ENERGY

Survey on new electrical devices with different technology compared to existing electrical devices

Project KK51525

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Agenda
Presentation – August 23, 2017

1. **Scope & Objective**
2. **Methodology**
3. **Key findings**
   - Relay protections
   - Circuit breakers, medium voltage
   - Surge arresters, medium voltage
4. **Recommendations**
5. **Discussion & Questions**

Scope (original)

Define the current status of relevant equipment, characteristics that matters and important specifications.

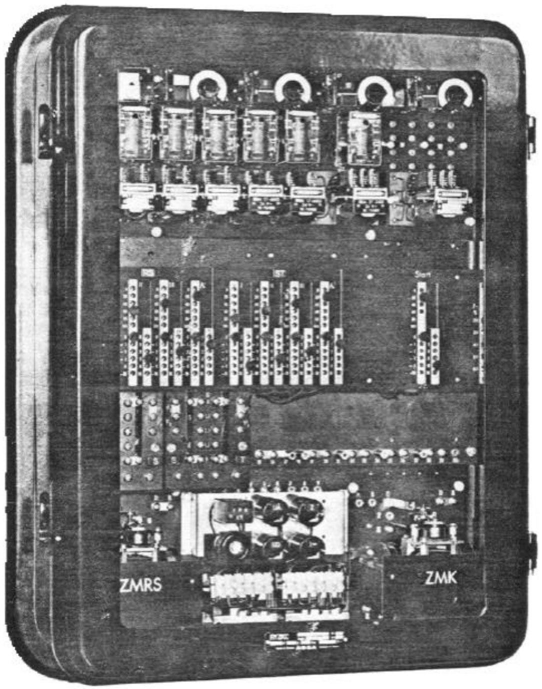
	Relay protections	**Circuit breakers**	**Surge arresters**
Description			
Key characteristics	Electromechanical, solid state, microprocessor	Air, oil, vacuum, SF6 circuit breakers	Gap, gapless arresters
Specifications	Speed, sensitivity, accuracy, functions, etc	Pre-strikes and re-ignitions, operating time, etc	Discharge/Energy Absorbing Capability, shot durability, etc
Comparisons			
Challenges and risks			
Considerations			
Conclusions and recommendations			

*Devices to include in the survey shall be decided in the initial stage of the project, from both a technical and an economical perspective and specific requirements operating nuclear power plants must be defined.

Objective

The project aims to gain a better knowledge of what the market offers regarding relay protections, surge arresters and circuit breakers. This will denote that future changes of specific devices can be done with better knowledge of the individual behavior and characteristics of the device and how it affects the surrounding systems and devices in the plant.

Source: ABB

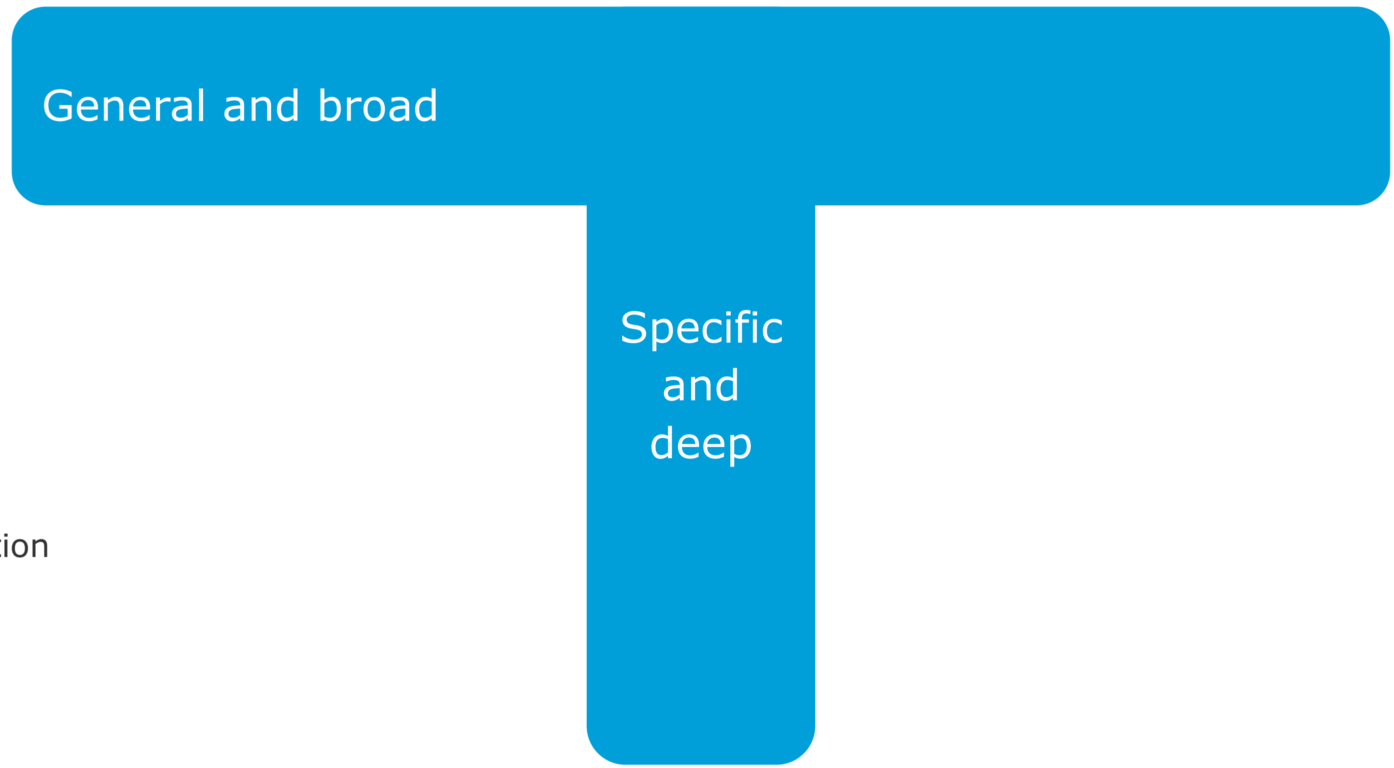


Source: Distansskydd typ RYZKC
ASEA Information RFR April 1969 Utgåva 2
Bl. 720 R (954) 10.68

Methodology

Different sources were used to identify, study and compare alternatives and characteristics of the different devices

- Literature
  - Textbooks
  - Guides
- Papers and reports
  - Conferences
  - Research
  - Thesis
- Articles
  - Magazines
  - Online publications
- Supplier information
  - Representative selection
  - Contacts
- User input
  - Ringhals
  - Forsmark
  - OKG
  - TVO



Key findings
Relay protections

Relay Protection	Electromechanical	Static Solid State	Numerical Microprocessor
Flexibility	Single function	Essentially single function per unit	Multiple functions
Maintenance	Moving parts require maintenance	Less maintenance	Self-monitoring and self-testing (does not replace all maintenance)
Accuracy	Low accuracy, need for calibration	Better accuracy, less calibration	High, less calibration
Speed	Slow, although some were fast	Higher operating speed Shorter reset time	Sensitive and fast
Environment	Inherently immune to electrical transients (EMI, RFI, etc.) May malfunction during seismic activities	Resistant to seismic forces Susceptible to electrical transients	Resistant to seismic forces Susceptible to electrical transients
Complexity	Rudimentary functionality Logical functions require use of external relays and extensive wiring	Basic adjustment of characteristic curves Logical functions require use of external relays and extensive wiring	Extensive capability gives numerous settings Programmable logic built in
Reporting features	No fault data recording	Like electromechanical until hybrids with a combination of analog analysis and micro-processor logic evolved	Recording and reporting possibilities. Communication for protective functions

Key findings
Relay protections

Main result	Electromechanical / static		Numerical	
	Single (1 of 1)	Redundant (1 of 2)	Single (1 of 1)	Redundant (1 of 2)
Dependability	98.4%	**99.5%**	99.4%	99.4%
Security	68.1%	49.5%	**95.5%**	92.1%
Unavailability of line	0.02%	0.03%	0.01%	0.02%

Dependability – to operate when necessary

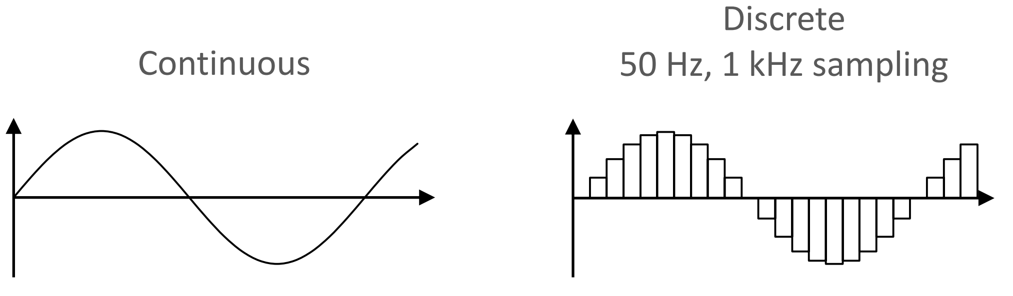
Security – to not operate on external disturbances

Self-supervision means earlier fault discovery and increase security

Key findings
Relay protections

Challenges and risks with new technology – Numerical protective relays

- Specialist competence required for each product family
- More possibilities give more complex systems – Risk for design or implementation errors
- Self-test can only verify that it works as programmed
- Product or tools become obsolete
- Firmware upgrades
- Cyber security
- Different behaviour between analogue and digital systems



Key findings
Relay protections

Advances in 2nd generation numerical protective relays

- Increased recording and reporting capabilities
- Graphical User Interface
- Templates for different applications
- Some relays have offline simulation
- Step by step guided settings

Key findings
Relay protections

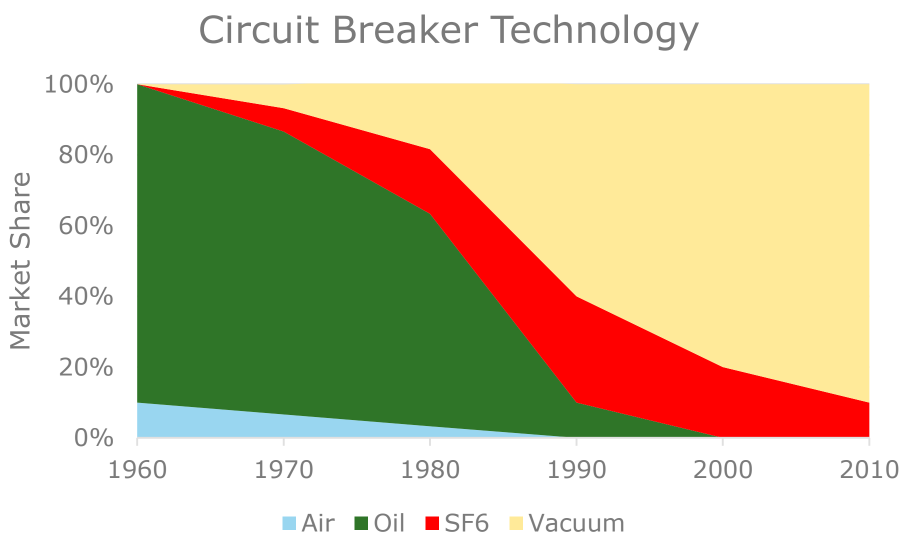
Measures and Considerations

- Invest in training and time to analyse and choose proper settings
- Keep documentation updated
- Adapt maintenance to new technology – Functional or scheme testing
- Evaluate manufacturer and performance of device based on historical data
- Collect information on both disturbed and undisturbed operation
- Evaluate any deviation from correct settings and expected behaviour
- IEC 61850 simplifies integration in local or global communication
- New firmware must be qualified before updating unit
- Special care: correct and verified and controlled installation and wiring
- Redundant systems, where needed, should neither be identical nor duplicated. Different independent systems and components to avoid common mode failures (ex. software bugs, sensor failure, power supply)

Key findings
Circuit breakers, medium voltage

Circuit Breakers	Oil	Air	SF6	Vacuum
Market introduction	1910's Minimum oil: 1930's	1930's	1960's for HV 1980's for MV	1960's
No. of operation: **Short circuit** **Full load** **Mechanical**			Typical 10-50 5000-10000 5000-20000	Typical **30-100** **10000-20000** **10000-30000**
Dielectric strength	High	Low	~3x higher than air	**~2x higher than SF_6**
Application	Outdated in MV	Obsolete technology	MV, HV	LV, MV, low end of HV
Breaking capability	Insufficient at times			
Advantages	Oil absorbs arc energy Good cooling	Airblast: Higher speed and faster arc quenching vs oil CB		
Disadvantages	Flammable Explosive	Large and bulky, air compressor required	**Greenhouse effect is 23 500 vs 1 for CO_2**	**Over voltage issues**
Maintenance	High cost	High cost, less required vs oil CB	Low cost	Low cost, long intervals
Maintenance procedures (shortened)	Extensive checking, cleaning, filtering, changing, adjusting, lubrication and/or testing of different parts	Clean, check, lubricate, replace and/or adjust different parts	Normal procedures consist of removing SF_6, filtering and storing until breaker maintenance and test has been performed when it is transferred back. Some CB:s are sealed for life with similar maintenance as VCB	Measuring change in external shaft position can indicate extent of contact erosion Condition of vacuum can be checked by a high potential test procedure Sealed for life
Speed	Slow	Airblast: Fast vs oil CB		Fast
Complexity	Simple construction			**~50% less components vs SF_6**

Key findings
Circuit breakers, medium voltage

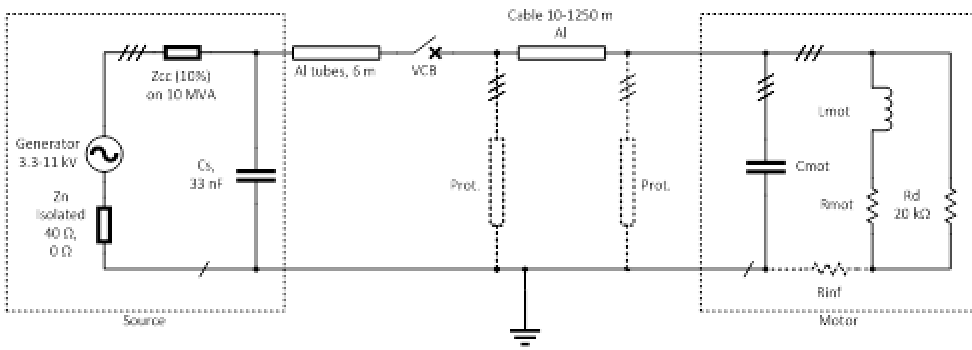


SF_6 circuit breaker's market share is decreasing much for environmental reasons

SF_6 has soft interruption characteristics – normally no need for protective devices

Vacuum circuit breaker dominate the market

Key findings
Circuit breakers, medium voltage

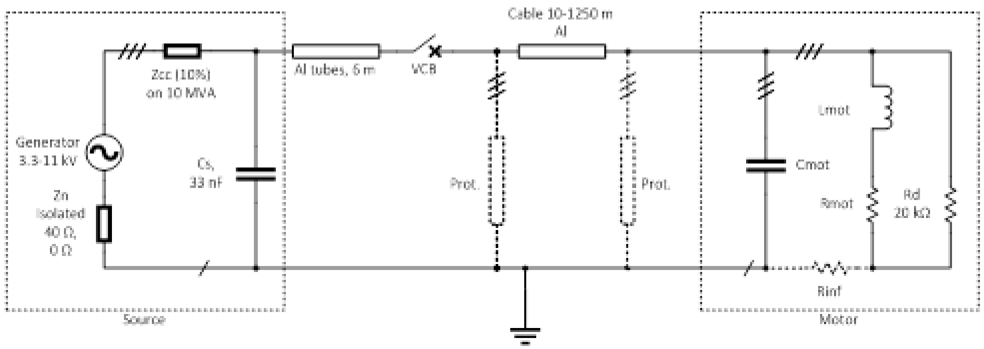


Overvoltage Protection Study on Vacuum Breaker Switched MV Motors*

- No protection
  - Overvoltage levels far above recommended dielectric strength for lightning strike

*Overvoltage Protection Study on Vacuum Breaker Switched MV Motors, D. Penkov, C, Vollet, B. De Metz-Noblat, R. Nikodem, Schneider Electric, PCIC Europe 2008

Key findings
Circuit breakers, medium voltage

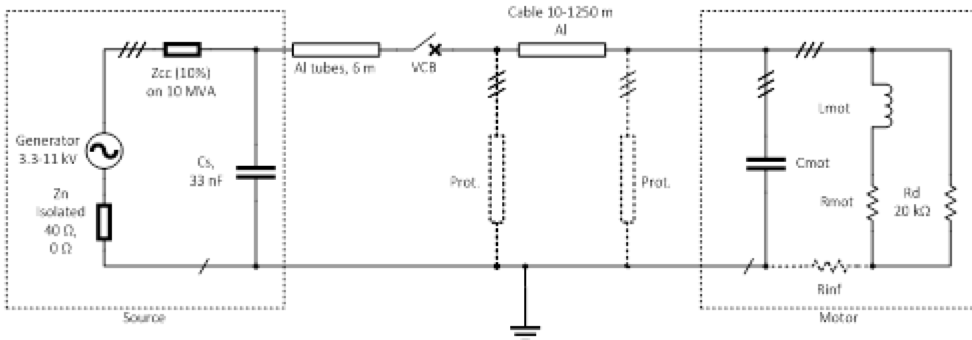


Overvoltage Protection Study on Vacuum Breaker Switched MV Motors*

- Protection by Surge Arrester (does not limit dV/dt)
  - 1 m cable <u>surge arrester to motor</u> terminal and arrester to ground. Overvoltages sometimes below 3 pu and average level never above 5 pu. Best result single core cable, with screens grounded on both sides
  - 3 m cable <u>surge arrester to motor terminal</u> and arrester to the ground <u>blinded</u> the surge arrester
  - 1 m cable <u>surge arrester to circuit breaker terminal</u> and arrester to the ground is less efficient. Possible to get an overvoltage level about 4 pu

*Overvoltage Protection Study on Vacuum Breaker Switched MV Motors, D. Penkov, C, Vollet, B. De Metz-Noblat, R. Nikodem, Schneider Electric, PCIC Europe 2008

Key findings
Circuit breakers, medium voltage

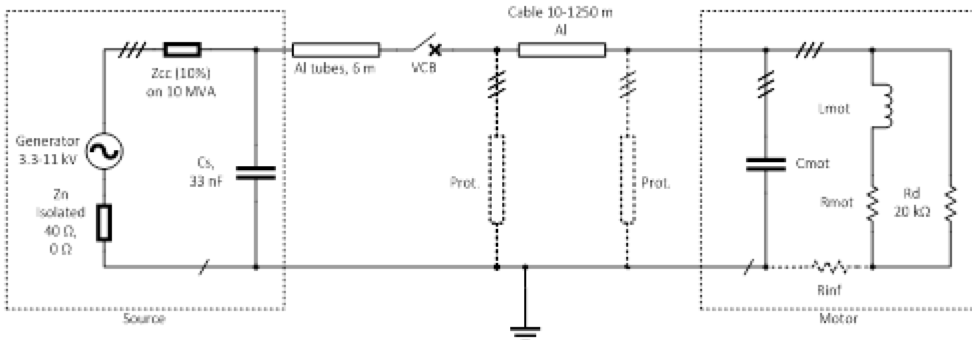


Overvoltage Protection Study on Vacuum Breaker Switched MV Motors*

- Protection by Surge Capacitor (3 m cable)
  - The overvoltage level < 3 pu (typically < 2 pu)
    Capacitor 500 nF. The capacitor quite independent of cable type (single or multicore)
    Motor starting current < 300 A @ 3.3 kV and < 200 A @ 11 kV.
    (Larger motors similar situation to the one without protection)

*Overvoltage Protection Study on Vacuum Breaker Switched MV Motors, D. Penkov, C, Vollet, B. De Metz-Noblat, R. Nikodem, Schneider Electric, PCIC Europe 2008

Key findings
Circuit breakers, medium voltage

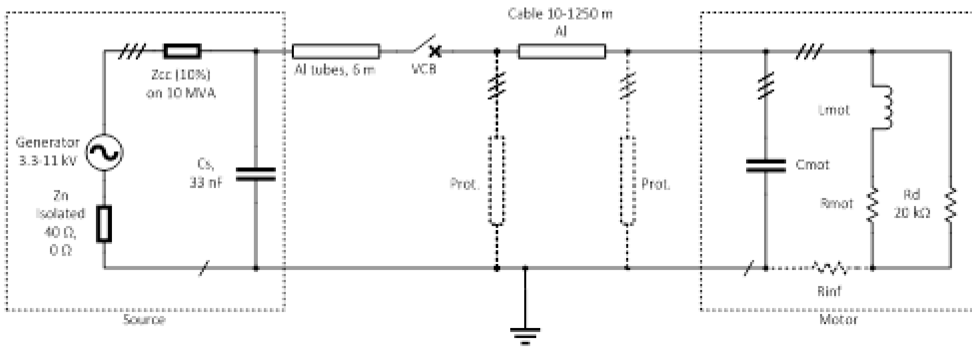


Overvoltage Protection Study on Vacuum Breaker Switched MV Motors*

- Protection by R-C (3 m cable)
  - Overvoltages << below 3 pu (motor side)
    R=30 Ohm, C=500 nF
    (stronger effect than R=30 Ohm, C=250 nF)
    Single core cables grounded on each side limited
  - Limitations on breaker side
    starting current < 600 A @ 3.3 kV and < 200 A @ 11 kV
    Overvoltage limitation < 3 pu
    Breaker side connection generally overvoltage < 5 pu with some exception on 11 kV

*Overvoltage Protection Study on Vacuum Breaker Switched MV Motors, D. Penkov, C, Vollet, B. De Metz-Noblat, R. Nikodem, Schneider Electric, PCIC Europe 2008

Key findings
Circuit breakers, medium voltage



Conclusion

- Surge arrester at motor (single core cable < 1 m) => 3-5 pu
- Surge capacitor 500 nF (cable < 3 m) => 2-3 pu
- R=30 Ohm, C=500 nF at motor (single core cable < 3 m) => far below 3 pu for all motors

*Overvoltage Protection Study on Vacuum Breaker Switched MV Motors, D. Penkov, C, Vollet, B. De Metz-Noblat, R. Nikodem, Schneider Electric, PCIC Europe 2008

Key findings
Circuit breakers, medium voltage

Replacement of air-magnetic circuit breakers
(or obsolete circuit breakers)

- Examine mechanical interlocks to avoid failures
- Ensure matching with original cell on-site. Include adjustable interface points
- Preferably, have factory represenative present at initial installation to resolve problems
- Circuit breaker interchangeability definition must be clearly understood by vendor and user

Key findings
Circuit breakers, medium voltage

Recommendation and considerations

- Vacuum Circuit Breakers if
  - Frequent switching
  - Protection of sensitive or older equipment possible
- SF_6 Circuit Breakers if
  - Soft interruption characteristics required
  - Protective measures can not be made

*Overvoltage Protection Study on Vacuum Breaker Switched MV Motors, D. Penkov, C, Vollet, B. De Metz-Noblat, R. Nikodem, Schneider Electric, PCIC Europe 2008

Key findings
Surge arresters

Surge Arresters	SiC, Porcelain	MO gapless
Market introduction	1940s	1970s
Expected life span	13 years	30+ years, but it is sacrificial to protect other equipment (not failure)
Acceptance	Obsolete	Superior
Maintenance	Regular inspections for damages	No maintenance under normal conditions. In some conditions inspection if cleaning is necessary
Isolation		Silicon potentially better short-circuit capability
Complexity	Gaps require elaborate designs for consistent spark-over level and resealing after a surge	Simpler design

Key findings
Surge arresters

- Metal oxide surge arresters have become the preferred technology and replaced silicon carbide
- Silicon moulded housing
  - No gas volume remains
  - No sealing problems
  - No inner partial discharges
  - Elastic
  - Self extinguishing
  - Water repellent even with pollution
- Metal oxide have lower losses than SiC
- HV station class MOV arresters typically claim energy capabilities exceeding twice those demonstrated by the SiC arresters

Information from different sources

Key findings
Surge arresters

Considerations

- Ideal location is at terminal of device to be protected
- Lower protective voltage level to absorb energy from vacuum circuit breakers
- Higher energy absorption level for handling lightning and switching surges from other sources
- Generally an arrester is dimensioned for a lightning level of 4 pu (ABB)
- Cool down period for a fully loaded arrester is normally 45-60 min

Information from different sources

Discussion & Questions

Vacuum Circuit Breakers

Electromechanical protective relays

Nuclear industry specific requirements

Common mode failures

Human factor or capability

Thank you!

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