LIMITS OF THE MV/LV GRID SUPPLIED BY RENEWABLE ENERGY

Hans-Peter VETÖ, TU Wien – Austria, vetoe@ea.tuwien.ac.at

Herbert HAIDVOGL, EVN Netz GmbH – Austria, herbert.haidvogl@evn-netz.at

Klaus CZERMAK, EVN Netz GmbH – Austria, klaus.czermak@evn-netz.at

Roman LECHNER, EVN Netz GmbH - Austria, roman.lechner@evn-netz.at

ABSTRACT

This paper analyzes different low voltage (LV) networks in terms of maximum feed-in through Photovoltaic (PV). Various technical possibilities are investigated to increase PV feed-in power, without violating the upper voltage limit, or causing overloads on the operating equipment.

INTRODUCTION

Three model-based low voltage networks (city, area of settlement dense built, area of settlement loose built) are considered in the simulation. The calculation is performed for a sunny summer day by 15min. values. The load profiles are considered purely in the form of 3-phase synthetic household load profiles [1]. The assumed annual electricity consumption per residential unit was adopted for the city with 3500kWh, for the area of settlement with 4000kWh.

Loads as well as PV infeeds of the respective residential units are combined per distribution cabinet (DC) or roof pole (RP). All PV infeeds are identical, symmetrically dispersed on the network and considered in optimal south exposure. The low voltage network is connected via a MV/LV-transformer (transformation ratio 50) to the medium voltage network, operated with 21.4-kV.

Three fixed transformer tap settings (ΔU=0%, ΔU%=-5% and ΔU=-10%) are considered. Furthermore, the power factor (cos(φ)) of the PV inverter is varied from 0.8 to 1. The permissible voltage limits are specified with ±10% (360 < 400 < 440 V). The maximum utilization of the cables and overhead lines, as well as the local power transformers is set to 100%. Retention or accumulation factors due to the ambient temperature of the cable are not included. Active energy losses (WV), reactive energy losses (QV) and PV peak power (PPVmax) are illustrated.

CITY NETWORK

The city network is considered as a pure cable network with a single cable type. 6 residential units are supplied from each distribution cabinet.

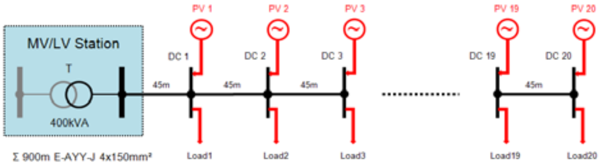

Figure 1: LV-Network - City

ΔU=0%

By changing the cos(φ) of the PV inverter, the injected active power can be increased without violating the upper voltage band. 4.4 to 7.65 kW per distribution cabinet can be fed into the LV network!

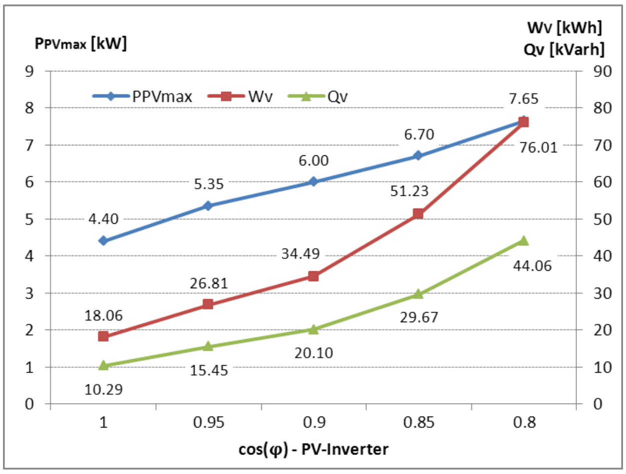

Figure 2: City – Tap 0%

ΔU=-5%

An increase of the fed in active power by the PV is possible only up to a cos(φ)=0.95, from then on, the thermal limit of the cable is reached. The comparison to Figure 2 shows that even at a cos(φ)=1, 9kW can be fed into the network, compared to only 7.65kW at a cos(φ)=0.8 at much lower power losses!

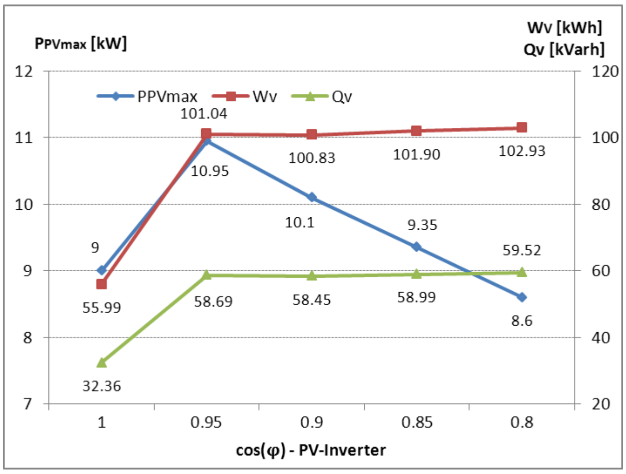

Figure 3: City – Tap -5%

ΔU=-10%

By changing the cos(φ) of the PV inverter, the active power feed-in can not be increased because the thermal limit of the cable has already been reached.

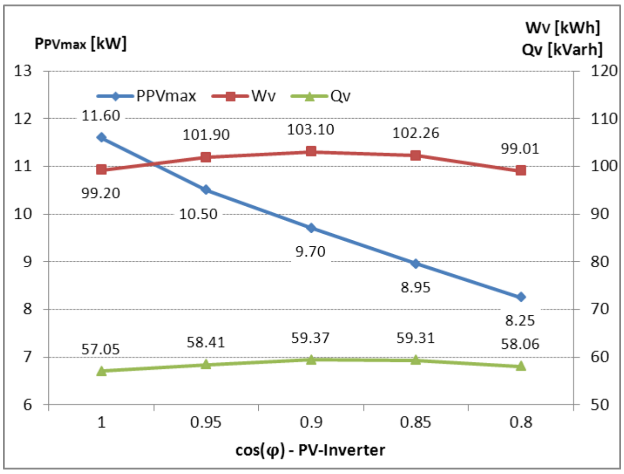

Figure 4: City – Tap -10%

AREA OF SETTLEMENT DENSE BUILT

The network of the densely built-up area of settlement is operated as a "mixed" cable and overhead line system. 5 residential units are supplied from each distribution cabinet or roof pole.

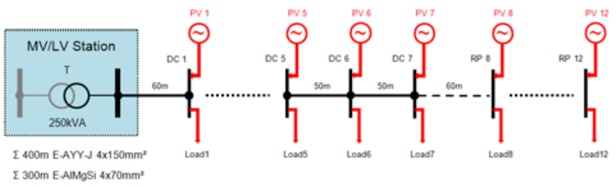

Figure 5: LV-Network – Area of settlement dense built

ΔU=0%

By changing the cos(φ) of the PV inverter, the injected active power can be increased without violating the upper voltage band. In comparison to the city network (Figure 2) 36% at cos(φ)=1 and 66% at cos(φ)=0.8 more PV can be installed into the grid.

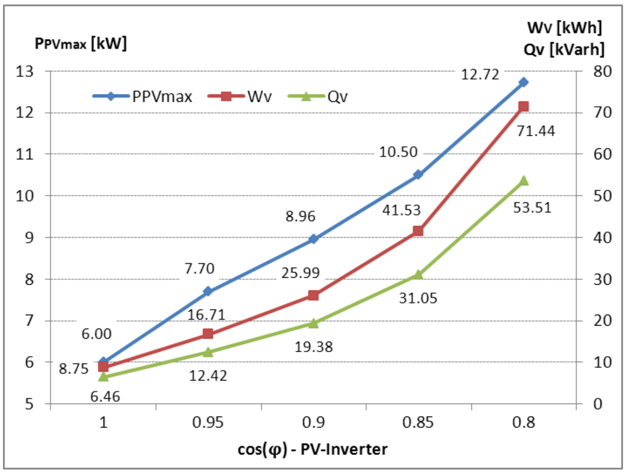

Figure 6: Area of settlement dense built – Tap 0%

ΔU=-5%

An increase of the active power feed-in by the PV inverter can be done only up to a cos(φ)=0.95, from that point on the thermal limit of the cable is reached. The comparison with Figure 6 shows clearly that at a cos(φ)=1 more PV can be fed into the grid at lower power losses (P_{PVmax}=13.2kW, W_V=43.13kWh) than at a cos(φ)=0.8 (P_{PVmax}=12.72kW, W_V=71.44kWh)!

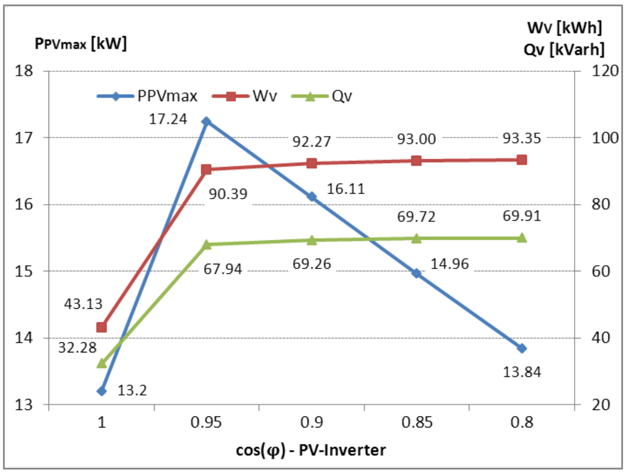

Figure 7: Area of settlement dense built – Tap -5%

ΔU=-10%

An increase of the PV inverter feed-in by changing the cos(φ) is not possible because the 100% load limit of the cable has already been reached.

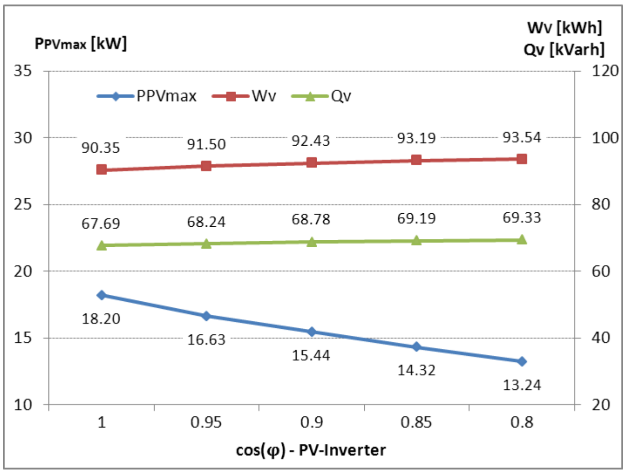

Figure 8: Area of settlement dense built – Tap -10%

AREA OF SETTLEMENT LOOSE BUILT

The network of the loose built-up area of settlement is operated as a "mixed" cable and overhead line system. 2 residential units are supplied from each distribution cabinet or roof pole.

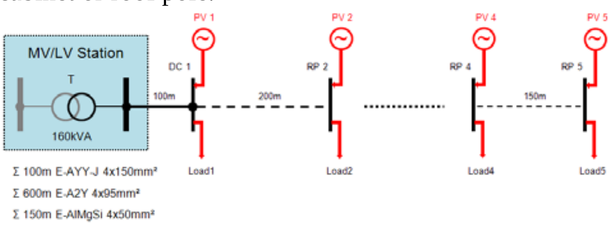

Figure 9: LV-Network – Area of settlement loose built

ΔU=0%

By changing the cos(φ) of the PV inverter, the injected active power can be increased without violating the upper voltage band. In comparison to the city network (Figure 2) 58% at cos(φ)=1 and 49% at cos(φ)=0.8 more PV can be installed into the grid.

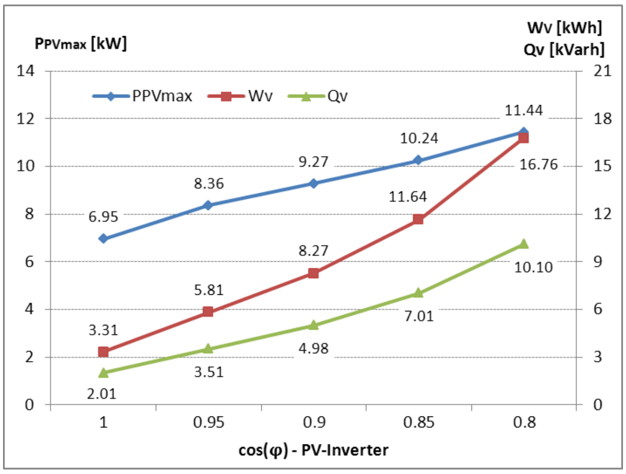

Figure 10: Area of settlement loose built – Tap 0%

ΔU=-5%

An increase of the active power feed-in by the PV inverter can be done up to a cos(φ)=0.8, from that point on the thermal limit of the insulated overhead line (E-A2Y 4x95mm²) is reached. The comparison with Figure 10 shows clearly that at a cos(φ)=1 54% more PV can be fed into the grid at 51% higher power losses (P_{PVmax}=17.65kW, W_V=25.4kWh) than at a cos(φ)=0.8 (P_{PVmax}=11.44kW, W_V=16.76kWh) !

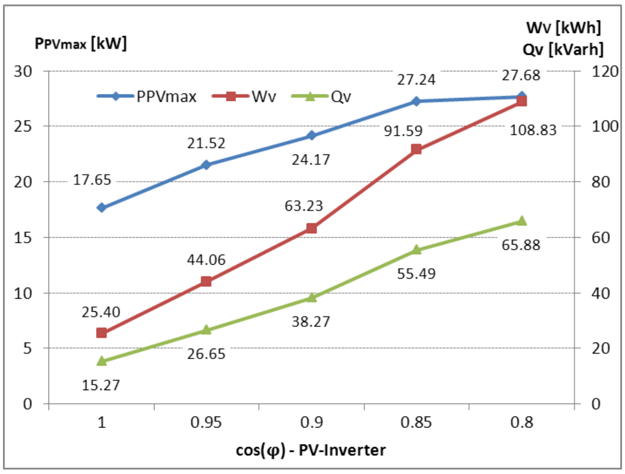

Figure 11: Area of settlement loose built – Tap -5%

ΔU=-10%

An increase of the active power feed-in by the PV inverter can be done up to a cos(φ)=0.95, from that point on the thermal limit of the insulated overhead line (E-A2Y 4x95mm²) is reached.

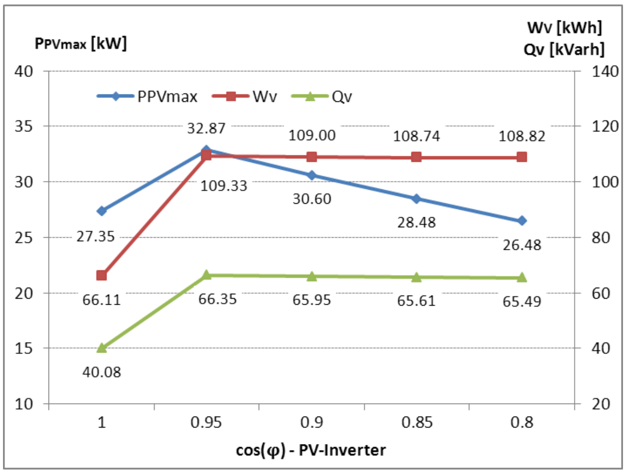

Figure 12: Area of settlement loose built – Tap -10%

ACTIVE POWER REDUCTION

To increase the installed PV power in the network, an automatic active power reduction has been considered after reaching the upper voltage limit. The active power feed-in of the PV inverter has been reduced to 90% ($P=0.9 \cdot P_{max}$) as soon as the upper voltage limit is exceeded. The power reduction is effected on that PV inverter, which is closest to the node with the voltage band violation. A network with an appropriate communication infrastructure is required, so that each PV inverter "knows" all node-voltages. Two limits (outer conductor voltage) are considered U_{max1}=440V, U_{max2}=433V. The cos(φ) of the PV inverter was set to 1! A "voltage control" by the tap changer has not been considered (ΔU=0%).

Findings

Figure 13 shows that by reducing the active power feed-in approximately 23% more PV power can be installed in all examined networks.

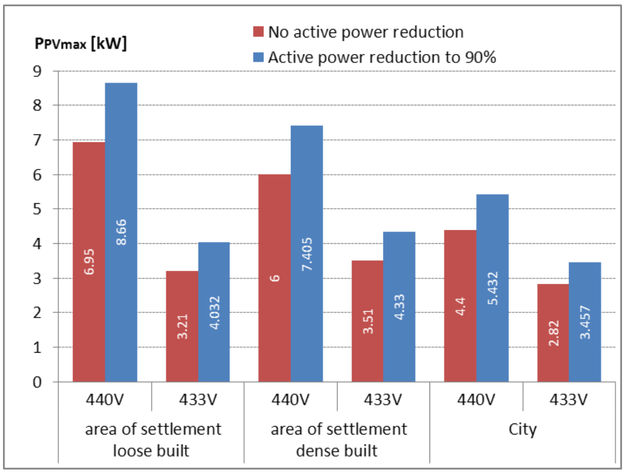

Figure 13: Active power reduction

SUMMARY

Figure 1 to Figure 12 show that by changing the cos(φ) of the PV inverter an enormous increase of installed PV capacity is possible. However, a high dependency on the supply voltage is given, so a rigid cos(φ) setting at the PV inverters with voltage reduction by the use of regulated distribution transformers leads to higher power losses and thermal bottlenecks!

Figure 3, Figure 7 and Figure 11 show that a voltage reduction of 5% is quite enough and a further reduction requires not only a regulatable local power transformer with a larger control range but also network expansion (larger cross-sections, double cable, …)

Another effective measure to increase the installed PV power is to reduce the active power after reaching the upper voltage limit.

REFERENCES

[1] F. Zeilinger, 2012, "Modell für hochauflösende synthetische Haushaltslastprofile" *http://publik.tuwien.ac.at/files/PubDat_209150.pdf*