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IEC 61850 and Measurements

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Introduction

The aim of current work is to face up the important aspects of the implementation the standard of International Electro-technical Commission IEC 61850 for control, monitoring and protection automation in the new Elering OÜ substation.

Overview of conventional measuring technology

The secondary equipment of transmission network substation is constructed from different devices that modify the semi-closed system of substation automation, control and monitoring. The definition of semi–closed system means:

- Communication topology (star) for internal data exchange within telematics system;
- Open remote handling connections of protection relays mainly for external data exchange.

The instrument current transformer is the primary device that makes current measuring opportunities available for relay protection and monitoring purposes.

The several substation bays shall be equipped current instrument transformer with CIT like HV power (auto)transformer bay, MV power (auto)transformer, HV/MV busbar coupler bay, HV power overhead and/or cable line bay etc.

The general content of the CIT is cap, bellow, primary rod with terminals, cores, casting, internal (oil-paper) and external (porcelain or composite) insulation, filling oil and body. The CIT may have few cores according to the request. Usually it is used for transmitting the measurements to the different protection relays (main and back-up relays). Hence the "*N-1*" criterion will be fulfilled if one core will rupture its proper work, i.e. other cores of CIT will remain in normal operation unharmed.

The instrument voltage transformer (VIT) is the primary device that makes voltage measuring opportunities available for relay protection and monitoring purposes. The several bays shall be equipped with VIT like power HV overhead/cable line bay, power (auto)transformer MV voltage bay etc.

The cap, bellow, bushing, casting, external (porcelain or composite) insulation, windings, iron core and terminal box are general parts of VIT. The VIT could be used in different type of performance:

- Capacitive VIT (single phase, more than 35 kV);
- Inductive VIT (three phase up to the 36 kV).

Nowadays the often used instrument transformer is combined instrument transformer that includes in one primary device case the current and the voltage instrument transformers. The main advantage of that is space saving in the switchyard and device cheapness.

The task of measuring transducer (MT) is the convert analog signals to the other level analog signals or digital signals. The MT input side is usually hardwired to the secondary circuits of the instrument transformers and output side is connected to the analog inputs or communication interface of Remote Terminal Unit (RTU).

The MTs could be connected into the loop or radially (star topology). The RTU and MT are using as well the industrial protocols and as communication protocol IEC 60870-5-102/103 [9] and IEC 61850.

The conventional telematics technical solution is the telematics structure based on star topology. E.g. the serial communication protocol of IEC 60870-5-103 will be used in direction of Intelligent Electronic Devices (IEDs) and the TCP/IP communication protocol of IEC 60870-5-104 – in direction of Remote Control Centre (RCC). The MTs are commonly hardwired (loop) to the RTU directly or via electrical/optical decoupling device. The telematics system shall be time synchronized (GPS) with appropriated time accuracy [10].

IEC 61850 station bus and process bus

There are several debating themes concerning to IEC 61850 implementation:

- Cost-efficient design by primary equipment;
- Cost-efficient solution (same network for different tasks);

- Device parameterizing transparency;
- Cost efficient device parameterizing work;
- Several services via same local area network (LAN);
- Large testing availability in IEC 61850 LAN;
- IEC 61850 interoperability of different vendors.

The Utility shall firstly read carefully through all parts of standard IEC 61850 and "pluck out" the key opportunities, needed for Utility. The tight consulting shall take a part between Utility and Manufacturer for better understanding of IEC 61850 benefits. Usually there are several basic questions that Utility should answer:

- How deeply to allow the IEC 61850 into the station bus, that get the maximum of the benefits;
- How deeply to allow the IEC 61850 into the process bus, that get the maximum of the benefits;
- Education and training steps for Utility specialists.

The process bus is distinctive by direct IEC 61850 implementation in the switchyard, e.g. measuring system and control of circuit breaker (is not under discussion).

There are the proposal requirements according to IEC 61850 for the SS telematics:

- The optical connections (e.g. optical LAN) should be used between substation IEDs, RTUs and workstations;
- The maximum of substation equipment functions like power transformer automatic reserve switching, load shedding automation, circuit breaker automatic reclose equipment, circuit breaker failure protection, current blocking logics, shall be realized using the standard IEC 61850;
- The communication protocol between IEDs, RTUs and workstations shall fully meet the standard IEC 61850;
- The substation (SS) shall have one physical LAN for telematics, automation, time synchronization, remote handling and interlocking logics all together;
- The one LAN interface is able to provide few services from different IP-addresses (e.g. IEC 61850 services, remote handling, time synchronization);
- The SS shall have one physical LAN for telematics, time synchronization and remote handling purposes. The maximum number of sequent connected RTU and IED devices shall be defined;
- The amount of switches connected in LAN is defined by voltage level and functionality of IEDs. E.g. one switch is per HV I. main relay protection, HV II. main relay protection, HV backup relay protection, together HV backup and MV relay protection and ancillary protection and functions (e.g. annunciator, power transformer ARS);
- The device certification of meeting the standard IEC 61850 (independent test-lab) [**Error! Reference source not found.**], e.g. IEC 61850-3 for switches;
- The IEDs, RTUs and workstations shall be time synchronized with accuracy of equal or less than ± 1 ms within IEC 61850 LAN;
- The system switching devices shall use the VLAN handling. The priority tagging, Rapid Spanning Tree Protocol or dual Self-Healing technology are mandatory for use;
- The system switching devices shall ensure "*N-1*" criterion for IEDs, RTUs and workstations;
- The recovering time (only by RSTP) of system switching devices is defined by amount of switches and the exact value of recovering time shall be calculated and agreed with Utility;
- The SS control interlocking (NOT the relay protection blocking) shall be realized for complete SS interlocking system by Generic Object Oriented System Event (GOOSE) messages (copper connections with interlocking coils shall remain in use). The GOOSE messages are part of Generic Substation Event (GSE) that contains also the Generic Substation State Event (GSSE). The main difference between GOOSE messages and GSSE messages is unique re-transmitting system of data set in GOOSE, but the status will be only transmitted within the change in GSSE message;
- The starting and blocking signals of automation, protection functions and trip signals shall not be realized by GOOSE messages;
- GOOSE messages shall be under supervision from protection relays. Hence the fast re-transmit on data change and the periodic slow re-transmit of GOOSE without data change (configurable retransmission time in ms) are required;
- Factory Acceptance Test for each IEC 61850 device and built system at factory;
- The all appropriated software, licences, tools (e.g. IEC 61850 substation configurator tool) and accessories concerning to the IEC 61850 shall belong to delivery;
- The using of Merging Unit (MU) is requested for measurement transmission tasks to the station bus from process bus;
- The measurement accuracy of instrument transformers shall be 0,2S for non-conventional (0,2S and also 0,5 for conventional types) [8];
- The sampling value of sampled measurement value for relay protection and measurement visualizers shall be at least 80 times per period and 256 for quality analyzer;
- The MUs shall be time synchronized with accuracy of ± 1 μs and simultaneously use same time;
- The IEDs, RTUs and workstations shall have certification of conformance test for IEC 61850 from independent test-lab;
- The parameterizing of SS according the IEC 61850; e.g. all new logical nodes shall be agreed with Utility, the creating or deleting of the device data set online is not allowed, because of modified data loss after device reboot;
- The appropriated ICD (IED Capability Description), SCD (Substation Configuration Description), SSD (Substation System Specification Description) etc. files for shall be delivered to the Utility after SS final commissioning. The Utility shall take into consideration that some parameterizing tasks (e.g. creation of Configured IED Description, Instantiated IED Description, System Exchange Description) will be done by Vendor software automatically without any influence and the necessity of handle them by human;
- The redundancy conditions (the RTU, LAN etc.);
- The industrial local PC workstation with full functionality of conventional RTU could be used instead of conventional RTU device installation.

Probable station bus solutions

The IEC 61850 is dedicated for internal using in SS

station bus and process bus.

Since the measurements transmission could be ensured by IEC 61850, no MTs are more needed for appropriated tasks.

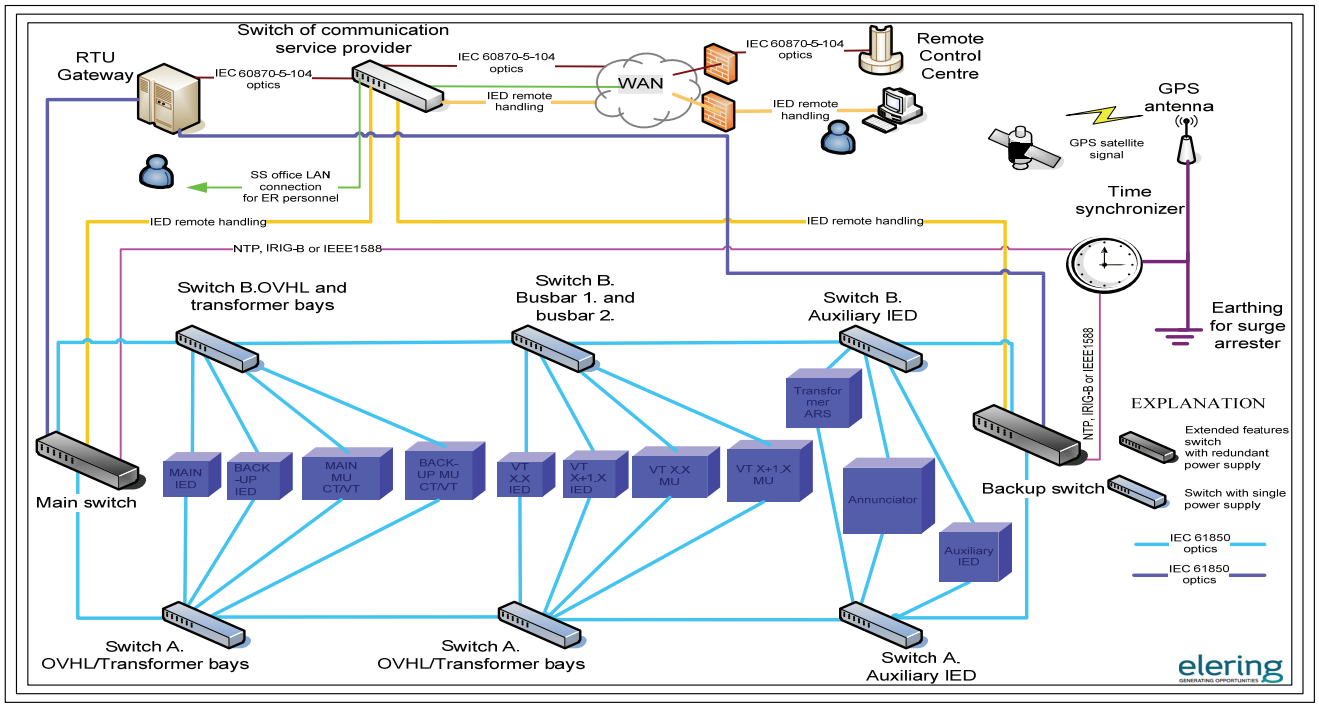

Fig. 1. Structure of IEC 61850 LAN (variant A)

The "Contra" technical key-attributes [Fig. 1]:

- A lot of switching devices (costly solution);
- Long period for recovery time. Probable data losses during the switch recovery time. This solution can be improved by reducing of the switch amount by integration the main and back-up switches into some bay switches. Or two IEDs shall be connected in sequence same switches;
- IED vendors could not always offer an IED with doubled IEC 61850 optical interfaces.

The "Pro" technical key-attributes [Fig. 1]:

- The "*N-1*" criterion is fulfilled for every switching device;
- The one malfunctioned IED does not influence other IEDs, RTU (or local PC workstation).

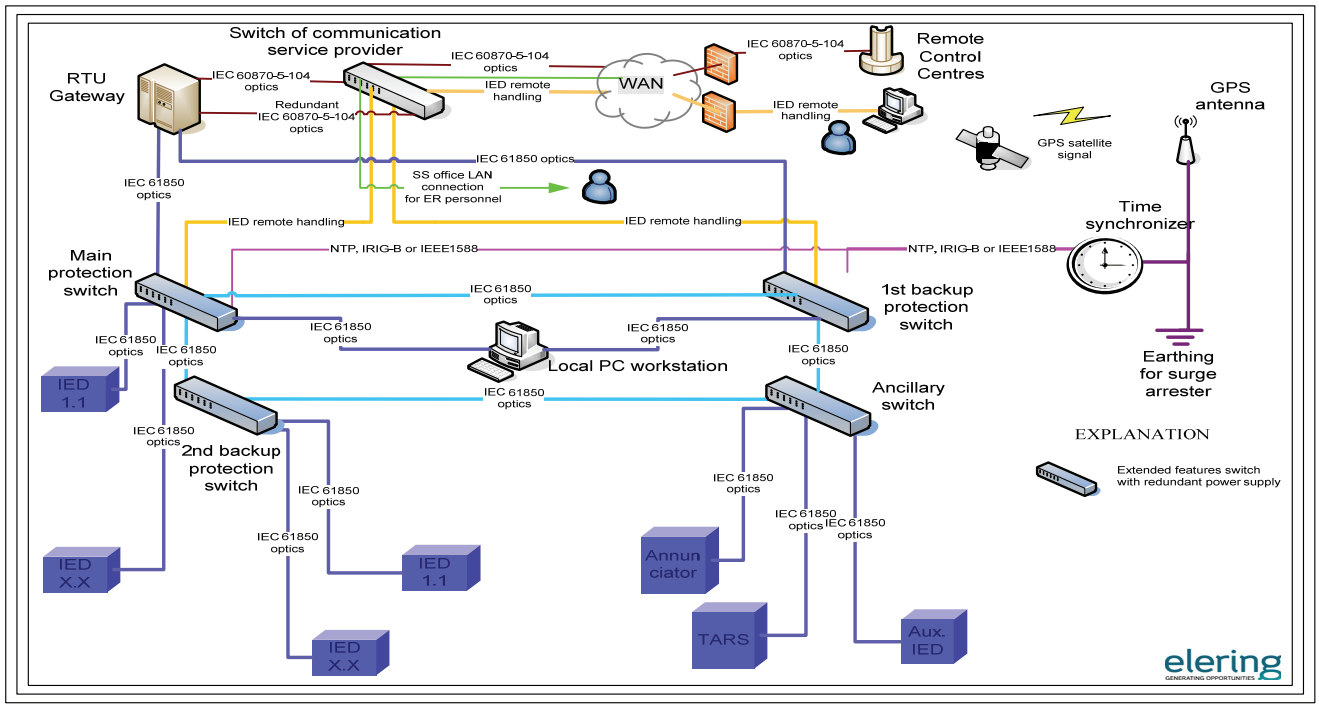

Fig. 2. Structure of IEC 61850 LAN (variant B)

The "Contra" technical key-attributes [Fig. 2]:

- Switches are not redundant.

The "Pro" technical key-attributes [Fig. 2]:

- The segregation of one malfunctioned IED;
- Cost-effective solution;
- One malfunctioned IED does not influence other IEDs, RTU (or probable workstation).

Probable process bus solutions

The non-conventional instrument transformers are built up using the physical effects of materials [4]. As a rule those are optic materials. The NCVITs and NCCITs shall meet the international standards (IEC 60044 - 7 and IEC 60044 - 8 correspondingly). The NCVIT is based on the electro-optic Pockels effect that produces birefringence in an optical medium induced by a constant or varying electric field. The birefringence is proportional to the electric field. The Pockels effect occurs only in crystals that lack inversion symmetry (e.g. lithium niobate $LiNbO_3$). The NCCIT is based on Faraday effect that is between light and a magnetic field. The rotation of the plane of polarization is proportional to the intensity of the component of the magnetic field in the direction of the beam of light.

The common benefits of NCCIT/NCVIT are lack of copper cabling, filling oil and SF_6, easy maintenance, light weight, easiness to monitor the measurements online and e.g. AIS NCCIT can be placed without a separate basement.

The drawbacks of NCCIT/NCVIT are mostly redundancy requirement (e.g. two separate current sensors or two separate NCCITs, redundant MU, two optical cables in the different cable duct), special water resistant and penetration protection for optical fibres.

The NCVIT and NCCIT have MUs that send the light signals to the appropriated light polarizers. After that MUs receive the signals back and convert them according to the IEC 61850. The sampling of SMV is adjustable between 80 and 256 samples per period, The common MU shall be equipped with redundant DC power supply module, redundant processor module, IEC 61850 redundant optical communication interfaces.

Some devices do not have united IEC 61850 interface for station bus and process bus; hence sometimes the separate IEC 61850 LAN may be used for that tasks (IEC 61850-9-2).

Conclusions

The implementing of measuring system based on the standard IEC 61850 involves the re-organizing of whole relay protection, substation automation, control and monitoring.

This essential aim of this work is the transforming the doubts and fears to the grasp the first implementation of IEC 61850 in the substation. The current work is based on secondary research type that offers different technical solution collations, models of new IEC 61850 implementing solutions and sets up the ground for Smart Grid future coming [11]. The better understanding of IEC 61850 issues, economic effect and ensuring the "*N-1*" criterion in designed bus topologies offers the innovative approach by planning of IEC 61850 substations. The article also shows that the implementation of IEC 61850 as simple communication protocol is the irrelevancy and misunderstanding of IEC standard in power energy sector. The primary achievement of work is implementing of many above treated proposal requirements of station bus in official procurement document of Estonian TSO.

The remote handling procedure sets also strict cyber security requirements to the build-up the connection. All security methods like VPN, passwords, encryption, firewalls, IP-control and management technologies, shall be applied for substation LAN. The Utility should get the overview of some public security standard [6] and maybe to use an outsourced consulting service concerning to cyber security topic.

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The technical solutions based on the standard of International Electrotechnical Commission (TC57) 61850 are changing the traditional imagination of principles for relay protection, local and remote supervision, measuring system, ancillary services etc. in substation. The complexity of managing the IEC 61850 substation building project forces to move forward by further specifying the requirements concerning to primary and secondary substation equipment. The implementing of IEC 61850 (e.g. measurements) requires the knowledge, avoiding the misunderstandings, confusions and even opportunism against the new technology within different level of Utility personnel (planning, asset managing etc.). Ill. 2, bibl. 11 (in English; abstracts in English and Lithuanian).

I. Dmitrenko. Standarto IEC 61850 pagrindimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 6(112). – P. 106–110.

Tarptautinė elektrotechnikos komisija keičia relinės apsaugos, vietinės ir nuotolinės sistemų priežiūros ir kt. techninius sprendimus. Atlikta standarto IEC 61850 apžvalga, pateiktos pagrindinės problemos, susijusios su atnaujintu standartu. Standartui IEC 61850 tobulinti reikia žinių, kurios padėtų išvengti nesusipratimų, painiavos. Il. 2, bibl. 11 (anglų kalba; santraukos anglų ir lietuvių k.).