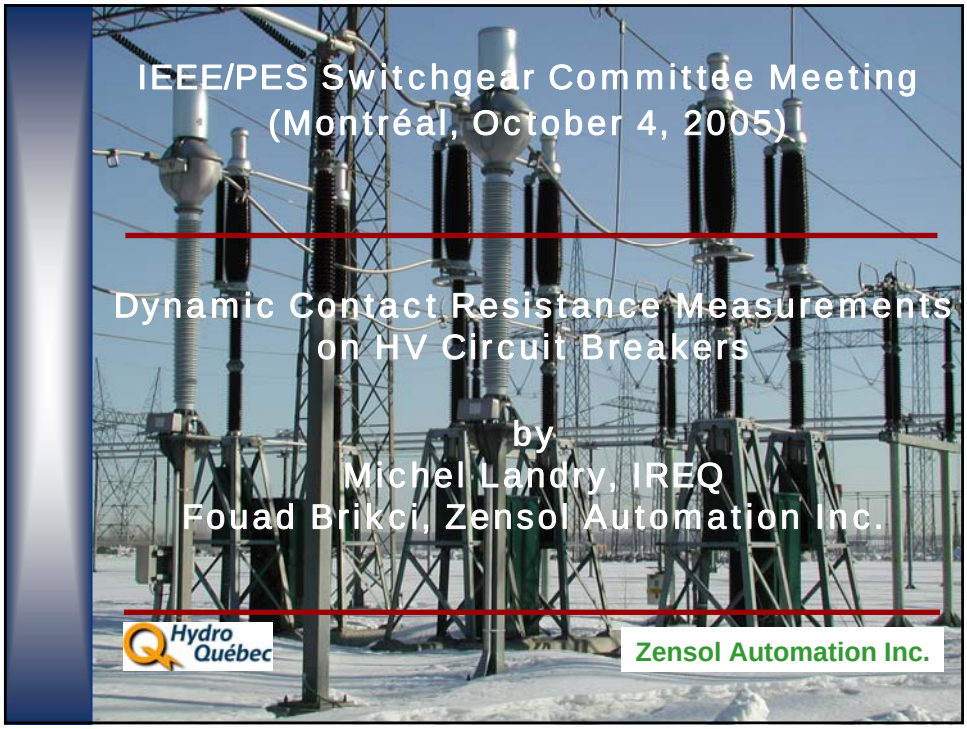

IEEE/PES Switchgear Committee Meeting (Montréal, October 4, 2005)

Dynamic Contact Resistance Measurements on HV Circuit Breakers

by
Michel Landry, IREQ
Fouad Brikci, Zensol Automation Inc.

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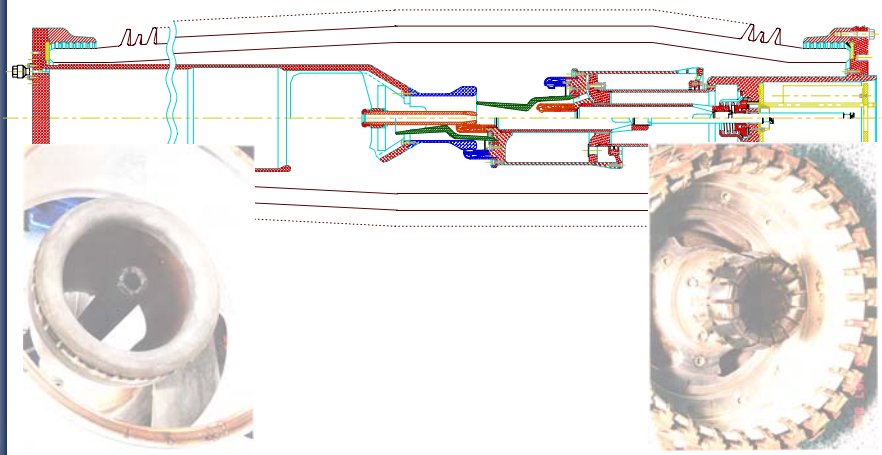
Interrupting chamber of an SF_6 circuit breaker

Fixed contacts

Moving contacts



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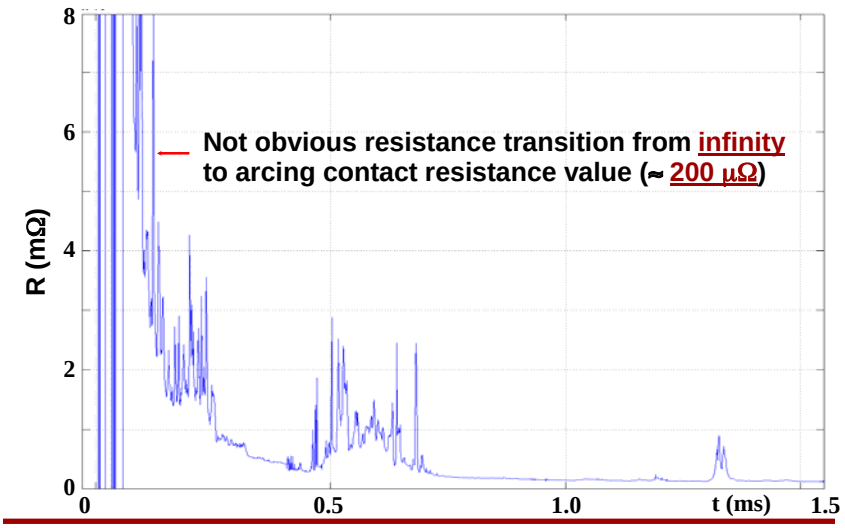
Measuring system and sensors for Dynamic Contact Resistance Measurements (DRM)

- **3 signals to be recorded**
  - The injected **current** (I_{DC}) of at least **100 A**
  - The **voltage drop** (V_D) across the breaker contacts
  - The breaker **contact travel** curve
- **Features of the acquisition unit**
  - **3** analog **12-bit** resolution **inputs**
  - Sampling **frequency** ≤ **10 kHz**
  - Total **acquisition time** = **30-100 s**
  - Connection to a portable computer
- **Sensors**
  - **Hall-effect current** sensor (LEM type)
  - **Voltage** sensor
  - **Linear** or **rotary** contact **travel sensor**

Measuring parameters

- **DRM during closing operations is impractical**
  - Abrupt resistance variation from **infinity** (open contacts) to arcing contact resistance value (≈ 200 μΩ)
  - **Undesired noise level** due to transient DC current at the moment of arcing contact touch
- **DRM during opening operations**
  - **Low contact speed** (≈ 0.002 - 0.2 m/s)
  - **Reproducible** measurements
  - **Easy** to interpret
  - Adequately **simulates** the **actual operating condition** of an in-service HV circuit breaker

Impractical DRM during closing operations



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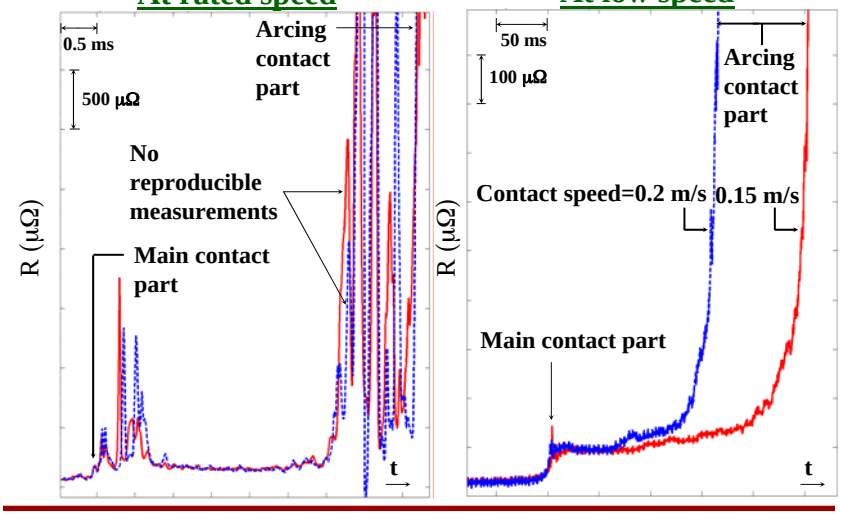
DRM on a break of a 315-kV capacitor-bank SF_6 circuit breaker



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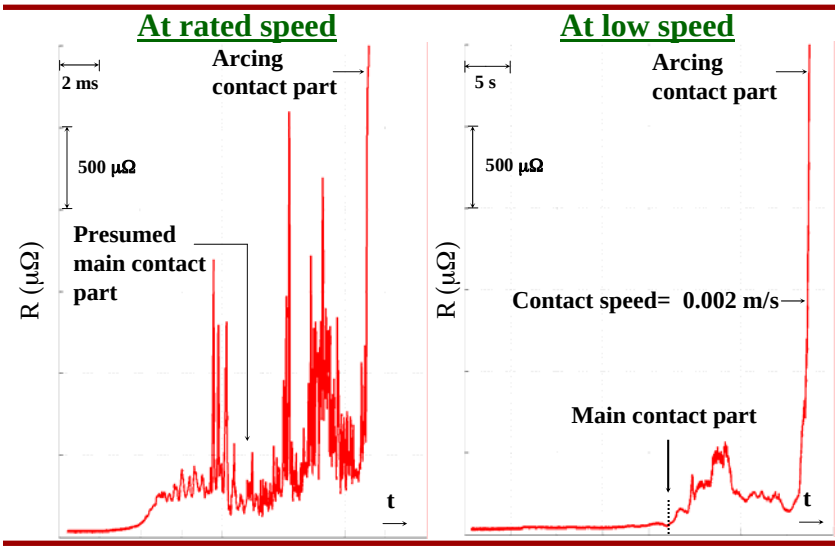
DRM on a break of a 120-kV capacitor-bank SF_6 circuit breaker



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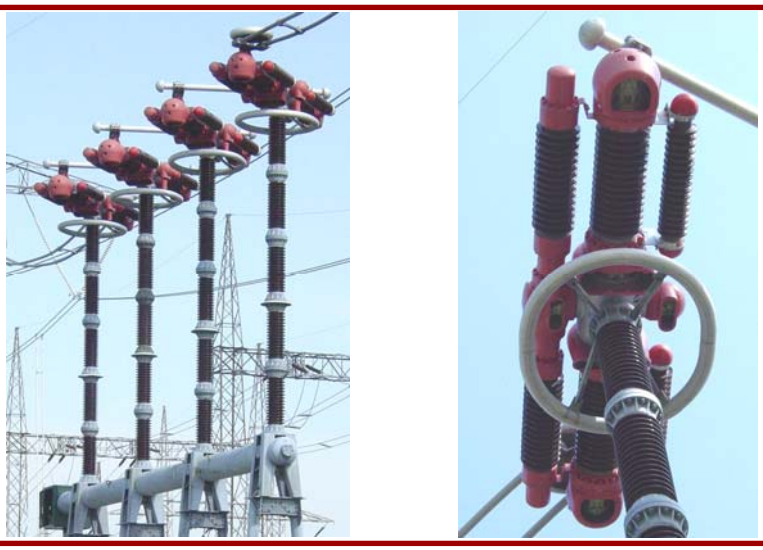
735-kV 8-break air-blast PK circuit breaker



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Contact sets of PK breakers used for developing new contact wear algorithm

Relatively new fixed contact (F1)

New moving contact (M1)

Slightly worn moving contact (M2)

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Contact sets of PK breakers used for developing new contact wear algorithm

Worn moving contact (M3)

Seriously damaged moving contact (M4)

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Laboratory test set-up using a vertical CNC milling machine

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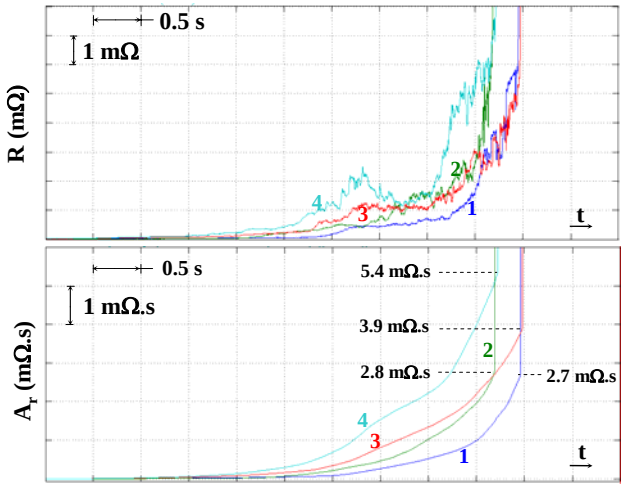
Contact wear analysis by evaluating the area beneath the dynamic resistance curve



1:Contact set F1-M1
2:Contact set F1-M2
3:Contact set F1-M3
4:Contact set F1-M4

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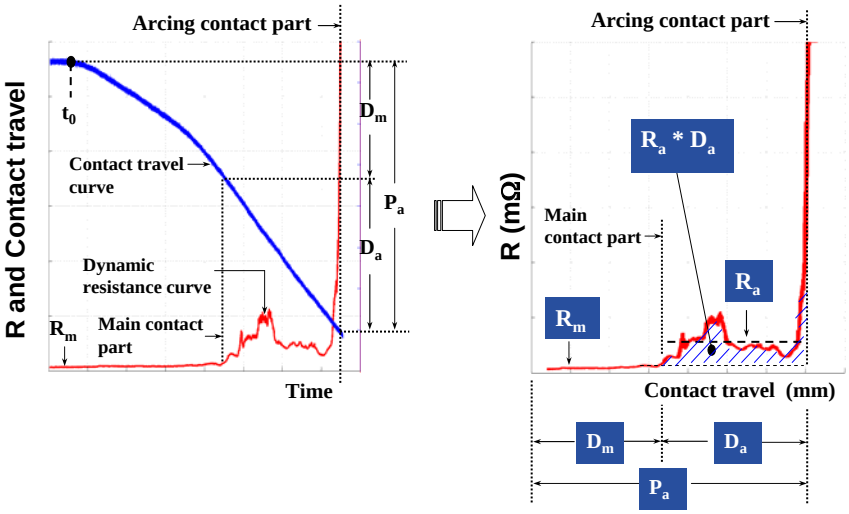
Parameters to be extracted from dynamic resistance curve



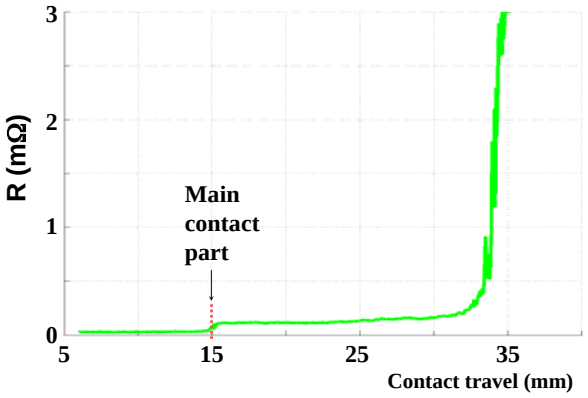
Case Study No. 1
315-kV capacitor-bank SF_6 circuit breaker

Case Study No. 1

DRM on a 315-kV capacitor-bank SF_6 circuit breaker

Operation counter reading	2492
R_m (μΩ)	29
R_a (μΩ)	185
D_m (mm)	15.1
D_a (mm)	19.5
P_a (mm)	34.6
R_a*D_a (mΩ. mm)	3.6

Arcing contact in excellent condition



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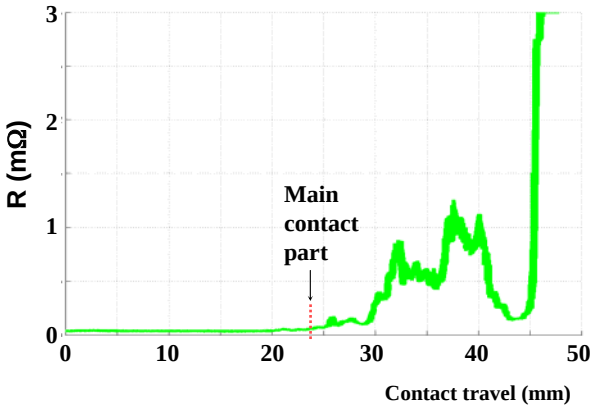
Case Study No. 2

DRM on a 120-kV capacitor-bank SF_6 circuit breaker

Operation counter reading	687
R_m (μΩ)	37
R_a (μΩ)	420
D_m (mm)	21.3
D_a (mm)	24.6
P_a (mm)	45.9
R_a*D_a (mΩ. mm)	10.3

Defective arcing contact



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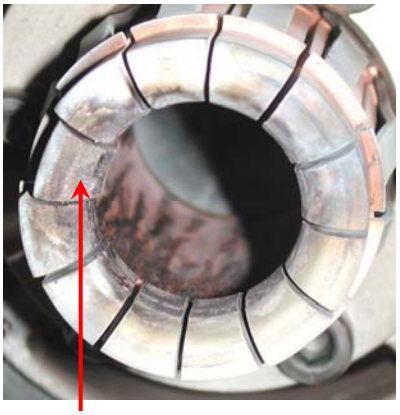
Case Study No. 2
Damaged moving and fixed arcing contacts

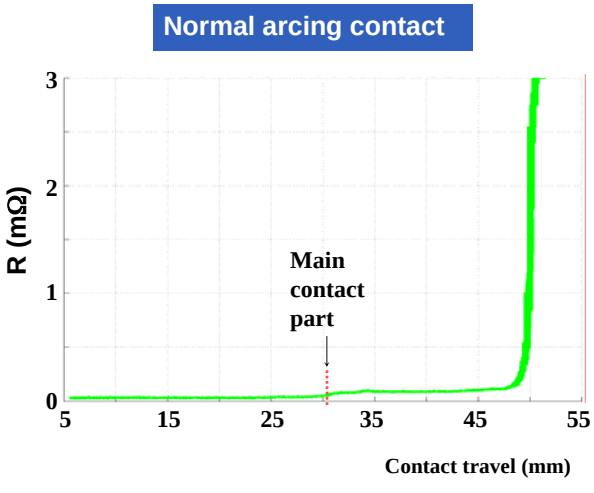


1 off-center moving arcing contact tip

Damaged fixed arcing contact

Case Study No. 2
DRM on the same break after contact overhaul

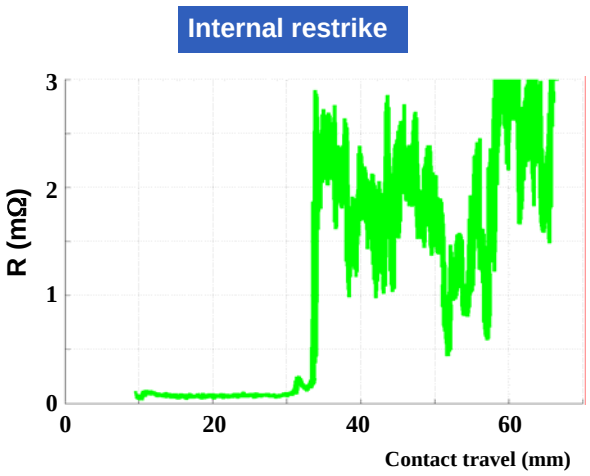
Operation counter reading	< 20
R_m (μΩ)	33
R_a (μΩ)	173
D_m (mm)	30.8
D_a (mm)	19.7
P_a (mm)	50.5
R_a*D_a (mΩ. mm)	3.4



Case Study No. 3
230-kV reactor SF_6 circuit breaker

Case Study No. 3
DRM on a 230-kV reactor SF_6 circuit breaker

Operation counter reading	204
R_m (μΩ)	74
R_a (μΩ)	1768
D_m (mm)	31.4
D_a (mm)	34.2
P_a (mm)	65.7
R_a*D_a (mΩ. mm)	60.3



Case Study No. 3
Arcing spots on the fixed contacts

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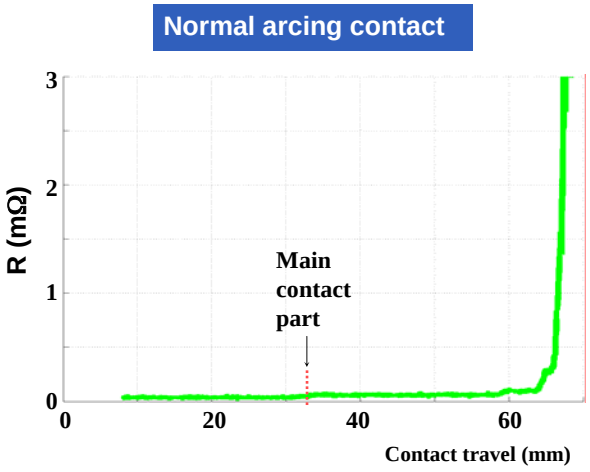
Case Study No. 3
DRM on a healthy break of another phase of a 230-kV reactor SF_6 circuit breaker

Operation counter reading	201
R_m (μΩ)	34
R_a (μΩ)	93
D_m (mm)	33.8
D_a (mm)	33.5
P_a (mm)	67.2
R_a*D_a (mΩ. mm)	3.1



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Dynamic Resistance Measurement Kit
Z-DRM-2

Stable DC current source

Data acquisition system

Voltage and current sensors

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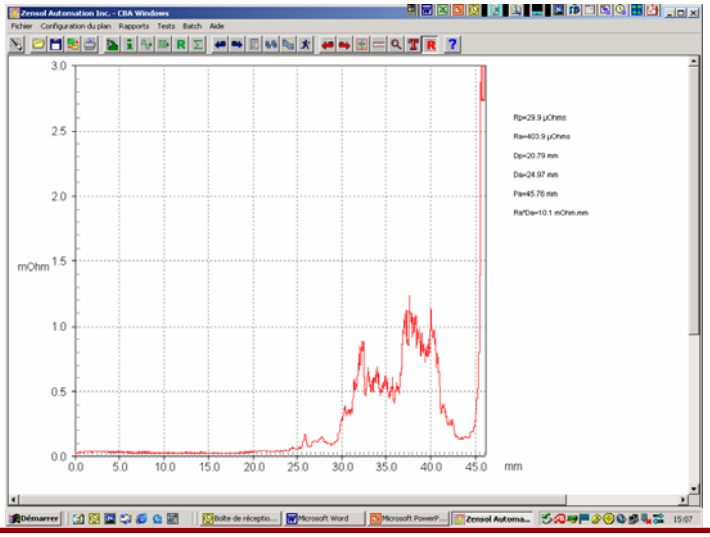
Resdyn software
(R as a function of the breaker contact travel)



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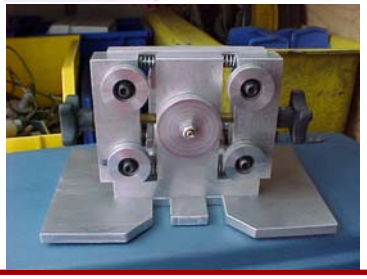
Dynamic Resistance Measurement Kit
Z-DRM-2 (Contact travel sensors)



Conclusion

- **New DRM method**
  - **Opening** operations at **low contact speed**
  - **Reproducible** curves **easy** to **analyze** and **interpret**
  - **Vital** information about the **breaker contact condition**
  - **Useful tool** for **maintenance planning**
- **Six vital diagnostic parameters**
  - Average **main contact resistance**
  - Average **arcing contact resistance**
  - **Main contact wipe**
  - **Arcing contact wipe**
  - **Position** of the breaker contact at the **arcing contact part**
  - Cumulative **area** beneath the **resistance curve (mΩ.mm)**