Power Plants
A1M15ENY

Lecture No. 2

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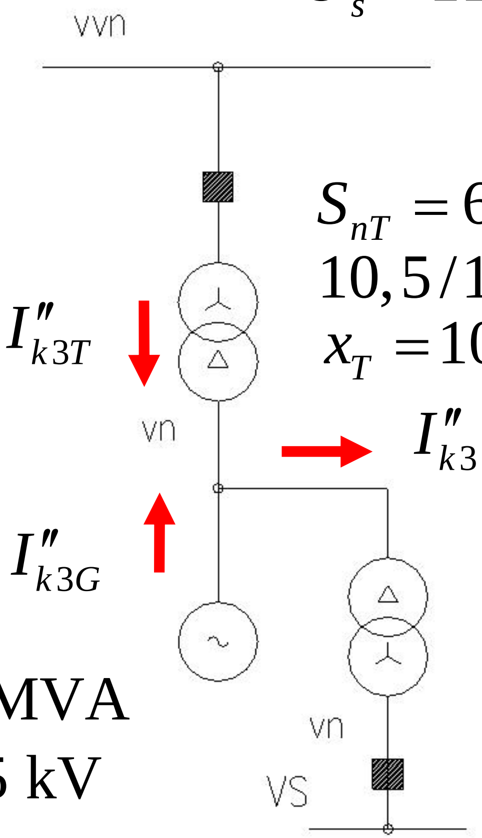
Example No. 1: Compute initial three phase short circuit current I”k3 in auxiliary. Neglect the contribution of the current of motoric load, take into consideration HV system as an infinity bus

$$U_s = 117 \text{ kV}$$



$$S_{nT} = 63 \text{ MVA}$$
$$10{,}5/121 \text{ kV}$$
$$x_T = 10\%$$

$$S_{nG} = 63 \text{ MVA}$$
$$U_G = 10{,}5 \text{ kV}$$
$$x''_d = 15\%$$

$$I_V = \frac{S_V}{U_V.\sqrt{3}} = \frac{63}{10{,}5.\sqrt{3}} = 3{,}46 \text{ kA}$$

$$I''_{k3T} = \frac{U_s}{U_V}.p.\frac{1}{x_T}.I_V =$$

$$= \frac{117}{10{,}5}.\frac{10{,}5}{121}.\frac{1}{0{,}1}.3{,}46 \text{ kA}$$

$$= 33{,}4 \text{ kA}$$

$$I''_{k3G} = \frac{1}{x''_d}.I_V = \frac{1}{0{,}15}.3{,}46 \text{ kA} = 23{,}1 \text{ kA}$$

$$I''_{k3} = I''_{k3T} + I''_{k3G} = 33{,}4 + 23{,}1 = 56{,}5 \text{ kA}$$

Initial short circuit current 56,5 kA in auxiliary is extremely high if we take into consideration normal operating current, in this case hundreds of amperes!

Example No. 2: Compute earth connection fault current in auxiliary system. Total length of the MV cable network is 20 km. Cable type used is 1 x 3 x 6-AYKCY 70/16. Auxiliary network is operated as IT(r) 6,3 kV

The sequence currents are equal in the case of single phase fault:

$$\hat{I}_1 = \hat{I}_2 = \hat{I}_0$$

Longitudial parameters are neglected, we take into consideration only capacitive susceptance

$$\hat{I}_1 = \frac{\hat{U}_1}{-\frac{j}{\omega.C_{/l}.l}} = \frac{\hat{U}_A}{-\frac{j}{\omega.C_{/l}.l}} = j.\omega.C_{/l}.l.\hat{U}_A \qquad \hat{I}_A = \hat{I}_1 + \hat{I}_2 + \hat{I}_0 = 3.\hat{I}_1$$

Correspondning fault current for the capacity $C_{/l} = 0,85.10^{-6}\ \mathrm{F.km^{-1}}$

$$I_A = 3.\omega.C_{/l}.l.U_A = \sqrt{3}.\omega.C_{/l}.l.U = \sqrt{3}.100.\pi.0,85.10^{-6}.20.6,3.10^3\ \mathrm{A}$$

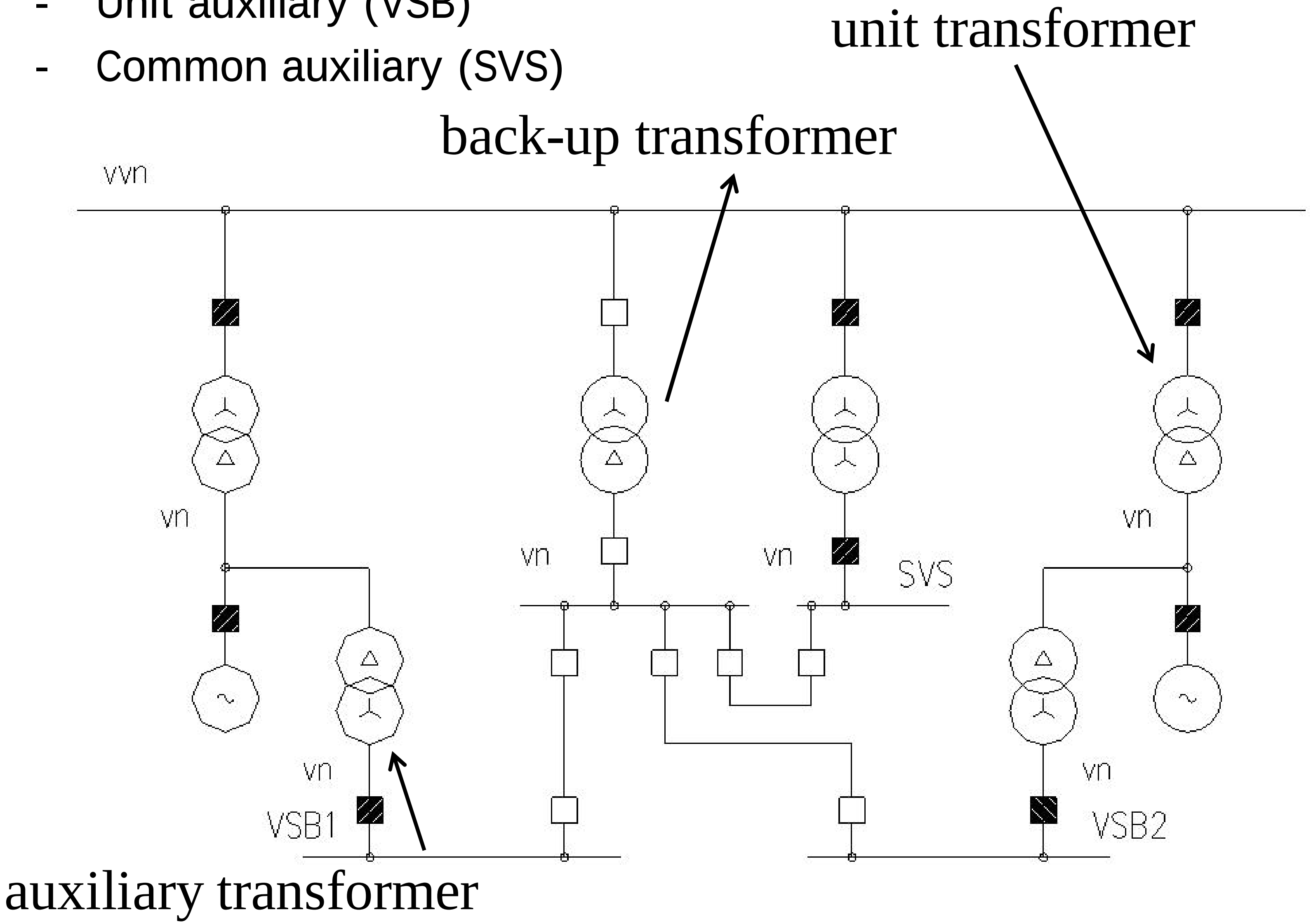
$$I_A = 58,3\ \mathrm{A}$$

This earth connection current can be dangerous for the generator! Manufacturers are commonly declaring cca 10 A as a safe value.

Auxiliary Topology

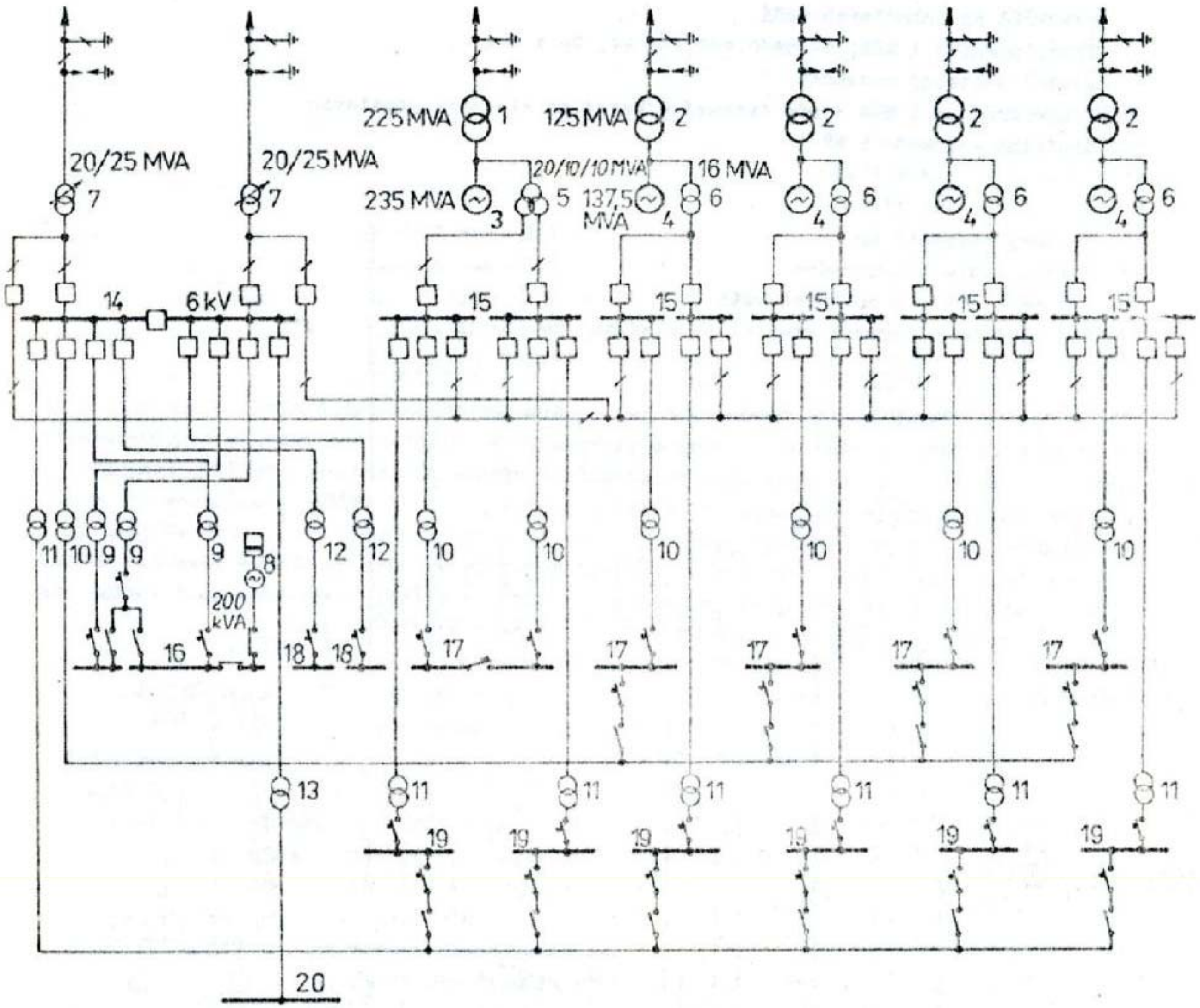
Multi-unit power plant – basic supply scheme

- Unit auxiliary (VSB)
- Common auxiliary (SVS)



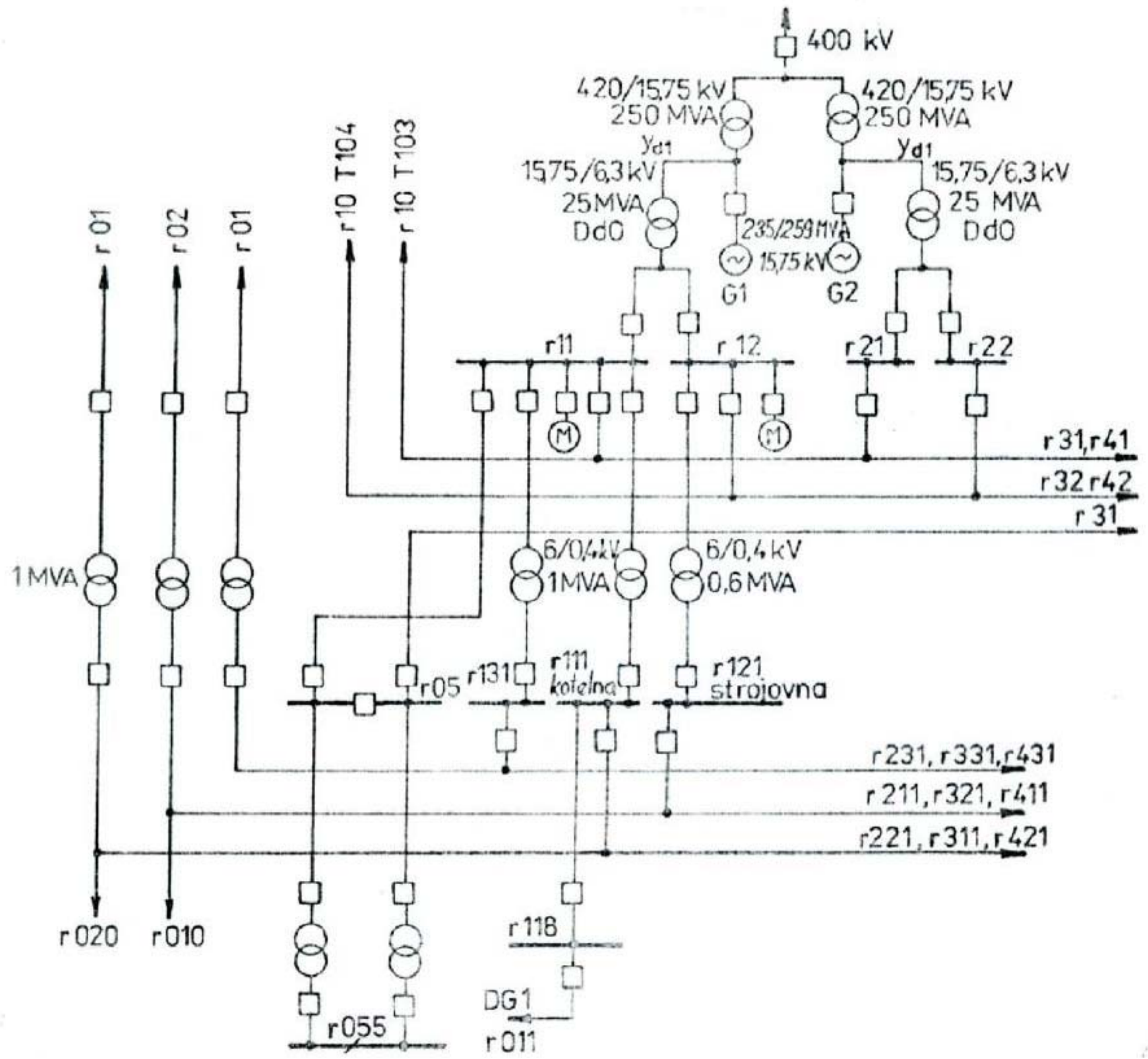
Auxiliary Scheme Examples

Conventional power plant 200 + 4x110 MW



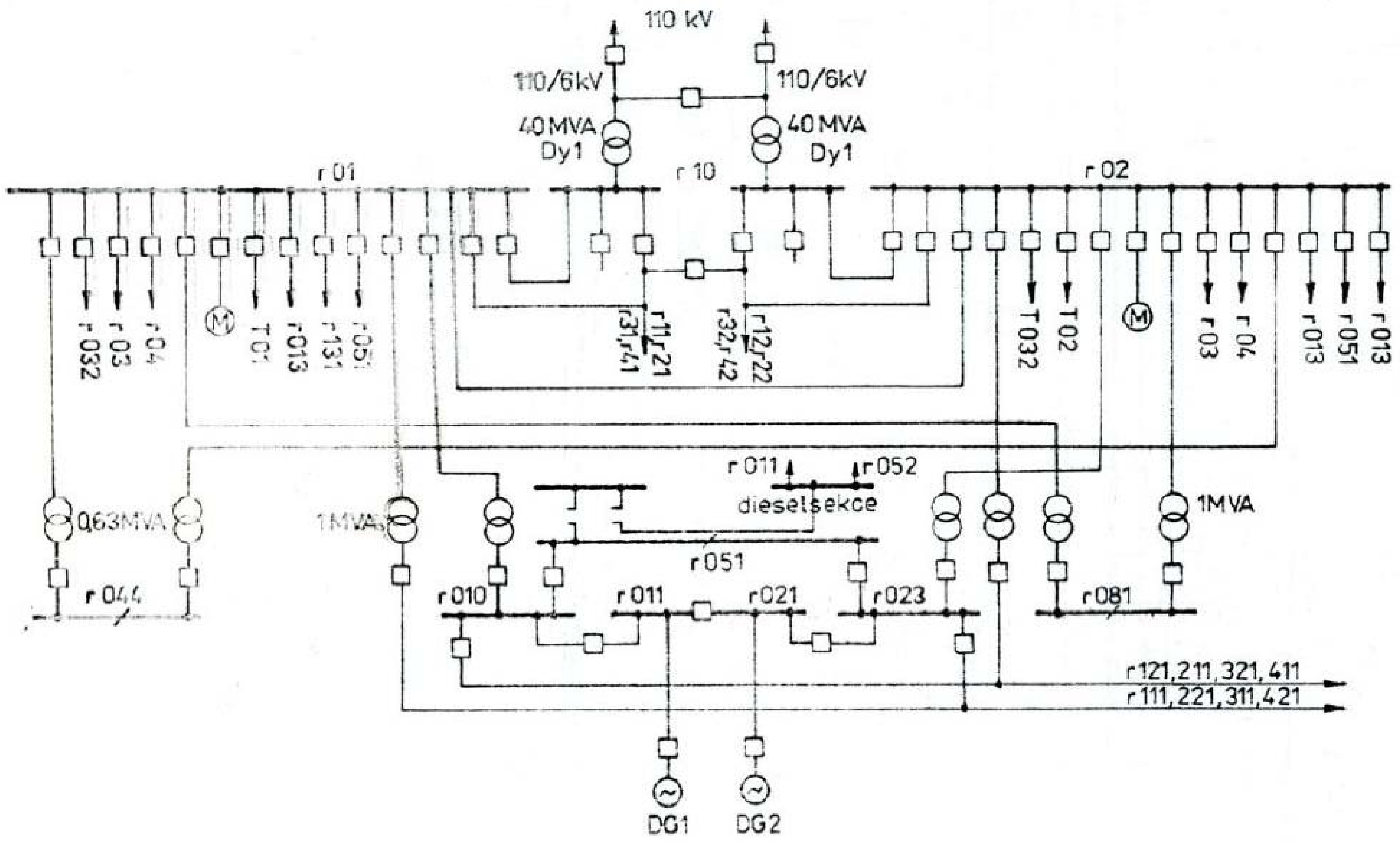
Auxiliary Scheme Examples

Conventional power plant, double-unit 2x200 MW



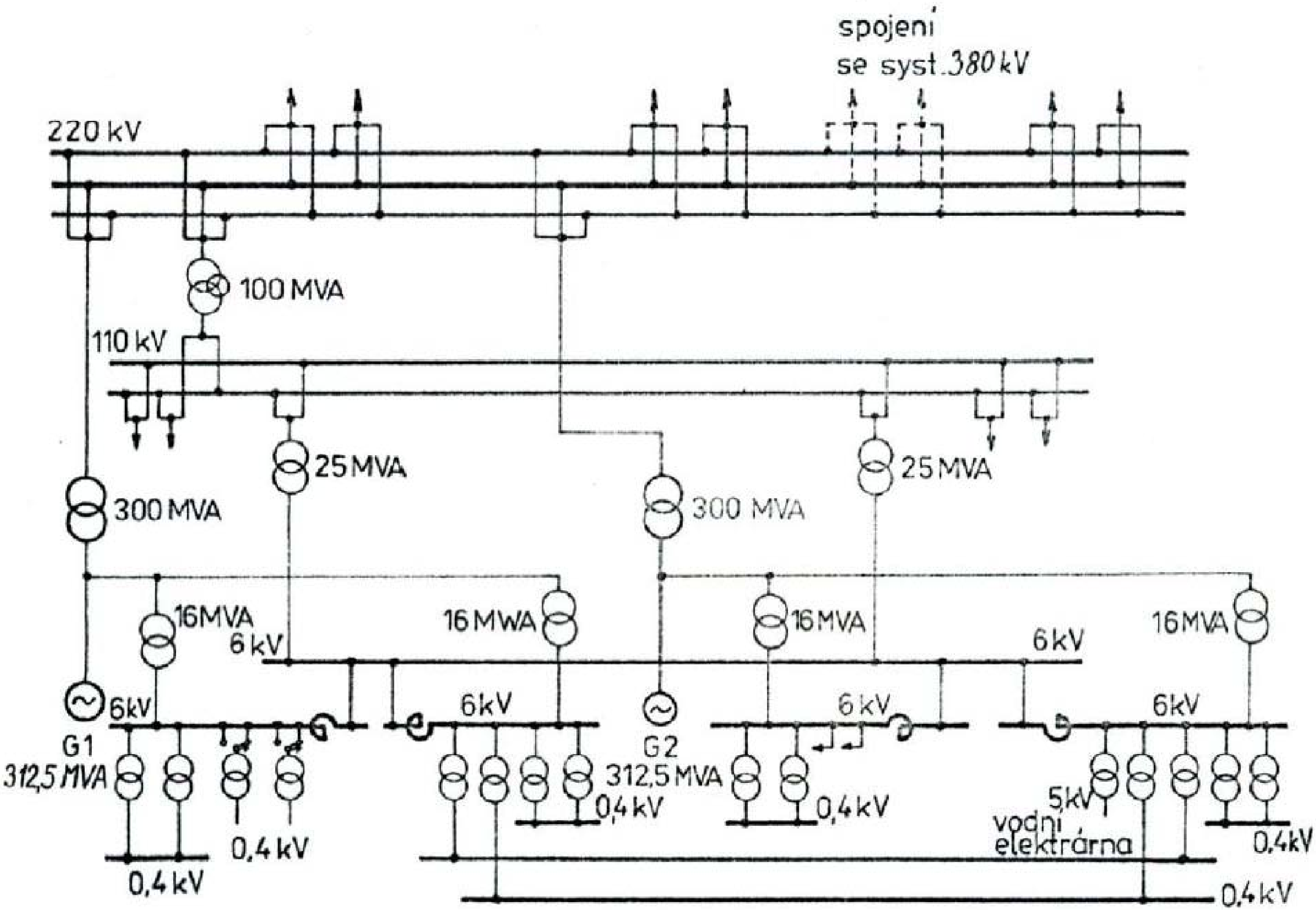
Auxiliary Scheme Examples

Conventional power plant, double unit 2x40 MW, Common aux. + diesel gensets



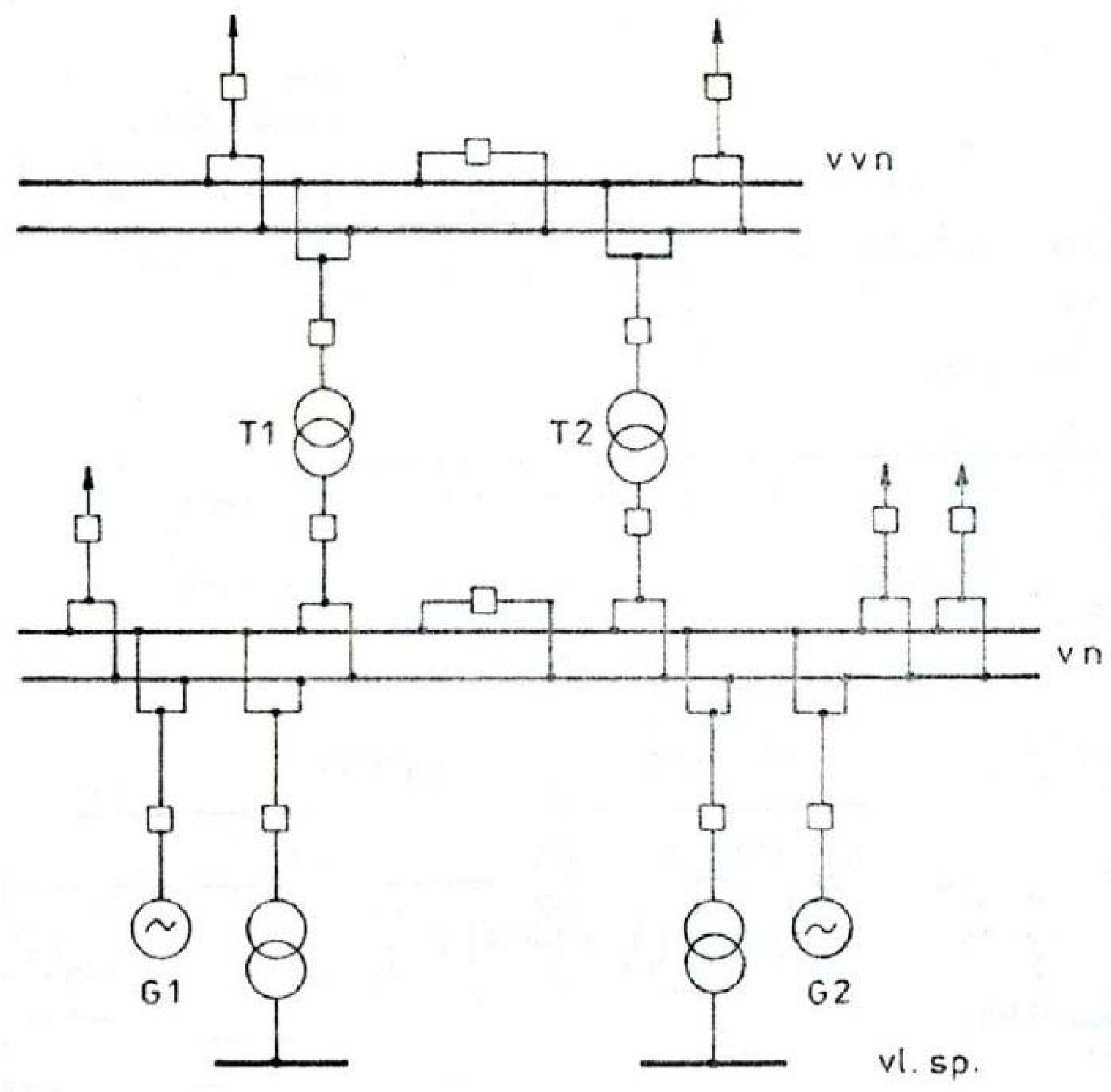
Auxiliary Scheme Examples

Conventional Power Plant, 300 MW



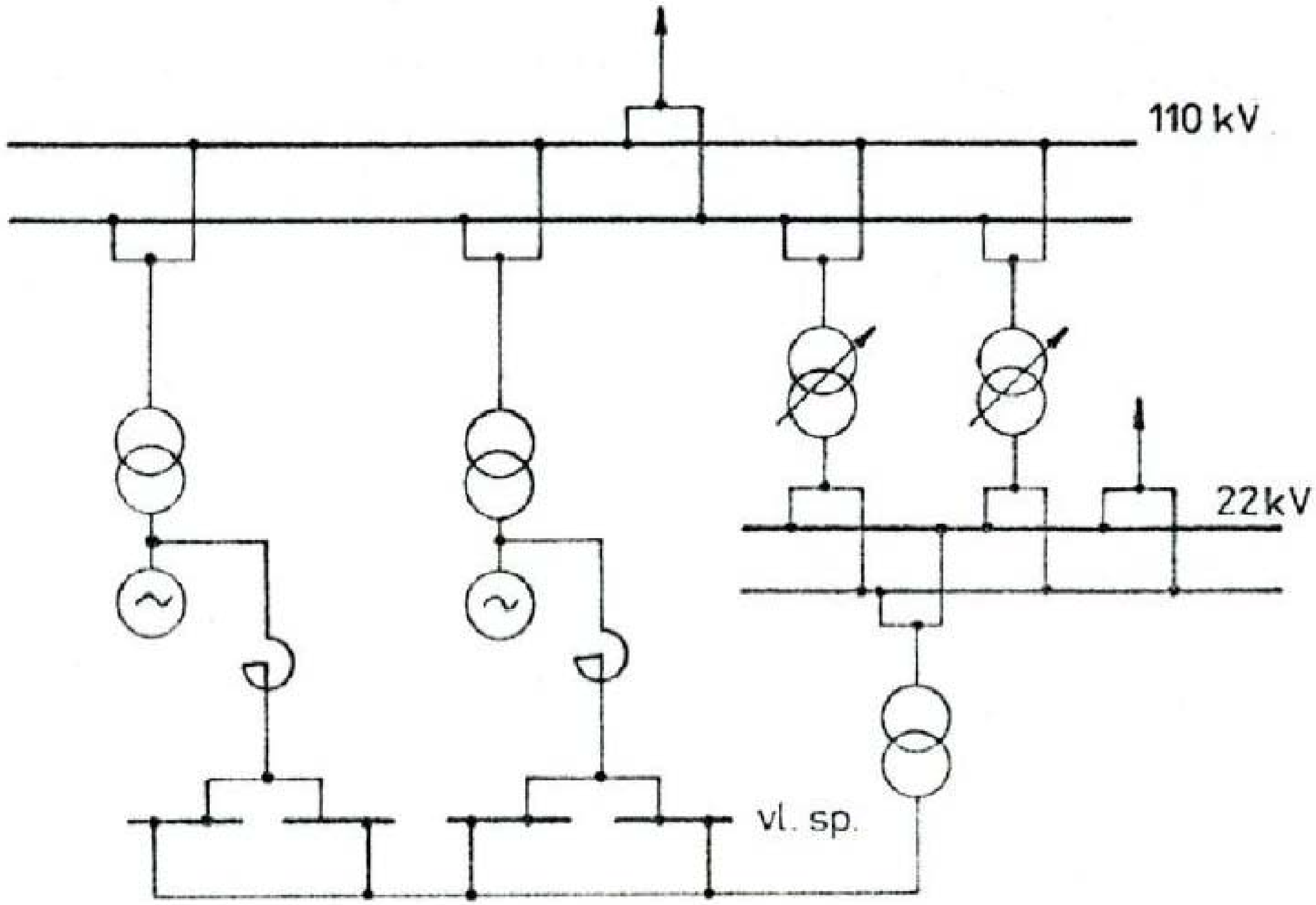
Auxiliary Scheme Examples

Typical CHP scheme with MV outlets to distribution network



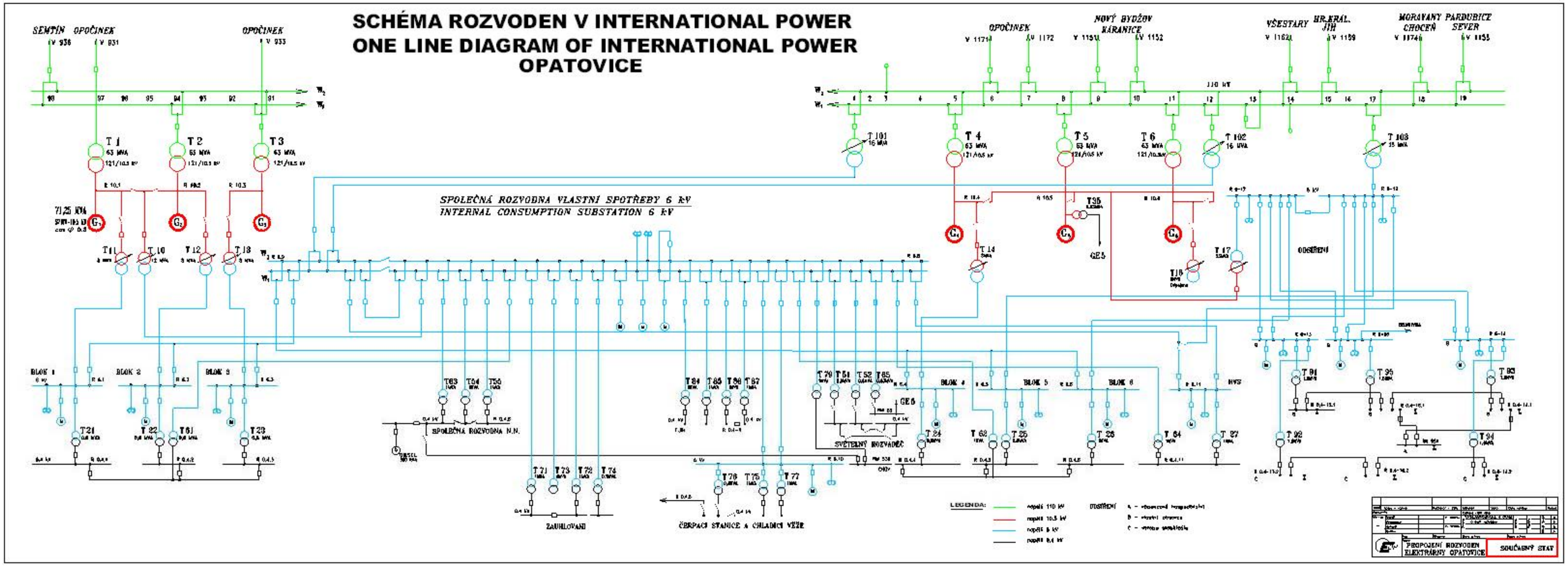
Auxiliary Scheme Examples

Alternative CHP scheme with MV outlets to distribution network with higher power output, short circuit currents are suppressed by reactors



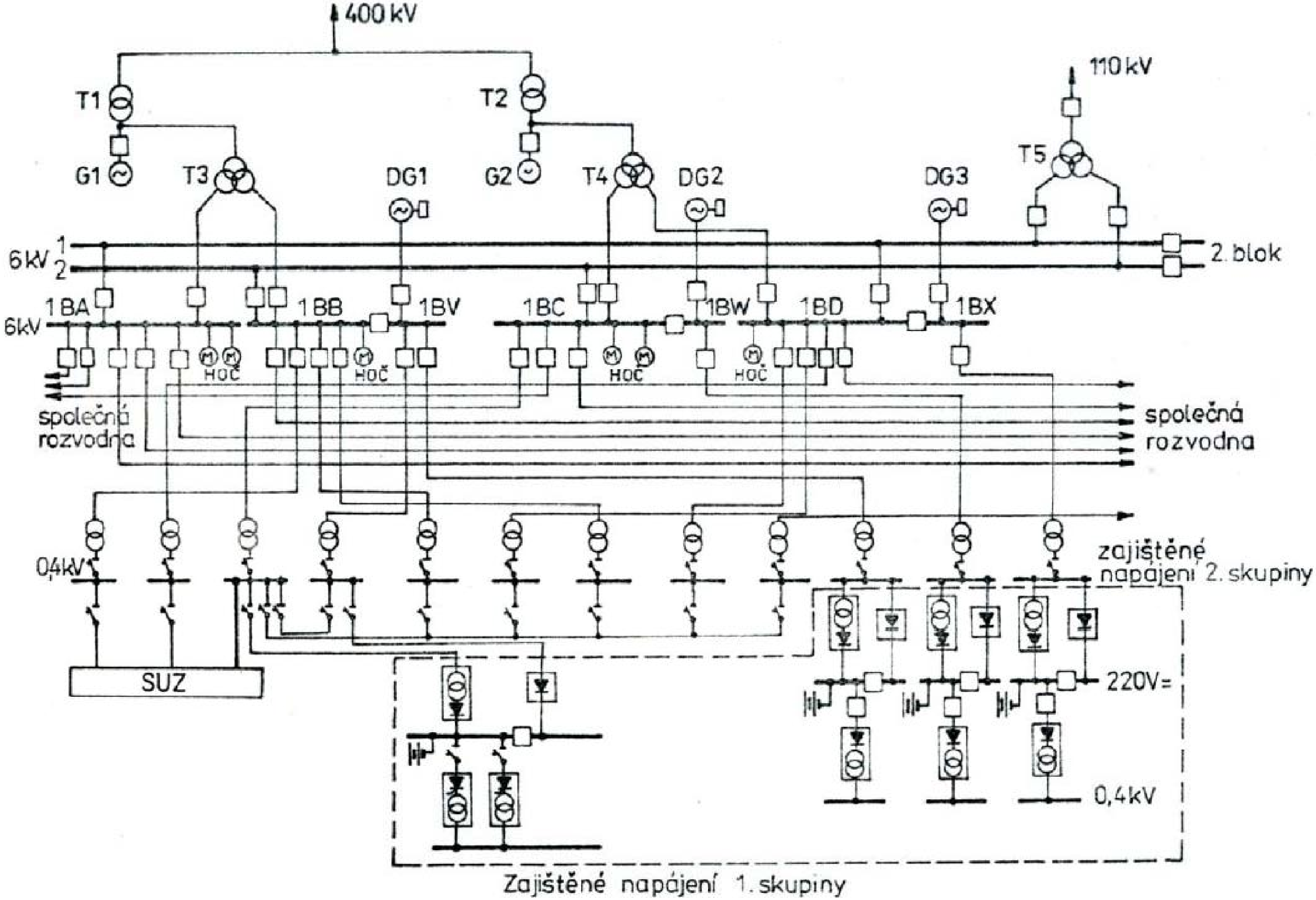
Auxiliary Scheme Examples

6x60 MW + CHP, Power Plant Opatovice



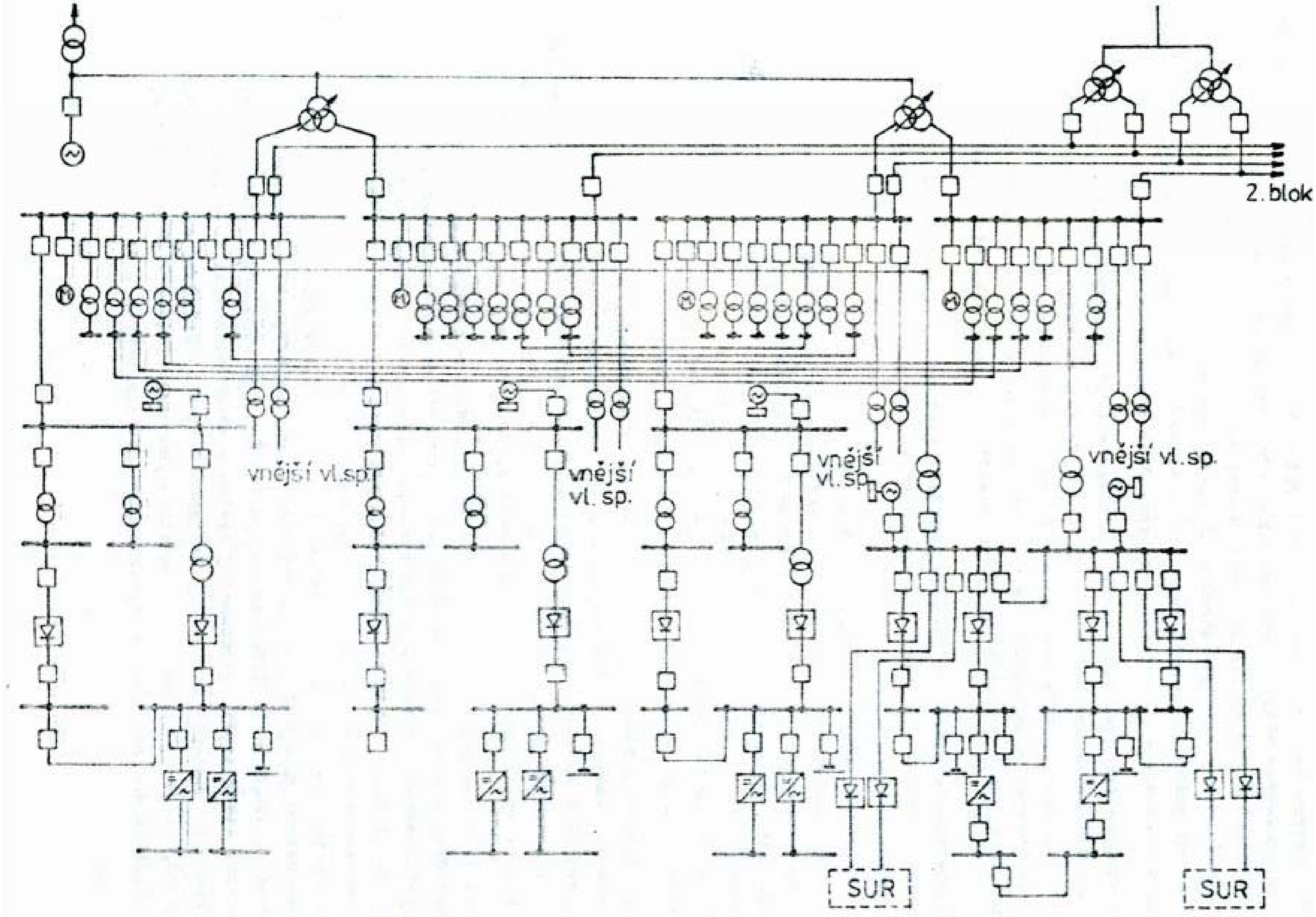
Auxiliary Scheme Examples

Dukovany NPP Auxiliary



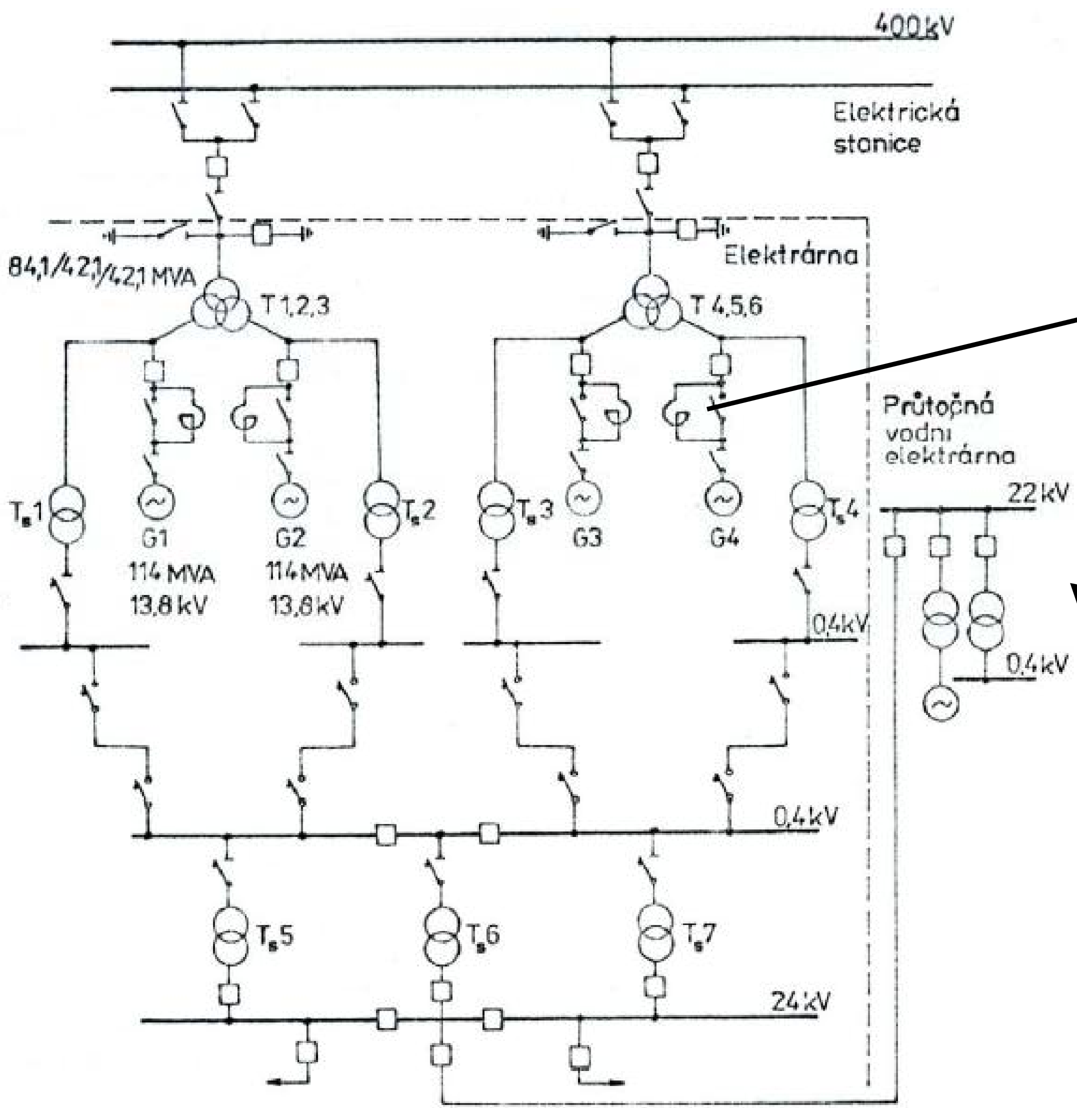
Auxiliary Scheme Examples

Temelin NPP Auxiliary



Auxiliary Scheme Examples

Pumped-storage Hydropower Plant Dalešice 4x105MW Auxiliary



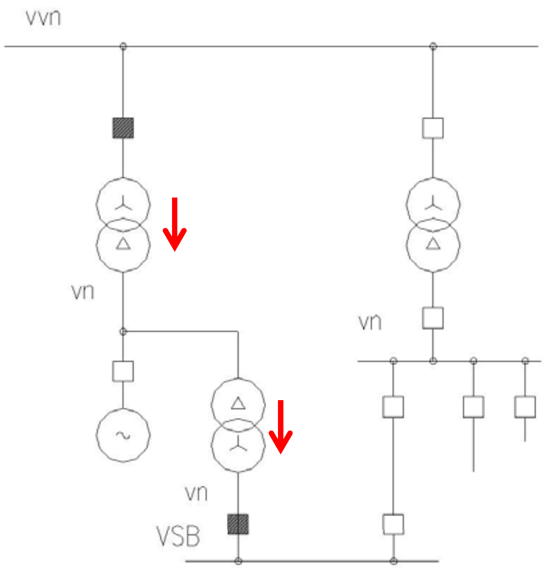
reactor for asynchonous start up of motorgenerator

Small HPP Mohelno as start up and emergency source

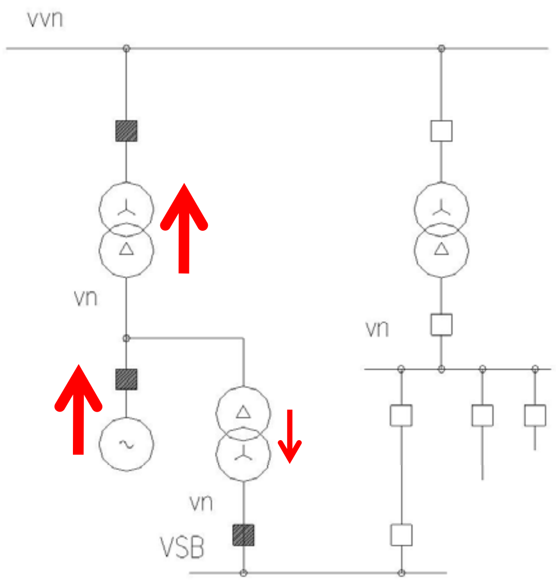
Auxiliary Scheme Examples

Summary:

<u>Start-up source:</u>

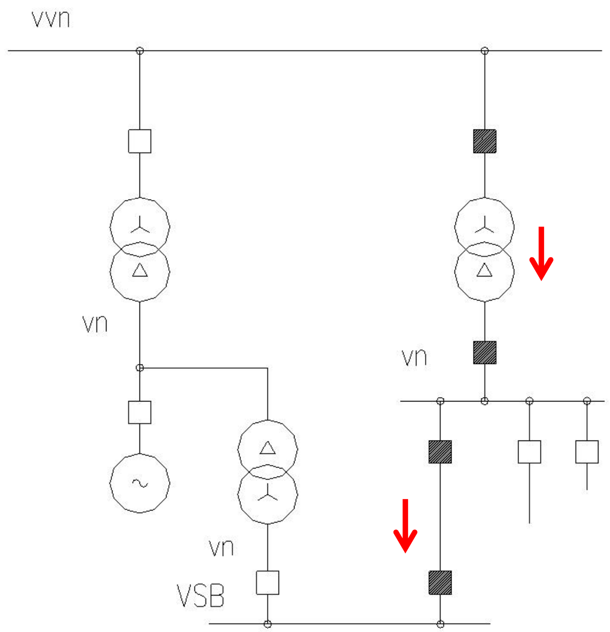


<u>Operating source:</u>

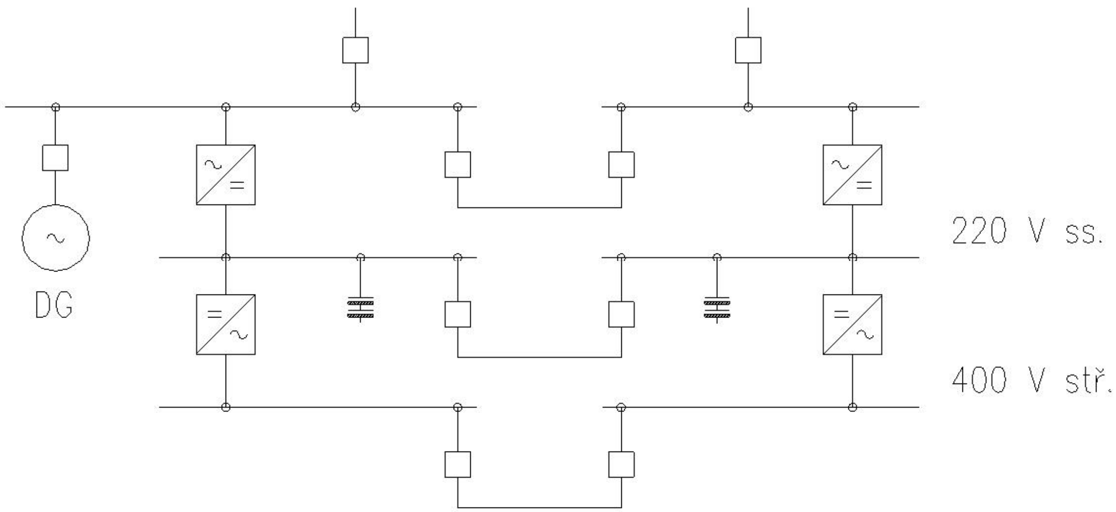


Auxiliary Scheme Examples

Back-up source:



Emergency source (diesel + UPS)



Auxiliary Source Dimensioning

Operating, start-up resp. back-up power need is calculated from total installed power of the consumption as

$$\sum S_P = \frac{\sum_i P_{ni}}{\cos \varphi_n}.\beta$$

with loading factor

$$\beta = \frac{k_V.k_S}{\eta_m.\eta_S}$$

factor of contemporary power

$$k_S = \frac{\sum_i P_{Si}}{\sum_i P_{ni}}$$

factor of workload

$$k_V = \frac{\sum_i P_i}{\sum_i P_{Si}}$$

η_m Mean efficiency of appliances under specified workload

η_S Efficiency of the supplying grid

Auxiliary Source Dimensioning

Rated (nominal) power of a supplying source must be:

$$S_Z \geq \sum S_P$$

Other requirements:

- **Electric machines' terminal voltage has to be acc. ČSN 38 1120 in tolerance Vn ± 5%**
- **min. voltage drop in the case of the biggest appliance start up should not be under 0,85 Vn, must not be under 0,8 Un**
- **min. voltage drop in the case of appliances' group start up must not be under 0,65 Un,**

In addition to that, for back-ups:

- **One back-up trf for 2 units, two for more than 2**
- **Every back-up trf. has to ensure full operation of the first unit + no-load operation of the second + 50% common aux. + (in the case of NPP) shut down the second unit**

Auxiliary Source Dimensioning

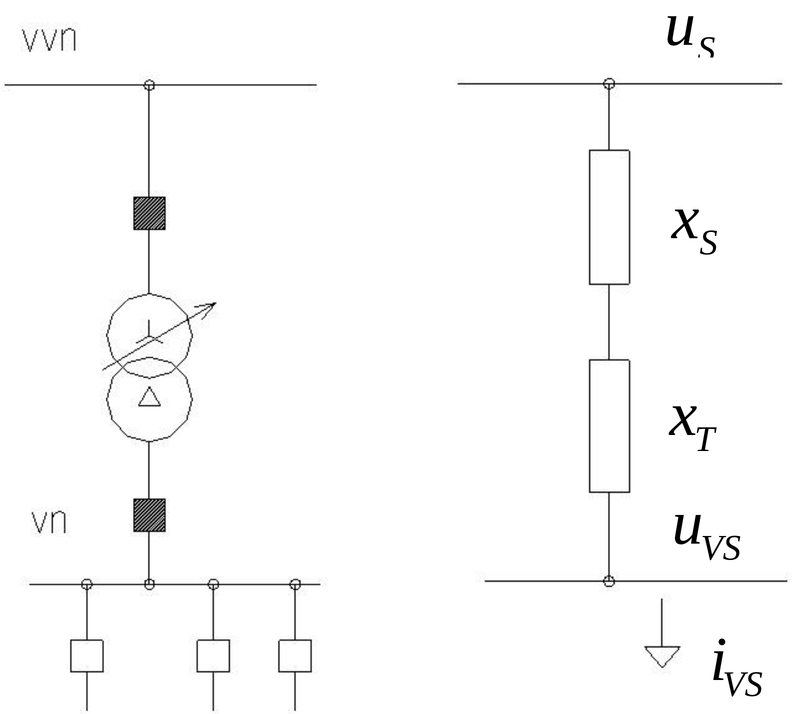
<u>Power source dimensioning, checkings:</u>

Network voltages + determination of trf. ratio:

- **In the case of normal operation**
- **In the case of the biggest appliance start up**
- **In the case of appliances' group(s) start up**

At the same time, protection set-up checking for extraordinary operation states is necessary!

Determination of Transformer Ratio



Generally:

$$\hat{u}_S = j.(x_S + x_T).\hat{i}_{VS} + \hat{u}_{VS}$$

Neglecting voltage difference caused by real part of the current we obtain:

$$u_S = (x_S + x_T).i_{VSj} + u_{VS}$$

$$\frac{U_S}{p.U_V} = \left[\frac{S_V}{S_{ks}} . \left(\frac{U_S}{U_V} \right)^2 . \frac{1}{p^2} + x_T \right] .i_{VSj} + u_{VS}$$

$$0 = \left(x_T .i_{VSj} + u_{VS} \right) .p^2 - p.\frac{U_S}{U_V} + \frac{S_V}{S_{ks}} . \left(\frac{U_S}{U_V} \right)^2 .i_{VSj}$$

Determination of Transformer Ratio

We gain *p* as a solution of following quadratic equation:

$$0=\left(x_T.i_{VSj}+u_{VS}\right).p^2-p.\frac{U_S}{U_V}+\frac{S_V}{S_{ks}}.\left(\frac{U_S}{U_V}\right)^2.i_{VSj}$$

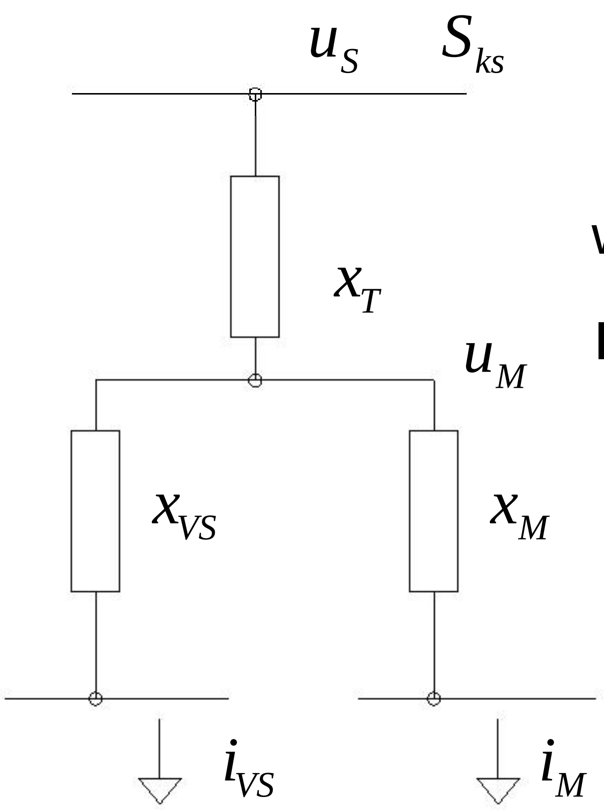
Assuming that the known variables are: $i_{VSj}, U_S, S_{ks}, x_T$

And required voltage is: u_{VS}

Appropriate ratio (tap) has to be determined for design operation states (unloaded, operation, the biggest appliance, start up etc.) Finally, the necessary voltage regulation range is determined (tap changer requirements)

The Biggest Appliance Start-up

The source has to be strong enough, in other words satisfy with its minimum short circuit power:



Total load will be:

$$x_Z = \frac{x_{VS} . x_M}{x_{VS} + x_M}$$

where x_M is start-up motor reactance

If base apparent power is trf. rated power: S_{nT}

$$x_M = \frac{1}{i_{zM}} . \frac{S_{nT}}{S_{nM}}$$

motor start-up current

Reactance of auxiliary load before start-up:

$$x_{VS} = \frac{1}{\sin \varphi_{VS}} . \frac{S_{nT}}{S_{VS}}$$

The Biggest Appliance Start-up

Trf. current will be:

$$i_T = u_M . \left(\frac{1}{x_{VS}} + \frac{1}{x_M} \right) = u_M . \left(\frac{S_{VS} . \sin \varphi_{VS}}{S_{nT}} + i_{zM} . \frac{S_{nM}}{S_{nT}} \right)$$

Corresponding value of short circuit power (p.u.) is:

$$s_{kM} = \frac{u_S}{x_T} = \frac{u_S}{u_S - u_M} . i_T = \frac{u_S . u_M}{u_S - u_M} . \left(\frac{S_{VS} . \sin \varphi_{VS}}{S_{nT}} + i_{zM} . \frac{S_{nM}}{S_{nT}} \right)$$

Nominal short circuit power :

$$S_{kM} = \frac{u_S . u_M}{u_S - u_M} . \left(S_{VS} . \sin \varphi_{VS} + i_{zM} . S_{nM} \right) = \frac{u_S}{\frac{u_S}{u_M} - 1} . \left(S_{VS} . \sin \varphi_{VS} + i_{zM} . S_{nM} \right)$$

Appliance’s Group Start-up

Analogically for k-appliances (the rest of auxiliary is neglected):

$$x_Z = \left(\frac{1}{x_{M1}} + \ldots + \frac{1}{x_{Mk}} \right)^{-1}$$

Corresponding value of short circuit power (p.u.) is:

$$s_{kM} = \frac{u_S}{x_T} = \frac{u_S}{u_S - u_M} . i_T = \frac{u_S . u_M}{u_S - u_M} . \frac{1}{S_{nT}} . \sum_{i=1}^{k} i_{zMi} . S_{nMi}$$

Nominal short circuit power :

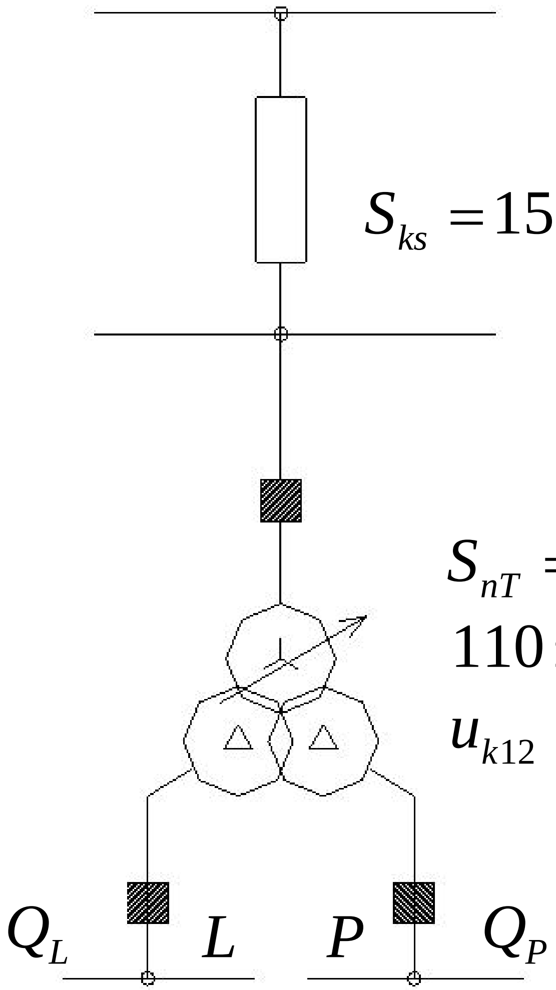
$$S_{kM} = \frac{u_S . u_M}{u_S - u_M} . \sum_{i=1}^{k} i_{zMi} . S_{nMi}$$

Addenum to 2nd Lecture

Determination of transformer ratio:

$$U_s = 116 \text{ kV}$$

$$S_{ks} = 1515 \text{ MVA}$$



Compute appropriate transformer ratios:

a) At full load

$$Q_L = Q_P = 23 \text{ MVAr}$$

b) At no-load

$$Q_L = Q_P = 0 \text{ MVAr}$$

In order to reach in both cases auxiliary voltage at level 6,3 kV

$$S_{nT} = 63/31{,}5/31{,}5 \text{ MVA}$$

$$110 \pm 8x2\%/6{,}3/6{,}3 \text{ kV}$$

$$u_{k12} = 9\%,\ u_{k13} = 9\%,\ u_{k23} = 18\%$$