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SPECIAL REPORT - SESSION 1

NETWORK COMPONENTS

Christophe BOISSEAU
Chairman - France
christophe.boisseau@enedis.fr

Arnaud ALLAIS
Special Rapporteur – France
arnaud.allais@nexans.fr

François GENTILS
Special Rapporteur - France
francois.gentils@se.com

Introduction

Session 1 deals with all aspects related to the components used in the electricity distribution networks:

- Cables and overhead lines,
- primary and secondary substations
- transformers
- switchgear plus their control
- protection and monitoring systems
- new active power electronics devices
- …

Session 1 covers topics related to the life cycle optimization of assets from design through installation, operation and maintenance, monitoring and diagnosis, to end of life management, including new techniques such as Big Data and Artificial Intelligence. The session also covers environmental aspects including eco-design and life cycle analysis, standardization, ergonomics and safety for both the operating staff and the public. It aims at providing an overview of the state-of-the-art in component design and proposals for future components: It includes the ones needed for smartgrids, e-mobility, smartcities and microgrids, as well as components for more resilient networks in the context of climate change anticipation. This session is an opportunity for DSOs and manufacturers to share their objectives.

136 papers have been selected for the Session 1 – Network Components – of CIRED 2021. They have been organized in four blocks, which are the same for both this special report and the Main Session.

The structure retained for these blocks is as follows:

Block 1 "Asset management and condition assessment of Network Components – Cables, lines and associated components" (25 papers):
- Testing & Monitoring
- Artificial Intelligence & Big data
- Health index, diagnostic and failures detection

Block 2 "Asset management and condition assessment of Network Components – Substations, switchgear and transformers" (39 papers):
- Upgrade to smart, and sensors integration
- Data for asset management
- Dynamic rating, adaptation to DER integration
- Use cases of diagnostic, maintenance, and retrofit

Block 3 "Innovation in Network Components – Cables, lines and new types of components" (27 papers):
- Materials & Models
- Metering & monitoring systems
- Systems for safety & security
- Components for protection & stabilization

Block 4 "Innovation in Network Components – Substations, switchgear and transformers" (45 papers):
- Greener components
- Smart substations
- Innovative network components
- Methods and tools for component design

6 papers per block have been selected for oral presentation in the main session (MS), and 6 other papers have been chosen for presentation in the Research and Innovation Forum (RIF) which details results of the research activity in the field of network components.

All other articles will be presented in the Interactive Poster Session (PS).

In addition to the Main, RIF and Poster Sessions, three Round Table (RT) discussions will take place within Session 1:

RT1 "DC network" (joint RT with Session 5),
RT2 "Secondary substation for the future",
RT4 "Green Network Solutions".

Block 1: "Asset management and condition assessment of Network Components – Cables, lines and associated components"

The 25 papers of this block are divided in 3 sub blocks:
- Testing & Monitoring
- Artificial Intelligence & Big data
- Health index, diagnostic and failures detection

Sub block 1: Testing & Monitoring (5 papers)
The key role of testing and monitoring is to support decision making of DSOs regarding the ability of existing assets to transmit the required amount of power. The paper **439** is showing that the use of VLF, DAC or slope voltages give similar PD results (see Fig 4 of paper 439) and measured PD are not correlated to dielectric losses. Indeed, the dielectric losses depend mainly on humidity and thermal degradation.

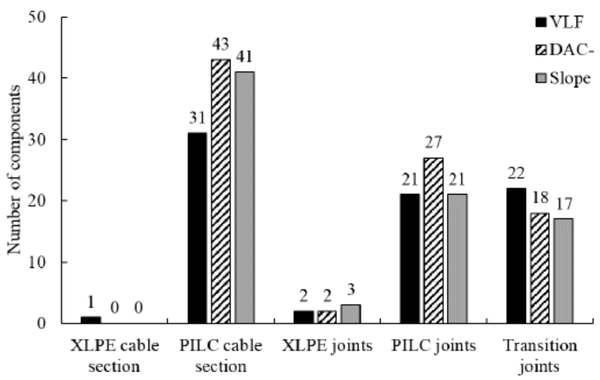


Fig. 4 of paper 439: Detected PD defects separated by component and measuring method

The alarm system of London underground distribution system based of continuous PD monitoring presented in the paper **747** shows that, with a good enough signal to noise ratio, combinations of PD presence and severity can be a reliable way to anticipate defects in MV grids for maintenance, pre-fault and life assessment.
The testing of MV collection cables in windfarms (**110**) and their thermal monitoring (**1118**) under severe weather conditions are key to increase the mix of renewable energy in actual grids.

The LV part of the distribution system is submitted to daily modifications, as presented in paper **249**, and a phase angle measurement can prevent from incorrect installations of meters with consequently false measurement of consumed energy.

Sub block 2: Artificial Intelligence & Big data (9 papers)

Prerequisite for deep learning tools are the availability of large amount of measurement as well as load and environmental data. Such tools have been applied to PD analysis in some underground networks, resulting in a diagnostic prediction accuracy of up to 98% within few milliseconds for internal, corona and surface discharges activities (**842, 942**), allowing DSOs to use PD for real time monitoring.
The ability of the full PD measurement chain to adapt in real time to assess and reduce the noise is a major improvement in the use of PD for monitoring (**108**).
Using a more general approach thousands of signals are collected in the frame of the Forsight project in UK (paper **837**) to create a priority map for the maintenance crews (see Fig. 5 of paper 837).

Fig. 5 of paper 837: Impedance contoured plan (D=distance in m, P= phase impedance in milliOhms). Locations highlighted

The overhead distribution network offers opportunities to test predictive or automatic recognition approaches based on data analysis as a lot of operational and environmental data are easily accessible. Combining operational data with failures modes of poles, the approaches used in the paper **464** allow adjusting the maintenance operations by up to 40% for certain types of poles. With the

deployment of network components recognition, developers are faced to low resolution recordings due to bad conditions or disturbance. In paper **702** the performances of low-light graphic recognition algorithm are assessed.
To reduce the complexity, paper **1046** proposes to create families of assets with similar characteristics and failure mode to predict the probability of failures in the future.
Paper **587** gives a quantification of the reduction of time to action resulting from digitalization and risk-based prediction tools (see Fig. 6 of paper 587).

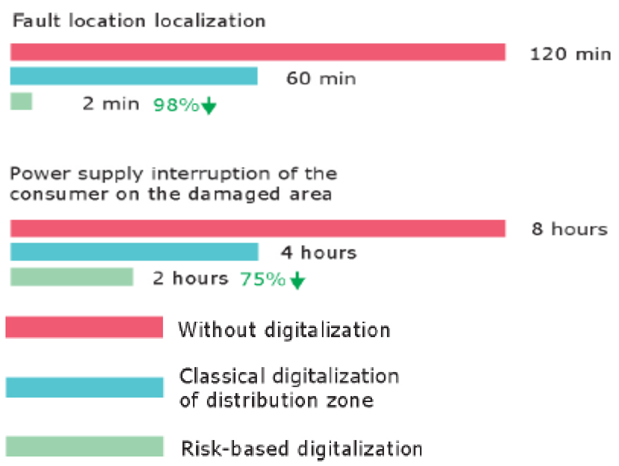


Fig. 6 of paper 587 (extract): Economic efficiency results achieved with the systematic implementation of artificial intelligence methods by the utility

Sub block 3: Health index, diagnostic and failures detection (11 papers)

The principle of Health Index is based on a continuous crossing of data based on failure or degradation measurement with characteristics and condition monitoring of asset. In the paper **788**, the methods have been applied to PILC cable showing through destructive analysis of cable samples continuous sign of degradation. In the case of XLPE cable the signs of ageing are less evident and can only be assessed by nondestructive methods like in the paper **780** with the comparison of PD and dielectric losses over a large population and over the years (see below fig 6 of paper 780).

Fig. 6 of paper 780: The dashboard with basic numerical and graphic information of a health index mapping- example of SOLAR system in Poland

The development of asset management tools based on health index often suffers from missing data, but paper **934** recommends that it should not prevent from deploying such tool that increases the added value of new available information or model all along the grid life.
An original approach is presented in the paper **738**: authors investigate synergies between long term risk assessment (based on incident statistics of MV lines) and short-term approaches related to storms using the same AI risk predictive tool.
In case of external aggression due to anchor (**917**) in the case of submarine cables or exceptional weather (**430**), we are often in the situation of high impact and low probability events. Several strategies can be deployed: either to increase assets resiliency when the root causes are easily identified, like for OHL in paper **430** and **738** or to focus on bringing back as fast as possible the equipment in operation, like in paper **917** on submarine cable with predefined repair scenarios triggered by the identification of failure modes just after the incident.

Joints have been always identified as the weakest point of the cable system. The paper 165 shows a root causes analysis of seasonal joint failure linked to weather or load. In the papers **246**, **415** and **500** the importance of joint preparation related to respectively the insulation system, the aluminum conductor splicing and the screen connection are highlighted.
The deployment of more intermittent energy has also an impact on the ageing of joints: paper **250** shows the effect of repeated sudden increase of power that can lead to failure.

Table 1: Papers of Block 1 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
108: Machine Learning Based Evaluation of Dynamic Events in Medium Voltage Grid Components	X			
110: Testing of Off-Shore Array Cables According IEC 63026 under Critical Weather Conditions				X
165: Extreme weather conditions effects on MV underground cable joints failures				X
246: Impact of “wrong” MV cables accessories assembly on its performances: an experimental study				X
249: AI procedure to detect incorrect installation and configuration of indirect power meters				X
250: Impact of energy intermittence on cables and their accessories reliability	X			
415: A Reliability Enhancement Study of MV Aluminum Cable Connections Regarding Connection Criteria and Processes				X
430: Root Cause Analysis of overhead distribution network failures due to heavy snowfall- a Case Study Gilan, Iran, Feb. 2019				X
439: Comparison of on-site partial discharge measurements using VLF-, DAC- and Slope-voltage forms and dissipation factor measurements on service-aged medium voltage cables	X			
464: Establishment of utility poles’ lifetime assessment by Artificial Intelligence with big data analysis				X
500: Medium voltage cable screen connection behaviour	X			
587: Using artificial intelligence to prevent distribution networks accidents.			X	
592: Power feeding equipment for the condition monitoring of insulators for overhead VHV power lines				X
702: Improving Power Distribution Facilities Detection in Low-Light Images with Deep Learning				X
738: Analyzing overhead MV network fault risk with AI				X
747: Partial Discharge alert system at London Underground				X
780: The SORAL project - management of the MV cable network based on the Health Index of the individual cable line, obtained from diagnostic measurements				X
788: Experience of Underground Cable Failures in a UK Distribution Network				X
837: Foresight - LV Network Visibility and Fault Recognition				X
842: A Study on Diagnosis of Partial Discharge of Underground Cables Using Deep Learning Diagnostic Model	X			
917: 115kV Composite Submarine cable failure investigation and analysis of cable quality				X
934: Digital tool to compute health index for underground medium voltage cables				X
942: Efficient feature extraction for machine-learning-based PD classification in medium voltage cables				X
1046: Data-driven methodology to predict distribution lines fault location				X
1118: Thermal analysis and debottlenecking of HVAC export cables for offshore windfarms	X			

Block 2: "Asset management and condition assessment of Substations Components"

The block 2 "Asset management and condition assessment of Substations Components" , as a continuation of the previous CIRED, follows fundamental trends: The first one is the development of more advanced monitoring solutions for components in service, the definition of precise health indicators to improve predictive maintenance, and finally data management methods, with the introduction of self-learning techniques (AI) in order to extract the relevant information and correlations. The purpose of all this is to achieve a better optimization of Capex and Opex for the DSO.
In parallel, the distribution networks face a second challenge with the integration of distributed and fluctuating energy sources, as well as new types of loads such as EV charging. Many papers deal with the adaptation of the network components to this evolving situation, especially with their "dynamic rating" capabilities. In this block, are also included many on-site maintenance or retrofitting stories, and also laboratory tests which allow to identify the degradation modes of real components, and the associated physical ageing laws.

The 39 papers of this block are divided in 4 sub blocks:

- Upgrade to smart, and sensors integration
- Data for asset management
- Dynamic rating, adaptation to DER
- Use cases of diagnostic, maintenance, and retrofit.

Sub block 1: Upgrade to smart, and sensors integration (10 papers).

Four papers of this sub block deal with transformers condition monitoring. Real-time indicators are often directly derived from current/voltage measurements (papers 338, 526), but alternative solutions exist (458, 843).

Paper **338** proposes a method to detect faults in a distribution transformer by studying the circulating current in delta winding. Even with only a one-turn winding short circuited, the shape and magnitude of the circulating current present a clear change. This default is not detectable by the load currents measurement.

In **paper 526,** two real-time degradation indicators are continuously calculated thanks to three phase and neutral current measurements on earthing transformers.

Fig. 2 of paper 526: Easy-to-install split-core current transformers on a grounding transformer.

In a first part, paper **458** proposes a real-time algorithm to monitor accurately the network fundamental frequency, its harmonics content, and finally the power quality indexes, which is of primary importance in the context of DER. In a second part, these variables are used as inputs, for a parametric thermal model for distribution transformer. Premature ageing of the transformer is detected by any deviation between the measured and calculated oil temperatures. The model parameters need to be updated regularly via periodical measurement campaigns, for example during maintenance operations.

Paper **843** describes non-electrical health indicators for power transformers. The focus is set on factors affecting their lifespan, on which operator and maintainers can react efficiently (as air-coolers clogging, breather efficiency, oil moisture, and on-load tap changer performance). The long-term objective is to estimate a unique health index for all the transformers in the fleet, that could be used to trigger maintenance operations.

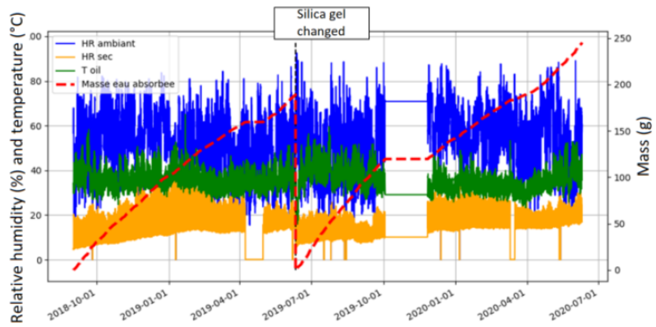


Fig. 5 of paper 843: Detection of the silica gel replacement need using the water-absorbed estimation (red dashed).

Three papers of the sub block concern partial discharge (PD) which is a localized non-disruptive discharge, indicating the insulation health status of the electrical assets.

The goal of paper **505** is to compare different typologies of PD sensors (TEV, HFCT, ultrasonic, capacitive) applied for the online monitoring of an MV GIS. Their optimal configuration and position are determined in the switchgear and its associated cables. PD signals from different artificial defects sources are used for this experimental study.

This methodology is also applied in paper **652**, that presents a convenient handheld measurement device to be connected to the voltage presence indicator during service operation. It gives to the operator important information about eventual partial discharge activity in the switchgear.

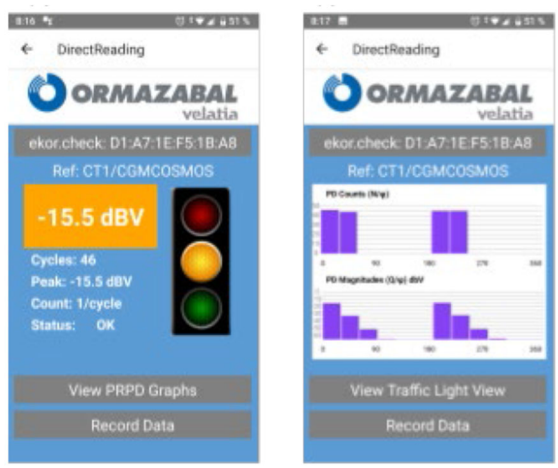


Fig. 13 (extract) of paper 652: Mobile application development running on operators' mobile phone, giving quick indication of PD level, and very simple PRPD pattern.

Paper **833** introduces a distributed PD monitoring architecture, based on the capacitive detection method and wireless communication. To ease the system commissioning, generic PD signal propagation models are created and experimentally validated for each constitutive component. The models are used as the building blocks allowing a broader understanding of PD propagation in an entire switchboard.

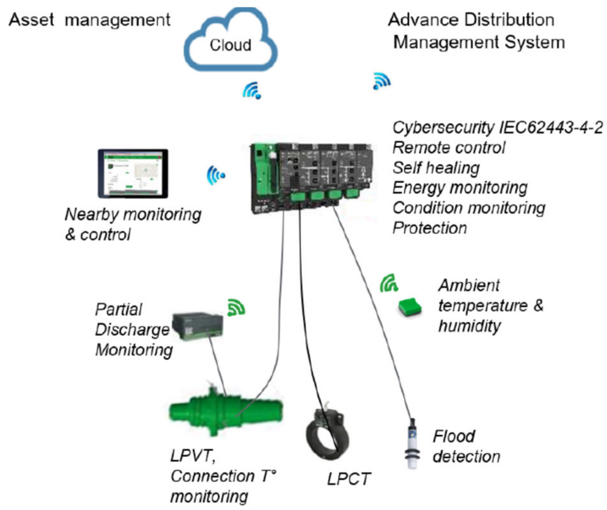


Fig. 3 of paper 833: Example of a digital monitoring architecture including PD

Switchgear thermal monitoring, using low cost camera is discussed in paper **675,** with the challenge to find an automatic real-time algorithm to analyze the thermograms. After a comprehensive review of the existing algorithms, the authors show that a relatively simple PixelCount method is efficient enough to extract the relevant information from the low-resolution images, and to distinguish faulty and healthy cases with a simple threshold.

The two last papers introduce the global "smartization" of existing substations. Paper **567** promotes the use of an integrated "all-in-one" system including control, monitoring and communication to simplify the installation complexity and limit the associated risks: less wiring, factory assembly and testing, simpler and transposable calibration of the sensors.

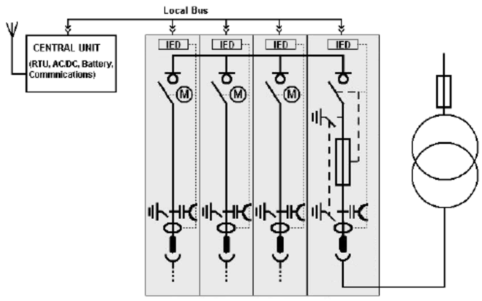


Fig. 4 of paper 567: Simplicity of a standardized cabling

Paper 588 is a comprehensive review of a substation monitoring architecture. It starts from the list of parameters to monitor, their respective assessment criteria. Then possible IoT sensors, data communication and treatment levels (edge or cloud) are proposed. It is expected that the predictive models will be obtained with an iterative process: over time, the devices will generate more and more data which can be used to improve the initial models and make failure predictions.

Context		Monitoring	Trends	Threshold
MV Switchgear	Main busbar	Hot-spots	✓	
	Switchgear insulation	Partial Discharges	✓	
Transformer	Oil	Partial discharges and temperature (non-invasive)	✓	
	Bushings	Partial discharges	✓	
	Humming	Audible noise		✓
LV Switchgear	Fuses	Current flow in downstream circuits		✓
Global	Operation	Power quality	✓	
	Grounding	Earth faults		✓
	Ventilation level	Outdoors and indoors temperature and moisture	✓	
	Fire risk	Air temperature gradients	✓	
	Flood risk	Water detection and water pump working status		✓
	Intrusion detection	Door and vents opening status		✓

Table 1 of paper 588: Type of analysis of each assessment criteria

Sub block 2: Data for asset management (12 papers)

This sub block covers all the challenges related to data for asset management, at different stages and with various complexity levels:

- Data collection
- Statistics and correlations
- Determination of variables of interest (for example: health index, probability of failure, Matrix of Risk, …)
- Self-learning algorithms, AI
- Data security,
- Data models and digital twins for a full digital representation of the network components.

Two papers relate experiences of data mining as a source for representing pre-fault indications. In paper **42**, operating times of a disconnector fleet are extracted from a SCADA system. In paper **362**, events from medium voltage protection relays have been collected during 28 months whereas faults in the network have been registered in parallel. The two papers show the complexity to analyze the data and to find proper fault prediction models. Results are often biased by external factors (as communication transfer time for the first one) and statistical and visualization methods are not efficient with a limited dataset.

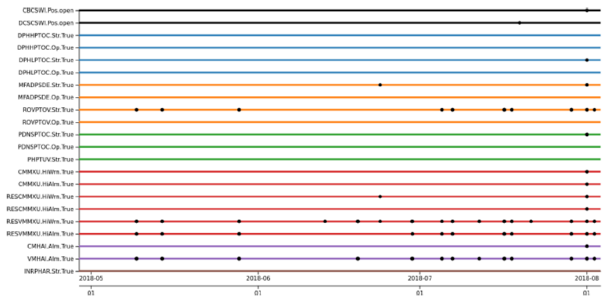


Fig. 8 of paper 362: Recorded fault pre-indication pattern from the protection relay

Paper **38** presents an evaluation methodology developed to rank the replacement of instrument transformers. “Condition Indicators” (i.e. Health Index) are determined and combined with a “priority indicator” reflecting the operating priority of the transformer station. Thus, a global Matrix of Risk is built.

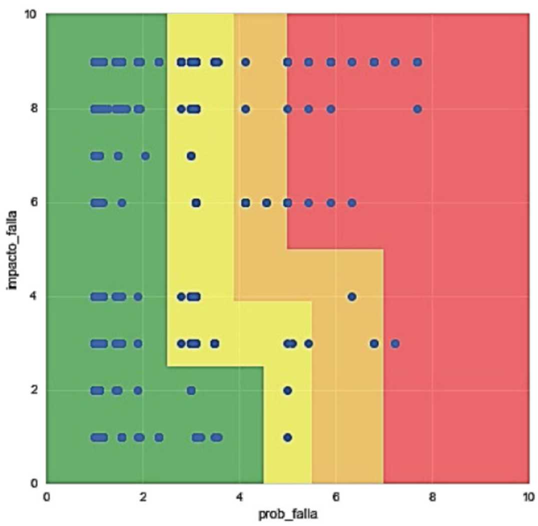


Fig. 4 of paper 38: Matrix of Risk of the Instrument Transformer fleet

The same approach is followed at a larger scale in the project "Analytics 4 Assets - A4A" described in paper **382**.
The methodology is derived from the CNAIM (Common Network Asset Indices Methodology) established by UK DNOs , which defines "Health Index (HI)" iteratively calculated with usage and environmental factors. In the A4A project, a special attention has been paid to the determination of 15-days ahead "Probability of Failure (PoF)", with additional data. Possible models are benchmarked in the paper **957**, for distribution transformers. The A4A dashboards are now used for the DSO investment and maintenance planning.

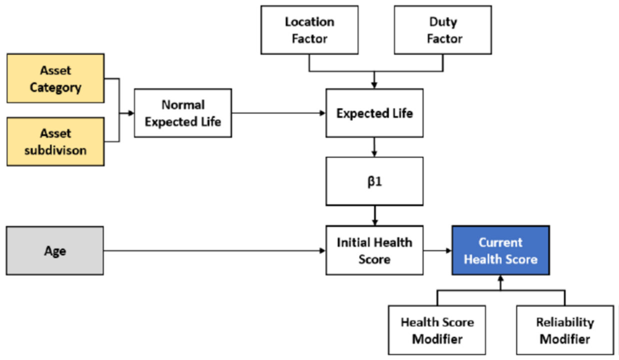


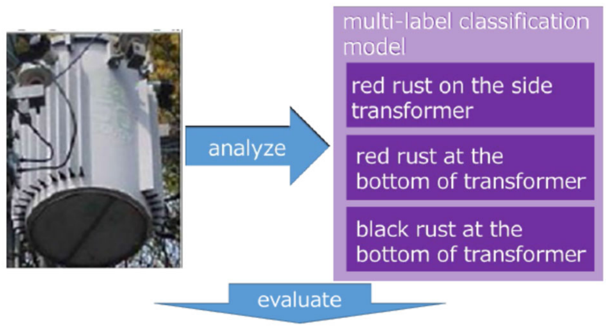
Fig. 3 of paper 382: CNAIM Methodology Main Blocks

Four papers (344, 442, 904, and 1149) relate the use of Artificial Intelligence (AI) to treat the data and establish predictive models.

In paper **344**, past dataset that could explain slow opening times of circuit breakers are extracted and analyzed thanks to the SAS software platform (as for example: last opening time of the circuit breaker; elapsed since the last corrective maintenance, command type, year of entry into operation…). A predictive model is established using the SAS Miner module. A significant part of the paper explains the methodology used for the algorithm training.

Paper **442** is focused on AI for image diagnosis to assess the rust status of steel tank of pole transformers. The recognition accuracy reaches the value of 77.3%.

DataPoste, a mobile application performing image recognition with deep learning is presented in paper **904.** It allows to automatically identify the equipment brand name and model reference from a captured picture. The Explainable Artificial Intelligence (XAI) method is used to provide more transparency and avoid "black box effect", thus providing higher rate of trust and acceptance from the end-users.



	A1	A2	A3	A4	B1	B2	C1	D1
red rust on the side	1	0	1	0	1	0	1	0
red rust at the bottom	1	1	0	0	1	1	0	0
black rust at the bottom	1	1	1	1	0	0	0	0
evaluate	replace				follow-up			No support

Fig. 3 of paper 442: Rust rank by multi-label classification model

In paper **1149**, an advanced vibration monitoring method can detect early symptoms of degradation of the operating mechanism of a circuit breaker. Machine learning models allow to identify abnormal conditions vs. the healthy breaker state.

The last three articles of this sub block assess the use of digital twins data models, to contribute to the management of all the assets for the DSO.

Paper **547** is a topical review on the challenge to deploy digital twins of HV equipment. The main types of twins and their usage are explained, and the requirements applying to the data and the data processes are derived.

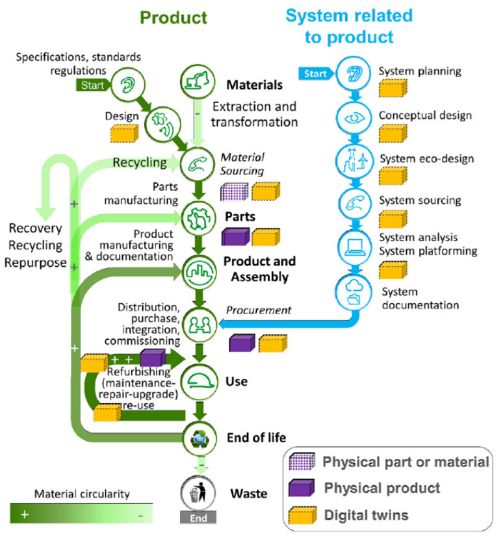


Fig. 3 of paper 547: Digital twins across the lifecycle of a given asset

Paper **266** discusses the needed standardized data models, based on the findings of two working groups: the French "GIMELEC ontology WG" and the IEC TC17 AHG7.

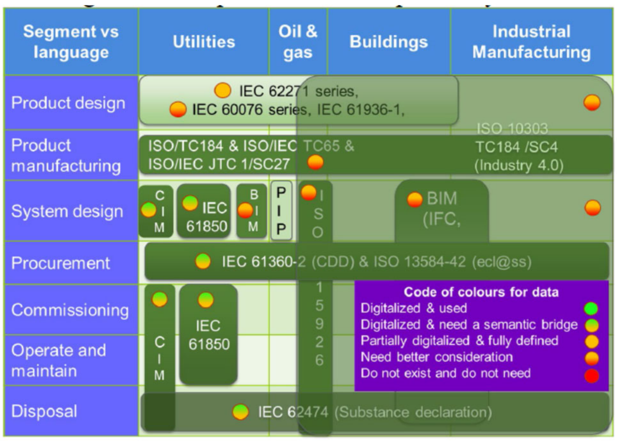


Fig. 1 of paper 266: Main current data models for HV equipment

Paper **538** follows the methodology issued from the IEC TC57, to review all the applications needed in order to have a proper inventory of traditional and digital assets

Sub block 3: Dynamic rating, adaptation to DER (8 papers)

The rise of renewable and decentralized power generation, as well as new electricity usages (for example electric vehicles) induces wider cyclic load in the distribution network. With dynamic rating, a high current can be allowed for a short period without exceeding the maximum design temperatures of the transformer/switchgear.

Paper **57** relates the development of a new HV fuse providing a significant improvement regarding the withstand to the cyclic current. A comprehensive study explains that the melting-elements progressively develop a grain-growth and become more sensitive against mechanical forces caused by thermal - expansion and contraction, in case of current cycles.

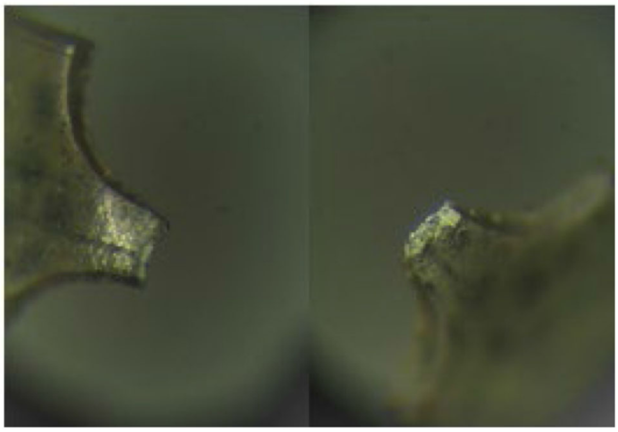


Fig. 4 of paper 57: Mechanically opened fuse notch after current cycles

Papers **260** and **261** report several case studies of optimal selection of transformer to be used with cyclic load application. Technical solutions are also proposed to improve the thermal withstand of the transformer insulation system.

Adaptative numerical thermal models are often used to estimate the overload possibilities of an existing component. The formulation is often issued from the relevant product standard. Papers **425, 427, 603 and 1058** report such studies applied to switchgear and transformers. However, paper **302** includes a more advanced physical model based on the heat balance equation. In all cases, the models are not fully predictive, and their parameters need to be adjusted, thanks to preliminary test campaigns on the equipment.

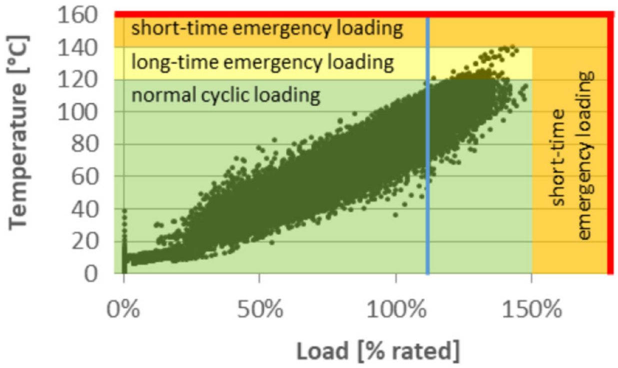


Fig.4 from paper 427: Typical example of a transformer load/temperature scatterplot at 140°C (limit for long-time emergency loading).

Sub block 4: Use cases of diagnostic, tests, maintenance, and retrofit (9 papers):

Four papers relate diagnostic, and maintenance operations on power transformers. Hot-oil spray and circulating methods are used to remove water contamination in paper **315**. The behavior of refurbished transformers with natural ester replacing oil is analyzed in paper **1116,** and electric properties of aged ester are characterized in paper **664.**

Paper **146** presents a test facility to reproduce transformer ageing. The originality of this device is a "thermal image box" allowing to insert insulating papers samples in the transformer circulating oil, in realistic operating conditions. Oil and paper samples are submitted to a permanent stress with a load rate between 130 % and 150 % of the transformer maximum nominal capability. In the end, the experimental results are compared to the aging model proposed by the IEC 60076-7.

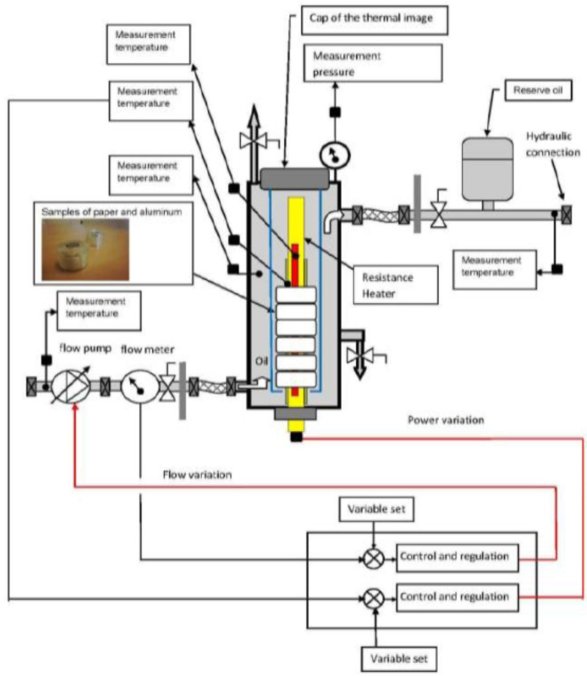


Fig.2 of paper 146: Transformer "thermal image box" to age paper samples

Retrofitting consists in replacing switchgear components to upgrade, renew, or provide more functionalities. Paper **928** reports a massive modernization of a primary switchgear installation, with the "retrofill" of circuit breakers (all-in-one solution combining a new CB, a new frame and new interfaces), as well as a remote racking solution to improve the safety of operators.

Paper **849** studies the replacement of SF6 by an eco-friendly gas in an existing outdoor circuit breaker (using vacuum interrupters as arc quenching chamber). Crucial modifications are required to adapt the design, showing the complexity of such operation.

Internal arc withstand can be improved in substation buildings made of concrete or bricks. Paper **117** report overpressure calculations, and structural simulation results of such buildings during an internal arc event. A simple and affordable pressure relief hatch is proposed to solve the overpressure problems.

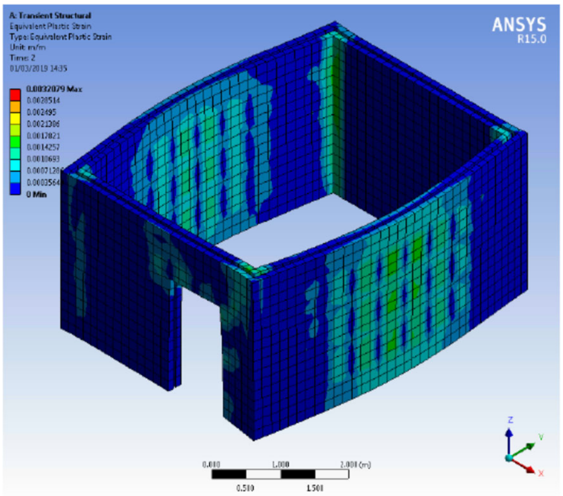


Fig. 2 of paper 117: Plastic deformation of brick substation during an internal arc event

In paper **235,** a wrong positioning of cable in a hydropower plant leads to a thermal failure due to the proximity effect. Thanks to thermal and magnetic field simulation, a better phase arrangement is identified.

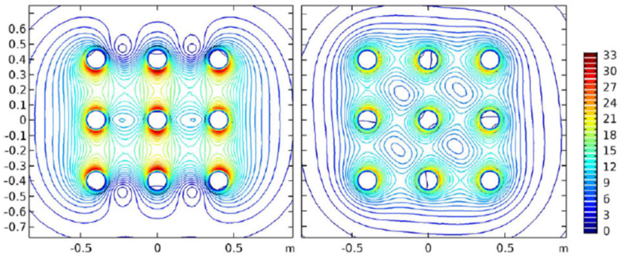


Fig. 12 of paper 235: magnetic field distribution in two cables arrangement: the case b) is more favorable to limit heating.

In paper **323,** an ageing test protocol and simple indicators are proposed to predict the behavior of lead-acid batteries. The degradation modes are discussed.

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	**MS a.m.**	**MS p.m.**	**RIF**	**PS**
38: Integrating different predictive determinations for the Condition Assessment of a HV instrument transformer fleet				X
42: Study of Manoeuvre Time of Distributed MV Disconnectors				X
57: HV Fuses with Improved Cyclic Stability ICS				X
117: Upgrading internal arc resistance of existing substations				X
146: Accelerated ageing test of MV/LV distribution transformers: Results and discussion	X			
235: Proximity Effect in High Current Conductors – A Case Study			X	
260: Overloadable distribution transformers for flexible loading in future distribution networks				X
261: Optimization of transformers for solar or battery storage installations based on a cyclic loading pattern				X
266: A standardized knowledge model for high-voltage equipment catalogue data contributes to simplify the life of end users and manufacturers				X
315: The Experience of Heavy Water Contaminated Power Transformer Field Repairing using Combination Method of Hot Oil Circulating and Hot Oil Spraying				X
320: Data-driven Transient Temperature Rise Prediction Model for Medium-voltage Switchgear				X
323: Predicting valve regulated lead-acid battery sensitivity to ageing processes				X
338: Fault diagnosis of transformer focusing on circulating current	X			X
344: Predictive Maintenance of HV and MV Circuit Breakers				X

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
362: Exploring evolving faults with interactive multi-time-scale visualization of protection relay events from a substation				X
382: Analytics 4 Assets – The Advanced Asset Management Project	X			
425: Practical verification of medium voltage switchgear thermal loadability based on the IEC62271 thermal model				X
427: Practical verification of power transformer thermal loadability based on the IEC60076-7 thermal model for top oil and hot spot temperature	X			
442: Image diagnosis using artificial intelligence for pole transformers				X
458: Harmonic analysis and distribution transformer monitoring				X
505: Online MV PD monitoring system: improvements on the automatic assessment of the insulation systems				X
526: Real-time Condition Monitoring of Grounding Transformers				X
538: From traditional to digital asset management of network components				X
547: How to overcome difficulties met in deploying digital twins of electrical assets over their whole life cycle? A data management perspective promoting the state of the art of knowledge management	X			
567: Advantages of Integral Remote Access Management in Smart Secondary Substations in terms of costs, reliability and personnel (e.g. COVID-19)				X
588: A comprehensive approach to the predictive maintenance of Secondary Distribution Substations: devices and methods				X
603: Temperature rise simulation model of RMU with switch-fuse combinations for future load profiles				X
652: Switchgear Sensorization for Flexible and Efficient Asset Management				X
664: Analysis of Dissipation Factor Tan δ of Natural Ester with Temperature Normalization				X
675: Automatic analysis of thermograms - challenge in thermal monitoring of switchgears using infrared cameras	X			
833: Innovative distributed architecture for continuous PD monitoring in MV substations				X
843: Online monitoring of power transformers to improve their operating and maintenance model				X
849: Retrofit of Outdoor Medium Voltage Circuit Breaker with Eco-Friendly Gas to replace SF6				X
904: DataPoste: an application based on Understandable Deep Learning to characterize transformer stations				X
928: Installed base Safety upgrade at power generation station				X
957: Analytics 4 Assets – The Advanced Asset Management Project applied to Power Transformers				X
1058: Thermal response time of the LV fuse gear in secondary substations and cable distribution cabinets				X
1116: Refurbishment of distribution transformers with benefits in the exchange of mineral oil by natural ester insulating liquid				X
1149: Vibration Monitoring for Medium-Voltage Circuit Breaker Drives Using Artificial Intelligence				X

Block 3: "Innovation in Network Components – Cables, lines and new types of components"

The 27 papers of this block are divided in 3 sub blocks:

- Materials & Models
- Metering & monitoring systems
- Systems for safety & security
- Components for protection & stabilization

Sub block 1: Materials & Models (7 papers)
The preservation of dielectric performance along the years for cable system is the fundamental hypothesis for energy distribution and transmission on existing and future networks. Innovation in this domain should propose new candidate materials with improved properties (paper **356**) but also give solutions to extend lifetime or lower environmental impacts of existing assets, like oil filled cable (paper **113**).

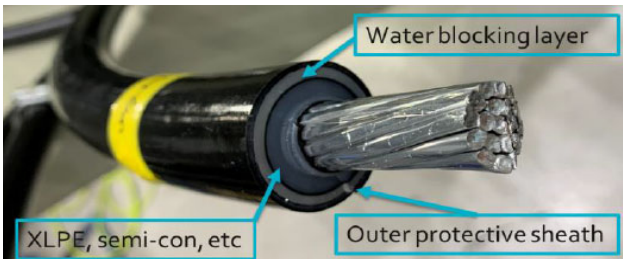


Fig. 5 of paper 356: Prototype cable using water-blocking sub-sheath layer

When exposed to abrasion or corrosion, overhead cables can show premature damage if an adequate protection has not been developed. And these developments require to reproduce complex phenomena. Stating some gaps in existing standards, the paper **597** presents a new abrasion bench to properly test cable and align all the actors to improve the products quality. In the paper **860** a simplified model allows to set up accelerate ageing test and to develop new hardware.
When the rating model of cable is associated to geophysical soil mapping and real time load, one can reach a very useful real time rating tool (**209**). To have a first reliable cable rating with concrete duct banks, a simplified model with an equivalent resistivity of soil has been developed (**553**).

Sub block 2: Metering & monitoring system (6 papers)

The MV smart meters can generate different types of data depending on the request coming from the central control system and vendors' product specificities. The paper **550** presents the development of a protocol adapted to the diversity of equipment to check the proper data collection from the smart meters and the execution of request to the smart meters.

New generations of passive voltage and current transformers integrated in the accessories (fig. below) are presented in paper **1034** and **744**, compliant with standards for metering and protection functions and allowing integrated architectures, easy to install and easy to connect to any existing IEDs.

Fig. 1 of paper 1034 (left) and fig. 1 of paper 744 (right): Example of Low Power Voltage **Transformer 24kV (green), Voltage Transformer** 24kV DIN size (brown) and new type C Bushing (red)

The papers **485** and **753** propose new configurations of metering system on MV grids with recommendation on the measurement chain (signal cable, IEDs). Improvement of existing standards to use passive low power instrument transformers are discussed.
The challenge of thermal monitoring of grids is the access to the cable or accessories core temperature without endangering the dielectric properties. The paper **1007** gives a solution coming as close as possible to the conductor by embedding the temperature sensors inside a type C bushing.

Sub block 3: Systems for safety & security (7 papers)
The underground networks are presenting many dangers and unauthorized access is a source of outages and accidents. An automated hatch is presented in the paper **517** to secure and monitor access to manholes.

Household PV panels connected to the grid can create a situation where the grounding of the cable at the transformer side is not enough to insure safe works conditions. A short circuit ring has been developed (paper **1056**) to be installed on the consumers side of the LV cable in the trench prior to cut the cable and prevents power inrush coming from the PV panels (fig 7).

Fig. 8 of paper 1056: Screwing contact of short circuit ring through core insulation to secure operation on LV grid with PV installations

The densification of urban area and the presence of electrical networks make it difficult to reinforce grounding when needed, both for existing and new installations. The paper **671** proposes a set of methods to monitor visually and electrically the soil condition during drilling and to find reliable spots to install grounding rods.

The paper **1097** presents a new type of cable path marker based on magneto-mechanical resonance with a typical lifetime of 50 years. Safety measures on grids must be extended to animals and the paper **1124** is presenting a feedback over the past 17 years of the solutions experimented on overhead lines to prevent accidents with birds.

Sub block 4: Components for protection & stabilization (7 papers)

A grid extension may lead to an increase of fault current beyond the limit of installed equipment. The paper **537** proposes a technology of permanent magnet bias fault current limiter that allows to reduce drastically the insertion impedance and the losses compared to equivalent 20 MVA@11 kV class current limiting reactors.

MVDC links are used to support locally MVAC grid, and such links require also to be protected against overcurrent. Paper **124** presents an adaptative hysteresis control to prevent upper current from being exceeded. Going deeper in the combination of AC and DC networks, the paper **1141** describes the architecture of a multiport active bridge converter where local renewable generation can be converted and distributed to AC and/or DC grids depending on the demand, creating a flexible bi-directional power sharing node between AC, DC and generation sources.

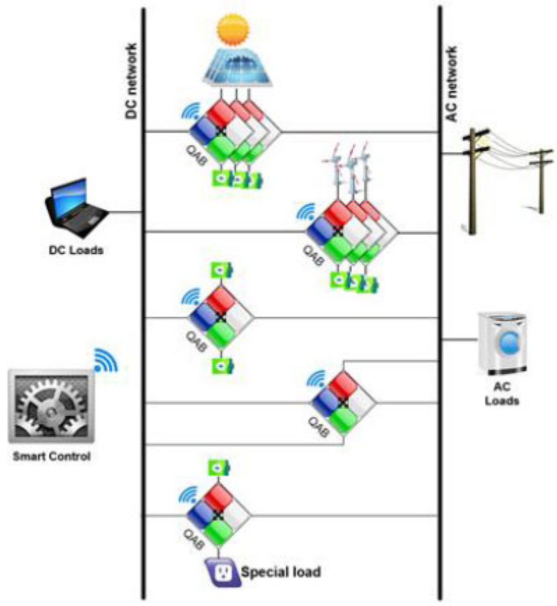


Fig. 4 of paper 1141: cluster of MAB converters in a smart grid with renewable generation, storage devices, AC loads and DC loads

Power Electronic devices (PED) based on SiC are used in the paper **943** to realize a soft meshing of two LV or MV grids allowing power flow with a galvanized separation and higher penetration of low carbon technologies. The paper **100** presents an optimized remote-controlled switch to reconfigure dynamically LV grids according to the active loads and power sources distribution in the grids, like EVs' charging stations and intermittent renewable generation. To democratize a digital version of protection relays, paper **955** describes a low-cost overcurrent relay based on three off-the-shelf components. Tests show compliance with existing standards.

In the case of battery storage integration to support local implantation of EVs, the paper **155** proposes an algorithm based on AI to choose the optimum sizing of the battery storage system.

Table 3: Papers of Block 3 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
100: Tapered link box switch for meshing low voltage distribution networks				X
113: Self-healing Dielectric Fluids for Fluid Filled Cables				X
124: MVDC solid state breaker/limiter control with adaptive hysteresis limits				X
155: Artificial Intelligence-based Optimization for Battery Energy Storage for E-Mobility Unpredictable Loads				X
209: An approach towards real-time cable ratings for underground medium voltage cables.		X		
356: Self-repair, water blocking materials for sub-sea power cables				X
485: Revenue Metering based on Low-power Passive Instrument Transformers complying with IEC 61869-10 and IEC 61869-11 Standards including Legislative View on Legal Metrology		X		
517: Automated Hatch for the Underground Distribution Grid with Access Control				X
537: Practical verification of a low-loss 11kV distribution grid Fault Current Limiter – the pmFCL				X
550: Testing solution for field data concentrators – Multi channel integration				X
553: Sensitivity analysis of cable trench modelling with concrete pipe block and several material layers for the ampacity 150kV cables				X
597: Ingenious abrasive-strength tests ensure EDP Distribuição Low Voltage overhead line insulated cables resilience				X
671: Guided hole excavating device for ground rod construction of power cable and the method for electric ground safety				X
744: Cable connection bushing type C according to EN 50181 with Rogowski coil current sensor and capacitive voltage sensor according to IEC 61869-10 and IEC 61869-11		X		
753: IEC 61869 -10 and IEC 61869 -11 passive sensors and their interface with IEDs				X
860: Hardware of Aerial Distribution Networks, for Use on the Seashore, Corrosion Resistant, Corona Discharges and Leakage Current				X
943: Development of Power Electronic Devices to provide dynamic power sharing on 400V and 11kV distribution networks		X		
955: Low-cost overcurrent protection relay based on a standard microcontroller				X
1007: Cable connection accurate monitoring by thermal sensor embedded in switchgear bushing		X		
1033: Distribution Network Modernization in TNB with the Application of Line Lightning Protection Device onto the 33kV Overhead Lines with High Soil Resistivity in Tenaga Nasional Berhad – Reimagined TNB Towards Grid of the Future		X		
1034: INTEGRATED LPVT's IN EACH FUNCTIONAL UNIT FOR SIMPLER PROTECTION AND CONTROL				X
1048: Physical and chemical research of the insulation of medium voltage cable lines.				X
1056: Short circuit Ring for enhanced safety and lower risk in underground LV networks with Bi-directional power supplies.				X
1094: Self-grounded pole for power distribution grids				X
1097: New advancements in electronic marking technology for underground asset				X
1124: Best practices and new opportunities for biodiversity protection facing power lines impacts				X
1141: Multi-port active-bridge converters: energy exchange blocks for smart grids			X	

Block 4: "Innovation in Substations Components"

The block 4 "Innovation in Substations Components" of the CIRED 2021 highlights two major themes: First, the development of greener network components, especially with the SF6 free topic, but without forgetting other technologies as bio-based insulation for transformers, energy efficiency, etc. The second major theme is the increase of embedded intelligence in the substation, or "smartisation": more sensors, more autonomy, more communication, and more remote control. This CIRED conference allows to compare the visions of end-users, as DSO, and manufacturers in several papers. Finally, innovations in traditional network components such as circuit breakers and transformers are also present: for example, circuit breakers with an enhanced capacitive switching performance, transformers with a better resistance to voltage transients, just to name a few. And of course, the development of simulation tools and test methods to improve the design process and the optimization level of the network components.

The 45 papers of this block are divided in 4 sub blocks:

- Greener components
- Smart substations
- Innovative network components
- Methods and tools for component design

Sub block 1: Greener components (16 papers)

The search for solutions to replace SF6 in MV GIS has been a major environmental topic of CIRED session 1 for numerous years (the last event being a round table organized in 2019 in Madrid). First SF6-free switchgear have been, or are about to be launched on the market by several manufacturers. The debate is still open between different technological options for medium voltage, and the 2021 session is a good opportunity to combine the requirements of end users (for example paper **873**) and the different proposals of manufacturers.

Paper **435** reminds the high complexity to assess the different alternatives with a holistic approach, as some criteria can lead to contradictory effects. The authors also underline the lack of regulatory framework, and accepted standards.

Two main families of technological solutions emerge, with the objective to keep the dimension of the current equipment:

- Solutions based on the use of air (or of its natural constituents with different mixing ratio) as insulating medium. This yields to an increase of the operating pressure, to retrieve the same electric strength than SF6. This can be technically mastered in MV GIS by the right tank design and testing approach (paper **847**), and counter-balanced using solid insulating materials to reinforce the insulation system (paper **88**).

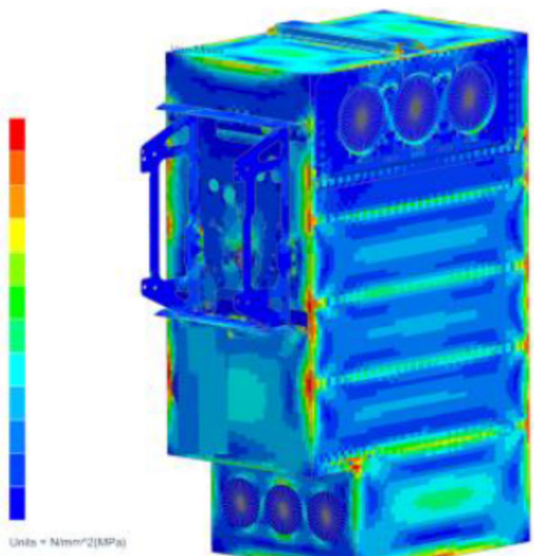


Fig.4 of paper 847: FEM simulation of the mechanical tension in an air pressurized welded vessel

- Solutions based on mixtures of gases including one fluorinated compound associated to a carrier gas, as nitrogen or CO2. This makes it possible to retrieve insulation properties comparable to those of SF6, and therefore to keep all the advantages of a similar filling pressure (as for example a lower risk of leakage). A comparative discussion concerning the filling pressure is proposed in paper **208**. The toxicological assessment of the new F-gas mixtures and their decomposition by-products is required to evaluate the risks in case of accidental exposure. Paper **268** estimates the potential risks similar to those exhibited with an SF6-filled equipment.

Innovative load-break switches, or current interruption technologies, are developed to be compatible with the new gaseous insulation technologies. Paper **614** presents a pilot project with a puffer-based load-break switch based on arc interruption in gas. Paper **683** details the fundamentals physical processes on the arc interruption processes in new F-gases mixtures.

Another approach is highlighted in papers **527** and **706**. They both report the development and field test of load-break switch concepts with vacuum interrupter (VI) in auxiliary-path, avoiding arcing phenomena in the gas.

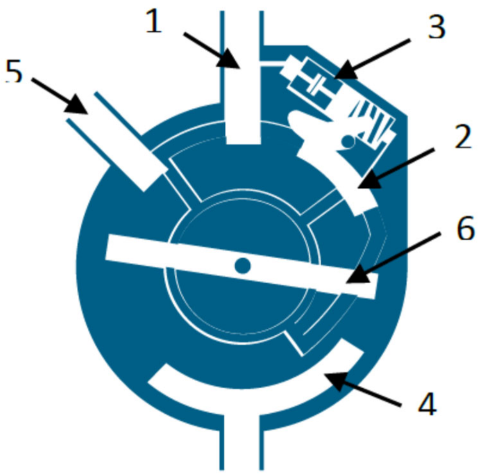


Fig. 1 of paper 527: Schematic diagram of a three-position load-break switch, with vacuum interrupter (3) in auxiliary-path.

Regarding transformers, a clear environmental benefit is also offered by the use of eco-friendly natural ester as an insulation fluid. Characterization of the electrical and thermal properties of new insulations fluids are presented in papers **183** and **262**.

Two life cycle assessment (LCA) studies are presented. In paper **381** green GIS and transformers for offshore wind turbine application are assessed. Paper **674** presents the evaluation applied to a GIS and compares different estimation methods. To get a global picture of the "environmentally conscious design of MV switchgear", a complete overview on the standardization framework is discussed in paper **265**.

The last ""green component" of this sub block is called GEM (for "Mobile Energy Generator") and is presented in paper **890**. It intends to replace classic diesel generators during outages and maintenance on MV grids, avoiding polluted gas exhaust as well as noise. A specific attention has been paid to the electrical protections, during usages both in islanded and grid-connected modes of the device.

Fig.6 of paper 890: "GEM" generator on a truck

Sub block 2: Smart substations (8 papers)

Smart substations need to meet the challenge of maintaining power quality and reliability, while supporting the integration of DER and new energy uses.

Starting with articles giving a broad vision, paper **622** discusses a prioritized list of requirements and associated technical challenges from a DSO perspective. All the items are ranked using evaluation criteria, grades, and weights. This work can be seen as the preparation of a R&D roadmap.

Paper **617** introduces an integrated approach, with the project "NEXTSTEP", considering concept of the smart substation as a whole. Advanced monitoring and control systems, but also eco design of the power equipment and of its housing are shown.

Fig. of paper 617: Smart Substation Eco-housing with usage of cork.

Paper **78** is a conceptual study dealing with the possible autonomy levels of a substation: enabling some activities (as control, monitoring, repair, and maintenance) to be performed without the presence of personnel in the substation. 6 autonomy levels are discussed.

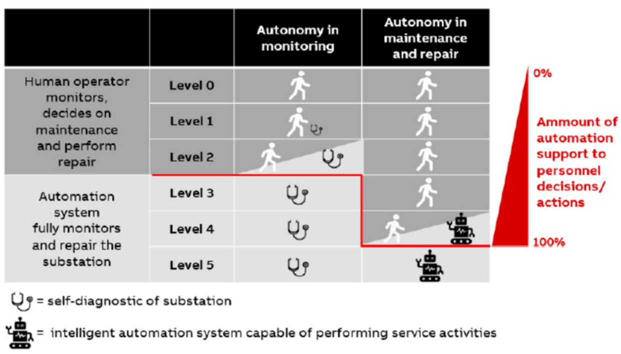


Fig.3 of paper 78: Substation autonomy levels vs. remaining needs of personnel intervention.

Paper **325** defines the functions of the Remote Terminal Unit (RTU), for control and monitoring of the substation, through a new dedicated French technical specification ST 64-S-63.

Paper **706**, already mentioned in the "green component" sub block, presents the digital architecture of an RMU, including cyber-security.

Papers **467** and **810** both focus on the control of the LV network side with OLTC (On-Line Tap Changer) transformer coupled to advanced LV network monitoring and real time algorithms. This is seen as a cost-effective solution to improve the capacity of the LV network, and to answer the simultaneous growth of DER (as micro photovoltaic sources) and the development of EV charging infrastructure.

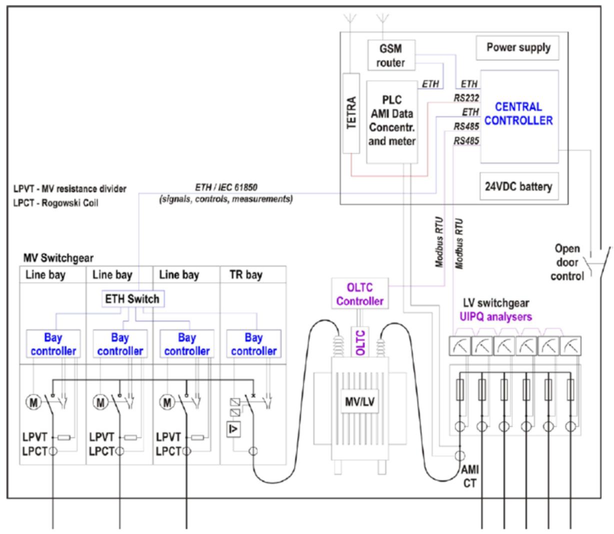


Fig.2 of paper 810: "Flexible substation" structure, with monitoring and control on the LV side with OLTC.

Paper **471** proposes an architecture for an automated LV feeder including fast auto-reclosing and fine tunable coordination and selectivity features. It combines a vacuum circuit breaker, a fuse link for the highest short circuit levels, a disconnector and an earthing switch. An advanced IED allows to perform supervision, control, and protection tasks.

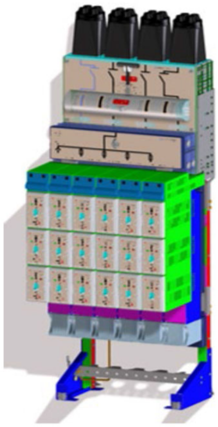


Fig. 3 of paper 471: Complete automated Low Voltage Board

To conclude this sub block, the last paper **509** presents a configurable MV test infrastructure representing a real network and integrating most of the communications technologies. It is used to validate the new “smart” technologies before their introduction on a real grid.

Sub block 3: Innovative network components (12 papers)

The third sub block consists of papers presenting innovative designs or functions for substations components.

Seven papers deal with vacuum breaking technology, six concern power transformers, of which two solid state transformer (SST) technology. The last paper presents an innovative self-powered ultra-fast earthing switch to mitigate the harmful consequences of an internal arc event.

Paper **189** presents the technical requirements, seen from a DSO, concerning primary 24kV switchgear equipped with vacuum circuit breakers. Different aspects are discussed: reduced dimension, internal arc withstand, …, one of them is the mitigation of all the overvoltage risks inherent to the use of the vacuum technology.

As an answer, paper **755** investigates the influence of axial magnetic fields on different contact material compositions for vacuum interrupters, to reduce the chopping current level. These abrupt current variations generate high overvoltage in case of inductive load switching, and possibly irreversible insulation damages.

A series of articles from the same switchgear manufacturer present a novel vacuum circuit breaker, for repetitive capacitive breaking operations. Several innovations are considered. An improved vacuum interrupter design and contact material allow to reduce prestrike during closing (paper **679**). Digitally controlled servomotor drives synchronize each individual pole operations with the network voltage waveform (paper **763**), to reduce inrush current.

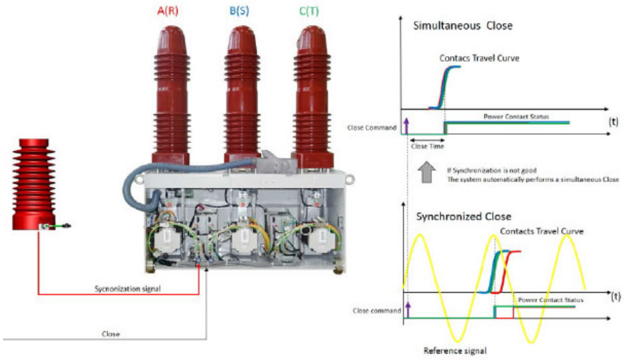


Fig. 3 of paper 763: Close Function, Synchronized and simultaneous modes.

A control unit (ACU), which is included in a scalable smart architecture (paper **767**), guarantees the switching stability in all operating and environmental conditions thanks to sensors and self-adaptative features.

This circuit breaker demonstrates an increased lifespan (up to 5 times vs. standard breakers) for repetitive capacitive load switching operations, which are more and more frequent to ensure power quality on the electrical networks. An adapted version of the circuit breaker technology is used in paper **784** in an experimental DC set-up, where the poles of vacuum breaker are put in series.

Paper **646** presents the design of a modular 72,5 kV recloser, to be used in transmission networks. It combines vacuum technology, solid insulation with epoxy overmolding and magnetic actuation of the poles.

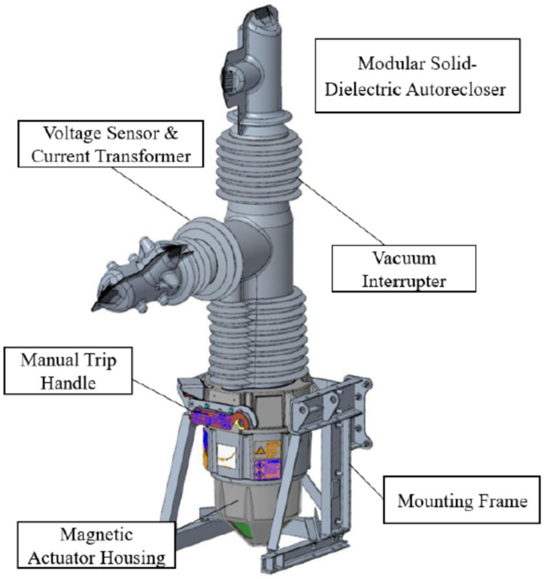


Fig. 1 of paper 646: 72.5kV solid dielectric vacuum recloser

Paper **746** proposes a new method to detect, trigger and power an internal arc short-circuiting protection device by means of several solar cells placed inside the switchgear. There is no need of any auxiliary power. The system can activate the mitigation device within less than 3ms (for a 2.1kA arc fault current) and remains insensible to other light sources (as flash, sunlight, lamps).

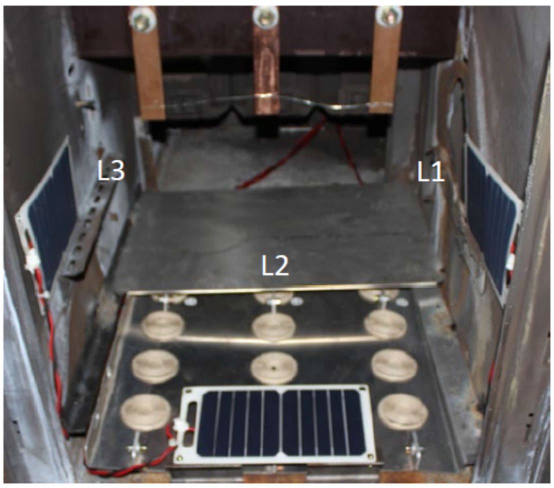


Fig 2 of paper 746: Solar cells installed in the cable compartment of a switchgear.

First in the group of papers dealing with innovative transformers, **paper 980** presents the design of a novel dry type transformer, resilient to transient voltage stresses generated by VCB operation. The concept is based on the shifting of natural transformer series resonance frequencies above the range of the expected reignition frequencies of VCBs (10 kHz – 90 kHz), to reduce the probability of interaction.
Novel designs are verified by a series of tests replicating switching surges and transients typical for VCB operation.

Parameter	change	effect on f_{res}
Number of turns	decrease	increase
Winding diameter	decrease	increase
Number of cooling ducts	decrease	increase
Width of cooling ducts	decrease	increase
Wire insulation	increase	increase

Table 1 of paper 980: Impact of design parameters on the transformer resonance frequency

Papers **62** and **642** present dry-type transformers design where the insulation has been improved thanks to the use of solid insulation materials. In paper **62**, a Solid Insulation Distribution Transformer (SIDT) for underground networks is presented. The insulation consists in Nomex paper and epoxy, and the enclosure is made of thermoplastic resin with a thermally conductive filler to dissipate the heat.

Fig.8 of paper 62: “SIDT” 3-ph 300kVA transformer

In paper **642** the design of a compact transformer with a 3D wound core layout, and VPI based insulation system (for Vacuum Pressure Impregnated) is shown.

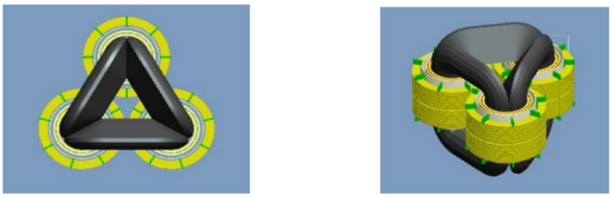


Fig 3 of paper 642: 3D wound coil layout

In both articles, the technical advantages, the design methodology, as well as the validation tests are presented, including fire resistance, thermal cycles and shock, electrical tests… An overload capacity study is also shown in paper **642**.

Last two papers in the transformer group concern the SST technology (Solid State Transformer).

Paper **365** highlights the technical-economical perspectives to use SST in a distribution network. On one hand, SST can support the energy transition though extra-functionality vs. CTT (conventional transformer with tap changer)

- An easier voltage regulation
- A DC connection point for storage
- Filter capabilities for harmonic mitigation
- …

On the other hand, SST cannot yet compete financially with a conventional transformer because of its high initial cost and relatively shorter life span. However, depending on the future energy scenarios (and the needed functionalities) and taking into account the decrease of power electronics cost, the authors conclude that the total system cost of an SST may be comparable to CTT in the future.

Paper **476** analyses the impact of standardized dielectric tests defined in IEC 60073-3 on SST (focusing on the IVW & IVPD and AV tests). Passing these tests yields to an over dimensioning of the power electronics (more stacks needed) and accordingly has an impact on the final cost of the transformer. A second part deals with the impact of high frequencies on the insulation ageing in an SST: the coils and the overmolding of Litz wires are concerned on the MV side.

Sub block 4: Methods and tools for component design (9 papers)

The last sub block groups papers dealing with various design tools for the development of substations components.

Three papers discuss dimensioning methods of transformers.

Paper **43** proposes a new sizing criterion for neutral earthing transformers, which is based on a limited earth fault duration (up to maximum 10 s) as per applicable IEEE and IEC standards. However, the sizing based on a continuous earth fault is still valid for medium voltage systems having their neutral point grounded through high resistance, or systems with long tripping time in case of earth fault.

In paper **115**, the reluctance network analysis is used to evaluate the magnetic flux density distribution in a hybrid core transformer consisting of amorphous and grain-oriented silicon steel cores. The results are compared with the traditional FEM approach. It is demonstrated that the hybrid core allows to increase the capacity and to reduce the standby power vs. non-hybrid transformer technologies, thus providing a substantial energy saving.

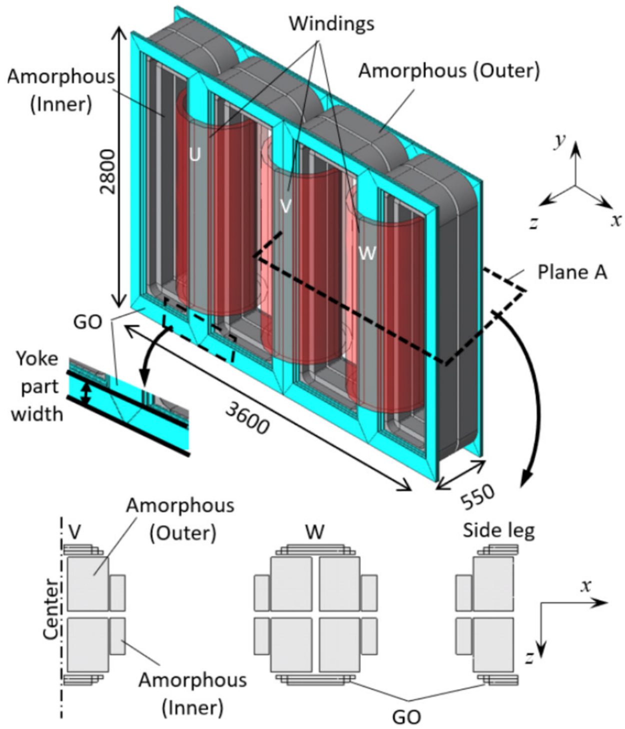


Fig. 1 of paper 115: Overall view and cross-section of the hybrid core of a 30 MVA three-phase prototyped hybrid core transformer.

Paper **768** aims to improve the modelling of saturation effects of power transformers, and their behavior during temporary overvoltage near the system frequency. The phenomena are highly non-linear and generate distorted secondary voltage and high primary side currents. Two methods of parameter identification and polynomial regression are proposed. Results are compared with experiments using a standard configuration and two overvoltage levels (1.14 and 1.3 p.u., the transformer initially being in a steady state).

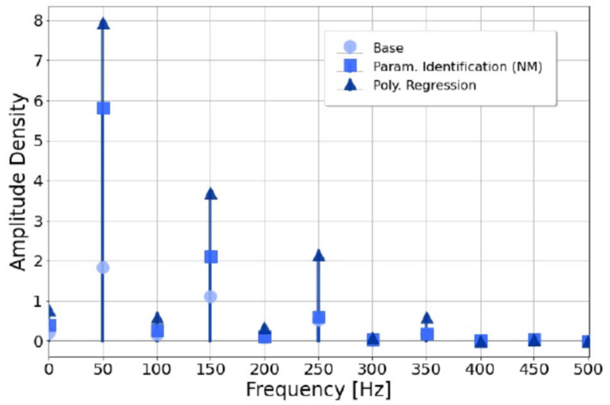


Fig. 8 of paper 768: Fourier Analysis of magnetizing current at 1.14 p.u. primary voltage.

Two papers of this sub block concern the modeling of internal arc faults in switchgear.

Unlike commonly used analytical or simplified CFD (computational fluid dynamics) internal arc models, which require multiple fit parameters, paper **97** integrates a full self-consistent arc physics representation, which allows to calculate the arc voltage, pressure, and arc displacement in the switchgear. Simulation and test results are compared.

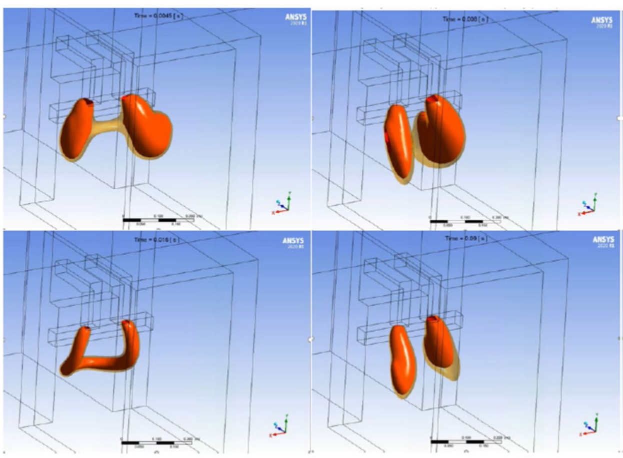


Fig. 4 of paper 97 (extract): Arc behavior evolution, shown as temperature isosurfaces at 4.5, 8, 16 and 90 ms.

The work presented in paper **512** also combines experimentation and CFD simulation for internal arc. Its purpose is to improve the prediction of cotton indicators burning, for different heat flux and exposure durations, which is the most prominent failure mode during internal arc testing.

Paper **865** discuss the cooling properties of pure air at different filling pressure, when used as a dielectric medium instead of SF6. The impact on the design can be evaluated using thermal network method (TMM) or CFD methods. The authors estimate that 3.25 bar of pure air provides a cooling performance equivalent to 1.3 bar of SF6 (absolute pressure).

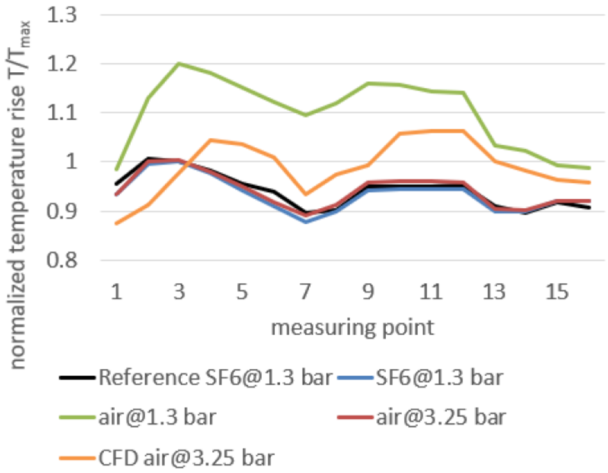


Fig. 4 of paper 865: Temperature rise obtained by the TNM and CFD model; comparison between SF6 and air.

Paper **145** is an experimental investigation of the role of eddy currents in the arc grids (also called arc "chutes" or "splitters"), on the arc motion in an LV circuit breaker.

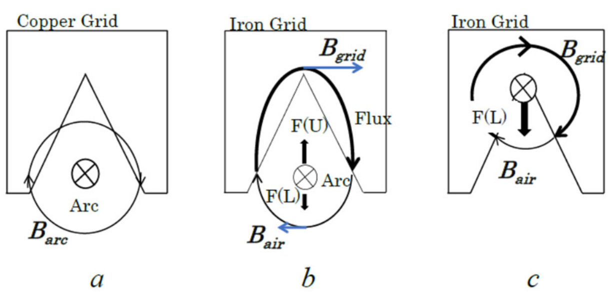


Fig. 7 of paper 145: Magnetic force and flux density in arc grid. (a) Cu grid, (b) Iron grid, (c)

Iron grid when the arc touches to the grid

The permanent reconfiguration of complex and interconnected grids will require an increase of mechanical endurance for all the switches and circuit breakers present on the network. Paper **525** propose a complete simulation workflow, to predict circuit breaker mechanical endurance. This approach combines several steps, starting from a global dynamic model and ending with a local fatigue analysis in the critical areal only.

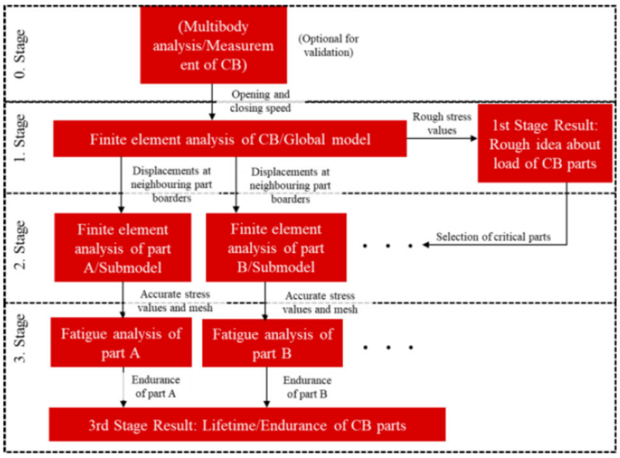


Fig. 4 of paper 525: Flowchart of novel workflow for endurance prediction of circuit breaker parts

Table 4: Papers of Block 4 assigned to the Session

Paper No. Title	**MS a.m.**	**MS p.m.**	**RIF**	**PS**
43: Optimization of earthing transformer sizing in medium voltage networks				X
62: Solid Insulation Distribution Transformer				X
78: Substation Autonomy Levels				X
88: Compact green MV GIS with atmospheric air: Innovation built on decades of heritage				X
97: Internal arc root movement and burn-through prediction by simulation using first principle			X	
115: Simple Analytical Method for Magnetic Flux Density in Amorphous and Silicon Steel Hybrid-Core for Three-Phase 30 MVA Higher-Efficiency Distribution Transformer				X
145: Arc drive due to the eddy current in iron arc extinction grid and interrupting performance				X
183: A new sustainable, readily biodegradable and high performance insulating liquid for power transformers.				X
189: Enedis requirements for use of Vacuum circuit breakers in MV switchgears for Primary substations				X
208: Future medium voltage switchgear: compressed air or alternative insulation gas?				X
262: Comparison of synthetic and natural esters with focus on thermal aspects of insulation systems				X
265: Standardized and life cycle approaches contribute to environmentally conscious design of digitalized MV switchgear				X
268: Evaluation of Sustainable SF6 Alternative Gas Mixtures Used in Electric Power Equipment				X
325: Enedis requirements for Secondary substations monitoring and control				X
Paper No. Title	**MS a.m.**	**MS p.m.**	**RIF**	**PS**
365: Feasibility of implementing MV/LV Solid state transformers in the Dutch electricity grids – from economic perspective		X		
381: Life Cycle Assessment of the 72,5 kV g3 GIS and 66kV/14MVA green transformer for integration of renewable energy from offshore wind turbine				X

435: Assessing real alternatives to MV SF6 gas-insulated switchgear		X		
453: Secondary Substation control architecture focusing on OLTC based transformer integration				X
471: First steps towards LV Network Automation Solutions				X
476: The impact of IEC60076-3 on solid-state transformer design				X
509: The challenge of grid pre-deployment validation of new technologies for flexible network operation				X
512: Enhancement of gas flow simulation of internal arc in medium voltage switchgear				X
525: Novel workflow for Prediction of Circuit Breaker Parts Endurance				X
527: Load-break switch with vacuum interrupter (VI) in auxiliary-path		X		
614: An ENEL-ABB collaboration to develop eco-efficient puffer-type load break switches for medium voltage applications: pilot project				X
617: NEXTSTEP – Developing future smart secondary substations				X
622: Challenges with an Active Distribution Network for a Swedish DSO: Preparation for technical specification of active secondary substations				X
642: Outdoor, 3D wound core VPI transformer				X
646: Modular Transmission-class Solid Dielectric Vacuum Autorecloser				X
674: Different approaches to LCA for calculating the environmental performance of network components				X
679: Performance of in-service shunt capacitor switching devices				X
683: Reason why small amount addition of polyatomic molecule improves current interruption performance is arc cooling caused by turbulent dynamics			X	
706: The Ring Main Unit of the future: green and digital for smart grid				X
746: Solar cell as trigger element for Ultra- Fast- Earthing Switch (UFES) for low- and medium- voltage; Self – powered				X
755: Influence of the Contact Material used in Vacuum Interrupters on the Chopping Behavior of Switching Arcs				X
763: Advanced Circuit Breaker for Capacitive load operations		X		
767: Smart Circuit Breaker: a unique and optimized solution for different applications				X
768: Implementation and parameterization of transformers with saturation effects for the simulation of transmissions of temporary overvoltages		X		
784: Medium Voltage circuit breaker for special applications: pilot experience with KEMA Laboratories.				X
810: Smart Secondary Substation as the source of the flexibility services				X
847: Pressure vessels for voltage levels ≥ 24 kV for SF6-free medium voltage GIS				X
865: Thermal management of MV GIS filled with pure air				X
873: Utilities concerns about alternative to SF6				X
890: A carbon free mobile supply solution combining Energy Storage System and local production, for planned and unplanned outages		X		
980: Novel distribution transformer design for data center applications resilient to transient voltage stresses generated by VCB operation			X	