Electrical Parts of Power Plants

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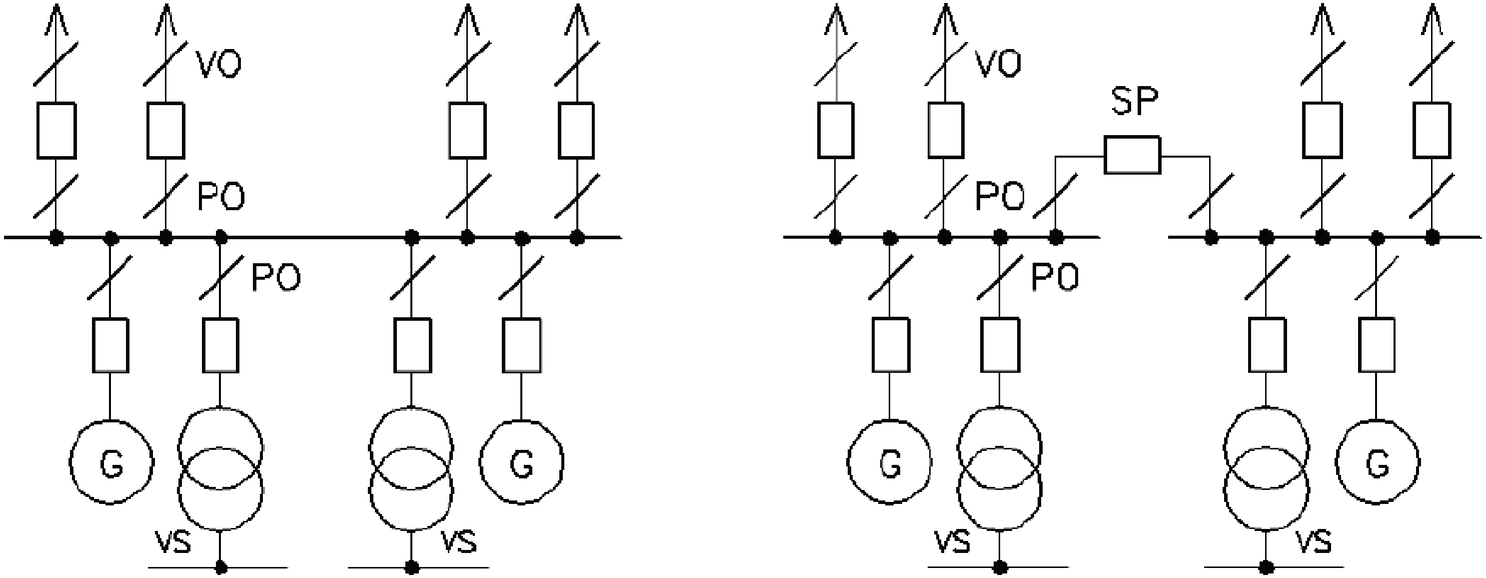
- Main tasks are:
  - **Take the power out** - generator connection with transmission grid
  - **Self-consumption** – supply assuring of main production facilities and auxiliary operations at electricity production
  - **Assuring of control and safety functions at electricity production**

Bus-bar systems

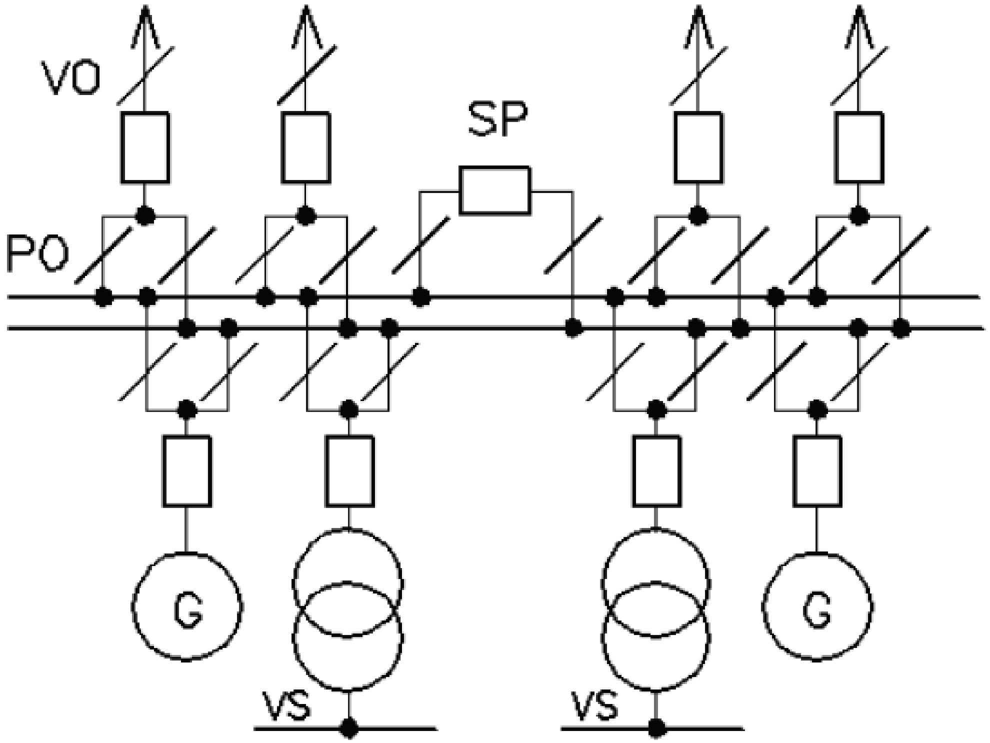
- Single bus-bar system (with/without sectionalization)



VO – feeder disconnector, PO – Bus-bar disconnector, VS – bus-bar of self consumption, G – generator unit, SP – Bus – bar circuit braker

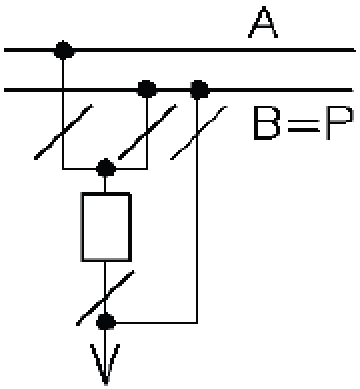
Bus-bar systems

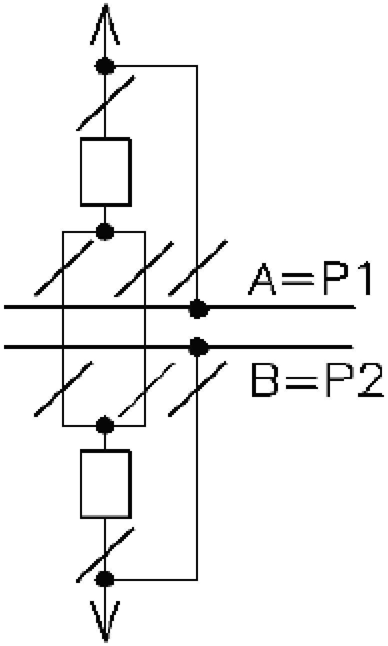
- Duplicate bus-bar system

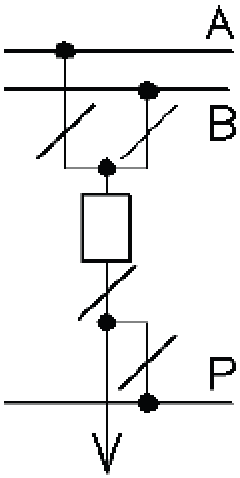


Bus-bar systems

- Systems with auxiliary bus-bar



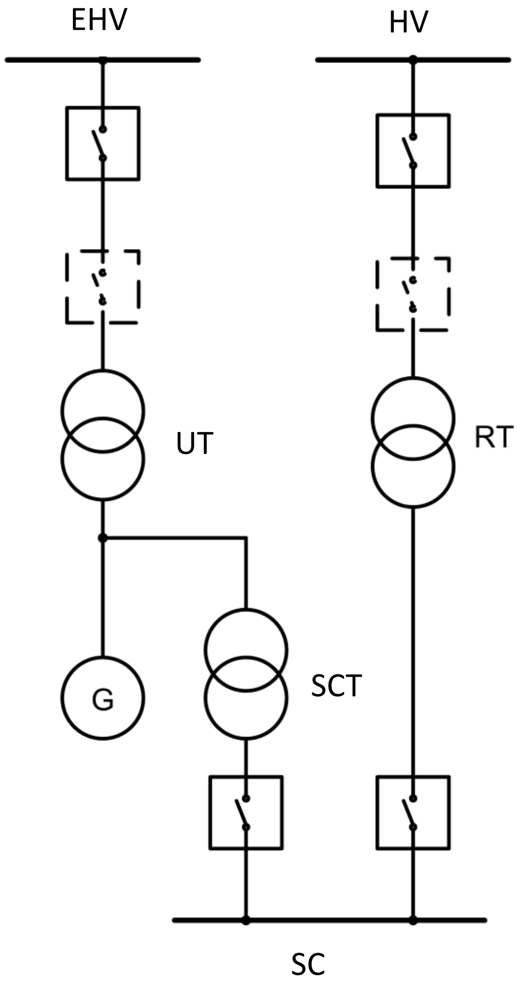


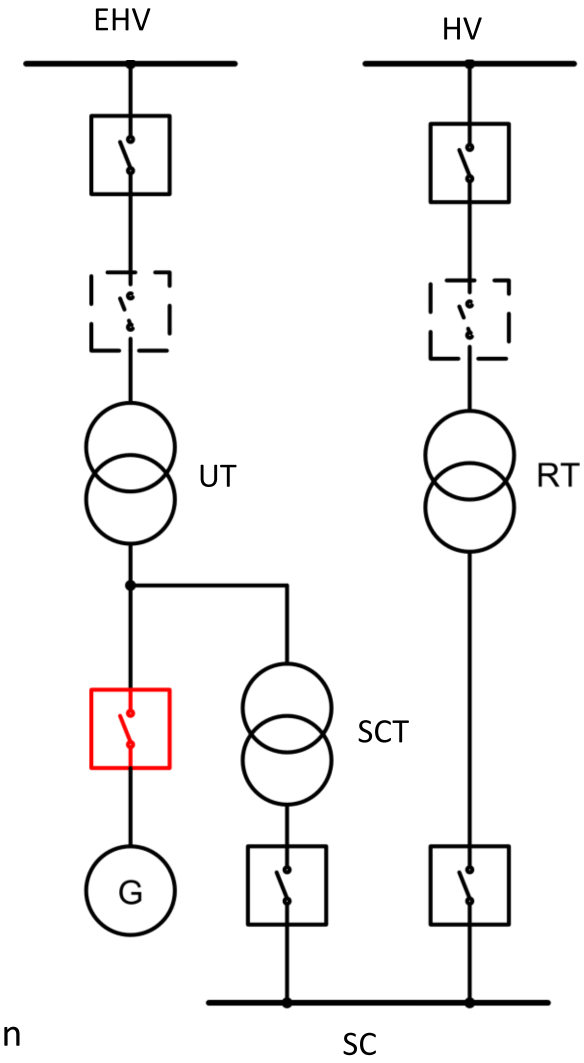


Self-consumption (SC) supply

- Starting source of SC
  - Power plant is started from an idle state, SC usually supplied from power grid or, in special cases from hydro power plant, dieselagregate, gas turbine generator etc.
- Operating source of SC
  - The power plant SC is supllied at normal operating condition from its own generator
- Backup source of SC
  - The power plant SC is supplied, in case of fault of operating source, usually from a power grid
- Emergency source of SC
  - Rundown of powerplant in case of faut of operating and backup source of SC

Fundamental electric scheme of SC supply





UT – unit transformer, RT – reserve transformer, SCT – Self consumption

Transformers

- Unit transformer
  - Oil filled transformers with power from tens to thousand 1000 MVA (the same value as the power of power plant unit)
  - The vector group is usually Dyn, connection D (delta) is on the generator side –> suppression of third harmonics and its multiples propagation
  - Size of unit transformers is limited by transport possibilities (large transformers are usually delivered as three one phase units)

Transformers

- Self-consumption transformers
  - Transformers for self-consumption supply, construction is given by a structure of SC
  - Minimal apparent power of transformer is specified as the sum of coincident power of devices in self consumption
- Reserve transformers
  - Transformer for self consumption supply in case of outage of operating sources

Self consumption design

- Power of SC source is evaluated in accordance with power summation all electrical appliances:

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

where the demand factor $\beta = \frac{k_z k_s}{\eta_m \eta_s}$

η_m is the mean of efficiency of appliances at given utilization, η_s is the supply grid efficiency, k_z and k_s are the utilization and diversity factors

Self consumption design

- The rated power of SC source S_z must then be:

$$S_Z \geq S_P$$

- Moreover, must be guaranteed:
  - Voltage across terminals of electric motors must be in the range ±5% V_n
  - During the start of the most powerful maschine the minimal voltage drop should not be below 0.85 V_n and must not be below 0,8 V_n
  - Voltage drop during the starting of maschine group must not be below 0,65 V_n

Self consumption design

- For backup sources must be further met:
  - At least one backup transformer must be available for two units, teo bacup transformers for more units
  - At the same time, each backup transformer must assure regular operation of one unit, No-load operation of second unit and 50 % of common self consumption
  - For nuclear power plants, the backup trnasformer must be able assure shutting down the second unit as well

Dimensioning of conductors

- Dimensioning respecting permanent current I_n
- Dimensioning respecting short-circuit currents I_k (thermal and dynamical effects)
- Mechanical stresses
- Voltage stresses (cable insulation)
- Enviroment condition and nonstandart modes of operation

Dimensioning for permanent current

- Balance equation of thermal powers

$$P_J + P_S = P_C + P_R$$

- Where
  - P_J are Joule losses
  - P_S is thermal power from the Sun
  - P_C is transferred heat by convection
  - P_R is transferred heat by radiation

Joule losses

$$P_J = I_n^2 R_{AC}$$

- Where
  - $R_{AC} = kR_{DC}\left(1 + \mathrm{b}\left(t_p - 20\right)\right)$ is AC conductor resistance, k is coefficient respects skin effect, proximity effect and hysteresis losses, b is temperature coefficient of resistance and t_p is temperature of conductor
  - $R_{DC} = \frac{\rho_{20}}{S}$ is DC conductor resistance, ρ_{20} is specific resistivity at 20°C, S is cross-section of conductor

Solar radiation

- Maximal intensity of solar radiation incident on a plane perpendicular to sun beams is A_m=1200W/m^2
- In the CE region A_m=1000W/m^2

$$P_S = A_m D a$$

- Where
  - a is coefficient of absorption of sun radiation
  - D is diameter of conductor

Heat convection

$$P_K = F\alpha\left(t_p - t_0\right)$$

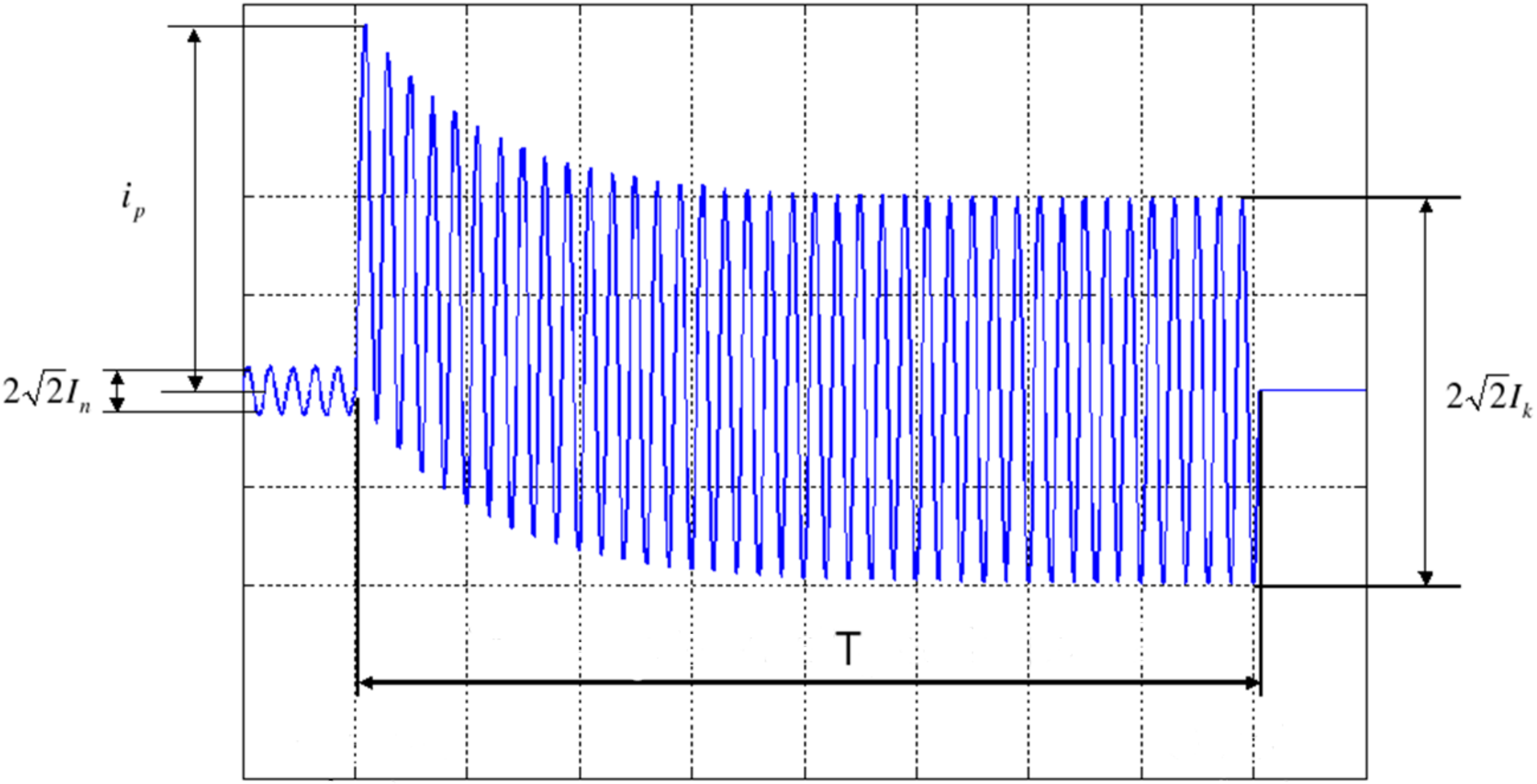
- Where
  - F is cooled surface related to 1m of conductor length
  - α is heat transfer coefficient
  - t_p is temperature of the conductor
  - T_0 is temperature of the environment

Heat radiation

$$P_R = \varepsilon \sigma \pi D \left(T_p^4 - T_0^4\right)$$

- Where
  - ε is emissivity factor
  - σ is Stefan-Bolzman constant
  - D is diameter of the conductor
  - T_p is temperature of the conductor
  - T_0 is temperature of the environment

Short-circuit current



I_p – peak short circuit current, I_k – steady state short circuit current

Heat effect of short-circuit current

Balance equation for the heat increase dW (J) in conductor of 1 m length:

$$I_k^2 R dt = m c_0 d\theta$$

where I_k is shor-circuit current, R is resistance of 1 m conductor, dt is the time duration of a short-circuit, c_0 is specific heat constant, m is the mass of 1 m conductor and $d\theta$ is the increase of temperature

The final equation for practical using is then in the form of:

$$\frac{I_k}{S} = \frac{1}{\sqrt{T}} \sqrt{\frac{\gamma c_0}{\rho_{20} b} ln \left(\frac{1 + b(\theta_e - 20)}{1 + b(\theta_b - 20)} \right)}$$

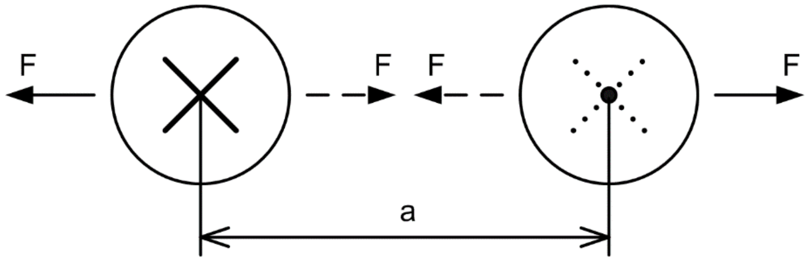
where γ is specific mass of conductor, S is cross section of conductor, ρ_{20} is specific resistivity at 20°C, T is time duration of short-circuit, b is temperature coefficient, θ_e is conductor temperature after the short-circuit and θ_b is conductor temperature before the short-circuit

Mechanical effect of short-circuit current

The attractive/repulsive force between two solid parallel conductors is given by equation:

$$F = \frac{\mu_0}{2\pi} i_1 i_2 \frac{1}{a}$$

where i_1, i_2 are instantaneous values of currents, a is axial distance, μ_0 is vacuum permeability



Mechanical effect of short-circuit current

In case of two phase short-circuit $i_1=-i_2=i_p$, and the force between conductors is:

$$F = \frac{\mu_0}{2\pi} i_p^2 \frac{1}{a}$$