Optimising hybrid systems design and performance

Michaël Kummert

SESG / BRE seminar – Electric heating: yesterday’s villain, tomorrow’s saviour? 17 April 2008
Outline

- Who am I?
- Hybrid systems
  - What is a hybrid system?
  - Types of hybrid systems
  - Importance of control strategies
  - Hybrid systems on the rise
  - Hybrid systems and electricity
- Optimisation problem
  - Design, operation, lifetime performance
  - The role of simulation
- Case studies
  - Design optimisation: NZEH
  - Design and control: hybrid GSHP system
  - Design, control and lifetime performance: GSHP + resistance
- Conclusions
Michaël Kummert

PhD in environmental sciences
- Passive/active solar buildings
- Model-based optimal control

Consulting engineer
- Low energy buildings, solar thermal systems

TRNSYS coordinator
- Modelling, simulation software development

Post-doc researcher / lecturer
- Net-zero energy houses, solar thermal, ground source heat pumps
· Who am I?

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· Conclusions
What is a hybrid system?

“Something (as a power plant, vehicle, or electronic circuit) that has two different types of components performing essentially the same function”

(Merriam Webster dictionary)

2 (or more) ways to perform the same task
⇒ control decision

Some examples (building services)

- Hybrid heating system
  - Radiant underfloor heating + radiators
  - Radiators (gas boiler) + wood stove
  - Underfloor heating + electric baseboard
  - Etc.
Basic control problem

- Which one of the 2, 3, ... components to use and when?
  - Meet demand
  - Maximise efficiency
    - Cost
    - Environmental impact (CO₂, etc.)
  - Ensure sustainability and long-term performance

⇒ Predictive control (optimal, near-optimal, rule-based, etc.)
Energy storage

- Options
  - Meet load directly
  - Meet load from storage
  - Recharge storage

- Constraints
  - Manage storage state of charge
  - Maximise efficiency (minimise cost)

⇒ Similar control problem
Types of hybrid systems

- Multiple energy sources
  - Gas / oil / etc. + electric
  - Renewables
    - Biomass + backup
    - Solar + backup
    - Heat pump + backup

- Storage
  - DHW storage
  - Buffer storage (building thermal mass!)
  - Ground source systems
  - Seasonal storage

- Multiple source / sink
  - Hybrid ground-source + boiler / cooler

- Multiple secondary systems
  - Undefloor + convectors, etc.
  - Desiccant / conventional AC systems
• Higher energy prices and climate change concerns
  • Renewable energy systems requiring backup
    • Intermittent supply
    • Economic or technical constraints
    • Encouraged by policies
      • “Merton rule”: 10, 20% renewable
      • Grants for heat pumps up to x kW
  • Interest in micro-generation
    • Economic optimum often includes backup
  • Net-zero energy or carbon neutral buildings
    • Only realistic solutions involve hybrid systems
  • Storage systems
    • Reduce cost
      • Time-of-Use electricity rates
      • Free cooling

⇒ These systems need to be optimised
⇒ Importance of predictive control strategies
Most hybrid systems involve electricity

- Heat pumps
- Small backup system
- Storage
  - Time-of-Use pricing
  - Cooling system performance (free cooling)

Future electric systems

- Will be hybrid systems
  - Heat pump / resistance
  - Solar / immersion
  - Microgeneration
- Will include storage
  - Off-peak rates / TOU

⇒ will require advanced control strategies
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What do we want to optimise?
- Design
- Operational costs (control strategies)
- Lifetime performance
- The 3 are interrelated
The role of simulation: combined optimisation

- Optimised design parameters
- System configurations
- Control strategies (sets of rules)
- Control setpoints, thresholds

→ Performance simulation

- Investment cost
- Operational costs
- Occupant satisfaction
- Life cycle performance

Weather
Occupancy
Fixed design parameters
Energy rates
Etc.
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The path to net-zero

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Design and control: Hy-GSHP
System performance

Energy input [kWh/day]

Time

Building 1, 1<sup>st</sup> year of operation
Design, control and lifetime performance

- GSHP system + backup resistance
Heating setpoint controller

- Orange line: Heat pump setpoint
- Red line: Backup resistances setpoint

Heating setpoints [°C]

Time of day [h]
Short time-step simulation (for 20 years!)

![Graph showing temperatures and heating power over time]

- **Tset**: Set temperature
- **Tdb,house**: Building temperature
- **Qheat,hp**: Heating power from Hot Water
- **Qheat,tot**: Total heating power
Life cycle analysis

Rule-of-thumb designs

- 3.5 kW heat pump
- 5.3 kW heat pump

Borehole depth [m]

Life-cycle cost [k$]
Conclusions

- Hybrid systems are on the rise
  - Renewable energy + backup
  - Net-zero energy or carbon neutral
  - Storage (time varying electricity pricing)

- Optimisation:
  - Design
  - Operation (control)
  - Lifetime performance

- Simulation can play a key role
  - Testing design configurations and variables, control strategies and setpoints/thresholds

- Electricity will play a key role in hybrid systems

- Future electric systems will be hybrid / have storage
15% renewable energy in dwellings

Grid
15% renewable

Heat pump
COP = 3

DHW
25
Sp heating 75

Solar 60%

Total renewable fraction = 15 + 56 + 0.15*29 = 75%

If 20% of dwellings, overall percentage = 15%