Control and integration of dispersed generation in distribution network

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Centralised vs decentralised: a paradigm shift?

- Large power plants
- Unidirectional power flow
- Monopolistic vertically integrated structure

- Small scale technologies
- Bi-directional power flow
- Liberalised market

Source: Enel Green Power (R. Vigotti)
Dispersed Generation - Driving Forces

- High efficiency in using fossil fuels (CHP)
- Integration of RES (as stated by EC)
- Opening of the electricity market
- Low scale factor on the cost ($/kW) of new tech
- No transmission costs, low distribution costs (depending on DG location)
- Expected (?) improvement in reliability and quality of power supply
DR Grid Interconnection Issues

Source: EPRI
DG - Existing Barriers

Apart DK and NL, Dispersed Generation is about 10% of installed generation capacity

- High technology cost (development still in progress for some technology)
- Existing distribution networks not designed for DG integration (need for new investments)
- Operation (protection setting, voltage regulation, etc.) of distribution networks to be modified
- Contribution of DG to security of supply not recognised
**SC actions in a short medium term perspective**

- Status of DG existing technologies (micro GT, diesel generators, wind turbines, wind farms, PV, CHP, solar thermal)
- DG economics (DG costs, transmission and distribution benefits); energy management and trading
- Integration of DG in distribution network (network interface, protections, quality of supply, stability of DG, safety of personnel)
Expected evolution of DG

- Development of active distribution networks with high penetration of DG with:
  - new MV and LV distribution structures
  - new operation criteria
  - use of storage and power electronics based devices
Main factors for a successful DG evolution

- Participation of DG to the liberalised market
- Improve of DG worthing, i.e. contribution to system ancillary services

The above requirements call for

the development of Distributed Automated Control Systems for DG with the wide use of Information and Communication Technology (ICT)
Energy Supply Systems in the 21st Century: *the dream*

- Wind Energy
- Long Distance Transmission
- Energy Management via Satellite
- Hydro Power
- Central Power Stations fossil fired and nuclear
- Combined Cycle Power Plant
- Solar Energy
- Fuel Cells
- Biomass Power Plant
- Superconductive transmission & Distribution

Source: *Enel Green Power (R. Vigotti)*
"The new grid will scrap the old assumption that power flows in one direction only"

Source: Enel Green Power (R. Vigotti)
DG Research Projects

- **GENDIS**, “Distributed Generation” by CESI with the collaboration of 7 Italian Universities

- **GDLINK**, “Integration of DG into the electrical national system” by 11 Italian Universities

- **DISPOWER**, “Distributed generation with high penetration of RES” funded within the 5th EC FP, by 36 Contractors from 11 European countries (CESI and Genoa University included)
The GENDIS Project

Main objectives

- Scenarios of DG penetration
- International standards and rules for DG integration
- DG impact on distribution networks: control & automation & protection, MV feeder voltage regulation, unexpected islanding
- Control and supervision of micro-grids with DG: power and power quality management systems, ICT systems
- Demonstration plant of MOFC+microGT. Sperimentation of SOFC. Laboratory testing of PEM
- Laboratory testing of advanced storage
The DISPOWER Project

Main objectives

- Strategies and concepts for grid stability and control
- Safety and quality standards in DG networks
- Quality improvements by decentralised inverters and generation systems
- Planning and design tools for reliable and cost effective integration of DG
- Internet based info systems for communication, energy management and trading
- Contract and tariff issues for energy trading, wheeling and ancillary services
- Test facilities development
Power Quality Operation and Management system: PoMS

PoMS is a communication infrastructure and optimisation tool for low voltage grids which is expected to perform power quality monitoring and control and to optimize grid operation through distributed generation control and demand side load management.
Decentralised Management of Power Supply Systems

Information network

Constant-speed converter:
Wind energy
Hydro power
Generator sets

Variable-speed converter:
Wind energy
Hydro power
Generator sets
Micro turbines

Direct converter:
Photovoltaic
Thermophotovoltaic
Fuel cell

Battery storage with bidirectional Converter

Flywheel storage with bidirectional Converter

power supply grid

Active power (P)

Active power (P) + Reactive power compensation (cos(φ)) + reduction of distortions (THD)
Test facility for DG operation and control: the site
Test facility for DG operation and control: the structure of the LV network
Test facility for DG operation and control: the PV field
Test facility for DG operation and control: hybrid PV-Wind-Diesel-Batteries

GFV1: Eurosolare 36SLA2  8.3 kW 100 m² Si-multi-crystal
GFV2: BP SOLAR MILLENIA  1.2 kW 20 m² Si-amorphous
GFV3: Siemens ST40  0.9 kW  10 m² Thin film

Diesel engine-asynchronous generator 10 kVA
Wind turbine simulator: electric motor+asynchronous generator 8 kVA
Test facility for DG operation and control: Solar Dish Stirling

CESI Eurodish:
Unique European Dish Stirling solar generator system (3rd prototype in the world)
based on the SOLO 161 Stirling motor
parabolic concentrator, 8.5 m diameter, 56 m²
2000 suns, 800°C, net efficiency 15%,
Two axis tracking: azimuth & elevation
10 kWe 400 V ac 3 p. Asynchronous alternator grid connected
Test facility for DG operation and control: Vanadium Redox Battery

Electrolyte tanks

Stack
- Nominal Voltage: 125 V
- Maximum Current: 500 A
- Operative Voltage: 100 – 155 V
- Number of cells: 100
- Manufacturer: SUMITOMO

42 kW 84 kWh
Test facility for DG operation and control: the metering field

- load power: variable
- segment length: variable
Test facility for DG operation and control: the

Wireless bridge *AIRONET* from Cisco: up to 20 km with special antenna, data connection speed from 1 to 11 Mb/s.

Protocol is IEEE 802.11 (named *Wi-Fi*)
Units must be provided with PCMCIA or PCI cards
Already used to interface PV hybrid system and Solar Dish Stirling with their remote control sites.