CIGRE US National Committee
2014 Grid of the Future Symposium

October 20-21, 2014
Houston, USA

Risk Assessment of Aging Power Transformers in the Transmission Network

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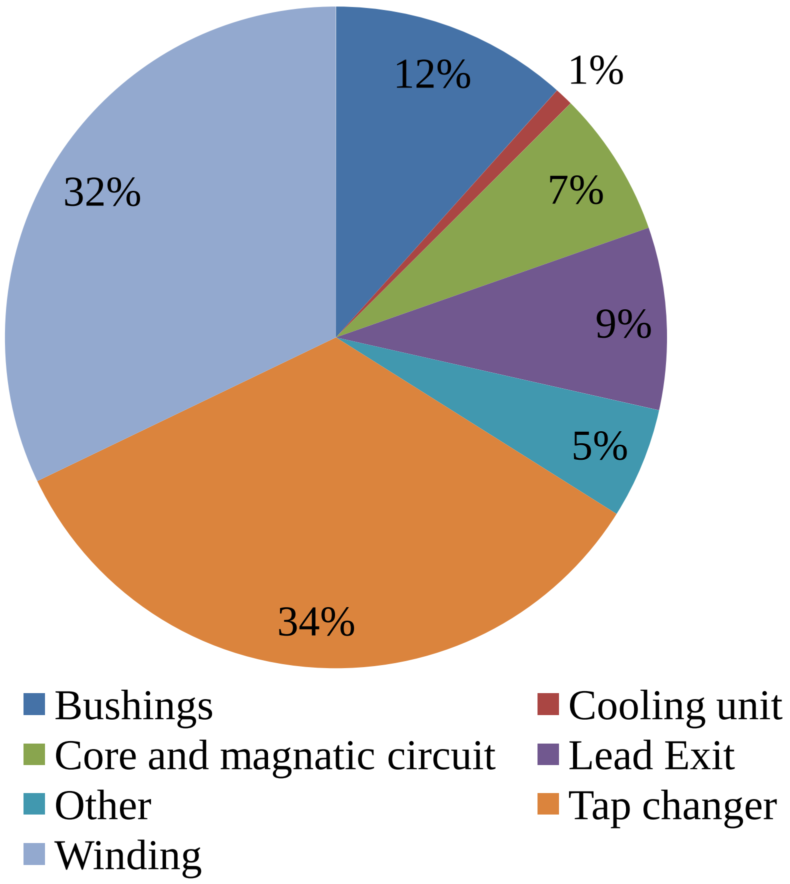
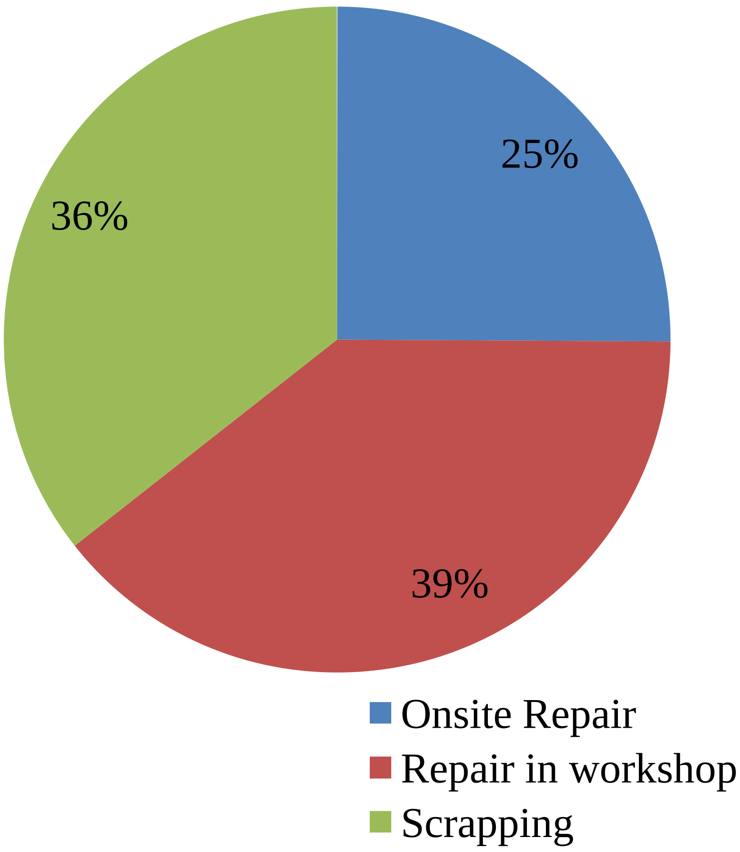
Outage reasons & effects of power transformer

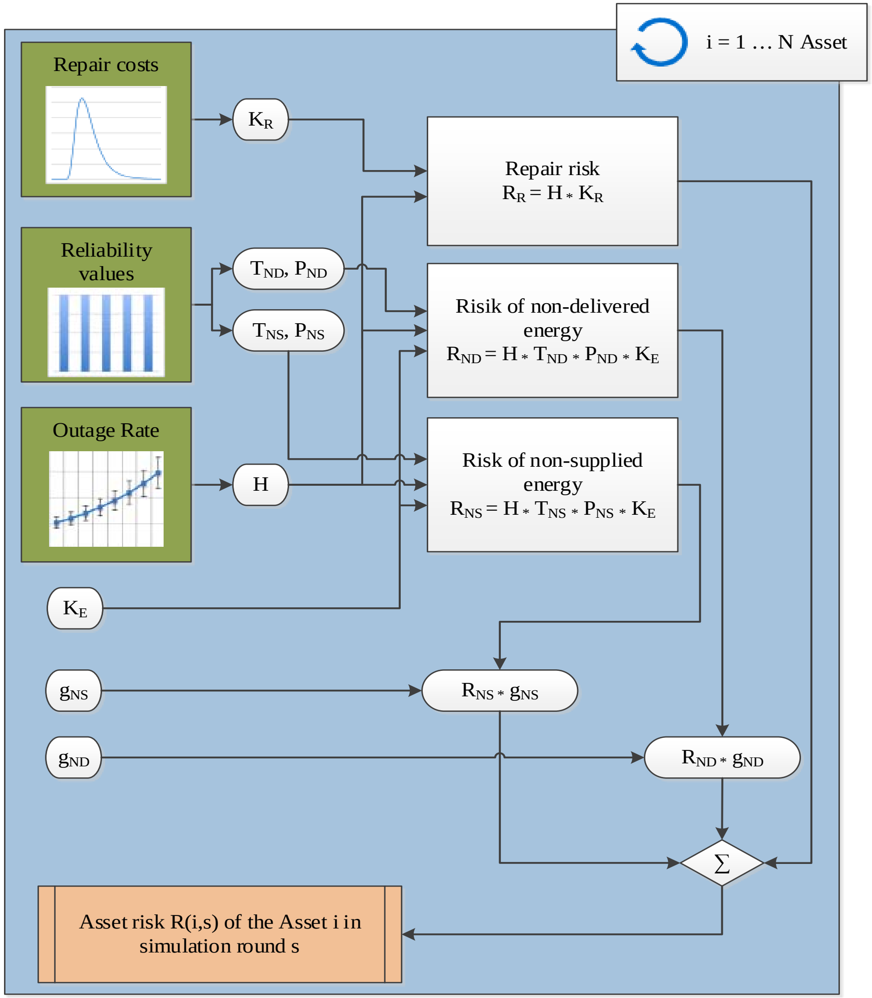
Cause for major faults



Cause for major faults



Risk Assessment of the assets in the TNM



Single asset risk determination with:

- Distribution function of Repair costs
- Age-dependent outage rates with distribution function
- Reliability data of all load & power plant scenarios
- Monte Carlo Simulation used for asset risk *V(i)* and overall risk V determination
- Value at Risk Method used to sort out extraordinary combinations with a confidence interval of 0.95

Power Transformers in the 380kV-level in the TNM

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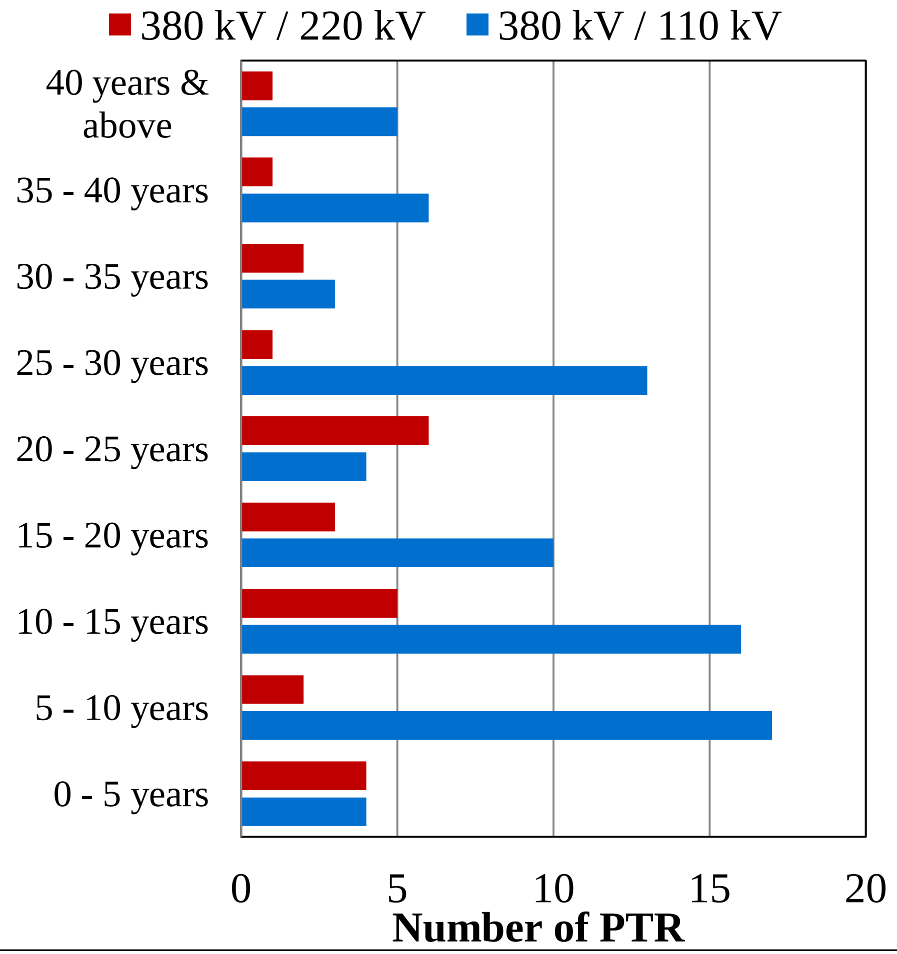
Age distribution of power transformer

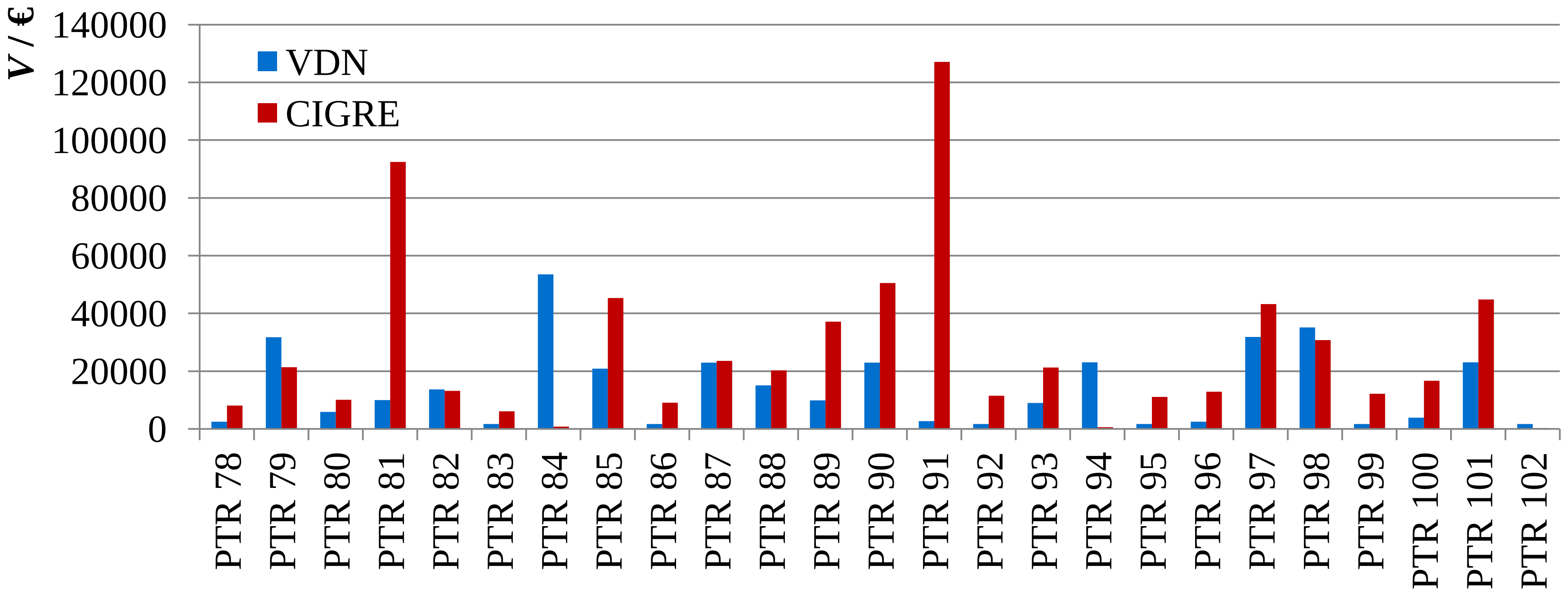


- 103 Power transformers
  - 25 380kV/ 220kV PTR
  - 78 380kV/ 110kV PTR

- Investment Costs:

380 kV / 110 kV (350 MVA)	3,500,000 €
380 kV / 220 kV (1000 MVA)	9,000,000 €

Comparison VDN & CIGRE



- Young PTR overrated
- Old PTR (AGE > 35 Years) underrated

Risk Assessment is wrong with VDN

Different activities of PTR investment strategies

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Activity	Description
Replacement (RP)	• Immediate renewal o f the asset • Hazard rate of new asset • Original price to CAPEX
Refurbishment (RF)	• Renewal of bushings & tap changer • Hazard rate reduction • 20 % Original price to CAPEX
Usual Treatment (UT)	• Normal inspection • No costs allocated to CAPEX • No Scrapping Risk

Different activities of PTR investment strategies

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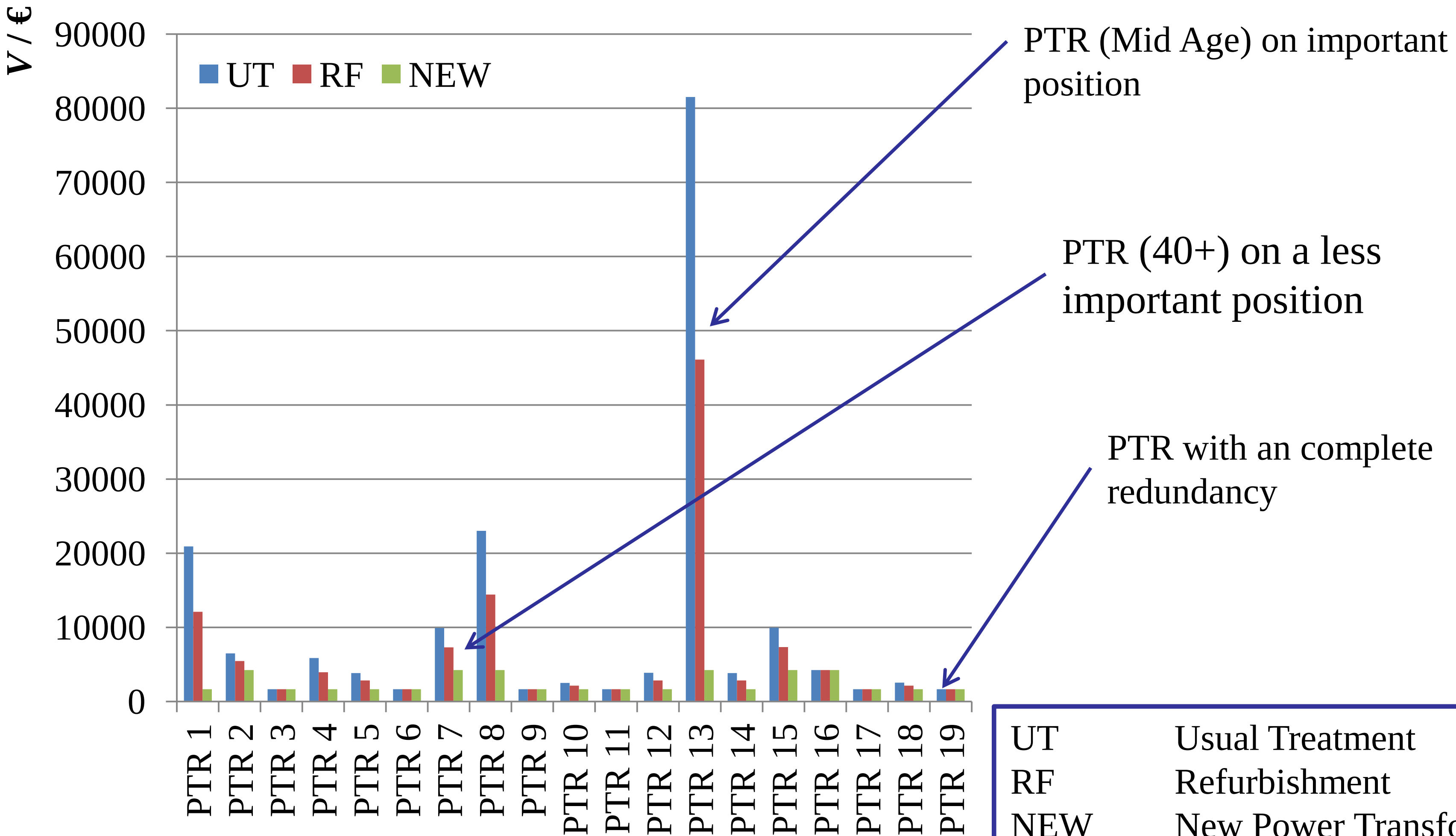

UT	Usual Treatment
RF	Refurbishment
NEW	New Power Transformer

Risk-minimizing multiple-choice knapsack problem strategy

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$$Min\,VaR = \sum_{i=1}^{N}\sum_{j=1}^{3} V_{ij} \cdot x_{ij}$$

$$\sum_{i=1}^{N}\sum_{j=1}^{3} C_{ij} \cdot x_{ij} \leq \text{LB}$$

$$\sum_{j=1}^{3} x_{ij} = 1$$

$$x_{ij} \in \{0,1\}$$

$Min\,VaR$	Minimal summarized VaR
V_{ij}	Asset VaR by activity *j*
LB	Investment budget
C_{ij}	Activity cost *j* for asset *i*
x_{ij}	indicates which activity *j* is used for which asset *i*

For an efficient solution of the equations the solution algorithm of Sinha and Zolters is used.

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Conclusions & further work

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- Refurbishment for old PTR (AGE 40+) is an bad investment
  - Residual risk through scrapping by core failures is to high
- the CIGRE hazard rate values have an higher age-dependency
- Change in legal situation to promote refurbishment
- 380 kV /220 kV PTR outages have an higher impact on the transmission system

- Revised risk assessment for power transformers is needed!
- Refurbishment only for mid age PTR (30-40)

End

Thank you for your attention.