4.5 Exploitation of the Thermal Capacity of Network Elements

Planning of networks include all components; it has to be considered

- peak load of the network
- rated current (power) of the elements
- outage of one critical element at the time (n-1)
- increase of load x_1 %/year or x_2 MVA/year
- time horizon 2 ... 5 ... 10 ... 20 years

Operation conditions

- operation planning means switching-off elements for maintenance, checking, cleaning, .. if possible at a time of low load
- unforeseen outages of elements can lead to an overloading of the remaining components
  - ➢ consequences:
    operation planning checks , before switching-off essential elements, the reliability of the system considering additional tripping of elements. Method has to be fixed definitely.
  - ➢ If critical situations can occur, decisions have to be made
    - bearing the risk of customers interruption
    - preparing and/or installation of substitute measures
    - preparing load shedding in accordance with customer
    - accepting overload in the limits of the dynamic thermal capacity. Bottlenecks in the current flow have to be considered.
      - ⇨ estimating the risk of additional outages and comparing the rated risk with the expenditures for additional installations or customers interruptions

Precondition for overloading elements - controlled

- knowledge concerning
  - ➢ bottlenecks
  - ➢ the thermal stress before overload occurs
  - ➢ the environmental conditions
  - ➢ thermal time constant of the elements
  - ➢ calculating acceptable overload $I = f(\Theta_0, \Theta_a, t)$
  - ➢ additional supervision to avoid destruction or damage of elements
  - ➢ control of overload effects, depends of frequency, stress and duration

Overhead Lines (OHL)

counting environmental conditions is difficult

- sunshine, wind, rain, ice, ...
- clamps as bottlenecks
- rope connectors
- line sack
- ....

➢ preventive calculation is difficult; investigations started 25 years ago in Germany. Effects only for lines with wide spans, considering the maximum sack.

Transformers

Loading Guide for Oil Cooling Power Transformers

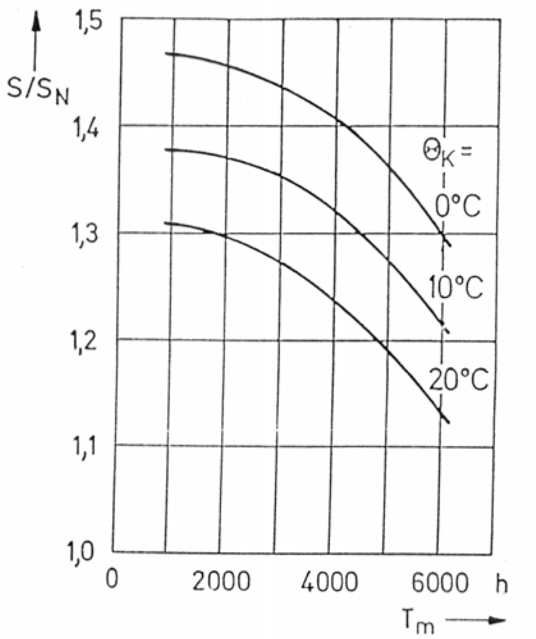
(IEC-Publication 354, May 1987)

	S_N ≤ 2.500 kVA	≤ 100 MVA	> 100 MVA
Normal cyclic operation			
I / p.u.	1,5	1,5	1,3
Hot-spot-temperature [^{0}C]	140	140	130
Long-time emergency operation			
I / p.u.	1,8	1,5	1,3
Hot-spot-temperature [^{0}C]	150	140	130
Short-time emergency operation			
I / p.u.	2,0	1,8	1,5
Hot-spot-temperature [^{0}C]		160	160

MV/LV transformers (250 kVA ... 800 kVA ... 1200 kVA)

- planned with rated current with expected load in next 2 .. 5 years
- measuring the maximum of the effective current (average 8 or 15 minutes)
- measuring the maximum of the oil temperature
- documentation of the annual load/temperature history

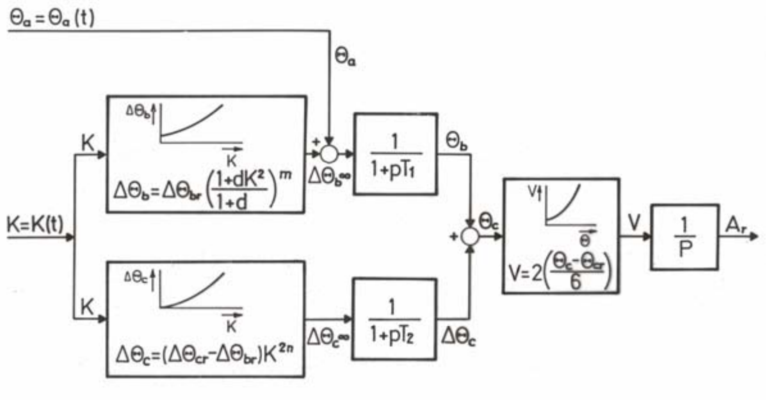
- calculating the life time consumption after the event
- reading the trailing measuring apparatus 1x per month during the high load season
- rating the correlation between maximum load and oil temperature



Rating of MV/LV transformers, related to nominal rating and depending on annual utilization duration

HV/MV transformers (16 MVA ...20 MVA ... 40 MVA)

- planned with rated current with expected load in next 5 .. 10 years, considering the (n-1) principle
- risk of overload considering the environmental conditions (e.g. winter season)
- load curve known by online supervision
- calculating life time consumption considering daily load curves
- considering switching-over possibilities to other injection points in the MV network



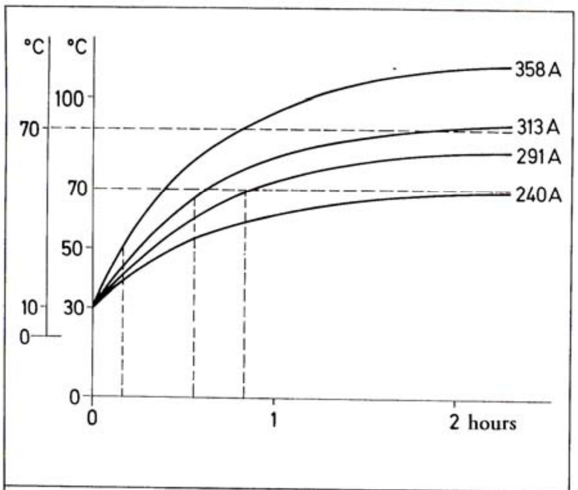
Flow chart for calculating temperature and aging (VDE 0536)

Coupling transformers (200 MVA)

- planned rated current with expected load in 5 ... 20 years; (n-1) principle
- in case of definite critical situations calculation with the thermal equivalent
- adapted protection system

Underground cables (UGC)

- uncertainty of soil behaviour
- accumulation of cables requires considering the accumulation factor
- temperature measurement expensive
- adiabatic calculation max. temperature Θ_{max} = f (starting temperature, load, time)
- attention:
  - ➢ high load capacity compared with OHL
  - ➢ rating the losses during life time by planning the cross section and the rope material
  - ⇨ bigger cross section for saving losses (money) and higher load capacity

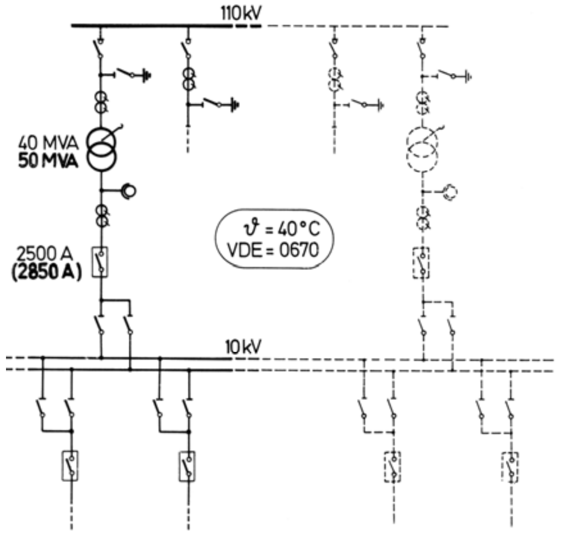


Conductor temperature as a function of I and t

Switchgear

Circuit breaker, load breaking switch, disconnector, ...

- construction essential
- contact critical (pressure, surface, cooling conditions, contact material, ...)
  - ➢ ohmic resistance increases
    - * losses/temperature increase
    - * risk of contact welding
  - ➢ testing of typical candidates (temperature, contact pressure, ohmic resistance,
    short circuit stress, functionality, ...



Substation: Circuit breaker with limited rated current

$$\Delta\vartheta \sim I^2$$

for an ambient temperature of 20° C

$$\frac{I_N^2}{I^2} \approx \frac{\Delta\vartheta}{\Delta\vartheta + 20°C}$$

$$I_{zul.20} \approx \sqrt{\frac{85}{65} \cdot (2{,}5kA)^2} = 2{,}86kA \quad \text{(air)}$$

$$I_{zul.20} \approx \sqrt{\frac{70}{50} \cdot (2{,}5kA)^2} = 2{,}96kA \quad \text{(oil)}$$

$$I_{zul.20} \geqq \mathbf{I} \geqq 2{,}5kA$$

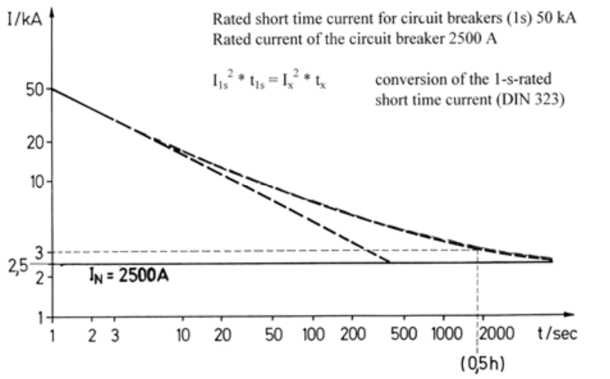
Converting acceptable current for lower temperature

contact parts (stringy)

Copper, silver-plated (VDE 0670 part 6)
Co- or Al-alloy

	limited temperature	limited temperature rise (ambient temperature 40 K)
switch-parts (in air)	105° C	65 K
switch-parts (in oil)	90° C	50 K

Limited temperature air/oil



Higher current as f(t)

Risks

Economical advantage of avoided investments has to be compared with

- risk of customers interruption
- risk of element damage
- expenditure and time for exchanging damaged elements
- outage costs for customers
- negative image under public and political aspects