Cooperative Control – from Microgrids to Systems of Systems

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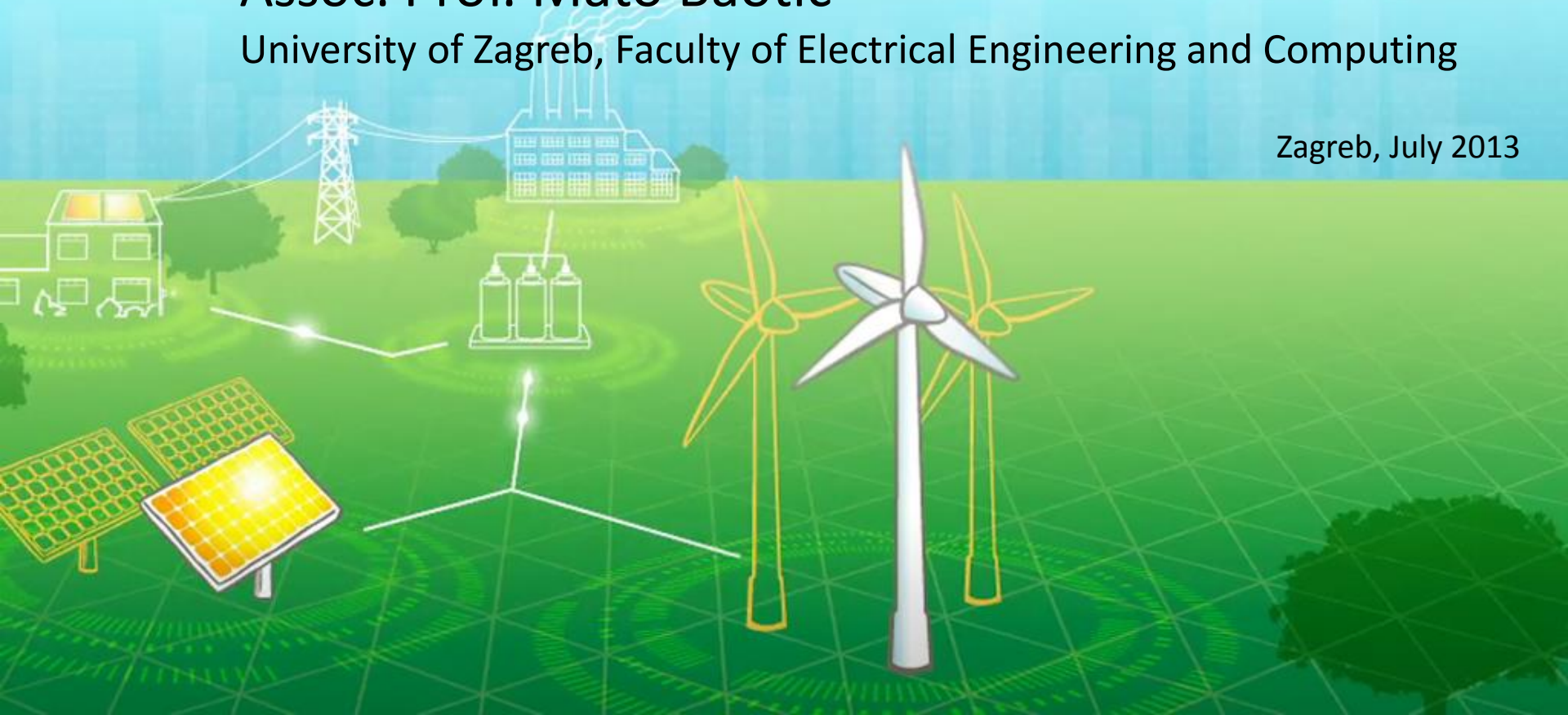

Projects

UNIZG-FER projects

- Optimization of Renewable Electricity Generation Systems Connected in a Microgrid (**MICROGRID**)
- Dynamic Management of Physically Coupled Systems of Systems (**DYMASOS**)
- Distributed Control of Large-Scale Offshore Wind Farms (**AEOLUS**)

MICROGRID

MICROGRID Project info

Project acronym:	MICROGRID
Project title:	Optimization of renewable electricity generation systems connected in a microgrid
Grant agreement no.	I-4463-2011
Funding scheme:	Croatian Science Foundation
Project start date:	January 1, 2012
Project duration:	36 months
Call topic:	Collaborative Research Programmes
Project budget:	194.411,80 EUR
Web page:	www.microgrid.fer.hr

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SEVENTH FRAMEWORK PROGRAMME
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MICROGRID

MICROGRID Project partners

- University of Zagreb, Faculty of Electrical Engineering and Computing (FER)
- University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture (FSB)
- Meteorological and Hydrological Institute of Croatia (DHMZ)
- Končar – Electrical Engineering Institute (KIET)

KONČAR
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MICROGRID

MICROGRID Project outline

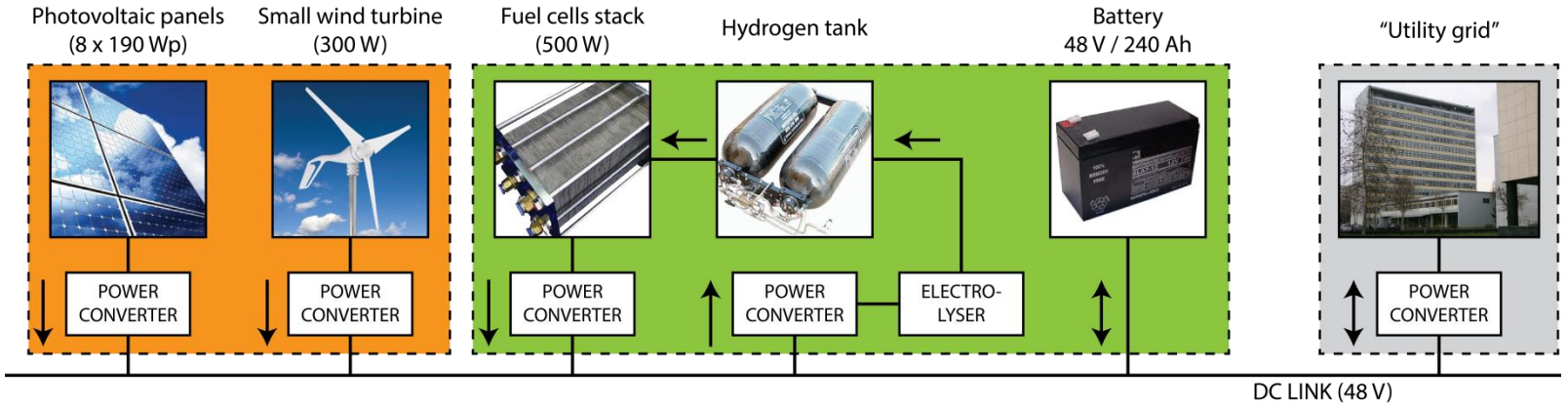
- Objective: Development of control and power management for DC microgrid systems
- Problem: Stochastic and intermittent nature of renewable energy sources
- Solution: Development of power profile prediction models for involved renewable energy systems, which can be utilised by model based optimal control algorithms

MICROGRID Work packages

1. Low-level microgrid control
2. Power flow management in a DC microgrid
3. Procedures for DC microgrid design and sizing
4. Weather service support for design and control of DC microgrids
5. Dissemination

DC microgrid setup

- Laboratory for Renewable Energy Systems (LARES) – www.lares.fer.hr
- DC link: 48 V
- Energy generation: Photovoltaic panels, Small wind turbine
- Energy storage: Fuel cells stack, Batteries



MICROGRID

Laboratory for Renewable Energy Systems (LARES)

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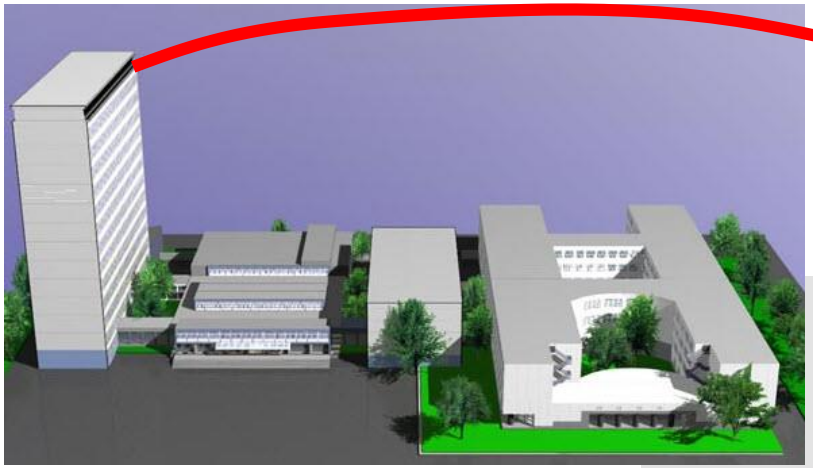

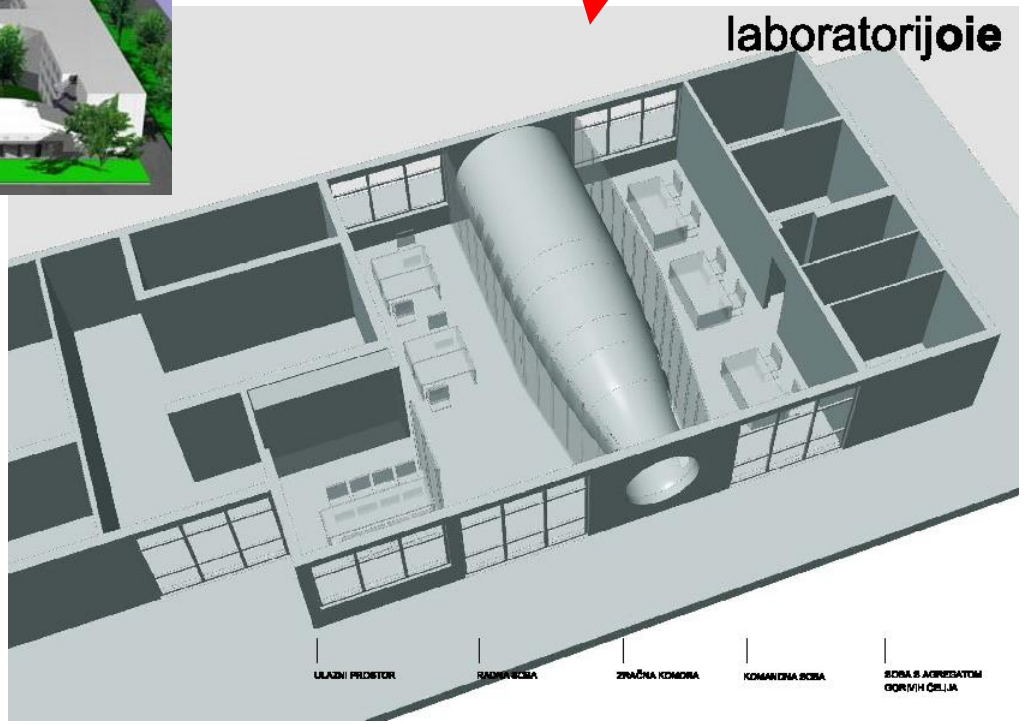

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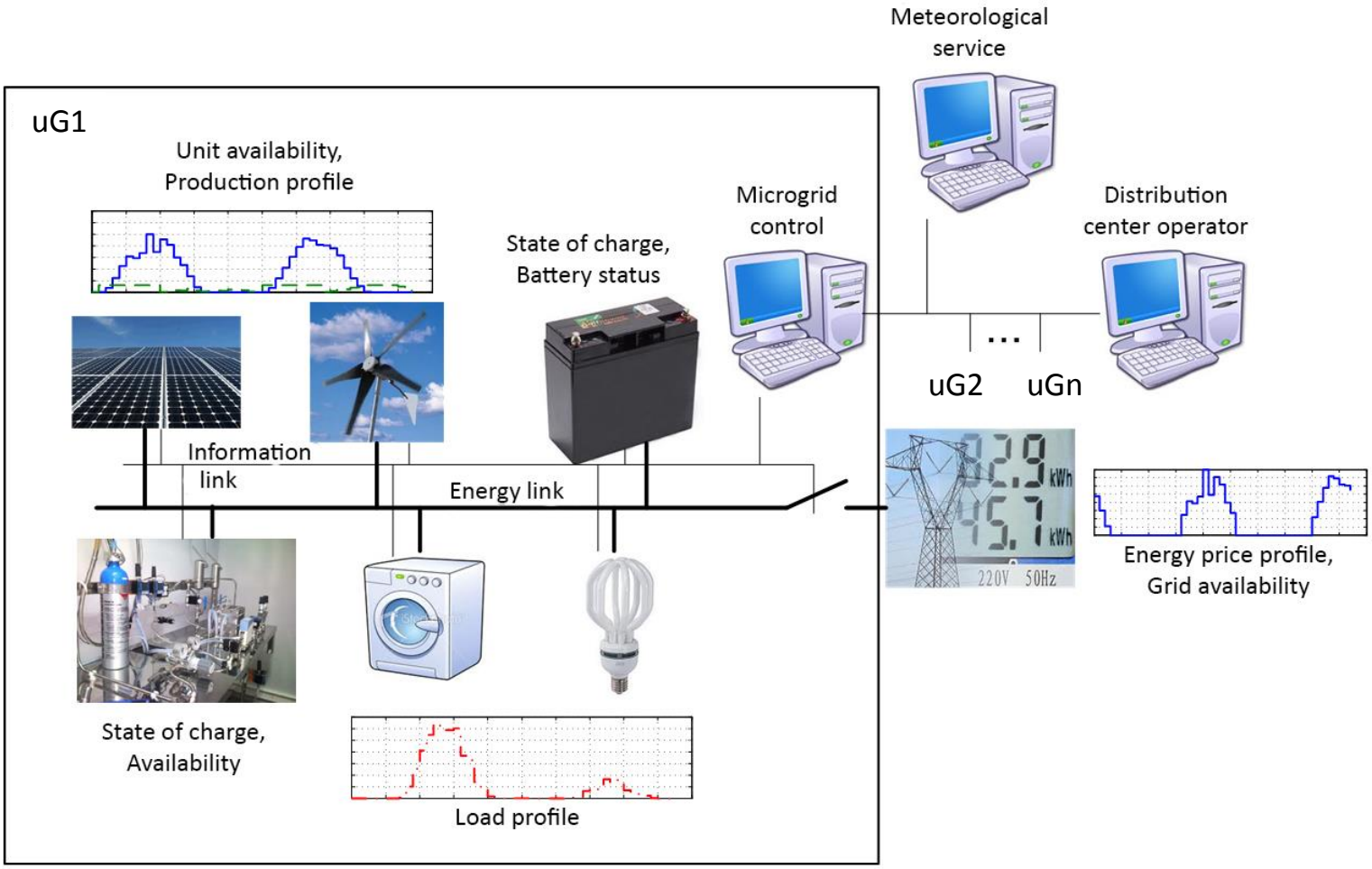
Microgrids → Systems of Systems



DYMASOS

DYMASOS Project info

Project acronym:	DYMASOS
Project title:	Dynamic Management of Physically Coupled Systems of Systems
Grant agreement no.	611281
Funding scheme:	FP7
Project start date:	October 1, 2013
Project duration:	36 months
Call topic:	Collaborative Research Programmes
Project budget:	3,433,742 EUR

DYMASOS

DYMASOS Project partners

- Technische Universitat Dortmund (TUDO - coordinator), Germany
- BASF SE (BASF), Germany
- HEP - Operator distribucijskog sustava d.o.o. (HEP), Croatia
- INEOS Manufacturing Deutschland GmbH (INEOS), Germany
- Universidad de Sevilla (USE), Spain
- Sveuciliste u Zagrebu Fakultet elektrotehnike i racunarstva (UNIZG-FER), Croatia
- Eidgenoessische Technische Hochschule Zurich (ETH), Switzerland
- Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH), Germany
- INNO TSD SA (inno), France
- Optimizacion Orientada a la Sostenibilidad SL (IDENER), Spain
- euTeXoo GmbH (TEX), Germany
- AYESA Advances Technologies SA (Ayesa AT), Spain

DYMASOS

DYMASOS Project outline

- Large interconnected systems with partly autonomously acting sub-units are called systems of systems
- DYMASOS addresses systems of systems where the individual units are coupled by flows of electric power, steam, gas, potable water, chemicals, etc.
- Within the project, new methods for the distributed management of large physically connected systems with local management and global coordination will be developed.
- The research is based on case studies in electrical grid management, including the charging of electric vehicles, and in the coordination of large chemical production plants

DYMASOS

DYMASOS Project outline

Objective: Improved system stability and lower resource consumption in industry and in electric-power generation and distribution.

Methodology:

- Modeling and control of large systems analogously to the evolution of the behavior of populations in biological systems;
- Market-like mechanisms to coordinate independent systems with local optimization functions;
- Coalition games where agents that control the subsystems dynamically group to pursue common goals.

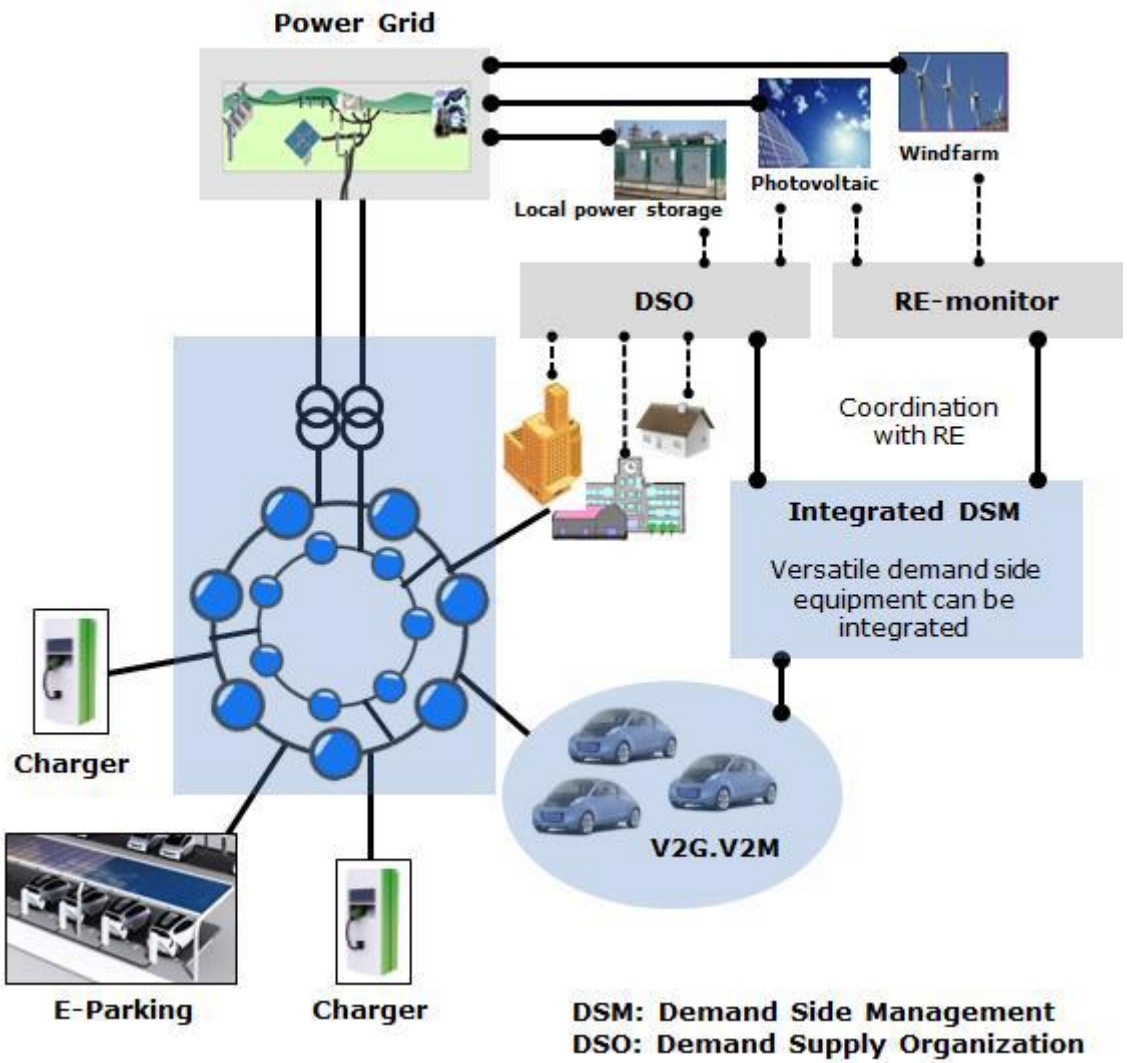
DYMASOS

DYMASOS Work packages

1. Population dynamics based approach to the management of systems of systems
2. Economics-driven coordination and market-based management of systems of systems
3. Coalition games in systems of systems
4. Engineering tools for SoS management
5. Industry-driven case studiesof real applications and synthesis
6. Dissemination, exploitation
7. Management

DYMASOS

Systems of Systems example



AEOLUS

AEOLUS Project info

Project acronym:	AEOLUS
Project title:	Distributed Control of Large-Scale Offshore Wind Farms
Grant agreement no.	224548
Funding scheme:	FP7
Project start date:	May 1, 2008
Project end date:	April 30, 2011
Project duration:	36 months
Call topic:	Collaborative Research Programmes
Project budget:	3,360,000 EUR
Web page:	http://www.ict-aeolus.eu

AEOLUS

AEOLUS Project partners

- Aalborg University (AAU - coordinator), Denmark
- Industrial Systems and Control Ltd (ISC), UK
- Lund University (ULUND), Sweden
- Sveuciliste u Zagrebu Facultet elektrotehnike i racunarstva (UNIZG-FER), Croatia
- Energy research Centre of the Netherlands (ECN), the Netherlands
- Vestas Wind Systems A/S (VESTAS), Denmark

AEOLUS Project outline

Development of:

- Models that allow real-time predictions of flows and incorporate data from a network of sensors, and
- Control paradigms that acknowledge the uncertainty in the modelling and dynamically manages the flow resource in order to optimise specific control objectives.

AEOLUS

AEOLUS Project outline

Horns Rev 1 wake effects. Photographer Christian Steiness. The above photograph shows the turbulence field behind the Horns Rev 1 offshore wind turbines

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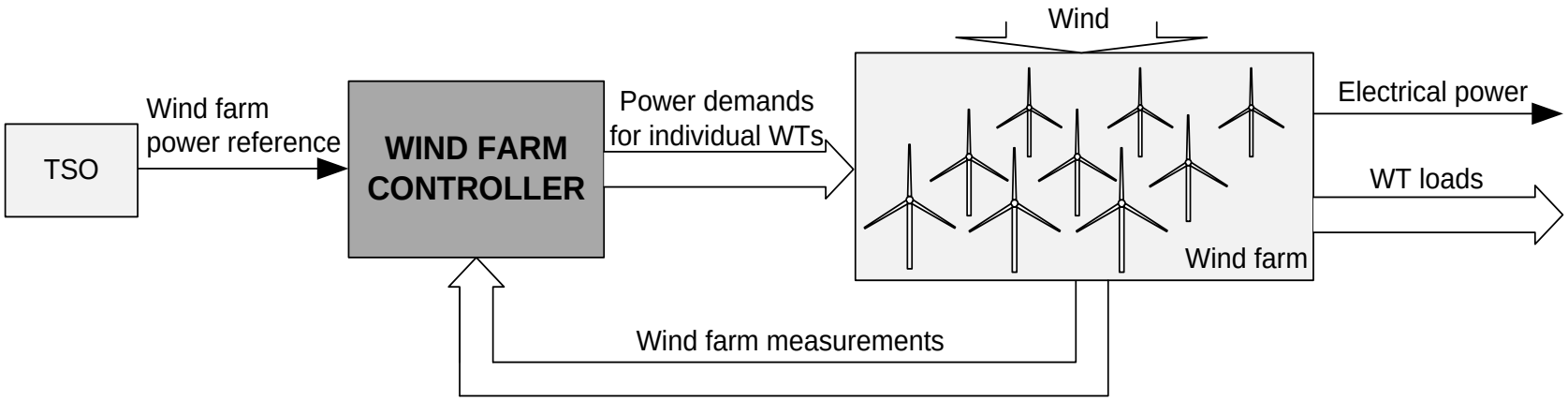
AEOLUS



Control system requirements:

- **track wind farm power reference**
- **reduce fatigue loads** of wind turbines – tower and shaft loads considered
- obtain **scalability of control algorithm** to different wind farm sizes

Control problem features:

- optimal control approach required
- variable constraints
- nonlinear system
- the system model size and complexity increases drastically with wind farm size

Conventional optimal control approaches not suitable for the problem!

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