Direct Current Systems and Renewable Energy Resources

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Schedule

1. Introduction
   - Assumptions
   - Problem
2. DC Can Help
   - Plants Connection
   - Power Flow Control
   - Power Quality
   - Plants' Construction
3. Proposed Solutions
   - RES in DC Distribution System
   - Small, Balanced, Dedicated RES Power Systems
4. Experiment
   - Test Stand
   - Results
   - Further Work
5. Conclusions

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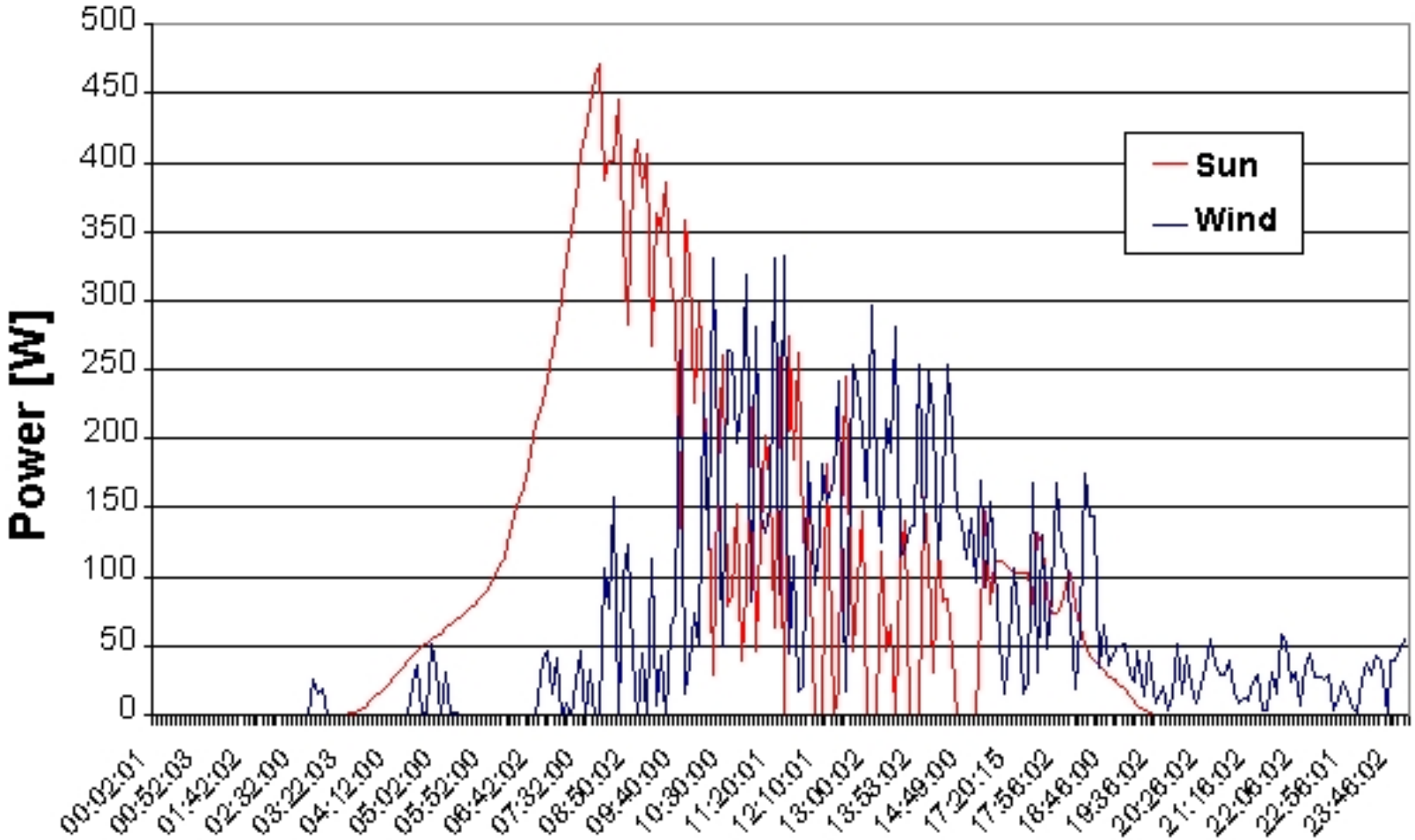
Assumptions

1. small capacity of power plants
2. high dynamics – rapid changes of signals
3. unstable power generation profile
4. distribution system
5. low voltage
6. simple construction of power plants and control systems
7. low costs of equipment and power

Solar or Wind Power Generation



Problems

1. voltage quality
2. power delivery reliability
3. sources synchronisation

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Synchronisation Process

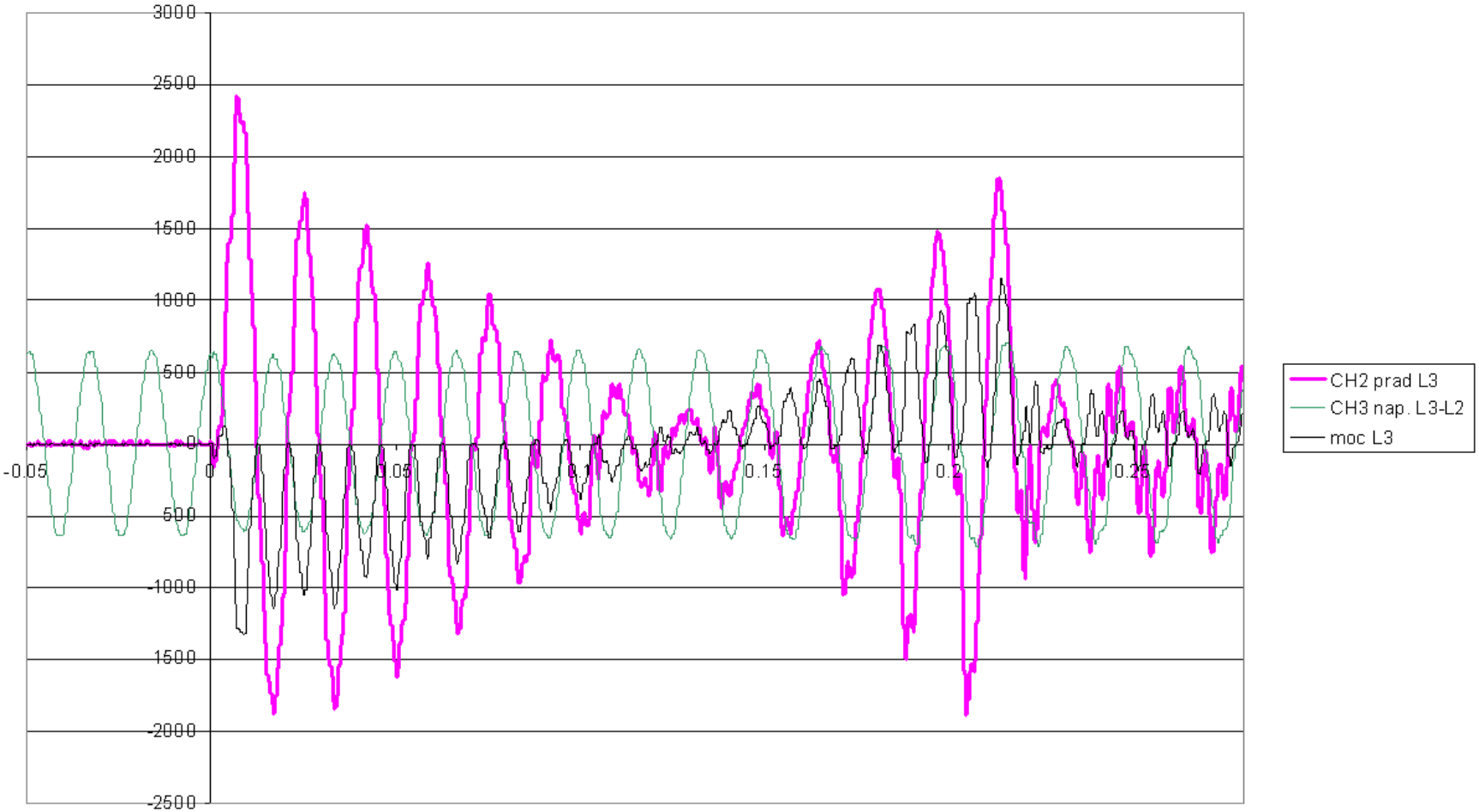
In AC System

1. amplitude, frequency, phase adjusting
2. closing plant's switch
3. keeping plant synchronised

In DC Systems

1. no synchronisation is needed

Unsuccessful Synchronisation



Power Flow Control

In AC System

1. power flow must be controlled by phase control
2. possible unexpected power flow
3. plants (inverters) can consume power

In DC Systems

1. power flow is equivalent to current flow
2. can be simply physically controlled
3. DC/DC converters are naturally one directional

Voltage Quality

In AC Systems

1. voltage wave shape
2. amplitude
3. frequency

In DC Systems

1. voltage level

Modern Power Sources

Modern power sources are usually DC sources

1. photovoltaic battery
2. fuel cell

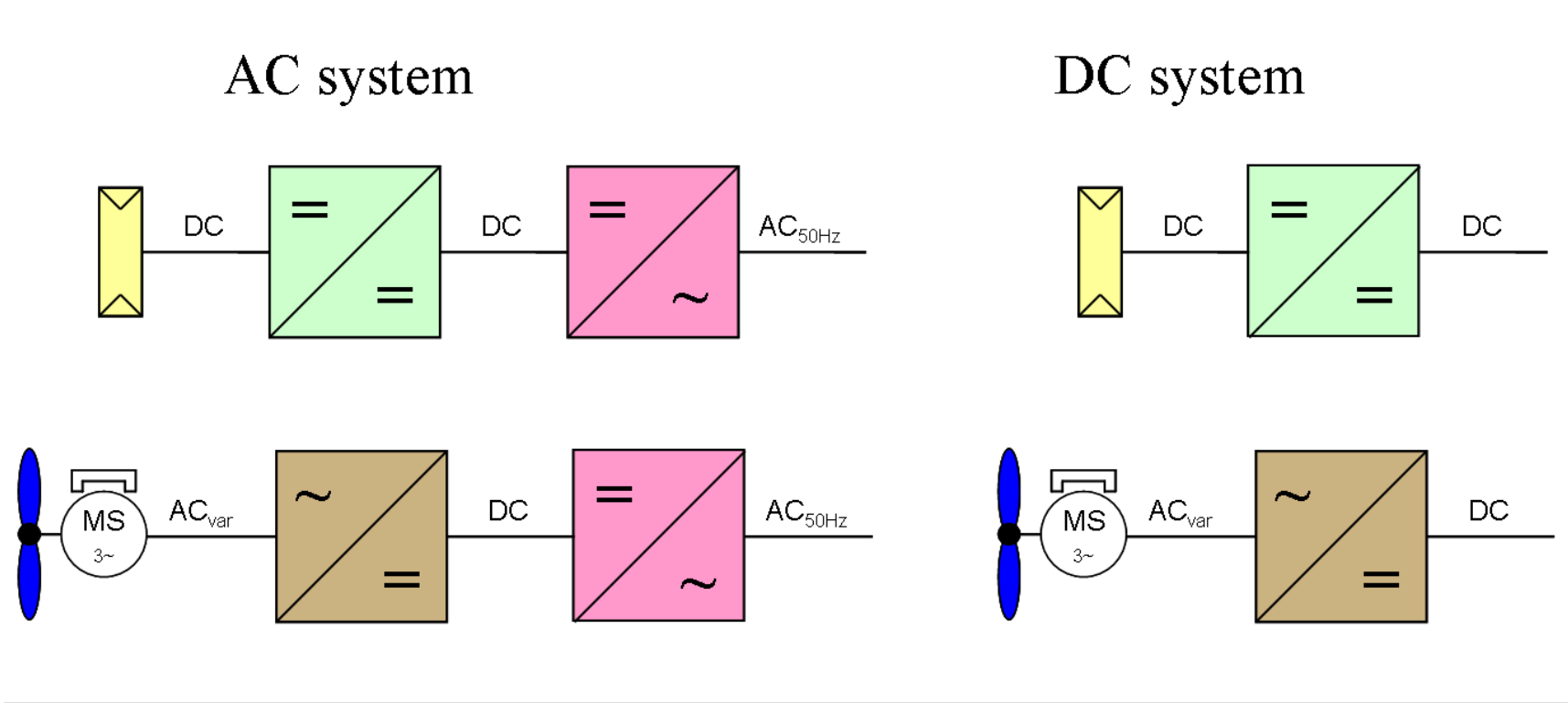
Also modern plants with permanent magnet synchronous machines uses DC circuit

1. wind turbines
2. combustion engine generators
3. gas turbines

Electrochemical storage devices can be easy introduced

1. batteries
2. supercapacitors

Power Plants Construction



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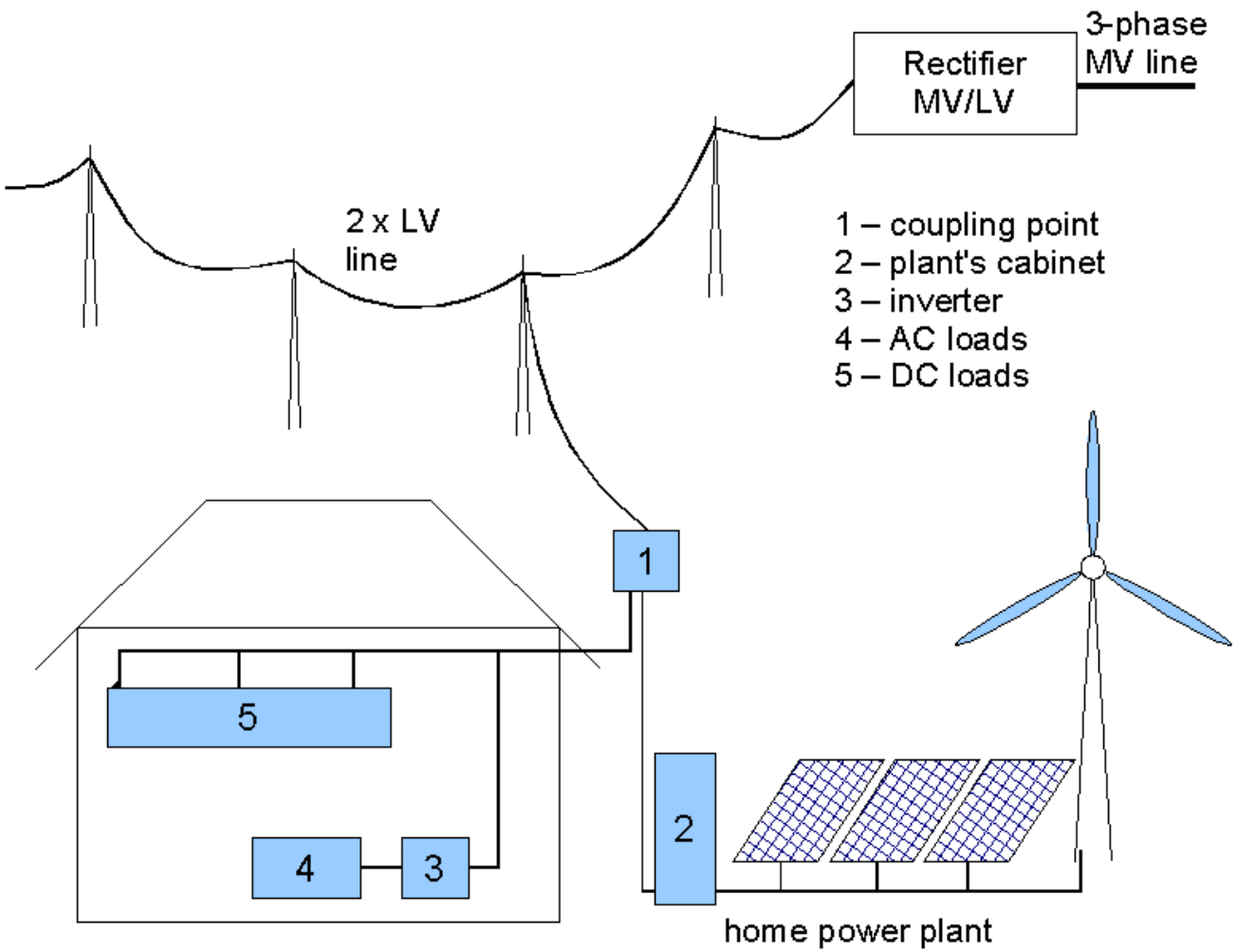
DC Distribution System

1. the system is balanced by power grid
2. plants' are not controlled by the system operator
3. everyone can instal rather small power plant
4. plants' capacity usually significantly lower than load
5. no storage is installed

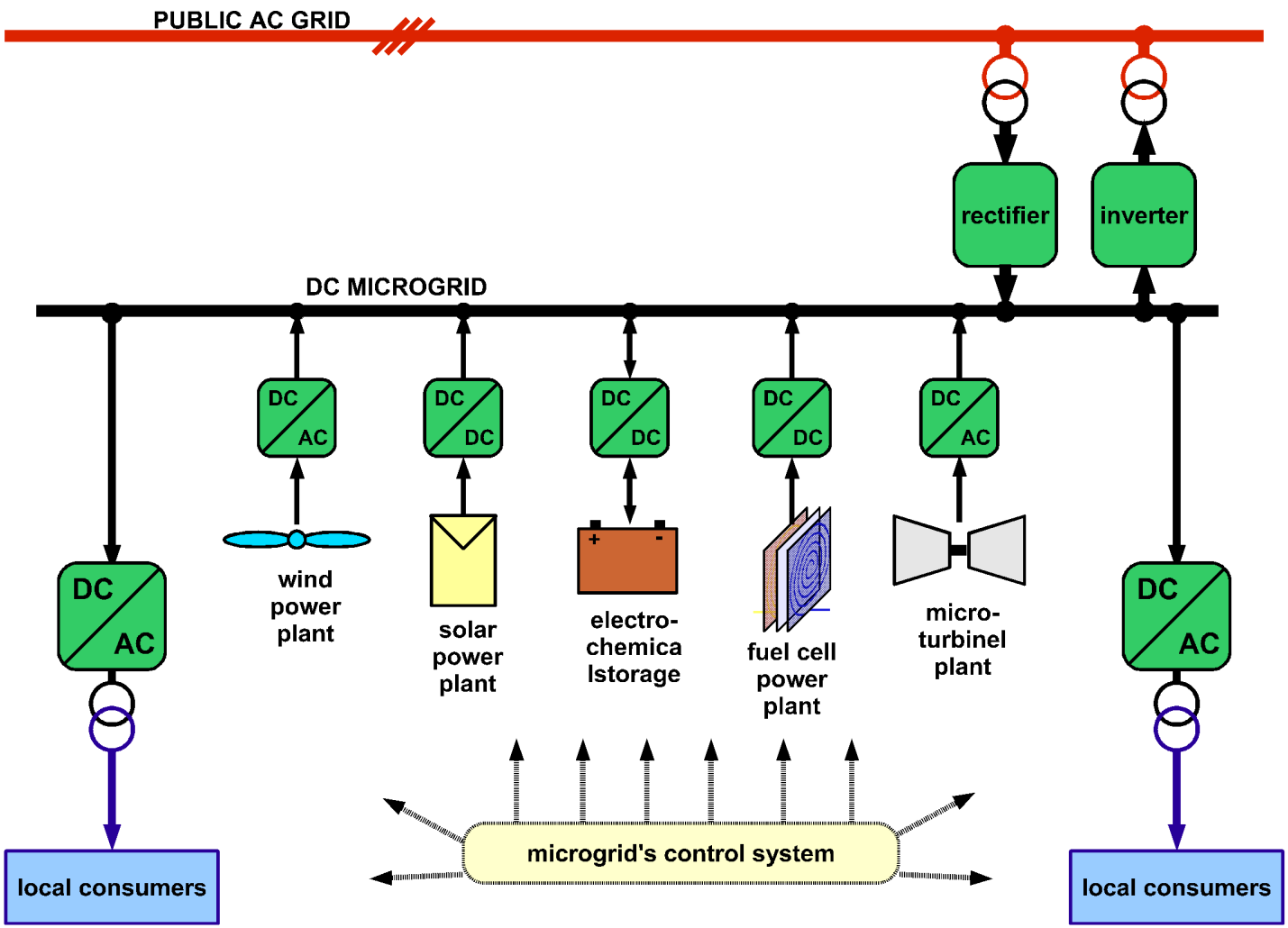
DC Distribution System



DC Microgrid

1. internally balanced power subsystem
2. designed to supply some area with locally produced energy
3. can be a source from power system point of view
4. power plants are controlled
5. plants' capacity cover all needs
6. storage is required

DC Microgrid Diagram



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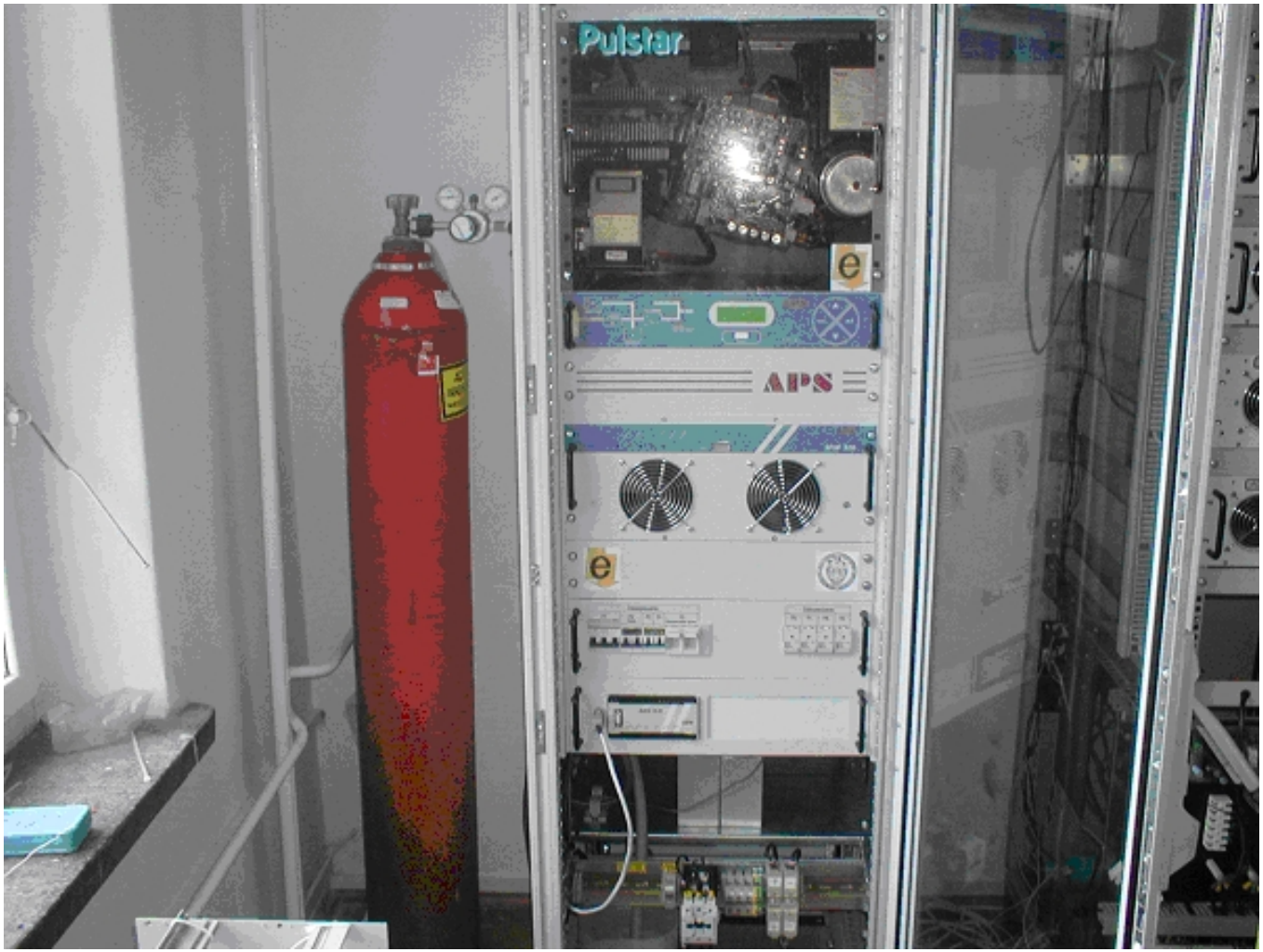
Author's Stand Parameters

1. network nominal voltage – 50 V
2. solar power plant – 2 kW
3. fuel cell power plant – 2.4 kW
4. lead acid battery storage – 40 Ah, 2 kW
5. AC network coupling converter – 3 kW

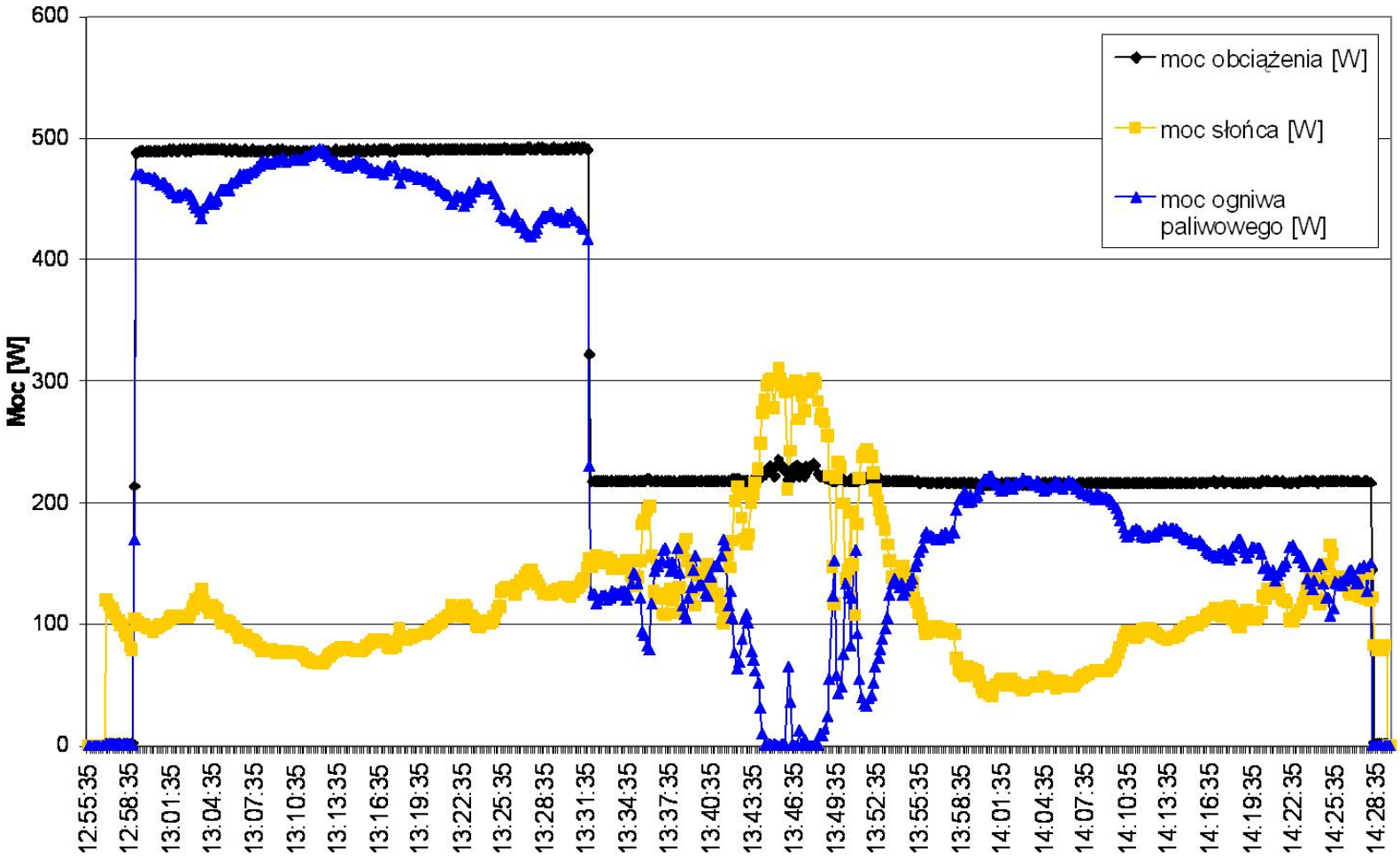
Photovoltaic Power Plant

Fuel Cell Power Plant



AC Network Coupling Converter

Example of Operation



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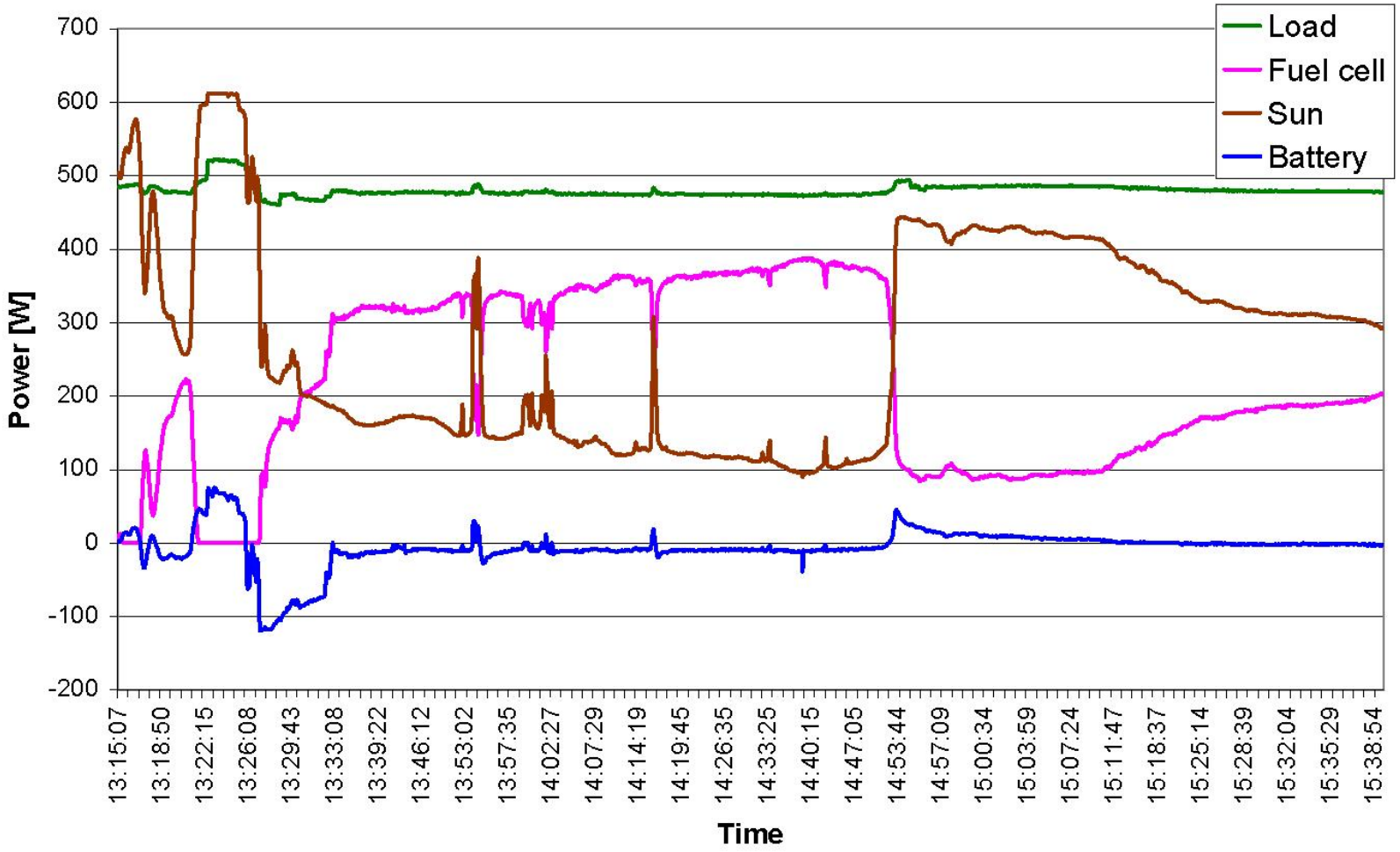

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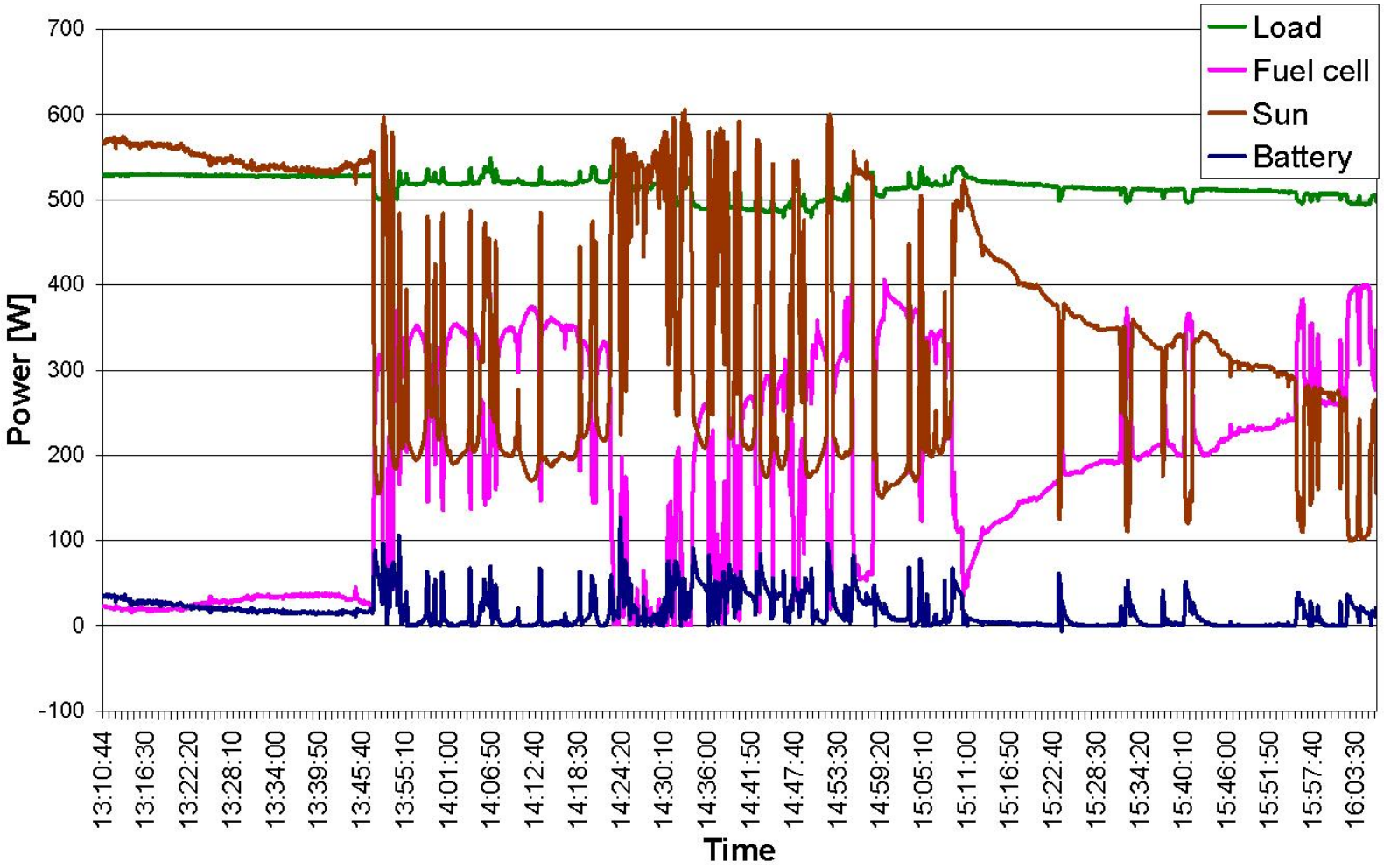


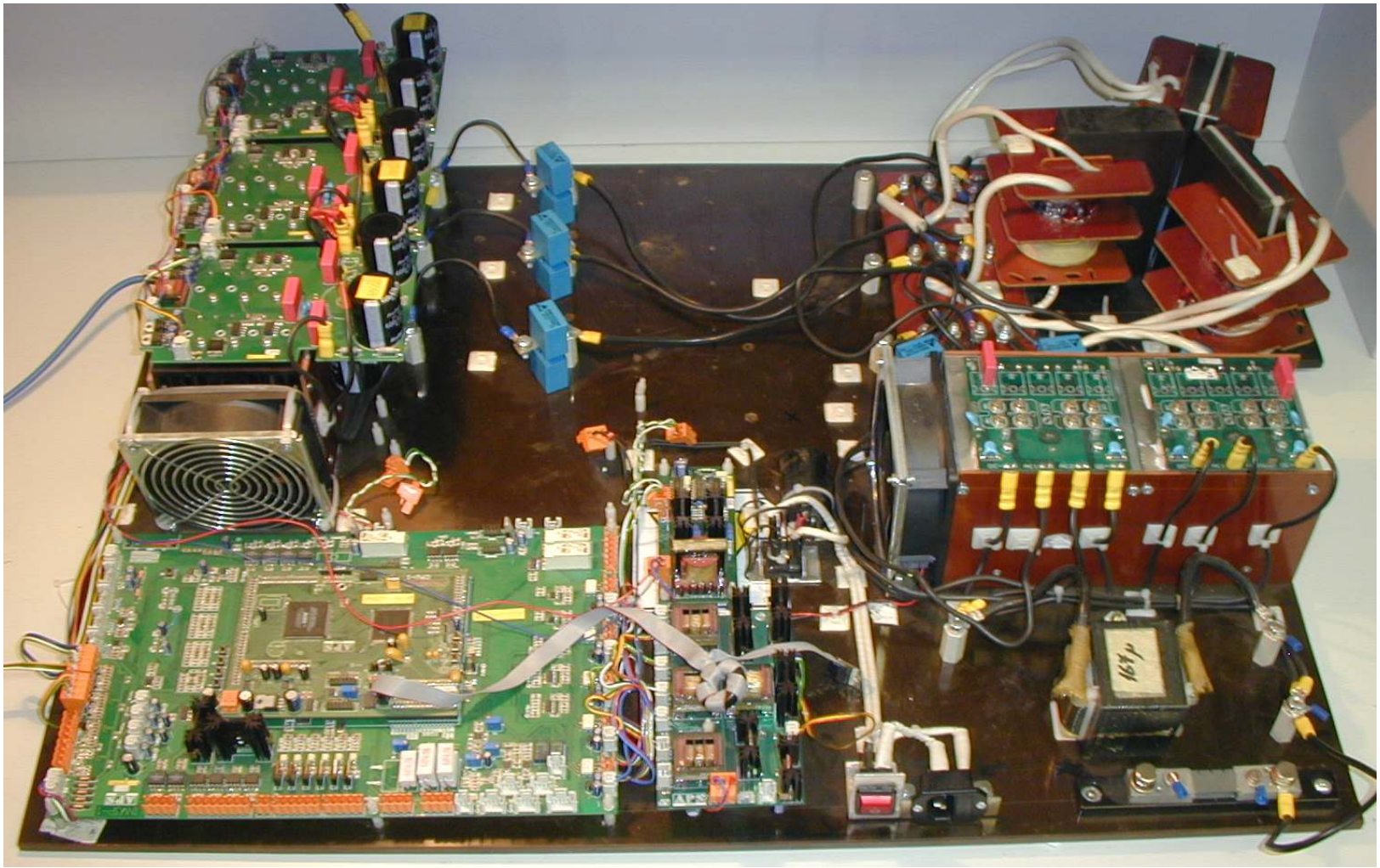
Results

1. power sources cooperate in the proper way
2. voltage is unstable
3. voltage is kept in required range
4. storage system needs to be redesigned
5. platns' controllers need to be tuned

More Power – Engine Generator

- rated power – 3 kW
- permanent magnet synchronous generator
- automatic start up

New Bidirectional Converter for Storage System



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Conclusions

1. I know that introduction of DC into power system awakes emotions and resistance, which cannot be explained with technical arguments.
2. System change can be hard, expensive as well.
3. Still some research is needed.
4. Generally the DC microgird operates as it was designed.
5. Behaviour of the storage device has decisive impact upon the microgird's operation.

Thank you!!!