European Distribution System Operators for Smart Grids

Minimum functional requirements for Smart Secondary Substations Lite

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1 Purpose of this document

With an increasing amount of decentralized generation and the rise of the electrical vehicle, monitoring the grid is becoming necessary. Strategic substations in the grid are being equipped with remote switching gear and extensive measurement devices. However, it remains very costly to equip all substations with this type of solution, and therefore grid operators are searching for alternative, economical, solutions.

Within the current market, it is difficult to find vendors able to supply low cost solution since their main focus has traditionally been to offer comprehensive solutions with a large number of functionalities. However, the benefits of such equipment are not always worth the high costs, which leads to a deadlock: vendors are waiting for clear requirements and orders from grid operators while grid operators are waiting for the market to offer low cost products before they place an order.

With a growing need for more functionalities in secondary substation, action is required to overcome the stalemate. In order to help the market, the DSOs have joined forces in other to define a minimum set of requirements for “smart secondary substations lite” (SSSlite).

The purpose of this document is to provide technology suppliers with insights in the minimal functionalities of secondary substations and a direction for their R&D in order to design products that meet the needs of the DSOs in Europe. This document is a first step in order to start a dialog between DSOs and their technology suppliers.

2 Reference documents and abbreviations

Normative Documents

Reference	Title
EN 50470-1	Electricity metering equipment (a.c.) – Part 1: General requirements, tests and test conditions – Metering equipment (class indexes A, B and C)
EN 60529	Degrees of protection provided by enclosures (IP Code)
EN 62053-23	Electricity metering equipment (a.c.) – Particular requirements – Part 23: Static meters for reactive energy (classes 2 and 3)
MID	Measuring instruments, Directive 2004/22/EC and amendment Directive 2009/137/EC

Abbreviations

Abbreviation	Full Text
DSO	Distribution System Operator
IP code	International Protection Marking
LV	Low Voltage
MV	Medium Voltage
RMS	Root Mean Square
SCADA	Supervisory Control and Data Acquisition
SSS Lite	Smart Secondary Substation Lite

3 Usage Scenarios

The development of the power sector in the European Union in the coming years will depend on sustainable development, and will be based on common use of renewable energy sources and increased energy consumption efficiency. Distribution networks, are currently facing a number of challenges such as DER integretation, simultaneity of electricity consumption, development of aggregation services, electric vehicles (soon) and so on. A future power grid will have to encourage and integrate in a smart way actions and behaviour of generators, consumers, and other energy market players, so as to provide reliable, economically viable and sustainable electricity supplies of electricity. Each of them involves the need to take up certain actions by OSD:

- improvement of the reliability and security of energy supply and ensuring high-quality energy,
- optimisation of the use of existing infrastructure and organisational resources,
- improvement of the efficiency of distributing power grid,
- creation of opportunities for increasing customer's active role in energy consumption management and energy generation,
- integration of distributed sources and balancing the system in terms of increasing the participation of distributed and disseminated generation,
- preparation of technical and organisational solutions to engage DSO in system balancing on distribution network level,
- improvement of the accuracy of forecasting the generation from distributed sources,
- preparing the system for the implementation of electric cars on a massive scale.

Overcoming these challenges can be done through the implementation of innovative smart grids solutions. The development of smart grid solutions requires an increase in observability of the MV and LV network. Increase of network observability can be provided by new solutions for secondary substation. Smart grid of the future will be provided many more information such systems than now, especially in medium and low voltage grids.

Conception of a smart substations, here called "SSSLite", should provide a better observability of MV and LV network necessary for more effective network management and meet the challenges facing the OSD. The SSSLite delivers minimum functionalities for smart substations to enable remote monitoring. The proposed solution is the starting point for a more elaborate solutions for remote monitoring, control and implement autonomous automatic functions related to the assurance of continuity and reliability of electricity supply to consumers. For this purpose, SSSLite is used by several user roles:

- The ***operational manager*** uses an operational station (for example, SCADA) to remotely monitor and control the functioning of the secondary substation and performs manipulations (remote control).
- The ***asset engineer*** uses the data generated by SSSLite for grid planning purposes (e.g. LV capacity data for grid planning, asset health data for maintenance planning).
- The ***back office*** is responsible for data collection and processing.
- The **manager** performs technical maintenance on SSSLite, e.g. Installation and configuration activities, maintenance and resolving of failures.

- The ***operational engineer*** uses the SSSLite to monitor the network status (e.g. outages, postion of switches, tripped circuit brakers, …).

This chapter describes the intended system behaviour of SSSLite based on a number of usage scenarios.

3.1 Measurement

SSSLite supports users by:

- Periodically determining the voltage and the current of a field.
- Providing this data with a time stamp.
- Saving this data for a set time (the oldest data is deleted after that time) - repository.
- Processing measurement data (for example, to determine the maximum current during a period or the delivered power in a period).
- Combining data with other data.
- Generating triggers (both notifications and alarms) from data.
- Securely sending these triggers to external systems and saving them as a notification in the log.
- Providing notifications with a time stamp and securely saving it.

The use cases below describe automatic monitoring of voltage and energy flows in an active distribution network.

MV Failure detection and location

The development of secondary substation will help DSOs to increase the reliability and quality of electricity supply. As most power grid failures occur in MV networks. An enhanced observability of these networks can improve power system operation and reduce failure rates. The SSSlite fault detectors should help to localise faster and more accurately any damage in an MV network. Information from MV Fault Passages should also enable the DSO to build more advance functionalities for its operation centre (DMS) and increase its operational efficiency. MV failure detection is the basis for building a more advanced system functionality – SCADA/DMS.

Technical requirements:

- MV Fault Passages Indicators
- Emergency supply necessary when the primary power supply fails (power for the purpose of Fault Passages and telecommunications devices)

MV Power flow monitoring

The growing share of distributed energy sources including renewable sources, active participation of customers in the energy market (prosumer) are increasingly creating overload of distribution network infrastructure (congestion) and voltage problems.

The development of MV Fault Passages give the possibility to increase observability of power flow and to measure voltage and current. Improve network observability can by use to monitoring MV network by operator centre.

Technical requirements:

- MV Fault Passages Indicators with voltage and/or current measurement

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MV Network planning and asset management
Designing the network more efficiently, better managing assets and using infrastructures at best, requires information about power flows in MV networks. Information about current and/or voltage level from MV Fault Passages can be used by development and asset engineers to optimise power flows.

Technical requirements:

- MV Fault Passages Indicators with voltage and/or current measurement

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LV Power flow monitoring
Currently DSOs have a limited observability over their LV networks. Improvement of LV monitoring (voltage and current level, active and reactive energy) can by use by operator centre. Dispatcher will be used information about power flow to network optimisation and will have ability to anticipate crises. Implementation monitoring in LV part of SSSL will bring many benefits and new functionality, such as:

- monitoring and protections of transformers
- protection system for two-way power flow
- monitoring of power quality
- development new smart grid functionality: Integration of DER at low voltage; reduction of technical and non-technical loses.

Technical requirements:

- LV monitoring: Active Energy, Reactive Energy, Current, Voltage

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LV Fault detection
One of the key challenges for DSO is to reduce power outages, also in LV grids. Current information about failures are mainly derived from customers. As a result, failure at low-voltage level often fuse on the feeder is damaged. Detection of a blown fuse will be used to reduce time of power outages in LV network.

Technical requirements:

- detect blown fuse devices in LV switchgear

LV Network planning and asset management
Building more efficient LV network planning and asset management with more optimally utilized infrastructures need better measurement data. Data from the LV side of the SSSLite can be used by development and asset engineers to optimise power flows in MV grids. Historical measured values and

a prediction can be used by grid operators and others to plan the use of the distribution network (for example, delaying scheduled maintenance, expansion of the network, etc.).

Technical requirements:

- LV monitoring: Active Energy, Reactive Energy, Voltage

LV Network control

SSSLite can supply the measurement data (the subject of this basic scenario), in addition to performing the data communication gateway function . Decentralised generators are connected to the network and are held responsible for the increase in the variation in voltage and the available power. SSSLite can supply the necessary measurement data to control function.

In the context of system, the interface with OLTC (On Load Tap Changer) for adjustable distribution transformers is an interesting topic. Measuring voltage changes caused by autonomously adjusting tap changers is desirable to perform a root cause analysis in the network (finding the reason for a voltage deviation). In addition, it is assumed that the future network will have the technical means to actively control the voltage and energy flows. Many aspects of this use case are directly relevant to SSSLite (SSS Lite provide information from monitoring) . Examples include switching capacitor banks and electricity storage.

Technical requirements:

- LV monitoring: Active Energy, Reactive Energy, Current, Voltage

3.2 Implementation

The way implementation is organised may vary from DSO to DSO, but will generally contain the following steps:

1. The ***manager*** draws up a proposal for the instrumentation of an MV/LV station and asks the ***technical support service*** to perform installation activities.
2. The ***technical support service*** determines which equipment must be installed and with which settings.
3. The field ***engineer***:
   - Mounts the SSSLite systems/subsystems in the MV/LV station;
   - Connects SSSLite/subsystems to a supply;
   - Connects the systems/subsystems/components to each other (via a local network/field network) so they can mutually exchange data;
   - Configures SSSLite so it can be used for the intended goals;
   - Uses the test facilities to verify the proper functioning of the compilation of the systems/subsystems, including their mutual links and the link(s) between SSSLite and the external systems via the WAN (if necessary, contacting the operational manager).

4. After finishing the activities, the ***engineer*** informs the technical support about the progress and the results of the installation activities. After the engineer has left the station, the manager gives the order to once again deploy the station (after re-enabling the MV voltage) and the functionality is available to Asset Management too.

3.3 Maintenance

SSSLite must enable remote grid management using modern means. The way support is organised may vary from DSO to DSO, but will generally contain the following steps:

1. SSSLite is self-analysing and reports deviations to an external system.

2. Failure notifications are shown on an external system to an ***operational manager***. Depending on the nature of the notification, the external system must automatically create a failure notification and forward that to a ***technical support service***.

3. The support in resolving the failure will go through a number of stages:
   - 3.1. From a central system (e.g. SCADA) the functioning of SSSLite system can be analysed based on the retrieved status data;
   - 3.2. If this does not reveal the cause, a “standard” failure engineer can go to the station and try to resolve the error using limited means;
   - 3.3. If this does not solve the problem, a second-line employee can be called in. This is especially the case if the failure is of a special nature and, for example, a laptop needs to be used on location for analytical purposes.
   - 3.4. If all these steps do not result in a resolution, the supplier of the equipment can be called in to help resolve the problem.

4. Functional Requirements

4.1. Environment requirements

4.1.1. Environment.General

Code	Description
EV.GN_01	**Temperature** Devices must be able to safely and correctly operate within the temperature range -25 °C to 55 °C.
EV.GN_02	**Humidity** Devices must be able to safely and correctly operate with up to 95% relative humidity without condensation.
EV.GN_03	**Protection Degree** Devices must meet the criteria of IP21 according to EN 60529.

4.2. LV Measurement requirements

This section applies to electric measurements at the low voltage side of the MV/LV transformer.

4.2.1. LV Measurement.Accuracy

Code	Description
LVM.AC_01	**Active Energy** Active energy shall be measured according to class of accuracy B (EN 50470-1/MID).
LVM.AC_02	**Reactive Energy** Reactive energy shall be measured according to class of accuracy 2 (EN 62053-23).
LVM.AC_03	**Current** Current shall be measured with an accuracy of at least 0,5% at maximum current.
LVM.AC_04	**Voltage** Voltage shall be measured with an accuracy of at least 0,5% at nominal voltage.

4.2.2. LV Measurement.EnergyAndPower

Code	Description
LVM.EP_01	**Power** The unit shall measure the average active power, both input and output (+A and -A), and the average reactive power in the four quadrants (+Ri, +Rc, -Ri and -Rc). The unit shall measure the power per phase and total. Active power shall be expressed in W and reactive power in var.
LVM.EP_02	**Power Integration Period** The power integration period, for average power calculation, shall be configurable between 1 min and 60 min.
LVM.EP_03	**Energy Registers** The unit shall register energy in different totalizers for active energy, both input and output (+A and -A), and reactive energy in the four quadrants (+Ri, +Rc, -Ri and -Rc). The unit shall measure the energy per phase and total. Active energy shall be expressed in Wh and reactive energy in varh.
LVM.EP_04	**Maximum Power Registers** The unit shall register maximum average active power, both input and output (+A and -A), and maximum average reactive power in the four quadrants (+Ri, +Rc, -Ri and -Rc). The unit shall register maximum power per phase and total. Active power shall be expressed in W and reactive power in var.
LVM.EP_05	**Maximum Power Reset** The Maximum Power Registers may be reset.

4.2.3. LV Measurement.Instantaneous

Code	Description
LVM.IT_01	**Instantaneous Power** The unit shall measure the instantaneous values of active power, both input and output (+A and -A), and reactive power in the four quadrants (+Ri, +Rc, -Ri and -Rc). The unit shall measure these instantaneous values per phase and total. Active power shall be expressed in W and reactive power in var.

LVM.IT_02	**Instantaneous Voltage and Current (RMS)** The unit shall measure the instantaneous RMS values of voltage and current. The unit shall measure these instantaneous values per phase. Voltage shall be expressed in V and current in A.
LVM.IT_03	**Power Factor** The unit shall measure the instantaneous power factor, per phase.

4.2.4. Measurement.IntervalValues

Code	Description
LVM.IV_01	**Channels** The unit shall possess the necessary number of channels for registering interval values.
LVM.IV_02	**Interval Period** The interval period, for each value registration, shall be configurable between 1 min and 60 min.
LVM.IV_03	**Active Energy** The unit shall register the incremental values for active energy, both input and output (+A and -A). The unit shall register these incremental values per phase and total. Active energy shall be expressed in Wh.
LVM.IV_04	**Reactive Energy** The unit shall register the incremental values for reactive energy in the four quadrants (+Ri, +Rc, -Ri and -Rc). The unit shall register these incremental values as the total for the 3 phases. Reactive energy shall be expressed in var.
LVM.IV_05	**Voltage (RMS)** The unit shall register the values for average RMS voltage, during each interval period. The unit shall register these values per phase. Voltage shall be expressed in V.
LVM.IV_06	**Storage Capacity** The unit shall have the capacity to store all referred interval value measurements for a period of 30 days, considering a 15 minute interval period.

4.3. Monitoring requirements

4.3.1. Monitoring.LV

Code	Description
MO.LV_01	**LV Feeder Failure** The unit shall be able to detect a blown fuse or an open circuit breaker at each LV feeder, per phase.

4.3.2. Monitoring.MV

Code	Description
MO.MV_01	**MV Fault Passage** The unit shall be able to detect a fault passage at an MV Feeder, identifying fault currents between phases and between phase and ground.
MO.MV_02	**Fault Currents** The fault currents, both for phase-phase and phase-ground, shall be configurable.
MO.MV_03	Fault direction The unit should be able to point into the direction of the fault.

4.4. Updating requirements

4.4.1. Updating.Firmware

Code	Description
UD.FW_01	**Update of firmware** In SSSLite, devices with a digital processor running firmware (or software), shall allow the local and remote updating of its firmware (or software), by loading new versions. If a device contains metrological parameters (e.g., meter unit constants, calibration constants), these shall not be changeable. The update of firmware will not influence the security of supply (no risk and no power interruption).

UD.FW_02	**Firmware validation** The device shall perform a validation on the newly loaded version of firmware (or software), in order to detect possible communication errors, wrong versions or malicious alterations, before considering it as a valid version and passing it control of the device. If the new version is not positively validated, the update must not take place.
UD.FW_03	**Firmware access level** The updating of the device firmware (or software) can only be done using the appropriate access level to the device.
UD.FW_04	**Firmware update log** The device shall log each firmware (or software) update. It shall log information that must include at least the new version, date and time of the update.
UD.FW_05	**Continuity of the update in case of communication failure** In case of a communication failure during a remote updating process of the firmware (or software), when the communications are restored the device shall ensure the continuity of the updating process from the point where it was interrupted. In case of power loss the process will restart from the beginning.
UD.FW_06	**Availability during update process** The device must keep all its functionality available during the update process. The only exception is the reboot period that may occur after the new version of firmware (or software) is received and validated.

4.5. Security Requirements

4.5.1. Access Control

Code	Description
SEC.AC_01	**Role-Based Access Control** The unit shall support the implementation of Role-Based Access Control. The unit shall support at least the roles described in section 3 that must have access to the unit. The unit shall allow roles to be bound to individual user accounts.
SEC.AC_02	**Individual Privileges** The unit shall allow that access privileges are configured per role.
SEC.AC_03	**Password Protection** The unit shall store passwords together with a salt using an allowed cryptographic hash function (see SEC.CO_04).

4.5.2. Communication Security

Code	Description
SEC.CO_01	**Confidentiality** The unit shall preserve confidentiality of communication on remote connections[1] through encryption (e.g. through the use of IPSec, OpenVPN or TLS) in a way that is compatible with the SCADA system, management systems or a central encryption point..
SEC.CO_02	**Message Integrity** The unit shall verify the integrity of messages received from remote connections using cryptographic Message Authentication Codes (MACs). If the integrity of a message cannot be verified the unit shall drop the message and log this event (See UD.FW_06, including the comment).
SEC.CO_03	**Replay Protection** The unit shall be able to detect replay attacks on from remote connections, and shall drop replayed messages and log this event (See UD.FW_06, including the comment).
SEC.CO_04	**Cryptographic Algorithms** The unit shall only use cryptographic primitives and key lengths that comply with the state of the art set by the *ENISA Algorithms, key size and parameters report*[2] (version 2014 or newer) to implement the security requirements.
SEC.CO_05	**Random Number Generators** The unit shall use a cryptographic (pseudo-)random number generator to generate all random values used in implementing the security requirements.
SEC.CO_06	**Cryptographic keys** The unit must have the capability to securely change its cryptographic keys, so that individual keys can be provisioned to each unit.

4.5.3. Hardening

Code	Description
UD.FW_07	**Attack Surface Minimization** All ports, interfaces, services, protocols and programs on the unit that are not needed to fulfill the functional requirements, shall be removed or disabled.

[1] A ‘remote connection’ is any connection that ends outside of the substation.
[2] ENISA European Network and Information Security Agency, Algorithms, key size and parameters report 2014, 2014.

UD.FW_08	**Disabling Unused Accounts** The unit shall not contain any default, guest and anonymous accounts. Vendor accounts could be defined by the end user if needed and agreed.
UD.FW_09	**Message Validity** The unit shall verify that all messages received on remote connections have a valid syntax and data format, and that the message's parameter values are in the allowed ranges. The unit shall drop invalid messages, that is, messages that fail this verification and log this event (See UD.FW_06). The unit shall not be negatively affected by invalid messages.
UD.FW_10	**Fail-Secure** The unit shall be fail-secure: if it fails, it shall not compromise the security of itself or other devices.

4.5.4. Logging

Code	Description
UD.FW_11	**Local Logging** The unit shall store all security events that occur in a local log file.
UD.FW_12	**Exporting of Logs** The unit shall allow exporting security events in a commonly supported format, i.e. syslog.

EDSO
for smart grids

EDSO for Smart Grids is a European association gathering leading electricity distribution system operators (DSOs), cooperating to bring smart grids from vision to reality.

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