European Perspective on Microgrid Resilience

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European Targets for 2030 (agreed 10/2014)

-20% Greenhouse Gas Emissions
20% Renewable Energy
20% Energy Efficiency
10% Interconnection

≤-40% Greenhouse Gas Emissions
≥27% Renewable Energy
≥27% Energy Efficiency
15% Interconnection

-80-95% Greenhouse Gas Emissions
Increased Renewable Energy
Increased Energy Efficiency

27% renewable energy in 2030: up to 45% renewable electricity
TOWARDS EUROPEAN MEGAGRID
facilitating decarbonisation of EU energy system

Shift from the Member State centric to a EU wide approach to decarbonisation (benefits exceeding €200bn by 2030)

• **EU renewable energy directive**
  – **Allows** member states with lower renewable generation potential or higher costs to fulfill their renewables targets in /with other member states
  – **Provides** incentives for investments in renewable power generation at most resourceful locations
  – **Facilitates** a cost effective development of renewable energy generation

• **EU wide deployment of RES**
  Inter-regional transmission change from minor trading & reserve-sharing role to a substantial energy exchange by :
  
  Supporting cost effective integration of RES

  A factor of three increase in inter-regional transmission capacity
The EU Megagrid (supergrid)
EU MEGAGRID

- **Integrates** offshore renewable generation (offshore wind - marine - tidal energy)
- **Enables** the exploitation of counter-cyclicality among primary RES
- **Enables** system to benefit from diversity in demand & supply across Europe
- **Allows** sharing of short & long-term reserves across european system (local level volatility reduces across dispersed areas).
SOLAR & WIND are seasonally complementary

Application of Smartgrid technologies and Microgrids
ENHANCING THE COST EFFECTIVENESS & RESILIENCE

Obstacles to overcome

• RES will displace energy produced by conventional plant but not the conventional generation capacity

• The utilization of generation capacity will reduce (from 55% to 35% 2025)

• The incorporation of the heat & transport sectors into electricity system will lead to a significant increase in peak demand disproportionately higher than the increase in energy

• The massive increases in power transfers across the EU regions will reduce system resilience by escalating the exposure of the system to large disturbances (vulnerability – blackouts)

Enhancing the Asset Utilisation

The system resilience & security need to be provided through more sophisticated control that incorporates advanced technologies (supported by appropriate communication & information technologies)

- **Network technologies**
  advanced measurement & network sensors, advanced power electronics technologies, various novel control & protection schemes

- **Demand-side response** (DSR)
  through utilising the inherent demand-side flexibility, particularly demand associated with heat and transport. Demand-side response can be used for real-time system management, while ensuring that the intended service quality is not adversely affected

- **Energy storage technologies**
  to support demand-supply balancing/control of network flows & hence increase utilisation of electricity infrastructure assets

- **Enhancing the flexibility of distributed and backup generation**
  can be used to facilitate more secure & cost-effective real-time demand-supply balance and control of network flows, hence enhancing the resilience of the local supply & the ability of the system to absorb intermittent generation and the regional level.

INTEGRATION OF MEGAGRIDS & MICROGRIDS
to facilitate cost effective & resilient evolution
Delivering resilience and security of supply from redundancy in assets to more intelligent operation.

MICROGRIDS can

- DISCONNECT from the traditional grid
- OPERATE autonomously
- HELP mitigate grid disturbances
- SERVE as a grid resource for faster system response and recovery

- HENCE strengthen grid resilience
MicroGrid - Basic Architecture

Control is the distinguishing feature of Microgrids

Microgrids Control: hierarchical, distributed

Two basic problems need to be addressed in MicroGrid’s operation

a) Voltage control - Frequency
b) Load-generation balance
- Droops for synchronising inverters with frequency and voltage
- Frequency and voltage of the inverter is set according to active and reactive power
Centralized & Decentralized Secondary Control

- The main distinction is where decisions are taken
- Centralized Control implies that a Central Processing Unit collects all the measurement and decides next actions.
- Decentralized Control implies that advanced controllers are installed at each node forming a distributed control system.
- Choice of approach depends on DG ownership, scale, ‘plug and play’, etc.
Shift from centralized to distributed control of MicroGrids
Shift from centralized to distributed control of Microgrids

New opportunities for enhancing cost effectiveness and security performance of future microgrids, with the objective deliver a truly integrated

• self-controlling,
• self-optimising,
• self-protecting electricity and
• self-healing networks.

Control needs to meet dynamically changing objectives while the network topology, network conditions and control infrastructure, are also changing. The key driver for real-time control is to improve supply resilience and quality of service to end consumers.

Using Multiagent systems: autonomous control process is assumed by each local intelligent controller IC, namely MCs and LCs.

The MAS theory describes the coordination algorithms, the communication between the agents and the organization of the whole system.
Multi Agent Systems

- Physical entity that acts in the environment or a virtual one
- Partial representation of the environment
- Agents communicate – cooperate with each other
- Agents have a certain level of autonomy
- The agents have a behaviour and tends to satisfy objectives using its resources, skills and services

Reactive
- Partial representation of the environment
- Autonomy
- Possesses skills

Cognitive or Intelligent
- Memory
- Environment Perception
- High level communication

Typical example: an ant colony
Typical example: the human society
The Kythnos Microgrid
Advanced Sunny Island inverters, to deal with islanded mode control
Intelligent Load Controllers

Settlement of 12 houses

**Generation:**
- 5 PV units connected via standard grid-tied inverters.
- A 9 kVA diesel genset (for back-up).

**Storage:** Battery (60 Volt, 52 kWh) through 3 bi-directional inverters operating in parallel.

**Flexible Loads:** 1-2 kW irrigation pumps in each house
The Kythnos System House
Step 1: The agents identify the status of the environment.

Step 2: The agents negotiate on how to share the available energy.
In each house an ILC is installed:

- Windows CE 5.0
- Intel® Xscale™ PXA255
- 64MB of RAM
- 32MB FLASH Memory
- Java VM
- Jade LEAP
Measurements

In this case the frequency if almost 52Hz. This is an indication that the batteries are full and the PV inverters via the droop curves limit their production.

The shedding procedures start later.
The Meltemi holiday camp in Greece with DGs & Intelligent Load Controllers has been used for implementing MAS technologies.
Field Test Schematic

PC
Jade Platform

Diesel

PV

Monitor & Equipment

Monitor Equipment

Load Controller

Load Controller

MGCC

ESCO

LAN
Actual Network Architecture
CONCLUSIONS

- The EU Megagrid is foreseen in order to exploit the very large resource of Solar Energy in Southern Europe & of Wind Power in Northern Europe.
- Microgrids with enhanced control capabilities can integrate & coordinate local distributed resources enhancing the resilience of the EU Megagrid & providing local supply restoration capabilities.
- Shift to distributed control enhances further the Microgrids resilience.