Mitigation of Voltage Rise Caused by Intensive PV Development in LV Grid

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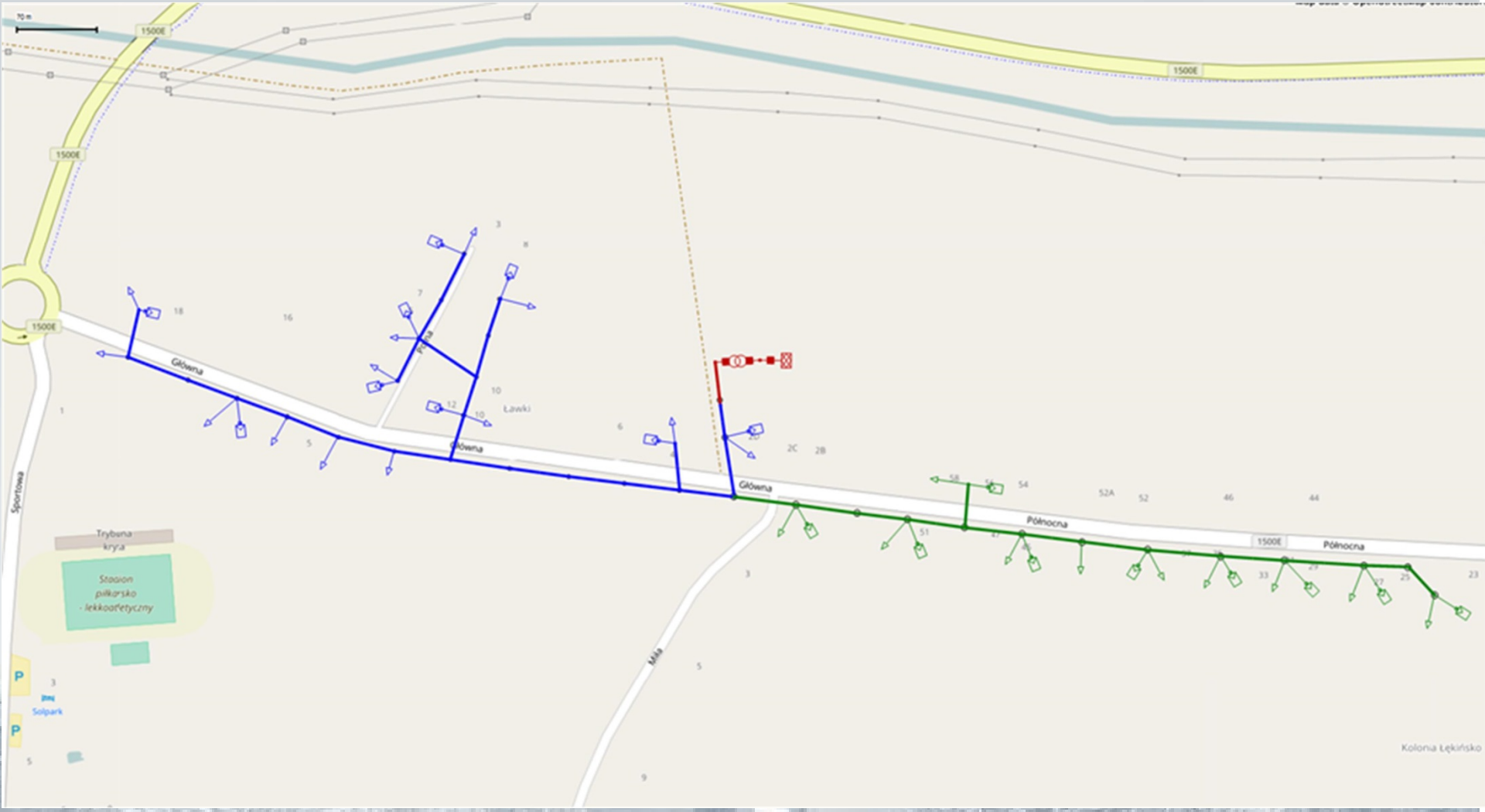
Photovoltaic sector in Poland

- low level of development (200 – 250 MW)
- no feed-in tariff (FIT)
- high investment costs (over 3,500 €/kwp for a rooftop PV system)

but also:

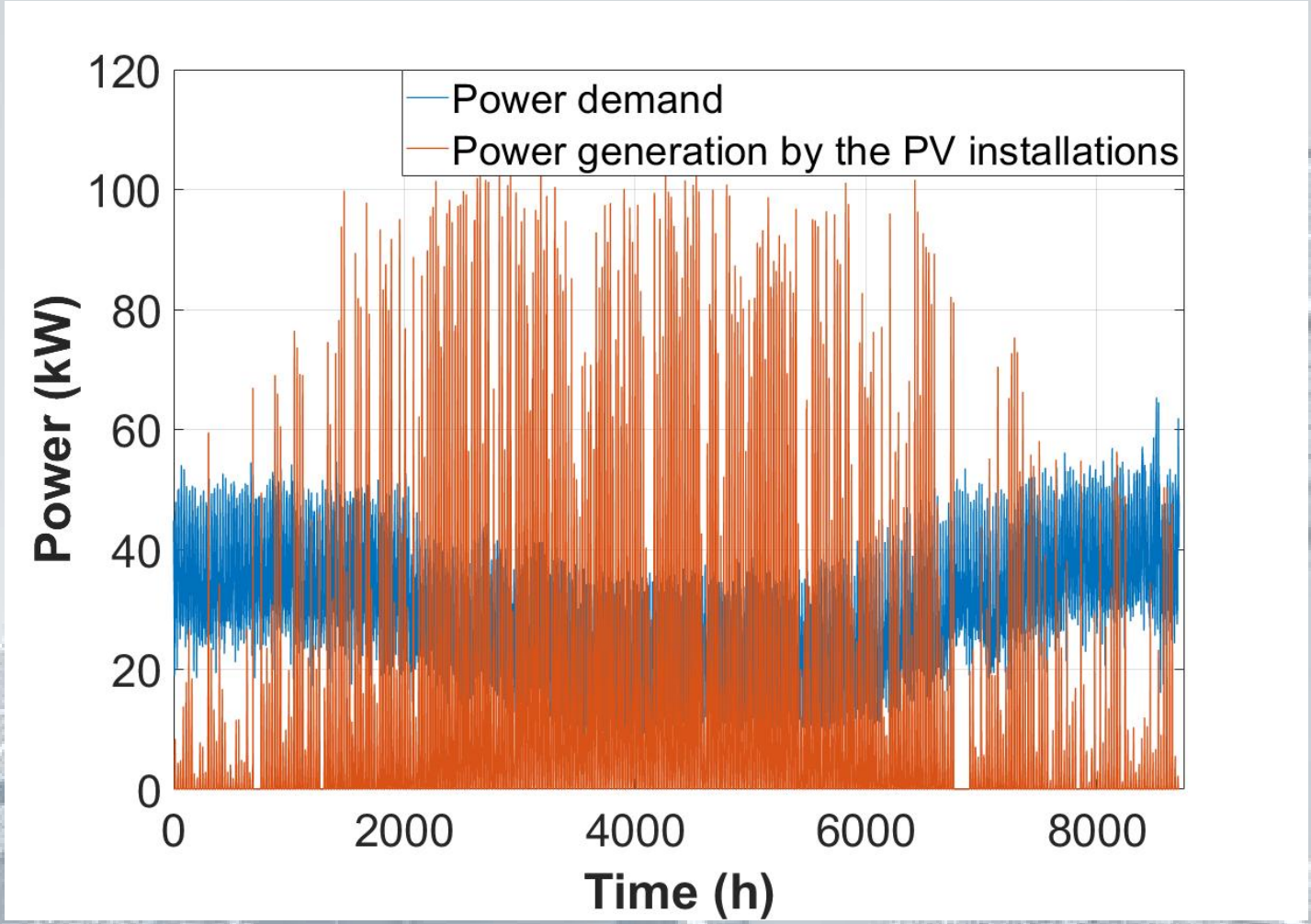
- noticeable increase in interest of PV installations
- attractive development forecasts (over 1300 MW in 2021)
- some local governments provide their support funds, which results in considerable concentrations of PV installations for individual locations and MV/LV substations

considered case: MV/LV substation Łękińsko, transformer nominal power 63 kVA maximum load 65 kW, total capacity of PV installations equal to 103 kW

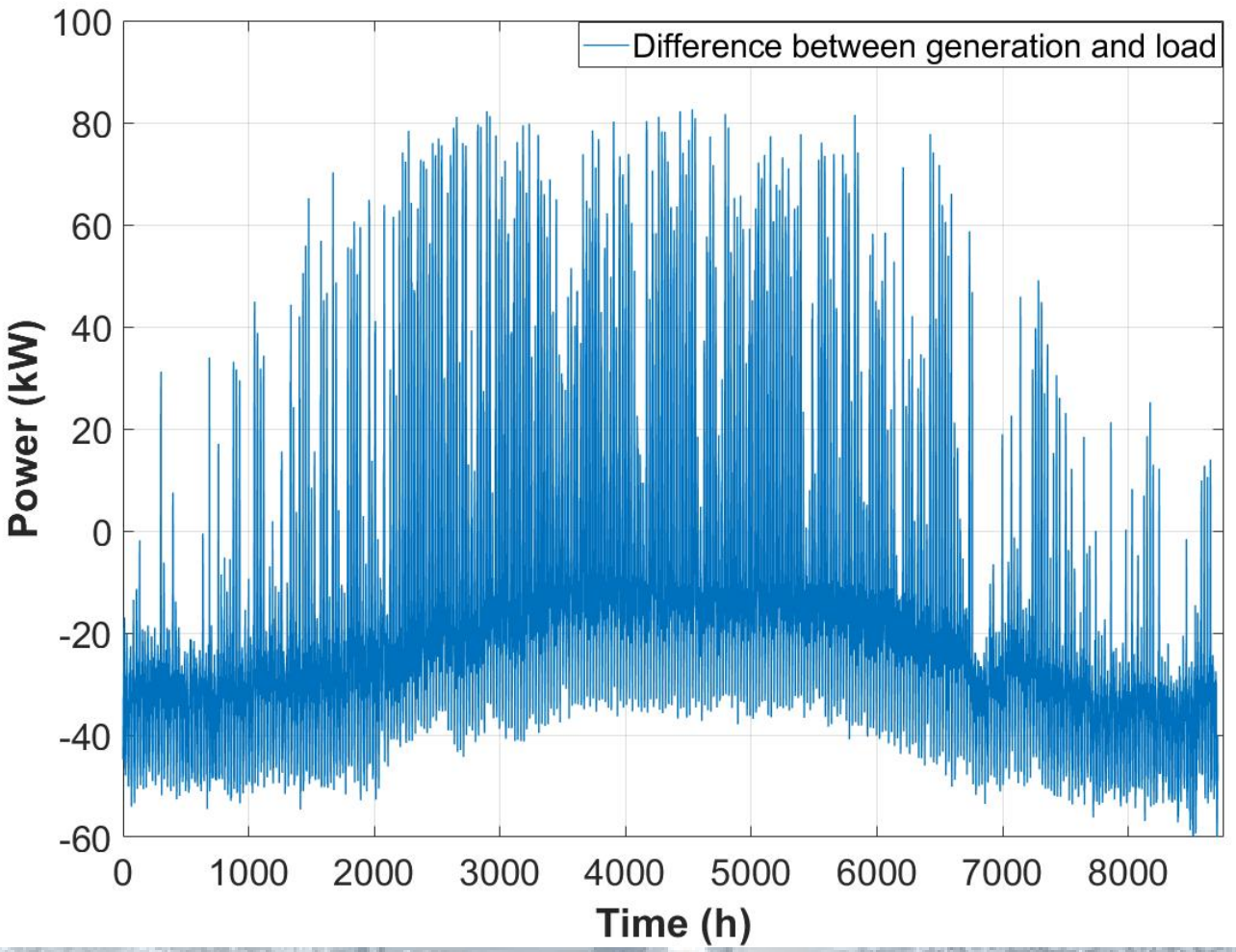


The analyzed transformer substation and low voltage circuits

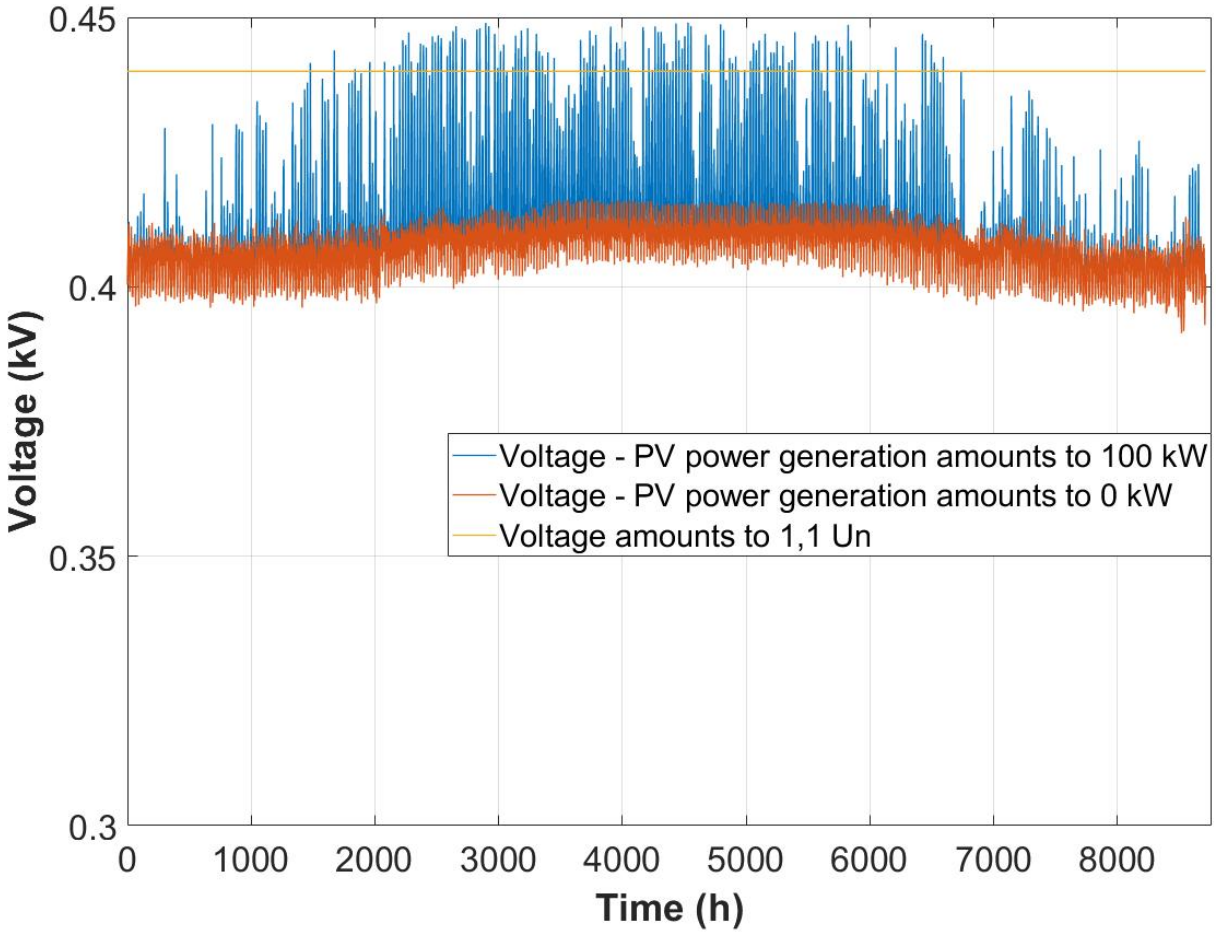
S_{nT}=63 kVA, P_{Lmax}=65 kW, P_{PV}=103 kW



Annual load curves of the analyzed transformer substation (S_{nT}=63 kVA) and the power generated in PV micro-installations of the total capacity of 100 kW connected to circuits that are supplied from this substation. Although the PV power generation level seems to be high, the amount of consumed energy is twice as high as the produced energy level.



Annual power generation surplus curve for the analyzed transformer substation (S_{nT}=63 kVA) generated in PV micro-installations of the total rated capacity of 100 kW connected to circuits that are supplied from this substation



Annual voltage variation curve at the terminal of one of the two circuits supplied from the analyzed transformer substation (S_{nT}=63 kVA) and of the power generated in PV micro-installations of the total rated capacity of 100 kW. For comparative purposes, voltage variation curves for the idle state are also presented

European Standard EN 50160

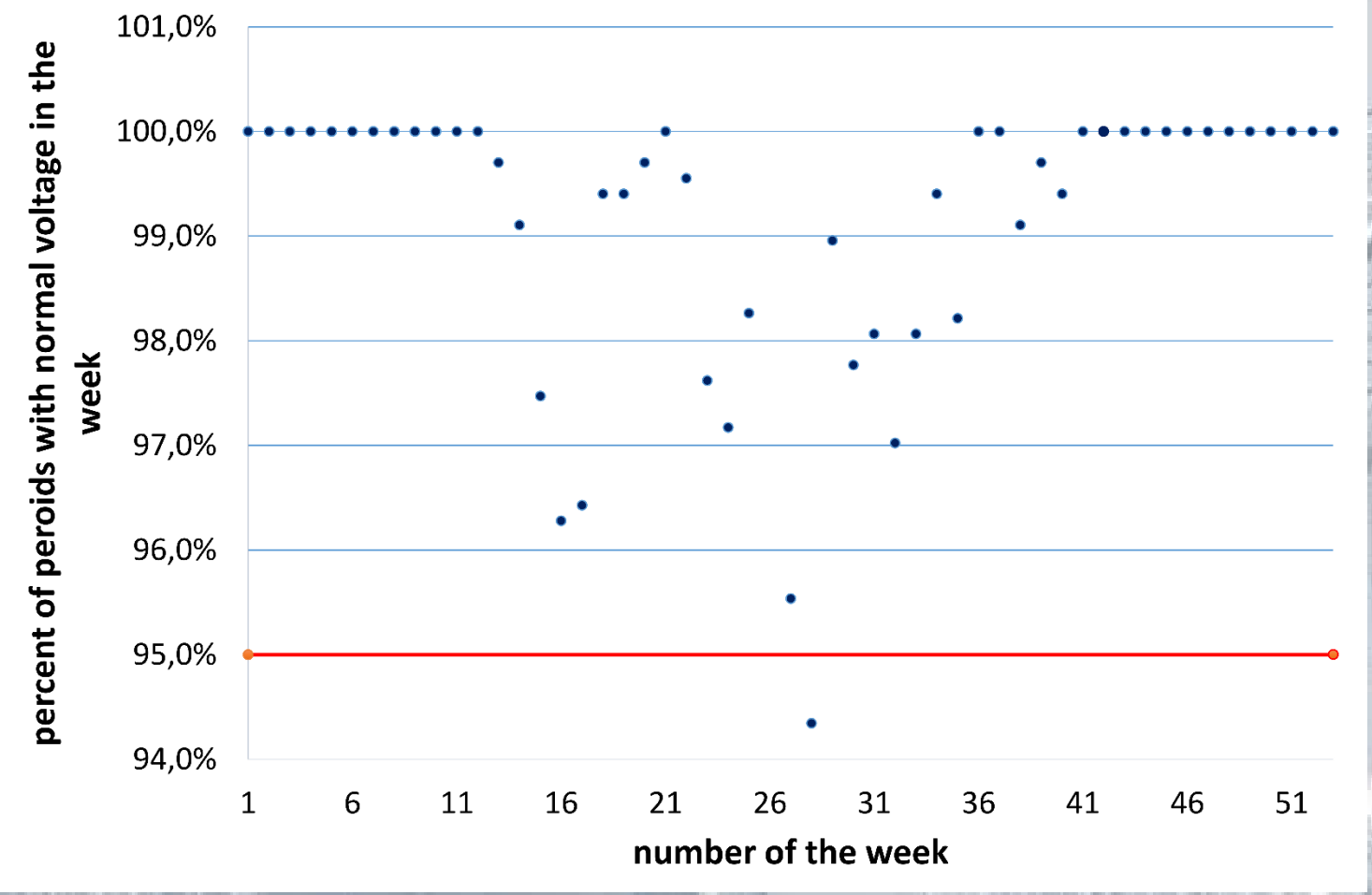
Voltage characteristics of electricity supplied by public distribution systems

2.3.2

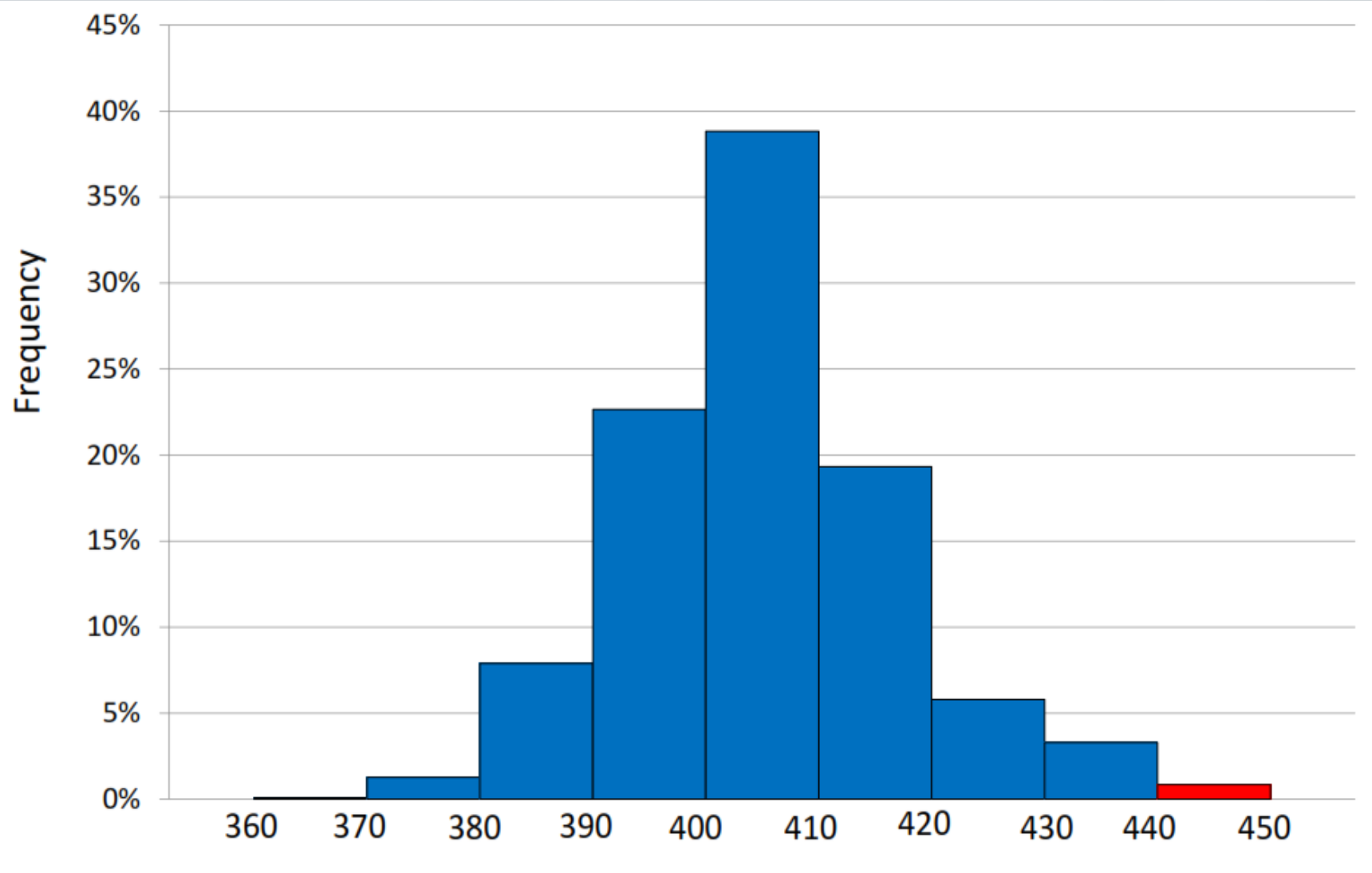
Under normal operating conditions:

a) during each period of one week 95% of the 10 min mean rms values of the supply voltage shall be within the range of Un ± 10%, and

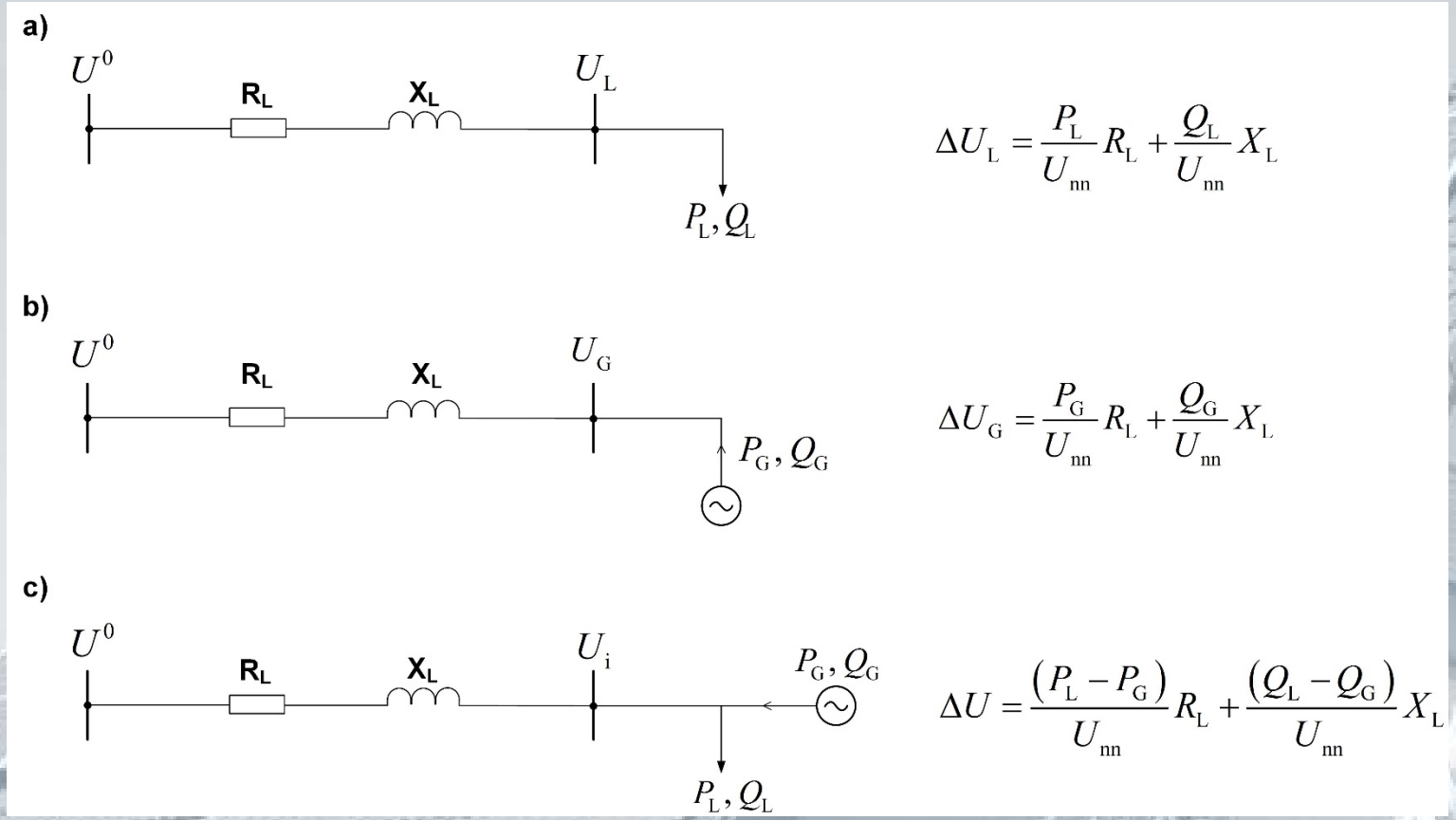
b) all 10 minutes mean rms values of the supply voltage shall be within the range of Un+10%/- 15%.



Results of annual voltage analysis for all periods of 10 min. Repeated for each week according to EN 50160 – requirement a



European Standard EN 50160 - requirement b



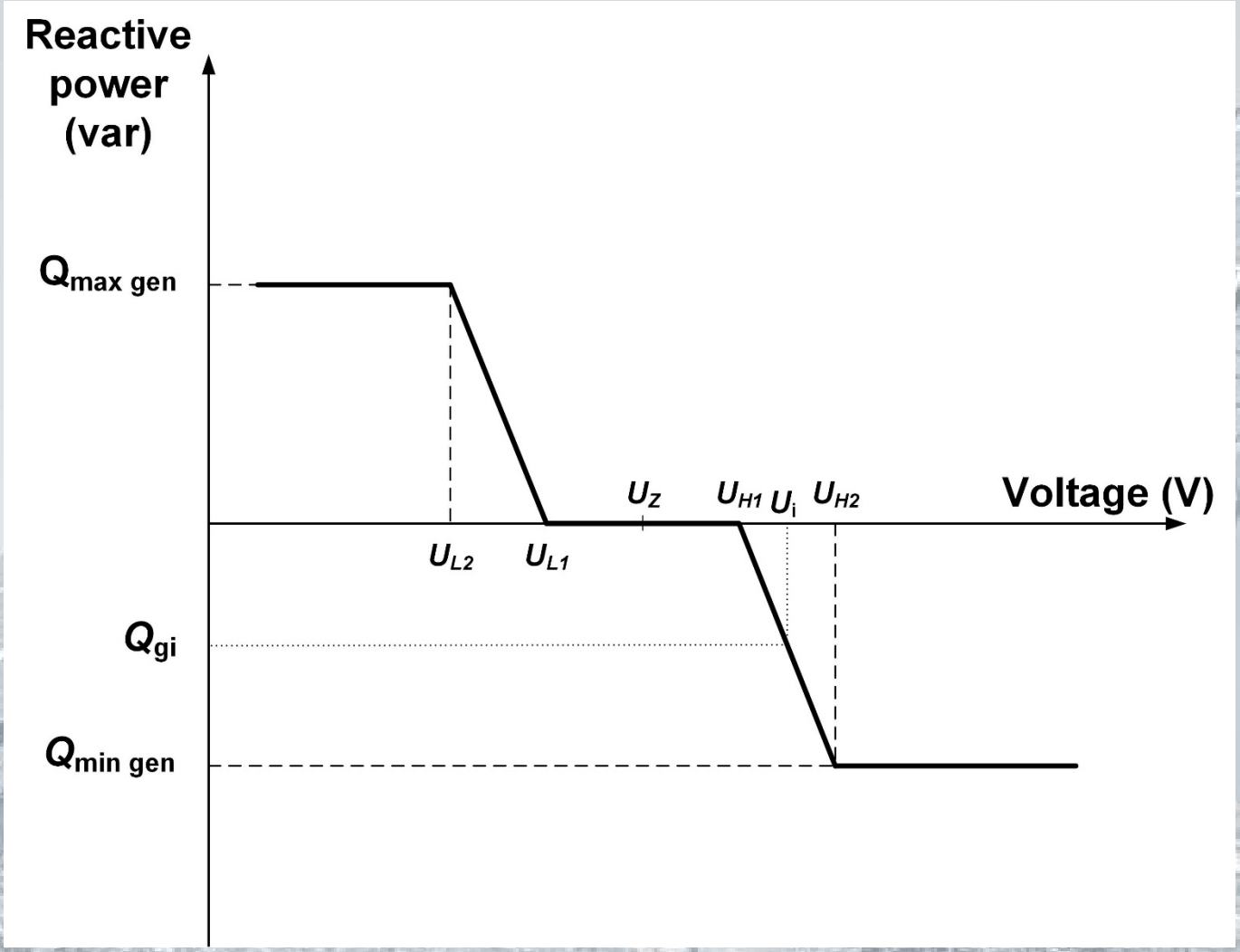
General characteristic of voltage conditions in LV grids – fundamentals

European Standard EN 50438

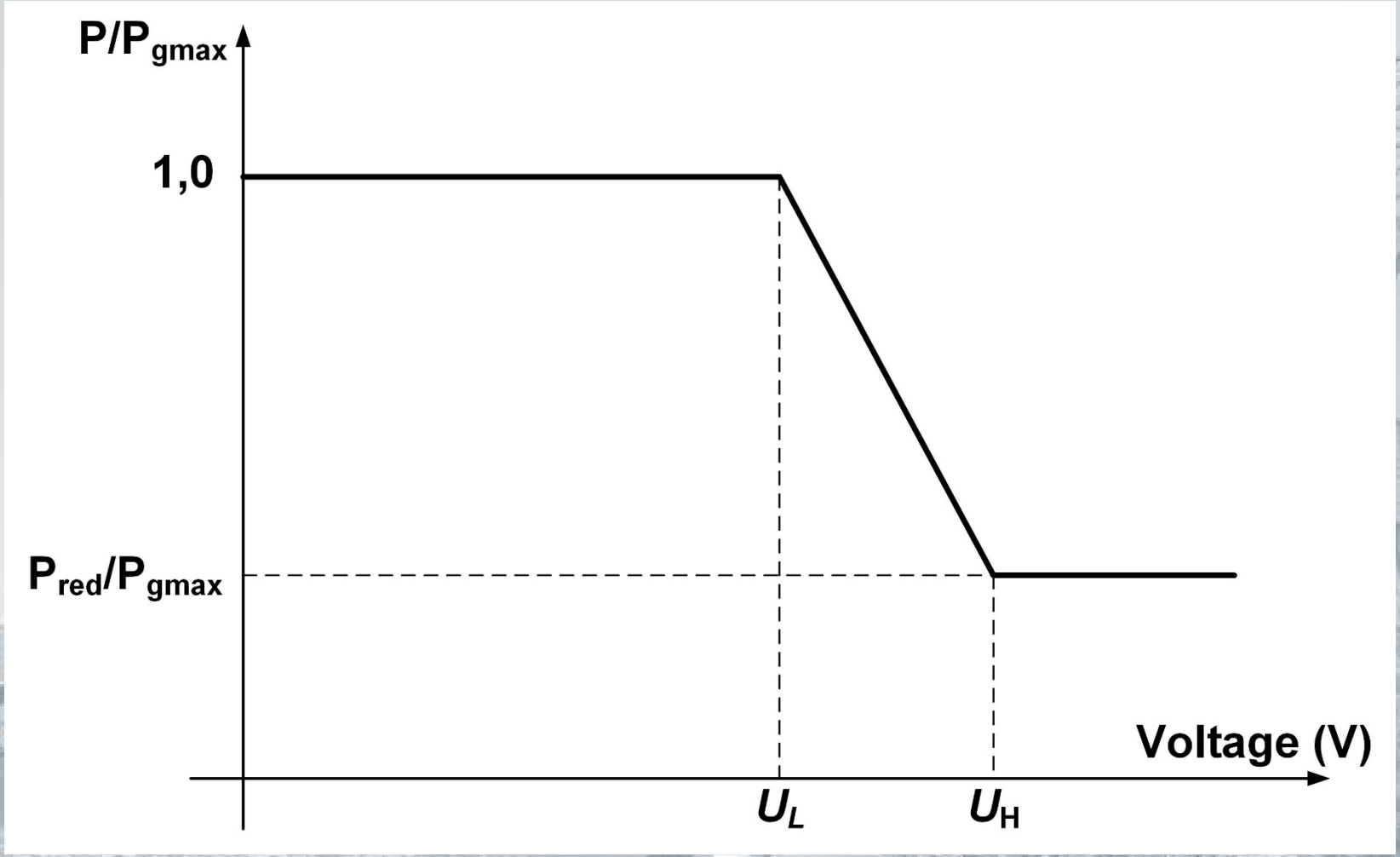
Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks

4.4.1 Modes of reactive power control:

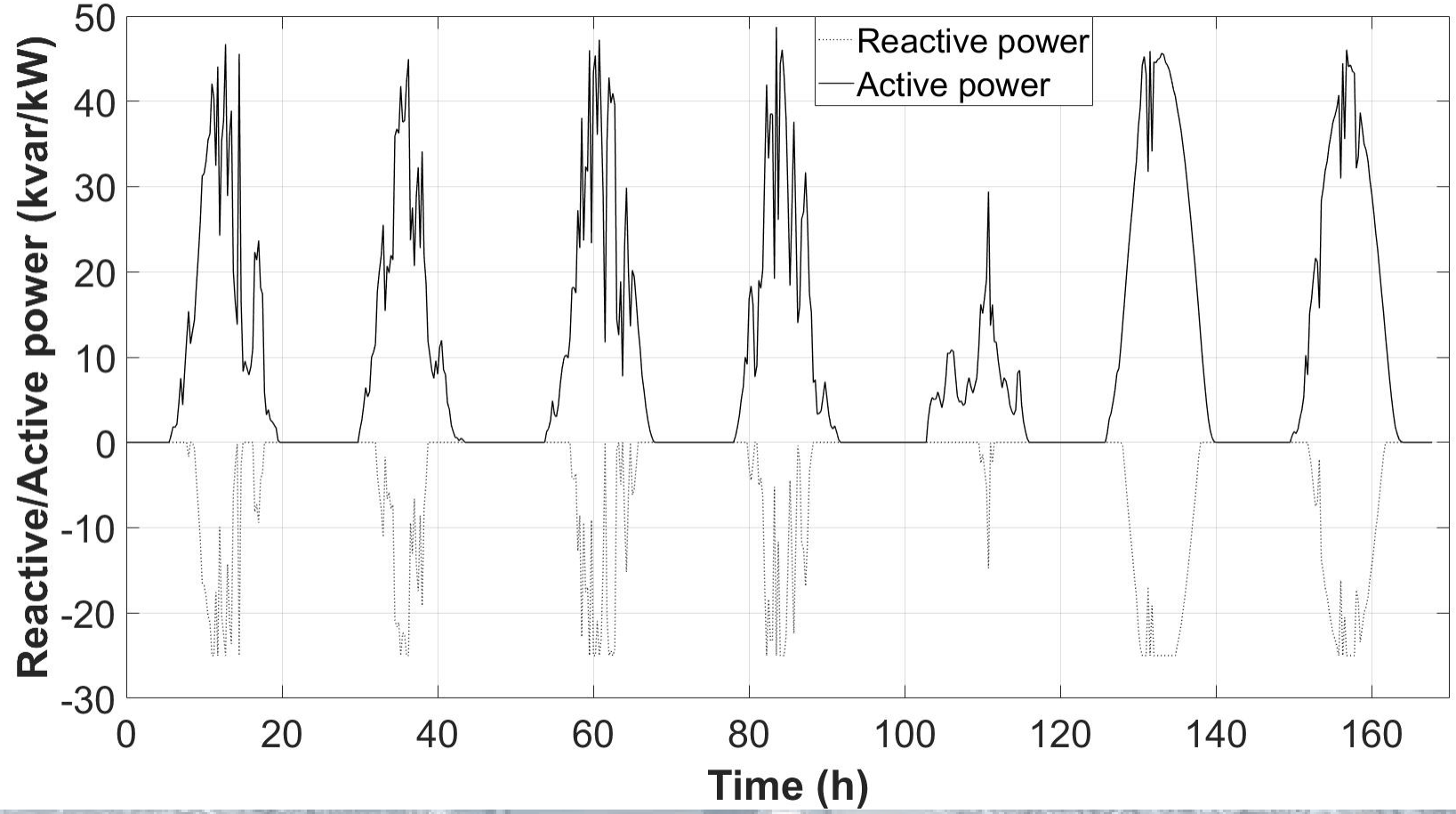
- cos φ fix (eg. cos φ=1)
- cos φ (P)
- $Q(U)$ – the most attractive solution



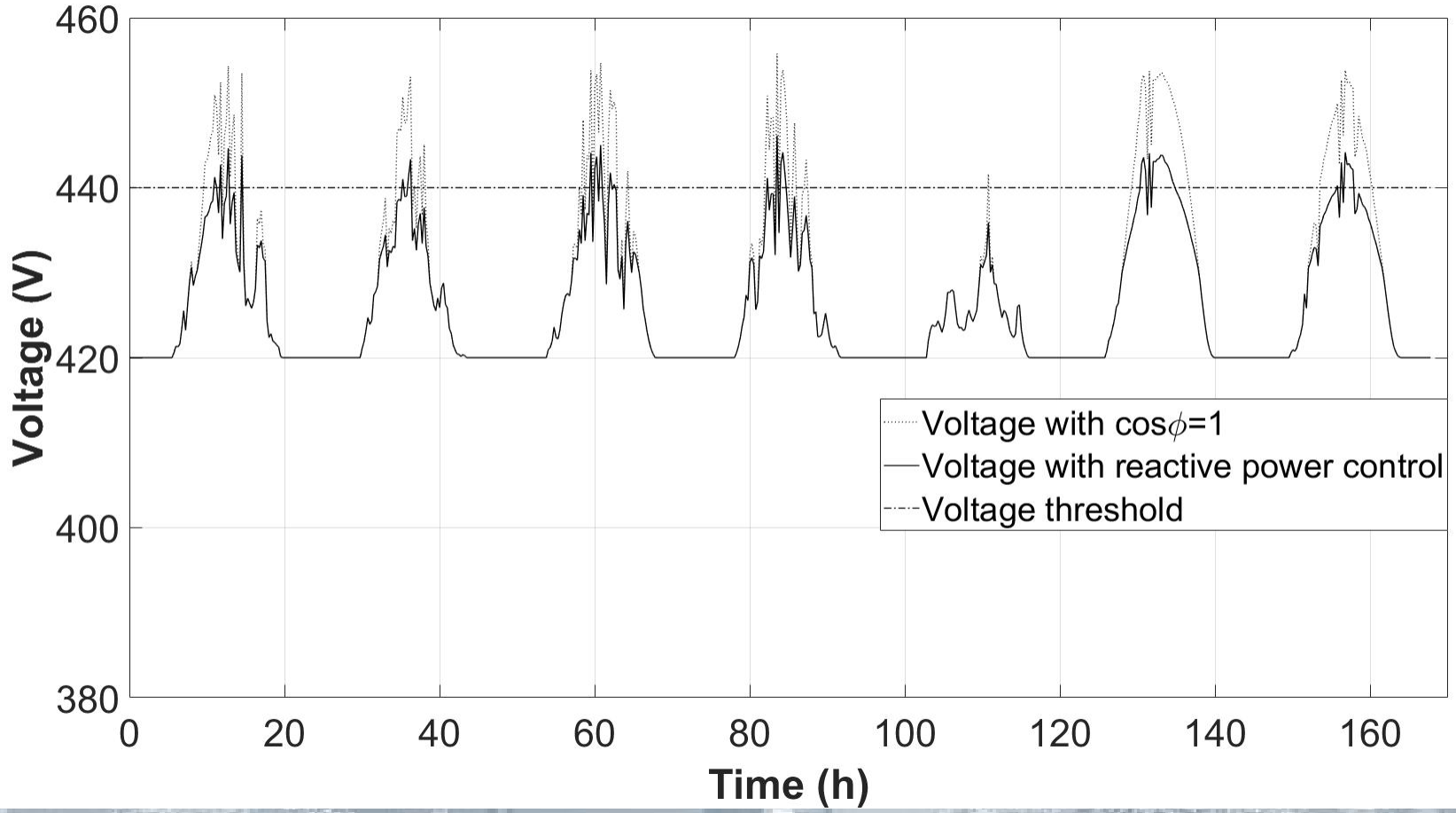
The curve *Q*(*U*), required for PV inverters according to the EN50438 (all settings can be changed)



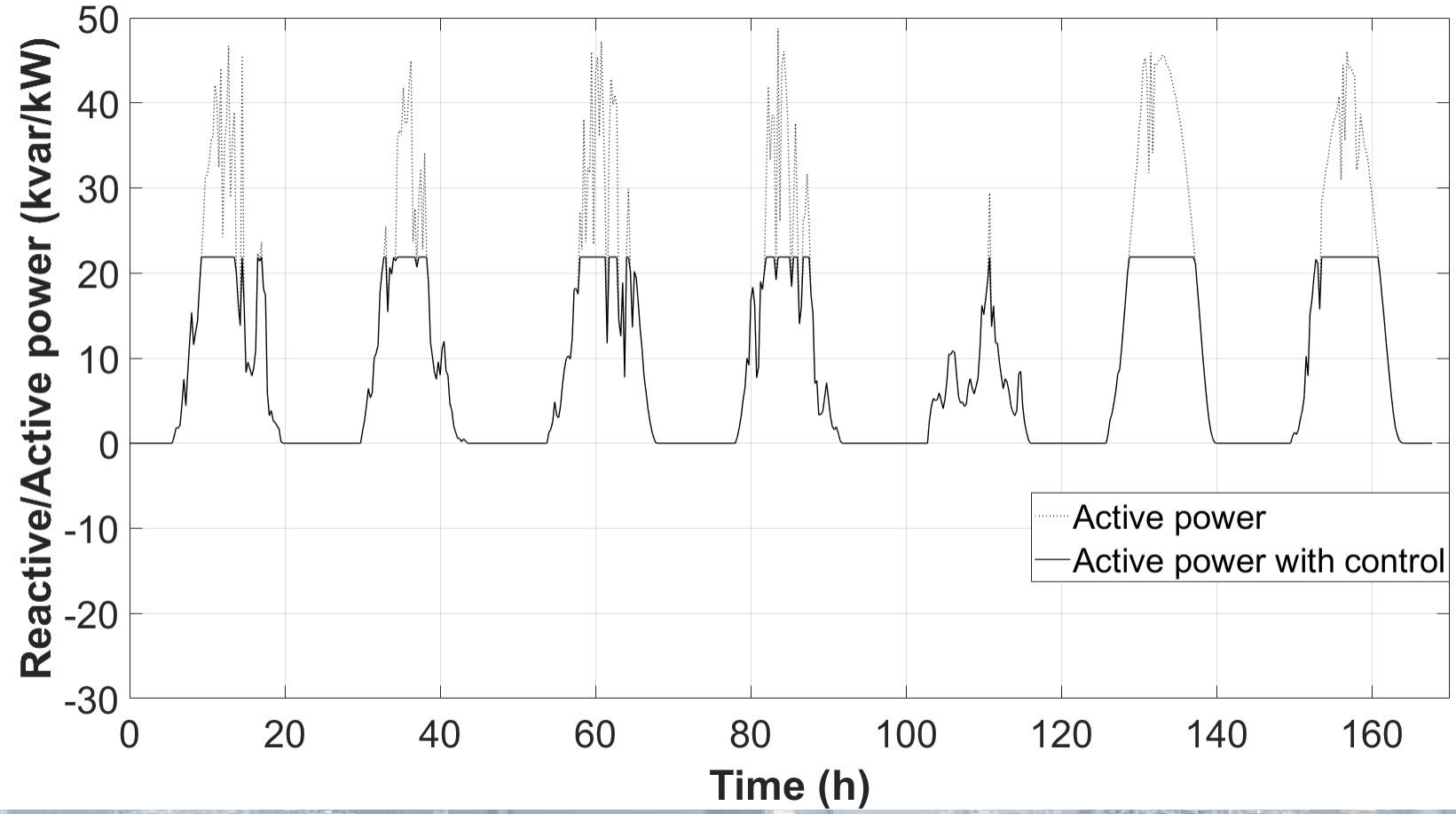
The response curve required for the volt-watt response mode according to the Standard ASNZS4777.2-2015 (all settings can be changed)



Weekly power output variation curve for a PV installation of P_{gmax}= 50kW

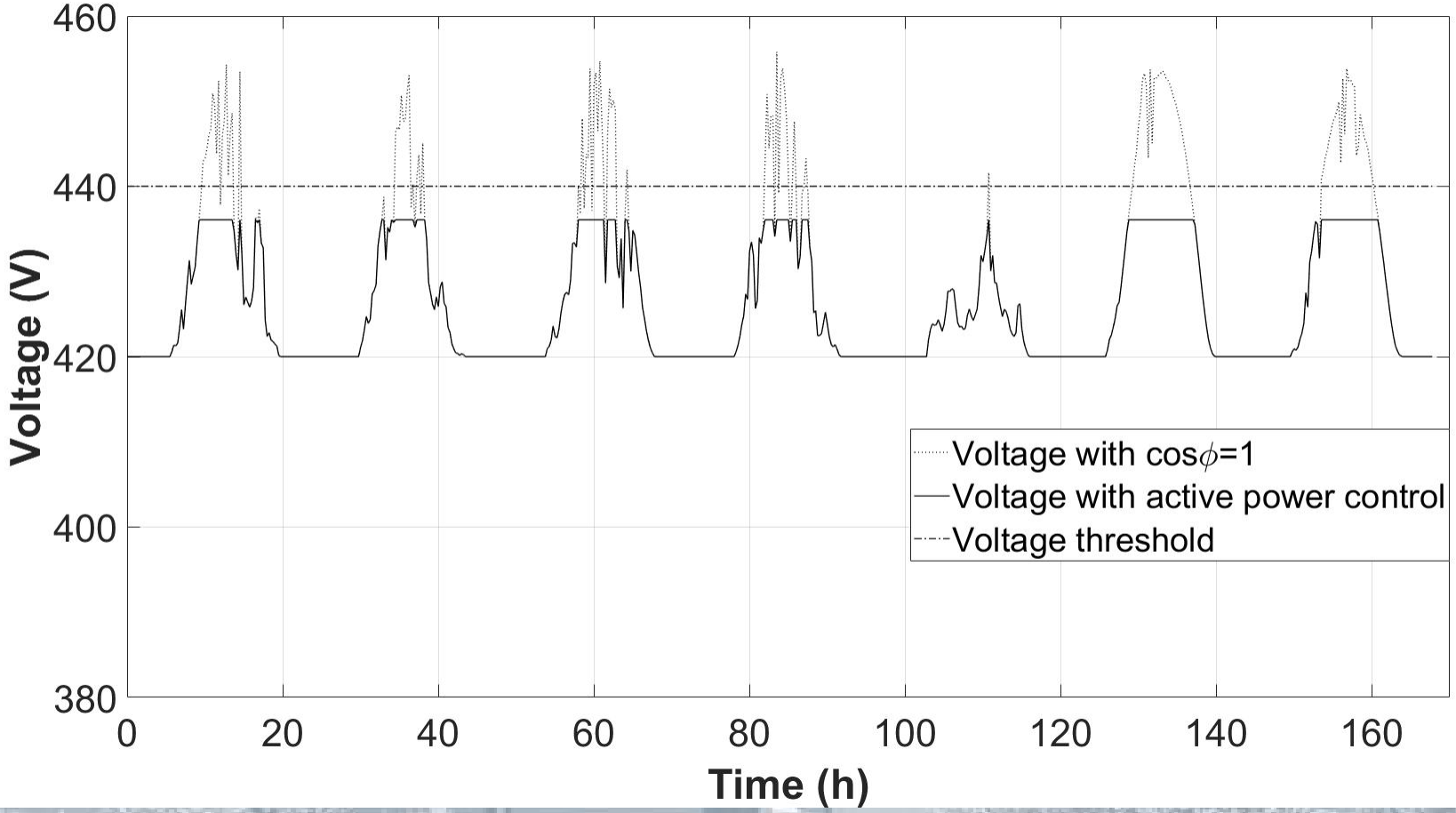


Weekly voltage variation curve at the PV installation connection point with the assumed cosφ=1 and the applied Q(U) characteristic

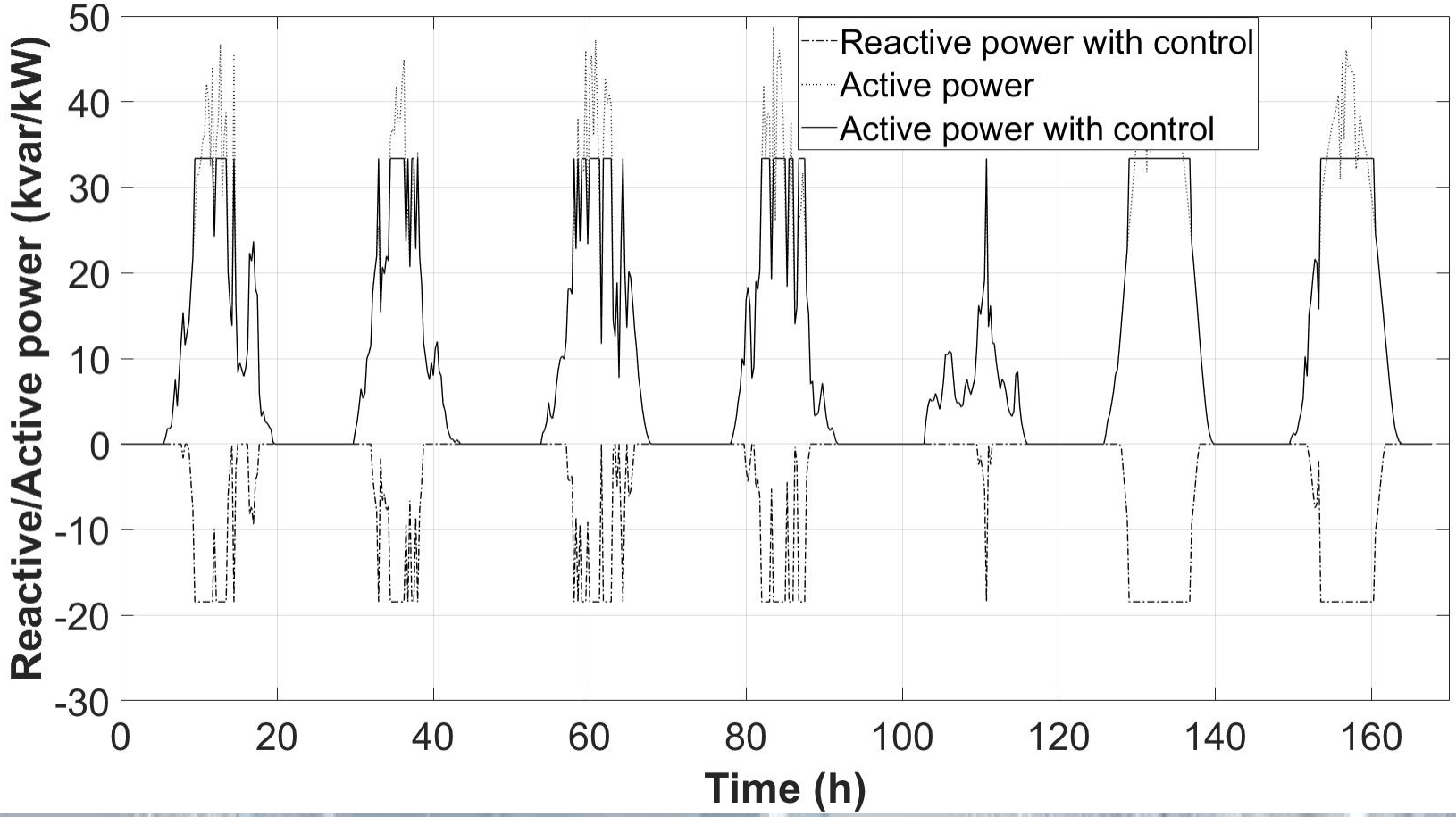


Weekly power output variation curve for a PV installation of P_{gmax}= 50kW without and with the application of the $P(U)$ characteristic (U_L=420 V, U_H=440 V)

$\Delta E_{PV}/E_{PV}$=26%,

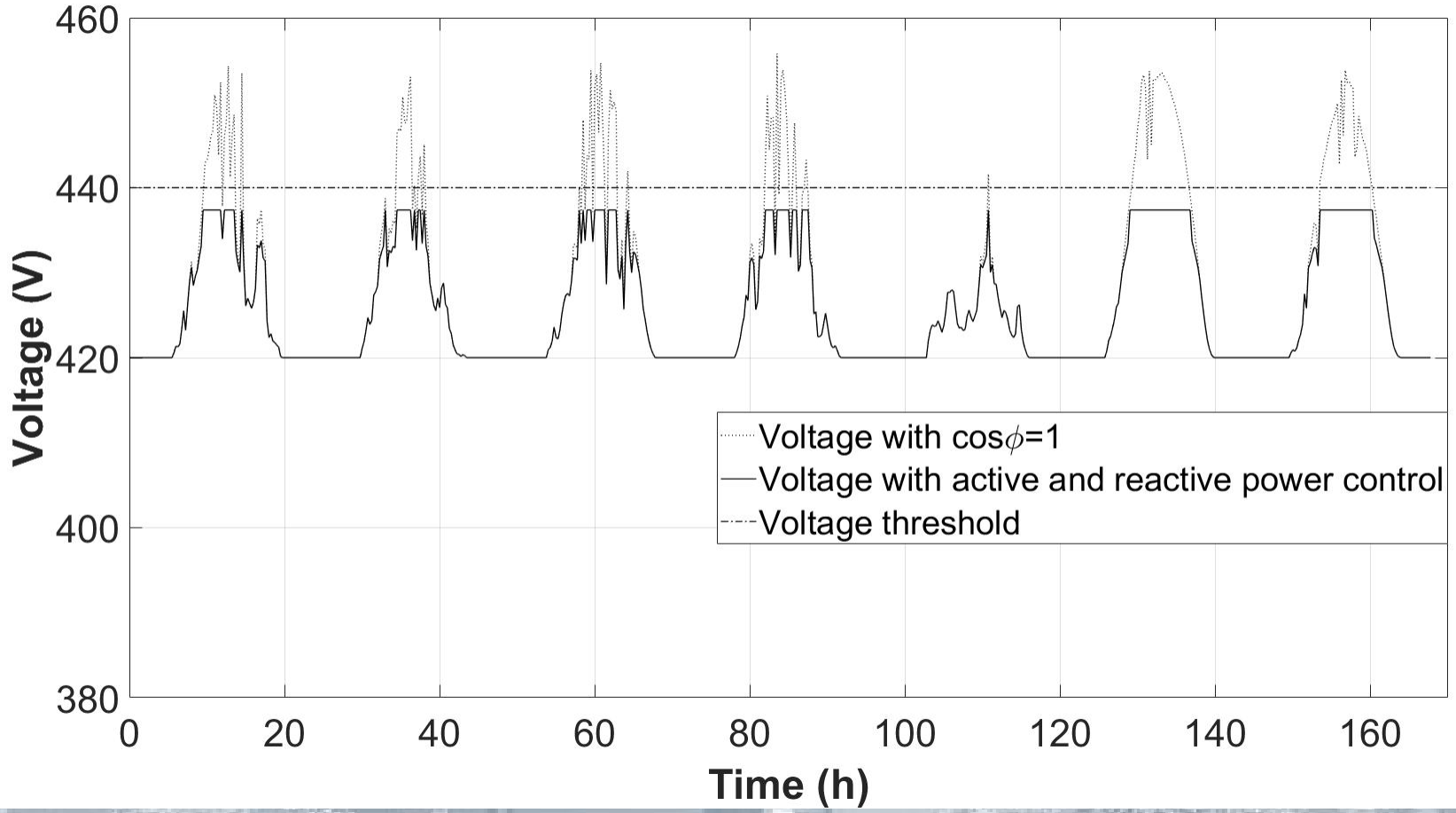


Weekly voltage variation curve at the PV installation connection point with the assumed cosφ=1 and the applied *P*(*U*) characteristic (U_L=420 V, U_H=440 V)

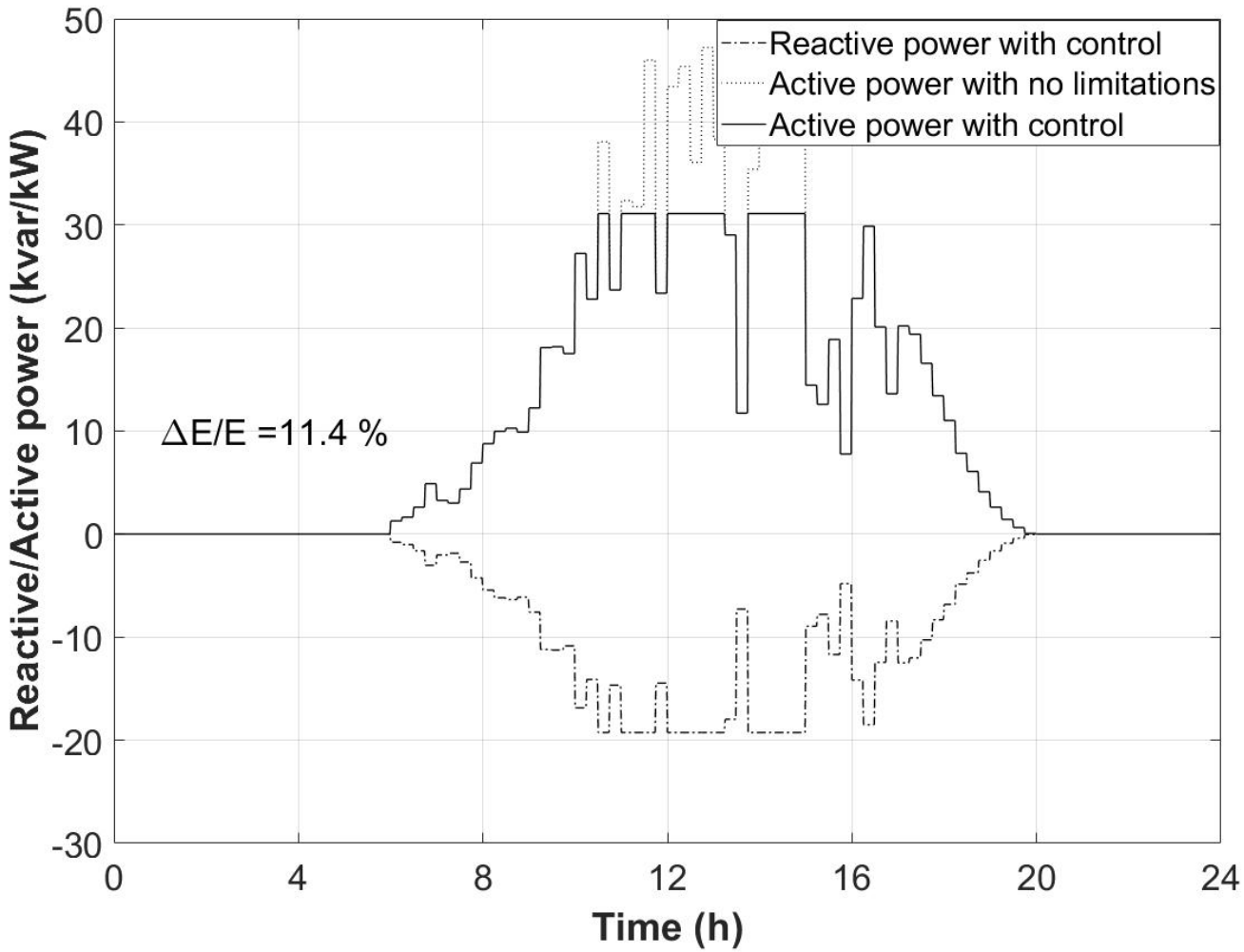


Weekly power output variation curve for a PV installation of P_{gmax}= 50kW without and with the application of the P(U) and Q(U) characteristics (U_L=435 V, U_H=440 V)

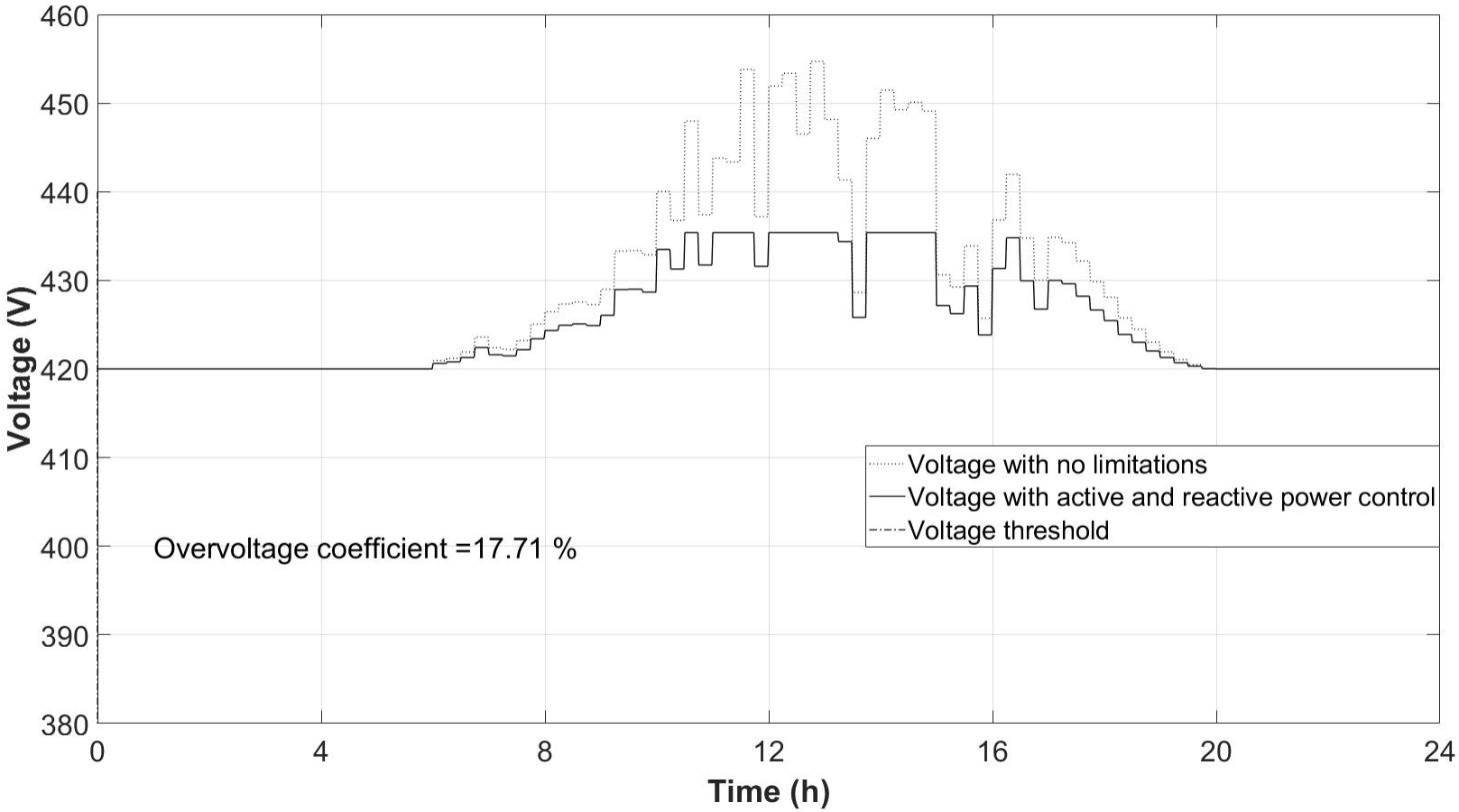
$\Delta E_{PV}/E_{PV}$=6%,



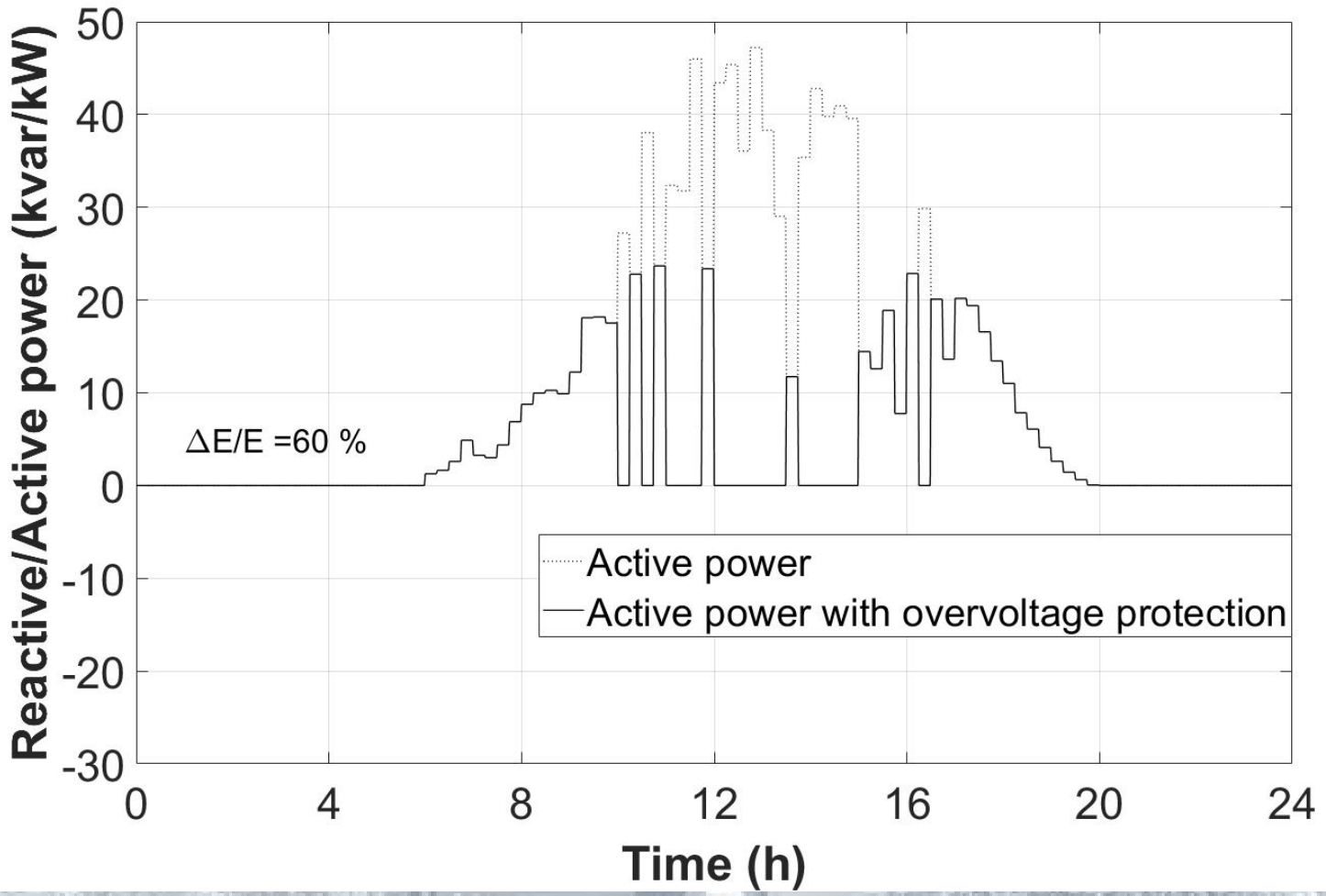
Weekly voltage variation curve at the PV installation connection point with the applied $P(U)$ and $Q(U)$ characteristics (U_L=435 V, U_H=440 V) in comparision with the case of cosφ=1



Effect of the characteristics *P*(*U*) and *Q*(*U*) for the selected day. Reduction of daily generation by 11%.



Effect of the characteristics $P(U)$ and $Q(U)$ for the selected day. Total voltage limitation below 440 V



Voltage limitation achieved using overvoltage protection. Reduction of daily generation by 60% ($\Delta E_{PV}/E_{PV}$=60%)

CONCLUSIONS

- Implementation of a large number of PV microgeneration systems in LV grids can cause disadvantageous voltage increase up to exceeding its allowable value of (U_{max}=440 V, U_{maxp}=253 V).
- Among a few methods for limiting those values during the greatest insolation hours, it is an adequate selection of the PV inverter characteristics – $P(U)$ and $Q(U)$ – that deserves a particular attention.
- Practical realization of that task requires involvement of the distribution system operators.
- Operators should carefully verify certifications presented by the equipment manufacturers and enforce activation of the discussed characteristics as well as the parameter selection to have them compliant with the recommendations.
- Such a solution makes possible to avoid additional investments in the LV network reconstruction and expensive control equipment such as on-load tap changing transformers and booster transformers.

Thank you for your attention