Optimized Power Flow Control Device Siting with Coupled Production Cost / AC Powerflow Modeling

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Background

- New renewable generators, often far from load centers, strain the existing the transmission system
- There is a need for new transmission to improve reliability and alleviate congestion
  - Challenges: high capital costs, long project timelines
- Grid Enhancing Technologies (GETs) such as power flow control devices (PFCs) could prove useful

Power Flow Control is a set of technologies that push or shift power away from overloaded lines and onto underutilized lines/corridors within the existing transmission network. Multiple power flow control solutions exist.

Key Challenges and Questions

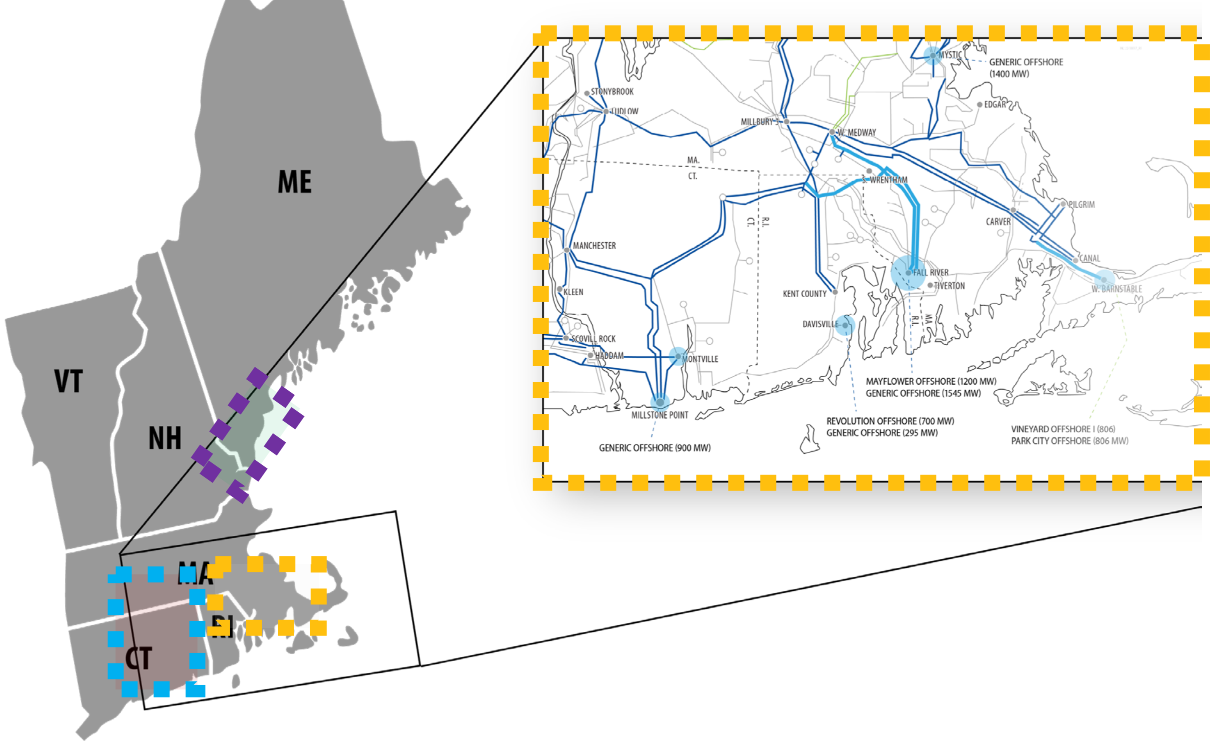
PFCs are a new technology, and are not considered in many transmission planning processes…

- How can the benefits of PFCs be quantified, in comparison to traditional transmission upgrades?
- The impact of a PFC varies depending on its location – how can we optimally site PFCs?
  - Considering large # of potential locations
  - Wide variety of system conditions

Project Overview

- Develop a robust method for assessing the impact of GETs using the ISO-NE system
  - Focused on the SEMA region
- Optimally site PFCs to address congestion challenges, evaluating the impact on **congestion** and **system reliability**

Selected Southeast Massachusetts (SEMA) for detailed modeling region



Integrated Reliability & Economic Planning

Couple steady-state AC powerflow analysis and economic production cost modeling software to identify optimal PFC locations

Integrated transmission planning

Reliability Transmission Planning

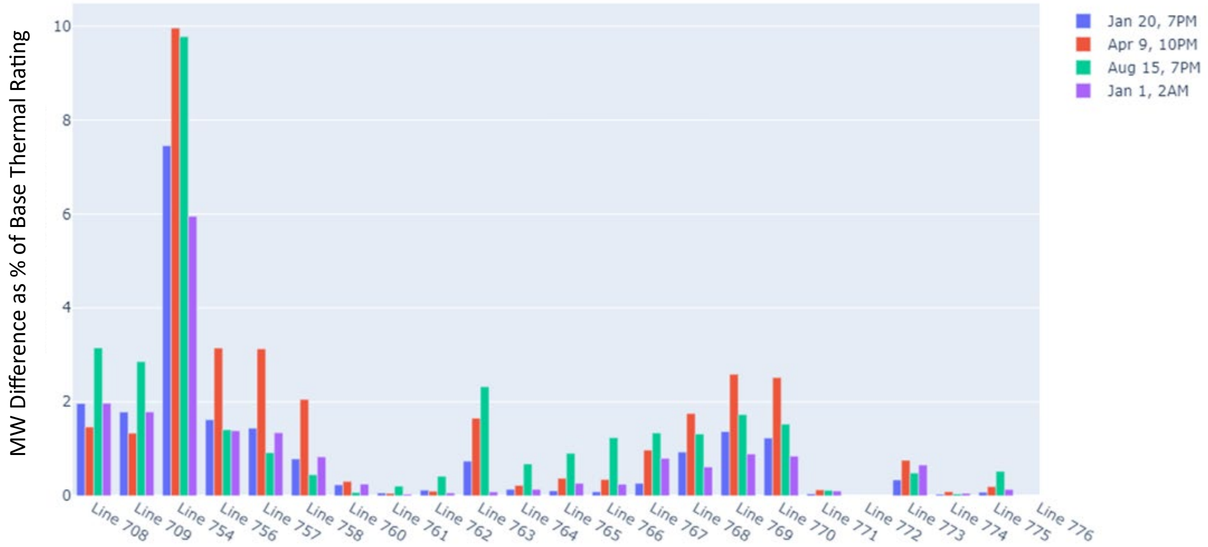
- PowerGEM's TARA (Transmission Adequacy & Reliability Assessment)
- Tests post-contingency power flow to validate system security
- Scales quickly across thousands of contingencies, large regions

Economic Transmission Planning

- EnergyExemplar's PLEXOS market simulation tool
- Detailed economic dispatch engine that optimizes across 8760 hours given constraints
- Provides cost model for power market, given generator and transmission constraints

Coupling DC Powerflow Production Cost Modeling and AC Powerflow Analysis

- PLEXOS production cost modeling uses DC powerflow
  - Less computationally intense
  - Able to solve and determine generation dispatch every hour for an entire year
- TARA uses AC powerflow analysis
  - Detailed powerflow solutions for key hours
- Align the two models so that generator and load dispatch can be passed between them with relative ease



Line Flow Comparison Between PLEXOS and TARA

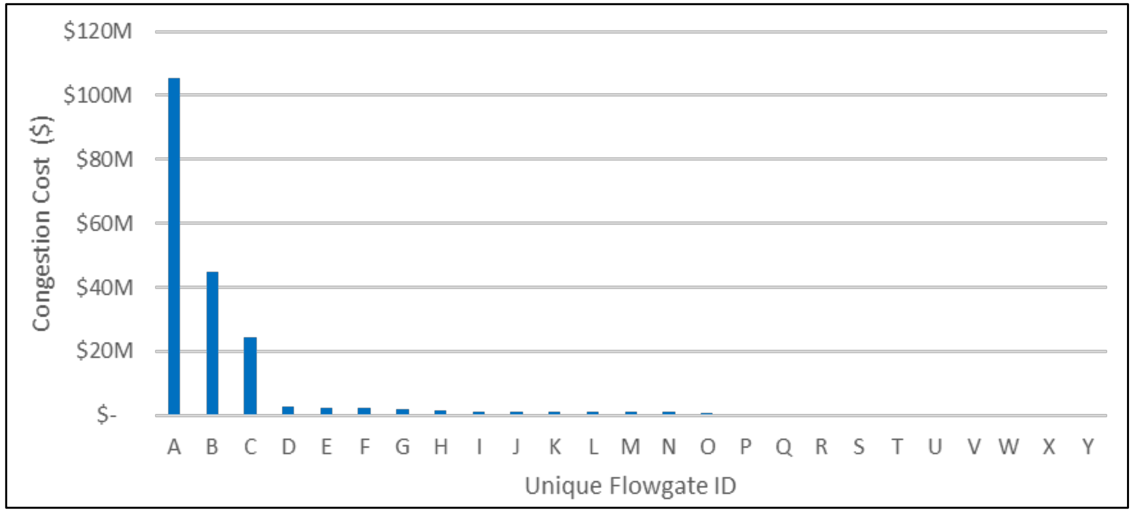
Identifying Key Hours in Production Cost Model

We can only pass a limited number of hours to TARA… target hours with unique combinations of congested flowgates

- In the ISO-NE system model, three key flowgates were consistently congested
- Hours with these flowgates congested in unique configurations were sent to TARA for analysis

Unique Flowgate ID	Flowgate 1-Direction To-> From	Flowgate 1-Direction From -> To	Flowgate 2-Direction To-> From	Flowgate 2-Direction From -> To	Flowgate 3-Direction A To-> From	Flowgate 3-Direction From -> To
A	✓	x	x	x	x	x
B	✓	x	✓	x	✓	x
C	✓	x	x	✓	x	✓
D	x	✓	✓	x	✓	x

Example of Unique Flowgate Combinations

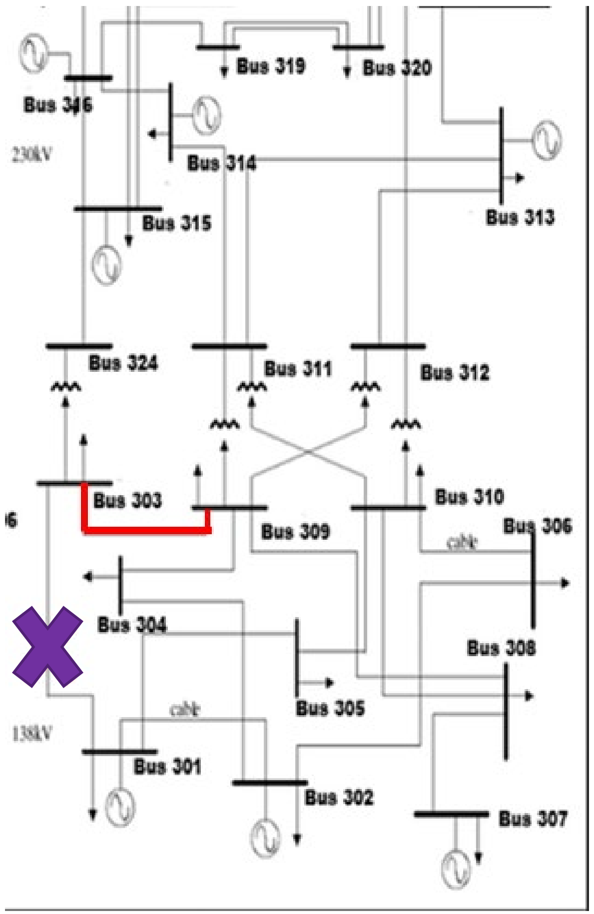


ISO-NE system congestion costs by unique combination of congested flowgates within the high priority area

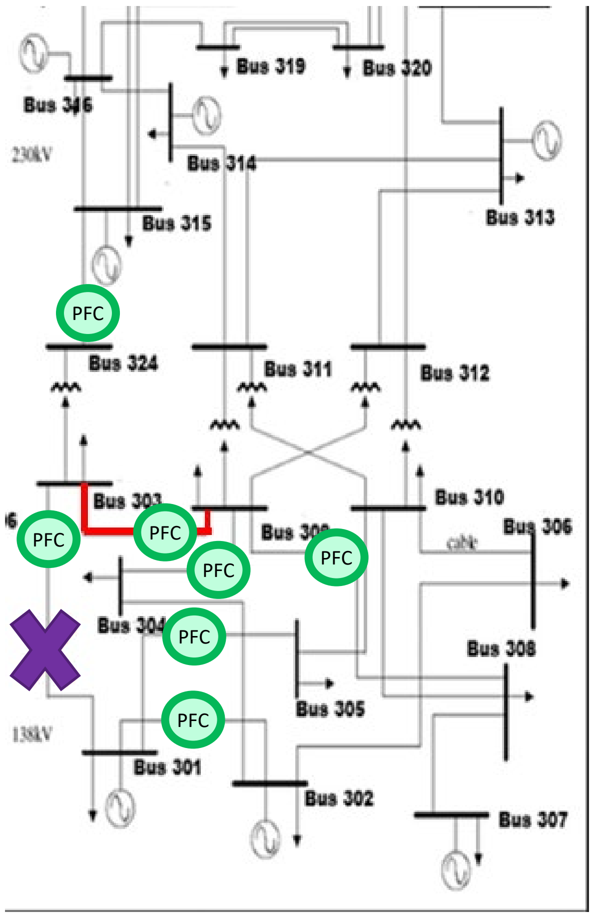
Flowgate: contingency + monitored element pair

Applying Methodology in Example System

For a specific hour and loss of 301-303-1, 303-309-1 is overloaded by ~80 MW



Test nearby PFC locations within 2 branches of bus 303



What is the potential impact of a small change at each PFC location on the 303-309-1 overload?

		MW Overload on 303-309-1
Contingency	PFC Location	
301-303-1	301-302-1	-0.54
	301-303-1	-0.06
	301-305-1	0.45
	303-309-1	9.82
	304-309-1	-0.93
	308-309-1	-0.93
	315-324-1	9.74

Example PFC Impact on MW Overloads – One Monitored Element

Apply Cost Weighting

Weight PFC impact by flowgate according to accumulated congestion rent

		Monitored Elements - Compare MW Overload with Base Case									
	FromBus	301			303		304	308	309		315
	ToBus	302	303	305	309	324	309	309	311	312	324
	ID	1	1	1	1	1	1	1	1	1	1
Contingency	PFC Location										
301-303-1	301-302-1	0.00	0.00	0.00	-0.54	0.00	0.00	0.00	0.00	0.00	0.00
	301-303-1	0.00	0.00	0.00	-0.06	0.00	0.00	0.00	0.00	0.00	0.00
	301-305-1	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00
	303-309-1	0.00	0.00	0.00	9.82	0.00	0.00	0.00	0.00	0.00	0.00
	304-309-1	0.00	0.00	0.00	-0.93	0.00	0.00	0.00	0.00	0.00	0.00
	308-309-1	0.00	0.00	0.00	-0.93	0.00	0.00	0.00	0.00	0.00	0.00
	315-324-1	0.00	0.00	0.00	9.74	0.00	0.00	-4.87	0.00	0.00	0.00

PFC Impact on MW Overloads - Unweighted

	FromBus	301			303		304	308	309		315
	ToBus	302	303	305	309	324	309	309	311	312	324
	ID	1	1	1	1	1	1	1	1	1	1
Contingency	PFC Location										
301-303-1	301-302-1	0.00	0.00	0.00	-1.68E+06	0.00	0.00	0.00	0.00	0.00	0.00
	301-303-1	0.00	0.00	0.00	-1.87E+05	0.00	0.00	0.00	0.00	0.00	0.00
	301-305-1	0.00	0.00	0.00	1.40E+06	0.00	0.00	0.00	0.00	0.00	0.00
	303-309-1	0.00	0.00	0.00	3.06E+07	0.00	0.00	0.00	0.00	0.00	0.00
	304-309-1	0.00	0.00	0.00	-2.90E+06	0.00	0.00	0.00	0.00	0.00	0.00
	308-309-1	0.00	0.00	0.00	-2.90E+06	0.00	0.00	0.00	0.00	0.00	0.00
	315-324-1	0.00	0.00	0.00	3.04E+07	0.00	0.00	-1.87E+08	0.00	0.00	0.00

PFC Impact on MW Overloads – Cost Weighting Applied

Contingency	Monitored Element	Congestion Rent from Initial Case
301-303-1	303-309-1	$3,117,740.00
301-303-1	308-309-1	$38,307,694.61

Example Congestion Cost Table

Rank PFC Locations

For a specific hour and contingency, a PFC location could **increase** MW overloads on one branch and **decrease** MW overloads on another

	FromBus	301			303		304	308	309		315
	ToBus	302	303	305	309	324	309	309	311	312	324
	ID	1	1	1	1	1	1	1	1	1	1
Contingency	PFC Location										
301-303-1	301-302-1	0.00	0.00	0.00	-1.68E+06	0.00	0.00	0.00	0.00	0.00	0.00
	301-303-1	0.00	0.00	0.00	-1.87E+05	0.00	0.00	0.00	0.00	0.00	0.00
	301-305-1	0.00	0.00	0.00	1.40E+06	0.00	0.00	0.00	0.00	0.00	0.00
	303-309-1	0.00	0.00	0.00	3.06E+07	0.00	0.00	0.00	0.00	0.00	0.00
	304-309-1	0.00	0.00	0.00	-2.90E+06	0.00	0.00	0.00	0.00	0.00	0.00
	308-309-1	0.00	0.00	0.00	-2.90E+06	0.00	0.00	0.00	0.00	0.00	0.00
	315-324-1	0.00	0.00	0.00	3.04E+07	0.00	0.00	-1.87E+08	0.00	0.00	0.00

PFC Impact on MW Overloads – Cost Weighting Applied

Sum across each row and take absolute value to get net impact of each PFC location on overloads (for the specific hour and contingency)

Contingency	PFC Location	Congestion Rent Weighted Reliability
301-303-1	301-302-1	1.68E+06
	301-303-1	1.87E+05
	301-305-1	1.40E+06
	303-309-1	3.06E+07
	304-309-1	2.90E+06
	308-309-1	2.90E+06
	315-324-1	1.56E+08

Weighted Reliability Metric for Each PFC Location, for a Given Dispatch Hour and Contingency

Sum results for all hours and all contingencies to assemble a complete ranked list of PFC locations

PFCLocation	Congestion-Rent Weighted Reliability
303-309-1	1.93E+09
315-324-1	1.07E+09
301-303-1	7.32E+08
301-302-1	6.76E+08
304-309-1	5.90E+08
301-305-1	4.24E+08
308-309-1	3.58E+08
NoPerturbance	0.00E+00

Final Weighted Reliability Metric for Each PFC Location

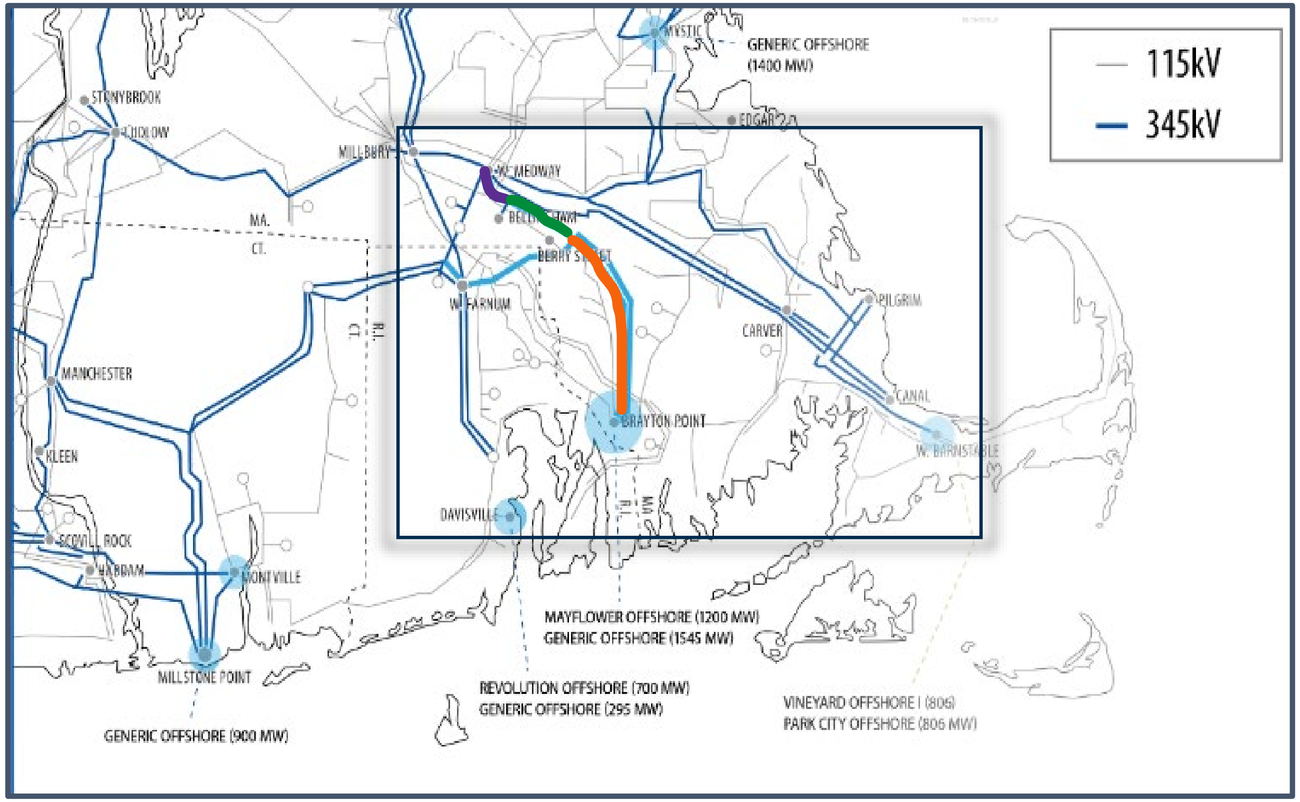
Applying the PFC Siting Process to ISO-NE

Three optimal PFC locations were identified.

These PFC locations were modeled individually in PLEXOS, to quantify the impact on congestion and production costs.

PFC Location	Ranking
Berry St - Brayton Point	1
Medway - Bellingham	2
Berry St - Bellingham	3

PFC Siting Process Ranking



Mapped PFC Locations

Results and Conclusions

ISO-NE Case Study

- **Significant improvements** in congestion rent and production costs, with payback periods < 1 year
- The results of the production cost analysis in PLEXOS were **consistent** with the ranking provided by the PFC siting process in TARA

Future Work

- The novel optimal PFC siting process can be further developed and worked into transmission planning processes
- AC power flow analysis coupled with production cost modeling allows planners to **holistically** compare the benefits of PFCs with traditional upgrades

PFC Location	Ranking
Berry St - Brayton Point	1
Medway - Bellingham	2
Berry St - Bellingham	3

PFC Siting Process Ranking

PLEXOS Production Cost Impact of Each PFC Location

PFC Location	Ranking	Congestion Rent Improvement ($M)	Production Cost Improvement ($M)	Total Curtailment Improvement (GWh)
Berry St – Brayton Point	1	10.4	4.3	181.8
Medway – Bellingham	2	8.0	3.1	146.2
Berry St – Bellingham	3	8.7	3.1	143.5

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