The Utility Effect in Cybersecurity of Demand-Response Systems

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Introduction and Background

- Cyber-enabled Demand Response: an electricity tariff imposed by central and utility regulators to motivate changes in electric use by consumers to:
  1. Better match the load requested with the supply
  2. Mitigate high market prices or to alleviate stresses on the grid under duress via real-time pricing signals
- Real-time component of the two-way communication link also exposes Demand-Response systems to cybersecurity threats
- Price-data injection: tariff dispatched by utility regulators to end-use customers is supplanted by the attacker's synthesized tariff;
  - Attack propagates miscommunication, and social and psychological disruptions—*Culture of Fear*

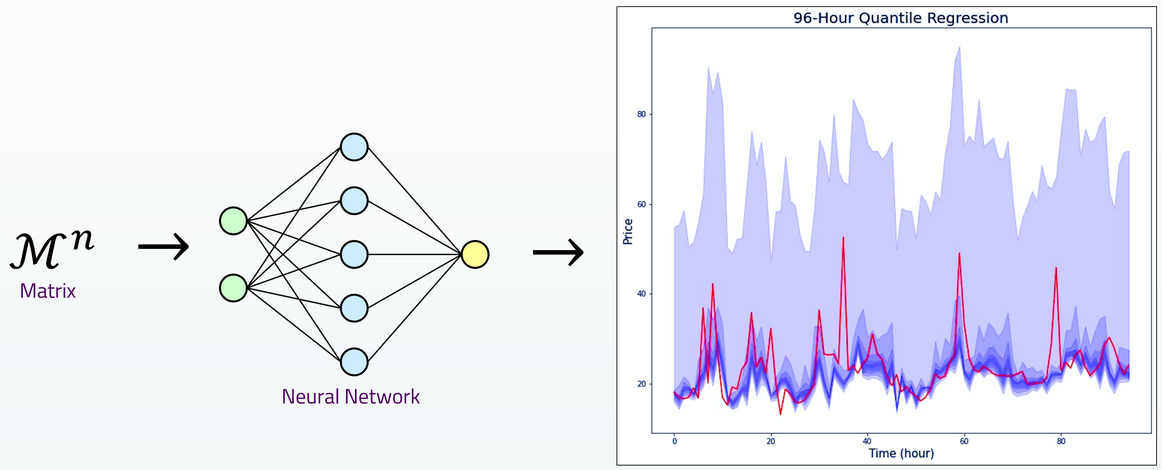
Aim

- The assured safety and reliability of Cyber-enabled Demand Response systems in the event of a malicious attack

System Under Attack (Simulated Model)

- Approach was built on the foundational constitution of the consumers' level of rational response—Prospect theory (PT) and Expected Utility theory (EUT) and the stability of a grid's operations thereafter
- Aggregated training data (LMP data of October 2020, Berks County, Pennsylvania) into a N-dimension matrix then inputted data into a quantile regression neural network that forecasts predicted quantile levels, τ = [0, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 0.99], of prices for a four-day period

System Under Attack (Simulated Model)



- Generated Piecewise CDFs and PDFs for each hour, from the forecast model
- Processed the PDFs through a conditional expectation price function, shown in Equation 1
  - $\mathcal{M}$ set of consumers associated with the Berks County node have knowledge of both current and future electricity prices

$$E(x|a \le x < b) = \frac{\int_a^b xp(x)dx}{\int_a^b p(x)dx}$$

Equation 1

- An optimized utility function with equation variables: flexible and inflexible load demanded, D_1 and D_2, price per kilowatt-load, P, a proportion of P, price compensation,P_c, and nonlinear constituent kappa, κ, are derived to assess the utility of a consumer m
- δ: the minimum load deferred

$$U(\delta) = \left[D_1 + D_2 - \frac{P + P_c}{2\kappa}\right]P - P_c\left[\frac{P + P_c}{2\kappa}\right] + \kappa\left[\frac{P + P_c}{2\kappa}\right]$$

$$\delta = \min\left(\frac{P + P_C}{2k}, D_2\right)$$

Equation 2

- Obtained $E(U(\delta))$ and $\{P(U(\delta))_n\}$ sequences for a given hour
- Attacks presented as a series of price manipulations of the original pricing data; the LMP prices are exploited via deterministic and gaussian percentage increase and decrease of the total set of prices, $p_{i/d}$ = [±0.10, ±0.20]

Results

- Findings of the simulation are held in abeyance.
- Initial results prove hopeful
  - Evaluation and method of analysis of the data produced must be advanced and expanded to thoroughly encompass its abstruseness
- Infer the utility of the consumers:
  - In $-p_{i/d}$ price data injection scheme, drastically change in manner that causes the consumers to participate in a continually irrational behaviour
  - In $+p_{i/d}$ scheme, consumers retain the comportment expected of end-users in an uncorrupted environ

Conclusions

- Cybersecurity concerns in Demand-Response systems are weapons that subject the common individual to torment and persecution
- Detection of irregularity in consumer's utilities can help to mitigate and eventually neutralize the effects of preliminary-to-full-scale cyber strikes

References

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