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Smart5Grid – 5G for the Support of Smart Power Grids: Millisecond Level Precise Distributed Generation Monitoring and Real-Time Wide Area Monitoring

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Smart5Grid

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

Content Overview

"Abstracted" Approach

- Smart Grid deployments in the energy vertical sector can strongly be supported and enhanced by the expansion of 5G infrastructures, *as the latter can offer better efficiency, observability and controllability of the power systems.*

- Our work focuses upon two selected cases of interest :
  - Millisecond level precise distributed generation monitoring *(Use Case 3 – Bulgaria)*
  - Real-Time Wide Area monitoring *(Use Case 4 – Greek & Bulgarian Demo)*

- Both use cases are described, conceptually assessed and evaluated *as of their main business goals and their benefits with emphasis for the inclusion of the 5G facilities.*

Introduction 1/2

- Large and interconnected power systems are seen as the "backbone" of the critical infrastructures in our society.
  - *So far telecom providers played little or no role in the communication infrastructure.*
  - *This status quo is expected to change drastically in the smart grid era!*

- The Smart Grid concept and its deployment environments are aiming to increase efficiency, resilience, reliability and security of the evolved and greener power grids, *by means of increased digital automation and control.*

- The Fifth Generation (5G) of communication networks provides the features allowing the power grid to incorporate the service requirements of:
  - *Large bandwidth*
  - *End-to-end latency*
  - *High reliability*
  - *Massive connection type*

Introduction 2/2

- The vision of the 5G is not only to “address” network requirements, but also to address entirely new challenges, to enable new services, empower new types of user experiences and connect new industries

- 5G is gradually applied to all aspects of power generation, transmission, transformation, distribution and use.

- Specifications such as:
  - Massive Machine Type Communication (mMMTC) specific for dense urban areas
  - Ultra-Reliable and Low Latency (URLL)

  can enable a significant shift for the smart grid’s communication layer.

- The flexibility of the 5G technology is the most valuable feature and “paves” the way for the transition from a “horizontal” service model (3G, 4G & LTE) towards a “vertical” dedicated service model *which, opens the path for a plethora of innovative applications across a variety of industry – or community related verticals.*

The Smart5Grid Concept 1/2

- The Smart5Grid EU-funded project is focused on boosting innovation for the highly critical and challenging energy vertical, by providing an open 5G enabled experimentation platform, customized to support the smart grid vision.

- The Open Smart5Grid experimental platform aims to be an ecosystem where 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*

  could “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 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 Concept 2/2

- Smart5Grid facilitates the current energy sector stakeholders as well as future smart grid shareholders through the adoption of 5G networks and the expected assistance of the NetApps to:
  i. Easily and effectively create and offer advanced energy services
  ii. Interact in a dynamic and efficient way with the surrounding environment
  iii. Automate and optimise the planning and operation of their power and energy services, thus enhancing marketing activity

- The emerging 5G mobile network along with the its fundamental features *(i.e.: uRLLC, mMMTC and eMBB)* and together with the innovative concept of MEC *(Multi-Access Edge Computing)* extends the capabilities of cloud computing by bringing it close to the edge of the network

UC#3 – Millisecond Level Precise Distributed Generation Monitoring - Overview

Smart5Grid

- The scope of UC#3 is the *millisecond level precise Distributed Generation Monitoring,* with a focus on renewable energy resources (RES).

- Real-Time (RT) monitoring of a wind farm is to be performed by using the emerging capabilities of 5G telecommunication networks.

- *Why Real-Time monitoring?*
  2 reasons:
  - The owners can predict and prevent on time potential future malfunctions which may result in financial losses.
  - The owners acting as BRP (Balancing Responsible Party) and BSP (Balancing Service Provider) are accountable for the potential imbalances and for the provision of the committed services in the real-time market.

UC#3 – Millisecond Level Precise Distributed Generation Monitoring - Goals

1. **High granularity precise monitoring of the RT power production** *will offer the capability to minimize their cost and being eligible for the provision of innovative flexibility services (voltage regulation, congestion management etc.).*

2. **Demonstration of a working solution of a distributed Renewable Energy Sources (RES) generator/producer**, *which could potentially be implemented on a bigger scale for other RES producers.*

3. **Utilization of a highly reliable and secure telecommunication connection between the wind farm and the dispatch centre for the operator,** *due to strict requirements set by power system operators.*

4. **Visualisation of end-users' behavior to optimally manage their energy profile** (*example of the case where the power plant manager "forgets" to inform the DSO of an operational maintenance downtime activity, which may result in heavy unbalance penalties*).

UC3 – Need for 5G Technology

- **Previous generations of wireless technology do not fulfill the criteria for low-latency and high reliability in millisecond basis**, as imposed by UC3 specifications.

- **Scalability aspect** – Anticipating and foreseen the massive deployment of Distributed Energy Resources (DERs) that are going to enter the grid, there is a need for new technology.
  The widespread of Internet of Things- (IoT-) enabled energy devices have different bandwidth as well as different QoS requirements.

- **Compared to optical fibre**, **5G offers a more flexible and cost-efficient way of communication.**

- **The rural location of the RES significantly increases the capex** in new projects due to the high cost for investments in fibre infrastructure. Hence, the utilization of 5G can provide incentives to RES owners to further invest in new installations by utilizing 5G networks, even for the last mile network connection.

UC3 – Main business goals and technical objectives

Main business goals

i. Offering predictive maintenance recommendation services in the wind farm (rural area) by receiving RT measurements from multiple sensors
ii. Providing RT monitoring services of the energy generation of the controlled wind farm in hard RT conditions
iii. Providing the wind farm owner live monitoring features through a web-based dashboard and/or an application upon a smartphone device

Technical objectives

1. Collecting RT measurements from the sensors.
2. Forecasting the energy production of the wind farm *in order to participate in the day-ahead, intra-day and balancing electricity markets.*
3. Collecting RT measurements of the energy production *in order to conduct RT control.*
4. Analysing data to offer data analytics services *regarding predictive maintenance and RT operation of the wind farm.*

UC3 – Benefits

- **Business:** Increased visibility in wind farm operation provides the owners fertile ground to better manage their assets and offer innovative flexibility services.
  It also offers appropriate incentives to producers for investing in new power generation, because of the well-functioning internal market in electricity.

- **Economic:** Knowledge of the RT production in a millisecond level basis, assists the system operator to minimize the overall cost and the owner can benefit financially by providing innovative services to the operator, such as voltage regulation.
  Replacing parts of the wind turbine on time, leads to continuous uninterruptible production and minimization of the maintenance cost.

- **Social:** Secure and uninterruptible energy provision to the end-user.

- **Environmental:** Higher participation rate of RES (Renewable Energy Sources) in the energy mix leads to cleaner energy production and lower levels of CO_2 emissions

- **Technological:** The use of IoT devices to work over 5G in real use cases, will pave the way for further adoption of IoT devices over 5G into other industry verticals.

UC#4 –Real-Time Wide Area Monitoring- Overview

- The **scope** of UC#4 is the **real-time monitoring of a geographical wide area** where cross-border power exchanges take place.

- The **interconnection flow between Greece and Bulgaria** is monitored leveraging the advantages that the 5G communications infrastructure provides.

- To achieve the enhancement of the interconnected power system operation, **live monitoring of the interconnected power system flows is of vital importance.**
  For that reason the PMU-PDC scheme will be used, enabling high data number and granularity.
  - Phasor Measurement Units (PMUs) measure grid current and voltage by amplitude and phase at several substations (nodes) of the transmission power system. The high-precision time synchronization of the measurements from different substations allowing better monitoring of system's state and detection of dynamic events. The PMUs are located in Thessaloniki and Blagoevgrad regions and will be used as the monitoring process of the RSC
  - A virtual Phasor Data Concentrator (vPDC) will be developed for the data gathering process according to C37.244 standard.

- **The utilization of 5G contributes to the connectivity between the PMUs and the vPDC offering its low latency and high reliability,** fulfilling the critical constraints of this UC.

UC#4 – Real Time Wide Area Monitoring - Goals

- Under a broader perspective, **the continuous expansion of the Distributed Energy Resources (DERs)** significantly increases the complexity of the power system **making its RT operation and control functions demanding and difficult to handle.**
- **The existence of a Wide Area Monitoring (WAM) is essential that is capable of capturing and alleviating dynamic phenomena that create hazardous conditions for the** stability of the entire European Power System.
- Multiple control areas exist in the European power system where each TSO is responsible for the control of its system.
- For the proper coordination between neighboring control areas, RSCs owned by adjacent TSOs are established.
- One of the RSC’s goals is the coordinated security analysis in multiple timeframes (day ahead, intraday and real-time).
- Offering an orchestratable vPDC service compliant with the energy, ETSI and cloud native standards.
- Offering a data network able to facilitate real time monitoring of critical energy KPIs (e.g., frequency) and automated control actions on a later stage.
- Offering a platform to bridge the application with the network and manage both of them according to selected KPIs, such as network latency.

UC4 – Need for 5G Technology

- *Fulfillment of latency, bandwidth, and reliability constrains that could not be reached by previous generations of wireless networks.*

- *Compared to the optical fiber used in most legacy grids, 5G offers a more flexible and cost-efficient way of communication, with similar values for the aforementioned metrics*

UC4 –Business goal and Service objectives

Business goal

i. The Primary Actor is the Regional Security Coordinator (RSC) which monitors both transmission grids.

ii. Both TSOs (i.e. Greek and Bulgarian) are facilitators providing access to the PMUs.

iii. The business goal is the RT monitoring of the power system so that it operates under secure conditions and is robust towards abnormal dynamic contingencies that threaten overall system balance.

Service objectives

1. PMUs monitoring status and visualization of their features in such a way that efficient suggestion regarding power system control will be offered to the TSOs.

2. Such indicators are:
   i. Voltage and current values and the angle between them.
   ii. Rate of Change of Frequency (RoCoF) value in both sides to be monitored.

UC4 – Benefits

- **Business:** Better monitoring of the power system helps the RSC (Regional Security Coordinator) to have an enhanced monitoring ability and supervision of their area by being aware of the adjacent energy network condition

- **Economic:** Better coordination, faults leading to severe conditions in the transmission system such as outages can be handled in time, saving TSOs (Transmission System Operators) from costs due to energy not being provided to customers.

- **Social:** Secure and uninterruptible energy provision to the end-users.

- **Environmental:** The high penetration of RES increases security issues due to their intermittent stochastic nature and the inverter-based grid connection.
  This use case fosters the coordination security, *an essential element in the penetration rate of RES, thus it can be considered that it has indirect environmental benefits.*

Concluding Remarks

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

- The core aim of the effort is to structure a modern platform able to serve high performance smart grids, especially with the implementation of appropriate VNFs and the corresponding NetApps.

- Smart Grid addresses very important challenges to communication networks:
  - Diversity of power grid services requires a flexible and orchestrated network
  - High reliability requires isolated networks
  - Millisecond level latency requires 5G networks
  - Network slicing allows customization of specific slices with different SLAs (Service Level Agreements)
  - 5G allows integration of a multiplicity of devices to smart grids and handling of immense data sets

Thank you

Wishing all the best for our common success!