Power Plants
A1M15ENY

Lecture No. 1

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Types and Operation of Power Plants

Type of technolgy:

- Thermal Power Plants (TPP)

Alholmens Kraft, FIN
240 MW

- fossil fueled

- biomass fueled

- with Combined Cycle Gas Turnine (CCGT)

EMĚ III 1x500 MW

Vřesová 2x185 MW

Types and Operation of Power Plants

Type of technology:

- Nuclear Power Plants (NPP)

NPP JETE 2x1000 MW

- Wind Farms

Mravenečník 1,6 MW

- Photovoltaics (PV)

FVE Hrušovany 3,73 MW

Types and Operation of Power Plants

Type of technology:

- Hydroelecrtric power plants (HPP)

HPP Dlouhé Stráně
2x325 MW

- Waste-to-energy power plants

- Other types (geothermal, tidal power plant ...)

Other clasifications

According to product:

- **Solely electrical energy production**
- **Combined heat and power production (CHP)**

According to arrangement:

- **Classical unit concept**
- **Interconnected technology**

Accorging to the type of turbine:

- **Kaplan, Pelton, Francis (HPP)**
- **Back pressure, Condensing, Condensing with bleeding (TPP)**

Accorging to the type of renewable source (RES):

- **Small hydro power plant**
- **Photovoltaics (PV)**
- **Wind power generation**
- **Others (geothermal, tidal, solar heating… etc.)**

ELECTRIC PART
OF POWER PLANTS

Quality of Electrical Energy

Generated electrical energy has to be in compliance with requirements to its quality

Above all from:

- **Distribution System Operator (DSO)**
- **Transmission System Operator (TSO)**

Why?

- **The Distributor is obliged to supply consumers with el. energy acc. to EN 50160 resp. its internal rules + energy law (CZ - Act No. 458/2000 Coll.) and other regulations**

This means technical requirements predominantly to:

- **Frequency**
- **Voltage level**
- **Content of voltage harmonics**
- **Content of voltage unbalance**
- **Reactive power compensation**

=> Quality metering

Transport Effectiveness and Reliability

The requirements again from:

- **Distribution System Operator (DSO)**
- **Transmission System Operator (TSO)**

Why?

- **The Distributor is obliged to supply consumers with el. energy acc. to EN 50160 resp. its internal rules + energy law (CZ - Act No. 458/2000 Coll.) + market mechanisms**

This means anoter requirements to the generated electrical energy:

- **Active power regulation**
- **Reactive power regulation**
- **Ability of „Black Start“**
- **Ability of „Islanding“**

=> Ancilliary Services (TSO), DSO dispatching

Power Plant Scheme Topology

Main requirements:

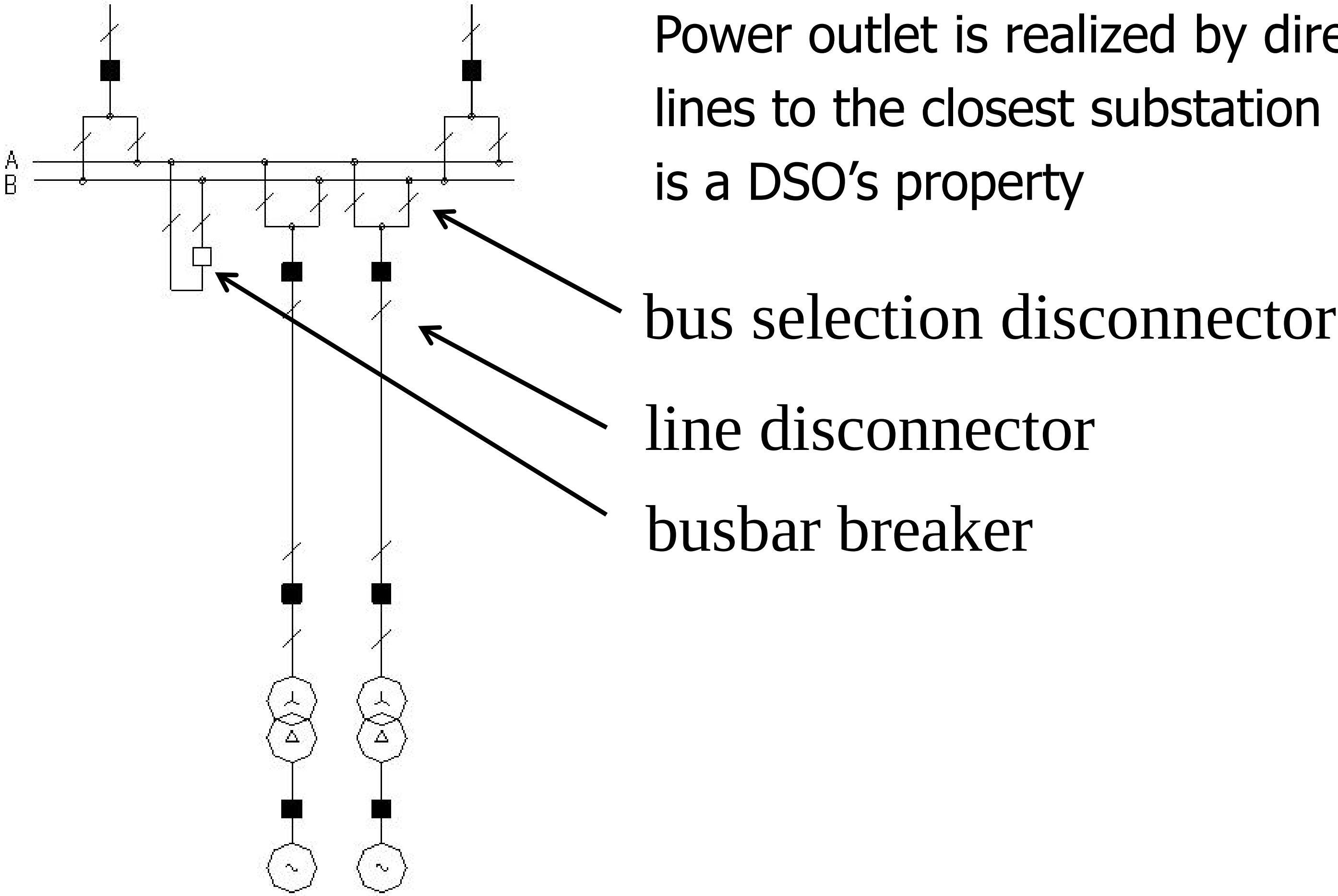
- Reliability and safety
  - back-up suply for auxilliary devices
  - back-up for power outlet (optional)
  - safety during manipulations, maintenance and revisions
  - ability of black start and islanding
  - ability of safe shut down the plant
- Operability
  - ability of device change without intervention to a common operation
- Effectiveness
  - ability of power outlet, which minimizes the losses in DS / TS

Power Plant Scheme Topology

<u>Power Plant Main Substation</u>

a) not present

Power outlet is realized by direct lines to the closest substation which is a DSO's property

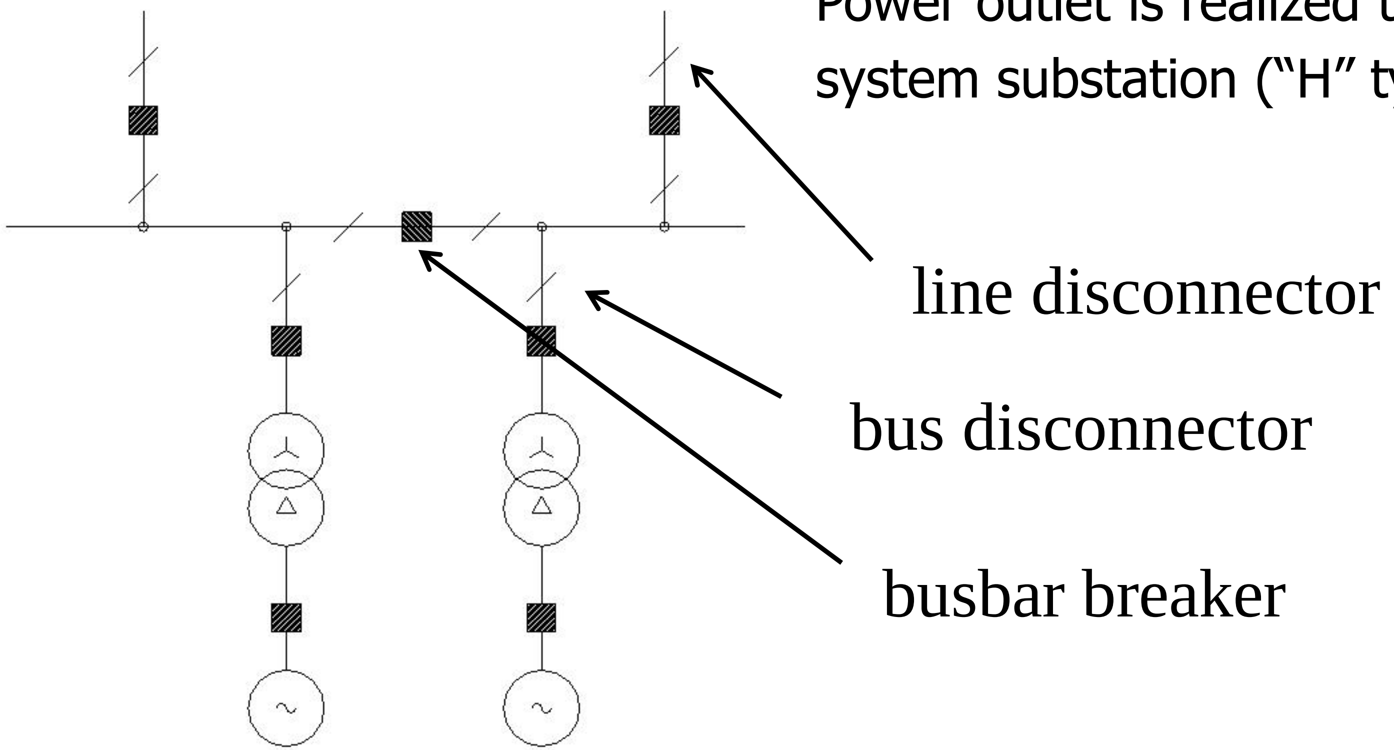


Power Plant Scheme Topology

<u>Power Plant Main Substation</u>

b) single bus system

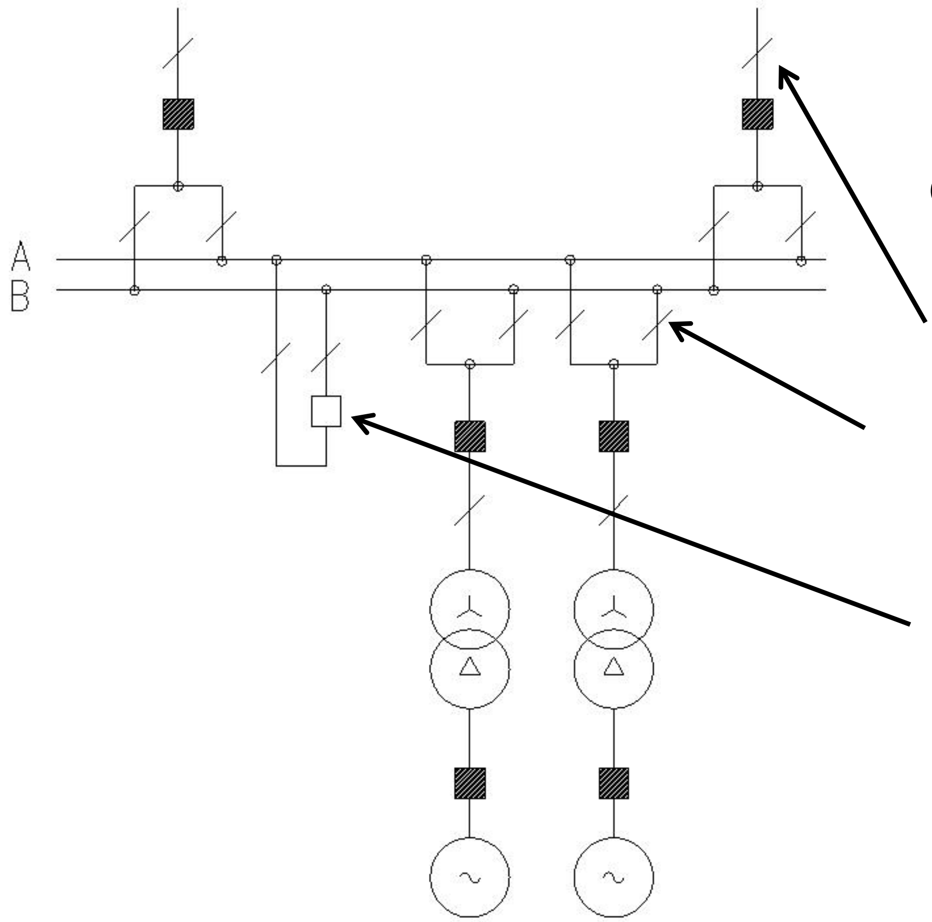
Power outlet is realized to sigle-bus system substation (“H” type)



Power Plant Scheme Topology

Power Plant Main Substation

c) double bus system



Power outlet is realized to double bus substation which is normaly operated into two independent network areas

line disconnector

bus disconnector

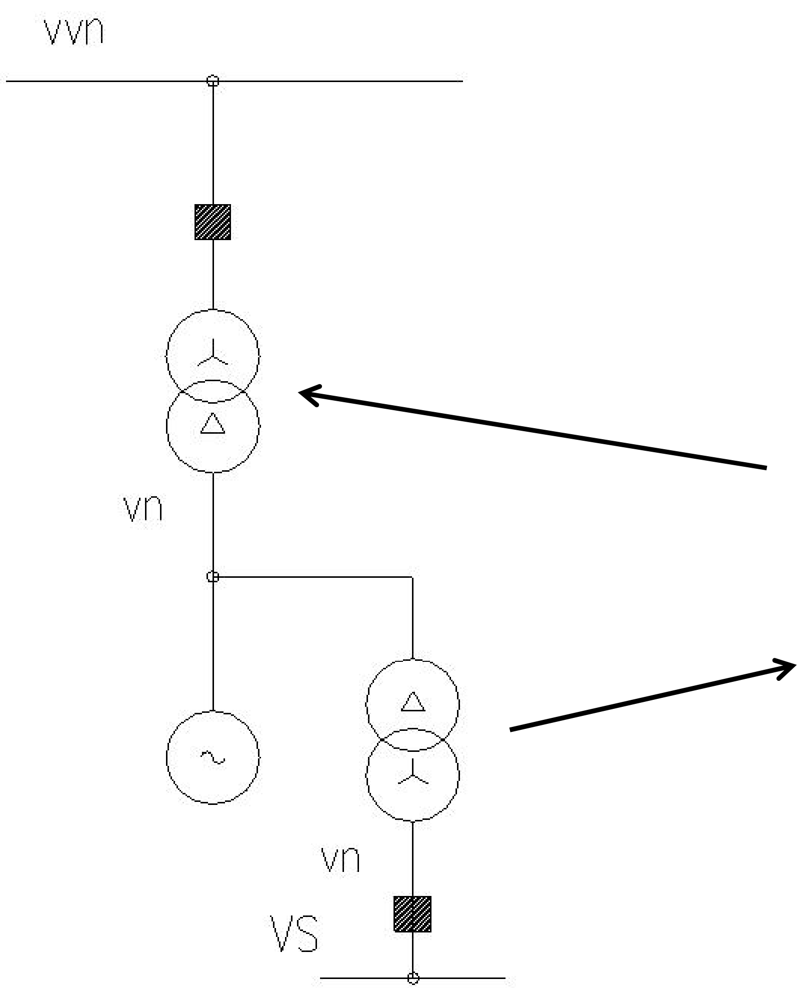
busbar breaker

Power Plant Scheme Topology

Unit Scheme

a) without generator circuit breaker

Strat-up (back-up) transformer is necessary also for unit faults. Cheap solution. It has been used for small sized units.

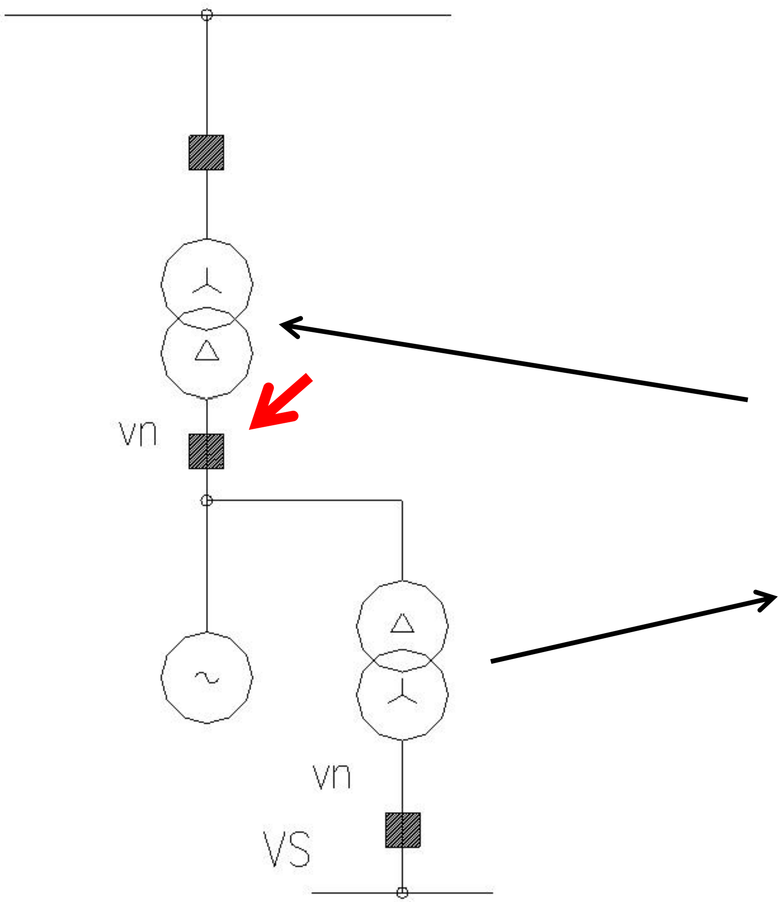


Power Plant Scheme Topology

<u>Unit Scheme</u>

b) with generator circuit breaker behind branch to auxiliary

Start-up (back-up) transformer is necessary also for unit faults. Ability of operation within fault on the unit transformer. This principle is used in NPP.



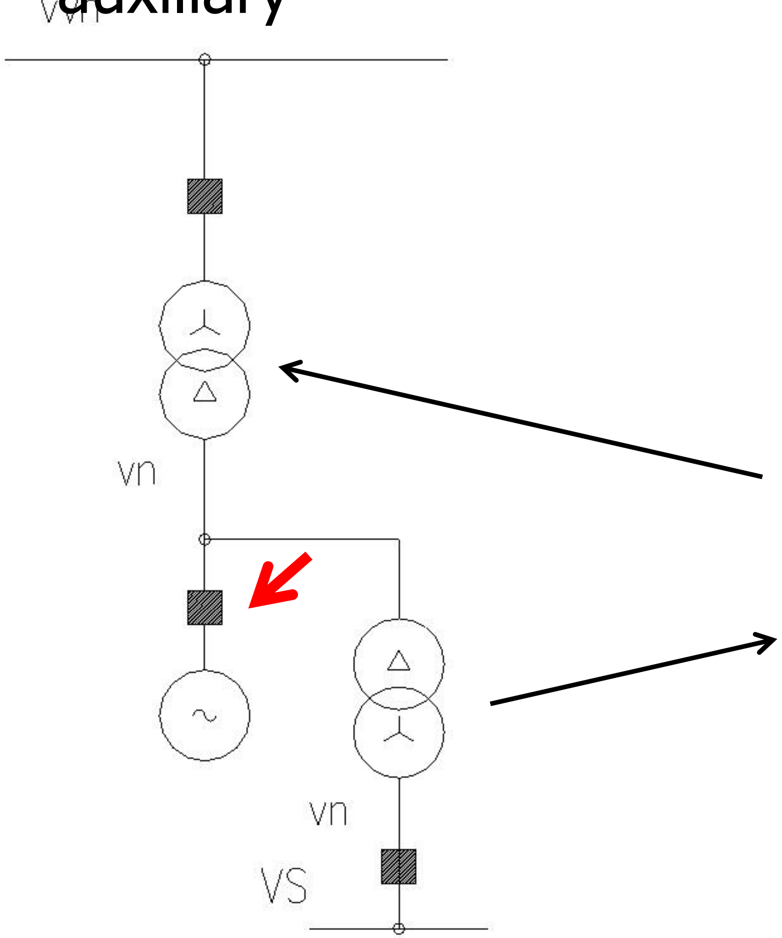
Power Plant Scheme Topology

Unit Scheme

c) with generator circuit breaker in front of branch to auxiliary

Unit transformer used for unit start-up

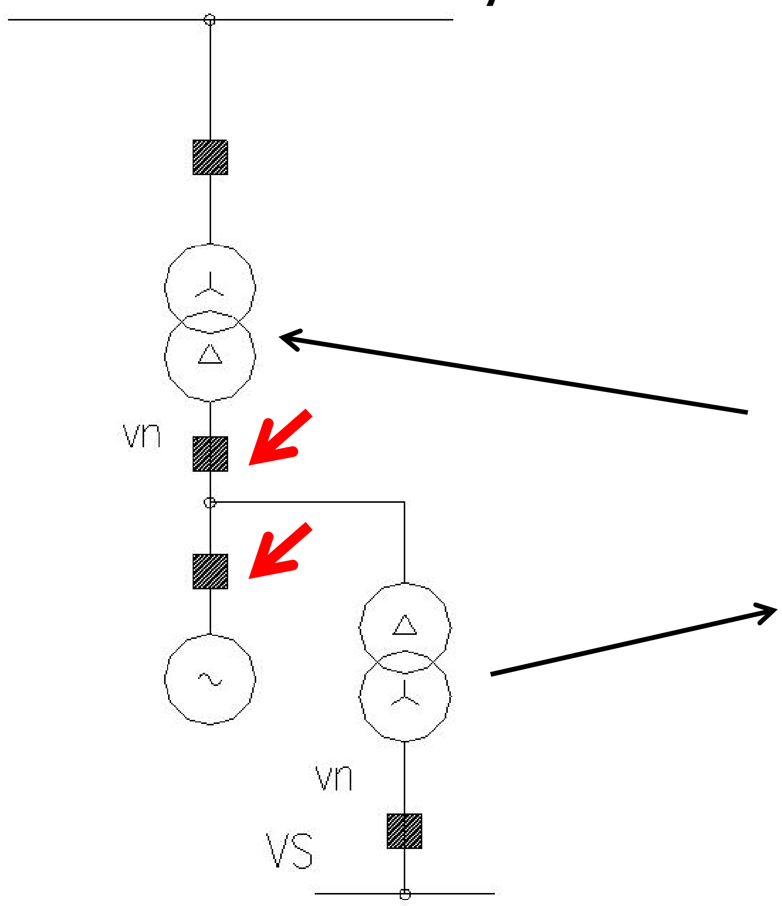
Despite start-up ability, back-up transformer is recommended also in the case of multi unit power plants of high rated power



Power Plant Scheme Topology

<u>Unit Scheme</u>

d) with generator circuit breaker behind and in front of branch to auxiliary



unit transformer

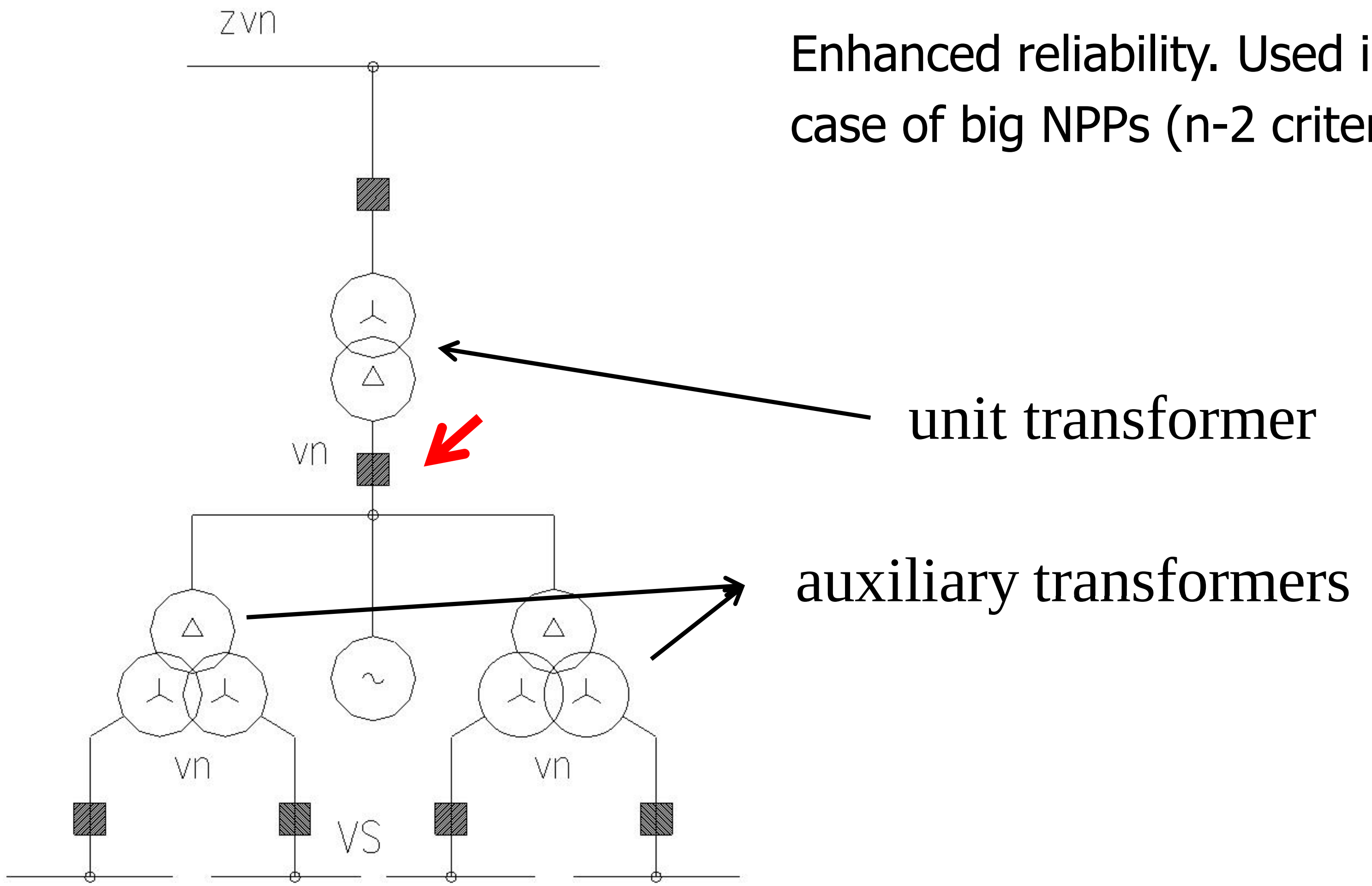
auxiliary transformer

Combination of the advantages b) and c)

Power Plant Scheme Topology

Unit Scheme

e) with generator circuit breaker + 2 x auxiliary trf.

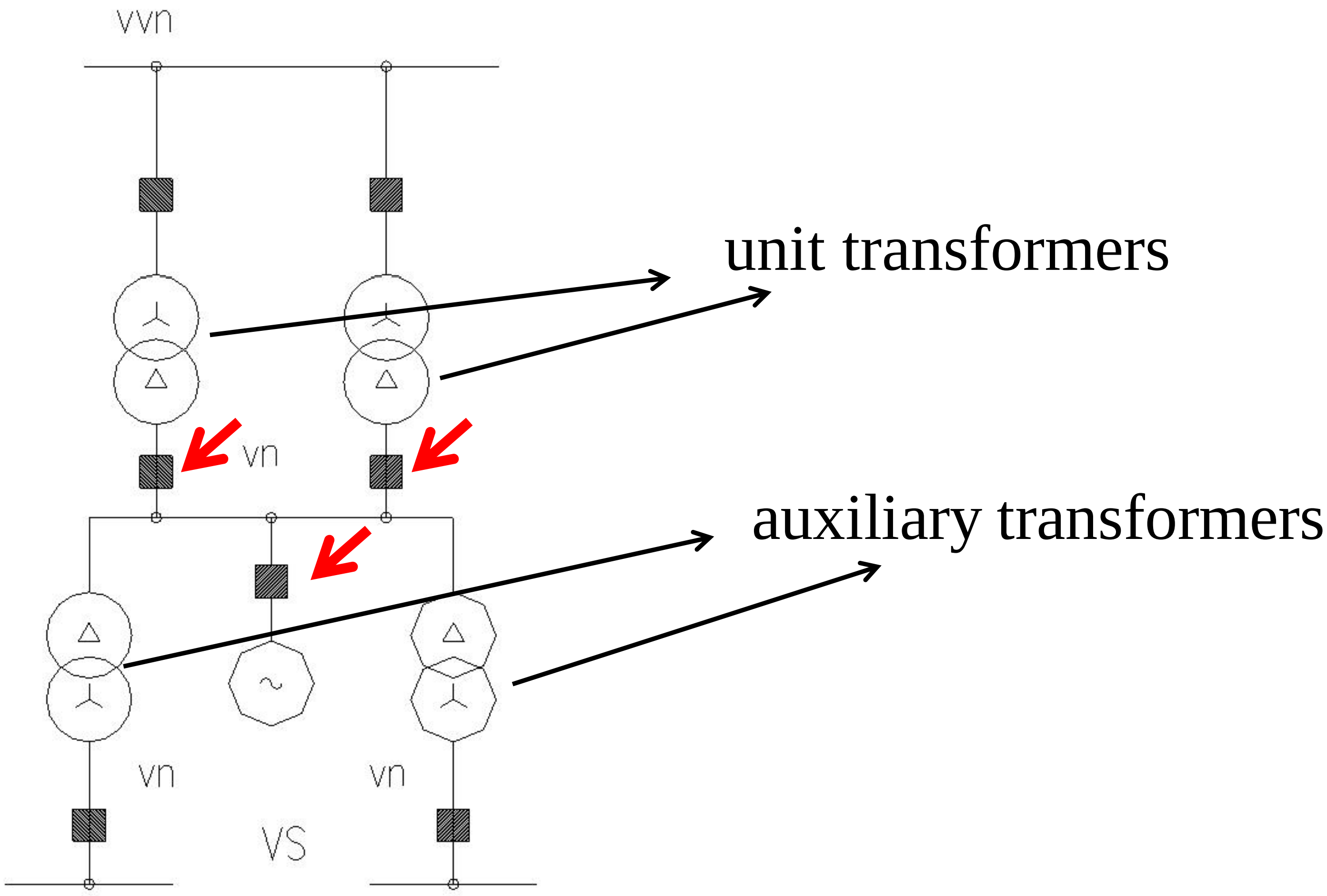


Enhanced reliability. Used in the case of big NPPs (n-2 criterion)

Power Plant Scheme Topology

Unit Scheme

f) with generator circuit breakers + 2 x aux. and unit trf.



Auxiliary

= Power consumption within generation in the main and secondary operation parts of the power plant

- Fuel transportation and processing + other necessary media for power generation (i.e. limestone, lubrication oil…)
- Feed water, cooling (or heat water) pumping incl. treatment
- Desulphurization of flue gases
- Transportation and processing of by-products (gypsum slurry)
- Air and flue gas ventilation
- Generator excitation, control system (I&C) and protection supply

Note:

In some operation parts is used steam as an energy source

(i.e. steam feedwater pumps, steam heatwater pumps etc.)

Auxiliary

Auxiliary share according technology type:

- Classical thermal power plant 7 - 11%
  (if steam feedwater pump is present 4 - 6%)
- CCGT power plant 5 - 6%
  (if steam feedwater pump is present 2,5 – 3,5%)
- Nuclear power plant 6 - 7%
- Hydroelectric, photovoltaic power plant <1%

Auxiliary share on total power generation is influenced by:

- other than electrical form of energy use (technological steam)
- quality and availability of the fuel
- operating point of unit determining total efficiency
- district heating operation
- failures and efficiency of the devices

Note:
In case of RES "declared auxiliary" dependent on legislation

Auxiliary

Auxiliary must ensure reliable and safe

- Start-up

  => appropriate transformer size

  => tolerable voltage drops

- Operation

  => back-up supply of technological substations

  => for NPP minimal frequency of shut-downs

- Shut-down

  During shutting down, it is necessary to ensure reliable supply to all essential devices, which outage could cause significant damages on technology or human life hazard. Typical applications are:

  => reactor cooling in NPP

  => turbine lubrication oil pumps

  => feedwater pump / emergency feedwater pump in TPP

  => metering, protections and I&C

Auxiliary

In spite of that, according an importance of devices for all operating configurations, up to three independent types of source are possible to design:

- working

  => for standard operation (without fault occurence)
- back-up

  => in the case of outage of working supply, supply recovery with delay

  Unit substation, Common auxiliary substation, other important technological substations

  Note: less important technol. substations are using 2 from 3, 3 from 4 reliability scheme
- UPS (online back-up)

  => without outage (rectifier+ battery / invertor)

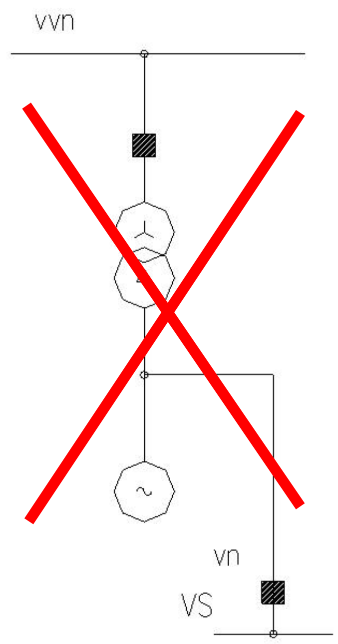
  AC: I&C, protections, metering, emergency lighting, oil pumps, substation instruments (230 V AC)

  DC: protections, DC emergency pumps, DC emergency lighting

  (110 or 220 V DC)

Addenum to 1st Lecture

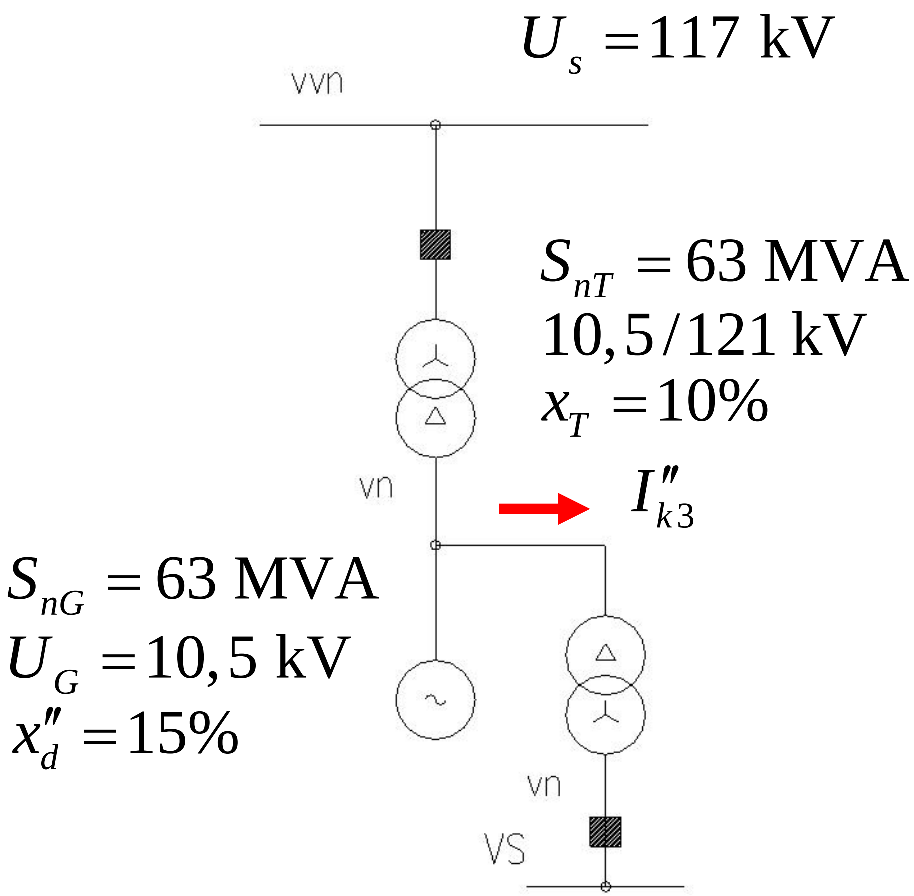
Auxiliary subst. of high and medium sized power plants is never directly connected with generator terminals, aux. transformer is always used!



Reasons:

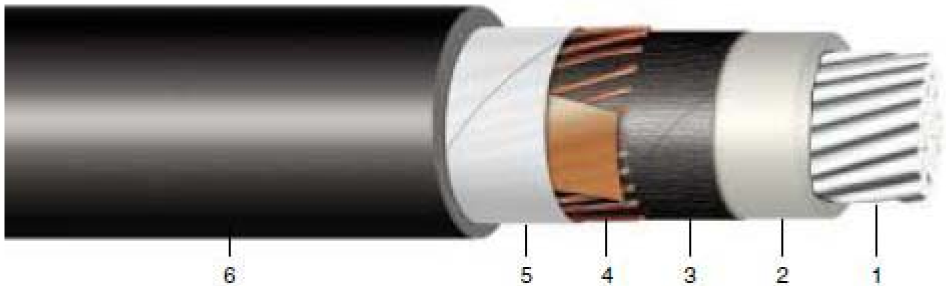
1) Different voltage levels
2) Big short circuit current in aux. substation
3) Big current of earth connection

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



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

6-AYKCY



Konstrukce:
1. Hliníkové jádro
2. PVC izolace
3. Polovodivá páska
4. Cu koncentrický vodič
5. Páska
6. PVC plášť

Počet a průřez žil (mm²) No. of cores (mm²)	Tvar jádra Shape of the conductor	Průměr inf. (mm) Diameter appr. (mm)	Hmotnost inf. (kg/km) Cable mass appr. (kg/km)	Poloměr ohybu (mm) Radius of bend (mm)	Činný odpor (Ω/km) Effect. resist. of conductors (Ω/km)	Ekvivalentní zkrat. proud (kA) Short circuit current-equiv. (kA)	Časová oteplovací konst. (sec) Time heating constant (sec)	Zatížitelnost na vzduchu (A) Current carrying cap. in air (A)	Zatížitelnost v zemi (A) Current carrying cap. in ground (A)	Kapacita (μF/km) Capacity (μF/km)	Indukčnost (mH/km) Inductivity (mH/km)	Obsah Cu/Al (kg/km) Content Cu/Al (kg/km)
1x35/16	RMV	21	569	315	0,868	2,660	195	135	147	0,660	0,600	157/105
1x50/16	RMV	22	660	330	0,641	3,800	273	163	173	0,730	0,590	157/150
1x70/16	RMV	24	747	360	0,443	5,330	338	205	212	0,850	0,560	157/210
1x95/16	RMV	26	856	390	0,320	7,230	419	250	252	0,960	0,540	157/285
1x120/16	RMV	27	955	405	0,253	9,130	497	290	286	1,050	0,530	157/360
1x150/25	RMV	29	1 149	435	0,206	11,400	810	327	314	1,150	0,520	245/450