Laboratory of Systems Control and Automation: Profile and Opportunities to Contribute

EERA ESI meeting, November 2016, DTU
LABORATORY’S PROFILE
Major research directions

✓ mathematical modelling of power systems and networks, investigation of their control issues;
✓ modelling and optimisation research of ICT-based control systems of power systems.

Vision

To become one of the major excellence centre in science and technology carrying out the research related to mathematical modelling of power systems and solution of control problems relevant for the sustainable operation and development of power sector.

Mission

✓ To carry out theoretical and applied research;
✓ To provide consultancies and problem solutions for power sector delivering them to public institutions and industry/business companies;
✓ To cooperate with Lithuanian higher education institutions contributing to the education of specialists for Lithuanian industry and research sectors.
OUR VIEWS ON GRIDS’ FUTURE
Smart technologies will be embedded into electrical power networks, pursuing efficiency and reliability targets, including high quality power supply to customers at acceptable and competitive prices.
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Enhanced Functions of Smart Grid

- Distributed Generation
- Monitoring
- Control
- Equipment
- Electric Vehicles
- Energy Storage Systems
- Flexible Electricity Market
- New Services and Businesses
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Smart Grid Structure
Mathematical modelling of electric power systems, analysis and estimation of parameters
Stability research of electric power systems (PSS/E): phase angle oscillations
Wind power plant control systems (PSS/E)

Model of inverter control system
- \( V_{\text{reg}} \)
- \( V_{\text{term}} \)
- \( I_p, (P) \) command
- \( E_q, (Q) \) command
- \( P_\text{gen}, Q_\text{gen} \)
- \( V_{\text{term}} \)
- \( V_{\text{term}} \)
- \( P_\text{gen}, Q_\text{gen} \)

Model of generator/inverter
- \( P_\text{gen}, Q_\text{gen} \)
- \( V_{\text{term}} \)
- \( V_{\text{term}} \)
- \( P_\text{gen}, Q_\text{gen} \)

Model of control system for wind turbine blades shift
- \( \text{Power setting} \)
- \( \text{Velocity setting} \)
- \( \text{Wheel velocity} \)
- \( P_\text{gen} \)

Model of wind turbine
- \( \text{Shift of blades} \)

Model of control system
- \( \text{Power setting} \)
- \( \text{Velocity setting} \)
- \( \text{Wheel velocity} \)
- \( P_\text{gen} \)

Diagram showing control system components and power generation process.
LOAD-FREQUENCY CONTROL
✓ Analysis of power system control problems;
✓ Development of control algorithms for load-frequency control, voltage control.
Load – frequency control of electric power system
Load – frequency control systems

Load-frequency control system for pumped hydro (MATLAB/Simulink)

Load-frequency secondary control model (MATLAB/Simulink)

Model of HVDC /B2B station (PSS/E)
The influence of mechanical inertia’s time constant ($M=2H$) in EPS for frequency deviation processes, when dead band of the primary turbine regulators is a) 10 mHz, b) 200 mHz

The influence of EPS droop for frequency deviation processes, when dead band of the primary turbine regulators are a) 10 mHz, b) 200 mHz (MATLAB/Simulink)
PARAMETER IDENTIFICATION
Parameter identification:  
Parametric identification

\[
A(q,a)y(t) = \frac{B(q,b)}{F(q,f)}u(t) + \frac{C(q,c)}{D(q,d)}e(t);
\]

Frequency variation characteristics: 1 – derived from factual values, 2 – derived from identified parameter values.

Autocorrelation function of random component of frequency measurements obtained from passive experiment.
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Parameter identification: Spectral analysis

\[
\hat{S}_{yy}(\omega) = \sum_{\tau=-M}^{M} \hat{R}_{yy}(\tau)W_M(\tau)e^{-i\omega\tau};
\]

\[
\hat{S}_{yu}(i\omega) = \sum_{\tau=-M}^{M} \hat{R}_{yu}(\tau)W_M(\tau)e^{-i\omega\tau};
\]

\[
\hat{S}_{uu}(\omega) = \sum_{\tau=-M}^{M} \hat{R}_{uu}(\tau)W_M(\tau)e^{-i\omega\tau};
\]

\[
\hat{G}_N(i\omega) = \frac{\hat{S}_{yu}(i\omega)}{\hat{S}_{uu}(\omega)};
\]

\[
\hat{S}_{vv}(\omega) = \hat{S}_{yy}(\omega) - \frac{|\hat{S}_{yu}(i\omega)|^2}{\hat{S}_{uu}(\omega)}.
\]

Amplitude/phase response characteristics of power systems derived from the model with imbalance power \( P_{nb} \) in model's input and frequency \( f \) in model's output.
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RENEWABLE GENERATION FORECASTING
Physical forecasting models

- Research and modelling of wind flow variation in different regions of Lithuania
- Development of short term wind power plant prediction system
Physical forecasting models

- Relief
- Meteorological forecasts
- MODEL
- WPP data
- WPP power forecast

Focus on short term forecasting period
Statistical / time series forecasting models
LABORATORY’S MAJOR RESULTS
International projects


Projects


Publications included in THOMSON REUTERS WoS


Chapters in books published by renowned international publishing companies


"REAL ACTIVITIES" PROPOSALS

EERA
ESI SP2
Proposed “real activity”:  
Coupling the wind and solar electricity generation forecasts in the EU with the exchanges of power generation reserves across the EU transmission networks  
(Task 2.1, 2.2, 2.3)  

Rationale:  
It is necessary to evaluate the demand of cross-border balancing power in EU regions caused by large-scale wind&solar electricity integration
Proposed “real activity”:
Development of integrated smart metering infrastructure (meters, communication, data concentrators) for electricity, heat, gas and water supply systems (Tasks 3.1, 3.2, 3.3)

Rationale:
Multi-energy meters may be more cost-effective than single-energy meters

Technology:
Two-way data communication (network operator to/from meter)

Major output:
Infrastructure architecture, synergy evaluation
EERA SP2 Forecasting, aggregation and control, WP3, WP4

*Proposed “real activity”:*
Development of innovative demand-side management methods targeted for integrated DA/real time control of loads in electricity, heat and gas distribution systems
*(Tasks 3.1-3.4, 4.1-4.5)*

*Rationale:*
The demand-side response could be introduced to heat and gas systems to support the demand response in electricity systems, virtual power plants and microgrids

*Major output:*
Demand-side response aggregation models, activation mechanisms, performance measurement indicators, synergy evaluation
Proposed “real activity”:

Feasibility of integrated outage management system in urban area for electricity, heat, gas and water supply networks enabling remote monitoring of networks, identification of equipment failure site, the joint repair crews, and outage data management system

*(Tasks 4.1-4.5)*

*Rationale*:

Integrated approach couples different networks thus needing less resources for monitoring, identifying, site-visiting, repair and analysis activities than in case of individual networks

*Major output*:

Procedures, methodologies, synergy evaluation
Proposed “real activity”:
Smart buildings and electricity & heat self-generating buildings interacting with electricity, gas, and districting heat and cooling networks

(Tasks 3.3, 4.1-4.5)

Rationale:
Building energy management systems have a huge energy efficiency potential

Scope:
Public and office buildings

Major output:
Infrastructure architecture, synergy evaluation
EERA SP2 Forecasting, aggregation and control, WP4

Proposed “real activity”:
Feasibility of integrated network wear monitoring system in urban area for electricity, heat, gas and water supply networks enabling remote monitoring of equipment wear level, calculation of work life resources and predictive scheduling of repairs and replacements of worn-out equipment

(Task 4.1)

Rationale:
Ageing of networks could be monitored and unexpected outages could be prevented.

Integrated approach suggests less resources than individual network resources

References:
European Technology Platform for Smart Grids (2013): strategic research agenda for 2035

Major output:
Procedures, monitoring system architecture, synergy evaluation
DRAFT IDEA FOR INTEGRATED CONTROL
EERA SP2 Forecasting, aggregation and control

Proposed idea: Control for integrated/multi-energy system

Problem: May the integrated control in short term and real time bring benefits and synergy?

Major output: 1) Outline of integrated control framework; 2) Control modelling results

LEI contribution: Control modelling for electrical system and grids

Expectation: Who will be able to couple 4 different energy systems?
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