D2 - 00

SPECIAL REPORT FOR SC D2
Information Systems and Telecommunication

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Special Reporters

The D2 Special Report has been updated according to the new requirements for the CIGRE 2021 Virtual Centennial Session. Revised parts are indicated in red.

The scope of CIGRE Study Committee D2 is focused on the fields of information systems and telecommunications for power systems. SC D2 contributes to the international exchange of information and knowledge, adding value by means of synthesizing state of the art practices and drafting recommendations.

SC D2's principal areas of interest:

- Studying and considering the evolution of information and telecommunication technologies to cope with traditional and new requirements driven by the digital transformation in power industry including extension of Distributed Energy Resources.
- Assessment of Technologies and architecture to assure business continuity and disaster recovery.
- Overcoming security threats in the deployment of the networks of the future and especially in Smart Grids.

Within D2 scope three preferential subjects were proposed for the 48th CIGRE Session:

PS1: The impact of emerging Information and Communication Technologies (ICT) on Electric Power Utilities (EPUs)

- The potential of Machine Learning and Artificial Intelligence (AI) in improving operations
- Enhancing asset and lifecycle management using Industrial Internet of Things (IIoT), Big Data and Analytics
- The role of Blockchain in facilitating efficiency of market operations

PS2: New cybersecurity challenges in the changing electricity industry

- Cybersecurity challenges in the use of industrial Internet of Things (IoT), Big Data and Cloud-based platforms
- Cybersecurity challenges related to DER and interconnection of new flexibility providers

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- Identification of cybersecurity threats using Big Data analysis and Machine Learning

PS3: Increasing operational efficiency using Packet Switched Communication technologies

- Challenges in the migration to packet switched networks
- Supporting the changing electricity industry with the use of existing and new communication technologies
- Supporting time critical operational services with time distribution and synchronization

A total number of 58 papers from 27 countries addressing 3 preferential subjects have been accepted: 28 papers for PS1, 15 papers for PS2 and 15 papers for PS3.

Contributors are welcome to prepare contributions in accordance with the questions raised by Special Reporters in the Special Report and add their valuable expertise to **SC D2 Group Discussion Meeting**, which will take place on:

- **Day 1 - Tuesday, August 24, 12:00-16:00 (CEST) for PS1.**
- **Day 2 - Wednesday, August 25, 12:00-16:00 (CEST) for PS2 and PS3.**

It will be managed via remote web interaction with a live broadcast from Palais de Congress, Paris.

Important points:

- *Access to contribution uploading is given only to duly registered delegates. As a consequence, registration to CIGRE Session should be finalized before uploading contribution(s) online. Register now for the Session Click here .*
- ***Contributors should upload their contribution** on the Registrations platform – "Contributions to Group Discussion Meetings" section - using their existing account and own credentials **by July 30, 2021**.*
- *Contributions should consist of: a written word version, a powerpoint presentation, a short summary of the contribution (3-5 sentences). Templates as well as a guide for contributors are available on the CIGRE Centennial website.*
- *Contributions will be made available to Study Committee Chair and Special Reporters for reviewing and comments. Contributors are encouraged to visit their account on the Registration Platform to see the result of this review. Any recommendations or changes to the contributions will be provided to the contributors by Special Reporters on the Registration Platform by **August 06, 2021**.*
- *The final decision on acceptance of the contribution will be provided to the contributors by **August 13, 2021**.*
- *There will be no poster session during the 2021 Virtual Centennial Session.*

Preferential Subject 1: The impact of emerging information and communication technologies on Electric Power Utilities

Introduction

This amazing preferential subject is related to the digitalization of Electric Power Utilities (EPUs). Emerging Information Communications Technologies (ICTs) such as: IoT, Big Data, Data Analytics, Artificial Intelligence and Machine Learning, virtual and augmented reality, drones and robots, blockchain are becoming a reality in EPUs. These technologies enhancing and optimize the operations, the asset management, and energy market operations.
The future is here. The technical papers show a small sample of what EPUs are doing around digitalization using emerging ICTs. The papers show different conceptual visions and applications of ICTs for different tasks and operations. It has been a fascinating experience to discover how EPUs are transformed to data driven smart energy management. Brief summary of all papers is given below.

A total of 28 papers have been submitted that may be grouped into the following sub-topics:

a) Design and strategies for application of emerging digital technologies in EPUs.
b) Applications of emerging digital technologies in EPUs,
c) Tangible applications of AI and ML in EPUs.
d) Methodologies and intelligent systems for new way to trade energy

Sub-topic a) Design and strategies for application of emerging digital technologies in EPUs:

The eight papers of first session address with the definition of the technological architecture and smart data management for EPUs. These papers discuss details of the strategy and design philosophy of the implemented technologies and platforms, covering system architecture, communications, data management, and data analytics based on AI and ML. The applications are focus in the improvement the operation and the maintenance of EPUs.

Paper Reference	Title	Country
D2-105	Developing Enhanced Information and Data Exchange to Enable Scalable TSO-DSO Interoperability	UK, FRANCE AND GERMANY
D2-106	Improvement of operability and maintainability using new information and telecommunication technologies	JAPAN
D2-111R	Application of modern information and communication technologies for improving the effectiveness of power systems	RUSSIA
D2-118R	Experience of development and implementation of automated system for monitoring and analysis of functioning of relay protection devices (IED's) and assessment of correct protection operation	RUSSIA
D2-122	MANINT Project: Digital Transformation of the Management of Transmission Grid Operating Asset	SPAIN
D2-123	A Multi-Agent System platform for State Estimation in power distribution grids in the context of distributed generation	ROMANIA
D2-128	On the Path to Autonomous Power System Management	GERMANY
D2-130	Management of data from smart measuring device for predictive maintenance	SLOVENIA

Table 1. Papers that cover the strategy and definition of technological architecture for smart data management on EPU

- D2-105 Paper from UK, France and Germany discusses the importance to use information technology standards (Use Cases and UML) and Smart Grid Architecture Model (SGAM) for the development of scalable and secure information systems for data exchange between TSOs and DSOs. It focuses on three main aspects: scalability, data security and interoperability. The result is the architecture of a system based on international standards such as IEC SyC Smart Energy Use Case Methodology, IEC TC57 CIM profile methodology, and Common Grid Model Exchange Specification (CGMES).
- D2-106 Paper from Japan shows how the emerging ICT can improvement the operation and the maintenance of EPU. Four applications of emerging ICT are presented. First case, is focused in the network construction of IoT and smart sensors for trend analysis and fault detection in thermal power plants. Second case, presents the development a wireless network based on IEEE 802.11ac standards for maintenance in substations. Third case, the implementation of smart glass sensors to determine the operational status in 500 distribution substations is presented. Forth case, describes a prototype of image analysis and processing for the detection of rust in transformers based on K-means clustering algorithm.
- D2-111R Paper from Russia presents examples of the application of cloud computing for solving a number of WAMS and WAMPACS (Wide-Area Monitoring, Protection, Automation and Control systems) problems using synchrophasor data as well as data from a variety of intelligent equipment devices of substation. The multi-functional converters of analogy signals with support of synchrophasor measurement technology and intelligent electrical equipment are the data sources for WAMS and SCADA. An improved asset management can be possible with the use of high-performance computing in solving large-scale problems of analysis of measuring data of power systems, including synchrophasor measurement data.
- D2-118R Paper from Russia describes the development of automated system for monitoring and analysis of functioning of numerical relay protection devices and assessment of correct protection operation for power facilities of 6-750 kV. The automatic monitoring and evaluation system of numerical relays reduces occurrences of incorrect protection operation and increase of the reliability of the protection system by timely detection of device multifunction. It also helps reduce O&M cost due to excessive maintenance that is consequence of preventive maintenance approach. The system has a two-layers architecture: lower level - collection, processing, storage data for monitoring IED's and local analysis protection operation are performed. Upper level of system includes data collection from lower levels, processing and storage results of monitoring IED's, global analysis of fault events and assessment of protection operation. The source of input data at substations is SCADA system, virtualization technology is used, communication between software components of the system is carried out using Web services and protocols based on HTTPS and the inter-level system interaction is based on simple object access protocol (SOAP).
- D2-122 The paper from Spain presents an overview of the MANINT project. MANINT integrates the entire set of digital transformation initiatives that Red Electrica de España is developing to achieve the implementation of a new transmission grid asset management model. The objective of this project is provided powerful analytical and cognitive capacities, which make it possible to transform the data, that has been historically captured and stored, into information and, subsequently, into great value knowledge to facilitate decision-making. It describes some lessons learned from the

experience with the system so far, with focus on the main challenges faced during the course of the project.

- D2-123 The paper from Romania proposes a multi-agent platform (MAS) for state estimation (SE) using a PMU data and a tool for optimal placement of PMUs. The proposed solution consists of a master-slave architecture consists of a SE agent whose purpose is to compute the system state vector. The SE agent collects the data regarding the topology of the network and its technical parameters. Based on the known number of PMUs in the network, SE agents create an equal number of agents, named PMU agent, who store in their memory the network characteristics: topology and physical parameters. The MAS algorithm for optimal placement of PMUs is developed under JADE framework, and triggered from the EPSA MatLab software tool. The results obtained show the relevance of using such self-adaptive systems to solve the issues inherent to the distribution network.
- D2-128 The paper from Germany shows how the autonomy could become the next big thing in power systems. It introduces the basic taxonomy to better structure the discussion of the transition to autonomous power system. It describes some of the most prominent software and hardware enabling technologies. To illustrate the possible perks autonomy bears, it discusses around two power system functionalities: expansion planning and reliability & resilience. Autonomy could be the mean to enable higher flexibility, speed of response, productivity and comfort while reducing the operating costs, frequency and impact of malfunctions caused by human errors.
- D2-130 The paper from Slovenia presents a data model for ingesting, storing, and analyzing metering data from smart metering in near real time. The big data analytic platform is implemented in the distribution system of Elektro Ljubljana. The proposed solution is proven to be effective to solve some of most pressing issues related with handling and managing large amounts of measurement data such as scalability, responsiveness and performance. The analytics includes a dedicated algorithm for predictive maintenance on current transformers and other measurement components.

Question 1.1: How the emerging ICT can improve the operation and the maintenance of EPU, what are its advantages, what are its requirements?

Question 1.2: What are the architecture of a high-performance computing for big data processing scheme including digital signal processing, mathematical statistics, data analysis, software engineering, etc.?

Question 1.3: How digital twin approach can support the analysis of failure events in EPUs?

Question 1.4: What is the expected evolution of the AI and ML models to contribute to the autonomy of the power systems?

Question 1.5: What is the importance to use architectures and standards for design and develop scalable, secure and interoperable information systems to exchange data in EPUs?

Sub-topic b) Application of emerging digital technologies in EPUs:
The eight papers of second session describe different applications on emerging digital technologies in EPUs. Some papers focus on new control approaches for distributed generation, including decentralized control and virtual dispatchers. Other papers deal more specifically with big data, data analytics techniques and AI for condition-based asset management and efficient asset replacement and maintenance policy.

Paper Reference	Title	Country
D2-102	Artificial Intelligence Applications to Electric Power Systems Asset Management	USA
D2-103	Failure reduction and predictive replacement approach for overhead lines using big data and advanced analytics	ITALY
D2-108	Adopting IIoT Technology to Realize Controllability of Existing Small-scale Distributed Energy Resources	TAIWAN
D2-110	Development of intelligent control systems for decentralized distributed energy resources based on a digital platform	RUSSIA
D2-113	Research and Application of Virtual Dispatcher for Smart Distribution Network Based on Artificial Intelligence	CHINA
D2-125	Impact of Big Data, Internet of Things and Analytics in Indian Power System - A Case Study	INDIA
D2-127	CNDbot: A Robot for Operation Information Management in the Colombian Power Grid	COLOMBIA
D2-129R	How to deploy Augmented Reality solutions into day to day DSO operations	SLOVENIA

Table 2. Papers that cover with applications of emerging digital technologies in EPUs

- D2-102 Paper from USA analyzes how the digitization of EPU based on IEC 61850 standard and Machine Learning and AI technologies can be used in various asset management applications. The modeling principles and system configuration language of the IEC 61850 standard can be used for the development of integrated asset management systems. A technology platform called as Artificial Intelligence Based Asset Management System (AIBAMS) is proposed for processing the huge amount of real-time data generates by protection, automation, monitoring and control systems. As future work, they propose the use of ML and AI technologies in specific asset management tasks to be implemented by the AIBAMS at the different levels of the system hierarchy.
- D2-103 Paper from Italy presents an engineering decision support system called MBI (Monitoring and Business Intelligence) developed and implemented by Terna in Italy. The system uses statistical and advanced data analytics software for improved asset management. The developed condition-based asset management system, that uses statistical and advanced data analytics techniques, allows for a more efficient asset replacement and maintenance policy of high voltage overhead line conductors. The replacement/repair strategy is based on the use a health index which a function of multiple parameters such as component age, geographical location, component technology and the failure and repair history. The MBI also assesses of different asset management policies on system reliability and the evolution of network failure patterns.
- D2-108 Paper from Taiwan shows 5 challenges for the control of Distributed Energy Resources (DERs) on a power grid and how can be solved with IIoT technology. The connection of one Modbus/RTU (inverter) to two Modbus/RTU masters (a DER owner and a grid operator) simultaneously to send data to centralized systems is presented. A Distributed Renewable Energy Advanced Management System (DREAMS), is used to realize controllability of small-scale DERs for the Taiwan Power Company based on a Modbus splitter, IIoT Gateway, and Docker container virtualization technology. The DREAMS system can help to break down data silos to enable real-time monitoring of solar energy demand and supply and quickly address issues/incidents in the grid and prevent them from getting out of hand by remotely controlling inverters at PV sites.

- D2-110 Paper from Russia describes the architecture and development of APlatform for intelligent control of distributed energy resources. The platform complaints with the standard ISO/IEC/IEEE 42010:2011 and It consists of seven modules: Internet of things, intelligent control, transactive energy, ontological and information models, document management, state monitoring and diagnostics, and information security. Intelligent models are designed for evaluation and forecasting of generation, consumption, and energy resources store, predictive health monitoring of assets and prediction of prosumers' load profiles using deep learning artificial neural networks. A prototype of the platform was implemented a prosumer demand response.
- D2-113 Paper from China presents the logical architecture for a smart virtual network dispatcher based on Natural Language Processing (NPL). The virtual dispatching agents can understand report calls from the field stuff and simple dispatch operation tickets, and be able to operate autonomously. Proposed system considers three core engines: 1) collection and sorting of distribution network information; 2) construction and training of voice platforms (Chinese speech recognition engine based on the open-source algorithm HTK); 3) integration and interaction of power systems (OMS, SCADA, OTS, Phone System, and DAS). The system support work of human dispatchers and it is in operation covering an area of about 683 km2 in Hangzhou, China, processing least 300 business instructions per day in the control center.
- D2-125 Paper from India presents the strategy and design of Unified Real-Time Dynamic State Monitoring system (URTDSM), covering the overall architecture, data management an integration, cybersecurity aspects, and data analytics applications in real-time time grid operation. It describes a Wide Area Measurement System (WAMS) implemented in the Indian power grid. The URTDSM project, retrieves and uses data from 1600 plus PMUs installed on substations at 400kV level and above, all generating stations at 220kV level and above, HVDC terminals, and selected interregional and international connection points, and implement various analytical applications, including oscillatory stability management, linear state estimator, online vulnerability analysis, line parameter estimation, and CT/CVT calibration.
- D2-127 Paper from Colombia describes the development of an information system for integration and validation of operation information (CNDbot) in the Colombian Power Grid. For integration of information generation and transmission processes uses a tool developed on Python. The tool for validation uses Selenium framework, commonly used for automatic testing of web applications. The tasks automated by CNDbot was validation of voltage Control Maneuvers, maintenance, international power transfers, regulatory quality calculations and daily operation summary. A considerable reduction in repetitive tasks was achieved thanks to this tool.
- D2-129R Paper from Slovenia presents an application of online augmented reality integrated with operational systems (AMS, GIS, SCADA) of Slovenian electricity distribution network. AR application was designed as a result of precise analysis and research work of some use cases. AR is the interface for different task: inspection, digital twin, geographical topology, key asset information, remote manager and guide manager. The AR web application platform can run in the cloud or on premise and have the task of combining information from different sources (EAM, ERP, GIS, IIoT, SCADA and other back end systems).

Question 1.6. What are the advantages of an asset management system based on the IEC61850 standard and artificial intelligence algorithms?

Question 1.7. What challenges have been faced data management and processing (sensor, data integration, processing, and analytics) for predictive asset management?

Question 1.8 What are the challenges and experiences about monitor and control DERs in real time using IoT technology?

Question 1.9 What are the challenges and experiences about a speech recognition learning using in smart virtual network dispatcher system?

Question 1.10 What challenges and experiences have been faced with the use of PMU data and Big Data Analytics for monitoring of power system, and operation planning?

Question 1.11 What are the potential applications of augmented reality in power systems? Currently, the applications of AR in power systems are feasible?

Sub-topic c) Tangible applications of AI and ML in EPUs:
The eight papers of this session are focused on tangible applications of AI and ML in EPUs. Eight good examples of AI and ML applications are presented: predictive lightning outage management, non-technical losses reduction, voltage violation prediction, diagnosis of transformer and circuit breaker, support system for post-fault restoration and power plants, drone for inspection of high voltage transmission lines and substations.

Paper Reference	Title	Country
D2-101	Big Data Analytics for Predictive Lightning Outage Management Using Spatially Aware Logistic Regression	USA
D2-104	Incremental machine learning implementation for voltage forecasts and predicted violation alerts	UK
D2-107	Applications Artificial Intelligence and Machine Learning Applications in the Distribution Network in Greece	GREECE
D2-109	Electric Power Utilities Disturbance analysis using Bayesian Networks of Events	MEXICO
D2-112	Machine learning as a tool to improve the efficiency of high-voltage power equipment lifecycle management	RUSSIA
D2-116	An Instance segmentation and Depth Perception Based Obstacle Detection and Distance Measurement Method for Substation Patrol Robot	CHINA
D2-117	An Intelligent Power Grid Post-fault Restoration Support System Based on Knowledge Graph	CHINA
D2-119	Development an AI Algorithm and Drone Operation System for Diagnosis of Transmission Facilities in KEPCO	KOREA

Table 3. Papers that cover tangible applications of Artificial Intelligence and Machine Learning in EPUs

- D2-101 Paper from USA proposes a model for short-term prediction of lightning outage probability in the transmission network, based on spatially aware logistic regression to provide fast and accurate prediction. The prediction model was tested using data from a large utility in the North America Western Interconnection. The results demonstrate the capability of the algorithm to predict lightning outage probability with high accuracy for a specific location. One of the advantages of this model is the capability to predict lightning outage probability for a specific location and even network components (specific lines and substations) rather than lightning outage expectancy over a larger geographical area as with other methodologies.

- D2-104 Paper from United Kingdom presents a proposal for power grid network anomaly prediction based on smart sensors, a data collection system, and voltage violation prediction algorithm based on machine learning (decision trees). The support system uses a real-time and historical voltage data and external environment data. The result is a system for the EPUs in taking preventive actions, reducing the risk of power outages and loss of the electrical system.
- D2-107 Paper from Greece describes the application of AI and ML technologies for asset management and non-technical losses reduction in Distribution Network. For the first case a roadmap for the integration of ML into asset management is presented leading to an innovative IoT solution with GIS enablement improving network management, operation and planning. Learning techniques are employed to collect data, such as patterns of operation, alarms, and faults of high value assets such as transformers, feeders, switchgear, mainly. The second use case comprises the adoption of AI and ML technologies for data analysis in order to minimize the non-technical losses caused by power theft. The result is a decision-making tool for meter and power supply inspections.
- D2-109 Paper from Mexico presents a methodology for situational awareness (perception, comprehension, projection, knowledge) based on algorithm for dealing with uncertainty and time called Bayesian Network of Events (BNE). The methodology for the diagnosis and prediction of events was evaluated for 4 common disturbances in a steam generator of a Power Plant. The results show good ability to diagnose and predict events with better results when intermediate events are detected. The formalism can be the engine machine of a support system for disturbance analysis or a system for alarm handling.
- D2-112 Paper from Russia shows the impact that the application of ML technologies can have on a lifecycle management for high-voltage electrical equipment, such as: power transformer and circuit breaker. The calculate of health index is based on basic markers and parameters (e.g. tan delta and insulation resistance). For assessing the technical status of power equipment, a mathematical model and state assessment models based on ML algorithms were developed. An improvement in accuracy by 5-6% is obtained in the power equipment technical state identification. The proposed model based on ML algorithms give the opportunity to determine the relationships (patterns, implicit dependencies, correlations, etc.) between different assets of a substation or a power plant with the objective of long-term forecasting of power asset state identification and its lifecycle management.
- D2-116 Paper from China describes a substation intelligent inspection based on patrol robots that can replace manual inspection of substation equipment. One of the main challengers for robot's intelligent inspection is the navigation, the authors proposes an obstacle detection and distance measurement based on deep neural network Mask R-CNN and RGB-D depth images. The deep neural network is trained using the pre-processed RGB images. The distance from the robot to the obstacle is measured by pixel-level matching and detection results from the Mask R-CNN. The proposed method has acceptable precision, good reliability, and low cost in simulated environments.
- D2-117 Paper from China proposes a knowledge representation for build a post-fault restoration method with intelligent assistance based on a knowledge graph. For the construction of the knowledge graph use a corpus based on Natural Language Processing (NLP). The knowledge graph establishes one-to-one associations of electrical network equipment, stations, personnel, safety margin index, failure

characteristics and other entities. An Aided Decision-Making system (ADS) was developed based on the knowledge graphs, the real-time status information, and the topological relational diagrams of the electrical network. The ADS significantly improves the efficiency of operators to restore the normal operation of the electrical network.

- D2-119 Paper from Korea describes of a system for diagnosis of high voltage transmission lines using autonomous drones. The autonomous drones tracing their flight routes and using the ground control system to carry out the maneuvers autonomously. For the diagnosis task some vision algorithms are developed based on AI technologies for the detection of failures in the elements of the line, mainly the detection of breakage of insulators. For image recognition, the system uses a deep learning algorithm. For the purpose of increase, the learning performance, the original images were divided into smaller squares of interest to increase the number of learning images, image segmentation. The proposed algorithm has a detection rate of 94% and an accuracy rate of 95.7% to determine the breakdown of an insulator.

Question 1.12: How the processing of various information sources allows the construction of robust predictive models?

Question 1.13: What types of AI and ML models can be used for prediction of non-technical losses energy in a Distribution network?

Question 1.14: What do you thing will be the future applications future of Artificial Intelligence and Machine Learning models for assets lifecycle management?

Question 1.15: What are the limitations or issues related to the development of robots and drones in supervision and diagnosis tasks for EPU?

Question 1.16: What are the experiences and issues related to the application of AI and ML in supervision, diagnosis, prediction, and forecasting tasks in EPU?

Sub-topic d) Methodologies and intelligent systems for new way to trade energy:
The four papers in this session address methodologies and systems for new way to trade energy. Two papers are focus on peer-to-peer energy trading. Two papers present the internet architecture for transitive energy. And one paper describes the application of blockchain technology for energy smart contracts.

Paper Reference	**Title**	**Country**
D2-114	Research on the Architecture of Intelligent Energy Service System Based on industrial Internet	CHINA
D2-120	Peer-to-peer energy trading: a case study in Thailand	THAILAND
D2-121	Facilitating Power Banking and Overarching arrangement through Smart Contracts based on Blockchain technology	INDIA
D2-124	Internet of Distributed Energy Architecture (IDEA): new approach to transactive energy	RUSSIA

Table 4. Papers that cover methodologies and intelligent systems for new way to trade energy

- D2-114 Paper from China describe the architecture of intelligent energy service system based on industrial internet of things. It describes the technical architecture, physical architecture, integrated architecture and security architecture of the system. The system was developed using a cloud platform and micro services, building an unified, open and integrated industrial Internet service platform that can meet the real-time and concurrent processing of massive data. A pilot application of the system in

Beijing, Shanghai is presented, includes intelligent energy data access, asset management, operation monitoring, operation management and supervision the operation of client side energy equipment.

- D2-120 Paper of Thailand provides an excellent example of what a live P2P market could look like in an urban environment, the Bangkok city. The trading pilot project in Thailand power market involves a community mall, a school, an apartment building and dental hospital with 653 MW solar PV installed capacity among all buildings. The simulation results show setting up a P2P community can enable up to 18% reduction of electricity consumption from the utility. The effects of P2P trading did not cause any voltage failure in the power network system. However, despite the advantages shown, there are legal and technical challenges for development of P2P communities.
- D2-121 Paper from India proposes a methodology based on Blockchain technology and the use of peer-to-peer smart contracts for power banking and overarching agreement. The objective is to build an online platform for transactions among all stakeholders, ranging from end consumers to power producers. Blockchain technology presents an opportunity for stakeholders to transact with one another directly thus avoiding third party fees, delays and building trust among themselves that fulfill their requirements, rather than being forced to adhere to third party demands. The use of blockchain technology-based Smart contracts will not only enable faster settlements but also provide transparent and audit-ready solutions.
- D2-124 Paper from Russia describes the Internet of Distributed Energy Architecture (IDEA) for grid and markets integration of distributed energy resources (DER), energy flexibility and transactive energy. IDEA provides framework for prosumers and their DER equipment interoperability within peer-to-peer trading and aggregators activity. The framework includes two main components: power cells (intelligent agents) and energy transactions system (energy, power and flexibility). The energy transaction can be between two power cells (peer-to-peer) and between a power cell and an Internet of energy service operator (peer-to-operator). There are three systems to ensure the interaction between power cells, their software agents and service applications, as well as to carry out energy transactions as part of the Internet of energy: the transactive energy system, the energy IoT and the Neural Grid (NG), a decentralized frequency and power flow control system. The presence of these three systems provides the possibility of seamless plug & play connection of new Internet of energy users and new power cells.

Question 1.17: What are the experiences and challenges with the integration of cloud internet, micro services, and industrial Internet for meet the real-time and concurrent processing of massive data?

Question 1.18: What are the legal and technical challengers have to be overcome for the development of P2P communities?

Question 1.19: What are the potential applications of Blockchain in complex power systems?

Question 1.20: What are technological and legal implications to be able to carry out energy transactions?

Preferential Subject 2: New Cyber Security Challenges in the Changing Electricity Industry

Introduction

The preferential subject focusses on the challenges arisen by the digitalisation needs of the energy transition and the progressive adoption of emerging ICT technologies and services within the Electric Power Utility organisations. Among the most relevant issues are the need to address organisational and technical changes to assure appropriate security levels to all the infrastructure, including legacy OT systems, IoT devices with limited resources and capabilities, new market, operation and asset management applications based on virtualised functions and managed by digital service providers.

Papers

Paper Reference	Title	Country
D2-201	Assessing Blockchain Technology to Enable High DER Scenarios Using Hardware in the Loop Testing	USA
D2-202R	Distributed Energy Resources and the Smart Grid: The Role of Soft Cybersecurity	BRAZIL
D2-203R	Leveraging SOC-as-a-Service to Counter Some of the Cybersecurity Challenges of Combined IT and OT Operations	USA
D2-204R	Applying Automated Cyber Risk Assessment for the Smart Grid	BOSNIA HERZEGOVINA
D2-205	CYber Resilience framework for ENErgy systems	ITALY
D2-206R	An Intrusion Detection System for the Smart Grid based on Computational Intelligence Algorithm	MEXICO
D2-207	Security threats and challenges in the transmission of condition and forecast data for determining the availability of substation equipment	GERMANY
D2-208	Collaborative Cybersecurity Solution for Substations	TAIWAN INDIVIDUAL
D2-209	Boosting Cybersecurity in Communication Gateways for Better Substation Protection and Control	TAIWAN INDIVIDUAL
D2-210	Critical Infrastructure Cyber Security: Applications of Machine Learning and Artificial Intelligence in Detecting, Responding to and Containing Threats	AUSTRALIA
D2-211	Cybersecurity challenges related to Distributed Energy Resources and Flexibility Providers	SPAIN
D2-212	Cybersecurity for EV charging infrastructures communications based on a tool developed to identify cyber-attacks and to restore security	SPAIN
D2-213	Cyber Secured Grid Operations with Machine Learning Implementation- A Case Study	INDIA
D2-214	Leading North American Electric Utility Implements Corporate Wide Standard for Secure Access & Device Management (SADM) to Improve Grid Reliability and Operational Efficiencies	CANADA
D2-215	Assuring secure access for operation and maintenance to substation-based telecom devices	FRANCE

Table 5. Papers for Preferential Subject 2

A total of 15 papers have been submitted that may be grouped into the following sub-topics:

a) Cybersecurity concepts,
b) New tools and platforms,
c) Emerging technologies.

Sub-topic a) Cybersecurity concepts:

- D2-202R New layers of agents are used to model emerging distributed resources and agents that provide services in an environment similar to that of the Internet. The paper discusses soft cybersecurity concepts, e.g., Reputation and Trust, to limit the interactions involving agents with unethical or hostile behaviours;
- D2-203R proposes the concept of a Federated Security Operation Centre to provide a cloud-based security arrangement for multiple small utilities. Interaction between managed security service provider and power utility managers provides real time threat detection with actionable responses;
- D2-211 discusses cybersecurity challenges related to Distributed Energy Resources and Flexibility Providers. It is necessary to regulate and ensure the level of cybersecurity in equipment and services to the DERs and flexibility providers using industry certification models;
- D2-214 provides an overview of the implementation of cybersecurity standard frameworks within utility organisations. A strategy is implemented to support proprietary and open-source device vendors for automated management with a cyber security focus.

Sub-topic b) New tools and platforms:

- D2-204R presents an automated model-based risk assessment to identify attack surfaces and paths with high fidelity models of the control system. An approach is developed to model control systems with several tables describing the physical devices and interfaces as well as the data flow for the system being assessed;
- D2-205 concerns a CYber Resilience framework for ENErgy system including modeling tools and experimental platforms used to derive key indicators in realistic communications for DER control. CYRENE cyber security functions are guided by the analysis of cyber-power scenarios based on standards and regulatory constraints;
- D2-206R develops and tests an intrusion detection and prediction system based on the artificial immune algorithm. The results show that artificial immune system is promising in identifying malware and intrusions in the networks;
- D2-210 investigates the application of Machine Learning techniques in detecting, responding to, and containing cyber threats. A case study is provided to discuss the architecture, current and planned applications as well as lessons learned and challenges.

Question 2.1: How can intrusive behaviours be built and updated by automatic tools for anomaly detection and attack forecast?

Sub-topic c) Emerging technologies and pilot projects:

- D2-201 presents an experimental setup using Blockchain technology to develop a security software tool for communication between DERs and a central management system. The blockchain technology utilizes a decentralised architecture to deliver security services such as authentication to the edge of the operating environment;
- D2-207 proposes a secure system module at substations using modern cryptography with low latency for the communication of control and monitoring systems. The secure system module is unique by use of dedicated hardware to handle cryptographic operations and the implementation of algorithms for encryption;
- D2-208 develops a collaborative cybersecurity solution based on different built-on cyber security approaches. Collaboration among different types of security solutions and between vendors and specialists in different domains is highlighted;
- D2-209 designs a three-pronged approach which entails baseline security requirements for communication gateways, protocol encryption, and Role Based Access Control (RBAC). Network access is based on the roles of users within the network. Communication gateways are capable of assigning the necessary permission;
- D2-212 discusses cybersecurity issues in EV charging infrastructures and communication protocols, covering also payment interactions and protocols between EV charging operators to allow commercial transactions of energy exchange using the Blockchain technology;
- D2-213 develops and tests a machine learning tool to help detect energy theft and cyber anomalies. The paper describes the design and implementation of a pilot study with an abnormal energy prediction algorithm as well as the technologies and potential benefits to the power networks;
- D2-215 assures secure access for operation and maintenance to substation-based telecom devices. Device level and perimeter control techniques such as traffic filtering, user authentication, role-based access control and encryption and isolation for device control links are placed in an overall architecture.

Question 2.2: What are the key challenges of cybersecurity solutions for securing substation environments?

Question 2.3: What are the effective solutions for the implementation of recovery strategies in response to detected intrusions?

Question 2.4: What is the level of device interoperability from different suppliers, as an essential requirement for a centralised security management?

Question 2.5: How long is the way to wide adoption of blockchains and distributed ledgers for the engagement of customers in the energy markets? Are the BC technologies actually distributed, secure, and scalable?

Question 2.6: What are the challenges in the implementation of EV authentication systems with multiple charging operators?

Preferential Subject 3: Increasing Operational Efficiency Using Packet Switched Communication Technologies

Introduction

The emphasis of this preferential subject to identify the issues facing power utilities worldwide in using packet switched communication technologies to replace legacy communication technologies, especially in the context of transporting time and operationally critical services such as protection over communication networks.

Based on the papers submitted, the themes that were discussed include protection over packet networks, time synchronisation, and migration strategy to packet networks, as shown in Figure 1.

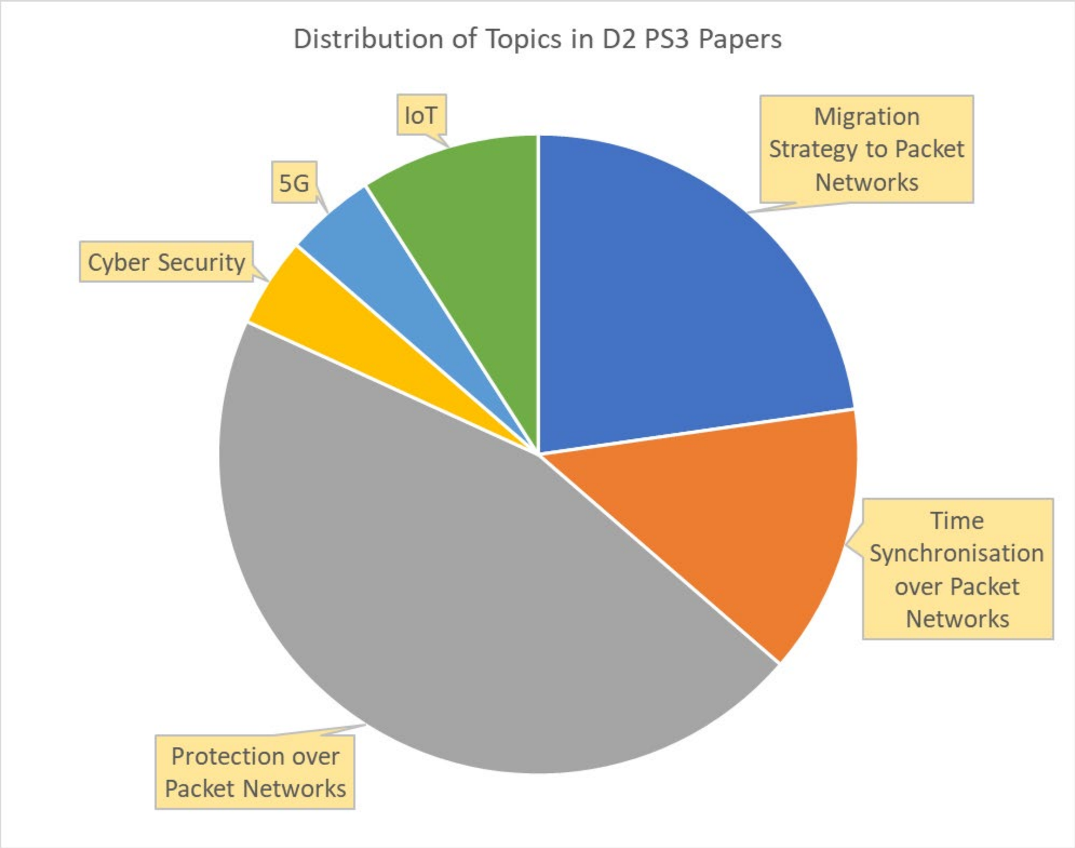

Figure 1. Distribution of topics in D2 PS3 papers

Papers

The following were the papers submitted for PS3.

Paper Reference	Title	Country
D2-301	Challenges in the Migration to Packet Switched Networks for Teleprotection Service of Power Transmission Lines	BRAZIL
D2-302	Time Distribution Applications in the Power Utility Environment	FINLAND

Paper Reference	Title	Country
D2-303R	SIARA – Proving suitability of R-GOOSE over Packet Switched Wide Area Networks for future wide area applications	UNITED KINGDOM
D2-304	Comprehensive Validation of Packet-Based Communications for Future Energy Systems	UNITED KINGDOM
D2-305R	Measures to improve the reliability of IP networks for electric power systems aiming at operation efficiency and cost reduction	JAPAN
D2-306	PACS challenges for Packet Switched Networks	VENEZUELA INDIVIDUAL
D2-307	Application of MPLS-TP for Transporting PowerÂ System Protection Data	AUSTRALIA
D2-308	Telecommunications Network Modernisation in Utilities: Challenges of Migrating from Time Domain Multiplexing (TDM) Technology to Packet Switched Network (PSN)	AUSTRALIA
D2-309	Verification and Validation of MPLS-TP for Tele-protection (Current Differential) services with existing TDM (SDH & PDH), Radio & WDM technologies through Proof of Concept	AUSTRALIA
D2-310	A Unified Communication Architecture for Smart Grid WAN/FAN/NAN Services	CHINA
D2-311	Migration to Packet Switched Networks in Iran National Grid Dispatching Center	IRAN
D2-312	Development of IoT Sensor System for Monitoring/Diagnosis of the Power Distribution System	KOREA
D2-313	Migration to Hybrid MPLS-TP & SDH Communication System for a More Reliable Performance of the 500 kV System	ARGENTINA
D2-314	Strategies for implementing teleprotection function over packet-switched networks	FRANCE
D2-315R	Using IEC 61850 for distance and differential protection over WAN MPLS-TP networks	SWITZERLAND

Table 6. Papers for Preferential Subject 3

A total of 15 papers have been submitted that may be grouped into the following sub-topics:

a) Challenges in the migration to packet switched networks.
b) Supporting the changing electricity industry with the use of existing and new communication technologies.
c) Supporting time critical operational services with time distribution and synchronisation.

The following were the summary of items discussed in each paper, grouped by the sub-topics.

Sub-topic a) Challenges in the migration to packet switched networks:

- D2-301 discusses carrying teleprotection service over MPLS with coverage of a test setup. The conclusion is that a packet switched network is suitable for teleprotection and the author provided recommendations in addressing some operational challenges.
- D2-303R provides an overview of a project that uses IEC61850-90-5 (R-GOOSE), along with the test results and findings. The author concludes that MPLS-TP can carry R-GOOSE messages. However, testing tools for R-GOOSE is not widely available and could potentially delay wider adoption.
- D2-304 describes the process of validating packet switched communication networks against a variety issues, including addressing asymmetry issues, integrating microwave links and providing reliable time synchronisation over WAN
- D2-306 discusses the challenges in carrying protection services over packet switched networks. It provides a summary of communication requirements of the various applications. In the context of the most stringent requirement of fault clearance, the paper shows that MPLS-TP is able to meet the requirement in carrying protection services.
- D2-307 discusses MPLS-TP as a packet switched technology that supports the power utility's applications, including protection services. It shows the findings from a testing on IEC 61850 and C37.94 over the technology.
- D2-308 discusses a power utility's journey in adopting IP/MPLS to carry its services, including protection. Test results are shown, along with a description of the use of its virtual laboratory which includes physical and virtual components.
- D2-309 describes the proof-of-concept test setup of MPLS-TP to carry protection services. Two circuit emulation techniques are described and compared.
- D2-311 describes the experience of a utility in migrating from a TDM-based legacy network infrastructure to a packet switched network.
- D2-313 provides an overview of the experience of a power utility in migrating from its legacy TDM-based communications network to a hybrid-based MPLS-TP and SDH network.
- D2-314 describes the strategies in implementing teleprotection over packet switched networks with an analysis of quality of service parameters. It concludes that quality of service must be adequately implemented in packet switched networks to support critical services.
- D2-315R describes using IEC 61850 differential protection over MPLS-TP with firewall and encryption functionalities enabled. The paper concludes that the network can meet the application requirements with no performance impact.

Question 3.1: Given the popularity and widespread adoption of C37.94 as a dominant communication technology for teleprotection, what would encourage native packet-based technologies (such as IEC 61850) to gain traction in their use to provide wide-area protection services?

Question 3.2: Communications networks are largely categorised into central-control model (SDH, MPLS-TP, SDN) and distributed control model (IP/MPLS, dynamic IP networks). Discuss pros and cons of each in the context of power utility applications.

Question 3.3: As critical applications are being migrated onto the packet switched communications network, it is becoming a critical network. Not only does the utility need to secure the network from third parties, it also needs to isolate the various applications on the shared network. Discuss the strategies in hardening and securing this network from external influences and misbehaving applications.

Question 3.4: With the increasing demand for utilities in migrating its applications to packet switched networks, how does cybersecurity fit into the picture in providing a secure framework in transporting critical applications over the utility's communication network?

Sub-topic b) Supporting the changing electricity industry with the use of existing and new communication technologies:

- D2-305R describes four case studies in utilising existing and new communication technologies to improve utility's operation. The case studies are: IEC 61850 over wireless, MPLS path redundancy scheme, a distributed IP-based control network, and using SDN to provide high availability.
- D2-310 discusses a unified network architecture using IoT-G for the distribution power utility, where the various layers of aggregation (HAN, F/NAN, WAN) are unified for operational efficiency.
- D2-312 describes the use of an IoT Sensor System to monitor field devices. The following applications are discussed: The detection of partial discharge of power distribution cable using an IoT sensor; monitoring of underground manhole hazards for flooding, fire and harmful gas; and monitoring of unauthorised access on electric power poles.

Question 3.5: Many IoT technologies and protocols use unlicensed spectrum. Given the nature of unlicensed spectrum and its drawbacks (i.e. shared, public open access), what role can these technologies play in improving the operations of power utilities?

Question 3.6: 5G holds much promise - however, real world use cases and solutions for power utilities are not widespread. What are the main applications or use cases that power utilities can look to improve with 5G?

Question 3.7: The SDN and SDWAN landscape is evolving from what they were a few years ago. The SDN solutions (opendaylight, openflow) is rarely used directly in power utilities in its OT network. SDWAN solutions are brought to the market by vendors as a proprietary and complex set of features integrated as a big black box which provides an appearance of simplicity. Do power utilities continue to see advantages or value in adopting SDN or SDNWAN? If yes, how would a utility use an SDN / SDNWAN solution?

Question 3.8: Edge computing or the intelligent edge is an interesting concept that may benefit the power utility. An intelligent computer which is environmentally hardened can process data closer to the source with lower latency and with less demanding WAN requirements. For example, when sources of data in the substations or in the field area network (FAN) need to send a large volume of data to be processed, the intelligent edge can be a potential solution. What are the other current and future use cases of the intelligent edge?

Sub-topic c) Supporting time critical operational services with time distribution and synchronisation:

- D2-302 provides an overview of the common time synchronisation methods and protocols used in power utilities, including SyncE, 1588v2 and the various PTP profiles and provides a brief comparison between the protocols. A case study is presented and the paper concludes that with proper planning, time distribution over packet networks can meet the requirements traditionally met by time synchronisation over TDM networks

Question 3.9: For IP-based applications that do not require high accuracy (for example, millisecond accuracy), what is the cost-effective approach in distributing the time throughout the network?

Question 3.10: As utilities undergo its migration from TDM to packet switched networks, it is likely that a hybrid network consisting of TDM and packet switched networks will need to be supported for some time. In addition to both core networks co-existing, a diverse set of timing protocols is also likely to be in use (for example, SyncE, IRIG-B, ntp, all being required). What is an effective way to distribute timing information in this hybrid environment?