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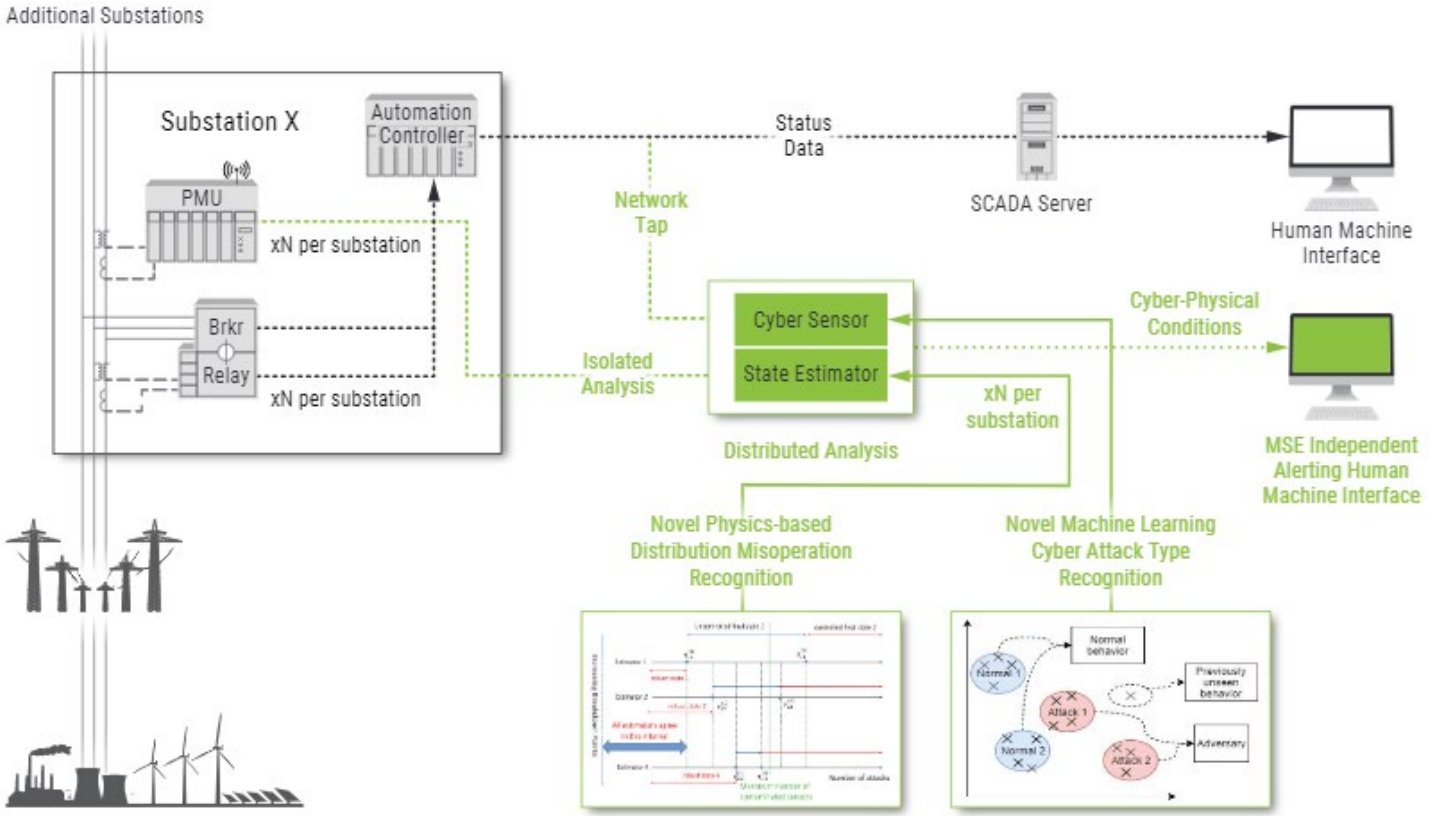
July 13, 2022

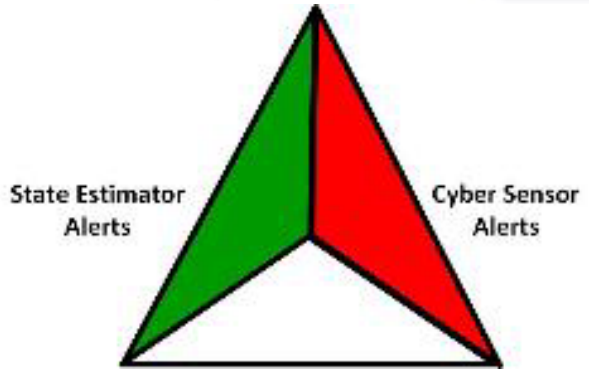
Master State-awareness Estimator (MSE)

Idaho National Laboratory

MSE Detailed View

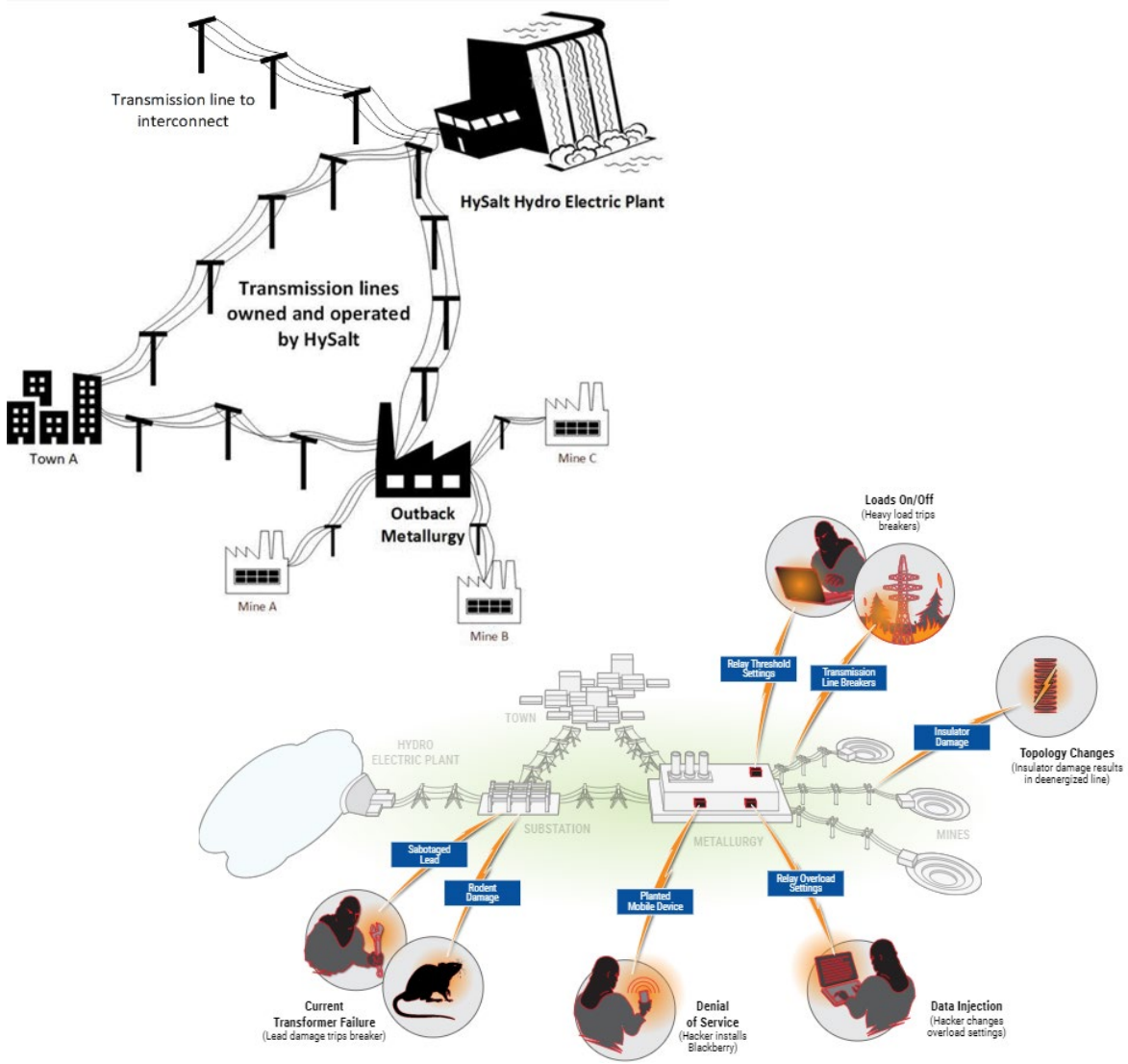
- **Cyber-Physical Integrated Analysis**
  - Independently evaluates cyber and physical information, through network and state estimation analyses
  - Sits on a network that is out of band from substation
  - Network analysis passively monitors isolated network, in addition to substation network, baselining normal traffic
  - State estimation analysis collects information out of band from phasor management units (PMUs)
- **Response**
  - Informs human machine interface (HMI) of bogus state and root cause of issue
    - The triad flashes red relative to recognized cyber sensor or state estimator alert
    - Prevents operator and device-initiated cascading failures through phased approach





Cyber-Physical Scenario Relevance

- HySalt Energy (HE) is a major power company that works in the generation and transmission across several parts of the national grid.
- As a result of their responsibilities, HE employees have direct access to several critical assets, including protection and control system devices.
- Cyber scenarios could entail a disgruntled employee, such as the engineer who programs their protection coordination devices but is declined continued employment.
- Physical scenarios could entail transmission line faults or nefarious manipulation of a substation equipment. The initiator of the physical scenarios could entail a forest fire near the transmission lines.

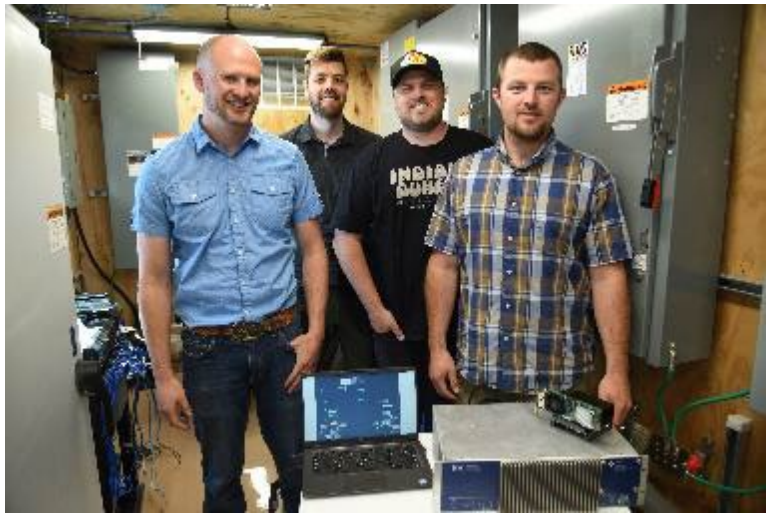


Cyber Test Scenarios

- **Detect data injection attack**
  - A successful log in to the relay at a level high enough to implement a settings change, change the CT ratio settings, then the MSE will be tested to verify it can sense a settings change.
  - A successful test will show that the MSE anomaly sensor detected the settings change.
- **Detect failed log in attempt**
  - The anomaly sensor will build a system baseline and understand what ‘normal’ looks like.
  - Once the MSE anomaly detection device is running, a log in with incorrect passwords will be attempted.
  - The test will be a success if the anomaly detection device detects the failed log in.
- **Detect denial of service (DOS) attack**
  - Once the MSE anomaly detection device is running a DOS test will commence using cyber flooding tools.
  - This will overload the communication to and from the protection device, verifying the MSE anomaly sensor is able to detect as a minimum, the creation of an abnormal traffic latency.
  - The test will be a success when a latency is noticed by the MSE algorithm. The anomaly detections system will also be able to notice a change of network traffic and report an error.

Physical Test Scenarios

- **Test the accuracy of the MSE estimator to detect emulated false data attack**
  - Adjust the current transformer ratio settings on a protective relay device such that it is producing inconsistent measurements.
  - A successful test will be the MSE sending an alert because the relay is consistently sending faulty data, based on the surrounding PMU monitoring devices.
- **Test the accuracy of the MSE at tracking system load/generation changes and resulting system state**
  - Implement change in load – switch load off-line or on-line.
  - The resulting change will cause voltage magnitudes and angle to change as well as power flows.
  - State estimator should correctly track these changes.
- **Demonstrate the ability to sense large changes in topology**
  - A recloser will be opened, changing system topology from a loop to two radials feeders. The MSE will monitor PMU data. The recloser will be closed to restore a loop.
  - The MSE should see a change in the flow of power above a detection threshold based on the PMU and signal an alert that the topology has changed.



Cyber Scenario Demonstrations

(Linked Demonstration Video)

Physical Scenario Demonstrations

(Linked Demonstration Video)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