RECENT DEVELOPMENTS IN TRANSFORMERS AND REACTORS

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Imagination at work

- Ecodesign requirements – low loss & high efficiency
  - Paperless CTC – improved space factor and optimum cooling
  - Non-metallic structure for reduction of stray losses
  - High performance GOS material – low loss & low noise
- Variable Shunt Reactors

❑ Ecodesign requirements – low loss & high efficiency

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❑ Variable Shunt Reactors

❑ Ecodesign requirements – low loss & high efficiency

Peak Efficiency Index :

$$PEI = 1 - \frac{2(P_0 + P_{c0})}{S_r \sqrt{\frac{P_0 + P_{c0}}{P_k}}}$$

Timeline

October 21, 2009	June 11, 2014	July 1, 2015	2017	July 1, 2021
EU adopted revised "Ecodesign Directive" (2009/125/EC) for Energy-related products – establishing a framework to be complemented by "implementing measures" (E.G. regulations on individual products and systems)	EU commission adopted a regulation to apply the defined ecodesing requirements on transformers and the regulation 548/2014 entered into force	Transformers need to be compliant with the efficiency requirements of „Tier 1" – level of the regulation	Mid-term assessment of the regulation by the European Commission	Transformers need to be compliant with the efficiency requirements of „Tier 2" – level of the regulation

❑ Ecodesign requirements – low loss & high efficiency

Rated Power (kVA)	Tier 1 (July 1, 2015)	Tier 2 (July 1, 2021)
	Minimum Peak Efficiency Index (%)	
3,150 < S, ≤ 4,000	99.465	99.532
5,000	99.483	99.548
6,300	99.510	99.571
8,000	99.535	99.593
10,000	99.560	99.615
12,500	99.588	99.640
16,000	99.615	99.663
20,000	99.639	99.684
25,000	99.657	99.700
31,500	99.671	99.712
40,000	99.684	99.724

Rated Power (MVA)	Tier 1 (July 1, 2015)	Tier 2 (July 1, 2021)
	Minimum Peak Efficiency Index (%)	
≤ 4	99.465	99.532
5	99.483	99.548
6.3	99.510	99.571
8	99.535	99.593
10	99.560	99.615
12.5	99.588	99.640
16	99.615	99.663
20	99.639	99.684
25	99.657	99.700
31.5	99.671	99.712
40	99.684	99.724
50	99.696	99.734
63	99.709	99.745
80	99.723	99.758
≥ 100	99.737	99.770

❑ Ecodesign requirements – low loss & high efficiency

- ➢ Paperless CTC – improved space factor and optimum cooling
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❑ Variable Shunt Reactors

➢ Paperless CTC

- ➢ Improved space factor
- ➢ Improved cooling performance
- ➢ Elimination of paper ageing
- ➢ Improved loss/weight performance
- ➢ Can be used up to 52kV Um / 250kV LI level

Contours of Total Temperature (c)

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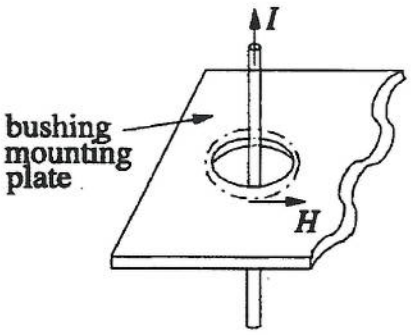
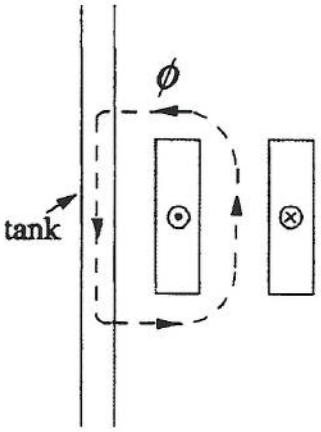
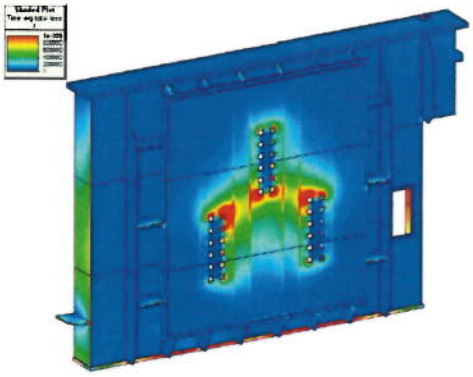
❑ Variable Shunt Reactors

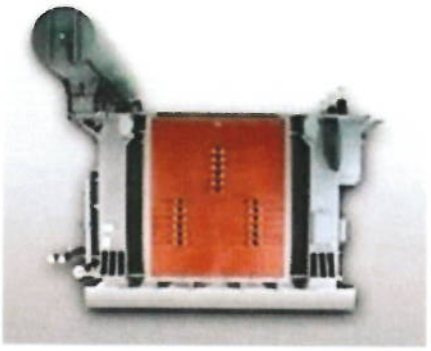
➢ Stray losses in tank wall



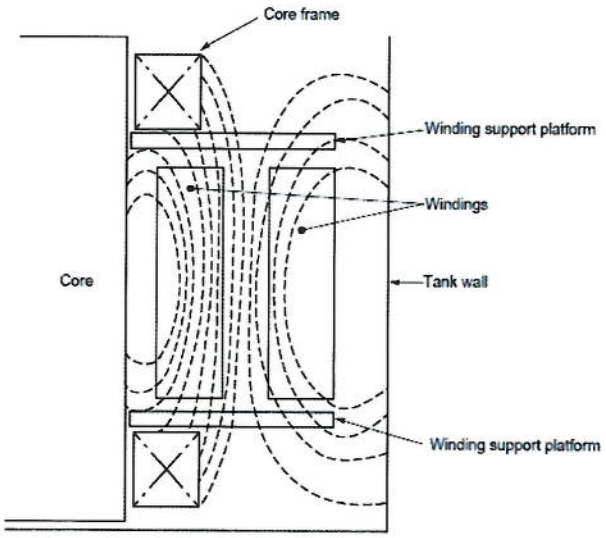


➢ Non-metallic tank wall

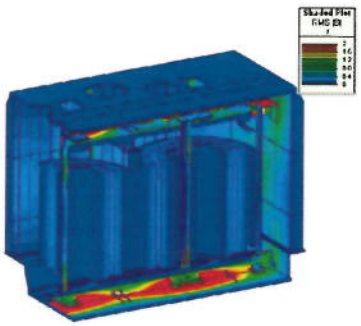


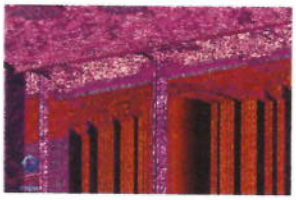


➢ Stray losses in core clamping structure



➢ Non-metallic clamping structure





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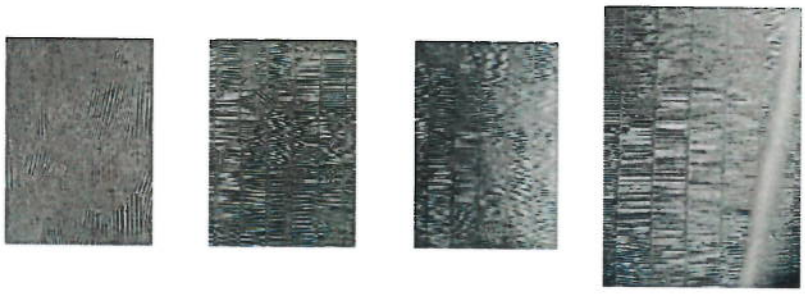
- Variable Shunt Reactors

- High performance GOS material – low loss

Losses = thickness + magnetic domain behavior



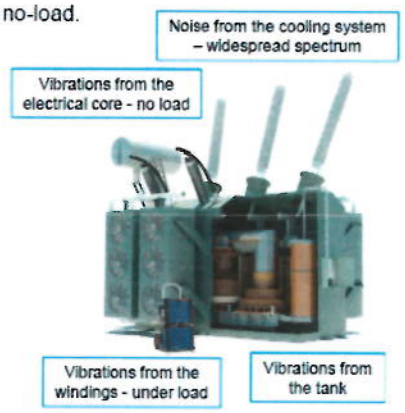
Lower thickness, improvement of texture, coating and laser domain refinement

➢ High performance GOS material – low noise

GOES core is the main part of transformer noise at no-load.

Key factors of suitable GOES for core noise

- ✓ Optimized magnetic domain structure
- ✓ Optimized insulation coating characteristics



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❑ Variable Shunt Reactors

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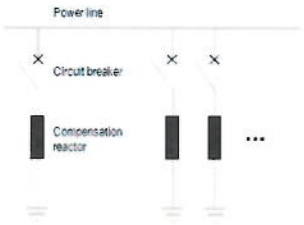
Shunt Reactors: *Used to compensate the capacitive VARs generated during low loads and switching operations in extra high voltage transmission networks, thereby maintaining the voltage profile of a transmission line within desirable limits.*

Fixed shunt reactor(s)



- Fixed inductance
- Switchable using circuit breakers
- Coarse adjustment through parallel combinations of **several** reactors

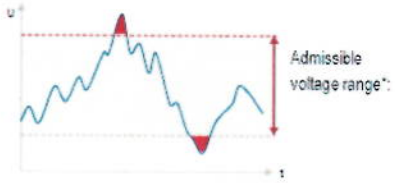
Precise regulation of a reactor

- Variable inductance
- Variable number of turns can be set using the on-load tap-changer
- **Precise tapping** of one reactor

❑ Variable Shunt Reactors

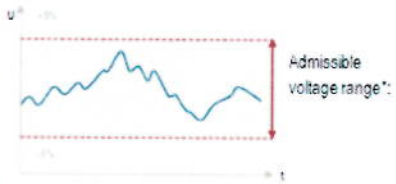
Can be regulated precisely and complies with narrower voltage ranges

Fixed shunt reactor(s)



- Strong and abrupt voltage changes
- Can only be coarsely regulated

Precise regulation of a reactor



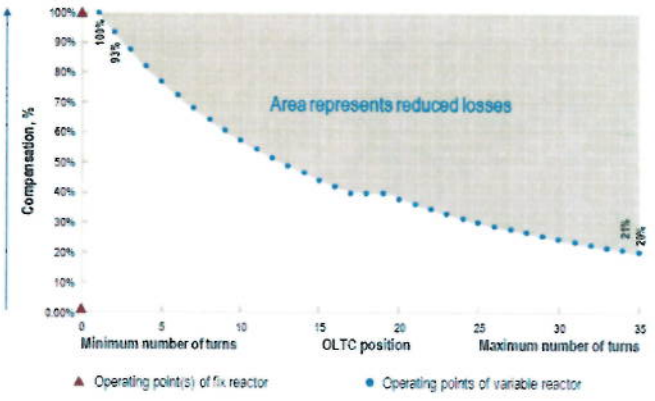
- Continuous voltage curve, narrow voltage range
- Increased grid reliability
- Fewer unscheduled grid interventions

❑ Variable Shunt Reactors

Adjusted compensation creates fewer losses during operation

Reactive power compensation with coarse - fine regulation

- Increasing core induction / iron losses
- Increasing winding current / copper losses



THANK YOU !