INCORPORATING PRIORITIZATION INTO CRITICAL INFRASTRUCTURE SECURITY AND RESILIENCE PROGRAMS

DUANE VERNER,[1] KIBAEK KIM,[2,3] AND FREDERIC PETIT [1,3]

[1] Risk and Infrastructure Science Center, Argonne National Laboratory

[2] Mathematics and Computer Science (MCS) Division, Argonne National Laboratory

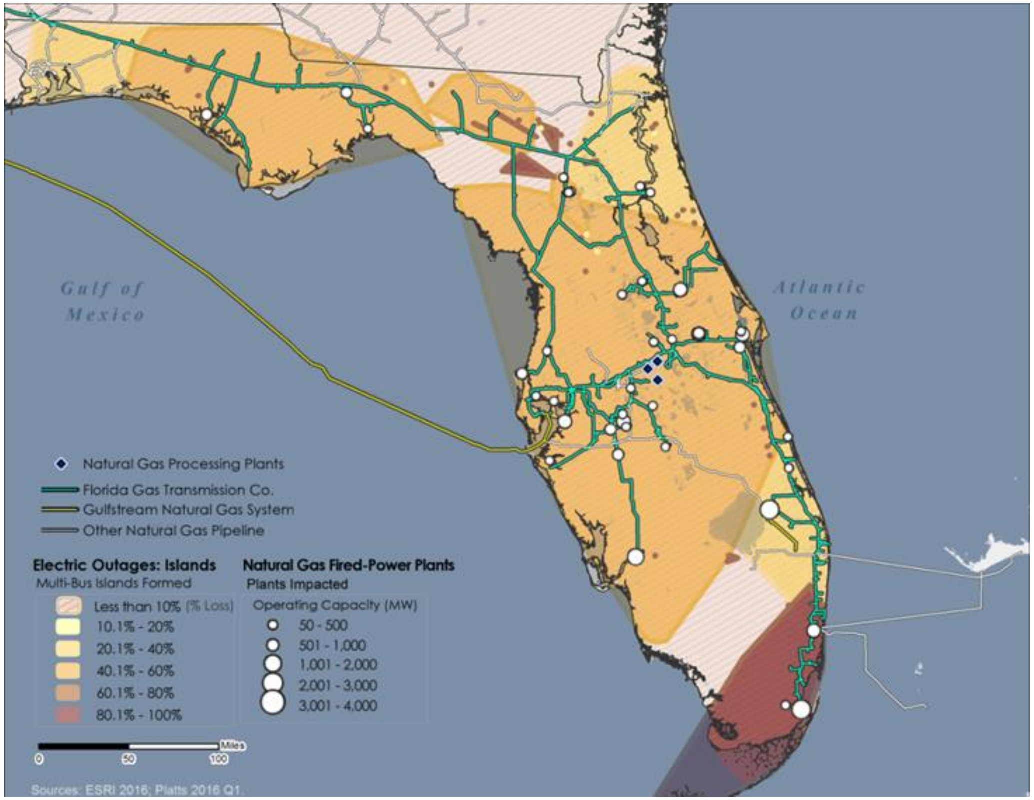
[3] Computation Institute, University of Chicago

C: Research Panels – Infrastructure Protection and Cybersecurity – Threat Identification and Prioritization
10th Anniversary Homeland Defense and Security Education Summit, Arlington, Virginia

Friday, March 24, 2017

HIGH-IMPACT FAILURES

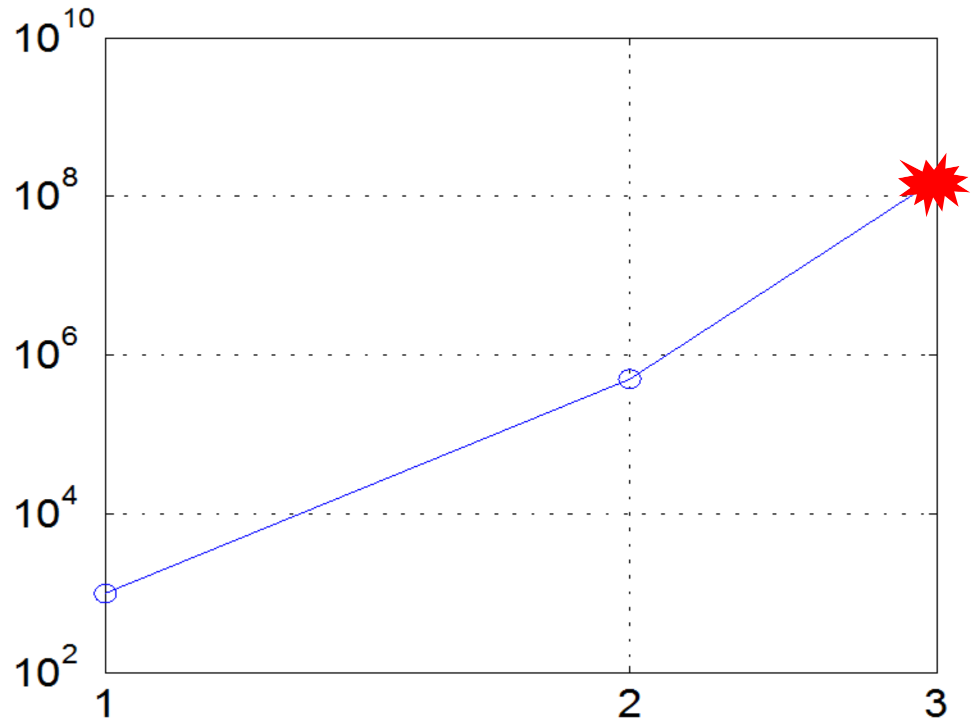
- Many high-impact failure scenarios are unknown and thus unmitigated (i.e., “black swans”)
- Interdependencies among critical infrastructure assets increase risk to the overall system
- Interconnected infrastructure components constitute a “system of systems” where the failure of one or multiple elements can generate cascading failures
- Identifying connections between infrastructure does not provide a sufficient understanding of why or whether a connection is critical to the operation of the system



Argonne NATIONAL LABORATORY

THE NEED FOR PRIORITIZATION

- The number of possible failure scenarios can be overwhelming
- It is technically and financially prohibitive to assess and prepare for all possible disruptions



Nearly one billion possible failure scenarios with an N-3 contingency for 1,000 electric power assets

OPTIMIZATION ALGORITHM TO PRIORITIZE INFRASTRUCTURE

- Managing risk associated with infrastructure interdependencies requires:
  - An understanding of infrastructure failures
  - An ability to prioritize protection and mitigation efforts

- The optimization algorithm assumes that the physical behavior of a system (e.g., a power network, gas pipeline, or coupled system) is described by the following optimization problem:

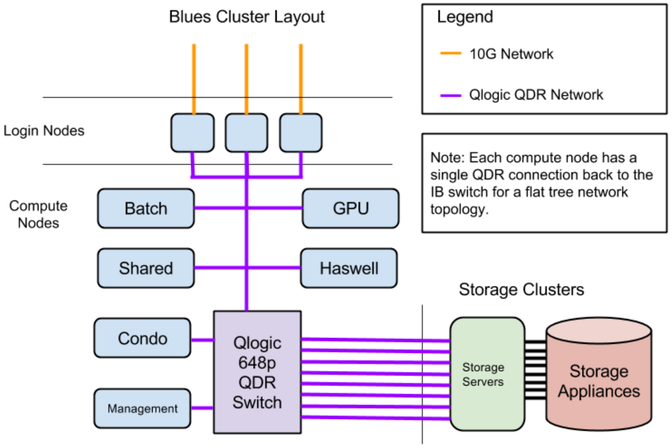
$$F(d) \coloneqq min_{u \in U(d)} f(u)$$

where:

- *d* is the 0-1 vector representing the failures at infrastructure assets,
- *u* is the control(s) that can be manipulated to mitigate disturbances, and
- *f(u)* is a system output metric of interest such as cost, delivered load, or deviations from a target operation

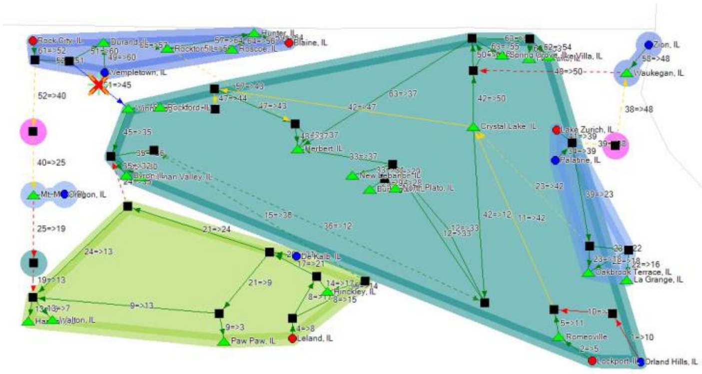
WORST-CASE CONTINGENCY ANALYSIS

- Finds a contingency d that causes the maximum damage to the system. The worst-case event (denoted by $d^{(1)}$) can be found by solving the optimization problem:

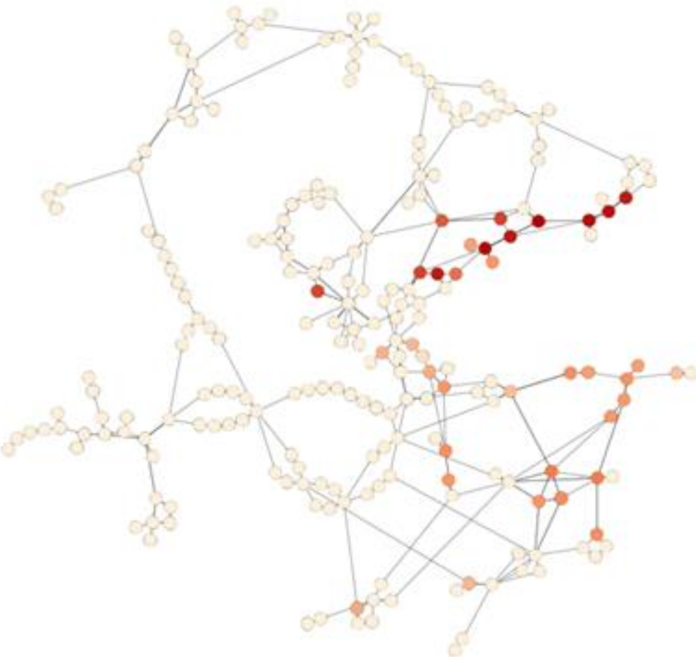


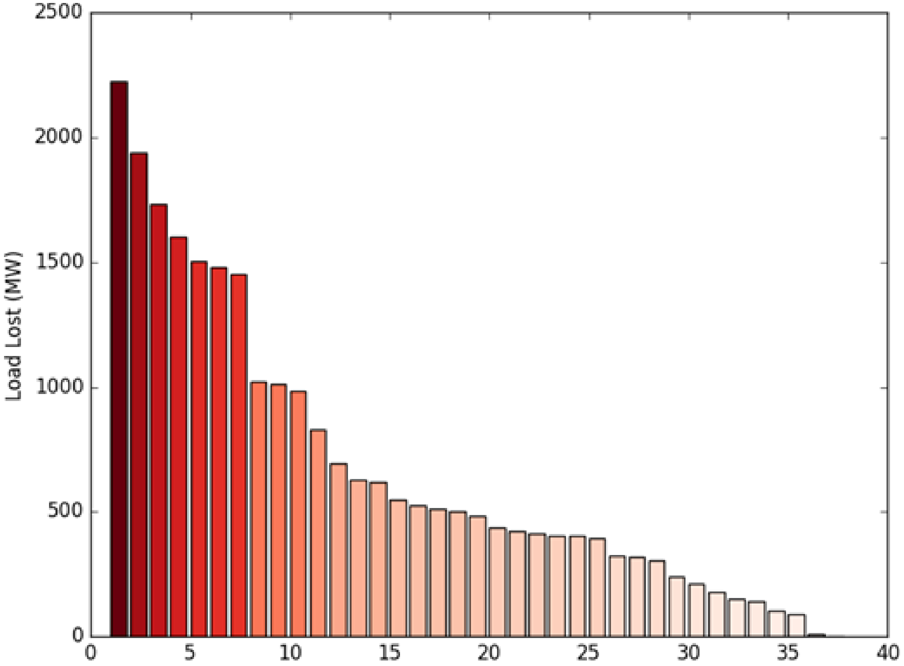
$$d^{(1)} = argmax_{d \in D} min_{u \in U(d)} f(u)$$

- Because of the computational complexity of assessing high numbers of failure scenarios, these studies are performed on Blues, a 350-node, high-performance computing cluster at Argonne
- The list of critical assets resulting from the optimization modeling can be analyzed further by infrastructure impact models



OPTIMIZATION ALGORITHM TEST SYSTEM RESULTS





Results of the optimization algorithm for the test system of the California Independent System Operator interconnected with the Western Electricity Coordinating Council

CONCLUSION AND NEXT STEPS

- The optimization approach “turns black swans gray” (i.e., turns previously unpredictable events into ones that can be anticipated to a certain degree)
- Protecting critical infrastructure, especially in complex urban areas, should focus on identifying and prioritizing potential failure points that would have the most severe consequences
- Analysts can use results from optimization modeling to identify priority assets for in-depth security and resilience assessments and to inform investment decisions related to infrastructure protection and mitigation
- The optimization approach can be applied to a wide range of studies, including natural and man-made disruptions, as well as hazard-agnostic considerations
- Argonne is currently refining the optimization approach through the Resilient Infrastructure Initiative, which is funded through Laboratory-Directed Research and Development resources

THANK YOU!

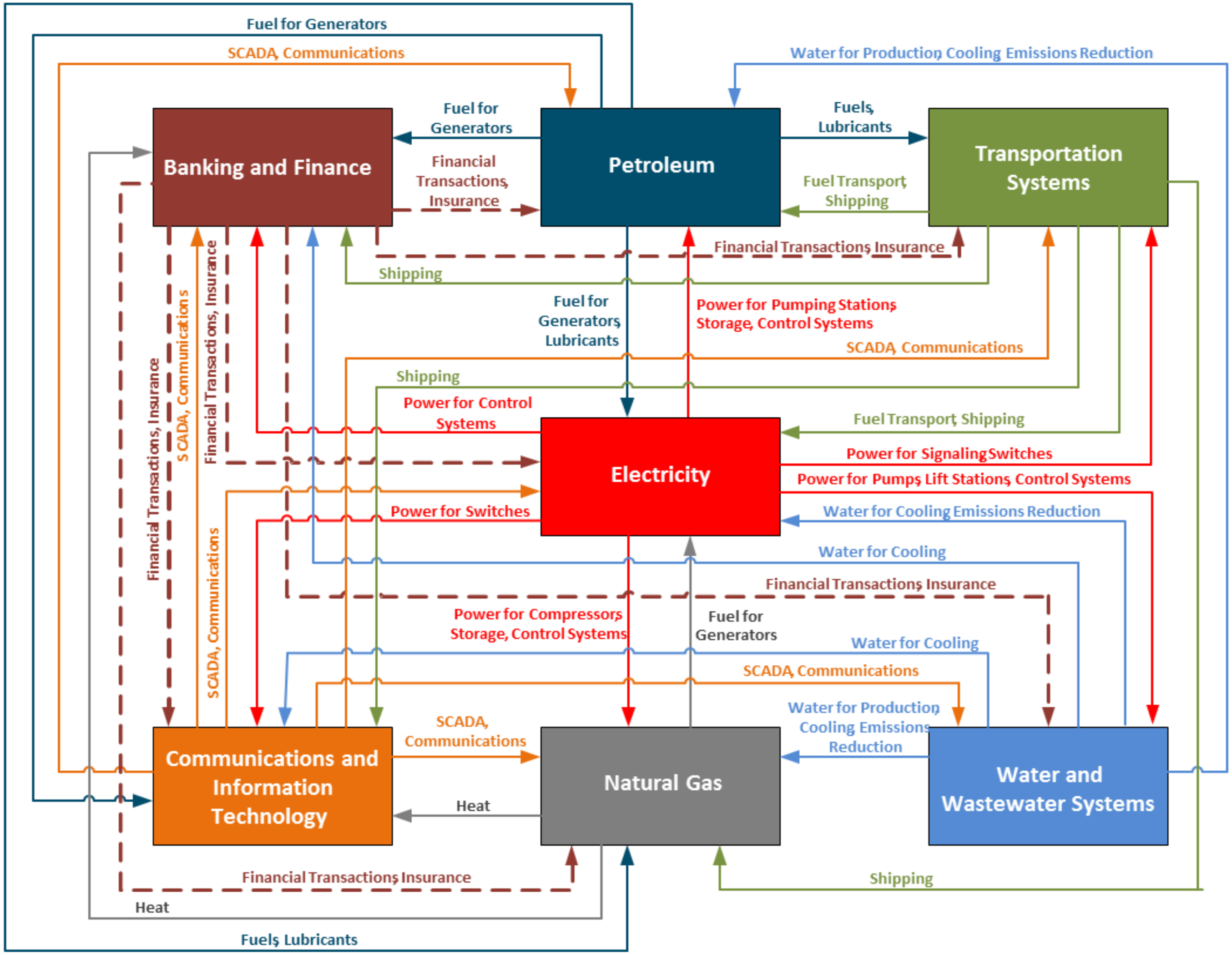
QUESTIONS?

Duane Verner	**Phone:** (919) 368-4908 **Email:** dverner@anl.gov
Kibaek Kim	**Phone:** (630) 252-4832 **Email:** kimk@anl.gov
Frédéric Petit	**Phone:** (630) 252-8718 **Email:** fpetit@anl.gov

Argonne NATIONAL LABORATORY

THE NEED FOR PRIORITIZATION

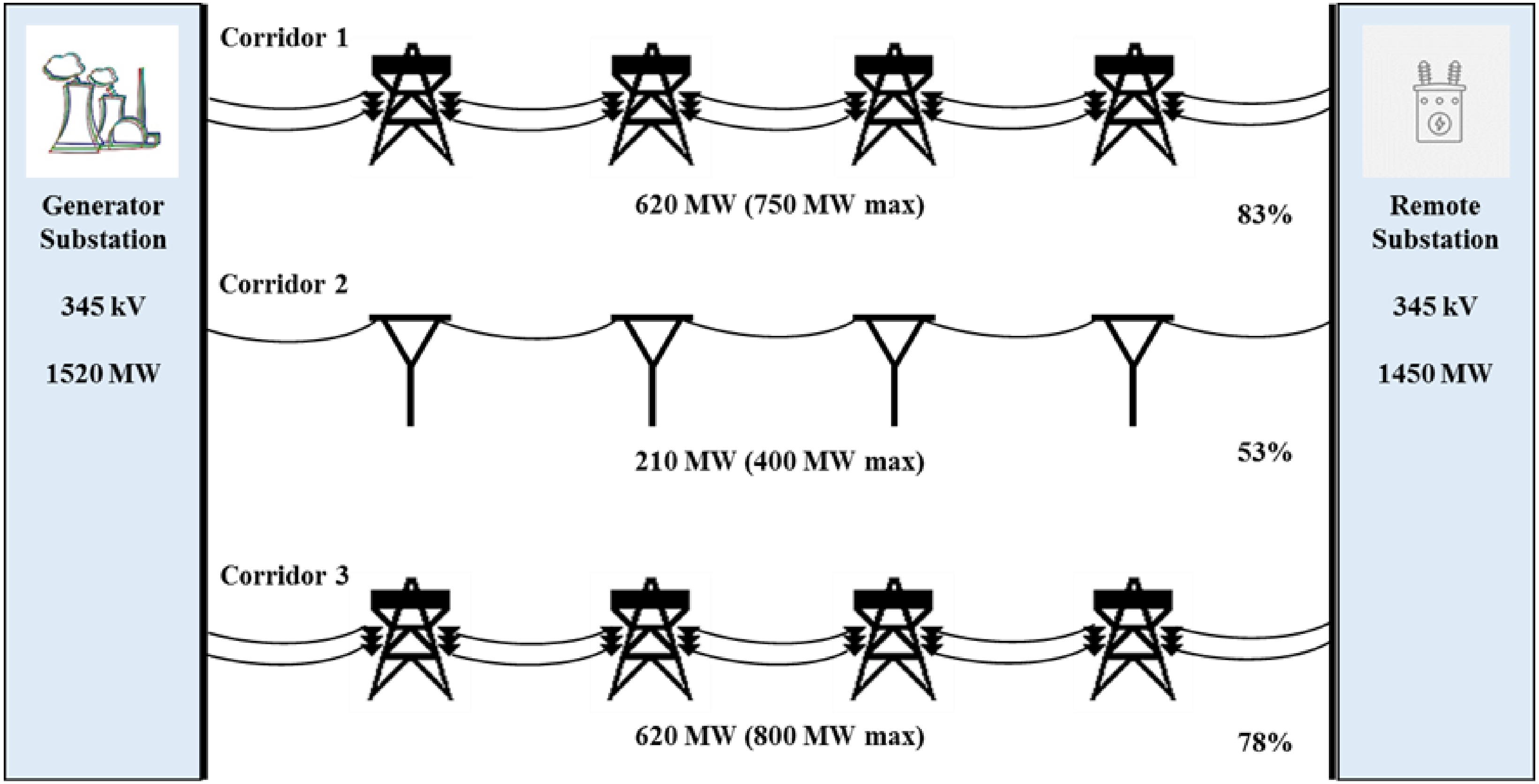
Critical infrastructure systems are complex and interdependent.



Argonne NATIONAL LABORATORY

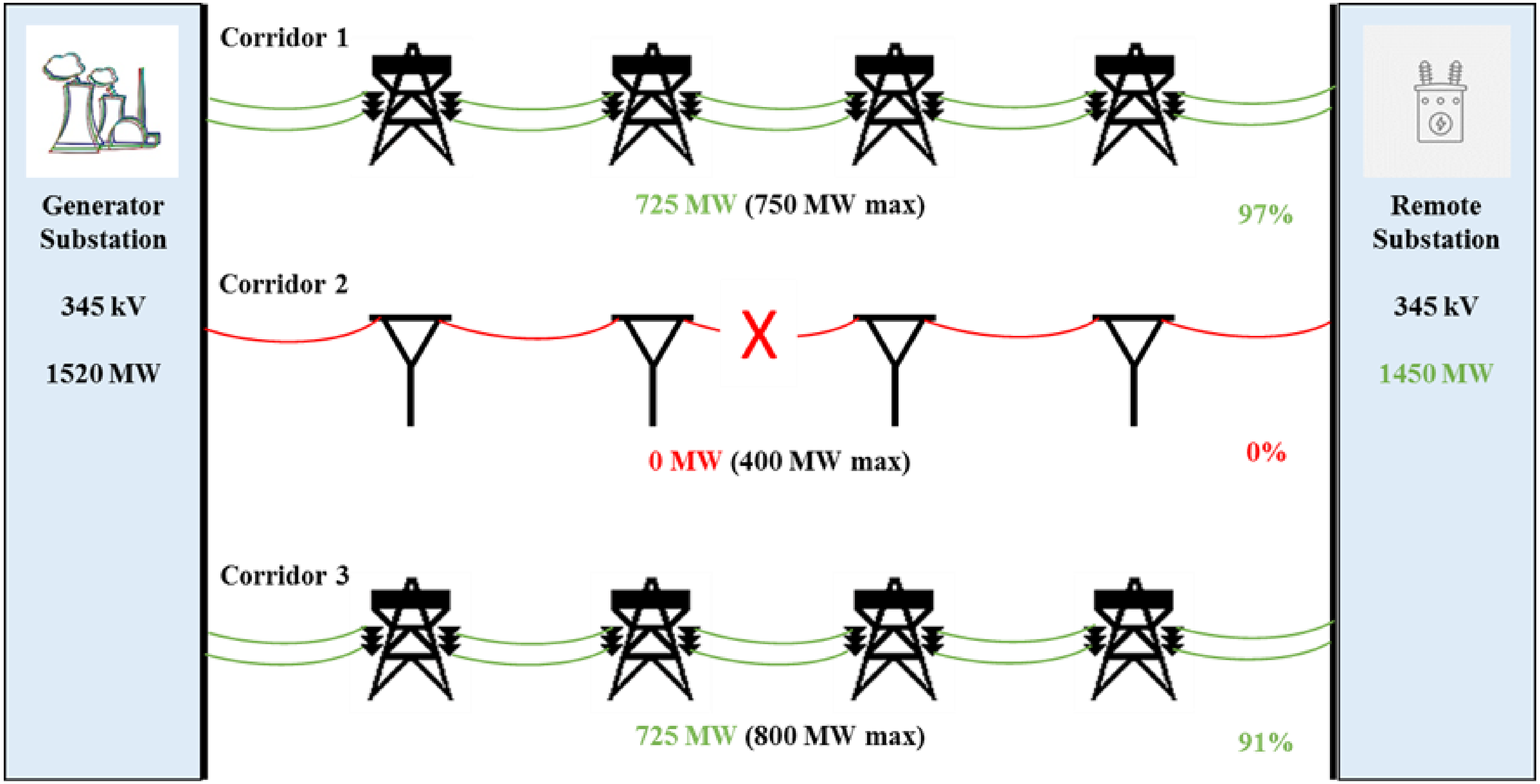
INFRASTRUCTURE FAILURES ARE NOT ALL CREATED EQUAL

Example of Electric Transmission Lines



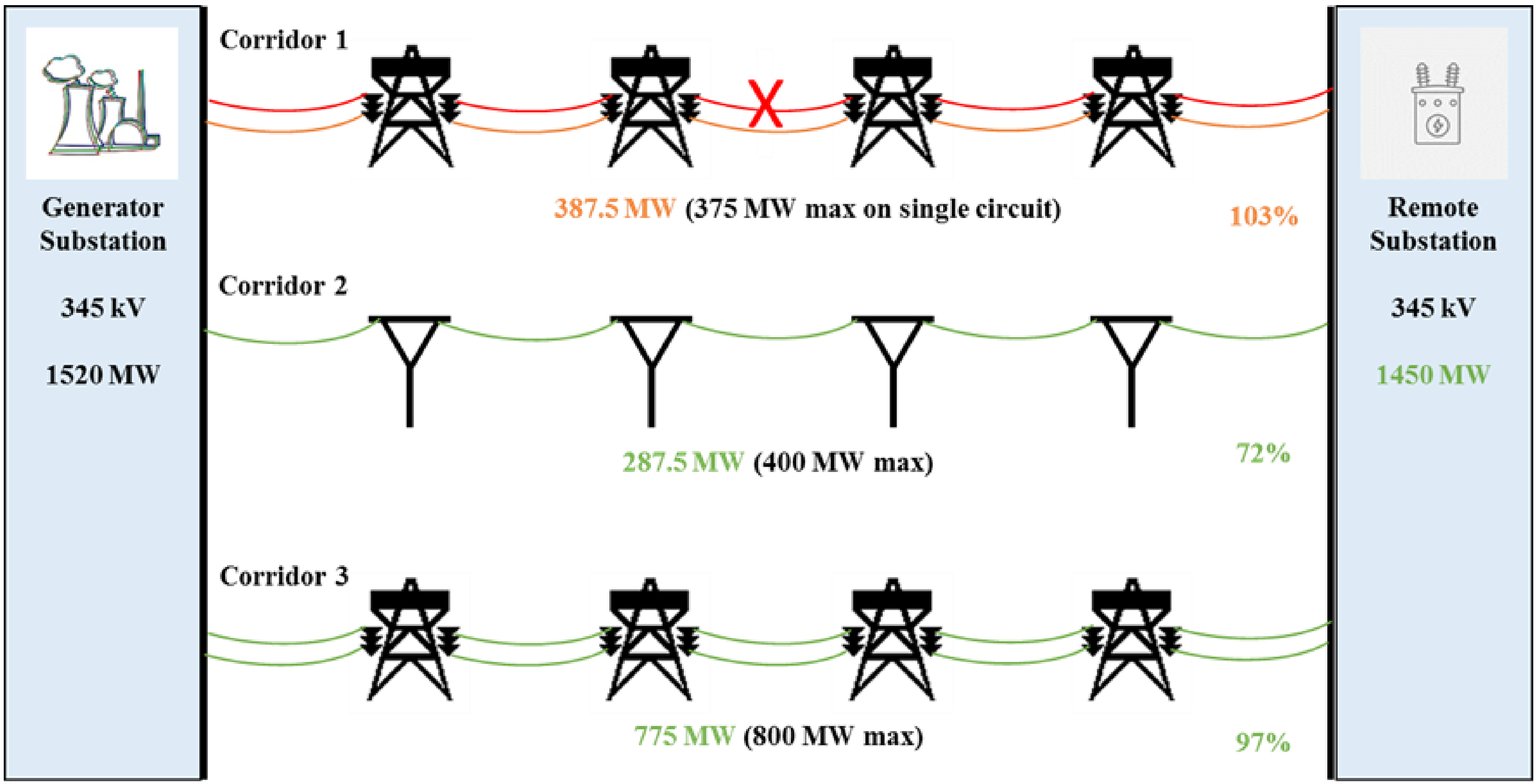
INFRASTRUCTURE FAILURES ARE NOT ALL CREATED EQUAL (CONT.)

Loss of Corridor 2 Circuit



INFRASTRUCTURE FAILURES ARE NOT ALL CREATED EQUAL (CONT.)

Loss of One Circuit in Corridor 1



Argonne NATIONAL LABORATORY

INFRASTRUCTURE FAILURES ARE NOT ALL CREATED EQUAL (CONT.)

Loss of Two Circuits in Corridor 1