4.3 Load Flow Analysis - Periodic Outage Calculation in HV Networks

Load flow has to be calculated for **meshed** networks. This is part of the planning method.

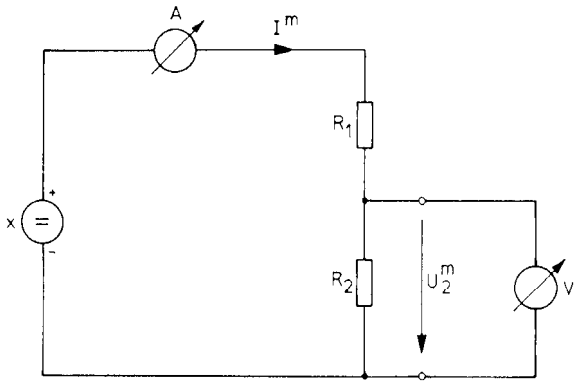
As an operational tool it is used for supervising network elements by pre-determination their load in case of an outage of such elements, the so called ***security calculation***. This work is normally done by the SCC computer system in the background and only ***critical situations*** are indicated to the operator. The inputs are coming online from the SCADA system concerning voltage, active and reactive power, network elements being switched on or off, using the adapted network equivalent matrix for the calculation.

Based on this security calculation with the foresighting outage calculation proposals for load decrease of overloaded lines by switching of other lines can be selected and shown on the screen.

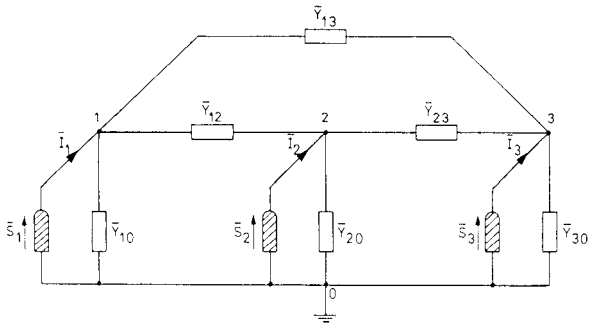
This method has to be applied too for calculating the setting of the distance protection.

* definition of network components by equivalent elements

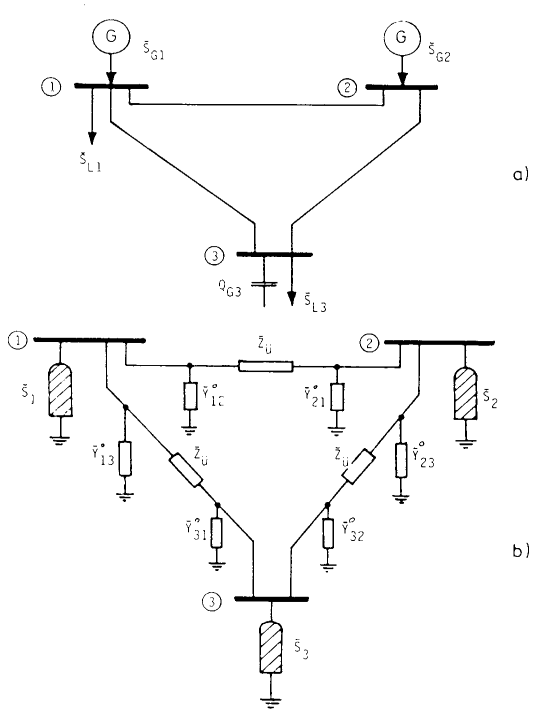
- synchronous generator/motor
- asynchronous generator/motor
- OHL, UGC
- transformer
- consumer



DC network with equivalent circuit



Simplified equivalent circuit by summarizing the net admittances



a) test network with three junctions
b) 1-phase equivalent circuit

junction power: $\underline{S}_i = \underline{S}_{Gi} - \underline{S}_{Li}$

*** input data of some nodes, not of all!**

- apparent power
- node currents
- node voltage

*** calculating**

- active power flow
- reactive power flow
- node voltages
- losses

*** network equation is non-linear**

- Newton - Raphson - Method usual
  (form the non-linear equation into a Taylor series one; linearisation)
- starting value of the voltage regulated node
- iteration and correcting the node voltage

*** planning:** **all variants can be determined**
starting with one voltage node and the injected currents

*** operational load flow supervision and control**

° same network model (admittance matrix)
° measured values available in a network
° calculating the real network situation
- the network situation must be determined completely and reliable
- measuring mistakes have to be filtered by statistics
- not measured values have to be calculated
- high measuring faults have to be explored, located and eliminated

- $\underline{Z} = \underline{H} \cdot \underline{X} + \underline{v}$

$\underline{Z}$ = measuring vector

$\underline{H}$ = measuring model matrix

$\underline{X}$ = system state vector

$\underline{v}$ = measuring fault vector

- weighting the difference (measured - calculated)
- sum of squared faults a minimum

* problems:

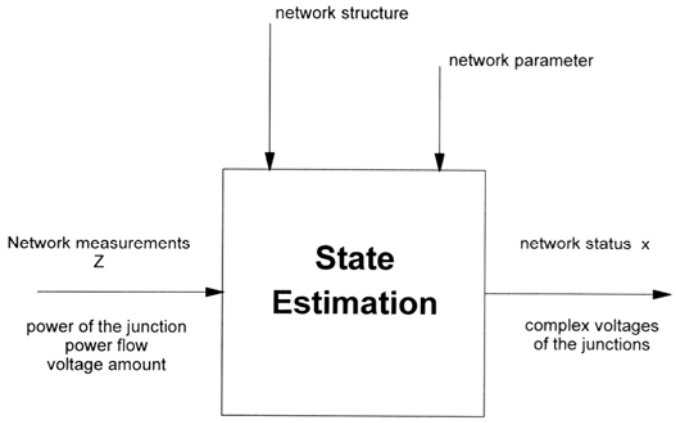
- measured values are not registered at the same moment
- instrumentation faults, A/D conversion faults, transmission faults
- equivalent diagram not precise enough

-> state estimation - load flow

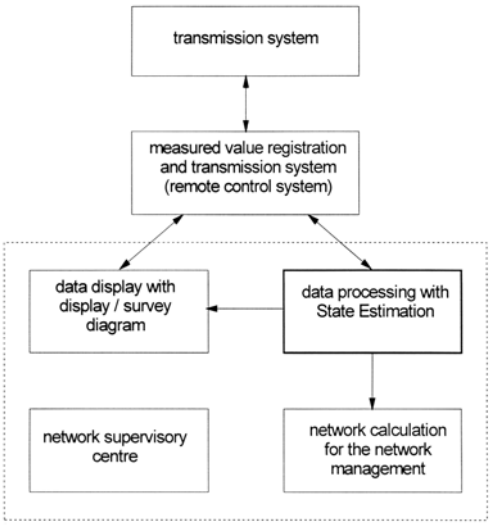
Planning a meshed network, the load flow calculation allows the precise determination of the active and reactive load, the losses as well as the complex voltage $\underline{U} \cdot e^{j\gamma}$ in dependence of the admittance of the network elements and the consumers load. The mathematical equation can be solved.

Regarding the network in its dynamic behaviour, the measured input data are more or less faulty. The reasons are the unavoidable measuring inaccuracy and the timely not synchronous registration. Therefore the most probable state of the system has to be estimated for the start position of the load flow of the network security calculation. Higher voltage networks have to consider coupling points and neighboured networks.

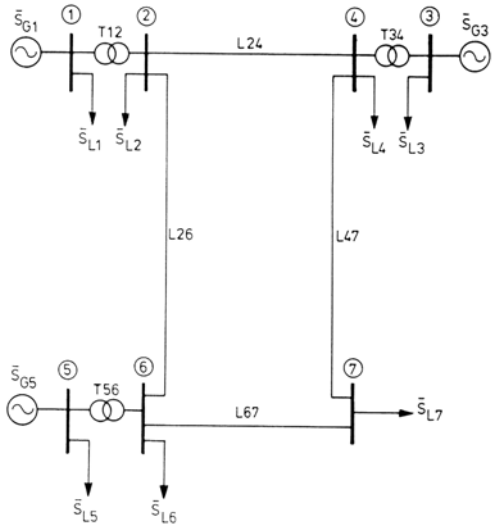
* calculating the not measured values
* identification of faulty measured values
* optimisation of the measured points to get better results



Simplified diagram of the State Estimator for the network management



State Estimation as the link between the present status of the network (measured) and the required network calculation for the network management



Test network with seven junctions for illustrating the principle of the power flow calculation