U.S. DEPARTMENT OF ENERGY | OFFICE OF CYBERSECURITY, ENERGY SECURITY, AND EMERGENCY RESPONSE

# Optimal Grid Design for Cyber-Physical Resiliency

## Los Alamos National Laboratory (LANL)

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**Cybersecurity for Energy Delivery Systems Peer Review**

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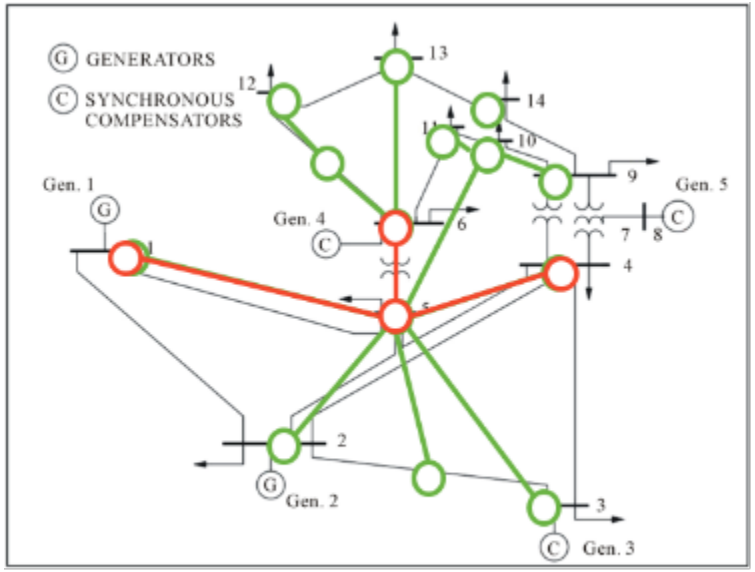
# Summary: Optimal Grid Design for Cyber-Physical Resiliency

## Objective

- Optimal placement of trust-worthy nodes and secure quantum links in order to minimize the impact of cyber-physical attacks on the power grid.

## Schedule

- 10/2017-10/2020
- Key deliverables and dates expected/met
- A design-support software tool that can help decision makers in adopting evidence-based investment strategies

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| **Total Value of Award:** | **$ 450K** |
| **Funds Expended to Date:** | **24%** |
| **Performer:** | **LANL** |

# Advancing the State of the Art (SOA)

- **Current SOA consists in linearizing power flow equations leading to weak approximations and sub-optimal investment decisions**
- **We will rely on exact mathematical models of the alternating current power flow equations proven to be sufficiently accurate**
- **We will implement realistic models on how the grid reacts to adversarial attacks**
- **Decision makers will have mathematical optimality guarantees when it comes to investing in building high-cost quantum channels and trustworthy nodes.**
- **With a flexible and reliable software tool that can optimize over the AC power flow equations, decision-makers can formulate and solve any decision-support problem.**

# Challenges to Success

## Build a scalable modeling tool for optimal grid design

- We are developing Gravity, an open-source, scalable modeling framework with state-of-the-art performance on AC power flow optimization.

## Understanding the interdependency between communication and physical layers

- Collaborating with SCADA experts to understand and model these interdependencies

## Formulating the underlying mathematical optimization models and designing scalable algorithms

- We have an initial formulation based on multi-stage mixed-integer nonlinear programming and initial solution techniques inspired by alternating attacker-defender algorithms.

# Progress to Date

## Major Accomplishments

- Literature review and first mathematical formulation
- Implementation of AC power flow models in Gravity
- Development of convex relaxations for AC power flow equations (needed to provide optimality guarantees)
- Connecting Gravity to state-of-the-art mathematical optimization solvers.

# Collaboration/Technology Transfer

## Plans to transfer technology/knowledge to end user

- Targeted end user: Investment Decision Makers in Grid Operators

- What are your plans to gain industry acceptance?
  - Compare our formulations with state-of-the-art power flow simulation tools, e.g., GridLAB-D
  - Reach out to industrial partners and test our algorithms on realistic data

# Next Steps for this Project

**Approach for the next year or to the end of project**

- Formulate the multi-stage attacker-defender problem in Gravity

- Develop scalable algorithms for solving the problem