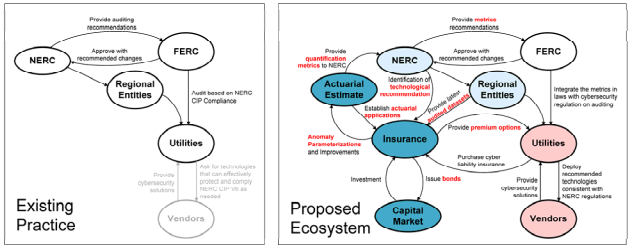
CPS: Medium: Collaborative Research: An Actuarial Framework of Cyber Risk Management for Power Grids

Investigators: **Chee-Wooi Ten (PI) and Yeonwoo Rho (Co-PI)**

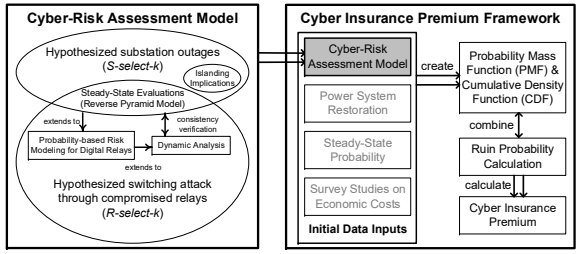
Profs. Ten and Rho ({ten, yrho}@mtu.edu) are with Department of Electrical and Computer Engineering and Mathematical Sciences, Michigan Technological University, Houghton, MI 49931

Investigators: **Lingfeng Wang (PI) and Wei Wei (Co-PI)**

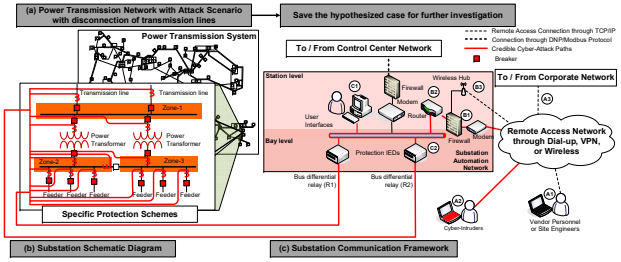
Profs. Wang and Wei ({wang289, weiw}@uwm.edu) are with Department of Electrical Engineering and Computer Science and Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53211



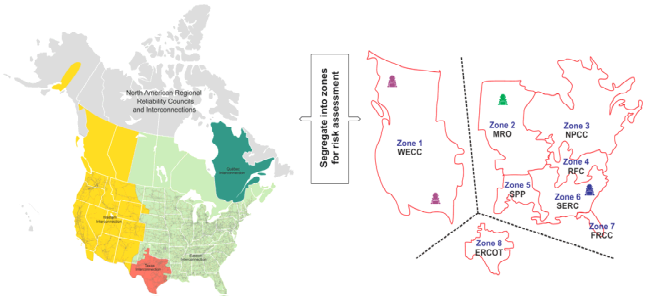
(1) Evolving ecosystem with insurance technological incentive



(2) Establishment of insurance framework



(3) Extraction of security events and logs as evidence of assessment during audit process



(4) Interconnection risk corresponding to each zone and individual utility asset owners

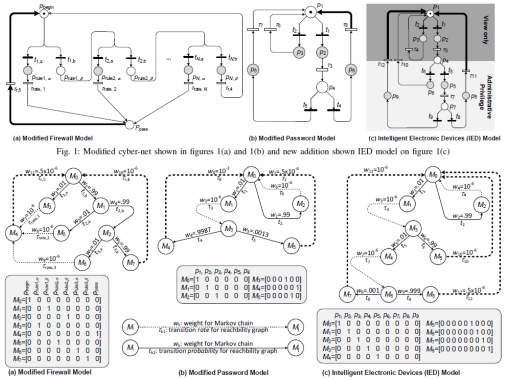
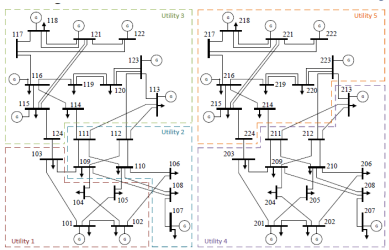


Fig. 1: Modified cyber-net shown in figures 1(a) and 1(b) and new addition shown IED model on figure 1(c)

(5) Reachability graph corresponding to each security technology.



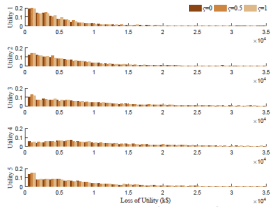
IEEE RTS-79 Reliability Test System on Five Utilities

Load Buses of Utilities

	Utility No.	Load Bus No.
RTS-79 System 1:	Utility 1	101,102,103,104,105
	Utility 2	106,107,108,109,110
	Utility 3	113,114,115,116,118,119,120
RTS-79 System 2:	Utility 4	201-210, 213
	Utility 5	214,215,216,218,219,220

$\varsigma = 0$	U1	U2	U3	U4	U5
Expected Value (k$)	3307	5037	9443	9914	7815
Standard Deviation (k$)	4137	6320	11494	11303	9590
Coefficient of Variation	1.25	1.25	1.22	1.14	1.23
$\varsigma = 0.5$	U1	U2	U3	U4	U5
Expected Value (k$)	3430	5150	9352	10404	7786
Standard Deviation (k$)	4714	6711	11138	12644	10245
Coefficient of Variation	1.37	1.30	1.19	1.22	1.32
$\varsigma = 1$	U1	U2	U3	U4	U5
Expected Value (k$)	3249	4947	9378	10089	7654
Standard Deviation (k$)	3874	6208	11223	14467	9384
Coefficient of Variation	1.19	1.26	1.20	1.43	1.23

Expected values, standard deviation and coefficient of variation of utility losses



Marginal Distributions of Losses of Utilities

(6) Risk interdependencies between control areas using IEEE RTS-79 reliability test systems

Challenges:

- The cyber insurance market for power grids remains in an emerging stage and it is yet to mature.
- This new business opportunity is distinctive as compared to the traditional insurance mainly due to the lack of actuarial loss data.

Solutions:

- The vulnerability and the steady-state probability of potential electronic intrusion to each power substation is analyzed.
- The economic surveys on the operational loss and direct costs are incorporated.
- The power system restoration process is applied to estimate the mean time to restore power (MTTRP).

Scientific Impacts:

- The ruin theory has been justified as a feasible method in the insurance model to extrapolate the "survival" possibilities for the insurance company.
- The proposed actuarial model would be beneficial to establishing a sustainable ecosystem of electric utilities.

Broader Impacts:

- The project develops cyber insurance models with a qualitative and quantitative approach to inform asset owners to plan their investment in enhancing security posture of a utility SCADA system.
- Increase social welfare, which would eventually facilitate the establishment of a mature market in cyber insurance for power grid.
- Inspire and stimulate actuarial research on many much-needed but challenging actuarial models, such as insurances for other high impact, low probability events and other critical infrastructures.

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