System Resilience Benefits of Dual-Fuel Capable Generators

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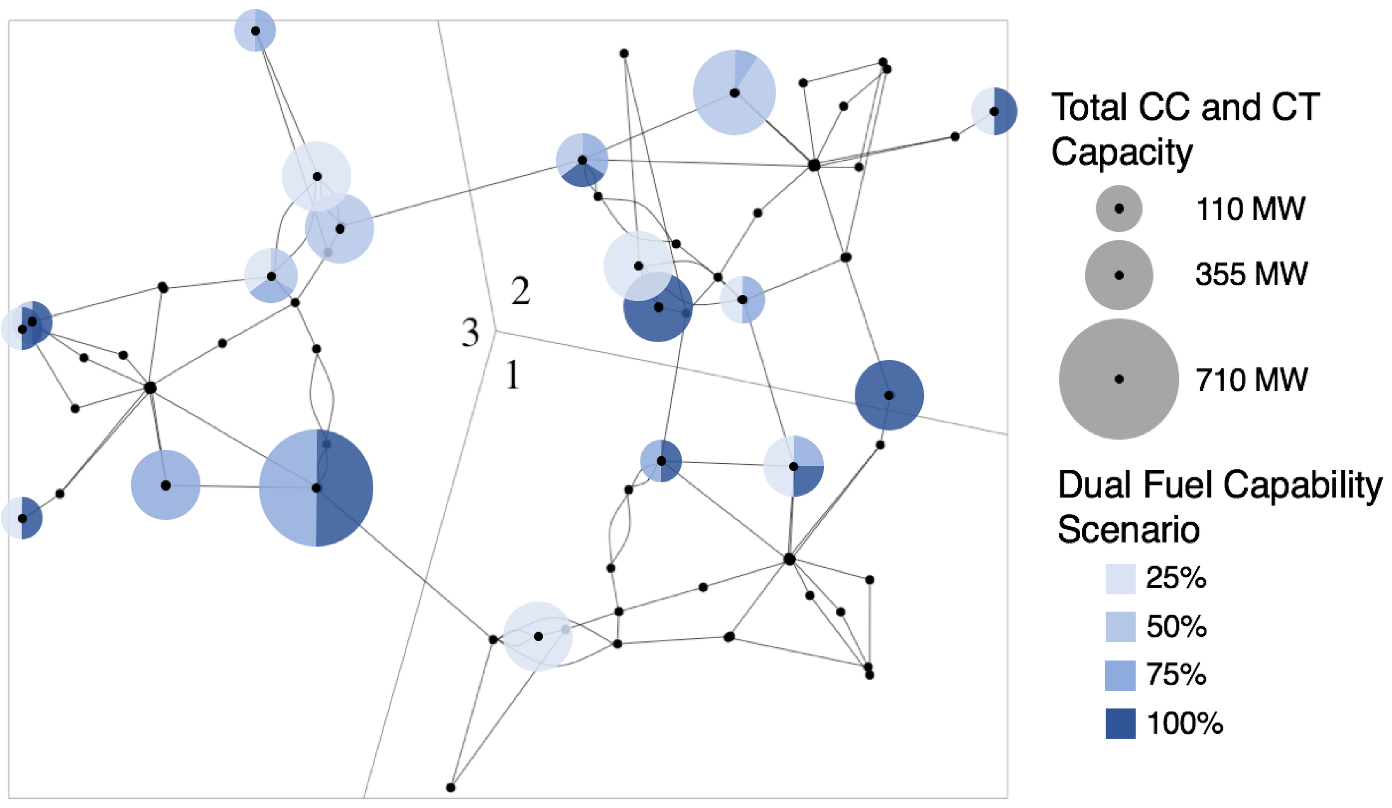
Motivation

- The U.S. has become increasingly dependent on natural gas (NG) for power generation.
- Extreme cold weather has occurred more frequently in the Northeast U.S. in recent years, increasing both heating and electricity gas demand.
- Regional power systems are now vulnerable to NG unit outages resulting from gas unavailability.
- It is vital to fully evaluate the impacts of gas unavailability on power system and propose mitigation solutions.

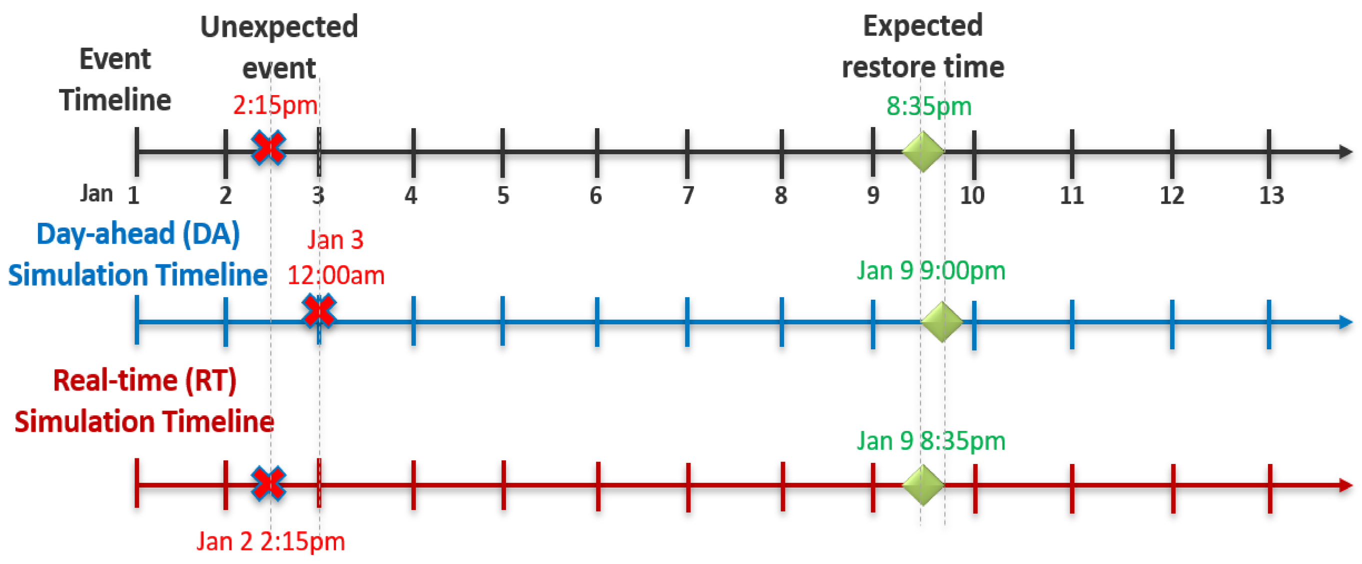
Objective

- Retrofit NG generators to make them dual-fuel capable is currently the most cost-effective mitigation solution [1] to gas unavailability event.
- This work:
  - Develop a dual-fuel generator model with fuel switching, dual fuel tank capacity, and tank refueling constraints.
  - Introduce an extreme event timeline model to simulate realistic power system operation under gas unavailability event.
  - Assess the impacts of gas unavailability events and the resilience benefits provided by dual-fuel generators.

System and Dual Fuel Scenario



Gas Unavailability Event Model



Model of Dual-Fuel Generator

- Dual fuel switching constraint:
  - The relationship between dual-fuel generator fuel offtake and generation

$$\begin{cases} vp_k^t f_{k,p}^t + vd_k^t f_{k,d}^t = H_k(g_k^t) \\ vp_k^t + vd_k^t = 1 \\ vp_k^t, vd_k^t \in \{0,1\} \end{cases}$$

  - $H_k(\cdot)$: a piece-wise linear heat rate for k
  - g_k^t: generation for unit k at time t
  - vp_k^t, vd_k^t: primary and secondary fuel status

- Fuel tank balance and capacity limit constraint:

$$\begin{cases} e_k^t = e_k^{t-1} + f_{k,d}^t \\ 0 \le e_k^t \le E_{k,max} \end{cases} \forall k, t$$

  - e_k^t: the inventory of the secondary fuel tank; $E_{k,max}$: the max tank capacity

- Fuel deliveries constraint:

$$e_k^{t-1} + d_k^t = E_{k,max} \forall t \in \mathcal{T}_D$$

  - d_k^t: delivered secondary fuel amount.
  - $\mathcal{T}_D$: tank refueling time instances.

- Final unit commitment (UC) formulation

Objective: minimize total generator startup and shutdown cost, fuel and dual-fuel cost, and penalty of unserved energy

Subject to

Power Balance | Generation Limit | Ramping Limit | Power Flow Limit | Fuel Offtake Limit

Generator unit commitment status with startup and shutdown transitions

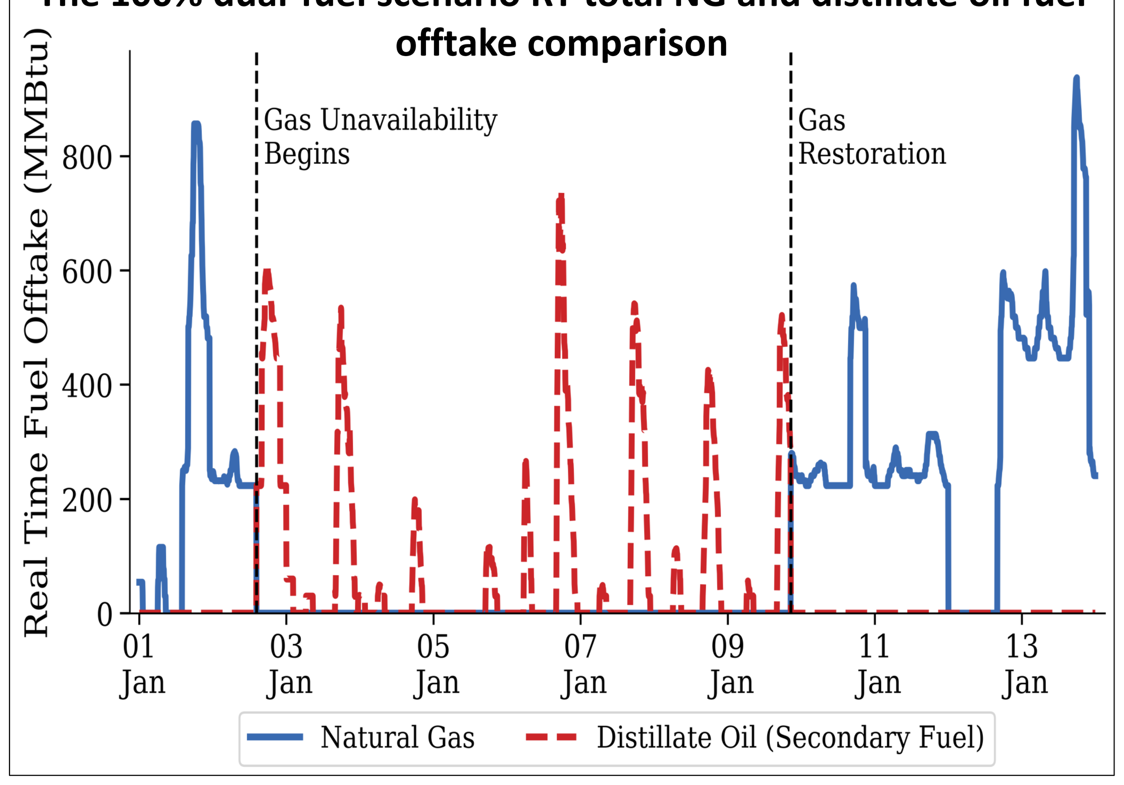
Dual Fuel Switching | Fuel Tank Blance | Fuel Tank Capacity Limit | Fuel Delivery

Numerical Results and Conclusion

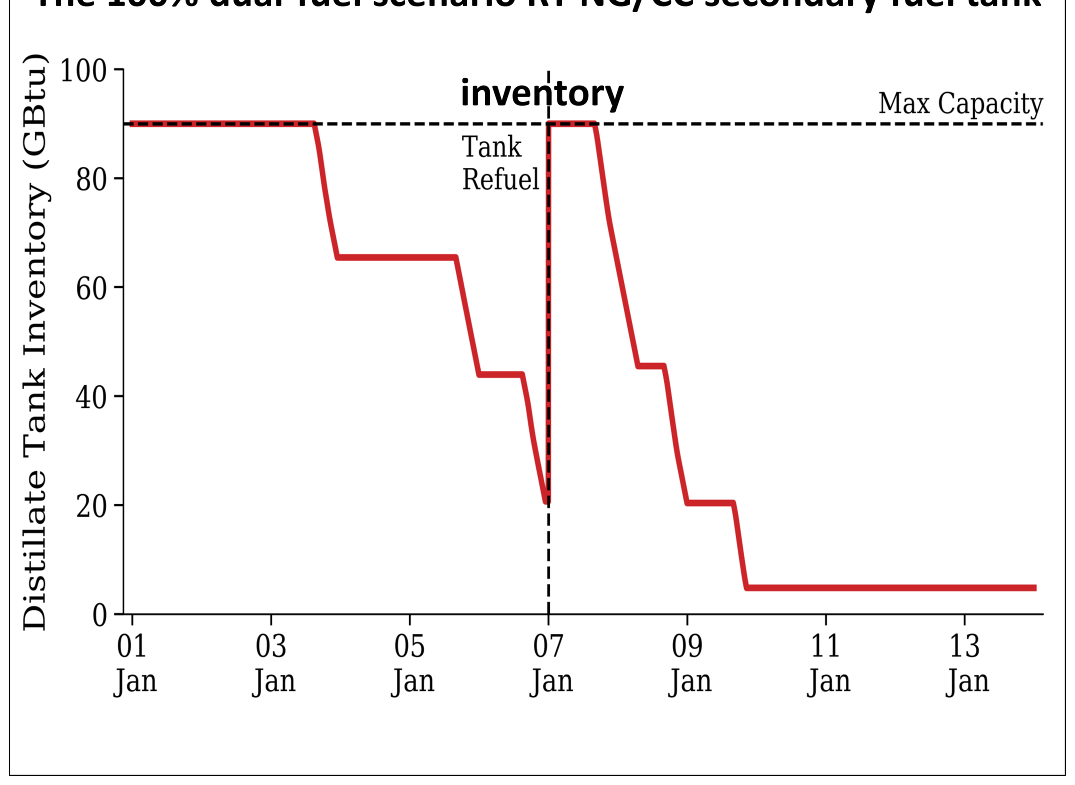
- **Simulation parameters:**
  - Natural gas (primary fuel) price: 3.887$/MMBTU.
  - Distillate oil (secondary fuel) price: 10.349 $/MMBTU.
  - Loss of load: 10000 $/MWh.
  - Max tank capacity equal to 1-day worth of fuel supply assuming units operating at 100% capacity.
  - Tank refueling occurs at the first hour of every week.
  - Model 0%, 25%, 50%, and 75% dual-fuel scenarios.
  - Simulation tool: PLEXOS 7.4

- **Dual-fuel capability validation:**

The 100% dual-fuel scenario RT total NG and distillate oil fuel offtake comparison

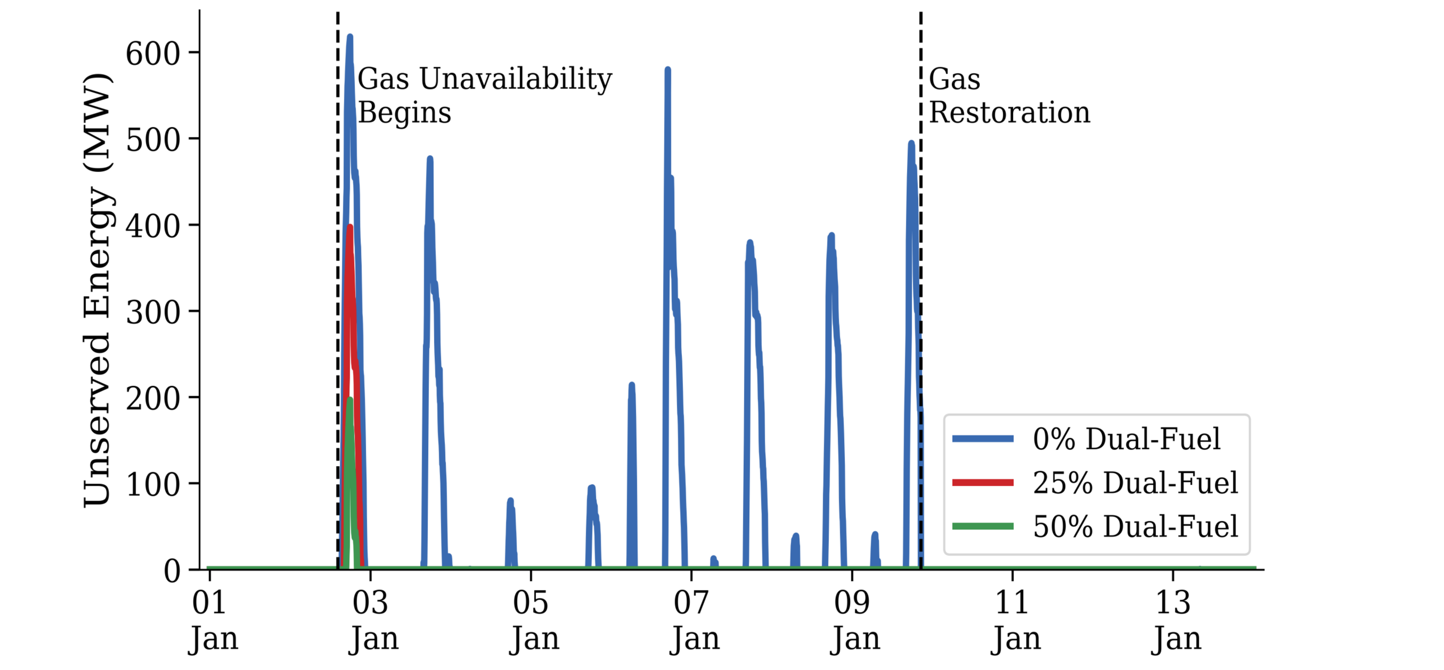


The 100% dual-fuel scenario RT NG/CC secondary fuel tank inventory



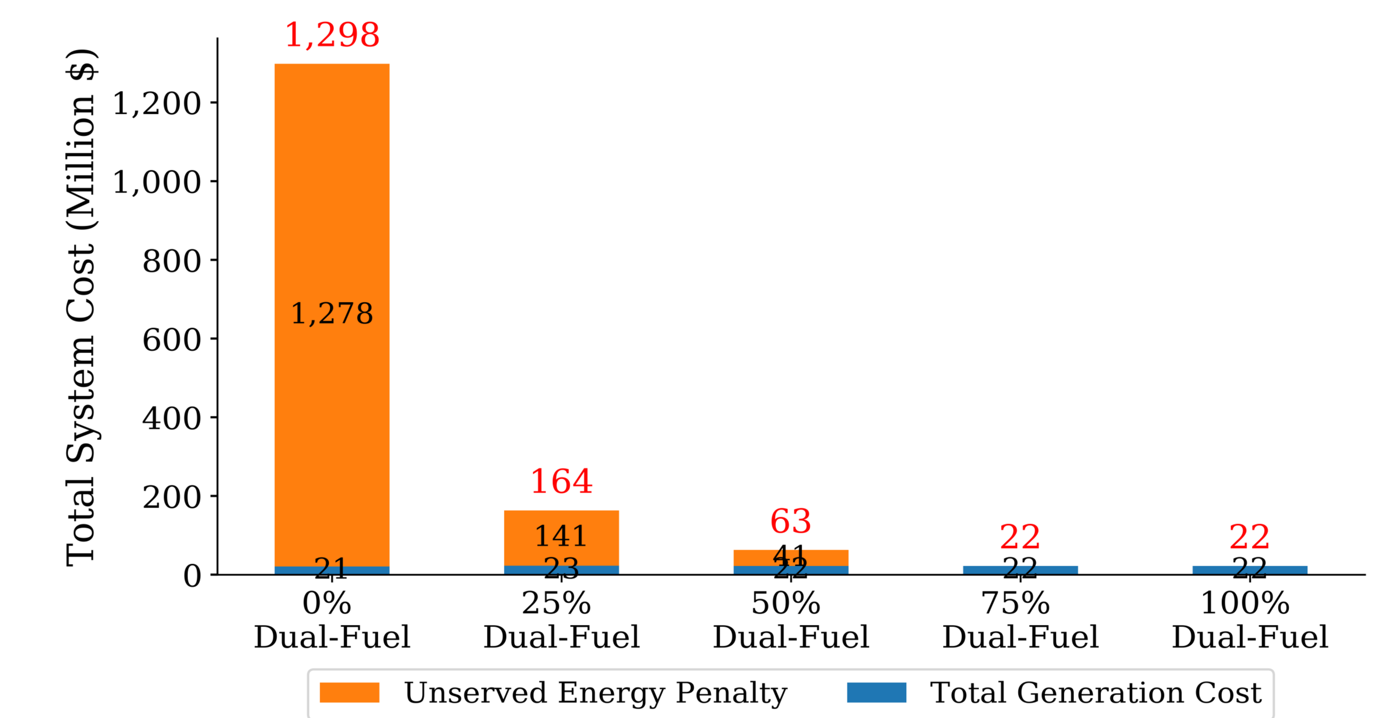
- **Dual-fuel resilience benefit:**

The unserved loads of 0%, 25%, and 50% dual-fuel scenarios during the simulation time period



- Gas unavailability event results in unserved load every day with a total of 10,647 MWh unserved energy during the event.
- Even 25% dual-fuel generators can reduce near 90% of the total unserved energy, and avoid loss loads after the first day.
- 75% dual-fuel generators can avoid unserved energy issue.

Comparison of total system costs comparison for all scenarios



- The large loss of load seen in the 0% dual-fuel scenario results in a significant penalty cost to the system.
- The 25% dual-fuel generator coverage helps decrease the total system costs significantly.
- 75% and above dual-fuel units can avoid loss of load penalty.

Conclusion:

- In the test system, all load can be provisioned when at least 75% of NG generator capacity is equipped with dual-fuel capabilities, saving a large amount of system cost in the event of serious fuel shortage.
- The system is more resilient with the increase coverage rate of dual-fuel generators

Reference:

[1] ISO - New England, Operational fuel-security analysis (Jan. 2018). URL https://www.iso-ne.com/staticassets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

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