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Management of MicroGrids

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Topics

- Introduction
- Technical and Economical Advantages of MicroGrids
- The MicroGrids Concept and the Project
  - The Concept
  - The Project
- MicroGrids Simulation Platform
- Management and Control
- Islanding and Black Start Function
- Protection
- Conclusions

Introduction

- In the last 20 years power systems witnessed important changes:
  - Centralized paradigm versus more decentralized and market driven approaches;
  - Legal and regulatory changes;
    - Vertical and horizontal changes;
    - New tariff systems;
  - Large technical advances (communications and computation);
  - Larger environmental concerns;

Introduction

- At the distribution level there were also important changes:
  - Dispersed generation at the MV level;
    - Attractive tariff and legal systems;
  - MV networks are active;
    - Eventually injecting in the HV network;
    - Changes in protection systems;
  - Impact of market approaches;
    - Separation between operation and retail – DSO – Distribution System Operator, retail companies and network companies;
    - Investments to ensure/improve Quality of Service.

Introduction

- Example – Portugal:
  - New Legislation – 2001 and 2002;
    - Payment according to avoided costs of power, of energy and of CO_2 emissions, including a Z factor depending on the technology and avoided costs of losses;
    - For each month m:

$$VRD_m = \left[PF(VRD)_m + PV(VRD)_m + Z.PA(VRD)_m\right].\frac{1}{1-LEV}$$

environmental term
technology prize factor
variable term
fixed remuneration
monthly remuneration

Introduction

- Next 10 to 20 years:
  - The change that occurred in MV networks may also happen in LV networks:
    - Connection of small modular generation sources;
    - Fuel cells, renewable generation (wind turbines and PV systems), micro turbines (natural gas or bio fuels);
    - LV networks will also become active;
  - The operation of these LV networks can be done in a traditional way or we can think of a change of paradigm !

Introduction
Traditional approach

- Portuguese legislation on generation on LV networks (March and July 2002):
  - micro-generation – activity predominantly to self consumption, but being able of delivering the excess to other consumers or to the grid;
    - Self generation – if at least 50% is for own consumption;
  - micro-generator – autonomous main generation equipment: motors, micro-turbines, or fuel cells, using synchronous or asynchronous generators, solar photovoltaic panels, and other autonomous generation equipments;
  - the power to deliver to the grid, in each reception point, cannot exceed 150 kW;

Introduction
Traditional approach

- Portuguese legislation on generation on LV networks (March and July 2002):
  - Payments to small generation in LV networks

$$VRD_m = VRD(BTE)_m + C_t . EEC_m . \frac{IPC_{dec}}{IPC_{ref}}$$

- $VRD(BTE)_m$ - amount in € - energy injected in month m, paid at the tariff for LV consumers with contracted power larger than 41,4 kW;
- EEC_m - value in kWh of the injected energy in month m;
- C_t – coefficient dependent on the technology (in €/kWh):
  - reflects the interest in developing or inducing the use of a particular technology;
  - reflects the amount required to turn the investment economically feasible

Advantages of microgeneration

- Environmental impacts:
  - Smaller than in traditional large thermal or hydro stations;
  - Increased awareness of consumers towards energy;
  - Reduction of gas emissions and mitigation of climate change;
- Operation and investment issues:
  - Reduction of the distance between generation and loads;
    - Improved reactive support and voltage profile;
    - Mitigation of distribution and transmission bottlenecks;
    - Reduction of losses in upstream networks;
    - Reduction or postponement of investments in transmission and large scale generation;

Advantages of microgeneration

- Power quality:
  - Increase reliability (interruptions and energy not supplied);
  - Increased quality of service;
  - Mitigate the impact of outages in distribution and transmission;
- Market issues:
  - Possible development of market approaches to integrate microsources;
  - Reduction of market power of larger companies;
  - Eventual contribution to reduce electricity prices since transmission and distribution networks are used in a less intensive way.

Challenges, difficulties and drawbacks of microgeneration

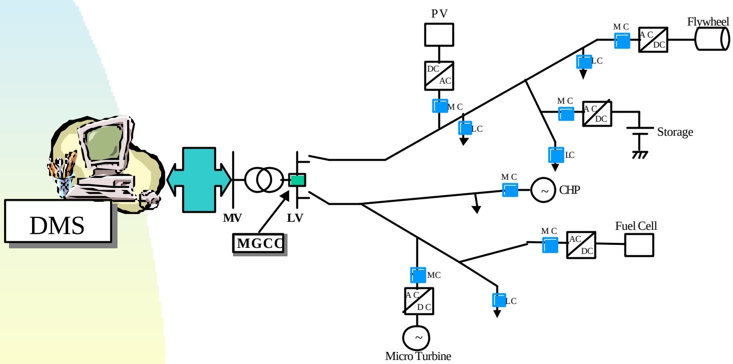
- High costs of distributed energy resources;
  - Transitory period with subsidies?
- Technical difficulties:
  - Lack of experience, regulations, norms;
  - Difficulty in controlling a large number of micro sources;
    - Most of them with power electronic interfaces
  - Dynamic problems (models and tools)
  - Need for specific communication infrastructure and protocols;
  - Very volatile resources (solar, wind,…).

New Paradigm - MicroGrid

- MicroGrid – association of a low voltage distribution network,small modular generation system and loads having some <u>local coordinated functions</u>;
  - Small urban area, industry, shopping centers;
  - Fuel cells, renewable generation (wind parks and PV systems), micro turbines (using gas or biofuels);
  - Typically in the range from 25 to 100 kW;
  - Combined Heat and Power (CHP) – increase the energy effectiveness;

New Paradigm - MicroGrids

An example



New Paradigm - MicroGrids

- MicroGrid components:
  - Small modular generation systems;
  - Storage equipment (batteries, capacitors, fly-wheels);
  - LV grid;
  - MGCC – Micro Grid Central Controller;
  - MC – Micro Source Controller;
  - LC – Load Controller.

New Paradigm - MicroGrids

- MicroGrid components:
  - MGCC – MicroGrid Central Controller:
    - Local central controller, to promote an adequate technical and economical operation policy, and to provide set points to LC and MC;
    - Interface with loads and micro sources as well as with the DMS system;
  - MC and LC Controllers:
    - Interfaces to control:
      - some loads (interruptability);
      - micro sources (active and reactive generation levels).

New Paradigm - MicroGrids

- 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,…);

New Paradigm - MicroGrids

Improved reliability and continuity

- MicroGrids can operate:
  - Emergency 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 (interruptability, storage devices, load shedding,…);
      - Eventually, triggers a black start function.

The MicroGrids Project

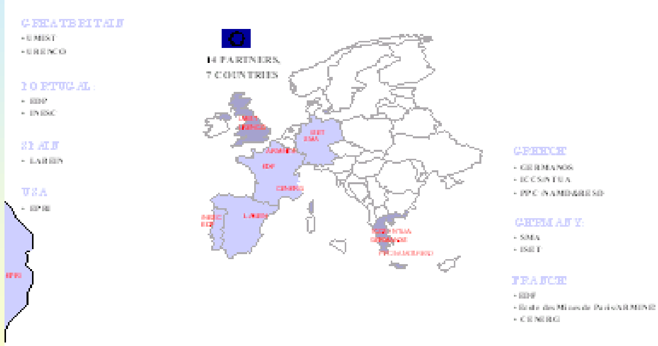
- EU financed research project in the scope of the 5th RTD framework.
- Objectives:
  - Contribute to increase the share of renewables and to reduce GHG emissions;
  - Study the operation of MicroGrids in normal and islanding conditions;
  - Optimize the operation of local generation sources;
  - Develop and demonstrate control strategies to ensure efficient, reliable and economic operation;

The MicroGrids Project

- EU financed research project in the scope of the 5th RTD framework.
- Objectives:
  - 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;

MICROGRIDS Project

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



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

The MicroGrids Simulation Platform

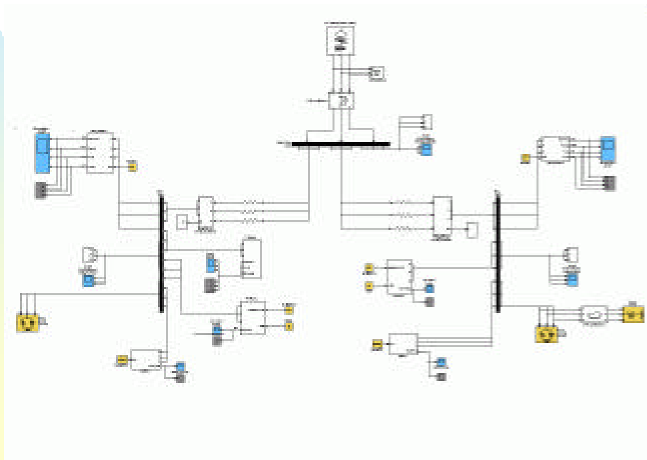
- Why? To investigate the technical consequences of the integration of microgeneration in LV grids;
  - Electronic interfaces;
  - Balanced and unbalanced operation;
    - LV loads, single phase generation devices;
    - Unbalanced faults;
  - Steady state and dynamic simulation;

The MicroGrids Simulation Platform

- What does it include?
  - Models of the different types of micro sources including power electronic interfaces;
    - MatLab Simulink environment;
  - Balanced and unbalanced Load Flow codes;
  - Simulation of disturbances:
    - Connection/disconnection of loads and micro generation;
    - Faults in the upstream MV network;
    - Faults in the LV grid;
    - Faults in the micro sources;

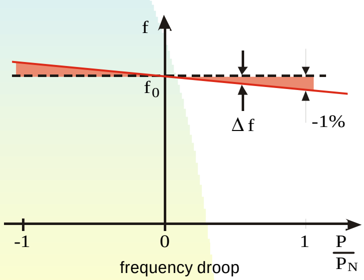
The MicroGrids Simulation Platform

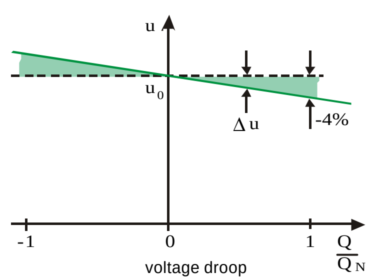
Example of a balanced operation model developed in MatLab Simulink



The MicroGrids Simulation Platform

When in islanding mode, micro generators participate in voltage and frequency regulation using the proportional concept of frequency and voltage droops.

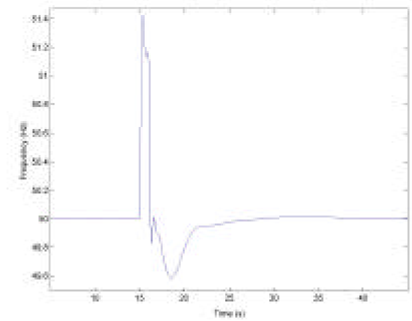




The MicroGrids Simulation Platform

Some results – disconnection of a 70 kW active load, followed by its re-connection 1 second later under islanding conditions.

frequency



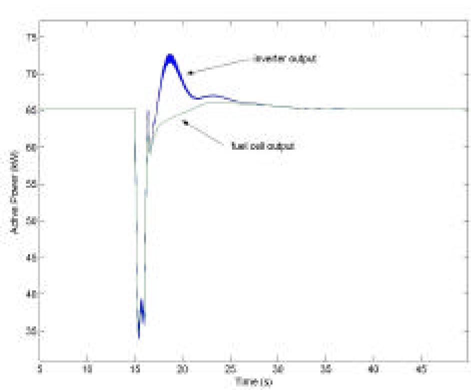
The MicroGrids Simulation Platform

Some results – disconnection of a 70 kW active load, followed by its re-connection 1 second later under islanding conditions.

Fuel cell and

inverter

power outputs

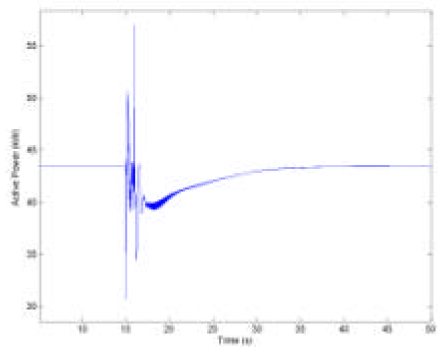


The MicroGrids Simulation Platform

Some results – disconnection of a 70 kW active load, followed by its re-connection 1 second later under islanding conditions.

Micro turbine

power output



MicroGrids – Management and Control

- Management and Control facilities in the MGCC for normal interconnected steady state operation:
  - Short Term Forecasting Tools;
    - Electric loads, wind, PV, heat;
  - Economic Scheduling;
    - Traditional cost minimization strategy to allocate pre-specified power to each source;
    - Market approach: receive bids sent by LC and MC, aggregate bids, send bids to MO, disaggregate dispatched power by micro sources;

MicroGrids – Management and Control

- Management and Control facilities in the MGCC for normal interconnected steady state operation:
  - On-Line Security Functions;
    - Analysis of operation points considering reliability, steady state security, dynamic criteria;
  - Demand Side Management Functions;
    - Interruptible loads;

MicroGrids – Management and Control

- Several aspects are under discussion:
  - Energy blocks from micro sources are too small to be markeatable;
  - Current micro source costs are still too high.
    - Transitory subsidized period?
- However:
  - The project has a 3 years horizon;
  - MicroGrids will hopefully be developed in the next 10 to 15 years;
  - It is an opportunity to develop alternative strategies and tools.

MicroGrids – Islanding and black start

- In case of failure of the MV or HV grids:
  - The distribution network may break into islands;
  - MicroGrids may maintain operation using local resources and under the control of the MGCC, MC and LC;
    - Change from power control to frequency control and load shedding;
  - The MGCC will also have a black start function:
    - In case of general system black out;
    - Grid reconnection during black start.

MicroGrids – Islanding and black start

- Frequency control and load shedding
  - Island operation following disturbances (voltage drops, faults, blackouts,…);
  - Load-tracking problems – slow response of micro-turbines and fuel cells;
    - Importance of storage devices;
  - Change from dispatched power mode control to frequency control of the islanded section.
    - New control strategies together with load shedding.

MicroGrids – Islanding and black start

- Local Black Start of the MicroGrid
  - After a general black out, if the main system is unable to restore after a specified time;
  - It is an area of research (MGCC, LC, MC);
- MicroGrid reconnection during black start of the main grid
  - Help the upstream DMS;
  - Problem – out of phase reconnection.
    - Are synchronization devices required?

MicroGrids – Protection

- MicroGrids are active networks;
  - Interconnection mode:
    - Fault on the MV side – isolate the MicroGrid as fast as possible;
    - Fault on the MicroGrid – isolate the smallest possible section;
  - Isolated mode:
    - Isolate the fault, micro generators,…
  - Most protection systems are short circuit based;
    - Power electronic devices usually don´t provide the required levels of short circuit currents;
    - Differential protection systems or zero sequence voltage relays.

MicroGrids – Conclusions

- MicroGrids can correspond to a novel look at LV distribution systems.
  - Change of paradigm – not just small scale generation connected to LV networks;
  - There are clear advantages (quality of service, reliability, postponement of investments, …);
  - There are still many difficulties (technical, legal and regulatory);
- The MicroGrids project is an opportunity to investigate these topics and to demonstrate results that may be generalized in the next 10 to 20 years.