Microgrids – A Possible Future Energy Configuration?

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Topics

• Definition
• Technical, Economic and Environmental Benefits of MicroGrids
• Conceptual design of MicroGrids
• Integration requirements and device-network interfaces
• Market and regulatory frameworks for MicroGrids
• Modelling and simulation of MicroGrids
• The MicroGrids Project
• Conclusions
What are MICROGRIDS?

Interconnection of small, modular generation to low voltage distribution systems forms a new type of power system, the MicroGrid. MicroGrids can be connected to the main power network or be operated autonomously, similar to power systems of physical islands.
Technical, economic and environmental benefits

• Energy efficiency
• Minimisation of the overall energy consumption
• Improved environmental impact
• Improvement of energy system reliability and resilience
• Network benefits
• Cost efficient electricity infrastructure replacement strategies
• Cost benefit assessment
Up to now:
• Central power stations
• Decentral heat production

In Future:
• Decentral combined heat and power

⇒ 1/3 less consumption of fossil sources of energy
Improvement of Reliability
Distribution of CMLs
Potential for DG to improve service quality

- Medium scale DG
- Central generation
- Small-scale DG

Voltage level

Security of supply
Network Benefits – Value of Micro Generation

~ .02-.04 €/kWh
Central Generation

~ .03-.05 €/kWh
Transmission

~ .05-.07 €/kWh
HV Distribution

~ .05-.07 €/kWh
MV Distribution

~ .1-.15 €/kWh
LV Distribution

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Cost benefit assessment
CMLs of European countries (in 1999) - Is it worth?

- Germany: 15 minutes
- Netherlands: 25 minutes
- France: 57 minutes
- Great Britain: 63 minutes
- Schweden: 152 minutes
- Norway: 180 minutes
- Italy: 191 minutes

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Cost of Power Outages for Selected Commercial Customers

- Brokerage Operations $6,480,000 per hour
- Credit Card Operations $2,580,000 per hour
- Airline Reservations $90,000 per hour
- Telephone Ticket Sales $72,000 per hour
- Cellular Communications $41,000 per hour

Source: “Reliability and Distributed Generation”, a White Paper by Arthur D. Little
Conceptual Design of MicroGrids

- energy management within and outside of the distributed power system
- control philosophies (hierarchical or distributed)
- islanding and interconnected operation philosophy
- type of networks (ac or dc, fixed or variable frequency)
- management of power flow constraints, voltage and frequency
- device and interface response and intelligence requirements
- protection options for networks of variable configurations
- next-generation communications infrastructure (slow, fast)
- standardisation of technical and commercial protocols and hardware
Internal and External Markets

(A) Markets within a microgrid cell (internal interaction)

(B) Markets outside a microgrid cell (external interaction)

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MicroGrids – Hierarchical Control

**MicroGrid Central Controller (MGCC)** promotes technical and economical operation, provides set points to LC and MC; Interface with loads and micro sources and **DMS**; **MC and LC Controllers**: interfaces to control interruptible loads and micro sources (active and reactive generation levels).

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Interconnected Operation

• MicroGrids can operate:
  – Normal Interconnected Mode:
    • Connection with the main MV grid;
    • Supply, at least partially, the loads or injecting in the MV grid;
    • In this case, the MGCC:
      – Interfaces with MC, LC and DMS;
      – Perform studies (forecasting, economic scheduling, DSM functions,…);
Islanding Operation

- MicroGrids can operate:
  - Island Mode:
    - In case of failure of the MV grid;
    - Possible operation in an isolated mode as in physical islands;
    - In this case, the MGCC:
      - Changes the output control of generators from a dispatch power mode to a frequency mode;
      - Primary control – MC and LC;
      - Secondary control – MGCC (storage devices, load shedding,…);
      - Eventually, triggers a black start function.

Improved reliability and resilience
Integration requirements and device-network interfaces

• operation as the “good” and “model citizen”
• seamless transition between connection/islanding
• resilience under changing conditions
• operation fault level management and protection
• recovery from disturbances and contribution to network restoration
• interfacing ac and dc networks
• Safety, modularity, robustness, low losses, calibration and self-tuning
Modelling and simulation of MicroGrids

- modelling of generator technologies (micro generators, biomass fuelled generation, fuel cells, PV, wind turbines), storage, and interfaces
- load modelling and demand side management
- unbalanced deterministic and probabilistic load flow and fault calculators
- unbalanced transient stability models
- stability and electrical protection
- simulation of steady state and dynamic operation
- simulation of interactions between Microgrids
Market and Regulatory frameworks for MicroGrids

- coordinated but decentralised energy trading and management
- market mechanisms to ensure efficient, fair and secure supply and demand balancing
- development of open and closed loop price-based energy and ancillary services arrangements for congestion management
- secure and open access to the network and efficient allocation of network costs
- alternative ownership structures, energy service providers
- new roles and responsibilities of supply company, distribution company, and consumer/customer
“Large Scale Integration of Micro-Generation to Low Voltage Grids
Contract: ENK5-CT-2002-00610

14 PARTNERS, 7 COUNTRIES

GREAT BRITAIN
- UMIST
- URENCO

PORTUGAL
- EDP
- INESC

SPAIN
- LABEIN

NETHERLANDS
- EMforce

USA
- EPRI

GREECE
- GERMANOS
- ICCS/NTUA
- PPC/NAMD&RESID

GERMANY
- SMA
- ISET

FRANCE
- EDF
- Ecole des Mines de Paris/ARMINES
- CENERG

http://microgrids.power.ece.ntua.gr

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The MicroGrids Project

R&D Objectives:

– Contribute to increase the share of renewables and to reduce GHG emissions;
– Study the operation of MicroGrids in normal and islanding conditions;
– Optimize the operation of local generation sources;
– Develop and demonstrate control strategies to ensure efficient, reliable and economic operation;
– Simulate and demonstrate a MicroGrid in lab conditions;
– Define protection and grounding schemes;
– Define communication infrastructure and protocols;
– Identify legal, administrative and regulatory barriers and propose measures to eliminate them;

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MICROGRIDS - 9 Workpackages

WP A: Development of Steady State and Dynamic Simulation Tools
WPB Development of Local Micro Source Controllers
WPC Development of Micro Grid Central Controller
WPD Development of Emergency Functions
WPE Investigation of Safety and Protection
WPF Investigation of Telecommunication Infrastructures and Communication Protocols
WPG Investigation of Regulatory, Commercial, Economic and Environmental Issues
WPH Development of Laboratory MicroGrids
WPI Evaluation of the system performance on study case networks
Challenges

Specific technical challenges:
- Relatively large imbalances between load and generation to be managed (significant load participation required, need for new technologies, review of the boundaries of microgrids)
- Specific network characteristics (strong interaction between active and reactive power, control and market implications)
- Small size (challenging management)
- Use of different generation technologies (prime movers)
- Presence of power electronic interfaces
- Protection
- Unbalanced operation
Highlight - Permissible expenditure to enable islanding

<table>
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<tr>
<th>Customer Sector:</th>
<th>Residential</th>
<th>Commercial</th>
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<tbody>
<tr>
<td>Annual benefit</td>
<td>1.4 £/kW&lt;sub&gt;pk&lt;/sub&gt;</td>
<td>15 £/kW&lt;sub&gt;pk&lt;/sub&gt;</td>
</tr>
<tr>
<td>Net present value</td>
<td>15 £/kW&lt;sub&gt;pk&lt;/sub&gt;</td>
<td>160 £/kW&lt;sub&gt;pk&lt;/sub&gt;</td>
</tr>
<tr>
<td>Peak demand</td>
<td>2 kW</td>
<td>1000 kW</td>
</tr>
<tr>
<td>Perm. expenditure</td>
<td>£30</td>
<td>£160,000</td>
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</tbody>
</table>

MicroGrid (2,000kW) £30,000 £320,000

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Highlight: MGCC Simulation Tool
Residential Feeder with DGs

Good Citizen Cost Reduction : 12.29 %

Model Citizen Cost reduction : 18.66%

Steady state security increases cost by 27% and 29% respectively.

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Study Case
LV Feeder
with DG sources

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Off-load TC
19-21 kV in 5 steps

0.4 kV

20 kV

20/0.4 kV, 50 Hz, 400 kVA
u_L=4%, r_L=1%, Dyn11

Circuit Breaker instead of fuses

Overhead line
4x120 mm² Al XLPE
1.5+3m

Pole-to-pole distance = 35 m

Possible sectionalizing CB

Possible neutral bridge to adjacent LV network
LV network with multiple feeders

[Diagram showing various feeders and load categories including:
- Overhead line: 4x120 mm² Al XLPE twisted cable, Pole-to-pole distance = 35 m
- Underground line: 3x150 mm² Al + 50 mm² Cu XLPE cable, Pole-to-pole distance = 30 m
- Residential load: Single residential consumer, Group of 4 residences, Apartment building
- Industrial load: Workshop, Commercial load
- LV network with multiple feeders with 3+N connections and various conductor sizes and currents]