

Dominion's Blackstart Restoration Plan Study



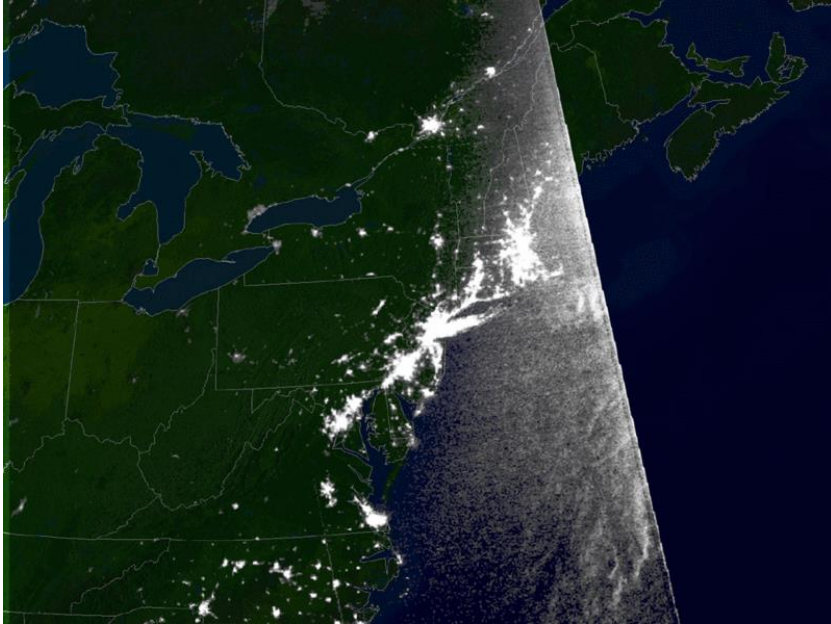
**Dominion
Energy[®]**

2017 Grid of the Future Symposium

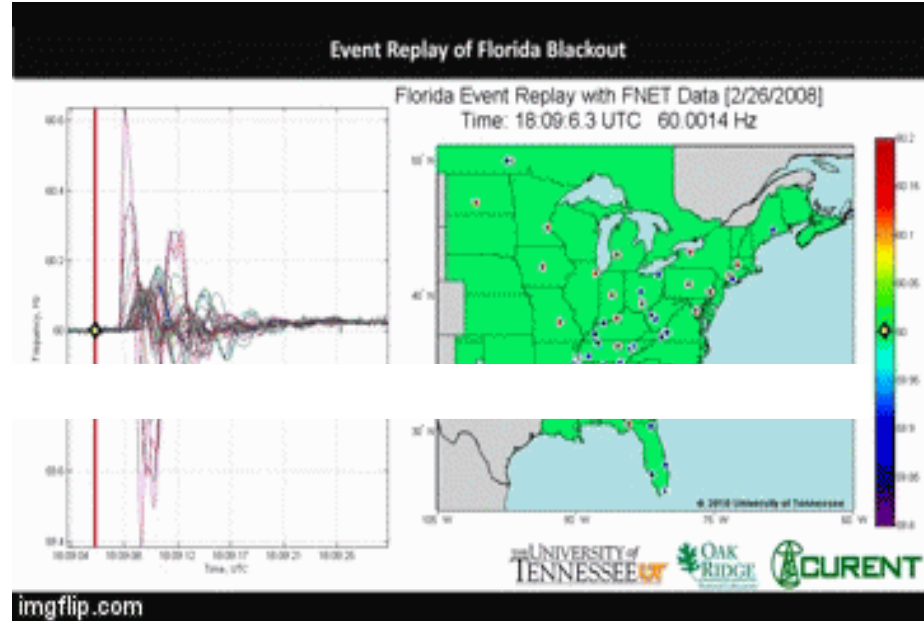
Yajun Wang, Hung-Ming Chou, Rui Sun,
Michael K. Thomas

Blackout

2



2003 Blackout



2008 Florida Blackout

Rare event, but have large impact

Need a plan to restore the system

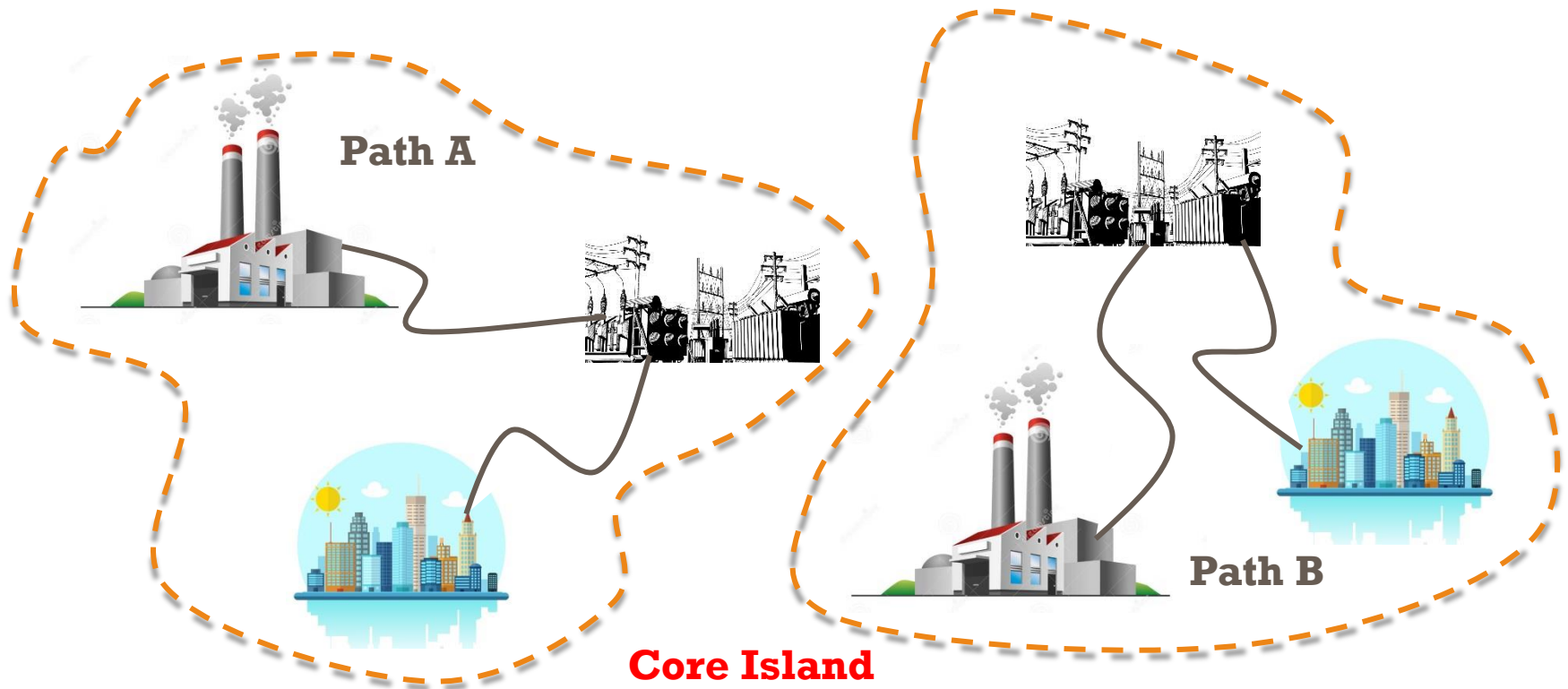
System restoration plan (SRP)

3

- Updated annually
- Reference
 - NERC ID NCR01214
 - PJM Manual 36

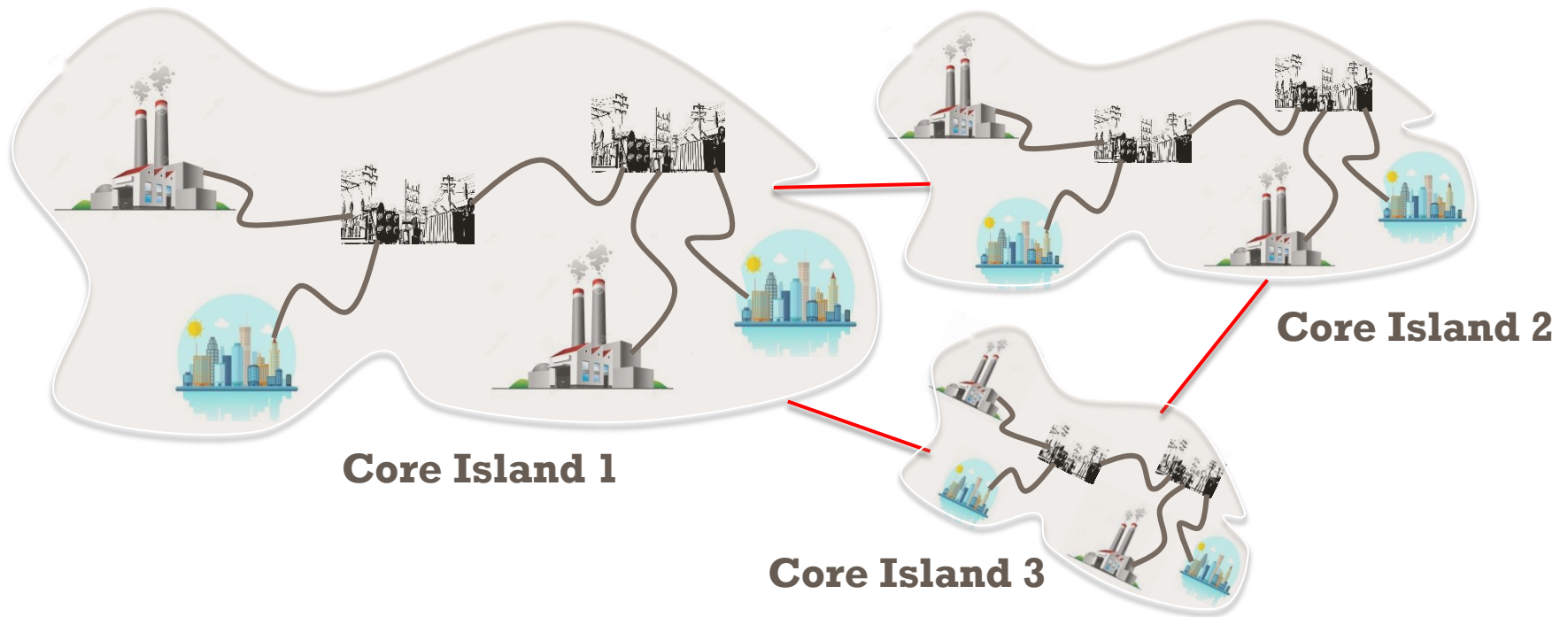
Core island approach

4

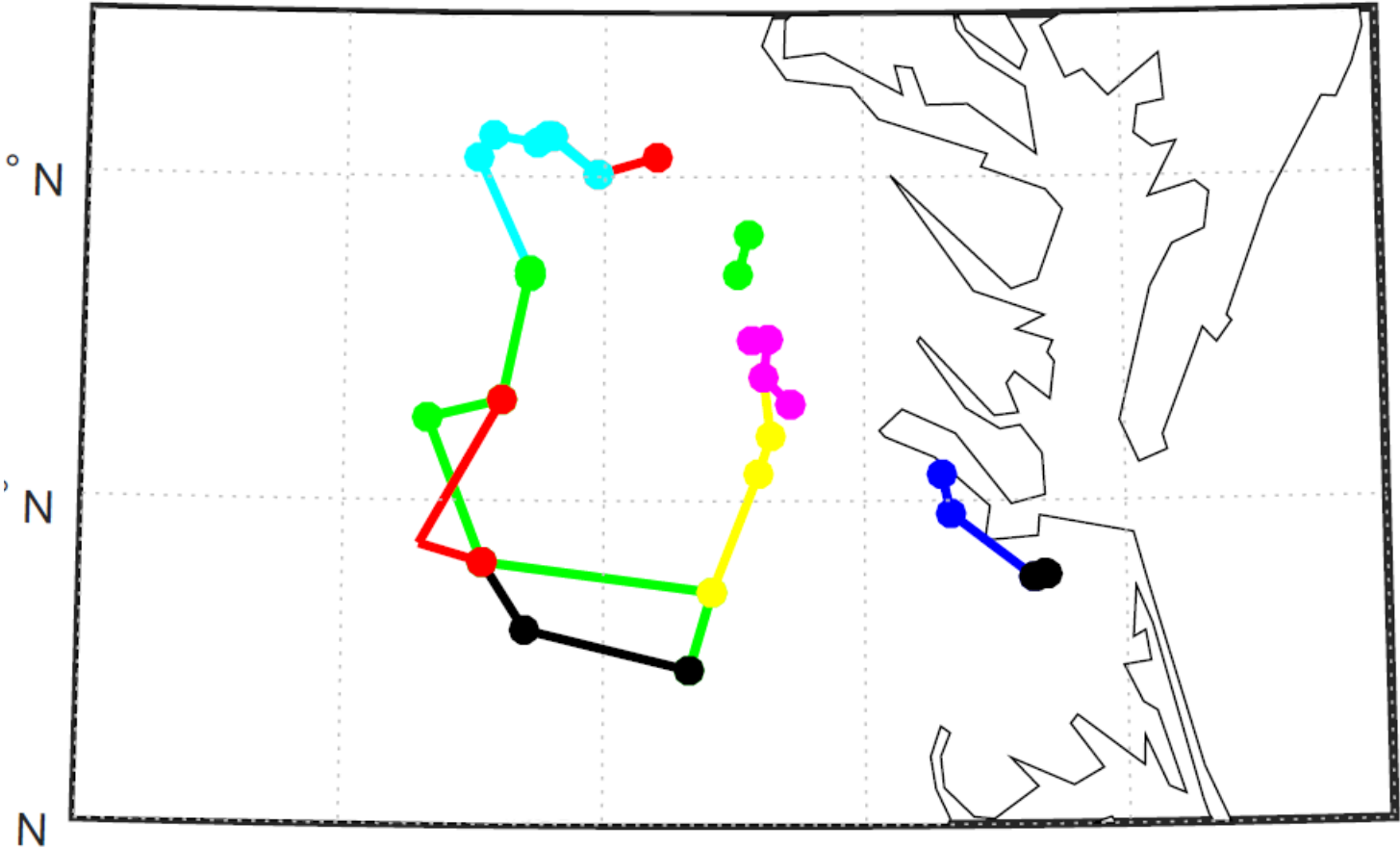


Core island approach

5



Blackstart paths under study



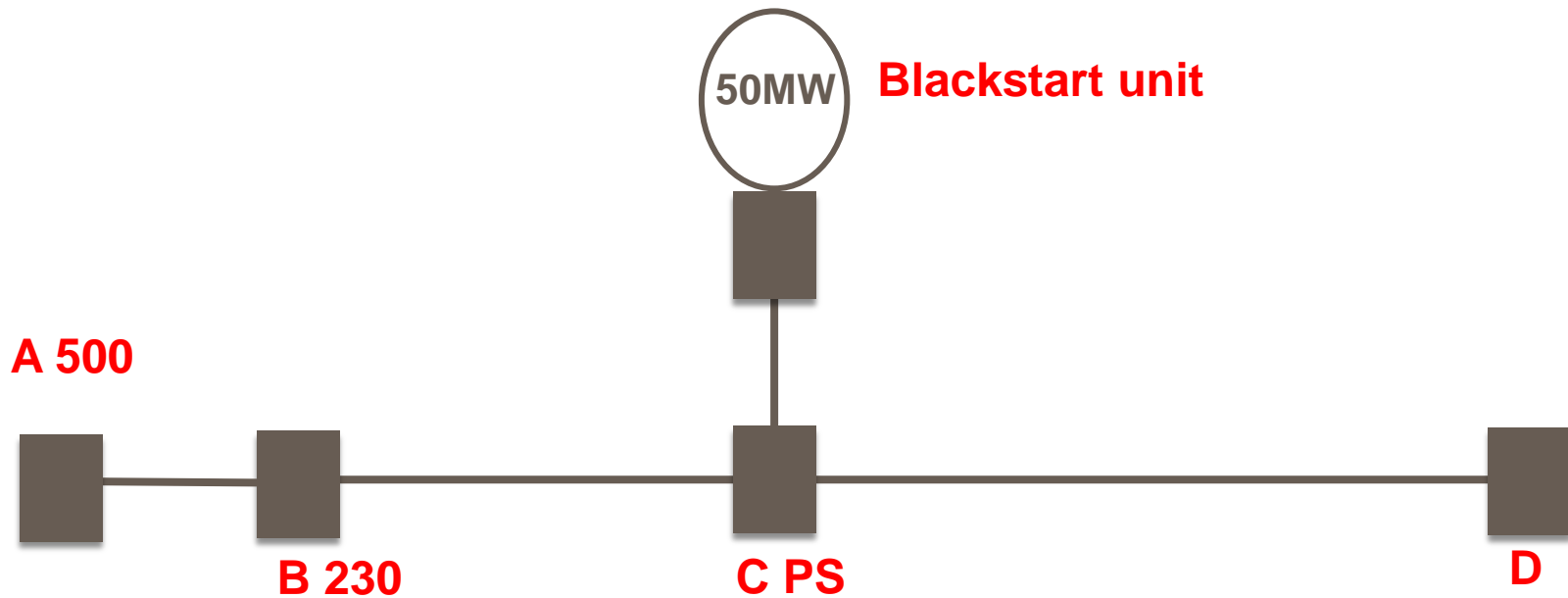
PSS/E criteria (Feasibility study)

7

- **Over/under voltage**
- Line loading
- Generator loading

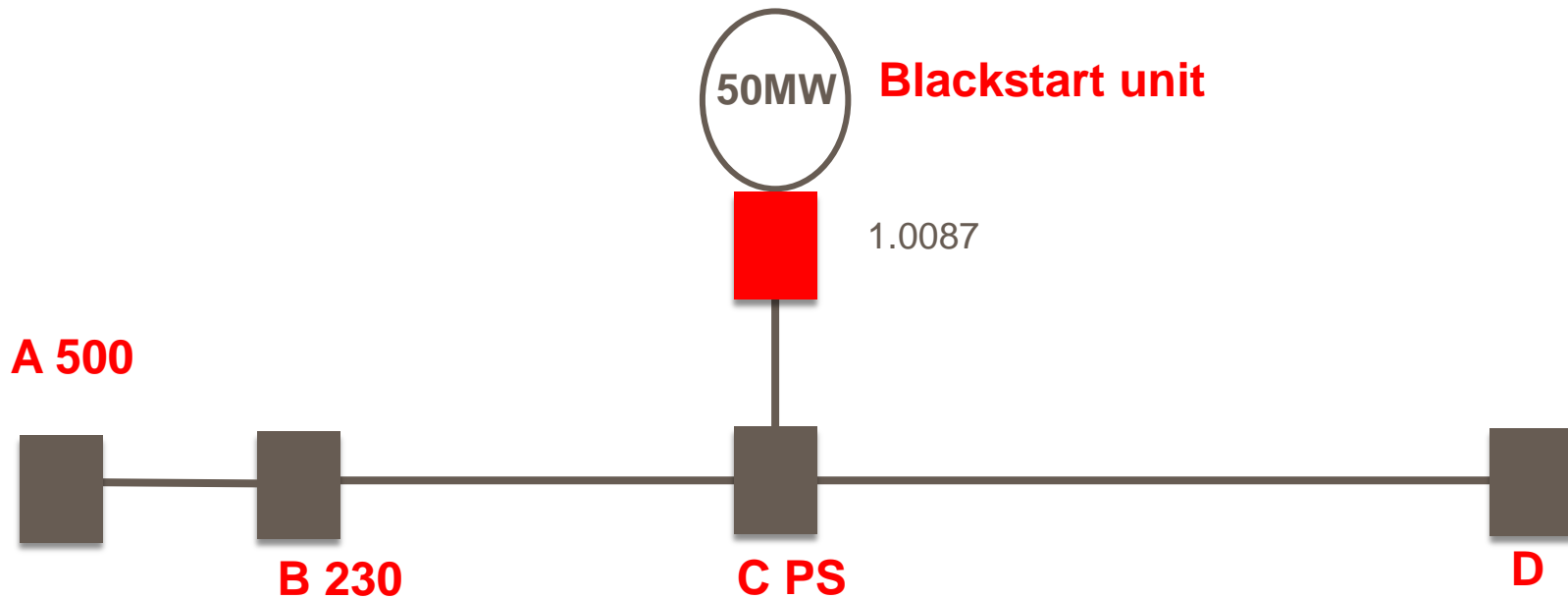
PSS/E study example

8



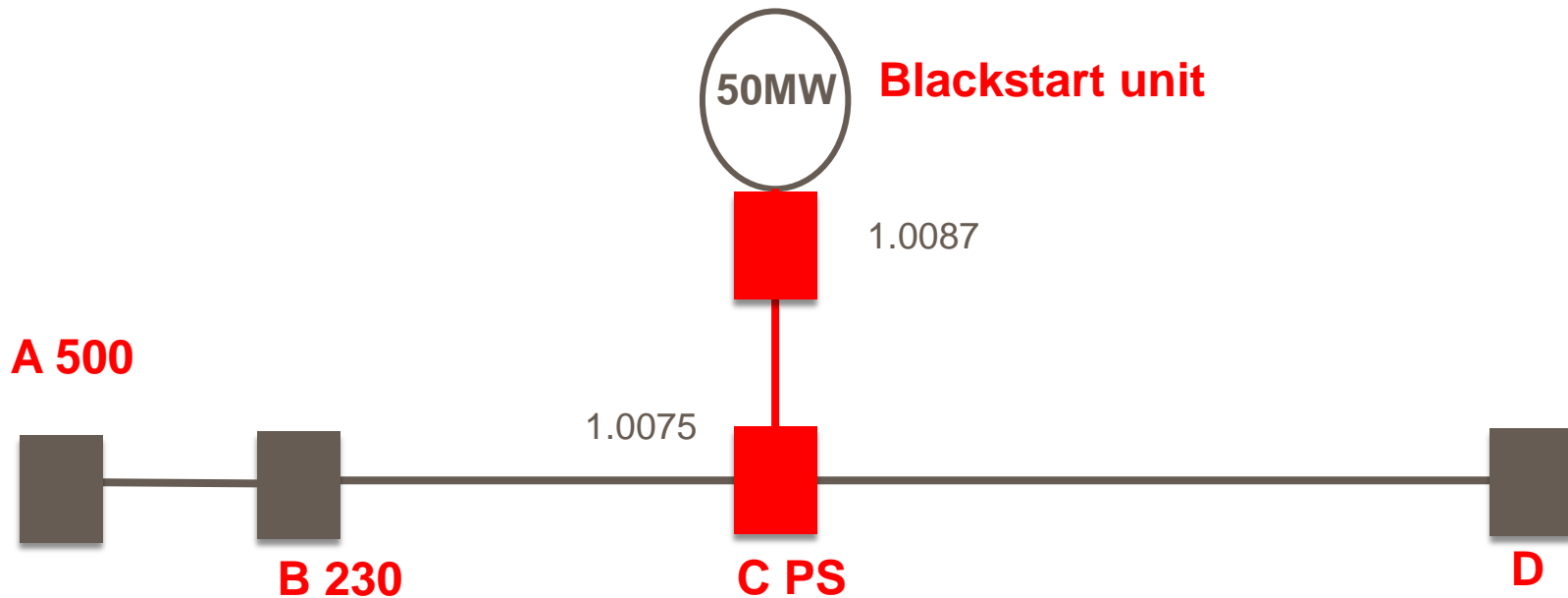
PSS/E study example

9



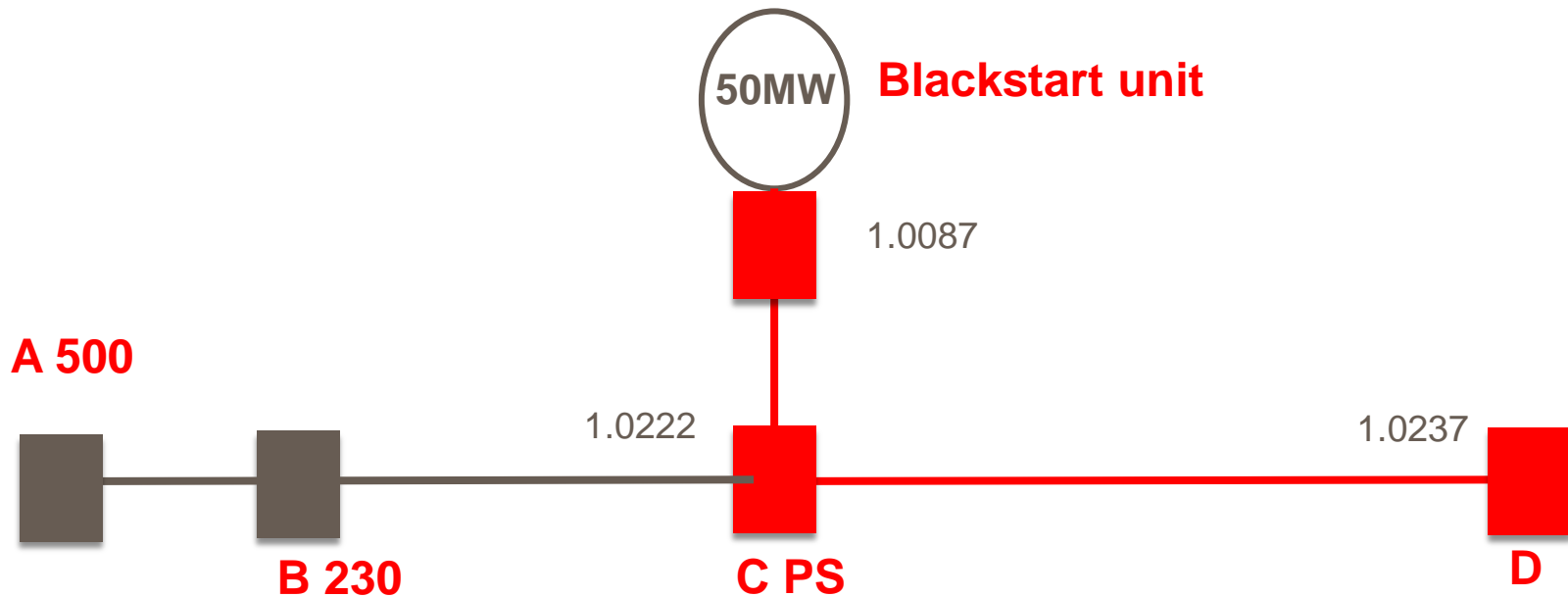
PSS/E study example

10



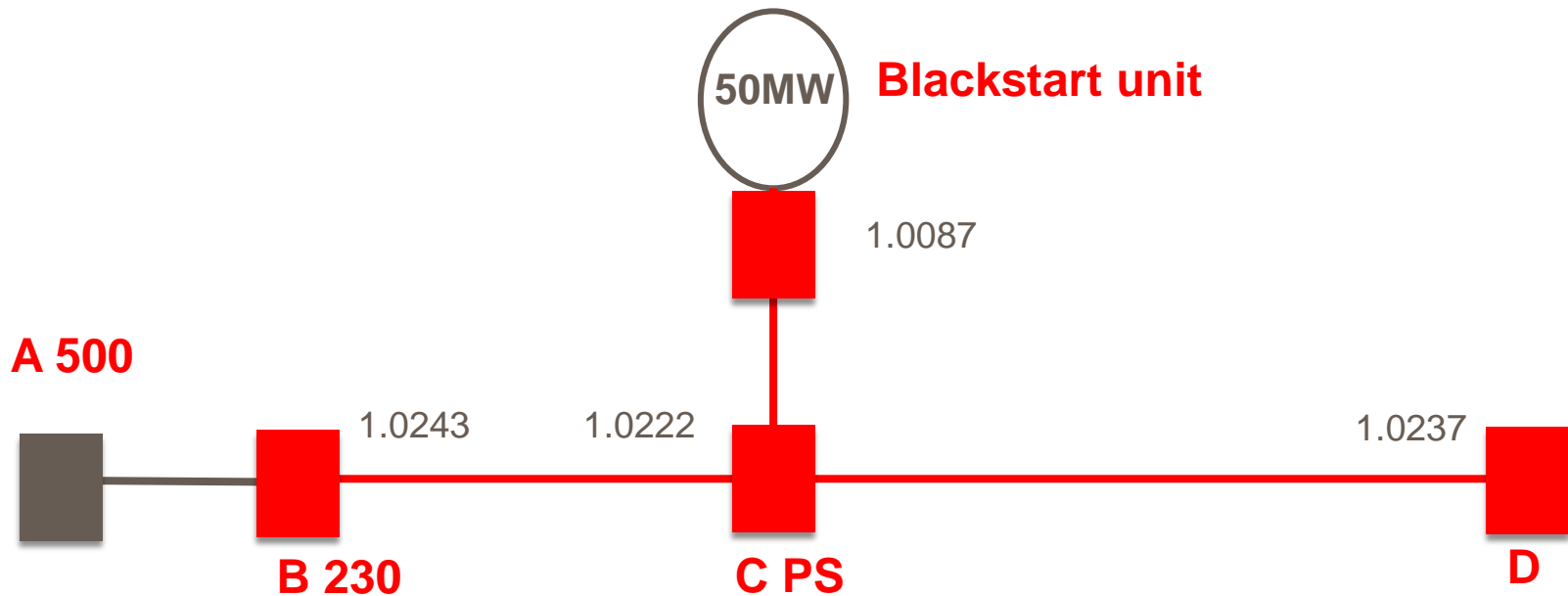
PSS/E study example

11



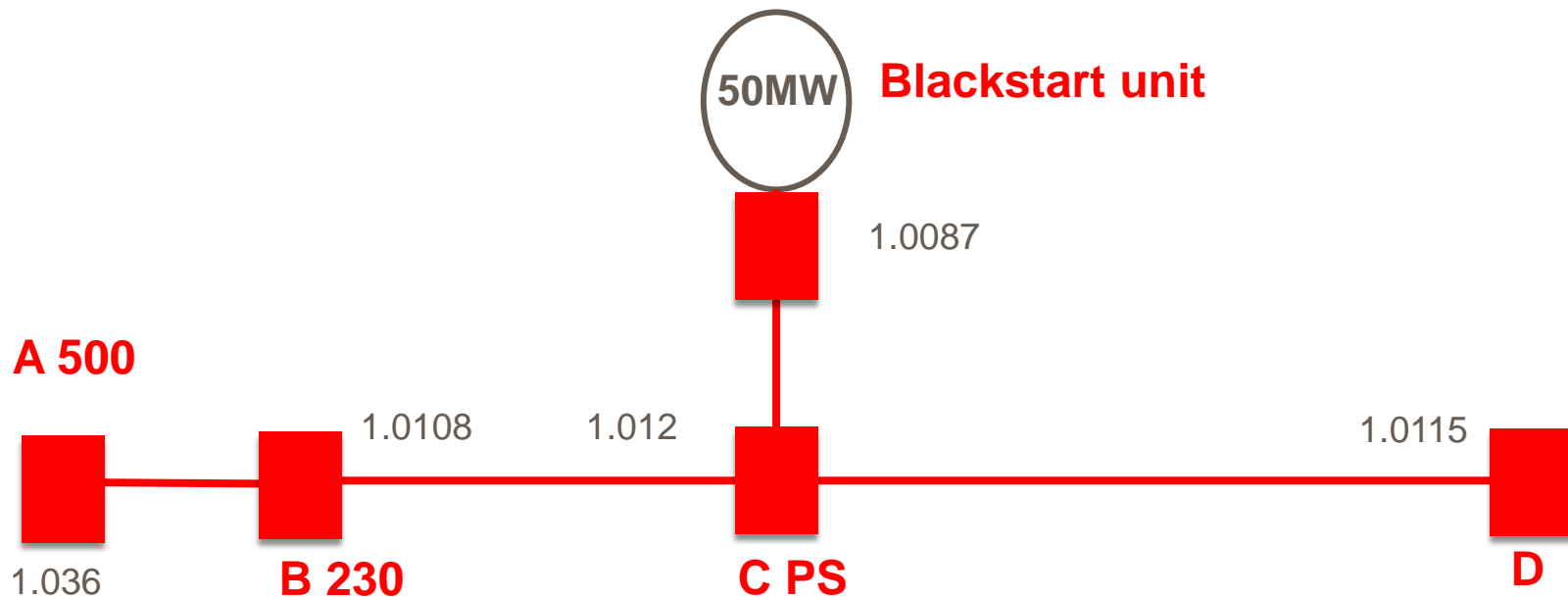
PSS/E study example

12



PSS/E study example

13



Bus status for restoration path A

14

| Bus | Base (kV) | Step 1-2 | | Step 3-4 | | Step 5-7 | |
|-----|-----------|----------------|-------------|----------------|-------------|----------------|-------------|
| | | Voltage (p.u.) | Angle (deg) | Voltage (p.u.) | Angle (deg) | Voltage (p.u.) | Angle (deg) |
| 1 | 13.8 | 1.0087 | -51.29 | 1.0087 | -51.29 | 1.0087 | -51.29 |
| 2 | 230 | 1.0087 | -53.53 | 1.0087 | -54.01 | 1.0087 | -54.28 |
| 3 | 230 | 1.0082 | -53.81 | 1.0082 | -54.29 | 1.0082 | -54.56 |
| 4 | 230 | 1.0075 | -53.95 | 1.0075 | -54.43 | 1.0075 | -54.7 |
| 5 | 500 | 1.0327 | -53.95 | 1.0327 | -54.43 | 1.0327 | -54.7 |
| 6 | 230 | 1.0087 | -53.53 | 1.0086 | -54.05 | 1.0087 | -54.32 |
| 7 | 230 | 1.0087 | -53.53 | 1.0085 | -54.07 | 1.0087 | -54.35 |
| 8 | 13.8 | 1.0047 | -53.48 | 1.0126 | -50.67 | 1.0025 | -50.89 |
| 9 | 230 | - | - | 1.0083 | -54.13 | 1.0087 | -54.42 |
| 10 | 230 | - | - | 1.0071 | -54.4 | 1.0086 | -54.73 |
| 11 | 115 | - | - | 1.0016 | -54.19 | 1.0018 | -54.47 |
| 12 | 230 | - | - | 1.007 | -54.43 | 1.0086 | -54.76 |
| 13 | 230 | - | - | 1.0075 | -54.43 | 1.0105 | -54.81 |
| 14 | 230 | - | - | - | - | 1.0111 | -54.84 |
| 15 | 230 | - | - | - | - | 1.0116 | -54.89 |
| 16 | 115 | - | - | - | - | 1.0048 | -54.94 |
| 17 | 230 | - | - | - | - | 1.0116 | -54.89 |

Machine status for restoration path A

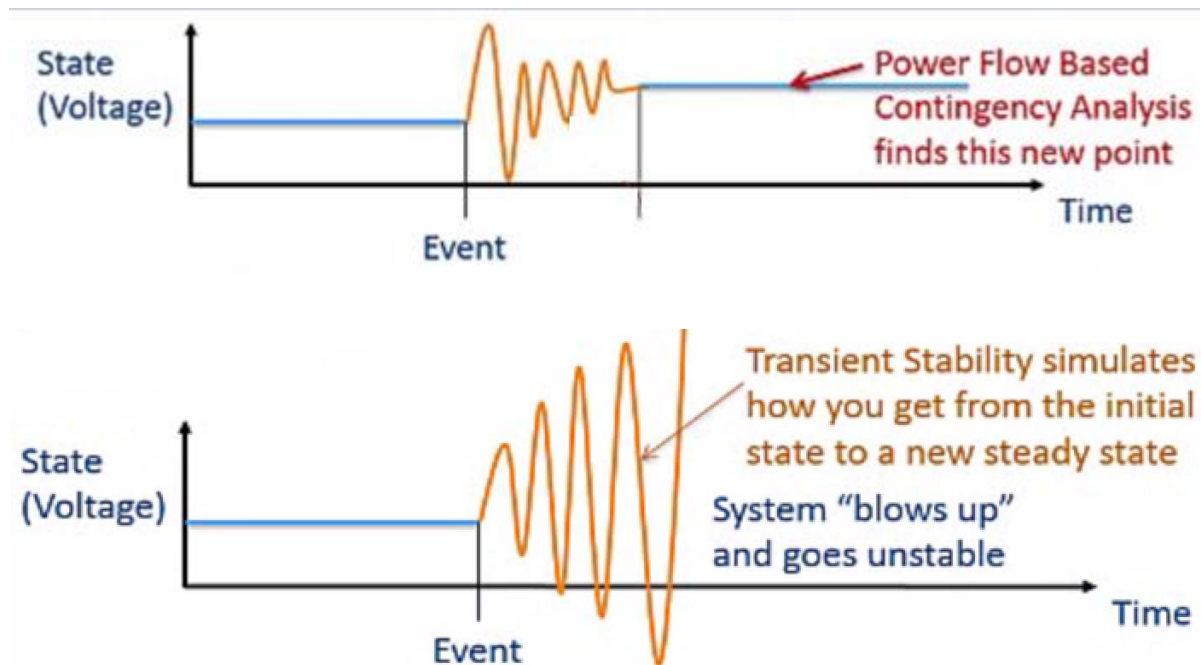
15

| Machine | Base (kV) | PMax (MW) | Step 1-2 | | Step 3-4 | | Step 5-7 | | Power Reserve (MW) |
|---------|-----------|-----------|-----------|-------------|-----------|-------------|-----------|-------------|--------------------|
| | | | PGen (MW) | QGen (MVAR) | PGen (MW) | QGen (MVAR) | PGen (MW) | QGen (MVAR) | |
| 1 | 13.8 | 72 | 33.214 | -0.2089 | 40.342 | -0.0849 | 44.369 | 0.011509 | 27.631 |
| 2 | 13.8 | 72 | 0.6 | -3.3915 | 50 | 3.4845 | 50 | -5.04305 | 22 |

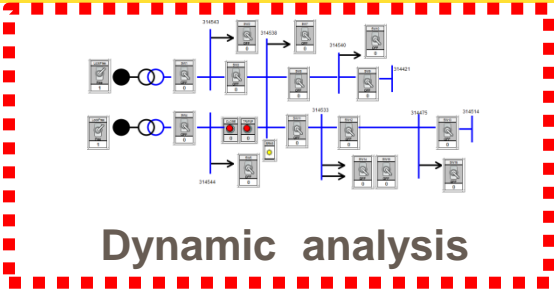
Steady state vs dynamic study

16

- Steady state load flow analysis is not enough



RTDS studies



Dynamic analysis



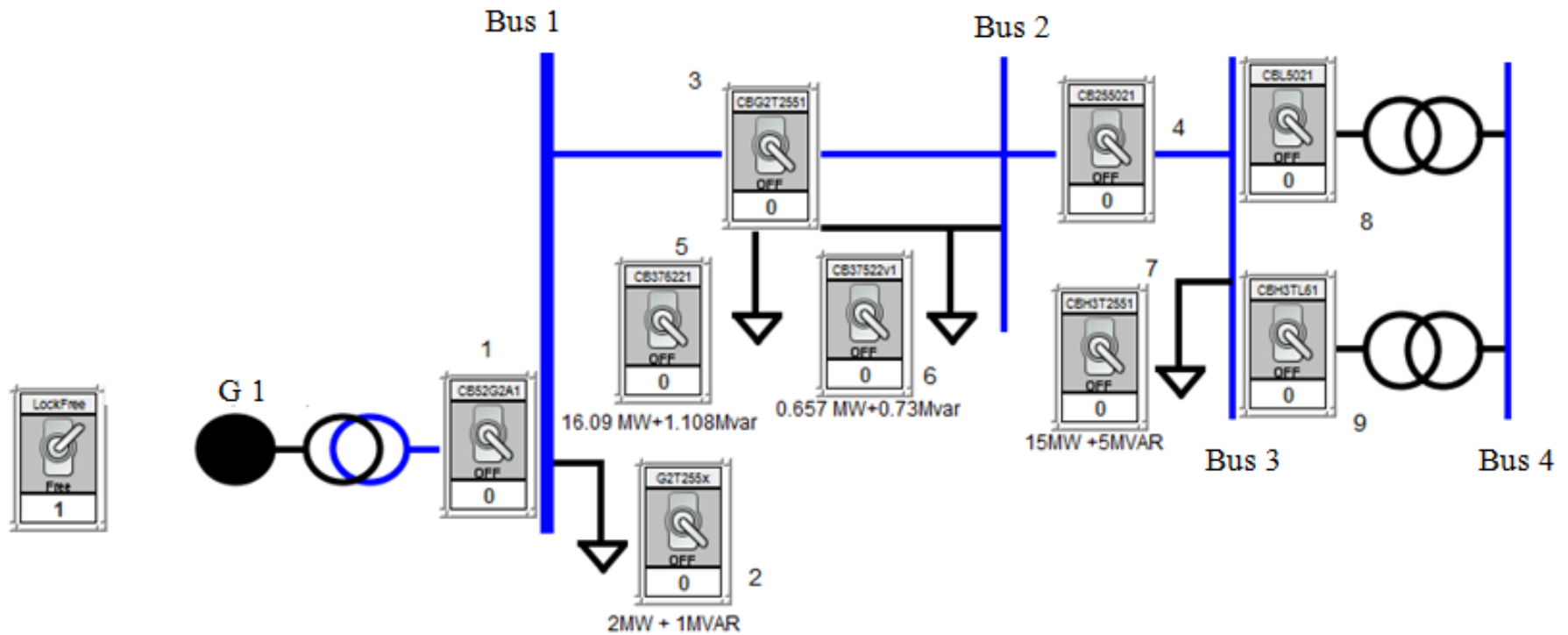
Protection validation



Synchronization of islands

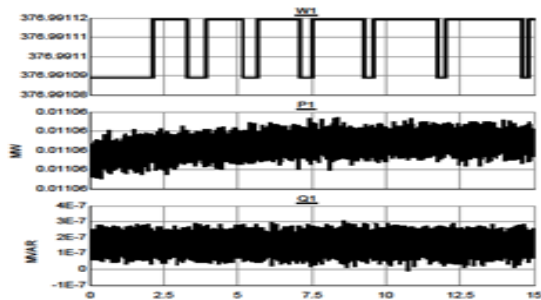
User interface in RTDS

18

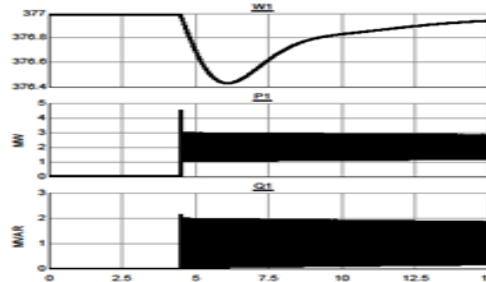


Gen speed, P and Q at each step

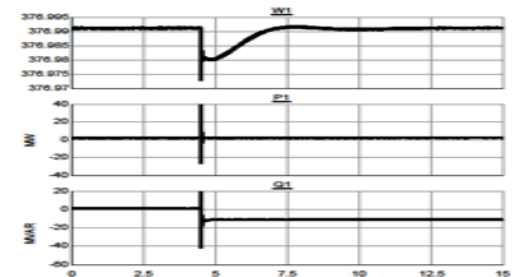
19



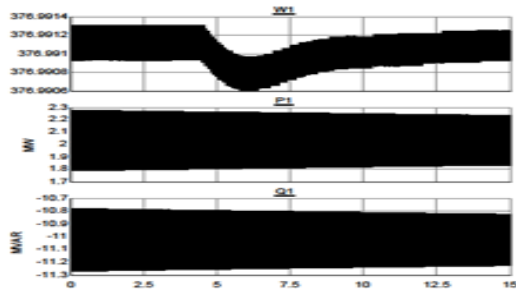
(a)



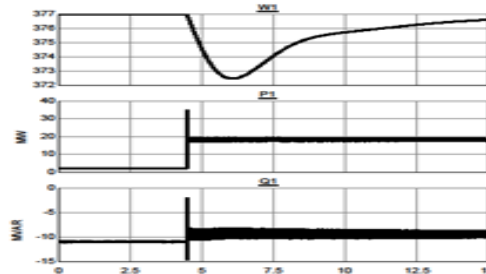
(b)



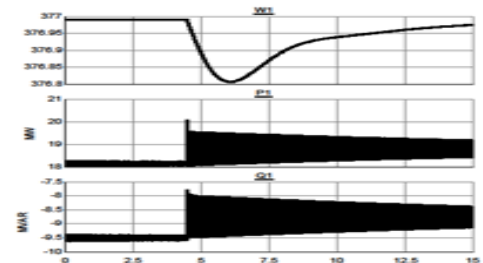
(c)



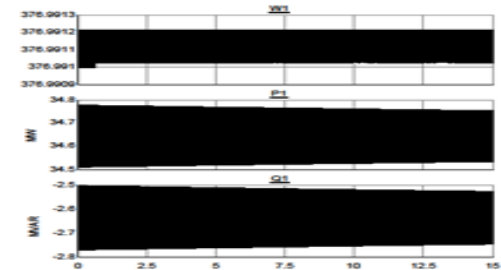
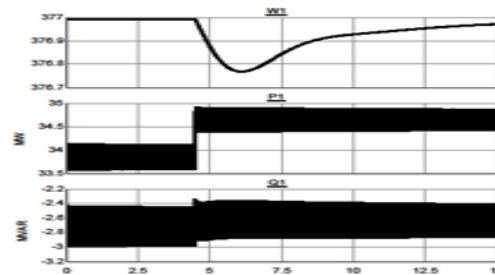
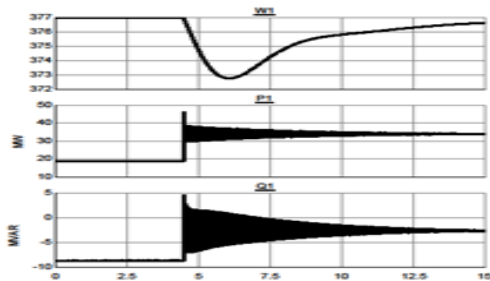
(d)



(e)

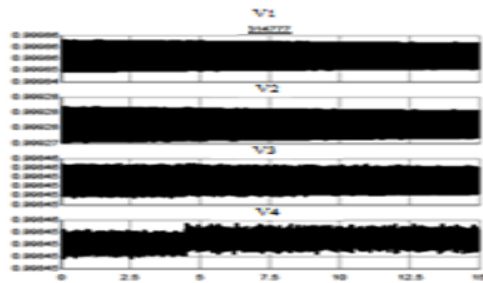


(f)

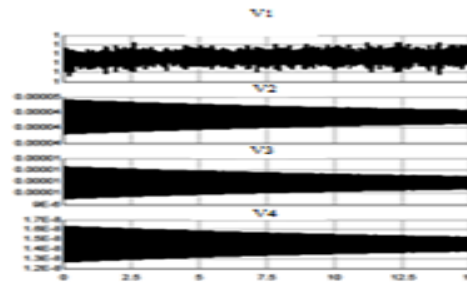


Voltage magnitude at each step

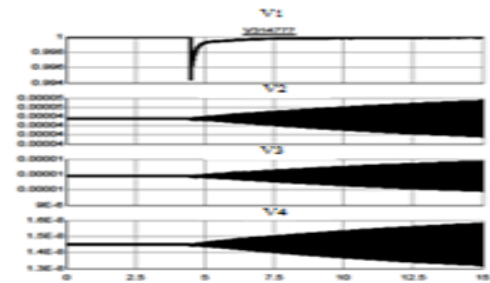
20



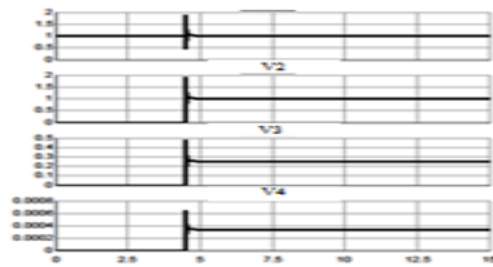
(a)



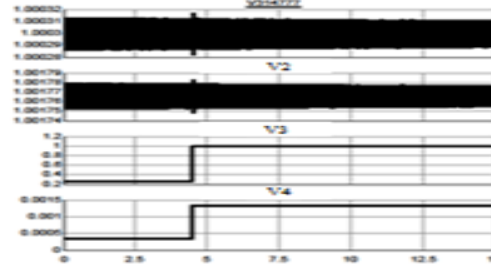
(b)



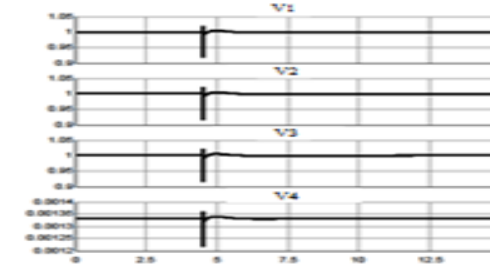
(c)



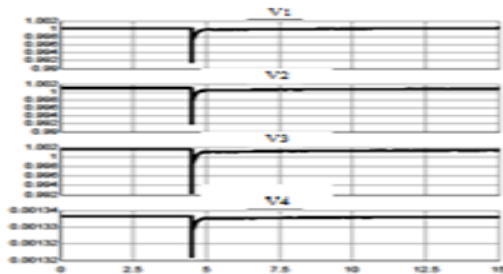
(d)



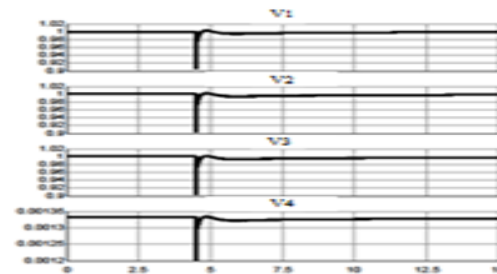
(e)



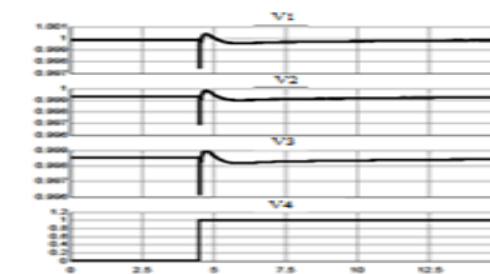
(f)



(g)



(h)



(i)

Challenges

21

- Improvement of generator parameter
- Improvement of load modeling

Conclusions

22

- Blackstart restoration path study
 - Using PSS/E
 - Using RTDS
- The plan is feasible based on PSS/E
- More work needs to be done on RTDS side

Thank you !!
Questions?

Hung-Ming Chou
Hung-Ming.Chou@dominionenergy.com
804-418-0598