Attack Graph Based Metrics for Identifying Critical Cyber Assets in Electric Grid Infrastructure

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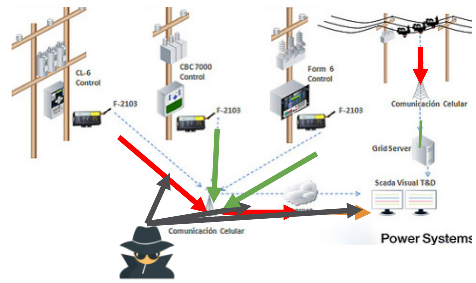
INTRODUCTION

Motivation:

Security metrics for assessing reliability and monitoring the risk to the cyber-physical power grid infrastructure are necessary in order to ascertain the impact of events such as cascading failures as well as identifying investments.

Goals of Security Metrics:

- Evaluating a portfolio of security configurations, controls, reliability of the operations in real-time
- Prioritizing critical assets
- Prioritizing efforts to secure critical assets
- Describing potential cyber-physical vulnerability

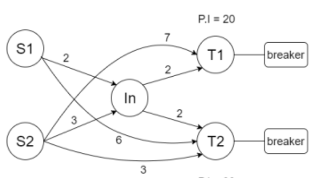


CHALLENGES

- **Data Availability**: Lack of the interconnections information between cyber and electrical topologies (control devices e.g., relays).
- **Scalability**: gathering and analyzing data in real-time.
- **Prioritization**: Considering all threat factors and prioritizing operations for risk mitigation.

PROPOSED METRICS

An attack graph is a graph representation that captures potential attack paths leading to specific threats to a given system.



$$M.T.S.I_t(i) = P.I_i * \frac{1}{\min\limits_{j\in S}(C_{min_{ji}})} = 20 * \left(\frac{1}{2+2}\right)$$

$$T.S.I = \sum_{i\in T} M.T.S.I_t(i)$$

Figure 1. Attack Graph and Security Indexes Examples

Attack Cost (*C*): Cost of exploitations of series of vulnerability from source node to a desired target node. This measure evaluates the chance of a potential threat.

Attack Impacts: The physical impact (*PI*) of a cyber attack on the electrical network.

1. **Target Nodes/Assets Metrics:**
   - M1: Min-Cost Target Node Security Index
   - M2: Target Node Security Index
2. **Stepping Stone Node Metrics:**
   - M3: Intermediate Node Min-Cost Betweenness Security Index
   - M4: Intermediate Node Betweenness Security Index
3. **Source Node Metrics:**
   - M5: Min-Cost Source Node Security Index
   - M6: Source Node Security Index
4. **Overall Security Metrics:**
   - M7: Total Security Index

ILLUSTRATION of CYBER-PHYSICAL VULNERABILITY

Q1: How do we determine critical assets from PHYSICAL perspective?

A1: N-1-1 simulations.

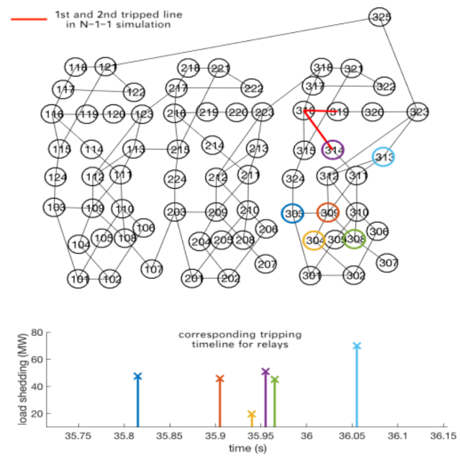


Figure 2. An example of N-1-1 simulation results fo RTS-96

Q2: How we determine critical assets from CYBER perspective?

A2: Proposed Security Metrics.

Description	Contingency	Load shed	Reach-ability Index	T.S.I
Line fault 1	line 103-124	47.25MW load shedding (LS)	0.8265	39.0521
Line fault 2	line 303-324	47.25MW LS	0.7624	36.0234
Line fault 3	line 207-208	45MW LS 1 generator and 1 load partitioned	0.8265	37.1925
Line fault 4	line 307-308	45MW LS 1 generator and 1 load partitioned	0.8265	37.1925
Line combo 1	line 119-120, 120-123, 118-121	0	1.5688	0
Line combo 2	line 108-110, 207-208, 307-308, 115-121, 215-221, 315-321	90MW LS; 2 generators and 2 loads partitioned	4.2357	381.213

Table 1. Prioritization of contingencies by applying security metrics for RTS-96

LIMITATIONS

- We currently have access to synthetic data. Real datasets are not available or frequently do not include all possible cyber-physical attack side-effect information.
- The security indexes values themselves do not have inherent meaning and just help us to prioritize cyber-security tasks in a specific system.

FUTURE WORKS

- Create an automatic approach to implementing the cyber-physical model for a larger utility case.
- Quantify the security metrics.
- Find an industry partner to validate the metrics against realistic scenarios.

REFERENCES

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