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Study Committee D1

Materials and Emerging Test Techniques

Paper D1-PS1-10831

On-load tap changer switching sequence monitoring – comparison of methods

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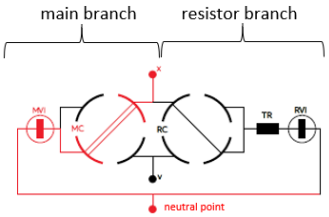
Motivation

- On-load tap changers (OLTC) only moving part in power transformers, responsible for more 30% of major failures
- Switching times important indicators for degradation and incipient faults

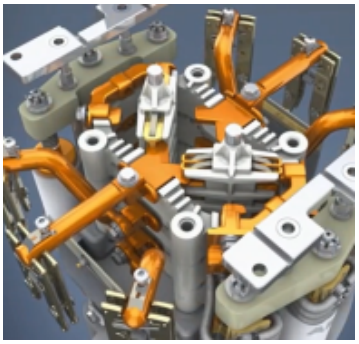
Method/Approach

- Three periods in switching sequence
  - Main vacuum interrupter open
  - Circulating currents
  - Resistor vacuum interrupter open



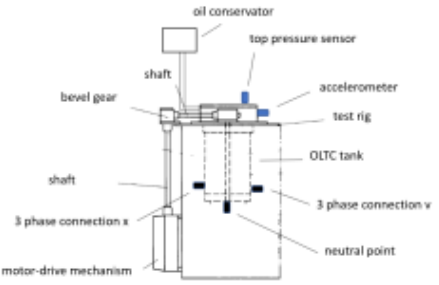
- OLTC operation simultaneously monitored by three methods
  - Vibroacoustic signal analysis
  - Voltage and current signal analysis
  - Oil pressure pulse signal analysis

OLTC Operation

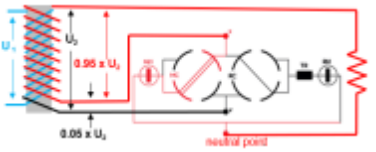


Experimental setup and test objects

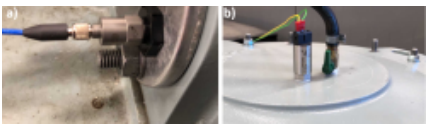
- Diverter-switch vacuum type OLTC set-up



- 400/400 V, 12 kVA transformer with one tap step (5 %) connected to the OLTC
  - Voltage dividers and current clamps on the transformer primary and secondary



- Sensors mounted:
  - Accelerometer and a pressure sensor mounted on the lid (Figure 4)



- External circuit connected for reference measurement

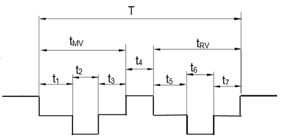


Figure 4. (a) The Accelerometer on lid wall. (b) Top part of the lid with bleeding valve and pressure sensor

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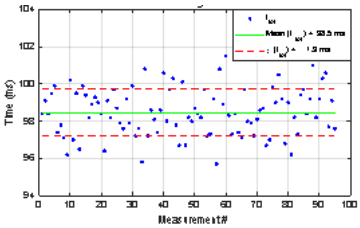
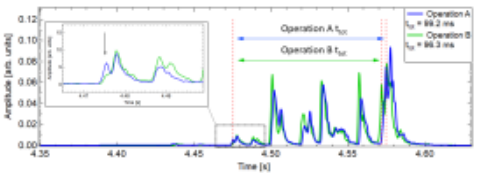
Reference switching time

- Reference total switching time of the OLTC is 98.5 ± 1.3 ms

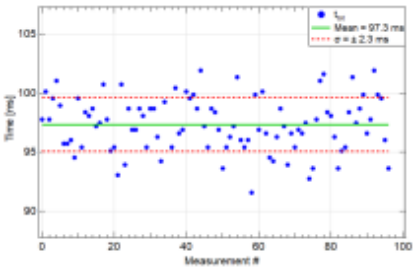


Results: Vibroacoustic method

- Vibration signals recorded at 60 kHz and high pass filtered before time extraction
- Relatively small vibration at vacuum bottle opening and its significant variation between tap operations poses a challenge for time extraction

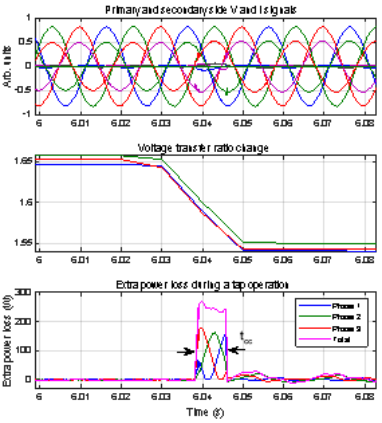


- Peak identification gives total switching time estimation 97.3 ± 2.3 ms

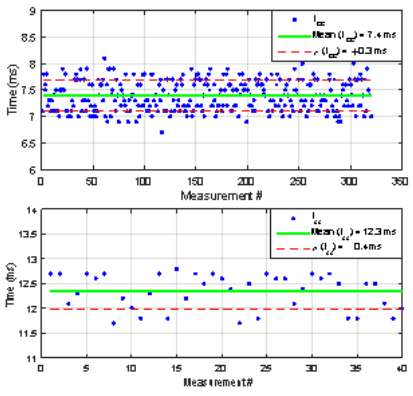


Results: Voltage and current method

- Circulating current time period (tcc) extracted by extra power loss analysis



- Tap operations performed with two different mechanically adjusted settings for tcc
- Quite good absolute accuracy for tcc was achieved, e.g., 7.4 ± 0.3 ms measured vs 7.3 ± 0.13 ms from reference measurement



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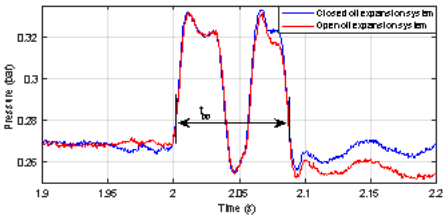
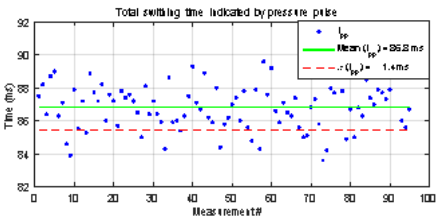
Results: Pressure pulse method

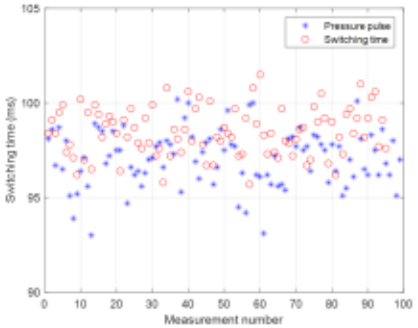
- Two pressure peaks generated between opening and closing of main and resistor side vacuum bottles



- Total switching time t_{tot} was estimated as the time between first positive and last negative flanks
- Many recorded pleasure pulses indicated a good estimate t_{pp} (86.8 ± 1.4 ms)



- Good agreement between pressure pulse and total switch time)



Discussion

- Three on-line monitoring methods to probe the OLTC switching time were compared
- Evaluation criteria
  - Robustness of analysis
  - Accuracy of method
- Vibration based analysis requires prior knowledge of switching pattern to extract total switching time
- Vibration analysis challenged by variation in vibration amplitudes in consecutive measurements
- Voltage and current analysis method is robust and accurate in estimating the circulating current time, but total switching time is not possible
- Pressure pulse method provides a good precision for the total switching time.
- Pressure pulse method provides confirmation of tap operation completion
- Pressure pulse method limited to vacuum type tap changers

Conclusions

- Voltage and current analysis and pressure pulse methods are found to be more robust in switching time monitoring than the vibration method
- All methods can achieve accuracy in ms range
- It is important to consult the manufacturer of the tap-changer for support with interpretation of results