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SPECIAL REPORT FOR SC B5
(Protection and Automation)

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Special Reporters

The CIGRE Study Committee B5 – Protection and Automation - covers within its scope - principles, design, application and management of power system protection, substation control, automation, monitoring and recording - including associated internal and external communications, substation metering systems and interfacing for remote control and monitoring.

Two Preferential Subjects are presented in this Special Report:

- PS1 - New protection and automation schemes based on enhanced communication possibilities
- PS2 - Expectations from stakeholders about IEC61850

Keywords:
Line Differential Protection, Line Distance Protection, Wide Area Backup Protection, Special Protection Scheme (SPS), Islanding Detection, Substation Automation, Automatic Voltage Control (AVC), OLTC, PMU, Synchrophasor, NCIT, IEC 61850, Process Bus, GOOSE Message, peer-to-peer [1] network IP/MPLS, Ethernet, Time-Division Multiplexing (TDM), Wavelength-Division Multiplexing (WDM), Multi-vendor Interoperability, Profiles, Engineering Tools, Conformance Testing, Sustainable Process.

[1] Note1: in this article a peer-to-peer network is a type of decentralized and distributed network architecture in which individual nodes in the network act as both suppliers and consumers of resources of any other substation.

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1. PS1 - New protection and automation schemes based on enhanced communication possibilities

Development of communication technologies offers a wide spectrum of new possibilities for improvement of protection and automation. Several new communications-enhanced protection and control schemes are emerging, including that for fast-acting protection and restoration, for wide-area system monitoring, and for distributed generation solutions. Besides communication, information collected by PMU and SCADA/EMS make protection algorithms and controls action more accurate and effective, and make system maintenance more efficient.

Fourteen papers on this preferential subject have been received, covering the following themes:

1. New schemes based on enhanced inter-substation communication
2. Time-critical applications using synchrophasor data
3. Power system stability analysis and action decision-making
4. New schemes based on enhanced intra-substation communication
5. Asset management and maintenance

1.1. New schemes based on enhanced inter-substation communication

Protection algorithms and control strategy are now getting more and more relying on system-wide information. Therefore, peer-to-peer communication between substations is in urgent need. Meshed peer-to-peer network logical topology is more suitable for wide-area communication than star type. Besides, there is a driving force for utilities to use an all-purpose communication infrastructure other than a dedicated one for protection application, for cost and maintenance issues.

Paper B5-101 (Canada) discusses multi-terminal line current differential protection (87L) using Ethernet-over-TDM (Time-Division-Multiplexing, SONET and SDH) for phase current data exchange and/or negative- and zero-sequence current as well. A terrestrial time system for synchronization (time-over-TDM) is proposed, which is more reliable by keeping several GPS clocks in the system networked in a ring topology.

Paper B5-111 (UK, Belgium) demonstrates the use of commercial IP/MPLS for line differential protection function using multiple protocols - IEEE C37.94, IEC 61850-9-2(SV), and IEC 61850-8-1(GOOSE). Fully redundant paths, which are switched over instantaneously and automatically, should be used to help provide resilience against equipment failures for protection application.

Paper B5-113 (Japan) concludes that IP over a small-scale and dedicated L2 network for protection system would satisfy the requirements on communication latency, jitter and reliability for multi-terminal line current differential protection. An additional timing measurement circuit is added inside the relay to measure the timing of sending and receiving to perform sampling synchronization.

Question 1.1: Are there any other practices or approaches on inter-substation peer-to-peer communication mechanism? How to achieve the sampling synchronization, minimize transmission latency and time delay jitter?

Question 1.2: For inter-substation communication, industrial Ethernet mechanism is more acceptable. Which one is more suitable for time-critical protection and control, L2 layer switch (MAC) or L3 layer switch (IP)? How to take pros and avoid cons?

Paper B5-104 (Croatia) proposed an algorithm for coordinated automatic voltage control of OLTC on radially connected power transformers, based on the communication between substations, using GOOSE message in accordance with IEC 61850. Both OLTC activities and reactive power consumption are reduced.

Question 1.3: In practice, how to publish local information and subscribe remote substation information in a standard way? Are there any examples of configuring .SED files defined in IEC61850-6 Edition 2?

1.2. Time-critical applications using synchrophasor data

Using voltage, current and phase angle information collected by PMU for time-critical applications will improve the present protection and control schemes which are mainly based on local information.

Paper B5-112 (USA) researches the feasibility of wide-area backup current differential protection based on Kirchhoff's current law across portions of the transmission grid beyond single protection zones using phase current Synchrophasor data collected by PMUs, which is much faster than conventional distance based backup protection. P Class (protection) synchrophasors defined in IEEE C37.118-2011 make it possible for wide area backup fault protection.

Paper B5-115 (Romania) presents a wide-area backup protection based on PMUs. Positive sequence voltage magnitudes at each bus and positive sequence current phase difference angles for each interconnected line are compared respectively, while minimum voltage value and maximum absolute angle difference value indicates the faulted line.

Question 1.4: Which deployment of wide area backup protection using P Class synchrophasor would be better: embedded in traditional protection, substation-wide centralized or multi-substation wide centralized. Should protection devices access PMU directly or by PDU (phasor data concentrator)?

Question 1.5: What are the trends of backup protection considering the development of communication? If the performance of such wide area backup protection is acceptable, will the traditional backup protection be partially or totally replaced? If so, how to construct a complete backup protection system? How to simplify the setting coordination of backup protection?

Paper B5-102 (Algeria and Belgium) adopts PMUs installed on both terminals of transmission line to detect a power swing and distinguish it from a fault for line distance protection, by calculating the value and variation of the apparent power absorbed by the line, and the difference in phase voltage angles between line terminals.

Question 1.6: Preventing unwanted trip during power swing or load encroachment while tripping correctly and timely for the fault is a challenge for distance protection, especially for zone 3. Are there any other algorithms for power swing or load encroachment detection for line distance protection?

Paper B5-107 (Spain) presents islanding detection methods based on vector shift, vector jump, vector surge, and synchrophasors (communications aided method) as well. The vector-shift relay is dedicated mainly to synchronous DGs, while the synchrophasors based method is especially valid for inverter-based DGs.

Paper B5-114 (Romania) summaries power transformer protection, line protection and islanding detection that are suited for network with large amounts of RES. The paper suggests an islanding detection method based on a wide-area detection scheme using PMUs.

Question 1.7: Are there any other islanding detection schemes based on other local or system-wide information with the aid of communication?

1.3. Power system stability analysis and action decision-making

Besides fast fault clearance, pre-fault stability evaluation and corresponding preventive action, disturbance detection, post-fault stability evaluation and remedy action are essential to keep the entire power system stable. Enhanced communication helps to collect information and make an action decision more timely.

Paper B5-105 (Saudi Arabia and Egypt) proposes a new heuristic real-time approach for controlled power grid separation based on “sweeping and keeping” algorithm procedures to overcome the drawbacks of the algorithm based on angle-modulated particle swarm optimization technique.

Paper B5-106 (Russia) describes new algorithms for a centralized system of emergency automation (CSEA) for dynamic stability purpose. A simplified computational model that is equivalent to a complete model can be obtained automatically for post-emergency control action calculation to ensure the required response speed.

Paper B5-116 (Korea) introduces an adaptive SPS which optimally minimize the number of generators to be tripped in a large power plant when faults occur on the outlet 765kV double circuit lines, according to a prepared scheme based on pre-fault periodical (every 4 minutes) on-line transient stability assessment with EMS data considering the total generation in the plant and fault location as well as system load condition. Additional tripping can be carried out to deal with uncertainty in simulation models and measurement data, based on the real time response of generators.

Question 1.8: With the help of communication, the performance of control actions in SPS, such as controlled separation, generator rejection, load shedding, HVDC regulation, etc. can be improved. In this case, usually the decisions are made and action commands are issued centrally in the control center, while actions are executed by IEDs in substations. In what way are the commands from control center sent to the IEDs in substations via communication channels?

1.4. New schemes based on enhanced intra-substation communication

The application of IEC 61850 and non-conventional instrument transformers will lead to a fully digital substation, where intra-substation communication plays a key role.

Paper B5-110 (UK, France, Belgium and Denmark) demonstrates the in-service advantages of IEC 61850-based digital implementation covering station bus (IEC 61850-8-1) and process bus (NCIT + IEC 61850-9-2) in a fully digital substation.

Question 1.9: What are the obstacles today for the application of a fully digital substation? How to overcome such obstacles?

1.5. Asset management and maintenance

Paper B5-108 (Spain) introduces the Integrated Maintenance Centre of Installations (CMI2) established within REE, which help human resources both in field and in control centre, to deal with management and maintenance process of lines and cables, HV equipments, secondary system and devices, in a coordinative way.

Question 1.10: Are there any experience of remote maintenance on protection devices, such as configuration and setting modification, firmware updating? Are there any concerns on communication security? What management & organizational changes are foreseen accordingly?

1.6. PS1 Conclusions

The performance of protection and control scheme can be improved greatly when using substation-wide or even system-wide information. Therefore, there is a trend to apply meshed or peer to peer communication intra- and inter- substations for protection and control purpose. Reliable and suitable communication network is a key issue for time-critical protection and control. Extending IEC 61850 processing bus within a single substation to multi-substation wide may be a good solution, but the performance of communication should be evaluated regarding the mechanism of multi-substation information configuration.

Synchrophasor seems to be the best sort of wide-area information which may improve the scheme of backup protection, power swing detection, islanding detection, et cetera. Accurate class of synchrophasor should be noticed when used for protection. The coordination of backup protections should also be reconsidered.

2. PS2 - Expectations from stakeholders about IEC61850

IEC 61850 is the unique standard ambitioning to address interoperability at communication, information and engineering levels. This special report reviews 15 papers covering the following themes:

1. Users Requirements
2. Standardization and Profiling process
3. Engineering Tools
4. Testing and Maintenance

2.1. Users Requirements

The proposed papers present users requirements from different domains perspectives (TSO, DSO, ...).

Paper B5-201 (Argentina) expresses the requirements from a TSO perspective for the development and implementation of projects within TRANSENER network, with the focus on a high quality of service and operations. The paper highlights some issues regarding DSAS specification within an IEC 61850 framework.

Paper B5-204 (Brazil) presents the results of a survey about modernization of automation systems of Brazilian hydroelectric power plants. The paper points out the fact that Engineering tools necessary to create the formal technical specifications in accordance with the IEC 61850 standard are missing. Furthermore, 38% of companies will not apply IEC 61850 standard.

Paper B5-209 (USA) states – notably based on several international surveys **-** that development of multi-vendor or vendor neutral software based tools that support the planning, engineering, design, testing and maintenance of these systems is currently inadequate. The paper points out the big challenge IEC 61850 implementation organizationally represents for utilities. Finally, some security issues are discussed in the paper, referring to IEC 62351 family.

Paper B5-210 (Japan) describes two major feasibility studies performed in Japan from which IEC 61850 standard potential improvements were identified. One important aspect expressed by the paper is the role that users (associations) have to play in order to define their common denominator and therefore ensure maximal outreach and long-term stability of the IEC 61850 standard (or profiles).

Paper B5-211 (Norway) expresses the users expectations regarding IEC 61850 from the Norwegian TSO viewpoint. The paper points out the absolute need of a robust system specification and strong collaboration between users and vendors. The authors emphasize the need to be able to implement, modify, expand and maintain IEC 61850 based SAS in an efficient way, with well-suited configuration tools and in a multi-vendor environment.

Paper B5-212 (New Zealand) describes the IEC 61850 evolution within Vector, Distribution System Operator (DSO) in New Zealand coping with the introduction of CIM (Common Information Model) and DMS (Distribution Management Systems). Moreover, the authors present an advantageous alternative to consequent financial investment (CAPEX) to solve an issue relative to increased local distribution network capacity.

Paper B5-213 (Thailand) presents experiences and expectations from Metropolitan Electricity Authority (MEA), DSO in Thailand. Among others, the paper described the following main obstacles encountered by MEA regarding its IEC 61850 implementation experience. Finally, MEA encouraged in its paper the standardization bodies to make IEC 61850 standard less flexible and to provide the users with more recommendations.

Question* 2.1.** In order to get multi-vendor interoperability over the life cycle of the system of assets, the utilities of a specific domain (eg. TSO, DSO, ...) could try to get a minimum common denominator of their requirements at the largest scale as possible (eg. group of countries, continent, ...). This is a way to ensure impact on the market and sustainability of the process. ***What is the status of different initiatives worldwide and for different IEC 61850 domains (TSO, DSO, ...) and how do the utilities currently define their IEC 61850 implementation roadmap taking into account the different activities on going within standardization bodies?

Question* 2.2.** The interface between IEC 61850 and CIM should be seamless. ***Are there concrete applications worldwide (or foreseen standardization evolution) with IEC 61850 and CIM mapping and what are the difficulties and opportunities detected?

2.2. Standardization and Profiling Process

In order to fill in the gap between what IEC 61850 currently provides and what the users expect from it (see section 2), defining sustainable processes between all the stakeholders is the key factor. Proposed papers present new trends and processes from standardization and profiling perspectives in order to reach that objective. A paper introduces a new requirement on IEC 61850 data modelling standardization with extension to protection settings.

Paper B5-202 (Belgium) produced by the Cigré Working Group B5.50, identifies on one hand user’s expectations regarding multi-vendor interoperability, tools and substation documentation. On the other hand, the stakeholders interactions are depicted in two dimensions: 1. the standardization process and 2. the implementation project process. The need of profiling the standard is emphasized in the paper.

Paper B5-206 (France) presents the challenge all market players face in order to reach the interoperability at information level. The paper discusses some methods to reach this objective and emphasizes the fact that right tools and appropriated education of all market players are also very important enablers to reach the final objective.

Paper B5-207 (Germany) has as main focus the idea of IEC 61850 standard profiling in order to improve interoperability, by keeping the right balance between restrictions and profile flexibility. The concept of Basic Application Profile (BAP) as a modular framework is introduced to reach this objective. The paper concludes that BAP needs to be standardized in order to ensure global outreach and long-term stability.

Paper B5-208 (United Kingdom) proposes to use IEC 61850 Substation Configuration Language (SCL) to represent protection settings. The paper states that this way of working has many advantages in comparison with proprietary parameters. According to the paper, the key challenge to implement this method consists to improve IEC 61850 data models which are not complete regarding protection settings.

Question* 2.3** Several activities to improve the IEC 61850 standard in order to reach a strong multi-vendor interoperability over DSAS lifecycle are on-going. Within this standardization process, each role of the different actors is key: IEC, UCA Iug, vendors and users. Question 2.1 gave the floor to utilities. This question is dedicated to the other stakeholders. ***What are the initiatives on-going in order to make sure the IEC 61850 standard improvement process delivers expected result and what is the roadmap (potentially different by domain) and associated deadline to get a significant and concrete result?

Question* 2.4.** Paper 207 presents the concept of Basic Application Profiles. ***What is the current status of BAP development in the different domains covered by IEC 61850?

***Question* 2.5.** Paper 206 emphasizes the crucial role played by UML in order to facilitate and ensure quality of standard publication and management. **Which level of UML knowledge is expected from the utilities?**

Question* 2.6** Paper 208 proposes to use IEC 61850 Substation Configuration Language (SCL) to represent protection settings and to enhance IEC 61850 data models. ***At utility side, are there concrete experiences to map proprietary settings parameters to standardized parameters and what are vendors and standardization bodies perspectives on that topic?

Question* 2.7 *What is the experience feedback regarding cyber security aspects and IEC 61850 / IEC 62351 family?

2.3. Engineering Tools

As expressed in several papers, ergonomic tools allowing efficient multi-vendor system configuration by masking standard complexity for the users are key factor to ensure a successful IEC 61850 implementation.

Paper B5-205 (Republic of China) points out the need to have an integrated tool to increase efficiency of general process around IEC 61850 based DSAS. The so-called "virtual contact" method provides to the utility staff his well-known classical environment to perform his different tasks, masking IEC 61850 complexity.

Paper B5-214 (Portugal) states that IEC 61850 has reached a maturity level in which the communication network is no longer the limitation for further benefits. The paper presents new requirements and drivers for IEC 61850 including suited multi-vendor (top-down) engineering tool environment, lifetime management, as well as process efficiency. A meta-modelling and domain-specific language approach is suggested.

Question* 2.8 *What is the potential time horizon to get mature system configuration tools available on the market and what are the key decision factors tool developers – IED vendor or not - can propose to utilities to make the choice between a system configuration tool produced by an IED vendor or by a tool exclusive vendor? What are the status and expectations regarding engineering process improvement in general (eg. quid creation of ISD – IED Specification Description File)?

2.4. Testing and Maintenance

Last but not least, testing and maintenance are two domains that will make IEC 61850 implementation succeed ... or not, as their impact is heavy of consequences on system reliability. Several papers deal with this topic and two are dedicated to it, from Brazil and Portugal.

Paper B5-203 (Brazil) presents the results of the Brazilian mirror group of WG B5.45: Acceptance, Commissioning and Field Testing Techniques for Protection and Automation Systems. The paper deals with the whole test process, from the conformance testing of products to maintenance tests. Some obstacles within IEC 61850 framework are pointed out.

Paper B5-215 (Portugal) presents the concept of Operation & Maintenance Support Systems (OMSS) as a critical requirement for utilities that focus more and more on system optimization, seeking to reduce global cost of ownership and exploring assets as close as possible to their technical limits. Required improvements of IEC 61850 are identified in this context.

Question* 2.9** A strong and sustainable process regarding documentation file management is key for the utilities in order to maintain/extend their systems in a reliable and efficient way. ***What are the different file management approaches at substation and bay levels and their associated consequences?

Question* 2.10** ***What is the status of testing at the standardization level and what are concrete experiences with O&M Support Systems from different stakeholder's perspectives?

2.5. PS2 Conclusions

At the time being, the utilities have to make sweat their crew to implement IEC 61850. More than ever, it is not ideal for a utility to waste time in integration efforts, nor cost effective – in the worst case – to have to replace a whole substation in case it is impossible to make a substation extension with another vendor. *Multi-vendor interoperability over lifecycle* is a must! *Engineering efficiency* (and not only effectiveness) or the ability to re-use engineering efforts is another important driver towards IEC 61850. Any solution to help to reduce the impact on the workload of the utility crew, constantly under increasing pressure by workforce retiring or wars of talent, is welcome. And that last argument is stronger than the *copper wiring cost reduction* often presented as one of the main driver - only valid for process bus application - to switch to IEC 61850.

The fact is, even if IEC 61850 helps going towards multi-vendor interoperability, we are not able to get from IEC 61850 what we could expect. The reasons why we are where we are more than ten years after the 1st release of the standard could bring debate. At the end of the day, the ultimate goal is to improve the IEC 61850 standard in order to get as soon as possible all the expected benefits. It is for sure that the involvement of all the IEC 61850 community (standardization bodies, conformance testing companies, vendors, users ...) is a must to reach this ambitious objective and Cigré Study Committee B5 has one key role in this fascinating journey.