

# Large-Load Contingency Events Grid Simulator

Christopher Griffith, Abdallah Al-Rawahi, Antonio Zavala,  
Abdulaziz Alzahameel, Cris Mendoza Team 22 Mentor: Dr. Kory Hedman

## Problem Statement

- Hyperscale data centers introduce large, fast-changing electrical loads.
- Traditional grid analysis assumes predictable load behavior.
- Existing contingency analysis focuses on component failures (generation or line outages).
- Large load effects are not fully represented resulting in:
  - Underestimated system stress
  - Unclear frequency/voltage response
- There is a need for a clear and interactive representation of grid behavior

## Key Insights

- Large data center loads reduce system reserve margin
- Reduced margin means less ability to absorb disturbances
- Under normal conditions:
  - System remains stable (N-1 secure)
- Large data center loads addition:
  - Same events become more severe
- Greater impact:
  - Increased frequency deviations
  - Increased voltage instability
  - Higher risk of load shedding
- Large loads can turn local events into system wide disturbances

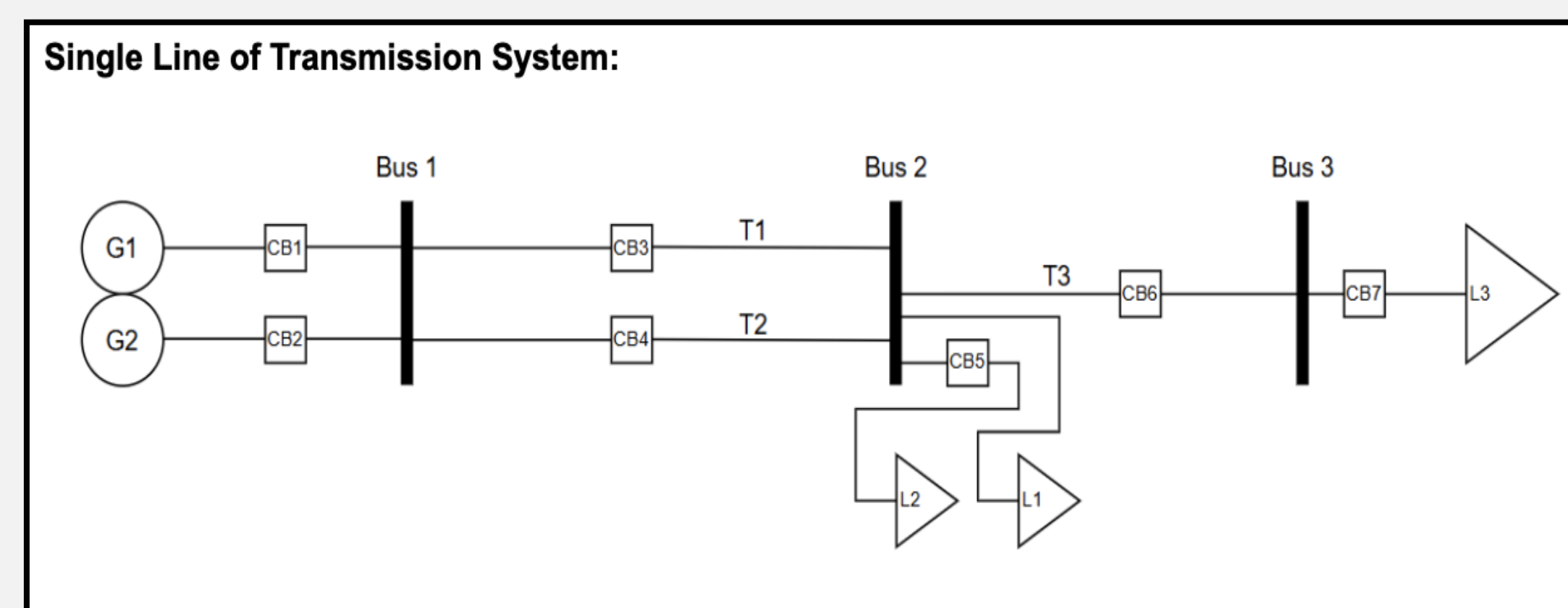
## Contingency Scenarios

Scenario	Description
Base Case	Normal operation with all components active
Generator Trip with Load	Loss of one generator (reduced generation capacity) with a large overall load demand.
Generator Trip no Load	Loss of one generator (reduced generation capacity) with less overall load demand.
Line Trip	Transmission line outage affecting power flow
Data Center Gain of Load	Rapid increase in load stress on the system
Data Center Loss of Load	Rapid decrease in load stress on system

## System Overview

A simplified 3-bus transmission system was developed

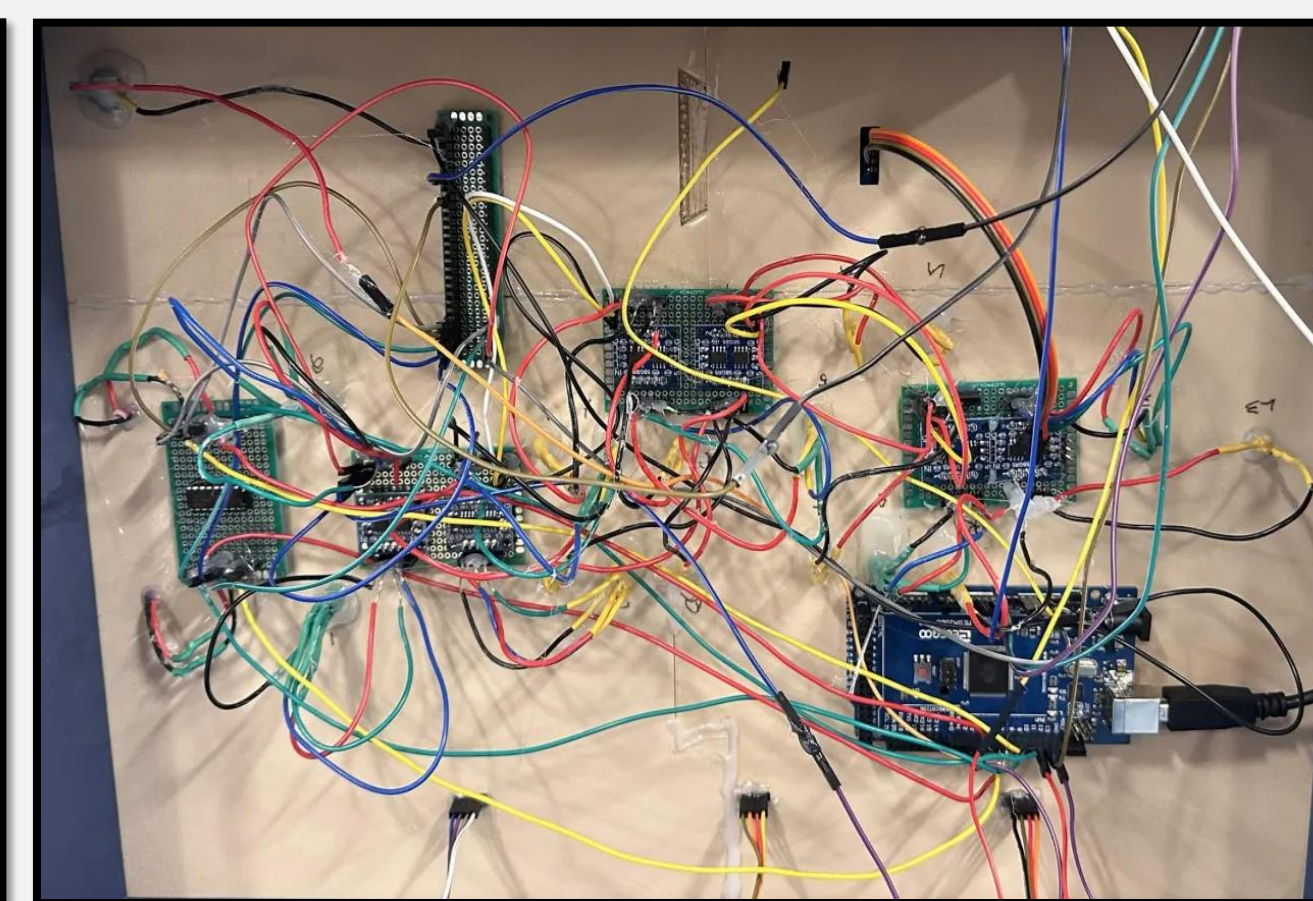
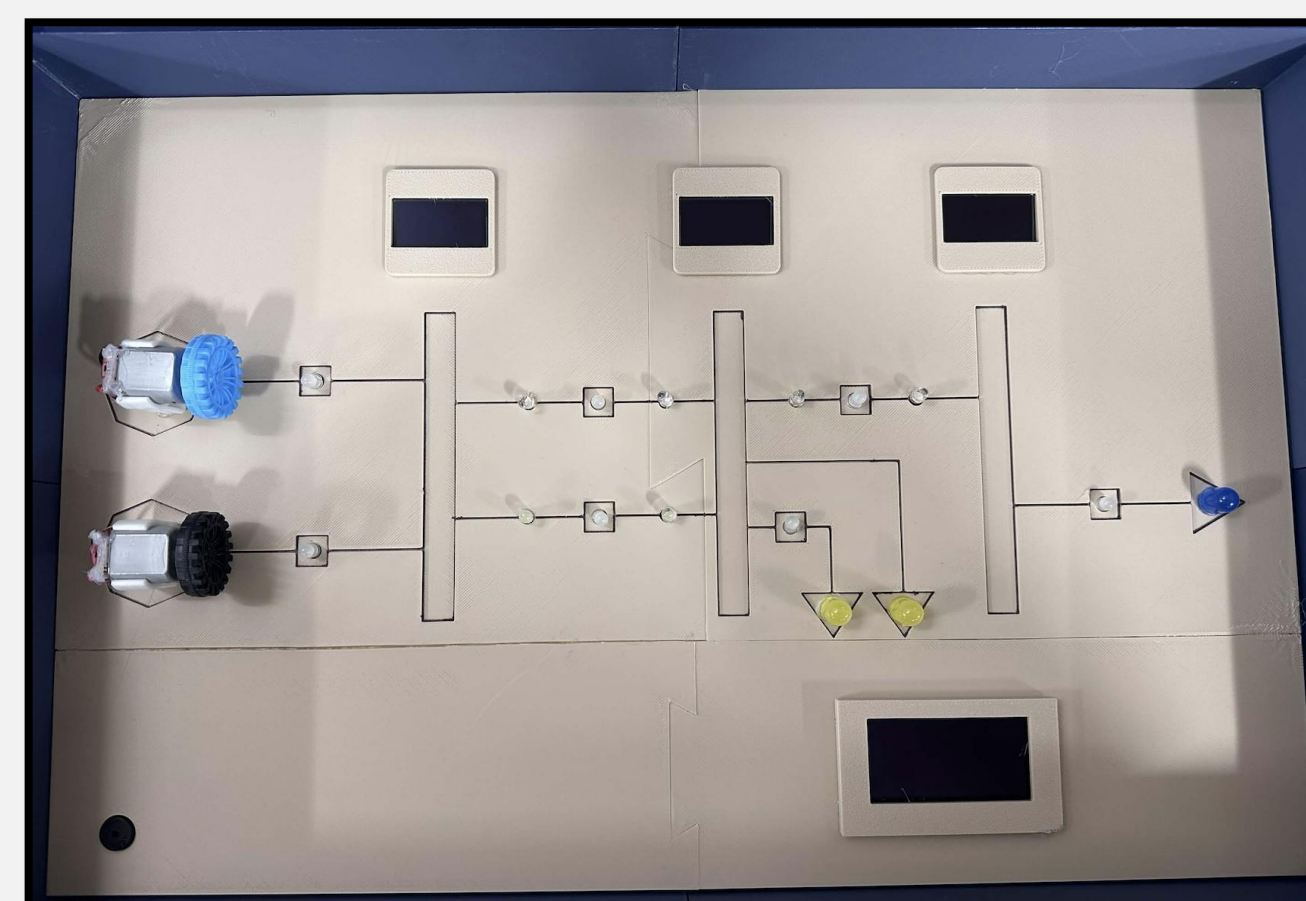
- Bus 1: Generation (two generators)
- Bus 2: Traditional load
- Bus 3: Data center load
- The system models how power flows and responds to disturbances
- Users can interact with the system to simulate grid events



## Prototype Design

An Arduino-based prototype was developed to simulate system behavior

- Two generators are represented using motor-driven outputs
- Push buttons allow users to trigger contingency events
- RGB LEDs represent circuit breakers and system states
- Multiple OLED displays provide real-time system information
- The prototype provides a visual and interactive way to understand grid behavior

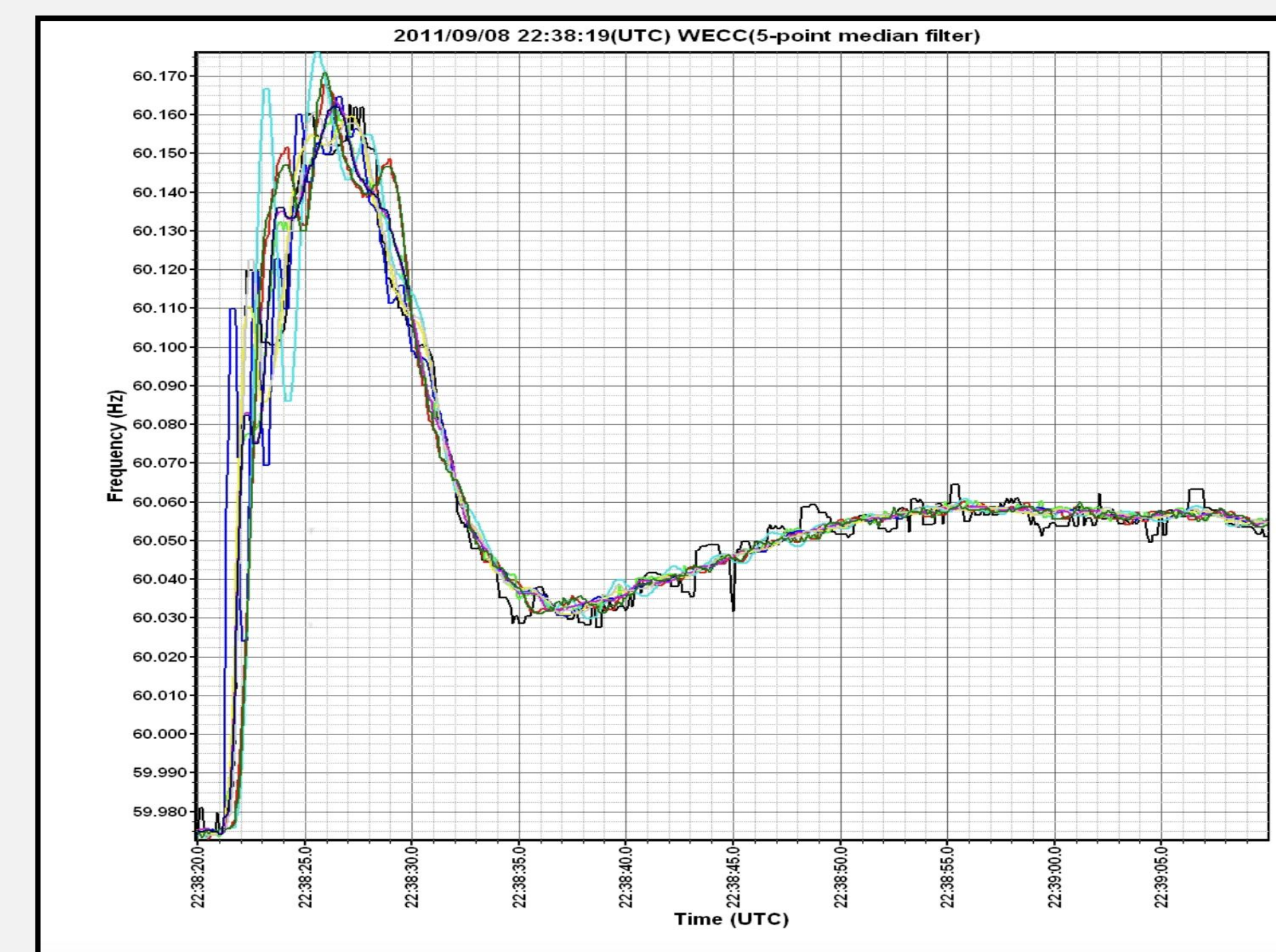


## Southwest Blackout 2011

The 2011 Southwest Blackout affected approximately 2.7 million customers leaving over 1.5 million without power and began with a single 500kV transmission line outage.

The resulting disturbance propagated across the grid, illustrating how power systems can experience cascading failures under stressed conditions.

As modern grids incorporate large, fast-changing large loads such as data centers, these disturbances can become more severe, highlighting the importance of contingency analysis.



Frequency response during the 2011 Southwest blackout (FNET/GridEye data, University of Tennessee).

## Conclusion

- A functional, interactive transmission system simulator was developed
- The prototype demonstrates how large loads impact grid reliability
- The system provides a clear and visual understanding of contingency behavior
- There is a need for new updated standards to regulate large load contingency events on the transmission grid