INTEGRATION OF RENEWABLES INTO THE SK ELECTRICITY GRID

ZÁPADOSLOVENSKÁ
DISTRIBUČNÁ

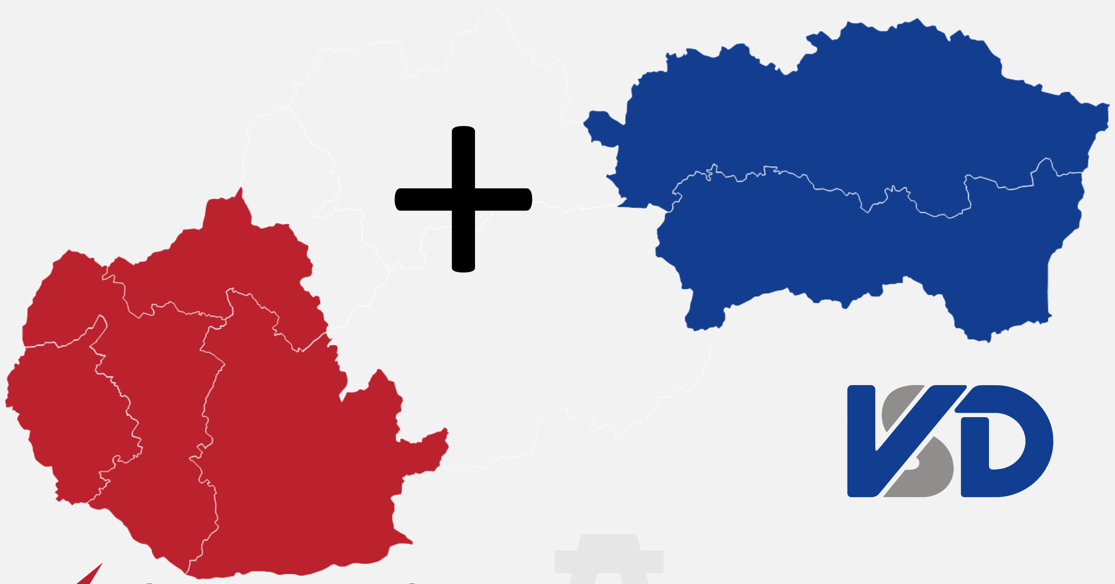
AGENDA

1. Introduction of distribution system operators ZSD & VSD
2. Future grid reality
3. Development and expectations of renewables
4. Related study of Technical university of Košice (TUKE)
5. Redesign of electricity grid

ZÁPADOSLOVENSKÁ DISTRIBUČNÁ

VSD

WE ARE THE BIGGEST DSO IN SLOVAKIA



ZÁPADOSLOVENSKÁ DISTRIBUČNÁ

~2.5 tis. employees

~1.9 milions of customers

Biggest DSO in Slovakia

We serve **7 out of 10** customers of Slovakia

30,2 thous. km2 covers 62% of Slovakia

Electricity distribution of 13,5 TWh

Length of operated lines 65 thous. km

Amount of operated transformer stations 16 thous. pcs

Yearly CAPEX ≈ 200 mil.€

FUTURE REALITY

The future of electrical energy infrastructure is influenced by several factors and trends:

1. **Renewables:** The growing share of renewables such as solar and wind energy will require a more flexible and decentralized distribution system.

2. **Decentralized production:** Electricity production will become increasingly dispersed, with more small scale electricity producers, including households with photovoltaic systems.

3. **Smart Grids:** Modernization of the electricity system for the purpose of more efficient management of electricity consumption and production in real time, including the use of digital technologies, sensors and artificial intelligence.

4. **Storage systems:** Batteries and other forms of electricity storage will play a key role in „balancing“, especially in the production of electricity from renewable sources.

5. **E-mobility:** The growing number of e-vehicles will increase the demand for electricity and require new solutions for charging, including smart charging stations and the integration of vehicle batteries into the electrical system.

6. **Cybersecurity:** With the growing digitalization of the energy infrastructure, it will be necessary to increase the level of cyber security to protect against threats.

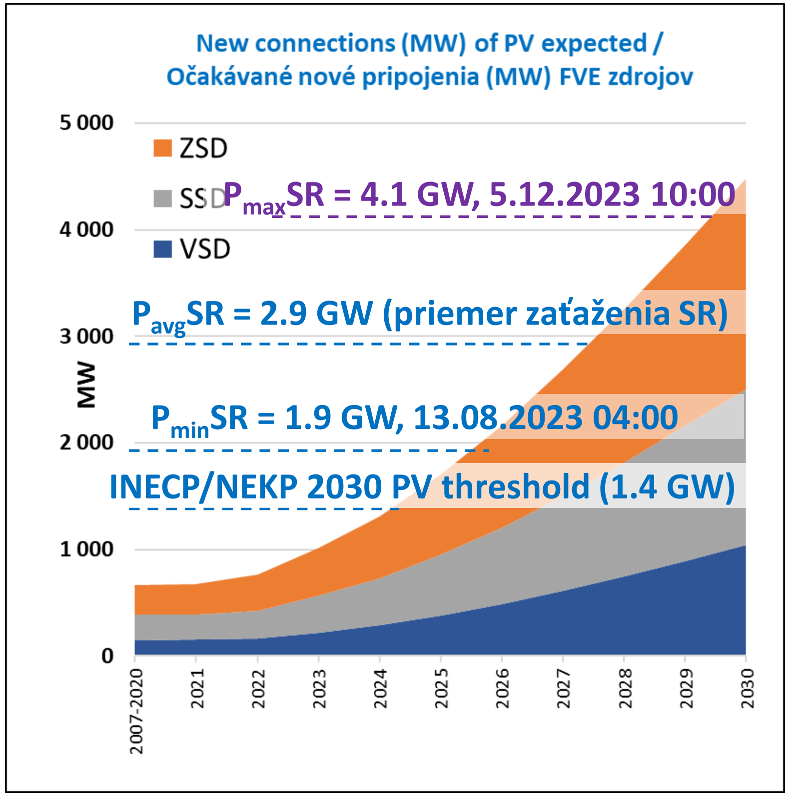
7. **Energy efficiency:** Improving efficiency in transmission, distribution, generation and consumption of electricity to minimize losses and increase sustainability.




REDESIGN OF EXISTING INFRASTRUCTURE

Why do we need to change a network that has been working reliably for decades?

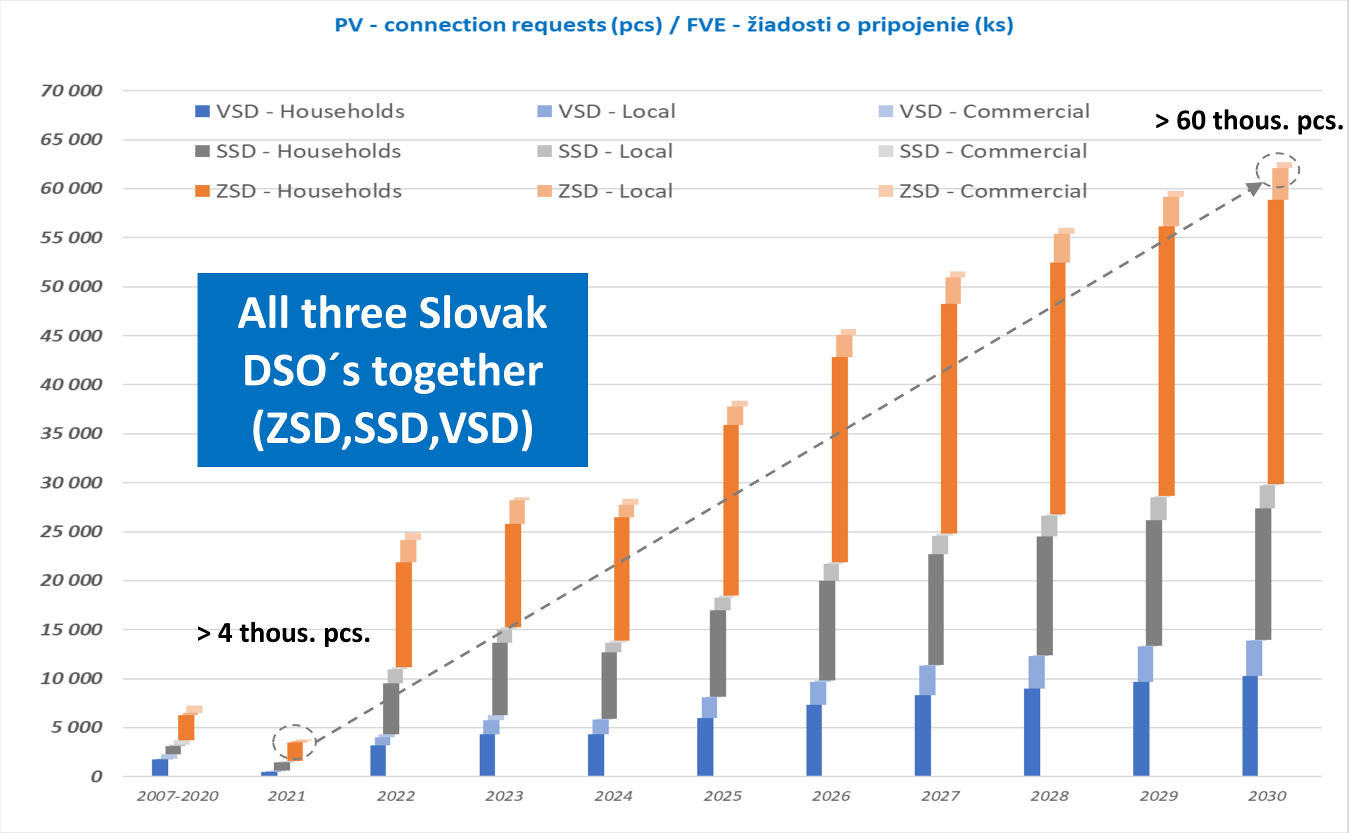
New business models - renewables - transport - heat - customer expectations



- Customers will actively enter the market (production, procurement, storage, reactions directly to stock exchange developments)
- The advent of e-mobility will cause an increase in capacity requirements for connection
- Integrating production into distribution systems that were not designed for it
- Increased numbers of heat pumps, or decentralized heating systems
- Mobility, heat, data availability - will depend on the availability of electricity

REDESIGN OF EXISTING INFRASTRUCTURE

During the years 2021 to 2023, we experienced a growing trend of connection requests (year-on-year to the level of 700-800%), while small scale (household) dominate the trends with an average installed power of 8 kW (legal limit is 11 kW).

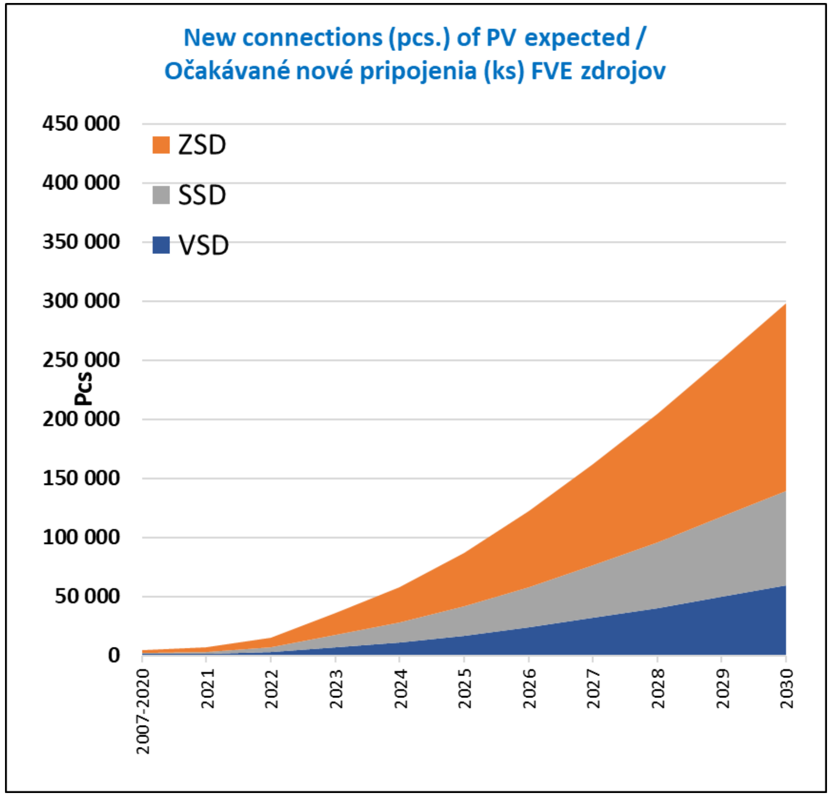


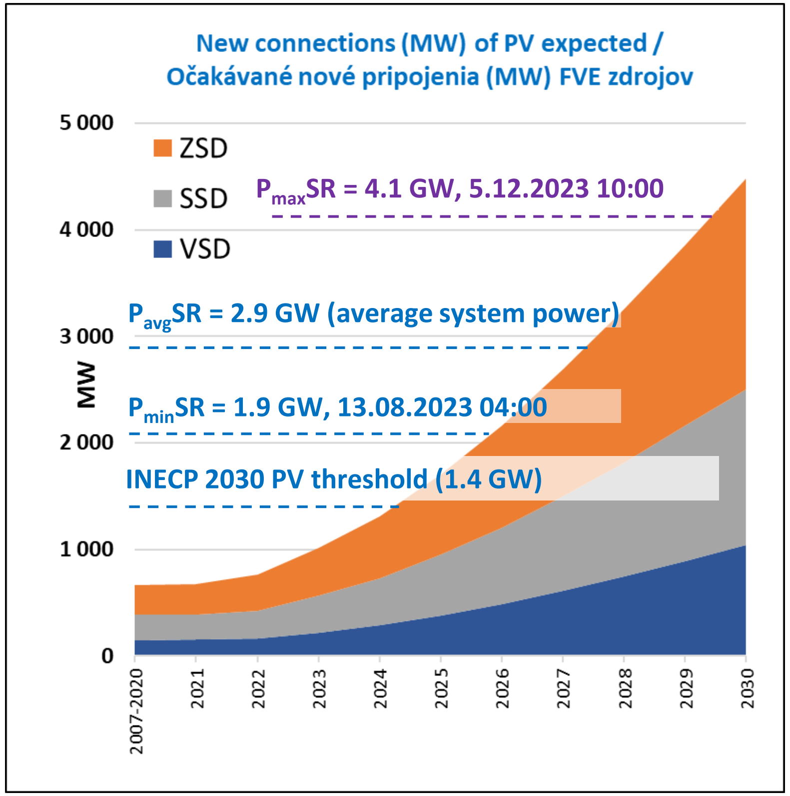
Expectations towards 2030 +

- the continued growth of the number of applications could, according to current trends, reach in 2030 the level of > 60 thousands of applications/year (all three DSO´s together),
- most applications will be small scale generation (households):
  - approx. 30 thousand pc/year in ZSD
  - approx. 15 thousand pc/year in SSD
  - approx. 10 thousand pc/year in VSD

REDESIGN OF EXISTING INFRASTRUCTURE

If the assumed scenario of the development of requests for connection is fulfilled, then the total number of all types of PV systems of all categories (households, local, commercial) in all three Slovak DSO´s in 2030 will probably be ≈ 300,000. pcs and their installed power > 4 GW.





Expectations towards 2030 +

- The continuing trend of connecting resources will probably significantly exceed the goals defined in the climate plan of the Slovak Republic (INECP).
- Such installed power should already exceed the maximum load of the entire electricity system in Slovakia.

STUDY ON INTEGRATION OF RENEWABLES IN LV GRIDS

Napájanie z transformátora T1	Pripojenie len 1-fázových zdrojov s dodávkou 3,68 kW, cosφ$_L$ =0,97 (do fázy - A)	Pripojenie len 1-fázových zdrojov s dodávkou 4,6 kW, cosφ$_L$ =0,97 (do fázy - A)	Pripojenie len 3-fázových zdrojov s dodávkou 11 kW, cosφ$_L$ =0,97	Pripojenie mixu 1-fázových zdrojov (4,6 kW do fázy - A) a 3-fázových zdrojov (11 kW), cosφ$_L$ =0,97, pričom v jednom uzle je jeden 1-fázový zdroj a jeden 3-fázový zdroj
FVE v 1/3 všetkých 26 odberných miest	A11 (obr. 2.2)	A12 (obr. 2.2)	A13 (obr. 2.3)	A14 (obr. 2.4)
FVE v 2/3 všetkých 26 odberných miest	A21 (obr. 2.5)	A[illegible]	[illegible]	A24 (obr. 2.7)
FVE vo všetkých 26 odberných miestach	A31 (obr. 2.8)	A32 (obr. 2.8)	A33 (obr. 2.9)	A34 (obr. 2.10)

12 different variants of PV penetration

Tab. 1.1 Parametre transformátorov VN/NN

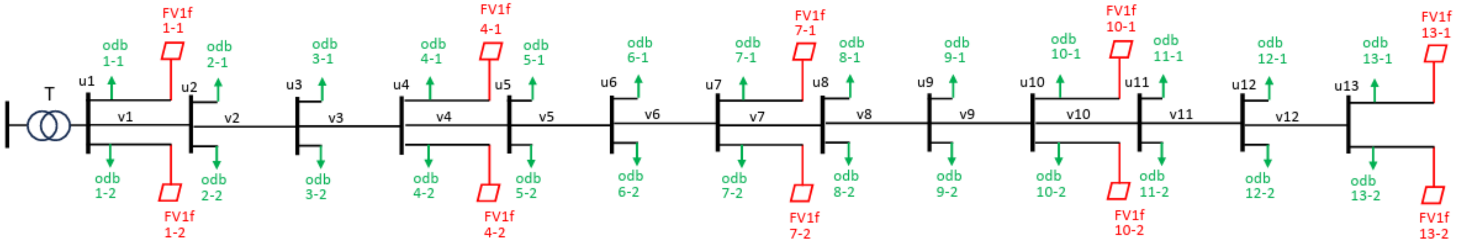
transformátor	S_n [kVA]	U_{1n} [kV]	U_{2n} [kV]	u_{k12} [%]	P_k [kW]	P_0 [kW]	zapojenie vinutí	S_{k3} na VN [MVA]	X/R [-]
T1	400	22	0,42	4	3,9	0,4	Dyn1	150	10
T2	630	22	0,42	6	5,6	0,6	Dyn1	150	10

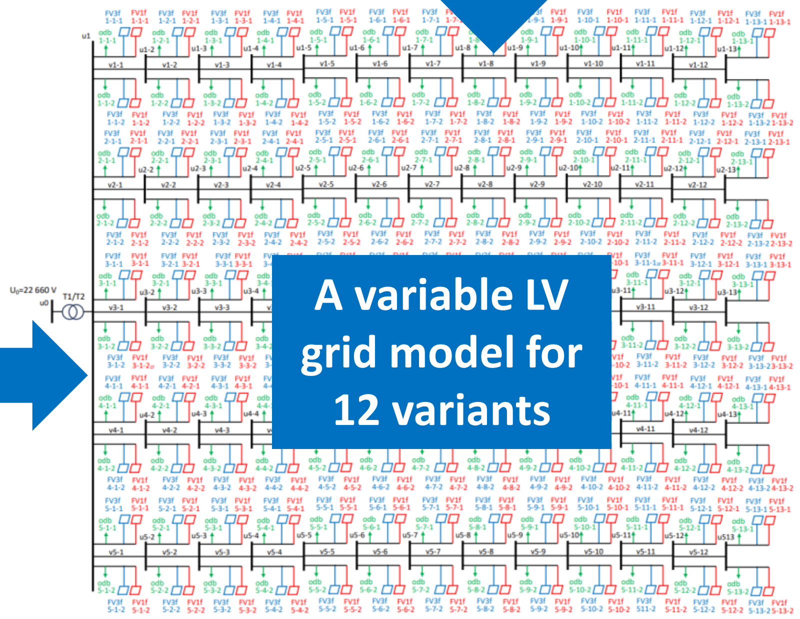
Tab. 1.2 Parametre NN vedení

vedenie (radiálny vývod)	typ	[illegible]	[illegible]	[illegible]	[illegible]vá dĺžka [m]
vedenie 1	AlFe 4x7[illegible]	[illegible]	[illegible]	[illegible]	600
vedenie 2	NFA2X 4x95	0,32	0,083	240	600
vedenie 3	NFA2X 4x120	0,25	0,082	280	600
vedenie 4	NAYY-J 4x150	0,206	0,08	254	600
vedenie 5	NAYY-J 4x240	0,129	0,08	332	600

2 transformer types
5 line types

E.g.: Variant A11 (≈ 1/3): 26 x off-take 2,9 kW p.u., cos φ = 1 / **10 x PV** 3,68 kW, cos $φ_L$ = 0,97):

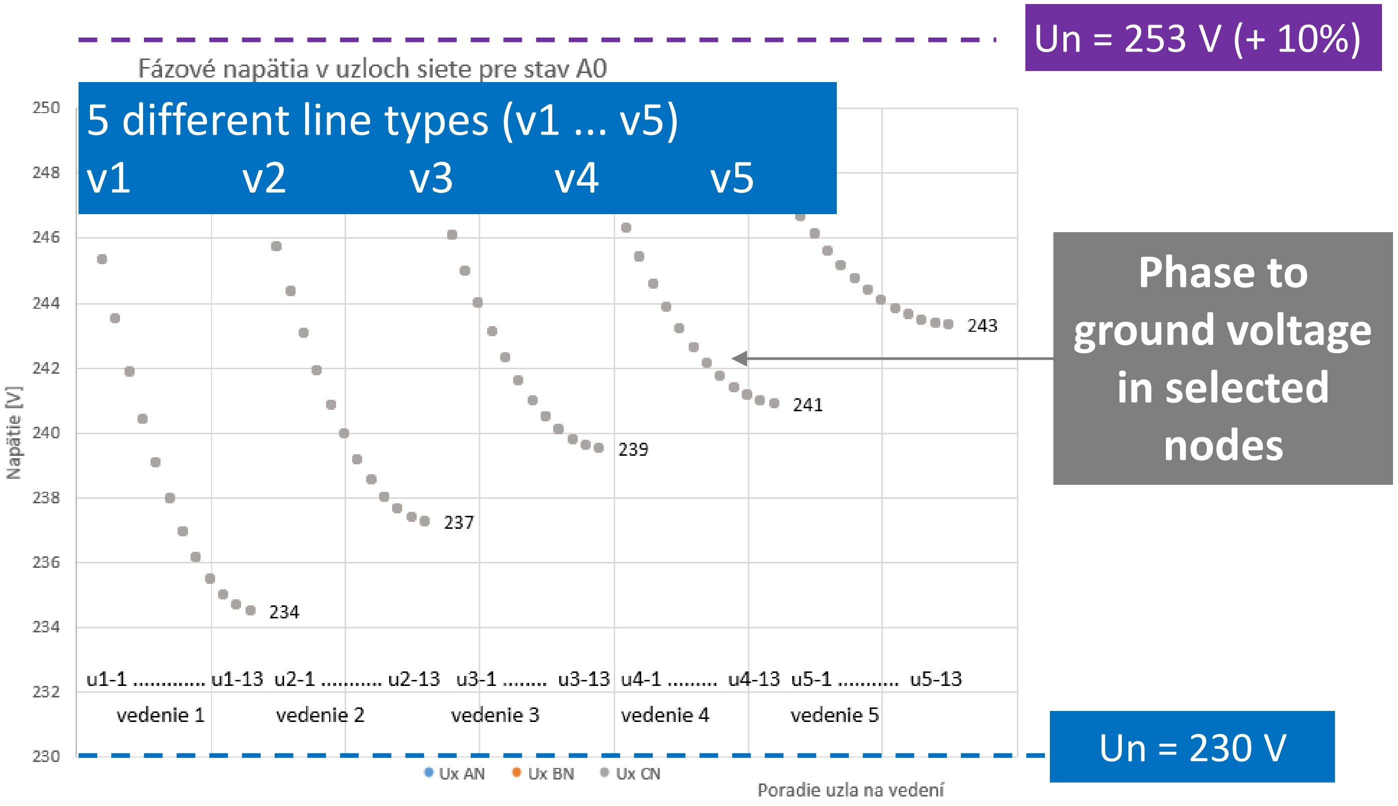


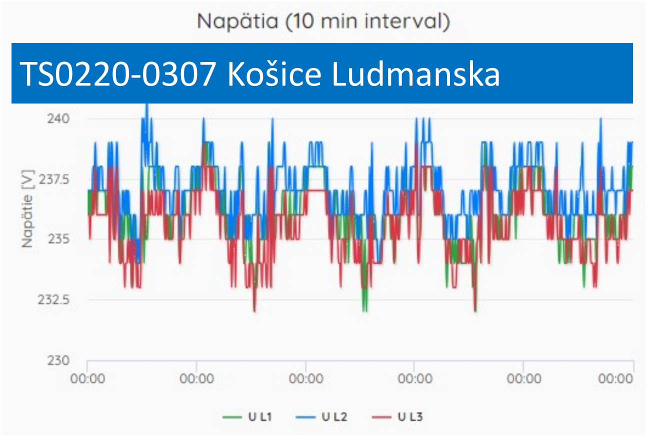


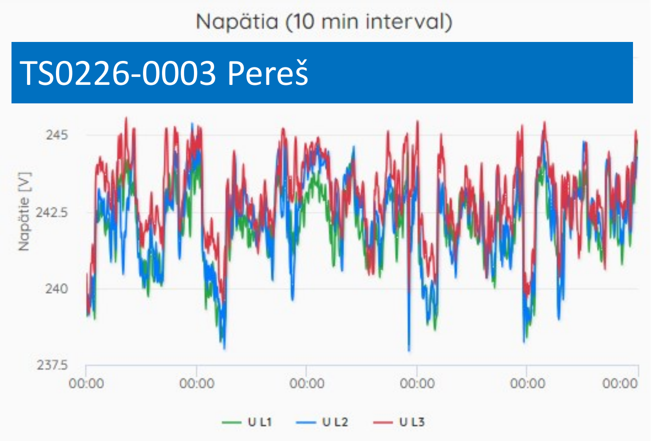
A variable LV grid model for 12 variants

STUDY ON INTEGRATION OF RENEWABLES IN LV GRIDS

Variant A0 (no generation) – as a reference for comparison with study variants A11 ... A34

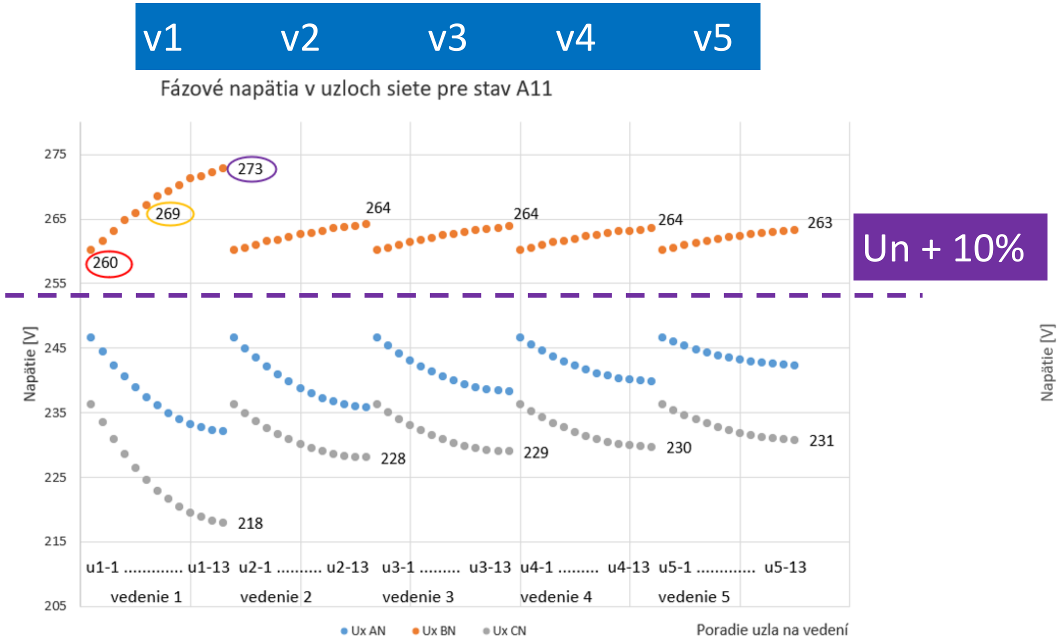


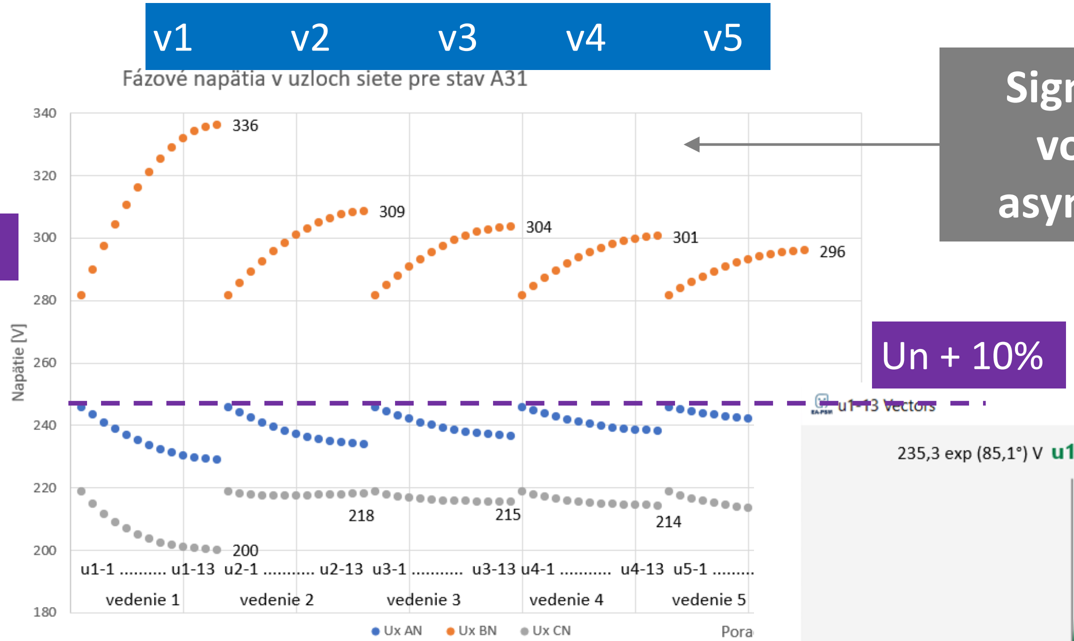




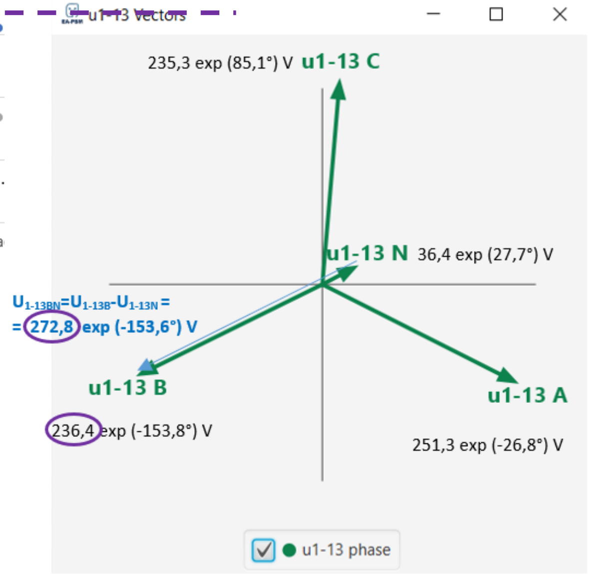
STUDY ON INTEGRATION OF RENEWABLES IN LV GRIDS

Variants A11 (1/3) vs. A31 (3/3) – single phase PV generation 3,68 kW p.u.





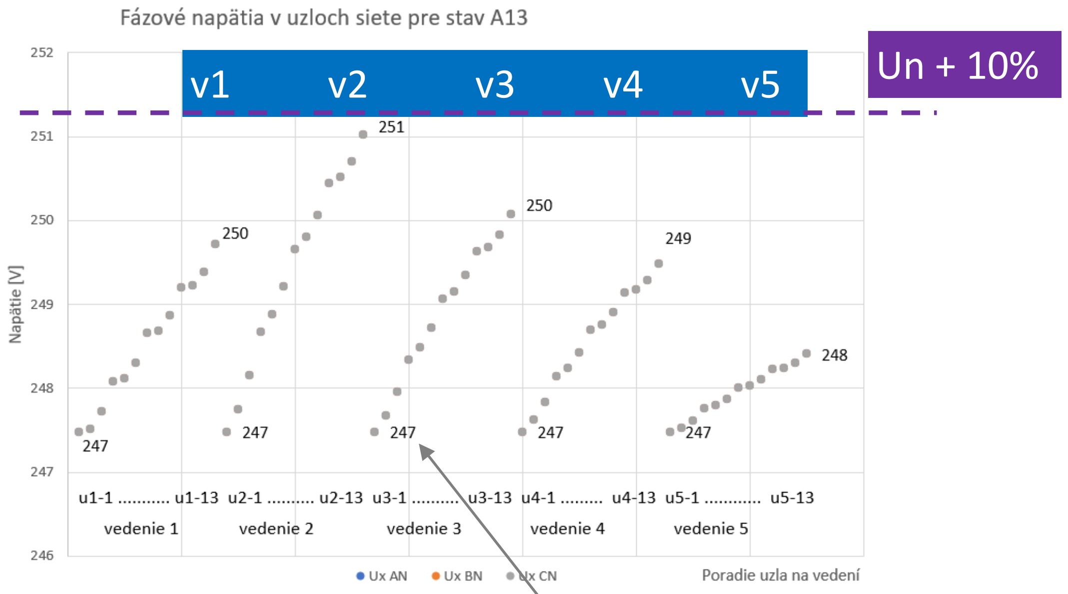
Significant voltage asymmetry

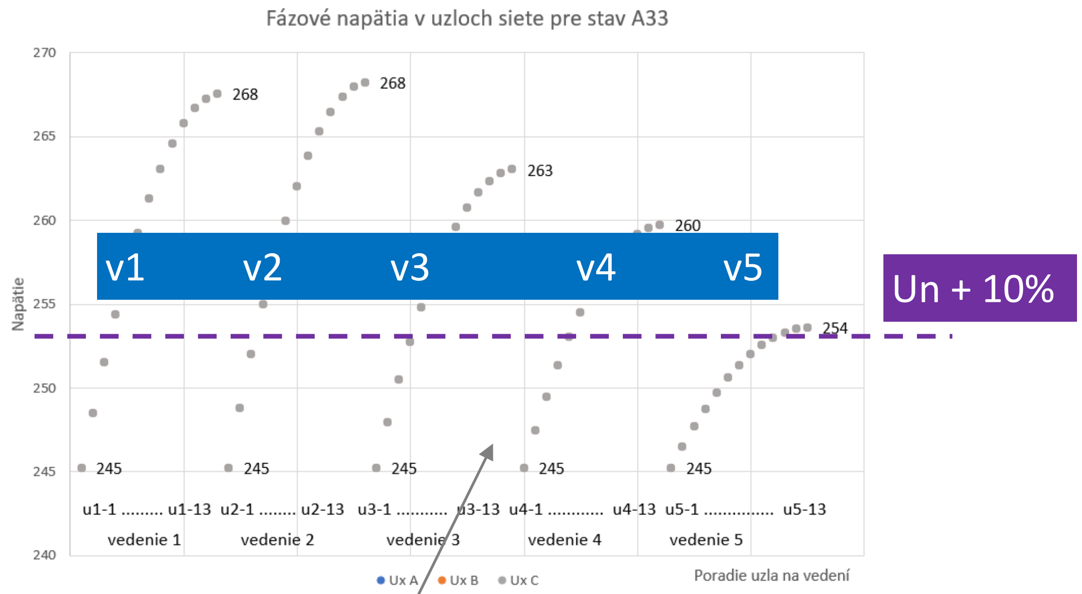


As depicted in the vector diagram, the phase with highest voltage change might differ to the PV connection phase due to the voltage shift of the neutral conductor relative to the center of the diagram (coordinate system).

STUDY ON INTEGRATION OF RENEWABLES IN LV GRIDS

Variants A13 (1/3) vs. A33 (3/3) – three phase PV generation 11 kW p.u.

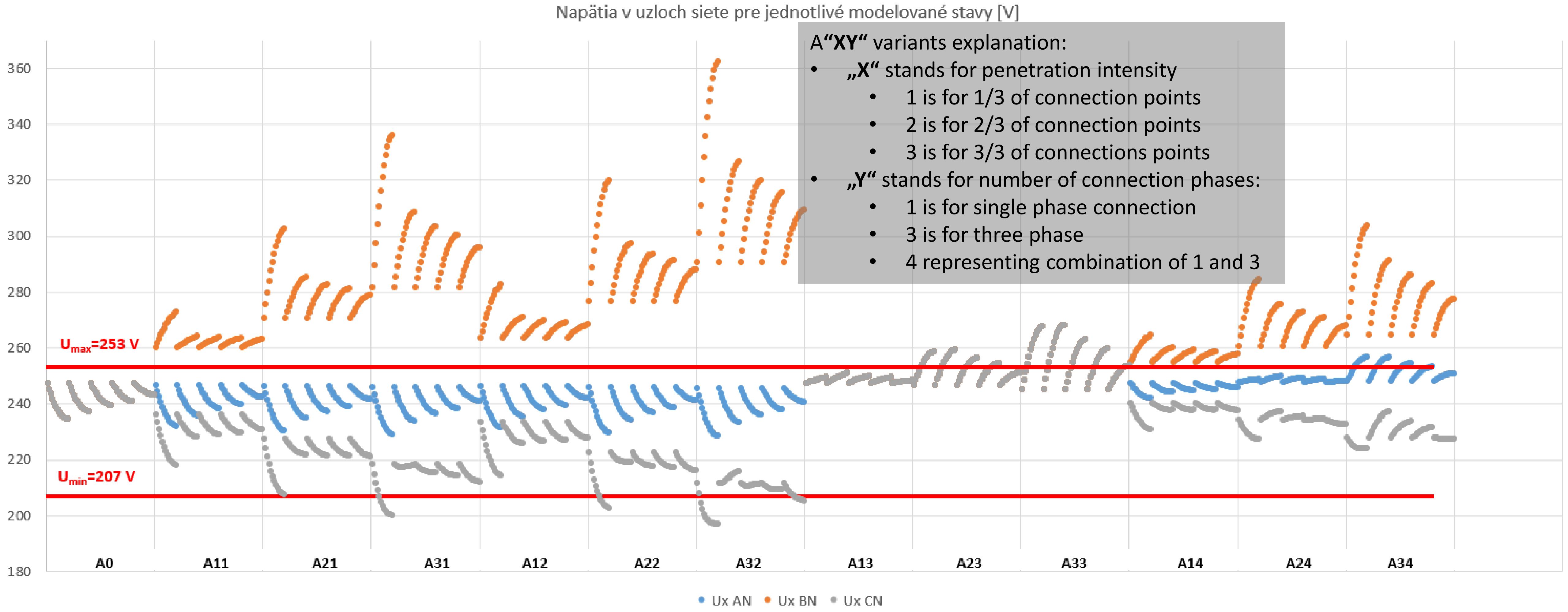




Symmetric three-phase PV generation can increase the possible connection 4 to 6 times more than in case of asymmetric single-phase PV´s

STUDY ON INTEGRATION OF RENEWABLES IN LV GRIDS

Complete set of variants – phase to ground voltage limits Un (V) +/- 10%

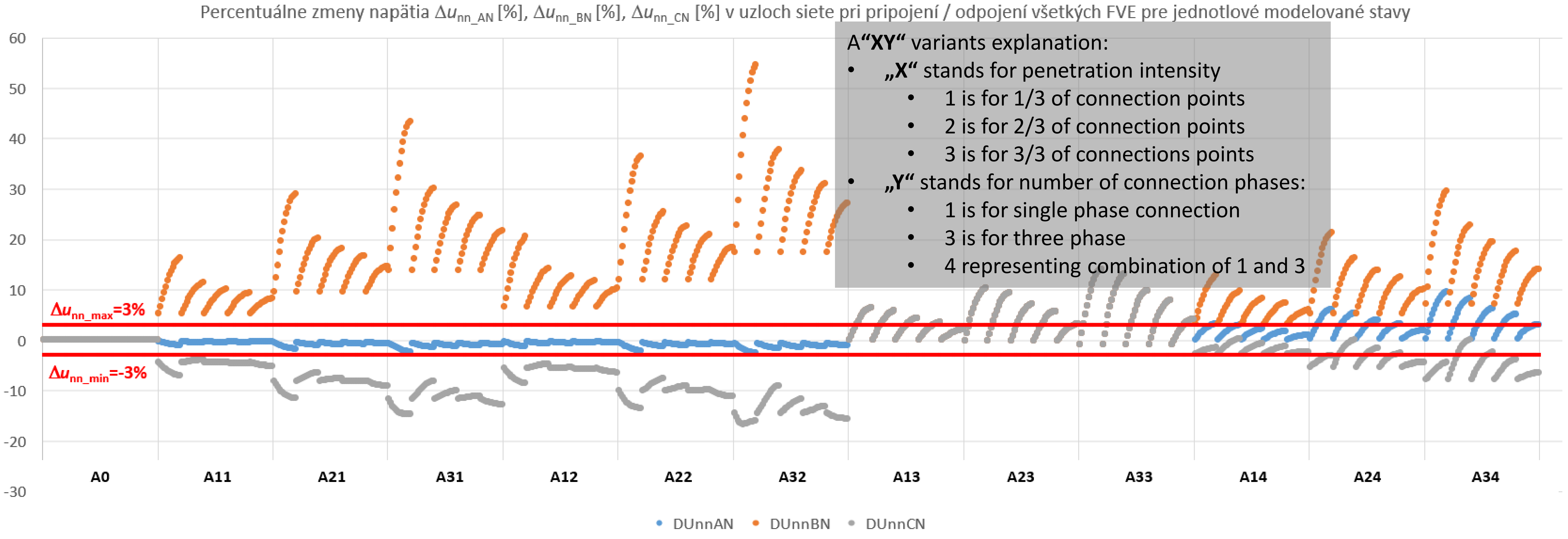


A"**XY**" variants explanation:

- „**X**" stands for penetration intensity
  - 1 is for 1/3 of connection points
  - 2 is for 2/3 of connection points
  - 3 is for 3/3 of connections points
- „**Y**" stands for number of connection phases:
  - 1 is for single phase connection
  - 3 is for three phase
  - 4 representing combination of 1 and 3

STUDY ON INTEGRATION OF RENEWABLES IN LV GRIDS

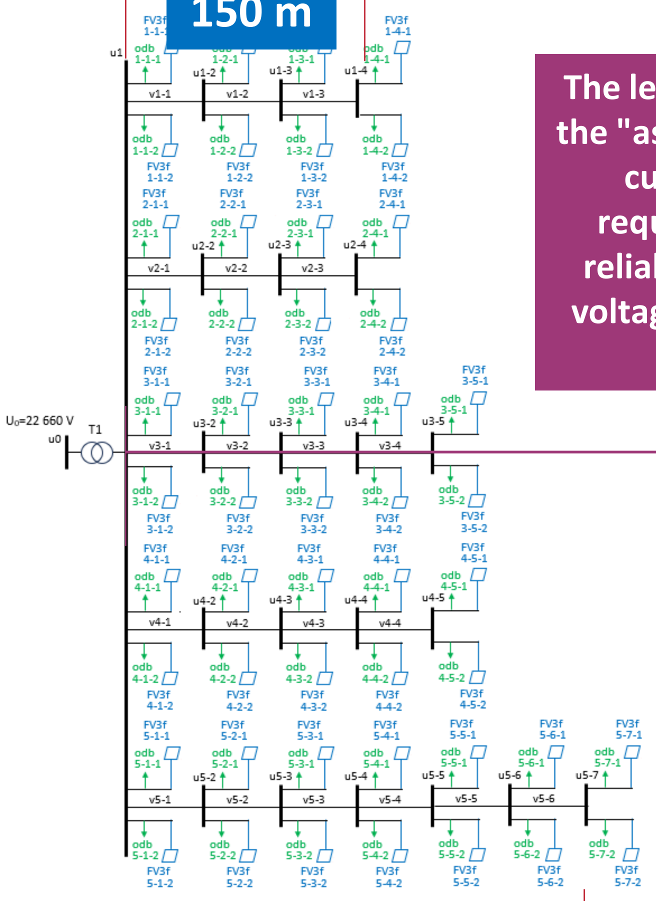
Complete set of variants – relative voltage change du (%) ≤ 3%



STUDY ON INTEGRATION OF RENEWABLES IN LV GRIDS

ELECTRIFICATION 2.0

150 m



600 m

300 m

The length of the LV line in the "as is" condition, which currently meets all requirements for safe, reliable and satisfactory voltage-quality electricity distribution.

The maximum length of the LV line, which will be acceptable during the intensive development of RES and e-mobility.

- The current generation will be part of a fundamental redesign of the LV distribution system – an increase in line cross-sections, in number of transformer stations – i.e. shortening of the "electrical distance" of the grid user to the MV/LV transformation.

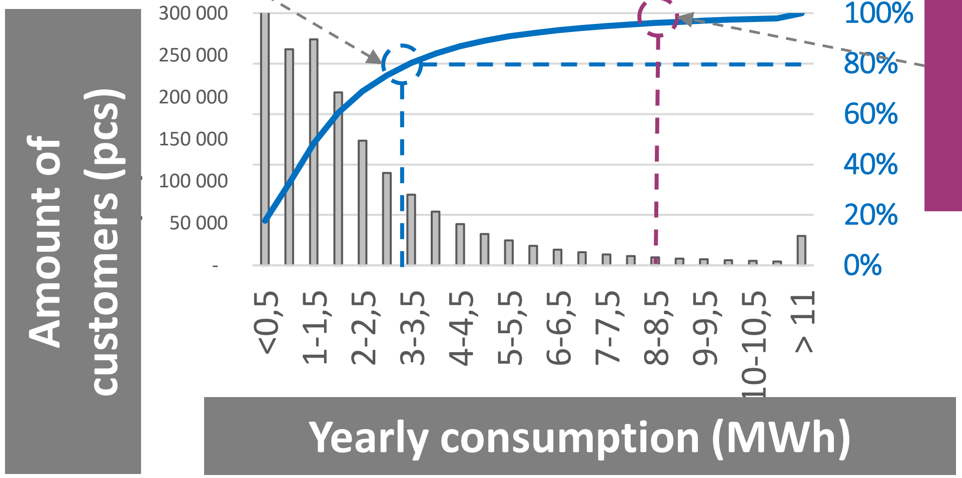
Officially the last electrified Slovak municipality of „Zlatá Baňa“ 4th of September 1960

- While the "first wave" of the electrification of the low voltage system in Slovakia lasted 40 years (1920 - 1960), at least the initialization phase of the "second wave" must be implemented within a 10-year horizon.

INTEGRATION OF RES (PV)

Present reality

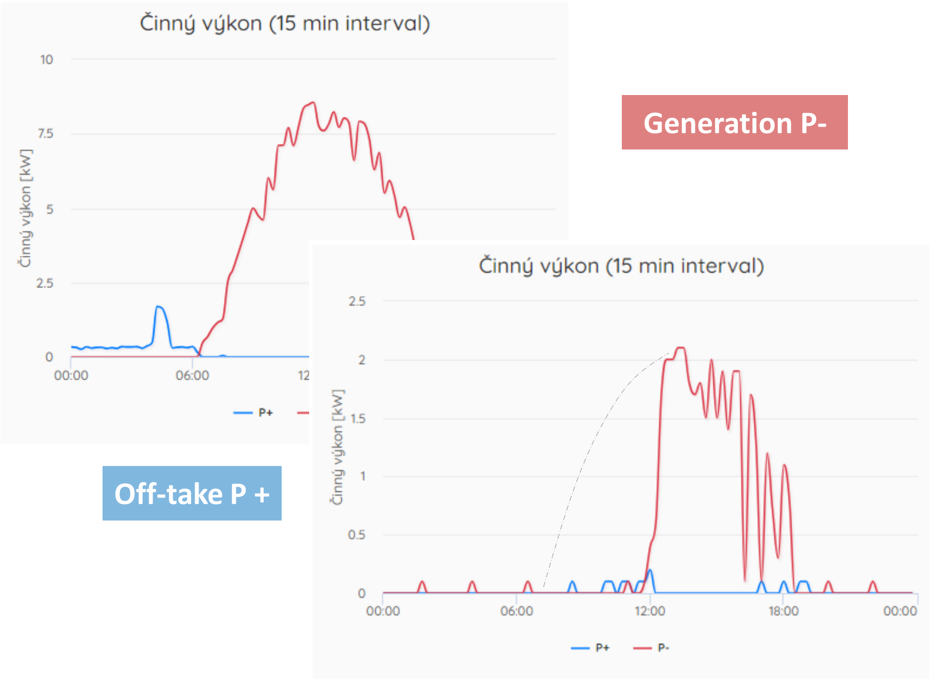
≈ 80% of households consume ≤ 3 MWh/year



Less than ≈ 5% of households consume > 8 MWh/year, despite this, the average power of connected PV in households in 2023 was at the level of 8 kW.

Mutual installation of electricity storage equipment in a ratio of 3:1 (BAT:PV) = the vast majority of electricity produced from PV is consumed in the home.

On the other installations without any storage, or with an inappropriate storage performance ratio, e.g. 1:1 (BAT:PV) supply electricity to the system most of the day:



- **Technical „to do list" for connection of small scale generation:**
  - Number of connection phases of the PV = number of phases of the household connection (i.e. preference for symmetrical three-phase sources)
  - The necessity of installing a suitable electrical energy storage (3:1)
  - Active management of the reactive component of electricity U(Q)

REDESIGN OF EXISTING INFRASTRUCTURE

Why do we need to change a network that has been working reliably for decades?

New business models - renewables - transport - heat - customer expectations

- The customer will adapt the consumption time profile to the stock market situation
- The integration of renewable sources for family houses will require a shortening of the distance between the MV/LV transformer station and the customer
- One fast charging hub for e-mobility 5MW - corresponds to the power needs of a smaller district town (Z. Moravce, Michalovce) - design for TEN-T corridors
- Increasing dependence of the entire society on the availability of electricity - will lead to greater pressure on the reliability and availability of the distribution infrastructure

THANK YOU FOR YOUR ATTENTION