Scalable and Safe Control Synthesis for Systems with Symmetries

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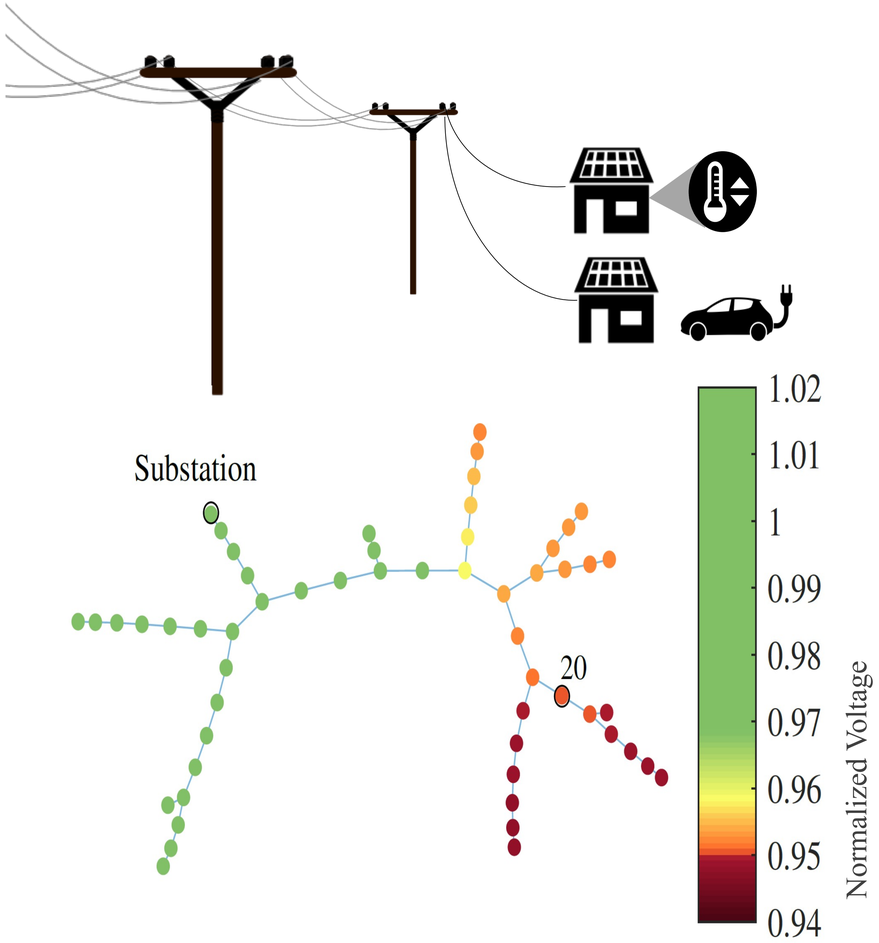
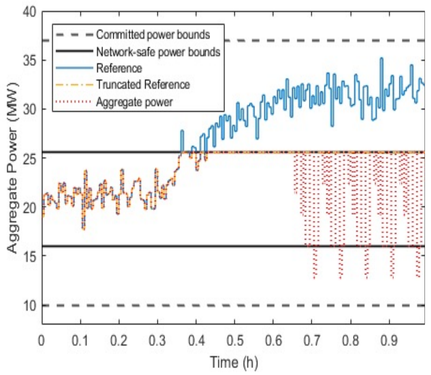
Challenge:

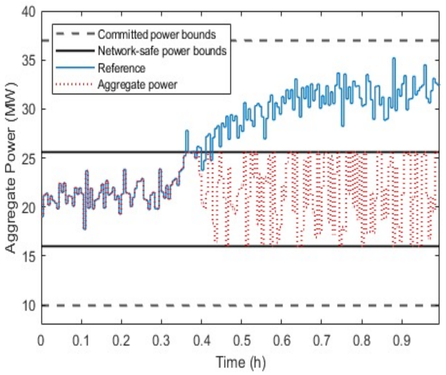
- Many complex engineered systems require scalable methods for ensuring safe operation
  - **Large collection**: Thousands of electrical loads (e.g., electric vehicles and air conditioners)
  - **Common objective**: Collective power consumption is coordinated to help balance supply and demand of energy on transmission network
  - **Safety constraints**:
    - Each load has constraints (e.g., temperature)
    - Groups of loads have collective constraints that ensure safe operation of distribution network

Solution:

- Massive scalability by utilizing symmetries (almost permutation invariance
- Implicit representations of safe sets that can directly be incorporated optimization based higher-level controls
- Incorporation of both cyber and physical constraints (distribution network, lockout constraints)







Scientific Impact:

- Methods apply to CPS that consist of large numbers of dynamically decoupled subsystems with symmetries
- Guarantees on recursive safety and feasibility while enabling easy integration to high-level learning/optimization-based solutions
- Scalability by exploiting symmetries of dynamics and specifications

Broader Impact:

- Improve the grid's ability to host higher percentages of renewable energy generation
- Support third-party aggregators' and residential customers' ability to participate in wholesale electricity markets
  - Educate next generation of CPS workforce
  - Collaboration with Michigan utility DTE Energy

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