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SPECIAL REPORT - SESSION 3

OPERATION, CONTROL AND PROTECTION

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Introduction

For CIRED 2021 about 280 abstracts have been received in Session 3. This means – for the first time in the last 20 years of CIRED-history – we received less abstracts (about 200) than for the CIRED before, for sure due the Covid-Crisis. Since still about 180 authors have been asked to submit a full paper, the ratio of acceptance was much higher this time (about 2/3) as in the past (about 1/3). Unfortunately for around 40 accepted abstracts the authors did not deliver a full paper – probably due to the Covid-Crisis, too. Therefore 147 full papers have been finally accepted. Fig. 1 gives an overview of the review process.

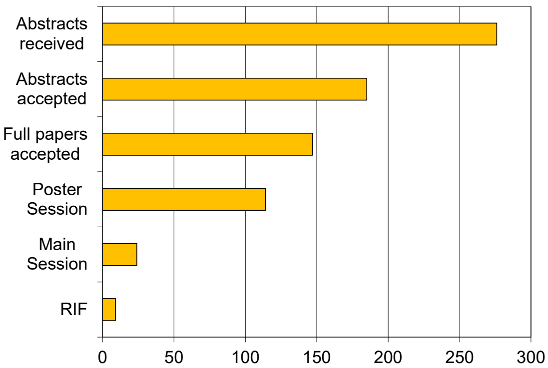

Fig. 1: Review process overview

Since CIRED 2021 was moved to an Online-Event 120 Poster presentations have been spread over nine Online Poster Streams, while 24 papers have been selected for an oral presentation in the Main Session and nine papers are allocated to the Research and Innovation Forums (RIF), of cause Online, too.

Session 3 Team (from left to right Andreas Abart, Ignaz Hübl, Markus Zdrallek, Carsten Böse)

Traditionally and according to the topics of the papers submitted, Session 3 is structured into three blocks: While the Operation-block contains four sub-blocks, the Control- and the Protection-block are divided into five respectively three sub-blocks.

The Session 3 structure of CIRED 2021 is as following:

Block 1 Operation

- TSO/DSO Interaction
- Workforce management & Crisis
- Maintenance
- Predictive Maintenance
- Distribution Management
- Forecasting & Demand Side management:

Block 2 Control

- Communication
- Cyber Security
- SCADA / Distribution Management Systems
- Flexibility
- Islanding
- Low Voltage Automation
- Medium Voltage Automation

Block 3 Protection

- Fault Location / Earth Fault
- Applications
- Algorithms & Simulations

An overview of the number of papers related to the different blocks and sub-blocks is given in Fig. 2.

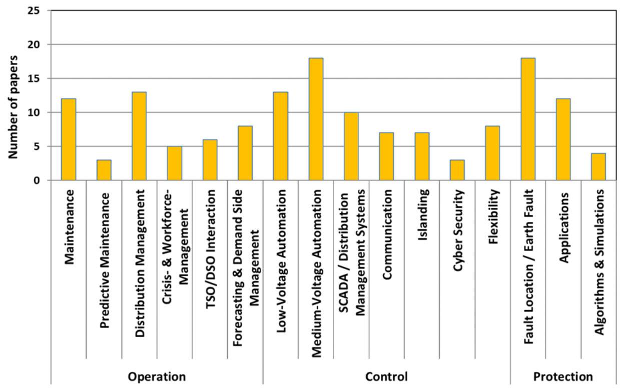

Fig. 2: Paper overview of blocks and sub blocks

Block 1: Operation

The contributions in the field of operation are focusing on reactive power management, UPS issues and virtual reality in Training for crisis, operation and assembling as well as maintenance with drones, capturing and evaluating pictures automatically based on Artificial Intelligence (AI). Also in signal analysis and forecasting an upcoming use of AI can be observed. There is an interesting mix of contributions in the field Distribution management about digitization of grid including thermal rating in MV feeders, microgrid applications and even dynamic topology in LV grids with soft open points.

Sub block 1: TSO/DSO Interaction

Due to decentralized generation and upcoming cables in DS a significant change in reactive power flow can be observed. There is an upcoming need of tight cooperation between TSO and DSO. Paper 699 from Czech Republic. Fig 1 demonstrates the growth of reactive power flows from 110 kV to TS in CZ.

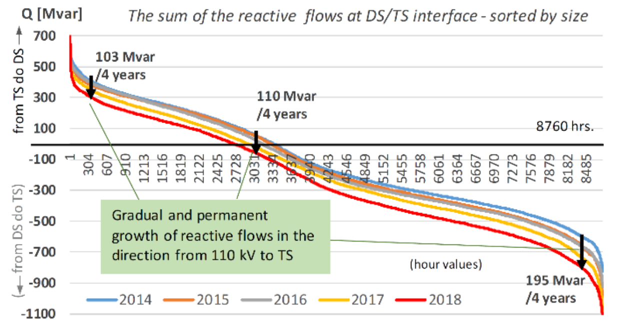

Fig. 3: Growth of reactive power flows from 110 kV to TS in CZ (paper 699)

Recommendations for future Q-management are in planning and operation are given. The provision of reactive power from decentralized generation in LV and MV grids and its impact on node voltages in superimposed networks is presented in paper 515 from Germany. From various simulations at of EHV/HV transformers an amplification effect (+32%) across the voltage levels is shown. Portuguese DS reports in paper 770 about dynamic reactive power management, optimizing the powerflow between DSO and TSO resulting in a significant reduction of losses and penalty cost demonstrated in real world. Authors from TSO and University are concluding in paper 521 that future penalty costs in Czech Republic should stimulate DSO to use tools already installed and to implement shunt reactors in primary substations.

Upcoming decentralized converter interfaced generation (CIG) and its impact on inertia as well as possibilities of under frequency load shedding (ULFS) requires intensifying the coordination between TSO and DSO. Paper 140 from Switzerland reports about hardware in the loop testing of ULFS. Authors from TSO, DSO and University are concluding that the main challenge for all players is to have available a robust common system defence plan. It has to be able to react with a certain selectivity in such a way that system balance can be established after severe events when the available normal system control reserves are already exhausted. In the same time the relay settings and capabilities shall ensure no load shedding in normal system operation conditions.

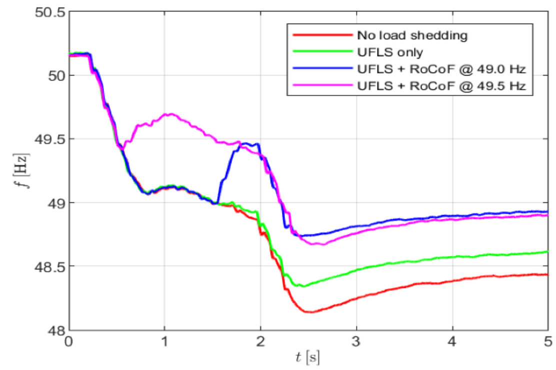

Fig. 4: Frequency curves for moderate RoCoF (Paper 140)

Paper 889 provide an insight on future use of flexibility, which is expected to be placed dominantly at the demand side. Authors from TSO and University conclude that the most significant increase of adequacy indicators due to additional load rises from heat pumps as well as close to constant addition to the load due to data centers. In regards of improvement of adequacy indicators DSR is important and requires further investigations.

Sub block 2: Workforce management & Crisis

In case of planned maintenance or disturbance in substations a mobile UPS (DC/AC 12/24/48/ 110/120/220/230 V) is required. Paper 1061 from an Austria DSO and manufacturer presents a comfortable implementation.

Fig. 5: Mobile UPS for substations secure supply (Paper 1061)

Results for an UPS for datacenter under test including faults are reported in Paper 633 from US.
Paper 217 reports about a Swiss railway tunnel supply by 1 kV equipped with an emergency generator including blackout and black start functions under test. An improper transformer (much higher inrush than specified) damaging a circuit breaker was identified and had to be replaced.

From Portugal, paper 900 reports about an update in the DSO's outage forecasting tool for heavy weather situations implementing successfully machine learning. Also from France a contribution (paper 154) introduce a comprehensive framework to forecast daily interruptions on the overhead network related to weather conditions using historical weather data from Météo-France and historical interruption data from French DSO.

Paper 345 reports about an successful experiment reorganizing operations teams from fixed to flexible ones resulting in saving time at increased number of kilometers but saving extra flexible teams and their vehicles.
From Slovenia, a dynamic Job-planning-tool aggregating the maintenance work to most efficient packages is presented in paper 773.
Virtual Reality in trainings for operations technicians is reported in paper 93 from Germany. DSO and University applied VR for training of emergency cases and installation of sensors for digital substation. The Authors conclude that VR-technology is ready for such applications and report a positive feedback from workers having completed the training.

Fig. 6: Virtual Reality training for emergence cases (paper 93)

Sub block 3: Maintenance
An Augmented reality experience for assembling complex components is reported from India in paper 494. The system supports the installation of products of one of the main manufacturers in the field of switchgears and offers also remote assistance.
Also in Portugal, an AR/VR-pilot with testing several use cases from simple assistance up to teaching has been implemented. Paper 394 reports besides advantages within the pandemic situation that execution time increases but lower error rates and more efficient and better documentation can be expected. The total evidence of benefit is not clear yet.
Drones (UAV) and artificial intelligent (AI) are used at a German DSO for inspection of overhead lines in MV and HV grid. The recognition of objects and condition required 1000 pictures for training the AI-system.

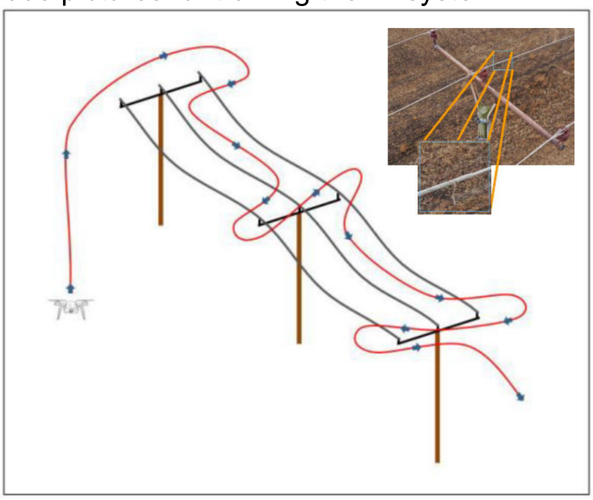

Fig. 7: A drone's route for inspecting MV-overhead-line and a damaged rope (paper 7)

The authors of paper 7 report about successful use and further development towards flights outside the visual range of drone controller, equipping substations with drone garages and setting up an event-oriented inspection. A very intensive use of UAVs is presented in paper 1114 from Malaysia reporting about decreasing outages and SAIDI as well as about reduced cost for inspection and savings in total.

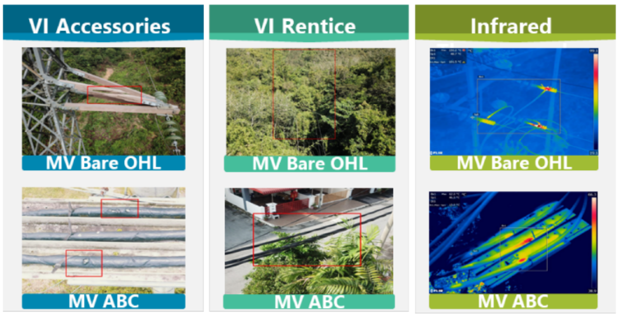

Fig. 8: Pictures from drones flight (paper 1114)

Paper 638 from Norway presents a workflow for training and serving deep learning models for picture classification and object detection. This paper gives very interesting insights on the system behind AI applications in inspection using pictures. Paper 760 from Slovenia presents a DSO use of augmented and mixed reality in real time from geographical information system with mobiles, tablets and AR glasses. Authors somehow underline the potential of these technologies but also discuss difficulties and problems.
Maintenance of lines and stations sometimes requires customer interruptions, causes additional constraints or affect the secure supply. Paper 1028 reports from Belgium about a decision-supporting optimization software for planning maintenance. The tool succeeded to reduce the number of outages by -19%.
The safety of Workers against electric shock but also other impacts is addressed in paper 1066 from Brazil. A DSO and university report about investigations of use cases regarding wearable sensing.
For detection on PD on cables, a new method from an Austrian manufacturer for cable testing is presented in paper 866. Instead of a high-frequency-current-transformer a voltage detecting sensor can be used. Thus, the cable can be kept in operation.

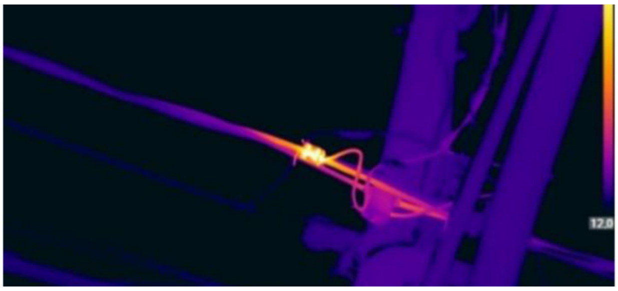
Fig. 9: Thermography for detection of bad connectors (paper 1016)

Paper 2016 reports maintenance by thermo-graphic pictures in Sao Paolo in Brazil combined with setting up a digital Twin (DT).

Sub block 4: *Predictive Maintenance*
Within the DT mentioned above IOT is implemented and used for a predictive maintenance 4.0 pilot. Authors of the related paper 1070 expect better power quality from improved asset management. From Japan, paper 186 reports the detection of faults in advance by detecting and analyzing transients. A travelling wave analysis combined with several further data are assessed in an AI supported system. This can be understood as a new age of operation as there are impacts on asset management as well as on operation resulting in preventive actions with at least less outages.
Prevention from faults caused by vegetation requires lot of maintenance by cutting trees and other plants. From Portugal, a new method of analyzing the vegetation from videos taken with moving vehicles is presented in paper 946. The solution is still under development and not ready to be deployed but seems to promises to become a helpful tool in future.

Sub block 5: Distribution Management
Smart and intelligent grids: Within Paper 4 a couple of Austrian DSO report about the future challenge distribution system operation. DSOs will extend load-flow-forecast coordinate with TSO on a cascade principle. This will require additional financial and especially human resources for operational planning on a 24/7 schedule. Several sensors for grid operation (MV/LV) have been installed at French DSO are presented in paper 570 including ICT aspects. On overview of digitalization projects at French DSO is given by paper 533.
At any fault but also in normal conditions transients are occurring. From transients

travelling waves are resulting. Their characteristics and the propagation time can be used for localization and maybe even fault prediction (paper 194, Russia).
A DSO from Brazil reports about thermal rating in MV Feeders in paper 925 using a limited number of temperature sensors as for feeders without sensors the temperature can be calculated from those with sensors. Paper 964 from Sweden presents a strategy to improve of SAIDI by sectionalizing and automating the MV Grid.
CIRED Working group 2018-03 (France, Spain, Italy and Portugal) has assessed several demonstrators for microgrid operation in connected and in islanded mode. As a result of this analysis paper 704 presents technical requirements for microgrids.
Paper 786 (France) reports about a microgrid simulation tool applied for operation of a microgrid as a digital twin. The full balancing of a small grid requires relatively large storage. Paper 1072 from Pakistan reports about a soft load shedding instead of forced load shedding.

In Portugal alerts of events (e.g. bad power quality) detected by smart meters are used for grid diagnostic (paper 551).
The idea to detect faulty conditions in LV Grids with data from distributed measurements is analyzed in Paper 811 from Czech Republic. The authors conclude, that using voltage data in highly connected mesh network cannot be reiable due to limited accuracy and recommend the use of total currents of MV/LV tansformers.

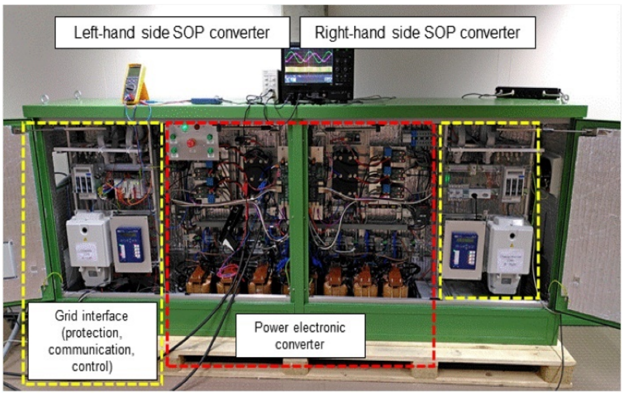

Fig. 10: Installation of SOP (Soft Open Point), AC-DC-AC converter

Soft open points (SOP – AC-Dc-AC 50 kVA converter) connecting LV grids for optimizing the load flow are presented in paper 6 from Switzerland. The authors present the results of a deep analysis of the demonstration succeeding in increasing the hosting capacity.

Sub block 6: *Forecasting & Demand Side management:* Portuguese DSO has set up a large big data platform for generation and load forecasting (Paper 536). 13 different machine learning models were tested and validated. Different optimization targets and the robustness against abnormal conditions were investigated. Paper 255 presents a simple Dynamic Short Term Correction model allowing for dramatic improvements of consumption load forecasts compared to GAM forecasts. This paper emphasizes that it is especially efficient during times of consumption habits changes
like the 2020 France lockdowns. From Portugal in Paper 778 reports about a Big Data application in forecasting.

Paper 712 (France) reports about optimize the consumption of a charging hub for electric busses. From Iran paper 414 reports the calculation of losses in distribution network.

Charging electric vehicle requires balancing of cost for wall boxes and grid with the expected quality of charging service. Paper 229 from Finland and Germany presents an algorithm using a charging price based prioritization resulting in a more efficient use of charging system. Paper 70 (Switzerland) presents results about different pricing for ancillary services and concludes that RES still need to be prioritized.

Paper 821 reports from Quality Of Service monitoring by the regulatory board in Cameroon. For three types of areas: metropolitan, urban and rural different SAIFI, a reliability rate as a percentage of feeders with a SAIFI less than 80h/year and the replacement delay of defect transformors is monitored.

For better finding of know how out of documents and reports a structured knowledgebase GENBERT is presented in paper 506 from Korea.

Table 1: Block 1 OPERATION

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
	Sub block 1: TSO/DSO Interaction				
0140:	Experimental and HIL investigation of under-frequency and rate of change of frequency load shedding schemes in interconnected networks with high penetration of renewable generation.	X			
0515:	Impact of reactive power provision by distributed energy resources on superimposed voltage levels				X
0521:	Mitigation of Reactive Power Overflows with Ancillary Services			X	
0699:	Utilization of the reactive power potential in the distribution networks in the Czech Republic	X			
0770:	Next day reactive power optimization real world application	X			
0889:	Resource Adequacy Methodologies – future flexibility options added to Austria’s generation fleet and its impact on adequacy	X			
	Sub block 2: Workforce management & Crisis				
0093:	The implementation of immersive Virtual Reality trainings for the operation of the distribution grid – development and integration of two operational use cases	X			
0154:	Daily wind-based interruption prediction in Enedis’ Medium Voltage Overhead Lines using time series data				X
0217:	Results of Blackout-Tests of 1 kV Supply for the New Swiss Railway Tunnel Eppenberg				X
0345:	Survey on flexible operation technicians teams rounds				X
0633:	System simulation and analysis of faults and transients in data center power distribution	X			
0773:	The use of job plans for dynamic calculation of resources				X
0900:	Forecasting the number of outage affected clients in extreme weather conditions				X
1061:	Implementation of a mobile uninterruptible power supply - device				X
	Sub block 3: Maintenance				
0007:	Automated overhead line inspection using UAVs and image recognition software				X
0394:	Application of Assisted Reality at Maintenance Activities: EDP Distribuição’s Pilot Project Results				X
0494:	Assembly and Installation Guidance by Augmented Reality				X
0638:	Workflow for training and serving deep learning models for image classification and object detection -- Application to fault detection on electric poles	X			
0760:	On-field asset & GIS utilization in real-time	X			
0866:	A new method to measure online PD on MV power cables by connection of a measurement system to the voltage detection system (VDS) of a switchgear				X
1016:	Thermographic inspection with mobile mapping system				X
1028:	An Integrated Planning Approach for the Scheduling of Grid Activities requiring Outages				X

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
1066: A Health, Safety and Working Procedures Management System Based on Sensor Fusion and Context Awareness for Power Distribution Utilities	X			
1114: Towards Distribution Network Enhanced Maintenance Regime for Medium Voltage Overhead Lines with the Deployment of Extended Applications of Unmanned Aerial System in TNB				X
Sub block 4: Predictive Maintenance				
0186: Development of Predictive Fault Detection and Cause Estimation with Sensor-equipped Sectionalizers in Advanced Distribution Automation System	X			
0946: Computer vision model for low voltage vegetation management	X			
1070: Predictive Maintenance 4.0: Concept, Architecture, and Electrical Power Systems Applications.				X
Sub block 5: Distribution Management				
0004: Future Challenges for Distribution System Operators				X
0006: Application of soft-open points for the interconnection of neighboring low voltage distribution networks	X			
0194: RELATIONSHIP OF ESSENTIAL WAVEFORM PARAMETERS OF TRAVELING WAVE WITH THE CAUSE OF THEIR OCCURRENCE				X
0533: Industrialization of French Smart Grid solutions for a more efficient, digitalized Distribution Grid				X
0551: Diagnosing problematic LV grids using georeferenced Smart Meter data				X
0570: Enedis IoT smart grid solutions for more efficiency				X
0704: Technical requirements for the operation of microgrids in both interconnected and islanded modes - Presentation of the working group CIRED 2018-03				X
0786: Use of a microgrid Digital Twin for advanced operation services				X
0811: Indication of abnormal operation conditions in a mesh network based on data from distributed measurement (LV)				X
0925: Intelligent System for MV Overhead Feeders Load Control for Emergency Operations				X
0964: Strategies for Implementing Monitoring and Remote Control Equipment in an Urban Distribution Network				X
1072: Soft Load Shedding based Demand Control of Residential Consumers				X

Paper No. Title		MS a.m.	MS p.m.	RIF	PS
	Sub block 6: Forecasting & Demand Side management				
0070:	Influence of network constraints and product split on the possible revenue of distributed generators providing ancillary services				X
0229:	Realistic QoS optimization potential in commercial EV charging sites through electricity price-based prioritization				X
0255:	Dynamic short term correction of energy consumption forecasts during CoViD-19 Epidemics				X
0414:	Estimation of energy losses in LV networks using data mining algorithm				X
0506:	GenBERT: A Joint Framework for Distilling the Expertise in Electric Power Utility Domain with BERT				X
0536:	Load forecasting optimization				X
0712:	Study of several electric scales to optimise electric bus depot connections to the grid under normal and abnormal operation conditions				X
0778:	PREDIS – State of the art cloud massive forecasting				X
0821:	Development of a method for monitoring the quality of service of distribution networks in Cameroon				X
0881:	Comprehensive large-scale distribution test networks				X

Block 2: "Control"

63 papers have been accepted for the block "Control" within 7 sub blocks:

- Communication (6 papers)
- Cyber Security (3 papers)
- SCADA / Distribution Management Systems (9 papers)
- Flexibility (8 papers)
- Islanding (7 papers)
- Low Voltage Automation (12 papers)
- Medium Voltage Automation (18 papers)

Compared to the previous conferences the two categories 'Flexibility' and 'Cyber Security' are added as new sub blocks in the control block of session 3.
The number of accepted papers is slightly higher than the number of selected control papers of the previous conference in Madrid. It can also be stated that the number papers in the sub blocks are similar to the previous conferences.

Sub block 1: Communication

Six papers representing the initiatives in the field of communication technologies.
Paper 523 from Spain shows the use of a Simple Network Management Protocol (SNMP) for monitoring and control in distribution automation systems. The paper shows a use case for a Spanish DSO with 250 devices.
The standard IEC 61850 is addressed by the paper 504 and 595. Paper 504 evaluates the applicability of IEC 61850 for SCADA system communication with centralized protection and control devices acting as communication gateway via public telecommunication networks. The authors describe the advantages of consolidation of multiple relays into one device and they stated that this will be paradigm shift to the traditional state of the art way we know from the communication between substations and control center.
First tests of IEC61850 with multi-vendors started about 25 years ago. Even if the standard is already well established in many utilities but it seems to need further testing in this area. The Portuguese paper 595 of EDP Labelec and E-REDES describe such a test with four well-known vendors. It shows the testbed (see Fig. 11) and finally limits of IEC61850 between different vendors. The content of paper 595 covers real questions of utilities considering the growing number of IED in public grids.

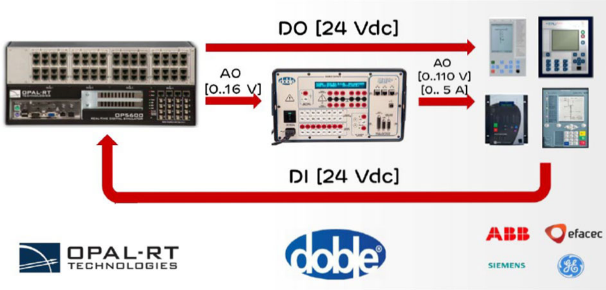

Fig. 11: Smartlab SAS overview (paper 595)

When talking about communication we also must consider mobile communication. Nowadays this is a discussion about the benefits of 5G. Two papers address this topic.
Western Power Distribution form UK testes the multi service and multi-vendor communication of LTE technology in their distribution networks. The LTE systems covers a 25 km radius from the central base station. The paper describes the test and results of application characteristics such as quality of Service, redundancy and latency.
Paper 243 concentrates on studying cellular network technologies (5G) in connection with distribution grid protection and fault location applications. The paper shows the result of performance and quality of service (QoS) test in two selected commercial mobile operators' networks. The results indicate that cellular networks have the potential to provide a communication platform to DSO but further enhancements are still needed.

Fig. 12: Mobile multicast test setup (paper 447)

Low inertia networks are mostly in not very well connected areas with limited access to telecommunication networks. Paper 447 from Finland introduces and analyses a cellular network multicast-based solution for providing fast frequency reserve capability. A test system is described to evaluate the performance and it shown that the requirements are fulfilled.

Sub block 2: Cyber Security

Three papers deal with the topic of sub block cyber security. The improvements in monitoring and control lead to higher reliability in network operation. On the other hand cyber-attacks can

lead to the opposite with high impacts that might cause long interrupts of the system.
The main objective of the German paper 769 is to analyze security concerns that may raise by applying virtualization in cyber-physical energy systems (CPES). The participation of new actors like active customers lead to high challenges to protect the systems against cyber-attacks. The paper shows a multi-layer model with several potential attack scenarios (see Fig. 13) and gives an overview of a virtualized CPES concept.

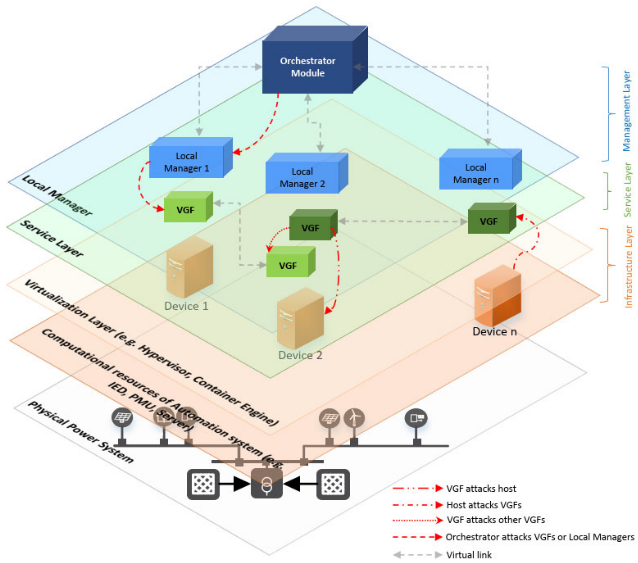

Fig. 13: Multi-layer model with potential attack scenarios (paper 769)

A second German paper 916 also address the threats of cyber-attacks. The proposed approach provides flexible and scalable replication of multi-staged cyber-attacks in a smart grid co-simulation environment. The paper presents a detection system that analyses the network traffic with machine learning algorithms. The co-simulation allows a replication of attacks as well as the evaluation of countermeasures.
Paper 967 from UK investigates managing the access to the configuration computer on the host computer which can be interfaced with common access control strategies. It combines multiple existing technologies to manage access to the HMI. The validation of the proposed architecture is done by a virtual site acceptance testing and training.

Sub block 3: SCADA / Distribution Management System

This sub block contains 9 papers. The main portion of papers addresses the increasing need for better performance of SCADA systems due to new challenges and increasing number of available data. New ways to deal with new technologies are presented and it will be interesting to observe how utilities will accept these upcoming technologies in future.

When talking about reliability of power systems we normally use traditional figures about the probability of components to investigate the reliability of the whole system. But how can new challenges influence the system availability in future. The topic is addressed by several paper if different focus.
Paper 24 from Sweden addresses the reliability aspects of dynamic thermal rating. Due to increasing load and infeed the equipment loading is continuously increasing since years. Reliability analysis deals with the availability of components and systems and the effect to the power supply. Dynamic thermal rating increases the risk of unnecessary operation and lack of action in the system due to errors in the calculation. This is a new approach which must be considered if DTR is introduced into a public supply system.
The identification of critical events is also subject of paper 128. The increasing dynamic behavior of distribution grids necessitates the need to monitor distribution grid in real time. Nowadays the central control centers are not fitted to deal with high numbers of alarm messages. If critical alarm message cannot be immediately identified this might lead to an increase of customer interruptions. The authors propose a framework that uses machine learning. The system was tested in a pilot project by a Dutch DSO.
Next level reliability and resilience on a cloud-based substation control system is discussed in paper 162. The paper conducts a qualitative assessment in for substation control system architectures (see Fig. 14). Conclusion of the authors: "Cloud-based SCADA systems improves sustainably resilience, supports high level reliability, and brings great flexibility with the principle of on demand compared to traditional SCADA." The future will show if and how SCADA as a Service will be established in the traditional utility business.

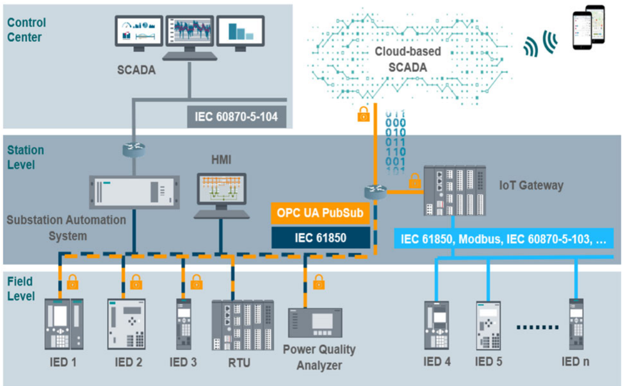

Fig. 14: Substation automation system with redundant SCADA system (paper 162)

The authors of paper 870 from Germany propose a high-performance computing power flow calculations grid simulation approach. The increasing and huge number of DER has an impact of the control mode on the operation. Nowadays planning of the operation as well as real-time operation in quasi-static mode need a lot of simulations in parallel. The paper shows the modelling of DER as well as the simulation based on real data from a German MV grid.

As already discussed in the previous papers the high number of available information are critical to analyze with traditional methods to identify faults in the power system. Several papers address the topic of providing relevant data to human network operators.
Paper 363 from Portugal discusses a strategy to handle the increasing number of date nodes (e.g. smart meter) and how to capitalize value form data. Can these information be used to enable proactive action on grid constrains even before customers report them? The paper shows the operational processes and conclude that there is huge improvement potential regarding aggregation and process optimization.
A similar topic is addressed by E-REDES and INESC TEC in paper 396 from Portugal (see Fig. 15). The authors describe the use of artificial intelligence in SCADA systems translating that avalanche of information into meaningful and fast insights to human operators. Two tools (Alarm2Insight, EventProfiler) were developed to demonstrate the capabilities of AI in SCADA. The authors show that the tool has the potential to support network operators in doing more and better-informed decisions.

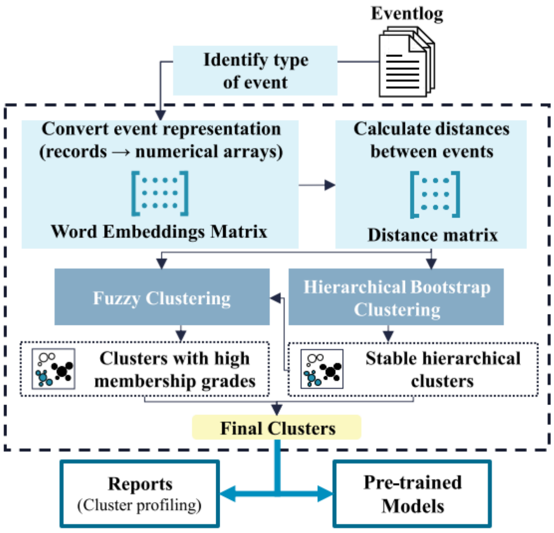

Fig. 15: Clustering process diagram (paper 396)

EASYINC is a project to reduce the cognative load of human operator while using as much information as possible. The Portuguese authors of paper 761present the development of an operation dashboard to provide all important information to an outage in near real time.

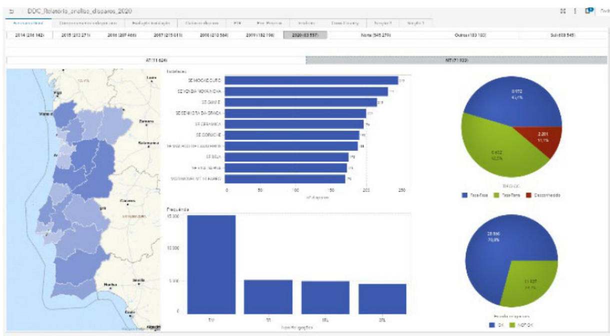
Fig. 16: SAS analytical dashboard over main algorithm output (paper 761)

Paper 513 present a hierarchical optimal power flow (OPF) algorithm implementation for active distribution networks of the future. The OPF uses decentralized field measurements (see Fig. 17) and provide a redundant solution to the centralized OPF approach. The algorithm is verified in a hardware-in-the-loop simulation and ready for a field test. Especially the flexibility and redundancy are promising for future implementation into the real world.

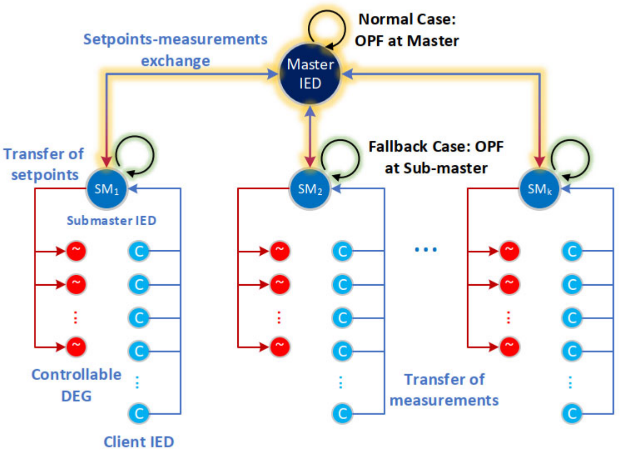

Fig. 17: Hierarchical OPF implementation (paper 513)

The Austrian and Chinese paper 63 show the difference in transient stability between grid forming and grid following. The emerging number grid forming inverters lead to completely different behavior in terms of synchronizing mechanisms. The paper analyses and compared the differences in transient stability between the two concepts. The paper shows that the robustness of synchronizing mechanism of grid forming inverters is better than that of grid following inverters.

Sub block 4: Flexibility

Eight Papers addresses the increasing needs for flexibility. This becomes more and more important of offer power system services based on the availability of flexible loads, generators and storages. Presently most of the approaches are still in the simulations phase and real time testing in the field is just starting.

Paper 882 from United Kingdom shows a technology assessment for flexible services in distribution grid. The paper offers a high-level view of the network flexibility procurement and use process which will feed into a DSO plan to procure flexibility services. It is a very good start into this sub block before going into the detailed simulations and flexibility tools.

Paper 198 from Switzerland proposes a DSO flexibility operation platform with DER management based on grid monitoring and control equipment at the secondary side of ML/LV transformers and LV street cabinets and DER. In this Horizon2020 project the benefits of reducing cost and improving hosting capacity of renewables are shown. The paper also shows that there is need to have knowledge of the LV system for grid operation. This is presently a discussion in many utilities.

French paper 205 present a modular mixed-integer linear programming (MILP) optimization motor for sort-term operational planning (see Fig. 18). The tool enables the DSO to adopt a global, techno-economic approach to solve network constraints through many available non-topological levers (including flexibility) and the rules related to their use.

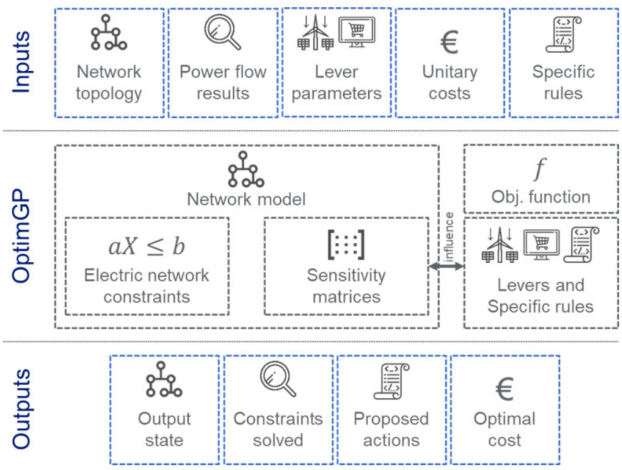

Fig. 18: OptimGP structure (paper 205)

Paper 388 from Germany introduces the implementation of an online aggregation of the flexibility potential in distribution grids. It shows how to combine state estimation with the aggregation of flexibility potential of DER as well as flexible power units (e.g. storage, loads and generators) to get from a passive distribution grid to flexible power grid. The algorithm will be tested in an online grid monitoring system.

Another approach of increasing flexibility in pubic grid is presented in paper 554 from Germany. In this paper, the application of self-learning algorithms based on reinforcement learning are applied for the task of optimally scheduling flexibility in distribution grids. It is shown that the methods are able to learn policies that control flexible devices in a way, such that the overall cost of operation is reduced.

The active response project described in paper 923 is implementing active management software to release constrains and mitigate the impacts of low carbon technologies by reconfiguring the network and actively controlling power flow. The algorithm was also tested against EV charging, which might lead to temporary overloading. In the scenario shown in

paper 923, the network was able to cope with up to a 150% increase in load without upgrade the infrastructure.
The authors of paper 1013 present an approach for a framework to test multi-use concepts for the coordination of flexibility resources in distribution grids. It allows testing in a large-scale co-simulation environment and in a cyber-physical smart grid laboratory (see Fig. 19).

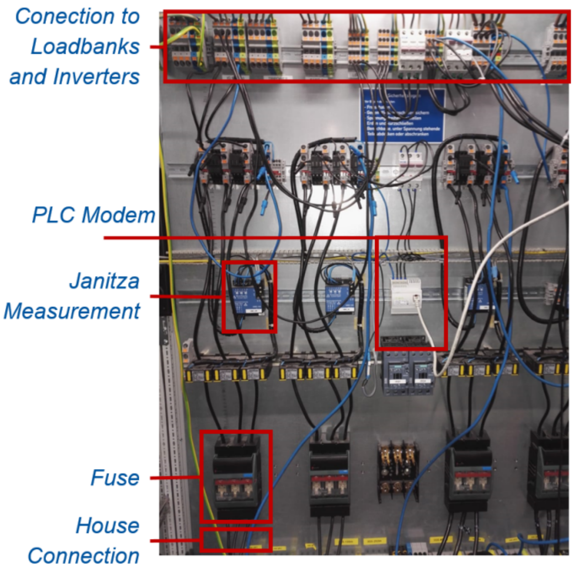

Fig. 19: Coupling point of the grid with measuring devices and broadband PLC modem (paper 1013)

Multi-agent systems have already been discussed in the previous two decades. Paper 963 from Finland and Iran took this topic to show an incentive-based management of multi-agent distribution systems in contingency conditions. In the proposed framework utilities provide incentives to agents collaborated in suppling isolated load demands as well as decreasing the operational costs of the grid during contingency conditions.

Sub block 5: Islanding
Islanding is also getting more important in well-developed power systems. 7 papers address this field. Two main aspects are discussed: islanding as basis for black start restoration and the technical challenges of temporary islanded mode operation.

Paper 196 addresses feasibility and socioeconomic aspects of black start services. The Spanish authors analyzed the impact of distributed generation on restoration process and the capability of the DSO to provide energy to the customers before the TSO is able to restore generation (see Fig. 20).

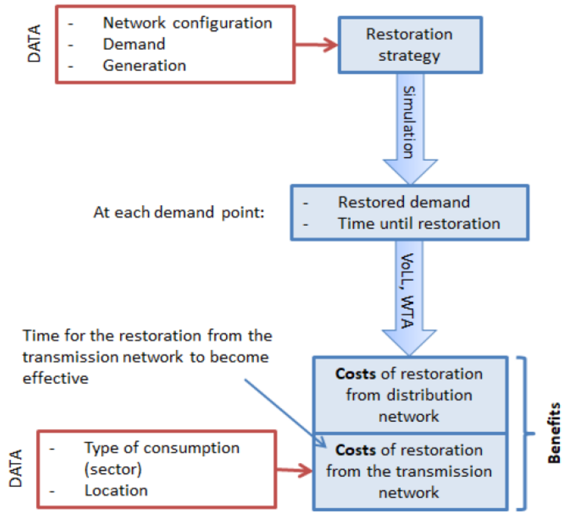

Fig. 20: High level diagram of the proposed methodology (paper 196)

Also paper 782 from the United Kingdom investigates the capabilities for black start. The paper explores the necessary model consideration for black start studies using distributed energy resources. The learnings from the distributed restart innovation project on three network areas in the UK is shown. The authors describe the effects from voltage regulation up to protection setting and show that the success of the restoration will directly depend on the capability of the anchor generator.
The focus of paper 827 from Germany is to present a designed energy management algorithm for temporary islanded microgrid operation (see Fig. 21). The algorithm uses forecasts to calculate new power set points for the distributed generator units and is suitable to achieve a required minimum operating time of 24 hours in 70% of the investigated scenarios.

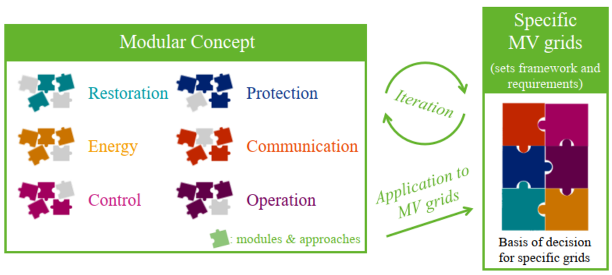

Fig. 21: Modular concept for temporary islanded mode operation (paper 827)

Paper 563 investigates the applicability of a distributed grid-forming control concept for the temporary islanded mode operation of existing medium voltage grid structures. Critical situations may occur after switching additional loads close to the grid forming converters. This load change has to be taken over by the grid forming converters completely as grid following converters increase the active power generation with time delay.

Operation principles for temporary islanded microgrids considering fairness of supply is described in paper 844. The paper introduces modelling techniques for technical constrains and degrees of freedom of temporary islanded microgrid operation by expanding algorithms for optimal distribution switching on medium voltage level. The authors introduce different measures of fairness and the effect on the operational scheme is assessed.

Paper 577 from Denmark describes experiments that were conducted with a commercially available current source PV inverter to characterize its behavior during loss-of-mains events using high-precision measurements in a controlled lab setting.

The US paper 958 shows the implementation and technical challenges for utilizing cogeneration to provide enhanced resilience to a hospital. It details the experience of designing a CHP based microgrid and the lessons learned in the process.

Sub block 6: Low Voltage Automation

12 papers addresse the topic of low voltage automation. These paper cover wide area of LV automation starting from trolley busses up to self-designed Smart Grid box of an Italian utility. The challenges of overvoltage regulation and overloading of equipment is mainly discussed in this sub block.

A special case of LV automation is addressed by paper 330 and 331. Both papers address the optimization of the LVDC traction network of trolleybusses in Germany. The studies have been carried out with Stadtwerke Sollingen, the city with the largest operating trolleybus system in Germany (51 trolleybusses, 6 battery trolleybuses, 22 rectifier stations).

Fig. 22: Catenary grid with 22 substations (paper 331)

Paper 331 focuses on the methodical grid state evaluation of a 660 V low voltage direct current traction network which serves as a power source for battery-trolleybusses. The main aspect is to process forecast data in order to define the grid state.

Paper 330 improves a simulation model for battery-trollybusses which operate in a low voltage direct current network. It considers three different methods for adjusting the maximum motor power in a time-critical manner to improve bus voltage profiles.

Paper 558 describes the verification of the simulation part of a universal control framework. In this regard, a key aspect for the accuracy is the modelling of latencies and dead times of control and communication of the devices involved. The paper proved that the time behavior can be reconstructed sufficiently, even if the particular inner workings are not known.

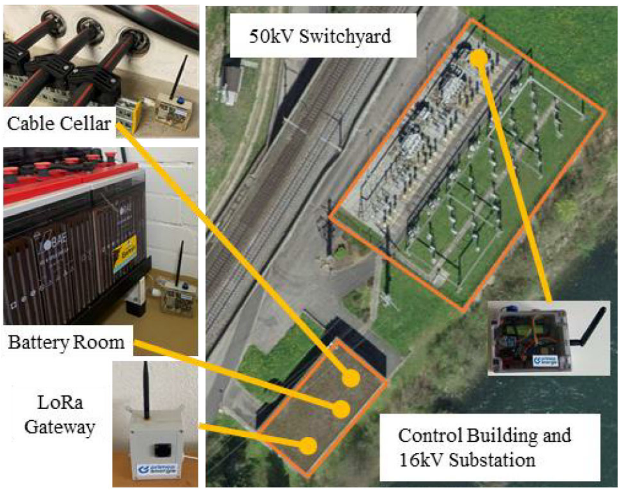

Fig. 23: Aerial view of the test substation and locations of end devices and the gateway (paper 630)

Paper 630 from Switzerland identifies and summarizes the technical characteristics of low power wide area network (LPWAN) technology needed for condition monitoring systems. It also presents a pilot project (see Fig. 23) to test the application of LoRaWAN in substations. The main goals of the pilot project are verifying building penetration in substations and assessing the deployment effort and scalability. The results of the pilot project demonstrates the outstanding building penetration capabilities of LoRaWAN.

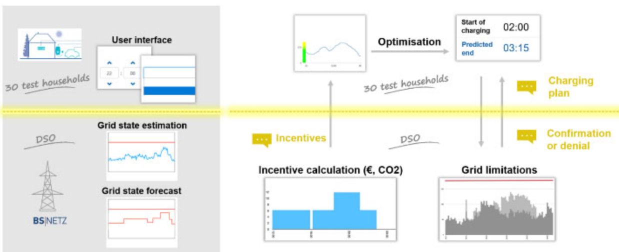

Fig. 24: Overview of the field test behavior and components (paper 708)

The number of electric vehicles increase in nearly every country and therefore the challenges for public distribution grid. Paper 708 presents a framework for a multi-level analysis of control strategies for electric vehicle containing theoretical, a simulation-based and a practical analysis (see Fig. 24). It presents results from the German research project Charging Infrastructure 2.0. The paper shows that different strategies have be studied carefully before a decision can be made. With the present simulation system an efficient platform is demonstrated to analyse control strategies on operational aspects.

The Austrian authors of paper 720 present an automatic grid reconfiguration approach for smart grid challenges. On the one hand new kind of loads (e.g. EV, heat pumps, …) lead to overloading due to changing effects in regards of simultaneity, on the other hand distributed generation lead to power quality problems. The project ‘Power System Cognification’ defines six use cases to tackle these challenges. The paper is focusing on the use case of overload prevention by temporary meshing and investigates the use of remotely controlled switching devices.

The CIRED WG 2019-5 is working on the requirements for monitoring and controlling LV grids. The report of the group is nearly finished and will be available at the end of the year. The data survey of distribution systems operators (DSOs) is presented, analysed and discussed in paper 728, to demonstrate the current vision on the evolution of LV networks. The results of the WG will also be presented in separate RT during CIRED 2021.

Paper 735 introduces the principle of voltage regulating distribution transformers and sheds light on their application to substantially increase network hosting capacity in distribution networks with high penetration of distributed generation and other low carbon technologies. The main focus is on the application conservation voltage reduction in low voltage networks to reduce energy consumption and carbon dioxide emissions. These effects have been validated in Electricity North West’s 24-month trial project “Smart Street”.

With increasing numbers of renewables and of active components like transformers with on load tap changers, too, voltage regulation is getting more and more complex. The paper 741 presents a voltage regulation approach that uses the machine learning technique called Double Dueling Q-learning (DDQN) as an extremely fast and adaptable alternative to coordinate in real-time the OLTC and the power factor of PV inverters. The case study considers a real Brazilian MV/LV three-phase feeder with 123 customers, 365 days of 5-minute resolution demand and PV generation profiles, and 60% of PV penetration.

Detailed three-phase electrical models are not readily available for most distribution companies but smart meter data is able to close this gap. Paper 785 proposes an approach to calculate

voltages without electrical models by capturing the nonlinear relationships among the historical data (demand and voltages) and the corresponding low voltage feeder using a Neural Network. The approach can make it possible for distribution companies to bypass the time-consuming process of producing LV network models and carry out accurate calculations for any type of scenario.
Paper 851 presents some obstacles faced during the development and implementation of the state estimation functionality into a real distribution network. A dedicated state estimation algorithm was developed and implemented into 2 MV and 3 LV Slovenian distribution networks.
In paper 989, e-distribuzione describes a new low voltage remote controlled grid node design, named Smart Street Box (see Fig. 25). The Smart Street Box design enables several functionalities relate to monitor and control, using a modular approach in order to gain flexibility and cost reduction. The communication is based on power line communication and it is design to robust against vandalism. The paper show and discusses all components needed in detail.

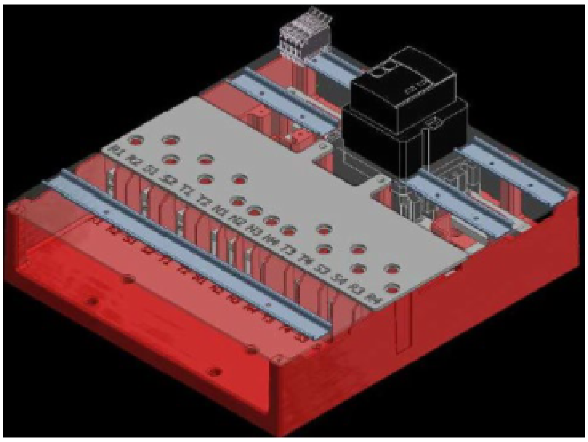

Fig. 25: Drawings of the junction board in remote control version (paper 989)

Sub block 6: Medium Voltage Automation
18 papers address topic of the MV automation sub block. This is slightly more than in 2019.

A very good start into the topic MV automation is paper 883. This Portuguese paper shows the past, present and future role of automation in the electrical grid. This article presents the evolutionary technological context for the Portuguese DSO and its contribution to the increase of service reliability. It also presents the development of technical specifications of equipment in alignment with the company strategies. The overview is starting in the late 70th of the 20th century and ends with outlook into the future (see Fig. 26).

Strategy (objective&Goals)		Year
Primary Substation Telecontrol	OPEX redution	80's
Primary Substation automation MV Network Automations (without telecontrol)	OPEX redution & Power Quality improvement	[80's and 90's]
Primary Substation standard project specifications MV Network Automation and Remote Control Project	CAPEX, Engineering & Maintenance costs redution	2000-2005
Primary Substation standard project specification revisions Project of "Distribution Automation"	OPEX redution & Power Quality improvement	2006-2007
InovGrid Project Distribuited protection in overhead MV networks (OCR3) Self-Healing for overhead MV networks	TOTEX redution & Power Quality and Energy efficiency improvement Integration of renewable and micro generation EV infrastructure development	2008-2020
Networks sensing Roadmap for self-healing applications New automation architecture for primary substations		{≥ 2020}

Fig. 26: Automation strategy milestones (paper 883)

Reclosers are a very well-known technology in many countries and might be also very useful for MV automation. Paper 98 from India contains detail experience sharing of overhead recloser deployment in suburban network, which helps the DSO to automatize its fault detection, isolation and power restoration for critical feeders by effective deployment of reclosers, configured either as sectionalizers or as reclosers. The feeder automaton pilot thus has resulted in manifold advantages for improving the performance indices for suburban network involving bare overhead lines.

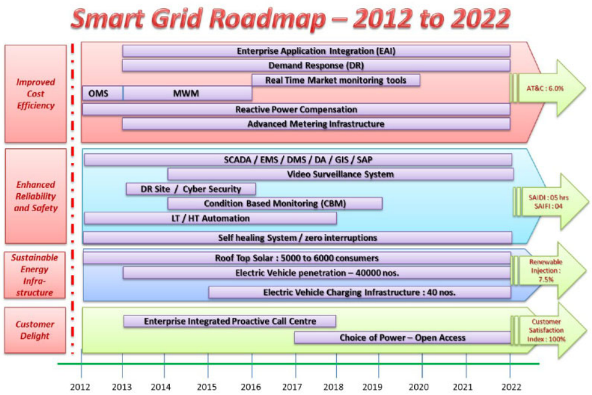

Fig. 27: Smart Grid Roadmap (paper 989)

The Belgium paper 233 presents a quadratic optimization model for line parameter estimation, with smart meters and/or PMUs. Specifically, the line length of multi-phase distribution lines is estimated. The approach considers that phase angle measurements of e.g. smart meters cannot be taken into account because of the accuracy of these devices. In a simulated setting, the line lengths are estimated with great accuracy.
Paper 427 from Slovenia shows a quality of dispatching algorithm that serves the dispatching department to validate the steps taken by the dispatchers. The algorithm considers the features of the event – if it is planned or unplanned, if the exact switching manipulations are taken by the dispatcher, if the users are notified for the planned work and if the users are supplied within the planned period. The algorithm is foundation to improving SAIFI/SAIDI and quality of power supply.

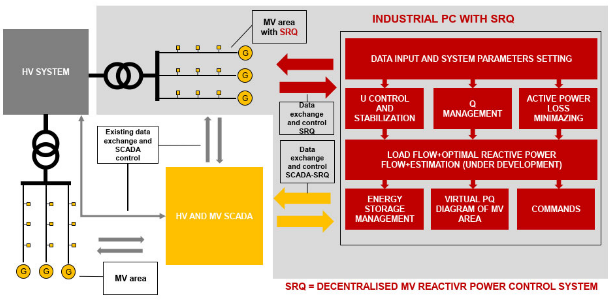

Fig. 28: Decentralized system for MV supply area control (paper 426)

Paper 426 from Czech Republic presents a new decentralized method of power and voltage control in medium voltage distribution systems. The paper shows results of influence of voltage tolerance range in MV modelled supply area on the available reactive power reserve on the HV/MV boundary. Decentralization is the way to control MV supply areas using complex systems for voltage and reactive power flow control that are not burdening SCADA systems.

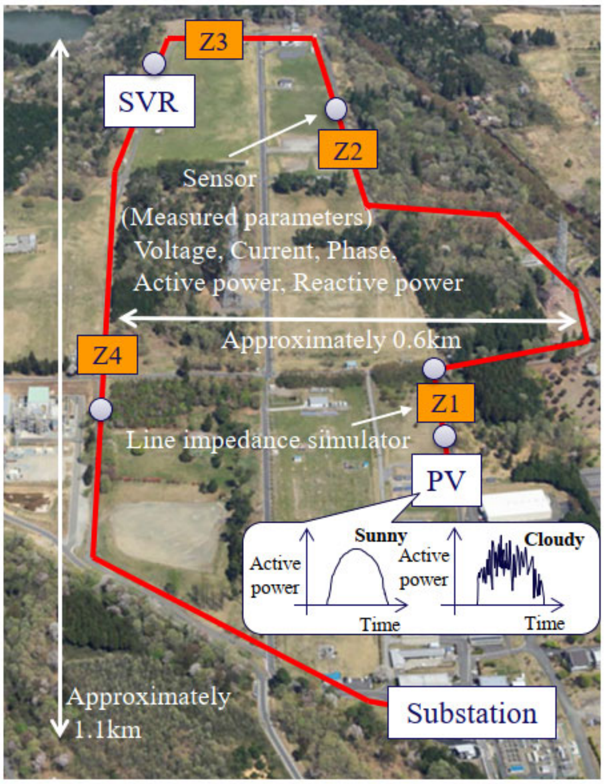

Fig. 29: Grid test area (paper 493)

The Japanese paper 493 shows the development of an advanced voltage-estimation method for the control of the step voltage regulators based on a simple calculation using measurements, including the unit line impedances in the distribution system. In the study, the authors fabricated a prototype step voltage regulator using the new method and the conventional line drop compensator method. A prototype test in a test area (see Fig. 29) has been carried out.

The Portuguese paper 457 discusses self-Healing from theory to reality (see Fig. 30). It aims to detail the challenges of legacy equipment's integration through a gateway of communications and lessons learned during the implementation of two distinct self-healing projects. The paper also discusses other rationales behind the decision making during the implementation stages as well as several technical insights.

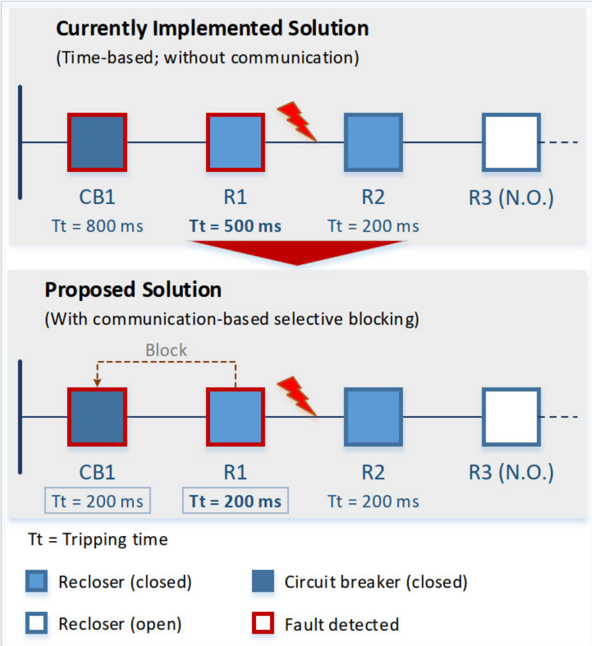

Fig. 30: Comparison of the conventional solution and the protection acceleration algorithm (paper 457)

Paper 511 presents results from pilot project and field tests of Smart MV switchgear technology, which was installed into Czech urban MV distribution grid. Main goal of the test was to verify reliability of fault detection based on MV sensor technology, in comparison with conventional MV measurement transformers. Furthermore, several other reliability aspects of Smart MV Switchgears were tested, as this technology is infrequent in Czech distribution networks.

In paper 579, the German author present an approach towards a dynamic description of an unbalanced distribution grid by an explicit ordinary differential equation model. The majority of monitoring and control applications at a distribution system control center rely on the assumption that the distribution network is in quasi steady-state. Known limitations of the quasi steady-state assumption are its inability to capture fast transients and harmonic distortion. The comparison between real measurement data and the model outputs demonstrates that the model can replicate the fast transients and harmonic distortion in the time-domain (see Fig. 31).

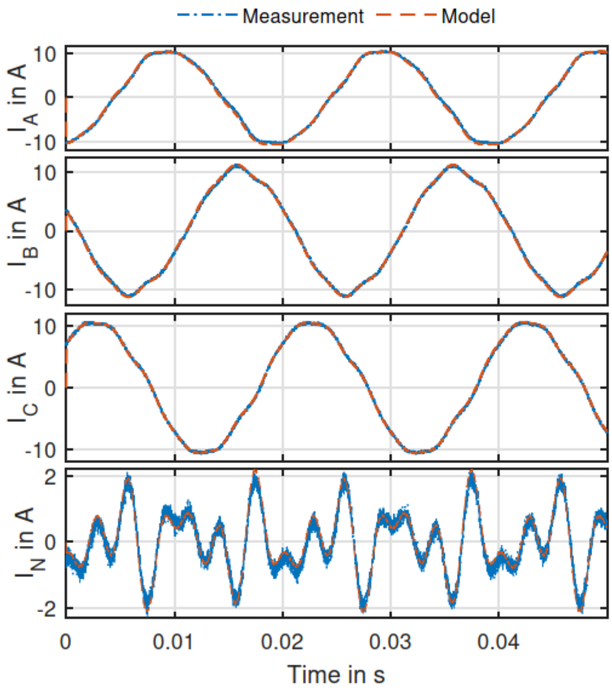

Fig. 31: Model performance (paper 579)

Interoperability of intelligent electrical devices (IED) of different vendors has to be guaranteed in modern Substation Automation Systems. Paper 589 presents an implementation of a solution for physical and electrical interoperability between IED set in a laboratory environment with a multi-vendor infrastructure called Smartlab-SAS (Substation Automation System). The laboratory should mirror an infrastructure where IED from different vendors function together without any issues, allowing for easy substitution from one IED to another from a different supplier and more maneuverability when facing IED failures.

The paper 645 is based on detailed restoration plans developed as part of the Distributed ReStart project to re-energize a distribution network under a grid supply point using DERs, after a complete system blackout. The restoration plans are developed considering the practical challenges around operation and control of a system which is traditionally restored by a top-down approach. The restoration strategies are guided by extensive steady state, dynamic and transient analyses undertaken on three case study networks in SP Energy Networks (SPEN) distribution license areas.

Paper 648 examines the impacts of autonomous smart inverter functions on the operation of a centralized voltage optimization scheme. The paper outlines the methodology employed, including an overview of the case study distribution circuit, the assessed smart inverter functions and control scenarios and presents the results analyzing the impact of smart inverter functions with and without a voltage optimization scheme.

The simultaneous charging process of multiple electric vehicles may cause violations of power distribution grids' operational constraints. Paper 771 investigates the impact on a medium voltage distribution grid of uncoordinated charging, coordinated grid-aware charging and coordinated grid-aware charging of EVs with reactive power support for voltage regulation. In all these cases, the EVs' charging policy is determined with an optimal power flow problem, where suitable sets of constraints are modeled to reproduce each specific case (see Fig. 32).

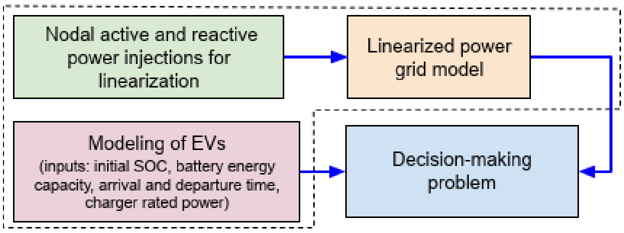

Fig. 32: Workflow problem formulation using OPF (paper 771)

Paper 800 presents a grid automation planning study for the Elektroistra Pula region (HEP ODS, Croatia) in order to increase the reliability by integrating automation functions into the medium voltage network. Based on network planning variants for the years 2022 and 2032 different automation scenarios with a changing degree of substation automation were proposed and analyzed. As a result, the technical and economic efficiency of the application of different standard and innovative solutions based on the synthetic network approach is compared and the optimal measures have been derived, in order to develop a methodology to transfer these results to additional networks.

Paper 818 proposes an innovative centralized approach for voltage constraints management in the medium-voltage distribution systems based on the use of deep reinforcement learning. This algorithm permits the distribution system operators to take control decisions in almost real-time, which are optimal in terms of operational costs, while being robust with respect to the model uncertainties. The developed control algorithm is tested on a real MV distribution system located in Benin.

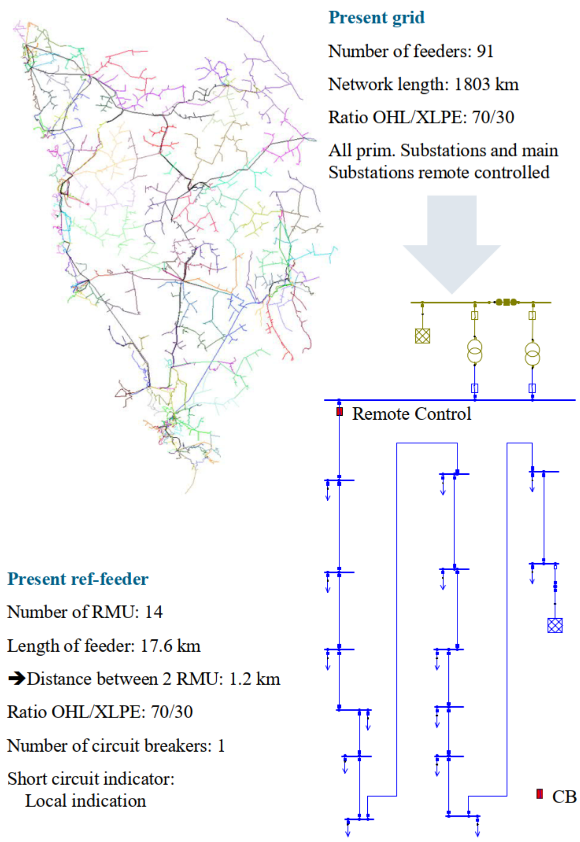

Fig. 33: SAIDI depending on feeder length and number of secondary substations of a feeder (paper 800)

Paper 1024 from Finland and Denmark discusses the lessons learned in implementation of coordinated voltage control demonstration. In this paper, the challenges for integrating smart substation automation system into traditional substation is presented. The preparation of a long-term field demonstration for coordinated voltage control in distribution grid in western Denmark is used as a case study. One of the results really represents the target of CIRED conferences to bring academics, researches, developers and operators together: "Academic studies usually make unrealistic assumptions for proofing the smart functionalities: perfect communication (no delay), accurate, instantaneous measurement data always available and no human errors and always up to date grid data documentations and configuration of devices".

The Brasilian paper 1053 presents a technique for optimizing voltage and reactive power control for medium-voltage power distribution grids, at the distribution management system level, in the context of advanced distribution automation. The control technique was integrated with the utility's legacy systems through an interoperability bus which uses the Common Information Model. It was applied in a pilot area, composed by four substations and their respective 28 power distribution feeders, with 153,215 consumers and 2,488 kilometers of extension for primary distribution network.

Paper 207 from Spain presents new embedded developments and algorithms for assessing parallel operation of power transformers in primary substations. Typical ENDESA's primary substations consist of two or three HV/MV transformers and several busbars (see Fig. 34). In order to reduce both complexity and investments, a new algorithm has been developed. This algorithm has been tested in over a dozen substation, being able to determine whether transformers are running in .

parallel just by checking online voltage and currents.

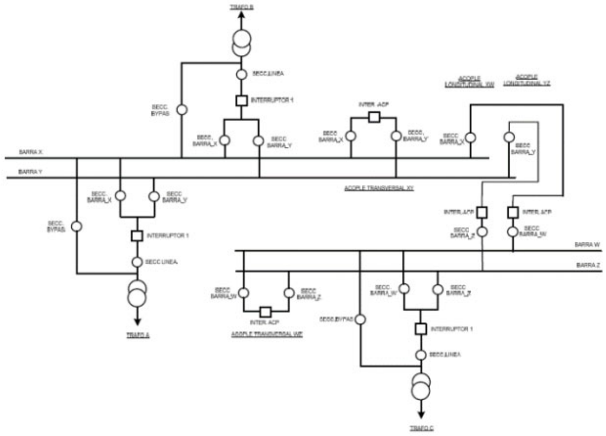

Fig. 34: Example of a single-line diagram of a 3-transformer primary substation (paper 207)

Table 2: Block CONTROL

Paper No. Title		MS a.m.	MS p.m.	RIF	PS
Sub Block 1: Communication					
0243:	Cellular networks providing distribution grid communications platform		X		
0244:	Predictable secure characteristics and standards, future proof 5G enablement - why Private LTE is the choice for Distributed Automation				X
0447:	Mobile network multicast supported maintenance of frequency stability in low inertia power grids				X
0504:	Applicability of IEC 61850 for SCADA communication with Centralized Protection and Control				X
0595:	Testing IEC 61850 in Multi-Vendor Substation Automation System				X
Sub Block 2: Cyber Security					
0769:	A Comprehensive Analysis of Threats and Countermeasures in Virtualization-centred Cyber Physical Energy System				X
0916:	An Approach of Replicating Multi-staged Cyber-attacks and Countermeasures in a Smart Grid Co-simulation Environment			X	
0967:	Enabling cybersecurity features using a layered connectivity to promote secure remote operation and maintenance				X
Sub Block 3: SCADA / Distribution Management Systems					
0024:	Reliability Aspects of Dynamic Thermal Rating in the Power Grid		X		
0063:	Differences in transient stability between Grid Forming and Grid Following in synchronization mechanism			X	
0128:	A novel approach using a machine learning classification framework to identify critical events in an increasing amount of control room alarm messages				X
0162:	Novel architecture for next-level reliability and resiliency substation control system in power distribution systems				X
0363:	From smart grid events to a proactive fault approach				X
0396:	Innovative Applications of Artificial Intelligence on SCADA Data				X
0513:	A robust hierarchical OPF approach for distribution networks with decentralized measurements				X
0761:	EasyINC – Near Real-Time SCADA Alarms Correlation Algorithm		X		
0870:	Fast parallel quasi-static time series simulator for active distribution grid operation with pandapower				X

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
	Sub Block 4: Flexibility				
0198:	Efficient distribution grid flexibility provision through model-based MV grid and model-less LV grid approaches				X
0205:	OptimGP – Industrial optimisation for Enedis' short-term operational planning				X
0388:	Online Aggregation of the Flexibility Potential in Distribution Grids using State Estimation			X	
0554:	Reinforcement learning based flexibility optimization in electrical distribution grids				X
0882:	Technology Assessment for Flexibility Services in Distribution System: NIE Networks Case Study				X
0923:	Implementation of the Active Network Management scheme for the Active Response to distribution network constraints project				X
0963:	Incentive-based Management of Multi-agent Distribution Systems in Contingency Conditions				X
1013:	Feasibility and socioeconomic study of black start services provision from distribution networks using distributed energy resources				X
	Sub Block 5: Islanding				
0196:	Feasibility and socioeconomic study of black start services provision from distribution networks using distributed energy resources				X
0563:	Impact of the selection of grid-forming inverters on the stable operation of medium voltage temporary islanded microgrids				X
0577:	Loss-of-mains detection in a household PV inverter: Test of the effect of active and reactive power balance				X
0782:	Model considerations for black start studies using distributed energy resources			X	
0827:	Emergency Power Supply using Temporary Islanded Microgrids – Design and Verification of Energy Management Algorithm				X
0844:	Operation principles for temporarily islanded microgrids considering fairness of supply				X
0958:	Utilizing cogeneration to provide enhanced resilience to a hospital campus: Implementation and Technical challenges				X

Paper No. Title		MS a.m.	MS p.m.	RIF	PS
Sub Block 6: LV Automation					
0330:	Power Control Model for Conventional and Battery Trolleybuses to Improve Voltage Profile in a DC Traction Network Simulation				X
0331:	Grid State Evaluation of a LVDC Traction Network: Methods for the Analysis of Forecast Data				X
0558:	Universal control framework for smart grids - verification results				X
0630:	Application of Emerging LPWAN Technologies in Condition Monitoring		X		
0708:	Multi-level Analysis of Control Strategies for Electric Vehicles				X
0720:	Low-Voltage Grids in Transition – Automatic Grid Reconfiguration Approach for Future Smart Grids Challenges			X	
0728:	A survey based on the state of the art and perspectives in the monitoring and the control of LV networks				X
0735:	Voltage regulated distribution transformers in combination with state estimation enabling conservation voltage reduction and integration of low carbon technology in low voltage networks.				X
0741:	Using Deep Q-Learning for Voltage Regulation in PV-Rich Distribution Networks: A Brazilian Case Study				X
0785:	Calculating Voltages without electrical models: Smart Meter Data and Neural Networks			X	
0851:	Implementation of the State estimation functionality in a distribution network				X
0989:	“Smart Street Box”: an innovative approach to remote control, monitoring & automation for LV Smart Grids		X		

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
	Sub Block 7: MV Automation				
0098:	Experience sharing: Feeder automation pilot from one of globally largest urban distribution network in India				X
0207:	New embedded developments and algorithms for assessing parallel operation of power transformers in primary substations.				X
0233:	Line Parameter Estimation in Multi-phase distribution networks without voltage angle measurements				X
0424:	Quality of Dispatching validation procedure for improved distribution network operation				X
0426:	Fast decentralized Power Flow and Voltage Control System in MV Grids				X
0457:	Self-Healing: from theory to reality. The Portuguese case study				X
0493:	Verification of the autonomous voltage control for SVR based on the advanced voltage-estimation corresponding to the voltage drop phenomenon.				X
0511:	Smart Switchgears with MV Sensors– Field Tests in Distribution Grid				X
0579:	Towards the explicit dynamic modelling of distribution grids in the time-domain				X
0589:	Physical and Electrical Interoperability for SAS IEDs – A practical implementation				X
0645:	System restoration strategies using distributed energy resources				X
0648:	Impact of autonomous DER smart inverter functions on centralized voltage optimization.				X
0771:	Scheduling the charge of electric vehicles including reactive power support: application to a medium-voltage grid				X
0800:	Development and application of a methodology for the integration of distribution network automation in HEP ODS		X		
0818:	An innovative centralized voltage control method for MV distribution systems based on deep reinforcement learning: application on a real test case in Benin				X
0883:	The past, present and future role of automation in the electricity grid – A Portuguese perspective				X
1024:	Lessons learnt in implementation of coordinated voltage control demonstration			X	
1053:	An experience of implementing voltage and reactive power control technique for a distribution management system				X

Block 3: "Protection"

In the block "Protection" we received 35 papers, covering the topics "Fault Location and Earth Faults", "Applications" and "Algorithms and Simulations". New developments and improvements of protection functions as well as methods how to detect faults easier and more reliable are discussed in some papers of this block. The upcoming communication technology 5G could be a part of protection-functions in the future, but IT-security will be a big issue. Also, very interesting are the result of practical field-tests and investigations in the MV and LV network.

Sub block 1 "Fault Location and Earth Faults"

The detection of faults in the grid is a big challenge till now and will be an area of research and development in the future. One topic is like a "never-ending story", how to detect high impedance earth faults and locate the faulty point. 18 papers are selected in this sub-block.

Starting with 2 investigations about arc during power system faults.

Paper 3 from the Slovak Republic is showing us that the arc during a power system fault is not only a pure resistance. The aim of this paper is to point out the technical problem in locating phase-phase arc faults on power lines, which is caused by the very nature of the electric arc. In the theoretical part of the paper, the cause of incorrect evaluation of the arc fault distance by standard protection relays is derived (Fig. 35).

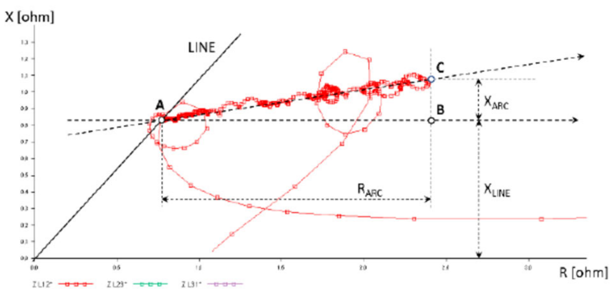

Fig. 35: Impedance trajectory as seen by the protection relay – real fault

In the experimental part, these statements are confirmed by measuring an artificial arc fault on the real power line during full operation (Fig. 36).

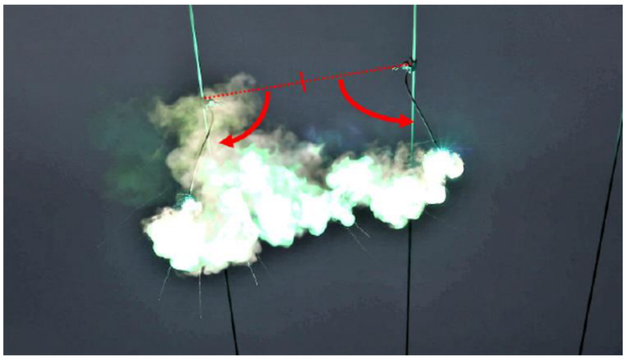

Fig. 36: Artificially created phase-phase arc fault.

Finally, improvements of the fault locator algorithms are proposed, which eliminate the influence of the electric arc at the fault location on the accuracy of the fault distance calculation.

New knowledge of the extinguishing of the freely burning arc in compensated and isolated networks is pointed out in paper 608 from Germany. The reason for the investigations was, that it was observed several times in the compensated 110 kV Network that in small networks with a size of approx. 30 A and with an overcompensation of approx. 30 A the arcs do not extinguish automatically. The very detailed transient earth fault tests in the compensated 110 kV Network of NetzOOE in Austria included 30 earth faults with different network size and tuning. To simulate real events, e.g., a tree falling into the line, a standard 110-kV-conductor support assembly was used and lifted with a mobile crane, see Fig. 37.

Fig. 37: Artificially triggered earth fault in a 110-kV-network

The first very interesting results are shown in this paper, more detailed investigations are needed.

The next papers are focused on arc suppression coils.

Paper 253 from the Czech Republic describes a new method of arc suppression coil (ASC) tuning. A multifrequency current injector has been tested not only in the Laboratory, but also in real networks in several European countries. It was confirmed that the new method can be used very reliably for arc suppression coil tuning. In this paper you can find detailed testing results and the benefits of the new method.

In paper 732 from the UK we are coming to the advanced earth fault detection in compensated networks. Sensor sets have been installed on overhead lines using the hot stick method (Fig. 38). Each sensor in a set has a label indicating the assigned phase that it should be installed on (A, B or C). There is also an arrow next to the phase label that indicates the direction of positive power flow. A key learning outcome from the installation phase of the project is to determine a consistent sign convention for power flow prior to the sensor installations. This is relatively straightforward for networks with radial feeders; however, the St. Austell 33 kV network is meshed with several 33 kV rings.

Fig. 38: Sensor installed using Grip-All hot stick

The tests showed that the sensor units were able to successfully detect all applied faults. High impedance faults including a 10 kΩ phase-to-earth fault impedance with a fault current of less than 400 mA where also successfully detected.

The biggest challenge for traditional protection is to detect high impedance faults.

Paper 74 from Sweden describes new technologies to detect low and high impedance faults. Integrated fault locating is based on two detection schemes – a very fast transient detection mainly for re-striking cable faults and a highly sensitive adaptive zero sequence admittance scheme to detect both low and high impedance faults on overhead lines and cables. Common for the algorithms is the use of neutral voltage (U_{en}) and feeder summation currents as detection criteria. Details and experience about this new development you will find in the paper.

A Time Domain Reflectometry (TDR) measurement (Fig. 39) has been studied and is described in paper 420 from Japan.

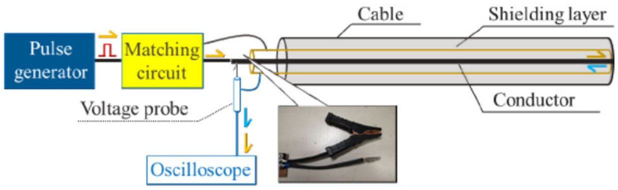

Fig. 39: Image of TDR measurement to the cable

This paper provides a basic study for effectiveness of TDR measurement in the uncharged state for underground distribution system including multi switchgears and ground-mounted transformers. The final goal of this study is to identify the fault part by constant monitoring in the charged state. This paper confirmed the effectiveness of TDR measurement in the uncharged state as the first step. In the next step, whether TDR measurement works in charged state will be verified.

“Earth fault localization in isolated uninterruptible power supply (UPS) networks – a new approach” is the title of paper 894 from Austria. The focus is directed on isolated DC systems.
Due to the special properties of DC voltage networks, some of the protective measures customary for AC voltage networks cannot be implemented in the same way. The design of the electrical network, the consumers and the protective measures thus determine reactions to insulation faults against earth. The new approach shows a simple and easy possibility to detect the faulty branch. By use of components such as a simple switch and resistors as well as avoidance of active current injection not only the

earth fault can be detected but also the fault current at the fault point is reduced. Experiences after installations in several substations show a very high acceptance by operational staff. The required time for fault location is reduced significantly compared to previous monitoring systems.

In paper 1074 from Brazil, you can find an experience of locating high-impedance faults through smart meters` alarms in power distribution networks. This paper researches a key Smart Grids' component: Advanced Metering Infrastructure (AMI), which is driven by monitored smart meters (SM). Furthermore, this paper discusses the devised methodology and presents some case studies to illustrate the location of both cable breaks and fuse-cleared faults. Then, final comments on the methodology's suitability to assist utility's engineers in enhancing power outage management strategies are drawn.

"Transient Earth Fault Protection based on Instantaneous Values" is the title of paper 716 coming from Spain.
This paper presents the principle of operation of a new algorithm based on instantaneous values to detect Transient Earth Faults, which has been validated by RTDS simulations and real cases from the field. The results of this study with RTDS (real time digital simulator) models confirms that the application field of the study of the Transient Earth Fault Protection (TEFP) unit includes all kind of systems where transient or intermittent earth faults appear, that is, high impedance systems with high capacitance in feeders, as i.e., isolated neutral system, compensated neutral system, resistive neutral system, inductive neutral system, or a combined neutral system.

Paper 501 from Finland describes how to improve earth-fault detection performance and supply security of cabled rural MV-networks with fault isolation. First the concept of fault isolation using ITRs is introduced, and the theory is discussed. The effect of MV/MV-isolation transformers (ITR) is studied both during earth faults and short circuits, including faults in the LV-distribution network. For this, simple hand calculation equations are derived. Techniques for fault detection in fault isolated networks are suggested and their performance demonstrated. The applied network data is obtained from practical networks of DSO Elenia Verkko Oyj in Finland enabling actual piloting and field testing of the proposed concept in later stage.

Fig. 40 shows an example of feeder distance protection application for a network of DSO Elenia Verkko Oyj. With proper settings, the protection zone covers the whole MV-OHL-section and can discriminate short-circuits faults from load currents in wide range of loading conditions. However, as the protection zone may also reach to the LV-side of the MV/LV-transformers, additional time co-ordination with LV-side protection may need to be considered.

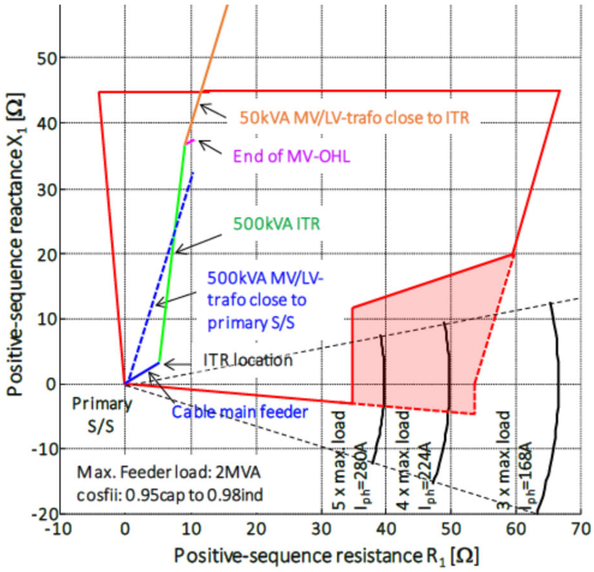

Fig. 40: Principle of applying distance protection as time selective backup protection for OHL-sections behind ITR

In the proposed concept, the isolation transformer together with necessary protection and communication functions and devices are located in a dedicated compact secondary substation (CSS). The principal design illustrated in Fig. 41.

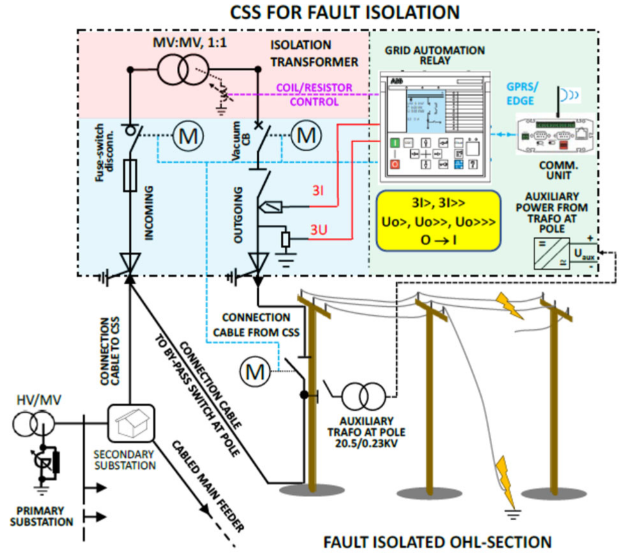

Fig. 41: The principal design of the CSS in the fault isolation concept.

Paper 491 from France analyses the impact of a massive integration of distributed inverter-based resources (IBR), and of the reduced transmission system short-circuit power on the spread of voltage perturbation on the distribution grids and on their stability. A typical transmission network and generic distribution grids are modelled considering IBR connected at the medium voltage (MV) level. It was assumed a scenario in which a portion of the power system contains 100% of the generation interfaced by power electronic inverters and connected to the distribution grid. EMT simulations were carried out to assess the effect of the dynamic voltage support (DVS) capability of IBR. It was shown that in reduced short-circuit level conditions, the DVS helps to reduce the voltage dip during the fault and to ensure a fast voltage recovery after the fault while respecting the Over-Voltage Ride-Through (OVRT) profiles of IBR at MV level.

The simulation results indicate that a lower level in the short-circuit power of the transmission network may present risks of phase-locked loop (PLL) instabilities of IBR connected at distribution grids. It was also shown that the DVS capability of distributed IBR helps reducing the voltage dip during the fault and to ensure a fast and stable voltage recovery after the fault while respecting the OVRT profile. The risks of anti-islanding protection trip due to under-voltage were also discussed. The study highlights the need to delay anti-islanding protection of IBR connected at MV level.

The next paper 455 coming from the Czech Republic deals with the issue of utilization of faulty phase earthing (FPE) technique as alternative to single phase fault auto reclosing in resistor earthed medium voltage distribution network. Possible integration of this technique to common protection concept as well as fault current limitation efficiency is discussed in the paper. To evaluate the benefits flowing from FPE utilization, a sensitivity analysis of FPE in simple distribution network was performed focused mainly on FPE impact on voltage dips and swells invoked at low voltage level.

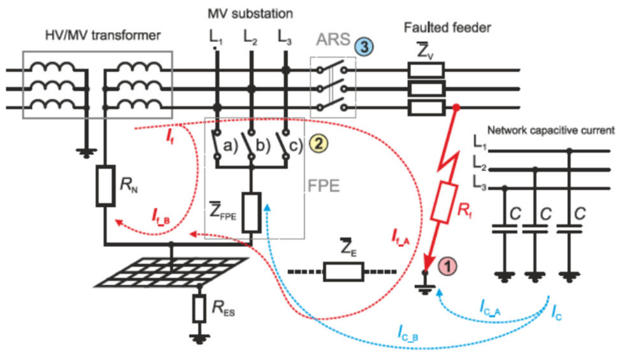

Fig. 42: Simplified scheme of the distribution network during application of FPE

To evaluate the operational efficiency of FPE as substitute for the auto reclosing, the impedance conditions of network path and fault are very important, because they are related to fault current redistribution between fault location and FPE location after application of FPE during single-phase faults, see Fig. 42.

In paper 234 from Belgium a holistic study was carried out regarding the earth voltage rise due to earth faults in MV networks presenting either only underground cables or a mix of underground cables and aerial lines. The matter was investigated both via simulations with electrical models in a dedicated modelling tool (EMTP-RV) as well as via two dedicated field tests where a live MV cable was faulted (Fig. 43) via a dedicated cutting plyer and exhaustive measurements were carried out.

Fig. 43: Fault's arc in the Walloon network

In this paper the modelling method and assumptions for the parametric simulations are first presented, followed by the simulations results as well as the field tests and measurements that ensued. It was observed that all else being equal, earth voltage rises are much higher in mixed networks than in pure underground cable networks, due to interruption of the metallic screens and the consequent obligation for the fault current to return via the earthing connections at some point. The earth voltage rises in the pure underground cable network were ultimately relatively low in most scenarios.

Paper 240 from Ireland shows “Optimised solutions for MV neutral treatment and earth fault detection”.
This paper introduces a hybrid solution featuring arc suppression, supplemented by faulted phase earthing for standard risk feeders, or by selective tripping for high-risk feeders, supported by sophisticated fault location techniques. This is an elegant solution providing high levels of supply continuity, supply quality, safety, and operational simplicity. Future flexibility is provided to meet the ever-changing demands of distribution networks.

A new method for measuring the earth fault-distance in compensated and isolated networks is described in paper 600 from Germany.
With the new method it is now possible to find a distinction and to carry out an earth fault distance measurement.
The detailed results from real earth fault tests in a meshed 110-kV-network (ICE = 900 A) with overhead-lines and a 20-kV-network (ICE = 600A) with cables will be presented.

Paper 936 from Austria shows practical approaches and methods for determining additional thermal loads on equipment like cable shields or transformers and the proper continued functioning of existing systems such as the selective earth fault detection. Influences and limits are shown, and their results are used, to answer the open questions, considering existing framework conditions.

Cross-country faults (CCFs) in resonant-earthed networks are analyzed in paper 324 from Sweden. The approach of this paper focused mainly on evaluation of Distance Protection and its impedance measurement during CCFs.

In paper 922 from Norway a novel method for placement of intelligent electronic devices (IEDs) is proposed, where the IEDs are defined by a probability of failure to deliver the service required (due to internal failure or communication interruption). The solution of the optimization problem is based on the application of Genetic Algorithm, with the objective to minimize the total annual cost, which is a compromise between the interruption costs of energy not supplied (CENS) and the yearly expenses (and the reliability) of each IED installed.

Sub block 2 “Applications”
In the sub block “Applications” we received 13 papers with very different topics. The common topics of this papers the practical tests or the implementation of functions in real systems. Several papers are focused on protection, automation and control applications based on IEC 61850.

Paper 974 from the UK describes how to improve reliability on IEC 61850 substations.
This paper focus on two aspects of LAN-integrated protection systems: Identifying which device should alarm each communication loss,

including IEDs and Switches.
This paper also addresses monitoring strategies to enable early identification of conditions which could lead to a failure on demand. The objective is to increase availability even if the mean time between failures is reduced.
The importance of device and network monitoring, and how it can be used to identify malfunctions as soon as they happen to prompt maintenance and minimize the period of unavailability is highlighted.

Paper 1130 coming from France is titled with "Functional specification of protection, automation & control applications based on IEC 61850 independent of their implementation".
With the new possibilities described in this paper, a user will be able to use IEC 61850 file format to express automation application requirements, by expressing the electrical topology in the application scope, along with the functions used to manage this application & the data exchanged between functions to operate properly the application with the values of the application parameters.
Based on this standardized expression of the user requirement, a system engineering, equipped with correct tools, will easily use aggregation of application function specifications as system specification without need to redefine all requirements.
The European project H2020 Osmose task 7.1 is working on improvement of the specification process to provide such capability, and the result is directly reused by the IEC Technical Committee 57 to write the new standard part IEC 61850-6-100.

The next paper 1135 coming from Austria is focused on "Redundancy for Power Utility Communication Networks".
With the proliferation of IEC 61850 and moving the information transfer from hard-wired signals to message exchange over the power utility communication network, this network became a mission critical part, so redundancy was required for the communication network as well. This applies in particular when using Sampled Values for delivering the measurements from the power system to the protection relays. Thus, redundant communication networks are a precondition for the Digital Substation.
The redundancy mechanisms (Parallel Redundancy Protocol) PRP and (High-availability Seamless Redundancy) HSR serve this requirement. The two concepts have their specific strengths and can be even combined. But there is no ideal network architecture that serves every need equally well. Thorough thought must be given to select a design that best fits a specific protection, automation, and control system.

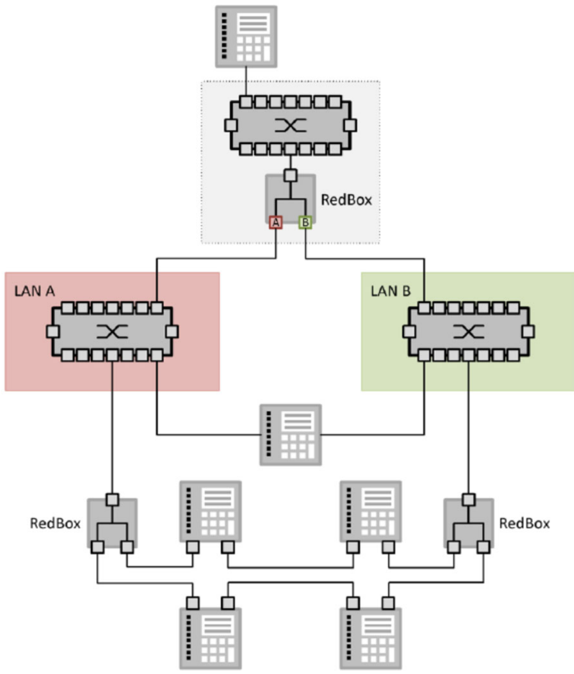

Fig. 44: Coupled PRP and HSR networks

The two RedBoxes in Fig. 44 coupling the PRP and the HSR network operate in a special coupling mode. As they are both duplicating messages which are already duplicated in the PRP network, there would be four copies of a message in the HSR ring. The two RedBoxes are aware of each other and discard excessive duplicates, so that only one duplicate of a message is traversing the HSR ring in each direction.

In paper 334 from France is shown how designing a 5G based smart distribution grid protection system.
Fault Detection, Isolation, and Service Restoration (FDIR) systems, which utilize real-time data exchange from various Intelligent Electronic Devices (IEDs), would require better communication technologies to this purpose. To mitigate these risks and provide new functionalities, a new paradigm could be considered for the design and operation of power distribution grids if all the devices could be interconnected through secure, reliable, and low latency communication infrastructure.

A 5G wide-area communication network has the potential to act as key enabler for future smart grid applications. Next generation of power protection schemes can leverage the use of 5G to become more efficient, faster, and less expensive. Therefore, the execution time of such FDIR system will be reduced from a few minutes to only a few seconds, and it will possibly embed advanced protection functionalities. The outage risk will be mitigated, and thus supply quality will improve considerably.

Paper 58 from Greece describes a solution against protection scheme design complexity in modern active distribution systems.
To deal with protection scheme design complexity in modern active distribution systems, a plug-and-play (PnP) protection scheme is proposed. This protection scheme does not require any relay settings, traditionally resulting from a protection design study, and is, as far as possible, independent of a particular distribution system. This paper provides a high-level description of the plug-and-play protection concept and applies it to a real medium-voltage distribution system with distributed generation. The plug-and-play protection scheme proves effective under different fault/system scenarios, serving as a promising solution against the increased protection scheme design requirements of modern active distribution systems.

Paper 66 from Indonesia shows an implementation of non-cascade protection system on switchgear using the Half Down Section method. This protection system is made for backup when the main system is fault. So, the blackout area can be minimized (Fig. 45).

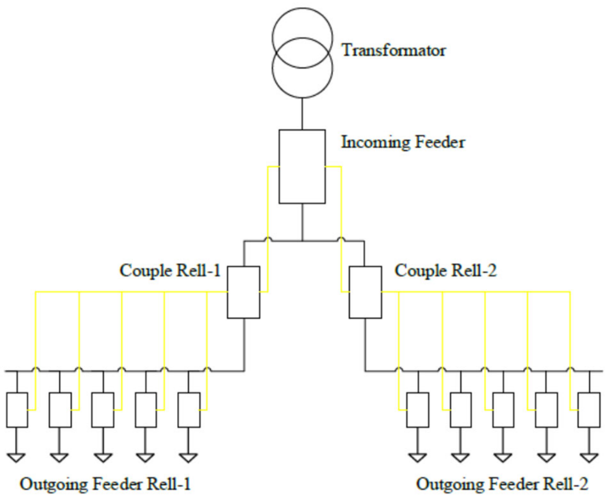

Fig. 45: Scheme of Half-Down Section Protection System

The Half-Down Section Protection System can be an alternative feature that can be used to mitigate mechanical failures that can occur in feeders. The System can be optimized using the IEC 61850 standard with Generic Object-Oriented Substation Event (GOOSE). The implementation using GOOSE can reduce the copper wiring for signal transfer between IED relay.

Paper 236 from Belgium has the title “False Tripping of a MV Bundle Feeder due to Inductive Coupling”.
In this paper the field test and corresponding measurements setup are first exposed, followed by the measured results. The modelling method and assumptions are then detailed, before exposing the simulations results and comparing them with the field test measurements.
A suitable use case for the field test was identified in an urban area near Antwerp in Flanders. A bundle feeder of roughly 2,5km is leaving the main HV/MV station and one of the two bundle cables is laying in the same trench as another feeder for a total of 650m. This latter feeder is where the controlled earth fault is to be performed, downward of the section of close parallelism between cables. A schematic illustrating the situation is shown in Fig. 46. The expectation in this case, based on previously observed occurrences and preliminary simulations on said occurrences, would be that the fault current in Feeder 3 induces a zero-sequence current circulating in the closed loop formed by Feeders 1 and 2.

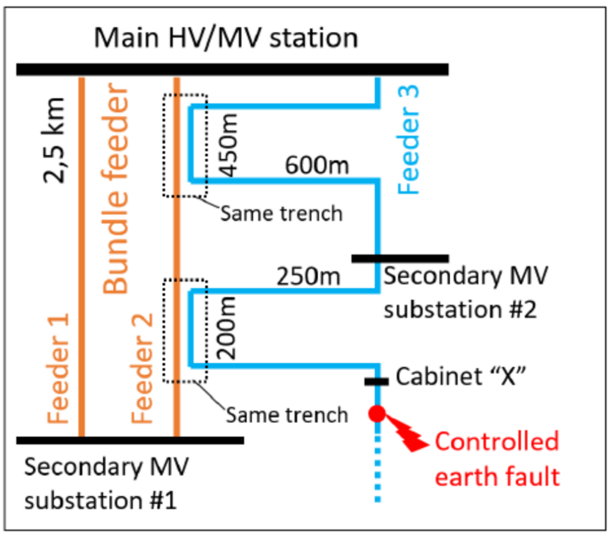

Fig. 46: Schematic of the use-case selected

Fig. 47: Cutting plyer used to perform an earth fault

A controlled single-phase earth fault was executed thanks to pneumatically controlled cutting plyers placed around one monopolar cable, as illustrated in Fig. 47.
Finally, and since the previous mitigation measures are not always obvious to implement and/or verify, a final solution to avoid false tripping of bundle feeders in case of a fault on another feeder could be to wisely adapt the zero-sequence time thresholds for tripping on the breakers of the bundle feeder.

Paper 628 from Finland presents a concept where current circuit supervision is done in a substation level with new centralized protection system, by utilizing Six Sigma principles. This increases the overall visibility to the system and can be used for optimizing the scheduled testing procedures. The concept is tested based on data gathered from a substation pilot installation during a period of two years. In addition, recommendations are given for applicability of Six Sigma principles for measurement supervision, in terms of required data points and measurement intervals.
The main idea of the Centralized Protection and Control (CPC) concept is to move the protection and control functionality from multiple bay level devices to one central device within a substation, leaving only the process interface functionality in the bay level merging units (MU), see Fig. 48.

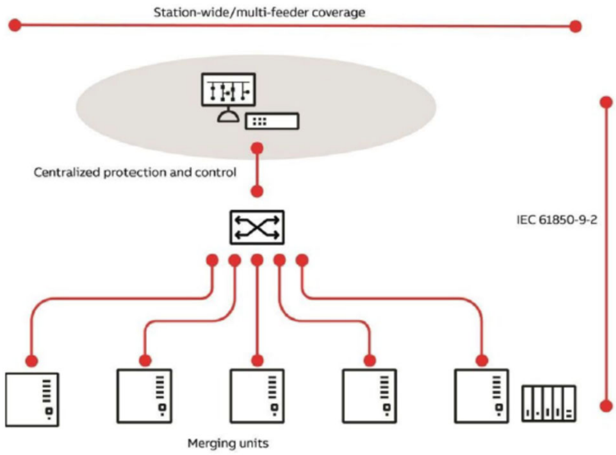

Fig. 48: Centralized Protection and Control concept

The method was tested based on data gathered from a pilot substation containing a CPC. The pilot was done on a 110kV/20kV substation with a double bus-bar and one power transformer. The substation had one incomer bay, one bus-coupler bay, bays for substation self-supply, one bay for capacitor bank and seven outgoing feeders. In total, the substation had 13 measurement points, so the CPC received simultaneously 13 separate IEC 61850-9-2 streams.

In paper 711 from Germany the “Impact of Changed Reactive Power Flows on Protection Relays in the Future Distribution Grid” is discussed. In this paper, the protection systems in two distribution grids are analyzed in more detail under the influence of a changed reactive power flow. Two types of protection systems are implemented on the lines of different busbars, which act as grid interconnection points to the overlaying grid operation. By changing the operating modes of the generation units – under- and over-excited – the future reactive power flow could be adjusted. The examinations of the OC relays in both DSO grids results in false tripping of the protection devices for a Power Factor (PF) of 0.7 cap. Following the analysis of the OC relays, the evaluation of the Distance relays is carried out. It could also be determined that in no study case the relays were triggered falsely. Furthermore, an investigation will be carried out to determine whether the protection devices in the transmission grid are influenced by the reactive power changes in the distribution grid.

Paper 743 from the Czech Republic is focused

on “Control and Protection of AC/DC Hybrid Microgrids”.
In this paper, an internal protection of hybrid inverter was tested in a laboratory experiment. The experiment was focused on measuring the short-circuit current at AC bus of hybrid inverter working in off-grid mode. The result of the experiment refers to collision between TN networks standards and real fault clearing time, which was significantly longer than 0.4 s. The paper includes proposed recommendation to solve this issue.

Paper 862 from The Netherlands describes meshed operation of MV networks using intelligent RMU and innovative fault location. Traditionally, the Liander MV distribution networks have a meshed structure split into radial feeders by so called Normally Open Points (NOP). By implementing a combination of two technologies, intelligent Ring Main Unit (iRMU) and Smart Cable Guard (SCG), meshed operation of two or three feeders becomes feasible (Fig. 49). The intelligent Ring Main Unit with normally closed circuit-breakers is used to interconnect the feeders involved. The circuit breakers in this iRMU are controlled by fast operating protection. When a fault occurs these circuit breakers open almost immediately resulting in traditional radial operation, so the fault can be cleared using the default protection scheme. Smart Cable Guard is used to exactly locate the faulted cable section, resulting in fast isolation and network restoration. Measurements in an already operational meshed network confirm the expected advantages.

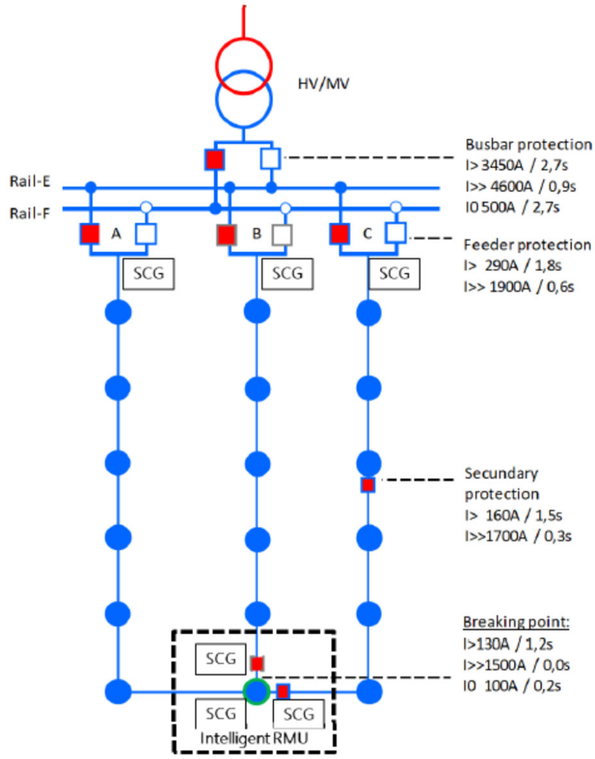

Fig. 49: Schematic view of a meshed operated network with the relevant protection settings and location of SCG

In paper 686 from Norway a mixed application of analog and process bus environment in transformer differential protection is tested.
The transformer differential protection (87T) operates based on the summation of current at all terminals as shown in Fig. 50. An inaccuracy in measurement acquisition or network delays in one of the terminals may cause delayed or nuisance trip signals.

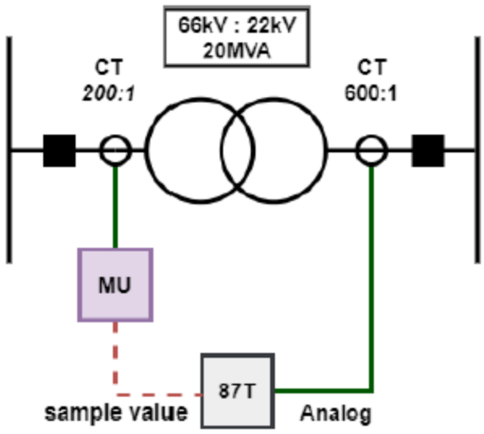

Fig. 50: Mixed application transformer differential
This paper tested differential protection in hybrid analog/digital mode with mixed vendors in a few

faults, operation, and switching scenarios Fig. 51. The results of the MU comparison show some deviations between vendors. This is particularly pronounced in the extracted 2nd and 5th harmonics used for inrush/over-excitation blocking. Although the protection IED operated correctly during inrush, internal/external faults with CT saturation, the protection relay had issues with inconsistent blocking of over-excitation. In addition, the result of network imperfection affected the protection IEDs and resulted in long delays in the relay response. The result obtained from this series of test indicates that some combination of vendors merging units in asymmetrical chain acquisition transformer protection may result in performance shortcomings. This shortcoming related to the blocking signal in over-excitation scenario.

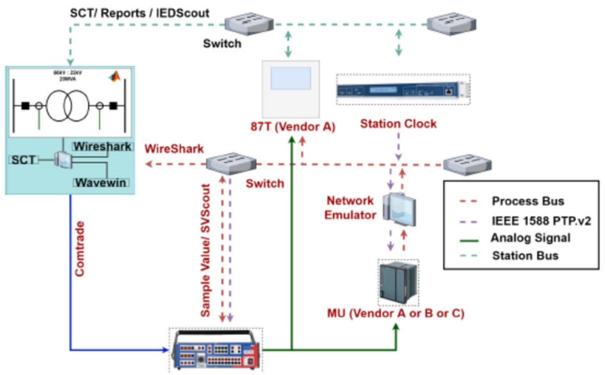

Fig. 51: Test setup for testing mixed-application of analog and process bus.

Analysis of fault condition caused by phase interruption of HV overhead line are presented in paper 815 coming from the Czech Republic.
The paper deals with the issue of single-phase interruption in HV distribution grid due to conductor rupture. Based on the real fault that occurred in the Czech distribution grid, a mathematical model was built to perform simulations and analysis of results were conducted. The main objective is to give recommendations to DSO how to identify this type of fault and reveal the risks of this fault for the grid operation.

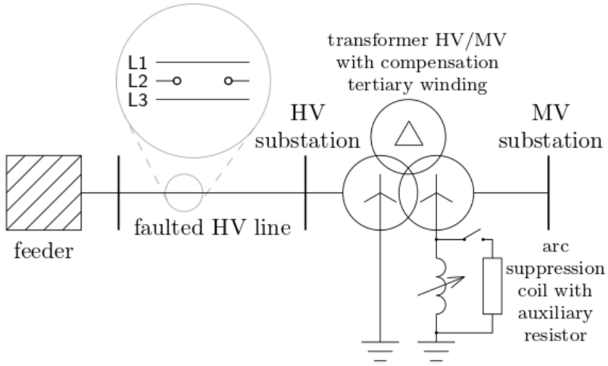

Fig. 52: Single-line diagram of the grid model

The grid model used for the study was based on the real grid configuration before failure, which can be simplified into a radial operation as shown in Fig. 52. Note that the HV (110 kV) grid is operated as solidly grounded, the MV (22 kV) grid is operated as impedance grounded through an arc suppression coil (ASC) with an auxiliary resistor RA (used for a short-time increase of an earth fault current), which is typical configuration applied for Czech MV grids where predominate overhead lines. Fault location is at the beginning of the line.
It is important to clearly distinguish between phase interruption on HV line and earth fault (EF) in MV grids. Key indicators are current unbalance on HV line and internal EF, i.e. EF is not identified on any MV feeder by EF protection. To prevent the grid from L-L overvoltage, it is important to control OLTC respecting level of all L-L voltages.

Sub block 3 “Algorithms & Simulations”
New developed algorithms or protection functions to solve challenges are presented in 4 papers of this sub block. Simulations are confirming the stability and functionality as a prerequisite for practical use. The commonality in this sub block is the development of new ideas and improvements in the field of protection.

Paper 169 from Egypt describes “An Innovated Adaptive Protection Algorithm for Distribution Networks Including DG Units”.
In this paper, an adaptive overcurrent protection algorithm is presented. The algorithm relies on modifying the conventional inverse overcurrent protection settings to adapt with the on-going changes within the network. The proposed algorithm was tested on IEEE 34 system using MATLAB /SIMULINK for various fault cases with different locations and different fault resistances. The simulation results show the effectiveness of

using the adaptive over current relay in reducing the operating time through all simulated cases with different fault resistance. Also, the adaptive relay is higher sensitivity for severe cases of high impedance faults.

Paper 221 from Sweden is focused on “The Real Time Voltage Calculation Method of Series Compensation Circuits for Time Domain Protection Solution”.
This paper proposes a real time calculation method which can be used to calculate the transient voltage waves during the fault period so that the core problem for the time domain distance protection based on compensated voltages calculated at reach point can be solved. It is obvious that the given real time calculation method for series compensation (SC) capacitor voltages is quite accurate to match the actual SC circuit voltage during the first 10ms period following the fault occurring time. Based on the given calculation, time domain protection with differential equations as given in equations could provide much accurate reaching point voltages so that the incremental voltages at the reach point could also be obtained with good accuracy in the first 10ms of the fault period. The given method has been verified with typical conditions of local compensated line and it could be used for time domain protection function for series compensated line protection purpose with accepted approximation for accurate calculation.

Modelling of active zero-sequence currents in distribution grids mixing overhead and underground segments is the title of paper 463 coming from France.
The DSOs face new challenges with the rapid development of the distribution grid and the extensive use of cables in some countries. In case of a different modelling options fault, they are more and more likely to meet a reconfiguration scheme where the system capacitive and active currents might be close to the acceptable limits required by protection scheme.
In this paper, we carry out a comparison of different modelling options with a few field measurements. To validate the accuracy of the proposed modelling options, a wider set of networks should be tested and correlated with field measurements.

Paper 789 from Germany presents a new version of the DEFIT (Determination of Earth Fault Inception Time) algorithm whose task is to determine the inception time of earth faults.
The task of the Detection Earth Fault algorithm is to check for each sampling point t_k whether there is a transient event, which may be an earth fault. Input variable of the algorithm is the zero-sequence voltage U_0. Consequently, transient events that do not affect the fundamental frequency component of the zero-sequence voltage are not detected. Examples for such transient events are short-time arcs and switching operations at other locations in the system.
The difference in the zero-sequence voltage U0 at sampling point t_k with respect to the preceding sampling point t_k - T_{DEF} is calculated according to equation (2). For this calculation, the time T_{DEF} should be chosen as a multiple of the period T of the fundamental component.

$$\Delta U_0(t_k) = U_0(t_k) - U_0(t_k - T_{\mathrm{DEF}}) \qquad (2)$$

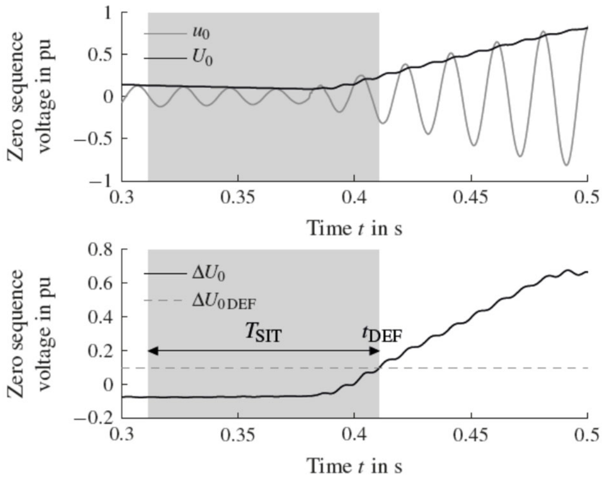

Fig. 53: Detection Earth Fault algorithm

This difference is compared with the threshold $\Delta U_{0\ \mathrm{DEF}}$, as depicted in Fig. 53. The sampling point t_k at which the difference in the zero-sequence voltage ΔU_0 exceeds the threshold $\Delta U_{0\ \mathrm{DEF}}$ is set as the start time t_{DEF} for the Search Inception Time algorithm.
Being tested with several thousand records, the new version of the DEFIT algorithm shows very good results for a wide range of different transient events.

Table 3: Block PROTECTION

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
Sub block 1: Fault Location / Earth Fault				
0003 Electric arc during power system fault is not pure resistance. Why it contains "inductance"?		X		
0074 Ultra-sensitive localization and neutralization of low and high impedance earth faults in distribution networks				X
0234 Earth voltage rise in MV networks - Holistic simulations evaluation and field tests validation				X
0240 Optimized solutions for MV neutral treatment and earth fault detection				X
0253 Practical use of a new method of arc suppression coil tuning.				X
0324 Cross-Country faults in Resonant-Earthed Networks				X
0420 Fault location by TDR (Time Domain Reflectometry) measurement using pulse waves for underground systems				X
0455 Faulty phase earthing as an alternative to autoreclosing in resistor earthed networks				X
0491 Power systems with massive insertion of distributed resources: impacts on distribution grids				X
0501 Improving earth-fault detection performance and supply security of cabled rural MV-Network using galvanic isolation				X
0600 New Method for Measuring the Earthfault-Distance in Compensated and Isolated Networks		X		
0608 New Knowledge of the Extinguishing of the Freely Burning Arc in Compensated and Isolated Networks		X		
0716 Transient Earth Fault protection based on instantaneous values				X
0732 Advanced earth fault detection on arc suppression coil earthed networks				X
0894 Earth fault localization in isolated uninterruptible power supply (UPS) networks – a new approach				X
0922 Genetic Algorithm for Placement of IEDs for Fault Location in Smart Distribution Grids				X
0936 Practical proof of cable shield and equipment loads as well as the correct functioning of selective earth fault location through decentralized compensation in urban medium-voltage networks		X		
1074 An experience of addressing high impedance faults in power distribution networks through smart meters' alarms				X
Sub block 2: Applications				
0058 Plug-and-play protection: A solution against protection scheme design complexity in modern active distribution systems				X
0066 Implementation of non-cascade protection system on switchgear using the half down section method				X
0236 Friendly tripping of an MV bundle feeder due to inductive coupling				X
0334 Designing a 5G based Smart Distribution Grid Protection System				X
0628 Application of advanced current measurement condition monitoring method with centralized protection and control solution				X

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
	Sub block 2: Applications				
0686	Interoperability testing of conventional and process bus technologies in differential protection schemes		X		
0711	Impact of changed reactive power flows on protection relays in the future distribution grid				X
0743	Control and Protection of AC/DC Hybrid Microgrids				X
0815	Analysis of fault condition caused by phase interruption of HV overhead line			X	
0862	Meshed operation of MV networks using intelligent RMU and innovative Fault Location				X
0974	How to improve reliability on an IEC 61850 substation				X
1130	Functional specification of protection, automation & control applications based on IEC 61850 independent of their implementation				X
1135	Redundancy for Power Utility Communication Networks				X
	Sub block 3: Algorithms & Simulations				
0169	An Innovated Adaptive Protection Algorithm for Distribution Networks Including DG Units				X
0221	The real time voltage calculation method of series compensation circuits for time domain protection solutions				X
0463	Modeling of active currents in distribution grids mixing overhead and underground segments				X
0789	New Algorithm for Determining the Inception Time of Earth Faults in Resonant Earthed Neutral Systems - Improving the Sensitivity of Detecting High Impedance Earth Faults		X		