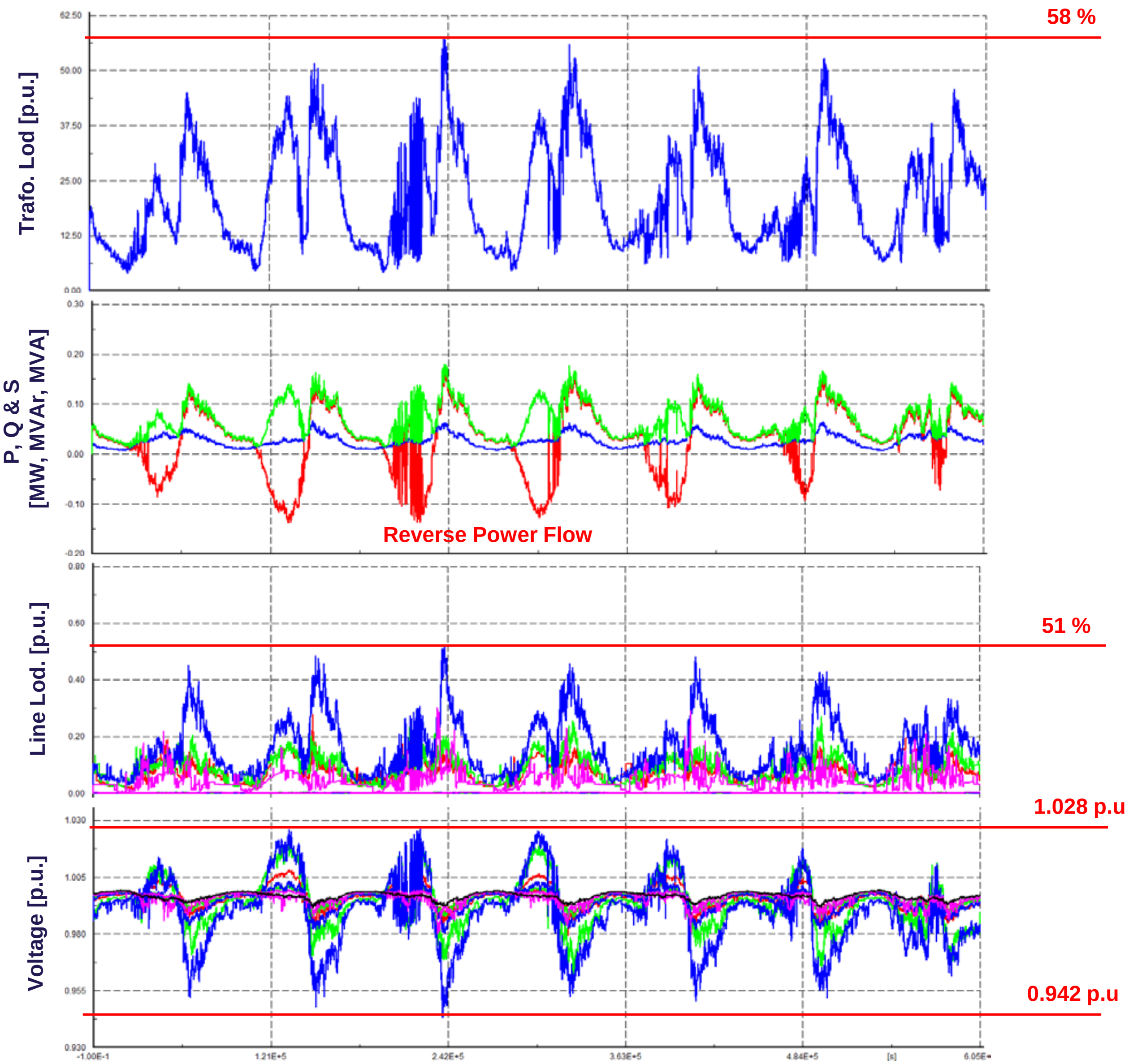
PRELIMINARY RESULTS

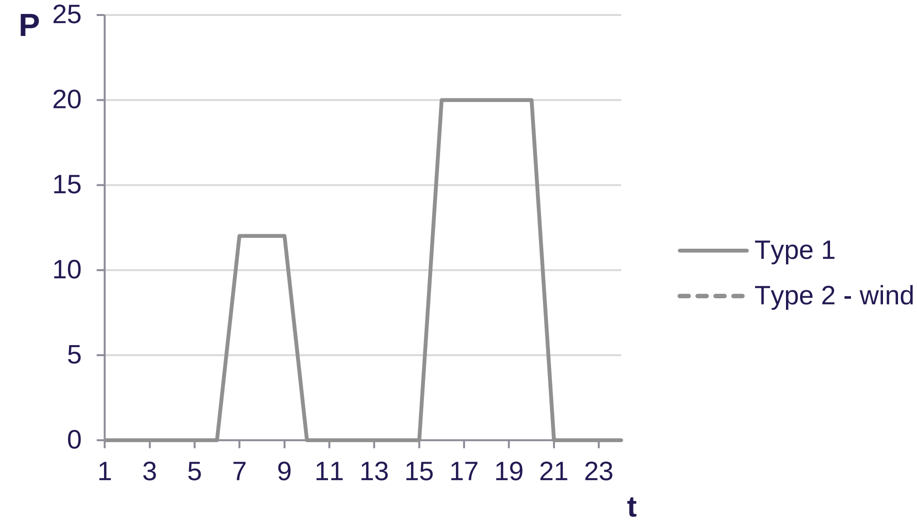
SECOND WEEK OF JULY – 50% OF PV



NEXT STEP – FLEXIBILITY FACTOR??

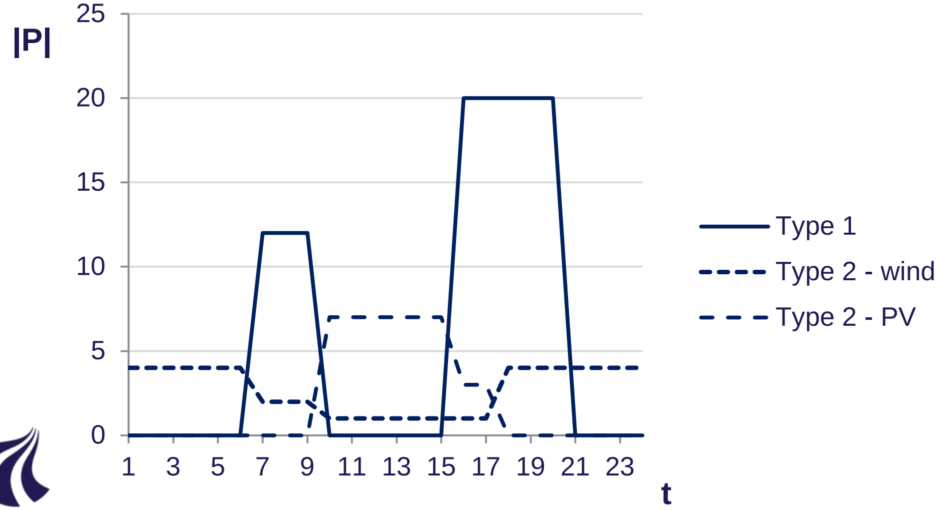
BUILDING FLEXIBILITY - POTENTIAL

- Type 1: Construction + HVAC systems
- Type 2: Appliances – washing machine, tumble dryer



NETWORK FLEXIBILITY - NEED

- Type 1: Too low Voltage – too low generation / too big demand
- Type 2: Too high Voltage – too big generation / too low demand



NEXT STEP – FLEXIBILITY FACTOR??

LOAD COVER FACTOR $$\gamma_{\text{load}} = \frac{\int_{\tau_1}^{\tau_2} min[g(t) - S(t) - \zeta(t), l(t)]dt}{\int_{\tau_1}^{\tau_2} l(t)dt}$$

FLEXIBILITY FACTOR = $$\frac{\int BULDING(SHIFTED\ EL)dt}{\int NETWORK(NEEDED\ TO\ BE\ SHIFTED)dt}$$

NEXT STEP – FLEXIBILITY FACTOR??

- What is the reference network configuration?
- Scale issue: 1building vs. LV network
- Building flexibility type 1
  - Default numbers/input for simulations (similar as Be10)
  - Catalogue with different construction and HVAC configuration
- Building flexibility type 2
  - dependent on the occupants and their practice, but maybe possible to have some default profiles
- Simulation practice
  - Building – annual
  - Network – 1 summer day and 1 winter day
- On-site generation adds complexity
- …