by Jorge Miguel Ordacgi F. , Allan Cascaes Pereira, Iony Patriota de Siqueira and Raul Balbi Sollero , on behalf of Brazilian CIGRÉ SC B5 , Brazil

Perspective, Strategy and Applications of IEC 61850 in Brazil

For the first time in history on substation secondary systems, the Brazilian Protection and Automation Community (BPAC) is ready for a major technological change. For once in our lives, we will not be learning from products. We could prepare our specialists before the arrival of IEC 61850 based systems. Since 2005, BPAC has been prepared by conferences, seminars and specific courses sponsored by Brazilian CIGRÉ Study Committee (SC) B5 with full support from International CIGRÉ SC B5 – Protection and Automation. The "International Conference on IEC 61850" was followed by a number of courses and seminars with the attendance of Mr. Ivan De Mesmaeker and many other distinguished international invited speakers. Among them, Dr. Alexander Apostolov – PAC World Editor – played a most important role providing many courses, so BPAC could be trained on IEC 61850.

The First Phase or Initial Vision: Development and application of IEC 61850 to the power system and industry in Brazil may be described in three phases.

The introduction of IEC 61850 in Brazil started in the 2004 - 2005 period, when the new standard was first published. The response of BPAC was of technical curiosity. Practically nothing was known about the subject and BPAC had no idea of whether this standard would be accepted and practically applied in other countries. The huge size of the standard printed Parts 1 to 10 led any prospective reader to run away from it. The strong activity of the Brazilian SC B5 was very important then, helping BPAC to get acquainted to the standard. A Brazilian Mirror Group was created in 2004 to follow what was under way in WG B5.11. A preliminary study of the standard was initiated. Also, Brazilian SC B5 started presenting a series of conferences and training courses, given by highly skilled international specialists or by experienced manufacturer engineers.

Another initiative was the creation of a Joint Working Group (SC B3, B5 and D2) involving countries of RIAC –Region Ibero Americana del CIGRÉ, to study IEC 61850 applications under the viewpoint of the respective countries. A joint report will be available by the end of the year.

The Second Phase: Along the second phase of development (2006 to 2008), several applications of IEC 61850 were started. A common characteristic of this phase was the use of a conventional functional specification, stating that the substation protection and automation system should comply with IEC 61850.

In 2008, WG B5.11 mirror group promoted a workshop in Rio de Janeiro, inviting specialists from manufacturers, utilities and large consumers. The subject was "Applications and Projects Applying IEC 61850 Standard in Brazil". The main conclusion was that IEC 61850 number of applications was much larger than initially considered. The applications reported varied from large EHV substations to distribution and industrial substations, including sugar cane alcohol (methanol) refineries.

A huge oil company now working with gas generation, decided to apply IEC 61850 in many important plants and substations. Its projects have a lot of functionalities using IEC 61850 principles: automatic load shedding; motor re-acceleration; generation control; generator automatic synchronism; interlocking; start-up and shut-down of motors; source automatic transfer with or without instantaneous paralleling; bus protection using reverse blocking; breaker failure protection; measurement of electrical quantities; SOE recording; supervision of circuit breaker tripping circuit and oscillography. All the logic and other information among the protection IEDs employ GOOSE messages. These messages are used even between different voltage levels of a substation or power plant. GOOSE messages are used even for critical

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functions such as tripping, blocking and interlocking orders. For security reasons, these critical messages have hardwiring as a back up in the first projects.

The Third Phase: It has been characterized by deeper knowledge from utilities about IEC 61850 potentialities and preparation of functional specifications establishing the main principles and criteria to be followed by manufacturers. Specification preparation has been often preceded by a wide discussion among technical personnel of operation, maintenance, fault analysis and protection areas, about the advantages of applying the new standard and what is the impact of this new technology in the professional profile and on the organizational structure of the companies.

Now saying that the digital system must comply with the IEC 61850 standard is clearly not sufficient. The necessary definitions and criteria to facilitate the future expansions must be stated. It is also important that protection, automation and control engineers participate more deeply in the definition of the different aspects and details of the projects.

One example is the initiative of a distribution company which decided to make a Master Plan to establish basic criteria for using Smart Grid and IEC 61850. A more detailed technical specification with application of IEC 61850 is under way. Figure 1 indicates, in a simplified way, one of the alternatives considered for the LAN configuration.

Another example is the decision of a transmission utility to start a study to modernize its EHV large substations through IEC 61850. Many other utilities are also developing studies and preparing criteria and specifications to apply the new standard to their substations in the correct way.

The new technological stage represented by IEC 61850 still does not have the necessary development in Brazilian universities, as well as in many other South American Countries. Several knowledge areas – electrical, communication and computing science engineering – shall be urgently joined within an IEC 61850 environment, so they can be researched, developed, taught and put into practice for the benefit of professors and students. Specific R&D IEC 61850 based projects are still very few at universities, but some more will begin next year, involving the students in this new technology and preparing the required manpower for the real projects. The correct functioning of an integrated protection and automation system which complies with IEC 61850 and IEDs of different manufacturers requires the execution of functional and interoperability tests, preferably in a commercially neutral environment.

It is important that protection, automation and control engineers participate in the definition of different aspects and details of IEC 61850 projects.

A university laboratory is a nice place to have a small pilot project. There, it shall be possible to verify whether the SAS, including the communication network and the IEDs, will adequately execute the protection and automation functions in use, maintaining the specified performance. The most critical point will be the operation of the distributed functions involving IEDs from different manufacturers and considering the most unfavorable scenarios for data flow and other signals which may occur in the communication LAN. The availability of a laboratory environment also allows the simulation of faults on each IED, like wrong logical node parameters and their impact on functionality and performance. Component faults can be generated in order to avail

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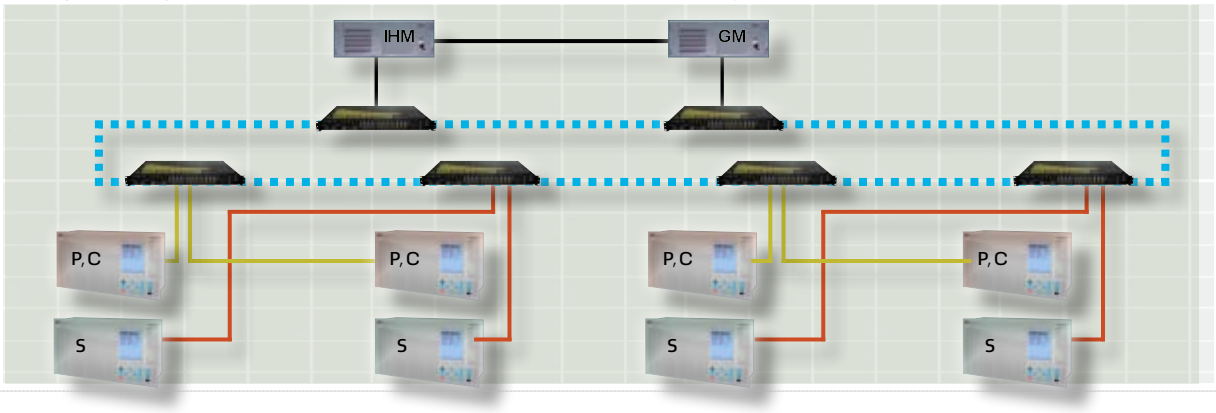
1 One of the Alternatives for LAN Configuration:
a simplified way, one of the alternatives considered for the LAN configuration



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test case coverage, or its capability to detect any kind of failure. This can be instrumental, for instance, to generate and test maintenance procedures, and for training purposes. The authors have been calling attention to the need for suitable preparation of technicians and engineers who will be involved with the areas of substation PA&C, so that IEC 61850 can be more readily assimilated and used in all possible applications

Research and development

R&D Policies for Brazilian Electric Energy Industry (BEEI): Starting in 1999, a significant part of the activities of R&D for BEEI is regulated by law (and foreseen in the concession contracts), with the objective of encouraging the constant search for innovations and to confront the associated technological challenges. Under this law the electric power G, T and D utilities should apply a minimum of 1% of their net operating yearly income in BEEI R&D Program.

It is the responsibility of the Brazilian Electricity Regulatory Agency (ANEEL) to regulate investment in this program, evaluate and approve the conditions for the research and following up on its results. Many projects have been carried out under this program that is the main funding source for research in Brazil, typically involving collaboration between utilities and universities

SCADA and SE Automation through IEC 61850: The program mentioned above and Brazilian SC B5 action in disclosing the new technology were powerful inducers of some early experiences and effective adoption of IEC 61850 based automation systems in new substations and, particularly, in new bays of existing substations. Soon became apparent, though, the need for a flexible Substation Concentrating Unit to perform functions as:

- Concentration and management of the supervision and control information from the existing relays and remote terminal units, through legacy protocols (serial and TCP/IP based) and, also, integrating them with the new IEC 61850 IED network (possibly with equipment from different vendors)
- Communication with a multiplicity of S&C systems as: local MMI, remote regional center, ISO, third party accessing TRANSCOs, etc, using different communication protocols
- Acquisition, processing, storage and distribution of analog and digital information (status, alarms and SOE) from the legacy relays and RTUs and also the new IEDs to the control centers, at maximum specified delays
- Issuing controls to the legacy infrastructure and the new IEDs
- Implementation of substation wide automated functions and sequences (isolation of a circuit breaker for maintenance, energization of a parallel transformer, etc.) involving both legacy automation infrastructure and new IEC 61850 IED network
- Bring to SCADA/EMS the significant productivity gains enabled by IEC 61850 in the substation project and configuration, through automated database generation tools based on SCL language. Incidentally, this has become one of the most recognized benefits of this new technology, significantly reducing engineering time and cost

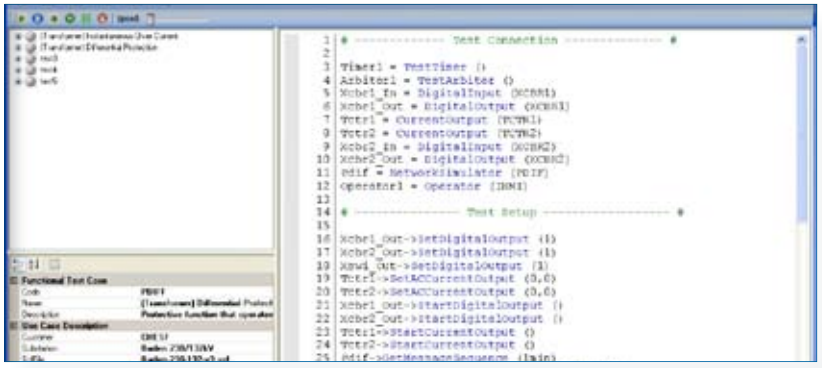
Based on these needs, CEPEL (Electric Power Research Center), back in 2004, decided to invest decisively to enable its SCADA system to become a full IEC 61850 client, filling the gap between SCADA and substation automation systems. Some technical characteristics of this SCADA system revealed to be valuable for this task. From its very origin in the last decade, this system faced the challenge of overcoming some common general issues typical of current SCADA/EMS architectures: lack of standards, leading to difficulties with portability,

There is a need for suitable preparation of specialist in IEC 61850.

The Brazilian Electric Energy Industry is in constant search for innovations and solutions to technological challemges through an extensive R&D program.

2 SMASH project platform

A modeling, testing and diagnosing platform as proposed by WG B5.32



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interconnectivity and integration of new functions; limited innovation, probably associated with small market size and absence of standard requirements; and excessive dependence on a limited number of viable EMS vendors.

The resulting product reflected the special position of a R&D Center as a provider of EMS. Specifically, the system managed to be modular enough to incorporate continuous innovations; also, the strict adoption of official and de-facto standards (C, Unix, TCP/IP, Java,) enabled the support of multiple hardware and software platforms (PC/Xeon-Linux, Sun-Solaris, Itanium-HP/UX, etc, even in heterogeneous networks). Additionally, extensive connectivity and third party integration capability was obtained from strategies and technologies as:

- CIM – Common Information Model for EMS data exchange
- WEB Suite: HTTP; FTP; HTML; XML
- Native implementation of ICCP, IEC/60870-5-10x, DNP 3.0 and other standard and proprietary communication protocols

These technologies and standards proved to be effective to achieve a very flexible and adaptable product.

Nevertheless, the major leap in the last years was the disclosure of IEC61850 standard. This kind of architecture shown on Figure 1 has been successfully applied in a number of real projects in Brazil, sometimes involving many dozens of IEDs.

Involvement with standardization

Brazil has a steady investment in new substations and power plants, mainly in northern region, concurring with a continuous growth and refurbishment of existing installations. For these assets, market trends dictate the use of current and future proof technologies, so a strong commitment to use IEC 61850 based systems is common for major utilities, as follows:

- Participating in international standardization efforts
- Structuring of national normalization bodies
- Training and promotion of the standard use
- Testing and evaluating the standard effectiveness

To closely monitor and help IEC 61850 development, Brazil has nominated a permanent member on IEC TC 57 and its WG 10, backed by a local mirror committee.

A strong commitment to the use of IEC 61850 is common in Brazil.

Due to its current number of plants under commissioning, the interest is centered mainly on functional testing of IEC 61850 based systems. In line with this focus, Brazil has recently convened CIGRÉ WG B5.32 – Functional Testing of IEC 61850 Based System, whose report is being proposed by SC B5 to be standardized by IEC. The document describes an object oriented approach, using UML, text and XML formats, as the result of a joint effort of experts from many countries. It is expected to be a major step in the direction of standardization of functional testing. Some Brazilian universities are already testing this concept, by sponsoring academic thesis and research programs on IEC 61850 based systems. For instance, Figure 2 shows the SMASH project, a modeling, testing and diagnosing platform as proposed by WG B5.32. This project is under construction by Chesf and UFCG (Universidade Federal de Campina

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3 IEC61850 post graduation Course

The course was sponsored by the Informatics and Automation Technology Institute (ITAI)

From 2006 on, many vendors offered courses about their visions on IEC 61850 so that the multiplying effect was enough to cover all BPAC.

Grande). Recently, in cooperation with Omicron and Adimarco, Chesf has conducted the successful testing of an IEC 61850 based IED from a remote site, located 839 km apart from the testing set.

To support its normalization effort, the mirror committee of IEC TC 57 will develop a national standard equivalent to IEC 61850, under the sponsorship of ABNT (Brazilian Association for Technical Standards) and its electricity committee (COBEI). The current task is to produce an equivalent of Part 10 with focus on conformance testing. After publication, it will impact the specification of systems and laboratory testing by utilities, research centers, testing facilities and universities. A similar committee was recently commissioned to propose a national standard equivalent to IEC 61400, in line with the goal to increase the wind power share on national energy matrix. Its current task is to develop a standard for wind farm communication, monitoring and control, in line with Part 25 of IEC 61400, following IEC 61850 methods.

Aside from these efforts, Brazil has launched perhaps the world's first post-graduation course in automation of electrical processes with emphasis on IEC 61850 (Figure 3), through ITAI (Informatics and Automation Technology Institute) under the sponsorship of Itaipu Binational. This course aims at training industry experts in specifying, designing, maintaining, integrating, commissioning and testing IEC 61850 based systems for substations, wind farms, hydro power plants, and distributed energy resources (DER). Its contents are independent from IED manufacturers and focused on the integrator and user needs. This is complemented by several symposia and short courses about IEC 61850, promoted by Brazilian CIGRÉ SC B5. Brazilian utilities are also commissioning multiple supplier IEC 61850 based SAS. To probe the interoperability features, some utilities have installed their own test bench for experimenting new projects (Figure 4). This test bench uses IEDs from several manufactures, standard satellite time servers, networked by switches from independent suppliers, and monitored by a SCADA system and open-source network analyzers, all communicating by IEC 61850. This scheme is kept constantly in service to support internal training, maintenance and testing of relay settings and automation schemes.

Concerns and dreams about the future

Having an interconnected power system 4,000 km long (North-South), Brazil optimizes its interconnections power flows, thanks to different hydrologic regimes among its hydro generation areas. So, active and reactive power flows experience wide changes during the year. It is not uncommon that sudden changes be imposed by contingencies or by mutual assistance with Uruguay and Argentina. One example of this operation criterion is having heavy loaded interconnection lines during light load conditions. Another one is the recent installation of usually light loaded interconnections across transmission trunks between hydro generation areas and load regions, so the trunks may help one another in case of internal contingencies through light loaded paths. Soon, Brazilian System will be 4,000 km large as well.

Involvement is required at all hierarchical levels of the industry.

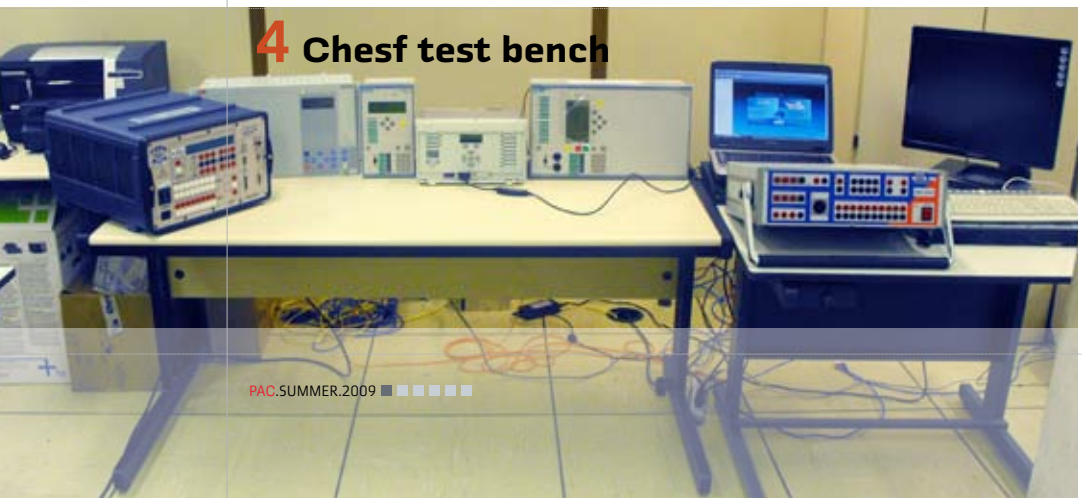
All mentioned above may be enhanced and optimized again in wider and more accurate basis, if new tools are effectively introduced and applied up to the limits of their capabilities. Among them, IEC 61850 plays an utmost important role, but secondary systems based on the new standard will have to be applied considering local and system wide viewpoints.

Despite having specialists ready to handle IEC 61850 systems, Brazil needs them to be in permanent evolution. This means the involvement of all hierarchical levels. Only by convincing utilities' managers, directors and CEOs, it will be possible to spread knowledge absorption and to go beyond training.

Of course Brazilian SC B5 is a natural forum for training, but stronger stimulation is needed to involve the managerial level with this subject. It could be done by (ANEEL) or Brazilian ISO (ONS). The authors believe that once ANEEL, ONS and utilities' boards are "polarized", Brazilian SC B5 will be able to handle all details.

IEC 61850 is being enhanced to be suitable for power plants and inter-substation applications. Process bus is already a reality. IEC 61850 will probably be the most adequate vehicle to introduce interoperability and other facilities at control center level. These

Testing of individual IEDs and their interoperability is essential for the success of any IEC 61850 based project.



4 Chesf test bench

statements show that a distributed processing net (DPN) from the bay up to the control center levels will be feasible in a few years (Figure 5). To reach such a goal, secondary systems shall be considered a cooperative service, so the way for national planning will be paved. Then the usual questions (what, why, who and how?) will be raised – and solved. If national planning is not achievable, than the utilities and Brazilian ISO will behave as the opposite of "The Three Musketeers": each one for itself! Through this winding path the same goal may be reached, but spending much more energy.

DPN optimized use from the bay up to the control center levels raises many issues, as stated in the paragraphs below

Nowadays the basis for adaptive protection is well established for intra-substation applications. On the other hand, the adaptive protection concept and application to cope with system-wide prevalent conditions (SWPC) is yet to come. Many line and transformer protection settings could be automatically optimized for SWPC forecasted by operative planning studies. For functions as out of step blocking and tripping (68OSB and 68OST) and loss of synchronism (78), the inclusion of system-wide adaptive features will be most welcome. The proper control center level (utility, regional or national) shall be defined. How to calculate and mostly how to decide the moment for a setting change are the main challenges for national and international R&D activities. The same certainly will benefit adaptive control systems. Adaptive features will be implemented easily at substation or power plant level by IEC 61850 based systems.

Brazilian Grid Procedures demand that the secondary systems of new installations shall be capable of supporting generic Special Protection Systems (SPS). Efficient SPS require both local and upper level facilities for their broad application. There are expectations that the SPS added cost imposed to secondary system costs shall be reduced by overall optimization provided by IEC 61850 inherent benefits. Among these benefits, interoperability is the one that leads to reduced engineering costs for similar SPS!

Metrological studies are needed for defining one single measuring system for all supervision, control and measuring (including revenue measurement) functions. In a DPN environment, measuring systems (MS) shall move from many independent systems to a single one – at least to a single basis. The profusion of MS based on independent IEDs and the legacy of old MS sometimes imposes misleading interpretation when distinct readings of the same electrical quantity are compared. Reaching measurement uniqueness requires metrological studies not yet performed in Brazil or elsewhere and depends on large international debates that may be carried out by CIGRÉ SC B5 and pushed by PAC World. How can one have a secondary system with all facilities provided by IEC 61850 and insist on having different methods to measure frequency, voltage and current and then calculate active and reactive powers and energies by distinct algorithms? How to proceed in substations and power plants where phasor measurement is required for system wide applications? The challenge is stated!

The Distributed Processing Net (DPN) from the bay to the control center will be feasible in a few years.

In a DPN environment, SCADA systems shall evolve to handle information with high added value and not process data anymore. The transformation of data into information shall start at IED level, maybe at merging unit level. The evergreen concept is the way for SCADA systems to keep pace with the evolution reached at substation level through IEC 61850. Energy management systems (EMS) will be spared for more sophisticated goals. The combined use of IEC 61850 and phasor measurements will certainly lead to system topology/ state monitoring and dynamic state estimation. Static state estimators and topology estimators will not be necessary anymore. As Dr. Apostolov stated during his courses in Brazil: "power systems are on their way to use dynamic state estimators and all the benefits they will bring in ensuring the stability of large electric power systems".

Brazil is applying and handling IEC 61850 in a consistent way, according to its secondary system market evolution. Operational hierarchy and organizational management upper levels shall be "polarized", so IEC 61850 broader application may benefit the countr.

5 DPN Basic Concept