Special Report - Session 3
OPERATION, CONTROL AND PROTECTION

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Introduction

For CIRED 2017 about 350 abstracts have been received in Session 3 showing the still enormous need of further development in the area of operation, control and protection of distribution grids. Due to the high number of abstracts, Chairman and Rapporteurs of Session 3 had to be –once again– quite strict in rejecting papers. Since the quality of abstracts and full papers has been constantly increasing during the last years, even well written abstracts had to be rejected in order to keep a manageable number of papers during the conference

Therefore 175 abstracts –about half of the proposals–were accepted by National Committees and the Technical Committee (TC). Finally 156 full papers have been accepted for Session 3.

Fig. 1 gives an overview of the review process.

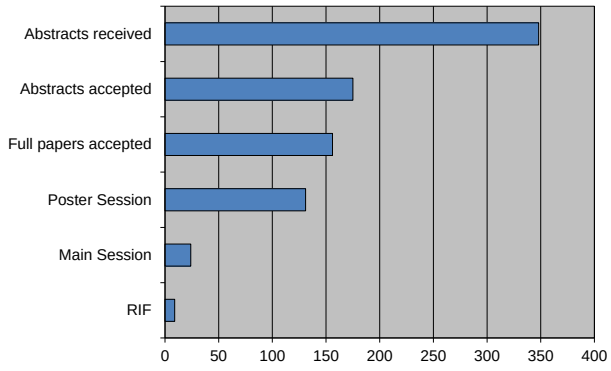

Fig. 1: Review process overview

All authors are asked for a poster presentation during CIRED 2017, 24 of them will additionally present their paper in the Main Session and nine papers are allocated to the Research and Innovation Forums (RIF).

Traditionally and according to the topics of the papers submitted, Session 3 is structured into three blocks, each one divided into three to six sub blocks:

Block 1 Operation

- Maintenance and Condition Assessment
- Distribution Management
- Crisis- and Workforce-Management
- Ancillary Services on Distribution Level

Block 2 Control

- Medium-Voltage Automation
- Low-Voltage Automation
- SCADA / Distribution Management Systems
- Communication
- Islanding
- IEC 61850

Block 3 Protection

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

Grid **operation** is very significant to guaranty the supply of electrical energy. New developments and operational IT based Distribution Management Systems are the most discussed topics in the operation block. One focus is the load forecasting with distributed energy resources with the goal reduction of losses.

But also Crisis- and Workforce Management is an important part of operation. More and more extreme weather caprioles

are the trigger for new strategies how to manage crisis and forecast fault situations in the distribution grid.

The subject Condition Assessment and Maintenance has been established. Once again a lot of papers have been submitted for this topic. Nevertheless it is a major problem because most maintenance and renewal strategies are fundamentally based on a correct assessment of the component condition.

A new and upcoming topic of operation is the Ancillary System Service on Distribution Level. Caused by decentralized renewal generation in MV and LV grids ancillary services are more and more important to stabilize the grid.

One major aspects of the contributions in block **control** covers the funded project ELECTRA IPR. In the sub block medium-voltage automation and SCADA/distribution management systems several papers. Another main focus of the papers is still the method of self-healing grid. This topic is highlighted in nearly all sub block. Islanding is still a topic, compared to previous conferences the papers do not describe the detection of islands but the operation of islanded grids and microgrids.

The **protection** block covers new applications of established protection concepts, several types of fault locations (e.g. earth faults, high impedance faults), new algorithms and simulations and the new sub block fault ride through. For a long time the topic "fault location" is a wide field of developments, simulations and practical experiments. New protection algorithms and strategies are developed and shown in simulations as well as in applications. Applications and practical tests are very interesting and most important to support new protection devices and systems.

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

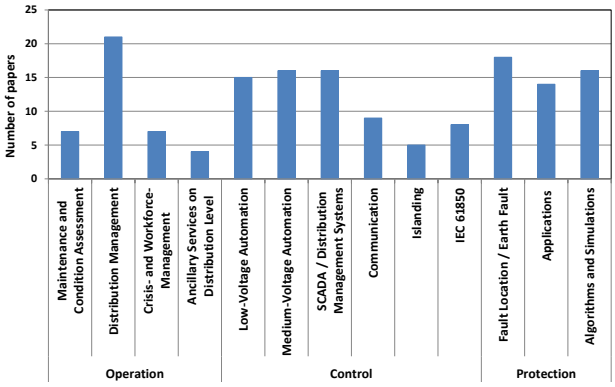

Fig. 2: Paper overview of blocks and sub blocks

Block 1: "Operation"

Significant for the operation block are the widely dispersed tasks in operating distribution grids. 39 papers were received in this block, covering several issues in the area of grid operation. For giving a better overview, this block is divided into four sub blocks:

- Distribution Management
- Crisis- and Workforce Management
- Condition Assessment and Maintenance
- Ancillary Services on Distribution Level

Sub block "Distribution Management"

The major number of papers is related to the sub block "Distribution Management". 21 papers where received coming from the UK, Canada, the Netherlands, Germany, Portugal, Italy, Finland, Belgium, France, Spain, Egypt, Japan, Russian Federation and Austria.

Paper 0040 from France describes the approach for the roll-out of technical smart grid industrial solutions. The *Enedis* roadmap shows two main objectives, modernise network management processes and infrastructures and to provide assistance to stakeholders of the electric power system and regional power systems in the French energy transition. The Smart Grid roadmap is continuously enriched with new use cases and new solutions.
In paper 0168, coming from the UK, the performance of a 33kV distribution grid with a proposed medium voltage DC link between the island of Anglesey and the mainland in North Wales was assessed. This work found that the use of an MV-DC link increased the MV network´s DG hosting capacity, but the network losses depend on the load and generation conditions and control strategy.
The focus of paper 0190 from the UK and paper 0209 from Austria is on reducing technical losses on a very different way. Paper 0190 proposes a means by which the effectiveness of CVR (Conservation Voltage Reduction) in reducing technical losses can be better quantified in the presence of harmonic current and voltage distortion. It is argued that the classic approach to ZIP load modelling can be extended to incorporate a metric for THD_I (Total Harmonic Current Distortion) which may be modelled as a function of applied voltage in a similar manner to that of P and Q. Paper 0209 describes a simple tool for power flow calculations on medium voltage network lines with the goal to calculate the network losses for every single MV-line in a fast way with sufficient accuracy and how to combine this tool with a forecast tool.
Paper 0298 from Japan, presents a method how to find faulty points on power lines in distribution grids. The proposed method combines the existing estimation based on

the phase plane trajectory with statistical analysis for estimating causes of faults from current waveform data when a power failure occurs on a distribution line.
A study on load forecasting using statistical analysis is presented in paper 0304 coming from Japan. The accuracy of load current forecast in a specified zone in a distribution system is examined in this paper, using the load forecast method and measurement data.
In paper 0325 from Belgium a convex power flow model for scalable electricity market modelling is shown. Within a Smart-Net project, the idea is to consider the grid´s physical behaviour in market clearing approaches.
Paper 0423 from Canada discusses the challenges of modelling large distribution networks, characterized by tightly coupled transmission lines, unbalanced phase loads and power electronic interfaces generating sources, on a real time simulator. The steady state results are compared against a non-real time simulation tool and the published IEEE data to validate the accuracy of the modelling approach taken.
The correlation between failure rates and different weather factors is discussed in paper 0610 from the Netherlands. Historical weather and failure records of a Dutch Distribution System Operator (Aliander) are analysed and verified using data set from recent component failures.
Paper 0649 from the UK indicates that asset condition information can have a positive impact on network operation. This is illustrated by a case study, where a number of network reconfigurations are examines in a representative distribution network and the results show that by taking asset condition information into account (Fig. 1), then an improved operation of the network can be achieved.

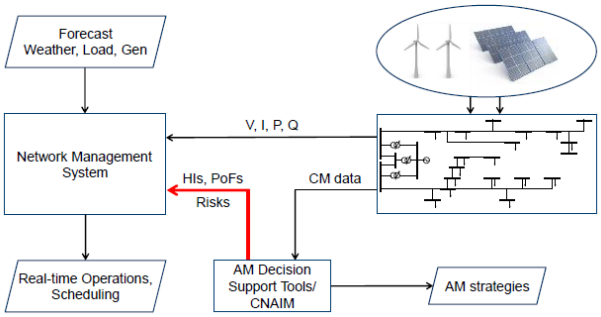

Fig. 1: Integrated Asset Management and Network Operation Concept

In paper 0660 from Portugal presents a reliable system to monitor and control street lighting in the grid of the Portuguese DSO (EDO and EFACEC). An architecture overview and some details about the implementation of the central management system are shown in this paper.
Self-healing is the focus of paper 0712 from Egypt. This paper suggests a simple control technique for self-healing with intelligent switching for distribution networks (IEEE test feeder).
Paper 0722 from Russia addresses analyses of a feedback of different fault indicator performance, based on data collected from the pilot projects in South East Asia and from the field tests provided by St. Petersburg suburb power distribution utility “Lenenergo”, Russia. The tests in real network conditions highlight the necessity of accurate study of the network before installing fault indicators.
In paper 0770 from France three complementary prototype tools which take advantage of augmented and virtual reality (Fig. 2) to help the field technicians to perform network operation in a more effective way and with an increased safety. A field-test program was conducted. The main outcome expected is to identify the new technical solutions capable of bringing in the short and medium term most value to the technicians in terms of performance and safety, and then to develop the corresponding operational tools and solutions.

Fig. 2: Technician equipped with augmented-reality glasses

Paper 0784 from Spain presents analysis of smart meter events, aimed to enhance low voltage network operation by the detection of voltage deviations, repetitive incidents or even outages prevention. The main challenge of using smart meters events is the vast amount of data.
Paper 0871 from the UK describes the operation of the Adaptive Power Restoration Scheme (APRS), a unified algorithmic approach to implementing self-healing networks in the event of an unplanned outage (fault) on the 11kV/6.6kV network.
In paper 0899 from the Netherlands is shown how Alliander carries out a large standardisation framework for primary, control and protection equipment and has chosen for separation of concerns when integrating the secondary systems into substations and distribution stations. Results, lessons learned and next steps are discussed in this paper.
Paper 0965 from Germany shows reference architecture for open, maintainable and secure software for the operation of energy networks. The goal of a consortium (openKONSEQUENZ) is to significantly reduce maintenance costs of their system-landscape by decreasing system complexity and vendor dependency as well as increasing software quality, usability and enhancing safety and security in critical infrastructures.
Paper 1037 from Finland presents how Helen Electricity Network Ltd managed to improve its electricity supply

reliability between the years 2008 and 2016. This was achieved by implementing six development tracks. The results of the development project have been even better than expected. Helen has reached its SAIDI level target by the year 2015.

Paper 1214 from France: DSOs have to face technical and economic issues, existing and new, while optimizing OPEX and CAPEX. In the same time, Internet of Things (IoT) technologies and connected things are emerging in Smart grid developments. The issue here is to develop new cloud services to have an easy and scalable LV grid management tool, similar to a LV SCADA. ESR (main regional DSO in France) and SOCOMEC started a project to explore a digital LV grid management. First results of 5-months operation expected in June.

In paper 1330 from Italy new operational criteria and challenges for the large scale deployment in the network of e-distributione are discussed. E-distribuzione has started to develop an innovative selection system of network failures, based on logic coordination between protection systems, in order to optimize the time equivalent of electrical fault extinction and consequently reduce the equivalent customer moment. This proposed solution will not modify the typical scheme of operation of MV distribution feeders.

Sub block "Crisis- and Workforce Management"

In this sub block we have 7 papers discussing the prevention and pre crisis plans of weather caused major disturbances in the electrical power supply.

Weather-related major power disruptions caused by storms, foods or other very extreme conditions are the topics of three papers from countries very different located.

Paper 0188 from Argentina describes an Emergency Operational Plan (EOP) implemented in the system of Argentina´s largest DSO (Edenor). The Pre Crisis Plan covers different types of climatological events in which the managers of several units must ensure the availability of staff and resources of the company as well as staff and resources of their suppliers.

Paper 0405 from the UK explores the journey that GB Distribution Network Operators have made over the past 15 years to improve the resilience of their networks to the risk of flooding (Fig. 3). It proposes how the lesson learnt from these incidents can be built into future resilience planning and policy on a national level with government and local stakeholders.

Fig. 3: Foot of tower 132kV following movement of river

Paper 0628 from Finland shows how crucial it is to have efficient coordination in major power disruptions and obtaining the right and up-to-date information when coordinating a situation during weather-related major power outages. This paper will present in detail the situational awareness tool which was designed to meet the requirements for the overall situation awareness.

The next four papers are dealing with Work Force Management (WFM).

Paper 0390 from the UK offers a vision of how electrical utilities will redesign their asset operations by placing mobile technology at the centre of their model.

In paper 0710 also coming from the UK is described in detail the new work processes being implemented at SP Energy Networks (SPEN) to move from a centralized to a de-centralized approach. The intent is to improve customer service, and use technology as an enabler to standardise process in the context of a changing workforce.

Paper 1203 from Brazil presents the application of a new real-time methodology for commercial and supply restoration service prioritization and crew dispatch for service assistance. The prioritization of services is based on a multi-criteria analysis method, named as MACBETH, whereas the Ant Colony Optimization metaheuristic algorithm is applied for crew dispatching.

Paper 1212 also coming from Brazil aims to describe a dashboard that presents relevant information to the operation, maintenance and planning of sub-transmission systems, underground distribution systems and aerial

distribution systems, developed as part of the "Smart Grid Project" of Brazilian utility AES Eletropaulo. Also, it was developed an application for smartphones containing information that were considered important to be viewed remotely by operators and field teams.

Sub block "Condition Assessment and Maintenance"

The main topics in this sub block are Preventive Maintenance, Monitoring on Operating Resources and Strategies of Condition Assessments. In this sub block we received 7 papers presenting maintenance strategies and new applications.

Paper 0195 from Japan explains the result of an experiment on Time Domain Reflectometry (TDR) in real-scale distribution system. It is attempt to apply a new method for locating faulty points by injecting high-frequency short pulse into overhead distribution line (Fig. 4). Through these experiments, we confirm this method is applicable to specify the fault point with high accuracy.

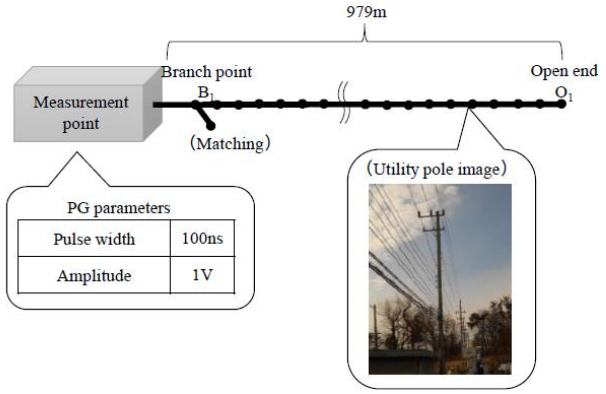

Fig. 4: Test circuit composition of real-scale distribution system

Paper 0426 from the UK describes how ScottishPower has been able to detect and locate the position of recurring faults on their LV network more accurately than with any other method, using a combination of the triggered TDR (Time Domain Reflectometry) and TRS methods of fault location. Both TDR and TRS methods have proved especially useful when addressing customer complaints of flickering lights, and equipment mal-functions, where there has been no supply interruptions reported. Flickering lights are usually an indication that transitory faults are taking place so their detection and location is essential to a 'pro-active' fault management strategy.

Paper 0290 is coming from Brazil presents the methodology developed or the analysis of inconsistencies in transmission and distribution lines. The results obtained so far, indicate that the methodology will succeed in Overhead Transmission Line (OHTL) inspection, due to the high quality of the images, allowing for identification of existing problems in the line components, thus significantly increasing the efficiency of inspections, mainly in areas of difficult access.

Paper 0711 from Japan describes a new system named DAMRAS (Distribution Asset Management and Replacement Assist System) that can collect and accumulate defective events without omission have also been developed, which can strengthen the analytical capability of such events and lead to formulating efficient maintenance measures. These systems are designed so that the field workers can carry out advanced maintenance operation precisely with less effort than ever.

In paper 0718 from Finland novel cloud based fleet analytics was utilized for advanced asset management. The target was to optimize the maintenance and testing procedures of the secondary system in primary distribution substations. The project was able to prove that some level of maintenance activities could be avoided by analysing process data from real fault incidents, and that cloud environment is suitable for performing required fleet analytics.

The goal of paper 0724 from Portugal is to present the field experiments of an Unmanned Aerial Vehicle (UAV) developed by EDP Labelec in partnership with INESC TEC. The paper details the EDP Labelec hexacopter UAV (Fig. 5) and its capability to perform autonomous inspection of electrical assets through visual and thermographic images.

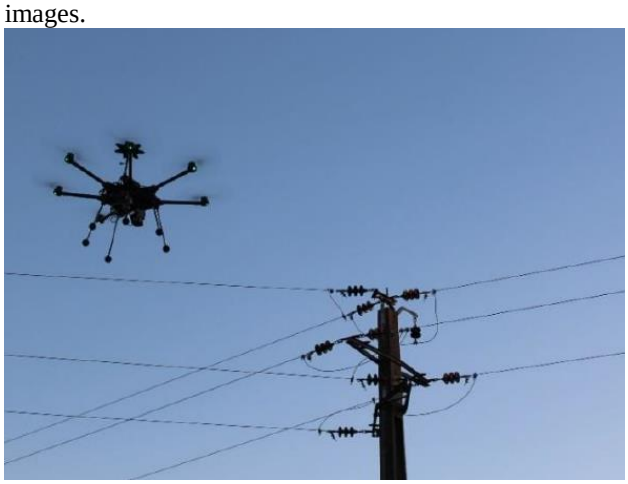

Fig. 5: UAV during an Aerial Power Line inspection

Since 2016, the UAV is already in operation by the EDP Labelec field teams to perform electric visual inspection.

Paper 1356 from the UK offers an overview of a through fault current (TFC) monitoring system and the results of a trial performed on a TERNA HV/MV transformer. The purpose of the trial was to detect over-currents and demonstrate that most events occur without the utility being aware. The record of such activities will allow ranking the transformer fleet, improving maintenance schedule, correlating multiple on-line data and extracting new parameters to be added to the TERNA Health Index.

TFC monitoring is a valuable feature for TERNA to rank the transformers based on external event occurrences. Data

can be then correlated to other on-line diagnostic parameters, especially DGA, to plan condition-based off-line tests and maintenance.

Sub block "Ancillary Services on Distribution Level"

Ancillary Services on Distribution Level is a new sub block and covers several services supporting the TSO operation for stabilising the grid.
Paper 0414 from France aims to propose a joint DSO-TSO coordination for reactive power management within a HV grid based on an Optimal Power Flow (OPF) technique.
The objectives of the control are to maintain a suitable HV voltages profile while limiting the EHV/HV reactive power exports. To this end, the control yields a reactive power target at each HV/MV interfaces. This target is then assumed to be considered by the real-time Volt Var Control (VVC) of MV grids that adjusts, among others, the reactive power references of distributed generation.
Paper 1033 from Austria aims to analyse, define and describe common requirements focusing on a technical, stakeholder and market perspective. The project DeCAS (Demonstration of Coordinated Ancillary Services) (Fig. 6) develops solutions for the coordinated activation of ancillary cross-voltage-level services considering the different objective functions of individual voltage levels.

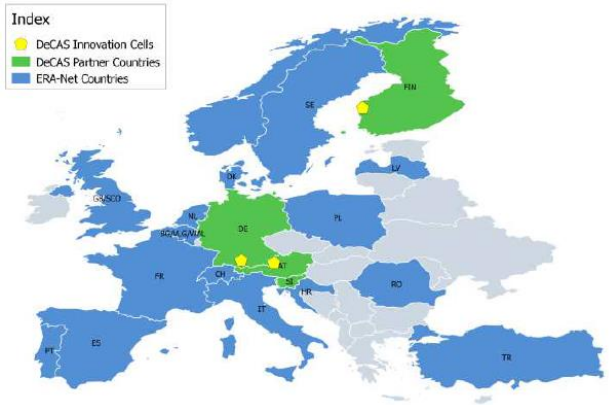

Fig. 6: Location of the DeCAS Innovation Cells

Paper 1182 from France describes the specific initiatives rolled out since 2014 in the frame of Operation and Control coordination between RTE and Enedis in both Operational Planning and Real time. The anticipated constraints on both sides at different time intervals by respective OP tools along with reinforced data exchanges should allow to make appropriate decisions to optimize HV and MV network functioning today and in the future.
Paper 1199 from the USA presents a methodology for addressing the problems faced in deploying microPMUs at the distribution level. The addition of DER on low and medium voltage networks, combined with lack of visibility of the real-time state of distribution networks, makes it difficult for transmission system operators to have visibility of the network beyond the grid supply points. A solution to this is to install µPMUs at the distribution level to provide increased visibility within WAMS.

Table 1: Papers of Block 1 "Operation" assigned to the Session 3

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Distribution Management					
0040	Enedis approach for the roll-out of technical smart grid industrial solutions				
0168	Control Strategies of VSCs in an MVDC-link in a 33 kV Distribution Network			X	
0190	Enhanced ZIP Load Modelling for the Analysis of Harmonic Distortion under Conservation Voltage Reduction			X	
0209	Loss Estimation of Medium Voltage Lines based on Real and Synthetic Load Profiles				
0298	A Study for Cause Estimation of Faults using Statics Analysis				
0304	A Study on load current forecasting using Statistical Analysis				
0325	Convex power flow models for scalable electricity market modelling				
0423	Real-Time Simulation of Large Distribution Networks with Distributed Energy Resources				
0610	Risk Prediction in Distribution Networks based on the Relation between Weather and (Underground) Component Failure				
0649	Incorporating Asset Management into Power System Operations				
0660	SmartIP - Central Management System for Public Lighting in Portugal				
0712	Smart Fault Management Scheme for Electrical Distribution Networks				
0722	Evaluation of practical experience of Fault Indicator performance in Medium Voltage Networks				
0770	Enedis field experience of augmented and virtual reality technologies at the service of network operators	X			
0784	Adopting Smart Meter Events as key data for Network Operation	X			
0871	Next-Generation Adaptive Network Restoration on Distribution Feeders				
0899	Standardization to reduce lifecycle cost and lead time with improved quality, efficiency and flexibility				
0965	A Reference Architecture for Open, Maintainable and Secure Software for the Operation of Energy Networks				
1037	Helen Electricity Network Ltd's Process Towards High Level of Supply Reliability				
1214	IOT Services for a Smart LV Grid Management				
1330	Smart Fault Selection: New Operational Criteria and Challenges for the Large Scale Deployment in e-distribuzione's Network				
Crisis and Workforce Management					
0188	Emergency Operational Plan – Crisis Situation Management				
0390	Creating a Mobile Centric Operational Model in Utilties				
0405	The Future of Flood Resilience for Electricity Distribution Infrastructure in Great Britain (GB)	X			

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Crisis and Workforce Management					
0628	Efficient Coordination in Major Power Disruption	X			
0710	De-Centralized Working for Outage Management, including Auto-dispatch				
1203	Service Prioritization and Crew Dispatch in an Electricity Utility				
1212	Dashboard and Smartphone Application to Support Operation and Plannning of Electric Distribution Systems				
Maintenance and condition assessment					
0195	TDR Measurement with Utility-Pole-Interval Resolution of Real-Scale Distribution System				
0290	Autonomous Inspection in Transmission and Distribution Power Lines - Methodology for Image Acquisition by Means of Unmanned Aircraft System and its Treatment and Storage				
0426	Locating the causes of recurrent supply interruptions and flickering lights on ScottishPower's low voltage cable network using travelling waves				
0711	Advancement in Maintenance Operation for Managing Various Types of Failure and Vastly Aging Facilities				
0718	Optimization of Secondary Testing with Cloud Based Fleet Analytics				
0724	Field Experiments in Power Line Inspection with an Unmanned Aerial Vehicle				
1356	Terna Fleet Management of Power Transformers: On-line Monitoring to Predict Winding Deformation and Plan Proper Maintenance				
Ancillary Services on Distribution Level					
0144	A joint TSO-DSO reactive power management for a HV system considering MV systems support	X			
1033	Requirements for coordinated ancillary services covering different voltage levels	X			
1182	DSO TSO Coordination Needs induced by Smart Grids: the Ongoing French Project between RTE and Enedis				
1199	Improving Actionable Observeability of Large Distribution Networks for Transmission Operators to Support Improved System control, Fault detection & Mitigation				

Block 2: „Control“

Block 2 covers all relevant topics for distribution system control methods within 69 papers. The complete control block is divided into the six subblocks where the main focus of the papers is on MV automation, LV automation and SCADA/distribution management systems:

- Medium-Voltage Automation
- Low-Voltage Automation
- SCADA / Distribution Management Systems
- Communication
- Islanding
- IEC 61850

Sub block “Medium-Voltage Automation”

16 papers have been selected for subblock “Medium Voltage automation”. In most of the papers the challenges for voltage control in power systems with high number of decentral generation unit are covered. Also the ELECTRA project war covered frequently and mostly by international teams of authors.

The Iranian Paper 0074 describes a self-healing function based on a multi-agent system design. Within this paper the benefits of microgrid system. The microgrid balance the consumption and generation in a total system by balancing the load demand of the single microgrids. The author explains the behaviour by a simulation of a 4 feeder (1069 node) example network.

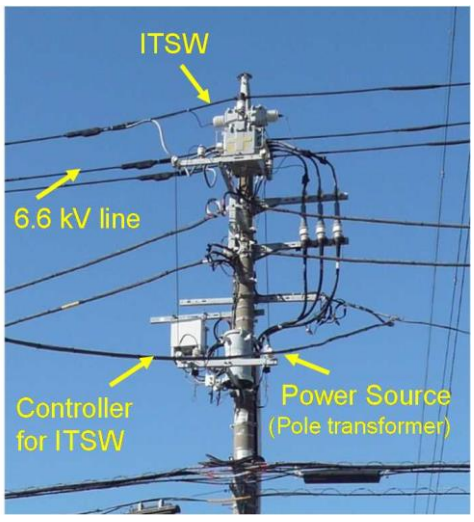

Fig. 7: Overall view of Switch (Paper 0150)

Especially in large networks self healing becomes more and more interesting. The Chinese authors of paper 0511 show the self-healing by using distributed intelligence. This include the self recognition of the network as wells as fault location, isolation and service restoration process. The paper also describes the pilot project installation.

Also the Norwegian paper 0883 is covering the intelligent handling of faults. The paper present first result from a pilot project on using fault indicators and self-healing and it compares five different automation cases from case 1 with no sensors up to case 5 with a fully automated system.

Voltage control is one of the most important aspects in existing power system with high penetration of decentralized generation. This aspect is covered by the Japanese paper 0150 that shows a field demonstration and evaluation of a central voltage control. Fig. 7 shows the installation of equipment with the Information Technology Switch (ITSW).

Voltage stability is also the main topic of paper 0297. The Austrian researchers of the University of Graz show the usage of the Thevenin impedance for voltage stability monitoring methods. The real-time calculation only requires system topology information as well as PMU and SCADA data. The paper descirbes in detail who the Thevenin impedance will be used and show the analysis for 9 bus netwok.

Paper 0948 presents a novel method for the combined control of OLTCs and local installed compensation equipment with the consideration on holding the voltage stability margin in the required limit. Also this paper uses the Thevenin impedance for the voltage control algorithm.

Another pilot project is described in paper 151 from Belgium. The DSO Eandis started an intelligent control of a wind turbine to increase the utilization of a power system. The monitoring system can by used by wind farm operators to optimize the infeed.

A very interesting aspect of network automation is the interation of MV and LV automation functions. The topic is covered by the German paper 0538. The presented results demonstrate that a LV smart grid system can be a useful and reliable MV actuator. The possible actuator flexibility of the LV system can be easily implemented into a MV control strategy.

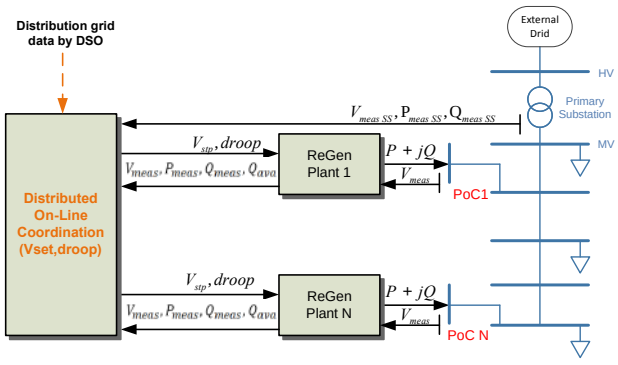

Fig. 8: Scheme for Distributed On-Line Coordination (Paper 0554)

Paper 0554 from Denmark focusses on distributed voltage control coordination between renewable generation plants in medium voltage distribution grids. In this paper it is shown that reactive power provision increases the power losses in the grid to a significant extent. A real-time coordination concept is developed which utilizes communication systems with on-line signal exchange between the assets. Fig. 8 shows the scheme for distributed on-line coordination.

Paper 0914 describes the central voltage control system, aiming to optimise the network voltages and release network capacity by dynamically adjusting the previously static target voltage settings of substations' voltage control relays. This paper is based on learning to date from Western Power Distribution's (WPD) Tier-2 Low Carbon Networks (LCN) Fund project, Network Equilibrium.

The authors of paper 0946 simulated a MVDC link under faulted and normal conditions. This link offers the flexibility by decoupling P and Q power flows.

The paper 0615 from USA present two visualizations of the controllability of substation voltage in a multiphase distribution network with distributed energy resources (DER). We utilize a linearized unbalanced power flow model to formulate a mathematical program that determines the voltage feasibility and cost to move substation voltages.

One focus of papers are based on the **ELECTRA project** and **web-of-cells**. Authors from Spain, Turkey, Belgium and Austria described a voltage control strategy design with the research project (paper 0749). The so-called Post-Primary Voltage Control (PPVC), aims to keep the node voltages at any time within the bands de- fined by the regulations and to minimize the power losses in the system by calculating the optimal voltage set-points for the different nodes.

Also in the content of ELECTRA paper 0788 from Greece, UK, Belgium and Denmark deals with the Frequency Containment Control use case and, in particular, its implementation in the context of operation constraints imposed by different system conditions. The paper shows the web-of-cell program and the fuzzy control as well as the positive simulation results.

Paper 0904 presents the research and development results on grid state forecasting, a structural and algorithmic approach (CARMA-Algorithm) with a practical scope of application. The German authors focus on a modular bottom- up concept and a smart time series analysis for implementation purposes on a decentralized autarkic grid automation system.

In paper 1057 the authors share the experience they gained in the field of Medium Voltage (MV) distribution automation, with particular focus on the use of Low Power Instrument Transformers (a.k.a. sensors) and their implications from the perspective of safety, installation procedures, accuracy, standardisation, interoperability etc. The paper presents the key learnings from several small pilots and one massive scale project, IBERDROLA's STAR project, a smart grids project aiming to provide automation solutions for a MV network of 90,000 secondary substations which is entering its final stage after 6 years.

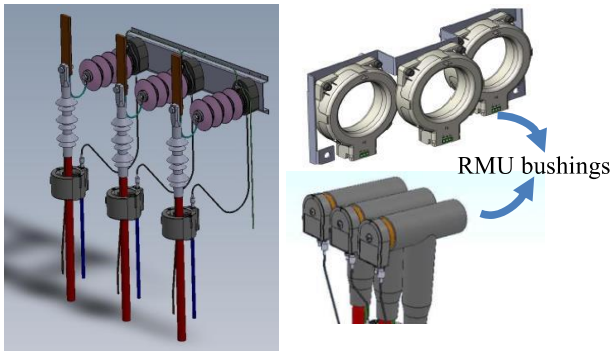

Fig. 9: Installation in AIS (left) and GS (right) RMUs (Paper 1057)

Sub block "Low-Voltage Automation"

15 paper cover the low-voltage automation. Main focus is on increasing the utilization of equipment and the voltage control.

Paper 143 from Czech Republic deal with the design and operation of intelligent RMUs equipped with transformater with on load tap changes. The paper demonstrated the installation and operation of smart substations (see fig. 10).

Fig. 10: Substation MV/LV Jarohnevice with the transformer FITforemer REG (Paper 0143)

Energy storage can be an alternative to traditional conventional power system reinforcements. Paper 0481 presents two control algorithms used with an energy storage device deployed as part of New Thames Valley Vision Project. The two algorithms are aimed at equalising phase loading with correction of power factor and providing voltage support with an algorithm for active and reactive power control.

Due to the increasing number of decentralized generation it is important to manage the infeed of units. Paper 0490 from UK shows an active network management system for low voltage networks. The system has successfully connected 200kW of renewable generation whilst maintaining network voltages within statutory limits.

Unsymmetrical conditions a typical for low voltage connections of decentral small generation. Paper 0599 proposes a hybrid voltage control regulator to control each phase separately. Numerical simulations that validate the proposed method are shown in this paper.

The large potential of smart meters for wide area voltage control is demonstrated in paper 0678 from Japan. The selection method of representative smart meters and voltage control utilizing smart meters is studied, and the performance of the voltage control is evaluated.

From Greece and Denmark paper 0686 investigated the loss of inertia or implementation of synthetic inertia taking into account that electric vehicles can be used to provide the fast regulation services. The paper evaluates and experimentally shows the capability and limits of EVs in providing synthetic inertia services.

Paper 0792 from Poland shows the management and control of LV networks of the UPGRID project. The UPGRID project intends to develop and demonstrate a new level of monitoring and control for the MV and LV grids that is essential to leverage a smooth integration of DER and engage end user to participate in the new power system operation paradigm.

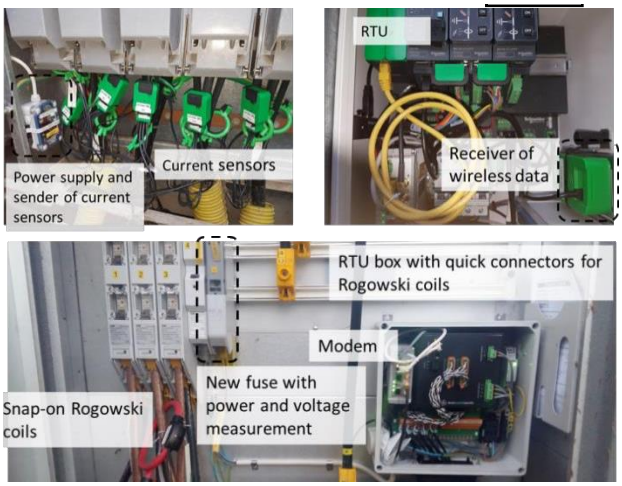

Fig. 11: RTUs with wireless LV sensors and snap-on Rogowski coils (Paper 0966)

Another UPGRID demonstration is shown in paper 0966. This paper describes a practical demonstration of low and medium voltage network monitoring through information exchange between metering, SCADA and network information systems to increase observability of the network for operators, and provide more information for network planners. Practical experiences and recommendations for secondary substation retrofitting are provided based on 18 installations of remote terminal units, fault locators and line sensors in 10/0.4 kV secondary substations (see fig. 11).

Another field test has been done in the Netherlands. Paper 1026 of the University Eindhoven describes a real field implementation of an on-load tap changer based smart solution in a rural Slovenian LV network. The field trail revealed that redundancy and cyber security are the main concerns for DSO.

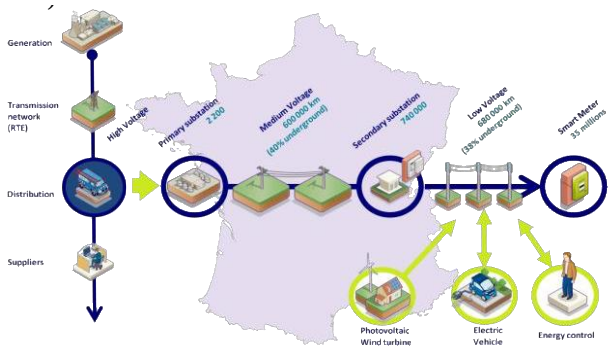

Fig. 12: Schematic drawing of network operated by Enedis (Paper 1060)

The paper 1060 also shows an implementation. In the scope of the French smart grid demonstrator GreenLys, and in order to limit voltage variations, an on-load tap changer has been experimented in a secondary substation in Lyon since November 2015. It has been associated through Power Line Communication with several voltage sensors wisely placed on the LV network to get a precise vision of the voltage on the network fed by the transformer (see fig. 12).

Smart City Demo Aspern is a demonstrateon smart grid infrastructure in Vienna. The Austrian authors of paper 1080 prensents an approach of smart grid application and shows the interaction and first application results and field experiences. The main focus of the paper is plug-and-play application and its benefits. It describes several applications used in Aspern in detail.

The step from network operation to the consumer is covered by paper 1192 from UK. This paper highlights the impact of smart building within heavily utilized networks. The impact of demand-side response is shown by integrating 10 city centre building of this year's CIRED hosting city Glasgow. For building that demand-side response was implemented, grid relevant load reductions of 20& of controllable load were seen.

A control system for microgrids is presented in paper 1220 from UK and France. This paper introduces a perspective on automated control systems applied in a microgrid.

Sub block "SCADA/Distribution Management Systems"

16 papers cover the topic SCADA & Distribution Management systems. In this field five paper presenting results of the ELECTRA IPR. A second topics is self-healing.

The first paper of the CIRED conference 2017 (paper 0001) from Austria introduces an Integrated Grid Management System using a SCADA-approach including the high-, medium- and low-voltage level to further optimize the workflow for distribution grid operation. It deals with the new challenges and possibilities of a fully centralized grid operation system using digital data from various sources such as SAP, Workforce Management, Geographical Information Systems, Meter Data Management and customer applications.

"Data analytics for automated fault diagnosis and prognosis" is the topic of paper 0262. This paper details the design and development of an automated decision support system for fault diagnosis and prognosis, which can detect and diagnose evolving faults by analysing PMAR data and corresponding SCADA alarm data.

Paper 0301 form Germany and Belgium and explains the using of synchrophasors in distribution networks for synchronized switching. The paper shows the results of a pilot phase in Brussels has been shown.

Reports of real implementation and testing is one major interest of CIRED conference and paper 0379 covers this by an implementation of decentralized grid operation. The group of German, French, British and Spanish authors show a field test of one of the main demonstrators in the EU-funded project DREAM.

The Portugese authors of paper 0397 presents smart SCADA data analysis tools and the benefits in grid operation as it simplifies dispatching centres activities. These tools also come in handy to identify problems such as circuit breakers failures or protection relays malfunctions in a much easier and automatic way, thus, helping to assess the reliability of the protection system with direct impact on grid operation.

Paper 0484 from Austria Belgium, Italy, Spain and UK describes a decentralized control scheme for reserves activations in the future (2030+) power system. The proposed **Web-of-Cells** concept has been developed within the European **ELECTRA** Integrated Research Programme on smart grids. This paper shows a detail overview about the web-of-cells concepts.

Web-of-Cells is also the main focus of paper 0613. The authors analyse the operator point of view of the Web-of-Cells concept defined in the EU project ELECTRA, by identifying operator tasks into the supervision of a highly automated power system, and the information requirements to facilitate appropriate operator situation awareness.

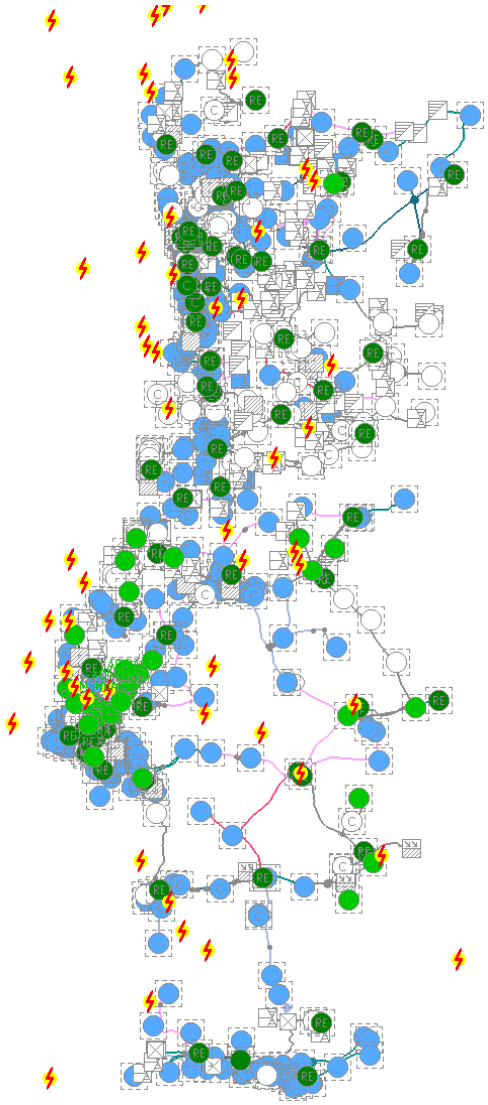

Fig. 13: Geographical distribution of lightning strikes over one week on Spring overlap with the HV network representation (Paper 0397)

The future requirements for control center is also a topic in the ELECTRA IPR project. Paper 0772 outlines an overview of the requirements for control rooms. The roles and activities in the future control centres will evolve with respect to the switching, dispatching and restoration functions currently active. The control centre operators will supervise on the power system and intervene - when necessary - thanks to the maturation and wide scale deployment of flexible controls.

Operating power systems is an extremely challenging task, not least because power systems have become highly interconnected, as well as the range of network issues that can occur. It is therefore a necessity to develop decision support systems and visualisation that can effectively support the human operators for decision- making in the complex and dynamic environment of future highly automated power system. Paper 1107 aims to investigate the decision support functions associated with frequency deviation events for the proposed web-of-cells concept.

Another paper about the result of the ELECTRA project ist paper 1363. This work is focused on short-term frequency behaviour and it is part of the ELECTRA IRP European Project studies on novel observability and control concepts for future power systems characterized by high levels of generation from Renewable Energy Sources (RES).

Self-Healing is not only an automation function it has also to be considered in the control centers. The Indian paper 0923 describes the impact of self-heal in Tata Power distribution grids and the experience of more than one years implementation.

The Brazilian paper 0945 introduces an alarm processing without using any connectivity information of the substation electrical network. In order to do so, timestamp and location readily defines specific alarm patterns. The fast alarm processing allows fast recognition of the most important events in a substation: typically, more than 70% of the alarms belong to the three groups presented in this paper.

Greece authors of paper 1014 presenting the consideration of a modernization of existing SCADA system. Especially the modernization of information and communication technology is in the main focus of this paper. The paper presents the current state of the most important ICT systemsof the DSO, in an attempt to point out the diversity and complexity of the ICT infrastructure of such a large organization, and, then, it proposes the implementation of the Enterprise Service Bus (ESB) approach.

Operating power systems is an extremely challenging task, not least because power systems have become highly interconnected, as well as the range of network issues that can occur. It is therefore a necessity to develop decision support systems and visualisation that can effectively support the human operators for decision- making in the complex and dynamic environment of future highly automated power system. Paper 1107 aims to investigate the decision support functions associated with frequency deviation events for the proposed web-of-cells concept.

The French paper 1169 is presenting intelligent network assets supervision and control. It describes the renovation project – so called herafter i3C as intelligent Control, Command Coordination project - in all its aspects from initial genesis to the actual status of prototypes. It fully addresses the emergence of a “Management System “ infrastructure, widely based on standards introduction (IEC 61850-61968) - while highlighting their limitations and their necessary evolutions to cover the Smart Grids emerging needs.

E-distributione of ENEL group is presenting improvements of MV grid control, remote operations and reliability through advanced TLC network and SCADA architecture in paper 1341. The paper shows that DSO’s networks play a leading role in data acquisition, integration and processing to manage energy flows, automatic grid configuration, renewable DG dispatching and power losses optimization.

Fig. 14: Grid Area Subdivision, Server Farms, MCR and SCR (Paper 1341)

Sub block “Communication”

The sub block Communications is presented by 9 papers. Most of the paper cover the questions about performance and cyber security. One paper shows the needs for monitoring the system. In all cases the papers show the results of field test.

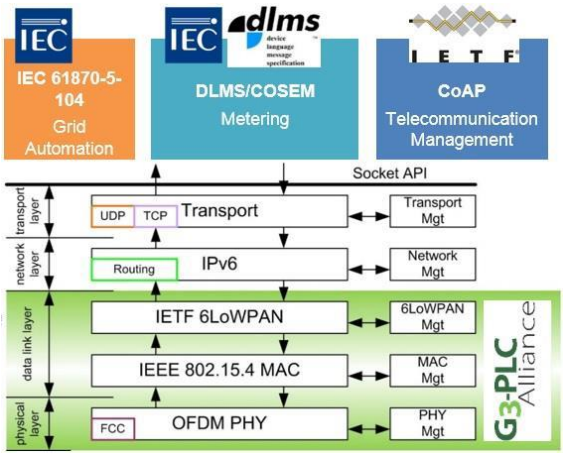

Fig. 15: MV G3-PLC communication profile (paper 0081)

The French paper 0081 shows an experimental project. The authors committed their expertise to solve the technical challenges inherent to the project's aim: develop a full IPv6 G3-PLC telecommunication infrastructure covering both medium voltage (MV) and low voltage (LV) grids to support smart grid and smart metering use cases. Different specific to heterogeneous use cases related to MV and LV smart grid, smart metering and telecommunications management are carried over a same G3-PLC-based multi-service telecommunication infrastructure.

Paper 0167 gives an overview of remote management and its practice. This paper focuses on the opportunities which are based on adaption of IP based telecommunication protocols IEC 60870-5-104 and IEC 61850.

Another field test is presented by Brazilian authors. Paper 0183 is about the ELEKTRO pilot project. The target of this project is to reduce local SAIDI (System Average Interruption Duration Index) with a new concept of grid automation. By the end of 2016, a total of 163 systems were in operation within a park of 1660 telecontrolled reclosers inside operational area, with an amount of 90% of this equipment communicating by GPRS to the Operational Center. Based on the results the DSO developed an expansion strategy with local automation server and one operational center. The ICT infrastructure will be changed from GPRS to private fiber or licensed radio.

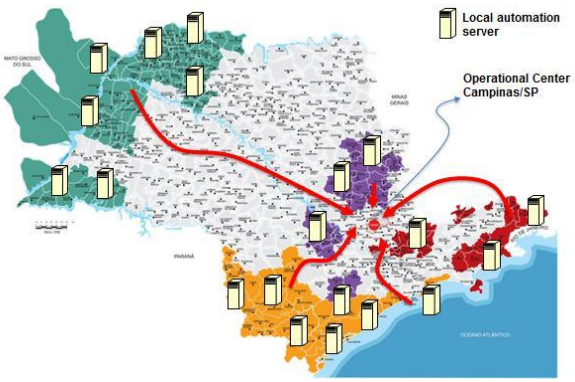

Fig. 16: Expansion strategy for next years. Private local communications and one automation server per city (paper 0183)

Paper 0302 discuss the PLC communication for smart meter integration. The Japanese authors show there experience of the past 9 years with an installed base of 7 million smart meters.

An aspect with increasing importance for communication concepts is the cyber security. Paper 0980 discusses alternative fault location, isolation and system restoration placements in terms of cyber security . the paper compares centralized, decentralized and local self-healing configurations.

Also paper 1028 covers the cyber security topic. The authors from the Netherlands discuss requirements for RTUs with much better security compared to tenders in the past. The paper also shows minimum requirements, awarding criteria and recommended assurance and explain the use of new requirements in an example project.

Another paper that covers the cyber security is paper 1328 from France. This paper describes the perspectives for the design of distribution automation architecture and devices addressing the cyber security aspect of the modern grid.

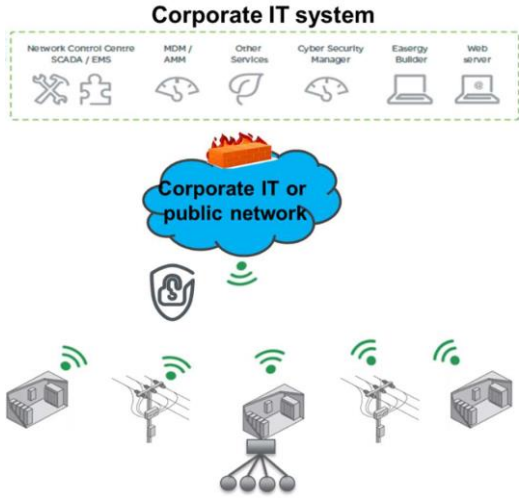

Fig. 17: Increased variety of interfaces & data flows (paper 1328)

The Chinese paper 1032 discusses the reliability and security of wireless communication. Within this paper the performance of different wireless technologies have been analysed and the reliability evaluation and security protection in this paper offer quantified investigation on the technical suitability and introduce security enhancement measures, thus providing suggestions for the safe and secure application of wireless network in power distribution network.

Paper 1170 from Slovenia describes an innovative method of ICT network infrastructure monitoring for vital network services. The paper coves the concept and use cases taken from existing DSO environment. Monitoring of communication infrastructure is getting more important due to the increasing need of information for network operation.

Sub block "Islanding"

Five papers have been selected for sub block islanding. Compare to the previous CIRED conferences the aspect of recognizing islanded grid seems not to be important any more. All islanding papers cover the operation of islanded grids.

In paper 0248, a fractional-order PID controller is implemented for frequency deviation control of a proposed hybrid fractional-order power generation and energy storage system. This control strategy is designed based on coordination control of fractional-order fuel cell and supercapacitor bank models in a hybrid renewable energy system with stand-alone application.

Results of a field test are described in paper 0312. The authors investigated an islanded grid regarding its frequency stability. The research methodology of the research project LINDA is based on a transient simulation model of an exemplary grid section in southern Germany and staggered field trials. The tests are used to proof the concept in a real grid and collect data for optimization of the transient simulation model. The test pat was a drinking water supply facility. The paper show that simulation not always reflect the network behavior in reality.

Paper 0416 from USA describes applications for micro-PMU technology that address emerging issues in the distribution system due to stresses from dependencies on high DER penetration and microgrids. Lessons from the deployment of micro-PMU technology at a major utility and microgrid are shared in the paper, offering opportunities for enhanced analytics to inform command and control methods to manage the impact of these dependencies on events in distribution networks.

Paper 0781 shows a concept for Microgrid operation. With the concept of modular grids a decentralized operation of subgrids is achievable by the use of a power electronic grid interconnector. Paper 0781 shows a novel approach for an islanded operation of MGs to supply customers with energy during large-scale blackouts of the upstream grid. The case is based on a grid-supporting energy storage system. Within the paper, values for storage capacity and state of charge are defined for general use.

Fig. 18: Ivana K platform photographed from Ivana A Also problem could represent switching of large loads (asynchronous motor driven pumps) due to governor and/or Automatic Voltage Regulator (AVR) misfunctions (paper 1279)

A completely different area is shown in paper 1279. This paper describes the power supply of an island, an off-shore gas platform. This platform is supply by three gas motors and in case of emergency two diesel generator sets are available. Selected system consists a power management IED with remote I/O and measuring devices deployed throughout the power system. System relies on IEC 61850 GOOSE communication for fast and accurate data exchange. In the paper, the process of the system selection and implementation has presented and described according to the conducted procedure.

Sub block "IEC 61850"

For sub block IEC61850 eight paper have been selected.

Paper 0057 describes rules driven project specifications. The IEC 61850 series of standards has become the choice of standard to build power utility automation systems. With the use of standard file format exchange during the engineering process, the definition of information models, services and mapping them over a standard communication interface, the vision of a truly multi-vendor power utility automation solution has been made possible

Routable GOOSE message is covered by paper 0494. The expansion of IEC 61850 outside of the substation is the next step in the evolution of the standard that improves its functionality in order to better serve the Smart Grid. The paper discusses the definition of a routable GOOSE message, the differences with the conventional GOOSE and its applications for distribution automation and protection systems.

In Paper 495 the same author discusses the impact of IEC 61850 Edition 2. Edition 2 of IEC 61850 is the next step in

the evolution of the standard that improves its functionality in order to better serve the Smart Grid. The paper discusses the changes in the object modelling of multifunctional distribution protection IEDs and how they improve the efficiency of engineering and maintenance of distribution protection and control systems.

Concerning the realization of innovative solutions for the distribution grid, it is not only essential that new system functions, business cases or methodologies, etc. are developed and proven useful, but also that communication standards shall be extended to meet new requirements. The BMWi-funded project "Green Access" has analyzed which new functions could be adopted from standardization bodies for extending the communication standard IEC 61850. In paper 0798, project-related use cases are introduced and analyzed regarding their semantics, which currently cannot be properly modeled in IEC 61850.

Paper 0961 from Finland discusses the factors related to testing and commissioning works of protection and control systems on a primary distribution substation in case of traditional or fully digitalized application. With practical approach to the issue, differences in the actual testing works between the two scenarios during different test phases are presented. The paper considers the implication of the new technology to testing aspect (fig. 19)

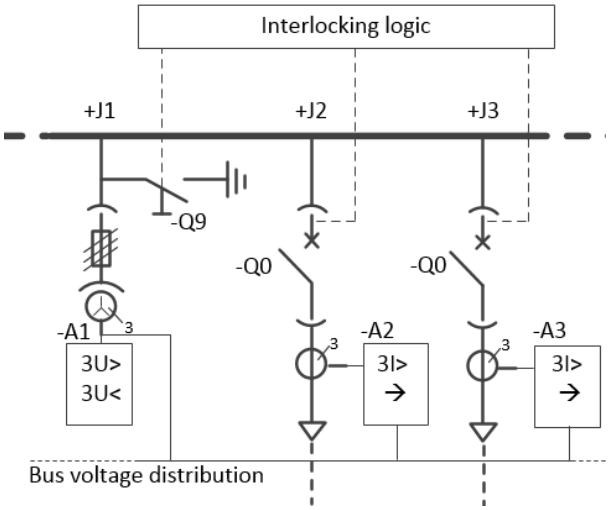

Fig. 19: Reference application with bus voltage sharing and interlocking using hard-wired signals (paper 0961)

Paper 0968 discusses different approaches that were developed in order to face the aforementioned challenges, while meeting present and future expectations and requirements (see fig. 20). Furthermore, it describes a field-based star-topology process bus with different hardware approaches. The contribution of this paper is the implementation of the IEC 61850 process bus. In addition, it offers further insights into the time synchronization and network utilization.

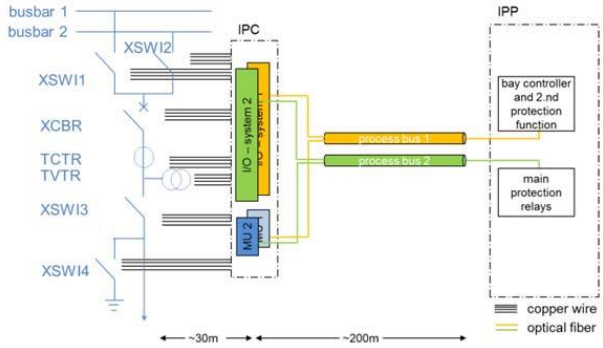

Fig. 20: Future Process connection for old substations (paper 0968)

Paper 1036 describes the Integrated Control and Protection System from the Windyhill 132 kV substation of the Scottish Power EN substation network.

Paper 1190 describes how IEC 61850-9-2 together with non- conventional measuring devices can be used in synchro- check application to improve the overall performance and functionality of the protection and control system in digital medium voltage switchgear. In this paper the authors have introduced how synchro-check control application can be used in an efficient way in Digital Switchgear for medium voltage primary substations with modern technologies. Digital Switchgear takes advantage from IEC 61850 by fully using all services and thus moving as much as possible data exchanges to digital communication bus.

Table 2: Papers of Block 2 "Control" assigned to the Session 3

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Low-Voltage Automation					
0143	Smart Substation MV/LV		X		
0481	Online Control Algorithm for Sub-half-hourly Operation of LV-connected Energy Storage Device owned by DNO			X	
0490	Active Management of Generation in Low Voltage Networks				X
0599	Development of Individual Control Method for Hybrid Voltage Regulator(HVR)				X
0651	Electric Vehicles and Low Voltage Grid: Impact of Uncontrolled Demand Side Response				X
0663	ADMS4LV - Advanced Distribution Management System for Active Management of LV Grids				X
0678	Distribution voltage Monitoring and Control utilizing Smart meters				X
0686	Implementation and Validation of Synthetic Inertia Support Employing a Series-Produced Electric Vehicles				X
0792	UPGRID Project - the management and control of LV network				X
0966	Enhanced LV Supervision by combining Data from Meters, Secondary Substations measurements and MV SCADA		X		
1026	Coordinated Voltage Control in LV Grid with Solar PVs: Development, Verification and Field Trial				X
1060	Experimentation of voltage regulation infrastructure on LV network using an OLTC with a PLC communication system				X
1080	Interaction of Smart Grid Applications supporting Plug&Automate for intelligent secondary substations		X		
1192	Smart Building Potential Within Heavily Utilised Networks		X		
1220	On GE Automated MicroGrid Control System				X
Medium-Voltage Automation					
0074	Multi-Agent System Design for Automation of a Cluster of Microgrids				X
0150	Field Demonstration and Evaluation of Centralized Voltage Control System for Distribution Network				X
0151	Pilot Project using Curtailment to Increase the Renewable Energy Share on the Distribution Network				X
0297	Voltage Stability Monitoring Methods for Distribution Grids Using the Thevenin Impedance			X	
0511	Fast Self-Healing Control of Faults in MV Networks Using Distributed Intelligence				X
0538	Interaction of MV- and LV- Automation Systems for a Smart Distribution Grid				X
0554	Decentralized voltage control coordination between renewable generation plants in MV distribution grids			X	
0615	Controllability, Measurement and Analytic Nodes in Distribution for DER				X
0749	ELECTRA IRP voltage control strategy for enhancing power system stability in future grid architectures				X
0788	Implementation of Fuzzy Logic for Mitigating Conflicts of Frequency Containment Control				X
0883	Smart Fault Handling in Medium Voltage Distribution Grids				X

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Medium -Voltage Automation					
0904	State Forecasting in Smart Distribution Grids: A Modular Approach using CARMA-Algorithm			X	
0914	Real-time, Centralised Voltage Control in 33kV and 11kV Electricity Distribution Networks				X
0946	Operation and Performance of a Medium Voltage DC Link				X
0948	A New Approach For On-load Tap-changer Control Based On Intelligent Voltage Stability Margin Estimation By Using Local Measurements				X
1057	Low Power Instrument Transformer based MV automation: Lessons learned and future applications				X
SCADA / Distribution Management Systems					
0001	Integrated Distribution Grid Management System				X
0262	Decision Support for Distribution Automation: Data Analytics for Automated Fault Diagnosis and Prognosis				X
0301	Using Synchrophasors in Distribution Networks for synchronized switching				X
0379	From Simulation to Reality - Testing Today a Decentral Grid Operation of the Future				X
0397	Improving Smart SCADA Data Analysis with Alternative Data Sources	X			
0484	The Grid of the Future and the Need for a Decentralized Control Architecture: The ELECTRA Web-Of-Cells Concept		X		
0613	The scenario-based approach adopted in the ELECTRA project for deriving innovative control room functionality				X
0641	Enel – Endesa SCADA – ADMS convergence assessment methodology				X
0772	Requirements for future control room and visualization features in the Web-of-Cells framework defined in the ELECTRA project				X
0923	Decentralized Control through Self Healing Grids.				X
0945	Fast alarm processing without connectivity information				X
1014	Towards the modernization of the SCADA Systems of the Hellenic Electricity Distribution Network Operator – Considerations and Steps Forward	X			
1107	Supporting Control Room Operators in Highly Automated Future Power Networks				X
1169	Intelligent Network Assets Supervision and Control in Enedis				X
1341	Improving MV grid control, remote operations and reliability through advanced TLC network and SCADA architecture.	X			
1363	Mitigating Power System Inertia ...				X

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Communication					
0081	An Innovative Solution Sustaining SCADA-to-Remote Terminal Unit G3-PLC Connectivity over Dynamic Grid Topologies				X
0167	Remote Management in Elektrilevi OÜ				X
0183	AIR - Intelligent Grid Automation				X
0302	Development of PLC system with large capacity and high reliability				X
0980	Cyber Security Considerations for Self-healing Smart Grid Networks				X
1028	Technology Independent Security requirements for successful procurement of RTUs to geht acceptable Risk Levels at DSOs				X
1032	Evaluating the reliability and Security of Power Distribution Wireless Network				X
1170	Service quality assurance in the IP networks for Smart Grids				X
1328	Cyber security aspects to design the distribution automation devices for the modern grid				X
Islanding					
0248	Fractional-Order PID Controller Design of Frequency Deviation in a Hybrid Renewable Energy Generation and Storage System			X	
0312	Determination of Load Frequency Dependence in Island Power Supply			X	
0416	Data Driven Approach for Monitoring ...				X
0781	Islanded Operation of Modular Grids		X		
1279	Power Management System Implementation on Off-shore Gas Platforms				X
IEC 61850					
0057	Rules Driven Project Specifications in the Context of IEC 61850 Basic Application Profiles	X			
0494	R-GOOSE - What It Is And Its Application In Distribution Automation				X
0495	Impact Of IEC 61850 Edition 2 On The Object Modeling Of Distribution Protection IEDs	X			
0798	Use Case-driven innovation for IEC 61850 modeling				X
0961	Comparison of Testing and Commissioning Activities in Traditional and Digitized Substation Protection and Control Systems				X
0968	Realisation of an intelligent and continuous Connection in substations				X
1036	IEC-61850 Control System at ST Windyhill Scotland				X
1190	Synchro-check in Digital Switchgear	X			

Block 3: "Protection"

In the "Protection" block 48 papers are discussed covering contemporary and unresolved issues. Very actual and interesting is the discussion about islanding protection, how to detect islanding and the ROCOF Function. There are some theoretical considerations as well as practical tests and applications in this block.

Sub block "Fault Location / Earth Fault"

In this sub block we discuss several kinds of faults in distribution networks. The big challenge is how to detect faults and automatically detect the faulty points in the grid. New optimized algorithms and strategies combined with established technical applications are presented in the following 18 papers.

Paper 0007 from Iran presents a new fault location method for an asymmetrical and unbalanced distribution feeder in the presence of distributed generations (DGs). The Artificial Neural Network (ANN) was studied and tested in a modified version of IEEE 34-bus test feeder with two fixed speed wind generators. The ANN could estimate correctly the distance of fault location to the substation using global inputs. For detecting exact fault location in different branches of distribution feeder, several other ANNs were applied for estimation of fault distance to the interconnection of DGs.

A new method detecting high-impedance faults (HIFs), typically with fault resistances between 10kΩ and 100kΩ, is presented in paper 0308 from Finland. Depending on the grounding type, HIF detection is based on the use of zero sequence current Io or negative sequence current I2 and doesn't need voltage measurement. Based on the simulations with different grounding practices and field data test results, the proposed method seems to be very promising for detecting also very challenging HIF cases. Effect of distributed generation (DG) on I2 values was also studied in simulations.

Paper 0382 from France presents a new solution for the phase to earth fault directional detection used in Fault Passage Indicators (FPI). The solution is based on several low power voltage sensors using capacitor on bushing or on head cable or resistive sensors. The principle of the phase directional detection remains on the conventional principle of protection relays (ANSI 67). The main algorithm improvement concerns the earth fault directional detection (ANSI67N), well adapted to low cost sensors and without setting depending on distribution network characteristics.

Paper 0524 from China focuses on the analysis and improvement of the Fault Section Location (FSL) technology on the algorithm level and to make algorithm more suitable for engineering practice. The system is designed to upgrade the Distribution Automation (DA) platform which is already built to avoid expensive re-development. The paper establishes a trial network in Xiamen, Fujian Province, China to comprehensively demonstrate the practicality of the new technique. The results show that the system can achieve accurate faulted section location and will be promoted for large-scale application.

Paper 0564 from Austria shows why the earth fault detection method based on 3rd harmonic works in large meshed 110kV networks. In the 110-kV-network the contact of Over-Head-Line (OHL) to meadow is one of the most common causes of earth-faults.

Fig. 21: Overhead line on meadow

Field tests have shown that overhead lines falling on meadows cannot be represented as constant linear impedance in the range of some 100 Ω. In this paper it was shown, that the 3rd harmonic is dramatically increasing during a single-line-earthfault (Fig. 22), especially if an OHL is falling on a meadow.

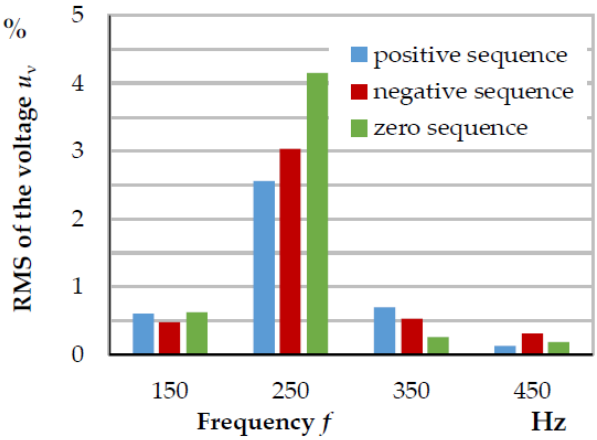

Fig. 22: Measured phase to earth voltage at the bus bar during earth fault

Paper 0565 from China is presenting a high-impedance fault (HIF) detection technology based on transient information in a resonant grounding system. A novel HIF detection method based on the comparison of the magnitude and polarity of the transient zero-sequence current's projection coefficient is proposed. The accuracy of the proposed method is verified by simulations and field data.

Paper 0622 from France presents an earth fault location algorithm based on optimization approach, which is developed for MV distribution networks with resistance-earthed neutral. The objective function is written based on relation between voltage and current measurements at substation, line parameters, fault distance and fault resistance. The optimization process is performed with MATLAB Optimization Toolbox that gives values to the last two variables. In 93.2% of test cases, the proposed

algorithm is able to identify correctly the real faulty section. It should be noted that in the fault location process the impacts of DG is not to neglect.

Paper 0759 from Germany presents a new approach for localizing ground faults, using transients in the currents and voltages. Our approach is based on the double sided estimation of the transient voltage at an unknown ground fault location. It is assumed that the calculated transient profile from both sides of the line is comparable for a known fault location. For better accuracy, an existing higher frequency spectrum is used, and through that, redundant information from each existing frequency is extracted. The precise idea, accuracy analysis, as well as further relevant benefits of our method will be thoroughly described in the paper.

Paper 0817 from the Czech Republic is focused on evaluation of different types of prototypes of automatics for additional faulted phase earthing (FPE), which are used for earth fault current reduction in resonant earthed distribution network. Three prototypes of these automatics have been installed in Czech distribution network (Fig. 23), the first one utilizes direct connection of faulty phase to earthing system of supply substation, the second one utilizes connection through resistor and the last one through reactor. The contribution is mainly focused on detail analysis of operational differences of these types of FPE systems based on case study of compensated distribution network. The main aim is to specify and describe benefits and disadvantages of individual FPE applications. The results could be used for evaluation of best solution of FPE application which could be chosen for an earth fault current reduction in compensated distribution network.

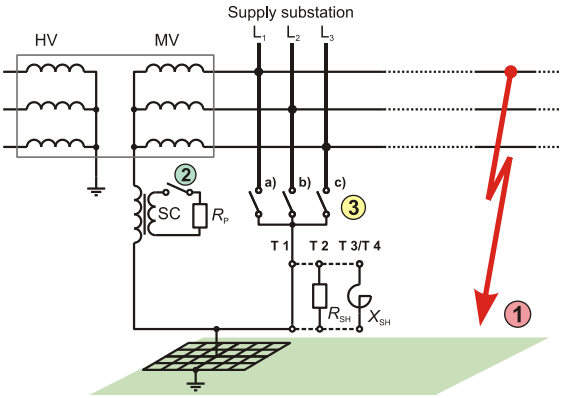

Fig. 23: Considered FPE application design (Type 1-4), 1. earth fault, 2. auxiliary resistor of arc-suppression coil, 3. FPE automatic

In paper 0862 from Finland the importance of residual current measurement accuracy on earth-fault protection performance in compensated MV-networks is analyzed. First the fundamental theory of directional earth-fault protection is recalled. Then the factors affecting the measuring errors of a Core Balance Current Transformer (CBCT) are described. Finally a selection guideline of CBCTs for residual current and neutral admittance-based directional earth-fault protection taking into account the measurement errors is given.

The further development of a project to locate OHL (Over-Head-Line) faults through the detection of radiated electromagnetic noise has been described in paper 0890 from the UK. Propagations tests have indicated that the arc induced radiation may be detected at distances up to 5 km. A trial system involving 4 receiving stations (Fig. 24) has been installed on a SP Energy Networks (SPEN) OHL network in the Edinburgh region. The maximum distance between the stations is ~4 km. The trial has revealed several problematic issues in the operation of the system that have now been resolved.

Fig. 24: Receiving station 1 mounted on OHL pole

Paper 0955 from Brazil discusses a new methodology for restoration of overhead distribution networks based on the application of temporary fault indicators. Unlike the traditional fault indicators, these are installed on the network only after the occurrence of the fault. Placed in key points of the network after the disconnection of a feeder, for example, the temporary fault indicators can sense the fault current after the first manual reclosing attempt. Then, they send this information to a portable operation unit that helps to pinpoint the faulty branch of the network by showing the fault´s path in a map.

Paper 0967 from Finland introduces a novel fault passage indicator function and device for compensated MV-networks. The operation is based on multi-frequency neutral admittance measurement together with a cumulative phasor summing technique. With this methodology, high-level requirements for indication sensitivity and selectivity can be

fulfilled during all types of earth faults that may be encountered in practical MV-networks. The performance of the first large-scale practical installation including several compact secondary substations and one pole-mounted load-break switch with fault indicator devices was validated with a comprehensive field test in an actual 20kV network.
Paper 1153 from the Netherlands presents the recent improvement on fault recognition and location process implemented within the Dutch distribution system operator Alliander. Several issues from the practical situations are addressed properly, including compatibility with the universal sensor data from different vendors, false recognition of fault and non-fault events, and inappropriate calculation moment for fault location. The fault recognition and location process is also integrated in a fully automated DMS system, to further improve the process of fault restoring and reduce the outage duration.
Paper 1205 from Spain describes an innovative and field tested solution in order to remotely detect high impedance MV faults caused by broken conductors (and any MV open phase situation). Field experiences show how this solution optimizes MV grid operation, decreasing blackout times, improving customers' perception and improving safety, as dangerous situations caused by faults in MV lines (loose conductors over resistive ground, etc.) can be identified.
In paper 1250 from Brazil is presented why RGE Sul (Southern Brazilian Utility) moves from its regular network standard to a new concept of power distribution system and why this company is changing to resonant grounding. The Resonant Grounding Project represents an important step forward in terms of Safety and Reliability, as presented throughout this article. After the implementation of the system in three substations, there were no serious accidents involving their medium voltage networks. There was also a significant reduction in the outages, since one of the main reasons for these shutdowns were transient faults and flash-overs on the insulators.
Paper 1355 from Germany presents an auxiliary fault locating service based on traveling wave analysis. Thereby, the main idea is to make use of the capacitive voltage sensors that are installed by default in substations standard for safety reasons. For simulation of fault generated traveling waves a representative medium voltage power system has been modelled in MATLAB/Simulink® with a simulation step time of 0.05 µs. Simulated three phase voltage sequence has been used as input for the measurement equipment with the transfer functions H1 and H2.

Sub block "Applications"

In this sub block we received 14 papers with very different topics. The focus of the papers in this block is the practical test or the implementation of functions in real systems.

Paper 0019 from France answers the question "Open or Closed Ring Networks"? The optimum is to operate sensitive power networks as closed ring protected by a scheme based on line differential relays embedding earth directional overcurrent blocking schemes that will still work when used as open ring.
Paper 0085 from Egypt presented optimal reclosing of circuit breakers for DG connected IEEE nine Bus system. The optimal reclosing technique (ORT) is derived from the total load angles of the DGs. First the optimal reclosing times are determined, and then the performance of the proposed reclosing method is compared with the conventional reclosing technique.
Paper 0184 from Croatia reports the issues related to over-voltages in low-voltage distribution networks characterized by high specific soil resistance. The novelty of the proposed solution is in using the external neutral conductor as the grounding electrode and neutral conductor. The validity of the solution is verified via extensive in-situ measurements using surge generator simulating the waveform similar to actual lightning waveform. Measurements are performed with and without neutral conductor from the cable, verifying the proposed solution against classical parallel grounding electrodes.
In paper 0278 from Argentina the question is discussed, why the operation failure of High Breaking Capacity (HBC) fuses (Fig. 25) is so frequent? Real typical cases of incorrect selection are presented, pointing out the consequences and risks. It is concluded that the only way to avoid errors in the selection is by means of the deep knowledge of the methodology of application of the HBC fuses.

Fig. 25: Laboratory test of a low current operation failure of an aged HBC fuse

Paper 0295 shows that there is a need for renewing earthing network design principles because at the moment, the connections between the secondary substations are not systematically taken into account in the non-urban areas' earthing design. Results shows that the resulting impedance was typically 50-80% lower than the secondary substations' individual earthing resistances. It means that there is great potential for savings in the earthing network without risking

the safety. This paper brings out recommendations how the design and measurement principles could be developed and which possible changes in the relevant standards.
Paper 0309 from Korea analyzed the change in fault current and its direction according to the connection between renewable energy (DG) and ESS (Energy Storage System). For stable power supply, the KEPCO (Korea Electric Power Corporation) investigated fault current change in the present one-way protective coordination system depending upon two-way aspect, renewable energy discharge and ESS charge/discharge action. Reference data are provided through the system to set the protective device values should be considered.
In paper 0386 from Spain the technical details adopted for the design of the hardware and software of a System Integrity Protection Scheme (SIPS) are reported. The criteria applied for ensuring as far as possible security and dependability of operation of SIPS are described, and the operational results of the first eighteen months of operation are reported also. The paper also presents the RTDS studies of the power system, to validate the correctness of operation of SIPS which includes modelling process description and the analysis tests results made in different power system topology and power flow conditions.
Paper 0736 from Germany shows, that a minimal effort voltage based add-on protection concept for the islanded mode of operation of the micro grid is feasible. Necessary investments could be restricted by the help of a supporting planning tool proving the feasibility of using a minimum effort add-on protection system. An according tool is implemented as a proof of concept and is successfully applied to show feasibility in a real world Microgrid. Potentials for further reducing safety margins and complexity of the planning process by a more precisely defined grid building units' fault behavior in islanded mode become obvious.
Paper 0763 from France brings details about the different settings used on the French grid, their advantages and drawbacks, and focuses on the benefits of the new setting which reduce the risk on the interconnected transmission grid stability while maintaining the distribution grid performance.
Paper 0863 from the UK presents the need to provide new equipment's with different requirements and constraints has pushed for the development of new transport networks configurations per the specification of a line differential protection. This new smart concept will be a step forward towards utilities moving to a reliable, cost effective and integrated protection relay to be implemented in any power networks. As seen from the tests and results presented in the paper, we can conclude that this new solution is reliable (dependable & secure) to protect the most stringent networks. The validation uses real cases and commercially available hardware, to determine the best settings and improve the efficiency in a line differential protection compared with the existing products in the market.
In Paper 1082 from Portugal is presented that the actions undertaken by EDPD, Siemens and INESC ID were essential to deepen the knowledge of ESS behavior in network fault conditions. The live short-circuit tests performed on the ESS were essential and proved the necessity to conduct real tests in addition to simulation in order to achieve an adequate protection for the ESS and the network. This allowed for the development of protection guidelines for ESS. EDPD ESS uses a two group of settings: one group to use in grid connection mode; and the other to use in islanding mode.
In paper 1160 from Greece, the adequacy of existing protection schemes in the Hellenic distribution system is assessed, examining a representative MV network with particularly high DG penetration. The deficiency of the applied protection practices so far is thoroughly discussed and justified by the obtained simulation results. Generally applicable solutions are proposed, which can lead to significant upgrade of distribution protection.
Paper 1282 from Canada proposes integrated asset performance monitoring and diagnosis, arc flash protection, ambient environmental monitoring, simple and intuitive configuration, safer HMI communications, instantaneous setting group change, etc. enhance overall safety and provide reliable operation. Next generation digital protection relays can be designed to further enhance asset performance monitoring, personnel safety, and reliability in a distribution substation. Integrated features can be applied as an enabler tool to further reduce damage to distribution substation assets, arc flash hazards/accidents, undetected hardware failures, human errors, etc.
Paper 1331 from Italy analyses the possible benefits associated with the disconnection of the cable's shields at the primary substation end, evaluating, throughout a specifically designed algorithm, the average thermal stress, as well as the life reduction, associated to a cross-country fault (CCF). This analysis is then further supported by a statistical evaluation that underlines the impact of the shield's connection on the average number of CCF on the e-distribuzione's network.

Sub block "Algorithms and Simulations"

16 papers are presenting new developed algorithms or protection functions to solve challenges. Simulations are confirming the stability and functionality as a prerequisite for practical use. The ROCOF Function and islanding protection is very actually discussed.

Paper 0192 from Iran presents a framework to design a protection system based on the commonly used Over Current Relays (OCRs) and Unidirectional Fault Current Limiters (UFCLs). An UFCL is used as the interface between the microgrid and the main distribution system. The PC design is tried to remain robust against changing the connection mode of the DERs. The sum of primary and backup operation times is considered as the objective function. OCRs' type selection parameters, OCRs' settings and UFCL characteristics are the optimization variables. To ensure the full Protection Coordination (PC), different

constraints such as Coordination Time Interval (CTI) constraint are also considered. The Grey Wolf Optimization (GWO) algorithm is applied to solve the optimization problem.

Paper 0205 from Germany outlines a possibility to estimate the influence of these new dynamic effects on grid protection behavior in steady state calculation methods. Different types of Decentralized Generation (DG) units as well as other influences, e.g. grid topologies, distribution of DG or protection concepts are taken into account. We will show that suitable steady state calculations are sufficient for practical protection analysis. The risk of undesirable reactions of the grid protection can be minimized by the use of the derived general recommendations.

Paper 0276 from Finland performs a viability assessment of the centralized substation protection and control (CPC) system in a number of architectures, using a modified algorithm of the Block-Layer reliability technique and a specific objective cost function. This paper describes the concept of centralized protection in substations and a number of involved architectures. Moreover, it describes the modified algorithm for reliability analysis and its important considerations. Results show that the centralized approaches are significantly more reliable than the traditional and cost-benefit increase with the increase of number of process bays in the substation.

Paper 0330 from the UK presents the experimental testing of commercial LV-connected PV inverters to characterize their behavior during fault conditions. Understanding this behavior is critical for the proper design and operation of distribution networks with a large amount of inverter-connected generation. The inverters were connected to the Power Networks Demonstration Centre (PNDC) LV distribution test network as shown in Figure 26. Hardware test results for a number of different inverters are discussed and compared. The challenges for modelling, particularly with respect to fault conditions, are discussed with an example simulation.

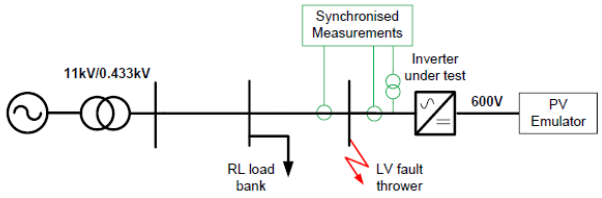

Fig. 26: Distribution network used for fault testing

Paper 0344 from Portugal presents the short-circuit studies that were performed for the distributed resource (DR) island system. For that purpose the actual secondary substation LV grid was modeled with MATLAB Simulink software, with real grid data provided by the DSO and with the grid embedded storage models provided by the manufacturers. The studies were performed for all foreseeable configurations (parallel and island) to ensure clearing of faulted conditions, and with different load scenarios.

Paper 0352 from France investigates the benefit of using the ROCOF by studying its effect on the Non-Detection Zone (NDZ) of the anti-islanding protection. For every case study, it was found that the NDZ of ROCOF thresholds are smaller than the NDZ of narrow frequency thresholds, which confirms that ROCOF improve islanding detection. The NDZ surface reduction using ROCOF is meaningful, although the exact value cannot be precisely estimated as it is directly dependent on the way the ROCOF is computed. The latter observation emphasizes the need to well design the frequency and ROCOF computations within the relay protection: making it both fast and reliable remains the core challenge of ROCOF-based protections. Furthermore it has also been observed that "standard" way of reasoning based on grid inertia might lead to wrong results as they are based on only synchronous generators in the grid.

Paper 0368 from Croatia describes development of the methods for islanding detection. Islanding of distributed generation can appear in cases of deliberate disconnection of network parts or disconnection due to fault. This article analyses the problem of distributed generation (DG) islanding in networks where islanding is not allowed. Time duration during which DG left in islanding mode must be disconnected is defined by networks automated processes (i.e. automatic recloser). Considering the fact that future smart grids will have even bigger degree of automatizations now is the moment to figure out how to decrease time during which DG operates in prohibited islanding mode.

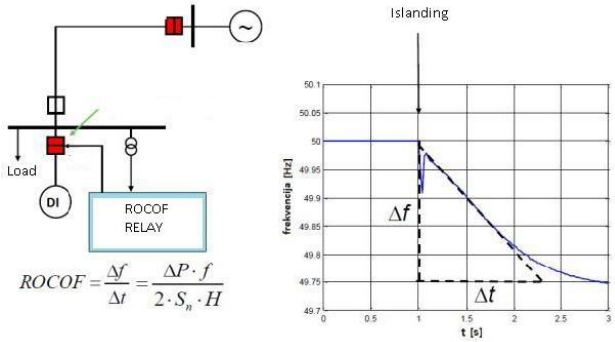

Fig. 27: Representation of values for ROCOF method

ROCOF Relay measures the voltage frequency and calculates the rate of change of frequency that is represented by the formula in Figure 27.

Paper 0392 from Portugal presents how EDPD Distribuição (EDPD) developed a program to optimize its current protection asset base that spans along several generations and technologies with different levels of protection functions. This program consisted of an exhaustive revision of all Medium Voltage (MV) protections function settings that comprised a total of 484 substations and switching stations, and over 5100 feeders within the entire mainland Portugal distribution grid. The main goals were to ensure protection relays coordination, guarantee sensitivity for electrically distant short-circuits and minimize voltage dips duration.

Paper 0459 from Portugal performs a new analysis of the network state on the LV side (near DG) under a ground fault on the MV feeder. Simulations of multiple scenarios show that the voltage on the LV side can significantly change by the ground fault on the MV side under certain conditions. It

was found that the voltage on the LV side can be influenced by two variables: the sum of the installed generation in the feeder (SG), and the feeder characteristics', such as length, or whether it is an underground cable or an overhead line. This condition is sufficient to insure the overvoltage protection trip even at the LV side. If there is a large power unbalance between generation and load at the feeder the frequency protection will also operate.

Paper 0606 from Germany presents a comparative study on algorithms that estimate the rate of change of frequency (ROCOF) for power system protection. We develop two algorithms that consider the rotation of the power system voltage represented in the complex plane. We also develop an algorithm that considers the instants when sequence of the voltage changes sign. We test these algorithms in simulation: An automated test bench evaluates the impact of sampling frequency, noise and harmonics on their accuracy.

Paper 0673 from the UK evaluates the performances of a wide number of DC protection solutions that have been proposed for the applications on an active LVDC last mile distribution network with local generation sources (including PVs and battery storages). Based on the findings, recommendations of LVDC protection for resilient operation are presented in the paper.

Paper 0714 from Germany is presenting that detailed protection planning becomes increasingly important in the future, using enhanced calculation, modelling and evaluation approaches, as developed within the project ProFuDiS. While the future protection-challenges in German MV grids can widely be solved using altered parametrization and application of the present digital protection devices, the usage of classical NH fuses for LV grid protection will be possible for most, but not all grids any more. While sufficient, but rather complex digital protection approaches are already available, the development of innovative, more cost efficient solutions for LV protection should be carried on. Additionally more precise regulations for the fault behavior of DG should be stated to allow effective protection planning and reliable and realistic fault simulation.

Paper 0716 from Norway proposes a communication–based scheme preventing islanding forming in a system. The scheme utilizes a new fast and universal indicator revealing fault positions. A locating algorithm is also applied to restrict unwanted disconnection of DG. The method is tested on a model in PSCAD/EMTDC of an actual 22 kV multiterminal grid grounded by a Petersen coil and including DG. The results show that the new indicator can reliably discriminate faults in the system. It has been found that precision of the locator utilizing two–point measurements is not sufficient and might lead to nuisance tripping of the DG. Using of multi–point measurements and the proposed indicator helps to solve this problem for a complex feeder topology. Finally, the same signals can be applied to enhance accuracy of the locator.

Paper 0793 from China proposes integration secondary equipment based new architecture of distribution network named Protection Intelligent Center (Fig. 28). The center takes over most functions of the former substation protection and automation. On one hand, the center can optimize protection principle. On the other hand, the center also alleviates the pressure of substation area in the city by concentrating the substation's secondary equipment and simplifies the rebuilding process after the disaster of regional grid.

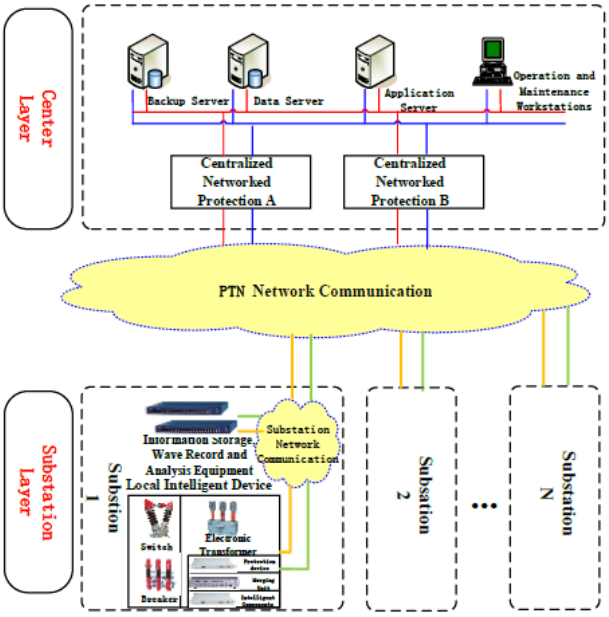

Fig. 28: The framework of protection intelligent center

Then explain the function concept, overall architecture, configuration and rapid disaster recovery of Protection Intelligent Center. This architecture provides a reference for the construction of urban intelligent power distribution substation.

Under emergency conditions portions of MV networks can be locally supplied for a significantly long time period by moveable generating units connected to the LV side of a standard distribution transformer, which in this case operates as a step-up transformer. It is therefore necessary to ensure a proper operation which must include the detection of any possible faulty condition. When the MV network portion is operated with isolated neutral (as it is usually the case), a reliability issue arises for earth faults detection by the protection system, due to the negligible capacitive fault current values.

In paper 0970 from Italy, possible detection methods are identified through analytical and numerical simulations and two promising solutions are proposed, i.e., the intentional earthing of one phase conductor and the connection of a suitable neutral forming transformer with earthed neutral terminal both operated at the MV side of the MV/LV transformer.

In paper 0993 from Germany, fault characteristics for different future LVDC network configurations are simulated (PLECS1) to analyze the maximum short-circuit current rating of the network. DAB (Dual Active Bridge) topology

for DC-DC converter is considered for the connection of renewable energy sources and MVDC link to the LVDC grid. Results show that due to the current limiting characteristics of DC-DC converter, there is a potential of decreasing the maximum SC rating of the protection devices in LVDC microgrids compared to LVAC grids.

Table 3: Papers of Block 3 "Protection" assigned to the Session 3

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Fault Location / Earth Fault					
0007	Fault Location of Unbalanced Power Distribution Feeder with Distributed Generation using Neural Networks				
0170	Impact of Voltage Fluctuation on Petersen-coil Control and results of a Tuning Method with evaluation of Side Frequencies				
0308	New method for High-Impedance Fault Detection				
0382	New solution of fault directional detection for MV Fault Passage Indicators				
0524	New Transient Fault Location Method in Non-solidly Earthed System for Distribution Network				
0564	Why does the Earth Fault Detection Method based on 3rd Harmonic work in Large Meshed 110-kV-Networks			X	
0565	High-impedance Fault Detection Based on Transient Information in Resonant Grounding System				
0622	An Optimization Algorithm for Earth Fault Location on MV Distribution Feeders				
0759	Accurate Localization of the Ground Faults in Non-Solid Isolated Networks based on Transients Analysis				
0817	Comparison of Different Solution of Faulted Phase Earthing Technique for an Earth Fault Current Limitation				
0862	Core balance CT selection for sensitive earth-fault protection applications in compensated MV-networks				
0890	Location of Arc Faults on 11 kV Overhead Lines using Radiometry		X		
0955	Restoration of Overhead Distribution Networks by Means of Temporary Fault Indicators Application				
0967	Application of Multi-frequency Admittance Based Fault Passage Indication in Practical Compensated MV-network				
1153	Improved Fault Location Algorithm for MV Networks based on Practical Experience				
1205	MV high impedance faults detection based on LV voltage measurements		X		
1250	Resonant Grounding applied in Brazilian distribution networks		X		
1355	Capacitive feeder sensors for an auxiliary fault locating service with traveling waves				
Application					
0019	Open or Closed Ring Networks?				
0085	Optimal Reclosing Time to Improve Transient Stability in Distribution System				
0184	Suppression of the Atmospheric Over-voltages in Grounding Neutral Conductor Low Voltage Grids				
0278	Why the operation failure of high breaking capacity fuses is so frequent?				
0295	Earthing Systems Connected via Metallic Screens of the 20 kV Underground Cables in Non-Urban Areas				
0309	New Protection Coordination System according to ESS and Renewable Energy expansion				
0386	Implementation of a System Integrity Protection Scheme (SIPS) in the Channel Islands		X		
0736	Feasibility of an Efficient Add-on Protection System for a Real World Microgrid in Islanded Mode		X		

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Applications					
0763	New settings including Rate of Change of Frequency for Interface Protection Relays used for Generators connected to MV grid				
0863	New and Smart Multi-Ended Differential Solution for Power Networks				
1082	Protection Scheme for Energy Storage Systems Operating in Island or Grid Connected Modes				
1160	Adverse Impact of Distributed Generation on Protection of the Hellenic MV Network – Recommendations for Protection Scheme Upgrade				
1282	Integrated asset monitoring, personnel safety, and reliability with next generation protection relays for distribution networks		X		
1331	Impact of the cables' Shields Disconnection on the Thermal Stress Reduction in Case of Cross-Country Faults				
Algorithms and Simulations					
0192	Designing a coordinated protection system for microgrids enabled with DERs based on unidirectional FCL				
0205	Practice-Oriented Consideration of the Dynamic Fast Fault Current of Power Park Modules in Grid Protection Analysis				
0276	Viability Assessment for a Novel Centralized Protection and Control System in MV Substations				
0330	Hardware based characterization of LV inverter fault response				
0344	Protection System Analysis in LV Grid, with High DG Penetration, in Parallel and Islanding Operation				
0352	NDZ of an anti-islanding protection with ROCOF threshold				
0368	Anti-Islanding Protection Of Distributed Generators With Regard To Sensitivity In A Balance And Power System Stability				
0392	EDP's Experience in Optimizing In-Service Protection System Units				
0459	The need for zero sequence voltage protection in MV networks with high levels of distributed generation				
0606	Rate of Change of Frequency Protection: Toward a Viable Algorithm for a Protective Relay				
0673	Evaluation of Existing DC Protection Solutions on the Performance of an Active LVDC Distribution Network under Different Fault Conditions				
0714	Challenges and Solutions for MV & LV Protection in Grids with Large Amount of Distributed Generation – A final Report from the German Research Project ProFuDiS				
0716	Fast Protection against Islanding and Unwanted Tripping of Distributed Generation caused by Ground Faults				
0793	A New Architecture of Centralized Protection Suiting Future Development Trend of Distribution Network				
0970	Reliable Protection Systems for Locally Supplied MV Distribution Networks				
0993	Estimation of Short Circuit Currents in Future LVDC Microgrids				