# Assessing Risk in Integrated Energy Infrastructure through Contingency Analysis

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## Motivation:

An Integrated Energy System (IES) represents a comprehensive infrastructure incorporating various subsystems like electricity, natural gas, and heating/cooling. Designed to enhance efficiency, reduce pollution emissions, and decrease dependence on fossil fuels, an IES stands as a critical infrastructure. Its direct physical connection to corresponding energy consumers underscores its importance. With rising awareness of threats from rare events like extreme natural disasters or deliberate attacks, the study of energy resilience gains prominence. Contingency analysis, integral to modern Energy Management Systems (EMS), plays a pivotal role in assessing system stability. Contingency analysis predicts and addresses problems caused by transmission line or transformer failures, like overloads or voltage changes which can cause potential network disconnections[1]. This proactive approach is crucial for managing interconnected networks effectively.

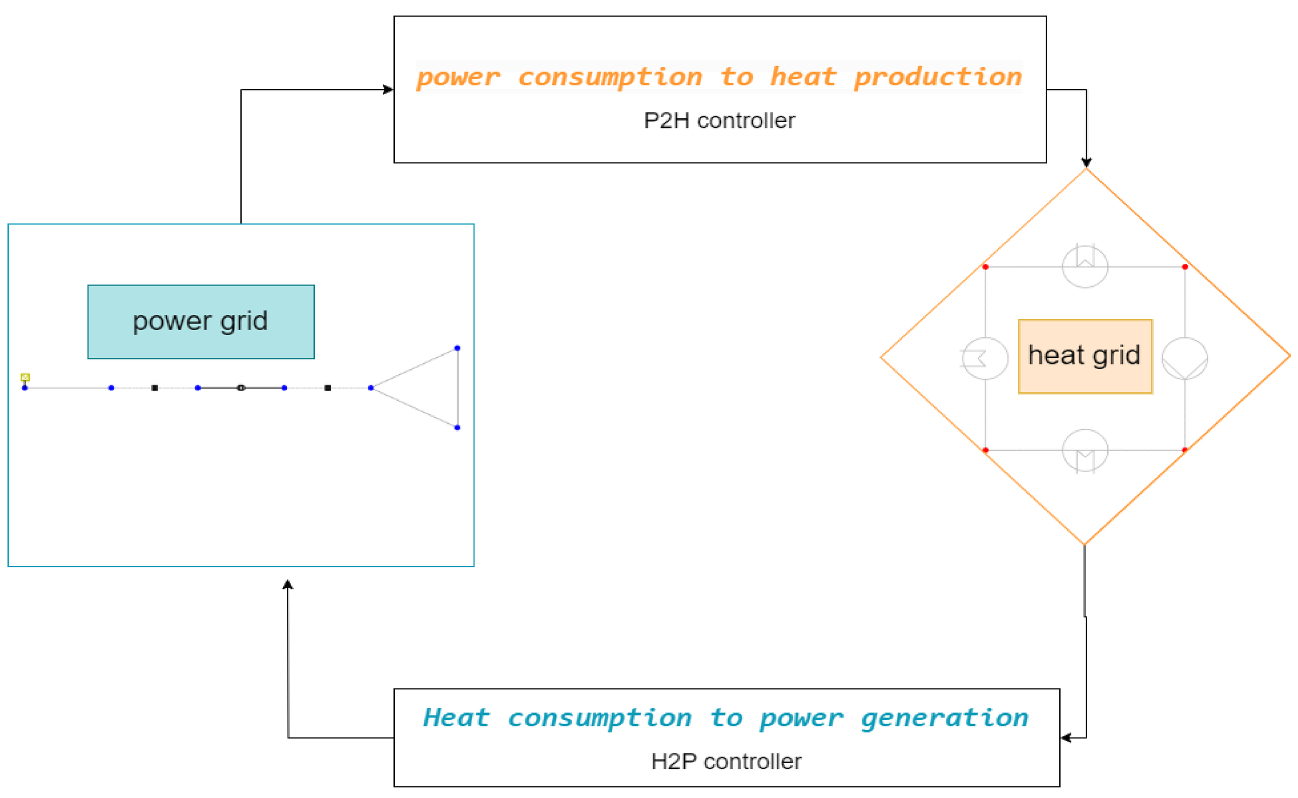


Fig 1: Power- heat sector coupled network

## Methodology:

- Created a power grid using pandapower[2].
- Set up a heating network using pandapipes[3].
- Integrated them using Pandapower and Pandapipes within a multinet-frame[3].
- Coupled a power network and a heating network using a power-to-heat unit (e.g., heat pump) and a heat-to-power unit (e.g., PV), respectively. These units have input values set in one network (power or heat consumption) and during simulation, output values are calculated using efficiency factors and written to the other network.
- Simulated contingency analysis considering (N-1) cases for analysis as contingencies. By systematically switching off individual lines, we identified critical lines prone to causing network disconnections due to overloads or voltage changes.

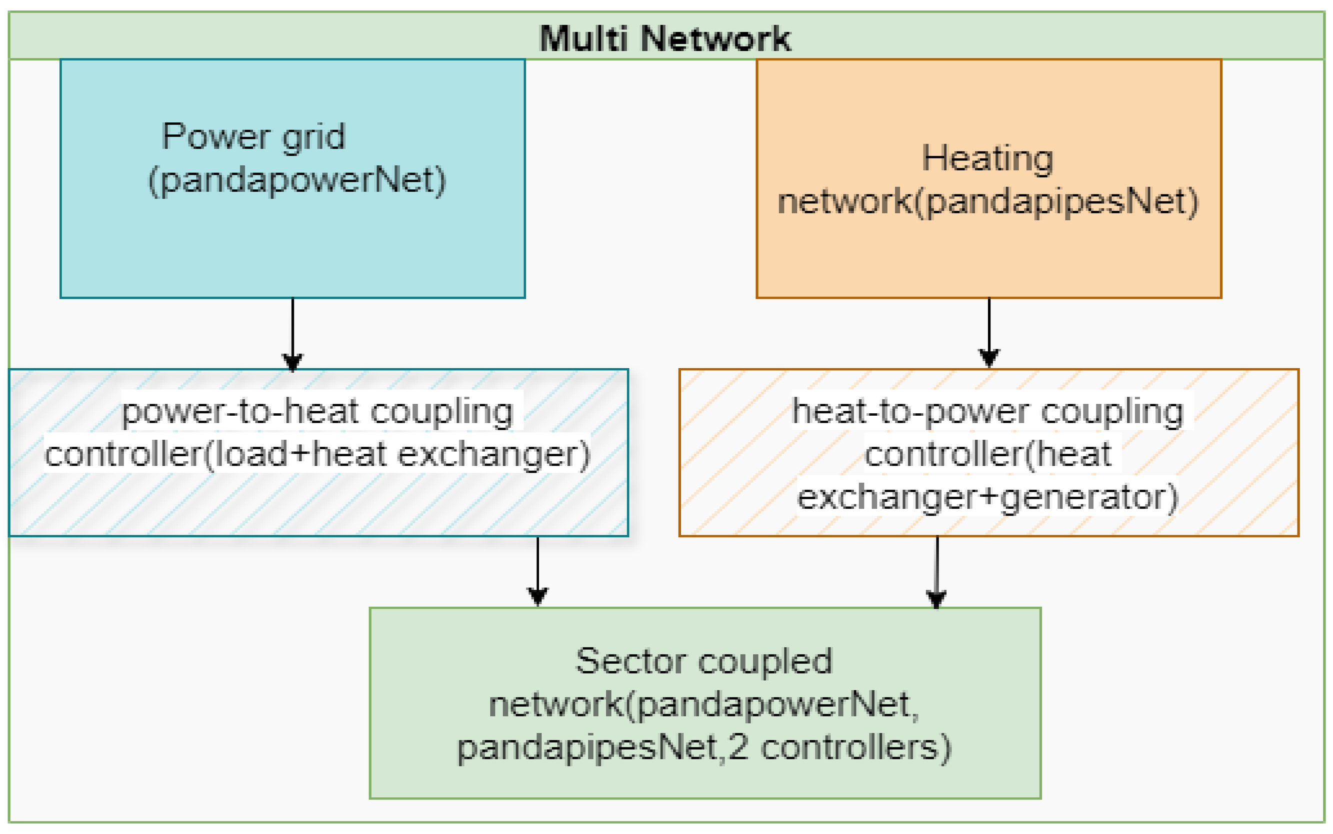


Fig 2: Multinetwork with controllers

## Results:

| Coupling Units | Initial value (MW) | Output value(MW) |
|---|---|---|
| Power to heat flow(heat exchanger) , P2H | 0.0 | 0.6 |
| Heat to power generation, H2P | 0.0 | 0.4 |

Table 1: Coupling unit values of power- heat sector coupled network

The P2H controller couples power and heating networks stored in a multinet. It reads power load values, applies efficiency factors and conversions, and writes resulting heat flows to heating elements. The H2P controller couples heating and power networks similarly, reading heat flows and converting it to generating power output. In our case study,The H2P controller has successfully updated the relevant generator value to 0.4 MW, and the P2H controller has successfully updated the heat exchanger of the heating grid to 0.6 MW from its initial zero value. The most critical lines are 0 and 3, according to the contingency analysis. The heating network could become disconnected as a result of their disconnection.

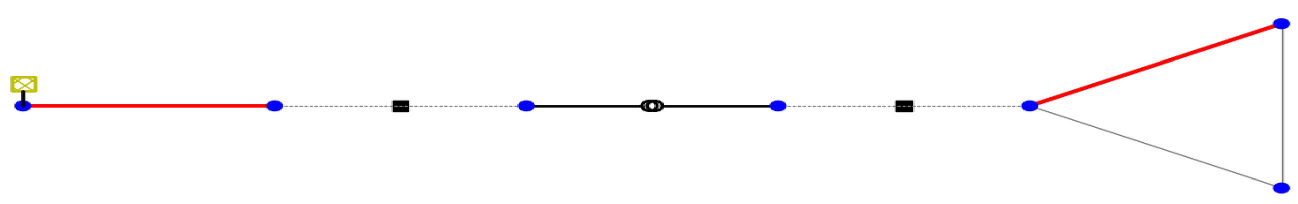

Fig 3: Critical lines (red lines) in contingency analysis

## Conclusion:

Contingency analysis emerges as a pivotal tool for investigating the resilience of Integrated Energy Systems (IES) in the face of future challenges. Its ability to anticipate and address potential disruptions underscores its importance in ensuring the robustness and adaptability of IES infrastructure. By proactively identifying vulnerabilities and mitigating risks, contingency analysis plays a crucial role in enhancing the resilience of IES, thereby contributing to a more sustainable and secure energy future.

### References:

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[2] Thurner, Leon, u. a. „pandapower—An Open-Source Python Tool for Convenient Modeling, Analysis, and Optimization of Electric Power Systems". *IEEE Transactions On Power Systems*, Bd. 33, Nr. 6, November 2018, S. 6510–21. https://doi.org/10.1109/tpwrs.2018.2829021.

[3] Lohmeier, Daniel, u. a. „pandapipes: An Open-Source Piping Grid Calculation Package for Multi-Energy Grid Simulations". *Sustainability*, Bd. 12, Nr. 23, November 2020, S. 9899. https://doi.org/10.3390/su12239899.