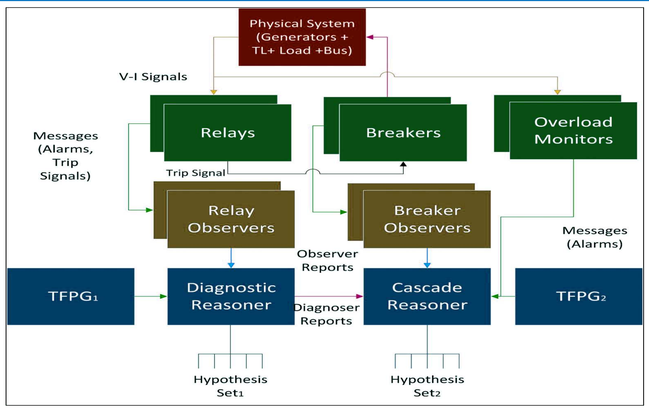
Diagnostics and Prognostics for the Electric Grid Using Temporal Causal Models

Rishabh Jain, Srdjan Lukic, NC State University, NC
Abhishek Dubey, Gabor Karsai, Vanderbilt University, TN

Award CNS:1329803

Objective:

- Develop a tool called 'Reasoner' to utilize the temporal and causal relationships between the power system events to diagnose potential operations, and prognose possible cascaded failures.
- Expand the Reasoner as a real-time reference for operators to assist on-field decision making for day-to-day operations, and training.



Motivation:

- Cascaded failures historically have human error and lack of coordination as one of the contributing factors. With increasing grid interconnectivity, it is increasingly difficult to monitor all nodes of grid and relate events between two different sections of the operating region.
- Need of a assisting tool with presence in the system to form reasonable hypothesis for potential misoperations and successive failures to assist with decision making and minimizing the risk of failure.

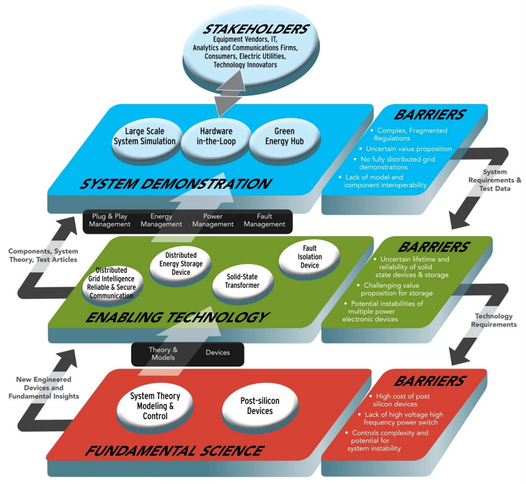


Fig: System Architecture

Technical Approach:

Temporal Causal Diagrams (TCD)

Composed of

1) 'Timed Failure Propagation Graphs' to capture the faults in network and effects across the system
2) 'Timed Discrete Event Models' of the system components which arrest the propagation of fault in a network.

Hierarchical Reasoning

Use of external simulators to refine system level hypothesis

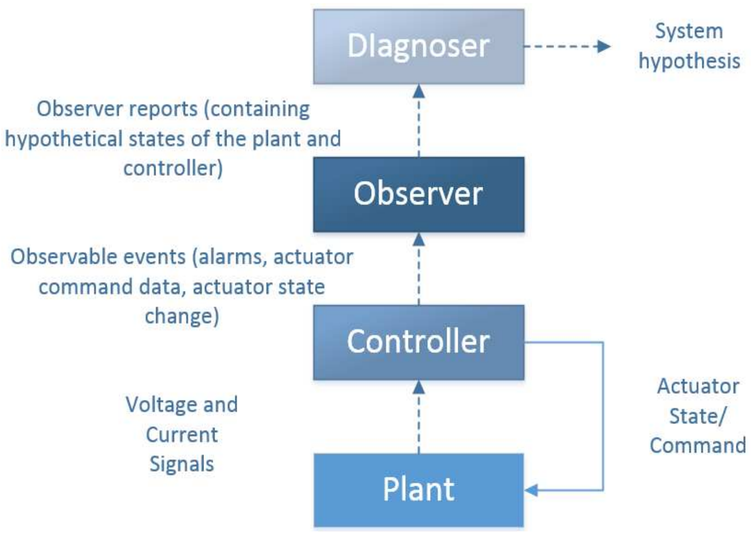
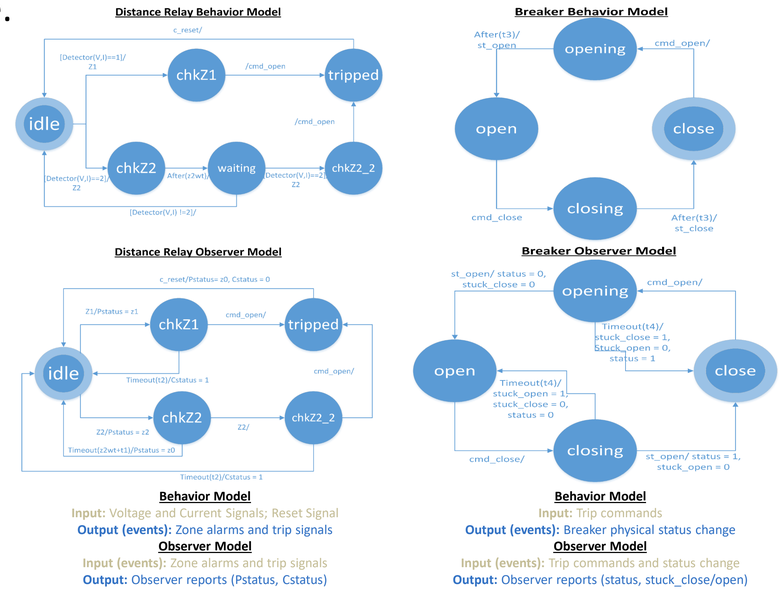
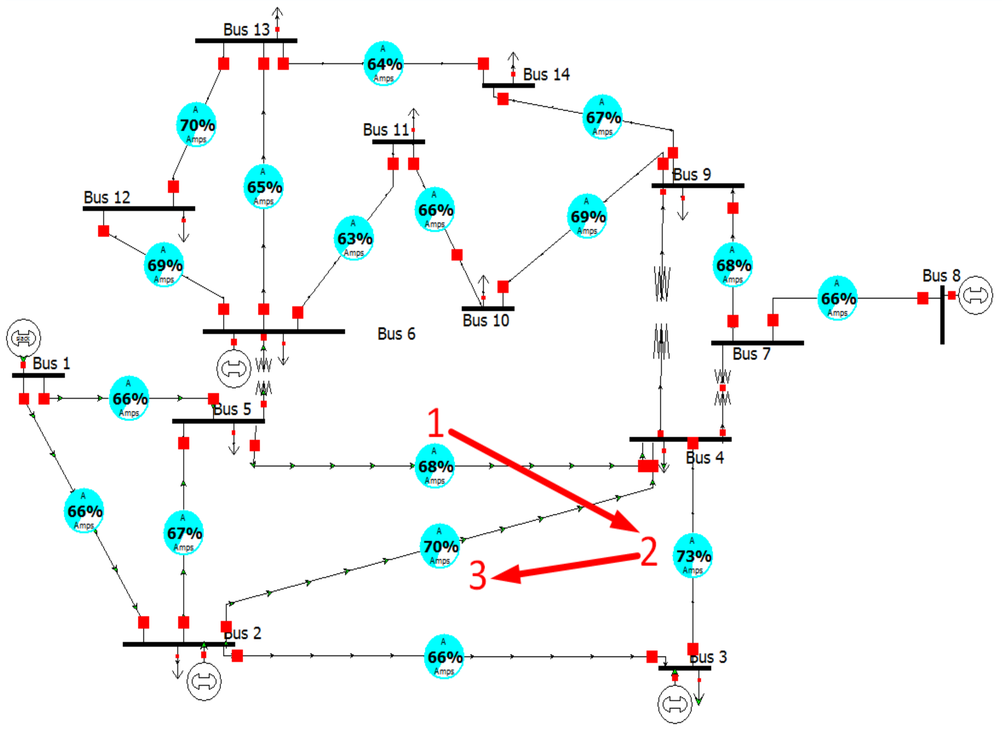


Fig: Heirarchical Reasoning

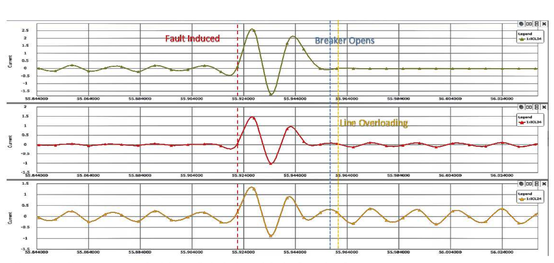


Case Study – IEEE 14 Bus System

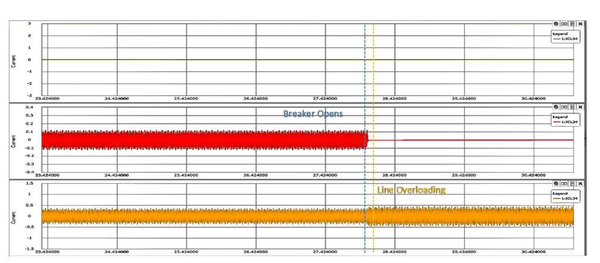


- E1: Fault in Line TL5_4
- E2: Distance Relays trip and isolate the line L5_4
- E3: Power redistribution; Overload in line TL3_4
- E4: Distance Relay for line TL3_4 trips due to load encroachment
- E5: Power redistribution; Lines L2_4 and L6_11 experience overload.
- E6: Inadequate Zone 2 settings for relays attached to L2_4 forces a misoperation.
- E7: Blackout

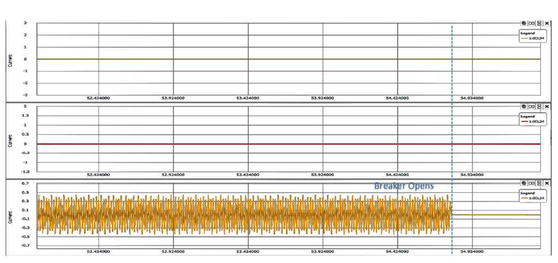
Simulation and Diagnosis Results



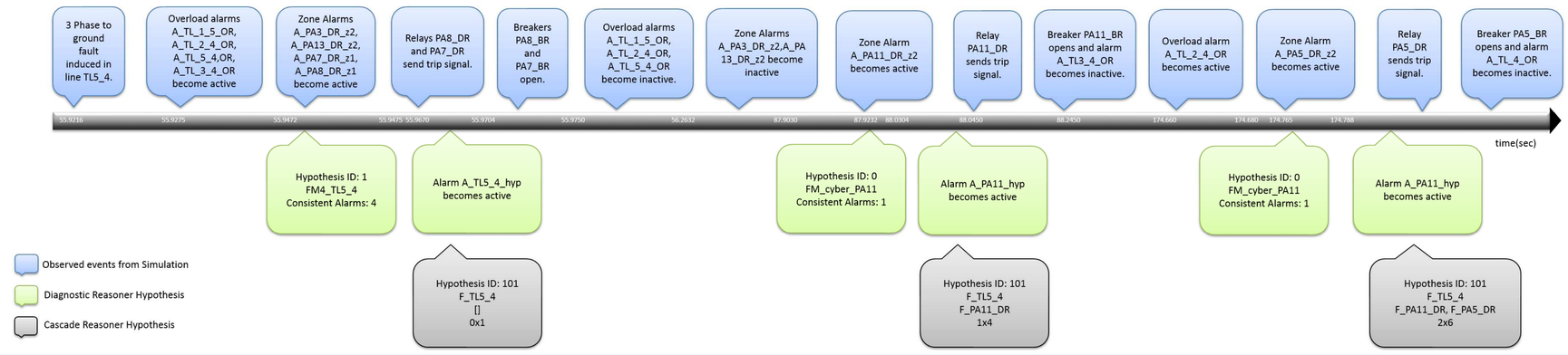
Surge in line currents in Lines 5-4, 3-4 and 2-4 after the fault at t = 55.9216 sec



Overloading of Line 3-4 after Line 5-4 is isolated, and leads to misoperation at t = 88.045 sec



Overloading of Line 2-4 after Line 3-4 tripped, and leads to misoperation @ t = 174.788sec



Accomplishments:

- Modeling use cases for a cascade scenario for IEEE 14 Bus system, and faults followed by relay mis-operation.
- Development of accurate Reasoners and appropriate observers to test against the above use cases
- Successful demo presenting 1) The fault scenarios and Cascade failures with corresponding relay operations as observed from the system using the Real Time Digital Simulator, 2) Observing the same scenarios from Reasoner's perspective:

✓ System level Reasoner was able to identify relay misoperation, and prognose next possible failures.

Next Steps:

- Develop algorithms for hierarchical reasoning and techniques for integration with exogenous reasoners.
- Integrate exogenous reasoners using the hierarchical architecture.
- Refine prognostic techniques, design algorithms, and evaluate performance.
- Develop TCD component models of common smart grid transmission system.