Study Committee A2

POWER TRANSFORMERS AND REACTORS

Paper ID: 10803

420 kV Shunt Reactors for Reactive Power Compensation Explaining the Trends Favoring Air-Core Dry-Type Technology

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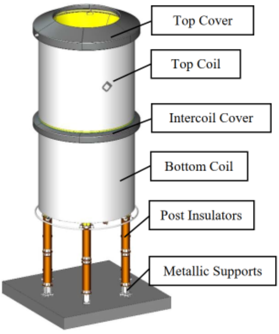
Motivation

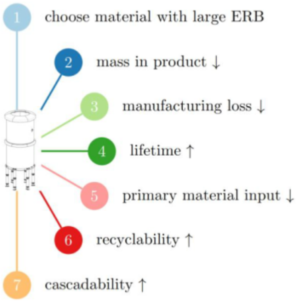
- Air-Core Dry-Type Reactors for reactive power compensation of high voltage transmission systems
- Comparison between iron-core liquid-immersed and air-core dry-type high voltage shunt reactors (HVSR)
- Application example with 420 kV air-core dry-type shunt reactors installed on the transmission network of a well-known German transmission system operator

Basic Design and Construction of Air-Core Dry-type HVSR



- Depending on the system voltage several of these stacks can be connected in series

Sustainable Circular Economy



- A sustainable circular economy builds on the sustainable resource base and aims to make the best possible use of the limited resources

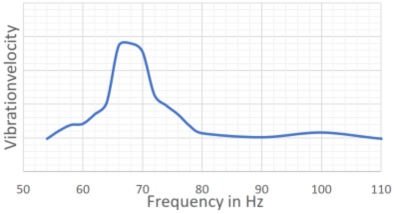
Comparison between Oil- and Dry-Type Reactor Technology

- Air-core dry-type HVSRs have **a lower degree of complexity** than iron-core liquid-immersed HVSR
- **Most of the materials** used in both types **can be recycled** in a certain way. For **air-core dry-type reactors up to 90 %** of the used mass can be recycled
- Comparable in losses and

- Liquid-immersed HVSR require additional concrete for firewalls, cable ducts, oil containment, …
- Air-core dry-type reactors have **no saturation but** an **external magnetic field**
- **Reduced costs** for spare parts, transportation and operation of air-core dry-type HVSR

HVSR Testing

- Loss-measurement for air-core dry-type reactors is different compared to iron-core liquid-immersed HVSR.
  - Measurement performed in metallic free environment at any voltage (extrapolated to U_r)
  - Conversion factor used to correct losses for coil windings measured in factory environment
- Measurement of axial resonance



- Measurement of acoustic sound level according to **IEC 60076-6 and IEC 60076-10**
  - Voltage is generated with series resonant circuit
  - **Reference measurement** performed in outdoor environment
  - **Routine tests** in factory environment **corrected** according to ISO 3744

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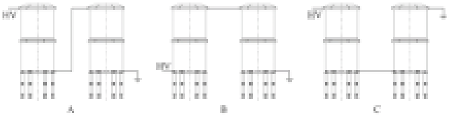
continued

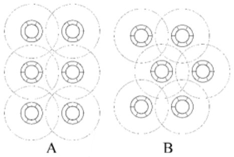
HVSR Single-Phase Arrangement

- Stacking of individual windings technically beneficial (coupling between units) . One phase of 420 kV HVSR is composed of two series connected stacks
- More than two units should not be stacked due to mechanical reasons



- Arrangement C combines advantages like **field-cancellations** and thus reduced induced currents in the grounding grid, **positive mutual coupling** of the stacks, **interchangeability** and **reduced stress** on the **support insulators**

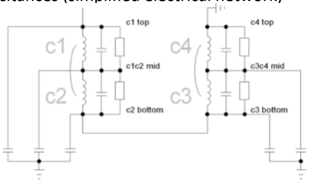
HVSR Three-Phase Arrangement



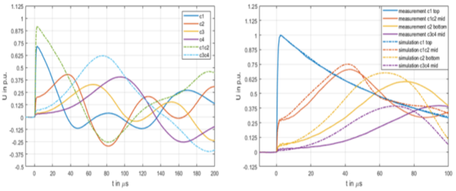
- Shift of the middle phase (scheme B) leads to a better fit of the phase arrangements (identical C2C-distances)
- Improves unbalance situation in side-by-side installations due to improved cancellation effects

Transient Voltage Considerations

- Non-linear transient voltage distribution, governed by capacitances (simplified electrical network)



- Measurement and simulation show excellent accuracy



Conclusion

- Environmentally friendly and can be designed to even exceed existing technical requirements for con-ventional HVSR
- Benefits in terms of lead time, product standardization, spare parts management, thus reducing total cost of ownership
- For the specific project (see figure below) air-core dry-type rectors are the preferred solution for reactive power compensation