Jeju 2011 Symposium on Microgrids

Overview of Tecnalia's Microgrid Projects and Secondary Control

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1.Introduction to Tecnalia-Energy

1.1 Tecnalia Research & Innovation
1.2 Tecnalia-Energy

1.1 Tecnalia Research and Innovation

- Tecnalia was born in 2010 with the merging of 8 companies
- Tecnalia is now the first private R+D company in Spain and the fifth in Europe with 1.400 people and 125 M€ of turnover

1.2 Tecnalia-Energy

Active Electricity Distribution

Control & Conversion of Electrical Energy

Materials and processes for Energy

Electrical Equipment Test & Certification

Energy Sector

The largest private research organisation in Spain in the Energy field in terms of:

Turnover

15

Million €

Staff

124

2. Microgrid research projects in Spain

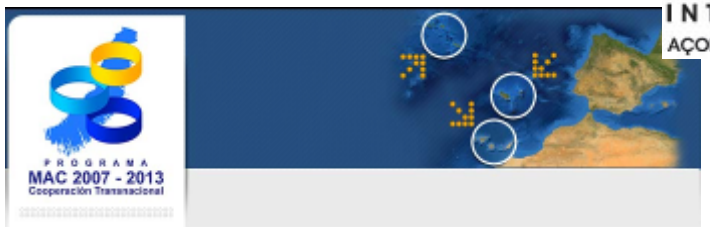
2.1 PIMEs project: Salburua Microgrid
2.2 La Graciosa island Microgrid
2.3 Villa Solar Decathlon Europe
2.4 Other projects

2.1 PIMEs project: Salburua Microgrid

- Development of the concept of an energy sustainable neighbourhood, based on Microgrids and replicable in different countries.
- Demonstration sites in:
  - Dale (Norway):
  - Szentendre (Hungary)
  - Salburua (Spain): 2 areas of intervention:
    - A block of flats: Natural gas CHP and PV panels are being installed for space heating and domestic hot water
    - A group of 4 blocks of flats: Space heating and domestic hot water needs, natural gas CHP, solar thermal and heat pump, connected to a geothermal seasonal heat storage

2.2 La Graciosa island Microgrid

- In the scope of the TRES project 2010-2012 (Transition towards a sustainable energetic model for Madeira, Azores and Canary Islands)
- European funds (FEDER) for the cohesion of regions in Europe
- Characteristics:
  - Weak electrical networks (poorly interconnected) add high restrictions for renewable generation (non-controllable)
- Objectives
  - Facilitate the deployment of renewables in islands
  - Development of forecasting models (wind and solar)
  - Dynamic stability studies
  - Evaluation of electrical storage technologies
  - **Demonstration of the results in La Graciosa island as a Microgrid**



2.3 Villa Solar Decathlon Europe 2012

- Roots in the US DOE Solar Decathlon (competition between universities over the world)
- Main objective is to design and build a self-sufficient house powered only by solar energy
- Implemented with technologies for an efficient use of the house's resources
- Tecnalia's role:
  - Technical specification (basis of competition) in order to obtain an electrical integration of houses as a Microgrid connected to the distribution network
  - Efficiency must be considered at the local level (house) and at the community level (Microgrid)
  - Apart from lighting, heating and cooling loads, the EV recharge must be considered

2.4 Other projects

- Optimagrid:
  - Project for developing Microgrids for industrial facilities
  - PV (25 kW), wind generation (20 kW), diesel generation (55kW) , flow batteries (50 kW x 4 hours), lead acid batteries (50 kW x 2 hours)
- IREC Microgrid:
  - Experimental station in which research can be conducted into the integration of all components into a new energy supply system.
  - Integration of: conventional microgeneration technologies (diesel or natural gas engines), emerging technologies (microturbines or energy from storage devices), and renewable technologies (small wind turbines or solar generators).
- iSare project:
  - Smart Microgrid in the Miramon Technology Park (San Sebastian) to be operational in late 2012
  - Will enable companies to develop and validate equipment designed to enhance the capabilities of electricity distribution networks of the future
  - Storage systems, generation and micro grid architecture, made up of interoperable communications, a control centre, and charging points for EVs

3. Tecnalia's Microgrid laboratory

3.1 Tecnalia's laboratory

3.2 New facilities under development

3. Tecnalia's Microgrid laboratory

3.1 Tecnalia's laboratory

Power Sources:

- Diesel Generator (2x55kW)
- µTurbine (50kW)
- Pacific Power Sources - programmable network simulator- (2x62.5kVA/50kW)
- PV single phase (0.6kW and 1.6kW)
- PV (3.6kW three phase)
- Wind Turbine (single phase 6kW)
- Ballard Fuel cell (1 kVA)
- DC power source (125 kW)

Static Switch:

- Islanded – Grid connected

Main switching board:

- Three busbars (Three phase)
- Most devices can be connected to any busbar

Tests switching board:

- Concentrates all load banks at a single connection

Communication network:

- Ethernet, WiFi, RS 485 & RS 232, TCP/IP, ModBus…

Storage:

- Flywheel (250kVA)
- Ultracapacitor bank (48V 2.8MJ)
- Battery banks (48V-1925Ah and 24V-1120Ah)

Controllable load:

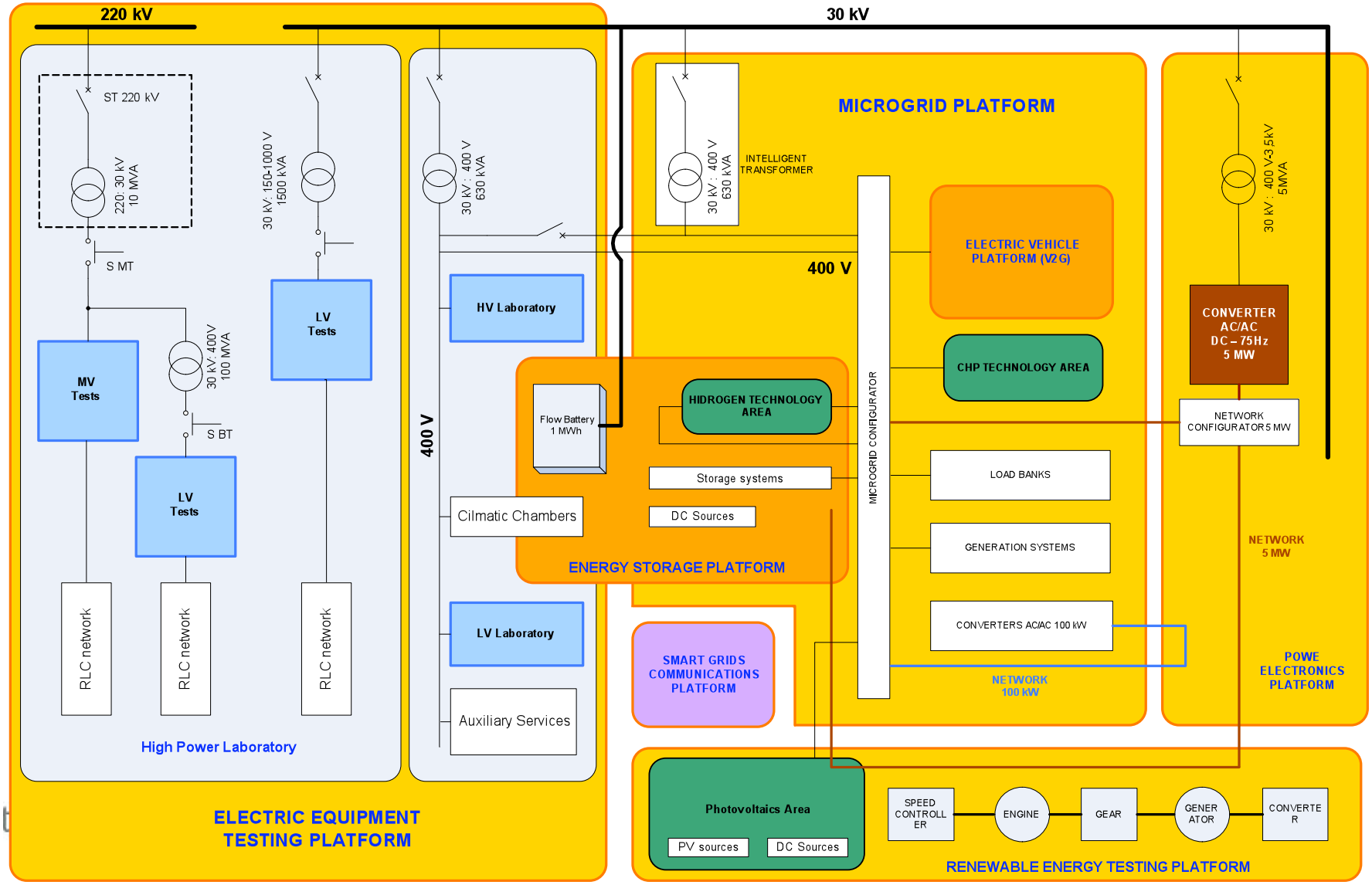
- Resistive load bank (150kW & 55kW)
- Reactive load banks (up to 200kVARr reactive or capacitive)

Other:

- Line simulator (R & X)
- DC Network, Rectifier and PM1000 Inverters (2x100kW)
- Hidrotec
- EV platform
- Kubik

3. Tecnalia's Microgrid laboratory

3.2 New facilities under development



4. Secondary control implementation

4.1 Secondary control of Microgrids
4.2 Design of the control system
4.3 Hardware
4.4 Generation, Load and Grid bids
4.5 Bid/Offer matching
4.6 Tests

4.1 Secondary control of Microgrids

- Secondary control in transmission networks

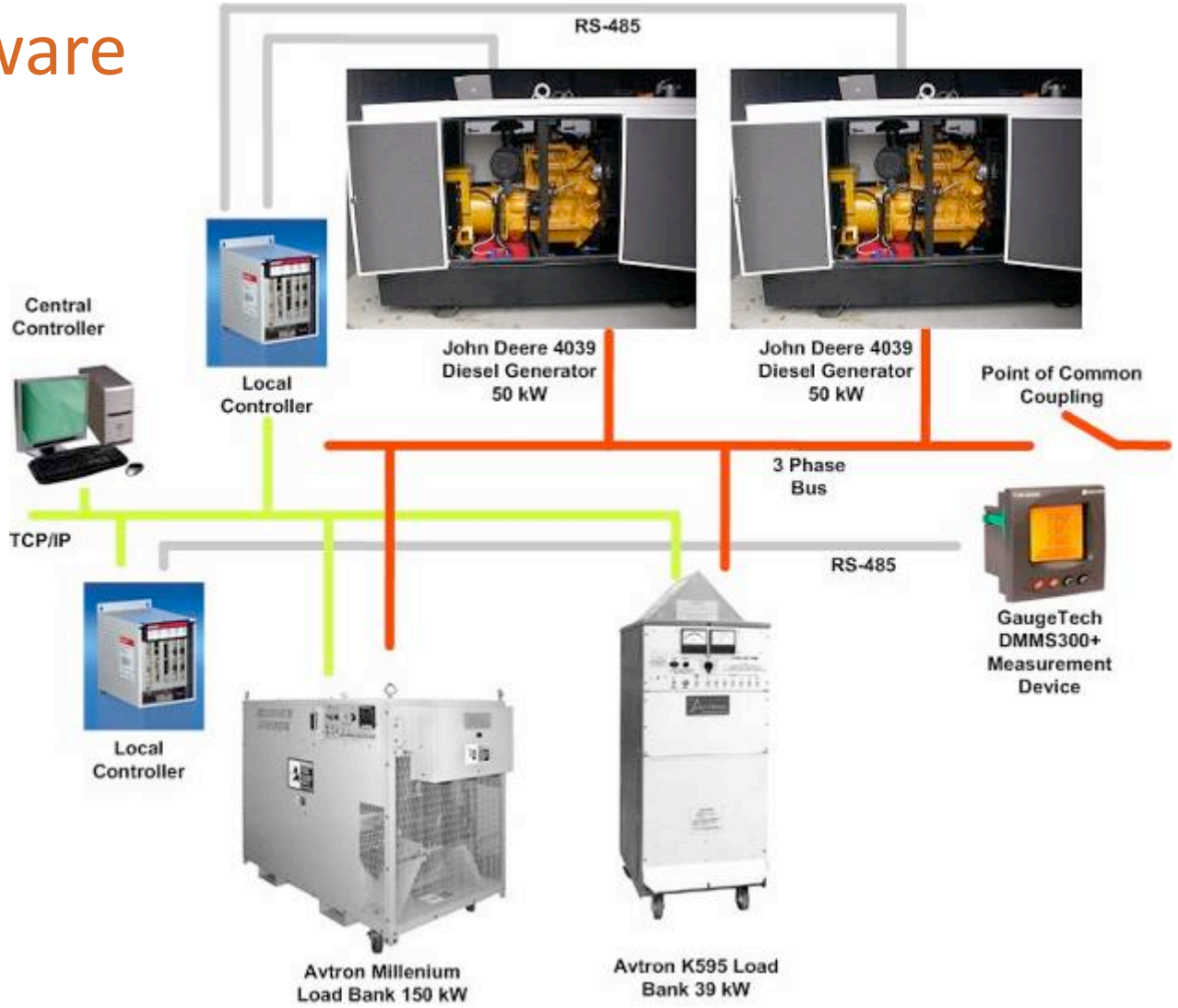
  "automatic control in charge of ensuring that power exchanges between control areas are maintained as scheduled and that the frequency is kept close to the reference value within allowed limits"

- Secondary control in Microgrids
  - Grid Connected: Maintain the power exchange with the Main Grid as previously scheduled
  - Islanded: Recover frequency after changes in load

4.2 Design of the control system

- Market model:
  - Each device provides bids or offers
    - Generators: based on operating costs
    - Loads: based on priority
    - Storage: based on energy price and SOC
    - Main Grid: based on deviation price
  - Supply and demand are matched so a marginal price is obtained
  - Each device is assigned a power set point

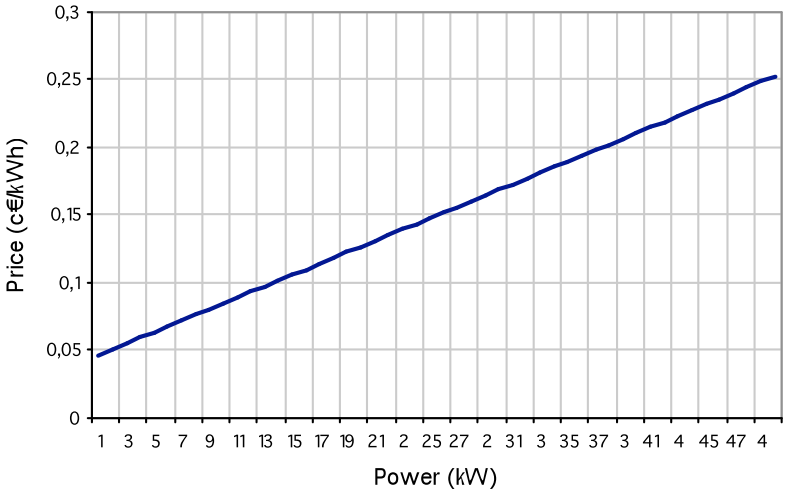
4.3 Hardware


RS-485
Central Controller
Local Controller
John Deere 4039 Diesel Generator 50 kW
John Deere 4039 Diesel Generator 50 kW
Point of Common Coupling
3 Phase Bus
TCP/IP
RS-485
GaugeTech DMMS300+ Measurement Device
Local Controller
Avtron Millenium Load Bank 150 kW
Avtron K595 Load Bank 39 kW

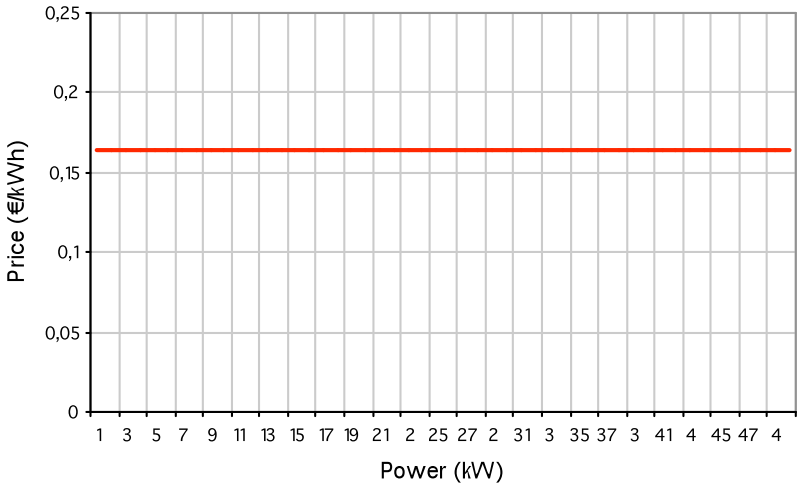
4.4 Generation, Load and Grid Bids/Offers

- Generation supply offers
  - Cost equation $C = a + b \cdot P + c \cdot P^2$
  - Incremental cost

$$\mathrm{MC}_{\mathrm{microturbine}} = 0.0021P + 0.0427$$

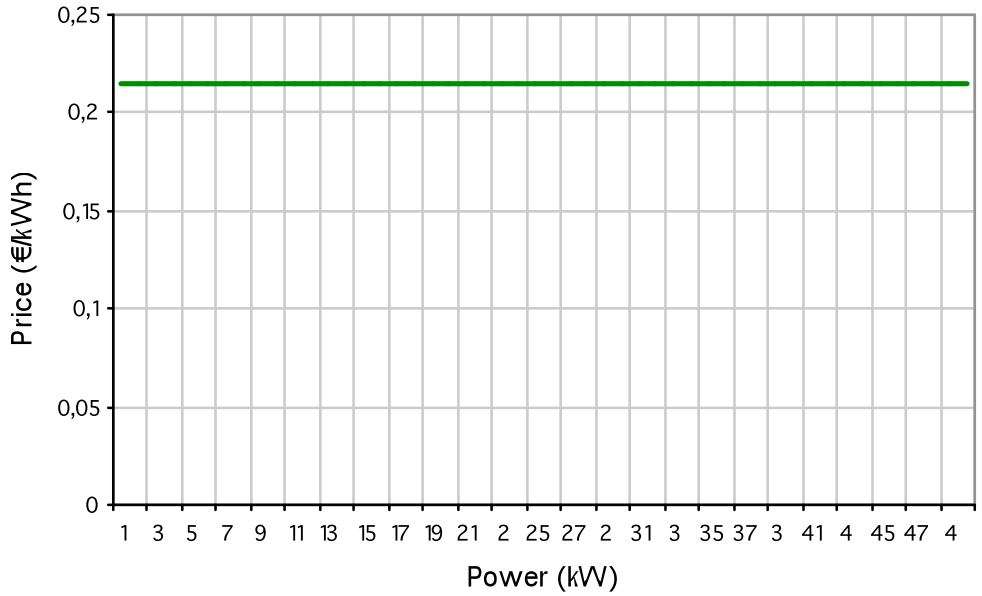


$$\mathrm{MC}_{\mathrm{diesel}} = 0.1647$$



– Electricity price from the Grid

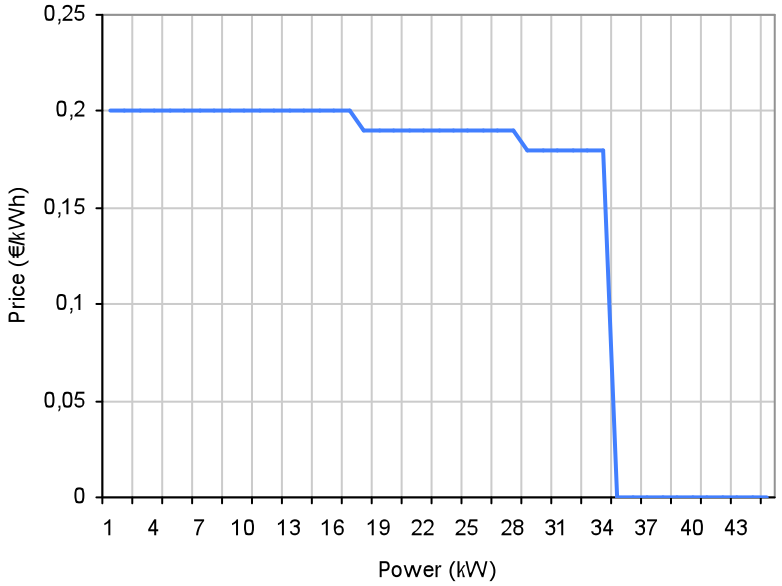
- Represents the price of the deviation costs



– Load bids

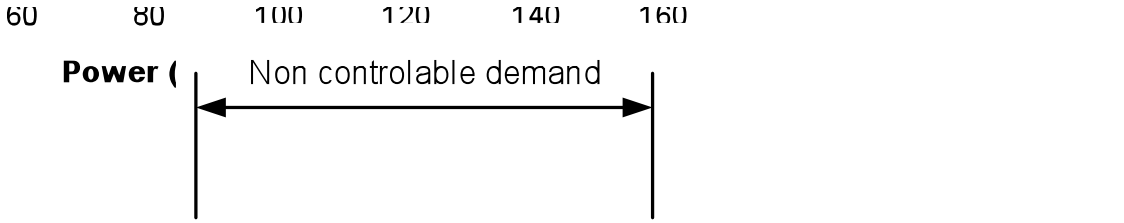
- Non-priority loads will be progressively disconnected when 80% of the Microgrid capacity is reached

Load	Rated Power (KW)	€/kWh
k595-5	5.56	0.18
k595-6	11.11	0.19
k595-7	16.67	0.20



4.5 bid/offer matching

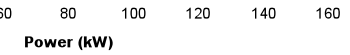
$$P^{nonctldemand} = P^{nonctlcomp} + (P^{export} - P^{import}) + MRE$$

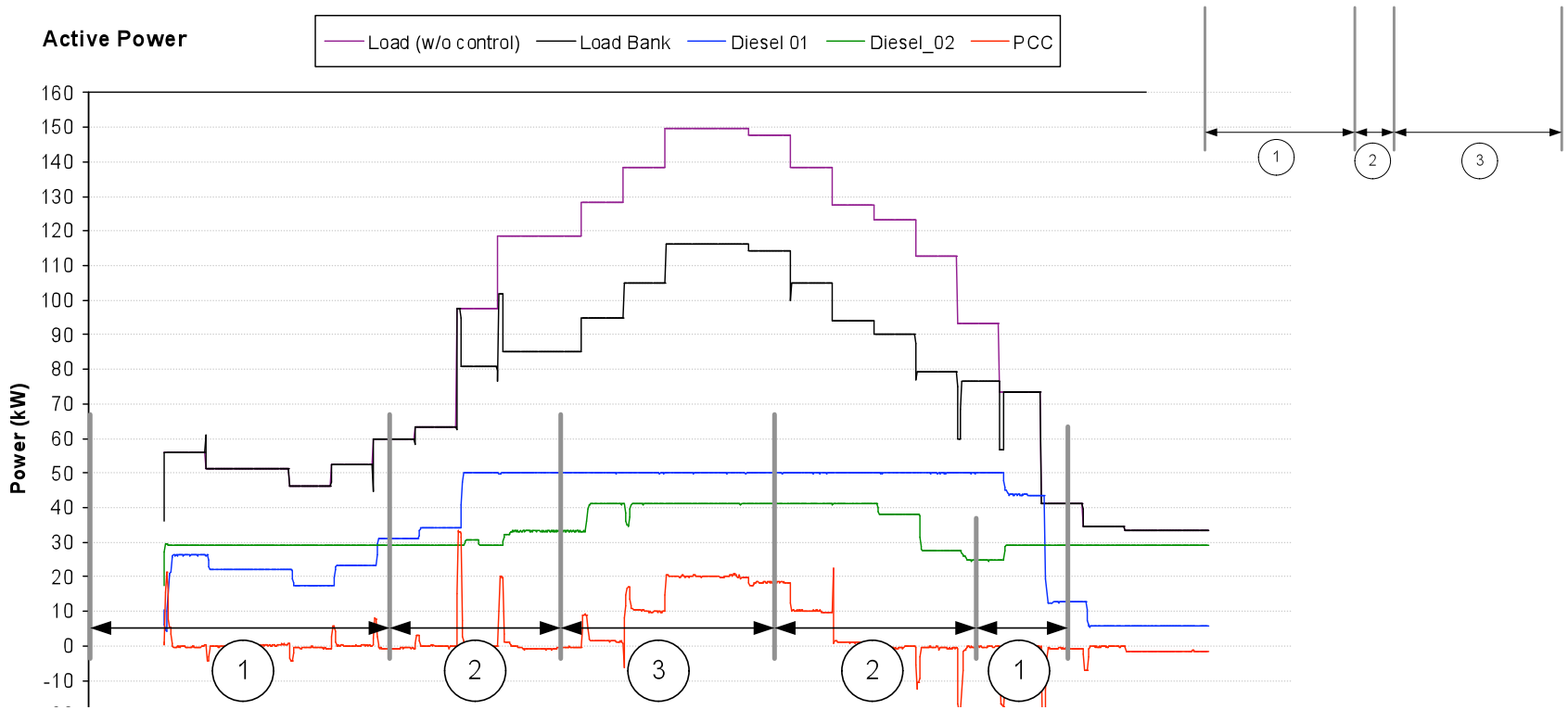


4.6 Tests

- Measurement cycle 1 second
- Control cycle 5 seconds
- Test 1: Microgrid connected to the main grid
  - Objective: Zero power exchange with the main grid
  - Building normal load profile scaled to 100 kW

Results (Grid Connected)

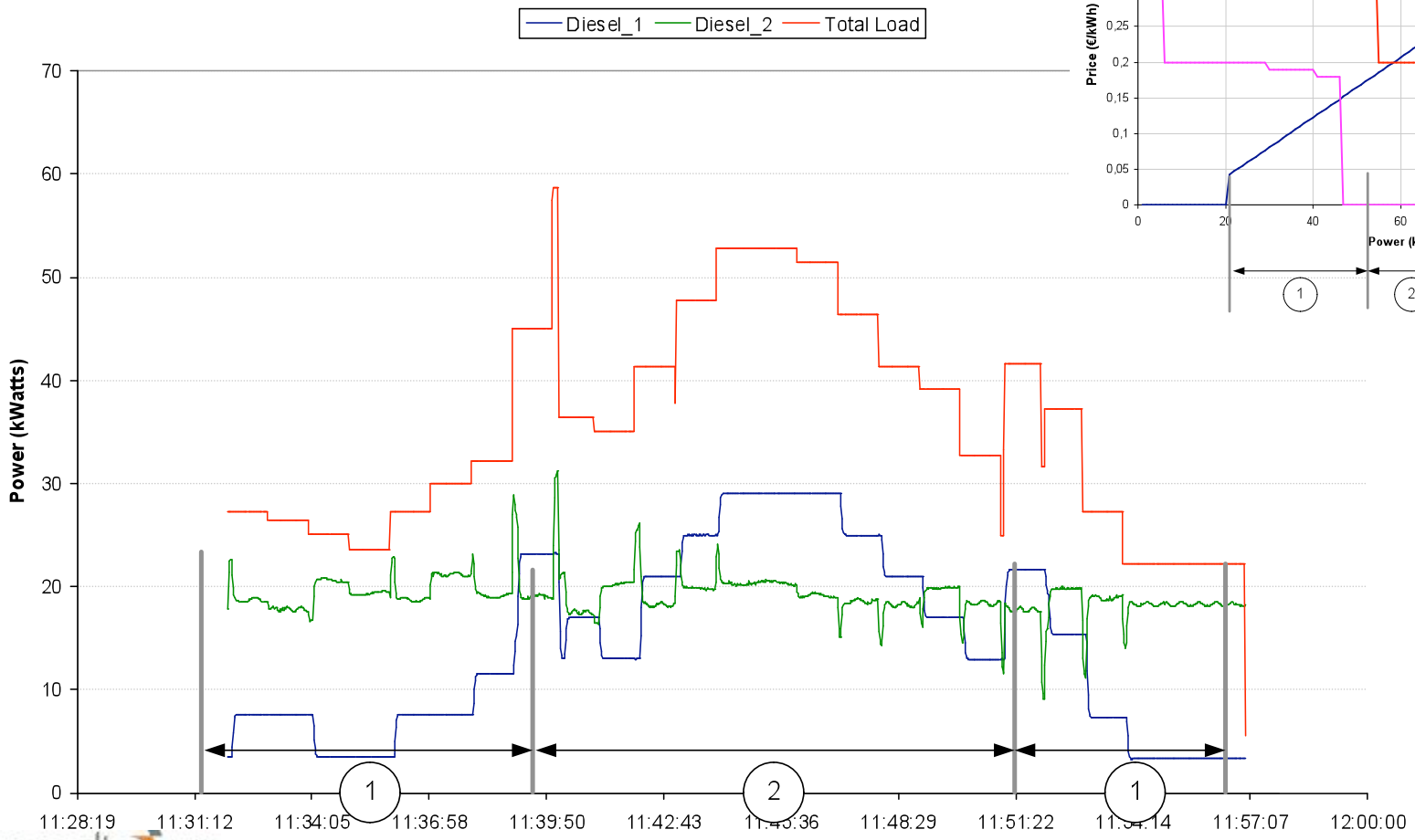


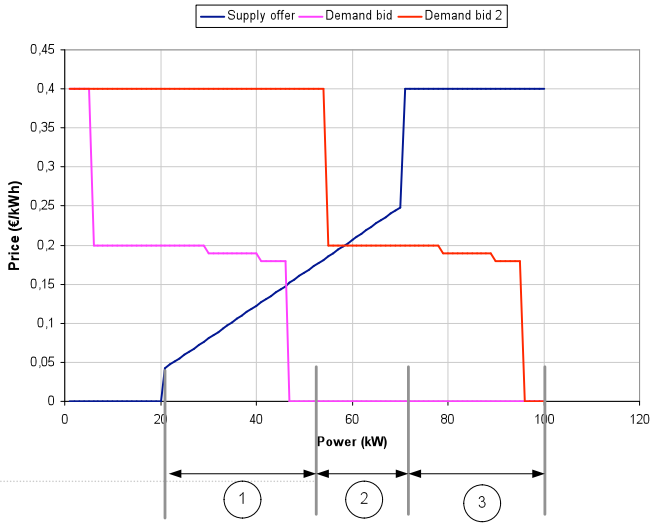


Test 2: Microgrid in islanded mode

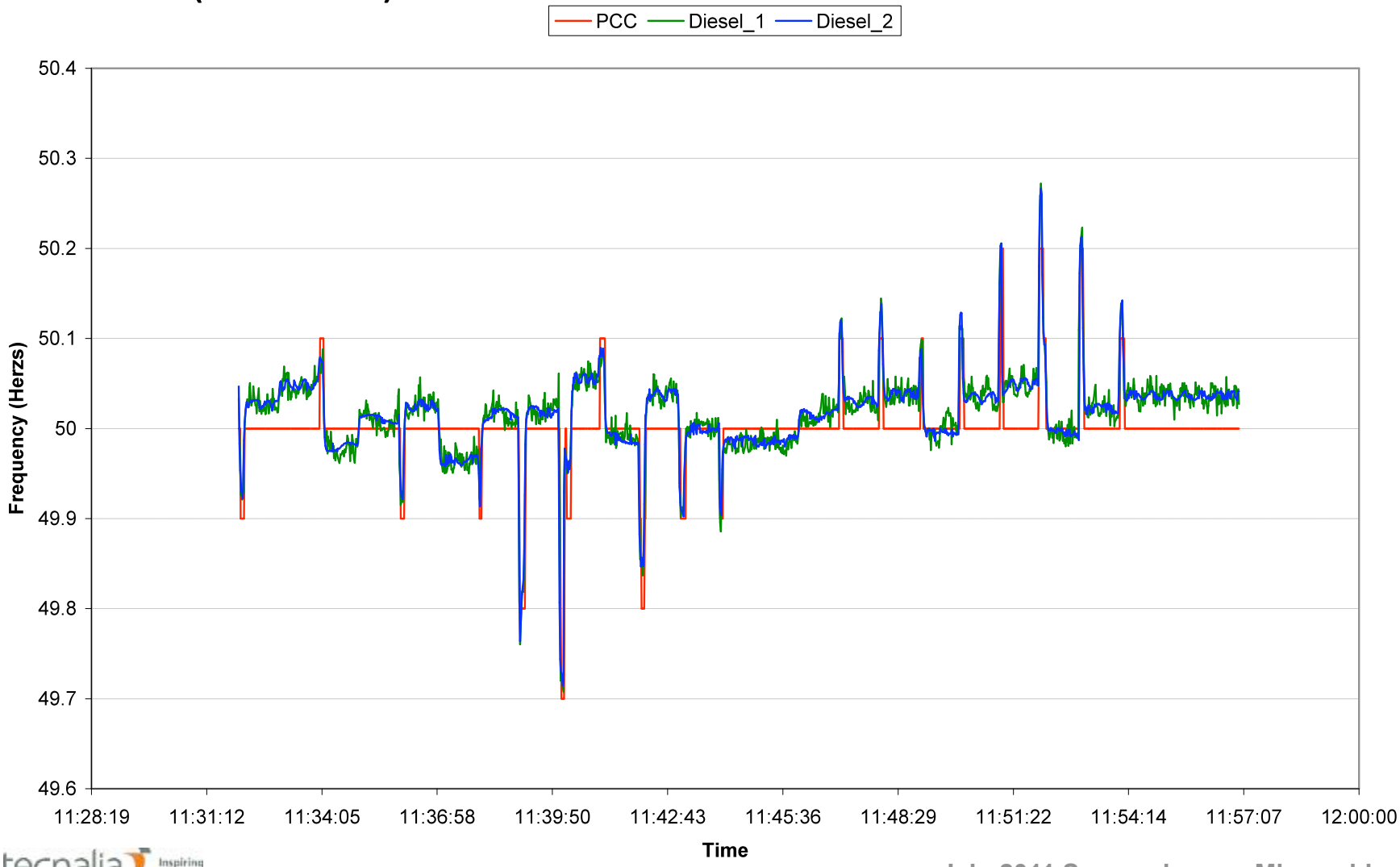
- Objective: 50 Hz frequency should be maintained
- Diesel_1 as voltage source (Base power 20 KW)
- Load profile scaled to 80 kW

Results (Islanded)





Results (Islanded)



5. Conclusions

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1. Several Microgrid research projects are being developed in Spain
   - PIMEs: Residential Microgrid in existing households
   - La Graciosa: Microgrid for renewable integration in an island
   - Villa Solar: Contest for solar sustainable houses with Microgrid functions
   - Others
2. Tecnalia's laboratory and the new facilities under development are a flexible platform for Smart Grids technologies testing and research
3. Practical implementation of a secondary control system
   - Real time (secs) control
   - Supply/demand balance problem
   - Most economical operation
   - Grid connected and islanded modes
   - Market based model

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Thank you for your attention !!

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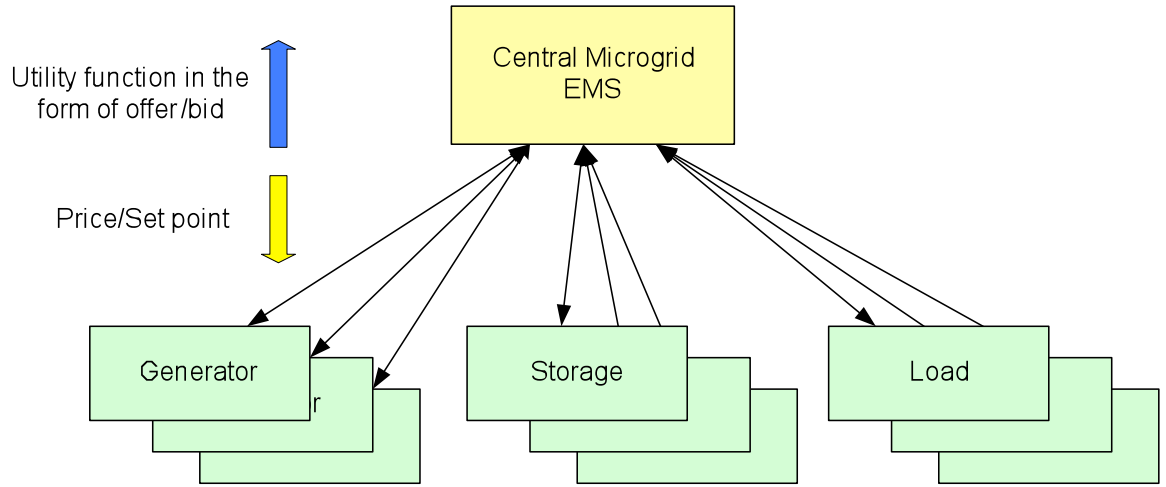
4.1 Microgrid Energy Management System

- Flexible control and monitoring system for DER coordination in a Microgrid
- Implementation based on Multi Agent technologies:
  - Modular
  - Plug&Play
  - Decentralized



4.5 Software deployment