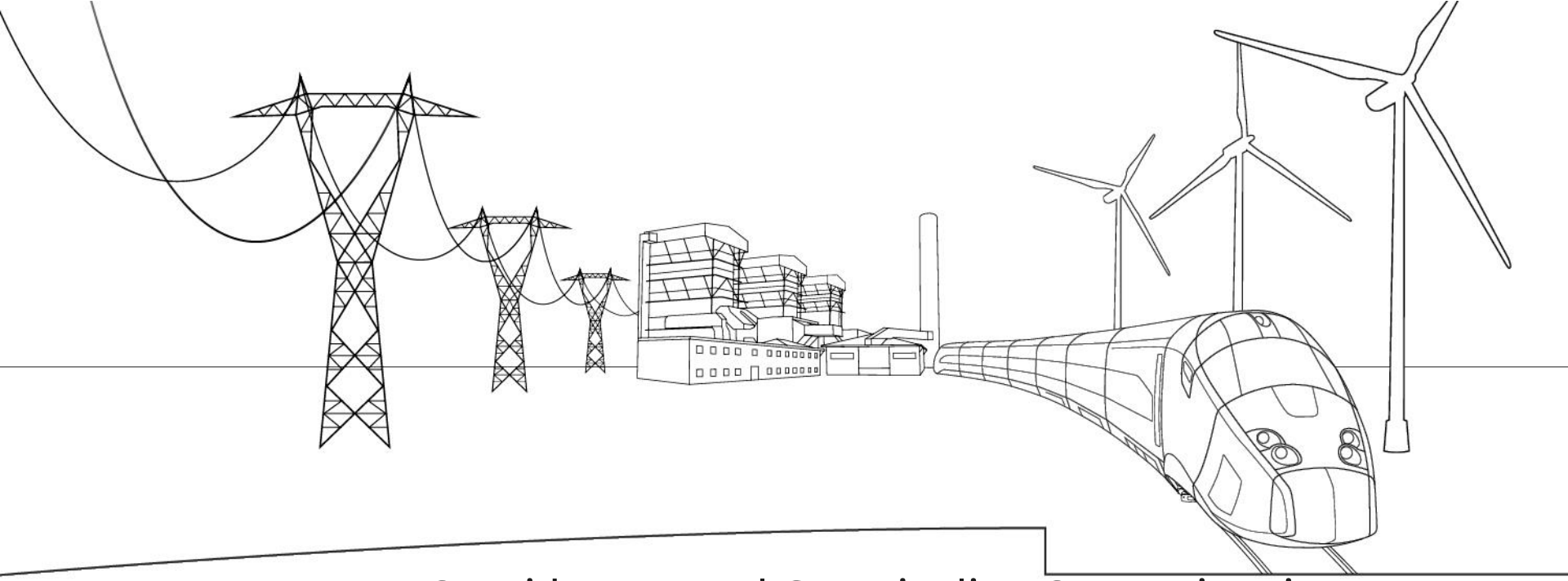

Consider Natural Gas Pipeline Constraints in Electricity Market Operations

Xing Wang, Alstom Grid
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FERC Technical Conference: INCREASING REAL-TIME AND DAY-AHEAD MARKET EFFICIENCY THROUGH IMPROVED SOFTWARE

June 22, 2015

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Shaping the future

Gas and Electric Coordination

- Hot Topic in power industry due to increasing power generation dependency on natural gas
- ISO-NE and PJM have been particularly concerned with their exposure to natural gas related risks
- FERC calls for closer coordination between gas and electric operation
- Electricity wholesale markets operation needs better model of natural gas supply risks

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Outline

- Overview of Natural Gas Pipeline System and Gas Wholesale Market
- ISO-NE's Challenges and Experiences on Gas and Electric Coordination
- What Have Been Done and What Can We Do
- Consider Gas Pipeline Risks in Electricity Market Operations

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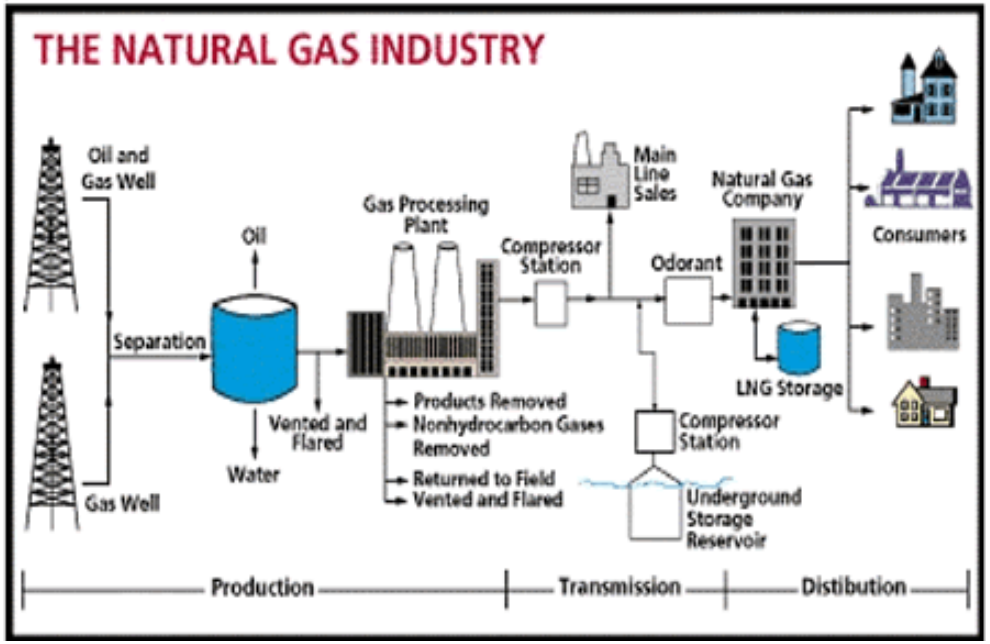
Structure of Natural Gas Industry

- Natural Gas Production
  - Exploration
  - Gas Processing
- Gas Transmission and distribution
  - Midstream
  - Pipeline
  - Local distributor
- Customer
  - Large industry customer
  - Power Generator
  - Local distribution Company



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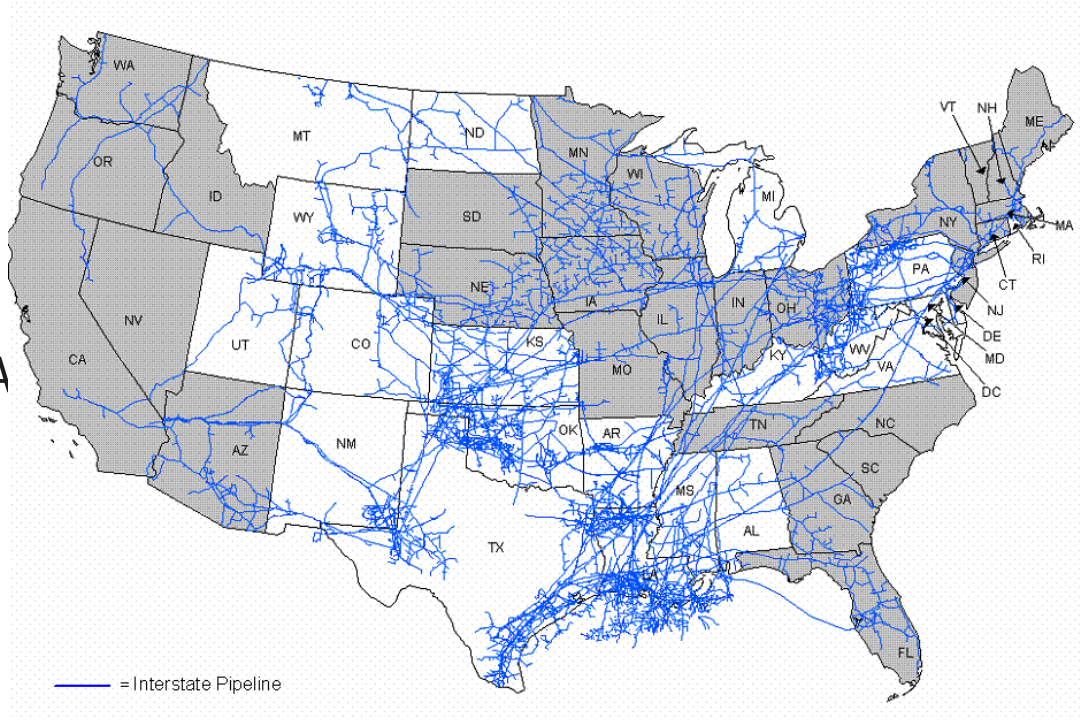
Natural Gas Transportation

- Gas Pipeline
  - Intrastate 29%
  - Interstate 71%
- Major Elements
  - Transmission Pipe
  - Compressor Station
  - Metering Station
  - Valves
  - Storage
  - Control Station and SCADA
    - flow rate through the pipeline
    - operational status
    - pressure
    - temperature readings



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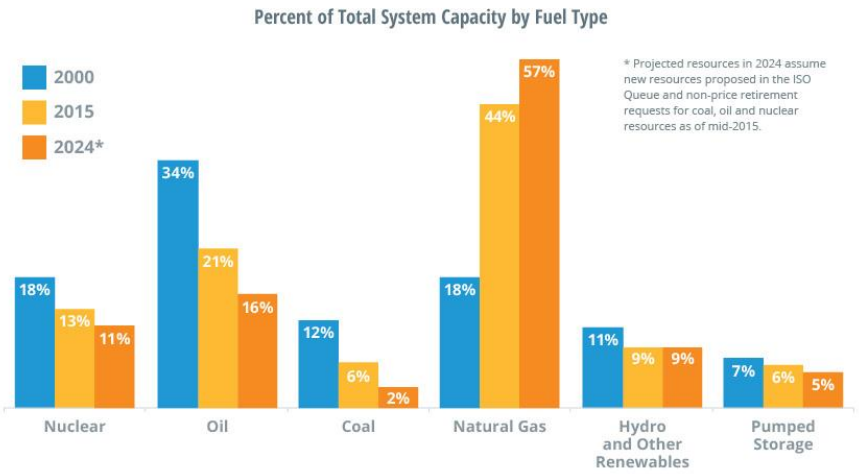
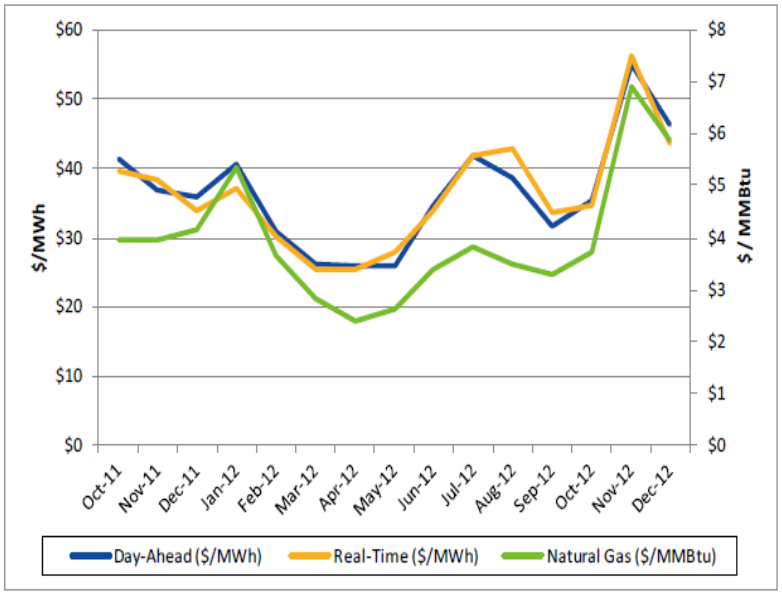
Natural Gas Dependency in ISO NE

- New England region is heavily depend on the natural gas generation.





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System Operational Challenges

- Natural Gas Pipeline Capacity Limitation
  - Natural Gas The regional gas delivery system is in very tight balance on a winter peak day even before any gas sector demand growth is assumed.
- Curtailment of Non-firm Natural Gas Contract
  - Curtailment of non-firm gas contract under Pipeline Maintenance
- Pipeline Operations can affect power system reliability
  - Pipeline Outage
  - Flow Balance
- Misalignment of Gas and Electricity Markets Timing

What Have Been and Are Being Done

- Electricity Day-Ahead Market and Natural Gas Day-Ahead Market timeline alignment
- Information sharing with Pipeline Operations
- Intra-day and Hourly reoffering capability
- Pay-for-Performance Rules in Forward Capacity Market provide gas generators financial incentive to secure fuel arrangements and ensure reliable performance

What Else Can We Do

- Information exchange between pipeline operators and market operators
  - Establish required pipeline data model and messages
  - Leverage experiences from Common Information Model
  - Potential RT gas situation awareness in grid control room

- Enhance gas model in market operations
  - Model natural gas pipeline topology
  - Model natural gas storage, contracts, and other constraints
  - Model the correlation between gas pipeline pressure and gas fired generators' ramping capability
  - Model gas pipeline contingencies

Consider Gas Pipeline Constraints in Electricity Market Clearing Processes

- More a reliability concern than an economic concern at this stage
- More a Day-ahead and Intra-day concern than a real-time concern
- Limited gas pipeline data available for Electricity Market Operators so far
- Reliability Unit Commitment may be the right process to consider gas pipeline constraints
- Pipeline constraints can be enforced to influence unit commitment solution, or they can just be monitored to produce warning messages if gas pipeline constraints are violated.

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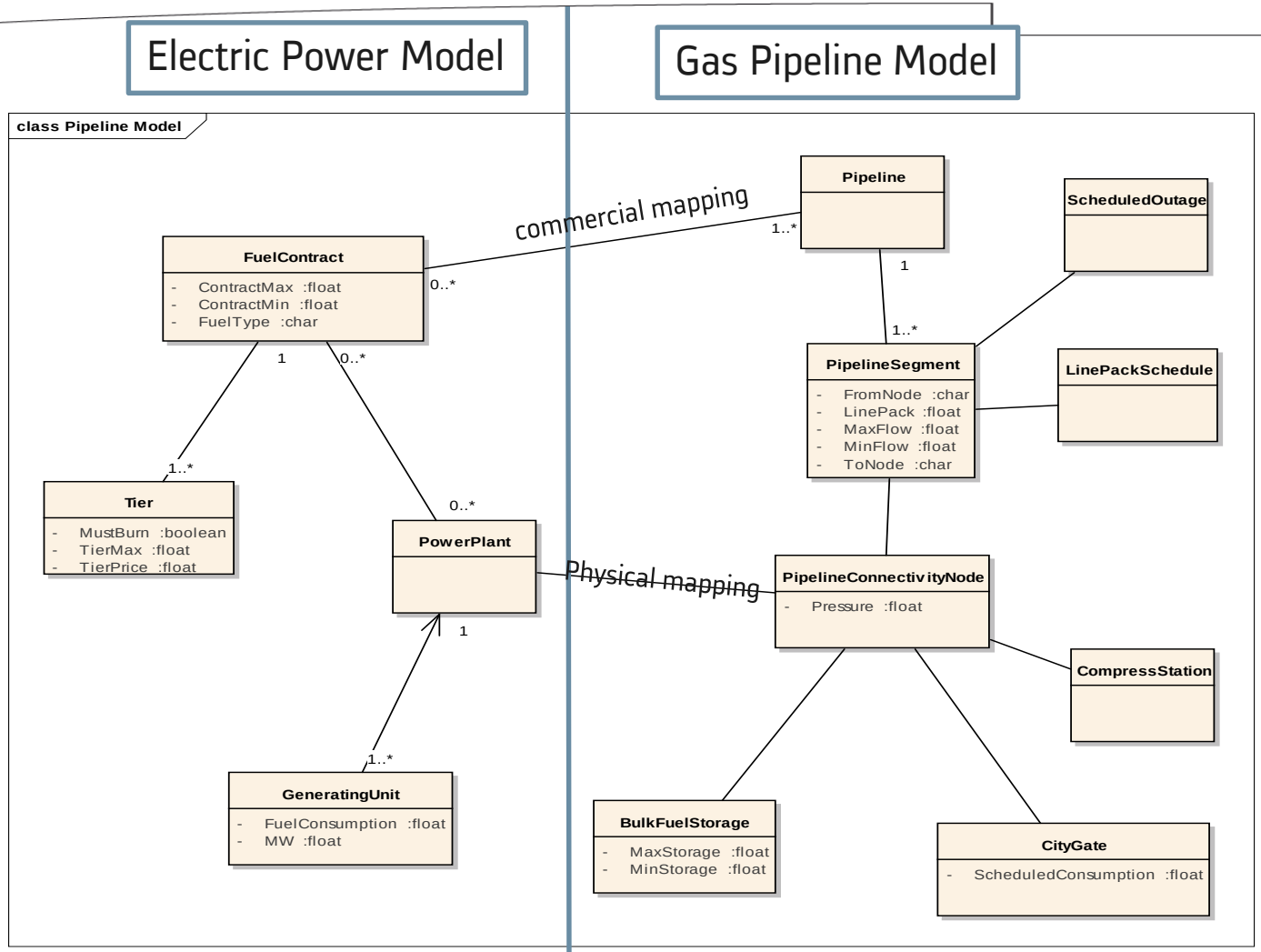
Price-based and Fuel-based Hybrid Unit Commitment and Dispatch Model

- UC/ED objective functions are still based on offer prices;
- Plug the fuel model and fuel contract model into SCUC and SCED formulation;
  - Require unit heat-rate curves if we want to calculate its fuel usage (derived from unit startup/shutdown and dispatch MW with unit HRC based fuel model);
- Allow more accurate fuel and pipeline constraints than generic energy constraints
- Allow modeling pipeline topology, gas storage, pipeline pressure etc.
  - Depending on what pipeline data can be available
  - Start with simplified linear model
- More accurate modeling of unit availability based on real-time/scheduled pipeline outage information.

UML Class Model for Gas-Electric Coordination



UML model can be used to produce XML message profiles for data communication between pipeline companies and market operators

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Proposed SCUC Model with Gas Pipeline Constraints - 1

- Objective Function
  - Minimize Offer Price based unit commitment cost and energy production cost
- Decision Variables
  - Unit on/off status
  - Unit dispatch for energy and ancillary services
- Traditional SCUC Constraints:
  - Unit physical and temporal constraints (limits, min-up/min-down, etc.)
  - Transmission Security Constraints
  - Max Energy Constraints (based on offer data)
  - …

Proposed SCUC Model with Gas Pipeline Constraints - 2

- Gas Pipeline Flow Constraints:
  - Electrical energy (MWh) to Gas Flow Rate (MMBTU/h) conversion equations (based on Heat Rate Curves)
    - RTO/ISO has unit heat rate curves as part of participant registration data
  - Pipeline nodal flow balancing equations (Kirchhoff's 1st law), need following data:
    - Pipeline topology (can be derived from publicly available data)
    - hourly pipeline outages (publicly available)
    - hourly gas consumptions, forecasted line pack, etc. (need to be provided by pipeline companies)
  - Pipeline segment hourly flow limit constraints
    - Hourly flow limits needs to be provided by pipeline companies

Discussion

- Mostly useful when gas supply becoming constrained
  - Reduce manual effort to check gas supply feasibility
  - Commit gas generators when they are mostly needed
  - Model pipeline outages, and inter-related gas constraints due to upstream pipeline flow capacity limitation
- Driven by pipeline data availability.
  - Need at least: pipeline topology, segment flow limit, scheduled gas injection and withdraw at each connectivity node.
- Linear approximation of gas pipeline model
  - Focus on hourly gas supply constraints for each gas fired generator
- Need to study potential impact to SCUC performance

Conclusion

- The natural gas market and pipeline operation may create power system reliability issues.
  - Thousands of MW of generating capacity can be lost due to gas supply disruption, pipeline emergency, and limited pipeline capacity.
  - As gas units become baseloaded, the system is losing its ramping capability.
- Gas and electricity markets should work together to improve the overall market efficiency.
- Gas pipeline risks should be modeled in electricity market operation processes for reliability.