MICROGRIDS
Novel Architectures for Future Power Systems
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Control strategies with emphasis on decentralized control

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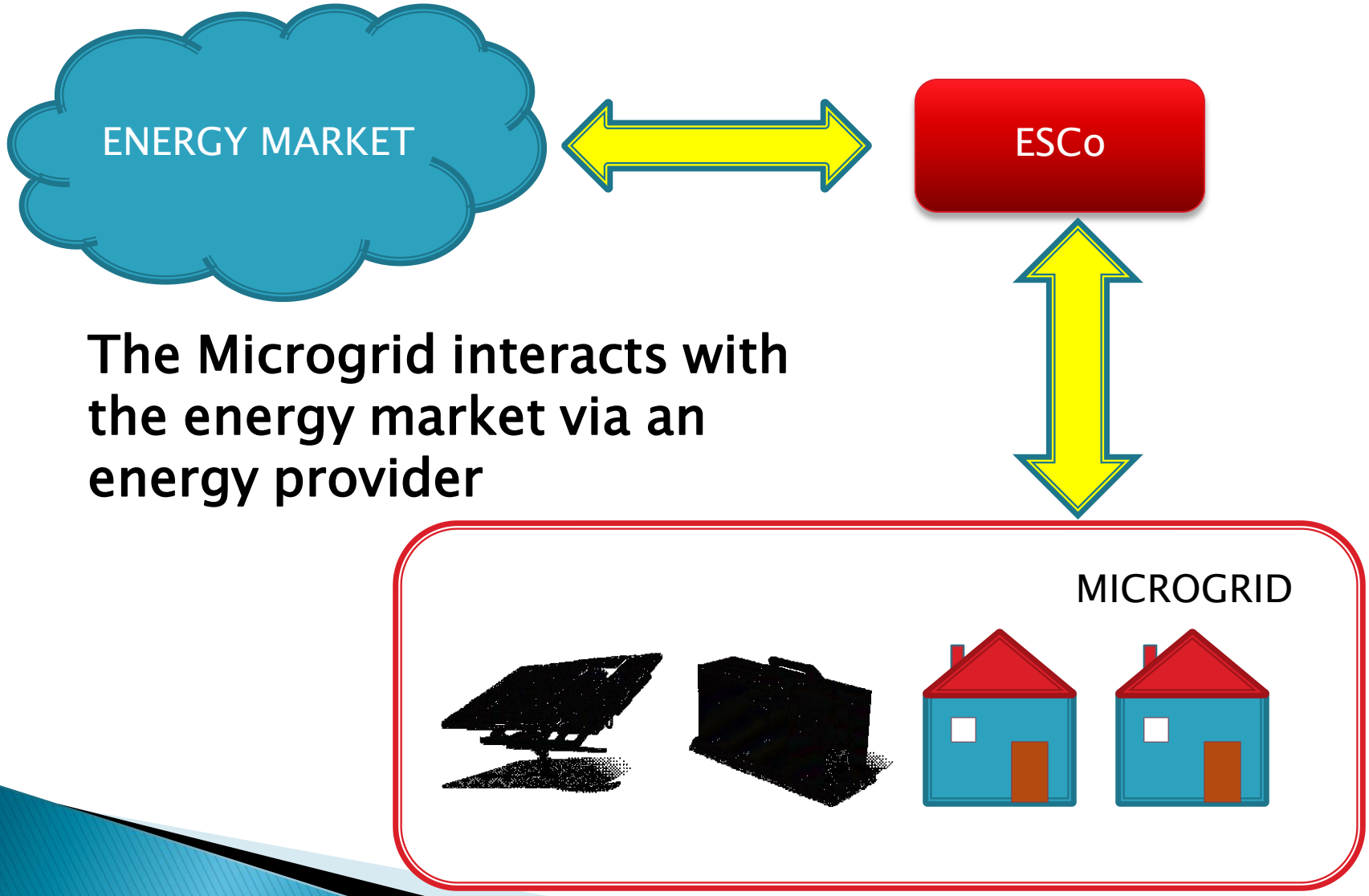
Outline

- Introduction
- Advanced control concepts for Microgrids
- Examples of implementation

Basic Challenges for Microgrids Control

- The legal framework/Market Structure
- Large Number of DGs and Houses with controllable devices.
- The solution should have very low cost per node.
- The Microgrid is a small electric system.
- The system should include DGs from different vendors and different principles of operation.
- The available communication infrastructure should be used in order to reduce the cost.

The Market Structure

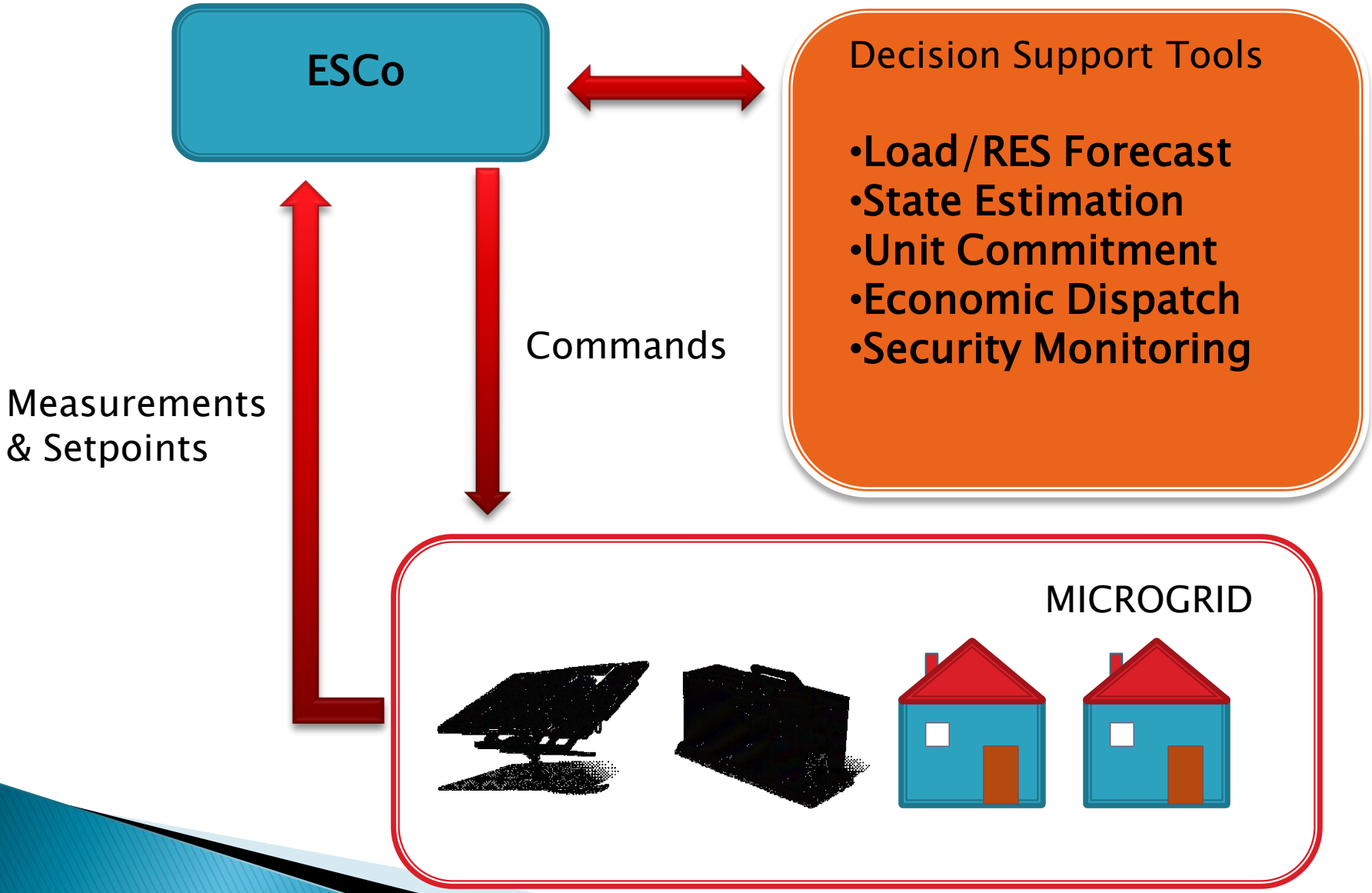


The Microgrid interacts with the energy market via an energy provider

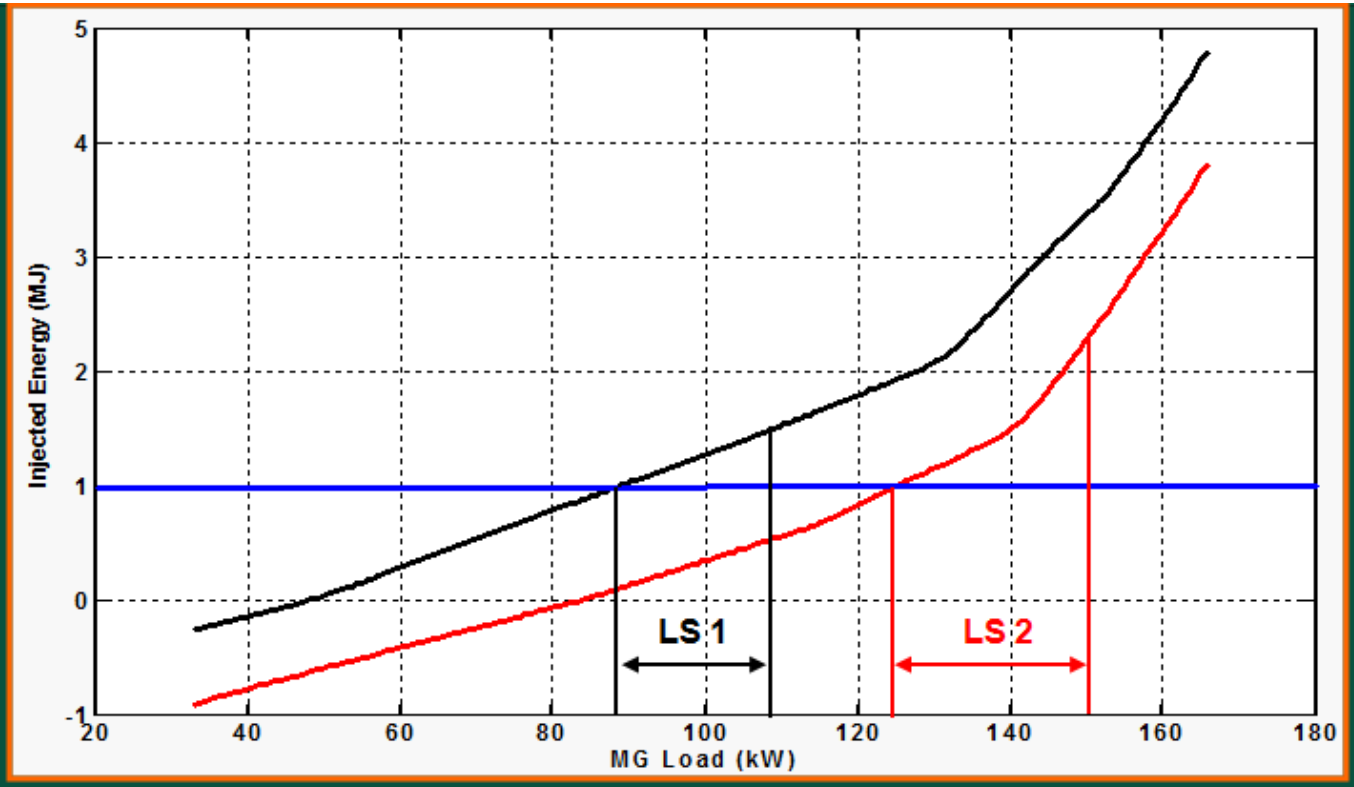
Centralized & Decentralized Control

- Two possible control architectures may exist.
- The main issue is where the decision is taken
- The **Centralized Approach** suggests that a Central Processing Unit collects all the measurement and decides next actions.
- The **Decentralized Approach** suggests that advanced controllers are installed in each node forming an distributed control system.

The Centralized Approach

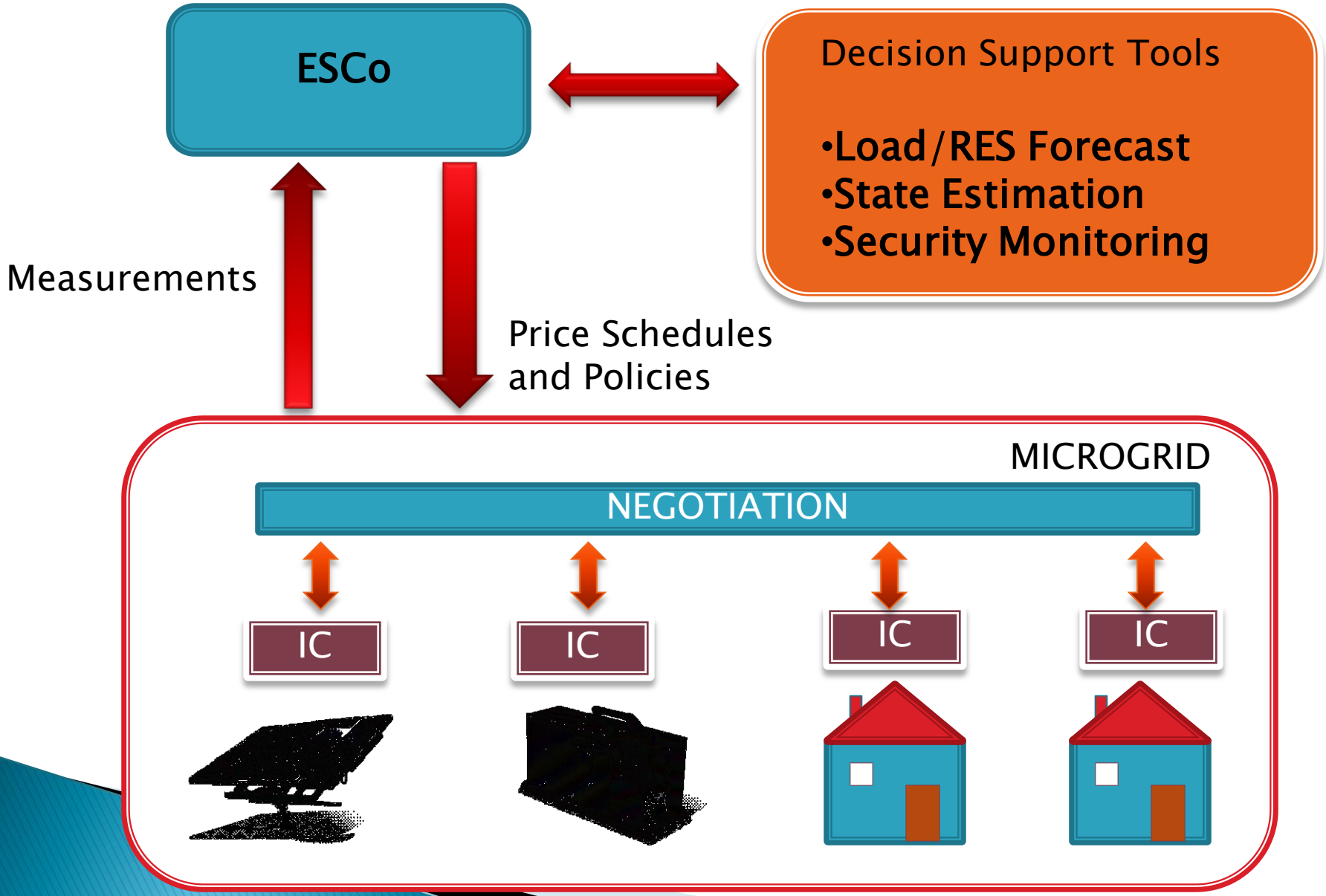


NN Tool Application – Load Shedding



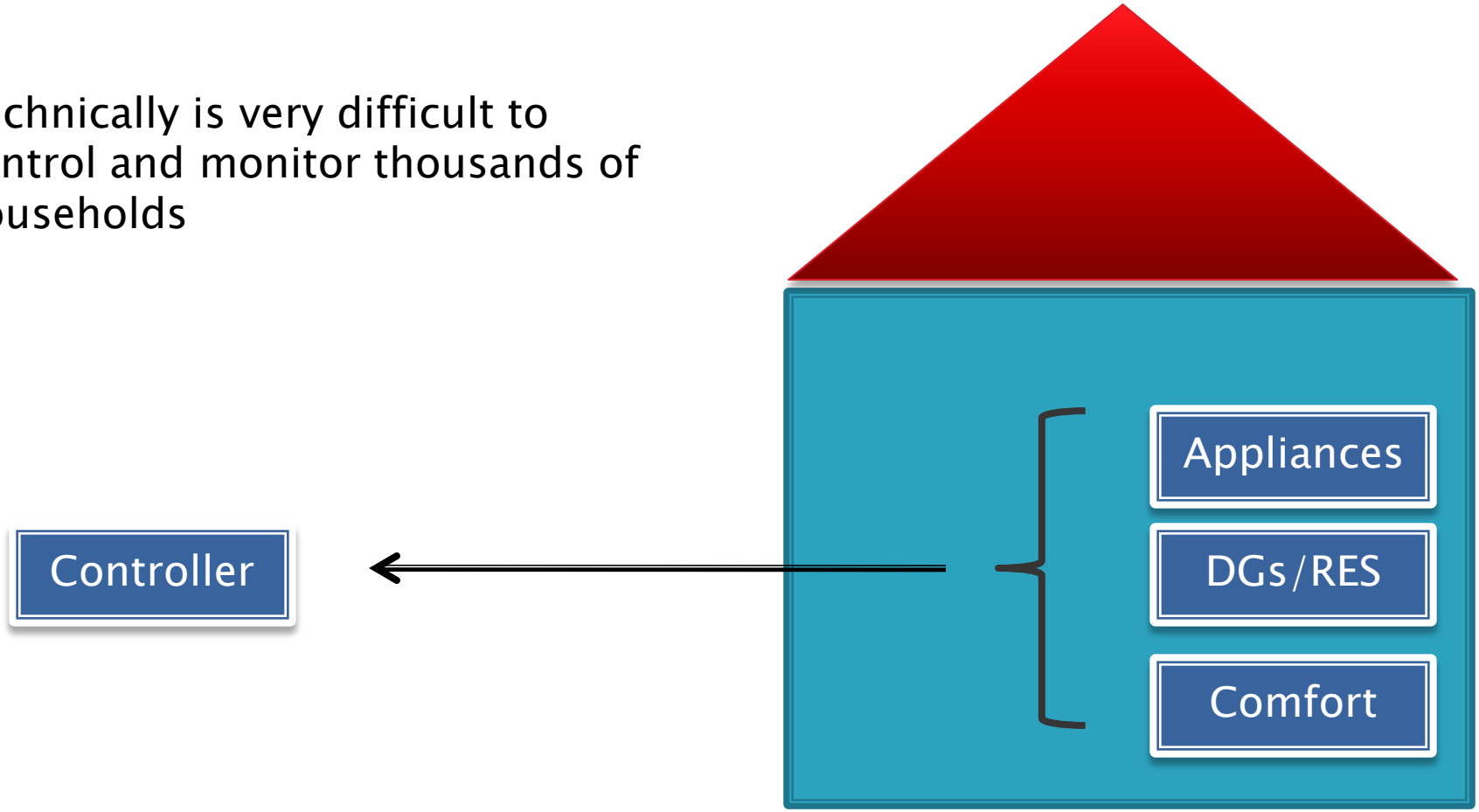
	Scenario 1 (black)	Scenario 2 (red)
PV Active Power (kW)	2.99	0.8
Wind Generator Active Power (kW)	1.43	12.32
MT 1 & 2 Active Power (kW)	7.7	20.08
MT 3 Active Power (kW)	3.81	29.1
SOFC Active Power (kW)	27.93	19.77
MG Load (kW)	108.4	151.35
Injected Energy (MJ)	1.48	2.4
Load Curtailment (kW)	19.3	26.1

The Decentralized Approach



Why is Local Control Important?

Technically is very difficult to control and monitor thousands of households



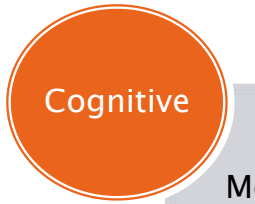
Implementing the Decentralized Control Concept

- One approach of implementation adopts the intelligent agent approach
- Next some basic concepts of the agent theory will be presented as well some practical examples.

The Agent

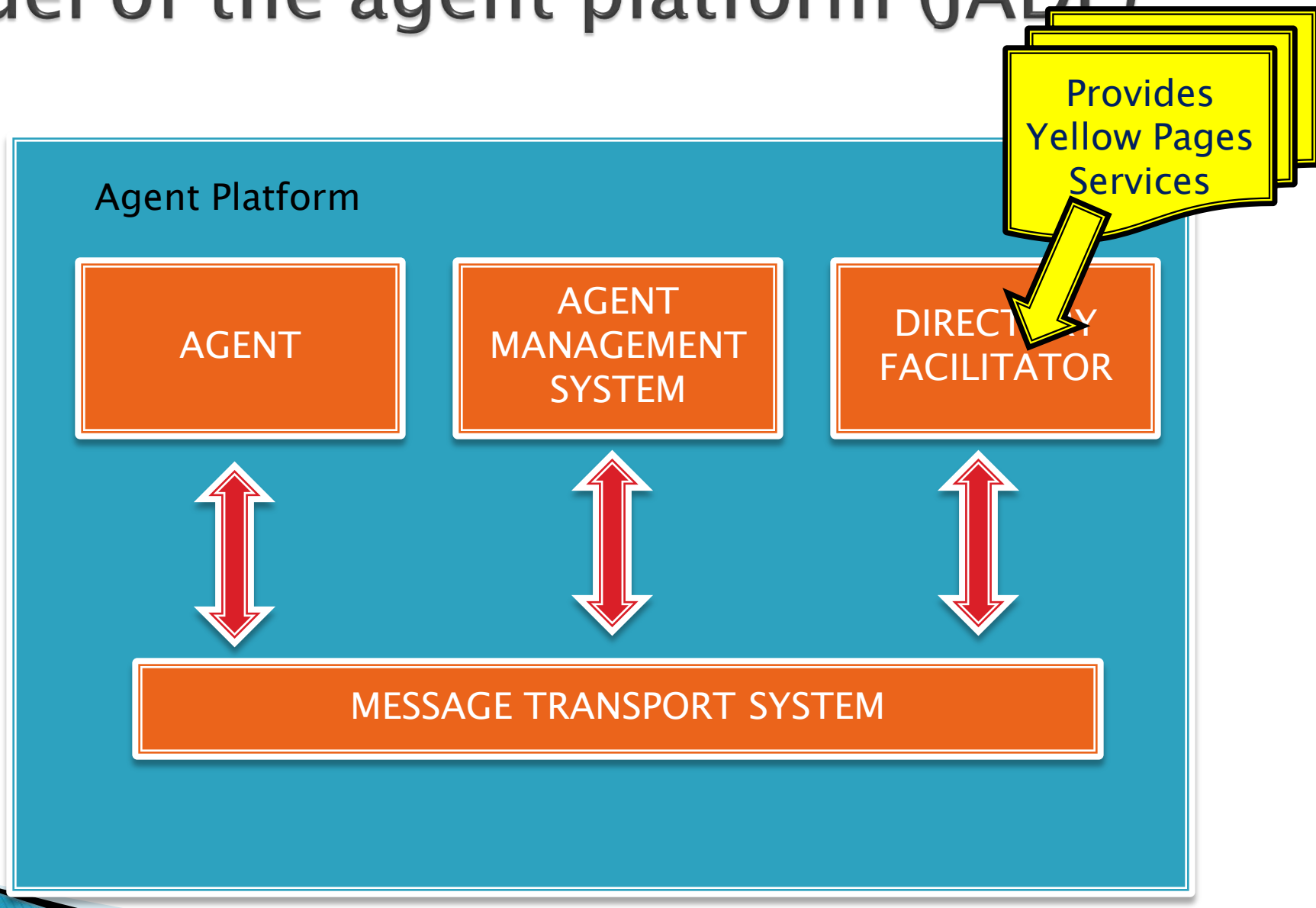
- Physical entity that acts in the environment or a virtual one
- Partial representation of the environment
- Agents communicate – cooperate with each other
- Agents have a certain level of autonomy
- The agents have a behaviour and tends to satisfy objectives using its resources, skills and services

- partial representation of the environment
- autonomy
- possesses skills



- Memory
- Environment Perception
- high level communication

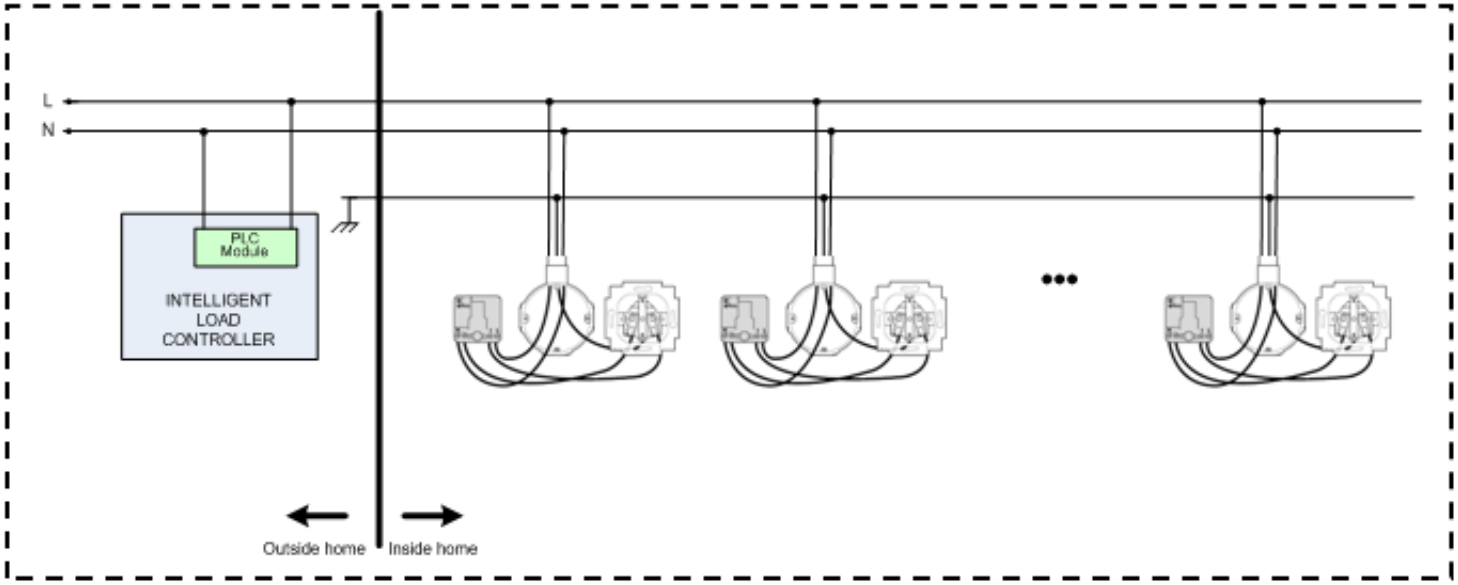
Model of the agent platform (JADE)



The Load Controller: a critical component

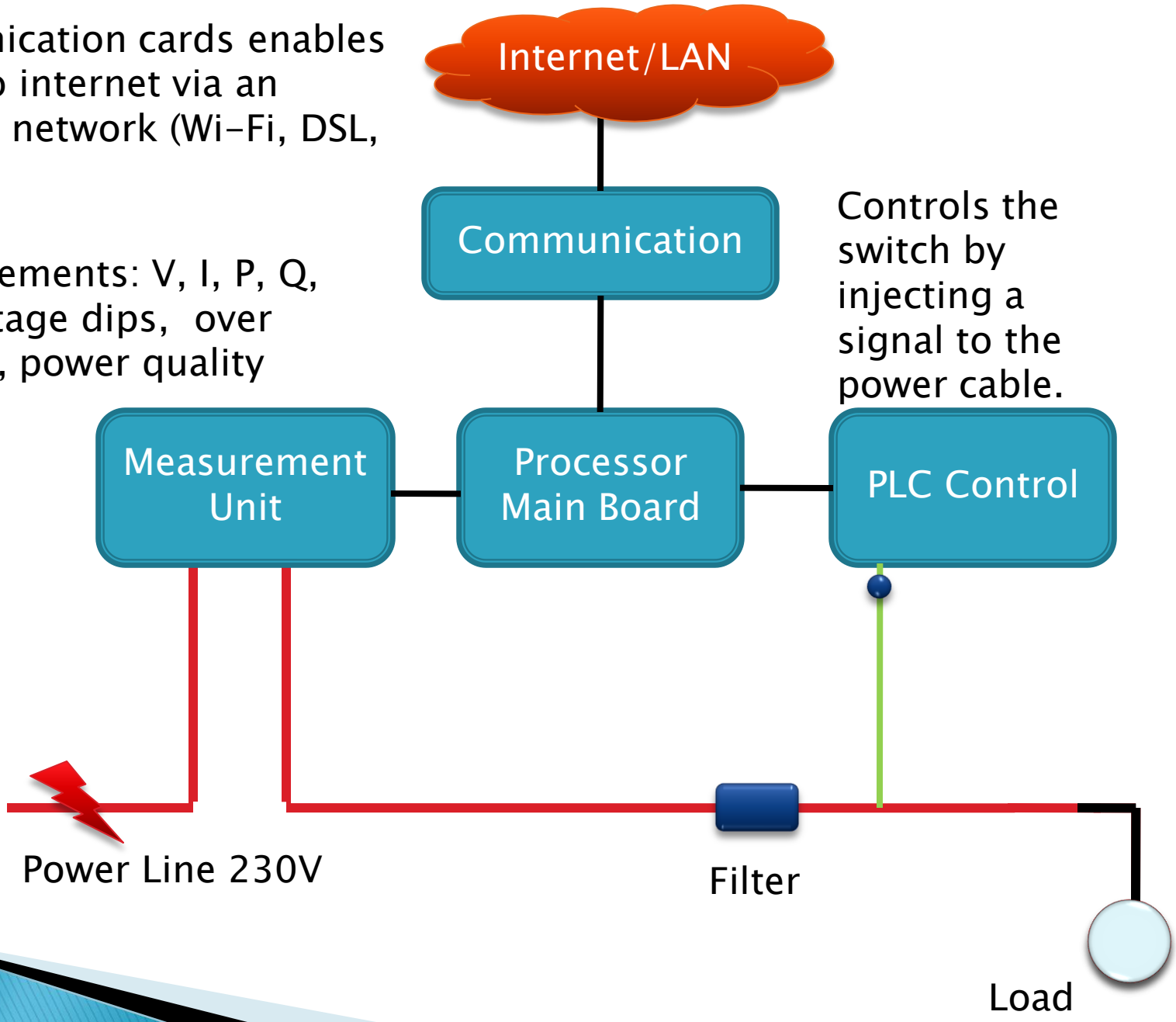
An Intelligent Load Controller has been developed:

1. Windows CE 5.0
2. Intel® Xscale™ PXA255
3. 64MB of RAM
4. 32MB FLASH Memory
5. Java VM
6. Jade LEAP



Communication cards enables access to internet via an available network (Wi-Fi, DSL, etc)

Measurements: V, I, P, Q, Hz, voltage dips, over current, power quality



Examples of Implementations

Example #1
Agent Based Control in a Kythnos

- The goal is to optimize the consumption of the houses
- The test site is a small settlement with 13 houses

The production system includes:

- 12 kW of PV
- 53-kWh batteries
- 5-kW diesel

Goals of the Experiment

Software

- Java/Jade implementation
- CIM based ontology

Hardware

- Embedded Controller
- Measurements
- Communication
- Control via PLC

Technical

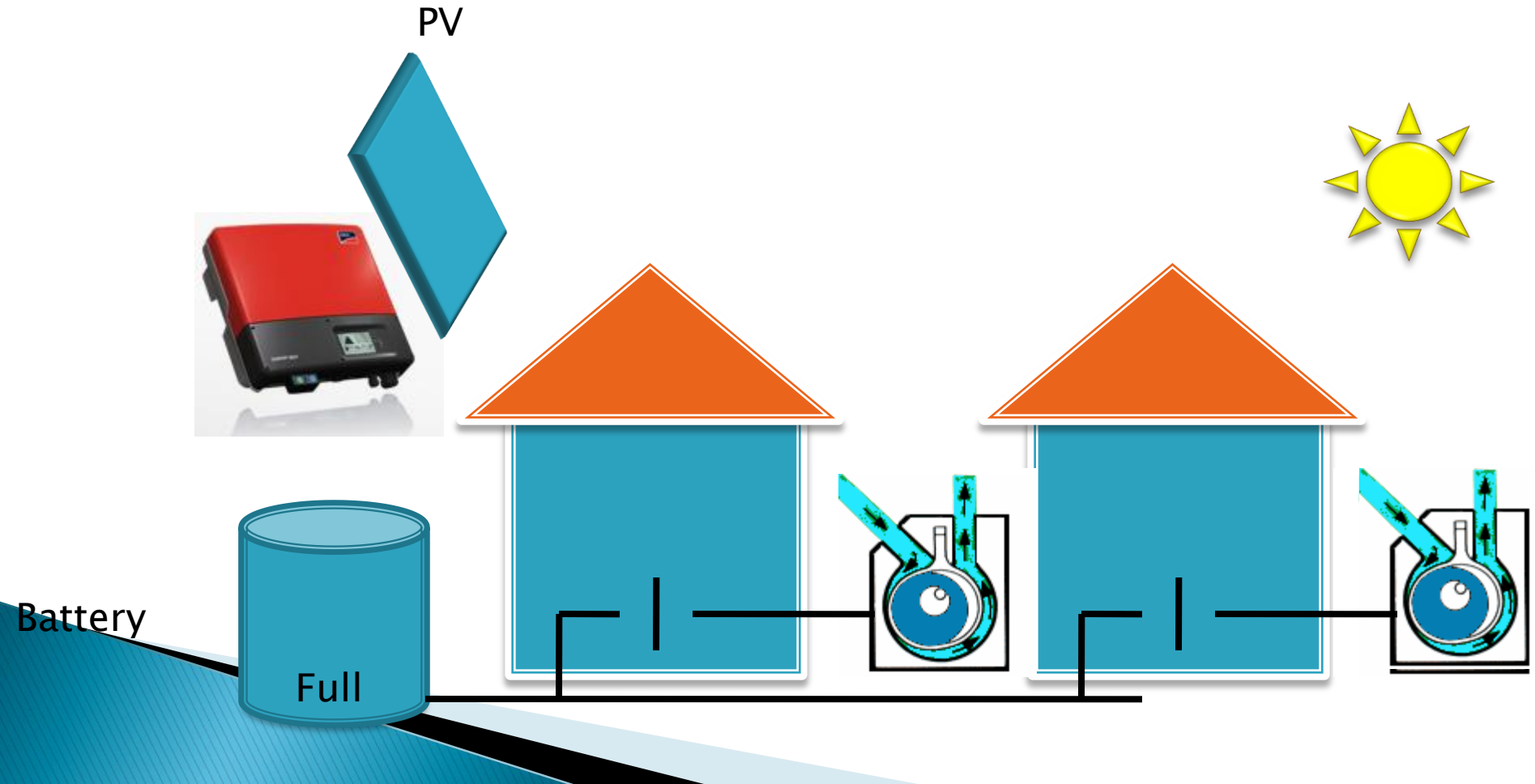
- Implement Distributed Control
- Test in real Environment

Electrical

- Increase energy efficiency
- Manage Non Critical Loads

The general idea:

The main load in each is the water pump.
The goal of the system is to limit the usage of the pumps



Installation of the Controllers

Outside System House

House 11

House 7

Inside System House

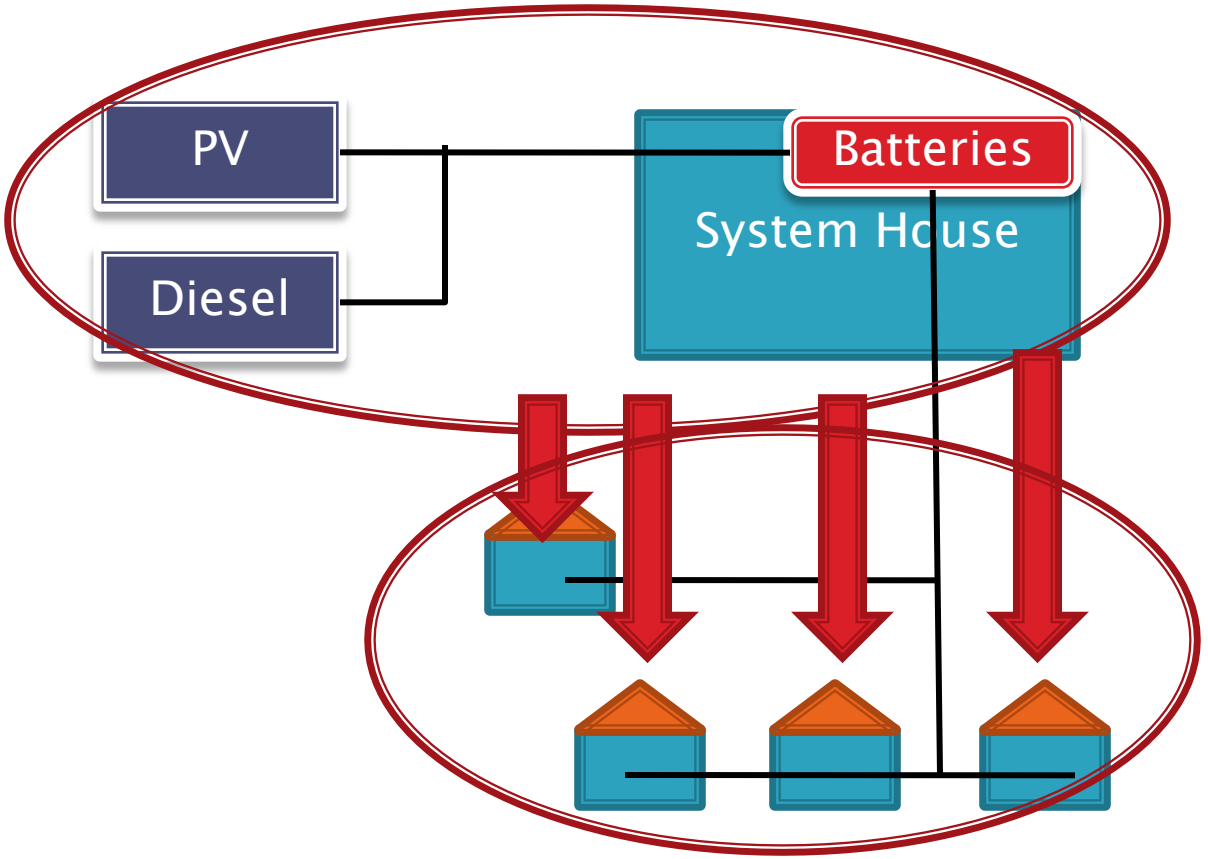
House 5

House 4

The Process of the experiment

Step 1: The agents identify the status of the environment

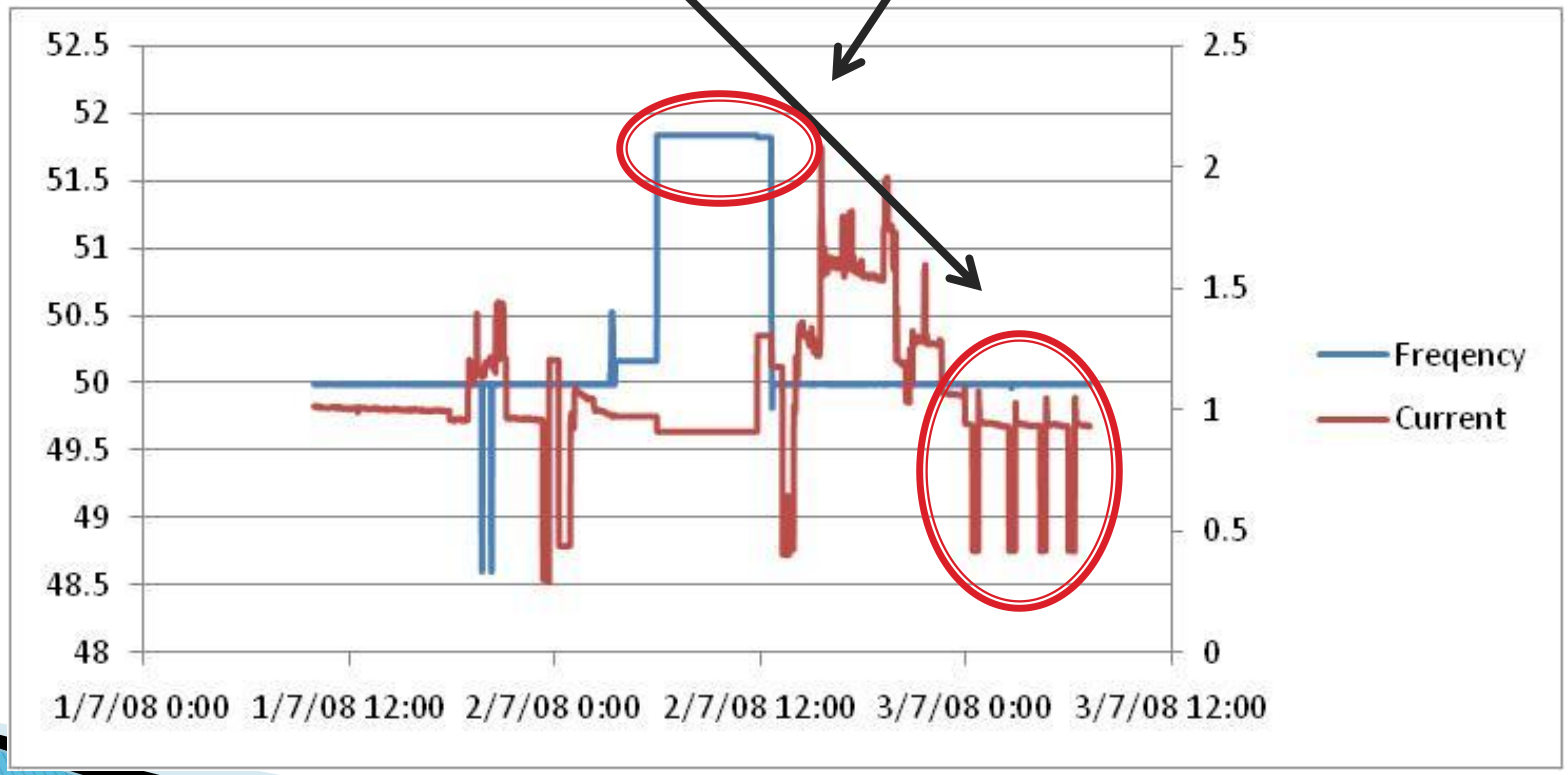
Step 2: The agents negotiate on how the share the available energy



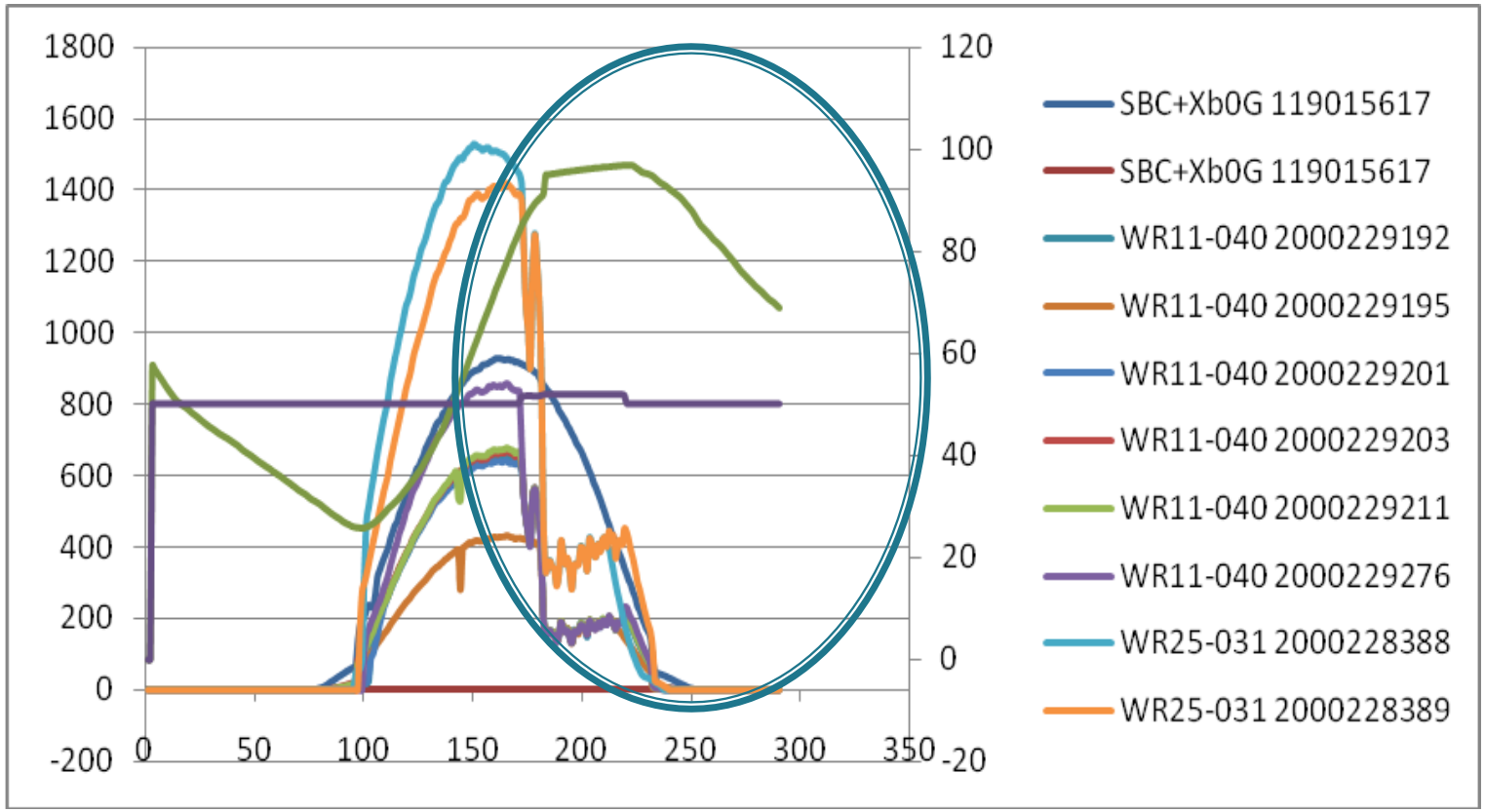
Measurements

In this case the frequency if almost 52Hz. This is an indication that the batteries are full and the PV inverters via the droop curves limit their production.

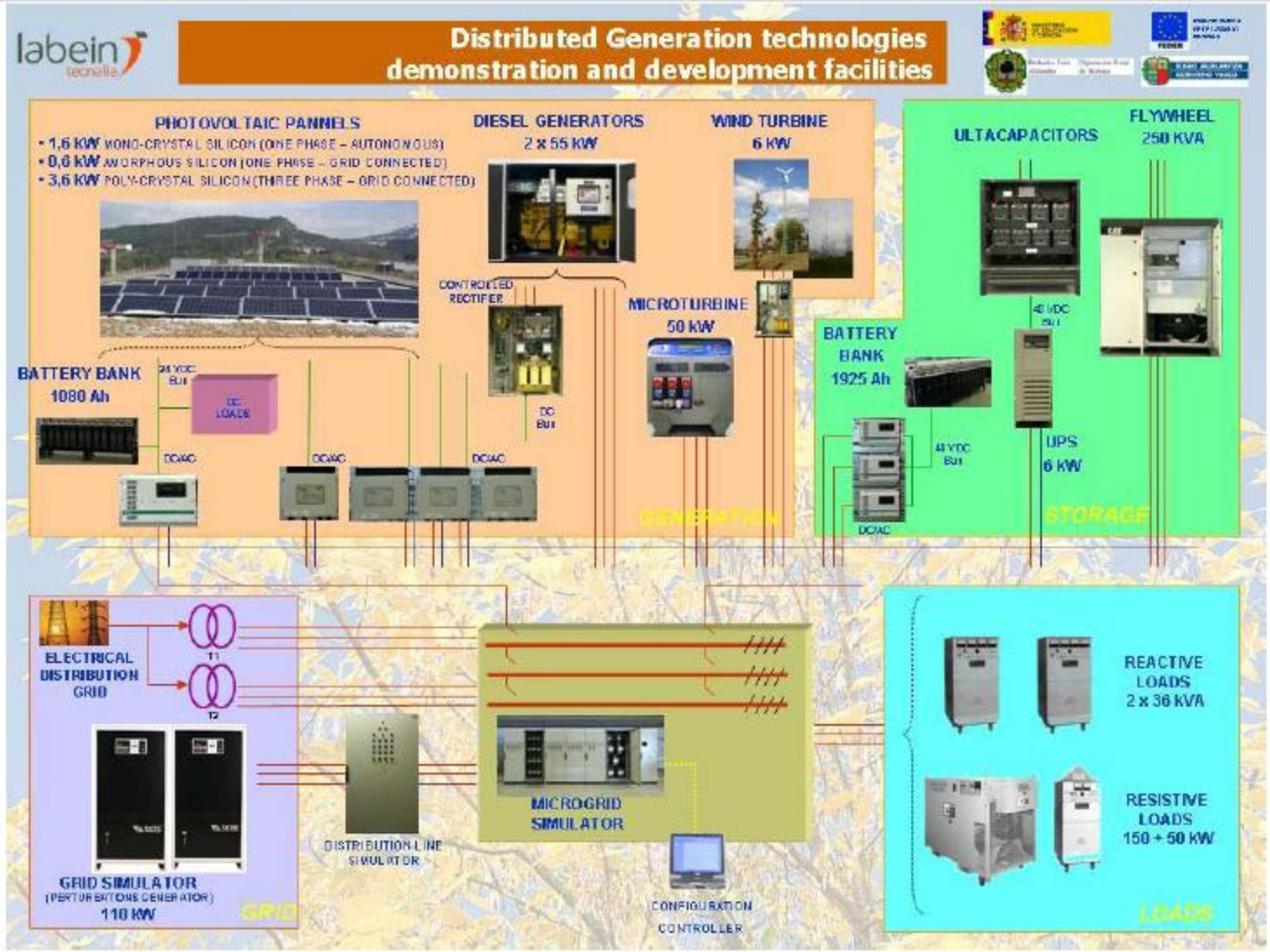
The shedding procedure starts later



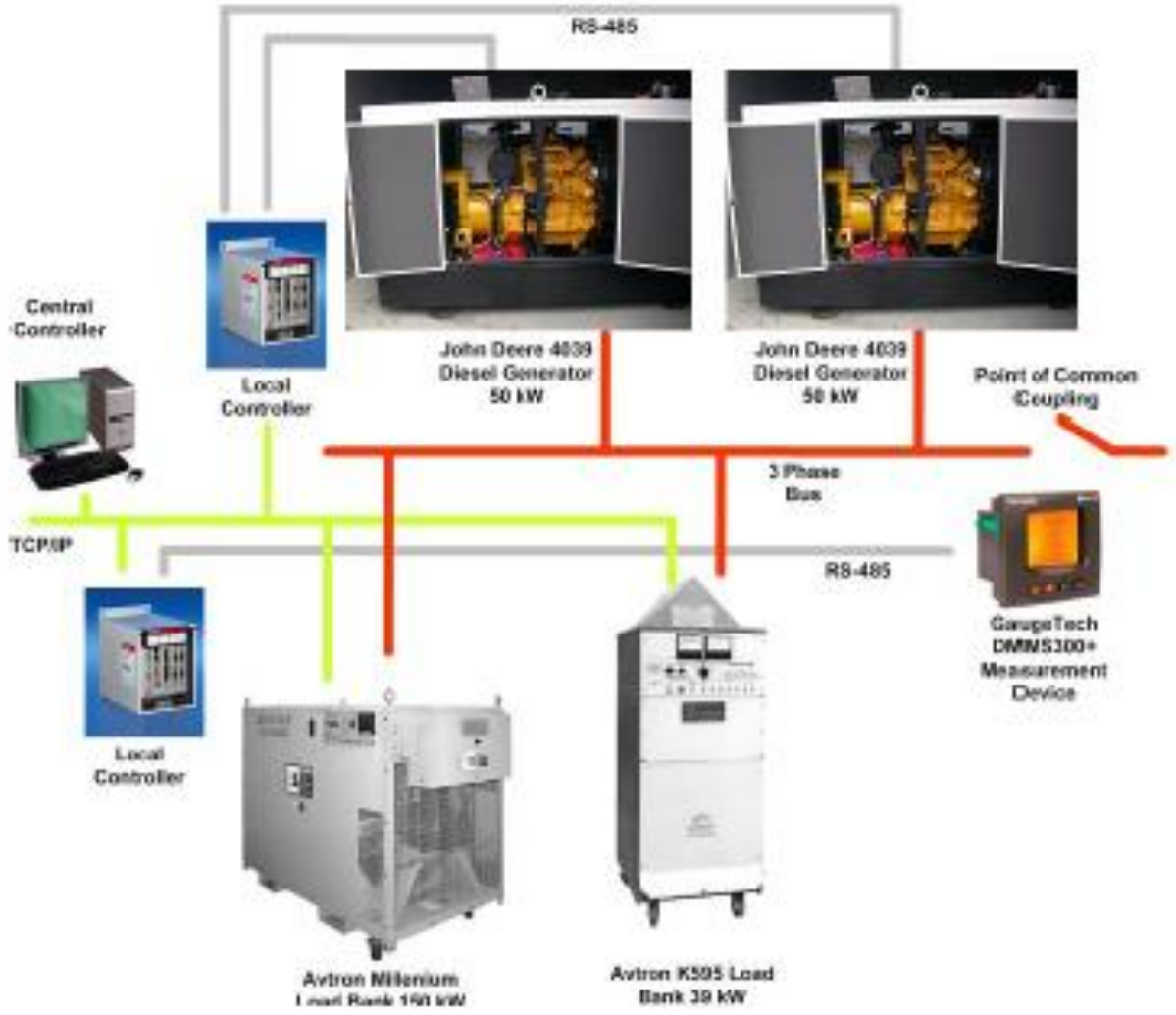
Measurements from Sunny Web Box (1/8/2009)



Example #2
Installation in LABEIN & Algorithm for secondary regulation



Laboratory Overview



The main characteristics of the developed system

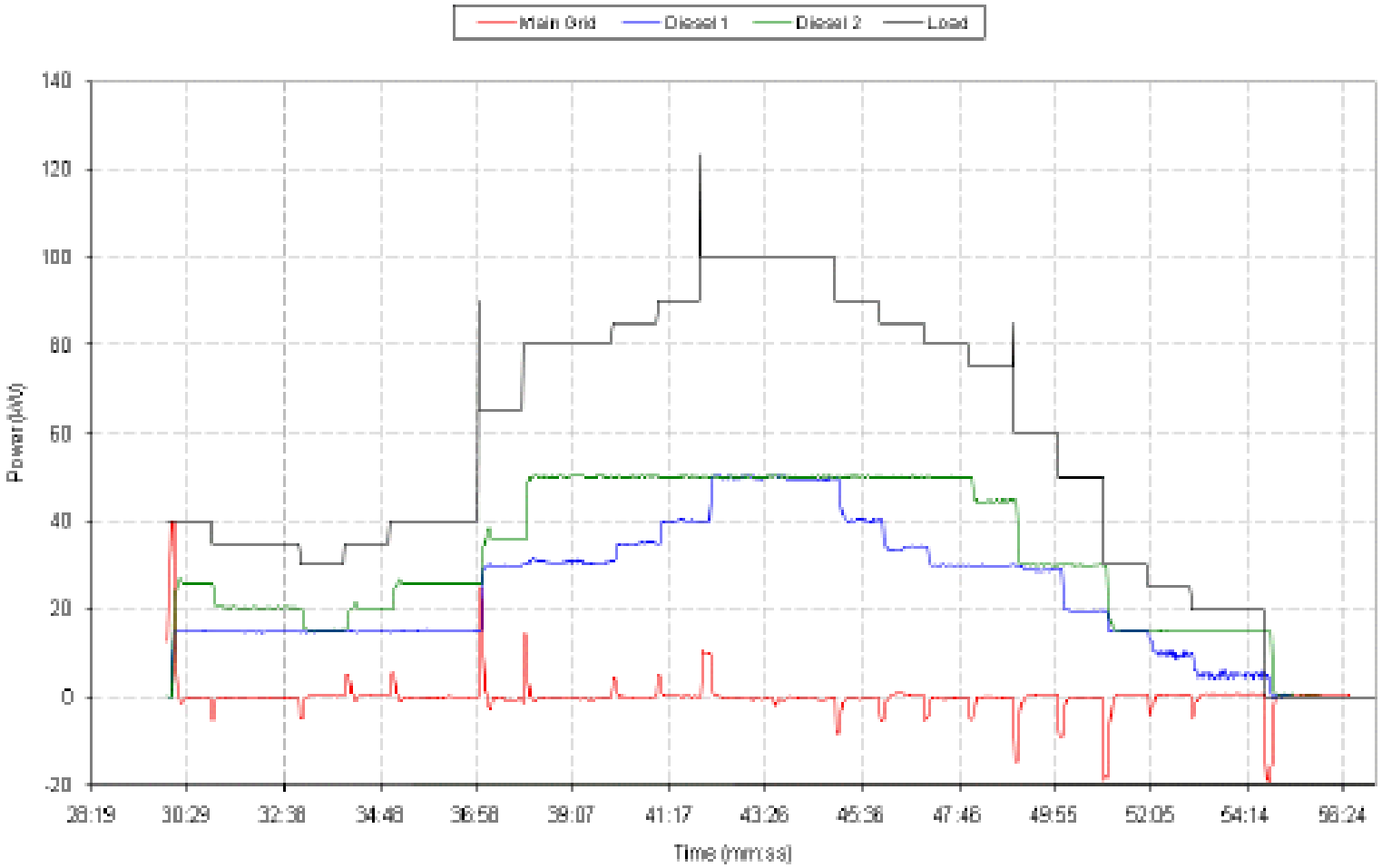
- Implementation of the Multi-Agent Concept based on Jade platform
- Plug & Play capability
- Extensible

Secondary Frequency Control

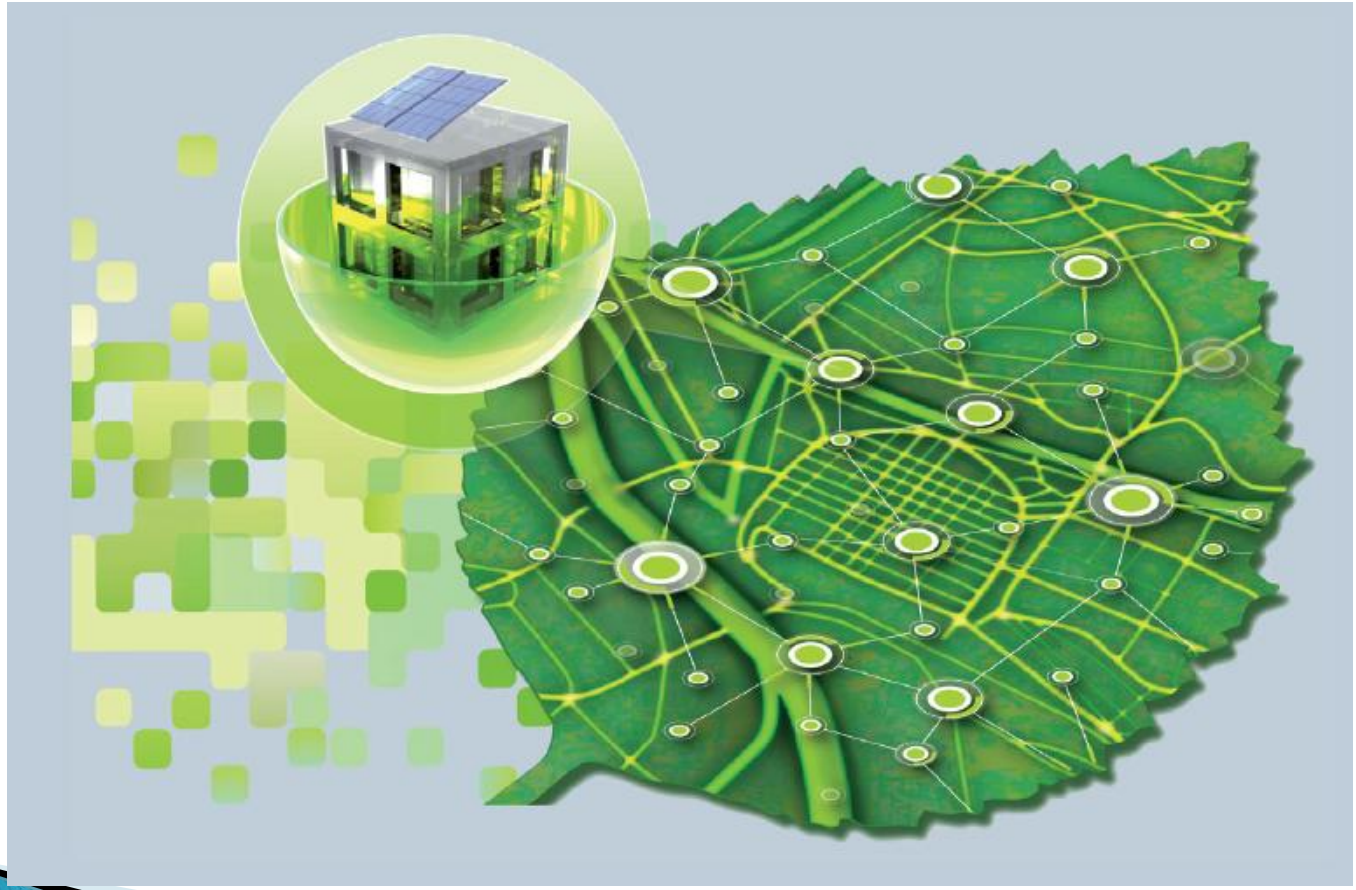
The objectives of the secondary regulation are:

- Microgrid in grid connected mode: The secondary regulation will try to maintain a previously defined power exchange schedule with the main grid.
- Microgrid in islanded mode: The role of the secondary regulation control is to maintain the frequency in the microgrid as close as possible to a reference frequency.

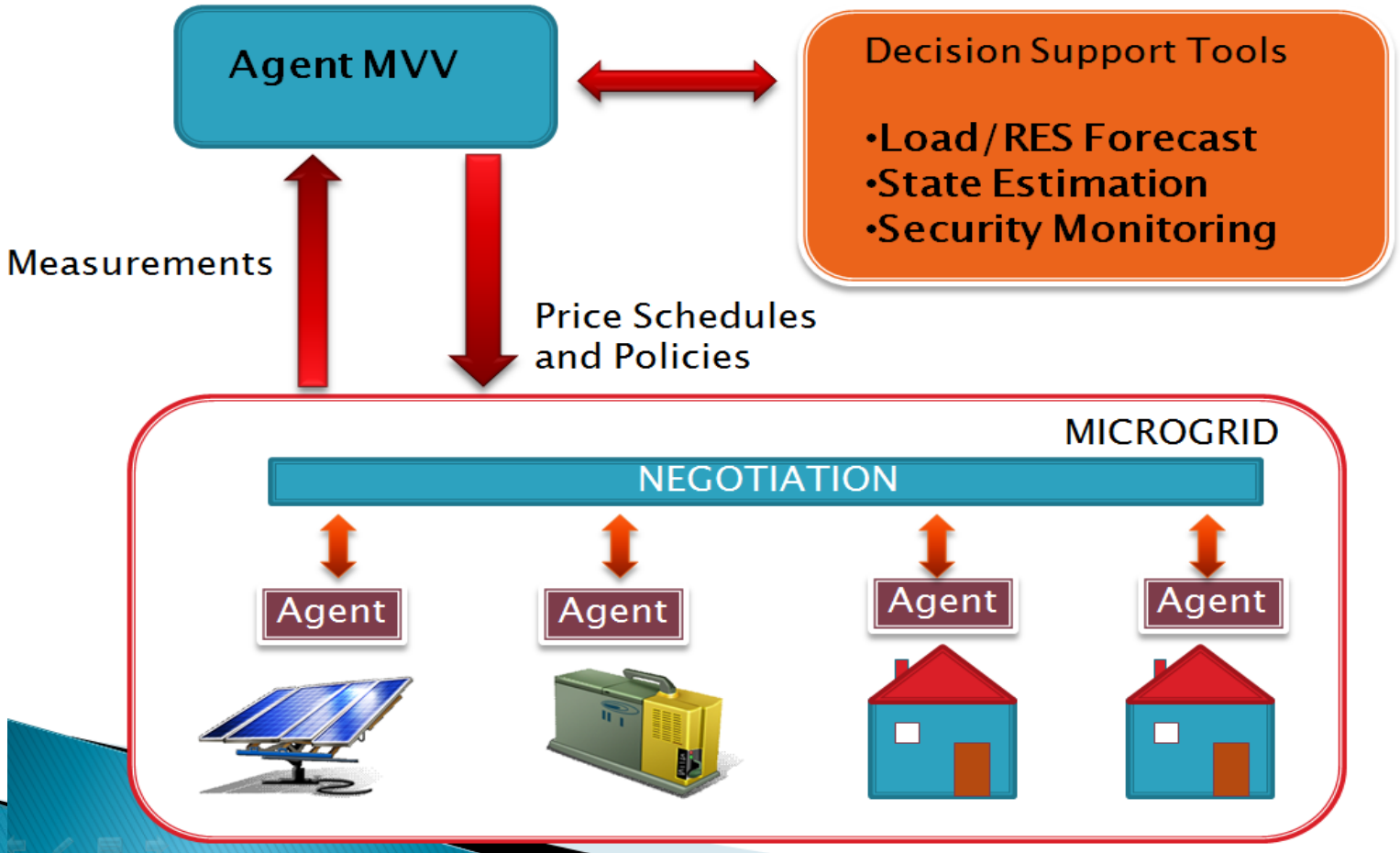
Results


Main Grid
Diesel 1
Diesel 2
Load
140
120
100
80
60
40
20
0
-20
Power (kW)
28:19
30:29
32:38
34:48
36:58
39:07
41:17
43:26
45:36
47:46
49:55
52:05
54:14
56:24
Time (mm:ss)

Example #3
Mannheim installation

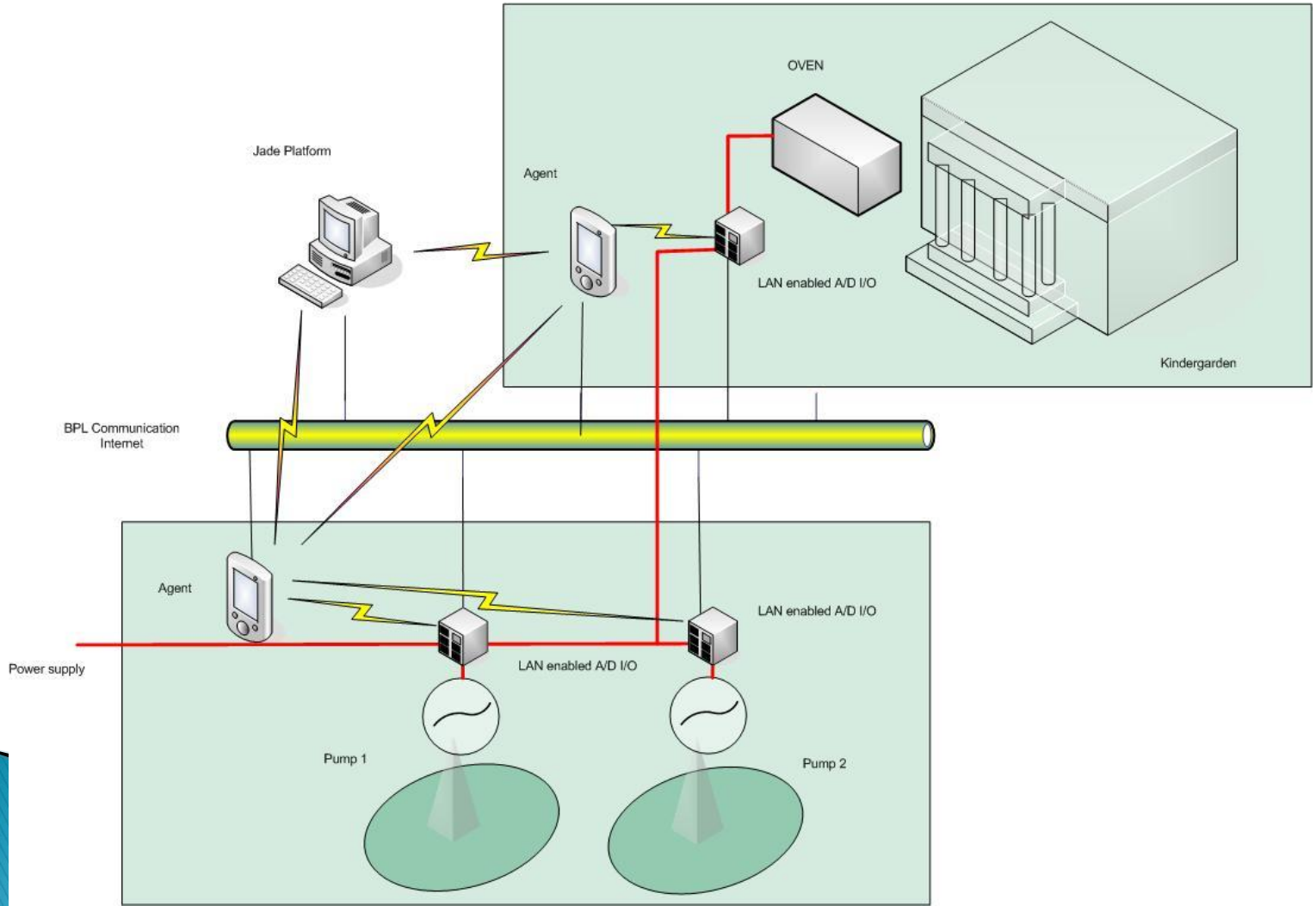


The configuration of the test site



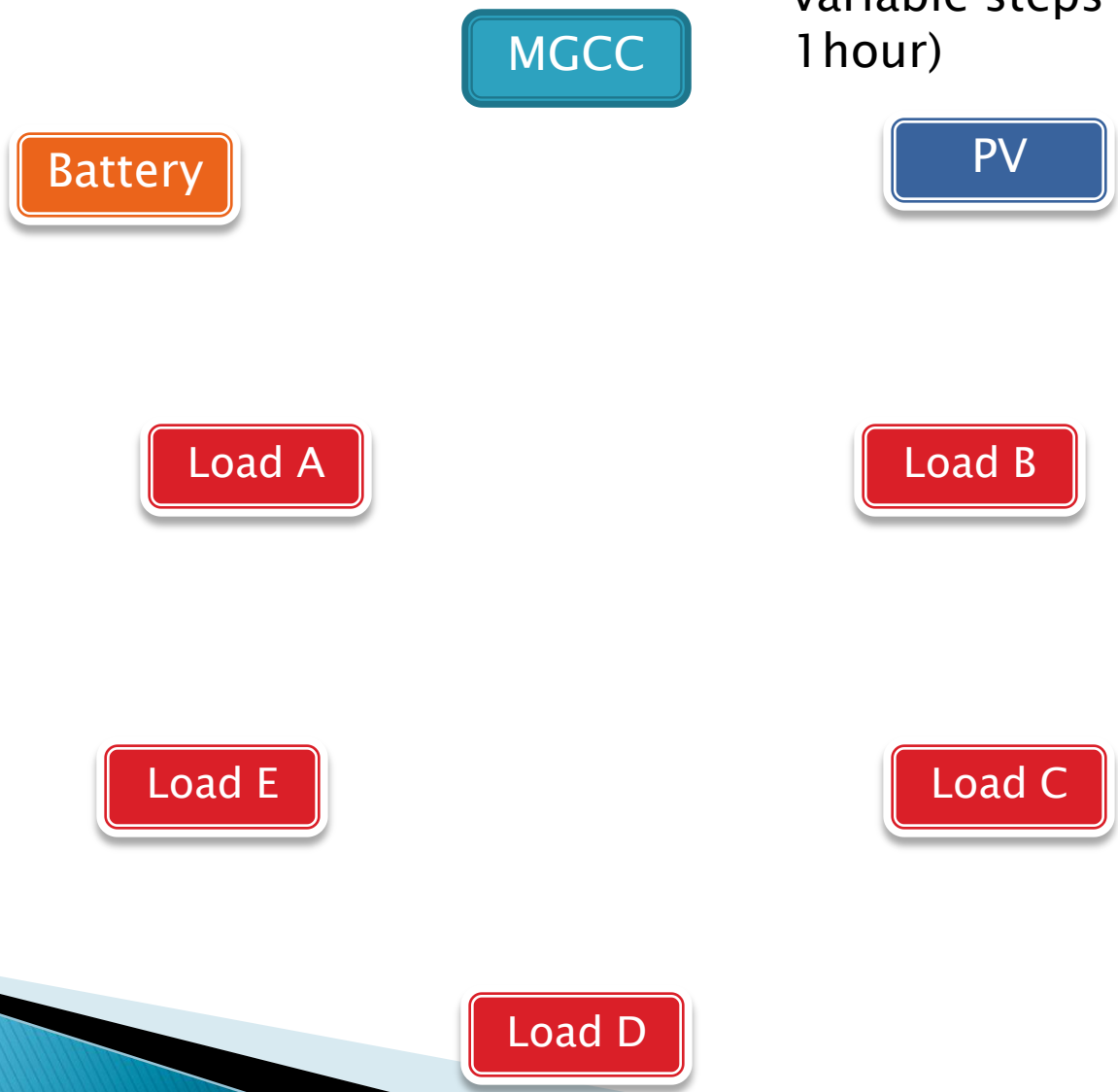
The physical configuration

The agent run on a remote PC and communicate via LAN with the Distribute I/O modules



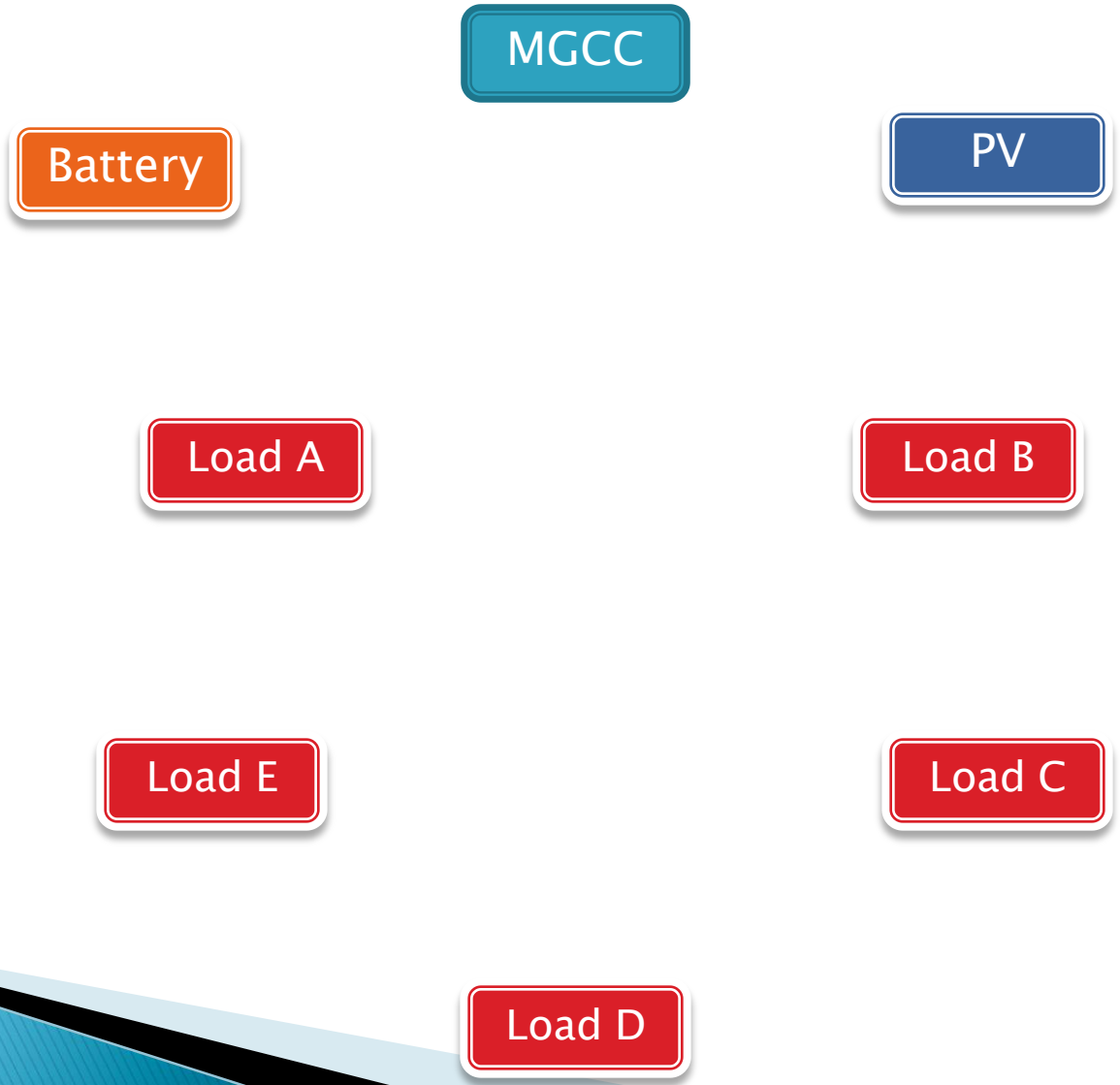
Negotiation

Start Negotiation.
The MGCC orders the system to start a new cycle. This can be done in variable steps (5min-1hour)



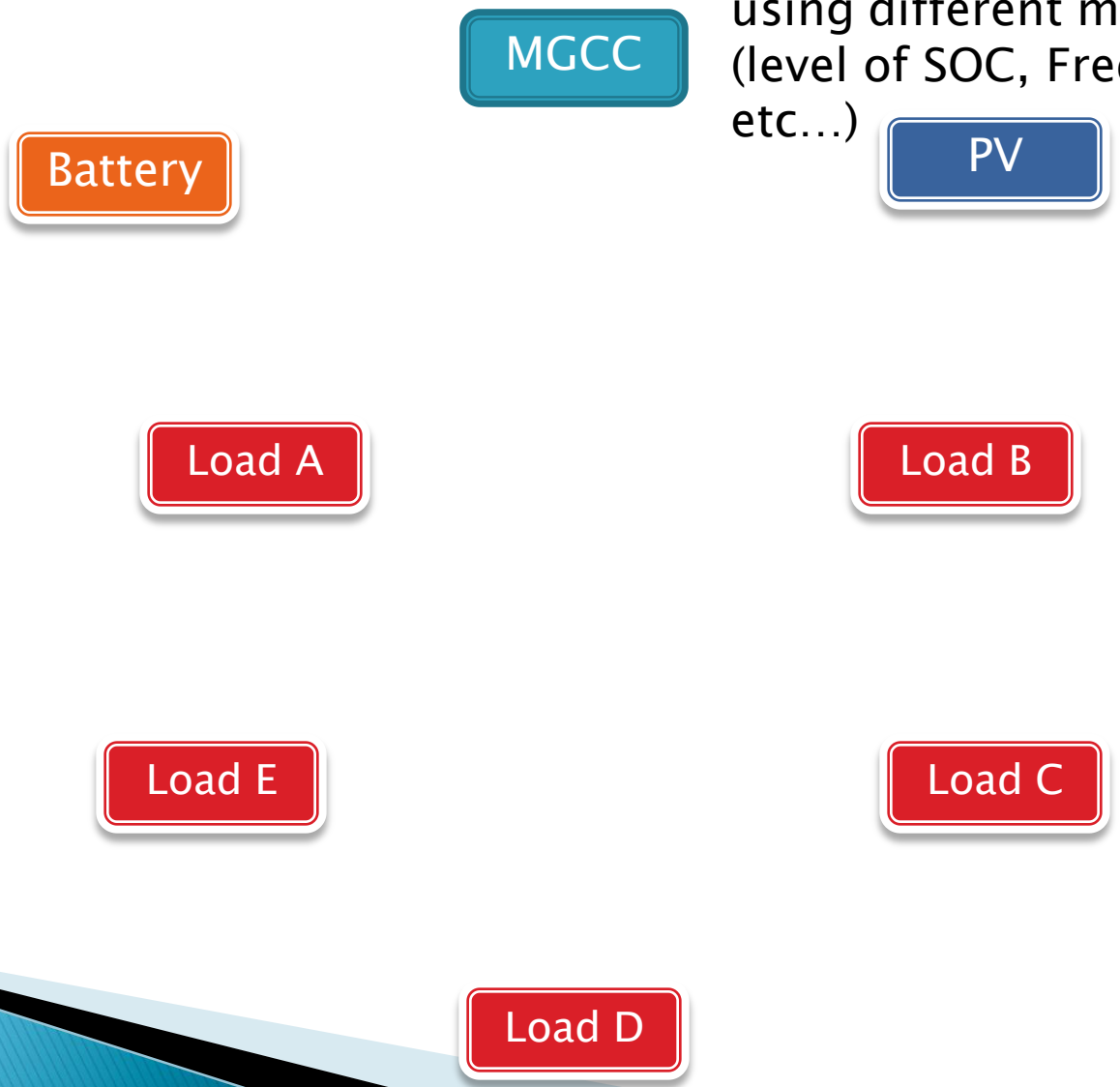
Negotiation

PV agent Announces Production



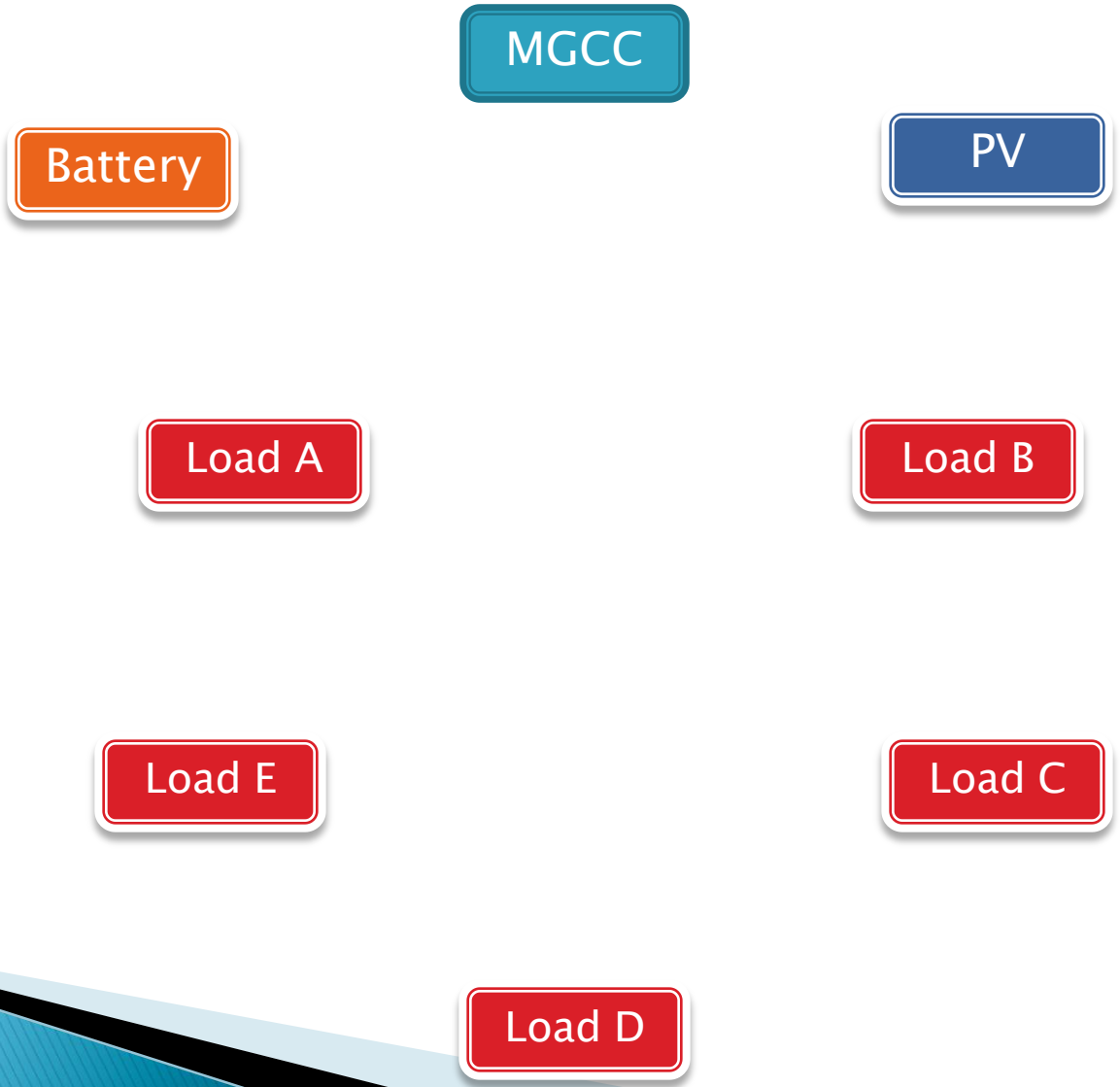
Negotiation

Battery agent Announces Production & SOC.
The estimation of the available energy can be done using different methods (level of SOC, Frequency, etc…)

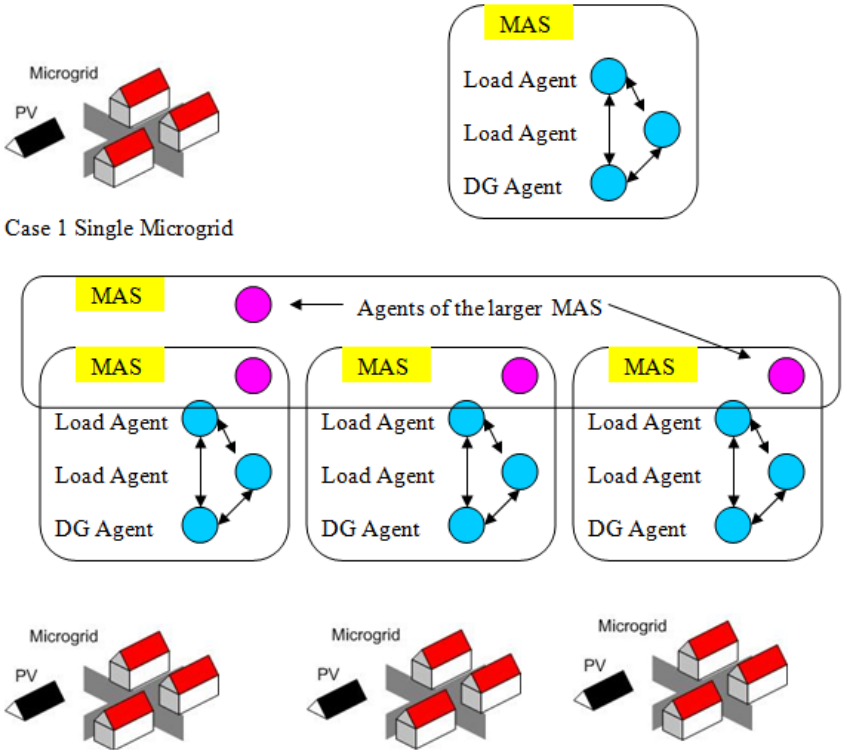


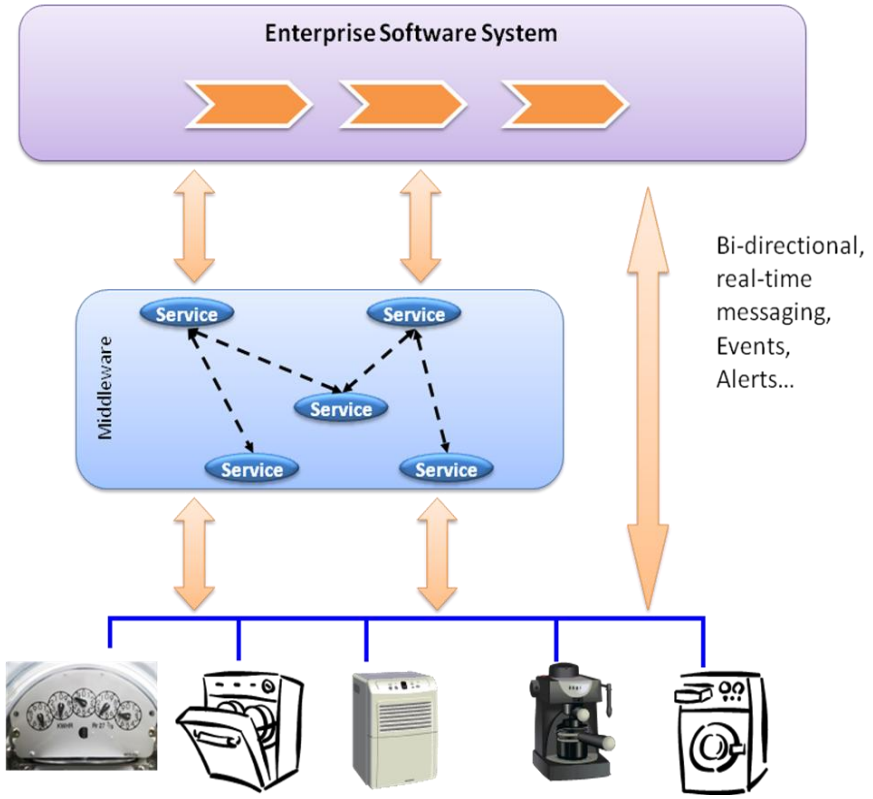
Negotiation

Agents Start Negotiating. The simple algorithm suggests that agents should consume equally.



Scalability (SOA)





Conclusions

- The Kythnos and Mannheim were the first test sites where the MAS system was implemented
- Several technologies have been tested: negotiation algorithms, intelligent load controller, wireless communication, CIM based ontology etc.
- The architecture is too complex for small systems but offers great scalability.

Further research- Open issues

- Agent algorithms and architectures (SOA) focusing in the management and market participation of large number of DGs and Controllable Loads.
- Hardware development (Load Controllers) focusing in cheap implementation with communication and control capabilities
- Standardization
- Larger test sites for future tests. Research for mass application
- Legal issues- Market structure.

Thank you