Study Committee A2

POWER TRANSFORMERS AND REACTORS

Paper ID 10884

Mobile Load Flow Reactor for 220kV

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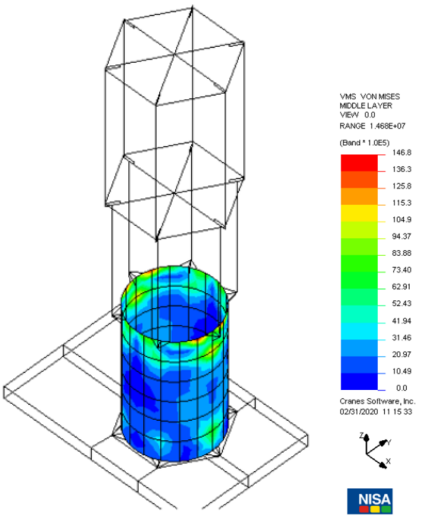
Motivation

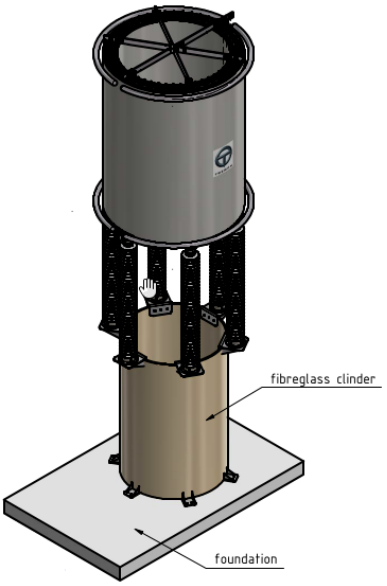
- Grid stability and resilience against network disturbances are impaired by the addition of decentralized power generation, such as wind and solar PV.
- Feasibility of a mobile, dry-type series reactor connected to 220kV for temporarily hardening the network is investigated.

Method/Approach

- The wind, short-circuit, seismic and static mechanical stability are verified using NISA FEA software
- The human exposure limits to electromagnetic fields are considered by calculating non-permitted zone near the reactor using FEM electromagnetic tools
- An equivalent circuit is created and analyzed to investigate the transient recovery voltage
- The mobility of the concept is evaluated based on size, mass, and the time needed to (re-)assemble.



Maximum stress distribution on the glass fiber cylinder in the FEM seismic verification. The values are everywhere below the limits.



The Load Flow Reactor Layout

Basic design of the air core reactor

- Aluminium winding
- Aluminium top and bottom winding structures (spiders)
- Multi package coil (5 packages concentrically arranged) with a mass of approx. 4400 kg
- Coil dimensions: h = 3040 mm, da = 2160 mm
- 6 insulators C8-1050, length 2300 mm, mass 184 kg each with minimum creepage distance of 7875 mm
- Support cylinder made of fiber-glass composite – height 2500 mm (accessible substation requirement), diameter 1639 mm, mass 625 kg
- Base concrete slab, minimum size 3940 mm x 2500 mm x 250 mm (min), approx. 6650 kg
- Total mass 12 788 kg, total height 8133 mm
- S/C current with the series reactor rated short circuit current (1s, rms) Ikd = 11.2 kA_{rms} /rated peak short circuit current Iks = 28.56 kA_{peak}

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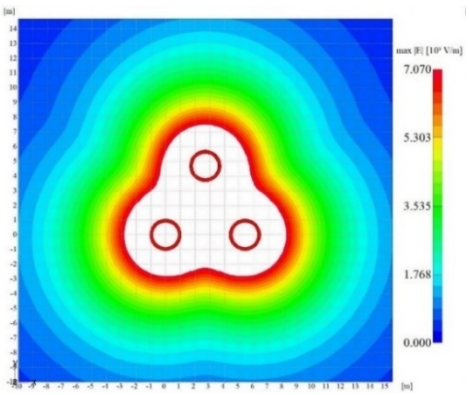
System requirements

- Parameters chosen for to get a flexible equipment that can be useful and installed in most of the circuits of the grid.
- A selection of issues to consider
  - Static mechanical stability
  - Transient short circuit force withstand
  - Wind forces & Seismic
  - B-field and E-field limits
  - Transient recovery voltage (TRV)
- Specified design parameters are listed below

maximum system voltage	245	kV
rated system voltage	220	kV
impedance / phase	10	Ohm
tolerance	± 5	%
rated current	1100	A
overload current 20 minutes	1265	A
rated frequency	50	Hz
BIL across reactor/to ground	1050	kV
system S/C current	50	kA
USCD e-very heavy	53.7	mm/kV
seismic NSCE-02	≤0.16	g
max. ambient temperature	45	°C
wind speed	140	km/h

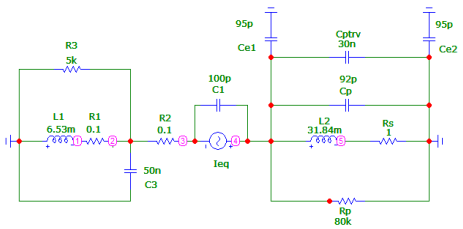
Electromagnetic field exposure

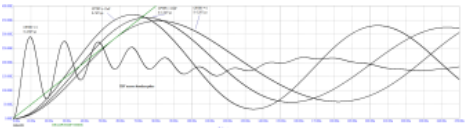
- A three-reactor arrangement was investigated
- Both the E-field and the B-field exposition were considered
- As an example, the prohibited area for General Public according to ICNIRP is plotted white based on the calculated E-Field.



Transient Recovery Voltage

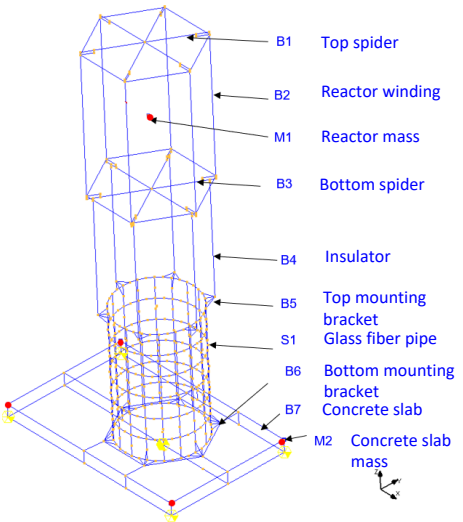
- Insertion of series reactance impacts TRV negatively.
- This can be mitigated by installing capacitors, preferably parallel to the winding
- A circuit model was used to determine the required capacitance value





Static and stability verification

- A FEM model of the reactor was prepared to investigate the stability of the structure against the static and dynamic loads.



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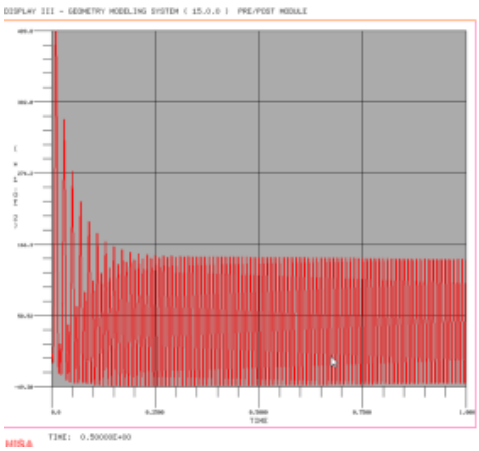
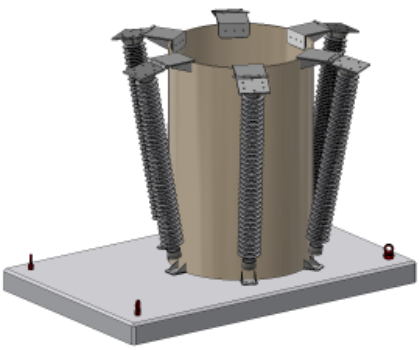
- The transient structural reaction at a short circuit in a 3-coil arrangement is presented in the figure below. The rocking mode frequency is about 2 Hz.



- Part 2: Reactor coil with suitable top fittings for the insulators.

Transport Concept

- The reactors shall be shipped in two parts per phase plus a small box for accessories and mounting hardware.



- Part 1: Self-supporting concrete slab, glass fiber support cylinder, and the insulators which are already installed and flipped downwards to limit the transport size to standard road transport.

Discussion

- The suitability of an air core dry-type reactor as a mobile solution for network hardening was investigated
- This new design is comparably inexpensive and quick to assemble
- The mechanical stability with the reactor standing on a self-supporting concrete slab was shown to comply with the specified standards.

Conclusion

- We propose the mobile load flow reactor as a feasible solution that increases network resilience for example after adding additional power generation.
- The assembly and dismantling concept facilitate a rapid relocation cycle (typically less than 4 weeks incl. road transport)
- FACTS based devices may provide smarter solutions, but with higher costs, higher complexity, long planning and installation times and a larger footprint.