CHALLENGES OF DIGITIZING THE ENERGY SYSTEM

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Die Energiewende – smart und digital
FVEE-Jahrestagung 2018
CHALLENGES OF DIGITIZING THE ENERGY SYSTEM

› Societal challenges driving new energy use cases
› New energy technologies are needed
› Communications can be based on 5G
› 5G Laboratory testing and Field Trials of solutions
HURRICANE OPHelia HITS IRELAND

- **Biggest storm** to have reached Ireland from across the Atlantic since records began
- **10th tropical storm** in a row to develop into a hurricane as it crossed the Atlantic – unprecedented in records
- Biggest storm to hit Ireland since 1961
- 39 storm days in a row last winter

Source: Irish Independent

'I've never seen anything like Ophelia' - Met Éireann's Evelyn Cusack

Meteorologist Evelyn Cusack has never seen anything like Hurricane Ophelia in her 35 years of forecasting Ireland's weather.
Power outage clusters in Ireland at 16.00, Monday, 16th October, 2017

- Crews have **less time to repair** damage as the storms become more frequent
- The need to reduce outage minutes for customers due to storm damage is driving increased **power network automation**
BIG STORMS CONTINUE

› 18 September, 2018 – Storm Ali

“The damage is mainly attributable to fallen trees on overhead lines as a result of the high winds”.

› At the height of the storm, **186,000 customers** were impacted.

› 12 October, 2018 – Storm Callum

› **30,000 customers** without power
Less rain so droughts and shortages are getting more common

Exceptionally warm periods and droughts are driving water utilities to increase metering, automation and the use of pumping to stabilise water supplies, increasing digital interfaces

Cascading effects to power infrastructure as nuclear power plants are being switched off when there is not enough water available to cool them in dry summer months (e.g. France)
**POWER GRIDS EVOLVE TO REDUCE CO2 EMISSIONS**

**New sector actors**, including:
- Virtual power plant operators (VPP)
- Service Providers (of technical and commercial services)
- Aggregators at all levels
- Microgrids operators

- More volatile renewable energy source generation
- More pro-summers
- More energy storage
- More sector actors
- New digital interfaces

- New techniques needed to **stabilise the power supply** at DSO and now at TSO level too
- New **black-out recovery** techniques needed
- Cascading effects of power outages are growing
SMART GRID INFRASTRUCTURES FACE INCREASING RISK DUE TO ATTACKS & TO HUMAN ERROR

Ukrainian power grid cyber attack (12/2015)

First known successful cyber attack on power grid!

1. Compromise of corporate networks via emails infected with phishing malware;
2. Seizing SCADA control, then remotely switching substations off;
3. Disabling IT infrastructure components;
4. Destruction of files stored on servers and workstations with the KillDisk malware;
5. Denial-of-service attack on call centres to deny consumers updating on the blackout.

European blackout (11/2006)

- Accidental cause
- Non fulfilment of the N-1 rule
- Insufficient inter-TSO co-ordination
- Graphic courtesy of ENTSO-E

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INCREASING RENEWABLE ENERGY = DECREASING SYNCHRONOUS GENERATION

Source: Renewables 2014 Global Status Report
FREQUENCY: ICT SCENARIOS

Objective
- Guarantee dynamic frequency stability of future power electronic AC systems

Approach
- Define tools and methods for frequency control based on power electronics AC systems and virtual inertia control

RESERVE Scenarios Frequency Control (10)

<table>
<thead>
<tr>
<th>Domain</th>
<th>TSO</th>
<th>Time Aspect</th>
<th>Sf_A</th>
<th>Sf_B</th>
<th>Centralised</th>
<th>Decentralised</th>
<th>Distributed</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>TSO</td>
<td>Inertial Ctrl [RoCoF]</td>
<td>up to 5 seconds</td>
<td>Up to 1 second</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>No centralised grid control</td>
</tr>
<tr>
<td>control</td>
<td></td>
<td>Primary control</td>
<td>up to 30 seconds</td>
<td>Up to 15 seconds</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Expect tighter time limits for the future.</td>
</tr>
<tr>
<td></td>
<td>TSO</td>
<td>Secondary control</td>
<td>up to 15 min</td>
<td>Much lower**</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Centralised grid control only</td>
</tr>
<tr>
<td>Frequency</td>
<td>DSO</td>
<td>Inertial Ctrl [RoCoF]</td>
<td>up to 5 seconds</td>
<td>Up to 1 second</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>No centralised grid control</td>
</tr>
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<td>control</td>
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</tr>
<tr>
<td></td>
<td>DSO</td>
<td>Secondary control</td>
<td>up to 15 min</td>
<td>Much lower**</td>
<td>✓</td>
<td></td>
<td></td>
<td>Centralised grid ctrl from TSO level</td>
</tr>
</tbody>
</table>

Note: the time limits are current expectations and requirements, difficult to provide hard limits for 10 years or beyond. Future solution will work better in case of even faster Inertial Control.

** Much lower than 15 min/Sf_A limit
VOLTAGE: ICT SCENARIOS

Objective
- Guarantee dynamic voltage stability of future power electronic AC systems

Approach
- Extend tools and methods typical of power electronics DC systems to future power electronic AC systems

RESERVE Scenario Voltage Control (2)

<table>
<thead>
<tr>
<th>Domain</th>
<th>TSO</th>
<th>DSO</th>
<th>Commercial Aggregator</th>
<th>Scenarios</th>
<th>Centralised</th>
<th>Decentralised</th>
<th>Distributed</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage control</td>
<td>DSO</td>
<td>No</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>Traditional: Centralised</td>
</tr>
<tr>
<td></td>
<td>DSO</td>
<td>Yes, optional</td>
<td>Sv_A Dynamic Voltage Stability Monitoring</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>Future: Decentralised</td>
</tr>
<tr>
<td></td>
<td>DSO</td>
<td>Yes, optional</td>
<td>Sv_B Active Voltage Management</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>Future: Decentralised</td>
</tr>
</tbody>
</table>

Blue=DC loads
Yellow=rectifiers
Green=invertors
Red=AC loads

Hybrid AC/DC Homes included

Note that future Voltage Control will use Decentralised network architecture, and it may include Aggregators which control parts of a DSO low voltage grid. Today, the aggregator is a commercial entity, it would not usually operate its own secondary substation automation unit (SSAU) where the voltage management of Sv_A is hosted or co-located. This is likely to change in the future.
BLACKOUTS: RECOVERY WITH RENEWABLE ENERGY SOURCES

• Trend towards
  • more locally distributed generation and storage,
  • less large conventional generation,
  • makes traditional methods of blackout recovery more difficult

• ICT is being increasingly applied in Smart Grid solutions, but it is rarely blackout-resilient

• Objective of the eSafeNet project:
  • Develop resilient blackout recovery concept and algorithms fit for future grids
    • consider power grid and ICT aspects
    • solution shall be applicable to real grids and technically realisable

• Enable Microgrid-based Blackout Recovery
  • Optimised, step-wise reconnection of loads and local generation, expanding energised area
  • One microgrid may give power to another
Mobile communication can support 2 microgrids

Power outage happens in Main grid

Ericsson Mobile System base stations

Multi-microgrid-based Blackout Restoration Procedure

1) Automatic, autonomous restoration of microgrids
2) Synchronise and connect microgrids together
3) Synchronise to Main Grid
4) Communications:
   - Power Line
   - 5G Mobile / LTE / NB-IoT
Ericsson Mobile System kicks-in running on power from outside the affected grid or using a secondary power supply from batteries and/or diesel generators.

Multi-microgrid-based Blackout Restoration Procedure

1) Automatic, autonomous restoration of microgrids
2) Synchronise and connect microgrids together
3) Synchronise to Main Grid
4) Communications:
   - Power Line
   - 5G Mobile / LTE / NB-IoT
SECURITY FOR UTILITIES - CORRELATING THREATS & ATTACKS WITH NEW COUNTERMEASURES

- NORM smart meter data (e.g. voltage, frequency)
- Simple and compound metrics (e.g. packets/second, average latency)
- DSO data and metrics
- DSOSMC/DE-SMIS processes NORM and internal logs data to detect an attack
- E-SMIS processes data from multiple DSOs, intertwined
- Countermeasures identification depending on the identified threat/attack
  - E.g. force NORM/PUF re-authentication
  - E.g. disconnect or reset a device
  - Control function to change configuration (e.g. reroute, block communication)
Motivation

- (Distribution) system operators (DSO) connect more than 95% of all customers to the power system and more than 90% of all renewable generation capacity is installed in distribution systems.
- DSOs have no possibility to communicate with each other in case of attacks.
- Same solutions in hardware and software are used all over Europe. This enables attacks on multiple systems at the same time.

“Small, but similar attacks” on each DSO might not be recognized on a DSO-level, even though the result might affect the whole of Europe.
New “automation functions” will be matured, integrated and offered as a service over private/public mobile networks (4G and 5G) to utilities.

Software functions, virtualized and turned into services, in this project:
- Fault Location Identification and System Restoration (FLISR = low latency time critical application), (5G needed)
- State Estimation, (NB-IoT or LTE or 5G – will work with all!)
- Load Forecasting, (NB-IoT or LTE or 5G)
- Power Control, (NB-IoT or LTE or 5G)
- Power Quality Evaluation (NB-IoT or LTE or 5G), and
- Utility KPI evaluation for QoS evaluation (LTE or 5G needed)
Commercial Utility networks will require
- Very high availability & reliability
- Secure communications to many new end points
- Latency at near real-time levels for the most advanced functions
- Service provider (utility) control of QoS and security
- Support for highly distributed power network architectures
- Flexibility to adapt as circumstances change
CHALLENGES OF DIGITIZING THE ENERGY SYSTEM

› Societal challenges driving new energy use cases
› New energy technologies are needed
› Communications can be based on 5G
› 5G Laboratory testing and Field Trials of solutions
Wireless Access Generations

The foundation of mobile telephony

Mobile telephony for everyone

The foundation of mobile broadband

The future of mobile broadband

The Networked Society

Providing a wireless connectivity platform for the services of the Networked Society
MASSIVE TRAFFIC GROWTH PUTS PRESSURE ON 4G

Data traffic growth between 2017 and 2023

8 X

1.5 X

more 5G data traffic in 2023 than total mobile data traffic in 2017

Need for 4G investments in capacity and coverage growth to ensure good user experience

4G capacity investments should be 5G-proof

Source: Ericsson Mobility Report
4G traffic figures also include a small proportion of other 3GPP traffic
5G OPEN FOR BUSINESS
Consumer needs drive evolution of mobile broadband content

User behavior changing
- Users spend more time on watching and sharing video

On-line content increasingly video
- Embedded in most online content (news, ads, social media, etc)

Emerging immersive media formats and applications
- HD/UHD, 360-degree video, AR/VR

Video of total mobile data traffic
- 75% by 2023

Video increasingly dominant

Driving MBB traffic growth
5G IS USE CASE DRIVEN

**Massive IoT**
- Smart meter
- Tracking
- Fleet management

**Critical IoT**
- Industrial application & control
- Traffic safety & control
- Remote manufacturing

**Enhanced Mobile Broadband (eMBB)**
- VR/AR
- 4K/8K UHD
- Smartphones

**Fixed Wireless Access (FWA)**
- Mobile / Wireless / Fixed
- Enterprise
- Home
### What to expect from 5G

<table>
<thead>
<tr>
<th>Feature</th>
<th>Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Data Rate</td>
<td>1 - 20 Gbps</td>
</tr>
<tr>
<td>User Experienced Data Rate</td>
<td>10 - 100 Mbps</td>
</tr>
<tr>
<td>Spectral Efficiency</td>
<td>×1 - ×3</td>
</tr>
<tr>
<td>Mobility</td>
<td>350 - 500 km/h</td>
</tr>
<tr>
<td>Connection Density</td>
<td>10k – 1M devices / km²</td>
</tr>
<tr>
<td>Network Energy Efficiency</td>
<td>×1 - ×100</td>
</tr>
<tr>
<td>Area Traffic Capacity</td>
<td>0.1 - 10 Mbps / m²</td>
</tr>
<tr>
<td>Availability</td>
<td>99.999% (of time)</td>
</tr>
<tr>
<td>Reliability</td>
<td>99.999% (of packets)</td>
</tr>
<tr>
<td>Latency</td>
<td>1 - 10 ms</td>
</tr>
<tr>
<td>Battery life</td>
<td>10 years*</td>
</tr>
<tr>
<td>Security</td>
<td>Strong subscriber authentication, user privacy and network security</td>
</tr>
</tbody>
</table>

*For low power IoT devices  
Source: ITU-R, NGMN, 3GPP
5G: ONE NETWORK – MULTIPLE INDUSTRY USE CASES

A common network platform with dynamic and secure Network Slices
5G: ONE NETWORK — MULTIPLE INDUSTRY USE CASES

A common network platform with dynamic and secure Network Slices

- 5X Lower Latency
- 10-100X End-user Data Rates
- 1000X Mobile Data Volumes
- 10X Battery Life
- 10-100X Connected Devices
- 10X Battery Life
- 1000X Mobile Data Volumes
- 10-100X Connected Devices
Give us more with 5G

Consumers predict most 5G services will go mainstream within three to four years of launch

Globally 5G services appeal to 76 percent of smartphone users and 44 percent among them are even willing to pay.

Timeline for services to go mainstream

Base: Smartphone users aged 15–65 with interest in 5G services across Argentina, Brazil, China, Egypt, Finland, France, Germany, Indonesia, Ireland, Japan, Mexico, South Korea, the UK and the US

Source: Ericsson ConsumerLab, Towards a 5G Consumer Future, 2018
## Enhanced mobile broadband
- Screens everywhere

## Automotive
- On demand information

## Manufacturing
- Process automation

## Energy & utilities
- Metering and smart grid

## Healthcare
- Connected doctors and patients

### Technologies
- Multi-standard network
- Cat-M1/NB-IoT
- Cloud optimized functions
- VNF orchestration

### On the road to 5G
- New tools
- Real-time information vehicle to vehicle
- Flow management and remote supervision
- Resource management and automation
- Monitoring and medication e-care

### 5G experience
- Immersive experience
- Autonomous control
- Cloud robotics and remote control
- Machine intelligence and real-time control
- Remote operations

### Gigabit LTE (TDD, FDD, LAA)
- Massive MIMO
- Network slicing
- Dynamic service orchestration
- Predictive analytics

### 5G NR
- Virtualized RAN
- Federated network
- Distributed cloud
- Real-time machine learning/AI
ENERGY & UTILITIES USE CASE EVOLUTION EXPLAINED

› Dynamic and bidirectional grid
› Smart metering

Current

On the road to 5G

› Distributed energy resource management
› Distribution automation

5G Experience (2023+)

› Control of edge-of-grid generation
› Virtual power plant
› Real time load balancing
ENERGY & UTILITIES USE CASE EVOLUTION EXPLAINED

Current

- Coverage
- Robust performance

On the road to 5G

- Reduced latency
- High throughput

5G Experience (2023+)

- Latency: 8ms
- Reliability: 99.999%

TECHNICAL REQUIREMENTS

- Multi-standard networks
- Cat-M1/NB-IoT
- Cloud optimized network functions
- VNF orchestration

TECHNOLOGIES

- Gigabit LTE (TDD, FDD, LAA)
- Massive MIMO
- Network Slicing
- Dynamic service orchestration
- Predictive analytics

- 5G NR
- RAN virtualization
- Federated network slicing
- Distributed Cloud
- Real time Machine learning/AI
5G Devices Availability

<table>
<thead>
<tr>
<th>Year</th>
<th>High band</th>
<th>Mid band</th>
<th>Low band</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>Early devices</td>
<td>FWA Smartphones</td>
<td>Tablets</td>
</tr>
<tr>
<td>2019</td>
<td>FWA Smartphones</td>
<td>Industry IoT FWA Smartphones</td>
<td>Tablets</td>
</tr>
<tr>
<td>2020</td>
<td>Massive IoT Industry IoT FWA Smartphones</td>
<td>Tablets</td>
<td></td>
</tr>
<tr>
<td>Beyond</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FWA: Fixed Wireless Access
ERICSSON HAS THE BIGGEST 5G MOMENTUM

5 announced 5G deals
40 operator MoUs
22 industry partners
45 university and institute collaborations

As of August 2018
Operator partners

**Announced 5G operator agreements**

As of August 2018
REQUIREMENTS AND 5G SOLUTIONS FOR SECURE UTILITY COMMUNICATIONS

› Commercial Utility network automation and Pan-European monitoring and countermeasures will require;
› Very high availability & reliability
› Highly secure communications to many new end points
› Latency at near real-time levels for the most advanced functions
› End user control of QoS and security

› New solutions based on 5G:
› 5G high availability & reliability
› 5G low latency for the most advanced functions
› 5G security features (e.g GBA)
› Edge processing for low latency and network resilience and survivability
› Network slicing for end user QoS and security control
› SDN for re-configuring networks on the fly for resilience
› 4G, NB-IoT for connectivity
CHALLENGES OF DIGITIZING THE ENERGY SYSTEM

› Societal challenges driving new energy use cases
› New energy technologies are needed
› Communications can be based on 5G
› 5G Laboratory testing and Field Trials of solutions
TEST SETUP AT RWTH, GERMANY WITH LIVE 5G MOBILE NETWORK
SUCCESS CYBER SECURITY TRIALS & TECHNOLOGIES
RE-SERVE - UP TO 100% RENEWABLES IN A STABLE ELECTRIC GRID

› Goals
  - New concepts for Voltage and Frequency Control
  - Enabled by 5G ICT & network slicing for real-time control applications
  - Pan European Real-Time Simulation Infrastructure (connecting labs from Italy, Germany, Ireland, Romania)
  - Harmonized Networks codes development

› Project details
  - Duration: October’16 – September 2018
SOGNO – DISTRIBUTION GRID
"AUTOMATION AS A SERVICE" FIELD TRIALS

Field Trial:
Monitoring and optimisation using SOGNO services

Reference site implementation providing all Turnkey services (Aachen)

SERVO system for Load balancing

5G Network

5G Local support
Server hosted on 5G Secure Edge Cloud

Secure server

5G Network

5G Local support
Server hosted on 5G Secure Edge Cloud

Secure server

Laboratory Trial:
Monitoring and optimisation using SOGNO services

Field Trial:
Monitoring and optimisation using SOGNO services

RWTH Smart Campus: Advanced control for distribution networks (Aachen)

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THE CHALLENGES OF DIGITIZING THE ENERGY SYSTEM

› Changing expectations regarding the role of the energy system
  – Addressing the challenges of climate change and cyber-terrorism as well as the risks of system complexity,
  – Changing priorities and lifestyles of young adults,
  – Rapidly changing business models towards services in society,
  – Increasing interconnections between vertical sectors at the data level to provide new services which is blurring the boundaries between sectors in the Smart City context
  – An increasing reliance of society on reliable communications and power supplies,

› The operation of the energy system is challenged by
  – New security threats and increased cascading effects of attacks,
  – New energy system solutions with increased requirements on ICT for connectivity, and control of energy networks, including many new distributed energy system architectures,

› 5G Concepts and systems will have a big role to play as part of the solutions!