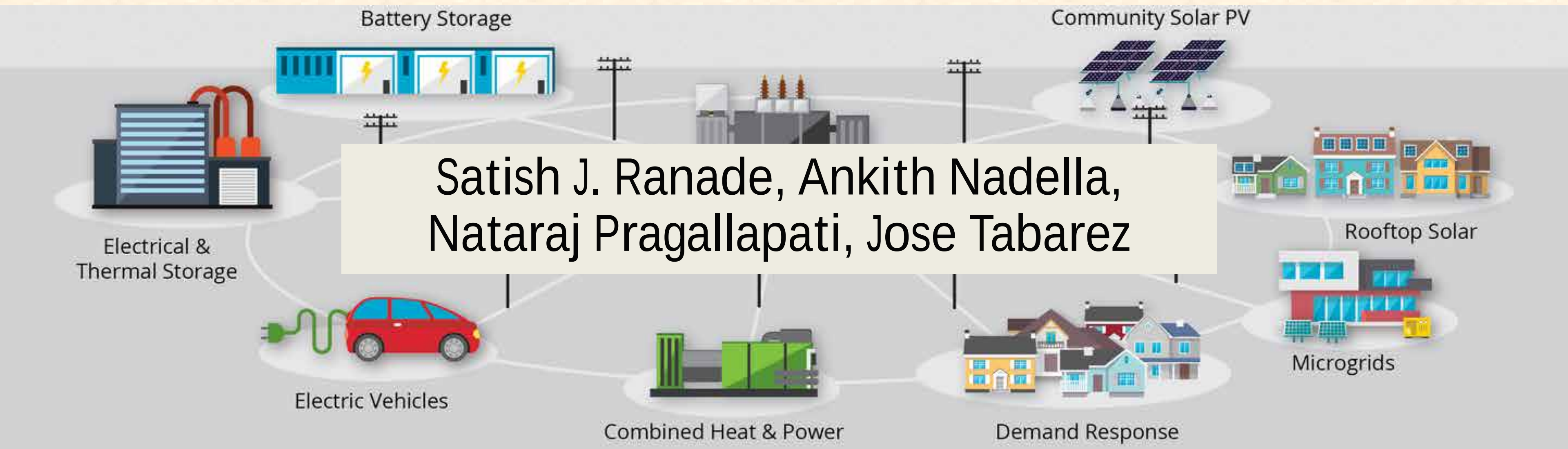
# The Grid of the Future Workshop

August 22, 2018 | Albuquerque NM

## Risk- and Resilience- Aware Distribution




Satish J. Ranade, Ankith Nadella, Nataraj Pragallapati, Jose Tabarez

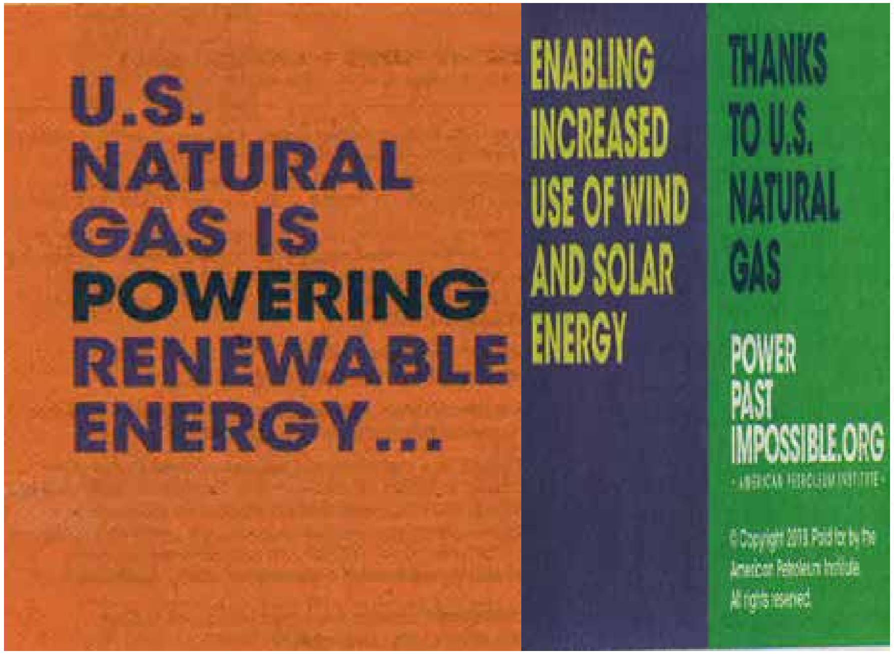
iCREDITS
NMSU Smart Grid CREST Center

This work was funded in part by the National Science Foundation under grant HRD-1345232 and by the Electric Utility Management Program

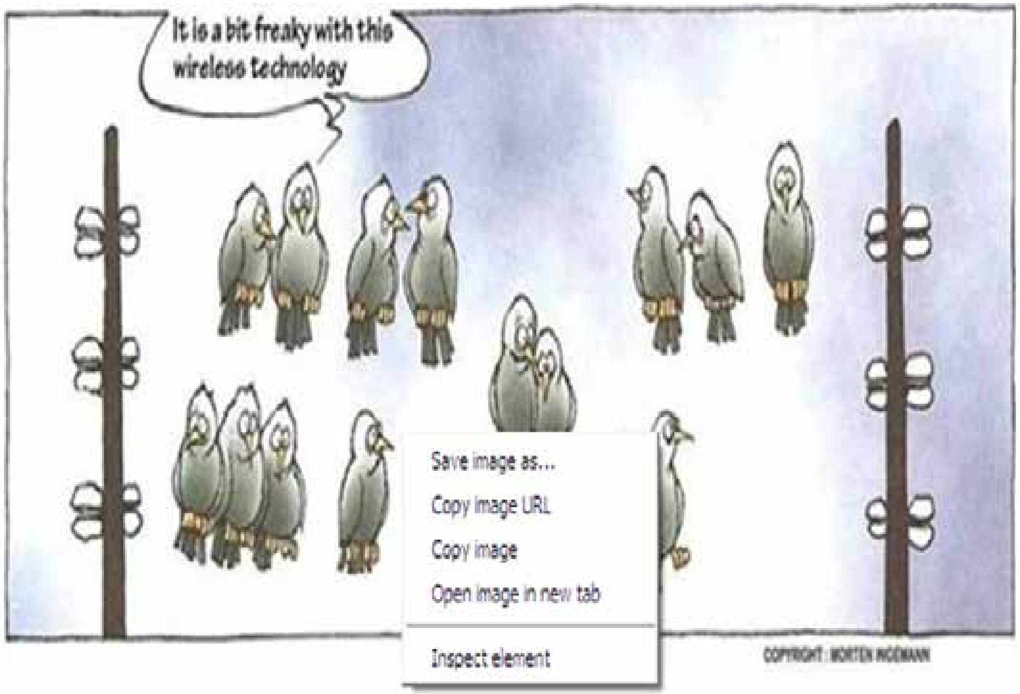
# Grid of the future

Generation

T&D




USA Today




Unknown

# Grid of the future – role of distribution

- Substantial growth in renewable
  - primarily solar
- Demand response taking shape
  - Aggregators, VPP, IOT
- Electric Vehicles
- Storage
- All integrated in distribution

- Environmental Benefits
- Owner -Economic/Soft benefits
- DISTCO
  - Business model?
  - Socialized Cost?
- Grid (of the future)
  - Grid Services
- Islands and Microgrids

# Grid of the future – role of distribution

DISTCO Business Model

Distribution centrally managed by DISTCO

DISTCO similar to ISO

Establishes Market

Hierarchical or Fully Decentralized

DISTCO manages network

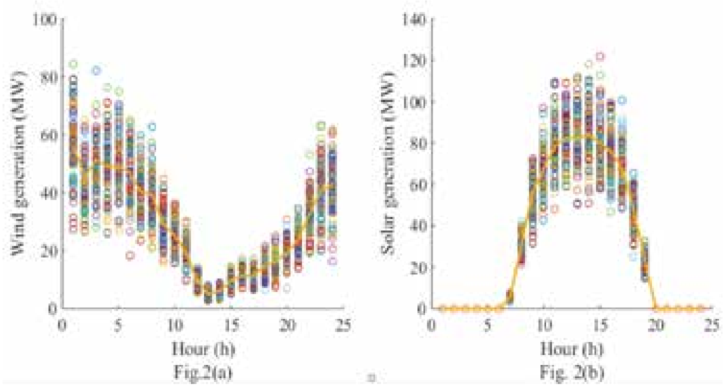
Virtual Market

- Technology
  - Distributed Resources
    - Anything that can participate in real/reactive power/energy transactions
  - Smart inverters used smartly
  - IOT devices
  - DR aggregators
  - Communications
  - Security
- Technology withdrawals
  - LTC, Regulators, Capacitors…

# Operational Risk

- Weather dependent renewable energy sources are uncertain sources.
- PEV mobility induces variability in G2V resource availability.
- Randomness/Unavailability of connected load.

Resulting deviation from forecasted values violates deterministic study based predefined operation schedules thereby introducing risk (load / price).



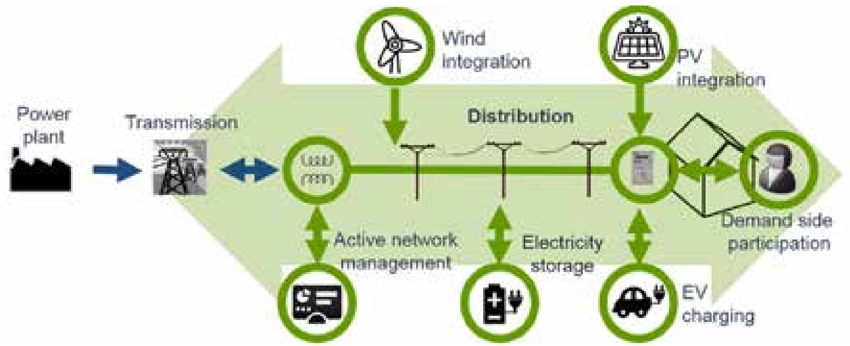
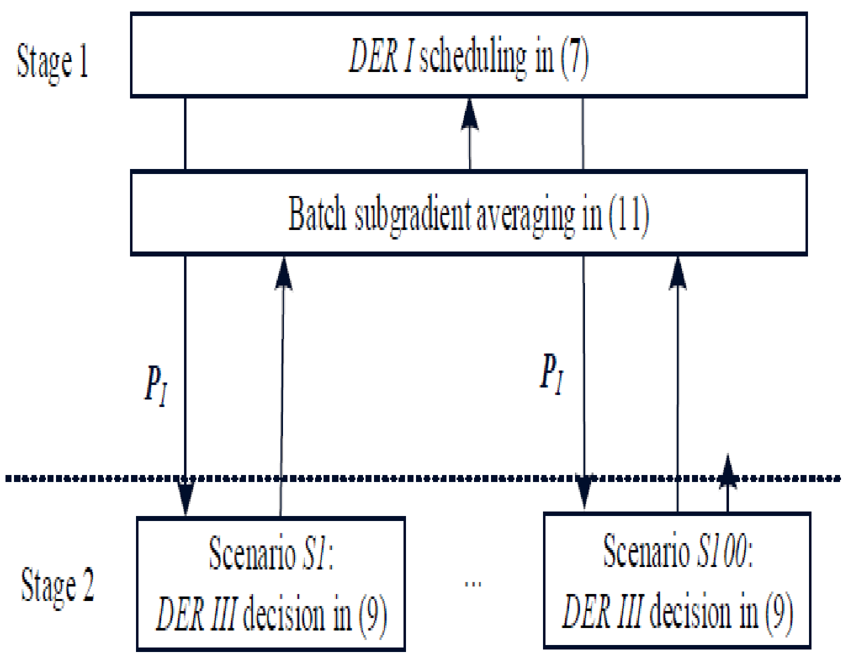




**Image credit:** https://www.edsoforsmartgrids.eu

# Stochastic Optimization

## 2 Stage Stochastic Optimization




The objective function of two-stage stochastic DER management is formulated as:

$$F = f1(P_I) + E[f2^S(P_I, P_{III}^S)] \qquad (7)$$

[Stage-1]

The cost of DA generation is given by:

$$f1 = \sum_{j\in DER\,I} C(P_{I,j}) \qquad (a)$$

$$P_I = \{P_{I,j} \in D_{I,j}, j \in DER\ I\}, \qquad (b) \qquad (8)$$

[Stage-2]

Under each scenario *S*, *recourse* problem determines the optimal decision $P_{III}^S$, given $P_I$, as defined below:

$$f2^S(P_I, P_{III}^S) =$$

$$\begin{cases} \min. \sum_{j\in DER\,III} C(P_{III,j}^S) + L^S(P_I, P_{III}^S) + R^S(P_I, P_{III}^S) & (a) \\ L^S(P_I, P_{III}^S) = -(\lambda^S)^T\left(\sum_{j\in DER\,I} P_{I,j} + \sum_{j\in DER\,II} P_{II,j}^S + \sum_{j\in DER\,III} P_{III,j}^S\right) & (b) \\ R^S(P_I, P_{III}^S) = 0.5\rho f\left\| \sum_{j\in DER\,I} P_{I,j} + \sum_{j\in DER\,II} P_{II,j}^S + \sum_{j\in DER\,III} P_{III,j}^S \right\|_2^2 & (c) \\ s.t. P_{III}^S = \{P_{III,j}^S \in D_{III,j}, j \in DER\ III\}, & (d) \\ \lambda^S \in D_\lambda = \{\lambda^{LB} \le \lambda^S \le \lambda^{UB}\} & (e) \end{cases} \qquad (9)$$

# Operational Risk

System with:
5 conventional generators
2 EV clusters
2 DR groups
Aggregated Solar and Wind

Objective:
Minimize cost+disutility+weighted risk

Disutility:
Cost of discretionary load curtailment
Risk:
Cost of critical load curtailment

TABLE V TEST RESULT OF FOUR CASES

| Index | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Cost ($) | 15088 | 15009 | 11095 | 11673 |
| Disutility ($) | 3859.9 | 3839.8 | 3091 | 2701.1 |
| Risk ($) | 5326.9 | 3398.4 | 0 | 0 |
| Number of EVs | 3000 | 3000 | 30000 | 40000 |
| Expected daily Energy (MWh) | 2745.4 | 2745.4 | 5791.0 | 6919 |
| Renewable generation level | 53.7% | 53.7% | 80.0% | 83.2% |
| Expected EV Energy (MWh) | 338.4 | 338.4 | 3384.4 | 4511.3 |

# Operational Risk

Day ahead schedules with 2 generators as recourse

Case 1  DR only, No EV management
-moderate renewable penetration
- High risk

Case 2  EV used for DR
- moderate renewable penetration
- Small EV penetration
- High risk

Case 3 Case 1  EV used for DR
- High renewable penetration
- High EV penetration
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# Operational Risk

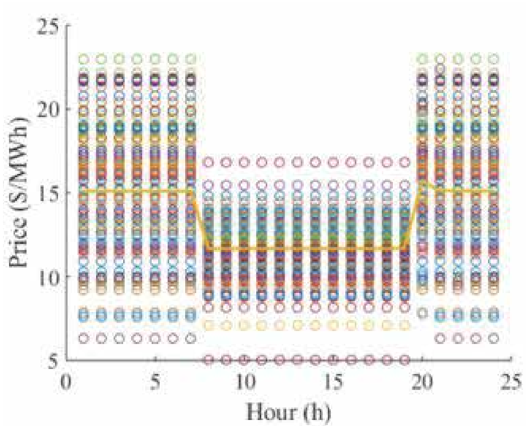


Fig.14(a)

Price

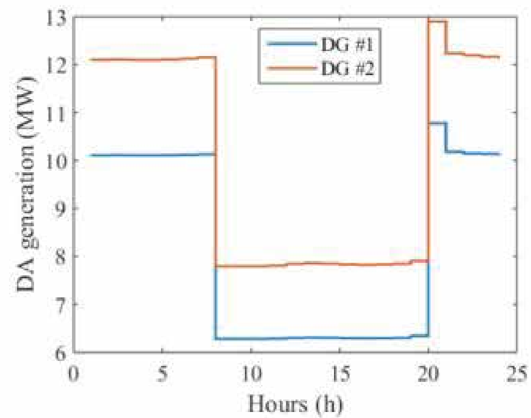


Fig.14(b)

DA Schedule

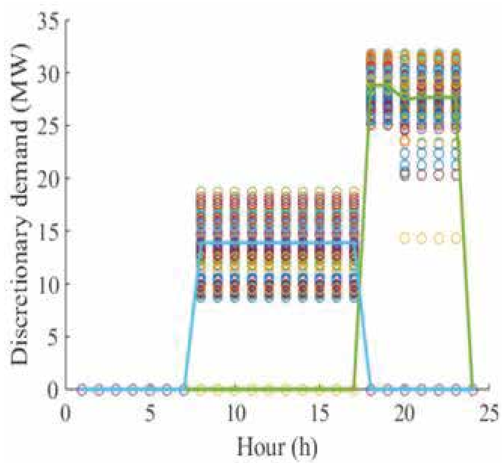


Fig.15(a)

DR

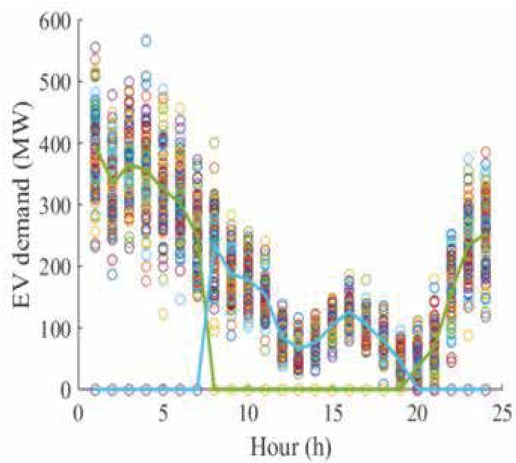


Fig.15(b)

EV

# Resilience
# (BPC Energy-Power-Resilience Primer)

NM STATE

**National Academies of Sciences, Engineering, and Medicine's "Enhancing the Resilience of the Nation's Electricity System" (July 2017)** "Resilience is not just about lessening the likelihood that that these outages will occur. It is also about limiting the scope and impact of outages when they do occur, restoring power rapidly afterwards, and learning from these experiences to better deal with the events in the future."

**PJM's "Evolving Resource Mix and System Reliability" (March 2017)** "Resilience, in the context of the bulk electric system, relates to preparing for, operating through and recovering from a high-impact, low-frequency event. Resilience is remaining reliable even during these events."

**President Barack Obama's Presidential Policy Directive-Critical Infrastructure Security and Resilience (February 2013)** "The term 'resilience' means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."

**Electric Power Research Institute's "Electric Power System Resiliency: Challenges and Opportunities" (February 2016)** "In the context of the power system, resiliency includes the ability to harden the system against—and quickly recover from—high-impact, low-frequency events."

(GAO) The nation's electricity grid is essential to modern life. We expect the grid to be resilient—to adapt to changing conditions, withstand disruptive events, and recover rapidly.

In a 2015 paper focused on developing a framework for resilience metrics, the Sandia National Laboratory recommended that metrics use a 'risk based approach.' This implies 1) resilience should be defined with respect to a specific threat (e.g. resilient to hurricanes); 2) resilience metrics should be focused on the consequences of a system failure rather than the system failure itself; and 3) resilience should be defined with respect to a specific system. Sandia created a seven-step Resilience Analysis Process to help utilities think through the creation of risk-based metrics.

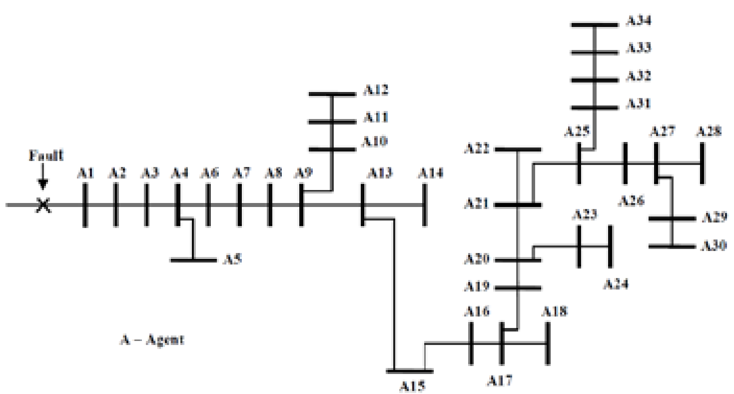
# Operational Resilience

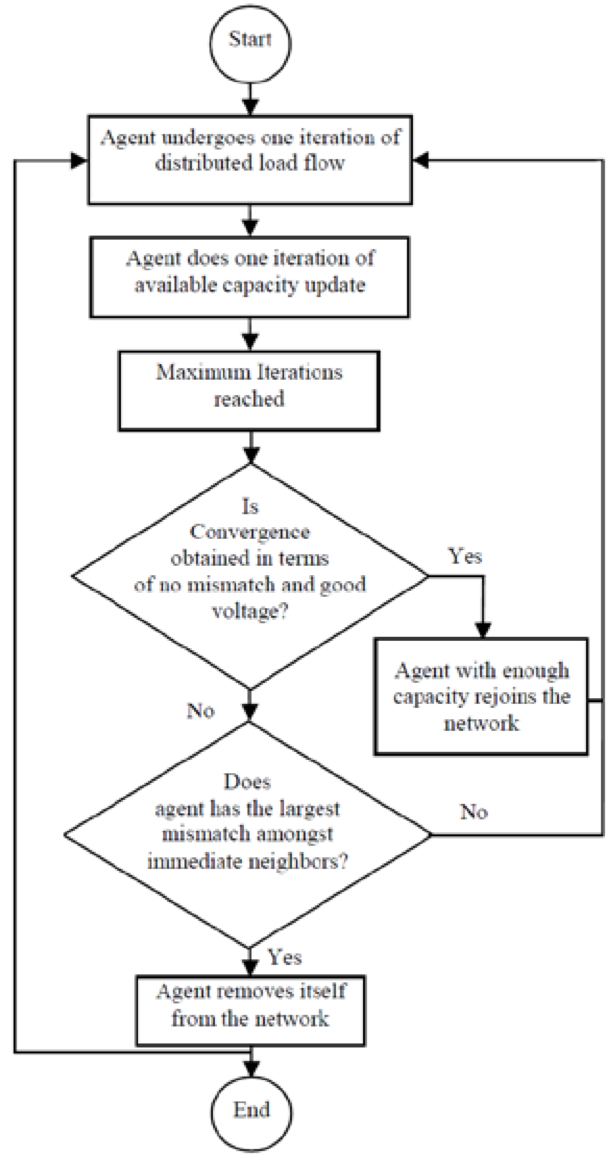
A feeder (IEEE34) with agents at each node

Neighbor-Neighbor Communication

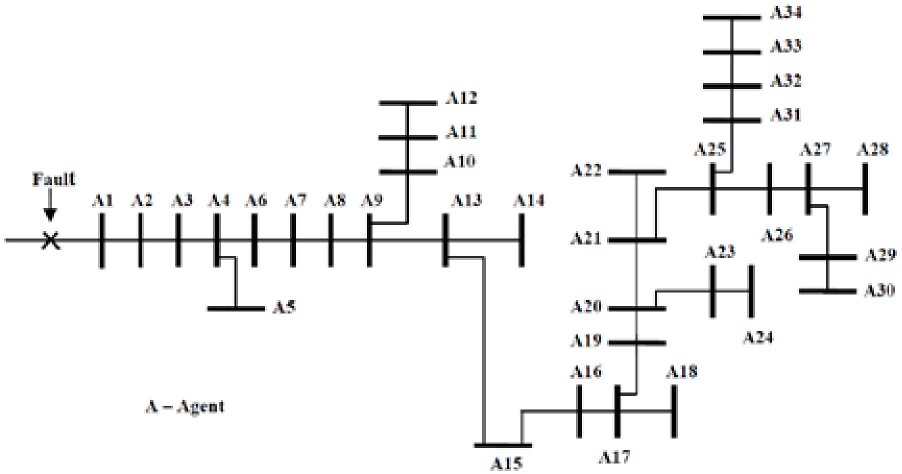
Given threat (loss of substation)
and system state

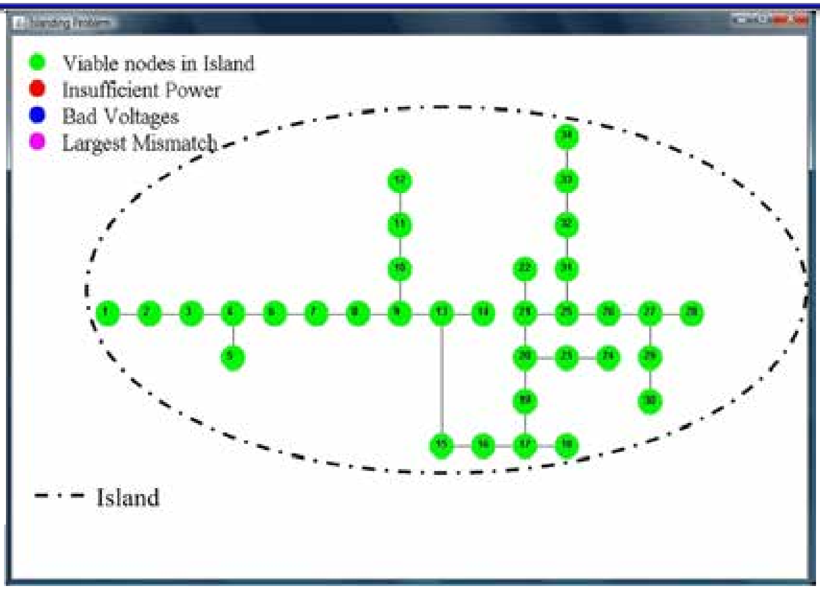
What are possible viable islands?

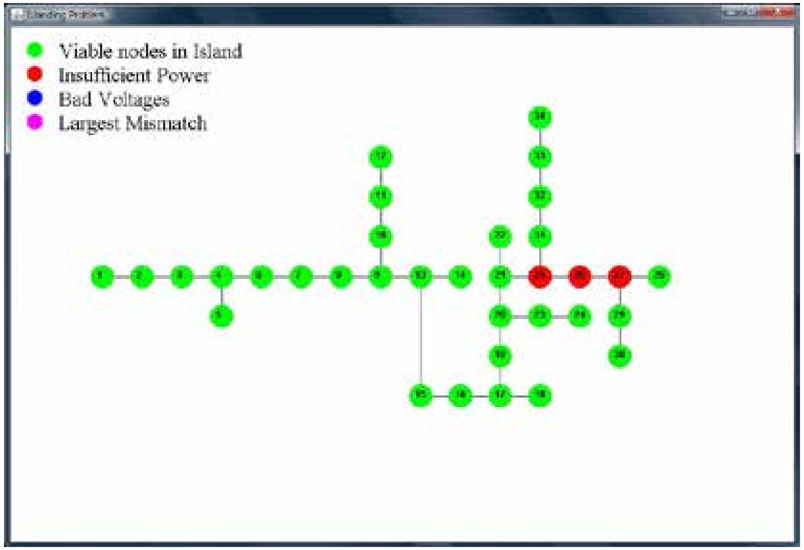


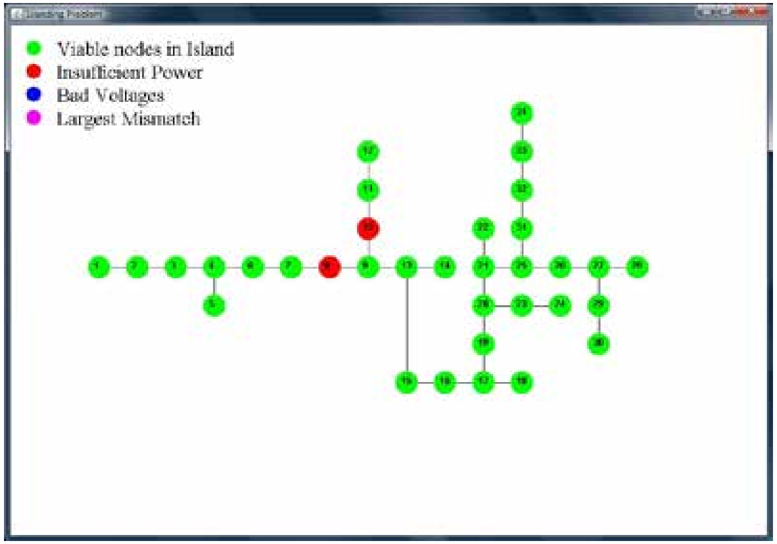



# Operational Resilience



# Summary

The distribution system is changing

DER Variability creates Risk

Engineering design/operation, risk/resilience, will depend on policy and operating structure

Need to talk in terms of infrastructure resilience

Some autonomy/decentralization possible and can provide benefits