SAND2019-7861D

Grid Stability Using Machine Learning State Space Navigation

Ross Guttromson, Stephen J. Verzi, Christian "Birk" Jones, Asael "Ace" Sorensen, Raymond "Ray" Byrne, Charles "Charlie" Hanley

Project Objective and Purpose

- During near blackout conditions, grid operators may have an opportunity to restore the system to a safe condition if a real-time decision support tool is available.
- This project investigates the development of a real-time decision support tool for that purpose.

Significance & Impact: Existing Planning and Operations

- In the infrequent occurrence when grid operations depart from planned criteria, how do we move to a 'good' operating point?

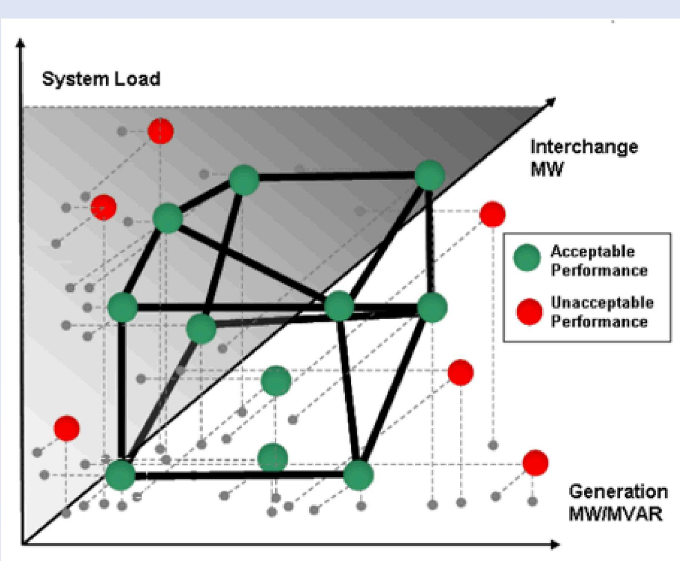
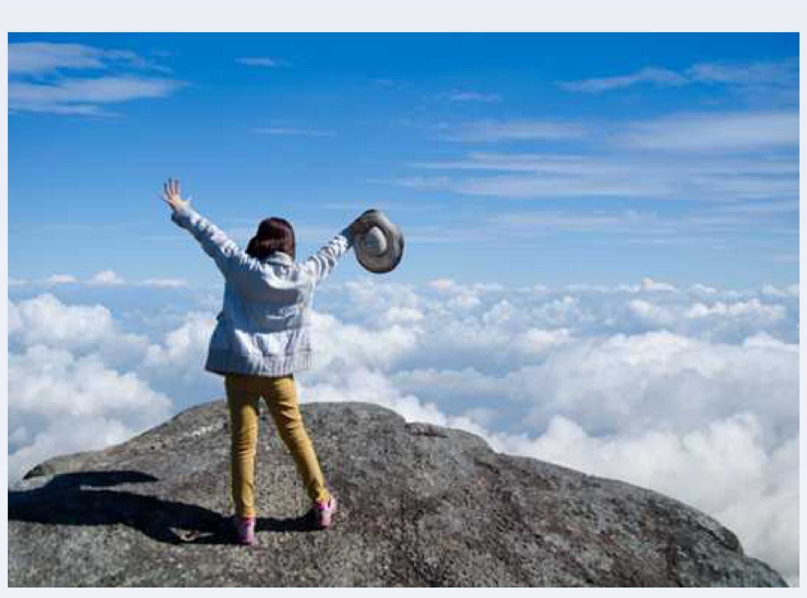


Figure 9 - "Scatter" plot of planning scenarios.

- Where are we? Where do we want to go? What path do we take?

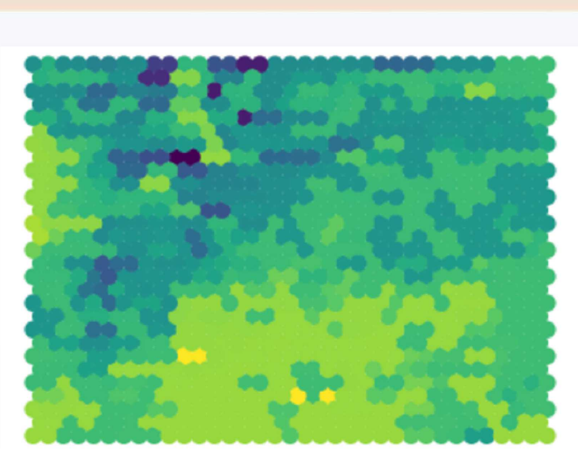
Significance & Impact: Metaphor For Stability Margin



Require "Stability" Margins of Interest

- Voltage Stability Margin
- Transient Stability Margin
- Non-Linear/Eigen-analysis Stability Margin
- System Voltage Margins
- Power Line Transfer Margins
- System Droop Margin

Technical Approach: State Space Visualization



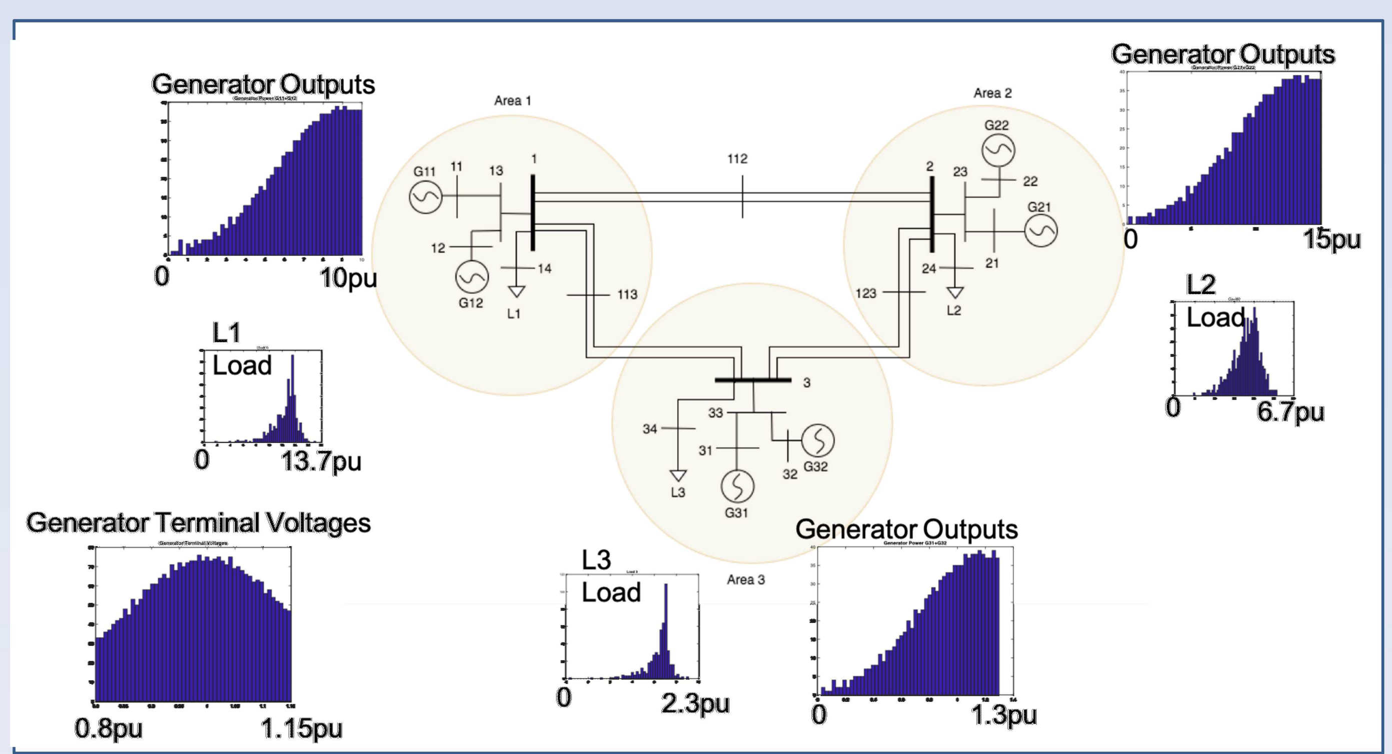
15-dimensional grid state data (1,001 precomputed points) flattened onto a 2D hex. Light yellow represents high stability scores, dark blue represents low stability. The plot shows spatial correlation and bounded stability regions, validating a machine learning approach!

Technical Approach: General Method

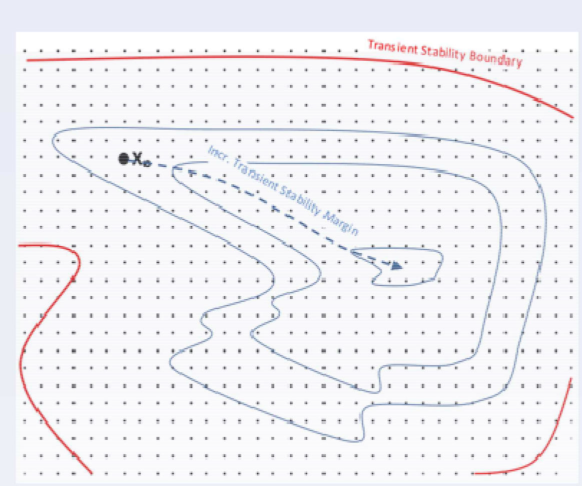
The solution method uses Deep Neural Networks combined with Monte Carlo Decision Trees to represent the sequence of control actions and dispatches needed for the grid to increase its stability margins.

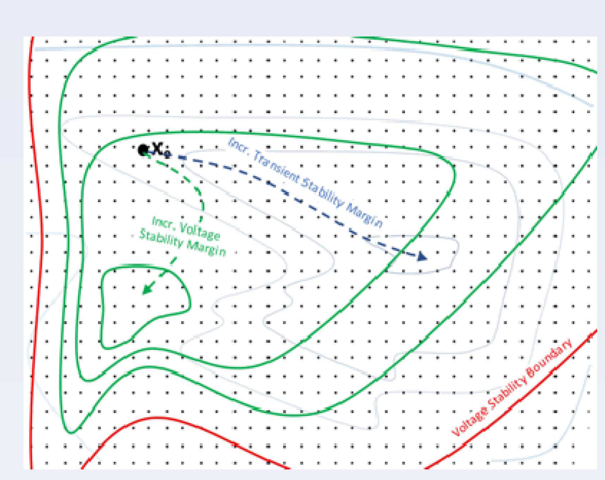
Our approach offers the potential of a speedy solution to this problem, with a low risk of non-convergence. The solution will not be proven optimal, although it will be demonstrated to be feasible and 'good' during off-line testing.

Technical Approach: Defining the State Space

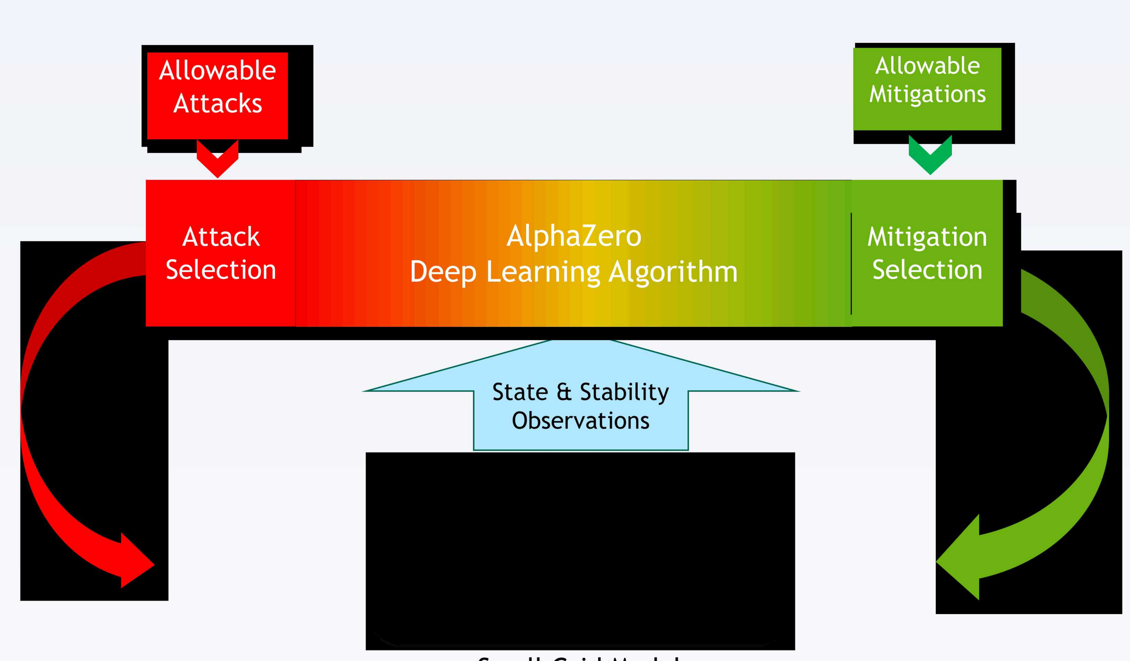


Technical Approach: Stability Margins


Transient Stability Level Curves


Transient Stability and Voltage Stability Level Curves

Technical Approach: Stability Margins

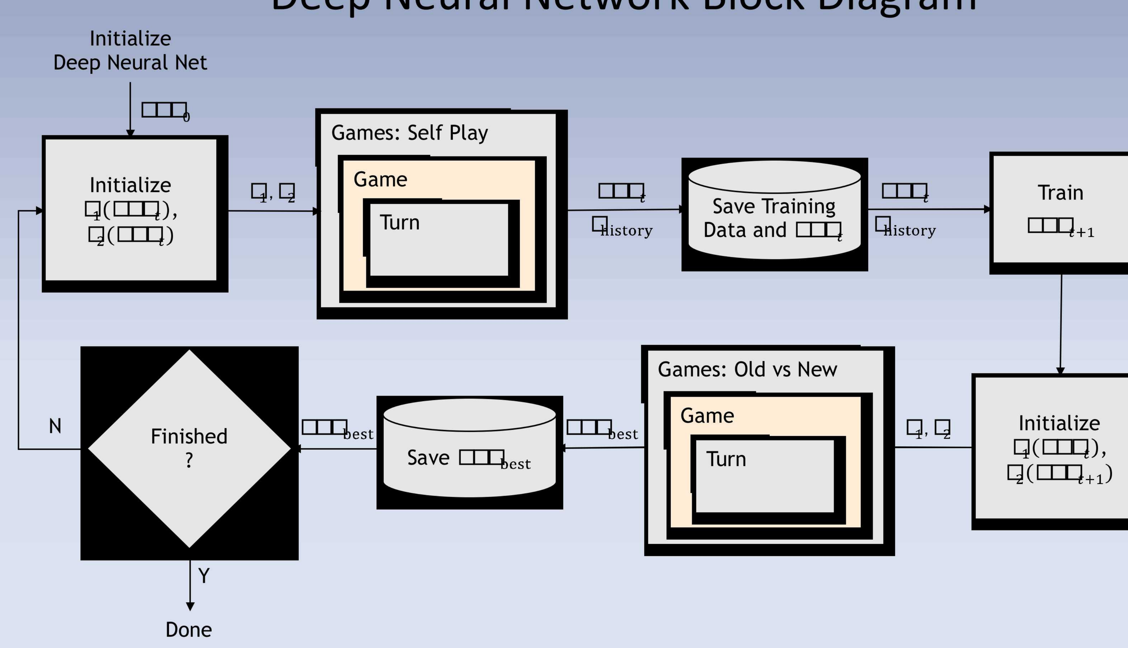


Reports and Publications

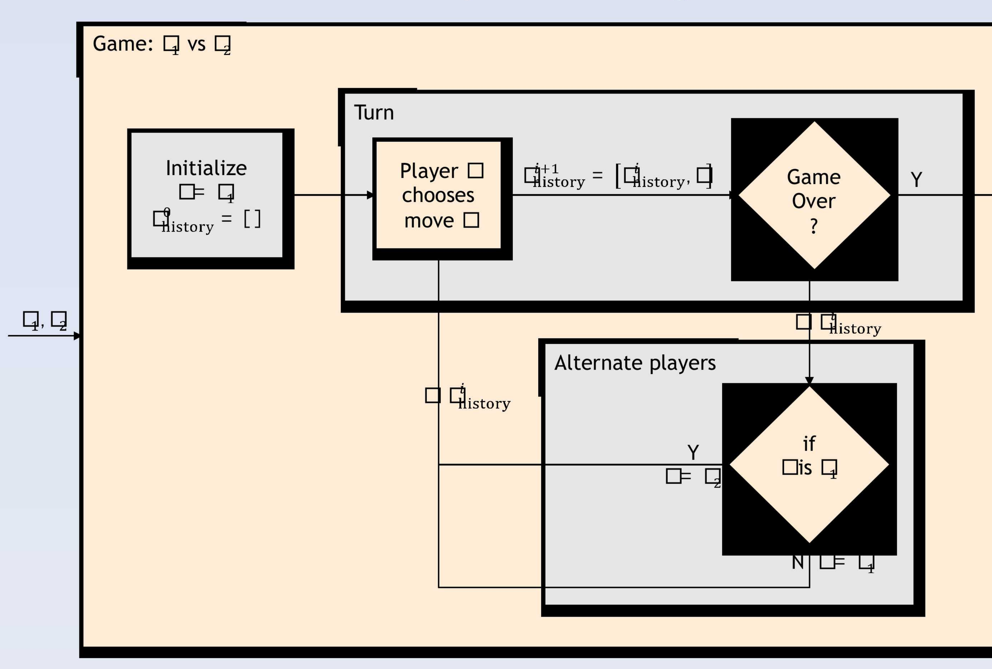
1. Guttromson, R., Verzi, S., Dawson, L., Levin, D., Melander, D., Sorensen, A., Cauthen, K., Wilches-Bernal, F., Berg, T., and Lavrova, O. (2018). "Integrated Cyber/Physical Grid Resiliency Modeling". Sandia Report, SAND2018-876234.

Technical Approach: AlphaGrid

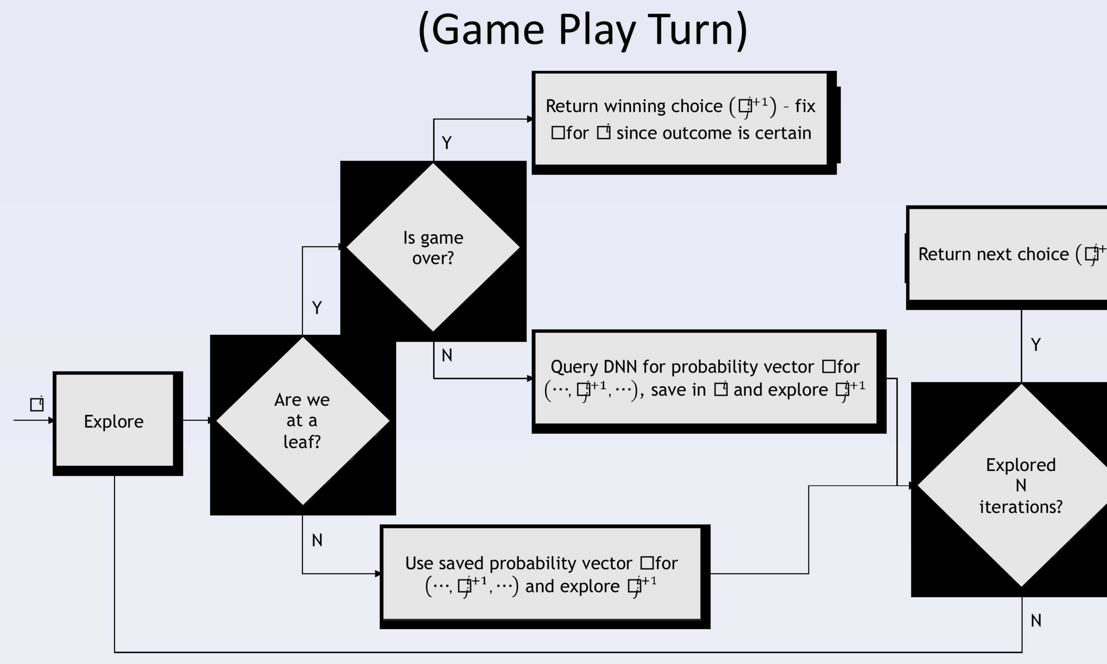
Deep Neural Network Block Diagram



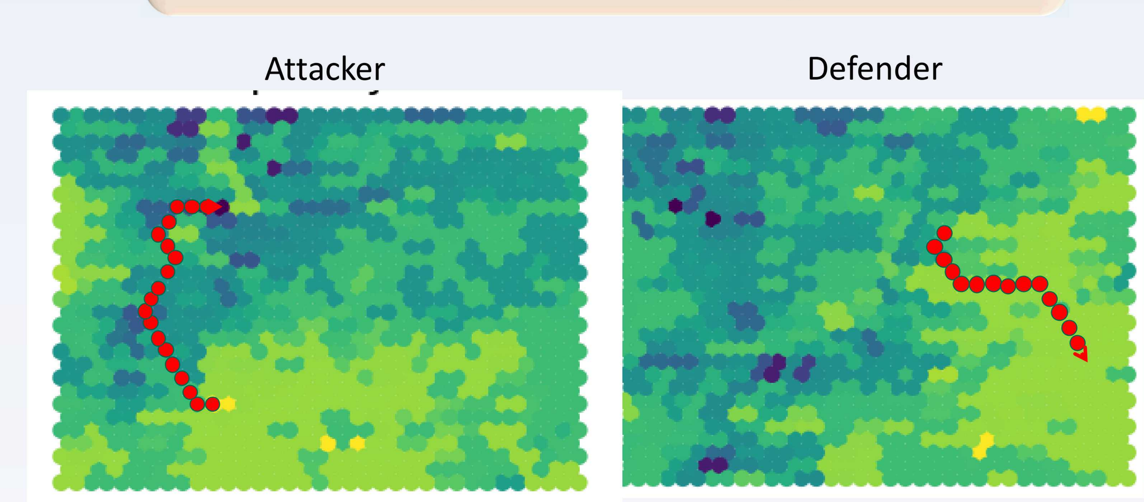
Game Play Block Diagram



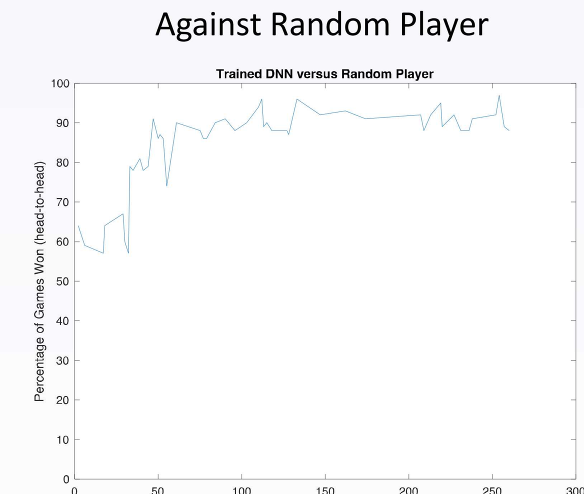
Monte Carlo Tree Search (MCTS) Block Diagram (Game Play Turn)

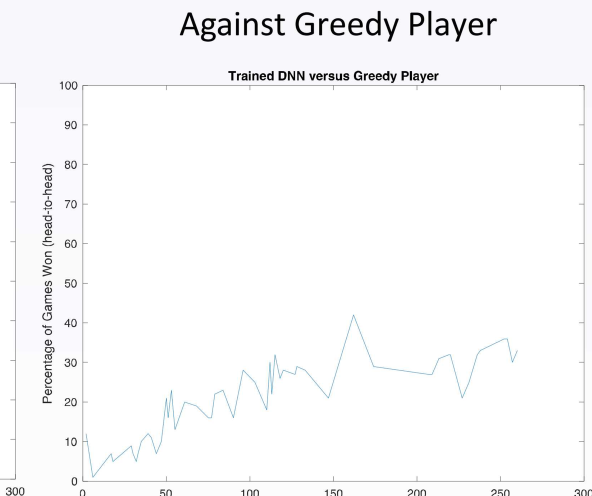


Technical Approach: State Space Navigation



AlphaGrid Preliminary Learning Results





Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND NO. SAND2019-XXXX C.