SAND2021-7969C

System Dynamics Society

WIP Presentation

Modeling of Natural Gas Networks for Consequence Analysis

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0:00-0:30

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Problem Statement

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- What are the consequences of a disruption to one or more components of a natural gas infrastructure network?
  - Examples
    - Victoria AU, September 1998
    - New Mexico & Arizona, February 2011
    - Texas, February 2021
  - Concerns
    - Integrated (multi-organizational) networks with contractual requirements for delivery
    - Different classes of consumers that depend on that network, with defined priorities for delivery
    - Duration and magnitude
  - Hopes
    - Multi-organizational structure can create opportunities to reduce impact

0:30-1:30

Approach

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- Leverage the processes employed by Corbet et al, 2018* for petroleum infrastructure
  - Develop a reduced-form network relative to the entire natural gas network
    - Nodes with a potential s_i (injection rate q_{si}, demand rate d_i)
    - Edges with a capacity c_{ij}
  - Satisfy demand subject to mass balance and capacity constraints
    - Flow rates given by

      $$q_{ij} = c_{ij}\, f\big((s_i - s_j)u_{ij}\big) \quad (1)$$

      where u_{ij} is a utilization parameter and

      $$f(x) \equiv 1 - e^{-x} \quad (2)$$

    - In equilibrium, net flow at each node i is 0:

      $$\sum_j q_{ji} + q_{si} - d_i = 0 \quad \forall i \quad (3)$$

    - The equilibrium solution is obtained by solving equations (1) – (3).
  - Treat nodal storage as variation in line pack of compressible gas in connected

*Corbet, TF, W Beyeler, ML Wilson, and TP Flanagan (2018). A model for simulating adaptive, dynamic flows on networks: Application to petroleum infrastructure. Reliability Engineering & System Safety 169: 451-465.

1:30-2:30

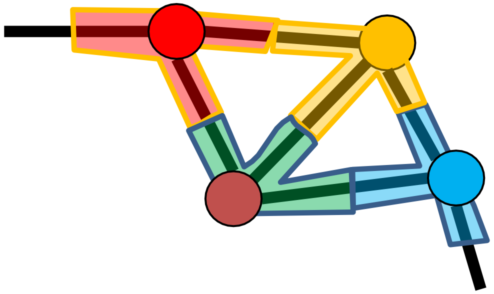
Approach

- Transient case: Net inflow into a node results in accumulation of stored fluid:

$$\sum_j q_{ji} + q_{si} - d_i = \frac{dv_i}{dt}$$
$$= \frac{v_i^T p}{2b}\left[\frac{1}{2}\left\{1 + \frac{(\frac{s-a}{b})}{\left[1+(\frac{s-a}{b})^2\right]^{\frac{1}{2}}}\right\}\right]^{p-1}\left[1+(\frac{s-a}{b})^2\right]^{-3/2}\frac{ds_i}{dt} \quad \forall i$$

(where *p*, *a*, and *b* are storage parameters

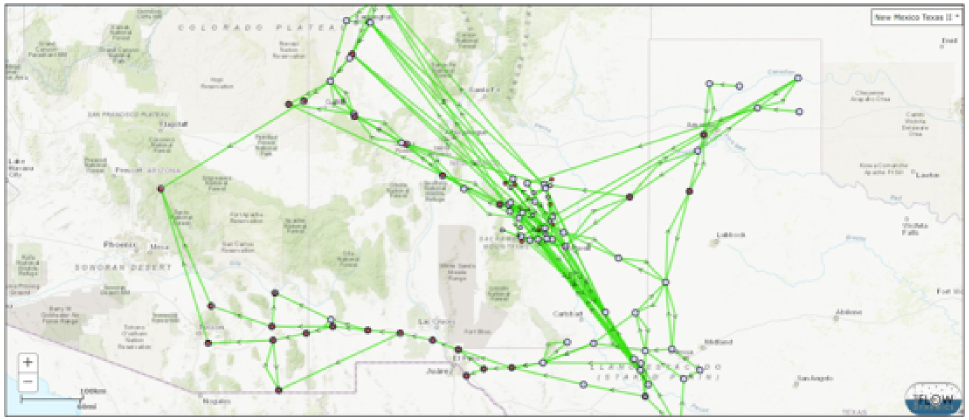
- Responsiveness and customer utilization parameters allow examination of a range of operator responses
- But gas is compressible!
  - Treat nodal storage as variation in line pack of compressible gas in connected pipelines



2:30-3:30

Progress, Insights & Questions

- Applied to the February 2011 "Big Chill" case
  - Modeled using data from multiple sources (FERC Form 567, FERC/NERC Report, NMPRC report) – primarily EPNG network impacted
  - Balanced to FERC Form 567 coincident day data
    - Receipt and delivery information on a single day at all points on the network used to ensure network structure was correct and model reproduced that result
  - Analyzed to compare results at demand points downstream of disruption in TX



NetFlow Dynamics Natural Gas Network for TX/NM/AZ

- Thoughts, feedback and questions welcome

3:30-5:00