ESF II project of the University of West Bohemia in Pilsen

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Voltage regulation in distribution system

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research,
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MINISTRY OF EDUCATION, YOUTH AND SPORTS

ZÁPADOČESKÁ UNIVERZITA V PLZNI

Voltage regulation in distribution system

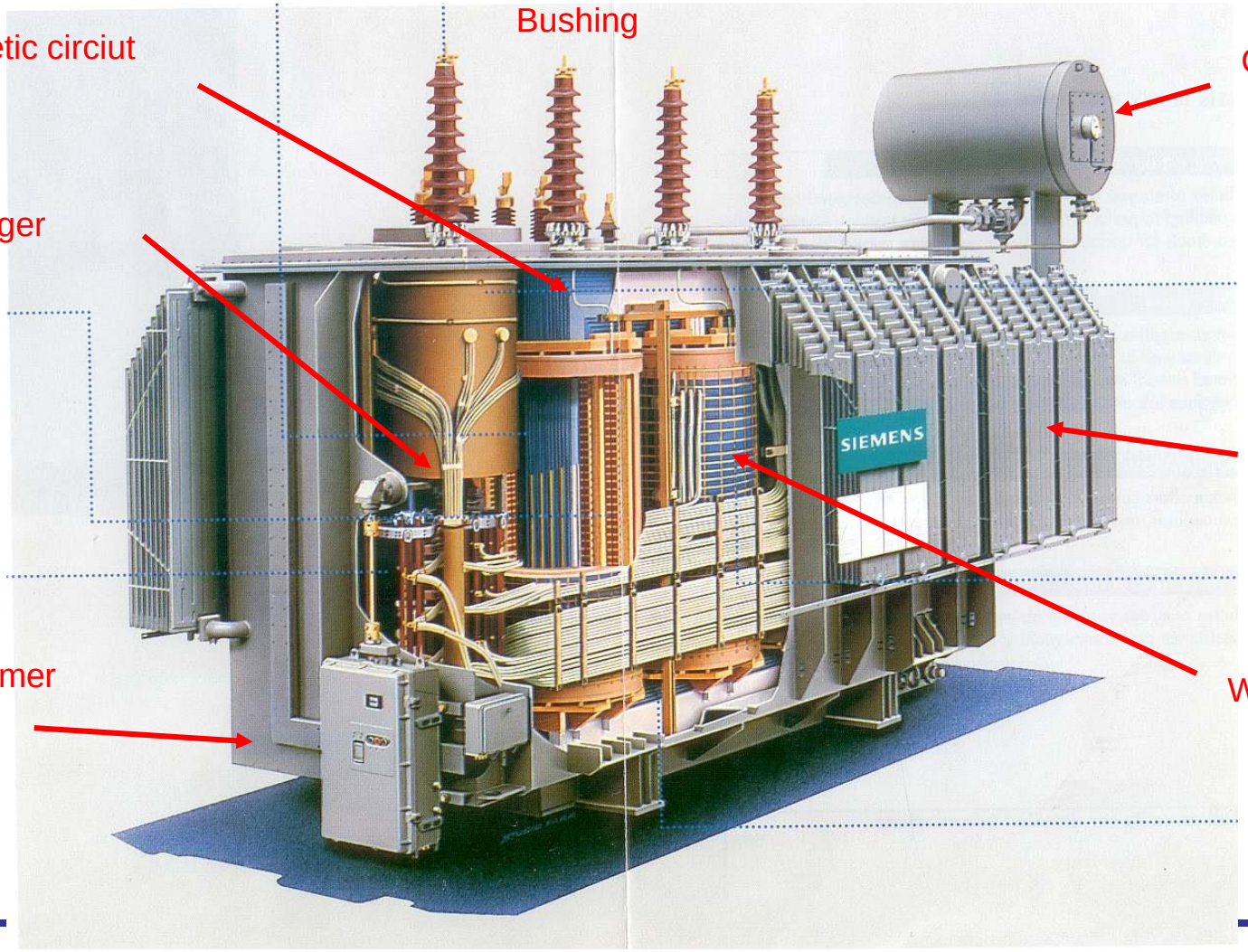
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Department of Power Engineering

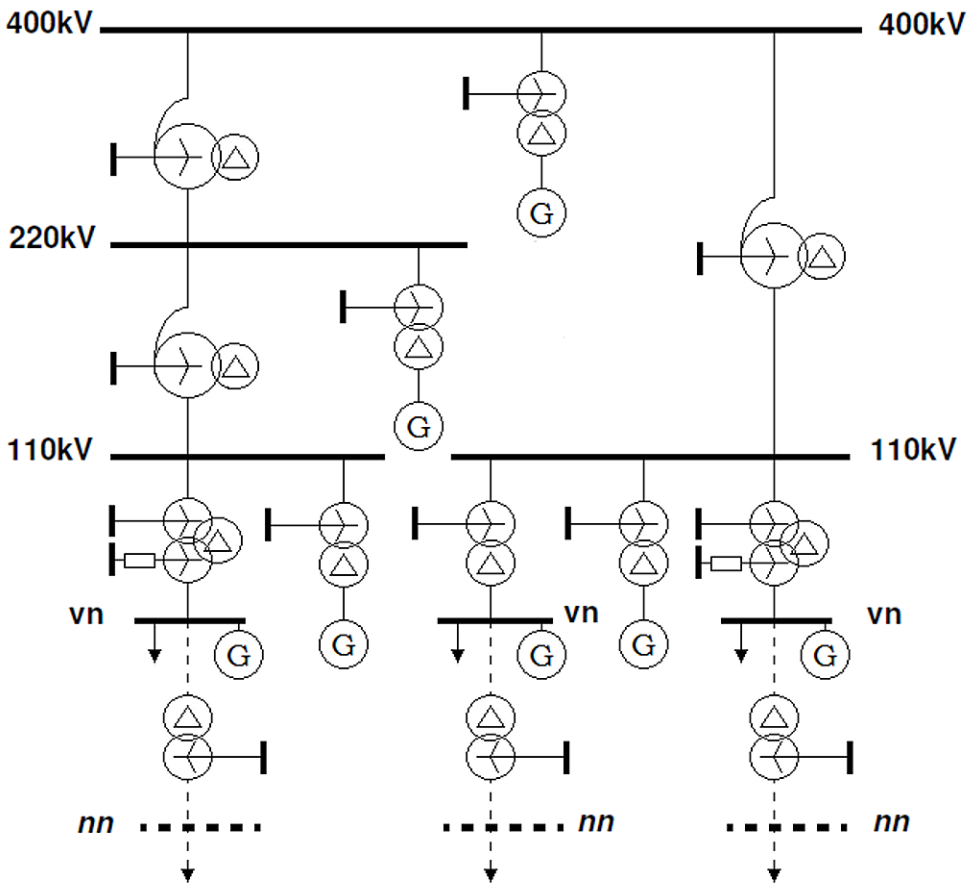
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Transformer 110 kV / MV

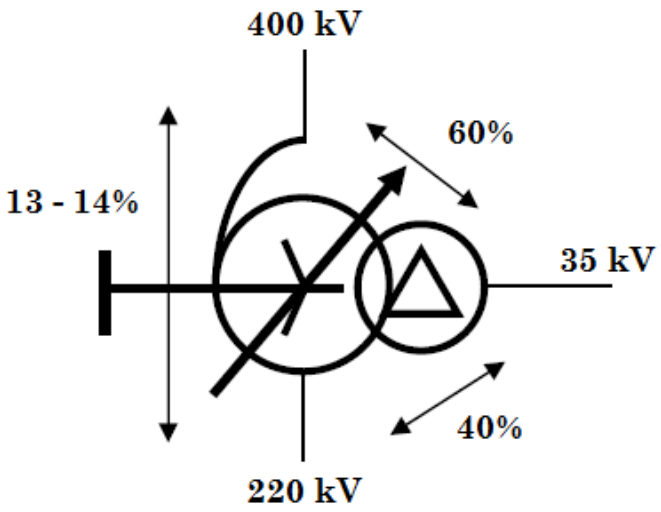


Transformer concept of Czech power system

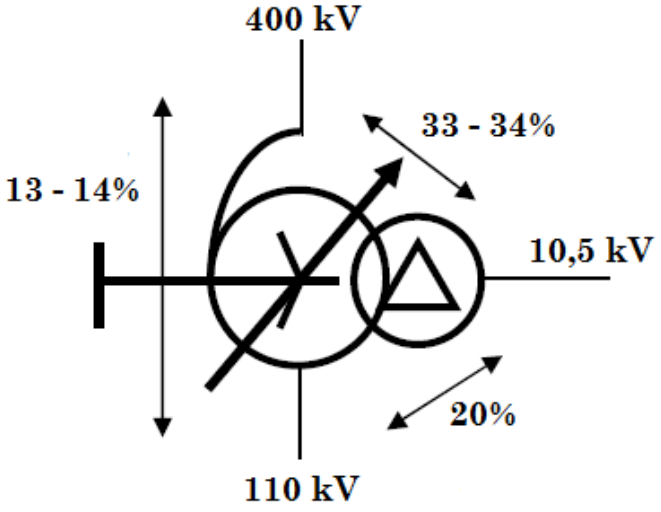


Transformer concept of Czech power system

400/220 kV transformers

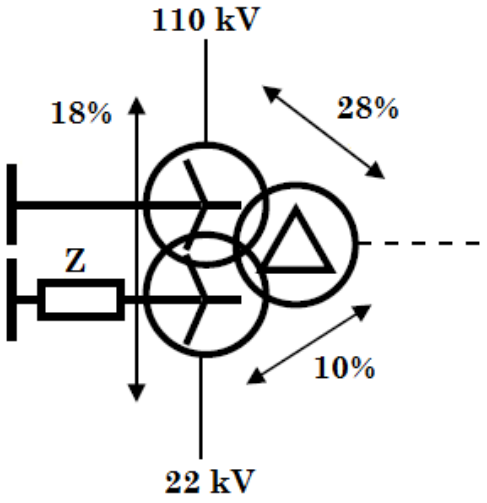


400 (220)/110 kV transformers

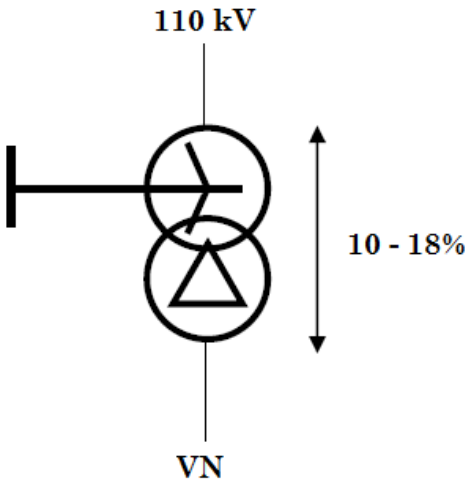


Transformer concept of Czech power system

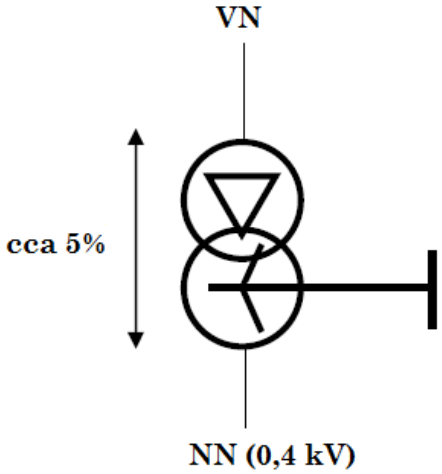
110/22 kV transformers



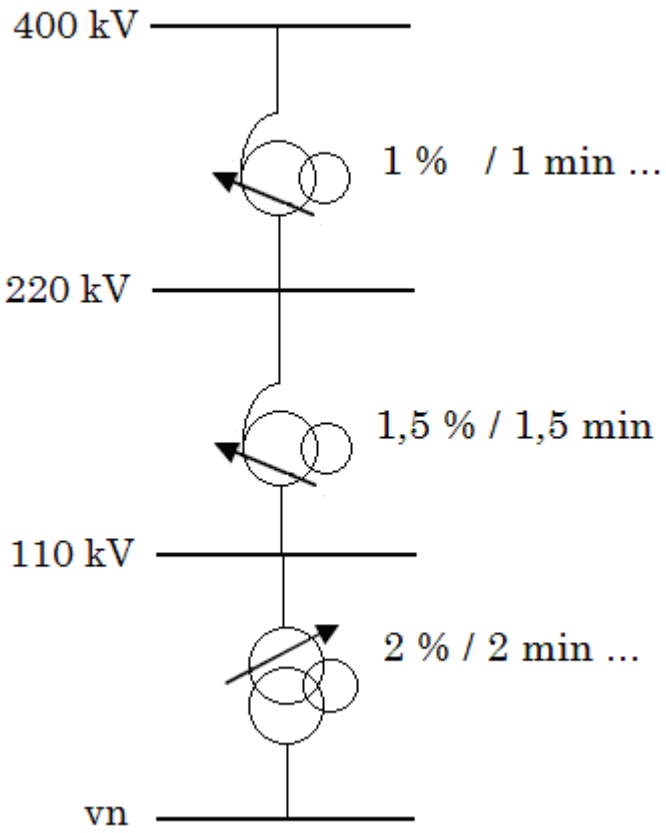
Transformers of industrial consumers



Distrubution transformers



Transformer concept of Czech power system



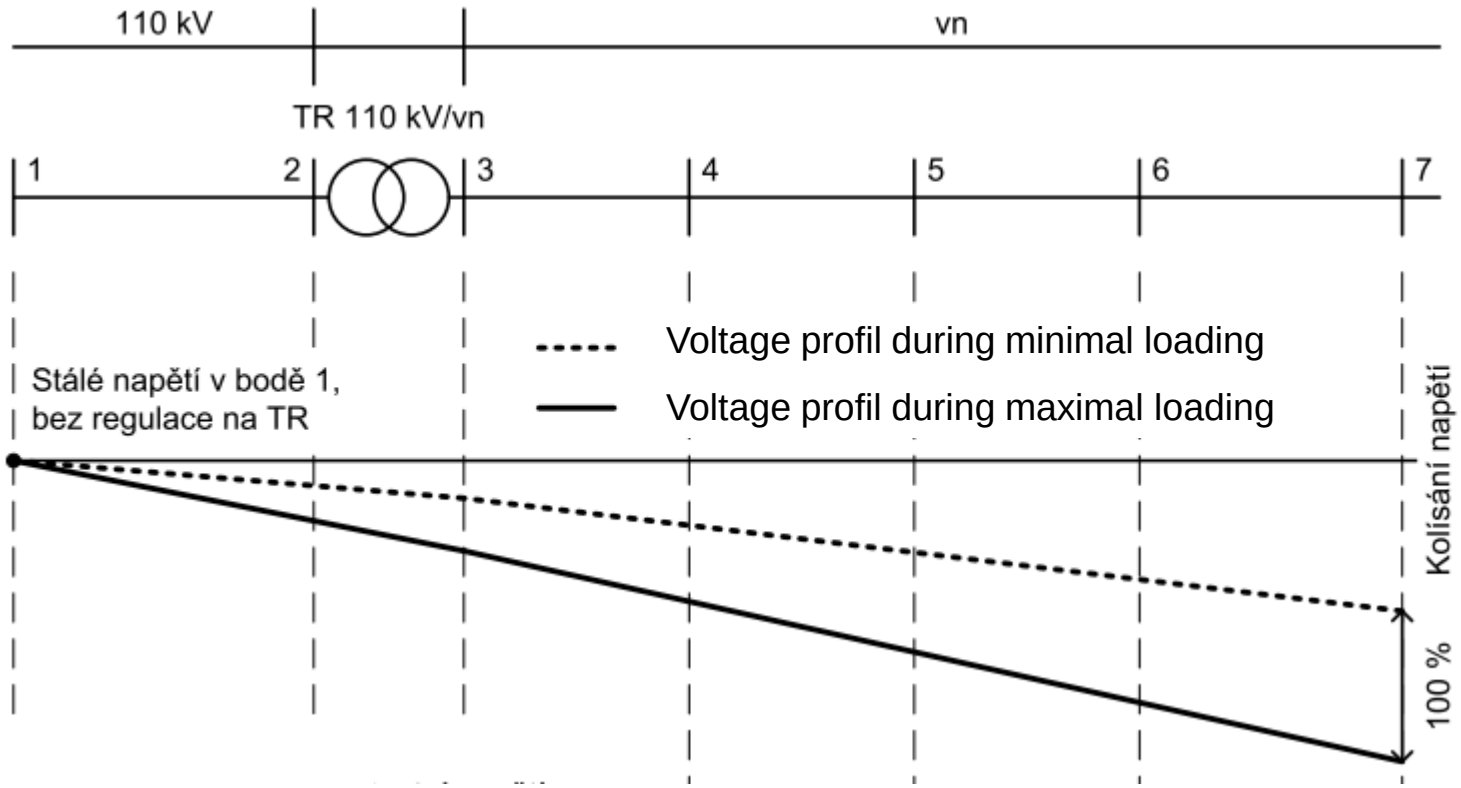
Voltage regulation step and timing

Trafo 110 kV ± 8x2% / 23 kV

Principal tap – ratio 110 / 23 kV

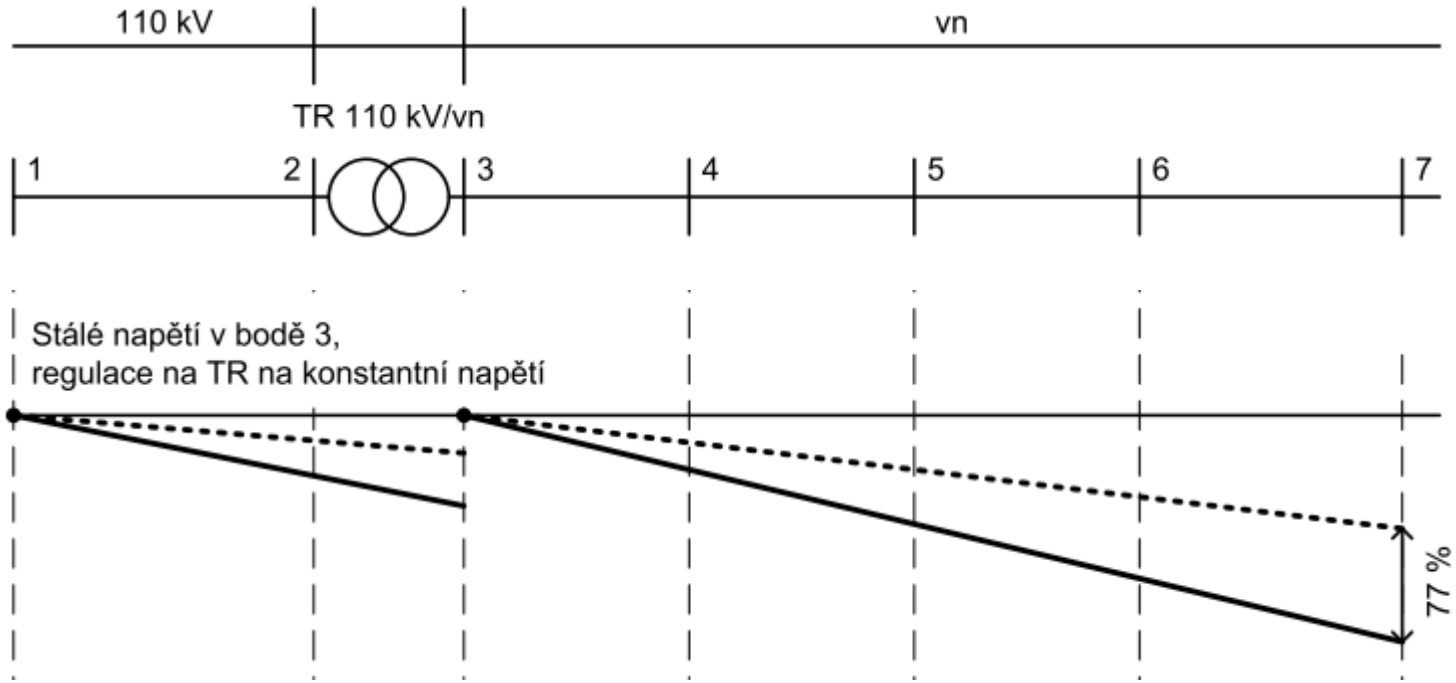
Voltage regulation in DS

Without any voltage regulation on TR 110 kV/MV



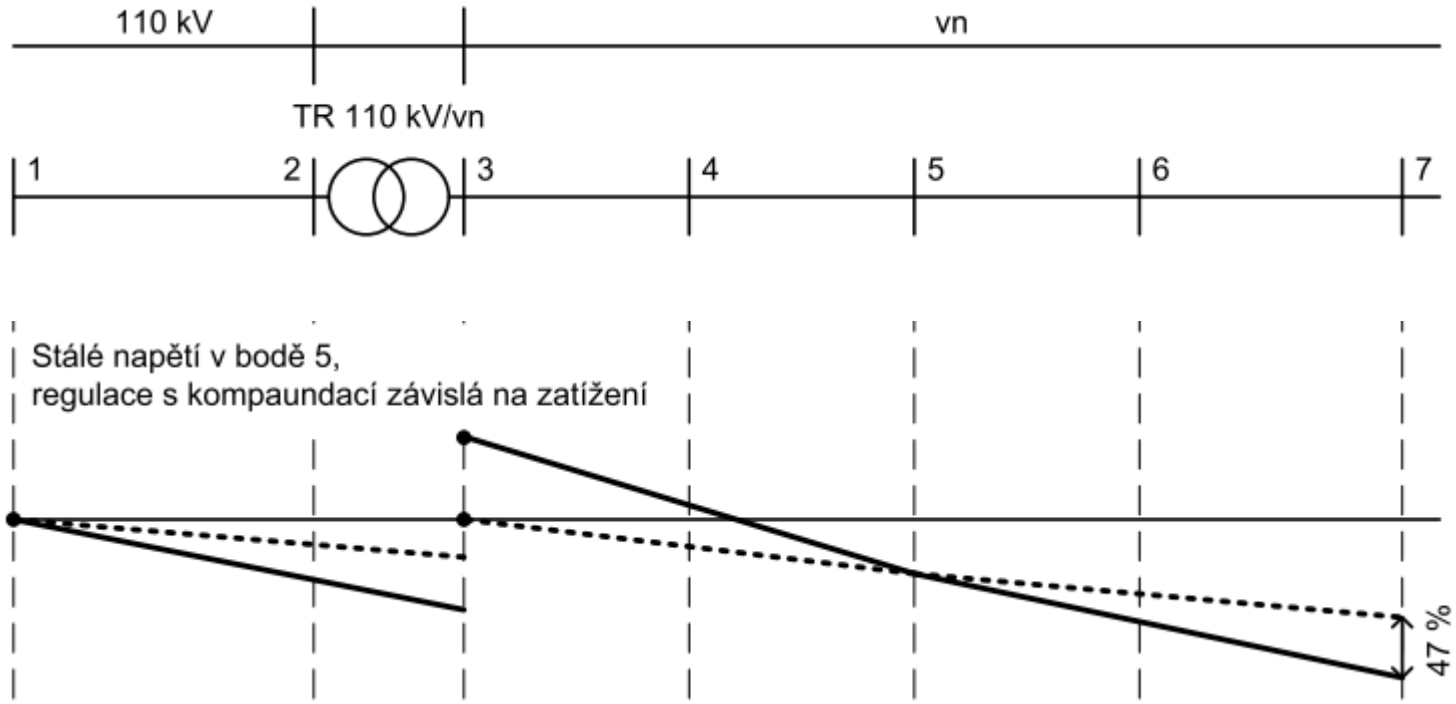
Voltage regulation in DS

Voltage regulation – constant voltage in MV substation (bus 3)
- Constant voltage 23,1 kV, i.e. 105 % Un



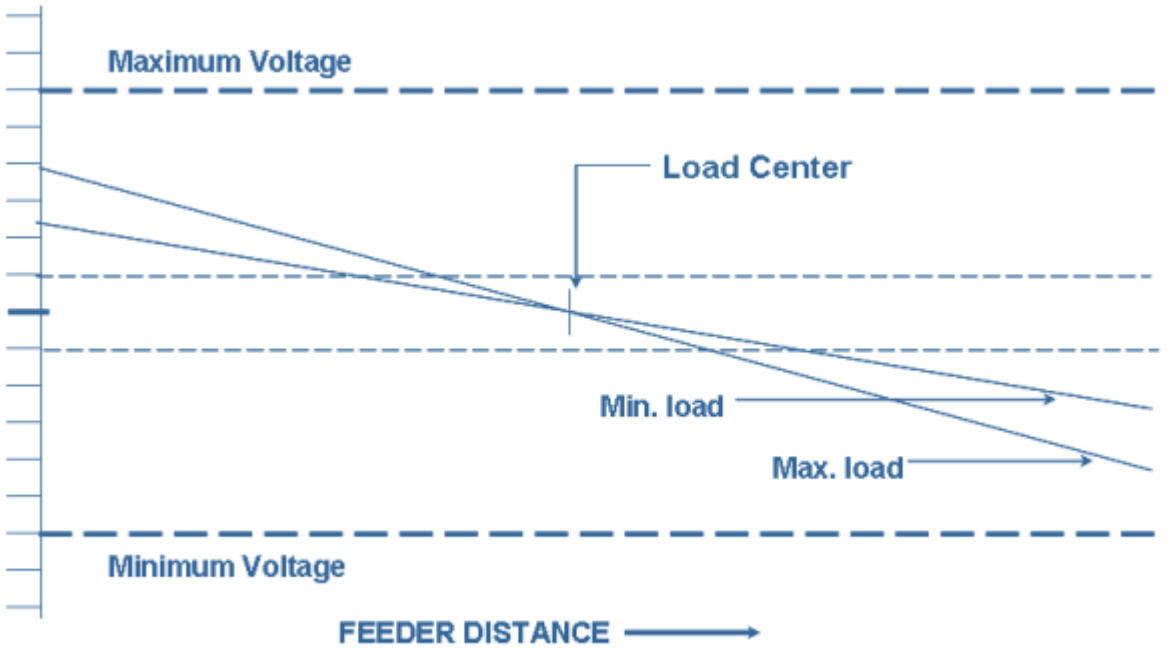
Voltage regulation in DS

Voltage regulation – variable voltage in MV substation (bus 3) in dependance on network loading (line drop compensation)



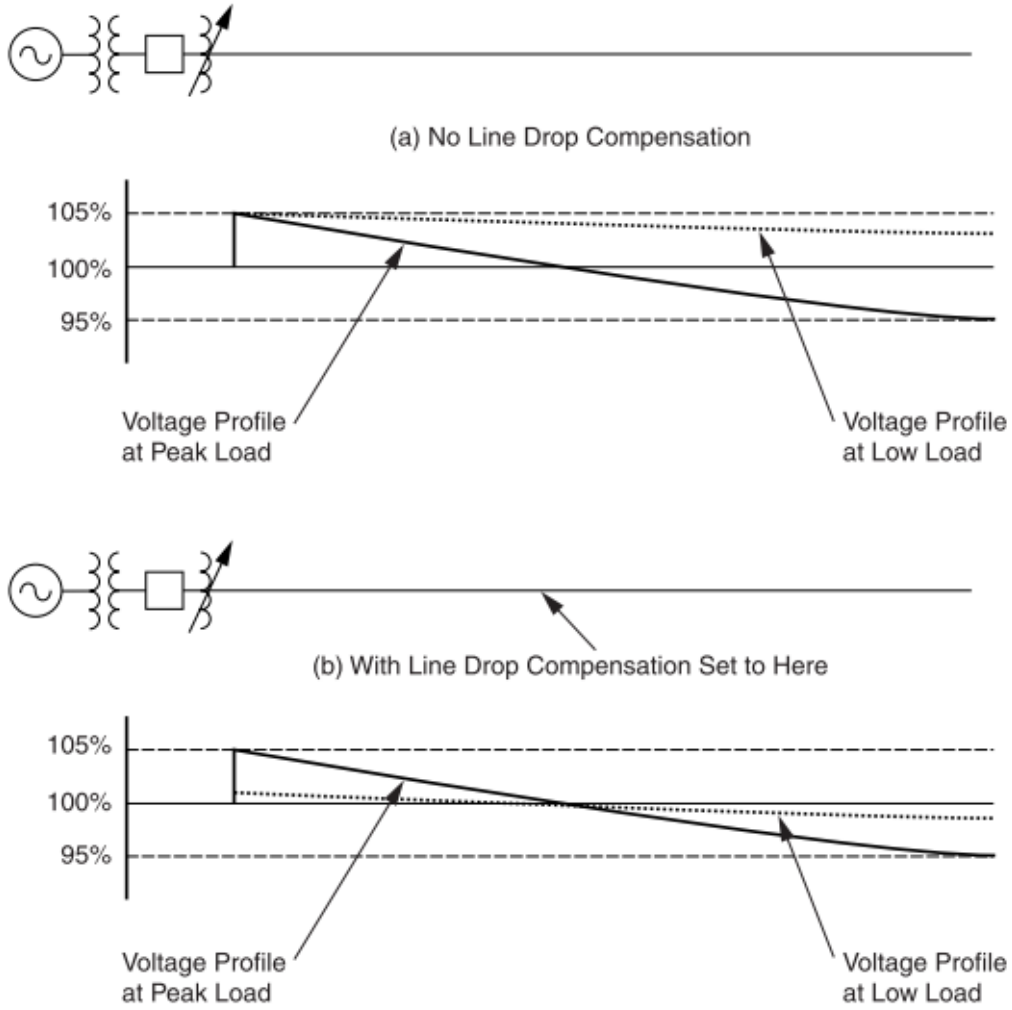
Voltage regulation in DS

Voltage regulation – variable voltage in MV substation (bus 3) in dependance on network loading (line drop compensation)



Voltage regulation in DS

Effect of line drop compensation on the voltage profile.



Voltage regulation in DS

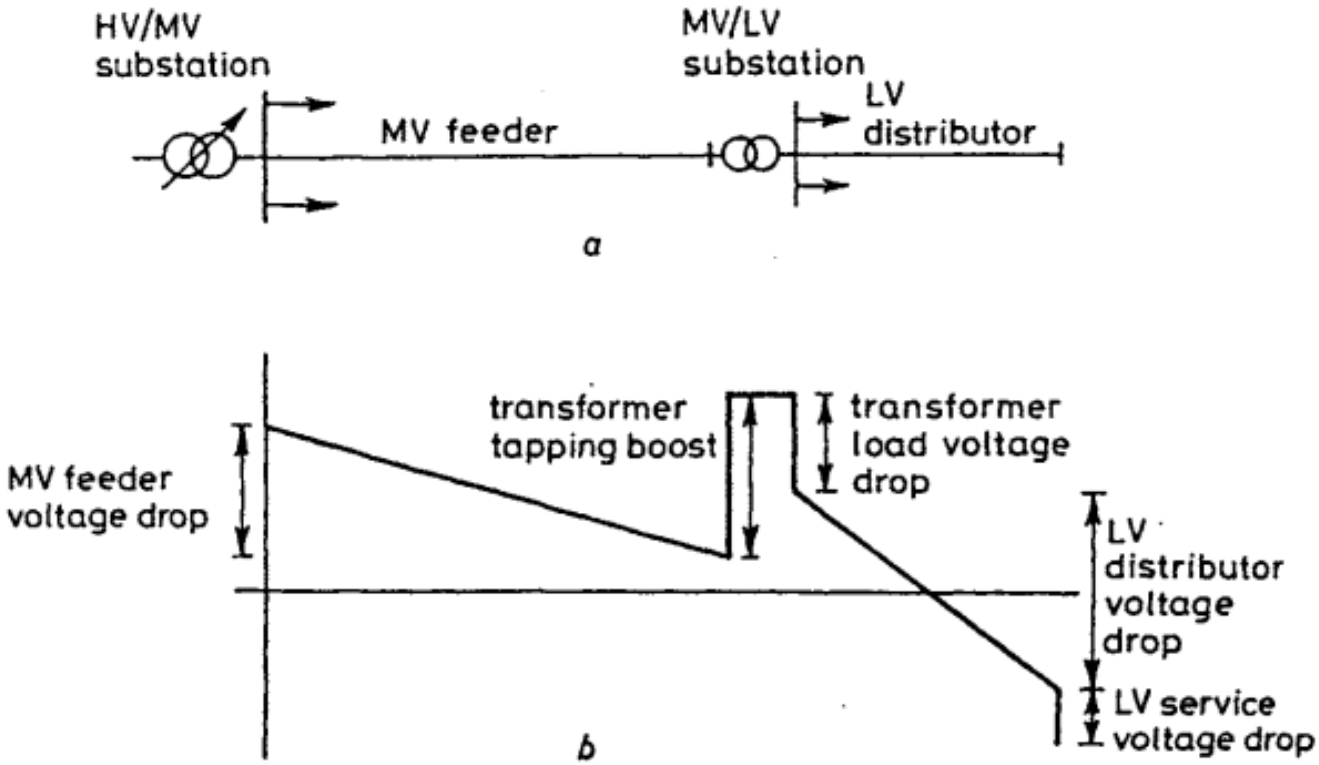
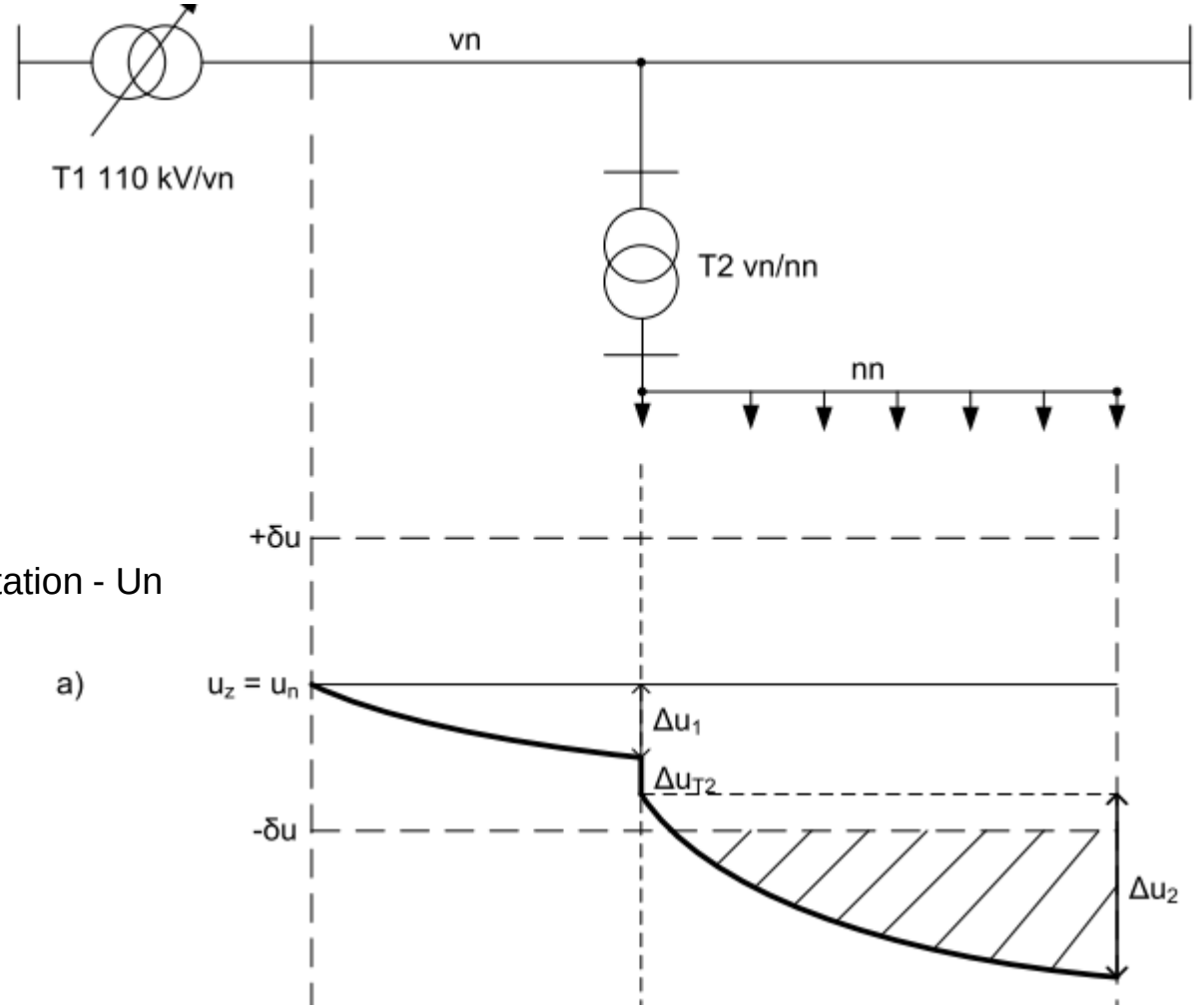


Figure 13.3 Voltage regulation on MV and LV networks

a Simplified distribution network diagram
b MV- and LV-network voltage variation

Voltage regulation in DS

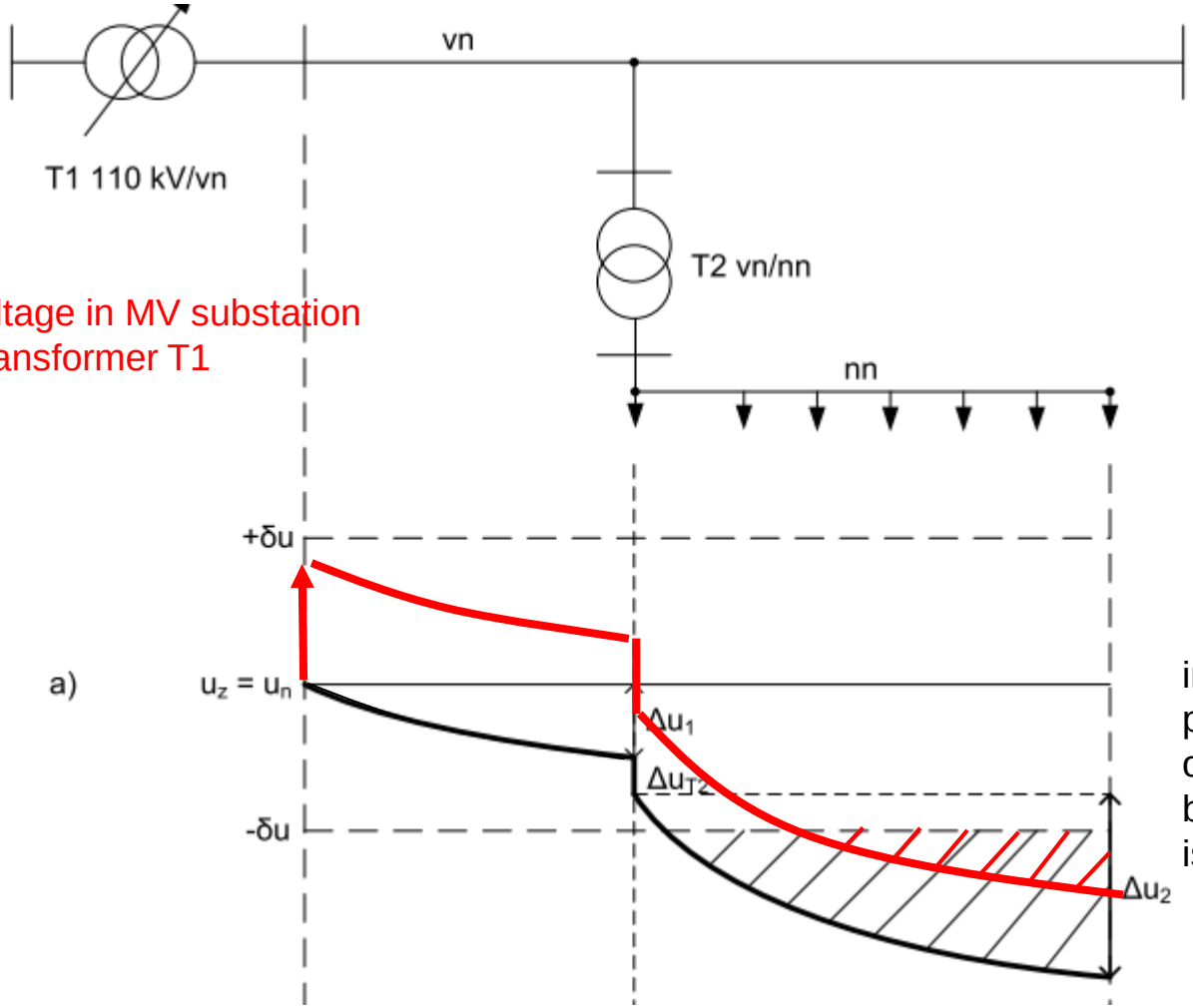


In MV substation - Un

in LV network
is undervoltage

Voltage regulation in DS

To increase voltage in MV substation
by means of transformer T1

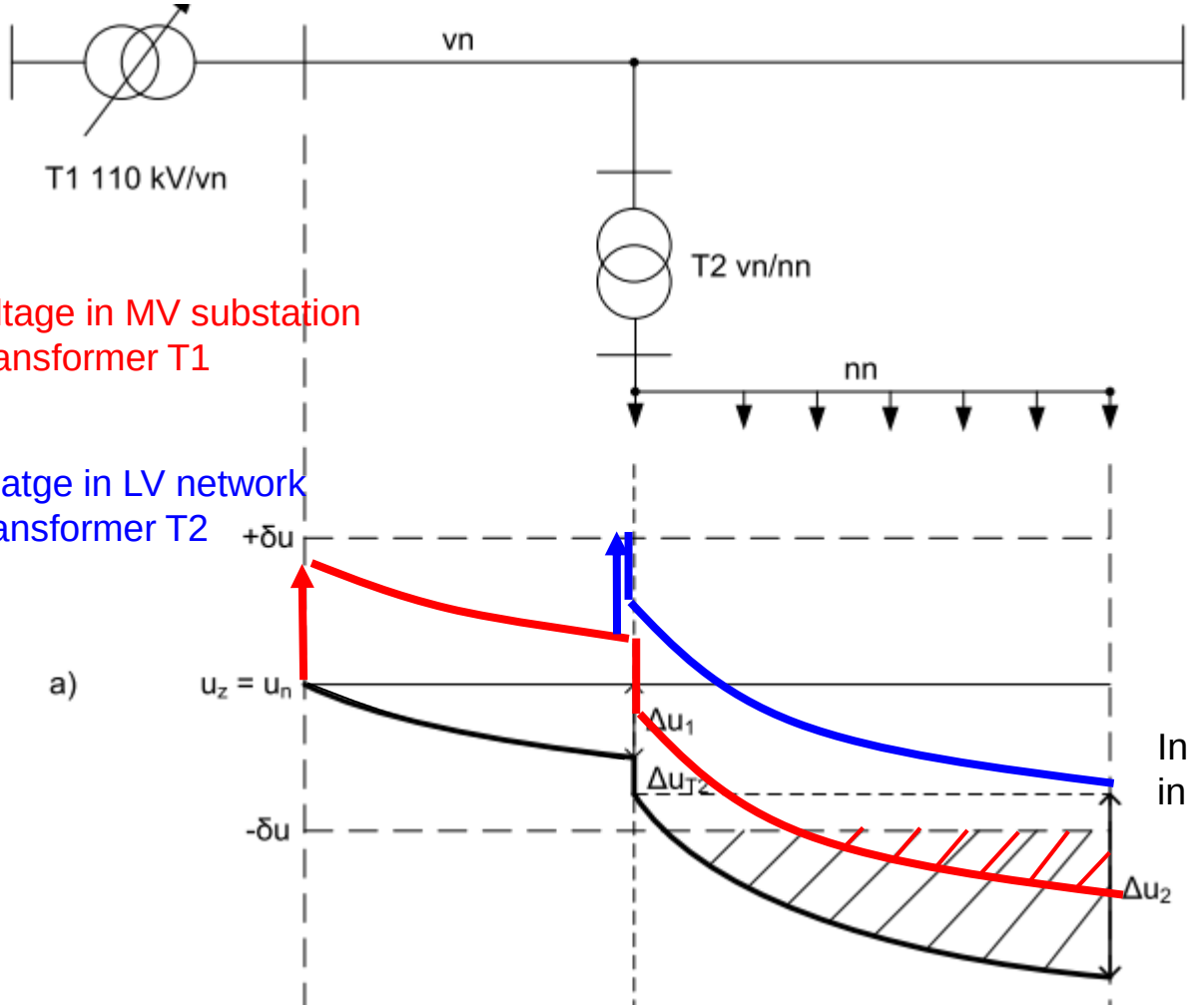


in LV network
partial improvement
of voltage conditions,
but in some parts
is still undervoltage

Voltage regulation in DS

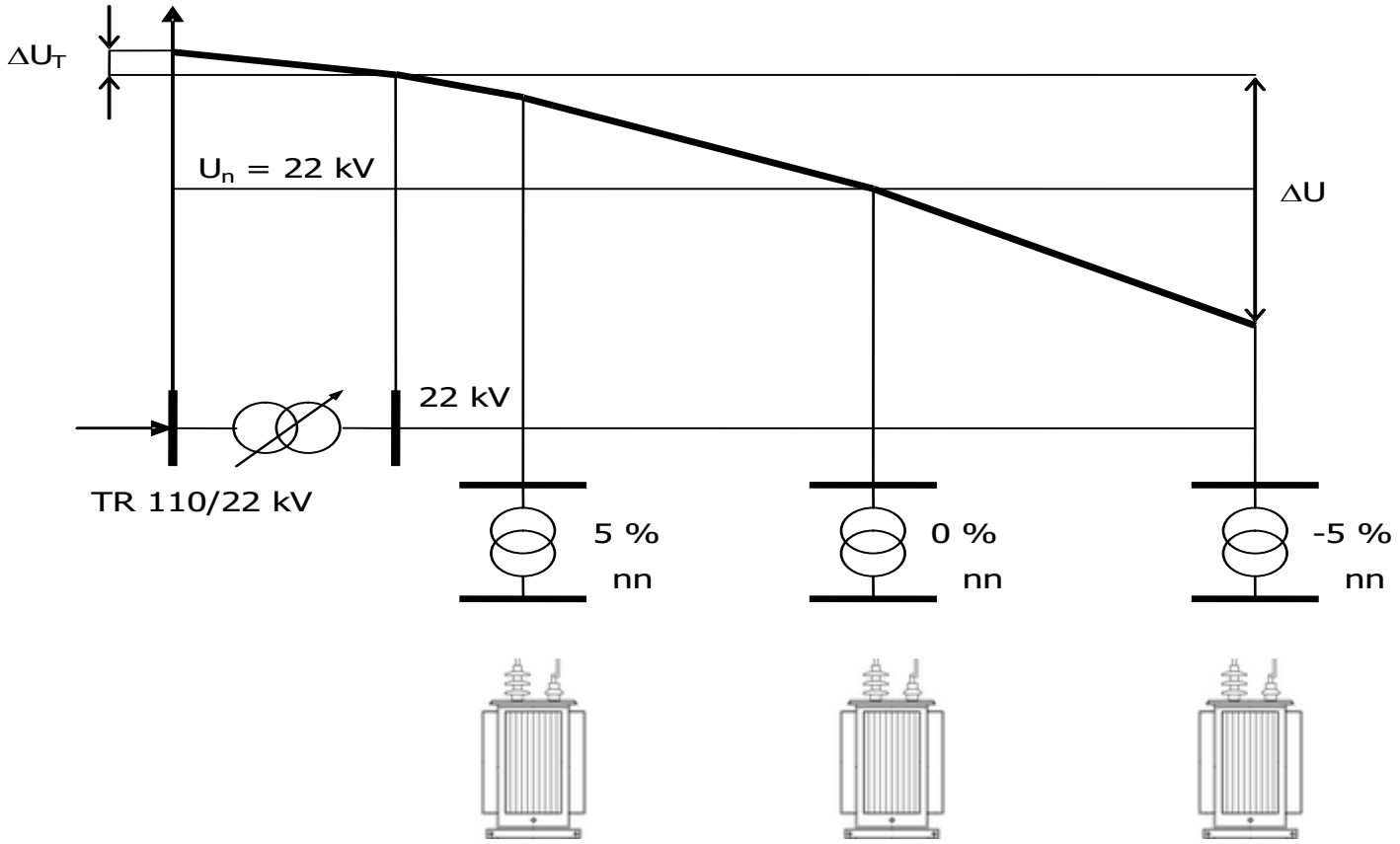
To increase voltage in MV substation by means of transformer T1

To increase volatge in LV network by means of transformer T2



In LV network is voltage in permissible band - OK

Voltage regulation in DS

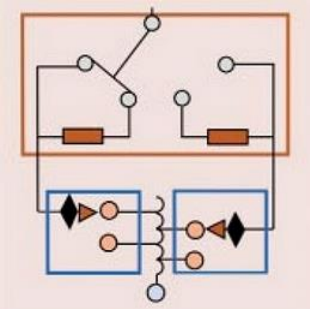


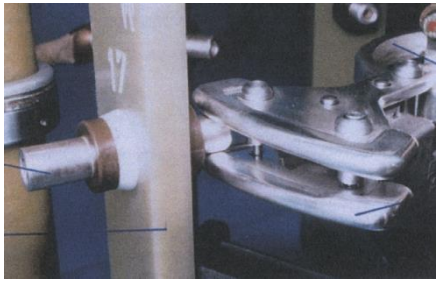
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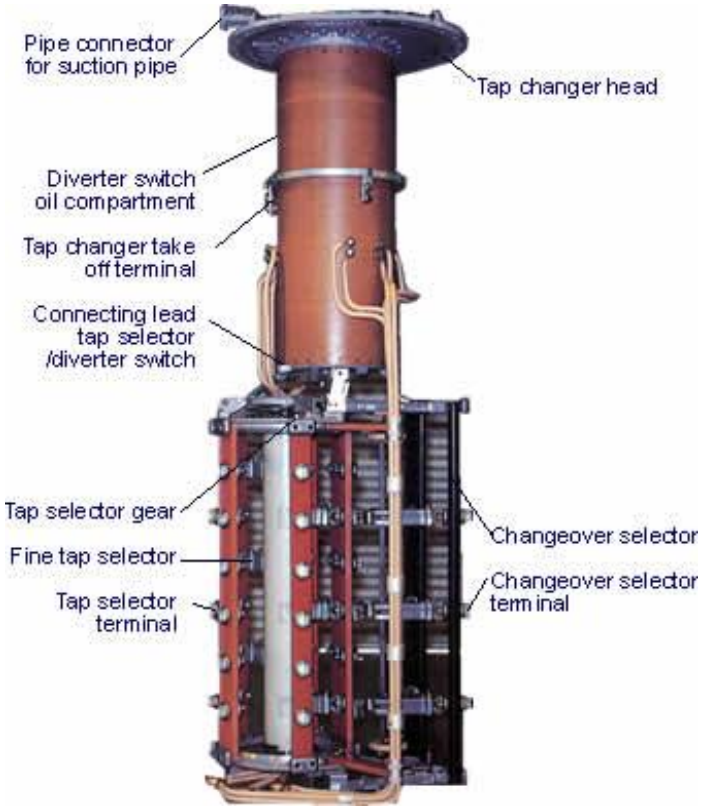
Voltage regulation

OLTC (on-load tap changer) transformers

- manipulation with tap changer without transformer switch-off
- EHV/HV, 110 kV/MV
- rarely MV/LV – cca 3 times expensive !







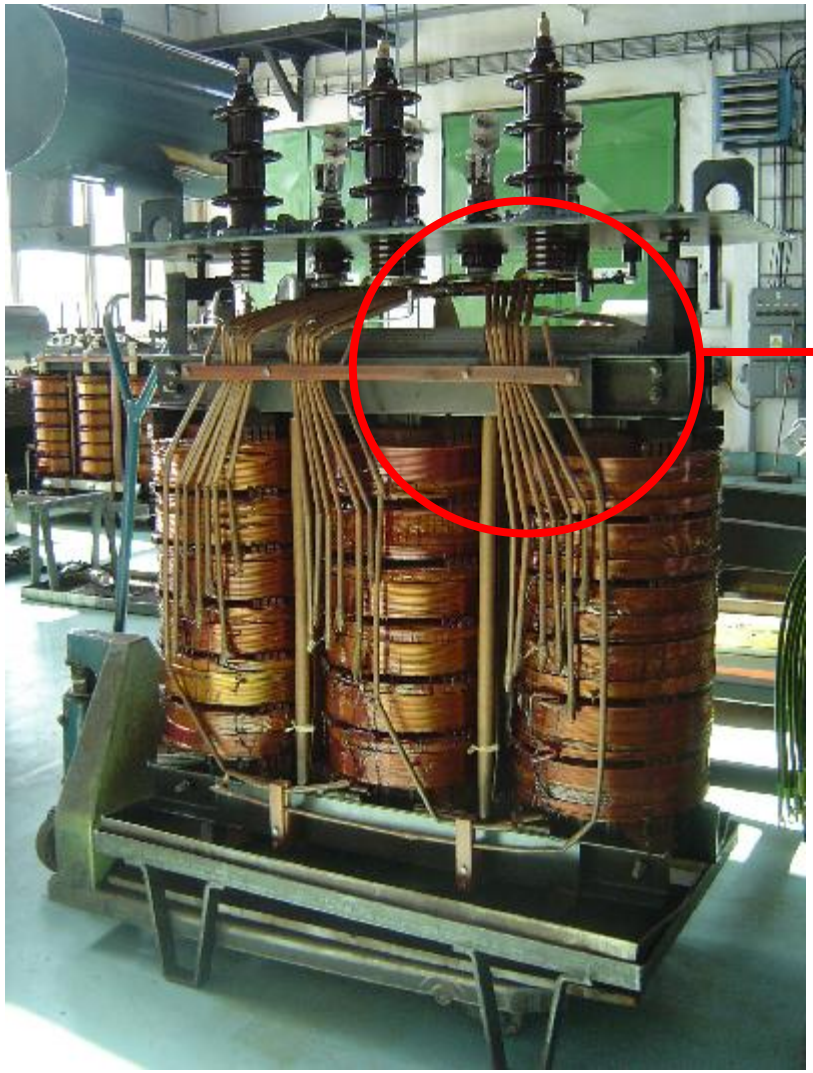
Off-load tap changer transformers

- manipulation with tap changer only if transformer is switch-off
- MV/MV and MV/LV

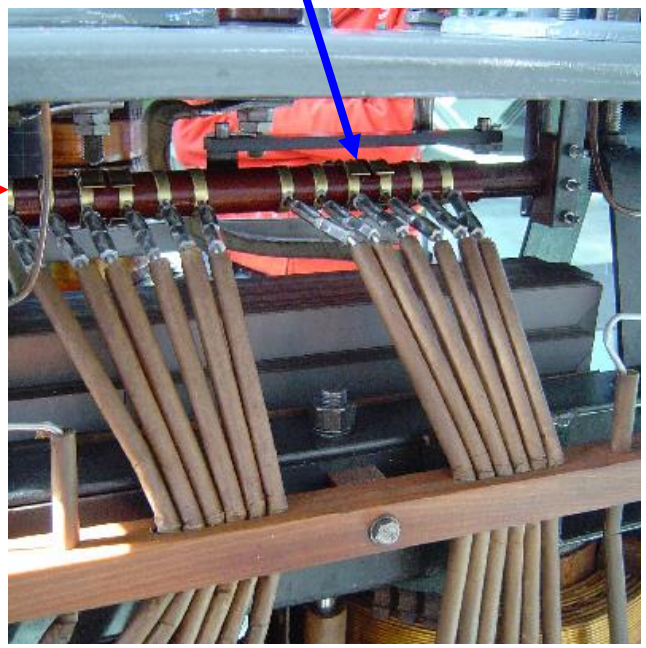


Transformers MV/LV

Tap changer



Tap selector



Transformers MV/LV

Tap setting on distribution transformers





Tap selector
external part

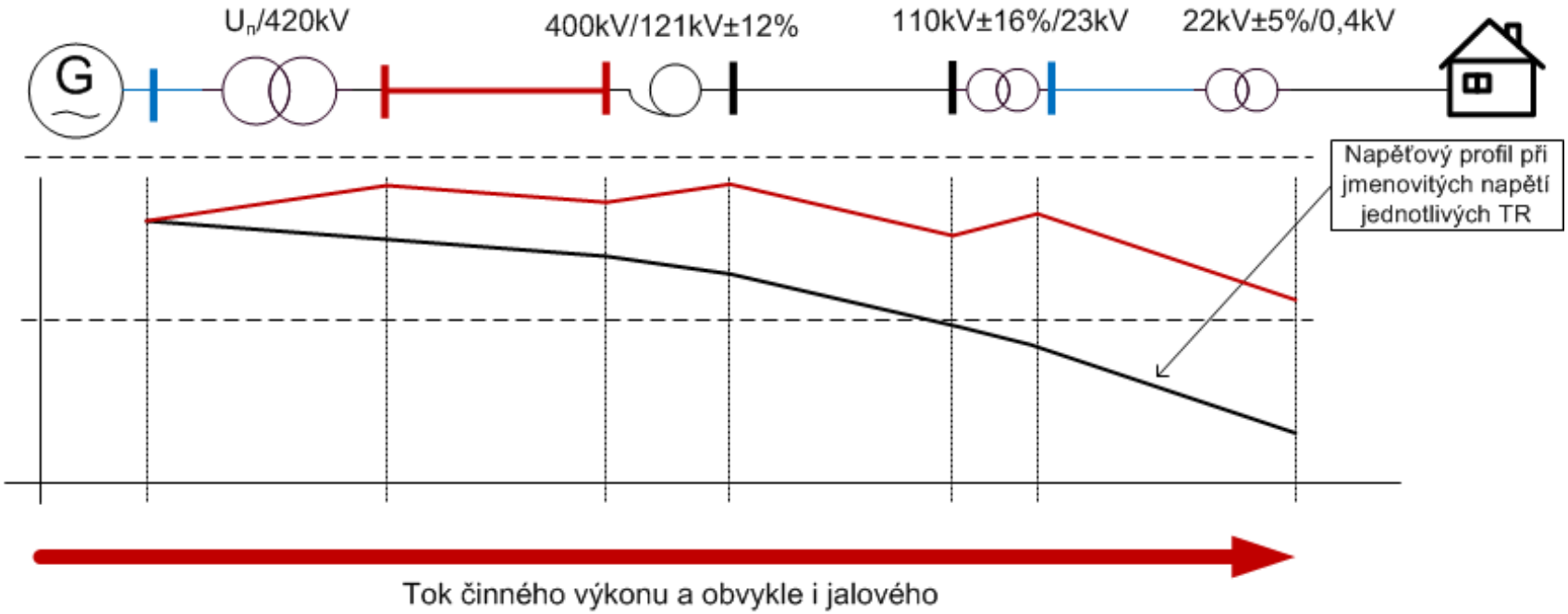


Older distribution transformers



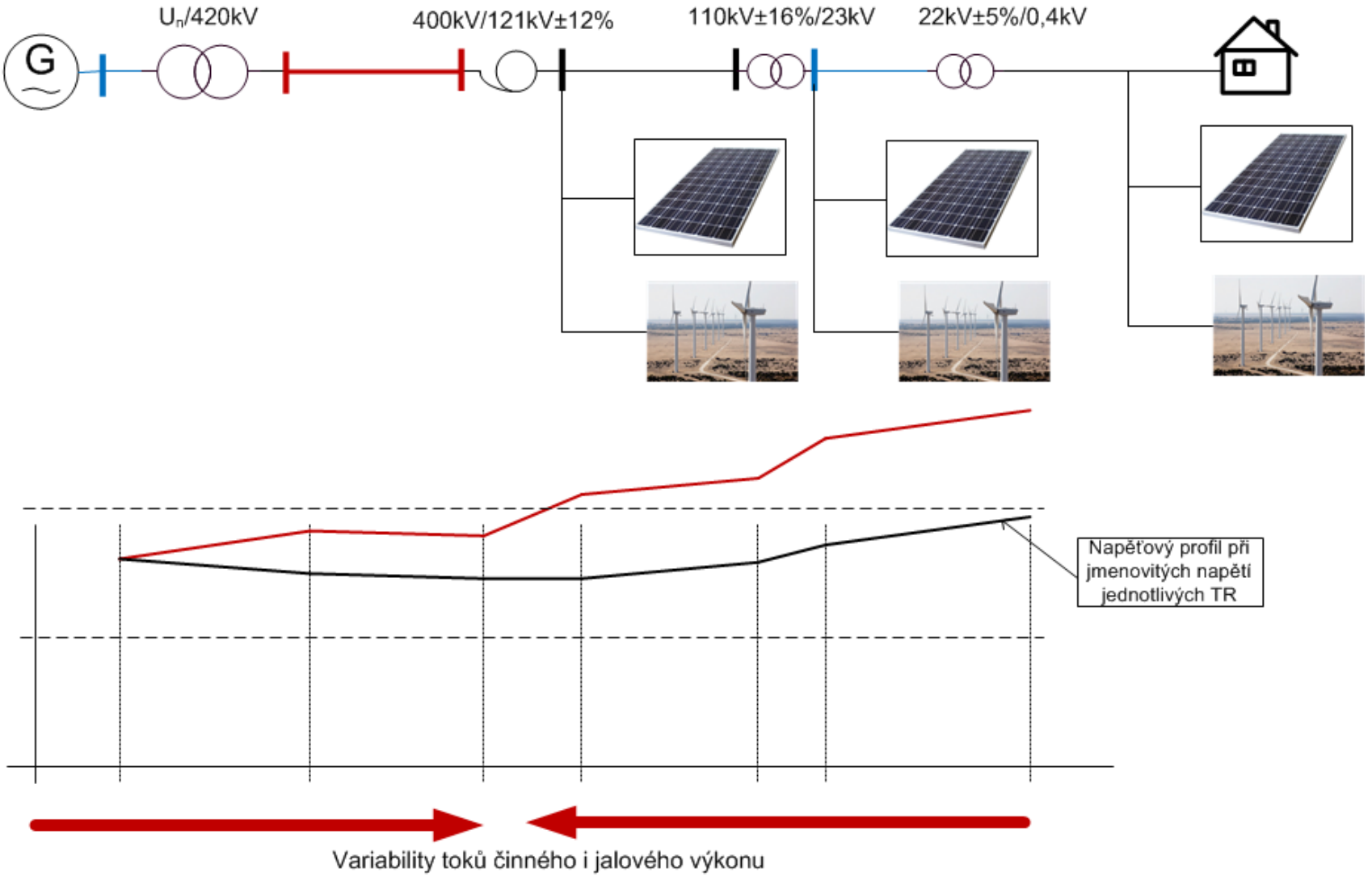
Effect of distributed generation on voltage

Voltage profile with tap-changing transformers (red) and without (black)



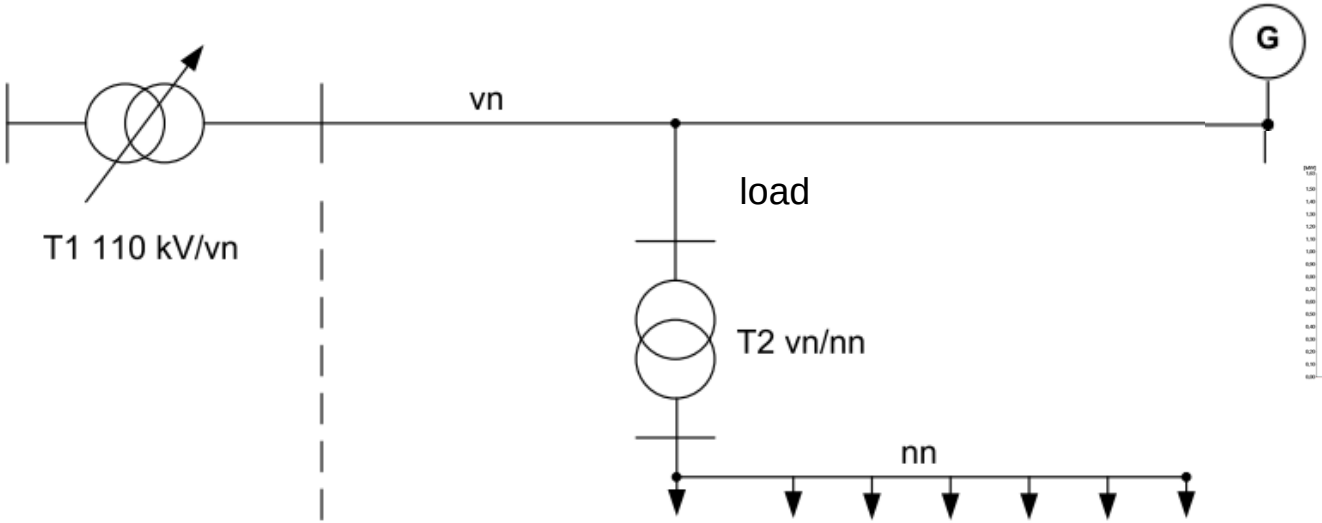
Direction of active power flow and usually also reactive power flow

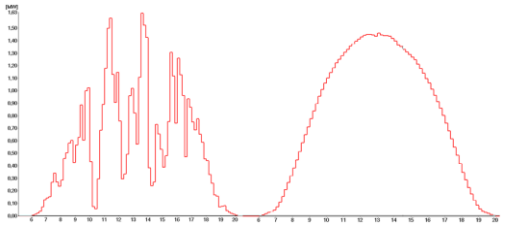
Effect of distributed generation on voltage



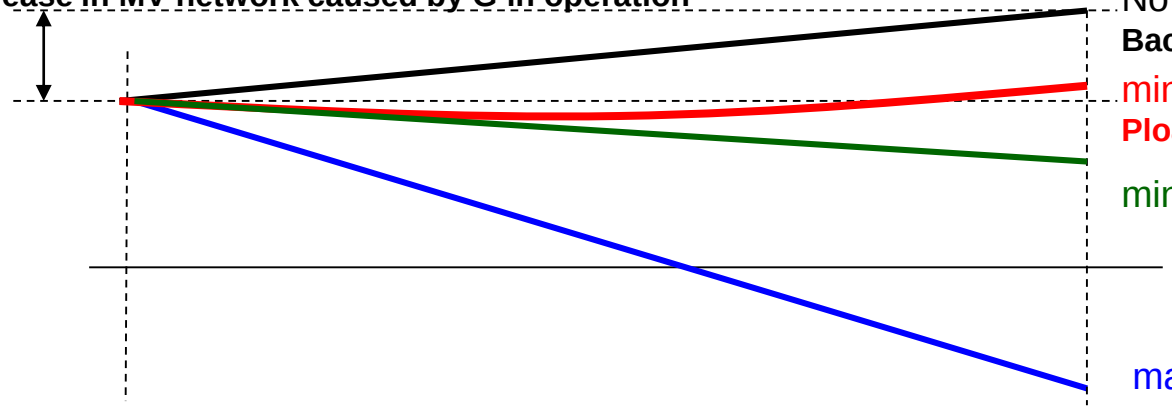
Variability of active and reactive power flows

Effect of distributed generation on voltage





Voltage increase in MV network caused by G in operation
max. 2% Un



No load, G in operation
Back flow into upstream network

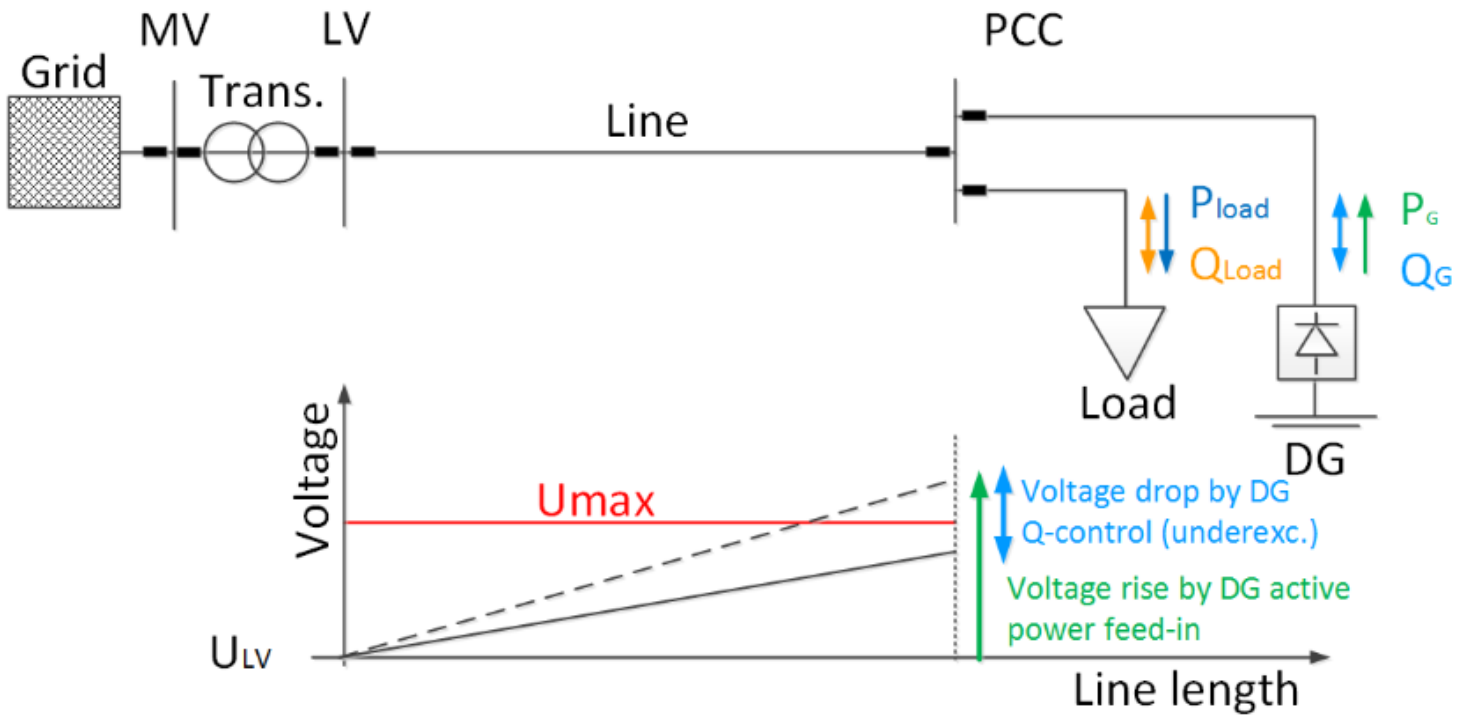
min. load, G in operation
Pload < Pgen ⇒ back flow

min. load, G out of operation

max. load, G out of operation

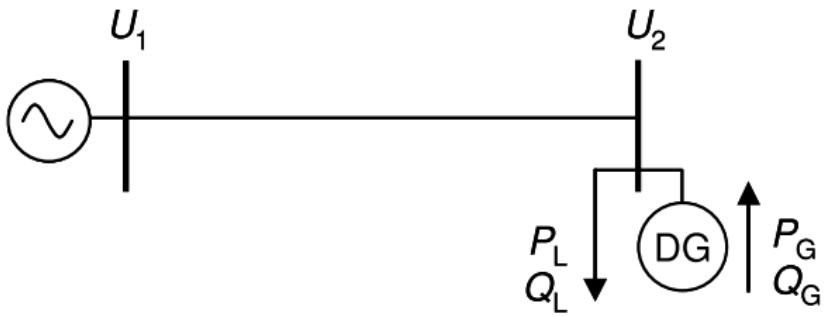
Similar situation in LV networks – voltage regulation more complicated

Effect of distributed generation on voltage



Voltage support of distributed generation

Voltage support by Q control



$$\Delta U = U_1 - U_2 \approx \frac{R(P_L - P_G) + X(Q_L - (\pm Q_G))}{U_2}$$

$+Q_G$ DG injects reactive power to system
$-Q_G$ DG absorbs reactive power from system $\rightarrow$ decrease of ΔU

Q(U) control mode of DG

