Intelligent Energy Systems Integration and CITIES



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.... balancing of the power system



■ Wind power □ Demand

In 2008 wind power did cover the entire demand of electricity in 200 hours (West DK)



■ Wind power □ Demand

In 2014 more than 40 pct of electricity load was covered by wind power.

For several days in 2014 the wind power production was more than 120 pct of the power load.

July 10th, 2015 more than 140 pct of the power load was covered by wind power



From large central plants to Combined Heat and Power (CHP) production

<u>Today</u>



From a few big power plants to many small **combined heat and power** plants – however most of them based on coal



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What has since been achieved: De-coupling of consumption and GDP growth



Source: Energy Policy in Denmark. Danish Energy Agency. December 2012



Energy Systems Integration

Energy system integration (ESI) = the process of optimizing energy systems across multiple pathways and scales

Intelligent Integration and Cities

Cities play an important role – for several reasons

Center for IT-Intelligent Energy Systems in Cities (CITIES) is establishing ITC solutions for design and operation of integrated electrical, thermal, fuel pathways in at all scales.

CITIES is the largest Smart Cities and ESI research project in Denmark – see http://www.smart-cities-centre.org .

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Future Electric Energy System

CITIES Centre for IT Intelligent Energy Systems

Control and Optimization

In New Wiley Book: Control of Electric Loads in Future Electric Energy Systems, 2015

Day Ahead:

Stoch. Programming based on eg. Scenarios

Cost: Related to the market (one or two levels)

Direct Control:

Actuator: **Power**

Two-way communication

Models for DERs are needed

Constraints for the DERs (calls for state est.)

Contracts are complicated

Indirect Control:

Actuator: Price

Cost: E-MPC at **low (DER) level**, One-way communication

Models for DERs are not needed

Simple 'contracts'

Direct vs Indirect Control

Table 3 - Difference between direct (DC) and indirect (IC) control.

Level	Direct Control (DC)	Indirect Control (IC)
111	$\min_{x,u} \sum_{k=0}^{N} \sum_{j=1}^{J} \phi_j(x_{j,k}, u_{j,k})$	$\min_{\hat{z},p} \sum_{k=0}^{N} \phi\left(\hat{z}_{k}, p_{k}\right)$
		s.t. $\hat{z}_{k+1} = f(p_k)$
	$\downarrow_{u_1} \cdots \downarrow_{u_J} \uparrow_{x_1} \cdots \uparrow_{x_J}$	$\min_{u} \sum_{k=0}^{N} \phi_j(p_k, u_k) \qquad \forall_j \in J$
IV	s.t. $x_{j,k+1} = f_j(x_{j,k}, u_{j,k}) \forall_j \in J$	s.t. $x_{k+1} = f_j(x_k, u_k)$

Forecasting is essential

Tools for Forecasting: (Prob. forecasts)

- Power load
- Heat load
- Gas load
- Prices (power, etc)
- Wind power prod.
- Solar power prod.
- State variables (DER)

Virtual Storage by Energy Systems Integration

Denmark: 48 pct of power load by renewables (> 100 pct for some days)

(Virtual) storage principles:

- Buildings (thermal mass) can provide storage up to, say, 5-12 hours ahead
- District heating/cooling systems can provide storage up to 1-3 days ahead
- Gas systems can provide seasonal storage

Case study

Control of Wastewater Treatment Plants

Waste-2-Energy

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Energy Flexibility in Wastewater Treatment

Sludge -> Biogas -> Gas turbine ->Electricity
Power management of the aeration process
Pumps and storage in sewer system

Overall goals: Cost reduction Minimize effluent concentration Minimize overflow risk

International Alliances on Energy Systems Integration

UCD, DTU, KU Leuven: ESI Joint Program in EERA

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Foster a Global Community

www.iiesi.org

Figure 1 International Institute[™] for Energy Systems Integration

Vision

A global community of scholars and practitioners from leading institutes engaged in efforts to enable highly integrated, flexible, clean, and efficient energy systems

Objectives

- Share ESI knowledge and Experience
- Coordination of R&D activities
- Education and Training Resources

Recent Activities

- 2013 IEEE P&E Issue on ESI
- 2014 Four workshops on ESI
- 2015 ESI 101 and 102 Courses

ELECTRIC POWER RESEARCH INSTITUTE

Thanks for your attention!

For more information: hmad@dtu.dk

Some 'randomly picked' books ...

2008

Some 'randomly picked' books (cont.)

2013

2015

