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An intelligent distributed system for flexible management of variable energy supply and demand in microgrids

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Część II

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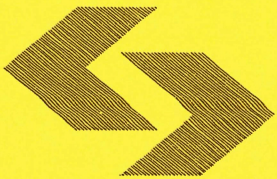

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SYSTEMS RESEARCH INSTITUTE
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Chapter 6

Experiments and performance

The algorithm for balancing the power was tested on simulated data. There were 19 devices considered in the grid. Simulation of each device and its agent were run on a separate machine. The database and the Morris Column agent were placed on an additional twentieth machine. Each computer was an Intel(R) Core(TM) i5-3450 CPU@3.10 GHz 8 GB RAM machine, with 64-bit Windows 7. The computers were connected by the 1 Gb Ethernet network. The test revealed that the balancing takes less than 60 ms, except for the initial slightly longer time (up to 800 ms). This longer initial time is due to the necessary registration of the agents to the Morris Column during the first few seconds and their interrogation of the devices about their operating points. Agents in the system are not centrally synchronized and the delays between agent initial actions caused initial delays in balancing the power.

To show how the system balances the power, a simple example has been planned. Only 3 devices are considered, a gas microturbine, a wind turbine, and a single consumer that has a total power demand of up to 100 kW in the peak time. Additionally, to make the power balancing possible, the external power grid is introduced that has unlimited power consumption and production abilities. The negotiating device agents try to avoid buying/selling the energy from/to the external grid agent, but instead strive to balance the power by negotiations between producers and consumers within the grid, and keep the exchange on the zero level.

The power produced or consumed by devices during the test are presented in Fig. 6.1. The gas microturbine operating point is bounded by 12,5 kW from below and 50 kW from above. When the total demand power from the microturbine is out of these ranges, the trade with the external grid has to be used to balance the energy. In Fig. 6.1 the negative value of the power for the external power grid means that the microgrid sells power. It happens when the power consumed in the microgrid is lower than produced by the wind turbines and the microturbine operating on the minimal level. On the other hand, when the power demand is greater than production by the wind turbine and the microturbine operating on the maximum level, the external grid compensates the lacking power, which is depicted by the positive values for the external grid.

To show more clearly the power balancing process, the sum of production and consumption are presented in Fig. 6.2. It can be seen that there are small imbalances in short periods that are due to lack of synchronization in the system, but also to the time aggregation on the graph (the data in Fig. 6.2 are averaged within one second period).

Balancing can be done faster than the time assigned for the devices to report their state. This shows that the power balancing system can be an efficient method for matching the produced power and the consumption. There may be some small imbalances, but the time of their existence is so short that they do not influence the operation of the system as a whole.

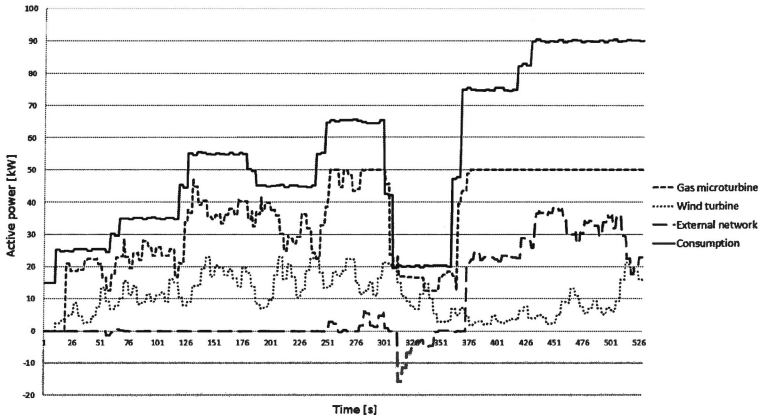

Figure 6.1: The amount of power produced by the controllable source, the uncontrollable source, the amount of power consumed by consumer and the amount exchanged with external power grid.

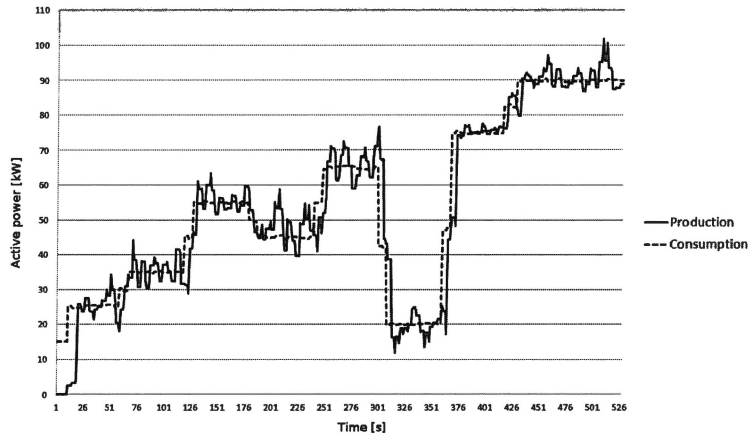

Figure 6.2: Aggregated powers of production by the microgrid devices and consumption.

6.1 Problems recognized during simulation

To perform the simulations faster the system time had to be sped up by factor 120, it made agents balance faster and the number of sent messages, entries and queries to the database increased a lot. That caused computers to use their processors to maximum during the time of the simulation. The difference between running simulation on single machine and in distributed environment is noticeable. The system is heavily multi-threaded and race conditions occur. Even though agent are not performing heavy computation their speed of performing constant check on devices and communication is an effort for the system. It is not possible to perform reliable performance test on single machine.

Testing should be performed on an adequate number of computers, where database has separate machine, then morris column, external grid agent and JADE specific tool agents (like DF) should be grouped on another machine. The device agents should be spread as uniformly as possible on the remaining available computers with strong suggestion of not placing more than 10 devices on single machine if the test is done with the time speed increase.

Abbreviation list

AI	Artificial Intelligence
AMS	Agent Management System
CGB	Condensing Gas Boilers
CHP	Combined Heat and Power
DEMS	Distributed Energy Management System
DSM	Demand Site Management
EMS	Energy Management System
FIPA	Foundation for Intelligent Physicl Agents
GUI	Graphical User Interface
GM	Gas Microturbine
JADE	JAVA Agent DEvelopment Framework
kW	Kilowatt
LECR	Laboratory of Energy Consumption Rationalization
LMEB	Laboratory of MicroCHP and Ecological Boilers
LPISE	Laboratory of Power Industry Safety Engineering
LST	Laboratory of Solar Techniques
LWPE	Laboratory of Wind Power Engineering
LV	Low Voltage
MABB	Matched-block bootstrap
MAS	Multi-agent System
MHPP	Micro Hydroelectric Power Plant
ms	miliseconds
MV	Medium Voltage
MVT	Micro Wind Turbines
P	power
PHEV	Plug-in hybrid electric vehicle
PV	Photovoltaic panels
Q	reactive power
RE	Reciprocating Engine
s	seconds
SMES	Superconducting Magnetic Energy Storage
SOA	System Oriented Architecture
U	voltage
VPP	virtual power plants
VP	virtual prosumer

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