Integrating electrical and thermal domains - A case study of the Danish Technical University campus

Thibaut Richert* (PhD student)
Oliver Gehrke (Scientist)

DTU - Energy System Operation and Management (ESOM)

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DTU Technical University of Denmark

Agenda

- Background - Context & Problem statement
- DTU campus
- Use Cases
- Modelling experience
- Conclusion

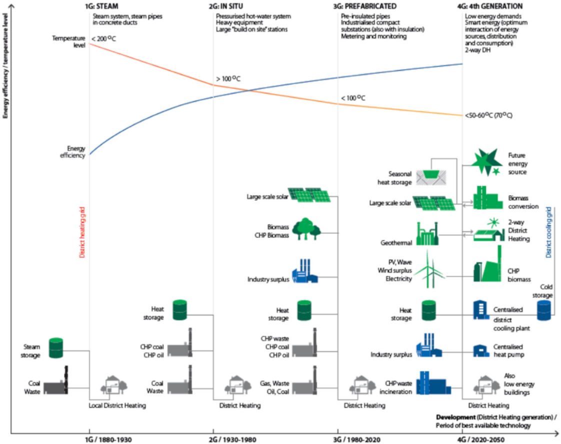
Background & Context

What big picture are we looking at?

- Integrated energy systems
- Multi-carrier energy systems
- Multi-source multi-products energy systems
- Energy systems coupling
- Multi-domain energy systems (MES)
- ...

Background & Context

What big picture are we looking at? - 4GDH and SMART GRID



credit: 4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems - Lund et al.

Background & Context

What will change?

What the future looks like in integrated energy systems

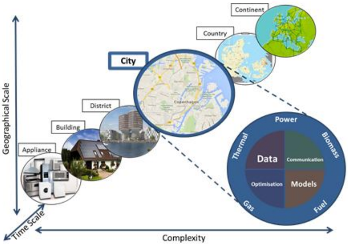
- Renewables
- Distributed energy resources
- Power-to-heat technologies
- Bi-directional flows
- Local heat injection
- Control aspect become crucial
- Communication will play a key role

Problem statement

What does this field of research lack?

What challenges are faced in integrated electro-thermal systems

- Complexity
- Temporal and spatial
- Correlation of uncertainties
- Operational time scales
- What about control?
- Characterisation, aggregation & simplification



→ Properly described Use Cases (UCs) based on a holistic methodology

DTU campus

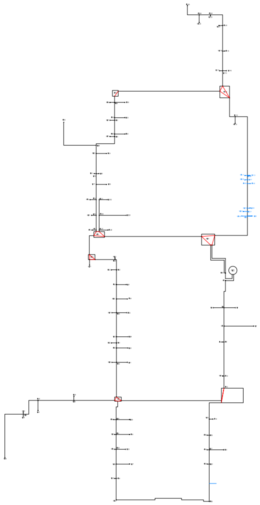
Overview

Key figures

- $\simeq$ 11.000 students
- $\simeq$ 6.000 staff
- Roughly 2km^2

DTU campus

System configuration - on Scale



DTU campus

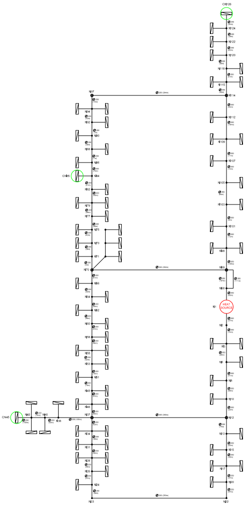
System configuration - Simplified

Key figures

- 68 Loads
- 126 Nodes
- Loops
- 3 critical points - Bypass
- 2 supply loops
- $\simeq$ 60.000 MWh/year heat

Potential

- 12MW of cooling (peak)
- 6MW of cooling installed
- Heat is wasted



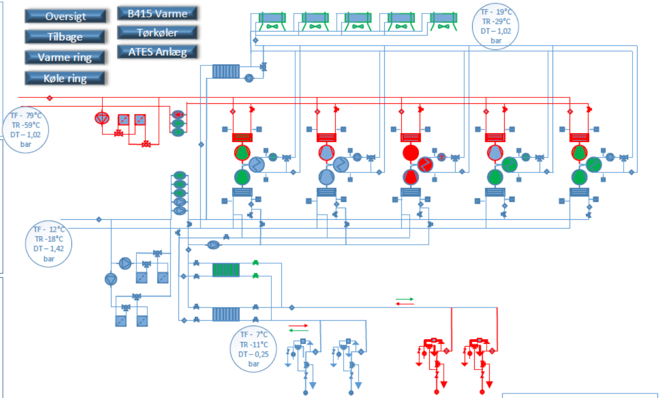
DTU campus

System configuration - Future Heat pump I

B215K M1
- Maskine 3 frigivet
- Maskine 3 i drift
- Maskine 3 auto
- Maskine 3 stop
- COP: 4,85
- Køle temp.: 11 °C
- Varme Temp.: 87 °C

B215K M2
- Maskine 3 frigivet
- Maskine 3 i drift
- Maskine 3 auto
- Maskine 3 stop
- COP: 4,85
- Køle temp.: 11 °C
- Varme Temp.: 87 °C

B215K M3
- Maskine 3 frigivet
- Maskine 3 i drift
- Maskine 3 auto
- Maskine 3 stop
- COP: 4,85
- Køle temp.: 11 °C
- Varme Temp.: 87 °C



B215K M4
- Maskine 4 frigivet
- Maskine 4 i drift
- Maskine 4 auto
- Maskine 4 stop
- COP: 4,85
- Køle temp.: 11 °C
- Varme Temp.: 55 °C

B215K M5
- Maskine 5 frigivet
- Maskine 5 i drift
- Maskine 5 auto
- Maskine 5 stop
- COP: 5
- Køle temp.: 12 °C
- Varme Temp.: 85 °C

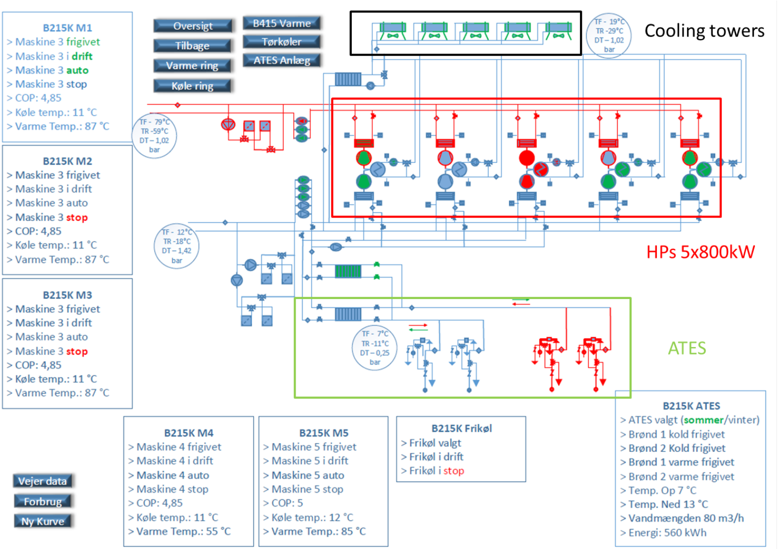
B215K Frikøl
- Frikøl valgt
- Frikøl i drift
- Frikøl i stop

B215K ATES
- ATES valgt (sommer/vinter)
- Brønd 1 kold frigivet
- Brønd 2 Kold frigivet
- Brønd 1 varme frigivet
- Brønd 2 varme frigivet
- Temp. Op 7 °C
- Temp. Ned 13 °C
- Vandmængden 80 m3/h
- Energi: 560 kWh

Vejer data
Forbrug
Ny Kurve

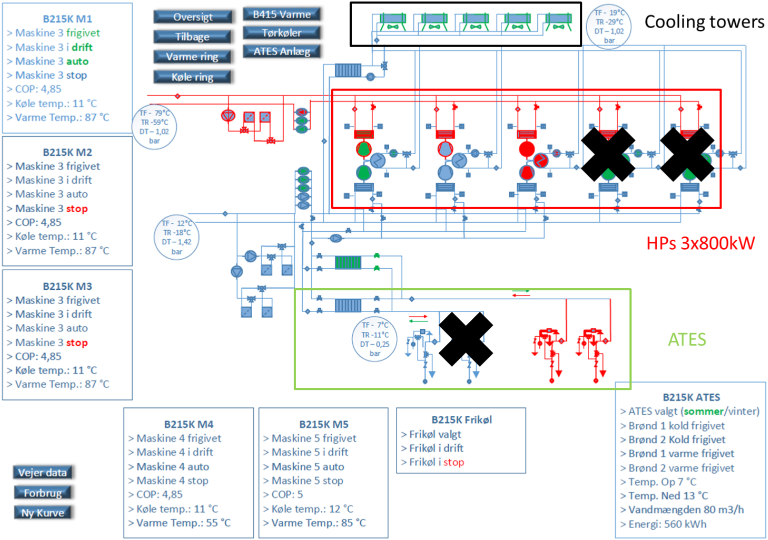
DTU campus

System configuration - Future Heat pump II



DTU campus

System configuration - Future Heat pump III

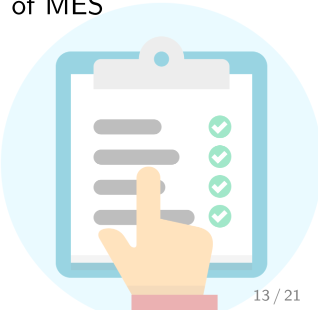


Use cases

Criteria - system operation focus

Requirements

1) UCs must be in line with the energy system evolution(s)
2) UCs must address some of the operational challenges
3) there should be a business case for the UCs
4) the UCs should grasp the control interaction of MES



Use cases

Definition

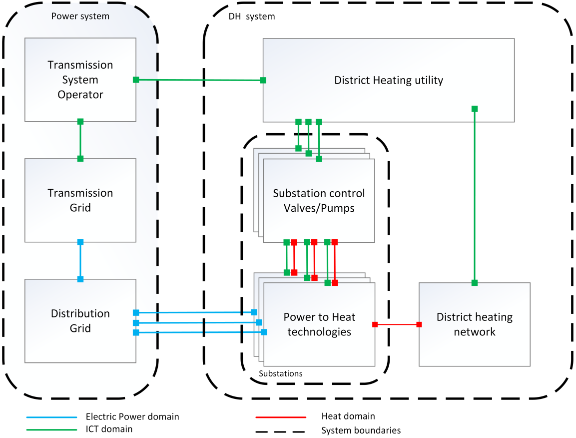
- **UC1** Decentralized feed-in in the DH network
- **UC2** District heating system providing ancillary services to the electrical system
- **UC3** Electrical system providing services to the heat distribution system

Use cases

Holistic view

System configuration

Domains refer to all physical or cyber-components belonging to a class of infrastructure



UC2 - DH provides ancillary services to the electrical system (TSO/DSO):

- Need for balancing - ancillary services
- Proliferation of DERs (e.g EVs)
- Aggregation
- Emergence of new market platform

UC3 - Heat peak-load shaving (mainly small) - Electrical system providing service to the heating system

- Heat load forecast
- Time lag (e.g due to high inertia)
- Change in operation of DH networks

Modelling tools

Requirements

Dynamic models are essential to understand interaction and characterize propagation of transient response from one system to another during normal and abnormal operation.

- Temperatures, flows, pressures, energy and power for the Heating domain.
- Energy, power, flows, voltage, frequency for the Electrical
- ICTs are beyond the physical coupling but of paramount importance when considering control aspects of these cyber-physical systems.

Modelling experience

- Modelling DH network is one "simple" thing
- Many tools exist
- Holistic vision becomes limiting
- API/co-simulation capable tools
- Co-simulation is a good candidate

Conclusion

What is next?

- UCs designed and representative of the future (hopefully)
- Dependant on external factors (i.e markets, policies, technologies)
- Maximize asset use
- DTU campus network is an interesting case study
- Data is key
- No single tool exists to address all UCs
- Co-simulation platform?
- Object-oriented, multi-domain modelling - Modelica?

Conclusion

рахмат
danke
謝謝
ngiyabonga
teşekkür ederim
Баярлалаа
mersi
barka
welalin
tack
спасибо
faafetai lava
vinaka
blagodaram
dank je
misaotra
matondo
paldies
grazzi
mahalo
tapadh leat
kiitos
dankie
спасибі
thank you
gracias
хвала
asante
manana
nanni
nandri
dhanyavad
obrigada
tenki
bedankt
bayarlalaa
gràcie
hvala
mauruuru
köszönöm
dankon
akun
djiere dieuf
mochchakkeram
murakoze
enkosi
dziękuję
дякую
mamnun
chnorakaloutioun
gratias ago
gràcies
sulpáy
go raibh maith agat
chokrane
sobodi
dėkuji
obrigado
sagolun
sukriya
kop khun krap
taiku
mèsi
didi madloba
ありがとう
tanemirt
grazie
arigatô
takk
dakujem
trugarez
najis tuke
kam sah hamnida
terima kasih
rahmet
rahmat
diolch
dhanyavadagalu
shukriya
mercé
мерси
감사합니다
xièxie
ευχαριστώ
merci