Graph-theoretic Model for Observability in Multi-carrier Energy Distribution Networks (MEDNs)

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Multi-carrier Networks

Energy networks: electricity (e1), heat (h), natural gas (g)

Decentralized energy converters (e.g. CHP, P2X)

Multi-carrier Energy Distribution Network (MEDN) [1]

Observability

An energy network is observable if all operational variables are determinable, based on the topology of the network, and the types and locations of the measurement points [2].

Monitoring

Monitoring of operational variables is essential as network constraints have to be met by the MEDN control:

- e1: voltage and current limits
- h: pressure, temperature and volume flow limits
- g: pressure and volume flow limits

Key Questions

Q1. How can we include the network topology and the operational variables in a unified MEDN model?

Q2. Based on that model, how can we determine observability in MEDNs?

Model

Steady state modeling as a graph $M = (V, A)$

- $V$: set of vertices
- $V_i \subseteq V$: set of transfer vertices of carrier $i \in [1, k]$
- $V_C \subseteq V$: set of converters (e.g. CHP, P2X)
- $V_T \subseteq V$: set of disturbances
- $A \subseteq (V^2)$: set of edges

Vertices and edges are related to effort and flow variables:

<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>Natural Gas</th>
<th>Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>effort $e$</td>
<td>voltage $U$</td>
<td>pressure $p$</td>
<td>pressure $p$</td>
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<tr>
<td>flow $f$</td>
<td>current $I$</td>
<td>flow $Q$</td>
<td>flow $Q$</td>
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</tbody>
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Future Work

- Derivation of an observability criterion for MEDNs
- Determination of a cost-optimal sensor placement

Literature
