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Smart5Grid: Demonstration of 5G Solutions for Smart Energy Grids of the Future

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Smart5Grid

Demonstration of **5G** solutions for **SMART** energy **GRID**s of the future

Summary

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Introduction_(1)

The "Framework"

- *The "**power grid**" (networks of power plants, energy transmission towers, substations, poles and wires) can be assessed as the **"largest machine in the world"**, as **electricity is the most versatile controlled form of energy.***

- ***For efficient transfer of electrical power, "smart grids" combine traditional grids with communication and information control technologies, targeting to achieve efficiency, cleanliness and security, and "reshaping" the modern landscape in energy transportation.***

- *The **fast development of 5G**, especially in verticals like the energy sector, will offer **more opportunities for growth and market evolution**, also providing options for innovation and investments.*

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Introduction_(2)

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5G Challenges for the Energy Sector

- ***5G networks will be an important ingredient for the development of smart grid technologies, especially allowing the grid to adapt better to the dynamics of renewable energy and distributed generation.***

- ***5G mobile networks will help to integrate previously unconnected devices to smart grids, for accurate monitoring and improved forecasting of their energy needs.***
- ***Managing of energy demand will become more efficient.***
- ***The smart grid will allow for:*** *(i) easier balance of the energy loads; (ii) reduction of electricity peaks and; (iii) reduction of energy costs.*
- *From the perspective of power supply,* ***5G is expected to enable better efficiency, observability and controllability of the power system, especially at the distribution side****.*
- *Energy suppliers will be able to collect and store power grid related data at much faster rates, ensuring secure and stable power supply, while risk mitigation and fault management will become simpler and more straightforward.*

Introduction_(3)

The Current State

- **Until today, the power distribution grids have only seen very little application of mobile-network technology and the coverage of the current communication networks remains practically low.**

- ***Most of the applied efforts practically focus on the three following pillars to achieve efficient communication at the power distribution level:***
  - ***Power Line Communications (PLC)*** *that use the distribution lines and cables as a transmission channel;*
  - ***Wireless or Radio Communications (WLC)*** *that use the radio technologies for transferring the information between two or more points, and;*
  - ***Fibre Optical Communications (FOC)*** *that use pulses of light through an optical fibre for transmitting information.*

Concerns for inactive involvement of telecom operators in the energy vertical

- *Utility companies may use communication networks based on a combination of two or more of these technologies for grid access, backhaul and backbone communications, based on specific applications.*
- *Network operators have not participated actively and widely in providing communication services for the transmission and distribution grid operation, due to the variety of network technologies being used by the power grid operators.*
- *Traditional 3G/4G public network is a large all-in-one channel / single shared network, where operators cannot provide different network slices to preferred customers.*
- *Using FOC to build communication networks on the distribution level has difficulties in the deployment due to the massive-connections and the wide areas where coverage is required.*

Introduction_(4)

The Way Forward

- ***"Smart grid transformation" must rely on existing electrical infrastructures of the generation, transmission, distribution and consumption levels of a power grid.***
- ***"Smart grid transformation" needs to connect energy metering and measuring devices through a communication network, that enables real-time information flow and control among power devices.***
- ***5G (due to the multiplicity of its benefits such as flexibility, reliability, coverage throughput, latency and massive device support), is the first communication technology expected to address the plethora of current and future challenges of the energy sector.***

The Smart5Grid Context_(1)

Basic Aim

- **Smart5Grid aims to introduce an open 5G experimental facility, supporting integration, testing and validation of existing and new 5G services and NetApps from third parties** *(i.e., SMEs, developers, engineers, etc., that do not belong in the consortium)* ***since underpinning experimentation with a fully softwarised 5G platform for the energy vertical industry <u>is one of the key targets</u> of the project*.**

- **In order to supply start-ups and newcomers with the opportunity to accelerate their growth in the high impact industry of the energy vertical, Smart5Grid aims to provide an open access NetApp repository, provisioning support and assistance to third parties through a clear and trustworthy experimentation roadmap.**

- **Smart5Grid aims to revolutionize the Energy Vertical industry through the successful establishment of four (-4-) fundamental functions (use cases) of modern smart grids:**
  - ***Automatic power distribution grid fault detection (DSO-Operations)*.**
  - ***Remote inspection of automatically delimited working areas at distribution level (DSO-Safety).***
  - ***Millisecond level precise distribution generation control.***
  - ***Real-time wide area monitoring in a creative cross-border scenario, thus assisting power grid operators and other energy stakeholders (e.g., smart grid operators, distribution system operators/transmission system operators, energy service providers, etc.)***

The Smart5Grid Context_(2)

Challenges

- ***Smart5Grid poses new challenges to communication networks requiring a flexible & orchestrated network, slicing and millisecond-level latency.***

- ***Power distribution companies need new tools to monitor/operate the distribution network and to maintain/increase reliability and Quality of Service (QoS), if they wish to transform today's power distribution grids into "evolved" smart grids, enabling efficient, fast and secure operation***

- ***Smart5Grid's effort identifies the following high-level requirements for the communication network that will allow building innovative and high performance smart grids:***
  - ***Very high device density for connecting thousands of energy metering and power electronic devices, in one location.***
  - ***Very high bandwidth to allow massive data flows from multiple devices simultaneously, permitting remote maintenance and substation monitoring.***
  - ***Ultra-low latency for fault detection, network isolation and operation of recovery devices within one power cycle (i.e. 20ms for the 50Hz frequency used in electric current).***

The Smart5Grid Context_(3)

Detailed project objectives

Objective #1: **Specifying the critical architectural and technological enhancements from previous 5G-PPP Phases** needed to fully enable an open experimental platform for the Energy vertical.

Objective #2: **Design, deployment, operation and evaluation –in real world conditions– of the baseline system architecture and of related interfaces** for the provisioning of an integrated, open, cooperative, and fully featured 5G network platform, customised for smart energy distribution grids.

Objective #3: **Development of an open NetApp repository**. In conjunction with the 5G network facility, the Open Service Repository will have access to network resources and it will be used to develop and accommodate NetApps, providing rapid access and execution environment to developers, third parties, and SMEs from the energy vertical sector.

Objective #4: **Development of high-performance NetApps** for the support of ambitious Smart5Grid energy-oriented use cases.

Objective #5: **Provision of a Validation and Verification (V&V) experimentation framework** for NetApp automatic testing, certification and, integration.

Objective #6: **Realisation of four advanced 5G real-life demonstrations over a wide set of energy related use cases**. Performance exhibition will be conformant to 5G-PPP KPIs.

Objective #7: **Conduction of a market analysis and establishment of new business models**. Detailed techno-economic analysis and road mapping towards exploitation and commercialisation by industry partners and SMEs are also of high priority for the project.

Objective #8: **Maximisation of Smart5Grid impact** to the realisation of the 5G vision by establishing close liaison and synergies with 5G-PPP Phase-2 and -3 projects and the 5G-PPP. **Pursuing of extensive dissemination and communication activities** and assessing the perceived impact from the stakeholders and the wider community.

Smart5Grid Use Cases

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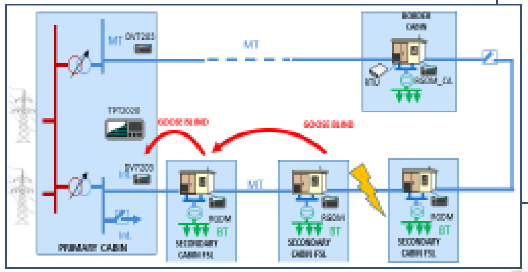
The Smart5Grid Open 5G platform will be demonstrated on four real-life environments of the south-eastern Europe.

The respective use cases target the entire energy service chain

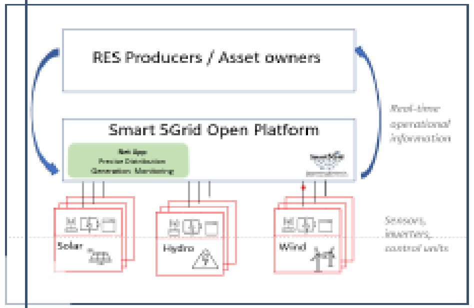
- ***from green power generation, coordinated cross-border transmissions system operation***
- ***to power distribution.***

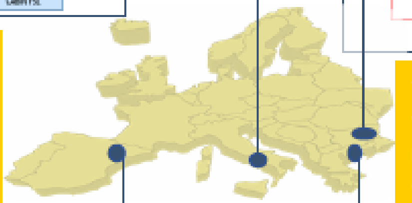
Italian Pilot (DSO-Operations) Automatic power distribution grid fault detection



This pilot will test in real life environment the use of 5G infrastructure and a dedicated monitoring NetApp for facilitating the debugging process of an advanced grid-fault detection and self-healing system in Olbia Region, Italy.

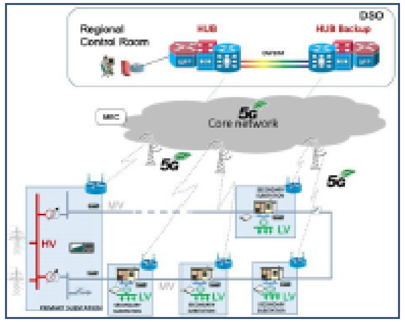
Bulgarian Pilot Millisecond level precision distributed generation monitoring





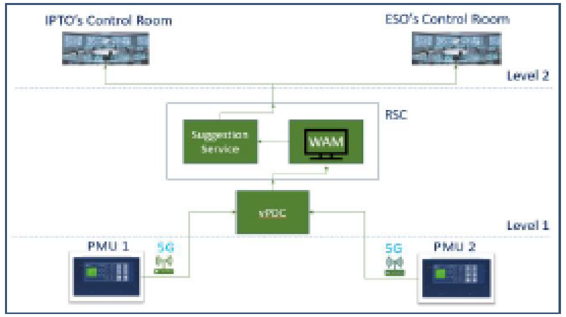
This pilot will test a use-case specific NetApp with the role to allow the electricity producers owning renewable generation assets to use fast, real-time cloud-based tools to monitor plant performance and production parameters for optimal operation and maintenance of the plants and for grid integration facilitation.

Spanish Pilot (DSO- Safety) Remote inspection of automatically delimited working areas at distribution level



This pilot will test a suite of safety monitoring NetApps which exploit user-plain function at the edge, end-to-end latency below 100ms on top of high localization precision.

Greek-Bulgarian Pilot Real-time wide area monitoring



This pilot will test in real life environment the 5G infrastructure and chain network virtualization functions under a Monitoring NetApp which ensures a virtual PDC role.

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Smart5Grid Use Cases – UC1_(1)

Automatic Power Distribution Grid Fault Detection (Use Case #1)

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Motivation:

- A **fault** in a distribution grid is an **abnormal condition** that can be caused by equipment (i.e. transformers and rotating machines) failure, human errors and/or various environmental conditions.

- **Such an error consists of a stressful situation for the DSOs, *since it can have a great impact on the supplied power quality.***
  A fault can create equipment damages and can reduce the electrical system reliability and stability resulting to power interruptions.

- **To maintain a reliable and high-quality power supply to consumers without any interruptions, smart grids and distribution networks require real-time self-healing** *(i.e. the identification and isolation of faults in the backbone network and automatic recovery in less than 1 sec).*
  Manual outage handling in a control centre fails to achieve such short restoration time *(manual switching takes on average 120 minutes),* ***thus automated fault detection solutions are widely used*** *to restore the power supply within a few hundred milliseconds.*

Smart5Grid Use Cases – UC2_(1)

Automatic Power Distribution Grid Fault Detection (Use Case #1)

Motivation:

- **DSOs are incurring high operational expenditures for inspecting and maintaining their infrastructures**, *as the inspection & maintenance of the energy distribution grid assets is a very demanding and essential task.*

- ***Up-to-now, such actions are undertaken by human maintenance crews through visual examination. Thus, dedicated personnel are often exposed to dangerous working conditions**, **such as high heights for tower/pylon climbing inspections**, **difficult ground patrols and often exposures to electrical risks** (e.g. electric arcs that can cause an electrocution) during substations' visits.*

- ***For personnel safety precautions, planned power disruptions are scheduled during the inspection and maintenance procedures and so the capacity and availability of the distribution network is reduced periodically.** When maintenance works are performed in the vicinity of critical equipment of the distribution grid (e.g., transformers, circuit breakers, switchgears, etc.) the working areas are restricted and only authorised personnel can access them.*
    - *It is critical for DSOs to obtain efficient and short-duration inspection and maintenance procedures from central offices to support the risk prevention and help field operators.*
    - *This is done through the provision of advanced information/data, with remote inspection and maintenance procedures, without compromising quality.*

Smart5Grid Use Cases – UC2_(2)

Remote Inspection of Automatically Delimited Working Areas at Distribution Level (Use Case #2)

Motivation:

- ***The Smart5Grid 5G platform will offer a solution for the improvement of working conditions for the power grid maintenance crews and inspection personnel***, *through remote inspection and control of the automatically delimited working areas.*

- ***The 5G eMBB features will permit high-bandwidth communication between the power grid monitoring equipment*** *(i.e. existing permanent and manual sensors and high-resolution cameras of various types)* ***and the cloud-based inspection platform***, ***to be processed with artificial intelligence (AI) and machine learning (ML) based algorithms and inference models.***

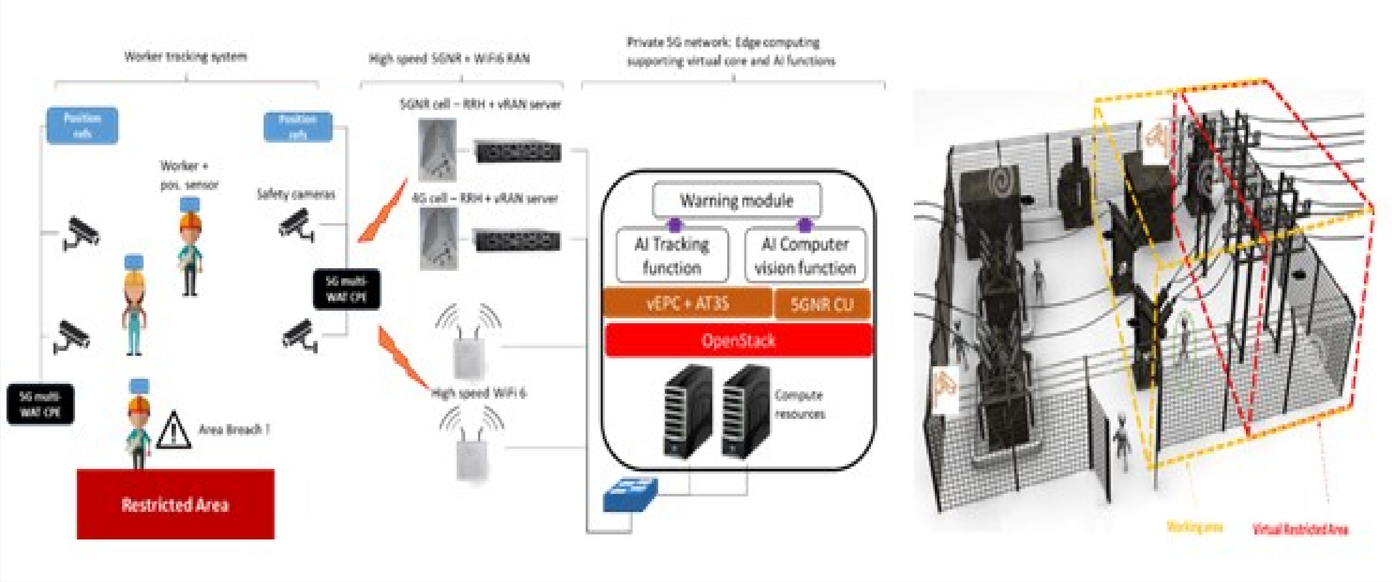
- ***The Smart5Grid project aims to enable remote inspections in high risk areas and real time execution, by serving a variety of distribution network applications and by providing accurate results and information*** *on the operational condition of the power grid assets through augmented reality.*
- ***For maintenance works real-time control will be enabled***, ***to assist the working procedures remotely and automatically*** *without exposing the supervisor personnel to dangerous conditions.*

Smart5Grid Use Cases – UC2_(3)

Remote Inspection of Automatically Delimited Working Areas at Distribution Level (Use Case #2)

- **Smart5Grid will demonstrate the capabilities of the developed NetApps for the remote inspection of automatically delimited working areas at distribution level through the deployment of a private 5G network.**

- ***The developed NetApp will:***
  - ***Generate a detailed 3D volumetric model of the configuration of the power grid assets*** *where the work will be carried out;*
  - ***automatically delimitate the working areas*** *and the authorised personnel;*
  - ***permit the real-time communication of big data*** *generated from the existing permanent and manual sensors and cameras within the working area;*
  - ***allow the real-time remote control of the work and capture the movements of the different operators*** *(authorised and non-authorised), and;*
  - ***provide instant warning signals and alerts.***



Smart5Grid Use Cases – UC3_(1)

Millisecond Level Precise Distribution Generation Control (Use Case #3)

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Motivation:

- ***Today, the vast majority of the communication technologies*** *used for the communication between the RES assets and the power grid* ***are still wire-bound****, including a variety of dedicated Industrial Ethernet and power line solutions,* ***as there was no need for wireless connectivity in the past****.*
- *In addition,* ***the absence of wireless communication has occurred also because most existing wireless technologies could not achieve the demanding requirements of industrial applications****, especially with respect to end-to-end latency, communication service availability, jitter, and reliability.*
- ***With the advent of future Smart Grids and 5G, this will change fundamentally, since wireless connectivity can increase the degree of flexibility, mobility, versatility, and ergonomics required for the energy networks of the future.***

- ***The modern smart grid era will depend on dedicated devices that can monitor the various assets and manage big data, through ultrafast communications and cloud-based apps for efficient processing and decision-making.***
- ***To do that efficiently, there is a need for devices that could help monitor, collect and store data based on which innovative solutions for improving the grid could be made.***
- ***Next-generation hardware and software technology with ultra-fast communications can ensure the smooth integration of the high RESs penetration to the smart grids.***

Smart5Grid Use Cases – UC3_(2)

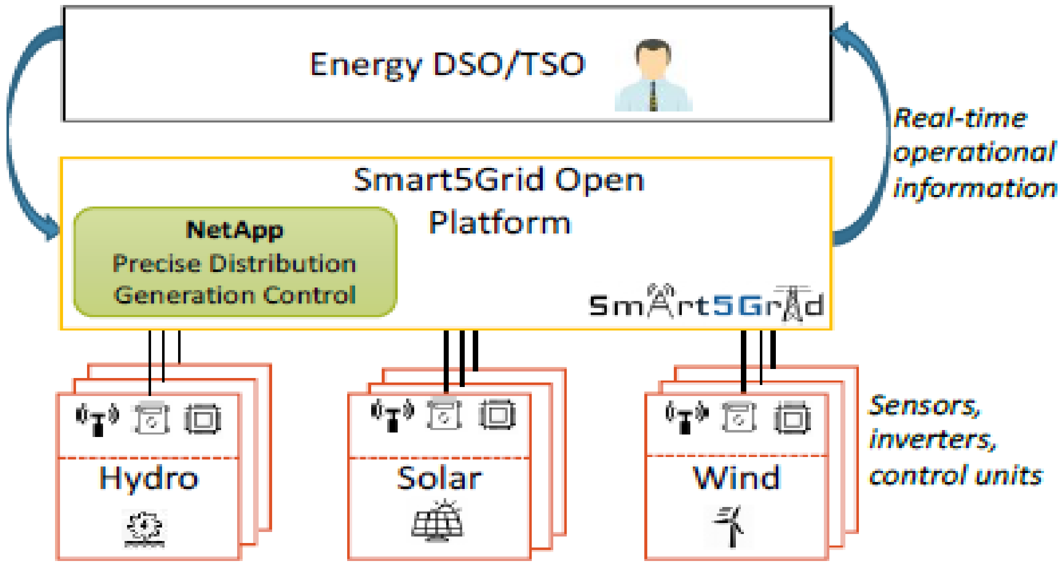
Millisecond Level Precise Distribution Generation Control (Use Case #3)

- ***Smart5Grid will enable the connection of thousands of Medium Voltage (MV) and High Voltage (HV) level decentralised RESs units and their inverters, to a platform with installed 5G communication protocols, which will allow their aggregation and control by the DSOs / TSOs in millisecond rates.***

- *Through the developed platform, **the electricity producers owning renewable generation assets can use fast real-time cloud-based tools to formulate optimal energy scheduling,** according to the power system needs.*

- *Additionally, **they will be able to monitor and rebalance the network by managing the distributed flexibilities provided by their decentralised energy resources** (i.e., Wind Plants, Hydro Plants, Storage and Dispatchable Loads) **according to the incentives provided by the grid services markets and business models** (i.e., aggregators)*

- ***All exchanged messages will be properly secured** (especially in terms of data integrity and authenticity), so that the probability of two consecutive packet errors to be negligible.*



Smart5Grid Use Cases – UC4_(1)

Real-time Wide Area Monitoring (Use Case #4)

Motivation:

- ***Inter-area frequency oscillations represent one of the major challenges that "face" modern power systems, since their appearance is increasing due to the vast changes (i.e. increased penetration of renewable sources, growing energy demand, etc.) and constant expansion.***
- ***The appearance of inter-area oscillations creates many issues*** *such as power quality degradation, limitation of transmission system capacity* ***and on several occasions, it can even lead to system instability.***
- ***The detection and observation of inter-area oscillations is possible only with the use of synchronised measurements provided by the PMUs ((Phasor Measurement Units).***
- ***Exploiting PMU inputs for a robust, decentralised and real-time operational solution, calls for a novel communication infrastructure that will support the Wide Area Measurement Systems (WAMSs) of each smart grid.***
- ***This will take place with the aim to detect and counteract power grid disturbances in real time, while providing the observability needed.***

Smart5Grid Use Cases – UC4_(2)

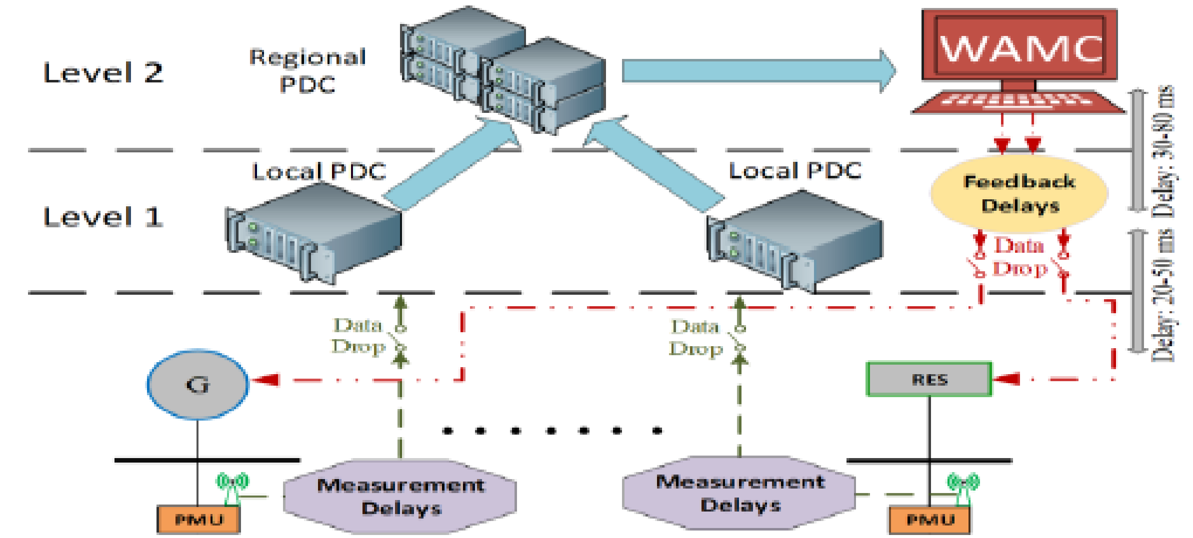
Real-time Wide Area Monitoring (Use Case #4)

- ***Smart5Grid is expected to significantly minimise the communication and transfer delays of the current WAMSs* *via a proposed framework for network configuration and applications for the real-time communication of the time-stamped phasor*, from each PMU (Phasor Measurement Unit) station to the developed virtual PDC (Phasor Data Concentrator).**

- *It is also expected that **the Smart5Grid communication platform will minimise the transfer delays of the PMU measurements and the feedback control signals, while it will also minimise the data dropouts** - such events are experienced using the contemporary communication infrastructure that often compromise the WAMS operation.*

- ***Message loss and corruption and interference with other, lower priority traffic will be avoided as much as possible**.*

- *In this sense,* **Smart5Grid is envisioned to significantly improve the reliability and the performance of the WAMSs,** *contributing in this way to the effective maintenance of the transmission and distribution power grid stability and reliability.*



Concluding Remarks_(1)

Synopsis

- ***Smart5Grid is among the on-going research initiatives supporting transformation of the power distribution grids towards smarter entities, via the beneficial incorporation of innovative 5G features.***

- ***Smart5Grid aims to identify high-level requirements for the communication network, allowing the structuring of innovative and high performance smart grids.***

- ***An innovative platform shall be deployed, via the adoption of 5G network infrastructure and the effective inclusion of suitable Network Applications consisted of chained VNFs.***

Concluding Remarks_(2)

Smart5Grid

Potential Benefits

- ***Through the effective adoption of 5G networks and the expected assistance of the respective NetApps, Smart5Grid facilitates the current energy sector stakeholders*** *(i.e. Distribution System Operators (DSOs) and Transmission System Operators (TSOs))* ***as well as future smart grid shareholders*** *(i.e.: Smart Grid Operators, Independent System Operators, Energy Aggregators, Regional Distribution Organisations and Energy Service Providers (ESPs), etc.)* **so that to:**
  - ***Easily and effectively create and offer advanced energy services;***
  - ***interact in a dynamic and efficient way with their surrounding environment (by assessing and considering multiple options), and;***
  - ***automate and optimise the planning and operation of their power and energy services, thus enhancing their market activity.***

- ***Smart5Grid envisages towards providing a more secure, reliable, efficient and real-time communication framework for the modern smart grids.***

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Concluding Remarks_(3)

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Expectations

- **Smart5Grid leverages on resilience and elasticity (i.e. network slicing) provided by the 5G technology to contribute to an open and flexible platform for secure testing, validation and operation of NetApps**, *specifically targeting to the Renewable Energy Sources (RES) production and distribution of vertical ecosystem(s).*

- **The emerging 5G mobile cellular network** along with the celebrated new features introduced with it (URLLC, mMTC and eMBB) and the concept of MEC which extends the capabilities of cloud computing by bringing it to the edge of the network, **will offer a competent environment for smart grids.**

- **The Smart5Grid architectural framework aims to enable efficient and cost-effective distributed State Estimation (SE) algorithms based on more sophisticated optimisation techniques**, *allowing for smart grid voltage and phase measurements to occur at a much greater frequency than it has been possible by using the legacy measurement infrastructure.*

- **Smart5Grid's open testing platform will allow the implementation and experimentation with appropriate VNFs** (Virtual Network Functions) **and NetApps**, not only to Smart5Grid partners but also to third parties, ***supporting and "giving rise" to an experimental execution environment*** *that increases reliability, availability and maintainability in smart grid energy networks.*

Thank you for your Attention!

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