

27 ... 29 MAI 2020

## High speed Observation of vacuum arcs between different contact diameter at TMF contact pair

Dietmar Gentsch ABB AG – ELDS – R&D, Kai Gorlt ELDS-EK / ABB AG – Ratingen

# Vacuum arcs between different contact diameter at TMF contact pair

## Overview

- **Introduction**

- **Vacuum interrupter principle**

- Basic tasks and interruption principle of vacuum interrupter
- Motivation and function description of arc movement
- Study under short circuit current conditions

- **Technical data and test results**

- High-speed arc observation during short circuit current interruption
  - Done between different TMF contact pair diameter
  - Comparison of all contact pair used within the study

- **Summary**



# Vacuum Interrupter families type series VG ...

## Introduction

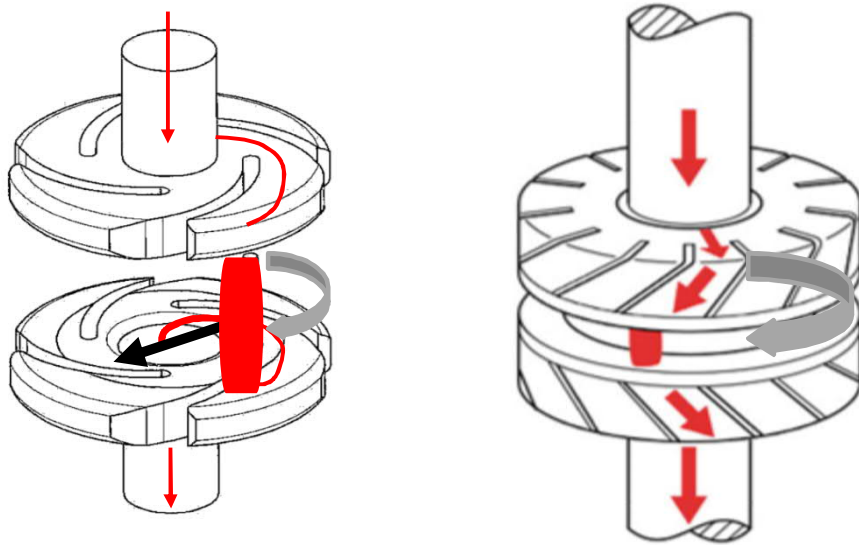


Vacuum interrupter family, maintenance free, robust, compact and optimized the VG- type series for ratings 1 ... 52 kV and ... 85 kA for multipurpose and switchgear application

# Vacuum arcs between different contact diameter at TMF contact pair

## Introduction

TMF spiral type left hand side and cup type right hand side



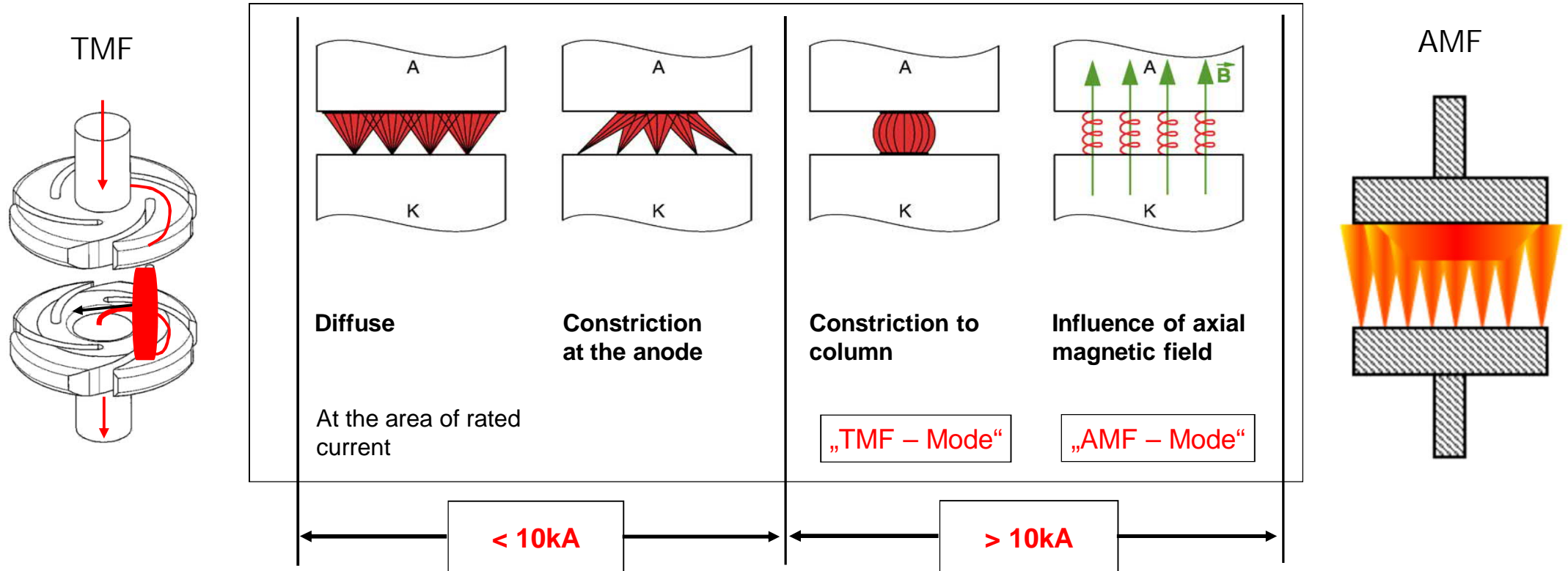
### Contact material (based on CuCr)

#### Function of the TMF contact system:

- The current path extended.
- Based on the current path there occur a magnetic force.
- Within the system only the “vacuum arc” moves and rotate inside the contact gap.
- Rotating column arc, to reduce the thermal local load at the contact surface.

# Vacuum Interrupter equipped with TMF contacts

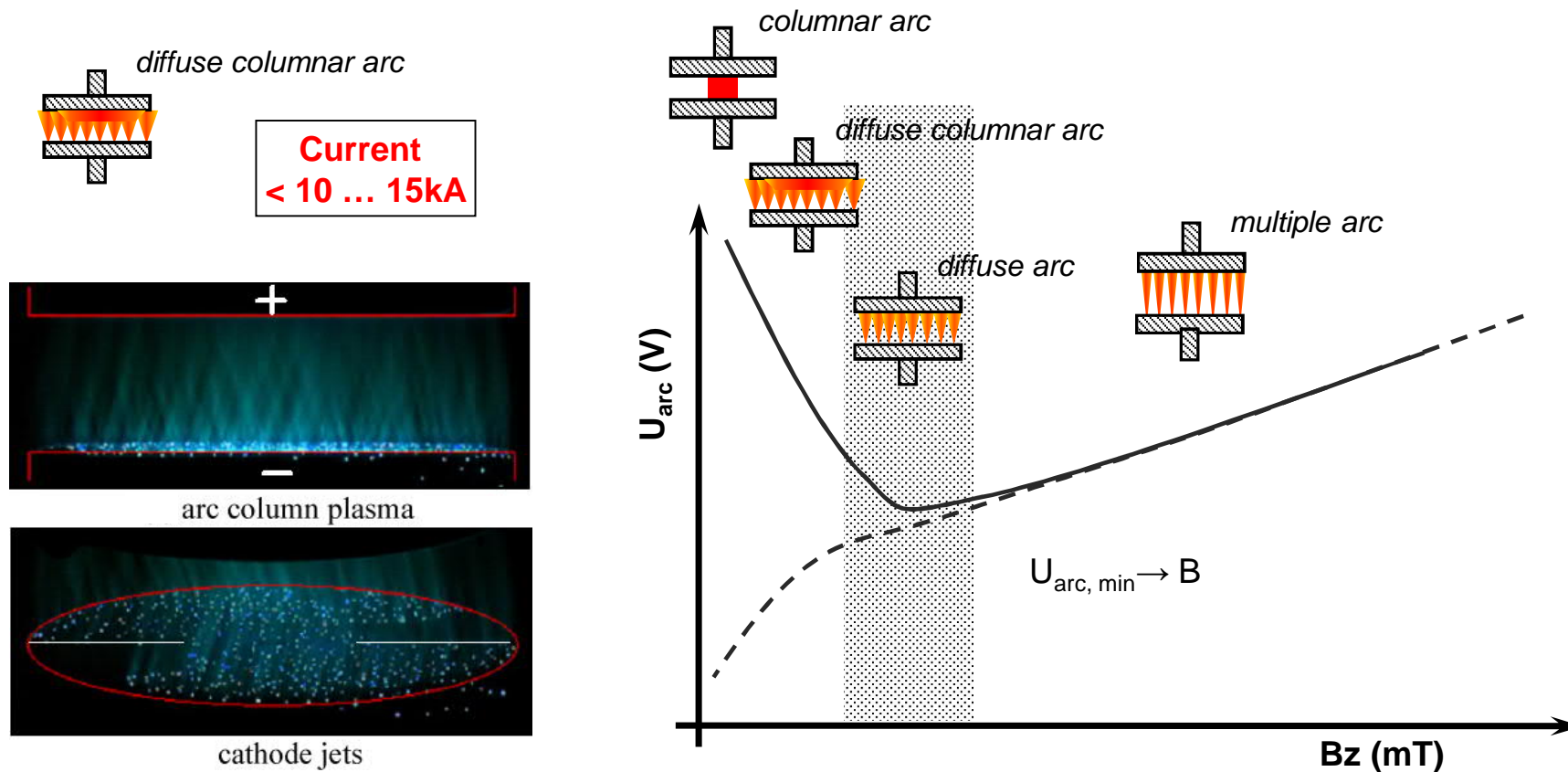
## Introduction



Schematic illustration of the different mode of the vacuum arc

# Vacuum Interrupter equipped with TMF contacts

## Introduction

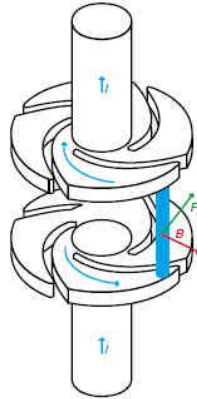


# Vacuum Interrupter equipped with TMF contact

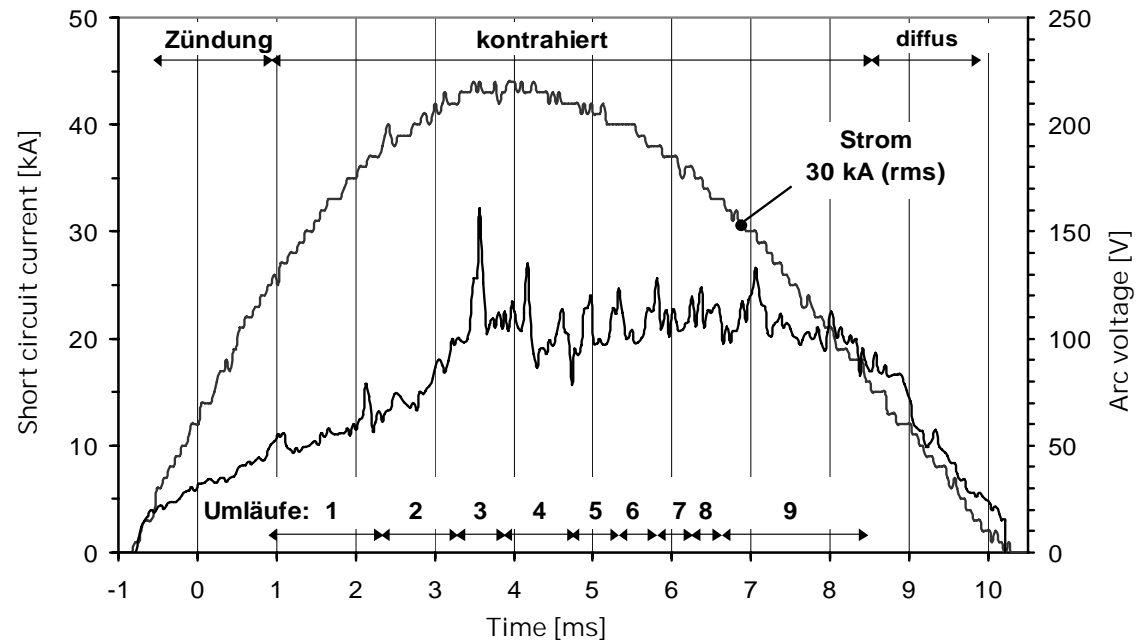
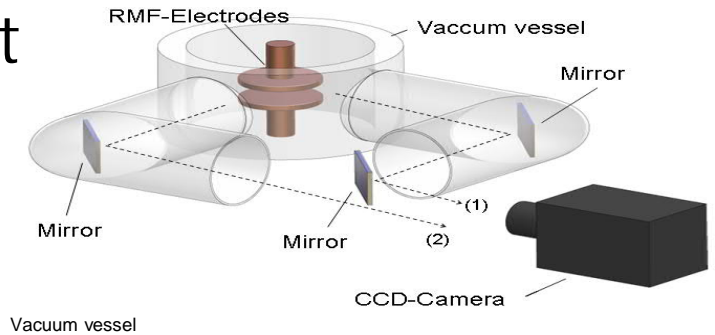
## Motivation and function description of arc movement

Video sequence of a short-circuit interruption  
(under TMF condition)

- Short circuit current: 30 ... 40kA
- Contact diameter: 68 mm
- Contact gap (open position): 10 mm



Rotating column arc, to reduce the thermal local load at the contact surface





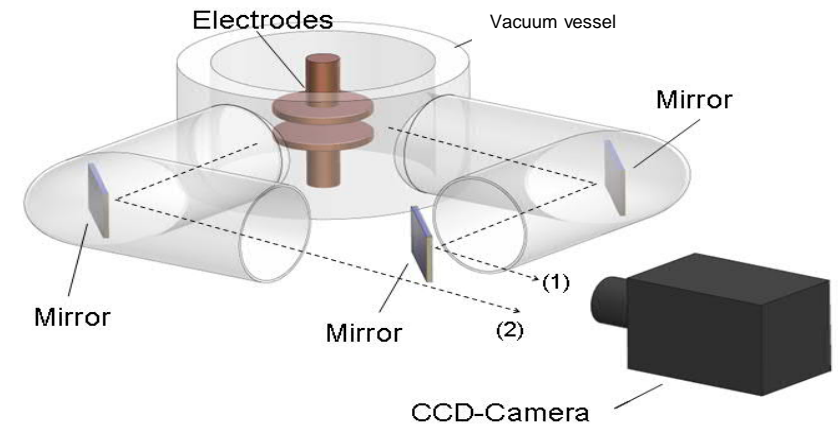
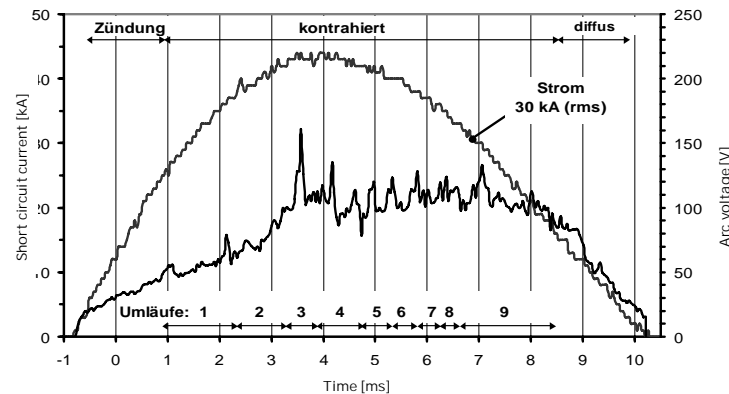
# Vacuum Interrupter equipped with TMF contacts

## Motivation and function description of arc movement

Video sequence of a short-circuit interruption

(under TMF condition)

- Short circuit current: 30 ... 40 kA
- Contact diameter: 68 mm
- Contact gap (open position): 10 mm





# Vacuum arcs between different contact diameter at TMF contact pair

## Overview

- **Introduction**

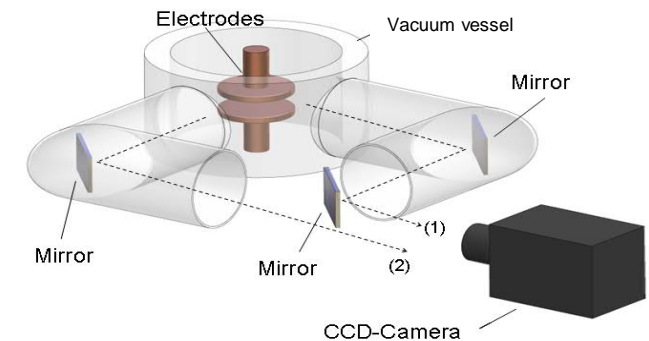
- **Vacuum interrupter principle**

- Basic tasks and interruption principle of vacuum interrupter
- Motivation and function description of arc movement
- Study under short circuit current conditions

- **Technical data and test results**

- High-speed arc observation during short circuit current interruption
  - Done between different TMF contact pair diameter
  - Comparison of all contact pair used within the study

- **Summary**



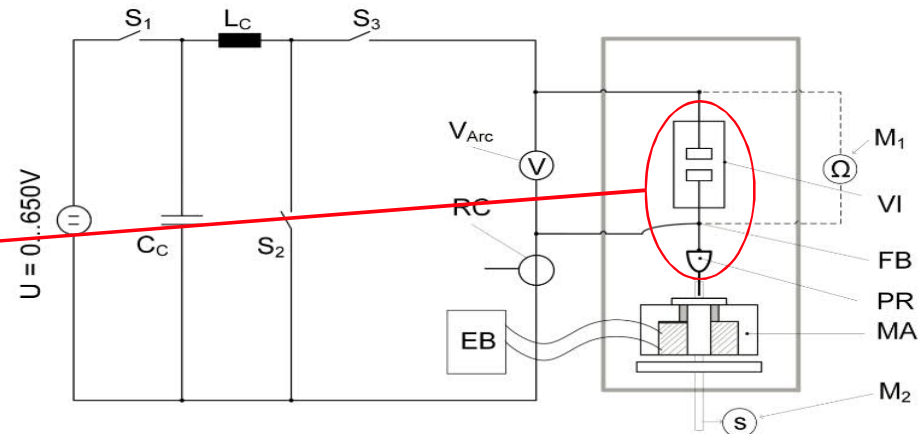
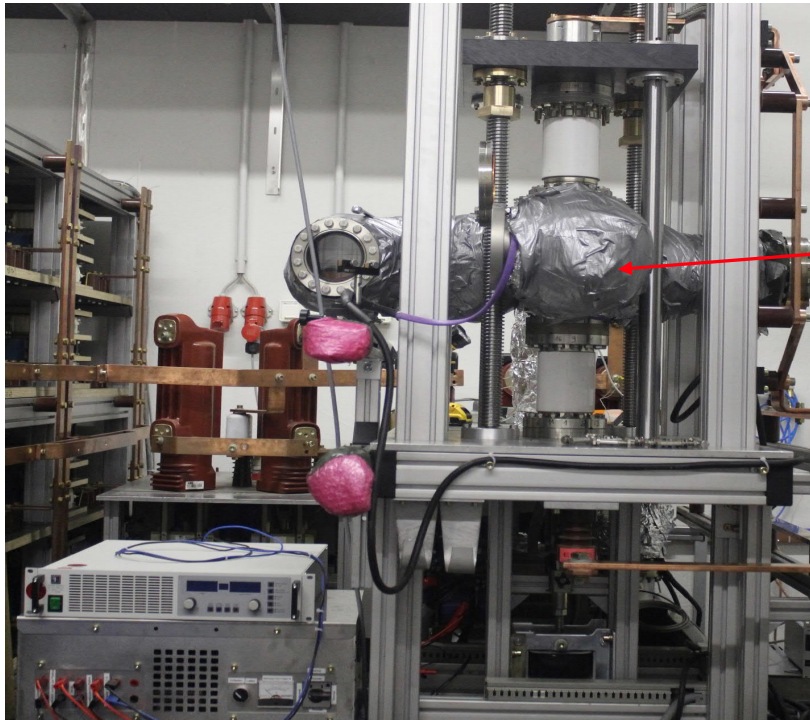
Schematic of optical setup: electrode pair at arc vessel, optical paths (1) and (2) are recorded side by side in one frame:

- Base to investigate the arc path and by time the velocity of arc.

# Vacuum arcs between different contact diameter at TMF contact pair

## Study under short circuit current conditions

Circuit diagram of the synthetic test circuit with the high current source at the test set-up vacuum vessel:

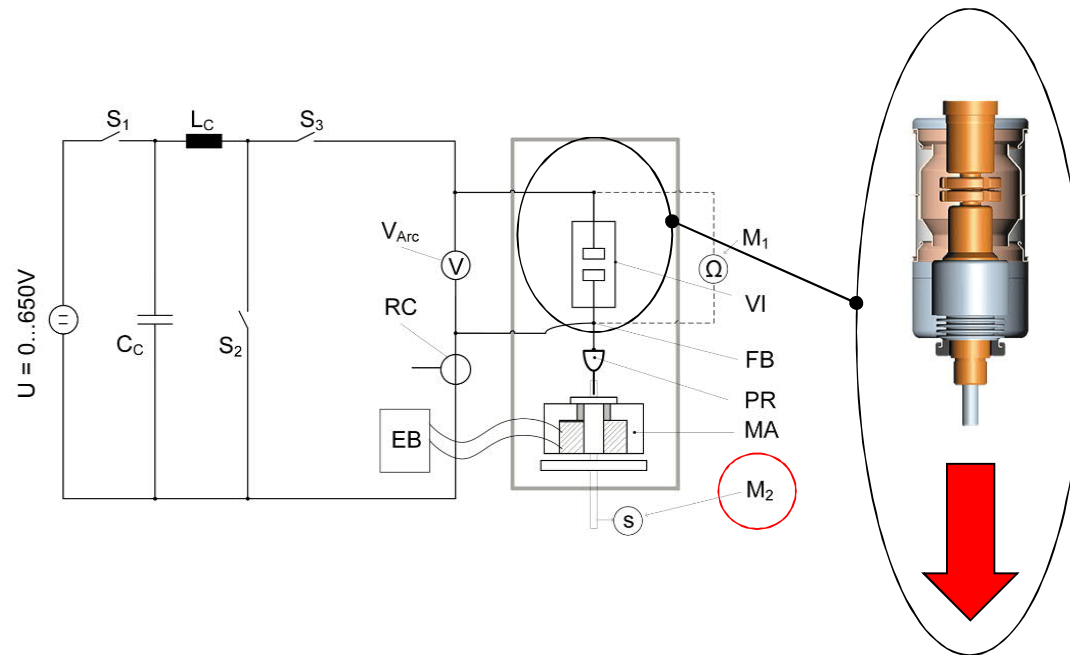


- At the high current source the DC power supply is max.  $U$ : 650 V.
- The vacuum interrupter (VI) vessel is driven downward by the magnetic actuator (MA) and the control unit (EB).
- The insulation push rod (PR); the current flow is established by providing a flexible band (FB) to the movable side of the VI vessel.
- After each operation the resistance of the current path is measured by the  $M_1$  device and the resistance after the operation measured by the  $M_2$  device.

# Vacuum arcs between different contact diameter at TMF contact pair

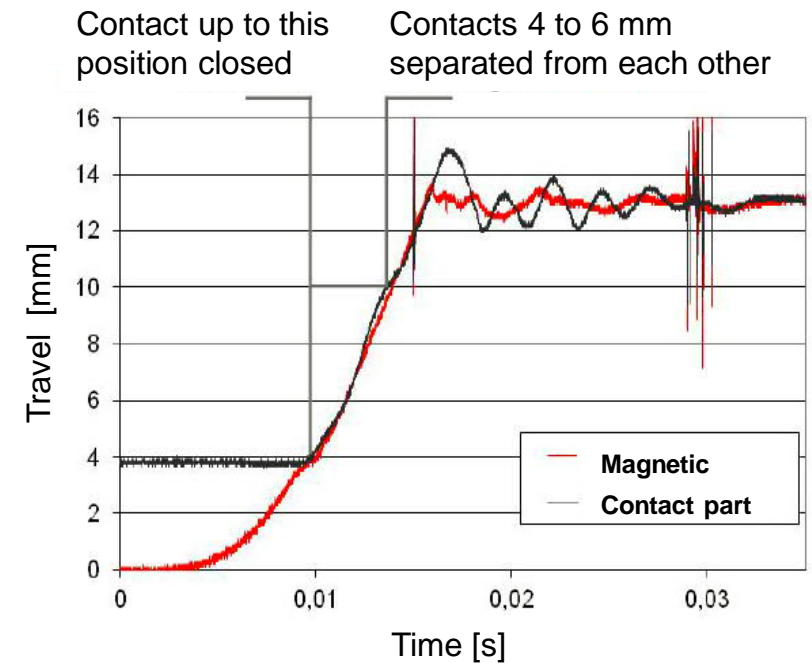
High-speed arc observation during current interruption

**Circuit diagram of the synthetic test circuit with the high current source at the test set-up vacuum vessel:**



**Travel-curve of the mechanical interruption:**

Contact part movement of the test switch at vacuum interrupter

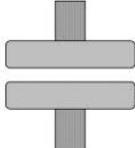
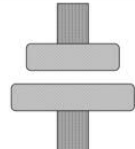
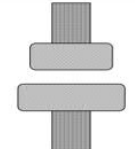
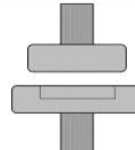


# Vacuum arcs between different contact diameter at TMF contact pair

## Study under short circuit current conditions

**Table 1: Investigated contact pair, principle and diameter**

\*) MK = Movable contact side; FK = Fixed contact the sketch upper side

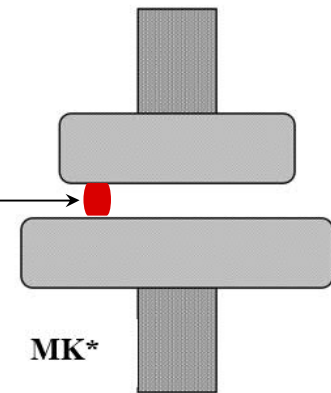
Contact pair	Contact type	Diameter
<b>a</b> 	(FK)* TMF – TMF (MK)*	70mm – 70mm (MK)*
<b>b</b> 	(FK)* TMF – TMF (MK)*	50mm – 60mm (MK)*
<b>c</b> 	(FK)* Butt – TMF (MK)*	50mm – 60mm (MK)*
<b>d</b> 	(FK)* Butt – TMF (MK)* Cup type	50mm – 60mm (MK)*

Conditioning sequence is carried out with start on MK (-)  
polarity: Example  $\Sigma$  5 operating: (-); (+); (-); (+); (-) and next start (-)

- 5 kA rms
- 8 kA rms
- 10 kA rms
- 15 kA rms ... diffuse arc
- 
- 20 kA rms ... columnar arc
- 25 kA rms
- 30 kA rms
- 35 kA rms

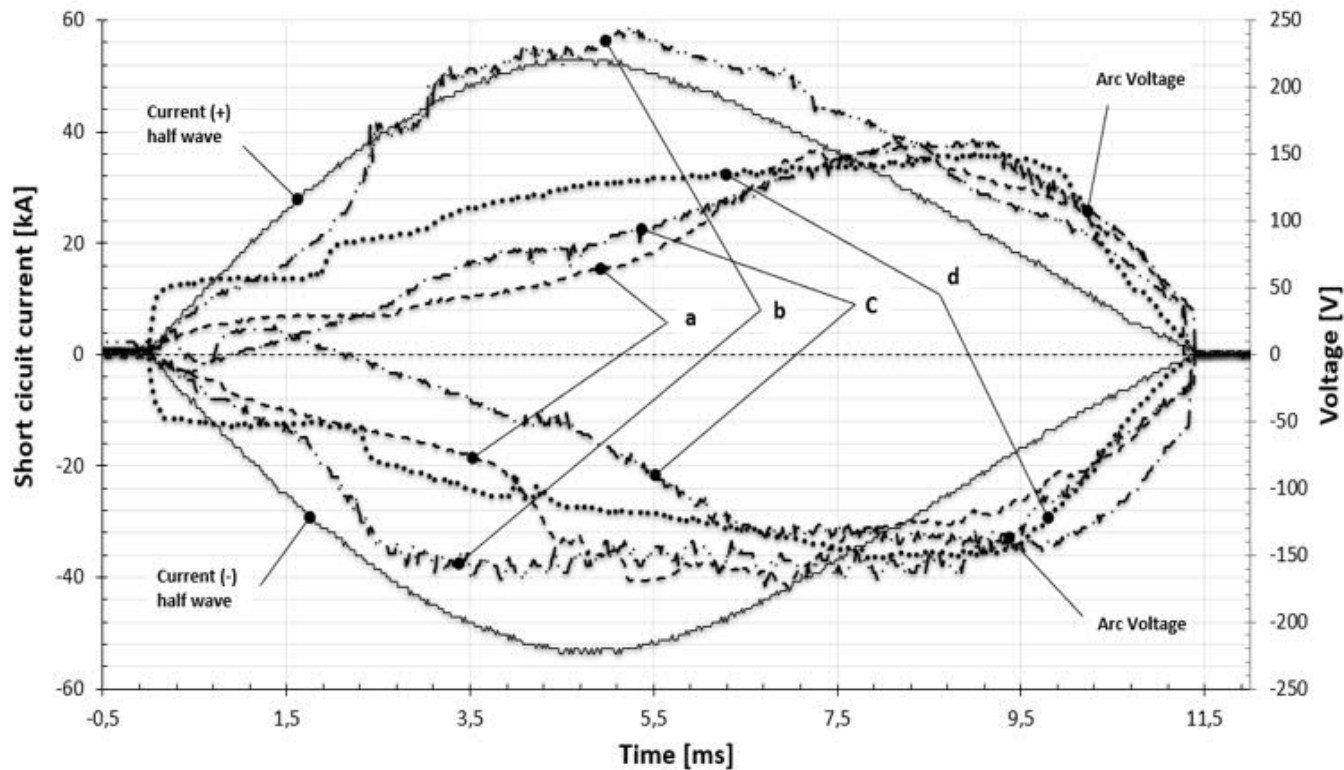
❖ In total 40 short circuit interruption operation.

\*) MK = Movable contact side



# Vacuum arcs between different contact diameter at TMF contact pair

High-speed arc observation during current interruption

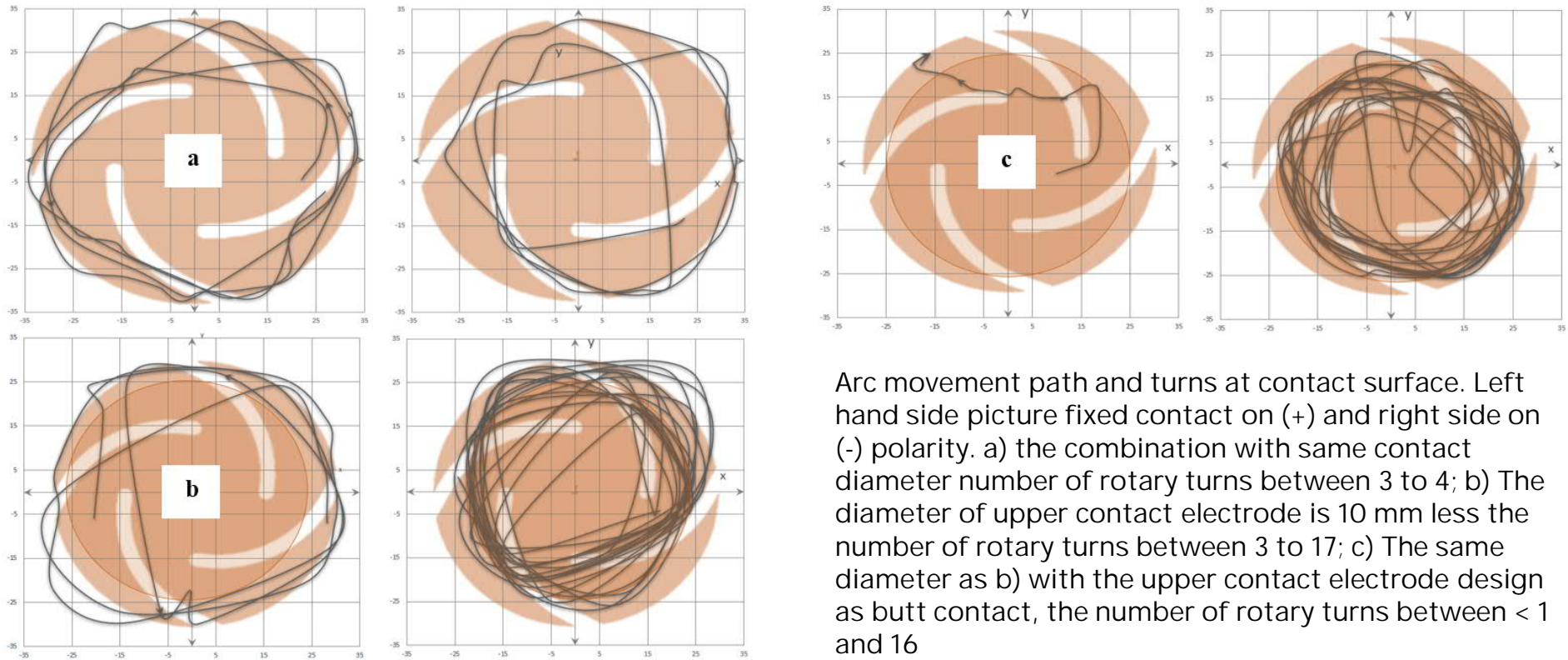


Single phase current interruption operation with (+) and (-) polarity figured at 35 kA<sub>rms</sub> obtained during interruption the corresponding arc voltage for the considered contact pair design a ... d (Table 1)



# Vacuum arcs between different contact diameter at TMF contact pair

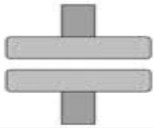
High-speed arc observation during current interruption

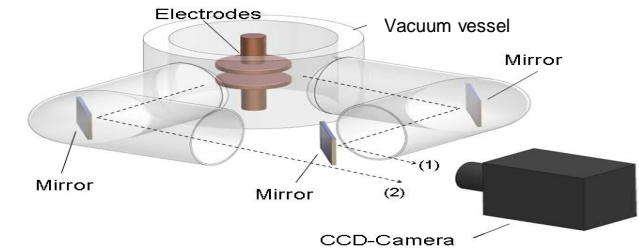


Arc movement path and turns at contact surface. Left hand side picture fixed contact on (+) and right side on (-) polarity. a) the combination with same contact diameter number of rotary turns between 3 to 4; b) The diameter of upper contact electrode is 10 mm less the number of rotary turns between 3 to 17; c) The same diameter as b) with the upper contact electrode design as butt contact, the number of rotary turns between < 1 and 16

# Vacuum arcs between different contact diameter at TMF contact pair

High-speed arc observation during short circuit current interruption  $35\text{kA}_{\text{eff}}$

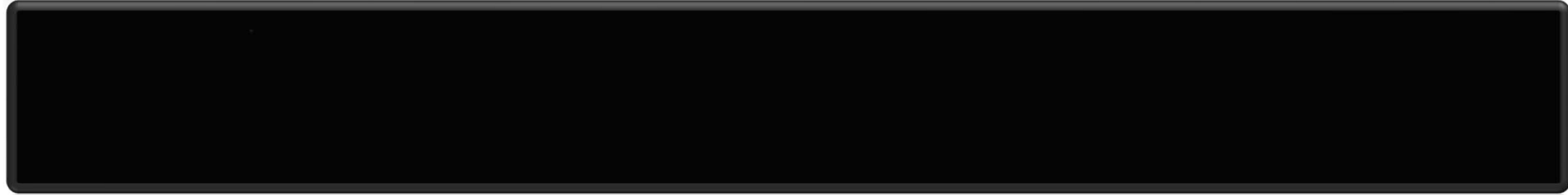
Contact pair	Contact type	Diameter
a 	(FK)* TMF – TMF (MK)*	70mm – 70mm (MK)*



Contact pair a) TMF – 70mm/70mm; Fixed side on (+) polarity: [VIDEO](#)



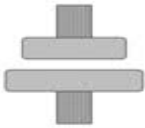
Contact pair a) TMF – 70mm/70mm; Fixed side on (-) polarity: [VIDEO](#)

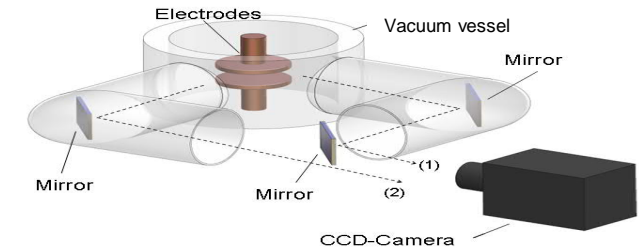




# Vacuum arcs between different contact diameter at TMF contact pair

High-speed arc observation during short circuit current interruption  $35\text{kA}_{\text{eff}}$

Contact pair	Contact type	Diameter
<b>b</b> 	(FK)* TMF – TMF (MK)*	50mm – 60mm (MK)*




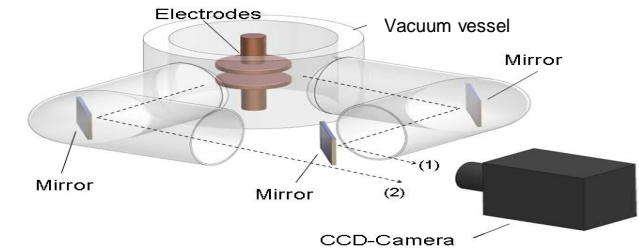
Contact pair b) TMF – 50mm/60mm; Fixed side on (+) polarity: [VIDEO](#)

Contact pair b) TMF – 50mm/60mm; Fixed side on (-) polarity: [VIDEO](#)

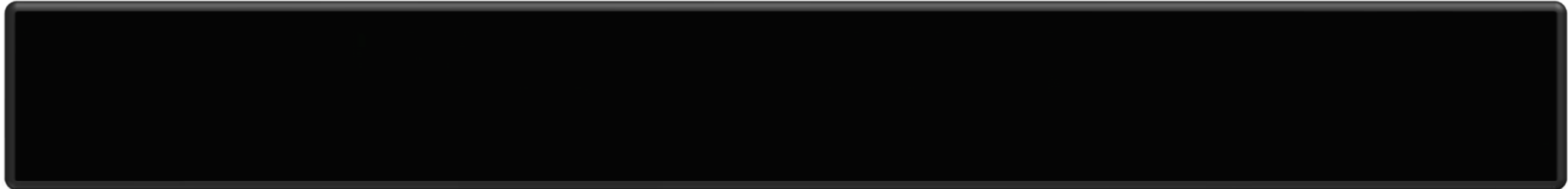
# Vacuum arcs between different contact diameter at TMF contact pair

High-speed arc observation during short circuit current interruption  $35\text{kA}_{\text{eff}}$

Contact pair	Contact type	Diameter
c 	(FK)* Butt – TMF (MK)*	50mm – 60mm (MK)*



Contact pair c) Butt – 50mm / TMF – 60mm; Fixed side on (+) polarity: **VIDEO**

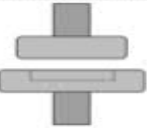


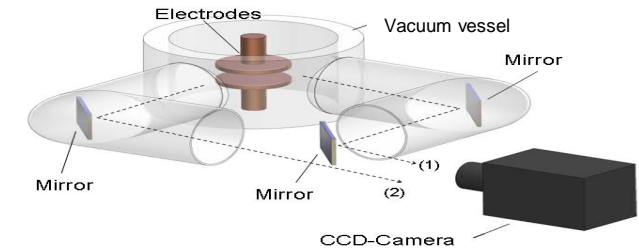
Contact pair c) Butt – 50mm / TMF – 60mm; Fixed side on (-) polarity : **VIDEO**



# Vacuum arcs between different contact diameter at TMF contact pair

High-speed arc observation during short circuit current interruption 35kA<sub>eff</sub>

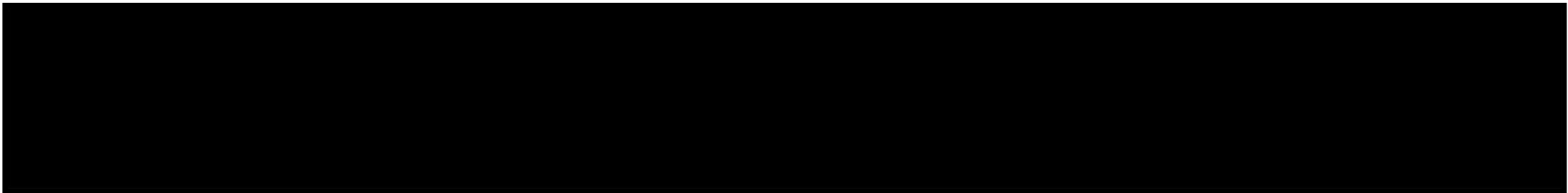
Contact pair	Contact type	Diameter
d 	(FK)* Butt – TMF (MK)* Cup type	50mm – 60mm (MK)*



Contact pair d) Butt – 50mm / TMF – 60mm; Fixed side on (+) polarity: **VIDEO** – Cup contact – Type



Contact pair d) Butt – 50mm / TMF – 60mm; Fixed side on (-) polarity : **VIDEO** – Cup contact – Type



# Vacuum arcs between different contact diameter at TMF contact pair

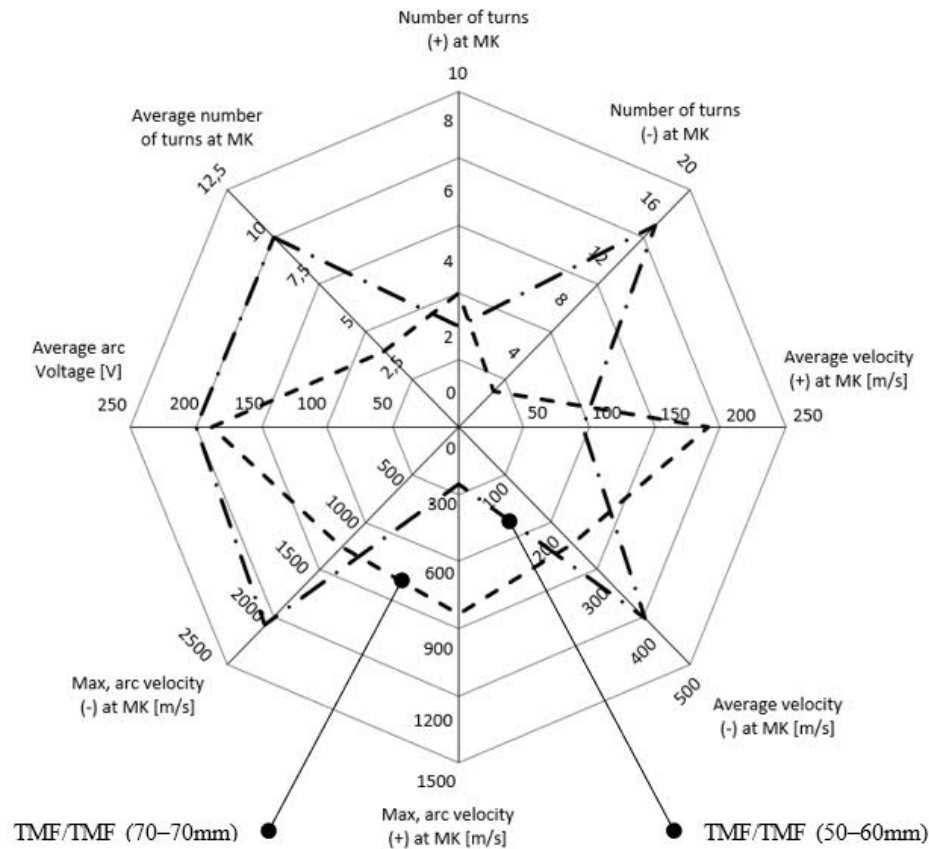
High-speed arc observation during short circuit current interruption 35kA<sub>eff</sub> – Overview Table 2

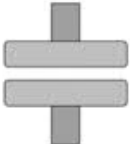

**Table 2: Survey of measured data at different contact pairs**

Contact pair	Polarity at fixed contact	Avg. arc velocity [m/s]	Max. arc velocity [m/s]	Number of rotary turns	Arc Voltage [V]
TMF – TMF (70 – 70mm)	+	191	838	4	187
	-	246	1261	3	170
TMF – TMF (50 – 60mm)	+	95	252	3	238
	-	402	2086	17	163
Butt – TMF (50 – 60mm)	+	10	49	< 1	137
	-	327	1384	16	89
Butt – TMF (50 – 60mm)	+	14	32	< 1	9
“TMF cup shape”	-	8	26	< 1	9

# Vacuum arcs between different contact diameter at TMF contact pair

High-speed arc observation during short circuit current interruption 35kA<sub>eff</sub> – Overview Table 2

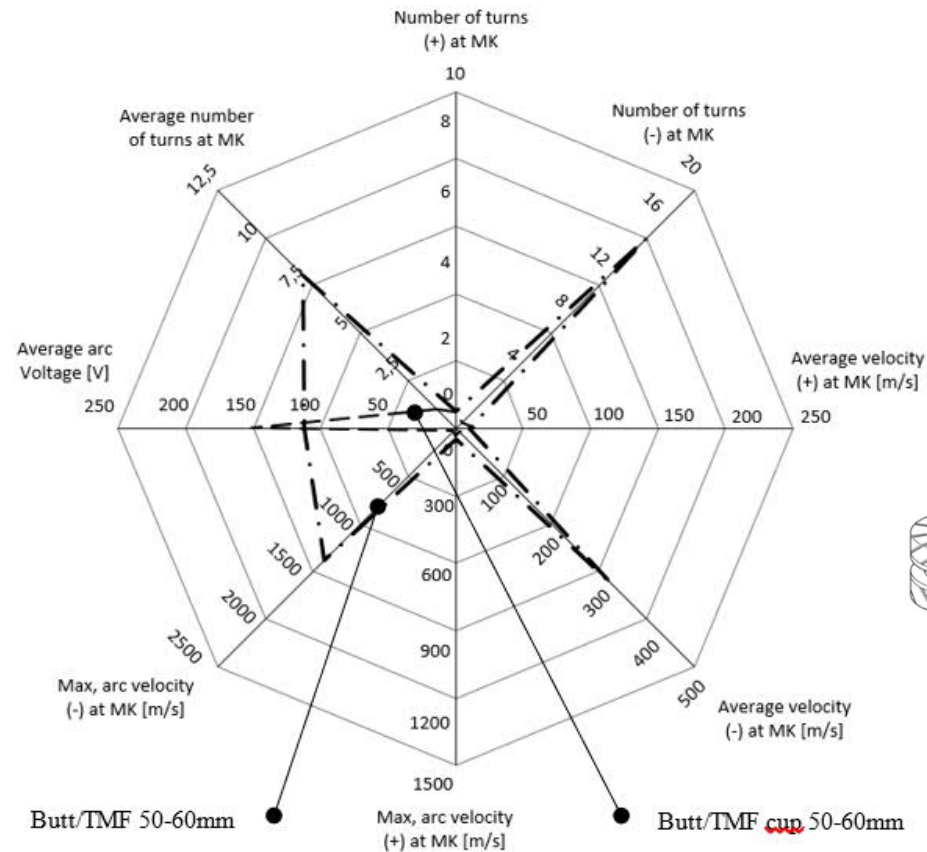


Contact pair	Contact type	Diameter
a 	(FK)* TMF – TMF (MK)*	70mm – 70mm (MK)*
b 	(FK)* TMF – TMF (MK)*	50mm – 60mm (MK)*

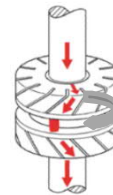
Arc parameter at 35kArms current half wave: the number of turns-, the arc velocity- at different polarity and the arc voltage for the contact pair combination: TMF 70/70mm and 50/60mm with 60mm on movable contact side

# Vacuum arcs between different contact diameter at TMF contact pair

High-speed arc observation during short circuit current interruption 35kA<sub>eff</sub> – Overview Table 2



Contact pair	Contact type	Diameter
c	(FK)* Butt – TMF (MK)*	50mm – 60mm (MK)*
d	(FK)* Butt – TMF (MK)* Cup type	50mm – 60mm (MK)*



Arc parameter at 35 kA<sub>rms</sub> current half wave:  
The number of rotary turns-, the arc velocity- at different polarity and the arc voltage for the contact pair combination: Butt/TMF 50/60mm and Butt/TMF cup design 50/60mm with 60mm on movable contact side

---

# Vacuum Interrupter equipped with TMF contacts

## Summary

- In case one contact diameter is selected smaller, the rotary arc movement comes higher especially when this contact is selected as cathode electrode.
- Furthermore, the rotary arc movement is the highest and the arc voltage becomes lower. That's connected to all other results of selected contact pair diameter:
  - Both the TMF contact pair in their optimized versions offer a controlled columnar vacuum arc behavior and stays under controlled arc mode, especially when using the same contact diameter on both sides.
  - TMF contact pair with reduced contact diameter the average- velocity and arc voltage is comparable higher. On the smaller contact the thermal stress will be higher compared to the pair with the same diameter on both sides.
  - In all given cases the butt – TMF contact pair combinations the arc control is partly or completely not given to reduce locally overheating and erosion of contact material.

For multipurpose vacuum interrupter application the use of contact pair with the same diameter has significant advantage in interruption performance.

In case higher arc voltage will be needed e.g. in DC application the use of one TMF contact smaller will be an advantage in case the arc voltage has an advantage in dedicated application.



Dr. -Ing. Dietmar Gentsch  
ELDS – Research and Development

E-Mail:

[dietmar.gentsch@de.abb.com](mailto:dietmar.gentsch@de.abb.com)



[new.abb.com](http://new.abb.com)

