Fault Current Limiters

Report on the Activities of CIGRE WG A3.10

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on behalf of Cigre WG A3.10

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Content

- Introduction
- Fault Current Limitation
- State of the Art
- Application
- Requirements
- Testing
- System Demands

Introduction

CIGRE WG 13.10 - „Fault Current Limiters“

- Established in 1996
- 15 members from 9 different countries
- First report in Electra and Cigre web 2001
- Technical Brochure 2003
- Work finished and Disbanded in 2003
- Further work WG A3.16

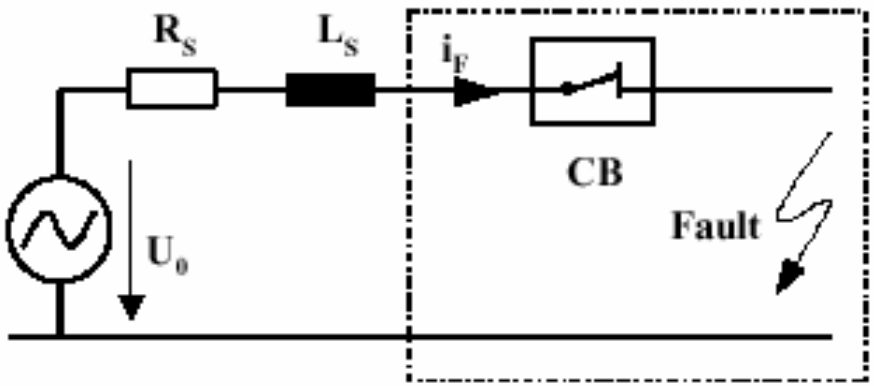
Introduction

CIGRE WG 13.10 - „Fault Current Limiters“ (FCL)

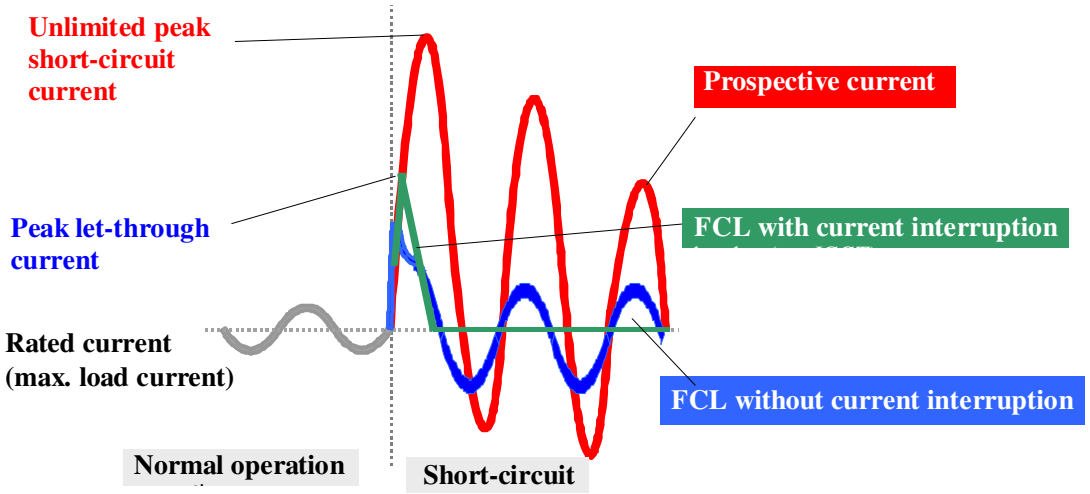
- Specification of FCL
- State of the Art of FCL
- Requirements (System Demands) Imposed on FCL
- Testing of FCL
- Literature List
- Voltage Levels:
  - ⇨ Medium Voltage: 1 kV ≤ Ur ≤ 36 (40.5) kV
  - ⇨ High Voltage: 52 kV ≤ Ur ≤ 145 kV *)

  *) Contributions to the WG considering rated voltages up to 420 kV were also taken into account

Fault Current Limitation

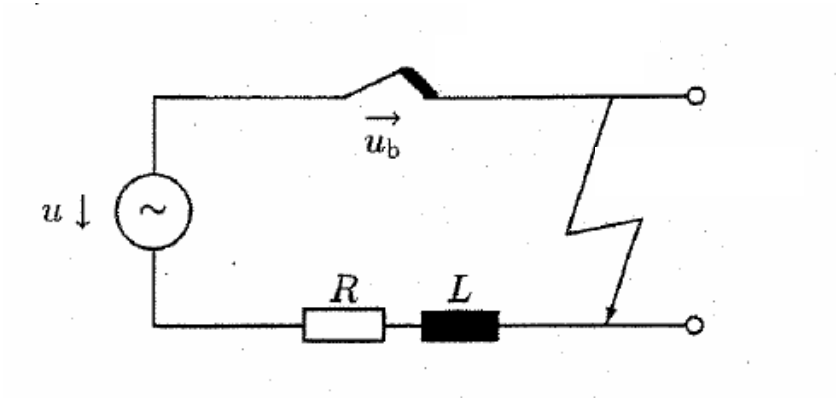


Equivalent Circuit Representing a Fault Condition

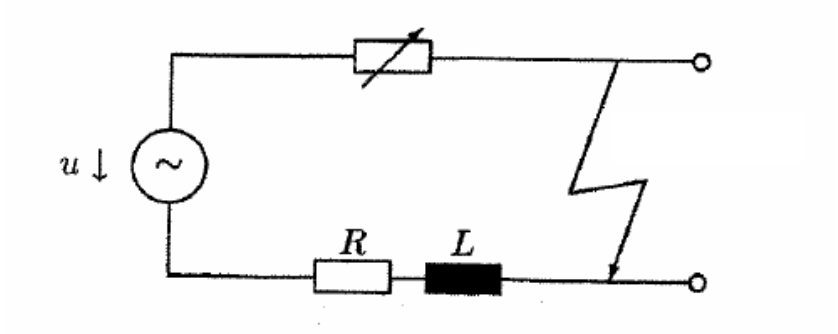


Typical Current Wave-forms Due to a Fault

Fault Current Limitation

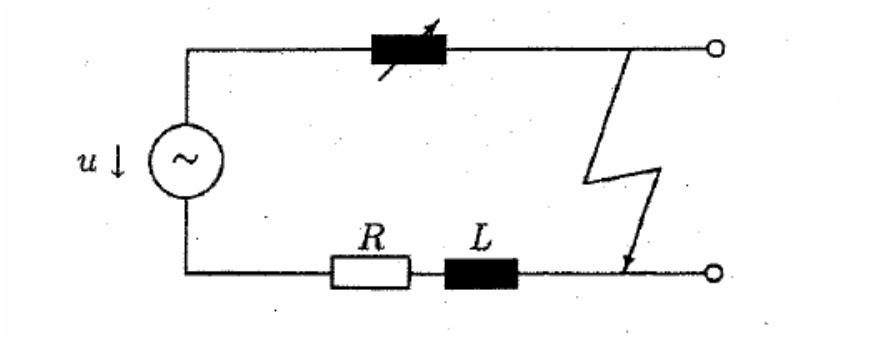


Arc Voltage (e.g. Fuse)

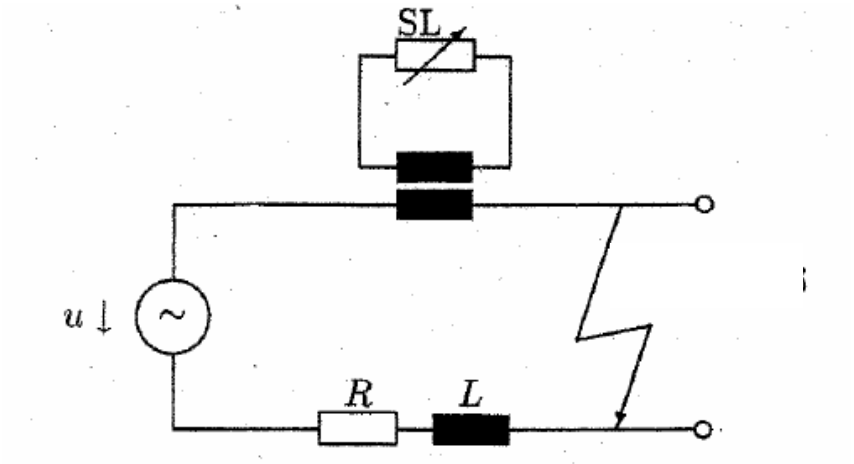


Nonlinear Resistance
(e.g. Resistive Type SCFCL)

Fault Current Limitation

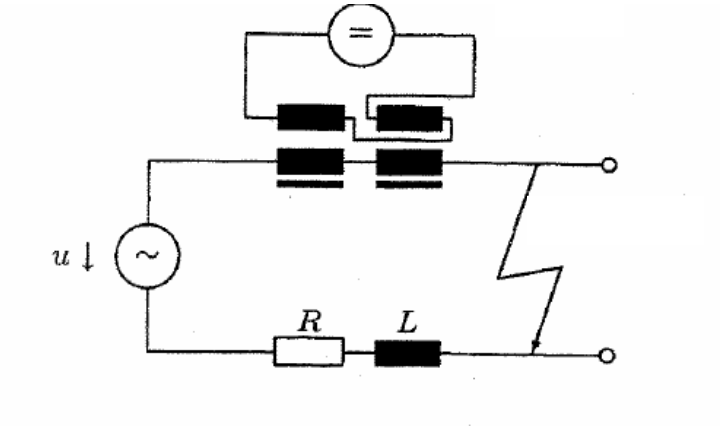


Nonlinear Inductance

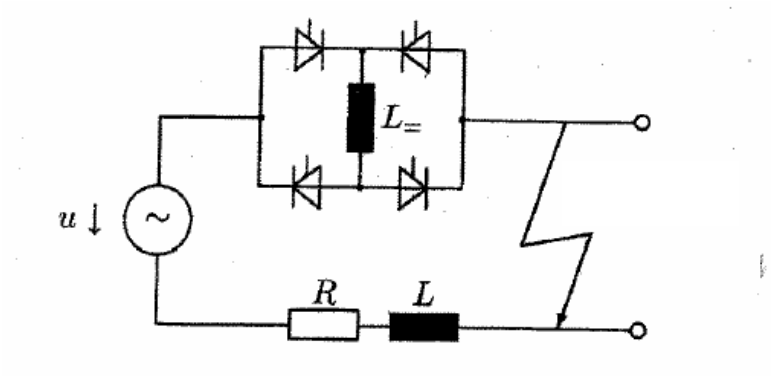


Nonlinear Inductance
(e.g. Inductive Type SCFCL
(„Shielded Core“))

Fault Current Limitation

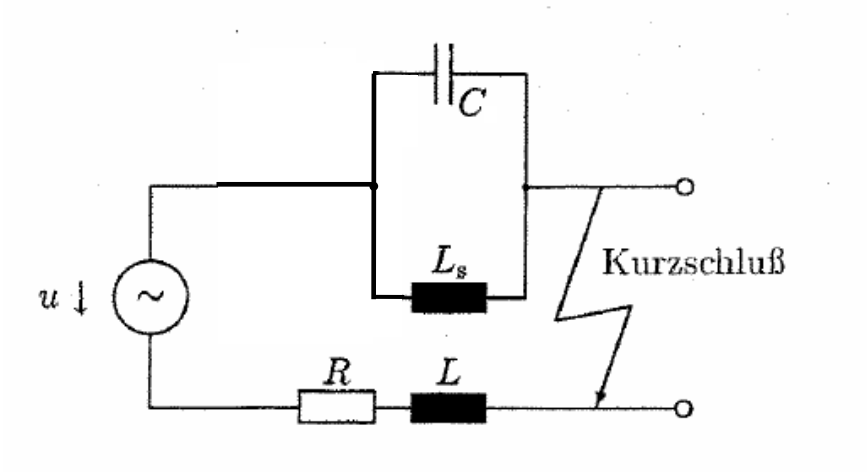


Transducer Principle
(e.g. Inductive Type SCFCL
(„Saturated Iron Core“))

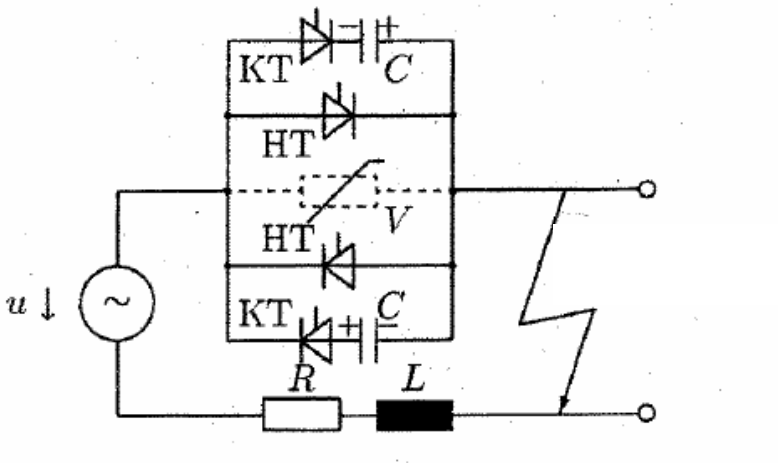


Inductance in D.C. Link
(e.g. Inductive Type SCFCL
(„Current Controller“))

Fault Current Limitation



Resonance Link



Current Limiting Solid-State Switch

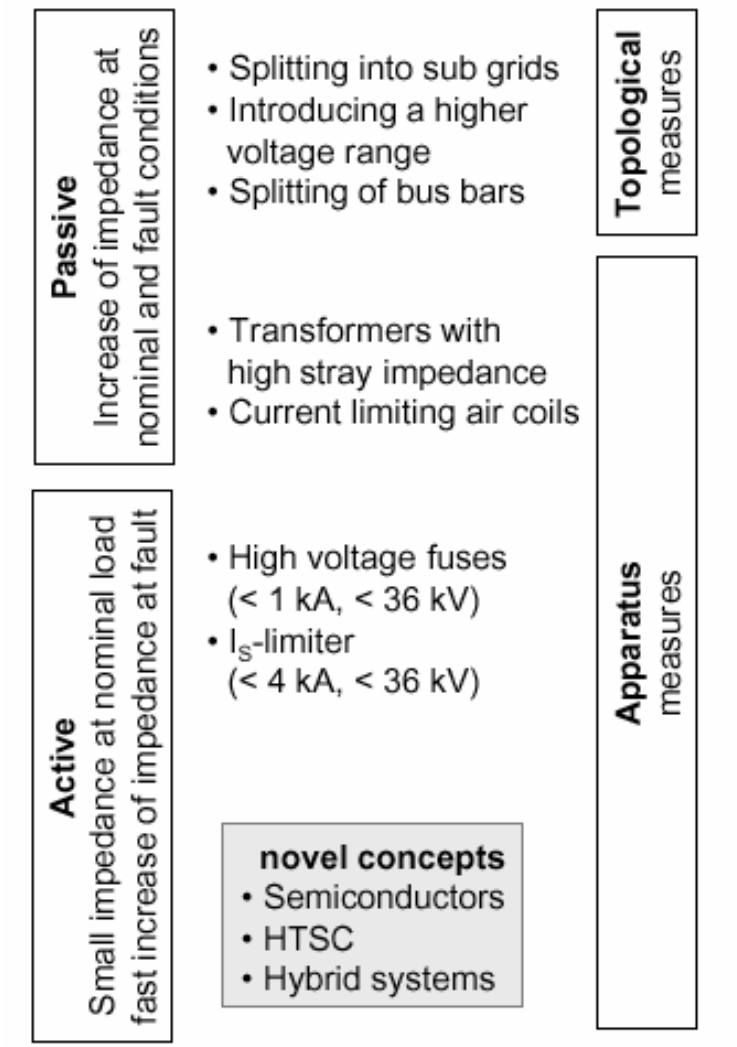
State of the Art of Fault Current Limiters

Alternatives to the Use of Fault Current Limiters

- Uprating of Existing Switchgear and other Equipment
- Changes in the Network Topology (e.g. Splitting of Grids or Splitting of Busbars)
- Introduction of Higher Voltage Levels
- Use of Complex Control Strategies like Sequential Tripping
- FACTS-Devices
- DC-Links
- Etc.

State of the Art of Fault Current Limiters

Characterisation



State of the Art of Fault Current Limiters

Characterisation

- „Passive“ and „Active“ Fault Current Limiting Measures

  ⇨ Passive: Increase of Impedance at Nominal and Fault Conditions (Example: Fault Current Limiting Reactor)

  ⇨ Active: Fast Increase of Source Impedance at Fault Conditions (Example: Superconducting Fault Current Limiter)

- Characterisation of Active Fault Current Limiters

  ⇨ Self-triggerd or External-triggered

  ⇨ With or without Current Interruption

  ⇨ „Resetable“ or „Non-resetable“ *)

  *) Parts of the fault current limiter need to be replaced after an operation

State of the Art of Fault Current Limiters

State of the Art

Type	Characteristics				Voltage Level
	Passive/ Active	Triggering Method	Current Interruption	Resetable	
Fault Current Limiting Reactor	Passive	----	----	----	MV, HV
Transformer with Increased Short-Circuit Impedance	Passive	----	----	----	MV, HV
High-Voltage Current Limiting Fuse	Active	Self	Yes	No	MV
Pyrotechnic Fault Current Limiter (I_s-Limiter)	Active	External	Yes	No	MV
Resonance Link ("Kalkner-Kupplung")	Active	Self	No	Yes	MV, HV

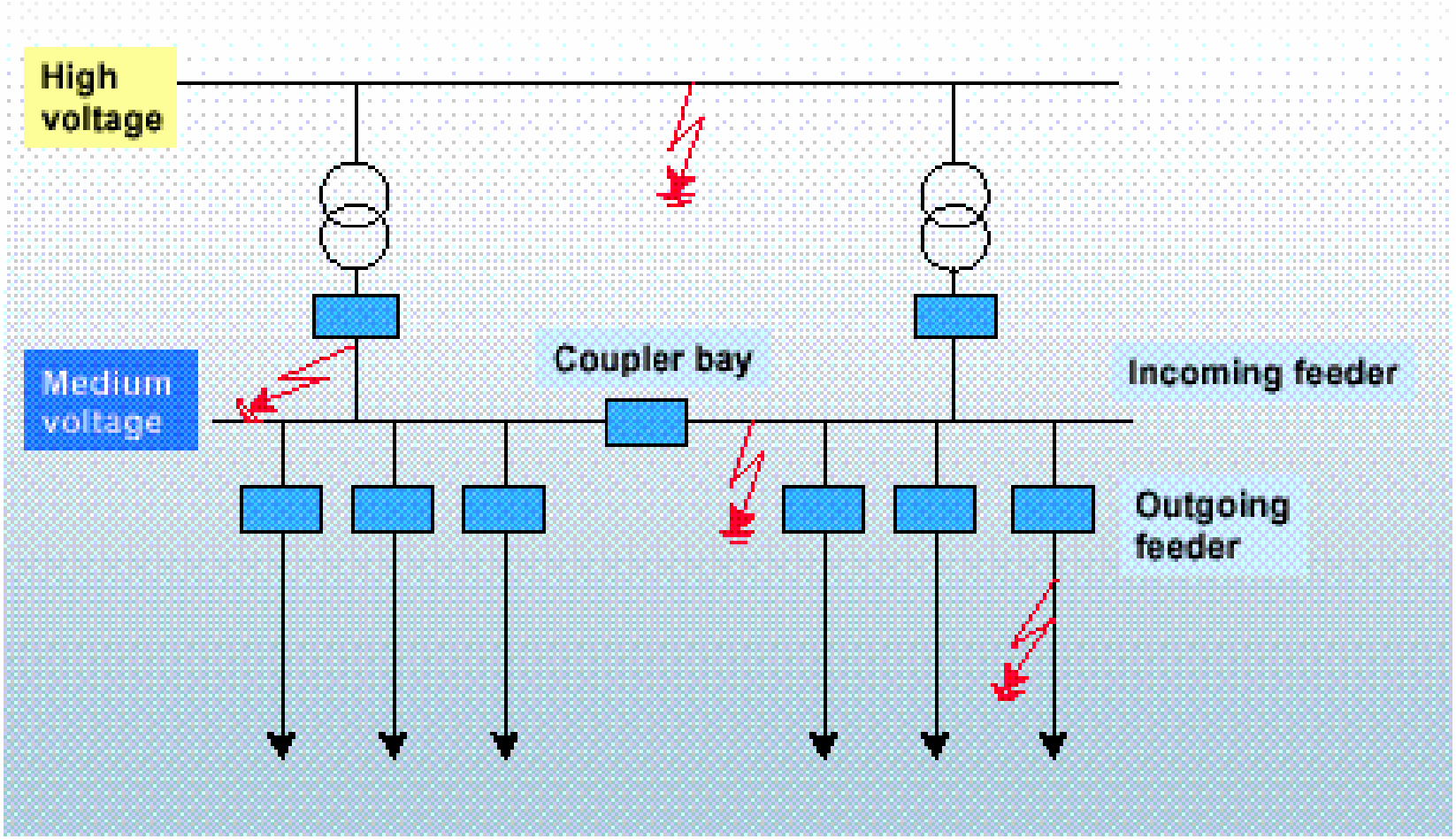
State of the Art of Fault Current Limiters

Novel Approaches

Type	Characteristics				Proto-type
	Passive/ Active	Triggering Method	Current Interruption	Resetable	
Resistive Type SCFCL	Active	Self	No	Yes	MV
Shielded Iron Core Type SCFCL	Active	Self	No	Yes	MV
Saturated Iron Core Type SCFCL	Active	Self	No	Yes	MV
"Current Controller" Type SCFCL	Active	External	Yes/No	Yes	MV
FCL with PTC Resistors	Active	Self	(Yes)	(Yes)	MV
Liquid Metal FCL	Active	Self	No	Yes	MV
Current Limiting Solid-State Switch	Active	External	Yes	Yes	MV
Solid-State Switch with Current Limiting Impedance	Active	External	Yes	Yes	MV
Hybrid FCL with Solid-State Switch	Active	External	Yes	Yes	MV
Current Limiting Circuit-Breaker (with High Arc-Voltage)	Active	External	Yes	Yes	MV
Resonance Link with Switching Device (Solid-State, Vacuum)	Active	External	No	Yes	MV

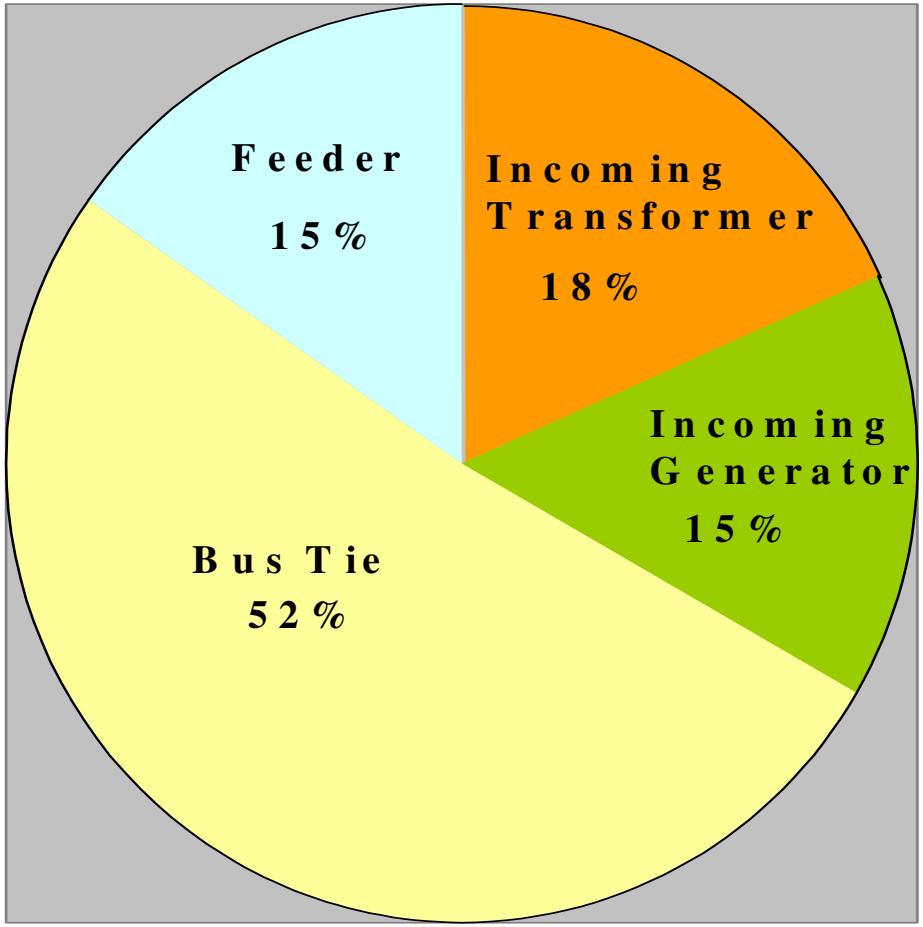
Application of Fault Current Limiters

Installation of Fault Current Limiters (Examples)



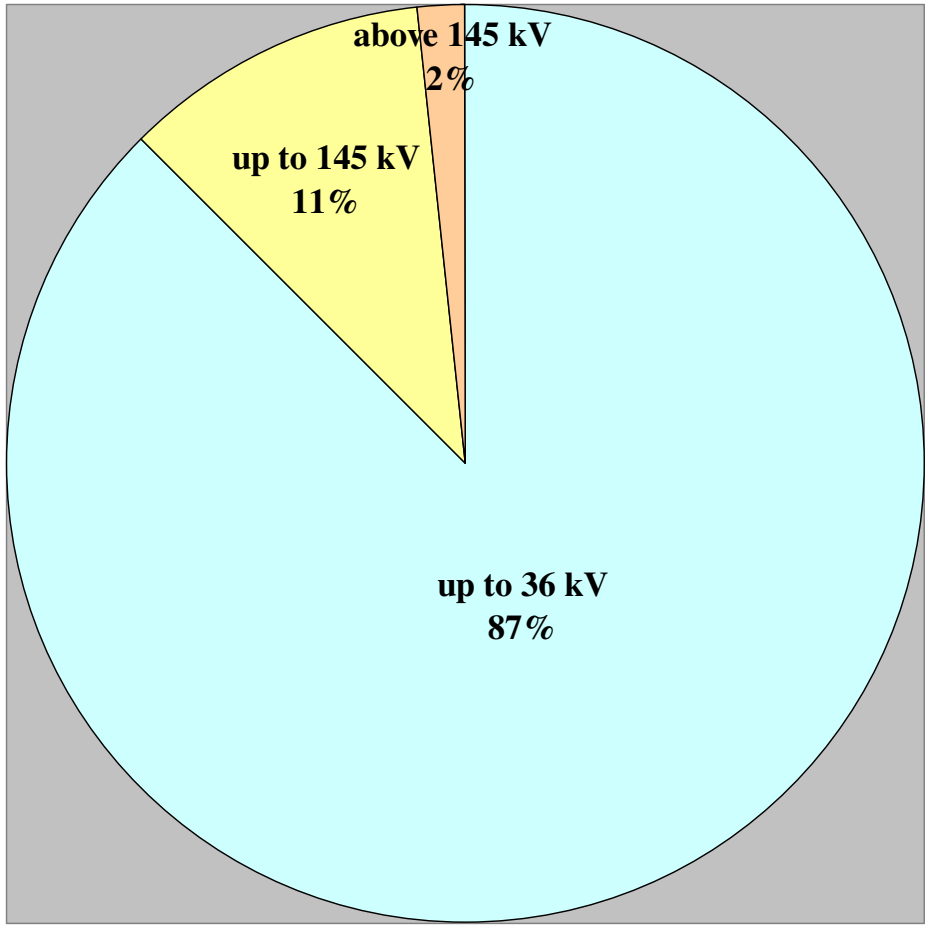
Application of Fault Current Limiters

Locations of Installation



Application of Fault Current Limiters

Voltage Levels



Application of Fault Current Limiters

Advantages of the Use of Fault Current Limiters

	Bus Tie	Incoming Feeder	Outgoing Feeder
Reduction of the Short-Circuit Current of the System	x	x	
Reduction of the Short-Circuit Current of the Feeder			x
Reduction of Voltage Sags and Flicker	x	x	x
Reduction of Harmonics	x	x	x
Higher System Availability	x	x	
Higher Loads in Sub-System	x		
Even Loading of Transformers	x	x	

Application of Fault Current Limiters

Effects of a Fault Current Limiter on the System

- Effects on Protection Schemes
  - ⇨ Relay Settings
  - ⇨ Selectivity
  - ⇨ Compatibility with Downstream Fuses
  - ⇨ Protection Blinding (e.g. in Case of Directional Protection)
- Effects on Conventional Switchgear
  - ⇨ Transient Recovery Voltage of Downstream Circuit-Breakers
- Effects on System Reliability
  - ⇨ Reliability of the Fault Current Limiter
  - ⇨ Effect of a Malfunction of the Fault Current Limiter
  - ⇨ Behaviour of the Fault Current Limiter in Case of an Internal Fault

Application of Fault Current Limiters

Effects of a Fault Current Limiter on the System

- Maintenance Requirements
  - ⇨ Maintenance Intervals
  - ⇨ Maintenance Duration

Application of Fault Current Limiters

Effects of the System on a Fault Current Limiter

- Undesirable Tripping of Fault Current Limiters
  - ⇨ Transient Currents Due to Single Phase-to-Earth Faults
  - ⇨ Inrush Currents Due to Transformer Switching
  - ⇨ Inrush Currents Due to Capacitor Bank Switching
  - ⇨ Starting Currents of Motors

- Ability of Fault Current Limiters to Withstand Fault Currents
  - ⇨ Fault Duration Depending on Protection System *)

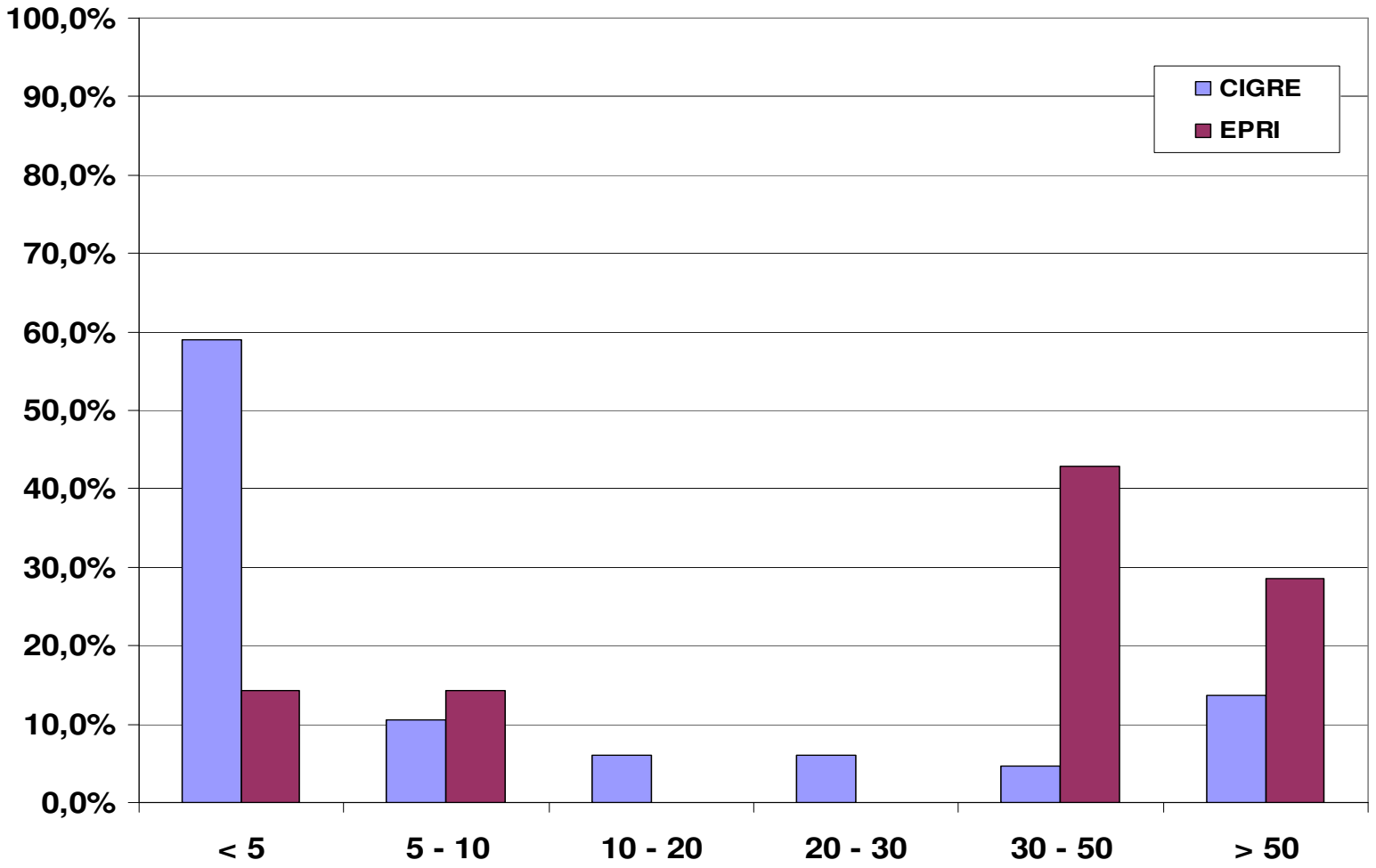
    *) if applicable also during several reclosing cycles

Requirements for Fault Current Limiters

- Low Impedance During Normal Operation (Low Voltage Drop across Device)
- Low Losses
- Adequate Current Limiting Performance
- Compatibility with Existing Protection Schemes
- No Deterioration of Limiting Behaviour during the Useful Life
- Low Maintenance Requirements
- No Risk for Operating Personnel
- Low Impact on the Environment

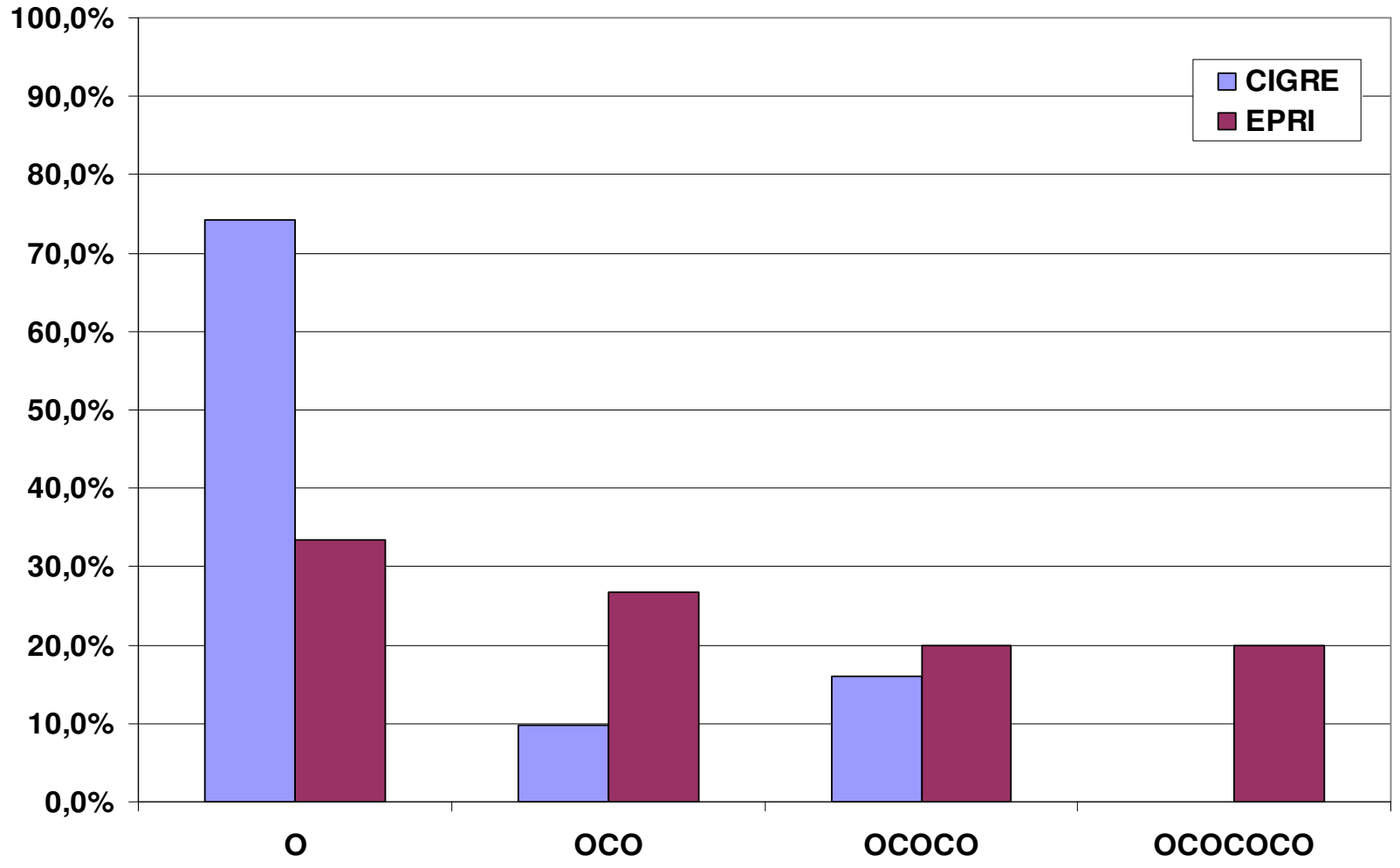
Requirements for Fault Current Limiters

Permissible Number of Operations



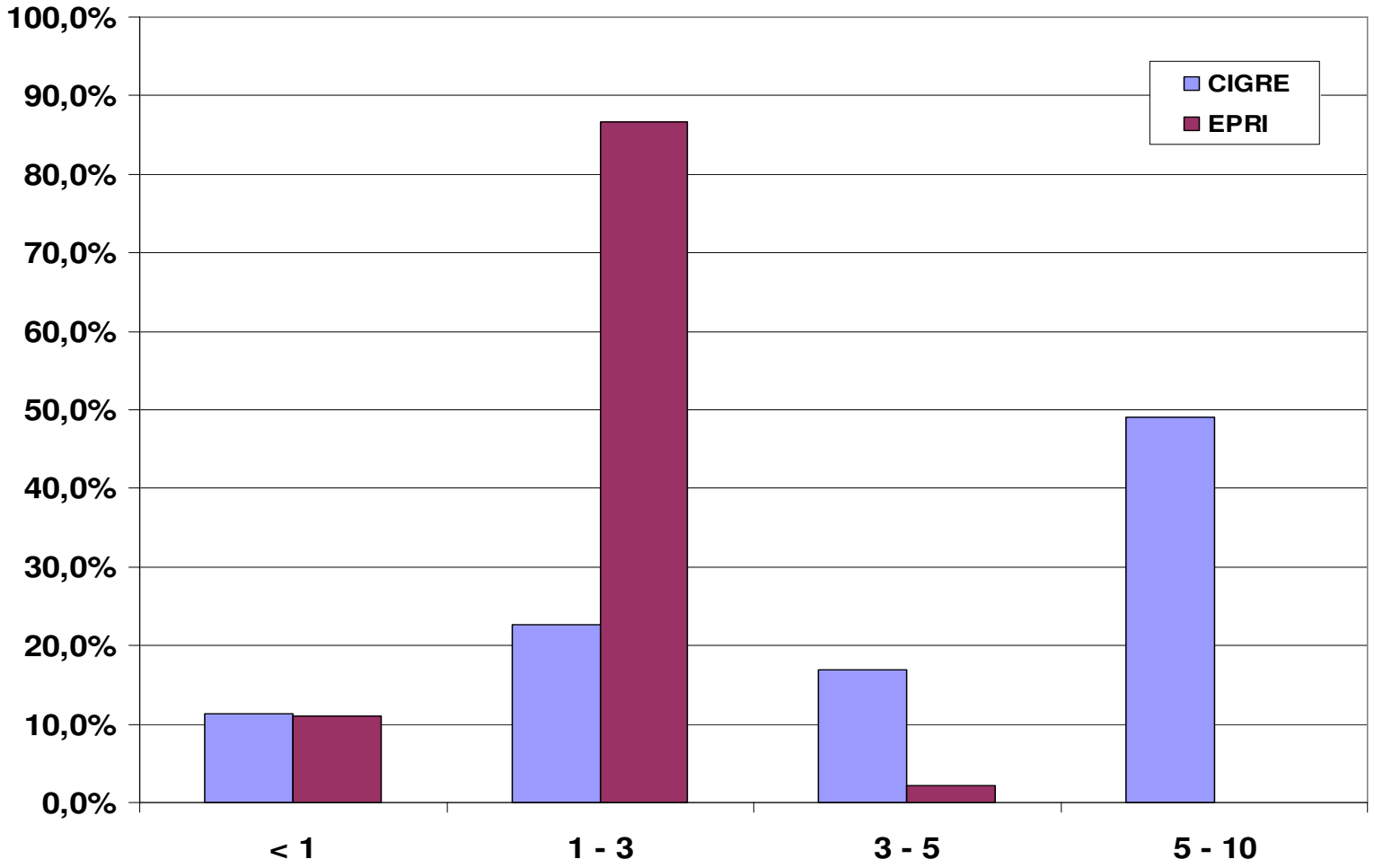
Requirements for Fault Current Limiters

Duty Cycle



Requirements for Fault Current Limiters

„Worth“ of a Fault Current Limiter to a Customer



Testing of Fault Current Limiters

- Existing Standards:
  - ⇨ Fault Current Limiting Reactors (IEC 60289)
  - ⇨ High Voltage Fuses (IEC 60282-1)
- For all other Types of Fault Current Limiters no Standards Exist
- Basic Procedures for the Testing of Fault Current Limiters Proposed by the WG

Testing of Fault Current Limiters

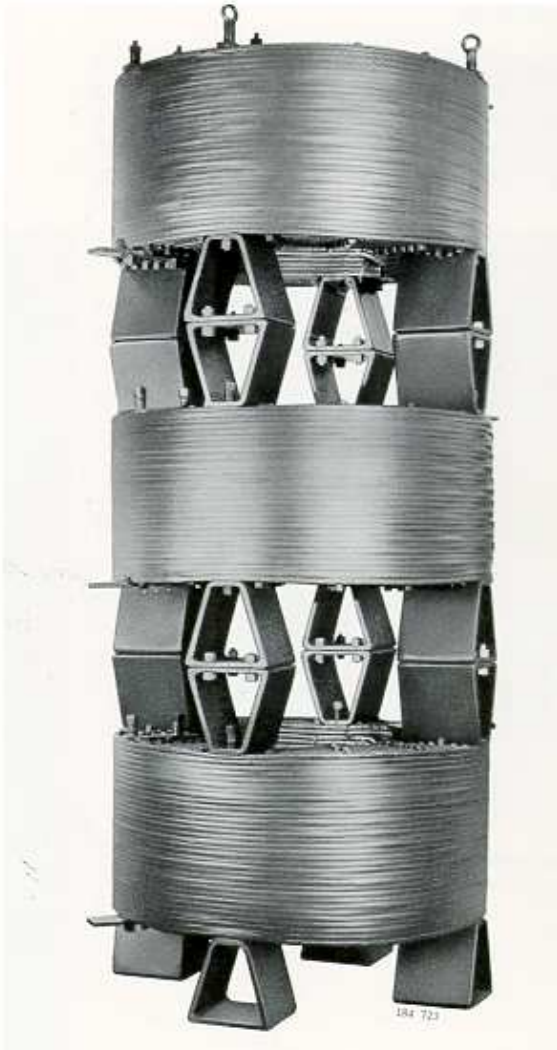
- Dielectric Test
- Temperature Rise Test
- Short-Time Withstand Current Test
- Breaking / Making Test
- Endurance Test
- EMC Test

System Demands – Utilities` Contributions

- Furnas, Brazil
- Electicité de France, France
- RWE Net, Germany
- EnBW, Germany
- National Grid Company, England and Wales
- Manitoba Hydro, Canada
- Hydro Québec, Canada
- Con Edison, USA
- KEPCO, Korea
- Experience in Japan

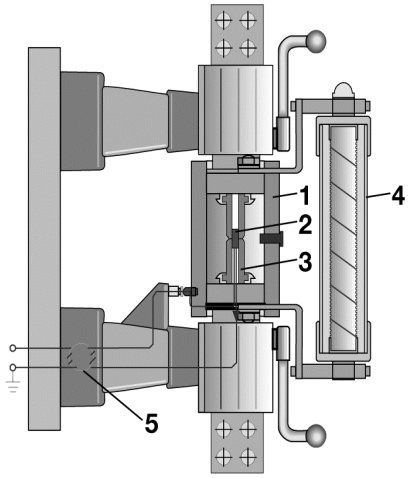
Application of Fault Current Limiters

Reactor



Application of Fault Current Limiters

Is-Limiter



Application of Fault Current Limiters

Electronic Limiter (Solid State Limiter)