Smart5Grid - 5G for the Support of Smart Power Grids:
Testing Strategy and Field Implementations for UC#4 Real-Time Wide Area Monitoring of Interconnected Systems

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Smart5Grid

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

Content Overview

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"Abstracted" approach

- The continuously growing, at a fast pace, and the integration of Renewable Energy Sources (RES) in the electrical grid imposes several operational issues for the Transmission System Operators (TSOs).

  - ❖ *This is due to the high stochasticity that characterizes their procedure of energy production.* Additionally, the increasing number of involved parties (producers, consumers and prosumers) requires computations in a much smaller timeframe, in order not only to detect the events but to react in time, so that to prevent faults in the transmission system.

- The criticality of the role of the Phasor Measurement Units (PMUs) is analysed in detail, which provides readings of Voltage, Frequency and Current.

- *The Role of the 5G is to transfer the aforementioned readings, with its Low Latency and High Availability Criteria.*

- *Smart5Grid's UC#4 Wide Area Monitoring tool is presented along with the associated Field Platform Implementations in Northern Greece and Bulgaria.*

- *A complete list of Field Platform Validation Metrics (FPVMs) is elaborated with the equivalent targeted values.*

Introduction 1/2

❑ Current electrical grids are large and interconnected power systems which have served well modern societies. However, a Vision of the Future must address factors such as:
- ✓ The growing demand for Energy
- ✓ Fast depletion of energy sources
- ✓ Unreliability
- ✓ Impact on the Environment

❑ The Smart Grid is a new paradigm shift that combines the electricity, information and communication infrastructures to create a more reliable, stable, accessible, flexible, clean and efficient electric system.

❑ So far, the communication networks dedicated for the needs of power control and automation were handled by the Transmission Systems Operators (TSOs)
- ➢ *Telecom operators played almost no role in the power grids communication infrastructure*
- ➢ *This is expected to change in the era of smart grid !*

Introduction 2/2

➢ **Fifth Generation (5G) Networks** will be an *important enabler* for the development of smart grid technologies. The *adaptation of 5G in the energy vertical* will allow the grid to integrate to the dynamics of renewable energy and distributed generation.

➢ Solar and Wind power tend to more prevalent in the near future, demanding more efficient monitoring and control mechanisms. Towards this direction, Fifth Generation (5G) Networks will assist smart grids to:

   ❖ Control easier bi-directional power flows
   ❖ Support distributed energy sources

➢ Network Slicing, being on of the "unconventional" 5G technologies can divide the physical network into several independent, isolated and demand-based logical networks, *which can ensure the efficient customization and smooth-going of various service needs*.

➢ 3GPP has defined three key sets of Network Slices for 5G Networks:

   ▪ Massive Machine Type Communication (mMMTC) *for efficient monitoring of remote equipment*
   ▪ Ultra-Reliable and Low Latency Communication (URLLC) *for handling of time-bounded traffic data*
   ▪ Enhanced Mobile Broadband (eMBB) *for handling of higher amounts of data in densely populated areas*

These features along with the flexibility of 5G Networks technology can enable a significant shift for the smart grid's communication layer.

- **Smart5Grid** is one of the 19 projects selected by the EC as part of the 5G PPP Phase 3, Part 6, (i.e.: *"5G innovations for verticals with third party services & Smart Connectivity beyond 5G"*), responding to 5G-PPP ICT-41-2020 Call.

- The main common objective of the nine selected projects finally funded under this Call is to provide 5G open experimental platforms that attract and offer opportunities for SMEs and developers to test Network Applications for specific vertical sectors and to create open-source repositories of such applications for wide use and towards standards development.

- Network Applications allow developers to concentrate on building the applications that are specific to the vertical domain on which they concentrate their expertise while leveraging the features and performance of 5G Networks.
  - Additionally, they create an abstraction of the complexities of the 5G Network into a set of requirements, captured in a Network Application descriptor.

The Smart5Grid Concept 2/2

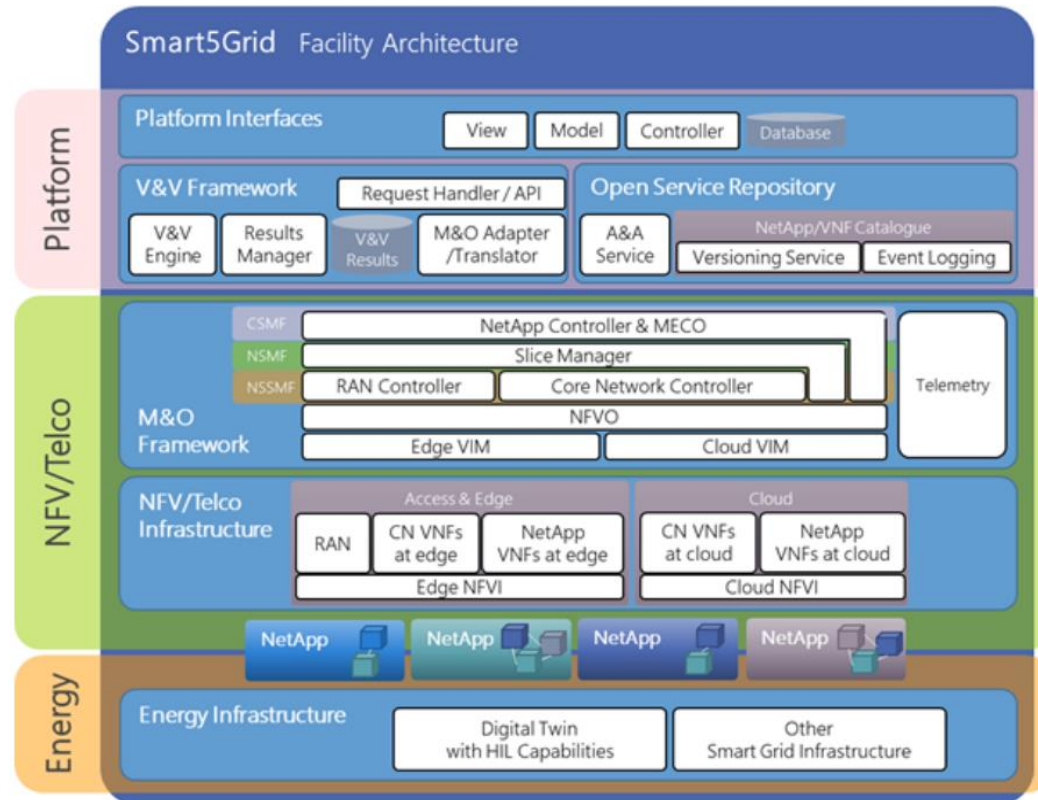The Open Smart5Grid experimental platform aims to be an ecosystem with various "players":

    i.   *Stakeholders in the energy vertical*
    ii.   *ICT Integrators*
    iii.   *Network Application (NetApps) Developers*
    iv.   *Actors in the telecom industry*
    v.   *Network Service Providers in general*

These can "come together" and work together towards the common goal of demonstrating the opportunities offered by the 5G technology in four meaningful cases, *specifically targeting to the Renewable Energy Sources (RES) production and distribution of energy In a vertical ecosystem.*

The four use cases are synoptically referred as below:

❖ UC#1 (Italy) –   *Advanced fault-detection, isolation and self-healing for the power distribution grids*

❖ UC#2 (Spain) –   *Enhanced safety tools for maintenance workers in high-voltage power stations*

❖ UC#3 (Bulgaria) – *Advanced and remote monitoring with millisecond precision for renewable-based power generation units*

❖ UC#4 (Greece and Bulgaria) – *Wide-area monitoring of cross-border transmission grids*

The Smart5Grid Functional Architecture 1/2

Smart5Grid Facility Architecture

Platform
- Platform Interfaces: View, Model, Controller, Database
- V&V Framework: Request Handler / API, Open Service Repository
  - V&V Engine, Results Manager, V&V Results, M&O Adapter /Translator
  - A&A Service, NetApp/VNF Catalogue, Versioning Service, Event Logging

NFV/Telco
- M&O Framework: CSMF, NSMF, NSSMF
  - NetApp Controller & MECO
  - Slice Manager
  - RAN Controller, Core Network Controller
  - NFVO
  - Edge VIM, Cloud VIM
  - Telemetry
- NFV/Telco Infrastructure: Access & Edge, Cloud
  - RAN, CN VNFs at edge, NetApp VNFs at edge
  - CN VNFs at cloud, NetApp VNFs at cloud
  - Edge NFVI, Cloud NFVI
- NetApp, NetApp, NetApp, NetApp

Energy
- Energy Infrastructure: Digital Twin with HIL Capabilities, Other Smart Grid Infrastructure

Smart5Grid's *functional Architecture consists of discrete layers:*

3

- **Platform** – OSR/V&V Framework

- **NFV/Telco** – M&O/NFV/Telco Infrastructure

- **Energy** – Field Devices

- **Platform Layer:** Provides the entry point to the Developers (UI) for the Smart5Grid facility and consists also a web application that manages the authentication and authorization of users. At this top layer also reside the:
  - Validation & Verification (V&V) framework which realizes the testing process for the correct performance of Network Applications.
  - OSR which enables 3rd party Developers to register their Network Applications.

- **NFV/Telco Layer:**
  - Management & Orchestration Framework manages the End-to-End lifecycle of a Network Application deployment. Also it deploys the software components in the form of containers which could be located at the "edge" of the Network to fulfil Low Latency Requirements
  - Telco (access and core network components) orchestrated to meet the demands of the Network Applications.

- **Energy Layer:** Contains the grid components that connect to the Network Applications, such as Cameras and sensors which may provide measurements to the Network Applications.

UC#4 – Real-Time Wide Area Monitoring - Critical Role of Phasor Measurement Units (PMUs) 1/2

➤ The scope of UC#4 is the real-time monitoring of a geographical wide area between Northern Greece and Bulgaria where cross-border power exchanges take place.

➤ The continuous expansion of the European high penetration rate of the Distributed Energy Resources (DERs) significantly increases the complexity of the power system thus making its RT operation and control functions difficult to handle.

➤ The role of the newly created Regional Security Coordinator (RSC) in Thessaloniki, Greece, is to promote regional cooperation and to support the strengthening of neighboring power systems.

➤ As the number of connected DERs, inverter-connected devices dominate, leading to lack of physical inertia. The lack of inertia results in significant variations in the Rate of Change of Frequency (RoCoF), resulting in critical changes in the dynamic behaviour of the system.

➤ This challenge makes the existence of a WAM essential for the stability of the entire interconnected European power system. WAM systems leverage the high accuracy of the PMUs combined with the ultra-low latency and high availability of modern telecommunication networks.

UC#4 – Real-Time Wide Area Monitoring - Critical Role of Phasor Measurement Units (PMUs) 2/2

➢ A Phasor Measurement Unit, also called as a PMU – or a synchrophasor – is a key tool used on electric systems to improve operators' visibility into what is happening throughout the vast grid network. A PMU is a device that measures a quantity called a phasor and it is considered as a most robust device that can enhance the observability of modern power system.

➢ The data originating from several PMUs, placed in a wider area of monitoring, are gathered by the Phasor Data Concentrators (PDCs) devices. Those devices subsequently forward the readings to the next layer of PDCs, until the readings reach the Supervisory Control and Data Acquisition System (SCADA).

➢ So far, the interconnection between PMUs and PDCs is realised through optical fibres with each other ensuring that the data will arrive on time to the destination and that there will not be any security breach or data leakage.

➢ Up to now, this architecture only permits central, predefined and cumbersome implementation of wide-area monitoring and control (WAMC) strategies.

➢ In addition, the installation of a new PMU and its connectivity with the rest of the system is a costly and troublesome procedure for the TSO. Therefore it is essential to optimize the number and installation location of PMUs.

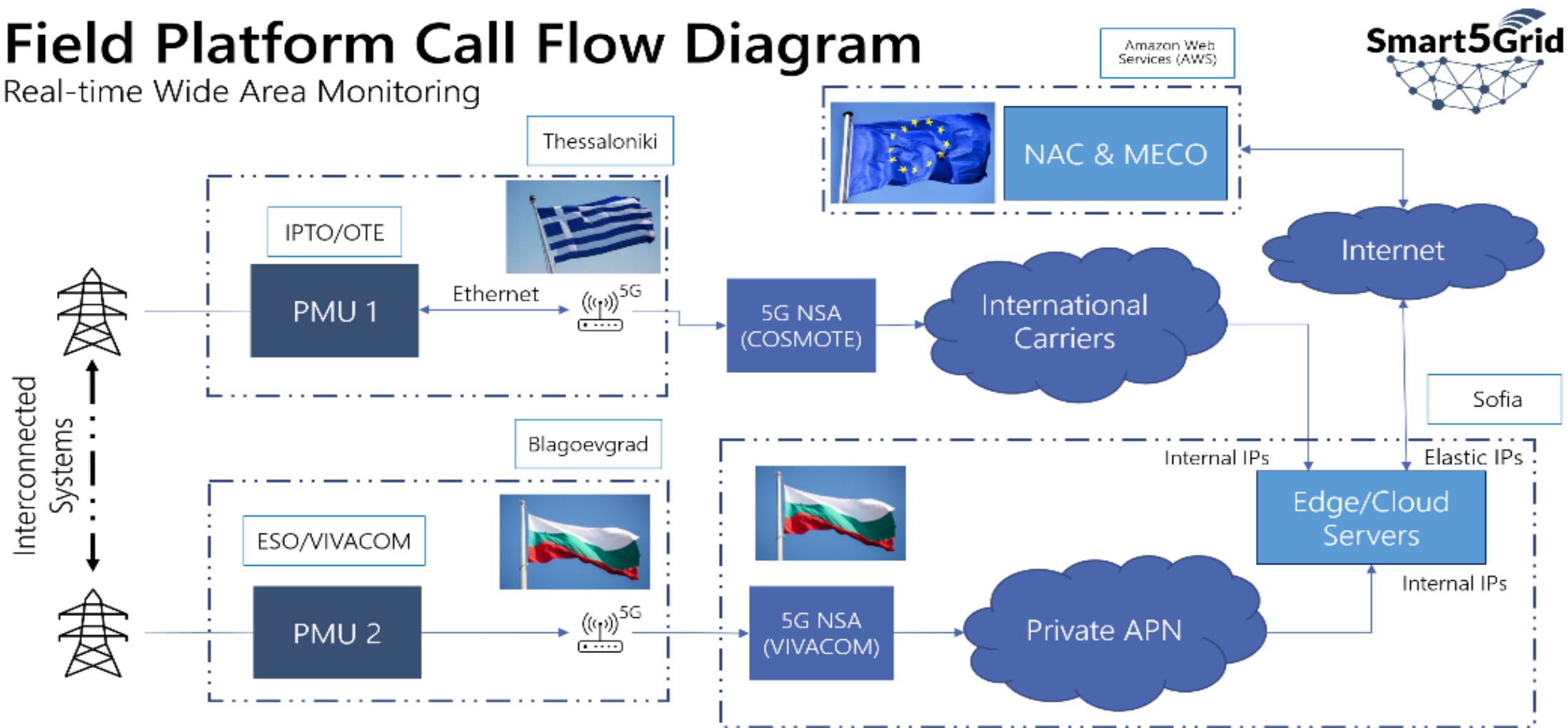# UC#4 – Real-Time Wide Area Monitoring - Need for 5G Technology

➢ To this part, the integration of 5G network can assist by ensuring the same network performance as the optical fiber in terms of low-latency, high-speed and zero data loss communication, that previous generations of wireless networks could not offer.

➢ Additionally, the virtualization and the edge computing that the 5G brings as an attribute, offer a new view of the possibility to deal with the PDC as a virtualized instance (vPDC) that can be deployed in any general purpose of the node instead of a monolithic and expensive device.

➢ Smart5Grid tries to fill in this gap by proposing a flexible wide area monitoring framework based on the deployment of vPDC instances across the grid enabled by 5G communication channels.

UC#4 – Field Platform Call Flow Diagram – Main Components

❑ **Interconnected Systems:** *The power interconnection line between Thessaloniki* *Greek* *TSO's (IPTO) Substation (Greece) and Bulgarian TSO's (ESO) Substation Blagoevgrad (Bulgaria).* *provide measurements*

❑ **PMUs:** *They measure voltage, current and frequency at high granularity.*

❑ **5G Non Stand-Alone (NSA) Networks:** *For both the Greek Side and Bulgarian Side of the Demo, the production Networks of COSMOTE and VIVACOM are utilized.*

❑ **International Carriers:** *Various Interconnection Scenarios of the Greek Site to the edge/cloud server at Bulgaria are currently under evaluation with respect to the Latency Network Requirements.*

❑ **Edge/Cloud server:** *Installed on the virtual machine in VIVACOM's cloud server in Sofia, Bulgaria.* *It hosts the Network Application created for the Real-Time Wide Area Monitoring.* ***It is composed of three (-3-) Virtual Network Functions (VNFs):***

➢ *Virtual Phasor Data Concentrator (vPDC) Service*
➢ *Wide Area Monitoring (WAM) Service displays information such as: device's current location, the nominal grid frequency [Hz], the current reporting speed [fps], Voltage magnitude and angle difference monitoring, derived from historical data of both sites.*
➢ *Advisory Service performs the task of proposing remedial actions to the TSOs.*

UC#4 – Wide Area Monitoring (WAM) Service
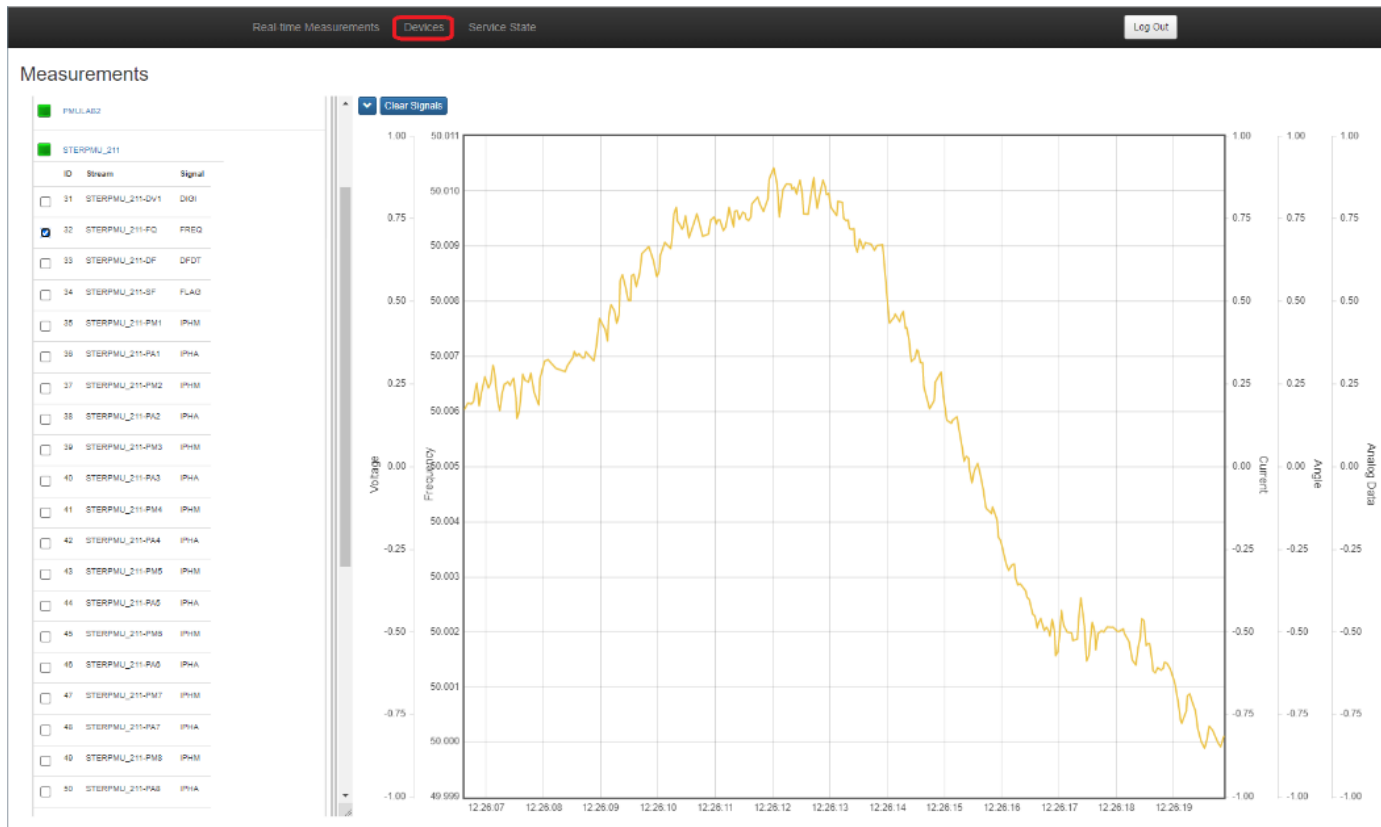
Example of PMUs data Visualisation Software,

with indicative values of current in the unit of time

UC#4 – Testing Strategy

- A complete list of Field Platform Validation Metrics (FPVMs) will be developed *for the scope of Real-Time Wide-Area Monitoring (RT WAM).*

- FPVMs may be considered as a "hyper-set" of KPIs consisting of:
  - Core Network KPIs *such as Latency*
  - Application KPIs *such as Application Packet Loss*
  - A combination of the above *such as Closed Loop Latency*

- The final choice of FPVMs depends on three main factors:
  - Satisfaction of the network requirements *as described in D2.1 – highlighting the advantages of leveraging 5G Networks*
  - Description of the overall performance *of the Field Platform for UC#4*
  - Availability of the Resources to measure on field *– 5G NSA commercial Networks are utilized with limitations due to data sharing constraints*

Concluding Remarks - Overview

- **Smart5Grid project is a modern EU-funded research oriented initiative**, around 4 distinct operational use cases scheduled to be implemented in 4 European countries.

- **Adaptation of 5G is an important enabler for the development of smart grid technologies**, *due to the inclusion of features such as network slicing.*

- **Smart5Grid's UC#4 deals with the Real Time Wide Area Monitoring (RT WAM)** of the interconnection power flow between Greece and Bulgaria.

- **Critical role of the Phasor Measurement Units (PMUs)** covered through COSMOTE's and VIVACOM's public 5G NSA networks

Thank you

Wishing all the best for our common success!