Great Lakes Offshore Wind: Utility and Regional Integration Study

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December 2, 2014

Project Summary

- DOE Project: DE--EE0005367
- Great Lakes Offshore Wind: Utility and Regional Integration Study
- Address technical questions and planning needs related to the integration of large-scale offshore wind into utility service areas including:
  - Transmission system upgrades needed to facilitate offshore wind projects
  - Impacts of offshore wind farm on operational steady state and dynamic stability
  - Wind energy integration into FirstEnergy/PJM system
  - General guidelines and recommendations for other offshore wind projects

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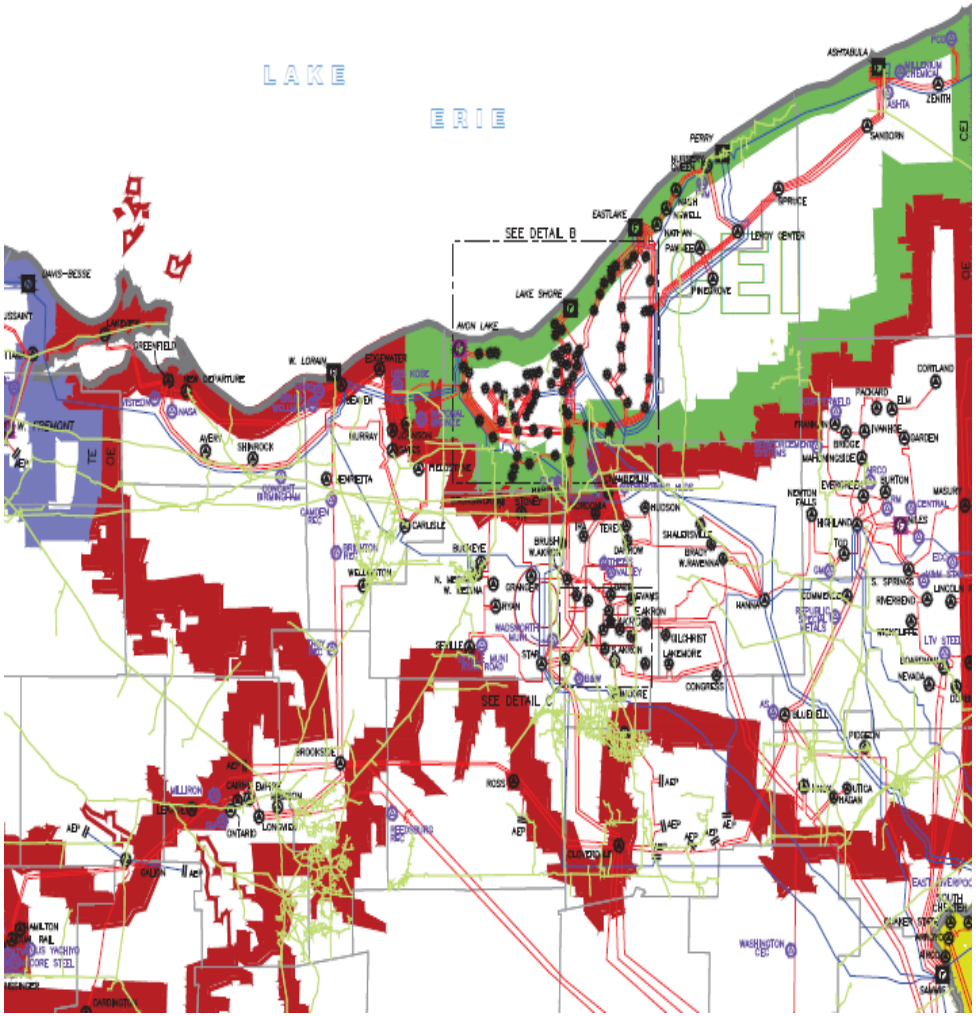
FirstEnergy Area Service Area

- More than 8000MW of installed generation capacity
- The transmission system has been heavily loaded



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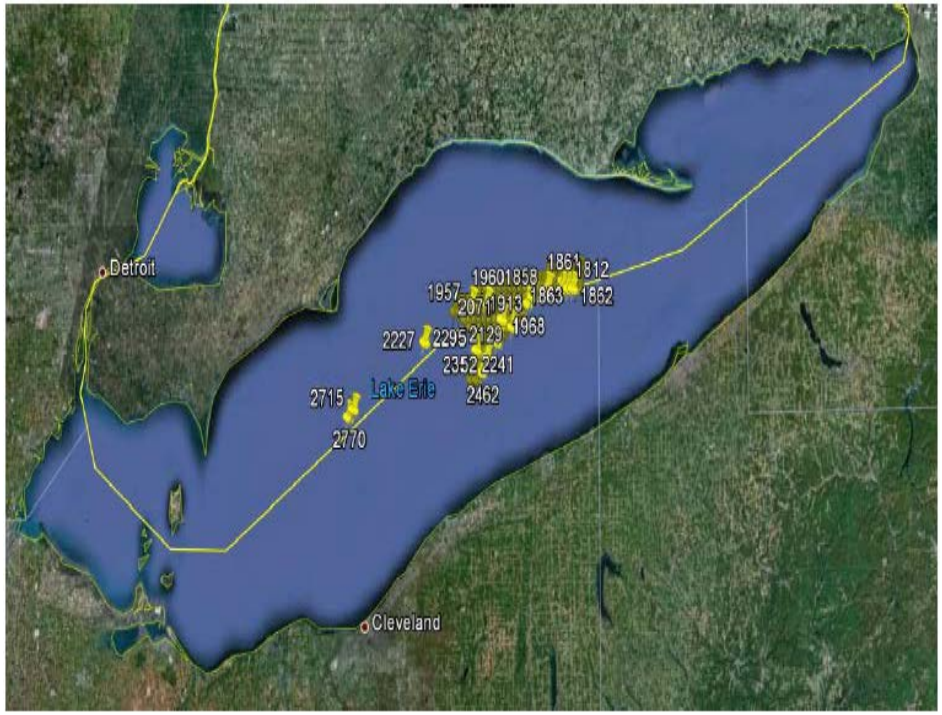
Offshore Wind Energy Generation Estimates

Expected 10-Minute Deltas for 1000 MW Lake Erie Wind Plant



% EXPECTATION	FREQUENCY	NEGATIVE DELTA	Positive DELTA	ABSOLUTE DELTA EVALUATED
---	Once in 3 Years	-360 MW	361 MW	360 MW
99.9 %	Once Every 2 Weeks	-136 MW	171 MW	170 MW
99.0 %	Once Every 1.5 Days	-72 MW	81 MW	80 MW
95.0 %	Four Times Per Day	-41 MW	44 MW	50 MW
90.0 %	Eight Times Per Day	-30 MW	31 MW	30 MW

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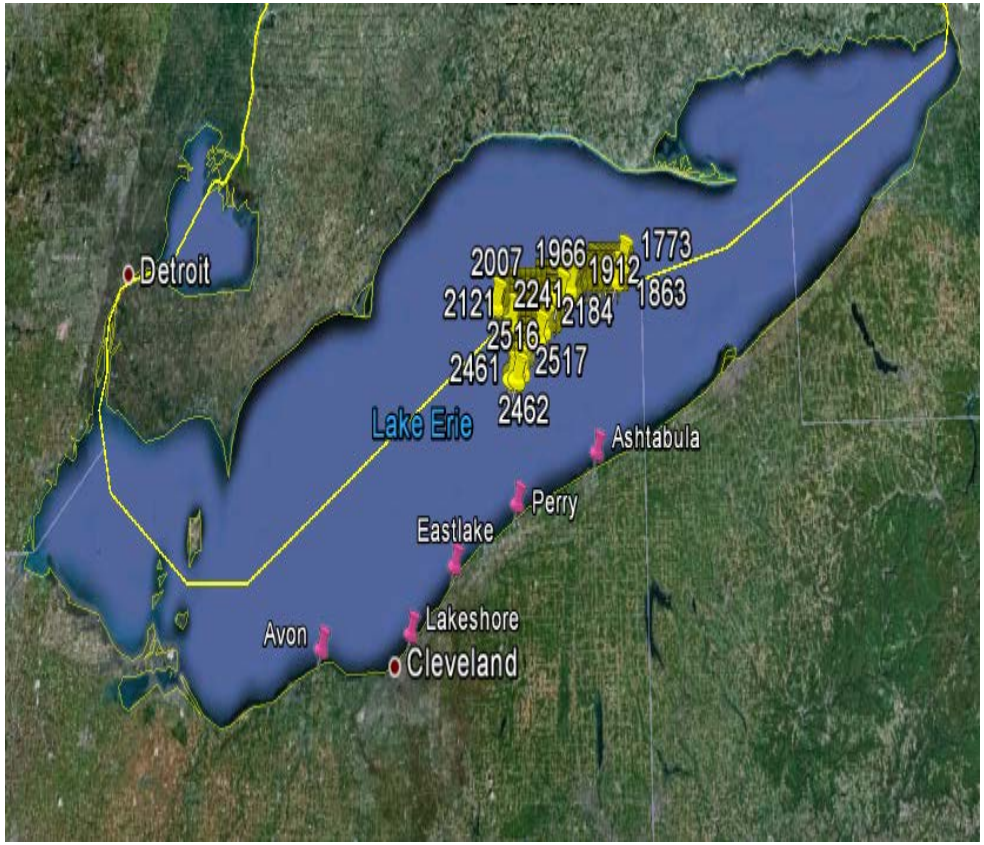
Sites selected for 1000 MW Lake Erie Wind Plant



Minimum Distance from Offshore Wind Farm to FE Substations

WIND FARM COLLECTOR SYSTEM TO:	MILES	KILOMETERS
ASHTABULA 345 kV SUBSTATION	21.0	33.8
PERRY 345 kV SUBSTATION	17.4	28.0
EASTLAKE 345 kV SUBSTATION	29.6	47.6
LAKESHORE 138 kV SUBSTATION	43.2	69.4
AVON 345 kV / 138 kV SUBSTATIONS	59.2	95.2

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Interconnection Scenarios

- EC01: Interconnecting a 1000 MW of offshore wind generation at
  - Perry 345 kV Substation

- EC02: Interconnecting five 200 MW of offshore wind generations at
  - Avon 345 kV Substation
  - Lakeshore 138 kV Substation
  - Eastlake 345 kV Substation
  - Perry 345 kV Substation
  - Ashtabula 345 kV Substation

- EC03: Interconnecting two 500 MW of offshore wind generations at
  - Avon 345 kV Substation and
  - Avon 138 kV Substation

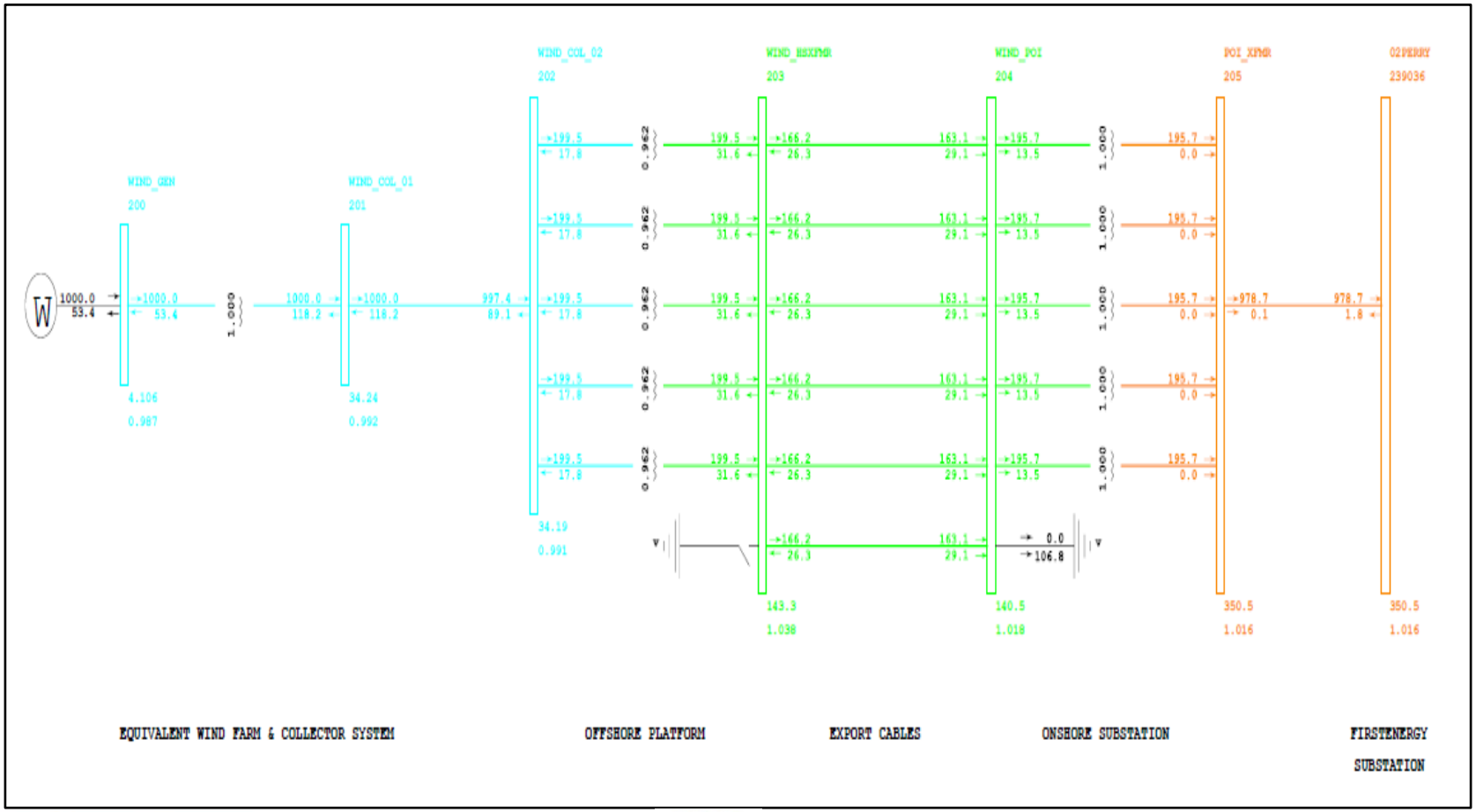
Steady State Analysis Scenarios for each POI

#	Perry	SVC	Reactive Support By Machine	Voltage Regulation
1	ON	OFF	NO	Wind Turbine, Generator Terminal
2	ON	OFF	NO	First Energy POI
3	ON	OFF	NO	Wind Farm Collector System
4	ON	OFF	Limited (+7.506 % / -7.506 %)	Wind Turbine, Generator Terminal
5	ON	OFF	Limited (+7.506 % / -7.506 %)	First Energy POI
6	ON	OFF	Limited (+7.506 % / -7.506 %)	Wind Farm Collector System
7	ON	OFF	Fully Capable (+57.824 % / -43.09 %)	Wind Turbine, Generator Terminal
8	ON	OFF	Fully Capable (+57.824 % / -43.09 %)	First Energy POI
9	ON	OFF	Fully Capable (+57.824 % / -43.09 %)	Wind Farm Collector System
10	ON	ON	NO	Wind Turbine, Generator Terminal
11	ON	ON	NO	First Energy POI
12	ON	ON	NO	Wind Farm Collector System
13	ON	ON	Limited (+7.506 % / -7.506 %)	Wind Turbine, Generator Terminal
14	ON	ON	Limited (+7.506 % / -7.506 %)	First Energy POI
15	ON	ON	Limited (+7.506 % / -7.506 %)	Wind Farm Collector System
16	ON	ON	Fully Capable (+57.824 % / -43.09 %)	Wind Turbine, Generator Terminal
17	ON	ON	Fully Capable (+57.824 % / -43.09 %)	First Energy POI
18	ON	ON	Fully Capable (+57.824 % / -43.09 %)	Wind Farm Collector System

#	Perry	SVC	Reactive Support By Machine	Voltage Regulation
19	OFF	OFF	NO	Wind Turbine, Generator Terminal
20	OFF	OFF	NO	First Energy POI
21	OFF	OFF	NO	Wind Farm Collector System
22	OFF	OFF	Limited (+7.506 % / -7.506 %)	Wind Turbine, Generator Terminal
23	OFF	OFF	Limited (+7.506 % / -7.506 %)	First Energy POI
24	OFF	OFF	Limited (+7.506 % / -7.506 %)	Wind Farm Collector System
25	OFF	OFF	Fully Capable (+57.824 % / -43.09 %)	Wind Turbine, Generator Terminal
26	OFF	OFF	Fully Capable (+57.824 % / -43.09 %)	First Energy POI
27	OFF	OFF	Fully Capable (+57.824 % / -43.09 %)	Wind Farm Collector System
28	OFF	ON	NO	Wind Turbine, Generator Terminal
29	OFF	ON	NO	First Energy POI
30	OFF	ON	NO	Wind Farm Collector System
31	OFF	ON	Limited (+7.506 % / -7.506 %)	Wind Turbine, Generator Terminal
32	OFF	ON	Limited (+7.506 % / -7.506 %)	First Energy POI
33	OFF	ON	Limited (+7.506 % / -7.506 %)	Wind Farm Collector System
34	OFF	ON	Fully Capable (+57.824 % / -43.09 %)	Wind Turbine, Generator Terminal
35	OFF	ON	Fully Capable (+57.824 % / -43.09 %)	First Energy POI
36	OFF	ON	Fully Capable (+57.824 % / -43.09 %)	Wind Farm Collector System

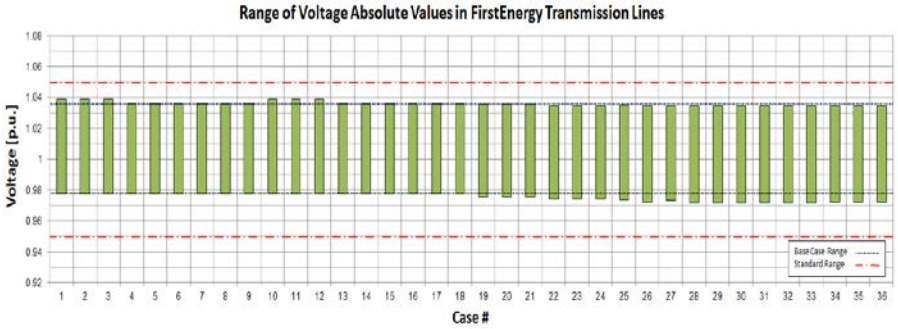
Modelling and Simulation (1)

- Appropriate models were developed in GE PSLF

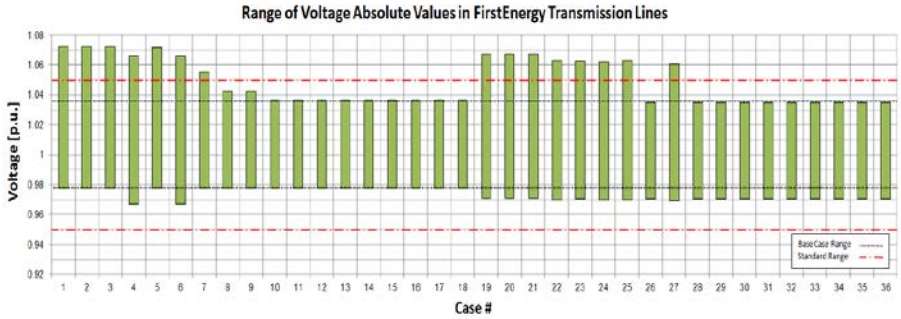


Voltages in FirstEnergy Transmission System

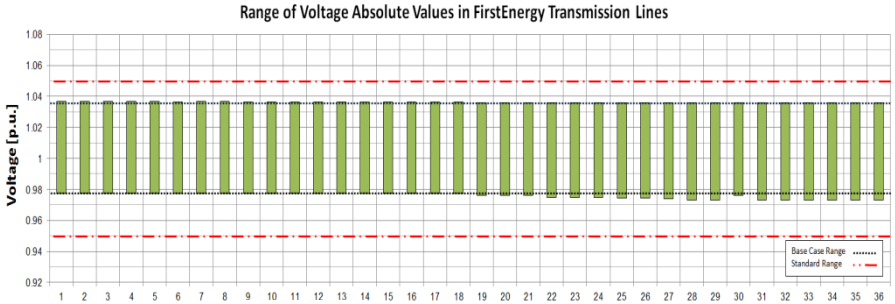
EC01



EC02



EC03



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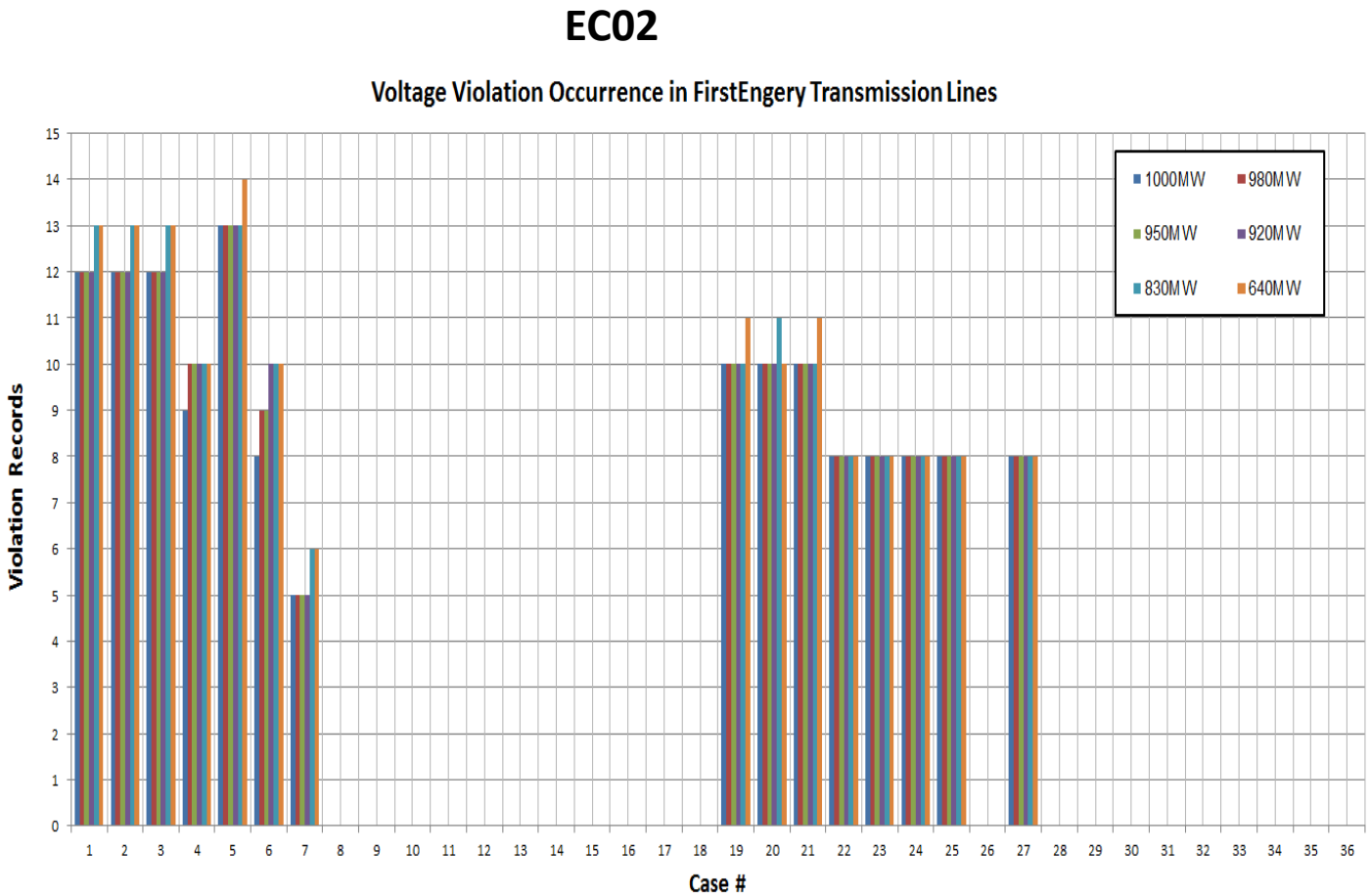
Voltages in FirstEnergy Transmission System*



*** EC01 and EC03 had no voltage violations**

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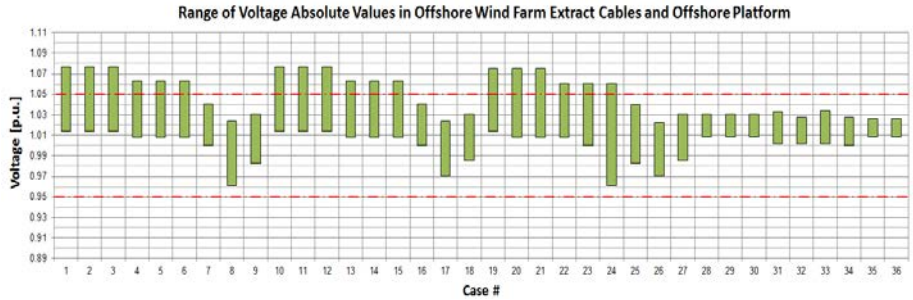
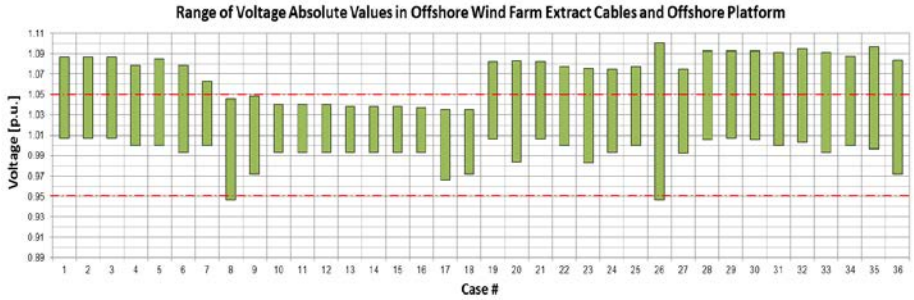
Voltages in Offshore System

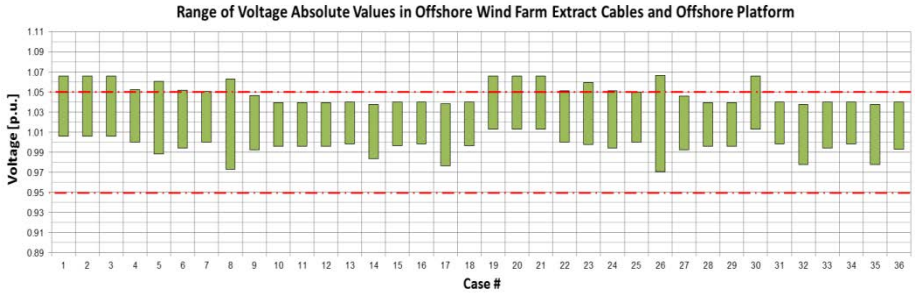
EC01



EC02



EC03



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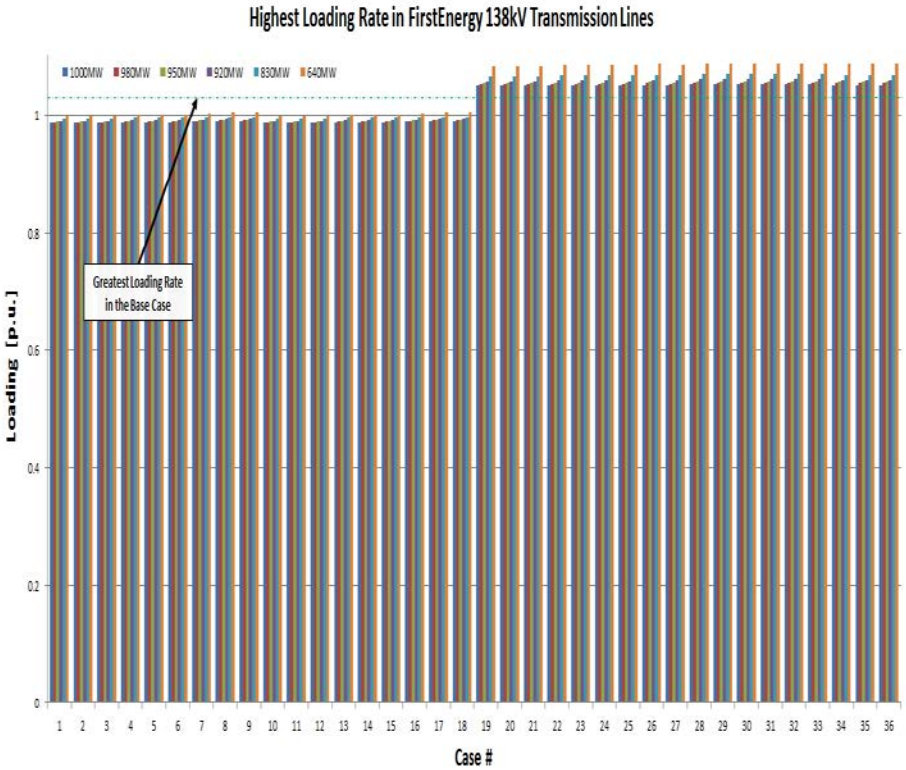

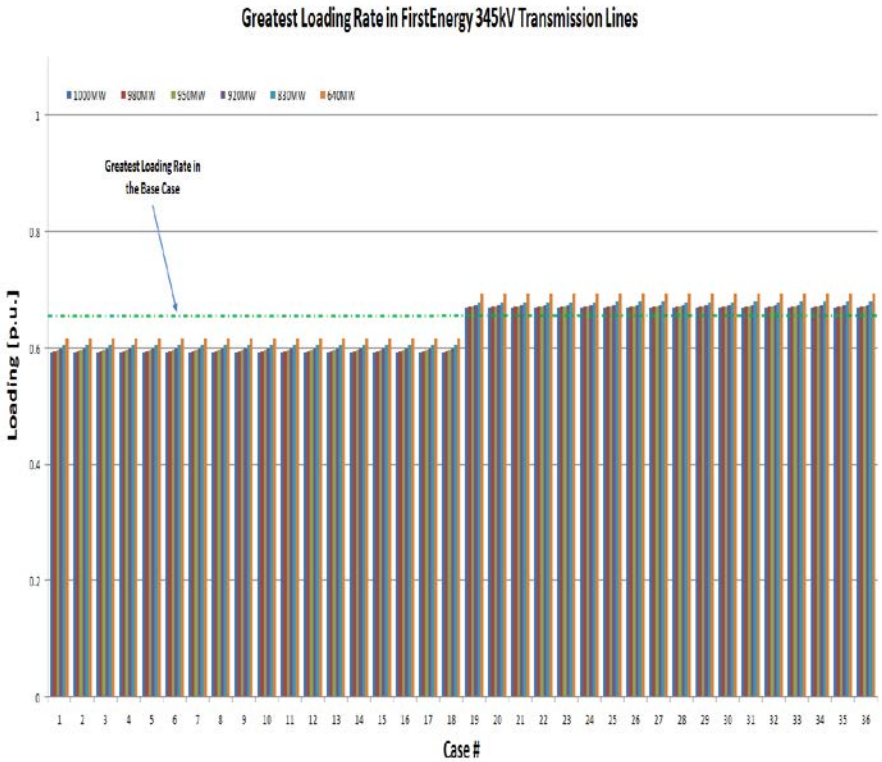

EC01

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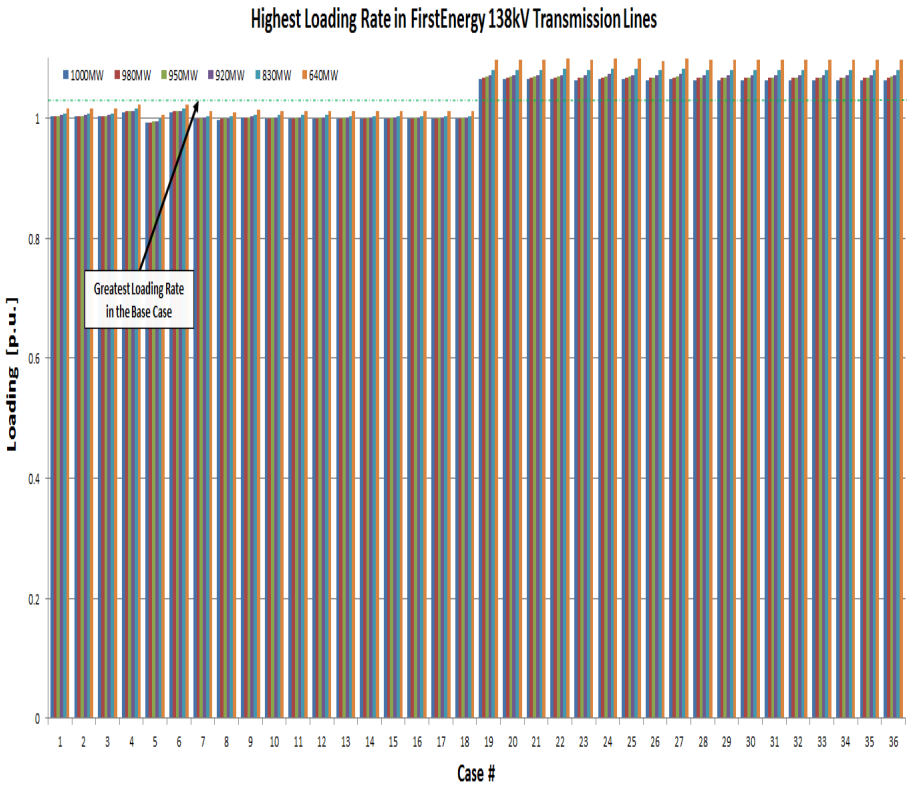
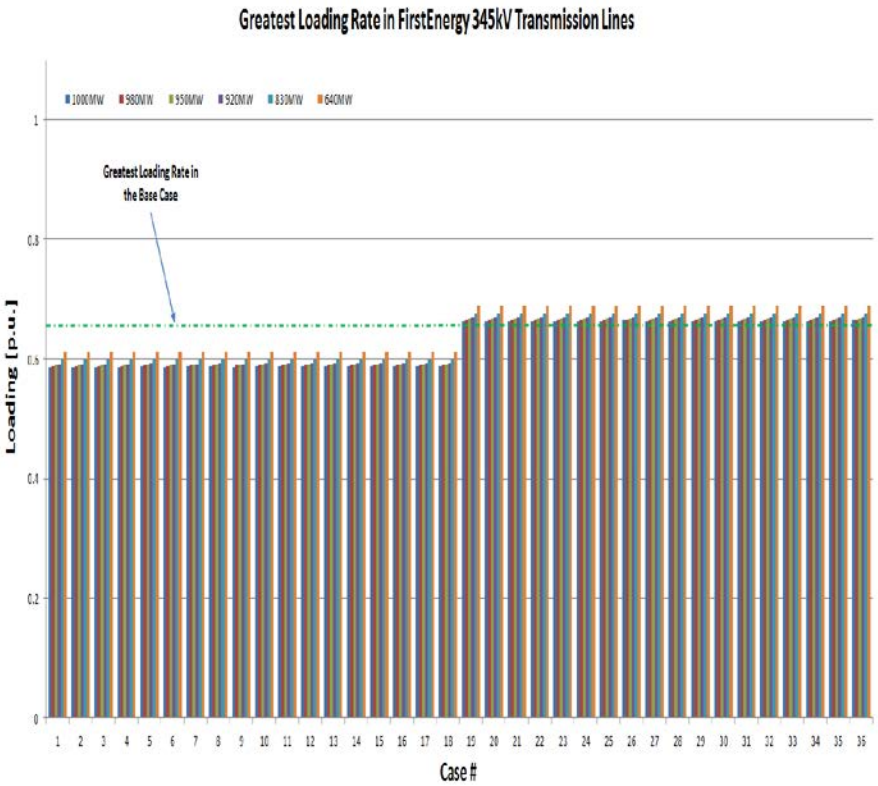
Loading in FirstEnergy Transmission System





EC02

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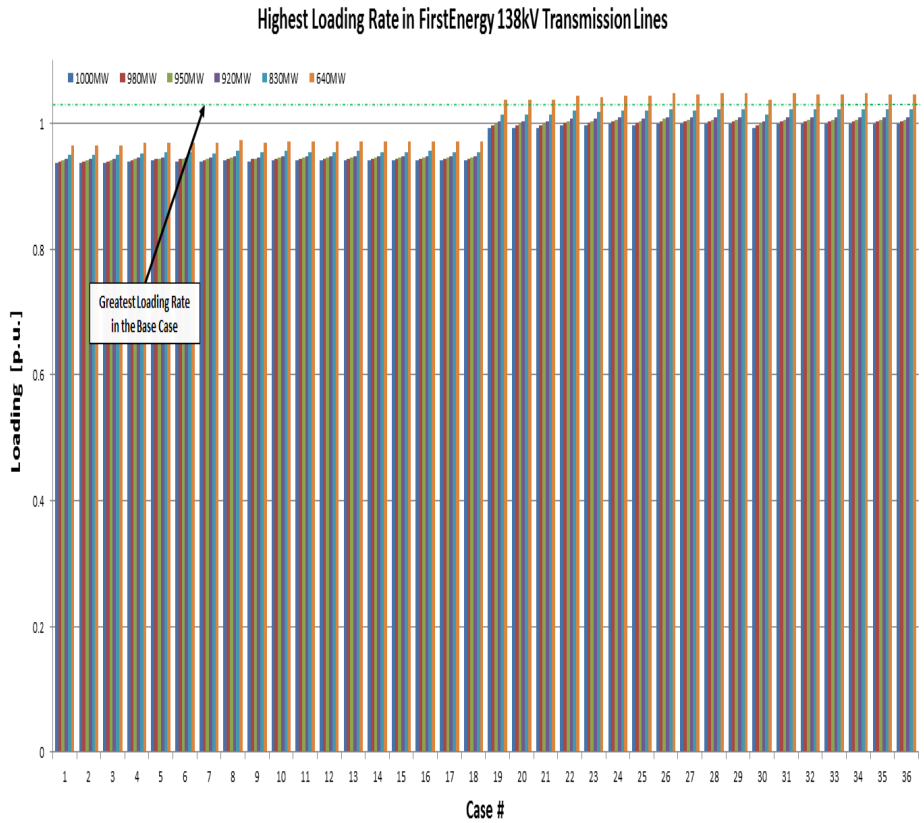

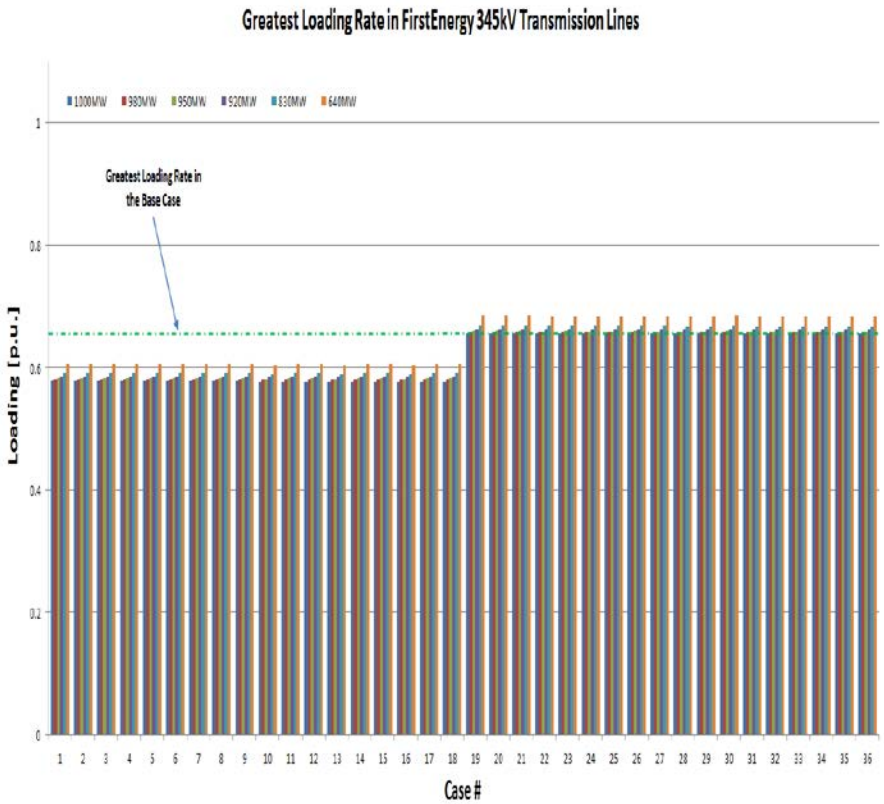

EC03

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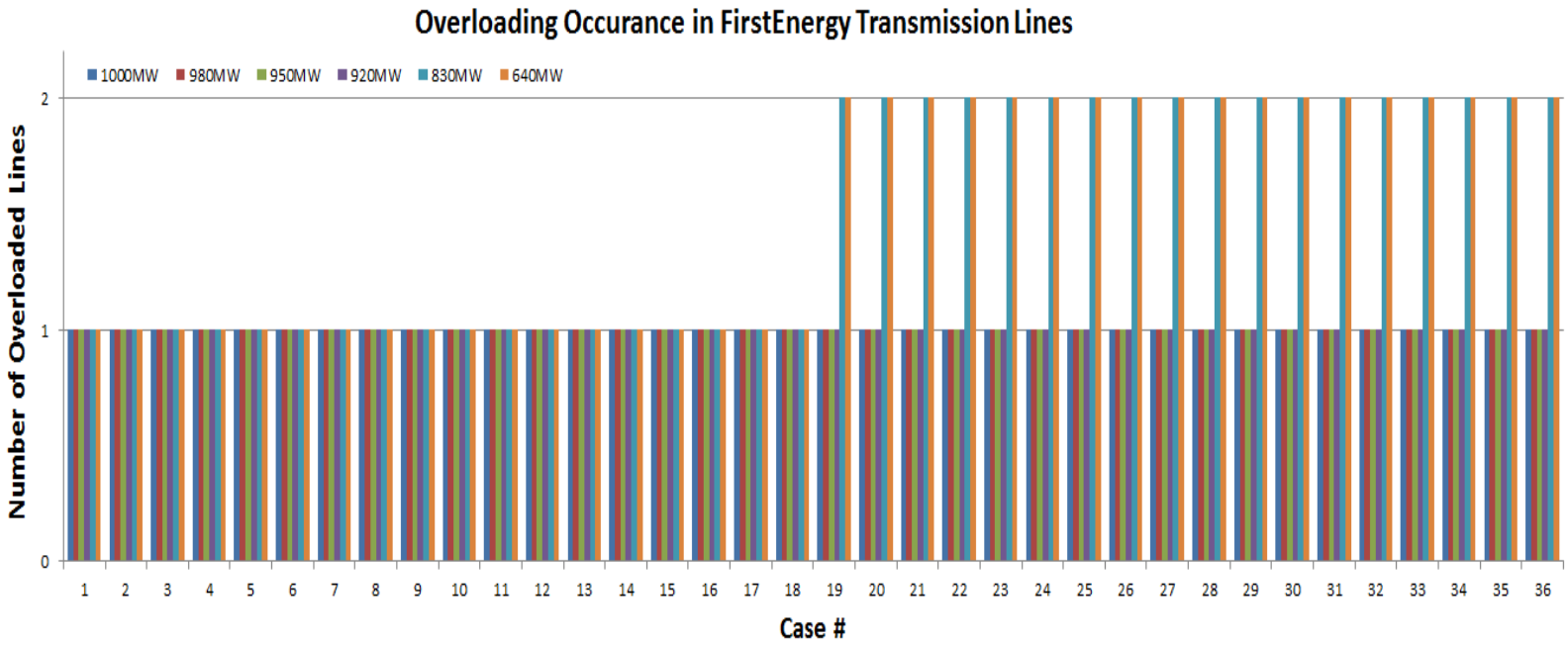

EC01

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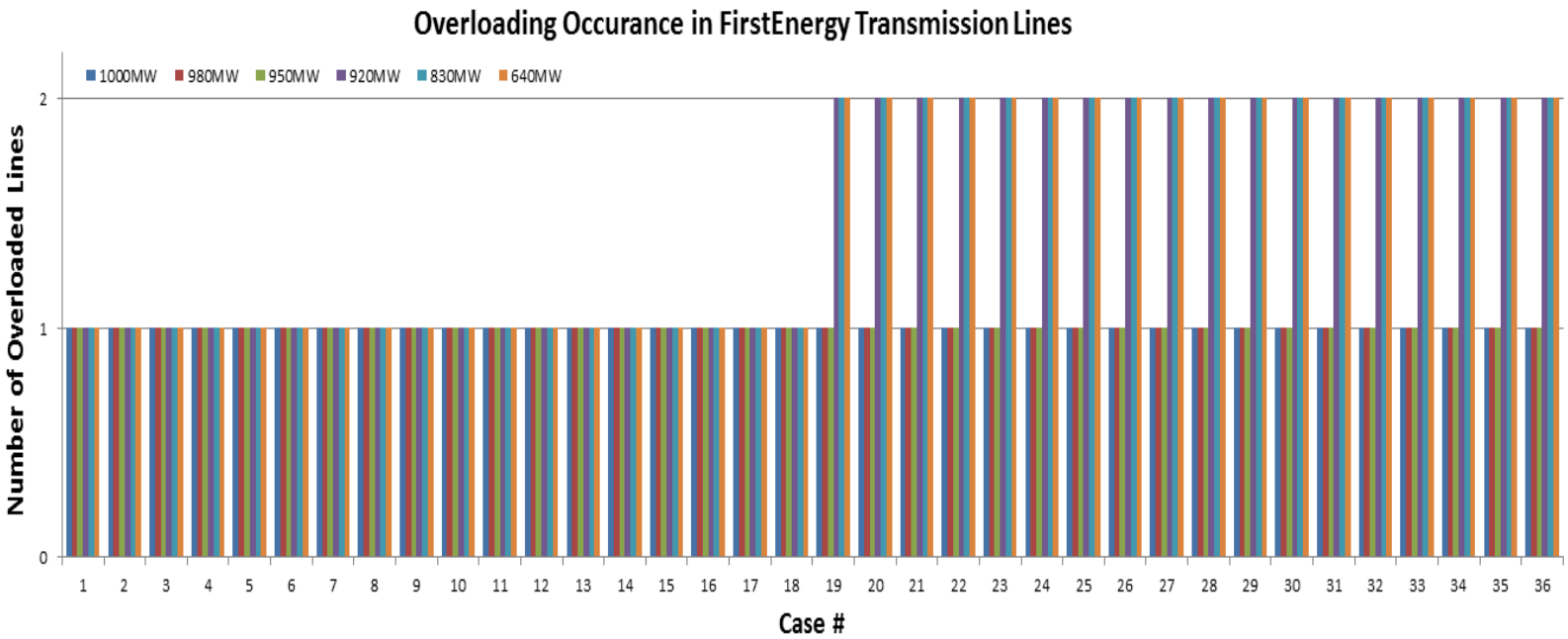

EC02

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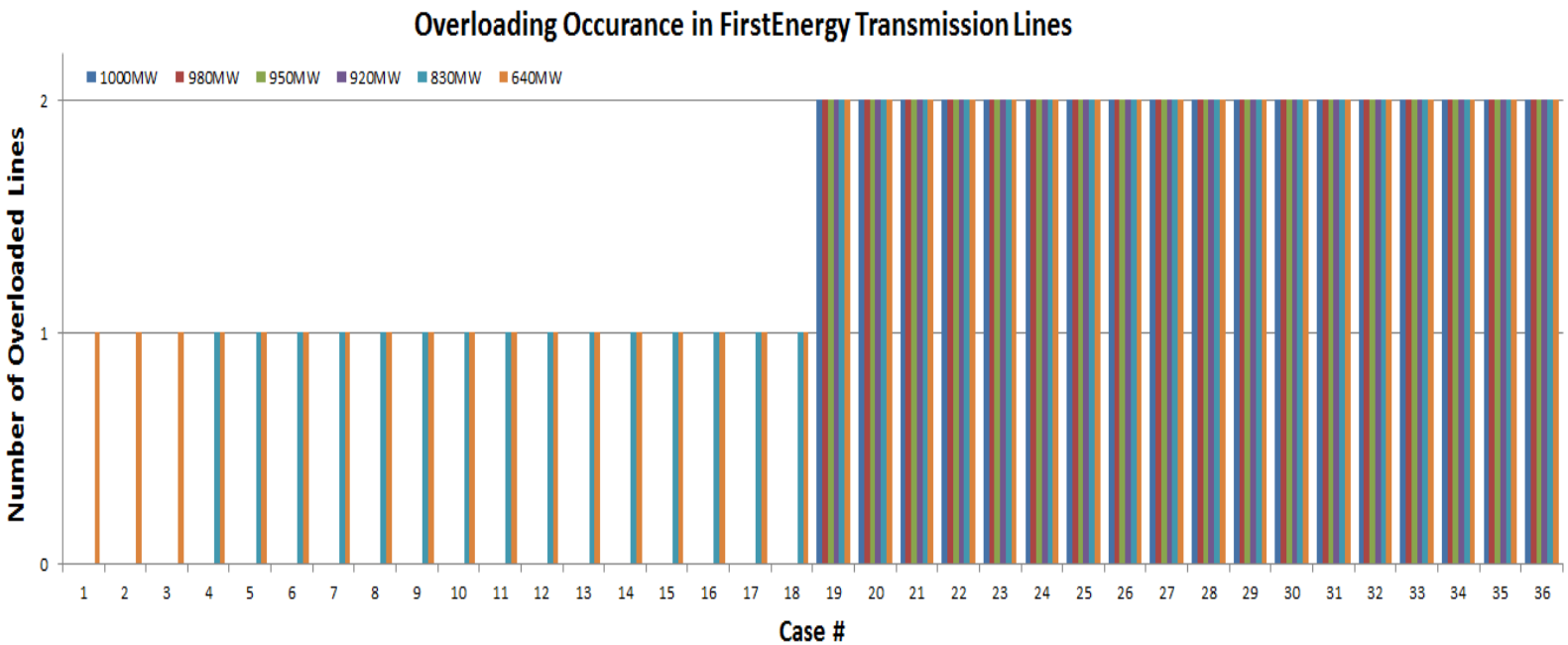

EC03

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Conclusions and Future Work

- Dominant impact on voltage regulation in the transmission system is related to the geographical location of the points of interconnection.
- The reactive power support capability of the machines installed offshore and SVC at the POIs are secondary and tertiary factors in voltage regulation.
- Installing SVC at POIs is important to delivering the best voltage regulation performance in the transmission lines and preventing voltage violations across offshore equipment and facilities, unless machines with full reactive support capability are used in the offshore wind farm.
- Using machines with the capability to provide reactive power support is an alternative for the SVC installed at the POIs.
- The level of loading of transmission lines depends primarily on the operation of Perry, the major bulk generation in the area. The geographical point of interconnection plays a secondary role.
- Small signal dynamic analysis (voltage and frequency) is ongoing and will be completed by 12/31/2014.