FUNCTIONAL TESTING OF IEC 61850 BASED SYSTEMS

REFERENCE TERM

TITLE

Functional Testing of IEC 61850 Based Systems

ENTITY

Cigré

STUDY COMMITTEE

B5 – Protection and Automation

TASK FORCE

TF B5.92 - Functional Testing of IEC 61850 Based Systems

CONVENOR

Iony Patriota de Siqueira/BR

PARTICIPANTS

The following Cigré members have already confirmed their participation:

Name	Country	Member
Iony Patriota	Brazil	Convenor
Pascal Postec	France	Regular
Marcelo Paulino	Brazil	Regular
Alex Apostolov	USA	Regular
Tetsuji Maeda	Switzerland	Regular
Dennis Holstein	USA	Regular
Fred Steinhauser	Austria	Regular
Damien Tholomier	France	Corresponding
Marcus Steel	Australia	Corresponding
Gareth Baber	United Kingdom	Corresponding
Benemar Alencar	Brazil	Corresponding

Ubiratan Carmo	Brazil	Corresponding
Benton Vandiver	USA	Corresponding
Ricardo Cartacho	Portugal	Corresponding
Allan Cascaes	Brazil	Corresponding
Artzol Garcia	Spain	Corresponding
Ren Yanming	China	Corresponding
Sun Bo	China	Corresponding

Besides these participants, voluntary contributions and support will be welcome from experts working for electric utilities, universities, research centers, power system operators, test equipment suppliers, Substation Automation Systems (SAS) manufacturers, etc. Many Brazilian companies have already manifested their support for this work. Ongoing research projects jointly supported by Chesf (Companhia Hidro Elétrica do São Francisco), UFCG (Federal University of Campina Grande), USP-SC (University of São Paulo at São Carlos) and Aneel (The Brazilian Electric Energy National Agency) will also provide guidance and suggestions for the project.

INTRODUCTION

Substations play essential functions to the generation, transmission and distribution of electric energy. From voltage elevation for long distance transmission, to voltage reduction, switching and regulation on urban, residential and industrial distribution, substations concentrate complex equipments that usually form the main assets and capital investment of utilities and electric systems. Due to ascending unit capacity, operation of these items demands, besides intrinsic functions of transformation, regulation and switching, a complex set of support systems and functions, including protection, reactive compensation, load and voltage control, isolation, supervision, etc. This diversity demands a complex set of local automation functions, enlarged by network and system wide control requisites.

Among substation equipments, protection and automation systems present a huge concentration of technological evolution, following the main stages experienced by electronics and, more recently, by telecommunication and software systems. Isolated systems do not meet today power system requirements, being replaced by distributed, but integrated, assemblies of software, hardware and telecommunication assets. Testing and verification of such complex systems require a substantial work from agents entitled of their maintenance, operation, acceptance, integration, commissioning, design and construction. Close cooperation will be necessary from specialists on:

- Substation Automation Systems (SAS);
- Telecommunication Systems;
- Power System Protection;
- Energy Metering;
- Substation Monitoring;
- Design and Specification of Substation Equipments;

- Development and Fabrication of Substation Equipments;
- Repair and Refurbishing of Substation Equipments;
- Research and Development of New Substation Equipments;
- Test and Simulation of Substation Equipments;
- Protection, Regulation and Monitoring of Substation Equipments;
- System and software integration;
- Etc.

The initial advent of digital substations was followed by a rapid evolution of software technology. Substation automation systems formed by distributed components represent now not only a technological possibility, but a market demand, made viable by the IEC 61850 standard. Interoperability among IEDs (Intelligent Electronic Devices), used in SAS, can be verified by conformance and type tests according to Part 10 of IEC 61850 ("Conformance Tests").

Conformance tests are suitable to guarantee the secure connection of IEDs, but they do not assure that interconnected IEDs meet the functional requirements of users. To these users (or stakeholders), it is necessary that the IEDs will perform the required functions according to established quality standards. Functional, systemic and integrated tests are needed to attest these requirements. Besides commissioning, it is also necessary to define recommended functional testing to prevent, or correct, incipient failures, or minimize their consequences to the substation and the power system. To achieve these goals, a structured methodology is needed to correlate each functional failure mode or fault with the ideal preventive test.

Among all current testing methods, functional testing shall excel in defining an integrated set of tests to identify and analyze failure modes (or faults) of modern substation protection and automation systems, while suggesting preventive and corrective actions to minimize failure impacts. Functional tests are also meant to certify the attendance of strict criteria related to performance, security and environment protection, simultaneously seeking to assure its economic viability.

OBJECTIVES

The main objective of this Task Force is to recommend functional tests for Substation Automation Systems based on IEC 61850. Six main areas shall be focused, according to the Creation Form submitted to Study Committee B5:

1. Functional testing of IEC61850 based systems
2. Distributed application testing;
3. Overall system testing;
4. Use of SCL (Substation Configuration Language) for the testing;
5. Functional test system requirements and definitions;
6. Functional testing considerations to be taken into account in the specification.

Conformance (type and interoperability) testing of IEC61850 based systems (and IEDs) will not be focused as they are already covered by module 10 of IEC61850. All IEDs will be assumed to conform to this standard.

METHODOLOGY

All functional tests will aim to find failures resulting from system setup, integration and/or component malfunctioning. Starting from a specification of an SAS, the methodology will seek answers to the following questions, in sequence:

- What system functions are specified for the SAS?
- Which functional failures may occur for each function?
- Which failure modes (faults) are common to these systems and their logical nodes?
- Which failure effects and symptoms may be used to identify them?
- Which failure consequences may result to the substation automation system?
- Which tests could identify and possibly locate these failures?

In answering these questions, the Task Force will seek general conclusions and consensus of value to system integrators, manufacturers, researchers, consultants, maintainers and operators of these systems. The following paragraphs present a sequential summary of the proposed methodology for the project.

The project will be developed in seven phases, named as:

(1) Conceptual consensus about IEC 61850;
(2) Conceptual consensus about the methodology;
(3) Functional identification and information gathering;
(4) Functional performance requirements;
(5) Failure Mode and Effects Analysis;
(6) Identification of applicable functional tests;
(7) Test documentation;

The start phase, **Conceptual consensus about IEC 61850**, will promote a discussion and exchange of experience and perceptions among participants, aiming at establishing a common conceptual reference for the project. An important artifact will be produced for the next phases, consisting of a UML model of all main concepts of IEC 61850, representing a consensus model of common SAS functions. Besides all major components such as servers, logical devices and logical nodes, the model will include the needed artifacts to represent functional failures and failure modes or faults to be sought by functional tests.

The next phase, **Conceptual consensus about the methodology**, entails discussion and definition of the methodology adopted by the Task Force. It is envisaged that this phase can be attained in close consonance or simultaneously with the previous one, perhaps on the first meeting. A high level architecture for a functional test platform, also expressed in UML, will be produced as the main artifact of this phase, including test case templates to be used on posterior phases.

The third phase, **Functional identification and information gathering**, will identify and document all typical functions and associated performance requirements, of a Substation Automation System. Part 5 of IEC 61850 has already listed all major functions common to SAS. The suggested artifact generated by this phase will specify a function and performance extractor from a SCL (Substation Configuration Language) file describing an SAS. UML again looks like a suitable tool to express this artifact.

The fourth phase, **Functional performance requirements**, will catalog all major quality requisite for each function of the previous phase. Performance requirements will serve as guidance to identify functional failures, or ways of not attending user's requisites.

The fifth phase, **Failure Mode and Effects Analysis**, will correlate functional failures of an SAS to failure modes of the component IED and logical nodes, extracted from the SCL file. Using the FMEA method, the following treats will be documented:

- Functions played by each system;
- Possible failures of each function;
- Modes of each failure;
- Effects of each failure mode;
- Severity of each effect.

Several tools may be used, such as Failure and Event Trees, derived from Logic and Functional Diagrams of the systems, and documented on standards FMEA forms.

In the sixth phase, **Identification of applicable functional tests**, activities and test cases will be determined that are technically suited to each SAS function, to prevent, detect or correct each failure mode, or alleviate their consequences.

The seventh and final phase, **Test documentation**, will use a structured process to document each test execution. The UML Test Profile of the OMG (Object Management Group) looks like an excellent candidate to define test cases for distributed software systems. Suitable templates will be derived to be used on the testing platform defined on phase two of the methodology.

All work of the task force will be supported by an internet project site, located at http://www.tecnix.com.br/cigreiec, with webmaster and web hosting services kindly provided by Tecnix Engenharia e Sistemas Ltda, an engineering consulting firm from Brazil.

DELIVERABLES

The following products will be generated by the task force:

- Technical brochure titled “Functional Testing of IEC 61850 Based Systems”;
- Summary article to be published by Electra magazine.

The Technical brochure titled “Functional Testing of IEC 61850 Based Systems” will be a printed manual with the results of all Task Force phases. The brochure will be structured as a reference document about applying functional tests to Substation Automation Systems, and also as a methodology of designing tests from an SCL file. It will be suitable as a reference text to system integration, commissioning and maintenance of SAS.

The summary article to be published by Electra magazine will resume all major aspects of the brochure and the work of the task force.

CONCLUSIONS

The analysis of functional tests of IEC 61850 based systems may suggest future extensions to complement conformance, type and interoperability tests already covered by Part 10 of IEC 61850. Also, their results could be published as papers authored by Task Force and Cigré members, on a colloquium or Paris Session promoted by SC B5.

SCHEDULE

The activity schedule will be defined by the Task Force, during its first meeting, with deadlines for the following suggested topics:

(1) Conceptual consensus about IEC 61850;
(2) Conceptual consensus about the methodology;
(3) Functional identification and information gathering;
(4) Functional performance requirements;
(5) Failure Mode and Effects Analysis;
(6) Functional Testing Tools
(7) Functional Test Specification;
(8) Test documentation;

Application of topics 3 to 8 to all possible automation functions will certainly need a major effort from the Task Force members. So, may be the job could be divided in two phases:

a. Methodology Definition phase
b. Application phase.

The Methodology Definition phase would perhaps follow steps 1 to 8 above, limited to a few selected automation functions, to just test and demonstrate the methodology. This would be the goal of TF B5.92.

The Application phase would be the aim of a new TF or WG, after approval by the Study Committee B5, to apply the chosen methodology to all major automation functions.

These decisions will be taken during the first TF meeting.