New Mexico
SMART Grid Center webinar series

NM SMART Grid Center Student Research Spotlight

Presenters: Jeewon Choi (UNM), Jacob Marks (New Mexico Tech), Adnan Bashir (UNM), Shubhasmita Pati & Rusty Nail (NMSU)

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SMART Grid Center webinar series

Next Webinar – CURENT NSF/DOE Engineering Research Center Overview

Presenter: Kevin Tomsovic, Director of CURENT, CTI Professor in the Department of Electrical Engineering & Computer Science at the University of Tennessee

April 22, 2020
Noon–1PM

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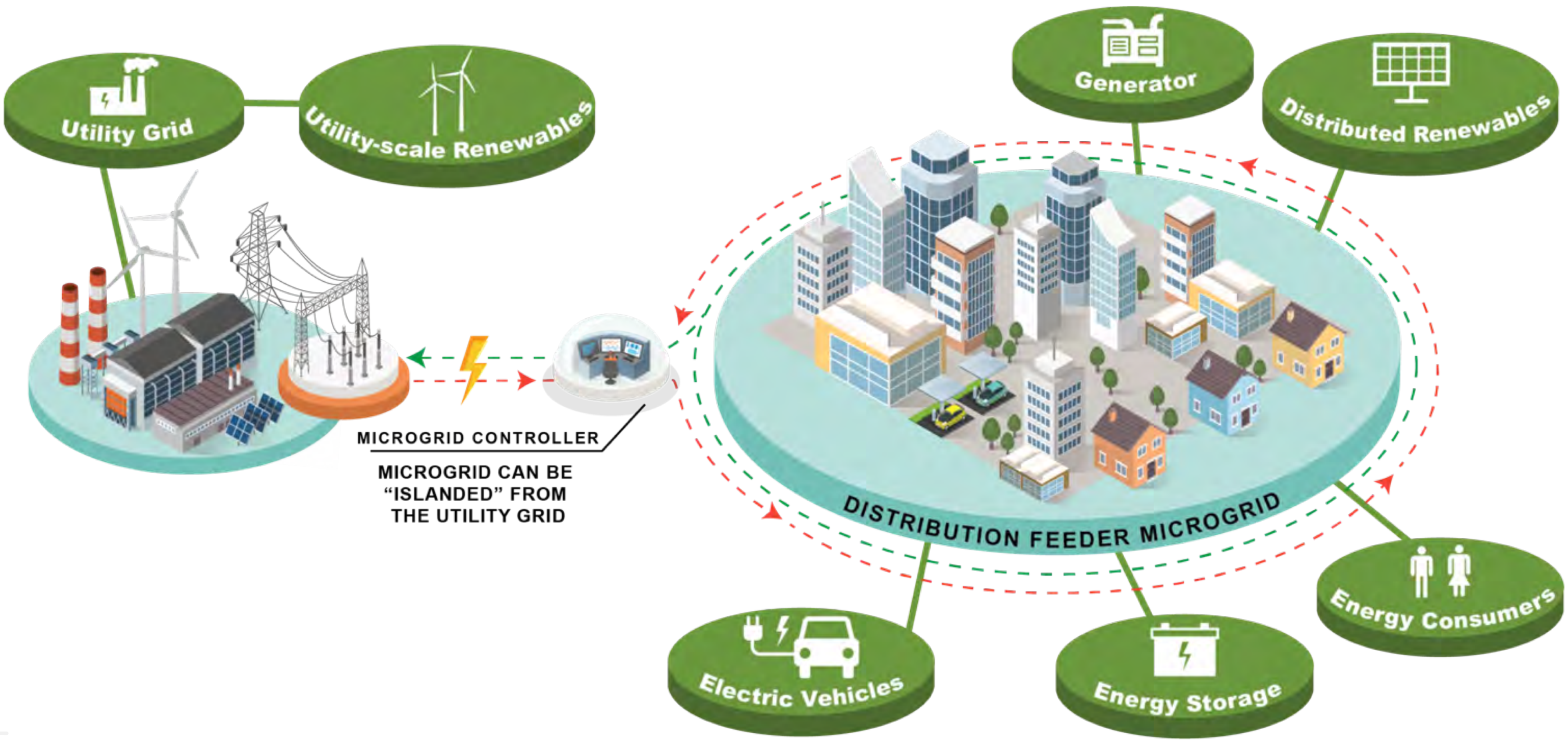
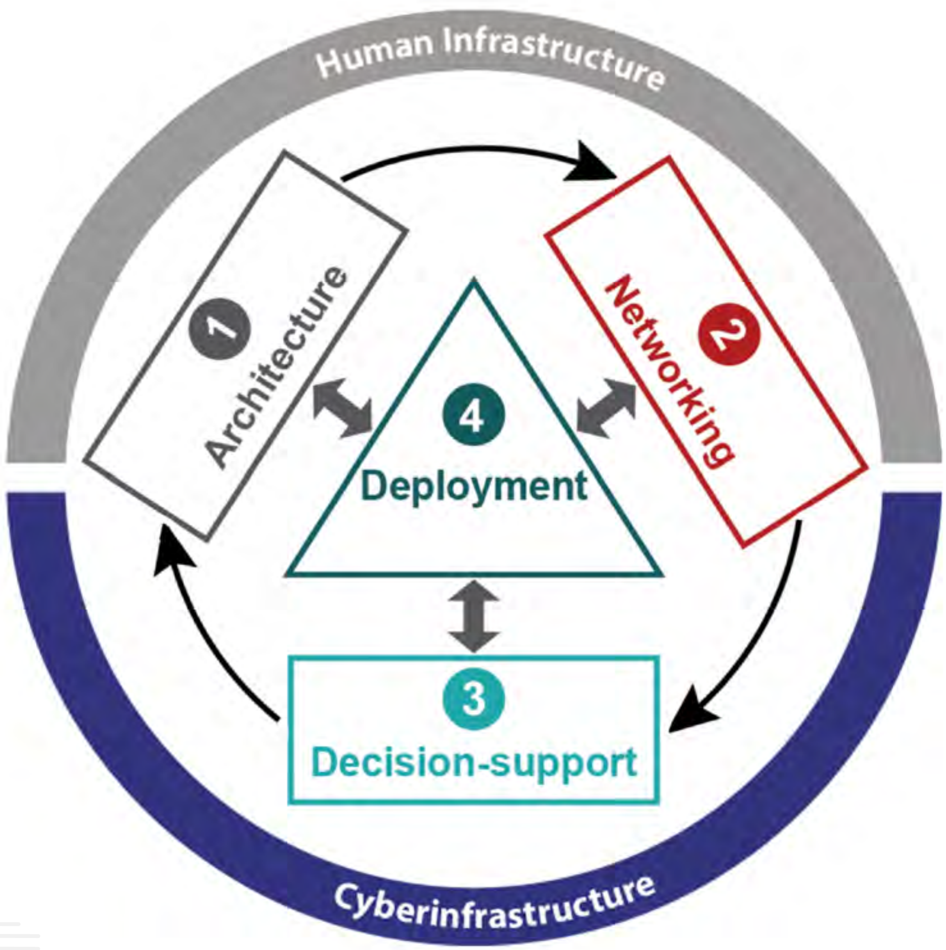
The NM SMART Grid Center Overview

Sustainable, Modular, Adaptive, Resilient, Transactive



NM SMART Grid Center Research Goals



- **RG1**: Create a comprehensive framework for distribution feeders to evolve into managed distribution feeder microgrids (DFMs)
- **RG2:** Design a network architecture for DFM infrastructure that is scalable, resilient, secure, and protects user privacy
- **RG3:** Integrate machine intelligence into decision making for the DFM
- **RG4**: Develop realistic scenarios for operation of DFMs in various stress conditions

NM SMART Grid Center Team

34	4	57	19	24
Faculty	Post Docs	Graduate Students	Undergraduate Students	Staff/Other

Differential Privacy in the Smart Grid

Jacob Marks

1. Smart meter privacy issues
2. Privacy preserving solutions
3. What is differential privacy?
4. How can differential privacy be used in the smart grid?

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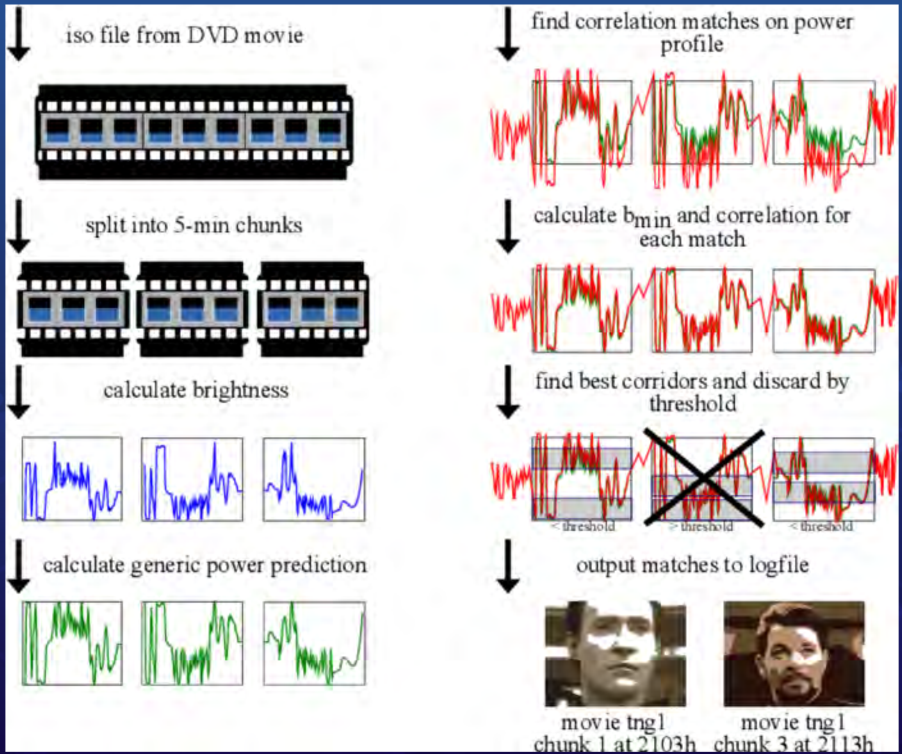
What Are The Privacy Concerns?

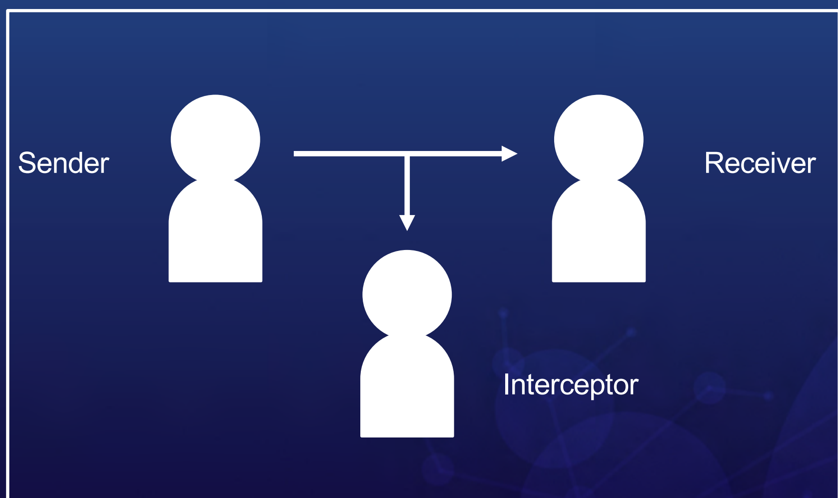
- Household occupancy
- Economic status
- Appliance usage
- Even what you're watching on TV



Multimedia Content Identification Through Smart Meter Power Usage Profiles
by Ulrich Greveler, Benjamin Justus, Dennis Löhr
https://www.semanticscholar.org/paper/Multimedia-Content-Identification-Through-Smart-Greveler-Justus/75b9a34cb6a0268ae7acaad34c7fcdedb450f160

Two Types of Privacy

Cryptographic Privacy



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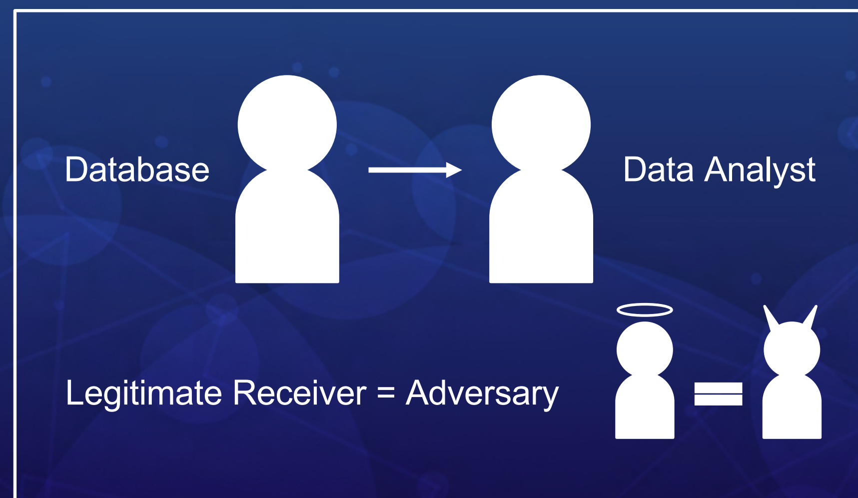
Statistical Privacy

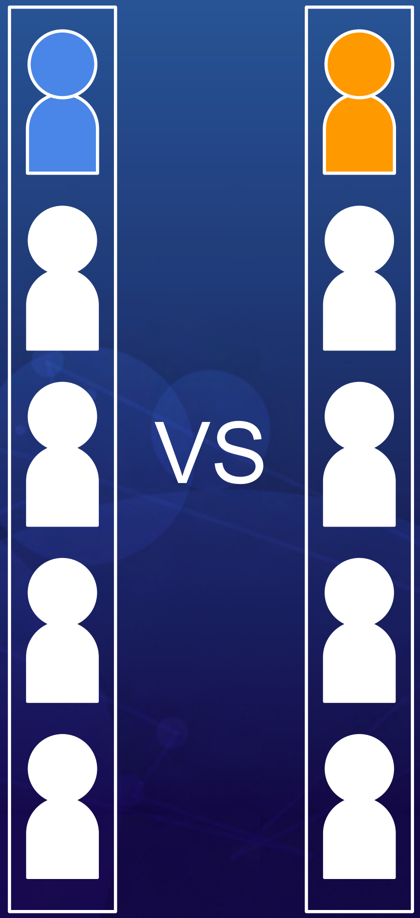


Differential Privacy

Goal:

It should be very unlikely that an attacker can identify if you are in a dataset.

Plausible deniability.



Differential Privacy

Definition:

$$P(A(D_1) \in S) \leq e^{\varepsilon} P(A(D_2) \in S)$$

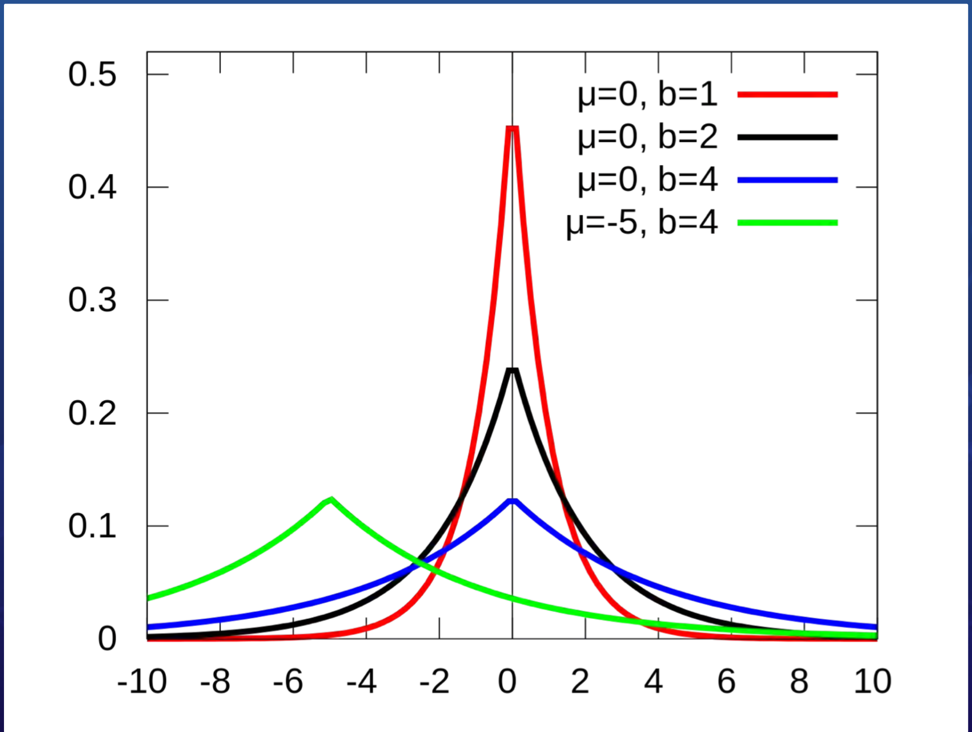
P	: Probability
A	: Mechanism
D_1	: Database 1
D_2	: Database 2
S	: ⊆ Range(A)
ε	: Privacy budget

"the modification of any single user's data in the dataset (including its removal or addition) changes the probability of any output only up to a multiplicative factor e^{ε}." (I have a DREAM!)

Differential Privacy

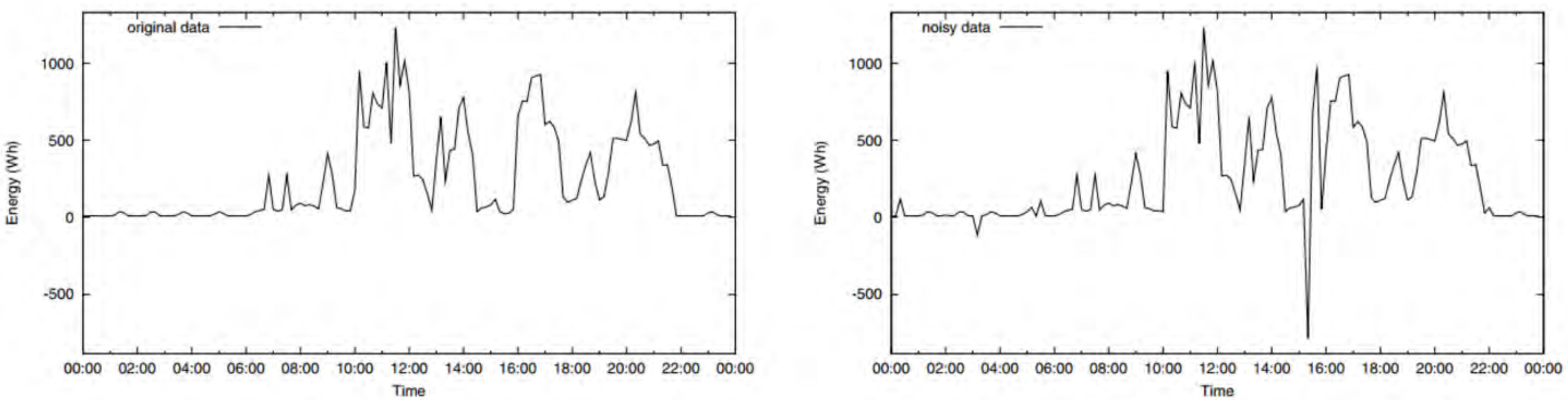
Laplacian mechanism

Added noise maintains differential privacy. However your data is now less good.



"Laplace distribution," *Wikipedia*. 20-Mar-2020, Accessed: 24-Mar-2020. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Laplace_distribution&oldid=946537954.

Differential Privacy



(a) X_t^i (b) $X_t^i + \mathcal{G}_1(N, \lambda) - \mathcal{G}_2(N, \lambda)$

I Have a DREAM! (DiffeRentially privatE smArt Metering)

Problems?

- Will data be accurate enough for use?
- Who will be trusted with the original data?
- Speed
- Accuracy
- Privacy
- Out of all DP solutions which are best?

Conclusion

- There are many privacy concerns associated with smart meters
- Cryptographic or statistical solutions could be used
- Differential privacy is especially promising
- Need more data on which differential privacy solutions work best

References

R. Lu, X. Liang, X. Li, X. Lin, and X. Shen, “EPPA: An Efficient and Privacy-Preserving Aggregation Scheme for Secure Smart Grid Communications,” *IEEE Transactions on Parallel and Distributed Systems*, vol. 23, no. 9, pp. 1621–1631, Sep. 2012.

Clement, Jana & Ploennigs, Joern & Kabitzsch, Klaus. (2013). Detecting Activities of Daily Living with Smart Meters. 10.1007/978-3-642-37988-8_10.

G. Ács and C. Castelluccia, “I Have a DREAM! (DiffeRentially privatE smArt Metering),” in *Information Hiding*, Berlin, Heidelberg, 2011, pp. 118–132.

S. Thorve, L. Kotut, and M. Semaan, “Privacy Preserving Smart Meter Data,” p. 5, 2018.

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C. Dwork and A. Roth, “The Algorithmic Foundations of Differential Privacy,” *FNT in Theoretical Computer Science*, vol. 9, no. 3–4, pp. 211–407, 2013.

Conclusion

- There are many privacy concerns associated with smart meters
- Cryptographic or statistical solutions could be used
- Differential privacy is especially promising
- Need more data on which differential privacy solutions work best

Smart Grid Data Generation

Presenter: Adnan Bashir
Advisor: Trilce P. Estrada

March 25, 2020

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Why synthesize smart grid data ?

1. Smart grid is still in evolution phase
2. Researchers don't often share their data
3. A lot of data needed to incorporate decision support
4. Mathematical modeling can be put to a good use

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What are available tools ?

1. *Generative Adversarial Networks*
   - We still need real data to generate new data
1. *Mosaik*
   - Combines simulators and models
1. *MATPOWER*
   - Steady-state power system simulation
1. *PYPOWER*
   - Power flow and Optimal Power Flow solver

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MATPOWER

1. Open-source power simulation and optimization
2. Runs on MATLAB & GNU
3. > 4000 citations since 2010
4. > 22,000 downloads / year

MATPOWER: Steady-state operations, planning, and analysis tools for power systems research and education
RD Zimmerman, CE Murillo-Sánchez... - IEEE Transactions on ..., 2010 - ieeexplore.ieee.org
MATPOWER is an open-source Matlab-based power system simulation package that provides a high-level set of power flow, optimal power flow (OPF), and other tools targeted toward researchers, educators, and students. The OPF architecture is designed to be ...
Cited by 4056 Related articles All 10 versions

Image Source: Google Scholar

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MATPOWER in action

```
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------  -------------  -----------------
Buses              30    Total Gen Capacity     335.0           -95.0 to 405.9
Generators          6    On-line Capacity       335.0           -95.0 to 405.9
Committed Gens      6    Generation (actual)    200.2               103.7
Loads              20    Load                   197.5               107.2
  Fixed            20      Fixed                197.5               107.2
  Dispatchable      0      Dispatchable          -0.0 of -0.0        -0.0
Shunts              2    Shunt (inj)             -0.0                 0.2
Branches           41    Losses (I^2 * Z)         2.72               12.21
Transformers        0    Branch Charging (inj)     -                 15.5
Inter-ties          7    Total Inter-tie Flow    49.8                53.0
Areas               3

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   0.970 p.u. @ bus 8          1.069 p.u. @ bus 27
Voltage Angle      -5.28 deg   @ bus 19         0.00 deg   @ bus 1
P Losses (I^2*R)             -                  0.25 MW    @ line 2-6
Q Losses (I^2*X)             -                  2.19 MVAr  @ line 28-27
Lambda P            3.74 $/MWh @ bus 1          5.14 $/MWh @ bus 8
Lambda Q           -0.05 $/MWh @ bus 29         1.17 $/MWh @ bus 8
```

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CKAN Data Repository

DEMO by Adnan Bashir

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Power System Resiliency

Shubhasmita Pati & Rusty Nail

Graduate Students
Klipsch School Of Electrical & Computer Engineering

New Mexico State University

Resilience

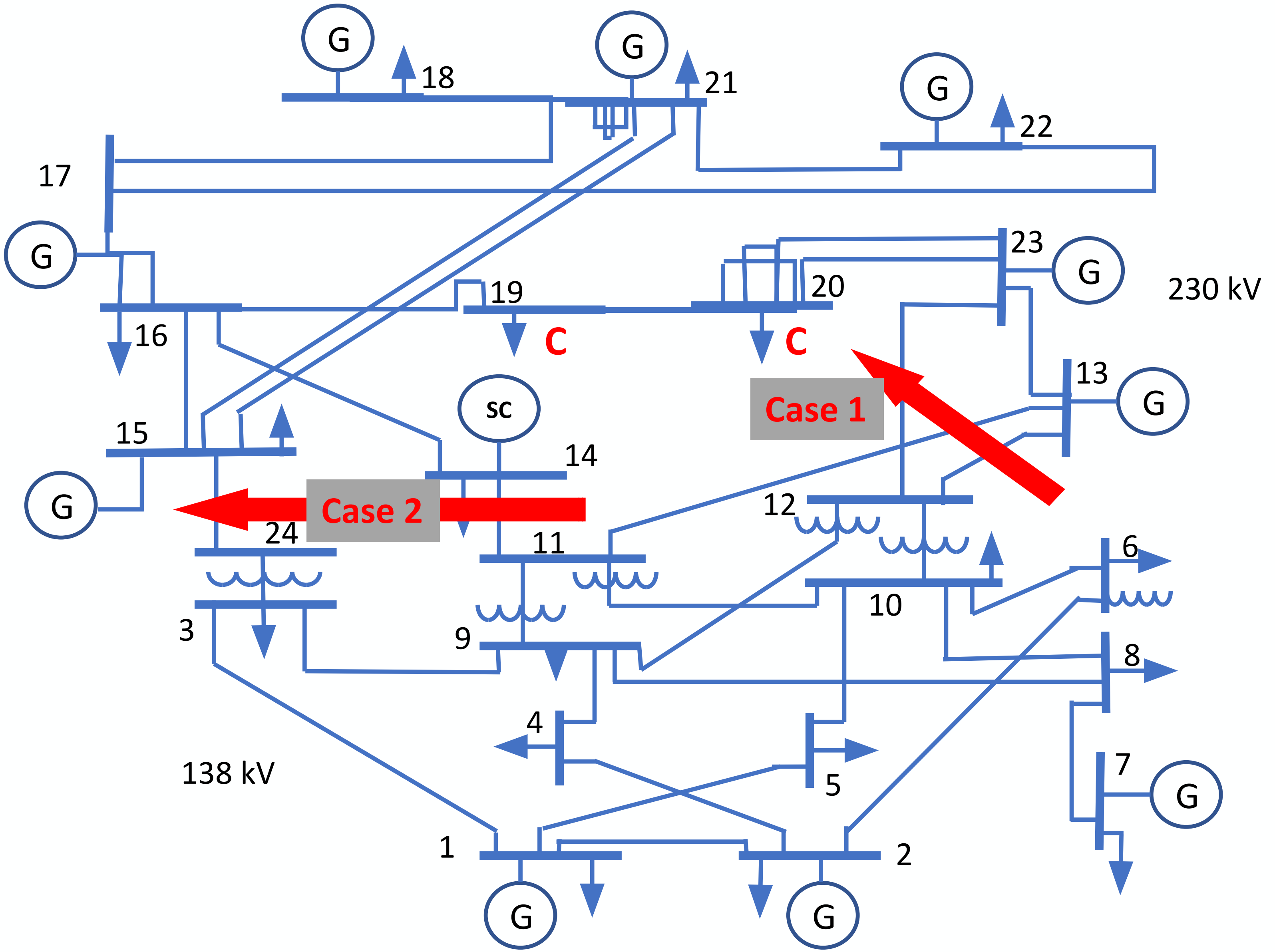
- Natural Disasters (Cyclone, Tornado, Hurricane) or cyber-physical threats :
  - What happens to the grid ?
  - “October 2012, Superstorm Sandy, New York, $50B loss”
- “The ability of the power system to recover either completely or partially from adversity is defined as Resilience”[1].
- Resilience depends on the adaptability of the grid to unexpected failures or disfigurements.
- Adaptivity in Biology : “ability of an organism to respond and survive environmental distress.”

[1] D. E. Alexander, “Resilience and disaster risk reduction: an etymological journey,”Natural hazards and earth system sciences, vol. 13, no. 11, pp.2707–2716, 2013.

Resilience VS Reliability

- Resilience deals with quick recovery through active management of the grid.
- Throughput (goodput) as the objective.
- Conditional probability.
- Time-sensitive criticality.

- Reliability deals with overall service improvement by building redundant infrastructure.
- Cost as the objective.
- Probabilistic.
- Continuity of service.



IEEE 24 Bus Reliability test System

C : Critical Loads

Research Challenge

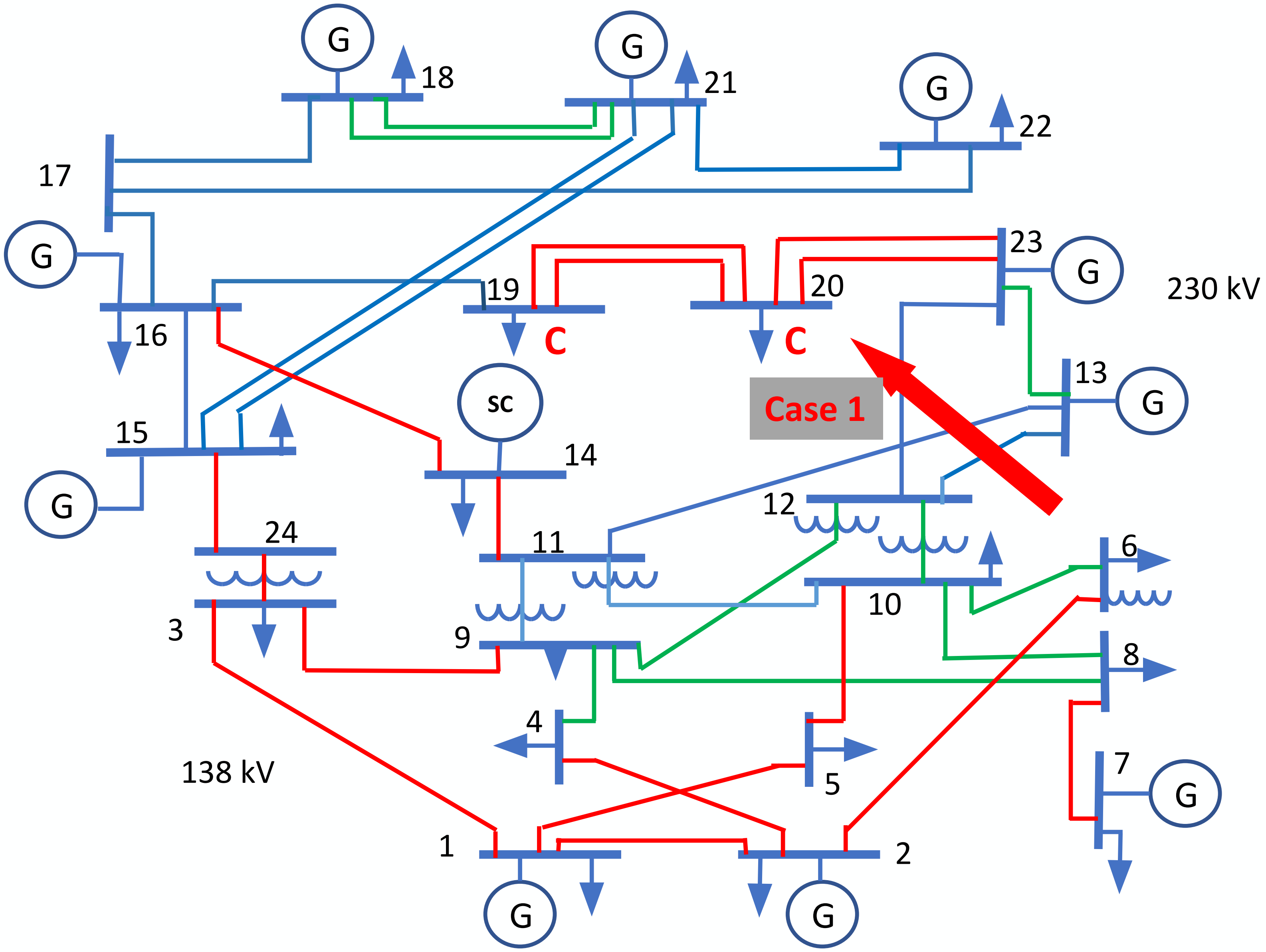
- Objective Function
- Minimize the mismatch between generation and demand with the constraint that the critical loads are always supplied.

$$\arg min \left(\sum_{i=1}^{N} P_i^g - \sum_{j=1}^{M} P_j^L\right)$$

P_i^g is the power delivered by source i , and
P_j^L is the power demand at j^{th} load.

Subject to : P_k^L >= C_k , $\forall k \in \{1, K\}$,

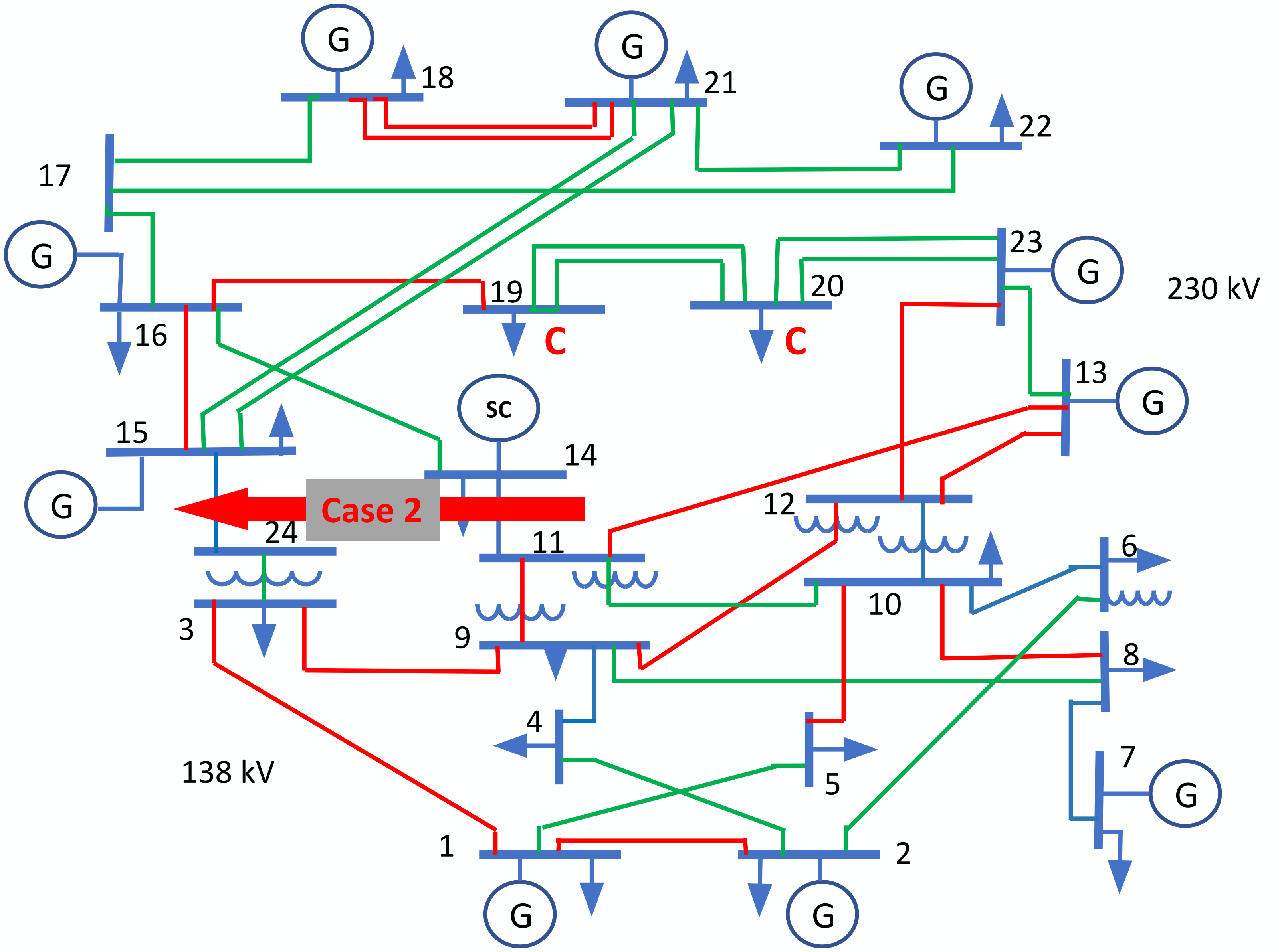
K is the number of critical loads
C_k is the minimum load required for k^{th} critical load



Lines that are getting overloaded (red) / (green) underloaded

No of overloaded lines : 14

No of under loaded lines : 9



No of overloaded lines : 18

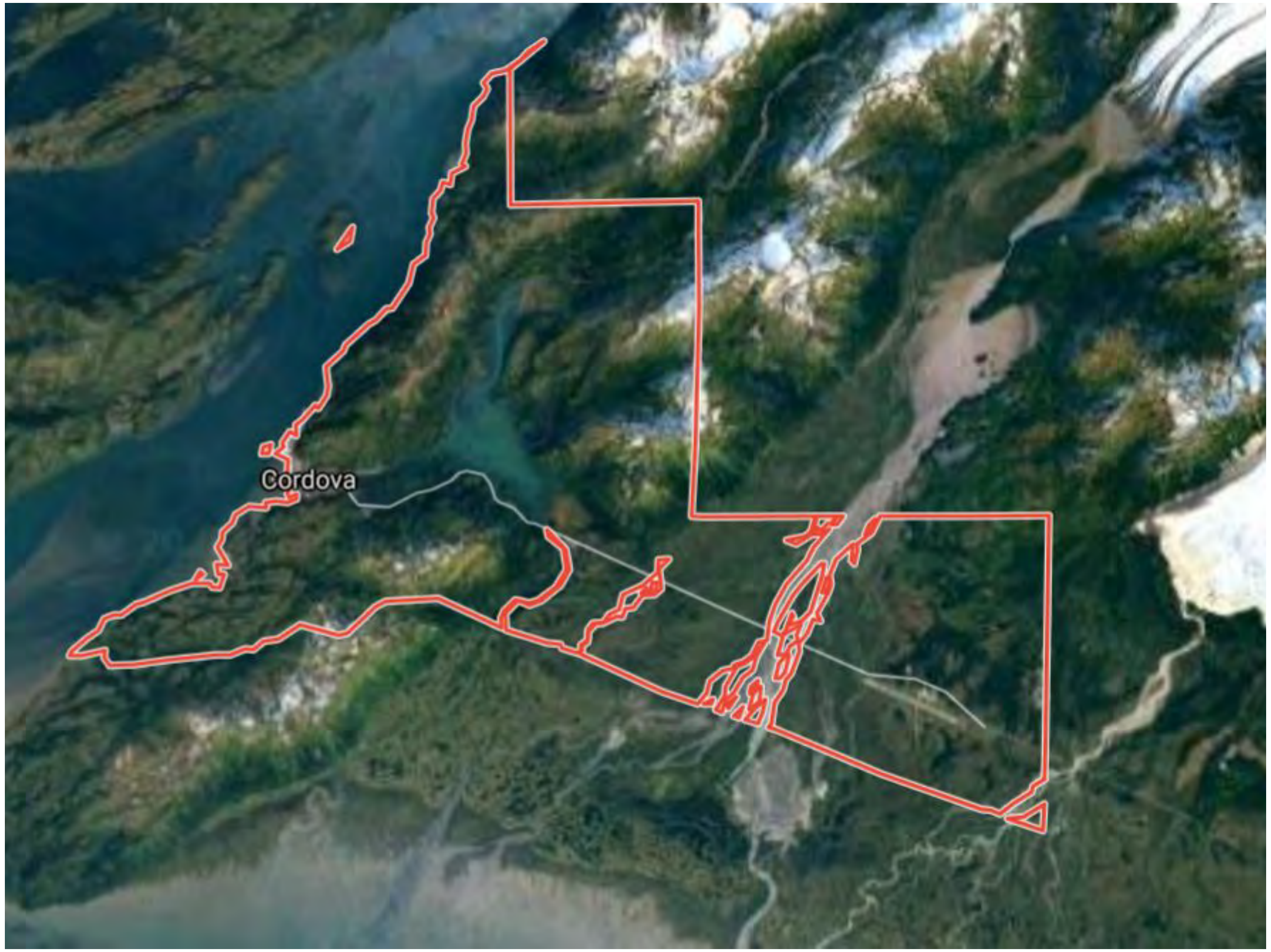
No of under loaded lines : 18

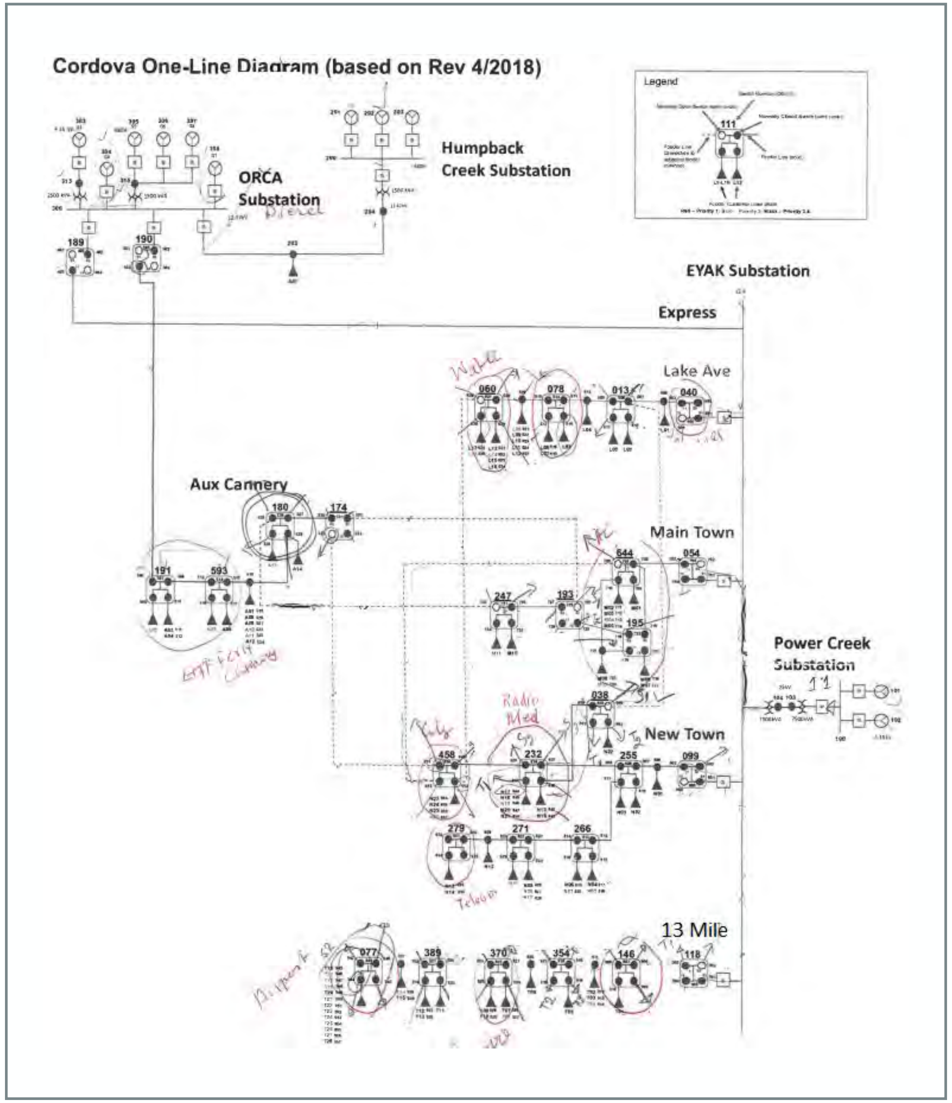
Applying Resiliency and Contingency Planning

- Natural smart grid, microgrid in Cordova, Alaska
- Cyber Security
- Natural Disasters
- Sensing and System Monitoring

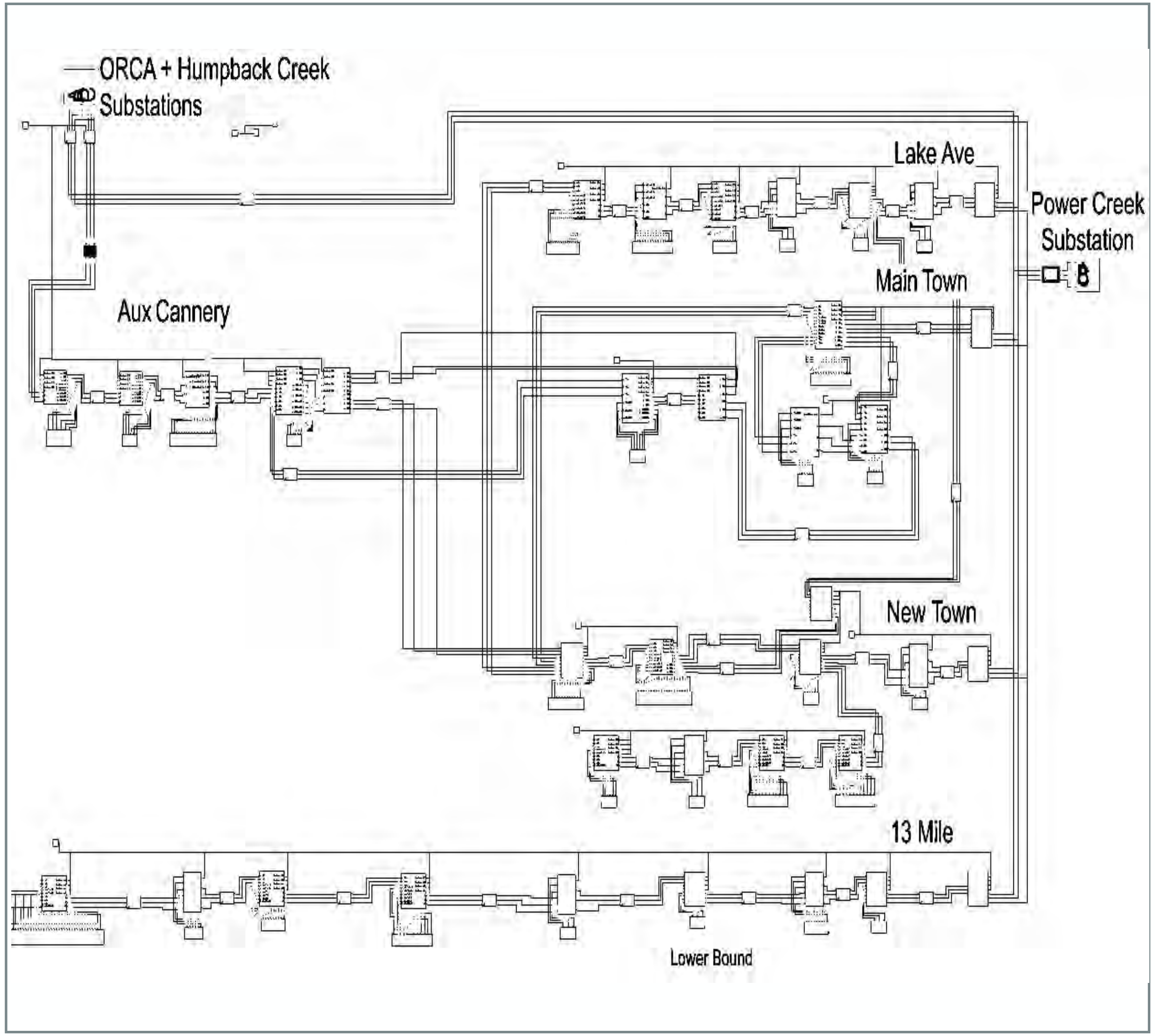
Applying Resiliency and Contingency Planning

- Google Maps – Satellite Image of Cordova, Alaska

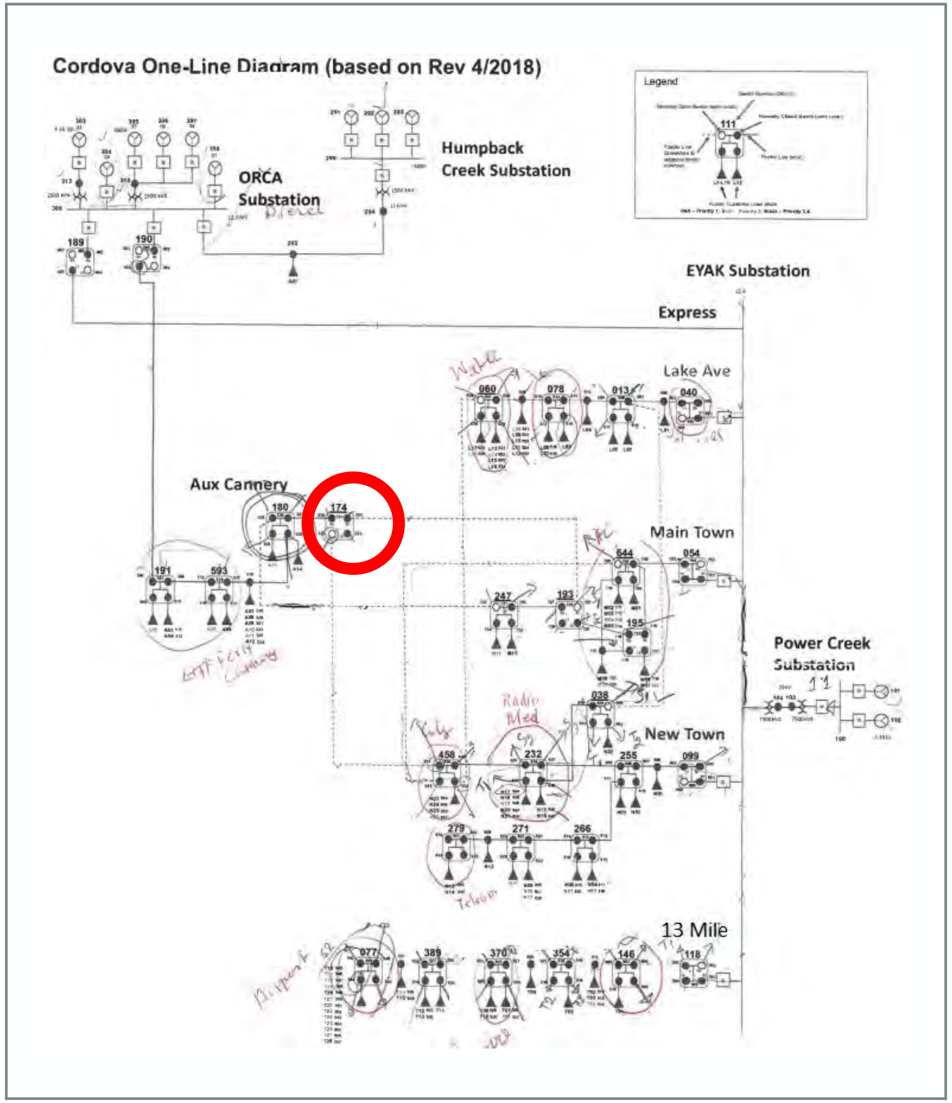




One-Line Diagram of Distribution System



MATLAB Simulink System Visualization



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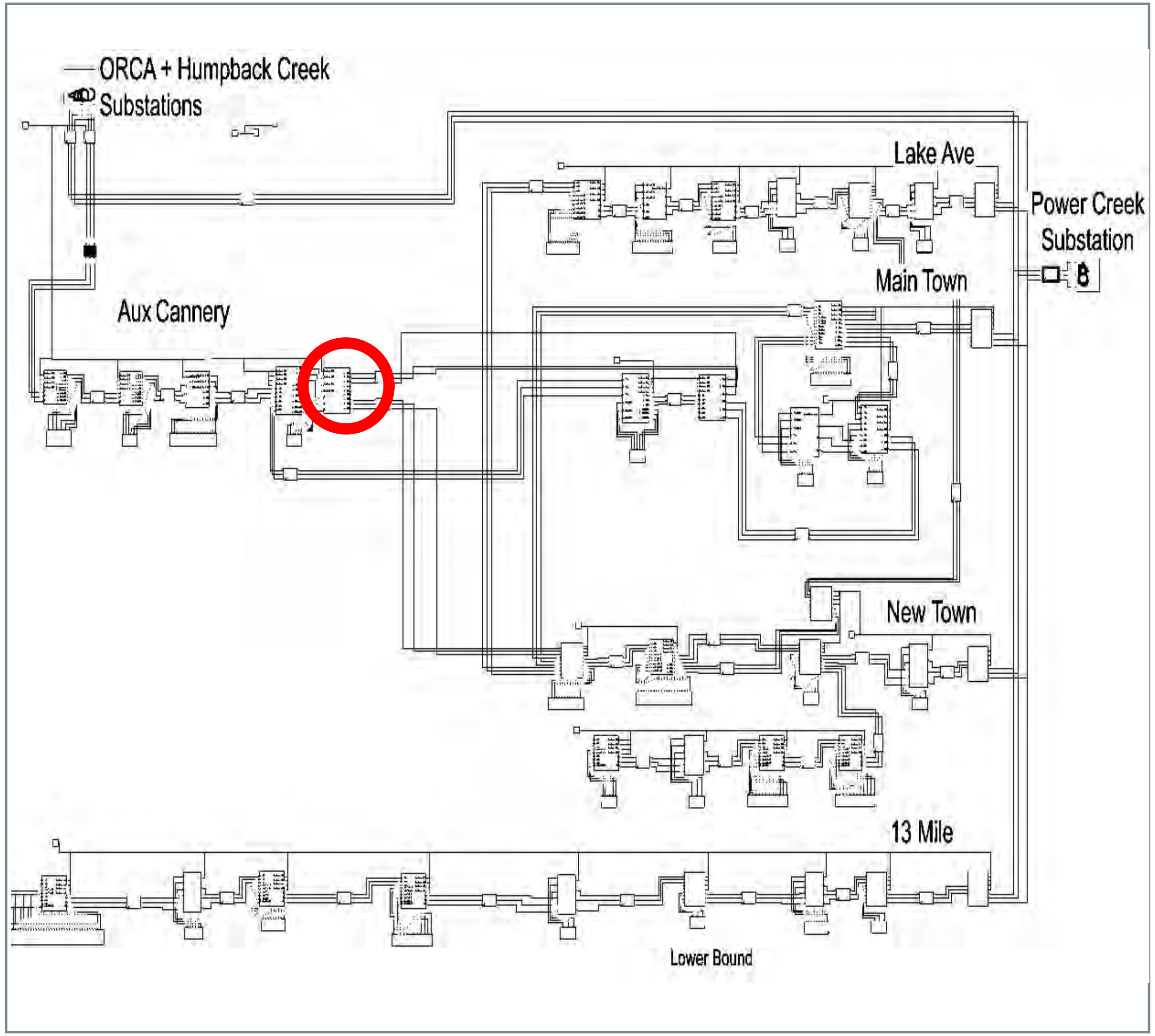
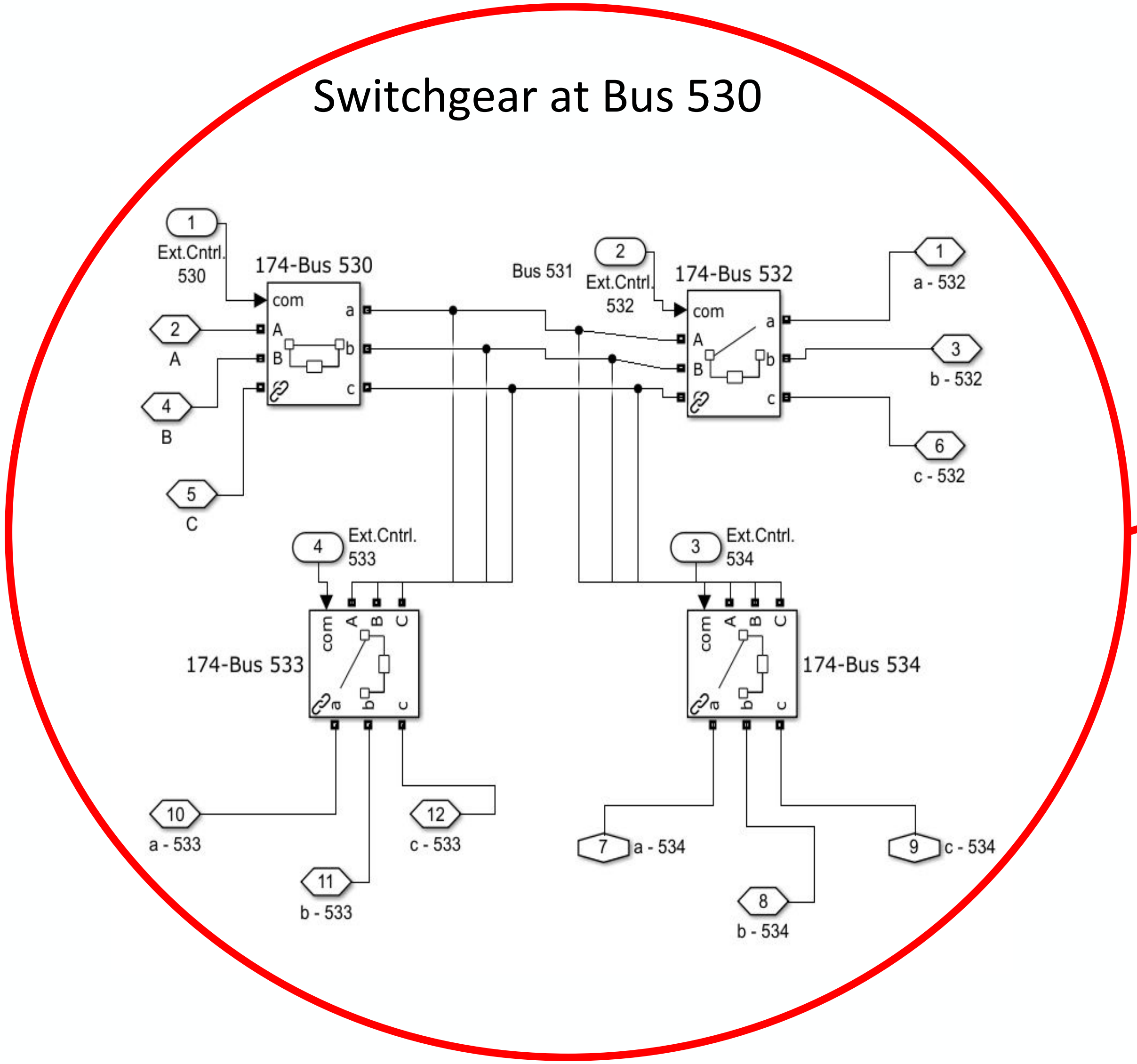
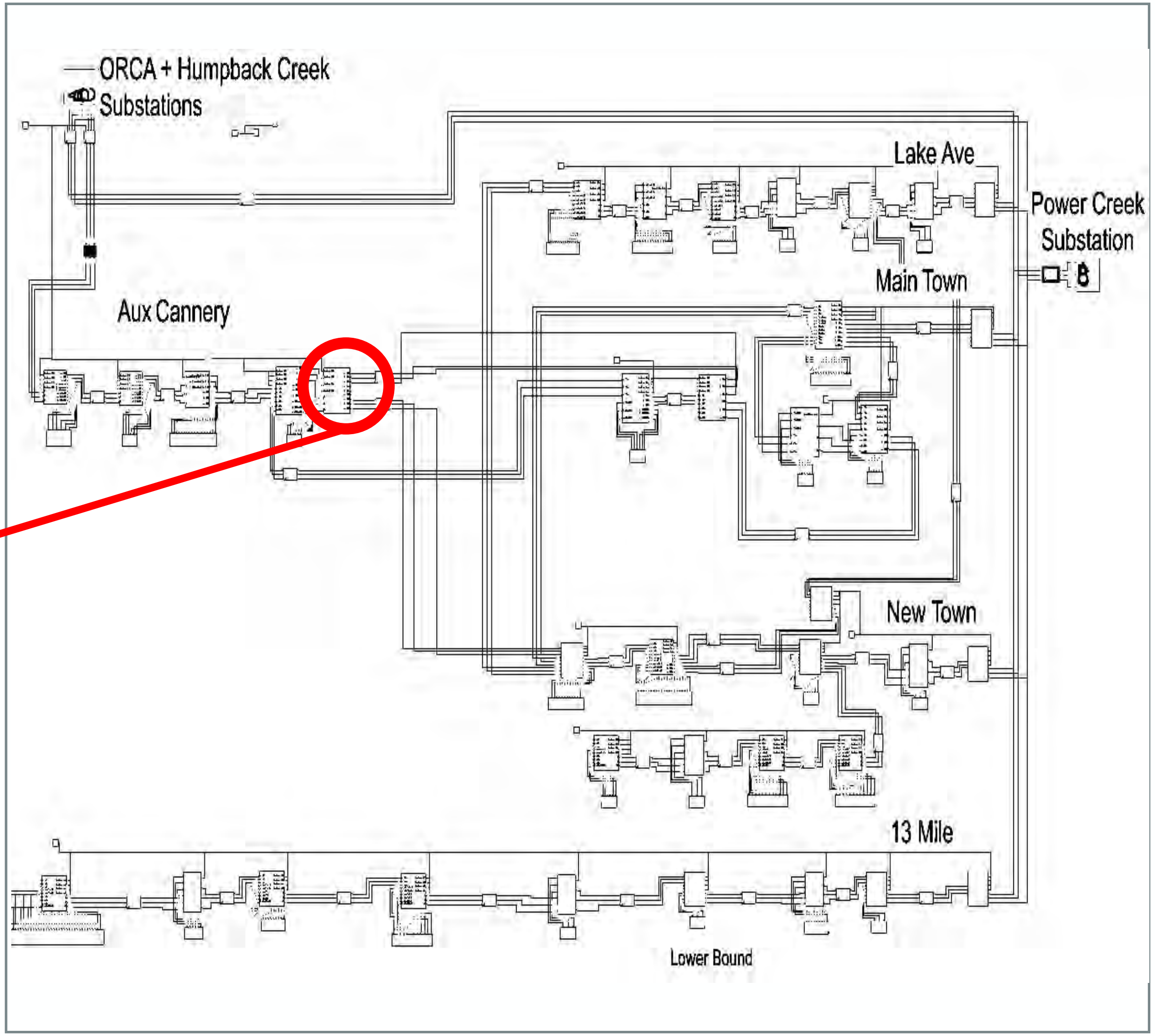


MATLAB Simulink System Visualization

Switchgear at Bus 530





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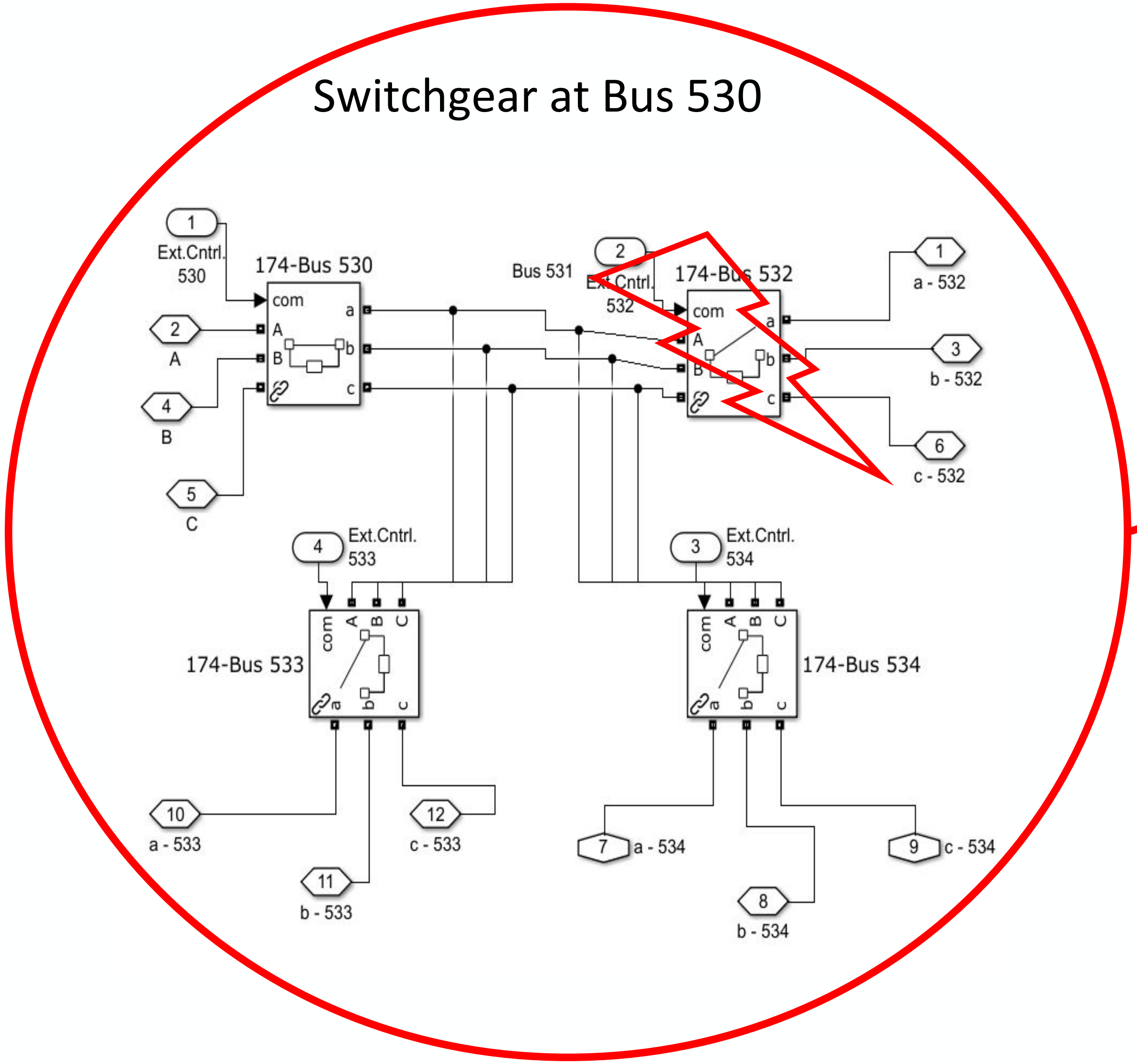

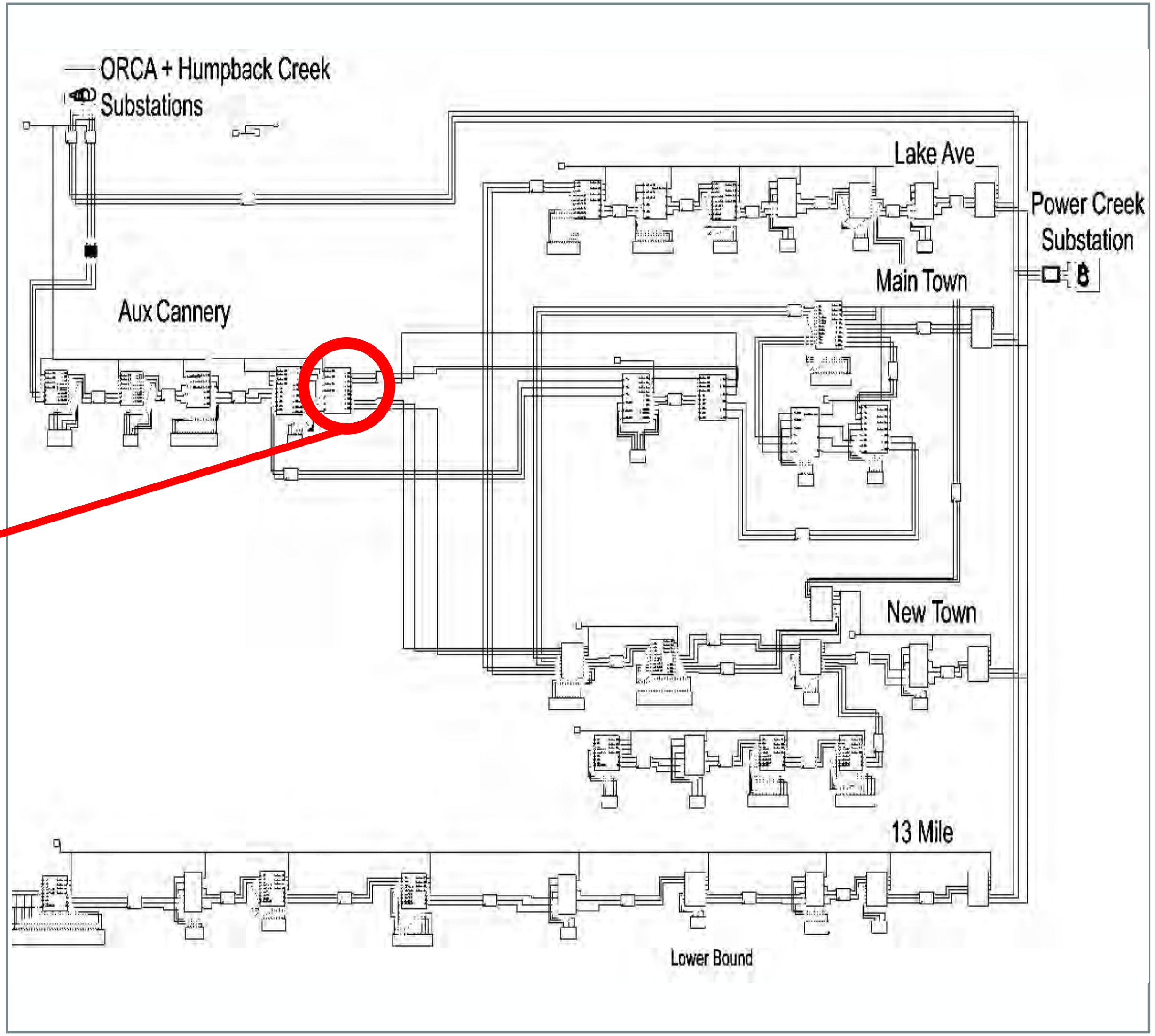

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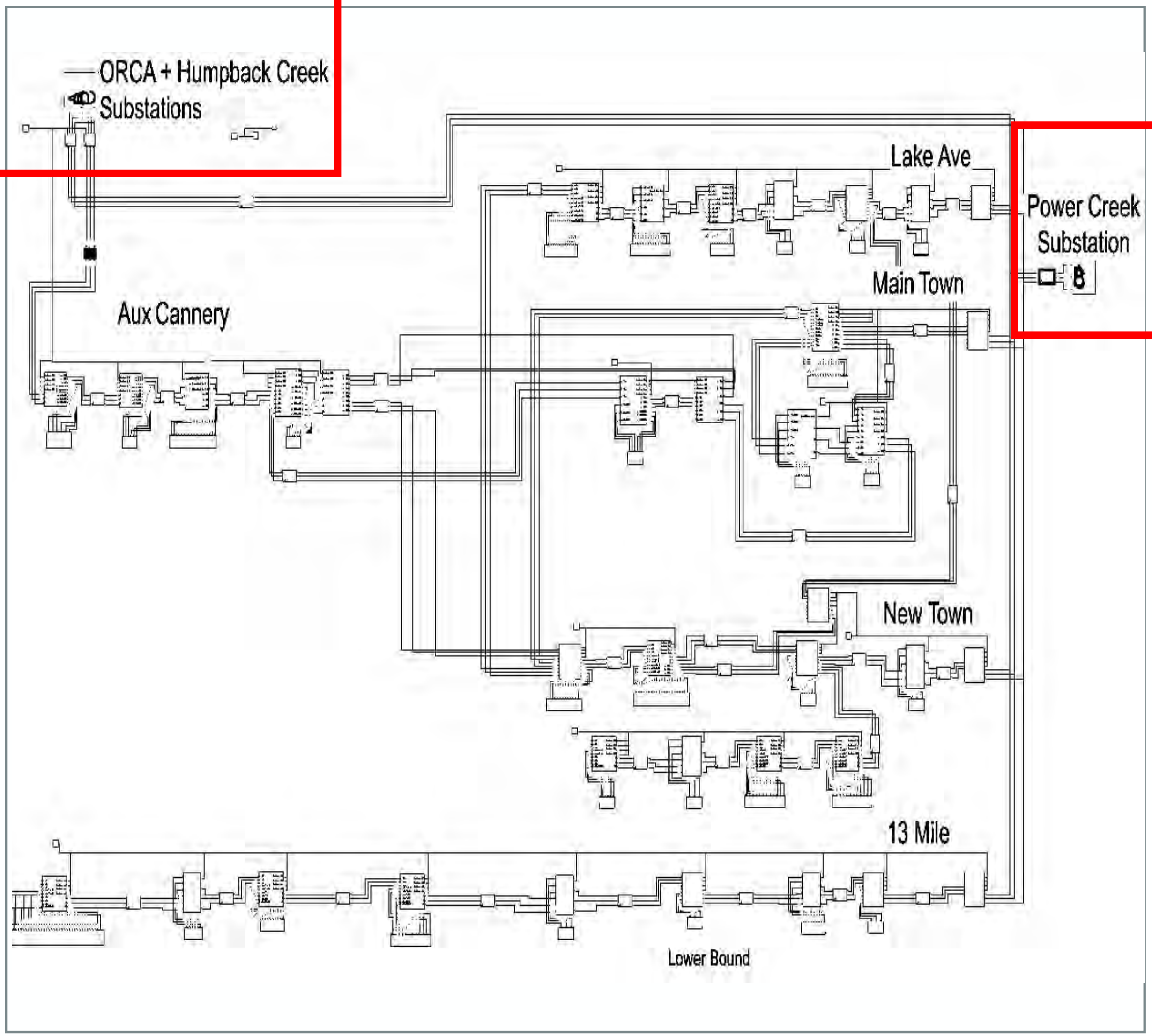
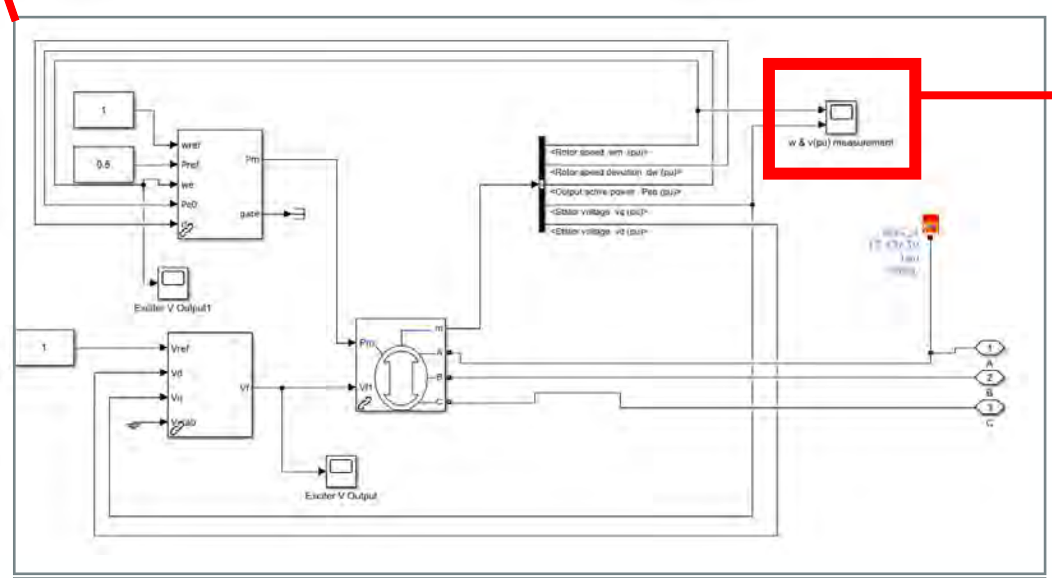
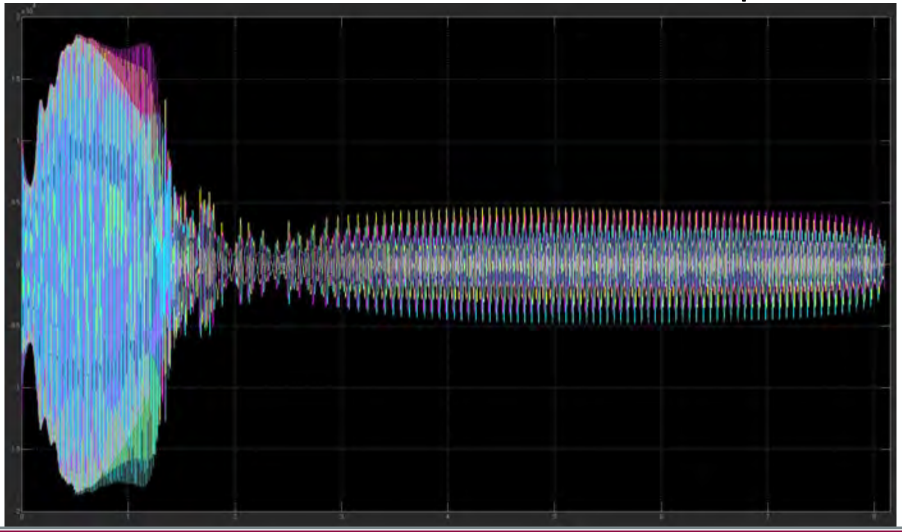


ORCA Diesel Generators



Substation – Generator Osciloscope



Recognizing the Realities of Resiliency

- Routine reevaluation of the system's adaptability
- We are considering significant portions of a power system to become inoperable
- What happens before, during, and after critical loads are sustained?

Future directions

- Statistical Distribution of the Load Profiles
- Time sensitive critical Loads (e.g. Metro System in the event of a Hurricane)
- DERs, Battery Placement, Switch Placement

Contact Information

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Q&A

Use Zoom Q&A Feature!

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