Active Distribution Networks

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Distributed Generation Technologies

Examples

Advanced Turbines

Reciprocating Engines

Fuel Cells

Photovoltaics

Wind

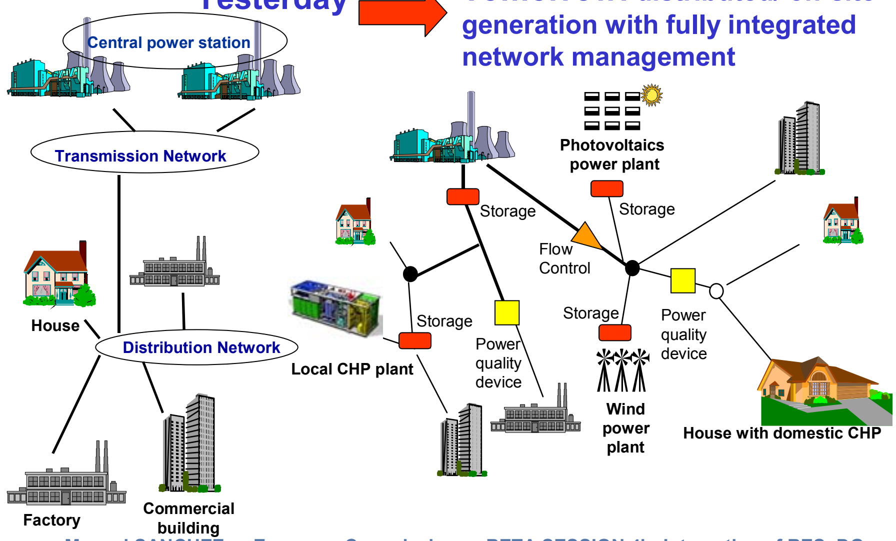
Thermally Activated Technologies

Microturbines

Barcelona 12-15 May 2003

The vision.....

Yesterday → **Tomorrow: distributed/ on-site generation with fully integrated network management**



Passive and Active Distribution Networks

Passive distribution networks

- Designed to accept bulk power from transmission system and distribute to customers
- Real time control problem resolved at planning stage

Ad hoc approach with existing practise ("fit and forget")

- No control over DER
- Limiting capacity of DER to be absorbed by the existing networks

  Rural network: voltage rise

  Urban network: fault level

Active distribution networks

- Local and coordinated control of voltage, flows and fault levels

ACTIVE DISTRIBUTION NETWORK OPERATION

- Advanced DMS for supervision, control & operational planning
- Active & Reactive Power Support (ancillary services)
- Islanding & Blackstart capabilities
- MicroGrids

ACTIVE DISTRIBUTION NETWORK PLANNING

- Network Reinforcement vs DG development
- Methods and new Tools for Design
- Harmonized Standards

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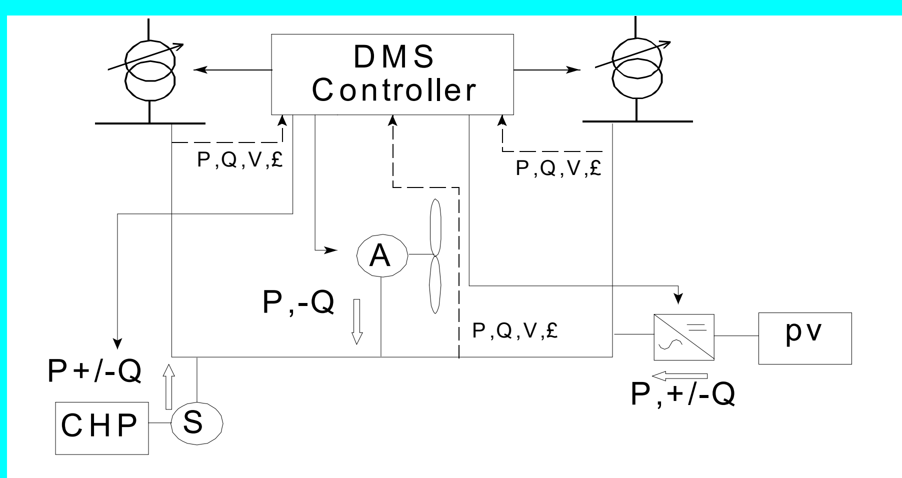
Active Distribution Network Operation



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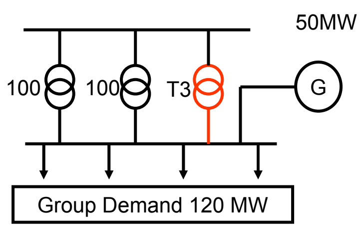
Network Security & Planning

Generation solution to network problems…

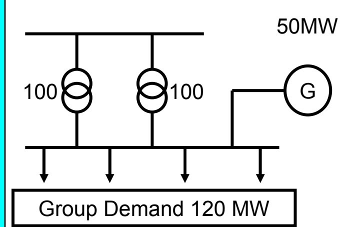
Current approach

Generator contribution ignored



Proposed approach

Generator contribution recognised



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Issues for Active Distribution Networks

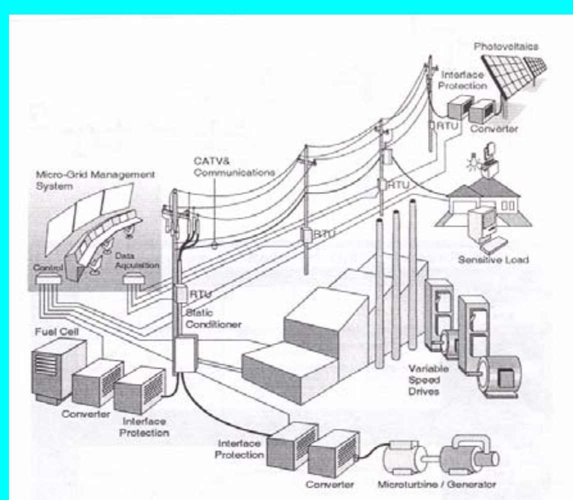
- **Need to understand and demonstrate the value of flexibility and controllability**
  - Technical benefits (security, reliability)
  - Economic benefits (cost savings, competitiveness)
- **Need to quantify the benefits of:**
- Enhanced security
  - Displaced central generation capacity
  - Reduced network investment
  - Reduced generation operating costs
  - Reduced outage costs
  - Increased competitiveness of DER
- **Need to explore alternative network control approaches**
  - Control of network topology (switching technology)
  - Coordination of operation of network control facilities
  - Coordinated (but decentralised) control of DER

DG Interconnection Technologies

- Plug & Play capabilities
- Active and reactive power support
- Load Sharing
- Fault Ride Through Capability
- Fault Current Contribution
- Power Quality Improvement, Active Filtering
- etc.

MICROGRIDS – Future Paradigm

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 islanded, in a **coordinated, controlled way**.



EU MICROGRIDS Project

"Large Scale Integration of Micro-Generation to Low Voltage Grids

Contract : ENK5-CT-2002-00610

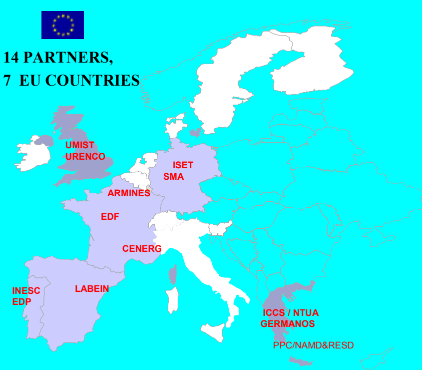
GREAT BRITAIN
- UMIST
- URENCO

PORTUGAL
- EDP
- INESC

SPAIN
- LABEIN

NETHERLANDS
- EMforce

14 PARTNERS,
7 EU COUNTRIES



GREECE
- NTUA
- PPC /NAMD&RESD
- GERMANOS

GERMANY
- SMA
- ISET

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

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

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Technical, economic and environmental benefits of Microgrids

- Energy efficiency
- Minimisation of the overall energy consumption
- Improved environmental impact
- Improvement of energy system reliability and quality of service
- Network benefits
- Cost efficient electricity infrastructure replacement strategies

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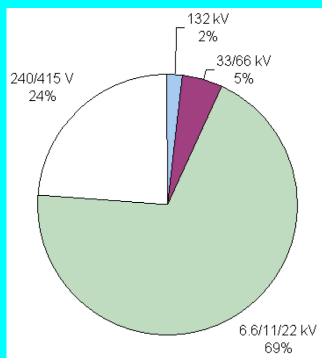
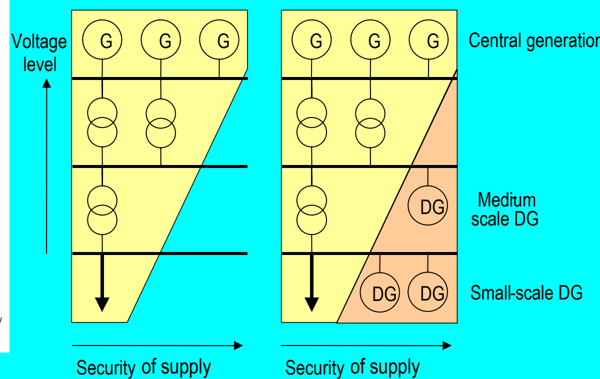
Potential for Microgrids to improve service quality



Distribution of CMLs



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Technical Challenges for Microgrids

- 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 and Safety

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Market and Regulatory Challenges

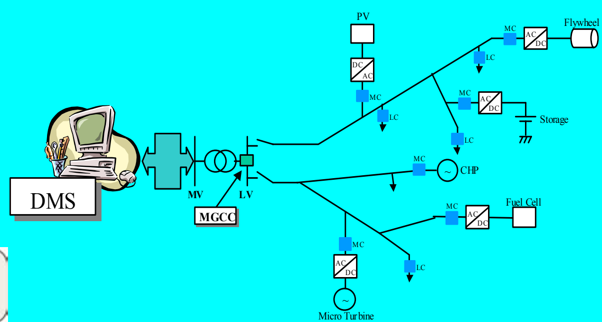
- coordinated but decentralised energy trading and management
- market mechanisms to ensure efficient, fair and secure supply and demand balancing
- development of islanded and interconnected price-based energy and ancillary services arrangements for congestion management
- secure and open access to 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

Microgrids Highlights

- Control philosophies (hierarchical vs. distributed)
- Permissible expenditure and quantification of reliability benefits
- Device and interface response and intelligence requirements
- Energy management within and outside of the distributed power system
- Steady State and Dynamic Analysis Tools

Microgrids – Hierarchical Control

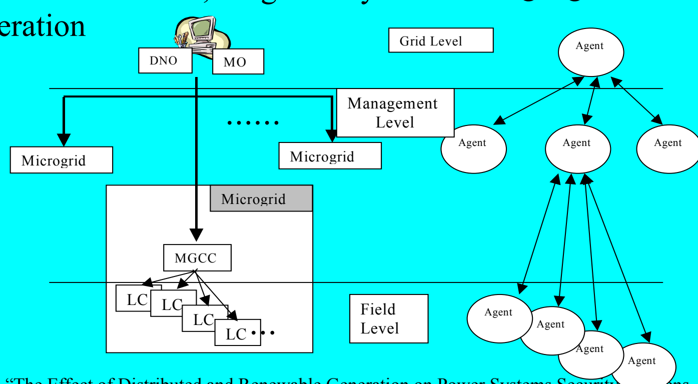
MicroGrid Central Controller (MGCC) promotes technical and economical operation, interface with loads and micro sources and **DMS;** provides set points or supervises LC and MC; **MC and LC Controllers**: interfaces to control interruptible loads and micro sources



Centralized vs. Decentralized Control

MultiAgent System for Microgrids

- Autonomous Local Controllers
- Distributed Intelligence
- Reduced communication needs
- Open Architecture, Plug n' Play operation
- FIPA organization
- Java Based Platforms
- Agent Communication Language



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Highlight: Permissible expenditure to enable islanding

Customer Sector:		Residential	Commercial
Annual benefit	=	2 €/kW_{pk}	25 €/kW_{pk}
Net present value	=	20 €/kW_{pk}	250 €/kW_{pk}
Peak demand	=	2 kW	1000 kW
Perm. expenditure	=	€40	€250,000
Microgrid (2,000kW)		€40,000	€500,000

Highlight: Reliability Assessment

- System Maximum Load Demand: 188 kW
- Capacity of System Infeed: 210 kW (100%)
- Installed DGs: 15 kW Wind, 13 kW PVs, 30 kW Fuel Cells, 30 kW Microturbines

	FLOL (ev/yr)	LOLE (hrs/yr)	LOEE (kWh/yr)
Infeed Capacity 100% (no DGs)	2,130	23,93	2279,03
Infeed Capacity 80% (no DGs)	58,14	124,91	3101,52
Infeed Capacity 80% (with Wind + PV)	14,02	41,67	2039,41
Infeed Capacity 80% (all DGs)	2,28	15,70	716,36

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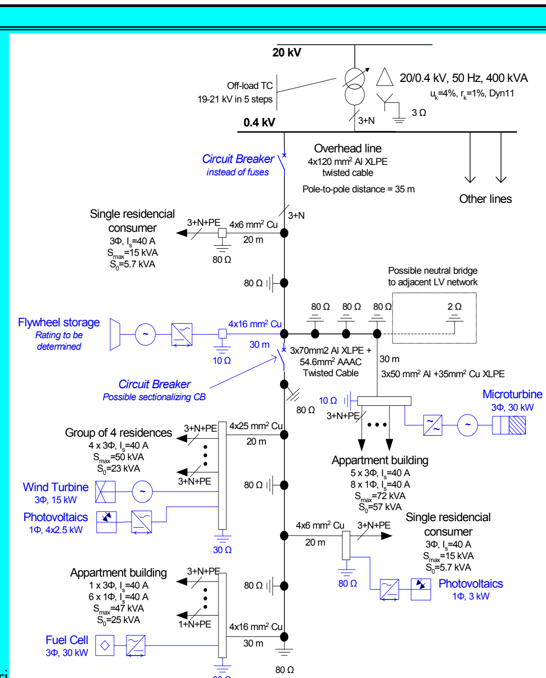
Participation of Microgrids in Energy Markets

- Microgrid Serving its own needs using its local production, when financially beneficial **(Good Citizen)**

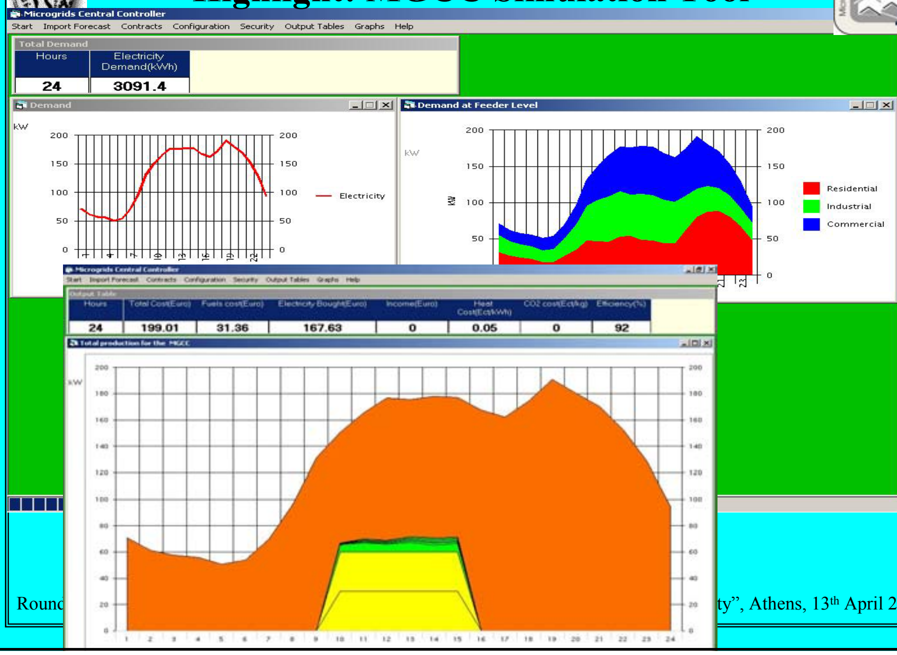
  MGCC minimises operation costs based on:
  - Prices in the open power market
  - Forecasted demand and renewable power production
  - Bids of the Microgrid producers and consumers.
  - Technical constraints
- Microgrid buys and sells power to the grid via an Energy Service provider **(Ideal Citizen)**

  MGCC maximizes value of the Microgrid, i.e. maximizes revenues by exchanging power with the grid based on similar inputs

Study Case LV Feeder with DG sources



Highlight: MGCC Simulation Tool

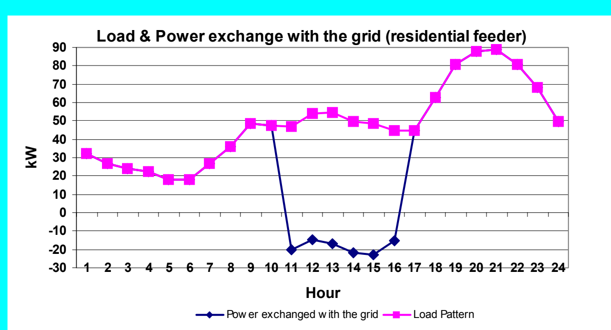


Residential Feeder with DGs

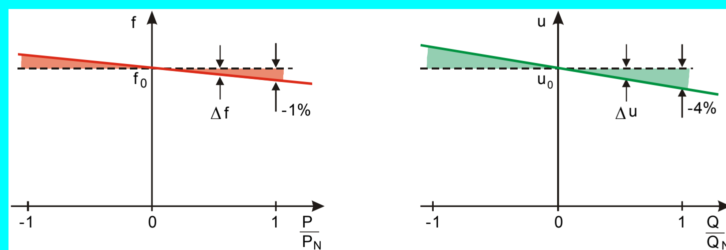
Good Citizen Cost Reduction : 12.29 %

27% reduction in CO_2 emissions

Model Citizen Cost reduction : 18.66%



Parallel Operation of Inverters

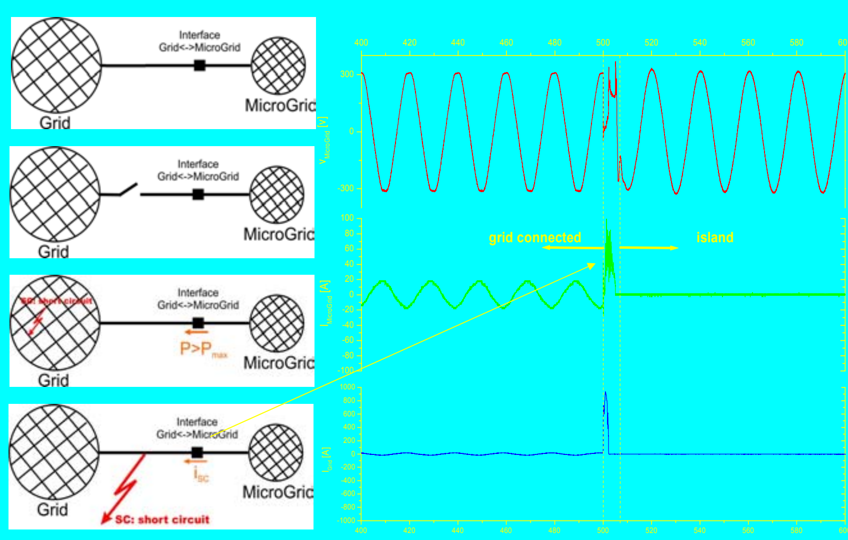


Frequency droop

Voltage droop

- Droops for synchronising inverters with frequency and voltage
- Frequency and voltage of the inverter is set according to active and and reactive power.

Highlight: Electronic Switch



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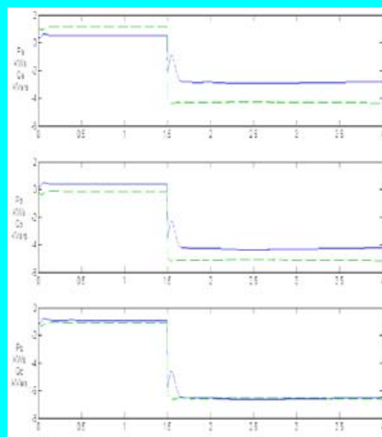
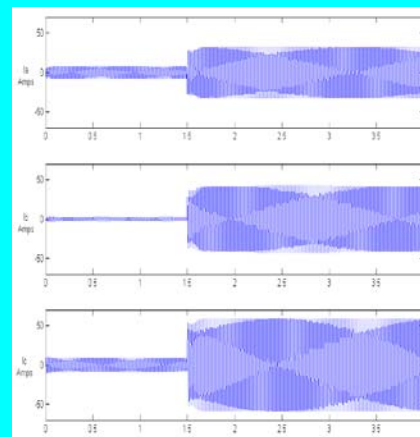
Highlight: Modeling and Simulation

Two battery invs + two PVs + one WT - Isolation + wind fluctuations



P,Q per phase Battery Inverter A



I per phase Battery Inverter A

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Conclusions – Open Issues for Active Distribution Networks

- **Planning and operation standards of active distribution networks**
- **Deployment rates of DER and need for new enabling technologies**
- **Criteria for provision of system security services by active distribution networks**
- **Strategies and technologies for coordinated network and generation control (energy transfer control, control of voltage, fault level and topology)**
- **Grid Code requirements for active distribution networks and generation interface requirements**
- **Service quality and outage cost performance of active distribution networks**