3GPP TR 22.867 V18.2.0 (2021-12)

** 

The present document has been developed within the 3rd Generation Partnership Project (3GPP TM) and may be further elaborated for the purposes of 3GPP.  
The present document has not been subject to any approval process by the 3GPPOrganizational Partners and shall not be implemented.  
This Specification is provided for future development work within 3GPPonly. The Organizational Partners accept no liability for any use of this Specification.  
Specifications and Reports for implementation of the 3GPP TM system should be obtained via the 3GPP Organizational Partners' Publications Offices.

3rd Generation Partnership Project;

Technical Specification Group Services and System Aspects;

Study on 5G Smart Energy and Infrastructure

(Release 18)

Keywords

Power, Meter, Automation

***3GPP***

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis

Valbonne - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

***Copyright Notification***

No part may be reproduced except as authorized by written permission.  
The copyright and the foregoing restriction extend to reproduction in all media.

© 2021, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC).

All rights reserved.

UMTS™ is a Trade Mark of ETSI registered for the benefit of its members

3GPP™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners  
LTE™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners

GSM® and the GSM logo are registered and owned by the GSM Association

Contents

Foreword 7

1 Scope 8

2 References 8

3 Definitions and abbreviations 11

3.1 Definitions 11

3.2 Abbreviations 12

4 Overview 13

5 Use cases 14

5.1 Use case of Distributed Energy Storage 14

5.1.1 Description 14

5.1.2 Pre-conditions 15

5.1.3 Service Flows 15

5.1.4 Post-conditions 16

5.1.5 Existing features partly or fully covering the use case functionality 16

5.1.6 Potential requirements 16

5.2 Use case of advanced metering 17

5.2.1 Description 17

5.2.2 Pre-Conditions 18

5.2.3 Service Flows 18

5.2.4 Post-Conditions 20

5.2.5 Existing features partly or fully covering the use case functionality 20

5.2.6 Potential New Requirements needed to support the use case 20

5.3 Use case of Distributed Feeder Automation 21

5.3.1 Description 21

5.3.2 Pre-Conditions 23

5.3.3 Service Flows 23

5.3.4 Post-Conditions 23

5.3.5 Existing features partly or fully covering the use case functionality 24

5.3.6 Potential New Requirements needed to support the use case 24

5.4 Use case of line current differential protection in power distribution grid 24

5.4.1 Description 24

5.4.2 Pre-conditions 26

5.4.3 Service Flows 26

5.4.4 Post-conditions 27

5.4.5 Existing features partly or fully covering the use case functionality 27

5.4.6 Potential New Requirements needed to support the use case 27

5.5 Smart Energy Differentiated QoS For Transported Encrypted Data 27

5.5.1 Description 27

5.5.2 Pre-conditions 28

5.5.3 Service Flows 28

5.5.4 Post-conditions 28

5.5.5 Existing features partly or fully covering the use case functionality 28

5.5.6 Potential New Requirements needed to support the use case 30

5.6 Service Lifetime for Utility Communication Services Deployments 31

5.6.1 Description 31

5.6.2 Pre-conditions 31

5.6.3 Service Flows 31

5.6.4 Post-conditions 32

5.6.5 Existing features partly or fully covering the use case functionality 32

5.6.6 Potential New Requirements needed to support the use case 32

5.7 Remote DSO management of connectivity for Smart Energy 32

5.7.1 Description 32

5.7.2 Pre-conditions 34

5.7.3 Service Flows 37

5.7.4 Post-conditions 38

5.7.5 Existing features partly or fully covering the use case functionality 38

5.7.6 Potential New Requirements needed to support the use case 39

5.8 Use case of Smart Distribution Transformer Terminal 40

5.8.1 Description 40

5.8.2 Pre-Conditions 41

5.8.3 Service Flows 41

5.8.4 Post-Conditions 42

5.8.5 Existing features partly or fully covering the use case functionality 42

5.8.6 Potential New Requirements needed to support the use case 42

5.9 Use case of isolation demand for energy applications 43

5.9.1 Description 43

5.9.2 Pre-Conditions 44

5.9.3 Service Flows 44

5.9.4 Post-Conditions 44

5.9.5 Existing features partly or fully covering the use case functionality 45

5.9.6 Potential New Requirements needed to support the use case 45

5.10 Utility End to End Security 45

5.10.1 Description 45

5.10.2 Pre-conditions 45

5.10.3 Service Flows 46

5.10.4 Post-conditions 46

5.10.5 Existing features partly or fully covering the use case functionality 46

5.10.6 Potential New Requirements needed to support the use case 47

5.11 QoS Monitoring and Reporting Mechanisms 47

5.11.1 Description 47

5.11.2 Pre-conditions 47

5.11.3 Service Flows 48

5.11.4 Post-conditions 48

5.11.5 Existing features partly or fully covering the use case functionality 48

5.11.6 Potential New Requirements needed to support the use case 48

5.12 Distribution Intelligence – FLISR (Fault Location, Isolation, and Service Restoration) 49

5.12.1 Overview 49

5.12.2 Feeder automation 50

5.12.2.1 Description 50

5.12.2.2 Pre-condition 50

5.12.2.3 Service flow 50

5.12.2.4 Post-condition 51

5.12.2.5 Existing features partly or fully covering the use case functionality 51

5.12.2.6 Potential New Requirements needed to support the use case 52

5.12.3 High speed current differential protection 52

5.12.3.1 Description 52

5.12.3.2 Pre-condition 52

5.12.3.3 Service flow 52

5.12.3.4 Post-condition 52

5.12.3.5 Existing features partly or fully covering the use case functionality 53

5.12.3.6 Potential New Requirements needed to support the use case 53

5.13 Use case of 5GS support for synchrophasors in wide-area Smart Grid 54

5.13.1 Description 54

5.13.2 Pre-conditions 55

5.13.3 Service Flows 55

5.13.4 Post-conditions 56

5.13.5 Existing features partly or fully covering the use case functionality 56

5.13.6 Potential New Requirements needed to support the use case 57

5.14 Energy Substation Surveillance 57

5.14.1 Description 57

5.14.2 Pre-conditions 58

5.14.3 Service Flows 58

5.14.4 Post-conditions 58

5.14.5 Existing features partly or fully covering the use case functionality 58

5.14.6 Potential New Requirements needed to support the use case 58

5.15 Distributed Energy Resources and Microgrids 59

5.15.1 Description 59

5.15.2 Pre-condition 60

5.15.3 Service flow 60

5.15.4 Post-condition 61

5.15.5 Existing features partly or fully covering the use case functionality 61

5.15.6 Potential New Requirements needed to support the use case 61

5.16 Protection of DER and grid interconnection 62

5.16.1 Description 62

5.16.2 Pre-condition 64

5.16.3 Service flow 64

5.16.4 Post-condition 65

5.16.5 Existing features partly or fully covering the use case functionality 65

5.16.6 Potential New Requirements needed to support the use case 65

5.17 Utility Service Operator M2M service management platform in Smart Energy 65

5.17.1 Description 65

5.17.2 Pre-condition 68

5.17.3 Service flow 69

5.17.4 Post-condition 69

5.17.5 Existing features partly or fully covering the use case functionality 69

5.17.6 Potential New Requirements needed to support the use case 70

5.18 Coordination for Energy Recovery Use Case 70

5.18.1 Description 70

5.18.2 Pre-conditions 71

5.18.3 Service Flows 71

5.18.4 Post-conditions 72

5.18.5 Existing features partly or fully covering the use case functionality 72

5.18.6 Potential New Requirements needed to support the use case 72

5.19 Applications Using IEC 61850-9-2 Sampled Values 73

5.19.1 Description 73

5.19.2 Pre-conditions 73

5.19.3 Service flows 74

5.19.4 Post-conditions 74

5.19.5 Existing feature partly or fully covering use case functionality 74

5.19.6 Potential new requirements and KPIs 74

5.19.6.1 Potential Requirements 74

5.19.6.2 Potential KPIs 74

5.20 Use case of power distribution grid state estimation service 75

5.20.1 Description 75

5.20.2 Pre-conditions 75

5.20.3 Service flows 75

5.20.3.1 Introduction 75

5.20.3.2 Power system requirements of SE service 76

5.20.4 Post-conditions 76

5.20.5 Existing feature partly or fully covering use case functionality 76

5.20.6 Potential New Requirements needed to support the use case 77

5.21 Use case of power distribution grid power control service 77

5.21.1 Description 77

5.21.2 Pre-conditions 77

5.21.3 Service flows 77

5.21.3.1 Introduction 77

5.21.3.2 Power system requirements of PC service 78

5.21.4 Post-conditions 79

5.21.5 Existing feature partly or fully covering use case functionality 79

5.21.6 Potential New Requirements needed to support the use case 80

5.22 Use Case of ensuring uninterrupted MTC service availability during emergencies 80

5.22.1 Description 80

5.22.2 Pre-conditions 81

5.22.3 Service flows 81

5.22.4 Post-conditions 82

5.22.5 Existing feature partly or fully covering use case functionality 82

5.22.6 Potential New Requirements needed to support the use case 82

5.23 Edge cloud driven data acquisition (edgePMU) 82

5.23.1 Description 82

5.23.2 Pre-conditions 83

5.23.3 Service Flows 83

5.23.4 Post-conditions 83

5.23.5 Existing features partly or fully covering the use case functionality 84

5.23.6 Potential New Requirements needed to support the use case 84

5.24 Use case of power distribution grid load and generation prediction service 84

5.24.1 Description 84

5.24.2 Pre-conditions 84

5.24.3 Service Flows 85

5.24.3.1 Introduction 85

5.24.3.2 Power system requirements of LP/GP service 85

5.24.4 Post-conditions 85

5.24.5 Existing features partly or fully covering the use case functionality 85

5.24.6 Potential New Requirements needed to support the use case 86

6 Considerations 86

6.1 Potential security considerations 86

6.2 Potential charging considerations 87

7 Consolidated potential requirements and KPIs 88

7.1 Consolidated potential requirements 88

7.2 Consolidated potential KPIs 91

8 Conclusion and recommendations 95

Annex A: Underground 3GPP Access 96

A.1 Description 96

A.2 Pre-conditions 97

A.3 Service Flows 97

A.4 Post-conditions 97

A.5 Existing features partly or fully covering the use case functionality 97

A.6 Potential New Requirements needed to support the use case 98

Annex B: Change history 99

# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

# 1 Scope

The present document is to address study use cases, potential new service requirements for 5G system to support Smart Grid including the following topics:

* Smart Grid services, e.g. IEC standards, and their communications requirements including capacity, latency, availability, end-to-end QoS, resilience/redundancy and security.
* Deployment requirements when considering constraints e.g. service lifetime, coverage (ubiquity), electromagnetic applicability (e.g. penetration, ability to operate in high EM environments,) etc.
* Additional requirements due to operational manageability – e.g. the ability to configure and monitor the real (achieved & up to date) availability of virtual network topologies
* New Smart Grid use cases and potential service function requirements: e.g. on-demand power supply, distributed power supply system, distribution automation, higher accuracy power load measurement and control, meter automation, etc.
* Communication KPI and service requirements for enabling microgrids, DER and specifically distributed generation (DG) that require 5G wireless communication (e.g. wind and solar energy generation, including scenarios at or near residential / consumer premises, etc.)

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] SunWeiqing etc. Generalized Energy Storage Control Strategies on User Side in Power Ancillary Service Market. Automation of Electric Power System Vol.44 No.2 Jan.25, 2020

[3] IEEE C37.2-2008 IEEE Standard Electrical Power System Device Function Numbers, Acronyms, and Contact Designations.

[4] IEC TR 61850-90-1:2010, Communication Networks and Systems for Power Utility automation – Part 90-1: Use of IEC61850 for the communication between substations.

[5] IEEE 1588-2019 – IEEE Standard for a precision clock synchronization protocol for networked measurement and control systems.

[6] IEEE Guide for Application of Digital Line Current Differential Relays Using Digital Communication.

[7] IEC 61850-9-3-2016 – IEC/IEEE International Standard - Communication Networks and Systems for Power Utility automation – Part 9-3: Precision time protocol profile for power utility

[8] 3GPP TR 22.804: "Study on Communication for Automation in Vertical domains (CAV)".

[9] Sendin, A., et. al., "Telecommunication Networks for the Smart Grid," Artech House, 2016.

[10] Goel, S., S. F. Bush, and D. Bakken, (eds.), IEEE Vision for Smart Grid Communications: 2030 and Beyond, New York: IEEE, 2013.

[11] US Department of Energy, "Communications Requirements of Smart Grid Technologies, 2010", accessed 14.08.20, http://energy.gov/sites/prod/files/gcprod/documents/Smart\_Grid\_Communications\_Requirements\_Report\_10-05-2010.pdf

[12] IT Process Wiki – The ITIL Wiki: Content is available according to Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Germany License. Access 14.10.20.

[13] Incident Management: <https://wiki.en.it-processmaps.com/index.php/Incident_Management> Content is available according to Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Germany License. Access 14.10.20.

[14] Change Management: <https://wiki.en.it-processmaps.com/index.php/Change_Management> Content is available according to Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Germany License. Access 14.10.20.

[15] Service Asset and Configuration Management: <https://wiki.en.it-processmaps.com/index.php/Service_Asset_and_Configuration_Management> Content is available according to Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Germany License. Access 14.10.20.

[16] Open PLC European Research Alliance (OPERA). https://cordis.europa.eu/project/id/026920

[17] "Applications of ITU-T G.9960, ITU-T G.9961 transceivers for Smart Grid applications: Advanced metering infrastructure, energy management in the home and electric vehicles", 06/2020. https://www.itu.int/dms\_pub/itu-t/opb/tut/T-TUT-HOME-2010-PDF-E.pdf

[18] M. Amin and A. Giacomoni, "Toward more secure, stronger and smarter electric power grids," IEEE PES'11, 2011.

[19] Eric D. Knapp, Raj Samani, "Smart Grid Network Architecture", "Applied Cyber Security and the Smart Grid", 2013

[20] 5G DNA White Paper: "5GDN@Smart Grid White Paper: Requirements, Technologies, and Practices" https://www.5gdna.org/

[21] IEEE Std 1344™-1995 (R2001), IEEE Standard for Synchrophasors for Power Systems

[22] IEEE Std C37.118™-2011, IEEE Standard for Synchrophasors for Power Systems

[23] IEEE Std 1588-2008, Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

[24] IEEE Std C37.238-2017 , IEEE Standard Profile for Use of IEEE Std 1588™ Precision Time Protocol in Power System Applications.

[25] IEEE Std C37.224-2013

[26] IEC 61850-90-5:2012, use of IEC 61850 to transmit Synchrophasors information according to IEEE C37.118

[27] IEEE Std C37.118.1a-2014: amendment 1 with modification of selected performance requirements.

[28] IEEE Std C37.118.2-2011

[29] IEC 61850-90-3-2016 – IEC/IEEE International Standard - Communication Networks and Systems for Power Utility automation – Part 90-3:Using IEC 61850 for condition monitoring diagnosis and analysis

[30] Budka, K, et. al., "Communication Networks for Smart Grids", Springer Verlag, 2014.

[31] Microgrid Knowledge: https://microgridknowledge.com/

[32] M. A. Haj-ahmed and M. S. Illindala, "The influence of inverter-based DGs and their controllers on distribution network protection," in Proc. IEEE Ind. Appl. Soc. Annu. Meeting, Oct. 2013.

[33] IEC, IEC 61850-5 communication networks and systems in substations – Part 5: communication requirements for functions and device models. <http://www.iec.ch>.

[34] Moreira, N., Molina, E., Lázaro, J., et al: "Cyber-security in substation automation systems", Renew. Sustain. Energy Rev., 2016

[35] EN 50549-1, "Requirements for generating plants to be connected in parallel with distribution networks—Part 1: Connection to a LV distribution network— generating plants up to and including Type B"

[36] EN 50438, "Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks"

[37] IEEE 1547 -2018, "Standard for Interconnecting Distributed Resources with Electric Power Systems"

[38] IEEE 1547.4-2011, "IEEE Guide for Design, Operation, and Integration of Distributed Resources Island Systems with Electric Power Systems"

[39] IEC 63547, "Interconnecting distributed resources with electric power systems"

[40] IEC 62898-1, "Microgrids—Part 1: Guidelines for microgrid projects planning and specification"

[41] IEC 62898-2, "Microgrids—Part 2: Guidelines for operation"

[42] IEC 62898-3-1, "Microgrids—Part 3: Technical requirements - Protection and dynamic control"

[43] BDEW, "Generating Plants Connected to the Medium-Voltage Network"

[44] IEEE 929-2000, "IEEE recommended practice for utility interface of photovoltaic systems"

[45] IEEE Std. 2030.7, "the Specification of Microgrid Controllers"

[46] DLMS/COSEM – Device Language Message Specification: <https://www.dlms.com/dlms-cosem/international-standardization>

[47] DLMS/COSEM Architecture and Protocols, Companion Specification for Energy Metering

[48] European Commission Electricity Directive 2009/72/EC

[49] IEC 61850-9-2:2011 Communication networks and systems for power utility automation - Part 9-2: Specific communication service mapping (SCSM) - Sampled values over ISO/IEC 8802-3

[50] IEC/IEEE 60255-118-1-2018 - IEEE/IEC International Standard - Measuring relays and protection equipment - Part 118-1: Synchrophasor for power systems – Measurements

[51] 3GPP TR 22.878: "Feasibility Study on 5G Timing Resiliency System"

[52] SOGNO project, Deliverable 4.6, "Description of the integration and testing of the solution including the 5G based advanced communication", <https://www.sogno-energy.eu/global/images/cms/Deliverables/774613_deliverable_D4.6.pdf>, June 2020.

[53] McKeever, P.; De Din, E.; Sadu, A.; Monti, A: "MAS for automated black start of multi-microgrids". In Proceedings of the 2017 IEEE International Conference on Smart Grid Communications (SmartGridComm), Dresden, Germany, 23–27 October 2017; pp. 32–37.

[54] Gazis, V.ASurvey of Standards for Machine-to-Machine and the Internet of Things. IEEE Commun. Surv. Tutor. 2017, 19, 482–511. [[CrossRef](https://ieeexplore.ieee.org/document/7516570)]

[55] Ghorbanian, M.; Dolatabadi, S.; Masjedi, M.; Siano, P. Communication in Smart Grids: A Comprehensive Review on the Existing and Future Communication and Information Infrastructures. IEEE Syst. J. 2019, 13, 4001–4014. [[CrossRef](https://ieeexplore.ieee.org/document/7516570)]

[56] Oueis, J.; Conan, V.; Lavaux, D.; Stanica, R.; Valois, F. Overview of LTE Isolated E-UTRAN Operation for Public Safety. IEEE Commun. Stand. Mag. 2017, 1, 98–105. [[CrossRef](https://ieeexplore.ieee.org/document/7992939)]

[57] Ali, S. Next Generation and Advanced Network Reliability Analysis Using Markov Models and Software Reliability Engineering; Springer Nature Switzerland AG: Basel, Switzerland, 2019.

[58] McKeever, Padraic & Sadu, Abhinav & Rohilla, Shubham & Mehdi, Zain & Monti, Antonello. (2020). Ensuring Uninterrupted MTC Service Availability during Emergencies Using LTE/5G Public Mobile Land Networks. Telecom. 1. 181-195. 10.3390/telecom1030013.

[59] eSafeNet Project, [Online], Available: <https://e-safe-net.de/>

[60] Insulae Project, [Online], Available: <http://insulae-h2020.eu/>

[61] SOGNO project, Deliverable 2.2, "Description of initial interfaces & services for grid awareness", https://www.sogno-energy.eu/global/images/cms/Deliverables/774613\_SOGNO\_D2.2.pdf, December 2018.

[62] edgeFLEX project, Deliverable 1.2, "Dynamic-phasor driven voltage control concept for current VPPs in large scale deployment deliverable", <https://www.edgeflex-h2020.eu/progress/work-packages.html>, 31.03.2021.

[63] edgeFLEX project, Deliverable 4.1, "Description of edgeFLEX platform design", https://www.edgeflex-h2020.eu/progress/work-packages.html, 31.03.2021.

[64] National Institute of Standards and Technology (NIST), "Timing Challenges in the Smart Grid", January 2017.

[65] 3GPP TS 22.104: "Service requirements for cyber-physical control applications in vertical domains".

[66] V. Cagri Gungor, Dilan Sahin, Taskin Kocak, Salih Ergut, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, "A Survey on Smart Grid Potential Applications and Communication Requirements", <https://repository.up.ac.za/bitstream/handle/2263/58376/Gungor_Survey_2013.pdf>

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

**Smart Distribution Transformer Terminal**: The smart terminal is usually deployed in the distribution transformer area. It can support multiple energy applications simultaneously. On the one hand, it connects with multiple energy application platforms through 5G communication system to exchange collected data and management data with multiple energy application platforms; on the other hand, it connects with diverse energy end equipment to collect related electricity data, some of which can be analysed and take action in the smart terminal.

**Physical Isolation communication service:** the physical isolation communication service for energy application means the communication network supporting the energy application utilizes dedicated network element and dedicated radio resource e.g. PRB pool, spectrum etc.

**Logical Isolation communication service:** the logical isolation for energy application means the communication network supporting the energy application may utilize shared network element or shared network resource e.g. VLAN etc.

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

BC Boundary Clock

GNSS Global Navigation Satellite System

PMU Phasor Measurement Unit

PTP Precision Time Protocol

TC Transparent Clock

TVE Total Vector Error

# 4 Overview

Communication infrastructure is essential to the successes of smart energy, generally termed the 'Smart Grid'. A power grid consists of four building blocks: power generation, transmission, distribution, and consumption. These different phases require different services, and these services have distinct communication requirements. Examples of communication include data collection, control and ongoing regulation, though these are functions of diverse services – e.g. SCADA applications for the Energy Management System (EMS) or Distribution Management System (DMS). Smart Grid communication infrastructure, overcomes different challenges in order to provide:

- Distributed power generation, increasingly including 'renewable' or 'clean' energy sources

- Safe & highly efficient power transforming & transmission

- Flexible & reliable power distribution

- Efficient & available power consumption

- Cyber security & resilience/redundancy

Smart Grid services today rely upon a range of telecommunications services, delivered through a blend of private networks and commercially provided services. As the energy system goes through changes, becoming more pervasive (in territorial terms,) complex and sophisticated to meet the above goals, there is a distinct opportunity for 5G to meet more of the utility communication sector's needs and thereby become increasingly relevant to this vertical, addressing existing shortcomings, as it builds out further capacity and enhances existing infrastructure. Many of these grid services are standardized by other standards bodies, e.g. IEC60870, IEC61850 and IEEE.

In summary, it is considered beneficial for 3GPP specifications in addressing 5G system support of different use cases and service requirements for Smart Grid.

# 5 Use cases

## 5.1 Use case of Distributed Energy Storage

### 5.1.1 Description

Distributed energy includes various forms such as solar energy, wind energy, fuel cell and gas combined. It is generally distributed in the user site, or near locations to realize energy generation, storage and supply. Distributed energy system has the characteristics of flexible location and decentralization, which adapts well to decentralized energy demand, and has reduced the huge investment required for upgrading the transmission and distribution power grid. It also works as a backup for the large power grid to improve reliability of whole energy supply. In storms, ice and snow weather, when the large power grid is severely damaged, distributed energy sources can form islands or microgrids on their own to provide emergency energy to important users such as hospitals, transportation hubs, radio and television.

But the distributed energy system has brought new technical problems and challenges to the power grid operation. When the distributed energy is connected to the large power grid, the energy flow on the distributed power grid becomes more complicated for that the user is becoming both the electricity user and the generator, and the current presents two-way flow and real-time dynamic changes. To improve the reliability, flexibility and efficiency of the distributed power grid, the communication system with a low latency, high reliability, massive connections and a high data rate is considered.

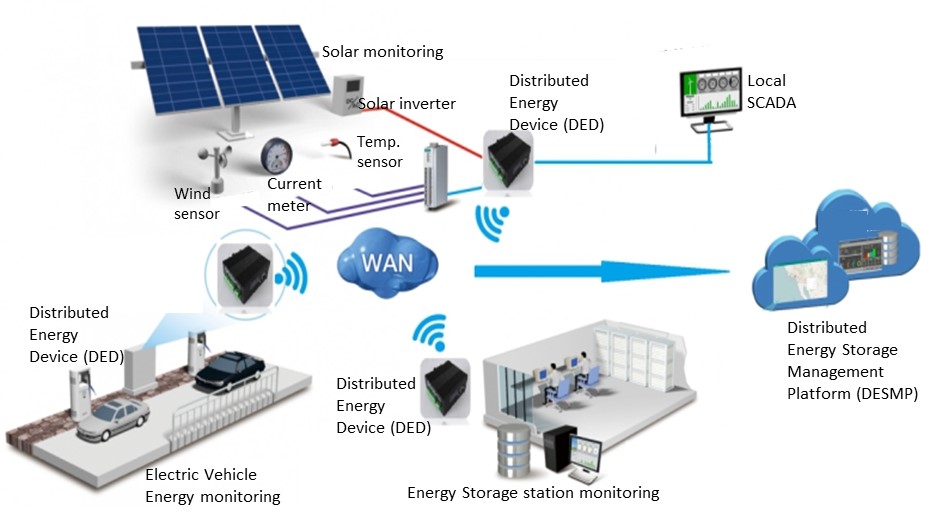


Figure 5.1.1-1: Example of Distributed Energy Storage grid architecture

Seeing Figure 5.1.1-1, it is one example of Distributed Energy storage grid architecture. The distributed power grid which is comprised of residential, commercial and light storage users, requires to exchange information among the Distributed Energy Storage Management Platform (DESMP) and the diverse Distributed Energy Devices (DED). The information exchanged in the distributed energy grid is not only to collect energy related data, but also to coordinate working flows of the distributed energy storage equipment, to change the equivalent load characteristics, and to realize flexible energy grid through load interaction etc.

The DED is plug-and-play and periodically collects the operating information, such as battery energy, charge and discharge energy, alarm information, etc., and transfers them to DESMP. The DESMP regularly maintains connections with the DED and determines the online status and issue instructions to the DED to control the switch of the device and set the energy etc. Further, it obtains the electricity, energy, load and other information of the grid-connected users in the area from the DED to support the decision-making of flexible interaction between the distributed energy storage and the large power grid, or to analyze the user's electricity habits to guide the operation of distributed energy storage.

### 5.1.2 Pre-conditions

Distributed energy system has the following functions: data acquisition and processing, active power adjustment, voltage and reactive power control, island detection, dispatch and coordination control, etc. It is mainly composed of DESMP, the DED and communication system.

The DESMP is located in region center. And the diverse DED can be deployed in buildings, indoors, outdoors, tunnels, ports and electric vehicles which may be faced a poor communication signal condition or even out of network coverage.

The 5G system connects the DEDs with the DESMP.

### 5.1.3 Service Flows

Every time after the DED and the DESMP establish a communication connection, the DED reports its configuration data to DESMP. For reliability, in general, the communications between DESMP and DED should be supported by multiple connections and backup each other.

The heartbeat data is always transmitted between the DESMP and DED to maintain a normal connection.

In the process of general service flow, there are three kinds of data exchange:

1. Command delivering: DESMP sends control commands to the DED. It always requires <10ms latency with 99.9% reliability communication service for control frequency, power etc.
2. Data reporting: equipment normal operation information, mainly including energy storage battery, energy storage converter, AC and DC charging and discharging equipment and other current operating data. It always requires <1s latency.
3. Other data: For example, the DED actively requests data, such as requesting the electricity price information from DESMP, and the AC/DC charging and discharging facility sends relevant information about the current charging and discharging under abnormal conditions.

Based on the general service flow, in different scenarios, the data collection requirement is different. The following lists two typical scenarios in distributed energy storage service (NOTE: these data are from CEPRI).

Case 1: data collection for energy storage in rural area

In the typical scenario of energy storage in rural area, it is always a large energy storage in one location. Considering the data collection, taking 100Ah lithium iron phosphate batteries as an example, the integration of a 2MWh energy storage container requires 6,250 batteries. So there are 6250 voltage and temperature collection points, and 780 current collection points, plus other 12-bit data e.g. alarms, internal auxiliary equipment such as air-conditioning, environmental monitoring and video. The collection data for the 2 MWh energy storage container is about 20,000 16-bit data and among them, the current related collection points is about 800, which need implement collection every millisecond and report every 10 ms, other 13000 points need implement collection and report every second.

Thus, there are at least two traffic models (except video) in the typical 100MWh energy storage station which is constructed by 50 2MWh energy storage containers. One is for current flow with (800\*50=40000) collection 16-bit data per millisecond, and every 10ms, the UL reported data volume is (40000\*2\*10=800 kbyte/10ms) which data rate is 640Mbit/s. The others are (13000\*50=650000) collection 16-bit data per second, and every second, the UL reported data volume is (650000\*2=1300 kbyte/s) which data rate is 10.4 Mbit/s.

Besides above, the surveillance video is the third kind of collected data. In every storage container, the typical video data is 12.5 Mbytes for every second. And in one energy storage station, there need 50 storage containers. Thus, the UL data rate per storage station is up to 12.5 Mbytes/s \* 50(containers) \* 8 = 5 Gbit/s.

Case 2: data collection for distributed energy storage in urban area

Virtual energy storage (VES) is a new type of energy storage system formed by the aggregation of user side power loads (such as air conditioning, refrigeration, heating, electric vehicles, etc.) with certain adjustment capabilities. [2]

In urban area scenario, electric vehicle is one type of VES element. It is a trend that the DED will be installed in the electric vehicle not only in the charging pole.

For electric vehicle, it is generally installed with about 7000 batteries which requires 7000 voltages, about 1000 current & temperature collection points at least. Further considering other collected data such as electronic control, charging and vehicle-grid interaction, for one electric vehicle, there is total about 10,000 16-bit data and among them, the current related collection data is more than 1000 16-bit data which need to be collected every millisecond and reported every 10ms, the others is more than 8000 16-bit data which need to be collected and reported every second.

So, there are also at least two traffic models in this case, one is the current model, every 10 ms, the UL reported data volume is (1000\*2\*10=20 kbytes) which data rate is 16 Mbit/s. The other is reported every second and the data volume is (8000\*2=16 kbytes/s) which data rate is 128 kbit/s.

### 5.1.4 Post-conditions

In urban public building, community, industrial park, rural village, this kind of distributed energy storage system with the help of 5G system works well and can supply reliable power for users.

### 5.1.5 Existing features partly or fully covering the use case functionality

The 5G system shall be able to provide required communication service for distributed power storage where it is indoor, outdoor, underground etc.

When required by regulations, the 5G system shall be able to utilize dedicated communication resource including core network and radio network to support physical isolation communication service for energy applications.

### 5.1.6 Potential requirements

[PR.5.1-001] The 5G system shall be able to provide required communication service for distributed energy storage according to the KPIs given in table 5.1.6-1 and table 5.1.6-2.

Table 5.1.6-1: periodic communication service performance requirements - data for distributed energy storage

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **scenario** | **use case** | **transfer interval target value**  **(ms)** | **message size**  **(byte)** | **data rate per storage location**  **(bit/s) (note 1)** | **communication latency (ms)** | **reliability** | **storage node density # /km2 (note 2)** | **active factor/ km2**  **(note 3)** |
| Dense Urban | Virtual energy storage monitoring | UL: 10 | UL:>20k | UL: >16 M  DL: >100 k | DL:10  UL:10 | DL: >99.90% | >1k | 10% |
| Virtual energy storage: other data collection | UL: 1000 | UL: 16k  DL: >100k | UL: >128 k  DL: >100 k | DL:<10  UL:<1000 | DL: >99.90% | >1k | 10% |
| Rural | Power storage station monitoring | UL: 10 | UL: 16k\*50 | UL: > 640 M  DL: > 100 k | DL:<10  UL:<10 | DL: >99.90% | >100 | 10% |
| Energy storage station operation data collection: other data | UL: 1000 | UL: 26k\*50  DL: >100k | UL: > 10.4 M  DL: > 100 k | DL:<10  UL:<1000 | DL: >99.90% | >100 | 10% |
| NOTE 1: This KPI is to require data rate in one Energy storage station which may via one or more 5G connections and via one or more 3GPP UE(s) at the same time.  NOTE 2: It is used to deduce data volume in an area which has multiple energy storage stations. The data volume can be deduced through follow formula: (Current + other data) data rate per storage station \* (Storage node density /km2) \* (Active factor/km2) + video data rate per storage station \* (Storage node density /km2)  NOTE 3: Active factor means the proportion that the number of active DED which are delivering its collected data during one second time window compared with whole number of DED in the area which has multiple energy storage station | | | | | | | | |

Table 5.1.6-2: Aperiodic communication service performance requirements - video for distributed energy storage

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **scenario** | **use case** | **data rate per storage station**  **(bit/s) (note 1)** | **communication latency (ms)** | **reliability** | **storage node density # / km2** |
| Rural | Energy storage station: video | UL: >5 G  DL: >100 k | DL:<10  UL:<1000 | DL: >99.90% | >100 |
| NOTE 1: The data rate is to require data rate in one Energy storage station which may via one or more 5G connections and one or more 3GPP UE(s) at the same time. It can be calculated with following formula: 12.5 Mbytes/s \* 50(containers) \* 8 = 5 Gbit/s | | | | | |

## 5.2 Use case of advanced metering

### 5.2.1 Description

Instead of recording and sending the metering data from a traditional wired electricity meter unit, electricity metering collecting can be executed by an UE integrated smart meter unit Smart meter units can send real-time metering data to the server in the Power Enterprise through mobile networks. In this way, the Power Enterprise based on the analysis of the user's power consumption behavior give users more scientific and reasonable power consumption suggestions, to develop users' power consumption and energy-saving habits. This is also a possible usage of AMI.

Advanced Metering utilizes AMI (Advanced Meter Infrastructure) system to collect, count, analyze, distribute and manage abnormal electrical energy data in the generation, transmission, distribution and using stages. It can collect real-time data of user power, monitor line loss, and power outage, real-time identify the change of household, calculate of three-phase imbalance, and monitor station voltage.

NOTE: The information obtained from smart appliances are never considered accurate nor guaranteed by certification authorities. This information is useful to customers to understand and influence their consumption patterns.

The AMI is usually comprised of smart meter, concentrator, two-way communication network, measurement data management system (MDMS), and an optional user indoor network (HAN). See Figure 5.2.1-1.

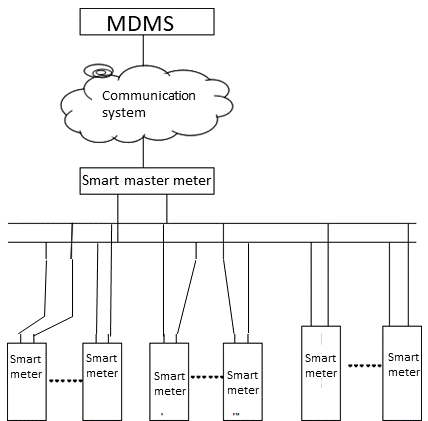


Figure 5.2.1-1: AMI example architecture

In general, the electric smart meter co-works with MDMS to deliver and perform control command for measuring instruments. The electric smart meters monitor relevant user energy status and deliver these data through concentrator to MDMS. The MDMS sends control commands according to its policy and status data collected. The remote commands from the MDMS include: tripping, closing permission, alarm, alarm release, power protection, power protection release.

Accurate Fee control is one of the basic service of advanced metering, when the user owes the fee or there is an emergency, it should be able to cut off or restore power supply in time, as the operation involves the safety& QoE of power users, a real-time response is required.

For the advanced metering application, the application layer through the communication protocol to encrypt and protect these key data, in order to protect all data, at least logical isolation is required, physical isolation is better.

NOTE: Billing may or may not be correlated with use of MDMS service, as in many geographies the DSO is a distinct business entity from the Retailer, who has the direct business relationship with the customer. In such a case, the smart meter information will not be correlated with any billing information and cannot therefore provide feedback to customers concerning the billing impact of their energy usage.

Due to massive electricity meter boxes and household appliances keep online at the same time, the amount of connections the mobile network maintains simultaneously is so enormous that challenging to the mobile network capacity. It is estimated that the increased connections will up to 50-100 times.

### 5.2.2 Pre-Conditions

SS is a power company and it constructs AMI system to deploy advanced meter service for its users. Operator TT has a contract with the power company SS to supply communication service for the AMI system.

Tom is one of the user of SS. In his house, all the electric equipment's energy data can be collected by smart meter and then reported to the MDMS of SS.

The smart meter is located in Tom's house or nearby and the MDMS is located in the remote city center. The distance between the smart meter and the energy management center can be as far as a middle size city range (e.g. Tens of km).

Peter is another user of SS. He has a contract with SS about smart energy usage in his house. SS provides electrical sockets with metering function for typical electrical appliances in his house and all the electrical energy generated by typical electrical appliances that from the electrical socket is measured in real time.

### 5.2.3 Service Flows

Scenario 1:

1) The smart meter in Tom's house report related energy usage data to SS.

2) The MDMS of SS sends commands to smart meter in Tom's home to adjust smart meter report frequency and content considering its whole energy working status.

3) The smart meter in Tom's home changes the report scheme accordingly.

4) When the MDMS detects that the user's remaining electricity will be run out, it will send an alarm command to remind the user to recharge as soon as possible;

5) When the user's remaining electricity is exhausted, the MDMS will issue a trip command and the smart meter need implement the trip action accordingly which requires the latency less than 200ms (command delivery + command action);

6) When there are special circumstances that cannot be cut off, the MDMS can issue a power protection command in advance to ensure that the smart meter will not trip for related circumstances.

Scenario 2:

1) After the smart meter in Tom's house reports the status data to the MDMS, it detects that something is wrong with Tom's home electricity supply system.

2) The MDMS asks the smart meter to report more information for troubleshooting.

3) The smart meter co-works with MDMS to resolve the problem.

Scenario 3:

The smart energy meter works as a home gateway, and every electric equipment with metering functions is connected and interacted with the smart energy meter through HPLC (high-speed power line carrier) or 5G. The figure 5.2.3-1 illustrates the typical scenario.

The electricity consumption information of various smart household appliances is delivered to the smart energy meter. Then the smart energy meter uploads them to backend platform through 5G system. These information are user private data and require physical isolation delivery with other application data.



Figure 5.2.3-1: smart meter works as home gateway

1) The socket measures energy data in real time and deliver it to the smart energy meter. The communication link between them can be HPLC (High-speed power line carrier) or 5G.

2) The smart energy meter acting as a data gateway can receive all the energy data in Peter's house and send them to the backend platform of SS.

3) According to the actual load of the energy grid, SS has the possibility to adjust user's energy usage in real time. For example, when the energy is overload, the backend platform sends control command to adjust the temperature of the air conditioner in Peter's house; when the energy load is reduced, it can encourage users to use more energy such as electric vehicle charging.

### 5.2.4 Post-Conditions

The energy related information from electric equipment can be reported to the MDMS on demand with required content and required communication performance.

The electric accurate fee control function can be implemented.

Co-working with smart meter, the MDMS can remotely troubleshoot energy problem for its user.

The power grid company regularly provides users with detailed energy consumption analysis reports based on the collected data, and guides users to use electricity scientifically and rationally.

### 5.2.5 Existing features partly or fully covering the use case functionality

The 5G system shall be able to support resilience to dynamic adjust connection service performance considering advanced metering demand.

The 5G system shall be able to provide connection service wherever indoor, outdoor, low and medium altitude for advanced metering applications.

The 5G system shall be able to support at least logical isolation communication service for advanced meter applications.

NOTE: The logical isolation communication service can utilize shared network element or shared network resource. To advanced meter application, it is the minimum requirement.

The 5G IoT device shall be able to connect energy equipment via 3GPP/non-3GPP connections to get energy data and to deliver the data to back-end energy applications via 5G connection.

### 5.2.6 Potential New Requirements needed to support the use case

[PR.5.2-001] The 5G system shall be able to provide required communication service for advanced metering application according to KPI given in table 5.2.6-1.

Table 5.2.6-1: Communication KPI for advanced metering (note 1)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **User experienced data rate**  **(bit/s)** | **Latency**  **(ms)** | **Reliability**  **%** | **Connection density** | **Coverage** |
| UL:<2M  DL:<1M | Accuracy fee control: < 100 (note 2);  General information data collection: <3000 | >99.99 | <10000/km2 (note 3) | N/A |
| NOTE 1: The KPI values refer [66].  NOTE 2: The accuracy fee control latency here is for communication one way latency from 5G IoT device to backend system while the distance between them is no more than 40 km i.e. city range. The command implementation needs 100 ms.  NOTE 3: It is the typical connection density in today city environment. With the evolution from meter centralization collection to sockets in home directly collection, the connection density is expected to increase 5-10 times. | | | | |

## 5.3 Use case of Distributed Feeder Automation

### 5.3.1 Description

With the increased requirements for a more reliable, uninterrupted and continuous power supply, shorten the accident isolation time to milliseconds is required to support regional non-stop power services which makes severe challenges for the master station in centralized distribution automation.

Therefore, intelligent distributed feeder automation has become one of the trends in the development of the power distribution grid. Its characteristic lies in the distributed sinking of the processing logic of the original master station to the intelligent power distribution terminal. Through the 5G communication among the intelligent power distribution terminals and distributed master station, intelligent judgment, analysis, fault location, fault isolation and non-fault area power supply restoration operations can be realized.

In this way, the fault handling process can be fully automated, the fault scope can be restricted and fault handling time of the distribution network can be decreased from seconds to milliseconds.

As illustrated in the Figure 5.3.1-1, the distributed feeder automation system is mainly composed of distributed master station, distribution monitoring terminal and the communication system. The distribution master station is mainly used for information gathering and human-computer interaction, and the distributed terminal is used for feeder status information collection, judgment, fault location, isolation and power supply restoration. The implementation result will be reported to the distribution master station. The communication system is to provide the communication link among the distribution terminals.

The distribution master station is usually connected with the 5G system via wired or LAN which is out of 3GPP scope. Distribution master station manages multiple distributed terminals.

Each distributed terminal here is served by 5G UE to exchange the collected data with other distributed terminals. And from application aspect, the communication between distributed terminals is peer-to-peer. The connection between the distributed terminal and the 5G UE is out of 3GPP scope.

The 5G communication here should have high reliability. Therefore at least two communication links are usually deployed for hot standby or transmitting data synchronously between two distributed monitoring terminals. And it has the same condition between one distributed terminal and the distributed master station.



Figure 5.3.1-1: Example of distributed feeder automation architecture

GOOSE protocol is a burst-based transmission application protocol used in Smart Grid. During the feeder system normal working phase, the heartbeat packet is periodic transmitted with 1s. When a fault occurs, it performs incremental periodic transmission with 2ms, 2ms, 4ms or 8ms time interval. After there is no sudden change in collected data, the heartbeat packet transmission of 1s is restored.

In general, the feeder distributed terminals can be deployed along the overhead line or integrated in one power distribution cabinet per one square kilometre. These two topologies will require different communication density.

Assumption of one CBD of a national sub provincial city, by calculating the load of various types of electricity consumption, it can be estimated the future power load in this area. Table 5.3.1-1 illustrates the typical estimated power load now and future in the area.

Table 5.3.1-1: the typical power load estimated in the CBD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Growth rate** | **Now(2020)**  **(MW)** | **Long future (2030)**  **(MW)** | **Power load density (Now)**  **(MW/km2)** | **Power load density (future)**  **(MW/km2)** |
| High | 1043 | 1454 | 20.72 | 28.89 |
| Middle | 1003 | 1348 | 19.93 | 26.78 |
| Low | 952 | 1277 | 18.91 | 25.37 |

Generally, one single urban medium voltage distribution line should not be separated exceed 4 segments, and the load of each segment should not exceed 1MW. So, for one single circuit 10kV distribution line, the line load should not be higher than 4MW (1MW\*4 = 4MW). In the medium level listed in the above table, the load density of the CBD area is about 20MW / km2, the number of 10kV lines per square kilometre can be calculated as follows:

N = 20mV / 4MW = 5.

According to the distribution network reliability configuration principle, one backup is required and the N will be 6.

Considering the switches per segment and additional switches on the high voltage side, the number of required distribution terminal n can be calculated as follow:

- Overhead line scenario: n = 6 \* (5+4) = 54.

NOTE: "6" represents the number of 10kV lines per square kilometre, "5" is switches number per line, "4" is the number of the boundary switch which is installed on the high voltage side of the distribution transformer of each segment of the line.

- Power distribution cabinets scenario: n = 6 \* (4 \* 3 + 1) = 78.

NOTE: "6" represents the number of 10kV lines, "4" means the number of distribution cabinet in one 10kV line. "3" is the number of switch including the boundary switch in each power distribution cabinet, "1" means every line end has a switch to monitor the line.

In the future, when the power load density increases, or with differential protection utilized in the Feeder automation, more distribution terminals (e.g. more than 100) need to be considered.

### 5.3.2 Pre-Conditions

Typically, the distributed Grid can be divided into urban and agricultural parts. In urban area, the power load is relatively concentrated, and the distributed grid working environment is better. But in the agricultural area, the power service range is very large, while the distributed grid has to face so many issues e.g. a large number of harmonic sources, three-phase unbalance, voltage flicker pollution.

Two 5G communication links are deployed for hot standby or transmitting data synchronously between UEs in distributed terminals and the network.

### 5.3.3 Service Flows

1) Data collection: The distributed terminal collects and reports related status information to the distribution master station or other distributed terminals in real time.

2) Fault detection and localization: The distributed terminal collects fault signal from itself and neighboring terminals. Then it executes data processing and fault location logic, and judges the fault whether an instantaneous or permanent fault.

a) When the distribution fault is an instantaneous fault, it will be skipped.

b) When the fault is a permanent fault, the distributed terminal will locate the feeder fault based on the signals of each power distribution terminal. The upstream power distribution terminal of the node will continue to send status information, while the downstream power distribution terminal will not report the fault signal. Therefore, in the corresponding fault node, only one switch should send out the fault signal. According to this feature, when a feeder fault occurs, every distributed terminal could judge its position relative to the fault location.

3) Fault isolation: When the fault node is determined, according to the preconfigured action order, all switches around the faulty node will be open to realize effective identification and isolation of the faulty area.

4) Fault restoration: For the restoration of power supply in non-fault area, it is necessary to clarify the number and wiring of the switches it tied to, e.g. when a fault occurs in the cabinet of the one-in-two-out ring main unit, if two outgoing lines have isolated power-loss area. The related distributed terminals will reconstruct the power distribution structure, and close the tie switch, to restore the power supply in the power-loss area.

5) Restoration confirmation: After the power supply is restored in the power-loss area, the system needs the distribution terminals report status information to determine whether the restoration is well done.

### 5.3.4 Post-Conditions

It can identify and shorten the power feed accident isolation time to milliseconds and support regional non-stop power services.

### 5.3.5 Existing features partly or fully covering the use case functionality

The 5G system shall be able to provide connection service wherever the distributed terminal is indoor, outdoor, low and medium altitude, or underground.

The 5G system shall be able to provide suitable APIs to enable application layer to monitor communication link status.

The 5G system shall be able to provide at least two back up communication links between every IoT device in a distributed terminal and the network.

### 5.3.6 Potential New Requirements needed to support the use case

[PR.5.3-001] The 5G system shall be able to provide required communication service according to KPI given in table 5.3.6-1.

Table 5.3.6-1: KPI for Distributed Feeder Automation (note 1)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **User experienced data rate**  **(bit/s)** | **IoT device to 5G network latency**  **(ms)(note 2)** | **Latency jitter**  **(µs) (note 3)** | **Synchronicity budget requirement (µs)** | **Reliability**  **%** | **Connection density** | **Coverage** |
| 2 M-10 M | <10 | <50 | <10 | 99.999 | 54 /km2 (note 4)  78 /km2 (note 5) |  |
| NOTE 1: The KPI values are sourced from [20]  NOTE 2: It is the one way delay from a distributed terminal to 5G network.  NOTE 3: The latency jitter is required for the switch off between the active and standby communication links  NOTE 4: When the distributed terminals are deployed along overhead line, about 54 terminals will be distributed along overhead lines in one square kilometre with the power load density is 20 MW/km2.  NOTE 5: When the distributed terminals are deployed in power distribution cabinets, and considering the power load density is 20MW/km2, there are about 78 terminals in one square kilometre. | | | | | | |

## 5.4 Use case of line current differential protection in power distribution grid

### 5.4.1 Description

Line current differential protection (defined as 87L in IEEE C37.2-2008 [3]) has been widely used in electrical transmission systems to protect High-Voltage (HV) transmission lines. As a proven protection mechanism, it is also deployed for power distribution networks to protect (Medium-Voltage) MV distribution lines where applicable. The popularity of line current differential protection comes from the fast protection mechanism, reliability and the absolute selectivity of protected zones. Therefore, for Low-Voltage (LV) and MV power lines (both underground and overhead), current differential protection could be deployed easily with cellular technology without having to lay dedicated communication cables, either in refurbishment or new distribution substation construction projects.

The mechanism of line current differential protection follows the Kirchhoff's current law, which is that the sum of currents at a junction of a circuit equals to zero. As illustrated in Figure 5.4.1-1, two protection relays deployed at two substations form the protection zone, within which the power line is protected from incidents such as short circuit. Each protection relay continuously measures its local current and transmits it towards the other. Each protection relay compares the locally measured current and the current received from the remote relay to calculate the differential current at a specific instant of time. Figure 5.4.1-1 shows two communication channels (illustrated as dashed arrow boxes) between the two protection relays. Here in this contribution the "communication channel" refers to the channel used for transferring the phase segregated current value data between the two protection relays. The current phasors from the two protection relays, deployed geographically apart from each other, should be aligned in time for the current differential algorithm to execute correctly. For Relay\_a, at a given moment the local current is I\_a'\_Tx, and the time-aligned remote current from Relay\_b is I\_b'\_Rx. Using them as input, the protection algorithm in Relay\_a derives the differential current. The same mechanism functions in Relay\_b. Whenever the differential current exceeds the threshold values as determined by the relay restraint characteristics, the relay will send a trip command to the circuit breaker (XCBR) to open the circuit, thus protecting the power line from being burnt down and any secondary damages a fireball blaze on the power line can cause.

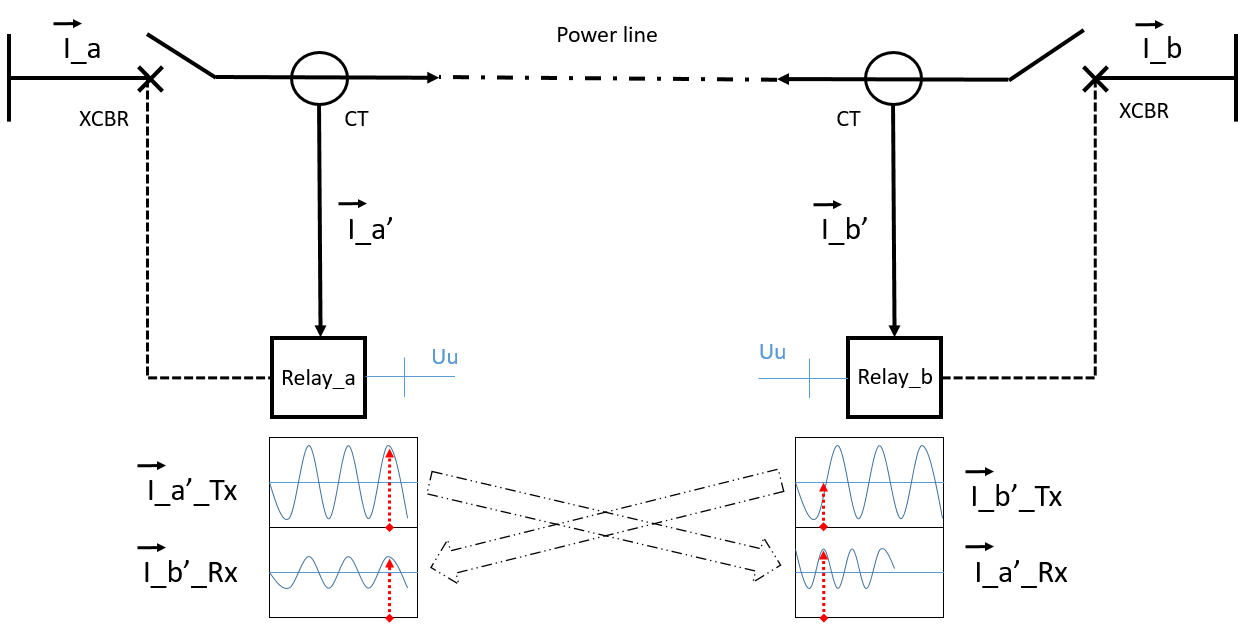


Figure 5.4.1-1: Line Current Differential Protection by two protection relays (Relay\_a and Relay\_b), deployed in two substations

The protection function of the protection relay depends on three things:

1. Sampling, buffering and transferring local current.
2. Receiving the sampled current values from the remote protection relay.
3. Time synchronization of the two protection relays - performing time-alignment of the locally buffered current samples with received remote samples.

In terms of sampling, a protection relay needs to sample the local current periodically, and transfers sampled data within a pre-defined time period T. In other words, the communication latency should not exceed T. Max of T is specified in IEC 61850-90-1 [4] to be between 5ms and 10ms, which infers the latency requirement for this use case. Secondly, once the buffered samples pertinent to the same instant in time are available, the relay must align them in time. As a relay needs to perform correct alignment of local and received data before calculating the differential current, the relay needs to know well enough when the remote relay transmits a specific data packet. Current clock synchronization is realized by relays attaching timestamps to measurement samples before transmission. A modern relay with an Ethernet interface normally needs to resort to IEEE 1588 Precision Time Protocol [5] for synchronization, since the relay assumes the Ethernet network to be non-deterministic.

Regarding time alignment of local and received remote data, two methods exist, namely the method to use external time source such as GNSS, or "channel-based" alignment method. Due to various reasons in some smaller substations a GNSS receiver is not available. Even for a substation installed with a GNSS receiver, relays shall fall back to channel-based alignment for time synchronization, should GNSS become unavailable. For this reason, support of the "channel-based alignment" is the focus of the proposed use case.

Different from GNSS-based alignment that is not adversely affected by communication channel asymmetry, the channel-based alignment is critically dependent on channel symmetry – near equal latency in transmission and reception directions between two protection relays respectively. Currently in the Smart Grid automation market, the max communication channel asymmetry is dependent on the chosen type of differential protection relay and is vendor-specific. For instance, an old-fashioned TDM-based differential protection relay is more sensitive to asymmetry than a modern type differential protection relay with an Ethernet interface. The latter can deal with asymmetry till 3ms, above which the relay will enter blocking mode. According to the IEEE C37.243 Guide [6], the asymmetry in terms of communication channel latency is around 2ms. From here on, focus is on how to satisfy channel-based alignment requirements using services from 5G system.

Option 1:

Per existing protection relay algorithm implementation, channel-based alignment presumes the delay in each communication direction to be (nearly) half of the RTT. If 5G system provides this condition, existing relay algorithm can be reused. According to IEEE C37.243 Guide, 2ms can be required as the max communication channel latency asymmetry between the two protection relays. Below are some additional details how protection relays performs channel-based alignment:

Relay\_a attaches a timestamp to the transmitted measurement data, Relay\_b receives the timestamp from Relay\_a and re-attaches the same timestamp to the next out-going data packet towards Relay\_a. By receiving the original timestamp in return packet, Relay\_a determines the RRT by subtracting the present local time with the returned timestamp. Halving the RTT, Relay\_a obtains the amount of time shift/alignment it shall apply to the current samples received from Relay\_b. Therefore, it is required that the communication channel from Relay\_a to Relay\_b incurs near-equal latency as the channel from Relay\_b to Relay\_a. Following this approach, excessive communication channel asymmetry between Relay\_a and Relay\_b will lead to misalignment of currents (such as the I\_b'\_Tx and I\_a'\_Rx at Relay\_b in Figure 5.4.1-1), manifesting in phase shift. This will result in increase or decrease of the apparent differential current, causing blocking of the protection or in the worst case a false trip and further negatively impact Smart Grid availability and reliability.

Option 2:

Alternatively, instead of requiring the communication channels (from Relay\_a to Relay\_b, and from Relay\_b to Relay\_a) to be highly symmetrical regarding latency, a different approach could be proposed as a new 5G service to improve protection relay design by the Smart Grid OEMs. To achieve the same goal as for Relay\_a to know how much it needs to time shift the received current samples from Relay\_b to align with its local current, it is sufficient if the 5G system could provide such a protection relay with the latency of the relevant communication channel (latency from Relay\_b to Relay\_a for Relay\_a, and latency from Relay\_a to Relay\_b for Relay\_b) with good confidence/precision. This provided latency value could either be estimated or assigned by the 5G system. In this way, the channel latency information is directly provided to relays by the 5G system, a protection relay does not need to carry out its own estimation. This could open new possibilities for the protection relay manufacturers to design new and possibly simpler time-alignment algorithms.

Option 3:

Using the existing IEEE 1588 time master of the NG-RAN. In this case, the complexity could be the use of the IEEE 1588 power/utility profile (a.k.a. IEC 61850-9-3 [7]) instead of using the telecom profile.

### 5.4.2 Pre-conditions

Typically in a distribution grid, a MV power line transmits electricity between two substations. Two protection relays are installed at both ends of the power line. Relay\_a continuously samples and measures the local current I\_a' and sends it to Relay\_b, so does Relay\_b.

### 5.4.3 Service Flows

1) Relay\_a samples local current values I\_a', stores them locally and sends them to Relay\_b periodically. Timestamp is attached to the sampled values to help Relay\_b match the data correctly.

2) Relay\_b samples local current values I\_b', stores them locally and sends them to Relay\_a periodically. Timestamp is attached to the sampled values to help Relay\_a match the data correctly.

3) Relay\_a receives samples from Relay\_b within the latency required by IEC 61850-90-1. Depending on the applied voltage levels, the max allowed latency is between 5ms and 10ms. Relay\_a stores the received samples in a local buffer.

Relay\_b receives samples from Relay\_a within the latency required by IEC 61850-90-1. Depending on the applied voltage levels, the max allowed latency is between 5ms and 10ms. Relay\_b stores the received samples in a local buffer.

4) Inside both Relay\_a and Relay\_b, a microprocessor decides that all the relevant data for a same instant in time are collected. The Relay then aligns these data and uses the algorithm to calculate the differential current for this time instant.

5) Differential current calculated at both Relay\_a and Relay\_b stays in the restraining region (below threshold). None of the relays trips. The system continues to function in normal condition.

6) (Example incident) Suddenly, a strong wind blows down a tree branch, which during the fall with its additional weight brings down the overhead distribution line close to the ground. The voltage of the power line causes an electric discharge with objects on the ground, causing spark leakage. This discharge causes current from both substations to flow with increased magnitude into the power line.

7) Since both the relays are still measuring the current and sends the sampled values to each other. Relay\_a detects from a very instant in time, the differential current exceeds the threshold. Relay\_a triggers a trip signal to the connected circuit breaker.

8) Circuit breaker opens, stops current from flowing into the power line to cause more serious damage.

### 5.4.4 Post-conditions

The abnormal condition of the power line in the protected zone is duly isolated from the electrical grid.

### 5.4.5 Existing features partly or fully covering the use case functionality

The communication mechanism is partly covered by existing 5G functionalities. Support of IEEE 1588 PTP is an existing feature. Additional traffic from running IEEE 1588 PTP is around 0.004 Mbit/s. In TR22.804 [8] there is attempt to touch upon the similar case, where the clock synchronization accuracy ≤ 10 μs, and latency requirement is 15 ms.

### 5.4.6 Potential New Requirements needed to support the use case

[PR.5.4-001] The 5G system shall support an end-to-end latency of less than 5 ms or 10 ms, depending on the applied voltage level. Here the end-to-end latency is between two UEs including two wireless links.

[PR.5.4-002.option1] The 5G system shall support communication channel symmetry in terms of latency (latency from UE1 to UE2, and latency from UE2 to UE1) between the two relays, with the max asymmetry < 2 ms.

[PR.5.4-002.option2] The 5G system shall provide a UE with communication channel latency from the remote UE, with an accuracy of the provided latency < 1 ms.

[PR.5.4-002.option3] The 5G system shall provide the protection relay with timing information with the comparable precision as GNSS-based precision. The IEEE 1588 time master in NG-RAN should provide protection relays with IEC 61850-9-3 based power/utility profile

## 5.5 Smart Energy Differentiated QoS For Transported Encrypted Data

### 5.5.1 Description

This use case describes a common need of Utilities with diverse substations that require communication. Diverse services' communication traffic need to be aggregated over a communication service in an encrypted form. This would prevent the 3GPP system from inspecting the traffic to identify and classify it (either in the downlink or uplink.)

The services that are listed in this section – Advanced Metering Infrastructure (AMI), Distributed Automation, Demand Response (DR), Distributed Generation (DG), Power Line Differential Protection are the 'classic Smart Grid services'. These are distinct from the services described in other sections that offer more advanced architectures. A single table of QoS values is provided in clause 5.5.6, with notes added to call out differences where they exist.

### 5.5.2 Pre-conditions

A Distribution System Operator (DSO) "U" receives telecommunication services from a MNO "T". U has deployed 100s to 10,000s of substations that generate service traffic of diverse criticality, QoS requirements, etc. U has arranged, via service level agreements (SLAs) specific QoS treatment for these different classes of service traffic with T. The use case focuses on a particular substation "S" and its communication by means of T's 3GPP network, to connect multiple services of different nature and traffic patterns, multiplexed over a single WAN connectivity.

### 5.5.3 Service Flows

S establishes sessions with the T's network. S appears as a UE to the 3GPP system. Behind S is a local network (in the substation). S serves as a router to the traffic in that network. S is able to categorize the traffic into different classes, each requiring distinct QoS treatment in the 3GPP system. S encrypts the traffic uplink, using an end to end encryption with the service termination in the DSO's network.

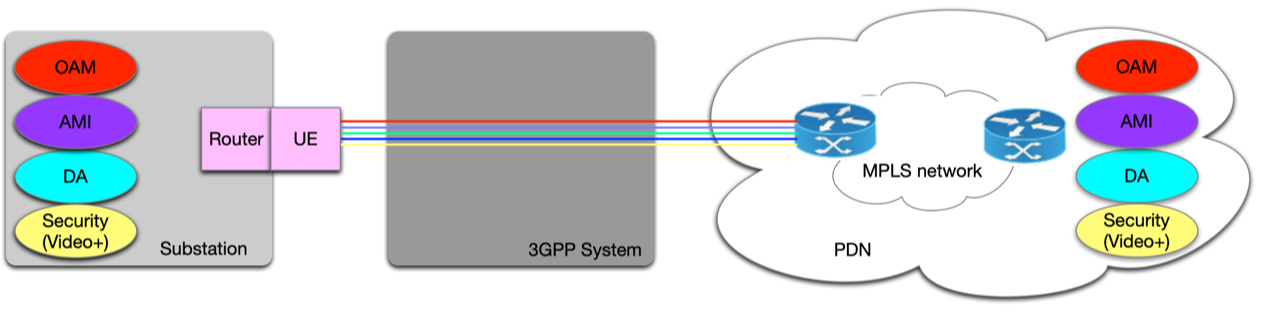


Figure 5.5.3-1: Multiple End-to-End QoS Flows from Substation to DSO Service Network

Downlink flows are also encrypted and characterized in such a way as that the 3GPP system handles the traffic with the appropriate QoS.

Instability of the connection with primary subscription could be an additional, more specific, KPI although this can be part of Availability KPI. This KPI will be measured by means of the number of Service Availability Failure Events (that is, the availability of the service could not be maintained beyond an acceptable threshold.) Another way of describing these failure events is as Fallback events carried out by the Dual SIM cellular device, where the UE employs the 'secondary' subscription (USIM) in order to achieve continual service when the primary service is not available.

This 'Service Availability Failure Event' metric is measured over a period of time, e.g. over the preceding month and accumulated during the last year.

### 5.5.4 Post-conditions

Traffic is delivered by the 5G system to support U from and to each S as required by the SLA. The traffic confidentiality is maintained.

### 5.5.5 Existing features partly or fully covering the use case functionality

TS 22.261 clause 6.7.2:

The 5G system shall allow flexible mechanisms to establish and enforce priority policies among the different services (e.g. MPS, Emergency, medical, Public Safety) and users.

NOTE 1: Priority between different services is subject to regional or national regulatory and operator policies.

The 5G system shall be able to provide the required QoS (e.g. reliability, end-to-end latency, and bandwidth) for a service and support prioritization of resources when necessary for that service.

The 5G system shall be able to support a harmonised QoS and policy framework applicable to multiple accesses.

The 5G system shall be able to support E2E (e.g. UE to UE) QoS for a service.

NOTE 2: E2E QoS needs to consider QoS in the access networks, backhaul, core network, and network to network interconnect.

A 5G system with multiple access technologies shall be able to select the combination of access technologies to serve an UE on the basis of the targeted priority, pre-emption, QoS parameters and access technology availability.

TS 22.261 clause 6.8:

Based on operator policy, the 5G system shall support a real-time, dynamic, secure and efficient means for authorized entities (e.g. users, context aware network functionality) to modify the QoS and policy framework. Such modifications may have a variable duration.

TS 22.261 clause 6.10.2:

Based on operator policy, the 5G network shall provide suitable APIs to allow a trusted third-party to define and update the set of services and capabilities supported in a network slice used for the third-party.

Based on operator policy, the 5G network shall provide suitable APIs to allow a trusted third-party application to request appropriate QoE from the network.

TS 22.261 clause 8.2:

The 5G system shall provide integrity protection and confidentiality for communications between authorized UEs using a 5G LAN-type service.

The 5G system shall provide suitable means to allow use of a trusted third-party provided encryption between any UE served by a private slice and a core network entity in that private slice.

The 5G system shall provide suitable means to allow use of a trusted and authorized third-party provided integrity protection mechanism for data exchanged between an authorized UE served by a non-public network and a core network entity in that non-public network.

Smart Grid services specified by IEC generally are defined only at layer 7. This means there are no defined KPIs for lower layer implementation. These values are determined through measurements and analysis. The research is already some years old. The bandwidth requirements are known to be increasing with time, as more services are added and services are deployed more extensively.

Specific QoS for different services is included in this section as it clearly corresponds to needs by Smart Grid. The following KPIs can be supported by existing requirements.

Table 5.5.5-1: KPIs for Smart Energy Services

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Service** | **Bandwidth (kbit/s)** | **Latency** | **Availability (%)** | **Density #customers/**  **km2** | **Coverage** | **Power supply backup (note1)** |
| Advanced metering infrastructure (AMI)  (note2) | 10-100 | 2-15 s | 99-99.99 | Minimum density  0.00136  Average density  106.56371  Max Density  22937.78217 |  | Not necessary |
| Advanced Metering (5.2.6) | UL: <2000 DL: <1000 | <100ms fee control <3000 general data collection | 99.99 | 105 |  | - |
| Distribution Automation (DA)  (note3) | 9.6-100 | 100 ms – 2 s | 99-99.99 | Concentrated rural  70.79562  Dispersed rural  Semi-urban  7.63437  Mandatory rural support  0.04765  Urban  11.02120 |  | 24h-72 h |
| Demand Response (DR) | 14-100 | 500 ms – several minutes | 99-99.99 | TBD |  | Not necessary |
| Distributed Generation (DG) | 9.6-56 | 20 ms – 5 min | 99-99.99 | TBD |  | 1 h |
| Surveillance (5.14.5) | 3000-5000 | (note4) | (note4) | 100/km2 | <40km  (city range) | - |
| NOTE 1: The Power supply backup KPI is provided for background information and a deployment issue.  NOTE 2: AMI referred to in this section is for remotely reading meters in real time  NOTE 3: DA referred to in this section uses a centralized architecture.  NOTE 4: The latency and availability of surveillance data can be compensated by local storage on-site. Therefore, no KPIs are given in the table. | | | | | | |

These values are given in [1] cited from [2] and [3].

### 5.5.6 Potential New Requirements needed to support the use case

Specific QoS for the Distributed Automation (DA) service due to its extreme availability requirements is included in this section as it clearly corresponds to needs by the Smart Grid.

**Table 5.5.6-1: KPIs for Smart Energy Services**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Service** | **Bandwidth (kbit/s)** | **Latency** | **Availability (%)** | **Density #customers/**  **km2** | **Coverage** | **Power supply backup (note 1)** |
| Distribution Automation (DA)  (note 2) | 9.6-100 | 100 ms-2 s | 99.999 | Concentrated rural  70.79562  Dispersed rural  Semi-urban  7.63437  Mandatory rural support  0.04765  Urban  11.02120 | TBD | 24h-72 h |
| NOTE 1: The Power supply backup KPI is provided for background information and a deployment issue.  NOTE 2: DA referred to in this section uses a centralized architecture. | | | | | | |

These values are given in [1] cited from [2] and [3].

Smart Grid services specified by IEC generally are defined only at layer 7. This means there are no defined KPIs for lower layer implementation. These values are determined through measurements and analysis. The research is already some years old. The *bandwidth requirements* are known to be increasing with time, as more services are added and services are deployed more extensively.

[PR 5.5.6-001] The 5G system should support a KPI associated with the "stability of the connection with a PLMN associated with a subscriber" as a more specific KPI (although this can be part of Availability KPI.) This KPI shall be measured by the number of Service Availability Failure Events (where availability cannot be maintained as required) during a time period, as specified in the service level agreement.

## 5.6 Service Lifetime for Utility Communication Services Deployments

### 5.6.1 Description

Energy infrastructure deployment occurs within a context where there is an expectation regarding service lifetime. The process of creating civic infrastructure requires significant oversight and consideration, and aims at long term solutions. This is true for all components of the energy system – generation, transport, distribution and customer premises components. The energy system is vast, so serviceability has to be considered so that the overall components require as little manual repair and maintenance as possible. Electrical infrastructure as a whole is meant to serve for multiple decades. Like physical civic infrastructure, utilities are mandated to target long term stable communication infrastructure that serve the public interest over an extended period of time. The service lifetime of diverse components are so long that newly deployed equipment must always consider interworking with legacy deployments.

Communication components of the energy system are no exception. Some communication services were deployed decades ago and continue operation (e.g. legacy teleprotection using copper wires as telecommunication.) In general, energy system communication services are defined at the application layer (e.g. by IEC). The role of the communication service is to carry these protocols with sufficient performance (throughput, reliability, maximum latency, jitter etc.) While it is possible to change communication infrastructure while maintaining the same services, this is done gradually. The communication infrastructure components are deployed with the intention that they will serve for an extended period of time – often decades, *the same time scales as the energy system components expected lifetime*. If more communication capacity is needed, this is added incrementally for new services, with attention paid to reduce change for existing components operation as much as possible.

The telecommunications system standardized by 3GPP supports backwards compatibility. There is a very strong commitment to support of legacy terminals. Cell phones from the mid-90s can still operate today. At the same time, the standard moves quite quickly (from an energy system perspective) with new 'generations' every decade – using different spectrum, radio protocols and networks. With 5G, service continuity and interworking with 2G and 3G has been discontinued, except for a few capabilities (e.g. 5G to 3G service continuity.) For energy infrastructure planning purposes, the 3GPP system needs to support long (e.g. 30-40 year) service lifetimes, in which terminals will be in continuous operation. The percentage of M2M-type operational services over 4G today is very low today, compared with the use of 2G and 3G.

Some features have been developed in 3GPP to facilitate backwards compatibility at different layers of the system. For example Dynamic Spectrum Sharing (DSS) in 5G allows different 3GPP RATs to coexist in the same carrier. This can facilitate migration or preservation of legacy radio technology.

The 'deployment' use case below considers these aspects from the perspective of a utility system operator. Unlike many use cases, this takes place over years.

### 5.6.2 Pre-conditions

Volt, a publicly traded utility company, operates the electrical transport and distribution network in more than one country. Interest in and regulatory requirements for Smart Grid services grows, and with it the demand for communication services. The existing communication infrastructure that Volt has deployed will become insufficient in the future, so Volt plans for deploying additional capacity. The target is to deploy communications equipment that will operate for 30-40 years. There are many technologies that Volt could choose for infrastructure, among them 5G standards. These technologies could be the basis for the utility private infrastructure, or could be used as a service if provided through a MNO. The entire process of planning, acquisition and deployment itself takes several years, but it has begun.

### 5.6.3 Service Flows

Volt identifies particular communication services to be addressed with LTE access to a 5GC, completes the evaluation, approval and investment process and begins to deploy. From the time that the planning started until deployment beings, five years have elapsed.

Some components of the system are 'IoT' sensors – in the transport and distribution system. These sensors are often deployed in locations that are inaccessible, where physical replacement would be unduly expensive. The overall planning and expectation is that these terminals will be in service for 35 years. (That is 40 years since the planning process began.)

The years go by, and Volt's 5G communication infrastructure continues to function. As 8G standards emerge on the market, Volt begins to consider how to replace that infrastructure – the 5G IoT sensors and other communications equipment deployed earlier. Some of the 5G components are not going to be supported by the new communication system (including integration of the 8G network with 5G networks, for example, due to the need for greater system security.)

### 5.6.4 Post-conditions

Volt has successfully operated their energy utility services, relying on 5G communication services, for over 35 years. They begin to deploy 8G technology fully expecting this to remain in operation until 2100.

### 5.6.5 Existing features partly or fully covering the use case functionality

Though not formally stated in 3GPP, successive releases and indeed changes to any release after it has been frozen, avoid incompatible changes. Any change, for enhancement, correction or simplification of the standards based system occurs only after comprehensive review and acceptance by the community of stakeholders. This expresses 3GPP standards' commitment to and emphasis on backwards compatibility.

Each generation includes comprehensive support for diverse telecommunications services. The degree of integration and service continuity offered by 2G through 4G was extensive. With 5G the compatibility has been reduced. This however does not mean that a 2G, 3G or 4G system cannot be operated at the same time as the 5G system, to maintain support for existing services. However, realistically, MNO access to spectrum and the efficient use of it, make it suboptimal for operations to maintain diverse legacy access networks. Utility equipment (routers and switches in operation) are therefore subject to different decisions to be taken by the different MNO's in the different world regions where Volt operates.

### 5.6.6 Potential New Requirements needed to support the use case

None.

## 5.7 Remote DSO management of connectivity for Smart Energy

### 5.7.1 Description

5G is expected to provide a highly reliable platform for communications. Requirements for industrial automation and URLLC (e.g. in TS 22.104) are extremely high and appropriate for connectivity for Smart Energy. However, network incidents could happen and the scenario in use case below may mitigate the impact of such a failure to further increase the system reliability.

It is important to emphasize that this use case is not theoretical. There are many substations around the world that use 3GPP access for communication services in more or less ad hoc fashion (where management interfaces between the 3GPP system and the DSO are not standardized.) This use case focusses on how 5G can provide service to DSOs as well.

A DSO has many, e.g. 100s to 10,000s of substations. These substations are managed from operation centers typically referred to as control centers.

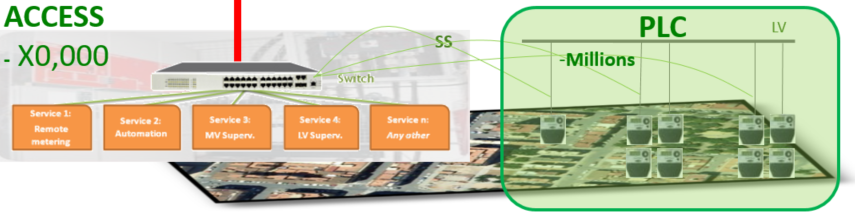


Figure 5.7.1-1: Remote DSO management of connectivity for Smart Energy

Within the substation there are many services (shown here remote metering, automation, MV supervision, LV supervision, etc.) In addition, there are power line communication links beyond, to customer premises equipment, that increasingly will spread the reach of IP services up to the smart meters. The thick red line represents the termination of communication outside the substation. For 3GPP telecommunication services supporting the DSO, the model of the interface between the switch and the network can be considered a 5GLAN service.

The actual topology between substations is more complex than shown, since there may be several communication services (back up links to provide greater reliability, etc.) For the purposes of this use case this is not considered further.

The traffic from the diverse services in the substation is aggregated before it leaves the switch and may be encrypted – the 5G system will not see the individual service flows. Of particular importance to the DSO is the interface exposed by the switch. Information about *this* from the mobile network that has proved very important in the past.

Previous generations of 3GPP systems, as deployed, did not effectively achieve high availability.

There are different alternatives to achieve high availability that a DSO might choose. This use case focuses on of the alternatives: closely monitoring actual performance. This is a way to enable DSOs to respond to possible future problems proactively. DSOs can troubleshoot more effectively. DSOs can continue service in the case of reductions in performance due to a number of factors. To identify these problems proactively, obtaining sufficient information about configuration and radio operation has been the key to identifying 'communication health' by the DSO, so as to identify patterns that result in poor performance and be able to react in a timely manner before communications performance declined to an inadequate level, e.g. by activating alternative access options to the 3GPP access whose performance shows signs of decline.

It is important to note that for the purpose of this use case, the UE that is considered is the devices that connects the substation network to the DSO's network, not any UE (e.g. a smart phone, or IoT device.) Nevertheless, it is seen by the 5G system as a UE.

Specific information that is required includes UE information, Connectivity status including QoS parameters, and session status information including user plane performance and fault information. Specific events should trigger a notification to the DSO from the MNO in a timely manner. Utilities (DSOs) can choose to rely on 3GPP technologies to enable telecommunications connectivity for mission critical services and sites. These technologies are used to connect endpoints (Substations) and a set of different Smart Grid traffic flows by means of a device with cellular WAN access.

As with any other type of telecommunications networks, the connectivity status and performance management information must be available.

In the event of an incident affecting the MNO's network, utilities need to be notified in a timely manner regarding the potential communication performance failure, so that a DSO can take proactive measures such as switching to an 'alternative' connection. This information could be predicted future events related to possible communication service degradation (derived from information exposed by an operator's network analytics), or it would be some additional information identified in close correlation with communication service degradation. The latter is the approach described further. This use case shows how an interface could deliver this information that could provide network management information to be accessible to utilities in a manageable way.

### 5.7.2 Pre-conditions

A DSO "U" has a service contract with a MNO "A" and MNO "B" to provide telecommunication service to U's substations. (U has *more than one* service contract in order to increase the *redundancy* and to achieve greater coverage, as a means of achieving higher availability.

The requirements described in clause 5.7.6 below do not depend on there being 2 USIM contracts. There is no interaction or communication between the two MNOs (A and B) implied by this use case.

U has shared parameters for delivery of information (e.g. monitoring and alarms) with A and B in advance from a standard set of them grouped in a SNMP MIB or any similar standard artefact offering the needed functionality, and established standard communication interfaces (e.g. APIs) that allow secure and highly available exchange of management data between U and A and B. The parameters and the communication interface must be standard for all MNOs and DSOs be able to receive a consistent service in the different world regions independently of the service provider.

In the following text IT management is discussed to motivate the management requirements and to explain the need. There is no intention however to require IT management at the process level be supported by 3GPP standards. Nor does this use case imply exposure or integration of IT management processes of the DSO or MNO.

The smart energy applications motivating this use case are distribution automation and distribution / substation automation applications involving supervision, control and data acquisition in order to recover from or avoid communication problems in substations. Though the availability requirements of these applications can be met by the 5G system, taken as an aggregate of several applications in a substation with critical importance to the energy system, the availability has to be extremely high. This is because the consequence of failure is severe – in terms of loss of business productivity and even risk of human life in a power outage. A DSO faces severe regulatory penalties in the event of outages that could be prevented.

The following IT processes are in place in U's network. Specific IT management objectives require timely and sufficiently detailed input. The processes that most concern this use case are Incident Management, Change Management and Service Configuration Management. These services are defined in [12]. The processes discussed in this section occur within theDSO network. Though there is no doubt a parallel set of processes within the MNO network, these are (aside from incident reporting and management data acquisition by the DSO network) out of scope. This may surprise the reader, but the reasons are the following.

1) It is the IT process requirements of the DSO that motivate the exposure of information by the MNO.

2) Though the details of the IT processes of both DSO and MNO are not matters of standardization, the interface between the two must be considered. If the DSO needs to employ different management standards with each communications provider, this increases complexity and the lack of standards based management interfaces constitutes a significant drawback when considering whether to employ and integrate services over a particular communication system.

Incident Management [13] is a process that can be triggered by a customer upon reporting an issue or raised automatically by an event monitoring system. Incident records correspond to the reported or raised event. It is vital to link incident management records to link them to Configuration Items (maintained in a database by means of the Configuration Management process [14].) A set of incidents may also motivate a Change, according to the Service Asset and Change Management Process [15].

Configuration Management is particularly important for the DSO, since they must track the total configuration of all essential systems, especially any change that occurs to components that could cause a system failure. Each item in the IT system is identified and has a controlled configuration that can be verified and audited. This allows other processes to be automated and the complete IT status to be taken into consideration in real-time, e.g. during an incident. If some components of the IT system are outside of the control of the DSO, the configuration of these must however remain constantly known. Any change to the configuration of these components requires notification to the DSO as it could possibly trigger an incompatibility with other configuration.

Change Management provides a process with significant oversight (record keeping and authorization), ability to undo the change if required through the linked process of Release Management, and an evaluation of the consequences of the change. It is particularly important that it is unacceptable under the Change Management regime that changes occur without passing through the process. For example, if a UE were to change the terms of its contract and service, or its SIM card and its configurations without going through the Change Management process this would be considered an Incident, resulting in immediate actions by DSO, and possibly further interactions with MNO.

The delivery of relevant information would be part of the service level agreement between the DSO and MNO. The information required by the relevant interfaces are listed below at a high level. A further analysis of the details of these requirements and how to fulfil them is out of scope of stage 1 specification.

In a DSO network operation center for U' s distribution services, a technician "Fred" observes a number of substation local area networks, ready to detect and resolve any sign of trouble that arises. Supplementing the DSO's network management information, the MNO exposes management data to enable Fred to properly respond to failures in the DSO network.

U uses a Dual SIM router which is configured to use MNO A as primary in normal conditions, failover mechanism to B is enabled so that standby connection can be triggered in the event of complete loss of connection or quality of connection below thresholds.

Utility DSO U's NOC (Network Operating Center) will perform efficient and effective monitoring of Smart Grid assets connectivity and incident resolution if it can rely on trustworthy information coming from the following sources:

- Health Check platform to monitor availability of the connection

- Performance Check procedures to monitor that performance levels are above required thresholds

NOTE 1: Failure of the Health Check or Performance Check will trigger the Incident Management process.

- Accurate and updated Inventory to geographically locate the Cellular connection (USIM) at a specific Smart Grid asset (typically Substation)

- Real time Access to MNO's SIM card Management and operation platforms (lifecycle control, i.e. whether the subscription is active, suspended, in ‘test’ mode, deactivated, etc. APN configuration,)

- Information provided by the MNO on a timely manner and related to radio access, for example RAT type and CellID.

NOTE 2: The timeliness requirements for monitoring depend upon the circumstances of the deployment. An example granularity for monitoring information is once per minute. This has proven sufficient in many deployments, but others with greater observed variation in performance could require greater granularity, e.g. every 30 seconds.

NOTE 3: The information provided for inventory, SIM platform configuration and cellular control plan operational parameters could be required for the Configuration Management process.

The usage of this data as a combined input to a single utility-owned "Monitoring and Management" (M&M) platform are instrumental for the DSO to make decisions and start actions that will impact the availability of the Smart Grid and, thus, the final service delivered to its customers. The utility DSO counts on a dashboard to represent the most relevant KPIs to the connectivity health status of the Substation switches and routers, to monitor the stability of the connection and the quality of the service delivered by the MNO.

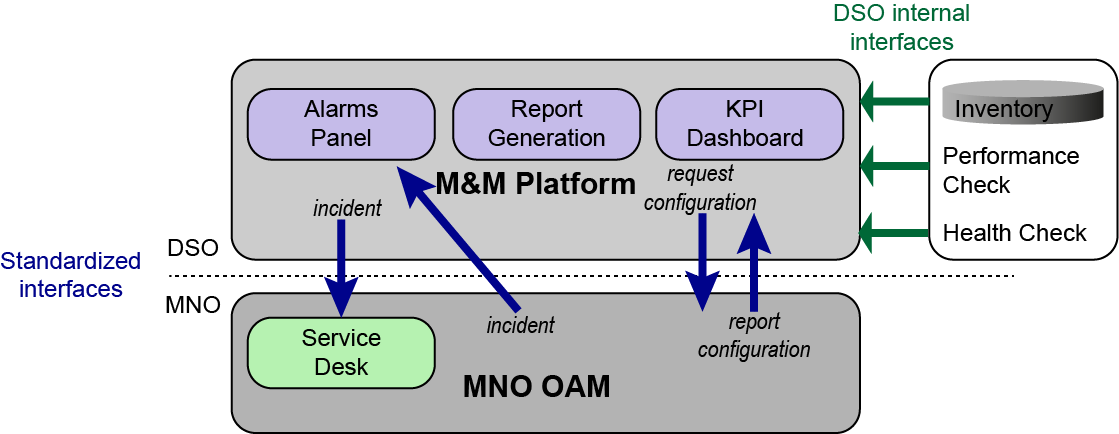


Figure 5.7.2-1: A DSO-MNO Management Model

The elements in this model are explained below.

The KPI Dashboard in the figure above contains information regarding the

- **Connectivity status** of the UEs and their status with respect to their service with the MNOs A and B. Inputs: volume of data consumption per substation and MNO A. Output: check whether expected traffic levels persist. If there is a massive failure to achieve KPIs, Fred (U) can switch to use the other MNO B. This permits detection of failure in a way that avoids massive incidents (part of the Incident Management process.)

- **Stability** of service of the UEs in terms of their mobile telecommunication service.

NOTE 4: Determination of which specific parameters should be exposed is out of scope of the present document.

Configuration is another aspect of stability. Any change to the service configuration (as agreed between U and MNOs A and B) needs to be reported. In addition, U needs to be able to request the configuration information. (This is an essential part of the Configuration Management process.)

- **Performance** determines if the mobile telecommunication network continues to perform as expected. U checks the performance by means of network tools, based on ping packets being sent (this increases traffic used over the connection with A and B.) This information is combined with AAA events (e.g. registration and deregistration with networks.) Output: Information on average performance indicators is obtained, including latency, packet loss rates, per technology. (This is an essential part of the Service Level Management process, not considered further in this use case.)

NOTE 5: QoS performance that becomes acutely inadequate constitutes a service failure incident. This is dealt with in a separate use case.

Report Generation

Reports from U are provided to A and B on a monthly basis. U expects a certain quality of service delivered by A and B. The achieved service levels are tracked and presented in the report. If A or B do not comply with the service level agreement, actions are specified in the SLA (and these are out of scope of this study.)

A DSO might request the following to be included in the report:

(1) Network performance (latency and packet loss above threshold),

(2) Network stability (the connection remains stable over time), (3) Accumulated alarms arising due to the MNOs network (e.g. massive or isolated RAN issues.)

NOTE 6: The list above is an example only. The specifics of report generation of is out of scope of the present document.

Alarms Panel

Alarms can be triggered so that incident's responsible parties are informed in real time and the remediation actions and/or escalation processes can be initiated. Alarms are reported by U to A and B as part of the Incident Management process. Incidents may be of the following forms (this is not an exclusive list):

- Massive incident where all UEs connectivity is affected whose SIM cards are provided by A or B.

NOTE 7: An incident reported by U to A or B could be caused (at least in part) by incidents in a single access point.

### 5.7.3 Service Flows

The service flows below are examples of typical situations encountered by "Fred", a technician at Utility U's Network Management Center (NMC), to illustrate the normal operation and maintenance processes (with emphasis on Change Management, Incident Management and Configuration Management):

1) Fred is checking M&M "KPI Dashboard" and, while looking at the Weekly graph of Connectivity status, he notices a sudden drop of accumulated traffic consumption of MNO A and a sudden increase of MNO B traffic. At the same time at "Alarms" panel there is an incoming alarm informing of a Massive event. An automatic ticket is created to MNO A and the counter of massive events is updated to be reflected in the next SLA monthly report to track MNO A's quality of service.

2) Fred tries to remotely perform a firmware upgrade to the Substation Automation unit and, after a couple of unsuccessful attempts, notices that the firmware upgrade cannot be fully completed because the connection is unstable. Fred checks the Stability graph on "KPI Dashboard" for this particular Substation code and confirms that there is a recurring cell roaming of MNO A's SIM card during the last 12 hours. Fred accesses remotely to the cellular router that is providing cellular access to the substation Automation units and provokes a failover to MNO B. This turns out into a stable connection which enables a successful completion of firmware upgrade process. At the same time, he checks the "Alarm panel" and confirms that a notification has been sent to the MNO A because this bad behaviour has been happening for the last month.

3) Utility U is embarked in the renewal of electric MV cables of a group of 10 Substations located in the proximity of "Main Convention centre". These Substations are using BPL (Broadband PLC over Medium Voltage) as the main backhaul connection with failover to cellular backhaul in case of main connection failure. Fred observes that the backup cell communication with MNO A for the 10 Substations is working, though runs unstably. Fred checks the "Dashboard KPI" Performance graph and confirms that the Substations' cellular connections have high latency and packet loss rate during day working hours for the last two weeks. At the same time, after checking Stability graph on "KPI Dashboard" Fred confirms that the USIM cards in the 10 Substations also present constant technology roaming from E-UTRAN service to UTRAN service. This issue has been affecting hourly smart meter readings. Fred remembers that there has been an Automobile Fair at the Convention centre in the last two weeks that might have affected the Radio resources available at the eNodeB. He checks the alarms and sees that there has been an alarm sent to MNO A to report on Service Quality degradation. This alarm triggers an auditing process lead by MNO's radio team in order to increase the capacity of 2 specific sectors of 1 eNodeB serving the Convention centre area. (This is an example of a performance based trigger for Change Management as part of the overall Service Level Management process between U and A.)

4) While analysing MNO A's monthly SLA report, Fred observes that the average latency of all connected SIM cards has dramatically increased in the last two months from an average of 200 ms up to 630 ms. Furthermore, there has been an accumulated amount of 10 massive incidents in the last month. This information is instrumental to contact MNO A that was aware of the massive incidents but was not of the increase in latency. In order to solve it the MNO takes appropriate action.

5) While monitoring the Performance graph on "KPI Dashboard", Fred observes high packet loss rate affecting all connected Substations through MNO B. This issue is starting to affect the smart meter reading rates. Fred promptly opens a ticket to MNO B (as part of the Incident Management process.)

Alternatively, if B detects a problem in their network that will degrade service levels in U's network, B will use a standard mechanism to raise an alarm in U's network. This will alert Fred, who will note that there is already an open ticket related to the incident, as well as other data associated with the service degradation.

6) MNOs A and B have recently informed DSO "U" about the imminent phase out of 3G services at national level. They inform about the process timeline which is planned to start in the next 6 months to be fully completed along one year starting in urban areas. Fred has been designated to coordinate the remediation activities that will avoid MNO's network operations to affect DSO U's Smart Grid operations. Fred checks "KPI dashboard" in "M&M platform" to do a first evaluation of the dimensions of the situation. The accumulated graph per technology and frequency band for each MNO shows that there are 20,000 substations currently connected by means of Cellular 3G. "3G remediation" project definition starts. (This is an example of the Change Management process informed by Configuration Management and performance data.)

7) "3G remediation" project requires DSO "U" to undertake both field and administrative operations. Field operations will consist on replacing cellular devices and SIM cards of MNOs A and B all over 20,000 substations. Inventory information of SIM cards' location available on "M&M" platform allows to efficiently coordinate field operations. (Configuration Management is needed during Release Management process. The release management process is not discussed further in this use case.)

8) Administrative operations consist on provisioning 20,000 new generation technology SIM cards of both MNOs A and B. "M&M" platform will enable a single interface of operation which will make the task more efficient and straightforward than it was before when provisioning had to be performed by means of two separate MNO's Web Portals. This is possible thanks to the fact that SIM card parameters (APN, status, IP, Subscription group, etc.) for both MNO's A and B are standard, delivered through the same API definition. This allows an easy integration of all MNO information into a single operating platform. (This is an example of Configuration management processes making use of standard interfaces.)

### 5.7.4 Post-conditions

U is able to work to maintain and improve the services they provide to their customers both during incidents and over time as part of Incident Management and Change Management processes. U is able to report incidents to A and B with standard mechanisms and content that will help the identification and solution of it with less effort and time. A and B receive input from U and is able to improve and maintain their service quality. A and B provide notifications to U regarding changes *for selected components* (e.g. specific UE aspects) to status and configuration (both long term and every time that specified components change) as per their service agreement. A and B can inform U of service changes in advance. A and B inform U when an incident occurs by means of standards based mechanisms.

### 5.7.5 Existing features partly or fully covering the use case functionality

TS 22.261 clause 6.10.2:

Based on operator policy, the 5G network shall provide suitable APIs to allow a trusted third-party to monitor the network slice used for the third-party.

The 3GPP network shall be able to provide suitable and secure means to enable an authorized third-party to provide the 3GPP network via encrypted connection with the expected communication behaviour of UE(s).

NOTE 1: The expected communication behaviour is, for instance, the application servers a UE is allowed to communicate with, the time a UE is allowed to communicate, or the allowed geographic area of a UE.

The 3GPP network shall be able to provide suitable and secure means to enable an authorized third-party to provide via encrypted connection the 3GPP network with the actions expected from the 3GPP network when detecting behaviour that falls outside the expected communication behaviour.

NOTE 2: Such actions can be, for instance, to terminate the UE's communication, to block the transferred data between the UE and the not allowed application.

Based on operator policy, the 5G network shall provide suitable APIs to allow a trusted third-party to scale a network slice used for the third-party, i.e. to adapt its capacity.

Based on operator policy, the 5G network shall provide suitable APIs to allow a trusted third-party application to request appropriate QoE from the network.

Based on operator policy, the 5G network shall expose a suitable API to allow an authorized third-party to monitor the resource utilisation of the network service (radio access point and the transport network (front, backhaul)) that are associated with the third-party.

Based on operator policy, the 5G network shall expose a suitable API to allow an authorized third-party to define and reconfigure the properties of the communication services offered to the third-party.

Based on operator policy, the 5G system shall provide suitable means to allow a trusted and authorized third-party to consult security related logging information for the network slices dedicated to that third-party.

Based on operator policy, the 5G network shall be able to acknowledge within 100ms a communication service request from an authorized third-party via a suitable API.

The 5G network shall provide suitable APIs to allow a trusted third-party to monitor the status (e.g. locations, lifecycle, registration status) of its own UEs.

NOTE 3: The number of UEs could be in the range from single digit to tens of thousands.

The 5G system shall provide suitable APIs to allow third-party infrastructure (i.e. physical/virtual network entities at RAN/core level) to be used in a private slice.

A 5G system shall provide suitable APIs to enable a third-party to manage its own non-public network and its private slice(s) in the PLMN in a combined manner.

TS 22.261 clause 6.26.2.3:

The 5G network shall enable the network operator to create, manage, and remove 5G LAN-VN including their related functionality (subscription data, routing and addressing functionality).

TS 22.261 clause 6.26.2.5:

The 5G system shall support traffic scenarios typically found in an industrial setting (from sensors to remote control, large amount of UEs per group) for 5G LAN-type service.

TS 22.261 clause 6.26.2.9:

Based on MNO policy, the 5G network shall provide suitable APIs to allow a trusted third-party to create/remove a 5G LAN-VN.

Based on MNO policy, the 5G network shall provide suitable APIs to allow a trusted third-party to manage a 5G LAN-VN dedicated for the usage by the trusted third-party, including the address allocation.

Based on MNO policy, the 5G network shall provide suitable APIs to allow a trusted third-party to add/remove an authorized UE to/from a specific 5G LAN-VN managed by the trusted third-party.

TS 22.261 clause 8.5:

For a private network using 5G technology, the 5G system shall support network access using identities, credentials, and authentication methods provided and managed by a third-party and supported by 3GPP.

23.628, 5.6.1 provides monitoring of UE location, IMSI-IMEI association changes, UE connectivity and PDN connection status.

23.502, 4.15.3.1 provides the analogous monitoring capabilities for the 5GC.

It may be possible for the utility to interact using non-standard means with the MNO to determine the status of any of their subscriptions (and associated UICC/USIMs.) This capability is entirely out of scope of 3GPP.

It also may be possible using non-standard means for the utility to request configuration default information related to their subscriptions (and associated UICC/USIMs.) This capability is entirely out of scope of 3GPP.

### 5.7.6 Potential New Requirements needed to support the use case

[PR.5.7-001] Based on MNO policy, the 5G network shall provide means to allow a trusted third party to monitor LAN-VN performance parameters, to configure and receive information for conditions relevant to a specific UE, specifically performance of the network and configuration aspects of the UE in the VN.

[PR.5.7-002] The 5G system shall provide a means by which an MNO informs 3rd parties of network events (failure of network infrastructure affecting UEs in a particular area, etc.).

[PR.5.7-003] The 5G system shall provide a means by which an MNO informs 3rd parties of congestion or other general performance degradation (especially if planned or known).

[PR.5.7-004] The 5G system shall provide a means by which an MNO can report site specific and massive events to 3rd parties.

[PR.5.7-005] The 5G system shall provide means by which an MNO informs 3rd parties of changes in UE subscription information. The 5G system shall also provide a means for 3rd parties to request this information at any time from the MNO.

NOTE: Examples of UE subscription information include IP address, 5G LAN-VN membership and APN/DNN. These changes can have strong impacts in the stability of the 3rd party service.

[PR.5.7-005a] Based on operator policy, the 5G system shall provide means for the 3rd parties to request changes to UE subscription parameters for access to data networks, e.g. static IP address, APN/DNN.

[PR.5.7-006] The 5G system shall provide a means by which an MNO can inform 3rd parties of changes in the RAT type serving UE, cell ID, quality of signal information, change in frequency band assigned with a suitable frequency via OAM and/or 5G core network to aid the 3rd party user in taking proactive actions to achieve their own service availability.

## 5.8 Use case of Smart Distribution Transformer Terminal

### 5.8.1 Description

The Smart Distribution Transformer Terminal is usually deployed in the distribution transformer area. It could support multiple energy applications simultaneously. Multiple kinds of energy data are collected firstly by the terminal and then delivered to related energy application platform. Some kind of data could be analysed, or even the terminal itself can make decision to perform real-time action. Figure 5.8.1-1 illustrates a work flow example of Smart Distribution Transformer Terminal.

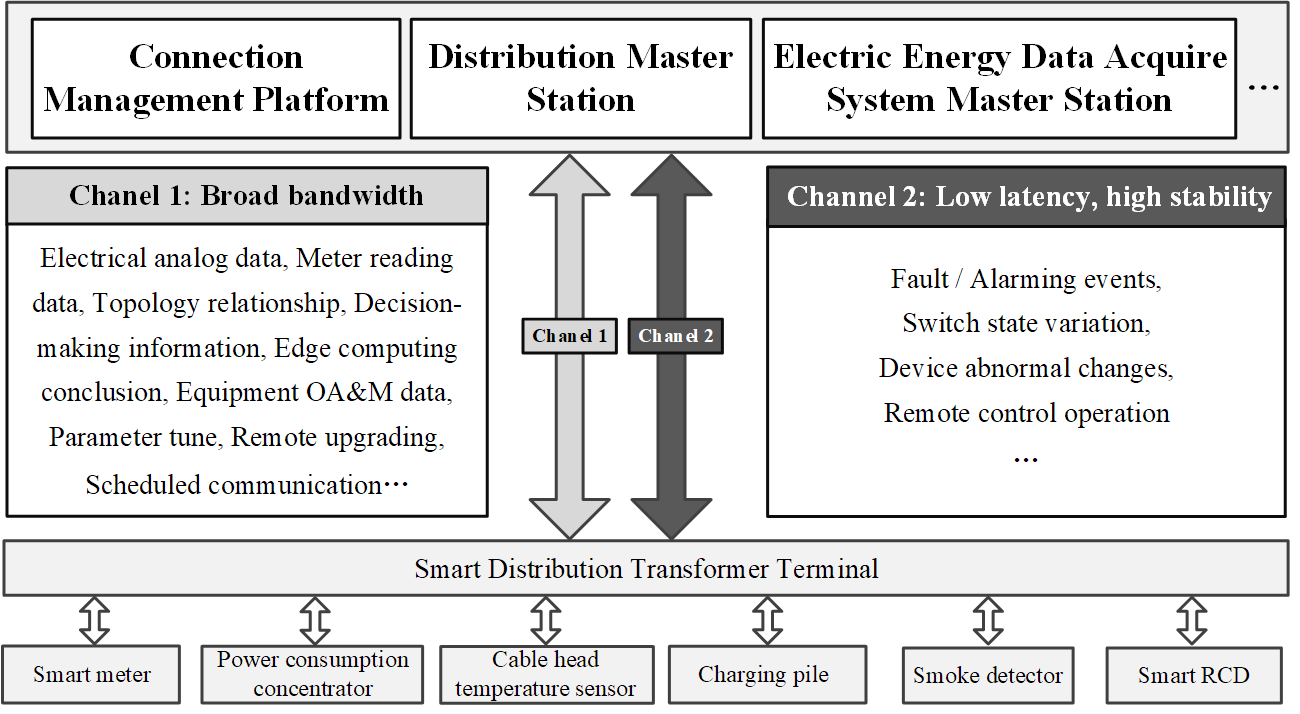


Figure 5.8.1-1: Example of Smart Distribution Transformer Terminal work flow

With the assistance of 5G system, it could report massive energy data separately to multiple energy application platforms according to their requirements. And data from energy application platforms could also be sent to terminal through 5G network, no matter it is business data or management data. Typical interactive data includes fault / alarming events, switch state variation, device abnormal changes, remote control operation, electrical analog data, meter reading data, topology relationship, decision-making information, edge computing conclusion, equipment OA&M data, remote upgrading, scheduled communication, etc. Some of this data is event triggered and requires a high priority for real-time communication while others may need a regular latency but broad bandwidth channel to fit their demands.

The energy application platform could be connection management platform (a.k.a. IoT platform), master station of distribution automation system and master station of electric energy data acquire system. In the future, there might be more platforms that need to transfer data through the 5G network.

In general, the connections between the Smart Distribution Transformer Terminal and application platform are provided by 5G system, while the connections between energy end equipment and Smart Distribution Transformer Terminal may be provided by 5G system either. When they are 5G connections, about 300 ~ 500 energy end equipment are connected to a Smart Distribution Transformer Terminal. The average application layer packet data rate for one kind of Smart Grid application between the Smart Distribution Transformer Terminal and energy end equipment is more than 2 Mbit/s in uplink e.g. smart metering, while the communication range is from 100m to 500m. In some cases, the data delivered to the Smart Distribution Transformer Terminal can be locally processed by the Terminal directly to improve working efficiency with the authorization of application platform. These energy applications and different data flows in one application require different communication services and different safety & isolation protection according to the Industry regulation. So, the Smart Distribution Transformer Terminal is required to isolate these energy data according to different application demands.

### 5.8.2 Pre-Conditions

The energy company EE has a contract with Tele-Operator TT. TT will provide 5G communication service for EE's energy services.

EE has deployed a lot of Smart Distribution Transformer Terminals which could utilize 5G communication links to connect with multiple energy application platforms. In general, one Smart Distribution Transformer Terminal is deployed in one distribution transformer area.

The energy application platform could be connection management platform (AKA IoT platform), master station of distribution automation system and master station of electric energy data acquire system. In future, there might be more platforms that need to transfer data through this network.

EE configures different communication services demands and safety & isolation demands for different energy applications.

EE also deploys a management platform to operate and manage its Smart Distributed Transformer Terminals which may be up to millions in the platform management scope. The connections between them also can be supplied by 5G system and are required as permanent links once they are established. The heart-beat information is transmitted when there is no management data.

### 5.8.3 Service Flows

1) The 5G system gets the demands of communication and isolation to establish two 5G communication links between the Smart Distribution Transformer Terminal and the energy application platform. One link is required with high data rate to deliver data e.g. electrical analog data, meter reading data, topology relationship, decision-making information, edge computing conclusion, equipment OA&M data, remote upgrading, scheduled communication, etc. The other link is required with low latency and high stability to deliver data e.g. fault / alarming events, switch state variation, device abnormal changes, remote control operation, etc.

2) In distribution transformer area A, 5G system is required to establish communication links for 500 energy end equipment to connect with the Smart Distributed Transformer Terminal. Thus, the Smart Distributed Transformer Terminal works as a service relay or gateway.

3) The energy end equipment in area A and area B e.g. smart meters, cable head temperature sensors, power consumption concentrators, smoke detectors, smart RCDs, charging piles and phase change switches, collect related data and secured deliver the data them to Smart Distribution Transformer Terminal.

4) The Terminal continues to deliver the collected data and analysis / decision information to different energy application platforms through the two 5G communication links with different isolation demands mentioned above.

- Some data e.g. energy consumption data in the distribution transformer, power line, and user point can be analysed by the Terminal and take some action e.g. adjust topology. Then the result data will be reported to related energy application platform.

- Some data is periodic collected and reported, e.g. energy quality data and energy equipment status data.

- Some data is event trigger and need to be reported in real time, e.g. the voltage, current, alarm data of each node in the low-voltage area.

5) The Smart Distributed Transformer Terminals management platform monitors all the working status of terminals and if needed, sends order to the terminal through the 5G communication link to maintain the Smart Distributed Transformer Terminal's normal work.

### 5.8.4 Post-Conditions

The energy application platforms receive the collected data in time and with required isolation protection.

The communication links status also can be monitored by energy company EE.

### 5.8.5 Existing features partly or fully covering the use case functionality

TS 22.261 clause 6.5.2, there is a related requirement:

Based on operator policy, the 5G network shall be able to support routing of data traffic between a UE attached to the network and an application in a Service Hosting Environment for specific services, modifying the path as needed when the UE moves during an active communication.

The 5G system shall be able to provide suitable APIs for the energy application platform to monitor the quality of the communication link.

The 5G system shall be able to supply end to end unified quality of communication service for Smart Distribution Transformer Terminal, i.e. from the energy end equipment to energy application platforms.

The 5G system shall be able to support millions of communication links between Smart Distributed Transformer Terminals management platform and Smart Distributed Transformer Terminals under its management scope.

When required by regulatory requirement, the 5G system shall be able to simultaneously supply multiple different isolation communication services for different energy applications.

The 5G system shall be able to support up to 500 communication links between the Smart Distribution Transformer Terminaland energy end equipments with the communication distance from 100m to 500m in one distribution transformer area.

The 5G system shall be able to support routing of data traffic between the Smart Distribution Transformer Terminal in the network and an application processing the data in a service hosting environment.

NOTE: The smart distribution transformer terminal is one kind of Grid terminal and may be deployed in network edge node.

The 5G system shall be able to supply a method for the application layer to authenticate and authorize communication network element used for the Smart Distribution Transformer Terminal.

### 5.8.6 Potential New Requirements needed to support the use case

[PR.5.8-001] The 5G system shall be able to provide required communication service according to KPI given in table 5.8.6-1.

Table 5.8.6-1: Key Performance for Smart Distribution Transformer Terminal

|  |  |  |  |
| --- | --- | --- | --- |
| **Average data rate (UL) (note 1)** | **End-to-end latency (note 2)** | Area user density | Range |
| >2 Mbit/s | 10 ms, 100 ms, 3 s | 500 devices /distribution area (note 3) | 100 m ~ 500 m, outdoor, indoor / deep indoor |
| NOTE 1: It is the smart metering application data rate between the Smart Distribution Transformer Terminal and energy end equipment. Once there are multiple Smart Grid applications, it is required more data rate.  NOTE 2: It depends on different applications supported by the Smart Distribution Transformer Terminal. The less the latency is, the more applications can be supported.  NOTE 3: The distribution area can be calculated as 3.14\*Range2. It is in general 0.031km2~0.785km2. | | | |

## 5.9 Use case of isolation demand for energy applications

### 5.9.1 Description

According to the regulation of China Grid industry, the power grid business is mainly divided into two working categories: production control and information management. The production control can be further divided into safety zone I and safety zone II. All the real-time monitoring, detection, and controlling energy production applications belong to safety zone I. And other non-controlling energy production applications belong to the safety zone II. The information management also can be further divided into safety zone III and safety zone IV. The applications belong to the safety zone III are information systems for power production, while the internal information services for the energy enterprises belong to safety zone IV. Following Table 5.9.1-1 lists the typical applications belong to different safety zones.

Table 5.9.1-1: typical safety zone and related energy application

|  |  |
| --- | --- |
| **Safety Zone type** | **Typical energy applications** |
| I | distribution automation system, substation automation system, relay protection, distributed energy storage, etc. |
| II | Reservoir dispatch automation system, electric energy metering system, relay protection and fault recording information management system, etc. |
| III | Dispatch production management system (DMIS), lightning monitoring system, power line inspection, statistical report system, etc. |
| IV | Management Information System (MIS), Office Automation System (OA), Customer Service System, etc. |

According to, different kinds of safety isolation requirements are applied to different safety zones:

a) The energy applications belong to production control category i.e. safety zone I and II need to be physically isolated from other applications which don't belong to production control working category.

b) The energy applications belong to information management working category i.e. safety zone III and IV can be logically isolation from other applications including non-energy applications.

c) The energy applications belong to a same working category can be logically isolated each other.

d) The energy applications belong to a same safety zone can be logically isolated each other



Figure 5.9.1-1: isolation demand for energy applications

Typically, the physical isolation requires the traditional wired communication link utilizing different time slots, wavelengths, and physical media to guarantee the safety demand. And the logical isolation may be supported by shared communication resource.

With 5G system is utilized to support Smart Grid applications, the different isolation modes will also be supported by 5G system. Not only core network, but also radio network and UE are involved. For 5G system, the physical isolation communication service means dedicated core network element and dedicated radio resource e.g. PRB pool, spectrum etc. The logical isolation communication service on the other hand may be supported by shared network element or shared network resource.

### 5.9.2 Pre-Conditions

The energy company EE utilizes 5G system to support multiple energy applications with different isolation communication services. Among them, the PMU belongs to safety isolation I, the electricity information collection belongs to safety isolation II, power line on-site patrol belongs to safety isolation III, Office Automation System (OA) belongs to safety isolation IV.

### 5.9.3 Service Flows

The 5G system deploys several communication links to support multiple energy applications.

One link is used to support PMU application and the dedicated core network element and dedicated radio resource have been configured in this link to guarantee the physical isolation demand.

One link is used to support electricity information collection application. It also belongs to safety isolation II which can be logical isolation with applications belong to safety isolation I and physical isolation with applications belong to safety isolation III and IV. So, it also can share network resource e.g. core network element and dedicated resource with PMU application.

One link is used to support power line on-site patrol application. It belongs to safety isolation III which require logical isolation. Considering applications belong to safety isolation I & II require physical isolation with applications belong to safety isolation III and IV, it can't share the network resource e.g. core network element and dedicated resource with PMU, differential protection and electricity information collection applications. But it can share network resource with other applications belong to safety isolation III and IV, even other internet applications.

One link is used to support Office Automation System (OA). It also requires logical isolation. So, it can share network resource with power line on-site patrol application.

The energy company EE also can monitor the above communication resource usage and communication link quality.

### 5.9.4 Post-Conditions

The energy applications can be work well and fulfil the isolation requirements with the assistance of 5G system.

The communication resource usage status and communication link quality also can be monitored by energy company EE.

### 5.9.5 Existing features partly or fully covering the use case functionality

When required by regulations, the 5G system shall be able to provide suitable [mechanism](https://cn.bing.com/dict/search?q=simple%20mechanism&FORM=BDVSP2) for the energy application to monitor the communication link quality and network resource usage.

When required by regulations, the 5G system shall be able to utilize dedicated communication resource including core network and radio network to support physical isolation communication service for energy applications.

When required by regulations, the 5G system shall be able to utilize shared communication resource including core network and radio network to support logical isolation communication service for energy applications.

The 5G system shall be able to simultaneously support multiple communication links with different isolation requirements according to energy management regulation.

### 5.9.6 Potential New Requirements needed to support the use case

None.

## 5.10 Utility End to End Security

### 5.10.1 Description

In some networks, communication is done in different security domains.

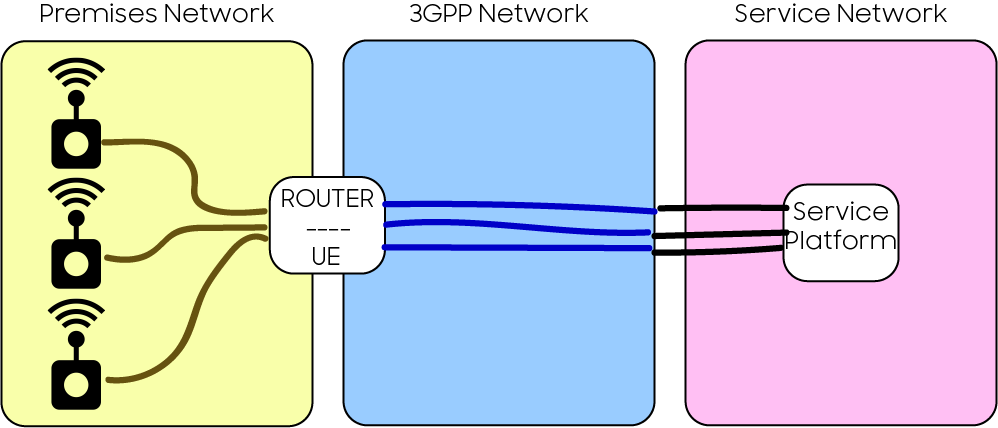


Figure 5.10.1-1: Different Security Domains

There are three domains depicted above. One is in the premises with the devices at the edge of the utility network, e.g. sensors. The second domain is the 3GPP network. The third is the service network. This scenario, to secure communication, requires application communication above the network layer (e.g. TLS or another transport layer security mechanism, S/MIME or another presentation layer security mechanism or encryption at the application layer.)

The situation becomes even more complex if there are multiple applications, different networks used at the edge and different communications systems used for the end to end service.

In this use case, integration of communication end to end with the 5G system presents benefits to end to end service delivery.

### 5.10.2 Pre-conditions

A gateway (UE and router) provides 5GLAN service from a Distribution Service Operator (DSO), EnergyCo to 1000s of sites (e.g. substations) in which there is diverse communication-enabled equipment.

This set of devices is provisioned with security configuration sufficient for authorization and registration with the 5G system. Specifically, the devices are equipped with USIMs or, in NPNs, with non-3GPP credentials, to allow for the network operator to perform Authentication, Authorization and Accounting (AAA.)

The service platform of EnergyCo is also has sufficient configuration to obtain services with the 5G system from a 'northbound interface'.

### 5.10.3 Service Flows

EnergyCo's equipment (e.g. sensors, remote controllable devices, etc.) within the premises of 1000s of substations uses its configuration authorize access to the UE/Gateway, which provides access to the 5G System for communication services. One such device sends an alert message to EnergyCo's service platform.

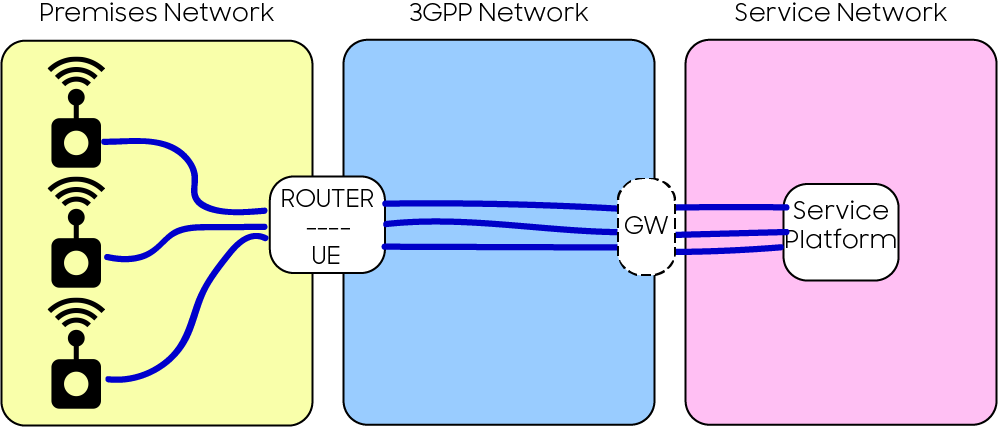


Figure 5.10.3-1: Different Security Domains

The communication between the device and the Router/UE is secured with respect to the constraints acceptable to EnergyCo. The communication through the 5G system employs 5G security, which provides secure communication to the service levels expected by EnergyCo. Finally, a secure session can be provided using credentials between the Service Platform and the 3GPP system – whose edge is depicted as a gateway (GW), if network layer security services are required by EnergyCo.

### 5.10.4 Post-conditions

The EnergyCo equipment to Service platform communication is secured end-to-end in a uniform manner for all their equipment, meeting EnergyCo's security requirements.

### 5.10.5 Existing features partly or fully covering the use case functionality

There are several ways that the existing 5G system could support this use case.

First, by means of alternative authentication methods between the equipment and the UE. The ' uniformity' in this case would rely upon establishing the same configuration and operation regime in the equipment and UE/Router in all installations.

TS 22.261 v17.3.0, clause 8.3:

The 5G system shall support operator controlled alternative authentication methods (i.e. alternative to AKA) with different types of credentials for network access for IoT devices in isolated deployment scenarios (e.g. for industrial automation).

The 5G network shall support a 3GPP supported mechanism to authenticate legacy non-3GPP devices for 5G LAN-VN access.

While this may suffice to secure the Equipment to UE/Router communication, it is not significantly different than the scenario described in 5.10.1. There is no 'end-to-end' support in this scenario, unless a security association is established between the equipment and the service platform (by means outside of the scope of 3GPP, i.e. over the top.)

Second, the equipment could establish a security association with the 5G system (not just with the router.)

TS 22.261 v17.3.0, clause 8.3:

The 5G system shall support a suitable framework (e.g. EAP) allowing alternative (e.g. to AKA) authentication methods with non-3GPP identities and credentials to be used for UE network access authentication in non-public networks.

NOTE 2: Non-public networks can use 3GPP authentication methods, identities, and credentials for a UE to access network but are also allowed to utilize non-AKA based authentication methods such as provided by the EAP framework.

In this approach, assuming the EAP framework chosen afforded sufficient security protections for the non-public network, the communication from the equipment to the Router/UE and through the 5G System would be in the same security domain. A gap (described below in 5.10.6) is the communication between the 5G System and the EnergyCo service platform, which is currently not defined in the 5G standard.

Third, the equipment in the EnergyCo network could be provided with sufficient credentials (including a USIM) to fully become authorized with the 5G System. In this case, end to end security is possible by means of the GAA framework.

TS 33.220 v16.2.0, clause 4:

The 3GPP authentication infrastructure, including the 3GPP Authentication Centre (AuC), the USIM or the ISIM, and the 3GPP AKA protocol run between them, is a very valuable asset of 3GPP operators. It has been recognised that this infrastructure could be leveraged to enable application functions in the network and on the user side to establish shared keys.

### 5.10.6 Potential New Requirements needed to support the use case

[PR.5.10-001] The 5G system shall enable support of a mechanism to support authentication and secured communication between the 5G system Core Network and a 3rd party's application function, in order to provide secure end to end communication service.

## 5.11 QoS Monitoring and Reporting Mechanisms

### 5.11.1 Description

This use case explores in more detail an aspect of service level management that is the business relationship between an energy utility operator, "EnergyCo" and the telecommunications operator, "Telecomm1". While their business relationship itself is out of scope of 3GPP standardization, there are aspects of the SLA, specifically agreements for achieving and monitoring performance and satisfaction of KPIs, and managing incidents improve the suitability of Telecomm1's service offerings for EnergyCo.

### 5.11.2 Pre-conditions

The different services offered by Telecomm1 should behave as expected according to the KPIs defined in the Table 5.5.1. Only if that is the case, is service delivery acceptable according to the SLA, to meet the different services' requirements (whether mission critical or not.) If the telecommunication service degrades below these KPIs, EnergyCo may experience a service interruption or degradation. This might affect mission critical operations and/or quality of service delivered ultimately to the customer.

The granularity of the use case considers the support of QoS to a particular UE, per class of service. This is the model described in 22.867, clause 5.5. Here the UE is a gateway serving as a router to a network: the UE is essentially a router with a mobile telecommunication interface for communication beyond the local network. Smart energy applications are not generally running on the UE – they are deployed in the network behind the UE. See figure 5.5.3-1.

This use case assumes that the SLA is in place and service is offered by Telecomm1 to EnergyCo. In addition, both interfaces and procedures are in place to respond to failures to deliver KPIs according to the SLA.

NOTE: The use case is based on real experience between utility and telecom providers but the identities of EnergyCo and Telecomm1 are fictitious.

### 5.11.3 Service Flows

For the KPIs, part of SLA definition between EnergyCo and Telecomm1, there is a report sent by EnergyCo to Telecomm1 on a monthly basis in order to inform of the degree of compliance of the requirements set in the SLA for the different KPIs. Telecomm1 will reconcile this report with their own records.

KPIs will be measured by means of EnergyCo owned Network Management platforms in real time. These platforms will check periodically the availability, latency and packet loss rate of the connection. Different periodicities can be configured and as a result average information will be obtained. Reports are available in order to deliver accumulated information of the different parameters on a daily, weekly, monthly or yearly basis.

This information will be checked in order to verify the degree of compliance of the SLA. Connectivity status, stability and Performance will be part the technology reports. Only Latency and Packet loss rate will be constantly measured as a part of Performance parameters, Throughput will only be measured during commissioning process. If there is a problem such as quality of service degradation (high latency and packet loss rate below thresholds) or instability of the connection affecting a specific substation or group of substations (connected to the same server) for more than one week an automatic alarm will be generated towards the MNO.

In the event of massive communication loss affecting most services and substations (quantity above % threshold), this will be detected in real time and an automatic alarm will be sent to the MNO.

In the event of sustained connection loss events affecting a number of Substations located within a well limited geographical area this might shed light on a problem related to a specific eNB site or sector. An automatic alarm will be generated and sent to the MNO.

### 5.11.4 Post-conditions

Since EnergyCo provides Telecomm1 with their report of service degradations, and Telecomm1 provides their report to EnergyCo, both organizations have a full set of records with respect to achieved performance of service according to KPIs in the SLA. It is possible for EnergyCo and Telecomm1 to reconcile the SLA and the achieved performance at any time.

Further, EnergyCo is able to alert Telecomm1 when critical events occur that affect performance in a manner that requires intervention (or at least scrutiny) by the MNO.

Finally, Telecomm1 can alert EnergyCo to issues they have detected.

This explains why regular periodic QoS reporting needs to be shared from the customer to the provider and vice versa.

### 5.11.5 Existing features partly or fully covering the use case functionality

No existing features have been identified that partially or fully cover the use case functionality.

### 5.11.6 Potential New Requirements needed to support the use case

[PR.5.11-001] The 5G system shall provide a mechanism for a 3rd party to report to a MNO service degradations, communications loss and sustained connection loss. These reports use a standard form. The specific values, thresholds and conditions upon which alarms occur could include e.g. the measured values for Latency, Data Rate, Availability, Jitter, etc. for a UE, its location, and the time(s) in which the degradation occurred.

NOTE 1: What the MNO does with such reports is out of scope of 3GPP specifications.

NOTE 2: The above potential requirement expresses the need for reporting by a third party to the 5GS and leaves it to downstream groups (in this case SA5) to work out the implications.

[PR.5.11-002] The 5G system shall provide a mechanism for a MNO to report to 3rd parties service degradations, communications loss and sustained connection loss. These reports use a standard form. The specific values, thresholds and conditions upon which alarms occur could include e.g. the measured values for Latency, Data Rate, Availability, Jitter, etc. for a UE, its location, and the time(s) in which the degradation occurred.

NOTE 3: What the 3rd party does with such reports is out of scope of 3GPP specifications.

NOTE 4: The above potential requirement expresses the need for reporting by the 5GS to a third party and leaves it to downstream groups (in this case SA5) to work out the implications.

## 5.12 Distribution Intelligence – FLISR (Fault Location, Isolation, and Service Restoration)

### 5.12.1 Overview

"Distribution intelligence" refers to the part of the Smart Grid that applies to the distribution system, that is, the wires, switches, and transformers that connect the utility substation to the customers. A key component of distribution intelligence is outage detection and response. Today, many utility companies rely on customer phone calls to know which areas of their distribution system are being affected by a power outage. Along with smart meters, distribution intelligence will help to quickly pinpoint the source of a power outage so that repair team can be immediately dispatched to the problem area. Most utility companies count on complex power distribution schemes and manual switching to keep power flowing to most of their customers, even when power lines are damaged and destroyed. However, this approach has its limitations, and in many cases an automated system could respond more quickly and could keep the power flowing to more customers. By having sensors that can indicate when parts of the distribution system have lost power, and by combining automated switching with an intelligent system that determines how best to respond to an outage, power can be rerouted to most customers in a matter of seconds, or perhaps even milliseconds.

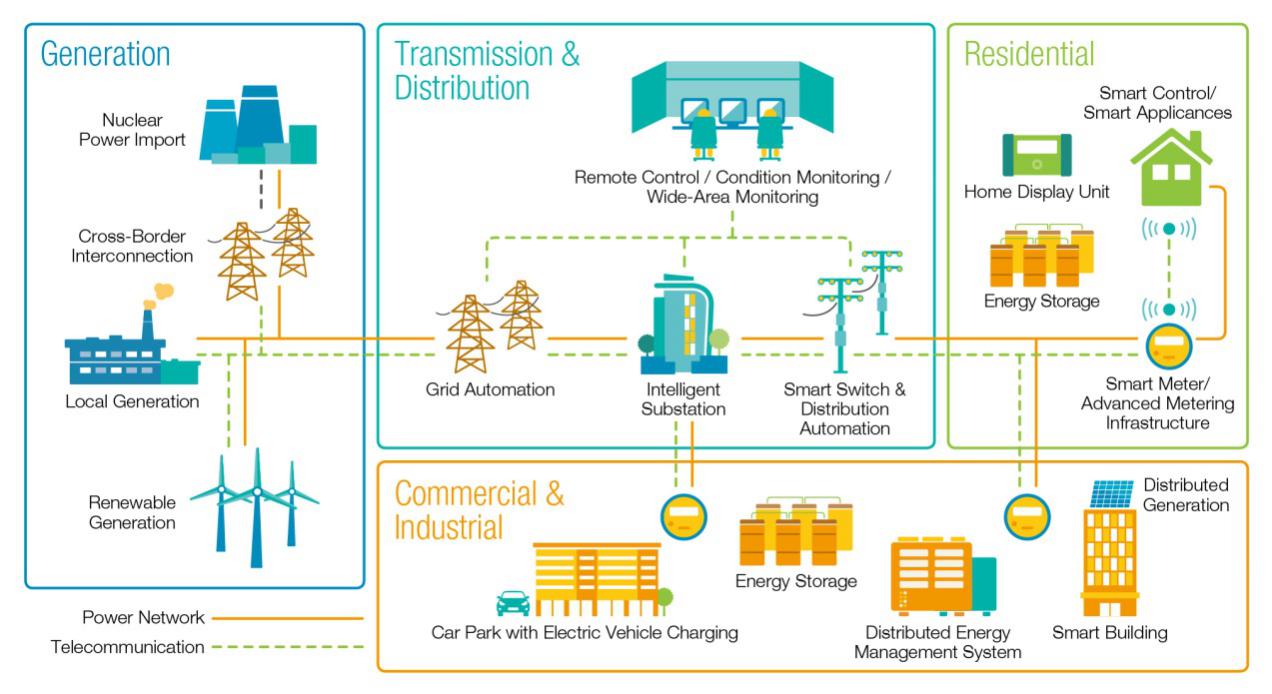


Figure 5.12.1-1: the big picture of Smart Energy

The automation in distribution with self-healing solutions is surely a critical challenge to consider in this transformational evolution towards Smart/Smarter Energy. Self-healing will enable system operators to benefit from a significant reduction in the outage duration and number of affected customers, which reacts quickly and precisely to power disturbances so that only those in the immediate neighbourhood are affected, while avoiding any interruption in power. Self-healing not only acts against grid disturbances, but secures the grid against disturbances spread. The basic requirements include [18]:

- Fast and proper detection of grid disturbances.

- Redistribution of grid resources to avoid adversative impacts.

- Assuring the continuity of service under any conditions.

- Minimization of service restoration time.

Reliable and secure communications are essential to enable self-healing in the Smart Energy. A precise and effective decision is based on analysing the power grid data, hence collecting and exchanging information, transferring results, executing decisions, and monitoring real-time device states in the grid are the responsibility of the communication system. To support fast and precise detection of grid disturbances 5G system is expected to provide communication services with ultra-low latency, ultra-high reliability and availability, as well as high data rate at both uplink and downlink.

Two approaches to detect grid disturbances are discussed:

1) feeder automation

2) line current differential protection

### 5.12.2 Feeder automation

#### 5.12.2.1 Description

Feeder automation is designed to utilise controller devices that are especially designed to support the self-healing of power distribution grids with overhead lines. The self-healing logic resides in individual controller devices located at the poles at the feeder level. Using peer-to-peer communication (e.g. via IEC 61850 GOOSE) among the controller devices, the system operates autonomously without the need of a regional controller or control centre. All self-healing steps carried out are reported immediately to the control centre to keep the grid status up-to-date.



Figure 5.12.2.1-1: Distributed Feeder Automation

#### 5.12.2.2 Pre-condition

The controller devices have been mounted, connected, and configured during commissioning and deployment. The configuration is usually not done via the mobile network but via local wired connection.

The controller devices are connected to the 5G network, and the peer-to-peer communication is enabled using IEC 61850 GOOSE (OSI Layer 2, broadcast/subscription Ethernet-based protocol).

#### 5.12.2.3 Service flow

Communications are enabled via 5G network among the controller devices

- among controller devices serving the same feeder and

- among the controller devices of the whole area and the control centre.

A feeder fault occurs. The controller device in the upstream of the fault point generates and transmits GOOSE signals to other controller devices serving the same feeder. Each controller device compares the GOOSE signals with the overcurrent signals of the current level, identifies the fault range, and then isolates the fault, implementing automatic power recovery in non-fault areas.

To prevent power disturbance, the overall feeder automation process must be completed within 100 ms. As discussed in [x3] with regards to the delay budget, the latency for one way transmission from one controller device to another needs to be kept at approximately 20 ms (this would allow for the necessary margin). To ensure precise fault detection and isolation, 10 μs or less time synchronization accuracy is also required.

Typically there are 10s of controller devices per km2. The geographical dimension of feeders is usually up to several km2.

#### 5.12.2.4 Post-condition

5G communication runs and power distribution is restored in the affected area.

#### 5.12.2.5 Existing features partly or fully covering the use case functionality

The use case "Distributed automated switching for isolation and service restoration" has been captured in TS 22.104 Annex 2.4.4, while the corresponding performance requirements have been specified in table 5.2-1 "Periodic deterministic communication service performance requirements":

Table 5.12.2.5-1: performance requirements applicable to this use case

| Characteristic parameter | | | | Influence quantity | | | | | |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Communica­tion service availability: target value (note 1) | Communication service reliability: mean time between failures | End-to-end latency: maximum (notes 2, 5) | Service bit rate: user experienced data rate (note 5) | Message size [byte] (note 5) | Transfer interval: target value (note 5) | Survival time (note 5) | UE  speed (note 6) | # of UEs | Service area  (note 3) | Remarks |
| 99.9999 % | – | < 5 ms | 1 kbit/s (steady state) 1.5 Mbit/s (fault case) | < 1500 | < 60 s  (steady state) ≥ 1 ms (fault case) | transfer interval | stationary | 20 | 30 km x 20 km | Electrical Distribution – Dis­tributed automated switch­ing for isolation and service restoration (A.4.4); (note 4) |
| NOTE 1: One or more retransmissions of network layer packets may take place in order to satisfy the communication service availability requirement.  NOTE 2: Unless otherwise specified, all communication includes 1 wireless link (UE to network node or network node to UE) rather than two wireless links (UE to UE).  NOTE 3: Length x width (x height).  NOTE 4: Communication includes two wireless links (UE to UE).  NOTE 5: It applies to both UL and DL unless stated otherwise.  NOTE 6: It applies to both linear movement and rotation unless stated otherwise. | | | | | | | | | | |

The gaps identified include:

- < 5ms end-to-end latency has been captured with no explanation in TS 22.104 (neither in TR 22.804);

- time synchronicity requirement is not addressed;

- fault detection and isolation is typically event driven and aperiodic communication may be sufficient.

#### 5.12.2.6 Potential New Requirements needed to support the use case

[PR.5.12.2-001] The 5G system shall be able to provide a periodic deterministic communication with the service performance requirements reported in the tables below.

Table 5.12.2.6-1: service performance requirements for Feeder automation

| Communication service availability | Max Allowed End-to-end latency (note 1) | Message size [byte] | UE speed | # of UEs | Service Area |
| --- | --- | --- | --- | --- | --- |
| > 99.999 % | 20 ms | < 100 | Stationary | ≤ 100/km2 | several km2 |
| NOTE 1: UE to UE communication. | | | | | |

Table 5.12.2.6-2: service performance requirements for Feeder automation continued

|  |  |  |
| --- | --- | --- |
| Number of devices in one Communication group for clock synchronisation | 5GS synchronicity budget requirement | Service area |
| ≤ 100/km2 | ≤ 10 μs | several km2 |

### 5.12.3 High speed current differential protection

#### 5.12.3.1 Description

The high speed current differential protection for smart energy distribution systems is capable of sub-millisecond fault detection. The approach utilises the natural characteristics of differential current measurements to significantly reduce fault detection times, which has been described in detail in clause 5.4. This use case focuses on the traffic characteristics.

#### 5.12.3.2 Pre-condition

Protection relays (e.g. relay\_a and relay\_b in Figure 5.4.1-1) are deployed and switched on in the distribution grid. All relays are connected to the 5G network and are synchronised with neighbouring relays in the distribution grid with a precision of <10 µs to ensure that the current values are sampled at the same time.

#### 5.12.3.3 Service flow

The protection relays exchanges the current samples via the 5G system. Each relay then compares the sent and received samples to determine if a fault has occurred in a protected area in order to isolate the fault. The detail of fault detection can be found in clause 5.4.

The sampling rate varies dependent on the algorithms designed by the manufacturers. A protection relay collects the current samples (with the typical message size of up to 245 bytes) at a frequency in the range of [600, 1200, 1600, 3000] Hz. The exchange of measurement samples is done in a strictly cyclic and deterministic manner. [6] [20] With the sampling rate of 600 Hz (6 times per 10 ms), the transfer interval would be 1,667 ms with the required bandwidth of 1.18 Mbit/s; for 1200 Hz (12 times per 10 ms), the transfer interval would be 0,833 ms with the required bandwidth of 2.36 Mbit/s.

As to the latency, as pointed out in clause 5.4 the maximum allowed end-to-end delay between two protection relays would be between 5ms and 10ms depending on the voltage levels as specified in IEC 61850-90-1 [6]. For some legacy systems the latency usually is set to 15ms [20].

#### 5.12.3.4 Post-condition

5G communication runs and power distribution is restored in the affected area.

#### 5.12.3.5 Existing features partly or fully covering the use case functionality

The use case "Application of differential protection in distribution Network of Smart Grid" has been captured in TR 22.804. However the use case and the associated service requirements are missing in TS 22.104.

The missing requirements based on differential protection in distribution network need to be captured.

#### 5.12.3.6 Potential New Requirements needed to support the use case

[PR.5.12.3-001] The 5G system shall be able to provide periodic deterministic communication with the service performance requirements reported in the tables below.

Table 5.12.3.6-1: performance requirement for High speed current differential protection

| Communication service availability | End-to-end latency: maximum  (note 1) | Service bitrate: user experienced data rate | Message size [byte] | Transfer interval: target value | Survival time | UE speed | # of UEs | Service area |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| > 99.999 % | 15 ms | 2.5 Mbit/s | < 245 | ≤ 1 ms | transfer interval (one frame loss) | stationary | ≤ 100/km2 | several km2 |
| > 99.999 % | 15 ms | 1.2 Mbit/s | < 245 | ≤ 2 ms | transfer interval (one frame loss) | stationary | ≤ 100/km2 | several km2 |
| > 99.999 % | 10 ms | 2.5 Mbit/s | < 245 | ≤ 1 ms | transfer interval (one frame loss) | stationary | ≤ 100/km2 | several km2 |
| > 99.999 % | 10 ms | 1.2 Mbit/s | < 245 | ≤ 2 ms | transfer interval (one frame loss) | stationary | ≤ 100/km2 | several km2 |
| > 99.999 % | 5 ms | 2.5 Mbit/s | < 245 | ≤ 1 ms | transfer interval (one frame loss) | stationary | ≤ 100/km2 | several km2 |
| > 99.999 % | 5 ms | 1.2 Mbit/s | < 245 | ≤ 2 ms | transfer interval (one frame loss) | stationary | ≤ 100/km2 | several km2 |
| NOTE 1: UE to UE communication. | | | | | | | | |

Table 5.12.3.6-2:

|  |  |  |
| --- | --- | --- |
| Number of devices in one Communication group for clock synchronisation | 5GS synchronicity budget requirement | Service area |
| ≤ 100/km2 | ≤ 10 μs | several km2 |

## 5.13 Use case of 5GS support for synchrophasors in wide-area Smart Grid

### 5.13.1 Description

Using phasors as a mathematical approach to describe a power system operation quantities is not new. With the advent of GNSS and other time sources that provide phasor measurement units (PMUs) with accurate timing signals, the concept of synchrophasor came into existence [21]. Modern PMUs and accompanying entities such as Phasor Data Concentrators (PDCs) [22] could connect to the time source and with each other in a number of different ways such as: using direct connection with GPS via an internal GPS receiver, using a connection via IRIG-B (legacy method) or IEEE Std 1588-2008 [23]/IEEE C37.238-2011[24] or PTP time synchronization profile in IEC 61850-9-3 [7] , over an Ethernet to achieve 1 μs time accuracy. This 1 μs time accuracy as referred to in these IEC standards assumes every PMU is has a built-in synchronization modem.

As a result, the phasors throughout a wide-area power system can be measured at different but strategically selected locations (such as at tie-lines and on the key network buses) in a synchronized fashion. This powerful possibility releases huge potential for power utility operators to innovate, so as to achieve various goals in safe, robust and efficient network operation and maintenance. Some interesting applications based on synchrophasors are: power system model validation, wide-area protection, advanced state estimation, frequency-control and oscillation mitigation, etc. With the fast adoption of DERs, the power system will undergo challenges of increased variability and unpredictability, which means the synchrophasors could offer utility operators an effective means to understand, respond and predict the real-time dynamics of the power systems.

Up till now, wide-area measurement systems based on synchrophasors have been under expansion in large scale throughout America, Europe, and Asia. It is an area of opportunity for 5G systems to provide connectivity and services. Thanks for the wide-area coverage of 5G, it is seen by many utilities that 5G could play a major role in supporting PMU wide-area applications paradigm.

Synchrophasors are measured and collected in a hierarchical structure to meet the power system needs. The figure below comes from [25]. But it is important to know that PDCs can have one to many interconnections with each other for the sake of e.g. redundancy. There could be many internal and external functions defined at each PDC, and PDCs could eventually interface with SCADA, EMS and DMS, where applicable. As defined in [25], a PMU and a PDC may transmit its data in one or more separate data streams. Each stream may have different content and may be sent at a different rate. The destination of each stream may be different device(s) and location(s) (multicast data is sent to multiple destinations). Each stream must then be individually controllable, and have its own identification and a separate configuration control. This feature is useful for sending data to different devices with different purposes, allowing streams with different wait times and class of service (M and P class), as specified in [22].

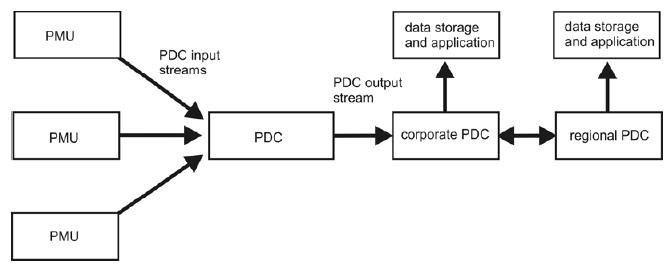


Figure 5.13.1.1: Synchrophasor data collection network [X6]

Within the synchrophasor system, PMUs can be configured with various reporting rates [25]. In a 60Hz system, reporting rates could be {12, 15, 20, 3, 60} per second, and in a 50Hz system, the reporting rates could be {25, 50} per second. It is encouraged to adopt higher rates up to 120 per second. Table 1 shows the corresponding reporting period 1/Fs.

Table 5.13.1-1: PMU reporting rate and the corresponding Reporting Period in IEEE Std C37.118™-2011 [25]

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Reporting Rate (Fs)**  **in Hz** | 12 | 15 | 20 | 25 | 30 | 50 | 60 | 100 | 120 |
| **Reporting Period (1/Fs)**  **in ms** | 83.3 | 66.67 | 50 | 40 | 33.3 | 20 | 16.67 | 10 | 8.3 |

With regard to the data flows, each synchrophasor data flow could have an individual QoS – the performance aspects are addressed in [27]. In [28], the real-time communication between PMUs is addressed, and there two performance classes (P and M) are specified with the corresponding dynamic performance requirements. The P class is mainly for protection and control purposes, which requires fast response, minimum filtering and minimum delay. The M class is mainly used for measurements in the presence of out-of-band signals, which requires greater precision and significant filtering, and allows slower response and longer delay. Intuitively, the higher the PDC in the hierarchy (as in Figure 1), the more prone to class M an application deployed there seems to be.

The measurement reporting latency compliance specification defines the PMU real-time output reporting latency is dependent on the corresponding reporting rate Fs. For both performance classes, the measurement reporting latency is defined in Table 2 [25].

Table 5.13.1-2: PMU measurement reporting latency

|  |  |
| --- | --- |
| **Performance Class** | **Max Measurement Reporting Latency** |
| P Class | 2/Fs |
| M Class | 5/Fs |

The communication end-to-end latency shall be the reporting latency subtracted from the reporting period. Therefore for different reporting rate, the communication latency is shown in Table 3.

Table 5.13.1-3: max End-to-end communication latency (ms) at different PMU reporting rate

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 12 | 15 | 20 | 25 | 30 | 50 | 60 | 100 | 120 |
| P Class | 83.3 | 66.67 | 50 | 40 | 33.3 | 20 | 16.67 | 10 | 8.3 |
| M Class | 333.3 | 266.67 | 200 | 160 | 133.3 | 80 | 66.67 | 40 | 33.3 |

### 5.13.2 Pre-conditions

Throughout the wide-area power system, according to the smart-grid application architecture, PMUs and PDCs are deployed at selected locations. A 5G UE is integrated into a PMU or a PDC. They are switched on. According to specified reporting rate, the synchrophasor data is collected, aggregated and made available to the applications accordingly.

### 5.13.3 Service Flows

1. In general, a PMU in a wired network can operate in unicast mode and multicast mode. The communication between PMU and its peers in wired networks is usually multicast in spontaneous mode [28] of operation.   
   Thus, while the use case is based on multicast in existing, wired networks, in this use case, we consider 5G technology to be capable of resembling the connectivity needs for the aforementioned spontaneous mode of PMU in a resource efficient way that might not always be multicast but could also be unicast.
2. PMUs are configured to operate in spontaneous mode to provide the measurement data to PDCs. According to U's deployment choice, a PDC can make use of data from multiple PMUs and/or from other PDCs.
3. In the grid, some busses may have priority over others, therefore data produced by PMUs deployed at different busses can have different priority too.
4. For a PMU deployed at a given bus in the grid, different types of data are generated to feed different applications of divergent criticality (such as monitoring, control, protection, state estimation, etc.). Also, the same data can be needed by different destinations requiring different QoS treatment. Because of that, these different streams of data is needed by different destinations with different QoS. Additionally, the algorithms a TSO or DSO decides to use further influences the difference in criticality (QoS requirements in other words) of various streams of data this PMU generates.
5. At company U, the automation engineer Antoine is installing PMUs in U's distribution networks according to the PMU-based WAN application design. For each PMU, he configures the data types, calibration factors, and other meta-data for the data that the PMU will send. Antoine also configures the PMU to transmit multiple data streams, each with different content, rate, format, priority. Each data stream shall have its own IDCODE so that the data, configuration, header, and command messages can be appropriately identified. Each stream shall be independently operable including command execution and data, header, and configuration messages.
6. PMUs transmits measurement according to the configured reporting period. Multiple data streams generated by the same PMU are transmitted by the 5G network with different QoS treatment as Antoine has configured on the PMU.
7. PDCs received the synchrophasors, performs configured local processing functions, forwards data further down the hierarchy.
8. Advanced logics in the applications receive the synchrophasors as prescribed, the designed logics such as control, protection and measurement are carried out as expected.

### 5.13.4 Post-conditions

Applications can execute designed logic to perform protection, control and monitor actions per design.

### 5.13.5 Existing features partly or fully covering the use case functionality

1. In TR 22.804, a similar PMU study proposes 10ms end-to-end communication latency.

2. In TS 22.104, for PMUs synchronization, 1 μ𝑠 is specified as 5GS synchronicity budget requirement in a service area < 20 km2.

3. Support of IEEE 1588 PTP is an existing feature. Additional traffic from running IEEE 1588 PTP is around 0.004 Mbit/s.

4. In TS 22.261, 5G system shall support operation of downlink only broadcast/multicast over a specific geographic area (e.g. a cell sector, a cell or a group of cells).

5. In TS 22.261, the 5G system shall support downlink parallel transfer of the same content, via broadcast/multicast and/or unicast, such that all receiver group members in a given area receive the media at the same time according to user perception.

6. In TS 22.261, the 5G system shall be able to apply QoS, priority and pre-emption to a broadcast/multicast service area.

7. In TS 22.261, The 5G network shall support parallel transfer of multiple quality levels (i.e. video resolutions) of broadcast/multicast content for the same user service to the same UE taking into account e.g. UE capability, radio characteristics, application information.

8. In TS 22.261, the Ethernet transport service shall support routing based on information extracted from Virtual LAN (VLAN) ID by the 3GPP system.

9. 5G system can provide 5ms with existing 5QI to support the 8.33ms latency as required by the class P PMU with highest reporting rate 120Hz.

10. In TS 22.261, the 5G system shall support on-demand establishment of unicast, multicast, and broadcast private communication between members UEs of the same 5G LAN-VN. Multiple types of data communication shall be supported, at least IP and Ethernet.

11. In TS 22.261, the 5G network shall enable member UEs of a 5G LAN-VN to use multicast/broadcast over a 5G LAN-type service to communicate with required latency (e.g. 180ms).

12. In TS 22.263 (VIAPA), Table 6.3.1-1 includes Note 4 that mentions the UL stream originating from a UE may be the source of a DL multicast stream.

### 5.13.6 Potential New Requirements needed to support the use case

[PR.5.13-001] 5G System should support the IEC 61850-9-3 [7] profile and IEEE Std C37.238-2017 [24].

[PR 5.13-002] 5G system should support at least one of the two profiles for synchrophasor communications: IEC 61850-90-5:2012 [26], or IEEE Std C37.118.2-2011 [28].

[PR.5.13-003] The 5G system should support the IEEE 802.1Q as the QoS profile, as defined in IEC 61850-90-5 [26].

[PR.5.13-004] The 5G system shall support delivery of the same UE originated data in a resource-efficient manner in terms of bandwidth to UEs distributed over a large geographical area.

[PR.5.13-005] The 5G system shall allow a UE to request a communication service to send data to different groups of UEs at the same time.

[PR.5.13-006] The 5G system shall allow a UE to request different QoS for the communication in each of those groups.

## 5.14 Energy Substation Surveillance

### 5.14.1 Description

The use case concerns the use of surveillance cameras in sensitive locations and the implications on telecommunications where that serves as the means by which the surveillance media data is collected in a remote location.

Closed-circuit video (CCTV) is the most bandwidth-intensive of all utility applications. The data rates depend on the required resolution of images, number of colors and frame rate. There are existing standards that reduce this data rate considerably while still providing excellent video quality. During incidents (such as security breaches, equipment malfunctions and power outages,) a higher resolution can be used.

Many utility substations today use fiber optic cables to provide sufficient communications capacity to transport surveillance media data. This use case explores the use of 5G instead either as the sole means for transporting surveillance media data, or as a backup in case the primary means of transport (fiber) has been compromised. This could occur inadvertently if the fixed communication network suffers damage, or intentionally as part of a coordinated local attack that compromises substation security.

While it is often necessary and prudent to transport surveillance media data continuously, there are approaches that reduce this need, e.g. triggers based on motion detectors, tampering (e.g. with cameras, locks, etc.), heat sensors, etc. In addition, video analytics can identify suspicious changes in a field of view within the secure permission, such as people present when they are unexpected, or people present at places within the secure perimeter for too long, etc. In this case, video could be stored locally and only transmitted on demand, or when triggered by an event. The design of a secure facility is beyond the scope of this use case. In any case, there are times in which transport of all surveillance data is needed – so the capacity model is based on this situation. This capacity may only be needed intermittently, for the reasons given above, or it may be required constantly.

Some regulations however, e.g. NERC CIP in North America, require continuous live video transport from cameras monitoring the substation's Electronic Security Perimeter.

Further, given the use of fiber optic cables, the networks are vastly over-provisioned. For this reason, even where regulation does not require constant video media transport for perimeter security, there is a tendency to transport all surveillance media, at all times.

The most common video codecs used are MPEG-2, MPEG-4 and more recently, the Motion-Joint Photographic Expert Group (M-JPEG). The frame rate commonly used is 25-30 video frames per second. The resolutions often used, per the Common Interchange Format (CIF), are QCIF (176x120), CIF (352x240), 2CIF (704x240), and 4CIF (704x480). [16] This reference is 7 years out of date, though, and the current rate used by some energy utilities is now HDTV (1280x720) resolution.

For the purposes of this use case HDTV with continual media transport will be considered as the service requirement, as this is most realistic looking forward in time. 1280x720 \* 8 bit resolution \* 30 frames per second = 2.4 (10)7 bits per second (uncompressed.) For H.264 compression (MPEG-4), this can be transported with 3 Mbit/s.

### 5.14.2 Pre-conditions

The substation has the capacity to generate surveillance data. The utility operator "U" needs for this data to be sent from the substation to a central operation center reliably, so they arrange services with a telecommunications service provider "T" for this purpose.

Surveillance cameras use mechanisms for mechanical panning, zooming and tilting (PZT) so they do not need to be more than high definition (HD).

### 5.14.3 Service Flows

There are two potential service flows.

a) Continuously transport surveillance media from the substation site to a central operation center.

b) When triggered due to local conditions or remote control, transport surveillance media from the substation site to a central operations center.

### 5.14.4 Post-conditions

The substation security has some assurance, as the substation surveillance media data that is generated on the site can be transported reliably to a central operations center.

### 5.14.5 Existing features partly or fully covering the use case functionality

The video rates described below can be supported by 5G. In fact, 4G suffices as a 'backup' mechanism to carry surveillance video data in some existing substations today.

Table 5.14.5-1: Transport of Surveillance HDTV KPI Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scenario** | **User experienced data rate**  **(Mbit/s per camera)** | **Latency(ms)** | **Reliability**  **%** | **Connection density** | **Coverage (km)** |
| Surveillance HD camera media | 3 (up 5 if a lot is going on) | (note 1) | (note 1) | ~12/sub-station | >=30km (city range) |
| NOTE 1: Media transport typically uses a streaming protocol that allows for buffering of media in the event of changes of latency (jitter) or intermittent failure. This may result in transient interruptions of the video stream but does not result in loss of media. For this reason, no KPI target is given for these metrics. | | | | | |

### 5.14.6 Potential New Requirements needed to support the use case

This use case is included for completeness but no new requirements have been identified.

## 5.15 Distributed Energy Resources and Microgrids

### 5.15.1 Description

Distributed energy resources (DER) become more and more important because of its close proximity to the user side and the convenience of complementary energy forms. The potentially large number of DERs have a direct impact on the operation and power trading of the power system, affecting the security, stability and operation efficiency of the system. The concept of microgrid was introduced to aggregate and optimise DER thus reduce the negative impact on power grids. As defined in [31], a microgrid is a self-sufficient energy system that serves a discrete geographic footprint, such as a university campus, a hospital complex, a business centre, or a residential area. Within microgrids there are one or more kinds of distributed energy (solar panels, wind turbines, combined heat & power, generators) that produce its power. In addition, many newer microgrids contain energy storage, typically from batteries. Some also now have electric vehicle charging stations.

The integration of DERs into the energy system cause many challenges into the communication field. The operational conditions of a microgrid may vary rapidly due to DER contribution with low inertia of nonrotating elements and rapid changes in weather conditions (wind and solar radiation) [32]. To incorporate more renewable and alternative energy sources, the communication infrastructure must have the ability to easily handle an increasing amount of data traffic or service requests and must provide a real‐time monitoring and control operation of all these nodes. A reliable communication between the system elements is crucial. In fact, any type of communication dependent electrical protection scheme requires robustness, a virtually full-time availability, and strictly bounded latency.

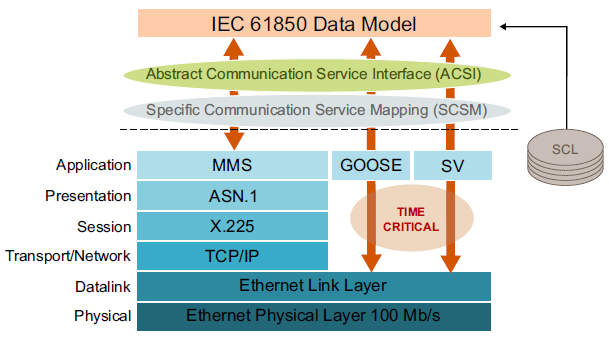


Figure 5.15.1-1: IEC 61850 communication stack

When it comes to communications architecture, IEC61850 is a widely accepted standard for automation and equipment of power utilities and DER, specifically for defining protocols for IEDs (Intelligent electronic devices) at electrical substations. IEC 61850 standard specifies the timing constraints for messages typically used in substations (table 5.15.1-1). GOOSE (Generic Object Oriented Substation Events) and SV (Sampled Values) messages are assumed as time critical messages, having the tightest deadlines (maximum allowed transfer time) among all IEC 61850 messages, corresponding to 3 ms. While GOOSE is typically used to transfer information closely related to monitoring and control functions (circuit breaker status etc.), SV is used to transfer numerical samples of current and voltage signals. The SV protocol works on a periodic information transmission model, regularly sending messages at a fixed rate. For protection purposes, the default rate is 4000 or 4800 messages per second for, respectively, 50 or 60 Hz power systems. On the other hand, the GOOSE protocol operates in a sporadic information transmission model, where a continuous flow of data is maintained to increase communication reliability. The typical sizes of GOOSE and SV messages are, respectively, 160 and 140 bytes. GOOSE messages are transmitted at two different modes: 1) Safe operation: 1 message / second (with the bitrate of 1.28 kbit/s); 2) Emergency operation: 32 message / second (with the bitrate of 40.96 kbit/s). SV messages are transmitted at much high rate 4800 message / second (with the bitrate of 5.376 Mbit/s).

Table 5.15.1-1: Time constraints for IEC 61850 messages [33]

|  |  |  |
| --- | --- | --- |
| **Message Type** | **Example Application** | **Time Constraint** |
| 1A—Fast messages**,** trip | Circuit breaker commands and states (GOOSE) | ≤3 ms |
| 1B—Fast messages**,** other | The same as above | ≤20 ms |
| 2—Medium speed messages | RMS values calculated from type 4 messages | ≤100 ms |
| 3—Low speed messages | Alarms, non-electrical measurements, configurations | ≤500 ms |
| 4—Raw data messages | Digital representation of electrical measurement (SV) | ≤3 ms |
| 5—File transfer functions | Files of data for recording settings | ≤1000 ms |
| 6—Time synchronization messages | IED internal clock synchronization | none |

In addition, the increasing number of renewable energy sources and micro-generators as well as the integration of a large amount of DER units in the microgrid has an impact on the scalability and the stability of the communication system. A certain level of redundancy is required in the system, e.g., backup channels, software components and devices, etc. Critical functionalities in a smart microgrid demand high reliability (99.999%) and stringent availability requirement (99.9999%).

The integration of networking and communication technologies in microgrids may cause vulnerabilities of cyber-attacks. In addition, due to the increasing number of distributed energy resources in the grid, the attack targets are also rising, producing more access points to disrupt the grid. Thus, a microgrid needs to be robust against security attacks. Table 5.15.1-2 summarizes the [34].

Table 5.15.1-2: general security requirements for different communication services [34]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Security requirements** | **Communication services** | | | | | **Security protocols** | | |
| **MMS** | **GOOSE** | **SVs** | **E2E PTP** | **P2P PTP** | **TLS** | **IPsec** | **MACsec** |
| Source authentication | MUST | MUST | MUST | MUST | - | x | x | - |
| Group authentication | - | - | - | MUST | MUST | - | - | x |
| Hop-by-hop integrity | - | MAY | MAY | MUST | MUST | - | - | x |
| End-to-end integrity | MUST | MUST | MUST | MUST | - | x | x | - |
| Confidentiality | MUST | - | - | - | - | x | x | x |
| Unicast key management | MUST | - | - | SHOULD | - | x | x | - |
| Multicast key management | - | MUST | MUST | SHOULD | SHOULD | - | - | x |

### 5.15.2 Pre-condition

The central controller(s) and IEDs have been mounted, connected, and configured during commissioning and deployment.

All devices are connected to the 5G network, and the communication is enabled using IEC 61850 standards.

### 5.15.3 Service flow

Communications are enabled via 5G network among the controller devices and IEDs.

SV messages are used to transfer numerical samples of current and voltage signals from Current/Voltage Transformers (CTs/VTs) to IEDs. The SV protocol works on a periodic information transmission model, regularly sending messages at a fixed rate. For protection purposes, the default rate is 4000 or 4800 messages per second for, respectively, 50 or 60 Hz power systems.

GOOSE is typically used to transfer information closely related to monitoring and control functions (circuit breaker status etc.), and GOOSE messages generally transmit binary data such as indications, alarms and tripping signals. For instance, a protection function issuing a trip command requires transfer times below 3 ms and hence, information is directly mapped into a GOOSE message. The GOOSE protocol operates in a sporadic information transmission model, where each message in a GOOSE transmission sequence has an attribute called Time allowed To Live (TTL) that informs the receiver about the maximum time to wait for the next transmission.

For such time critical applications, data is directly mapped to the Ethernet data link layer as GOOSE messages or SVs transmission using connectionless multicast addressing of frames.

### 5.15.4 Post-condition

5G communication runs and the "health" of the microgrid is maintained.

### 5.15.5 Existing features partly or fully covering the use case functionality

There is no specific description of the described use case in the existing SA1 TR/TS, and the KPI requirements are not captured yet. The use case "Distributed automated switching for isolation and service restoration" has been captured in TS 22.104 Annex 2.4.4, while the corresponding performance requirements have been specified in table 5.2-1 "Periodic deterministic communication service performance requirements":

As to the security requirements, there are existing requirements in TS 22.261 clause 8.9 "Data security and privacy":

The 5G system shall support data integrity protection and confidentiality methods that serve URLLC, high data rates and energy constrained devices.

The 5G system shall support a mechanism to verify the integrity of a message as well as the authenticity of the sender of the message.

The 5G system shall support encryption for URLLC services within the requested end-to-end latency.

### 5.15.6 Potential New Requirements needed to support the use case

[PR.5.15-001] The 5G system shall be able to provide periodic deterministic communication with the service performance requirements reported in the tables below.

Table 5.15.6-1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristic parameter | | | | Influence quantity | | | | Remarks |
| Communica­tion service availability: target value | Communication service reliability: mean time between failures | End-to-end latency: maximum | Service bit rate: user experienced data rate | Message size [byte] | Transfer interval: target value | Survival time | UE  speed |  |
| 99.9999 % | – | < 3 ms | 4.5 Mbit/s | 140 | ≤ 1 ms | transfer interval | stationary | 50Hz power system |
| 99.9999 % | – | < 3 ms | 5.4 Mbit/s | 140 | ≤ 1 ms | transfer interval | stationary | 60Hz power system |
| NOTE: UE to UE communication is assumed. | | | | | | | | |

[PR 5.15-002] The 5G system shall be able to provide a periodic deterministic communication with the service performance requirements reported in the tables below.

Table 5.15.6-2

| Communication service availability | Max Allowed End-to-end latency | Message size [byte] | UE speed | # of UEs | Service Area |
| --- | --- | --- | --- | --- | --- |
| > 99.9999 % | < 3 ms | 160 | Stationary | - | - |
| NOTE: UE to UE communication is assumed. | | | | | |

## 5.16 Protection of DER and grid interconnection

### 5.16.1 Description

Distributed Energy Resources (DER) and microgrid are typical ways to use renewables (e.g. wind, photovoltaic parks, etc.). They are fundamental elements of energy transition that form the pathway toward the global energy transformation to combat the global warming and the climate change. Take European Union as an example, the policy frameworks of EU 2020 Climate & Energy Package (COM/2010/0639), EU 2030 Climate & Energy Framework (COM/2014) and EU 2050 Climate-Neutral Economy (COM/2011/0885) have duly produced EU Climate Laws, EU Emission Trading Systems (ETS) and union strategy to stimulate the transformation. European member states interact with the European Commission to set up integrated National Energy and Climate Plans (NECPs). In many European countries, ENTSO-E grid code (RfG, DCC, HVDC) compliance guidelines for electricity transition framework are applied by energy and utility players with diverse focuses on the energy markets, system operation, and electricity connections.

Worldwide, for similar reasons, the renewable market is flourishing, as government and private sectors willingly encourage its adoption. With more DERs and microgrids maturing to participate in utility grid, their impact on the distribution networks need to be properly addressed. This contribution discusses the interconnection between renewables and the utility distribution network, and proposes the corresponding communication service requirements for protection mechanisms specifically.

Shown in Figure 5.16.1-1 is the ecosystem with existing DSOs and potential new stakeholders such as DER owners, DER operators, and/or DER aggregators. The focus of this paper is the interface for energy transport shown in red dashed lines. This interface includes both power interface (green line) and communication interface (blue line).

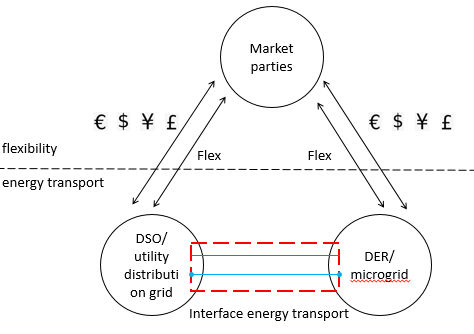


Figure 5.16.1-1: New ecosystem and the positioning of interfaces

The "interface energy transport" shown in Figure 5.16.1-1 could be embodied with a single Point of Common Coupling (PCC) illustrated in in Figure 5.16.1-2, where the power grid could be a medium voltage (MV) substation, and the microgrid could be controlled by its own micro-Energy Management System (µEMS). µEMS communicates with the Distribution Management System (DMS) of a DSO. It is worth mentioning that when the microgrid in Figure 5.16.1-2 is replaced with a single DER, the interconnection with the utility power grid can be more precisely called the Point of Connection (PoC).

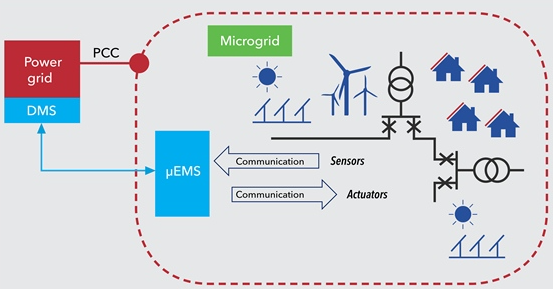


Figure 5.16.1-2: Microgrid controlled by its own EMS (Source: DNV GL). A microgrid is a group of interconnected loads and distributed energy resources with defined electrical boundaries that acts as a single controllable entity and is able to operate in both grid-connected and islanded mode [44]

From the electrical system's safety and operation resiliency point of view, renewables are not just plugged in to feed the utility grid energy. Because of renewable generation's unpredictability (generation with increased variability), connecting DER or microgrid into the public distribution network need to fulfil a number of standards and requirements – to consider the fluctuating capacity flowing into the grid, more bidirectional flows at distribution level, issues like generator synchronization, and operation threshold conditions for voltage and frequency (i.e. under-/over-voltage, under-/over-frequency). Aside from possibly being used for power flow management (e.g. downward dispatch/curtailment trigger, etc.), PCC is also a control reference point for two power systems to interact, including the control of voltage magnitude and frequency regulation, injection and absorption of reactive power by DER, etc. Based on abnormal operation conditions, many regional and international standards have produced guidelines for measurements and specified conditions for triggering protection [42] at the PCC interconnection. In this paper, the focus is on voltage and frequency protection. Tripping in this context is the action to clear abnormal conditions within a specific duration of time. Table 5.16.1-1 lists the required trip time values for different types of possible trips at PCC, based on a number of regional and international standards.

Table 5.16.1-1 Tripping time under certain abnormal conditions (s). The interconnection protection requirements vary among standards

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Under Voltage Threshold 2 | Under Voltage Threshold 1 | Over Voltage Threshold 2 | Under Frequency Threshold 2 |
| IEEE 1547 Cat I [37] | 0.16 | 2 | 0.16 | 0.16 |
| IEEE 1547 Cat II [37] | 0.16 | 10 | 0.16 | 0.16 |
| IEEE 1547 Cat III [37] | 2 | 21 | 0.16 | 0.16 |
| IEC 63547 [39] | 0.16 | 2 | 0.16 | n.a. |
| EN 50438 [36] | n.a | 1.5 | n.a. | n.a |
| IEEE 929 [44] | 0.1 | 2 | 0.03 | n.a |
| BDEW [42] | 0.3 | 1.5 – 2.4 | n.a | n.a |

It does not take much effort to notice that here the tripping time values for DERs are much more relaxed than those for a regular MV/HV substation. That is because for the PCC interconnect, protection functions are required to coordinate with other functions such as frequency ride-through and even ROCOF ride-through, meaning DERs are required to stay "on" for much longer. Furthermore, two thresholds are introduced for DER tripping to prevent it from happening prematurely, which would compromise the stability of the bulk power system.

There are many available algorithms available for an IED to detect abnormal conditions and to further determine whether the tripping conditions are met. More algorithms are based on continuous measurements and comparison of local and remote measurement provided by PMUs. With renewables and DERs proliferating in the distribution networks, decisions on PCCs would need real-time measurements from multiple strategically chosen measurement points in the network.

Purely based on the values in Table 5.16.1-1, it could be true that a PV-owner might opt for CS104 (or even OPC-DA, Profinet) that is simpler and cheaper to deploy. But these protocols are less flexible to support PMU multicast mode. That is where IEC 61850 adds value to the WAN protection mechanisms. In this case, multicast PMU data could be transferred via routable sampled values (R-SV) profile (IEC 61850-90-5). Similarly, the tripping command could be sent out by routable GOOSE (R-GOOSE) profile, or even as normal GOOSE provided the IED with protection functions and the circuit breaker for PCC are in the same LAN. When PMU data is multicast using R-SV profile, the transport should support source-specific advanced route path determination. This mechanism helps to mitigate the DDOS attacks known to multicast group addresses.

### 5.16.2 Pre-condition

A number of wind and PV-parks are connected to the medium voltage substations of a utility DSO. Interfaces including PCCs are established between these systems. P class PMUs are installed at selected busses containing a load. PMUs and IEDs with control and protection functions are connected to the 5G network. The DSO also has a centralized Wide Area Monitoring Protection Automation Control (WAMPAC) application in the control centre. Depending on the control and protection functions, PMUs and WAMPAC can subscribe to different data such as synchrophasor, frequency, frequency and the rate of change of frequency (ROCOF) generated from a specific source PMU. The communication is supported by IEC 61850-90-5 standards.

### 5.16.3 Service flow

Company U operates a large national grid. Thanks to U's existing IP/MPLS infrastructure, PMUs deployed in substations belonging to transmission grid are connected to this IP/MPLS network. The number of PMUs can range from a few hundred to tens of thousands. Each individual PMU continually streams measurement data to a number of PDCs located in control centers at different levels for monitoring and analysis performed by different teams (or analysis by IEDs – Intelligence Electronic Devices with e.g. protection functions). The network engineer Arjen configures in each IP/MPLS router, so that a dedicated VPN is used for transmitting R-SV (routed-Sampled Values) datagrams (Sampled Values can be generated by MU-Merging Unit, but here PMUs are able to generate Sampled Values too). Then, Arjen assigns IP addresses to PMUs from the IP/MPLS network. Due to the high number of PMUs, Arjen configures the IP/MPLS network to efficiently transfer the PMU data to destination PDCs. In the meantime, to improve security, Arjen uses the source specific multicast (SSM) feature to ensure the IP/MPLS network only forwards datagrams to receiving PDCs from only the source PMUs to which the receiving PDCs have explicitly joined. The multicast trees are static once the PMU application is up and running. Worth mentioning is that for each PMU, its corresponding multicast tree is built based on the WAN Smart Grid protection application logics. In other words, the multicast tree reflects where in the Smart Grid the R-SV measurement data from a particular PMU is needed.

With the renewables booming, the distribution grid of company U is connected to an increasing amount of PV parks and wind parks. At and around the interconnections, gradually more new PMUs are deployed. It is impractical to extend the IP/MPLS network physically to all these locations. Therefore, company U decides to make use of the 5G service from an operator KTT.

Now, for U's DERs and microgrids, Arjen again refers to the WAN Smart Grid protection application logics to configure the newly installed PMUs. The purpose is that these PMUs will virtually take part in the existing multicast trees in U's IP/MPLS network. Thanks to KTT's 5G\_LAN service, these PMUs and control centre IP gateways are added to the VPN that Arjen previously configured in the IP/MPLS network. See as the extension of U's IP/MPLS network footprint, 5G delivers the PMUs' datagrams conforming the source-specific multicast a priori.

As a result, 5G network provides communication among the PMUs with PDCs in the control centres. A PMU produces a single source of R-SV measurements, and the 5G network delivers the measurements efficiently to the intended group of recipients.

Suddenly an outage of a distributed generator at a given site causes generation load imbalance (site 1). Similar conditions happen to another distributed generators connected nearby (site 2).

PMUs measure synchrophasors, frequency and ROCOF associated with the fundamental/primary components at various interconnections with DERs.

PMUs multicast measurement data to the subscribers, which could be other PMUs and the WAMPAC.

At abnormal site 1, based on the PMU's locally measured ROCOF, the protection function decides the problem to be a weak load imbalance. So the protection will not be triggered since the frequency is supposed to restore after some time. At other abnormal sites 2, similar decisions are made by the local protection functions.

However, the WAMPAC receives measurement from all of these PMUs. Based on its global view, it detects that area with prevalence of under frequency conditions spread among a number of DERs could potentially cause severe impact on the overall distribution grid. The WAMPAC decides to trip the generators in some of these problematic sites (treating the under voltage condition as severe imbalance), so as to prevent system collapse.

### 5.16.4 Post-condition

5G communication works properly. System collapse is prevented ensuring system resiliency. Additionally, with data measured by PMUs, the DSO has a good real-time view of operation states of DERs and how the energy flows throughout the networks.

### 5.16.5 Existing features partly or fully covering the use case functionality

The communication delay KPIs can be supported by the existing requirements.

### 5.16.6 Potential New Requirements needed to support the use case

[PR.5.16-001] The 5G system shall be able to deliver data originated by a UE to a group of recipient UEs distributed over a large geographical area.

[PR.5.16-002] The 5G system shall allow the originating UE to send data to several groups at the same time.

[PR.5.16-003] The 5G system shall enable recipient UEs to indicate their interest in receiving data from a specific originating UE.

## 5.17 Utility Service Operator M2M service management platform in Smart Energy

### 5.17.1 Description

It is important to understand that this use case is widely present in the DSO networks in many regions across the world. This use case resembles the realistic situation in which a utility M2M system interacts with an MNO for consuming cellular technologies. This use case focuses on how 5G can provide improved management related services offered to DSOs, in the realistic real-life context. To bring context to this paper, the use case of AMI is used.

M2M has existed in DSO networks for a long time. Started with the support by legacy GPRS, CDMA, UMTS and later LTE, smart metering and AMI systems have enjoyed rapid deployment by a DSO to reach their operation and business targets. Not only for metering systems, but also a large number of DSOs have brought cellular connectivity to substations that are remotely located and have relatively less sophisticated Smart Grid applications running. For the sake of clear and comprehensive explanation, the architecture with TCP-UDP/IP communication profile from the DLMS/COSEM UA [46] international standard is referred to, so as to elaborate the topic of the hour in truthful context.

The concept is well-known, a device with a cellar module connects to the target server(s) via cellular connectivity. Figure 5.17.1-1 shows how the utility-adopted DLMS/COSEM standard utilizes this concept.

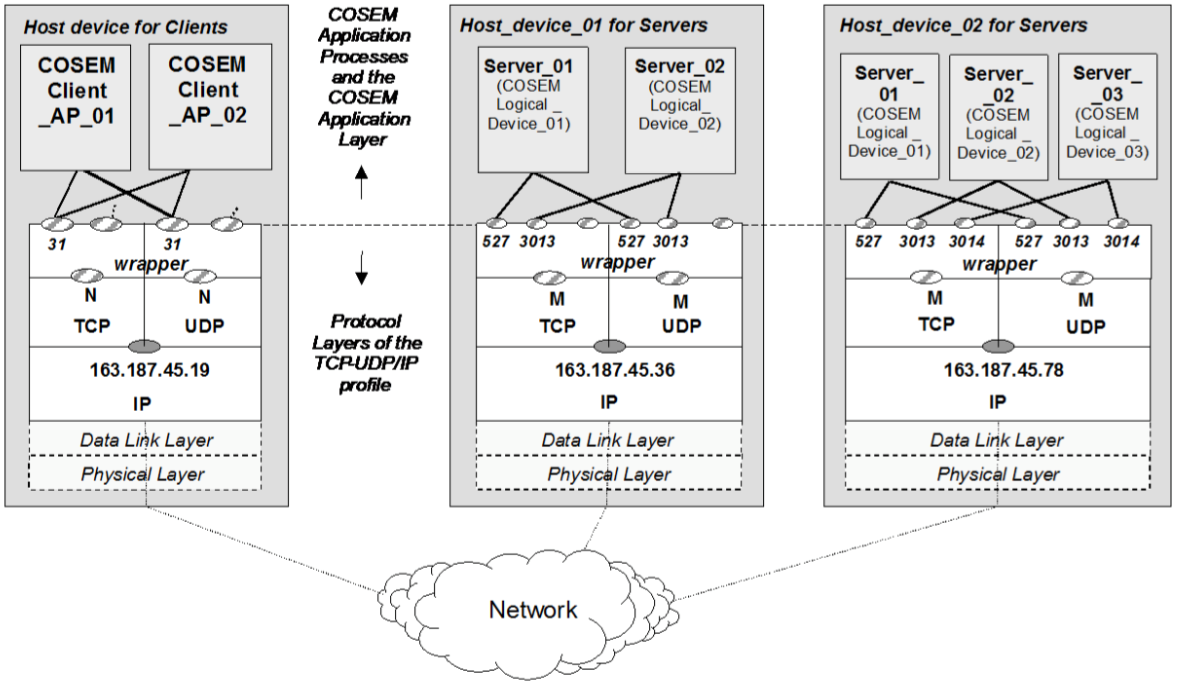


Figure 5.17.1-1: TCP-UDP/IP profile based utility M2M system illustrating a client reporting to two different head-end servers in the DSO's data centre [50].

Since the cellular connectivity is provided by an MNO, usually the DSO need to setup a dedicated VPN connection between its own RADIUS server and the MNO's RADIUS (as a proxy) to ensure the DSO's own RADIUS server will be responsible for the E2E authentication of the meters or the Smart Grid terminal devices. Figure 5.17.1-2 illustrates a typical situation, where a DSO called EDL has two separate subscriptions with two mobile operators for the many M2M devices they need to connect. The DSO manages its own RADIUS servers (RADIUS A and RADIUS B) in its own IT domain (e.g. own data centre or in a hosting environment), each RADIUS server has a secure tunnel to the peer RADIUS proxy in the corresponding MNO network (here namely the Operator A RADIUS and the Operator B RADIUS). The mechanism of a DSO's M2M system and the related RADIUS interaction is illustrated in Figure 5.17.1-3.

For the target M2M applications based on the TCP-UDP/IP profile in DLMS/COSEM [47], and the actual existing M2M management platform widely adopted in DSO's utility M2M infrastructure, it is very important for the DSO to expect successful data connection fulfilling the application's communication needs, as agreed in the SLA. In reality, even the most recently known metering applications in the European Union is the 15-minutes reading cycle [48]. That means, the successful meter reading as required by legislation is changing from once a month, to recently once a day and in the future once every 15 minutes. For a DSO's M2M head-end server, Smart Grid sector specifications have standardized wake-up mechanisms for the head-end server to contact the end devices for data retrieval, so that the data can be fetched within the service window determined by a specific business process. Realistically speaking, if the data must be available every 15 minutes, then the M2M service administrator has sufficient time (roughly a 15-minute window in this case) to trigger this wake-up process multiple times for retrieving the data. Another well-used resort has been that the DSO uses APIs of the MNO's SIM management platform to "reanimate" the device back to the mobile network connectivity by means of mechanisms such as reattach and re-registration.

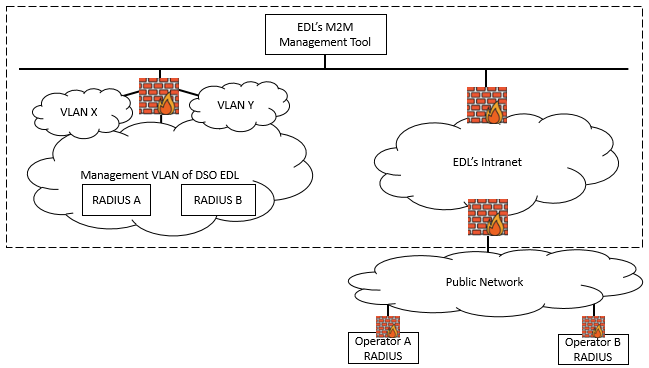


Figure 5.17.1-2: DSO EDL's management platform of MSM service. EDL has two subscriptions to two mobile operators.

From the experience of some DSOs, it has happened that some M2M systems relying on 2G/3G connectivity did lose contact with the head-end server(s) for hours or even for days, and sometimes a wake-up push message manually sent from the head-end might also fail in getting the M2M device back online (w.r.t connectivity). Apparently, the most and foremost target of 5G is to focus on how to provide more reliable connectivity to the M2M devices, through enhancement of technology evolution, and introduce adequate quality assurance mechanisms to add to warranty. In respect of this, the 5G technology already introduces ground-breaking improvement in connectivity KPIs including reliability.

Equally important, as the industry-wide wake-up procedure goes, a service maintenance personnel of a DSO might look into their RADIUS server to check the session establishment status. This process has been in existence, ever since legacy cellular technologies were used. But this manual process has been labour-intensive and at times impractical for utility the personnel, who in general do not always have sufficient mobile telecom expertise to analyse the RADIUS call flows. Therefore, it makes sense for a 5G operator to inform the DSO in easy-to-comprehend terms of the following information on a per-M2M-device basis:

* RADIUS session setup information
* Device session status information
* Device session setup success rate

Exposing these information during M2M service trouble-shooting can effectively improve the DSO's incident management process.

Certainly the M2M systems and applications will continue to proliferate in utility network. The reliance on 5G technology encourages the telecom providers to provide more relevant performance and events data to the DSOs. The genuine pursuit of a DSO is that by means of effective reporting the DSO obtains timely information and advice on maintaining resilient operation of their utility grid and services. This basically includes the following:

* 5G should introduce to an MNO means to keeping track of the offered connectivity's status, and to abiding by the factually contracted service KPIs (incl. availability) in the SLA;
* 5G should enable notifying a DSO in time the events related to MNO-planned maintenance (e.g. time period and impacted cell sites), for the DSO to timely adjust its service operation;
* 5G should enable reporting to a DSO the forecasted performance degradation over a specific geographic area (e.g. a cell sector, a cell or a group of cells).

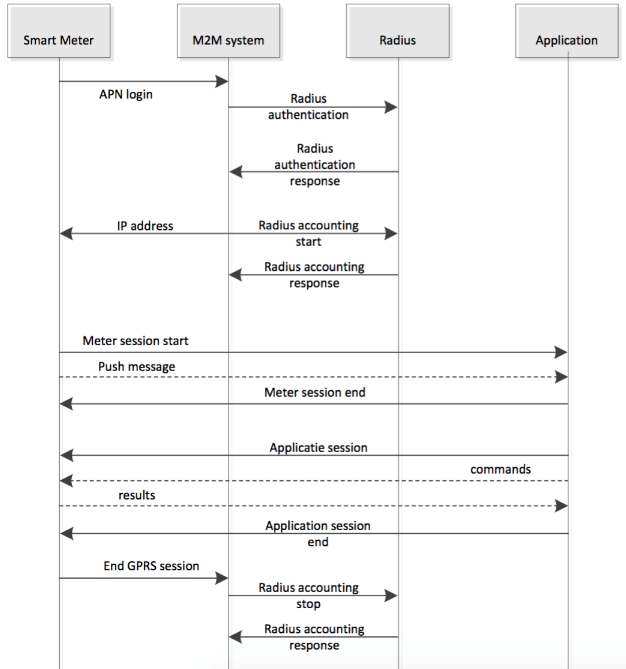


Figure 5.17.1-3: Illustration of a typical utility M2M management mechanism [50], implemented ubiquitously in currently available commercial M2M systems for utility operators.

### 5.17.2 Pre-condition

1. A DSO "UT" has a service contract with an MNO "TEL" for supporting its M2M services. In the service contract, UT and TEL have agreed on the SLA covering many aspects including the following:

* Justification of business needs
* Business process already in place on UT (the customer side)
* Desired outcome of the connectivity service in terms of e.g. availability, reliability, performances, etc.
* The classification of incidents (w.r.t. urgency etc.), and per classification the required response time, MTTR, and relevant information exposure if specifically requested.

2. UT has its ITIL process in place, of which the incident management process is expected to speed up incident resolution while minimizing operational and customer impact, in an efficient and cost-effective manner.

3. For event reporting and management related information exchange, UT and TEL have invested in setting up the infrastructure, which includes a secured highly-reliable BW-abundant OOB transport tunnel, secure interfaces (incl. layers across physical, VPN, APIs), and paid and governed by UT a special data collection and storage infrastructure (data centre or in the cloud) scaled properly to contain and store the exposed data from TEL, etc. UT is obliged by the CTO and the CFO to carefully consider the cost of such infrastructure.

4. M2M system of UT is up-and-running on 5G. The procured 5G service with provisioned availability provides reliable connectivity with sufficient performance to the M2M application.

### 5.17.3 Service flow

1) Pieter-Jansen is the M2M service administrator at UT. Every day his primary job is to monitor the service status of the applications underpinning the M2M service. Pieter-Jansen uses the GUI to check application status, and whether the M2M data has arrived in the head-end systems before the service window closes (e.g. new data should arrive in the system from an M2M device every 15 minutes). This is normally the case, and Pieter-Jansen could spend time learning UT's business processes related to this M2M service.

2) One morning while Pieter-Jansen arrives at work, eager as he always is he logs in the service manager portal to take a quick glance of the M2M service status collected last night. Frowning, Pieter-Jansen notices the GUI of the head-end system alerts missing data from a particular M2M device --- data missing for several continuous service cycles (e.g. 120 data points missing in the past 8 hour). Pieter-Jansen has the admin login credential to UT's RADIUS server, however, Pieter-Jansen is not specialized in telecom and has not gained experience in the corresponding IEEE protocols. His supervisor, one of the very few personnel at UT who understands both electricity and telecom was unfortunately under the weather and had called in sick. Pieter-Jansen therefore switches to the GUI that visualizes RADIUS session status in the historian with the data received from TEL's RADIUS servers. The data from TEL is translated in layman's terms, hence Pieter-Jansen easily understands that the authentication process of this M2M device has failed due to wrong credentials.

3) Pieter-Jansen goes on to check the logbook whether any recent changes have been introduced in UT's M2M system. He realized for this particular M2M device, the corresponding credential at the RADIUS server has been updated by the administrator of the RADIUS server at UT. Hence Pieter-Jansen calls that personnel to revert the credential. This M2M device soon comes back on the network and resumes to deliver data to the M2M head-end server.

4) Time goes on, summer holiday arrives and lots of people are leaving for the passionate south. TEL usually plans network maintenance services during this period. However, since TEL and UT have an SLA in the contract, TEL informs UT of the network activity and the perceived interruption of mobile service.

5) UT checks that the service interruption is within the availability window of the telecom service, and UT can timely inform the customers when the M2M service is expected to be unavailable. This process is agreed beforehand and is conformant with the grid code of the country where UT operates.

6) Therefore, UT confirms with TEL the acceptance of the period for the planned network maintenance to be carried out by TEL.

7) UT fulfils its role as public sector service provider conforming the national norm. TEL provides 5G service that fits UT's actual needs with minimal burden on the customer side.

### 5.17.4 Post-condition

UT is able to provide to their customers the M2M services both during incidents and over time.

### 5.17.5 Existing features partly or fully covering the use case functionality

TS 22.261 Table 7.5-2-1 captures performance requirements for high availability IoT traffic.

Under normal conditions, 5G service performance KPIs regarding bandwidth, delay, jitter, and availability are sufficient for utility M2M applications.

5G system can provide periodic performance reporting, the corresponding report interval can be configured by the application layer.

TS 22.261 clause 6.1.2.2:

The 5G system shall support means by which the operator can differentiate policy control, functionality and performance provided in different network slices. Therefore, the M2M service performance KPIs could be provided by means of network slicing.

TS 22.261 clause 6.23.2:

The 5G system shall provide a mechanism for supporting real time E2E QoS monitoring within a system.

The 5G network shall provide an interface to application for QoS monitoring (e.g. to initiate QoS monitoring, request QoS parameters, events, logging information).

The 5G system shall be able to log the history of the communication events. This includes for examples parts of the SLA that are not met, time-stamp of the events, and event position (e.g. UEs and radio access points associated with the events).

The 5G system shall support different levels of granularity for QoS monitoring (e.g. per flow or set of flows).

The 5G system shall be able to provide event notification upon detecting error that the negotiated QoS level cannot be met/guaranteed.

The 5G system shall be able to provide information that identifies the type and the location of a communication error. (e.g. cell id).

The 5G system shall be able to provide notification of communication events to authorized entities per pre-defined patterns (e.g. every time the bandwidth drops below a pre-defined threshold for QoS parameters the authorized entity is notified and event is logged).

The 5G system shall be able to respond to a request from an authorized entity to provide real-time QoS monitoring information within a specified time after receiving the request (e.g. within 5s).

The 5G system shall be able to provide statistical information of service parameters and error types while a communication service is in operation.

The 5G system shall provide information on the current availability of a specific communication service in a particular area (e.g. cell id) upon request of an authorized entity.

### 5.17.6 Potential New Requirements needed to support the use case

[PR.5.17-001] Based on MNO policy, the 5G network shall provide suitable means to expose to a trusted third party the communication network performance parameters

[PR.5.17-002] Based on MNO policy, the 5G network shall provide suitable means to proactively inform a trusted third party of possible events that could interrupt or cause performance degradation of the 5G service over a specific geographic area (e.g. a cell sector, a cell or a group of cells).

## 5.18 Coordination for Energy Recovery Use Case

### 5.18.1 Description

Utilities (DSO) make use of both Private and Public Wireless networks as access technologies for Smart Grid assets providing Smart Grid services, some of which can have a high level of criticality.

Public cellular networks are sometimes the only option to provide remote access to Distribution Automation (DA) assets.

Remote access to DA assets in a fault situation causing a power outage is a necessary condition to isolate the fault and restore the service promptly.

In order to guarantee high availability, the communication system providing remote access to the Smart Grid assets needs an uninterruptable power supply.

When DA assets are connected by means of Public 3GPP networks, they are typically served by a Node located in the proximity of the fault and hence affected by it because it happens to be fed by the faulty power line.

Power autonomy of cellular nodes is a key variable of a fault scenario in order to guarantee the correct and prompt resolution of the issue and the service recovery. Power autonomy of the mobile telecommunication system nodes is a variable that escapes the control of the DSO and relies exclusively on MNO's policies and 'implementation'.

A standard communication flow between parties would enable mutually beneficial coordination towards energy recovery. Both MNO and DSO could adapt their processes to the existing constraints,

### 5.18.2 Pre-conditions

Utility "U" has a significant percentage of Distribution Automation assets connected by Public cellular services. U relies on MNOs A and B for 5G services.

Distribution Automation is considered a critical service requiring high availability.

Cellular routers that enable remote access to the assets have dual cellular configuration in order to provide an extra level of redundancy and availability. This configuration enables a backup cellular connection with MNO B in case of failure of MNO A.

Access to Distribution Automation assets such as reclosers or SCADA switches must be available in a fault situation in order to restore the service. If the 5G node providing cellular coverage to the connected Smart Grid asset is fed by a line affected by the fault and the Node does not have an adequate UPS that enables access to remote operations to restore the fault, the loss of connectivity and the corresponding loss of remote control of the asset is inevitable.

DSO and MNO have an available channel for communication of energy outage incidents. This channel is bidirectional. The MNO can be made aware real time of an incident affecting DSO's distribution network with a result of power failure affecting MNO's Node(s) serving the Smart Grid asset. The communication channel can also inform the DSO of the MNO's autonomous power status in areas affected by energy outage.

### 5.18.3 Service Flows

Remote access and operation of Distribution Automation assets is performed from the Energy Control Center (ECC). Charles is an operator working at the ECC.

Service flow 1.

1. Charles observes a service interruption caused by a faulty power line. The power outage affects a significant number of customers in an urban area. In order to isolate the issue and restore the service to the affected customers, Charles needs to access a recloser (Distribution Automation Smart Grid Asset) connected by means of a cellular router served by MNOs A and B.

Service flow 1, alternative 1:

1.1.1 Remote Access to the recloser is possible but, after a short period of time, the connection is lost as both MNOs A and B's facilities in proximity of the energy outage have exhausted their autonomous power reserves.

1.1.2 The fault cannot be isolated remotely in time and in order to restore the service to customers, field crews need to be mobilised for onsite operation. Restoration time increases dramatically.

NOTE: If the power outage only affected one of the MNOs (e.g. A) providing coverage to the site where the DSO would apply DA to end the outage, then the other MNO (e.g. B) could provide communication service to enable the DSO to restore service.

Service flow 1, alternative 2:

1.2.1 U is informed by MNOs A and B that cellular Nodes serving the router suffered a power outage coincident in time with U's power line fault event.

1.2.2 Both A and B inform U that their nodes have UPS with very limited capacity.

1.2.3 Using information from U, the MNOs A and B have information that they can use to conserve the limited power capacity and enable U to communicate with the site of the fault.

Service Flow 2.

Some days later, a storm situation causes a service interruption in a rural area. The recloser located closest to the fault is connected by means of Private Wireless connection. Private Wireless repeater site is owned and maintained by U. Power autonomy in the repeater site is appropriately dimensioned to meet U's needs according to operations parameters The access to the recloser is possible and the fault can be solved in a minimal time with no service interruption to final customer in the area.

### 5.18.4 Post-conditions

The outcome of Service Flow 1, alternative 1 is unfortunate because it causes a lengthy service interruption for both energy and telecommunications service.

The outcome of Service Flow 1, alternative 2, allows this situation to be avoided. As the DSO and MNO have a standard channel for communication of energy outage incidents, they are both able to plan and execute recovery effectively.

The DSO can provide locality, communication requirements and estimated time of repair of an issue in DSO's Distribution network. The MNO can use this information, especially the recovery schedule, the location and the communication requirements, to enable remote access to the Smart Grid asset that will solve the issue.

For example, in the event of a service interruption or outage affecting a 5G node with a limited power autonomy, the Node has access to information coming from the Network so that it is able to detect the root cause of the problem and react accordingly. The Node is able to efficiently manage the resources and prioritize granting access to U's traffic. All the rest of processes that are not strictly necessary to the final aim of serving U's need of cellular resources become dormant.

MNO will inform DSO of the Power autonomy and location of the Node serving the Smart Grid asset that needs to be accessed for remote operations. The DSO will react accordingly, adjusting the operations taking into account the MNO communication constraints.

Thus, both parties will react accordingly, adjusting their processes to facilitate the resolution of the issue. U is able to successfully restore the issue affecting the line remotely so that the Node recovers the power supply after a short period of time. Once Power supply is back to normal, 5G node can resume its normal processes.

Energy system comes back online, taking into consideration the timing and UPS resource constraints of both MNO and DSO, as well as the locality of the incident. This is a marked improvement of the current system in which for availability considerations DSOs cannot rely upon mobile telecommunications for recovery with building a redundant infrastructure. This reduces the applicability of mobile telecommunications infrastructure to support energy utility communication.

Another alternative, shown in Service Flow 2, is that the MNO provisions their UPS resources sufficiently to suffer loss of service in the event of an energy system outage for a sufficiently long period of time to enable the DSO to restore service. The provisioning of the UPS can be informed by the outcome of past energy outage incidents, as well as historical information exchanged as per Service Flow 1, alternative 1 and 2 – as lessons learned.

### 5.18.5 Existing features partly or fully covering the use case functionality

Network slicing and QoS implementation in 5G networks enable the identification of DSO's service criticality.

### 5.18.6 Potential New Requirements needed to support the use case

[PR.5.18-001] Subject to regulatory requirements and operator policy, the 5G system shall support a mechanism by which an MNO can identify the uninterruptable power supply status of the MNO's infrastructure, specifying which physical regions would be affected in terms of physical topology, as this information will facilitate energy system recovery operations.

[PR.5.18-002] Subject to regulatory requirements, the 5G system shall support a mechanism by which a third party can communicate the energy system recovery status in terms of location and time table to the MNO, as this information will facilitate MNO operations to facilitate energy system recovery.

NOTE: It is assumed that once aware of the proximity and duration of the energy outage, the MNO may manage the 5G Nodes affected by the outage to make use of the power autonomy remaining in the 5G Nodes, e.g. prioritizing the delivery of resources to support the energy system operations communications. Power consumption for energy system operations must be optimized so that the service recovery can be remotely orchestrated by the energy utility.

## 5.19 Applications Using IEC 61850-9-2 Sampled Values

### 5.19.1 Description

As electric grids are expanding, there is an increasing need for fault detection and location as well as maintaining system stability in real time which requires precision timing. There is also a raising interest to have other clock synchronization sources in addition to GNSS.

IEC 61850-9-2 standard [49] specifies the protocol for transmitting measurement information in a power system using Ethernet. Standard also recommends the use of PTP (Precision Time Protocol) for clock synchronization and IEC 61850-9-3 standard [7] shall be followed whenever PTP is used. PTP accuracy is affected by network structure and devices in the network. Since different types of clock devices produce different time errors and jitters, overall time inaccuracy must be verified to make sure that application time accuracy requirements are fulfilled. Requirements in IEC 61850-9-3 [7] aim at achieving a network time inaccuracy better than 1μs after crossing 15 transparent clocks or 3 boundary clocks. PTP profile for power utility automation defines the inaccuracy as follows:

Table 5.19.1-1. Allowed inaccuracy defined by IEC 61850-9-3 [7]

|  |  |
| --- | --- |
| **Clock type** | **Inaccuracy** |
| Transparent clock (TC) | < 50ns |
| Boundary clock (BC) | < 200ns |
| Grandmaster clock | < 250ns |

Grandmaster clocks in substations today use a GNSS receiver to achieve accurate clock synchronization with holdover time even up to 24h (corresponding to <1μs accuracy). However, since the time source (GNSS) may become unavailable due to failure (e.g. broken antenna, satellite availability or interference), 5G is a candidate resiliency solution (see [51] clause 5.2). In order to reach the same level of measurement accuracy, 5G capable grandmaster clock should fulfil the requirement of maximum 250ns inaccuracy when its timing reference is used in the same location as of the Grandmaster clock that is used to synchronize the Smart Grid devices over Ethernet.

Synchronization requirements are related to various aspects. In particular, IEC/IEEE 60255-118-1:2018 [50] defines a Phasor Measurement Unit (PMU) that must maintain less than a 1% total vector error (TVE). Such error includes time, phasor angle, and phasor magnitude estimation errors. Standard also recommends that a time source that reliably provides time, should be at least 10 times better than values corresponding to 1 % TVE. Therefore IEC 61850-9-3 [7] should be followed whenever substation has PMUs either as standalone devices or PMU capable protection relays.

By using PTP within a substation the system can have multiple grandmaster capable clocks which, in case of failure of the current grandmaster, can be used to maintain accurate time between devices and processing sampled values. However, when sampled values are processed outside the substation, time inaccuracy limits defined by IEC 61850-9-3 [7] must be followed since the devices are not connected to the same grandmaster clock and therefore measurement timestamps may have too much inaccuracy. Application outside substation may be but not limited to Wide Area Protection.

### 5.19.2 Pre-conditions

A Smart Grid operator utilizes 5G wireless communications across primary and secondary substations. These communications report events and error detection recordings to a centralized monitoring station. Accurate time stamping across the sources is essential to provide a clear picture of the system. As outages in one area may have impact throughout the system, the 5G system may be used as a supplement to (e.g., integrated as alternative radio in the grandmaster clock) or as an alternative grandmaster clock. As a capable grandmaster clock, the 5G system should fulfil the accuracy requirements defined by IEC 61850-9-3 [7].

### 5.19.3 Service flows

Sensors across the secondary distribution centres provide timestamped event reporting to a centralized monitoring system. Each event is timestamped to aid in analysis.

The 5G system and the Smart Grid operator have 5G wireless communications configured across the Smart Grid network. Each source uses the same master clock and communicates over the 5G system, timestamps on the recordings are aligned for accurate analysis to be done at a centralized point.

Additionally, the 5G system will need to be compatible with requirements from IEC 61850-9-3 [3] when used in conjunction with GNSS for a timing service in a Smart Grid environment.

* Power system time accuracy from time source (ex. GNSS or UTC) to 5G end device when used as part of IEEE 1588 PTP sync device is 1μs (absolute time-synchronization in substation local area networks IEC 61850 Sample Values).
* For a 5G system entity acting as a PTP grandmaster in a subsystem, 250 ns accuracy applies between time source (ex. GNSS or UTC) and 5G end device.

### 5.19.4 Post-conditions

The Smart Grid can use 5G system as a supplement or backup to their GNSS receiver based (or wired) clock synchronization systems to improve accuracy and availability of the clock synchronization across the Smart Grid.

### 5.19.5 Existing feature partly or fully covering use case functionality

Rel-16 and Rel-17 requirements cover a good portion of the accuracy requirements for a 5GS timing resiliency system, including:

* Capability to meet 5GS synchronicity budget of ≤900 ns (factory) to <1 µs (wide area) as defined for Industry 4.0 applications in TS 22.104 [65]
* Propagation delay compensation, to ensure that clock synchronization can be conducted accurately across wide area deployments needed for power sub-station support
* Support for IEEE 1588 PTP [23]
* Clock synchronization to UTC leveraging 5G system C-Plane and/or U-Plane

### 5.19.6 Potential new requirements and KPIs

#### 5.19.6.1 Potential Requirements

[PR.5.19-001] The 5G system shall support a clock synchronicity budget requirement in a range between 1000 ns (when the timing reference is directly provided to the end station) and 250ns (when acting as a PTP grandmaster of the existing Ethernet-based synchronization network with up to 15 transparent clocks or 3 boundary clocks).

#### 5.19.6.2 Potential KPIs

Table 5.19.6.2-1: Clock synchronization service performance requirements

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **User-specific clock synchronicity accuracy level [6]** | **Number of devices in one Communication group for clock synchronisation** | **Clock synchronicity requirement (note 1)** | **Service area** | **Scenario** |
| 4 | Up to 100 UEs | <250ns - 1 µs [7] | < 20 km2 | Smart Grid:  Synchronicity between sync master and PMUs  This range covers the extreme cases where the  PTP clock in the end device uses 5G sync modem as direct time-source (1 µs)  The 5G sync modem acts as PTP GM or 5G sync modem provides PPS output to PTP GM at the top of the Ethernet based synchronization chain with up to 15 transparent clocks or 3 boundary clocks (250 ns). |
| 4a | Up to 100 UEs | <10-20 µs [64] | < 20 km2 | Smart Grid: Power system protection in digital substation with merging units, line differential protection and synchronization |
| 4b | Up to 100 UEs | <1 ms [64] | < 20 km2 | Smart Grid: Event reporting and Disturbance recording use-cases |
| NOTE 1: The clock synchronicity requirement refers to the clock synchronicity budget for the 5G system, as described in Clause 5.19.6.1. | | | | |

## 5.20 Use case of power distribution grid state estimation service

### 5.20.1 Description

The State Estimation (SE) service [52] supports the monitoring of the power grid. The goal of SE is to create insight into the operational state of the power network at any given instant in time, by processing the measurement information collected by the instrumentation deployed in the field. The SE service provides monitoring data which can be used by grid operators to assess the performance of their network and to detect possible anomalies in the grid operation. In addition, it can serve as an input for more complex management functions implemented by the Distribution System Operators (DSOs) to more reliably and efficiently operate. An example of a service which could use the SE monitoring data is the power control service [52]. Other services which could use the SE monitoring data include, but are not limited to, network topology reconfiguration, Volt-VAR control and, in the future, demand side management and demand response services.

### 5.20.2 Pre-conditions

The measurement devices are deployed in the field and capable to send the data to the DSO control centre (or whatever data concentrator).

### 5.20.3 Service flows

#### 5.20.3.1 Introduction

The SE service relies as input on the information of the electric grid topology, the electric line parameters and the real-time measurements provided by the instrumentation deployed on the field. Given this set of inputs, the SE service processes the received data to provide the most likely operating state of the network at the considered instant of time (the same time at which the measurements are collected). Finally, the results of the SE service are sent to the control centre (or whatever data concentrator) to give situational awareness to the DSO and, if needed, are made available for other control functions requiring this information. SE results are usually also stored in a database for possible a posteriori analysis.

For its operation, the SE service thus needs as input some important information of the grid characteristics, the deployed measurement infrastructure, as well as the real-time measurement data collected from the measurement units in the field. In addition, if the electric grid is reconfigurable (i.e. topology changes can be applied), the status of the switches and breakers should be also provided in input to the SE tool to make sure that the service is always considering the correct topology of the grid.

Beyond the grid data, which can be determined by the DSOs with a different degree of accuracy as the information of low voltage grids may be incomplete and inaccurate, the key point for enabling the SE service is the availability of measurement devices with real-time communication capabilities. Different from the transmission system, where a large coverage of devices is often available, the instrumentation penetration at the distribution level is usually poor with only few devices installed in specific points, like primary substations (high/medium voltage substations). As a matter of fact, the main power system requirement to enable the grid monitoring via SE is thus the deployment of devices providing the needed measurement data. Due to the large size of the distribution grids and obvious economic constraints, guaranteeing a full observability of the grid is mostly impractical and hardly achievable. The SE solution duly takes into account this aspect and aims at enabling the SE service using only few low-cost measurement devices deployed at strategic points of the grid (chosen by means of ad hoc meter placement strategies). Moreover, the conceived SE solutions are designed to maximize the accuracy performance even in presence of few measurement units in the field. However, it is worth noting that the accuracy of the estimation results strongly depends on the number of available measurements.

#### 5.20.3.2 Power system requirements of SE service

Needed components in the field: sensors and meters.

Information about the electrical grid: topology of the network; grid parameters (line impedance, transformer data, etc.); nominal power of connected loads and generators; location of the meters.

Type of measurements: voltage (both magnitude and phase angle), current (both magnitude and phase angle), active and reactive power are the measurements that can be used for SE purposes (it is not mandatory to have all the types of measurements reported).

Measurements number: the higher the number, the better the results.

Measurement accuracy: the higher the better; information on the uncertainty characteristics of both sensors and measurement units has to be known.

Measurement synchronization: highly recommended.

Additional data needed from the field: notification of switching events leading to a change in the network topology.

Real-time communication capability: yes, required.

Bi-directional communication: not required; the communication flow is mono-directional from the meters to the control centre.

Use of edge cloud. The concept of SE is based on a distributed architecture where both low voltage and medium voltage grids are divided in multiple, smaller areas. This is a solution to reduce the computational cost and execution time of the SE service, as the SE analyses for all areas may operate in parallel. One benefit of this solution is guaranteed scalability of the proposed architecture for SE. Given this framework, it is highly feasible that each local SE runs on a dedicated edge cloud.

### 5.20.4 Post-conditions

The operating state of the network provided to DSO at a given instant of time.

### 5.20.5 Existing feature partly or fully covering use case functionality

Table 5.20.5-1 shows communications requirements for the State Estimation service.

Table 5.20.5-1: Communications requirements of SE service

| **Characteristic parameter** | | | | **Influence quantity** | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Communica­tion service availability: target value** | **Communication service reliability: mean time between failures** | **End-to-end latency: maximum (notes 1, 2)** | **Service bit rate: user experienced data rate (note 2)** | **Message size [byte] (note 2)** | **Transfer interval: target value (note 2)** | **Survival time (note 2)** | **UE speed** | **# of UEs** | **Service area** |
| 99.99% |  | 100 ms to few seconds | ~ 5 kbit/s | < 1000 | 1 s |  | Stationary | < 30 per km2 | several km2 up to 100,000 km2 |
| NOTE 1: Unless otherwise specified, all communication includes 1 wireless link (UE to network node) rather than two wireless links (UE to UE).  NOTE 2: It applies to UL. | | | | | | | | | |

### 5.20.6 Potential New Requirements needed to support the use case

None.

## 5.21 Use case of power distribution grid power control service

### 5.21.1 Description

The Power Control (PC) service [52] optimises the management of the distribution grid power flows (at both medium voltage and low voltage level) for preventing possible contingencies, such as violation of the voltage limits, and overloading of grid components. The service also fosters a more efficient and reliable system operation. This is obtained through the smart control of the active and reactive power injected (or consumed) by converter-based components connected to the grid, such as Distributed Generation (e.g. photovoltaic plants, wind turbines) and energy storage units. For the management of the Distributed Generation based on renewable energy sources, an additional objective is to maximize the use of green energy while respecting the operational constraints of the electric grid, thus minimizing as much as possible the power curtailment of renewable generation. The use of smart power control service in the power grid with high penetration of renewable energy sources is expected to significantly improve the efficient operation of the grid, the power quality, and the grid reliability. This service can be defined as an "active service", since it actively acts on some of the power system components to modify their operation.

### 5.21.2 Pre-conditions

The State Estimation service (see clause 5.20 "Use case of power distribution grid state estimation service" above) is deployed and active in the power distribution grid. Output of the State Estimation service can be used by the PC service.

### 5.21.3 Service flows

#### 5.21.3.1 Introduction

The developed PC service is based on the operating conditions of the grid and processes this information to determine the optimal setting of active and reactive power generation for the distributed generation or, when available, of storage units. Different goals can be pursued to enhance the operation of the distribution grid, such as: the reduction of power losses during the operation with normal conditions; the minimization of voltage unbalance in case of high differences in the status of the three phases of the system; the minimization of possible active power generation curtailments during circumstances with over-voltage issues in the grid. The output of the PC service is a list of set points of active and reactive power (PQ set points) for the converter-based components connected to the grid. Consequently, the service needs bi-directional communication with the field to ensure proper delivery of the generated control commands.

The design of the PC service is coupled with the State Estimation service. According to this idea, the PC service takes as input the results of the State Estimation service, namely the voltage profile at the different buses and the information about the branch power flows and the power consumption (or injection) at the nodes. Together with this information, the service needs as input also the model of the electric grid, expressed in terms of network topology and line characteristics. More specifically, the list of inputs needed to enable the PC service includes the following data.

Static grid data:

* Electric grid topology (information about the nodes and the connection among the different nodes in the grid).
* Electric component parameters (e.g. impedances of the lines, impedances of transformers, etc.).

Real-time data:

* Estimation of the bus voltages, power flows in the branches, power consumption or injection at the nodes (as provided by the State Estimation service).
* Real-time notification of a change in a switch or breaker status.

The output of the PC service is the pair of active and reactive power set points for each converter-based component in the grid. The output of the power control service has to be sent to the converters in the field through communication technologies available in the field for control commands. Results can also be sent to the control room of the Distribution System Operator (DSO) for monitoring and can be stored in the database for possible a posteriori analysis.

Since the PC service relies on the results of the State Estimation service, some of the power system requirements for this service are in common with the State Estimation service. First, measurement devices with real-time communication capabilities are needed to guarantee meaningful monitoring of the electric grid. The accuracy of the estimated results provided by the State Estimation service can also affect the performance of the PC service. Similar to the case of the State Estimation service, a critical challenge for the application of PC at distribution level is the large size of the distribution grids. This calls for the design of distributed approaches where PC services act on small areas, possibly sharing some data with an upper level controller to ensure the coordination of the power control strategy in the whole grid.

Due to the active nature of this service, a bi-directional communication is needed with the field. Data are collected from the grid to enable the State Estimation service, while the output of the PC service is sent to the converter-based components for the control of their power generation (or consumption). This also implies the need to have converters able to communicate remotely, both for sending measurement data (if available) and for receiving the actuation commands. While converters available today do not always guarantee this behaviour, this requirement can be considered as realistic in future scenarios where the availability of communication capabilities is essential to enable the Smart Grid.

The PC service runs continuously and synchronously with the State Estimation service. In particular, a new iteration of the service is triggered by the collection of a new set of estimation results provide by the State Estimation service. Similar to the case of State Estimation service, there are not strict requirements on the reporting rate for the PC service. However, due to the highly intermittent behaviour of renewable energy sources and the possibility of sudden changes in the operating conditions of the distribution grid, it is recommended to run the PC service with at intervals shorter than one minute and possibly close to a few seconds.

#### 5.21.3.2 Power system requirements of PC service

Needed components in the field: inverters (controllable from remote), sensors and meters.

Information about the electrical grid: topology of the network; grid parameters (line impedance, transformer data, etc.); nominal power of connected loads and generators; location of the meters.

Type of measurements: the State Estimation service results are used in input to the PC service, so the same requirements as to the State Estimation service apply for this point.

Measurement number: the State Estimation service results are used in input to the PC service, so the same requirements as to the State Estimation service apply for this point.

Data volume: limited. In typical operations, one set of setpoints (i.e., active and reactive power, P and Q) is transmitted per minute with volt-reactive volt ampere curve; as an alternative, dynamic voltage control is recommended in case of disturbances. In such situations, the solution will transmit approximately 1 set of setpoints per second. P and Q are floating point numbers. The communication should be scalable, i.e., supporting changing grid topology with an increasing number of actors in the electrical grid.

Measurement accuracy: the State Estimation service results are used in input to the PC service, so the same requirements as to the State Estimation service apply for this point.

Measurement synchronization: the State Estimation service results are used in input to the PC service, so the same requirements as to the State Estimation service apply for this point.

Additional data needed from the field: notification of switching events leading to a change in the network topology.

Real-time communication capability: yes, required

Bi-directional communication: yes required; needed to collect measurement and switch notifications in one direction (uplink) and to apply the control signals to the inverter in the other direction (downlink).

Communication reliability and security: very high. PC service uses only a limited amount of command messages per actor, typically one actor for each switch, transformer, or major power generation unit. Since there will be only a limited set of such actors, the reliability of the data communication becomes particularly important, because losing just a single actor would impact the impact of the PC service. Likewise, it is essential that the data are transmitted in a secure way ensuring full data integrity because of automatic modification of grid edge settings; and in this context, higher security than for monitoring services expected.

### 5.21.4 Post-conditions

The management of the distribution grid power flows is optimised in terms of preventing possible contingencies and overloading of grid components. The efficient operation of the power grid, the power quality and the grid reliability are significantly improved.

### 5.21.5 Existing feature partly or fully covering use case functionality

None.

### 5.21.6 Potential New Requirements needed to support the use case

Table 5.21.6-1

| **Characteristic parameter (KPI)** | | | | **Influence quantity** | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Communication service availability** | **Communication service reliability: mean time between failures** | **Max Allowed End-to-end latency (notes 1, 2)** | **Service bit rate: user-experienced data rate** | **Message size [byte] (note 2)** | **Survival time** | **UE speed** | **# of UEs** | **Service area** |
| 99.99 % |  | < 30 ms | UL: < 100 Kbit/s | < 1000 |  | Stationary | < 300 per km2 | several km2 up to 100,000 km2 |
| NOTE 1: Unless otherwise specified, all communication includes 1 wireless link (UE to network node or network node to UE) rather than two wireless links (UE to UE).  NOTE 2: It applies to both UL and DL unless stated otherwise. | | | | | | | | |

## 5.22 Use Case of ensuring uninterrupted MTC service availability during emergencies

### 5.22.1 Description

During emergencies, public mobile land networks (PLMNs) may restrict network access, which may lead to a lack of service reliability for machine-type communication (MTC) in critical applications, such as power systems and in particular in microgrids. Microgrids are separate parts of a power grid, which can be controlled and operated individually in a so-called island mode or together as a whole. Existing features of a mobile network can be used to differentiate MTC of devices in a microgrid from other MTC or human-to-human (H2H) communication and ensure that these microgrid devices have service during emergencies, which enables use of mobile communication to co-ordinate the use of Distributed Energy Resources (DER) in microgrids, so that they can autarkically perform blackout recovery of an islanded microgrid. The idea is to ensure reliable communications for selected MTC devices during emergency conditions, without giving these devices additional priority over other network users during normal conditions or adversely affecting the service to prioritised users during emergencies. It was shown that this method allows the blackout recovery 100 times faster than with a conventional black start [58].

Figure 5.22.1-1 shows an example of power grid restoration after a large-scale blackout using conventional and autarkic microgrid blackout recovery methods.

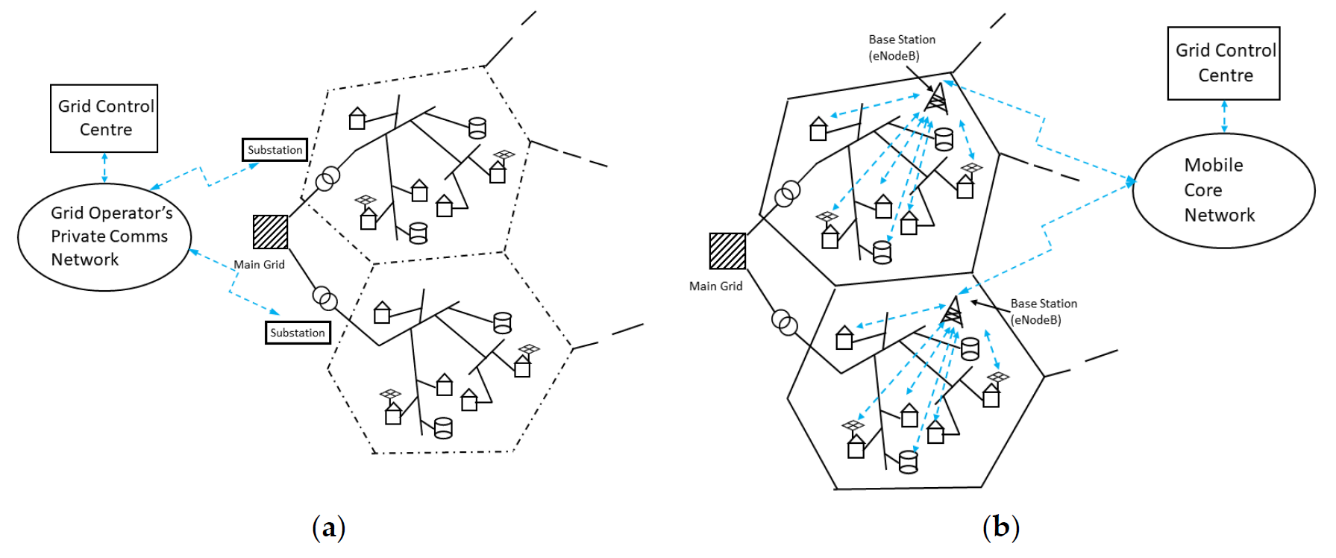


Figure 5.22.1-1: (a) Conventional grid restoration (hierarchical top-down blackout recovery) and (b) autarkic microgrid restoration (each islanded microgrid autonomously recovers from blackout) Figure taken from [58]

Grid restoration after a large-scale blackout is conventionally done by first starting power stations with black start capability, then expanding the re-energised grid to include more large synchronous power stations and expanding the re-energised grid. In this way, medium voltage and low voltage levels are re-energised hierarchically and top-down, i.e., from the transmission level.

The autarkic microgrid blackout recovery method presented in [53] assumes that the MV/LV grid is divided into a set of microgrids (Figure 5.22.1-1 (b)), which can be operated in island mode and are assumed to be autarkic, meaning that they have sufficient local energy generation and storage to be self-sufficient, and autonomous, meaning that they can manage themselves, although in normal operation they may be managed by distribution grid (DG) management systems external to the microgrid.

In the context of a microgrid, having reliable communications during a blackout means that the microgrid can continue to manage itself during blackout, i.e., even when the distributed energy resources (DER) in the microgrid are connected to a de-energised grid, the distributed controllers at the DER sites can continue to communicate with each other.

If communications from the microgrid to external management systems are working, the microgrid can perform autarkic blackout recovery under their direction. If, however, there is a loss of communication from the microgrid to external management systems, the microgrid can autonomously perform the autarkic blackout recovery. In any case, the autarkic blackout recovery relies on having communications which continue to function locally in the microgrid during blackout to allow the agents to act together to perform a black start using local DERs.

In the autarkic microgrid blackout recovery method, the medium/low voltage grid is assumed to be divided into a set of autarkic microgrids, as shown in Figure 5.22.1-1 (b), which are islanded in case of blackout. The DERs remain connected to the grid and continue to use their Multi-Agent System (MAS) MTC devices to communicate with each other and with the distribution grid control centre during the blackout [53]. In this scenario, each microgrid has its own gNB equipped with an emergency power supply. In case the emergency power supply for a gNB is not available, only this specific microgrid covered by the affected gNB cannot perform autarkic blackout recovery. However, other microgrids which are not affected by the malfunctioning gNB can still perform blackout recovery.

### 5.22.2 Pre-conditions

The MAS's within one microgrid must be covered by a large-scale, wide-area communications network, and the communications network must continue to operate during blackouts.

The network must support MTC and the MAS's can communicate within the microgrid using MTC.

### 5.22.3 Service flows

Blackout recovery using autarkic microgrids:

- Identify which nodes in the MAS are working

- Identify the current microgrid topology and DER capacity

- Re-energise the microgrid and the loads.

### 5.22.4 Post-conditions

The microgrids have recovered from the blackout and operate normally again.

### 5.22.5 Existing feature partly or fully covering use case functionality

None.

### 5.22.6 Potential New Requirements needed to support the use case

Table 5.22.6-1

| **Characteristic parameter (KPI)** | | | | **Influence quantity** | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Communication service availability** | **Communication service reliability: mean time between failures** | **Max Allowed End-to-end latency (notes 1, 2)** | **Service bit rate: user-experienced data rate** **(note 2)** | **Message size [byte]** | **Survival time** | **UE speed** | **# of UEs** | **Service Area** |
| 99.9999 % |  | 100 ms | < 1 Kbit/s per DER |  |  | Stationary |  |  |
| NOTE 1: Unless otherwise specified, all communication includes 1 wireless link (UE to network node or network node to UE) rather than two wireless links (UE to UE).  NOTE 2: It applies to both UL and DL unless stated otherwise. | | | | | | | | |

## 5.23 Edge cloud driven data acquisition (edgePMU)

### 5.23.1 Description

In the power grid, there are devices deployed to measure physical quantities from the grid, such quantities are e.g. electrical quantities such as amplitudes of voltage and current, phase, frequency or rate of change of frequency (ROCOF). One device that can provide such measurements is called a Phasor Measurement Unit (PMU). This particular device provides the above-mentioned values synchronized to a global time clock derived, for example from GPS. Such synchronized values can be used as an input to power distribution grid services, such as state estimation service [61]. Another possible service that relies on measurements of voltage, current and phase is a voltage control service [62].

As PMUs are very expensive devices, they are placed only at key points of interest. However, it is possible to use cheaper field devices that collect sampled measurement data and then process them in the edge cloud hosted PMU software, virtualizing the processing functionality of a traditional PMU, thus enabling the concept of the edgePMU [63]. Due to the lower processing requirements of the field devices, their cost is reduced, and they can also be deployed in the distribution grid providing power system operators with a more precise knowledge of the state of their grids. The edgePMU concept separates the data acquisition from the data processing by exploiting the computational capabilities offered by distributed 5G edge clouds.

The edgePMU, with its modular approach, tackles the growing need for low-cost measurement devices in distribution networks from a new perspective. It utilizes the scalability of cloud infrastructure and decreases the specialization needed in the data acquisition device, by providing flexible cloud solutions for different data use cases. Furthermore, the overall deployment is simplified from a communication point of view since there is no need for special communications cabling and a network infrastructure managed by distribution grid operators. This approach simplifies the adoption of PMUs in distribution networks by helping distribution grid operators gradually deploy their measurement architectures. In fact, the cloud-based approach offers great flexibility in the development of monitoring and automation functionalities, by gradually stacking services and processing modules. It also provides scalability opportunities, thanks to the cloud technology-based computational infrastructure. The increased computational power offered by 5G edge cloud compared to that of low-cost single board computers enables more computationally challenging algorithms to be deployed.

Here are the key features of the edgePMU concept [63]:

* High rate raw data transmission between the data acquisition unit and the edge cloud using 5G wireless connectivity
* The ability to deploy services or other applications on edge cloud infrastructure instead of having to deploy them in a traditional PMU with its high processing power
* A single field device can be used as a data acquisition unit for different services hosted in the edge cloud
* Services can be deployed, modified and upgraded on demand without the need to physically visit the sites
* The cloud-based software is not limited to only providing phasor measurements, but could also be used to calculate other metrics for power distribution grid services

### 5.23.2 Pre-conditions

Coverage by 5G communications networks of regions in which measurement devices and edge cloud are to be located is required. The voltage or current measurement sensors and their associated secure data acquisition units have to be deployed in the power grid.

The secure data acquisition unit is connected wirelessly by the 5G network to the edge cloud hosted services.

The service of phasor calculation is deployed in the edge cloud infrastructure.

### 5.23.3 Service Flows

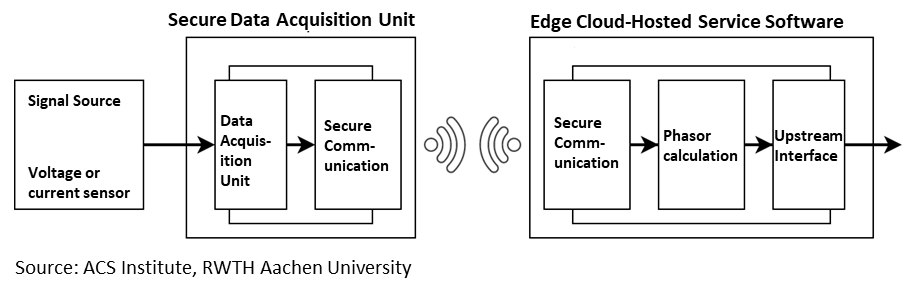


Figure 5.23.3-1: Service flow diagram for edgePMU use case

* The data acquisition unit is collecting data, such as voltage and current values, from the power grid.
* This data is then sent via secure 5G communication to the relevant service hosted on the edge cloud.
* After the data has been collected in the edge cloud, the service processes the data. A small buffer is needed for post-processing with the service hosted on the edge cloud.
* In the case of the phasor calculation service, the estimated phasors can be forwarded to further applications or actors, either hosted by the edge cloud or external to it.

### 5.23.4 Post-conditions

The relevant power distribution grid service is successfully deployed in the edge cloud and running smoothly.

The voltage or current measurements are collected by the data acquisition units and transmitted to the service hosted on the edge cloud.

The service deployed in the edge cloud provides upstream services, such as state estimation or voltage control, with the input data they need.

The resulting service output data, hosted on the edge cloud, is stored permanently or forwarded to upstream services.

### 5.23.5 Existing features partly or fully covering the use case functionality

Existing LTE wireless connectivity, if configured to provide the required latency, could support the transmission of field device measurement data to services hosted on clouds hosted on distribution system operator owned servers.

Latency: Lower than 2/Fs, where Fs is the output reporting rate of the edge cloud service. Example: 60 phasors per second at 60 Hz means Fs = 60 and 2/60=0.033 means the overall latency budget is less than 33 ms. Typical networks aim for 50 or 60 phasors, depending on the geo location. Higher reporting rates are also allowed by the standard.

Table 5.23.5-1:

| **Characteristic parameter** | | | | **Influence quantity** | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Communica­tion service availability: target value** | **Communication service reliability: mean time between failures** | **End-to-end latency: maximum (notes 1, 2)** | **Service bit rate: user experienced data rate**  **(note 1, 2)** | **Message size [byte]** | **Transfer interval: target value** | **Survival time** | **UE  speed** | **# of UEs** | **Service area** |
|  | > 1 year | < 33 ms | < 20 Mbit/s |  | ≤ 1 ms |  | Stationary |  |  |
| NOTE 1: Unless otherwise specified, all communication includes 1 wireless link (UE to network node or network node to UE) rather than two wireless links (UE to UE).  NOTE 2: It applies to UL. | | | | | | | | | |

### 5.23.6 Potential New Requirements needed to support the use case

None.

## 5.24 Use case of power distribution grid load and generation prediction service

### 5.24.1 Description

The Load Prediction (LP) and Generation Prediction (GP) service [52] aim at forecasting the future values of power consumption and injection, respectively, in order to give to the Distribution System Operator (DSO) the awareness on how the grid operating conditions are expected to evolve in the future. This service works by processing the historical data on the power consumption/injection of the customer, generator, or substation under analysis, and possibly taking into account other information that is likely to affect the power levels (e.g. like weather conditions, temperature, etc.). The forecast given by the LP and GP can refer to different time horizons and can have a different time resolution, according to the requirements of the DSOs. As an example, day ahead forecasts (for example with a time resolution of 15 minutes) can be generated in order to predict possible contingencies and, in case, to be prepared to take adequate countermeasures. Day ahead forecasts could be refined by shorter-term forecasts, e.g. a forecast referred to the next hour, which in general could be more reliable since it can be based on more recent information on the grid status. This could be, for example, a solution to apply preventive control schemes aimed at minimizing the risk of problems in the grid. On the other side, longer term forecasts (e.g. on a seasonal or yearly basis) are also possible and they can support DSOs in planning, and in supporting strategical decisions on managing and reinforcing the grid.

### 5.24.2 Pre-conditions

Power meters are available at the customer (or substation) site where the forecast is required. The State Estimation service (see clause 5.20 "Use case of power distribution grid state estimation" above) is deployed and active in the power distribution grid. Output of the State Estimation service can be used by the LP and GP service.

### 5.24.3 Service Flows

#### 5.24.3.1 Introduction

LP and GP service is based on historical data as the input information. In the case of the LP service, the needed historical data include the power consumption (demand) measured in the past with a time resolution that is equal (or better) than the one required in output for the service. As a consequence, the application of the LP service automatically implies the need to have power meters available at the customer (or substation) site where the forecast is required. In the case of the GP service, similar requirements also apply. Moreover, since the generation can be largely affected by external factors, additional information can be also needed. E.g., in case of a GP service to forecast the power generation from photovoltaic (PV) plants, additional factors such as weather conditions (irradiance, temperature, cloudiness, etc.) can play a relevant role to determine the expected power generation and they need to be duly considered by the service. In summary, the data required as input to the LP/GP service are:

* Active and reactive power consumption (or generation) measured at the customer (generator) or substation that is object of the analysis; data should possibly cover a quite long period of time (months or years) to lead to accurate results.
* Weather forecast data (irradiance, temperature, cloudiness, etc.) as input to the GP service.

Generally, the LP/GP service has loose power system requirements. It is worth noting that no data about the grid are needed for this service and that the measurement devices deployed to get the needed power data do not need real-time communication requirements.

#### 5.24.3.2 Power system requirements of LP/GP service

Needed components in the field: sensors and meters.

Information about the electrical grid: no details on the electric grid are needed.

Type of measurements: power measurements at the monitored load, generator, or substation (or both voltage and current in order to be able to compute the associated power).

Measurement number: for each point where an accurate forecast is needed, a meter providing power measurements (or information on both voltage and current) is needed.

Measurement accuracy: no strict requirements on the accuracy of the measurement chain.

Measurement synchronization: no need for accurate synchronization, but meter data need to have a time tag.

Additional data needed from the field: no additional data needed from the field.

Real-time communication capability: not required.

Bi-directional communication: not required, the communication flow is mono-directional from the meters to the control centre.

### 5.24.4 Post-conditions

The future values of power consumption and injection are forecasted. DSO is aware of how the grid operating conditions are expected to evolve in the future, e.g., to predict possible contingencies. Longer term forecasts can support DSO in planning, and in supporting strategical decisions on managing and reinforcing the grid.

### 5.24.5 Existing features partly or fully covering the use case functionality

Data transmission is based on the uplink direction only, when using historic values for load and power generated.

Load and generation prediction service does not take data from the field, but only the data stored in the database. Of course, the data stored in the database arrived at some point from the field.

Connection density. See State Estimation service (clause 5.20 "Use case of power distribution grid state estimation" above) for the number of substations where measurements that will be used for Load and Generation Prediction service can be collected. Additional measurements can arrive from generation plants and in this case the density of the connection end points will become higher comparing to State Estimation service.

In addition, residential smart meters could be also used in for LP/GP service. In this case the number of connection end points would increase drastically.

The connection density is the most critical requirements for LP/GP service. Accordingly, it requires enhanced coverage.

Latency. There are no critical latency requirements, since data are taken a posteriori from the database.

Sampling rate. See State Estimation service (clause 5.20 "Use case of power distribution grid state estimation" above) since the same data are likely to be used for LP/GP service. Note that for LP/GP service, sampling rate of 1 message per minute is enough.

Message size. See State Estimation service (clause 5.20 "Use case of power distribution grid state estimation" above) since the same measurement device can be used also for LP/GP service measurements collection.

Communications service reliability. Important but not critical. Prediction service works also if there are some missing values, since there are procedures to replace them.

Communication service availability. Not critical. 99.9% (3 nines meaning communications downtime per month of 43 minutes) or even more is acceptable.

Security. Important but not critical. If a few data are corrupted, it is not a big problem. Of course, if all the data of a certain period are wrong then also the prediction would be wrong. But in such scenario, there will be already other services that are more critical suffering from the bad data.

Table 5.24.5-1 shows communications requirements for the LP/GP service.

Table 5.24.5-1: Communications requirements of Load and Generation Prediction service

| **Characteristic parameter** | | | | **Influence quantity** | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Communica­tion service availability: target value** | **Communication service reliability: mean time between failures** | **End-to-end latency: maximum (notes 1, 2)** | **Service bit rate: user experienced data rate (note 2)** | **Message size [byte] (note 2)** | **Transfer interval: target value (note 2)** | **Survival time (note 2)** | **UE speed** | **# of UEs** | **Service area** |
| 99.9% |  | Not critical | 100 bit/s | < 1000 | 1 minute |  | Stationary | < 30 per km2 | several km2 up to 100,000 km2 |
| NOTE 1: Unless otherwise specified, all communication includes 1 wireless link (UE to network node) rather than two wireless links (UE to UE).  NOTE 2: It applies to UL. | | | | | | | | | |

### 5.24.6 Potential New Requirements needed to support the use case

None.

# 6 Considerations

## 6.1 Potential security considerations

(void)

In order to guarantee high level of secured communication for energy applications, as described in clause 5.10, it is important to support secured communication between the 5G core network and energy applications.

A new potential security requirement i.e. [CPR 009] is identified in clause 7.1.

## 6.2 Potential charging considerations

None.

# 7 Consolidated potential requirements and KPIs

## 7.1 Consolidated potential requirements

Table 7.1-1 - Consolidated Potential Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| CPR # | Consolidated Potential Requirement | Original PR # | Comment |
| CPR-7.1-1 | The 5G system shall support an end-to-end latency of less than 5ms or 10ms, as requested by the UE initiating the communication. | PR[5.4]-001 |  |
| CPR-7.1-2 | The 5G system shall support communication channel symmetry in terms of latency (latency from UE1 to UE2, and latency from UE2 to UE1) between the two UEs, with the max asymmetry < 2ms. | PR[5.4]-002.option1 |  |
| CPR-7.1-3 | Based on MNO policy, the 5G network shall provide suitable means to allow a trusted third party to monitor LAN-VN performance parameters, to configure and receive information for conditions relevant to a specific UE, network and specific configuration aspects of the UE in the VN. | PR[5.7]-001 |  |
| CPR-7.1-4 | The 5G system shall provide a means by which an MNO informs 3rd parties of network events (failure of network infrastructure affecting UEs in a particular area, etc.). | PR[5.7]-002 |  |
| CPR-7.1-5 | Based on operator policy, the 5G system shall provide means by which an MNO informs 3rd parties of changes in UE subscription information. The 5G system shall also provide a means for 3rd parties to request this information at any time from the MNO. (note 1) | PR[5.7]-005 |  |
| CPR-7.1-6 | Based on operator policy, the 5G system shall provide means for the 3rd parties to request changes to UE subscription parameters for access to data networks, e.g. static IP address and APN. | PR[5.7]-005a |  |
| CPR-7.1-7 | The 5G system shall provide a means by which an MNO can inform 3rd parties of changes in the RAT type serving UE, cell ID, quality of signal information, change in frequency band assigned with a suitable frequency via OAM and/or 5G core network to aid the 3rd party user in taking proactive actions to achieve their own service availability. | PR[5.7]-006 |  |
| CPR-7.1-8 | The 5G system shall enable support of a mechanism to support authentication and secured communication between the 5G system Core Network and a 3rd party's application function, in order to provide secure end to end communication service. | PR[5.10]-001 |  |
| CPR-7.1-9 | The 5G system shall provide a mechanism for a 3rd party to report to an MNO service degradations, communications loss and sustained connection loss. These reports use a standard form. The specific values, thresholds and conditions upon which alarms occur could include e.g. the measured values for latency, data rate, availability, jitter, etc. for a UE, its location, and the time(s) in which the degradation occurred. (notes 2, 3) | PR[5.11]-001 |  |
| CPR-7.1-10 | The 5G System should support the IEC 61850-9-3 [29] profile and IEEE Std C37.238-2017 [24]. | PR[5.13]-001 |  |
| CPR-7.1-11 | 5G system should support at least one of the two profiles for synchrophasor communications: IEC 61850-90-5:2012 [26], or IEEE Std C37.118.2-2011 [28]. | PR[5.13]-002 |  |
| CPR-7.1-12 | The 5G system should support the IEEE 802.1Q QoS profile as defined IEC 61850-90-5 [26]. | PR[5.13]-003 |  |
| CPR-7.1-13 | The 5G system shall support delivery of the same UE originated data to a group of recipient UEs distributed over a large geographical area in a resource-efficient manner in terms of bandwidth. | PR[5.13]-004 |  |
| CPR-7.1-14 | The 5G system shall allow an originating UE to request a communication service to send data to different groups of UEs at the same time. | PR[5.13]-005 |  |
| CPR-7.1-15 | The 5G system shall allow a UE to request different QoS for the communication in each of those groups. | PR[5.13]-006 |  |
| CPR-7.1-16 | The 5G system shall provide a mechanism for an MNO, based on MNO policy, to automatically report to 3rd party' service degradations, communications loss and sustained connection loss in a specific geographic area (e.g. a cell sector, a cell or a group of cells.) These reports use a standard form. The specific values, thresholds and conditions upon which alarms occur could include e.g. the measured values for latency, data rate, availability, jitter, etc. for a UE, its location, and the time(s) in which the degradation occurred. | PR[5.17]-002 |  |
| CPR-7.1-17 | Subject to regulatory requirements and operator policy, the 5G system shall support a mechanism by which an MNO can identify the uninterruptable power supply status of the MNO's infrastructure, specifying which physical regions would be affected in terms of physical topology, as this information will facilitate energy system recovery operations | PR[5.18]-001 |  |
| CPR-7.1-18 | Subject to regulatory requirements, the 5G system shall support a mechanism by which a third party can communicate the energy system recovery status in terms of location and time table to the MNO, as this information will facilitate MNO operations to facilitate energy system recovery. (note 4) | PR[5.18]-002 |  |
| CPR-7.1-19 | The 5G system shall enable recipient UEs to indicate their interest in receiving data from a specific originating UE. | PR[5.16]-003 |  |
| NOTE 1: Examples of UE subscription information include IP, 5G LAN-VN membership address and APN/DNN. These changes can have strong impacts in the stability of the 3rd party service.  NOTE 2: What the MNO does with such reports is out of scope of 3GPP specifications.  NOTE 3: The above potential requirement expresses the need for reporting by a third party to the 5GS and leaves it to downstream groups (in this case SA5) to work out the implications.  NOTE 4: It is assumed that once aware of the proximity and duration of the energy outage, the MNO may manage the 5G nodes affected by the outage to make use of the power autonomy remaining in the 5G nodes, e.g. prioritizing the delivery of resources to support the energy system operations communications. Power consumption for energy system operations must be optimized so that the service recovery can be remotely orchestrated by the energy utility. | | | |

## 7.2 Consolidated potential KPIs

Table 7.2-1 KPI Table of Periodic Communication Services

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Use case** | **Experienced data rate** | **availability** | **Transfer interval: target value** | **Message size** | **Service area** | **Max Allowed End-to-End latency** | **density** |
| 5.1  Distributed Energy Storage -monitoring | UL: > 16 Mbit/s (urban), 640 Mbit/s (rural)  DL: > 100 kbit/s  (note 1) | DL: >99.90% | UL: 10 ms | UL: 50 x 16 kbyte | - | DL:<10 ms UL:<10 ms | >10 /km2 (urban), >100 /km2 (rural)  (storage node density, note 2) |
| 5.1  Distributed Energy -Storage  Data collection | UL: > 128 kbit/s (urban), 10.4 Mbit/s (rural)  DL: > 100 kbit/s  (note 1) | DL: >99.90% | UL: 1000 ms | UL: 50 x 26 kbyte  DL: >100 kbyte | - | DL:<10 ms UL:<1000 ms | >10 /km2 (urban), >[100 /km2 (rural)  (storage node density, note 2) |
| 5.2  advanced metering | UL:<2 Mbit/s DL:<1 Mbit/s | >99.99% | - | - | - | General information data collection: <3000 ms  (note 3) | <10000/km2 (connection density, note 4) |
| 5.3  Distributed Feeder Automation | 2 Mbit/s to 10 Mbit/s | 99.999% | Normal:-1s;  Fault:2ms - | - | - | <10 ms  (see note 6)-  Latency jitter <50 µs  (note 5) | 54/km²  (see note 7)  78/km2 (connection density, note 8) |
| **5.5**  Distribution Automation (DA), centralized architecture | 9.6-100 kbit/s | 99.999% | - | - | - | 100 ms – 2 s | 100/km2 concentrated rural, 10/km2 semi-urban |
| 5.8  Smart Distribution Transformer Terminal | >2 Mbit/s (note9) |  |  |  | 100 m ~ 500 m, outdoor, indoor / deep indoor | 10 ms, 100 ms, 3 s (note10) | 500 /distribution area (note 11) |
| **5.12**  Distribution Intelligence – FLISR  High speed current differential protection (see NOTE 13 ) | 1,2Mbit/s~2,5 Mbit/s | > 99,999 % | ≤ 1 ms~2ms | <245 byte | - several km2 | 5 ms~15ms | ≤ 100/km2 |
| 5.15  Distributed Energy Resources and Microgrids  (note 9 ) | 5.4 Mbit/s | 99.9999 % | ≤ 1 ms | 140 byte | - | 3 ms | - |
| 5.22  ensuring uninterrupted MTC service availability during emergencies | < 1 kbit/s per DER | 99.9999 % | 100 ms  (notes 10, 11 ) | - | - | - | - |
| NOTE 1: This KPI is to require data rate in one Energy storage station which may provide via one or more 5G connections and via one or more 3GPP UE(s) at the same time.  NOTE 2: It is used to deduce data volume in an area which has multiple energy storage stations. The data volume can be deduced through follow formula: ( Current + other data) data rate per storage station \* (Storage node density /km2) \* (Active factor/km2) + video data rate per storage station \* (Storage node density /km2). In general, the Active factor is 10%  NOTE 3: It is one way latency from 5G IoT device to backend system while the distance between them is no more than 40 km i.e. city range. The command implementation need 100 ms.  NOTE 4: It is the typical connection density in today city environment. With the evolution from meter centralization collection to sockets in home directly collection, the connection density is expected to increase 5-10 times.  NOTE 5: The latency jitter is required for the switch off between the active and standby communication links  NOTE 6: It is the one way delay from a distributed terminal to 5G network.  NOTE 7: When the distributed terminals are deployed along overhead line, about 54 terminals will be distributed along overhead lines in one square kilometre with the power load density is 20MW/km2.  NOTE 8: When the distributed terminals are deployed in power distribution cabinets, and considering the power load density is 20 MW/km2, there are about 78 terminals in one square kilometre.  NOTE 9:It is the smart metering application data rate between the Smart Distribution Transformer Terminal and energy end equipment. Once there are multiple smart grid applications, it is required more data rate.  NOTE 10:It depends on different applications supported by the Smart Distribution Transformer Terminal. The less the latency is, the more applications can be supported.  NOTE 11:The distribution area is circular with range between 100 m and 500 m (0.031 km2 to 0.785 km2).  NOTE 12: UE to UE communication is assumed.  NOTE 13: Unless otherwise specified, all communication includes 1 wireless link (UE to network node or network node to UE) rather than two wireless links (UE to UE).  NOTE 14: It applies to both UL and DL unless stated otherwise. | | | | | | | |

Table 7.2-2 KPI Table of Aperiodic Communication Services

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Use case** | **Max allowed**  **end-to-end**  **latency** | **Experienced data rate** | **Communication service availability** | **Message size** | **Service area** | **Reliability** | **Storage node density # /km2 (note 2)** |
| 5.1  Distributed Energy Storage  Energy storage station: video | DL:<10 ms  UL:<1000 ms  (rural) | UL: >5 Gbit/s DL: >100 kbit/s  (see note 1) | - | - | - | DL: >99.90% | >[x]\*100 |
| 5.2  Advanced metering | Accuracy fee control: < 100 ms (note2); | DL:<1 Mbit/s |  |  |  | >99,99% |  |
| 5.12  Distribution Intelligence – FLISR  Feeder automation  (note 2) | 20 ms | - | > 99.999 % | < 100 byte | several km2 | - | - |
| 5.15  Distributed Energy Resources and Microgrids (note 2) | <3 ms | - | > 99.9999 % | 160 byte | - | - | - |
| NOTE 1: The required data rate in one Energy storage station which may provide via one or more 5G connections and one or more 3GPP UE(s) at the same time. It can be calculated with following formula: 12.5 Mbytes/s \* 50(containers) \* 8 = 5 Gbit/s  NOTE 2: The accuracy fee control latency here is for communication one way latency from backend system to 5G IoT device while the distance between them is no more than 40 km i.e. city range.  NOTE 3: UE to UE communication is assumed. | | | | | | | |

Table 7.2-3 Clock Synchronization Service Performance Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Use case** | **User-specific clock synchronicity accuracy level [65]** | **Number of devices in one Communication group for clock synchronisation** | **Clock synchronicity requirement** | **Service area** | **5GS synchronicity budget requirement** |
| 5.3  Distributed Feeder Automation | - | 54/km²  (note 1)  78/km2  (note 2) | - | several km² | <10 µs |
| 5.12  Distribution Intelligence – FLISR  feeder automation aperiodic deterministic communication  and  High speed current differential protection periodic deterministic communication | - | ≤ 100/km2 | - | several km² | ≤ 10 µs |
| 5.19  Applications Using IEC 61850-9-2 Sampled Values  Smart Grid: Synchronicity between sync master and PMUs This range covers the extreme cases where the PTP clock in the end device uses 5G sync modem as direct time-source (1 µs)  The 5G sync modem acts as PTP GM or 5G sync modem provides PPS output to PTP GM at the top of the Ethernet based synchronization chain with up to 15 transparent clocks or 3 boundary clocks (250 ns). | 4 | Up to 100 UEs | <250 ns-1 µs [7]  (note 3) | < 20 km² | - |
| 5.19  Applications Using IEC 61850-9-2 Sampled Values  Smart Grid: Power system protection in digital substation with merging units, line differential protection and synchronization | 4a | Up to 100 UEs | <10-20 µs [64]  (note 3) | < 20 km² |
| 5.19  Applications Using IEC 61850-9-2 Sampled Values  Smart Grid: Event reporting and Disturbance recording use-cases | 4b | Up to 100 UEs | <1 ms [64]  (note 3) | < 20 km² |
| NOTE 1: When the distributed terminals are deployed along overhead line, about 54 terminals will be distributed along overhead lines in one square kilometre with the power load density is 20MW/km².  NOTE 2: When the distributed terminals are deployed in power distribution cabinets, and considering the power load density is 20MW/km², there are about 78 terminals in one square kilometer.  NOTE 3: The clock synchronicity requirement refers to the clock synchronicity budget for the 5G system, as described in Clause 5.19.6.1. | | | | | |

# 8 Conclusion and recommendations

The study has analysed a number of use cases of Smart Grid which are enabled by 5G system. The use cases demonstrate the anticipated enhancements in the 5G system in order to use the 5G system

* to support periodic communication and aperiodic communication required by different Smart Grid use cases;
* to support clock synchronization required by Smart Grid use cases;
* to support required information exchange between 5G system and a trusted 3rd party;
* to support one or multiple profiles standardized in IEC or IEEE;
* to support secured communication between the 5G system and a 3rd party’s application function.

Security considerations are captured in clause 6. The consolidated potential requirements and KPIs are in clause 7 of the TR. The contents of clause 6 and clause 7 is proposed to be considered as the basis of normative Release 18 requirements to support the Smart Grid service.

Annex A: Underground 3GPP Access

## A.1 Description

The topic of this annex is transport networks, normally out of scope of 3GPP standardization. For this reason, the material is provided as an informative annex.

This use case considers how to provide 3GPP access underground. Equivalently, this use case considers providing 3GPP access anywhere in which 3GPP access cannot penetrate.) The use case considers what actions to take from the perspective of a facility – to provide smart energy services to components that are located underground.

This is a relevant use case for smart energy because there are many facilities in the energy system which are either underground or inside structures that have thick walls with little or no ability for transmissions to penetrate.

There are essentially three possible approaches – as shown in Figure A.1-1, below.

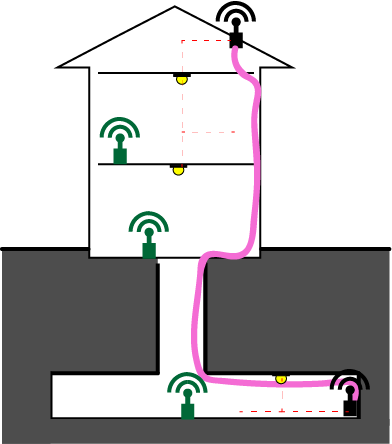


Figure A.1-1: Underground Access Approaches

The radio access on the roof can be **extended inside** by means of a cable as shown in pink (e.g. coaxial cable, with support hardware) to provide radio access to an indoor station (on the lower right, underground.)

Another approach is to provide a **gateway** **and a wireless extension topology**, as shown in green. This could provide backhaul to a 3GPP access station in the lower right. Alternatively, all access within the building and underground could be accomplished by means of non-3GPP access. The (fixed mobile) 3GPP access remains on the roof, as a gateway providing network access.

The third approach is to make use of the existing **power line deployment** in the building and underground as a means of providing backhaul to the underground access point. There are a number of Power Line Communications (PLC) standards that are already used to provide data access to the edge of the electrical network, especially to physical locations that cannot be accessed easily in other ways.

Two prominent examples are Open PLC European Research Alliance (OPERA) [16] and G.9960 [17], which are used for support of Ethernet functionality over medium and low voltage power lines in a restricted range. In OPERA, information is modulated using OFDM with a set of 1536 sub-carriers. Effectively, this network provides an Ethernet over a power-line. G.9960 achieves PHY data rates up to 20 Mbit/s and highly robust communications with PHY bit rates up to 5 Mbit/s (using 4x repetition encoding.) 3GPP components can be integrated above this layer two standard that carries Ethernet frames.

OPERA achieves PHY data rates of up to 200 Mbit/s with a bandwidth of 30 MHz (this is typically not achieved in practice. Implementation is done in either 5 MHz or 10 MHz channels with much lower maximum PHY bit rate up to 40 Mbit/s and 80 Mbit/s respectively), for medium voltage (MV) cables. These throughput levels are not achievable at all in low voltage (LV) scenarios in which medium conditions are different to MV's. (This is an area of current development at the time this document was written, with researchers currently performing tests to evaluate the LV scenario.) The evolution of Ghn defined in ITU standard G.9960 might be more adequate for LV broadband power line (BPL) and for this use case (use of the LV cabling within a building) because it was specifically defined for domestic cables.

Whereas adding a cable for range extension through a structure or wireless extension topologies entail extra planning, materials and complexity, power lines already exist in all (modern) structures.

## A.2 Pre-conditions

A facility will include components of the Smart Grid. The facility may either exist, or be planned and built from scratch.

The builders provide an efficient and effective means to extend wireless communication for Smart Grid communications underground (or in a portion of the facility which cannot be penetrated by emissions for wireless communications.)

Figure A.2-1 depicts an example deployment architecture.

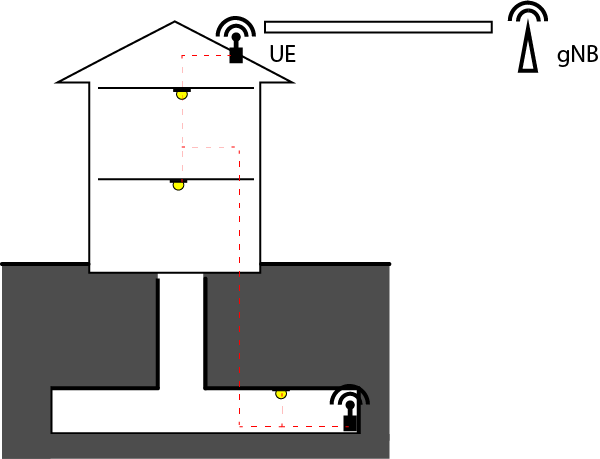


Figure A.2-1: Example Underground 3GPP Access Deployment using PLC

A PLC connection between the UE and the underground gNB has been configured. The UE has a preconfigured tunnel to the MNO's network. The UE's user plane tunnel transports both the user plane and control plane traffic of the underground gNB. The UEs that camp on the underground gNB have full 5G service, limited only by the (limited) bandwidth available (and added latency) due to the PLC and UE to gNB links.

## A.3 Service Flows

The power lines in the facility are checked for their suitability for transmission of communications data. Power line communication termination is placed in the radio access station in the roof and the 3GPP access indoor station underground. Communications through the facility enable communication to be performed by the indoor station, then using the backhaul provided by the PLC, to communication via the access station on the roof.

## A.4 Post-conditions

The facility has underground 3GPP communication without need for additional wires (for a coverage repeater) or an indoor wireless extension topology. While the performance of the underground access will be limited to the capabilities of the PLC performance, this suffices for the smart energy services operating in the underground location.

## A.5 Existing features partly or fully covering the use case functionality

There are multiple ways that the configuration described in A.3 could be realized with existing 3GPP standards. For example, the indoor station could be a gNB whose backhaul is supported by means of PLC.

Another possibility would be for the indoor station to provide non-3GPP wireless access underground. The PLC could provide backhaul to the rooftop UE. The rooftop UE would then provide network access through a PLMN.

## A.6 Potential New Requirements needed to support the use case

This use case is included for completeness but no new requirements have been identified.

Annex B:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/comment | New version | |
| 2020-08 | SA1#91e | [S1-203164](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\inbox\S1-203164r1.zip) |  |  |  | TR Skeleton agreed | 0.1.0 | |
| 2020-08 | SA1#91e | [S1-203165](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\docs\S1-203165.zip) |  |  |  | FS\_5GSEI overview | 0.1.0 | |
| 2020-08 | SA1#91e | [S1-203166](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\docs\S1-203166.zip) |  |  |  | FS\_5GSEI scope | 0.1.0 | |
| 2020-08 | SA1#91e | [S1-203337](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\Agendas\docs\S1-203337.zip) |  |  |  | Use Case of Distributed Power Storage | 0.1.0 | |
| 2020-08 | SA1#91e | [S1-203338](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\Agendas\docs\S1-203338.zip) |  |  |  | Use Case of Advanced Metering for Smart Grid | 0.1.0 | |
| 2020-08 | SA1#91e | [S1-203339](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\Agendas\docs\S1-203339.zip) |  |  |  | Use case of Smart Metering | 0.1.0 | |
| 2020-08 | SA1#91e | [S1-203340](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\Agendas\docs\S1-203340.zip) |  |  |  | Use Case of Distributed Automation | 0.1.0 | |
| 2020-08 | SA1#91e | [S1-203342](file:///D:\3GPP_SA1\TSGS1_91e_ElectronicMeeting\Agendas\docs\S1-203342.zip) |  |  |  | Use case of line current differential protection in power distribution grid | 0.1.0 | |
| 2020-08 | SA1#91e | S1-203343 |  |  |  | Smart Energy Differentiated QoS for Transported Encrypted Data | 0.1.0 | |
| 2020-08 | SA1#91e | S1-203344 |  |  |  | Service Lifetime for Utility Communication Services Deployments | 0.1.0 | |
| 2020-08 | SA1#91e | S1-203345 |  |  |  | Remote DSO management of connectivity for Smart Energy | 0.1.0 | |
| 2020-11 | SA1#92e | [S1-204093](file:///C:\Users\almodovarchicojl\Desktop\TSGS1_92_Electronic_Meeting\Docs\S1-204093.zip) |  |  |  | Remove editor note about underground coverage | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204417](file:///C:\Users\x250\Downloads\docs\S1-204417.zip) |  |  |  | Update to Advanced Metering UC | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204418](file:///C:\Users\x250\Downloads\docs\S1-204418.zip) |  |  |  | Update to distributed automation UC | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204419](file:///C:\Users\x250\Downloads\docs\S1-204418.zip) |  |  |  | Update to Remote DSO management of connectivity for Smart Energy Use Case | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204420](file:///C:\Users\x250\Downloads\docs\S1-204420.zip) |  |  |  | Update: Smart Energy Differentiated QoS for Transported Encrypted Data | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204421](file:///C:\Users\x250\Downloads\docs\S1-204421.zip) |  |  |  | Use case of Smart Distribution Transformer Terminal | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204422](file:///C:\Users\x250\Downloads\docs\S1-204422.zip) |  |  |  | UC of Isolation for Smart Grid Applications | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204423](file:///C:\Users\x250\Downloads\docs\S1-204423.zip) |  |  |  | Gateway vs. End to End Security Use Case | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204424](file:///C:\Users\x250\Downloads\docs\S1-204424.zip) |  |  |  | QoS Monitoring and Reporting Mechanisms | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204202](file:///C:\Users\almodovarchicojl\Desktop\TSGS1_92_Electronic_Meeting\Docs\S1-204202.zip) |  |  |  | Energy Substation Surveillance | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204341](file:///C:\Users\almodovarchicojl\Desktop\TSGS1_92_Electronic_Meeting\Docs\S1-204341.zip) |  |  |  | Underground 3GPP Access | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204342](file:///C:\Users\almodovarchicojl\Desktop\TSGS1_92_Electronic_Meeting\Docs\S1-204342.zip) |  |  |  | Use case on "Distribution Intelligence – self-healing" | 0.2.0 | |
| 2020-11 | SA1#92e | [S1-204343](file:///C:\Users\almodovarchicojl\Desktop\TSGS1_92_Electronic_Meeting\Docs\S1-204343.zip) |  |  |  | Use Case of supporting communication for the transmission of synchrophasors in wide-area Smart Grid | 0.2.0 | |
| 2021-03 | SA1#93e | [S1-210438](file:///C:\Users\sultan\AppData\Local\Microsoft\Windows\INetCache\Content.Outlook\4XT0V618\docs\S1-210438.zip) |  |  |  | Clarify the KPI table in section 5.2 | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210437 |  |  |  | Update to Distributed Feeder Automation use case | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210156 |  |  |  | Review of new requirements identified by 22.867 for 5.5 Smart Energy Differentiated QoS For Transported Encrypted Data | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210439 |  |  |  | P-CR 22.267 clause 5.5 – update KPIs and requirements | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210441 |  |  |  | Update to 5.8 Smart Distribution Transformer Terminal | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210442 |  |  |  | Review of new requirements identified by 22.867 for 5.9 Use case of isolation demand for energy application | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210443 |  |  |  | P-CR 22.267 clause 5.11 – QoS Reporting Requirement Update | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210444 |  |  |  | Smart Grid\_clarifications to requirements | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210445 |  |  |  | Update to the Use Case of supporting communication for the transmission of synchrophasors in wide-area Smart Grid | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210212 |  |  |  | Smart Grid\_Update to sec 5.13 | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210446 |  |  |  | Use case on "Distributed Energy Resources and Micro-Grids" | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210447 |  |  |  | Use Case for Protection of interconnection between renewable and utility grid | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210448 |  |  |  | Use Case of Utility Service Operator M2M service management platform in Smart Energy | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210449 |  |  |  | 22.876 P-CR: Coordination for Energy Recovery Use Case | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210450 |  |  |  | Use case on applications using IEC 61850-9-2 sampled values | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210451 |  |  |  | Use Case of power distribution grid state estimation service | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210452 |  |  |  | Use Case of power distribution grid load and generation prediction service | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210453 |  |  |  | Use Case of power distribution grid power control service | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210454 |  |  |  | Use Case of ensuring uninterrupted MTC service availability during emergencies | 0.3.0 | |
| 2021-03 | SA1#93e | S1-210455 |  |  |  | Edge cloud driven data acquisition (edgePMU) | 0.3.0 | |
| 2021-03 | SA#91e | SP-210205 |  |  |  | Presentation for information, MCC clean-up | 1.0.0 | |
| 2021-05 | SA1#94e | S1-211101 |  |  |  | remove the editor notes in section 5.1.5 and 5.1.6 | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211427 |  |  |  | Add reference for KPI in section 5.2 | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211428 |  |  |  | remove the editor notes in section 5.3 | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211429 |  |  |  | update KPI table and question to section 5.5.6 | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211430 |  |  |  | 22.867 P-CR: FS\_5GSEI P-CR for 5.7 – revisiting requirements | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211431 |  |  |  | Add a KPI table for section 5.8 | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211432 |  |  |  | Update to the Use Case of 5\_13 supporting communication for the transmission of synchrophasors in wide-area Smart Grid | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211433 |  |  |  | Update to the Use Case of 5\_16 Protection of DER and grid interconnection | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211434 |  |  |  | Proposal for consolidated potential requirements in FS\_5GSEI | 1.1.0 | |
| 2021-05 | SA1#94e | S1-211435 |  |  |  | Consolidated KPI for FS\_SEI | 1.1.0 | |
| 2021-06 | SA#92e | SP-210510 |  |  |  | Raised to v.2.0.0 by MCC for approval | 2.0.0 | |
| 2021-06 | SA#92e | SP-210510 |  |  |  | Raised to v.18.0.0 by MCC following approval | 18.0.0 | |
| 2021-06 | SA#92e | SP-210510 |  |  |  | Corrected logo (5G->5GA) | 18.0.1 | |
| 2021-09 | SA#93e | SP-211097 | 0001 | 1 | B | Addressing EN resolution in 7.1 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0002 | 1 | D | Addressing EN resolution for timely term meaning | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0003 | 1 | D | Addressing EN resolution for standard use cases in 5.7.1 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0004 | 1 | D | Addressing EN resolution for RAN parameters in 5.7.1 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0005 | 1 | D | Addressing EN resolution in clause 5.7.5 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0006 | 1 | D | Addressing EN resolution in clause 5.7.2 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0007 | 3 | F | Addressing EN resolution in clause 5.7.6 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0008 | 1 | F | Update Consolidated PR and KPI tables in Section 7 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0009 | 1 | F | Update to conclusion and recommendation | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0010 | 1 | B | Security considerations | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0011 | 1 | D | Editorial Updates to TR22.867 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0012 |  | F | Resolution of Editor's Notes from Clause 5.5.6 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0013 |  | F | USIM Related Requirements for Manageability | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0014 | 1 | D | Removal of Editor s Notes from Clause 5.11 | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0015 |  | D | Removal of Editor's Note in Annex A | 18.1.0 | |
| 2021-09 | SA#93e | SP-211097 | 0016 | 1 | B | Update Consolidated PR in Section 7 | 18.1.0 | |
| 2021-12 | SP-94 | SP-211496 | 0017 | 2 | D | Get the missing figure A.1-1 back | 18.2.0 | |
| 2021-12 | SP-94 | SP-211496 | 0018 | 1 | D | Removal of all existing Editor s Notes in TR 22.867 | 18.2.0 | |
| 2021-12 | SP-94 | SP-211496 | 0019 | 1 | C | Reference corrections for clause 2 and clauses in 5.13 | 18.2.0 | |
| 2021-12 | SP-94 | SP-211496 | 0020 | 2 | D | Filling all CPRs into a normalized table | 18.2.0 | |