Enhancements for ORU's Future: Design for Automation and Effects on Storm Management

Charlie Scirbona
Orange & Rockland Utilities

Robert Broadwater
EDD

Orange & Rockland
a conEdison, inc. company

Storm Impacts

Components of Resiliency

- **Absorptive capacity of the system**
  - How well a system can handle an event
    - the ratio of "customers remaining in service after an event" per "customers served"
  - Dependent on
    - Configuration – planning, protection and design standards, physical placement and location of facilities, circuit topology etc.
    - Controls – Construction standards, System Operator oversight
    - Operational Procedures - construction practices, maintenance practices, inspection programs, work practices
    - Time varying

Orange & Rockland
a conEdison, inc. company

edd

Components of Resiliency

- **Adaptive capacity of the system**
  - Ability to reconfigure after fault clearing
    - The ratio of "customers restored through restorative switching either automatic or manual" per "customers served"
  - Dependent on
    - Anticipating disruptive events – planning and design, system protection philosophy, circuit reconfiguration designs, strategic sectionalizing device placement, volt/var control device placement, control strategy
    - Recognizing unanticipated events – system protection equipment, volt/var control equipment, sensors, power quality node placement, DSCADA monitoring and alarming
    - Reorganize after an occurrence – Operator control, automation, auto [illegible] system, manual switching, coordinated volt/var control

Orange & Rockland
a conEdison, inc. company

edd

Components of Resiliency

- **Restorative capacity of the system**
  - How quickly the system can be returned to normal
    - Repair time
    - Switching time to return to normal
  - Dependent on
    - Extent of damage
    - Manpower availability
    - Accessibility of the problem area
    - Accessibility of replacement parts (on truck or in storeroom)

Orange & Rockland
a conEdison, inc. company

edd

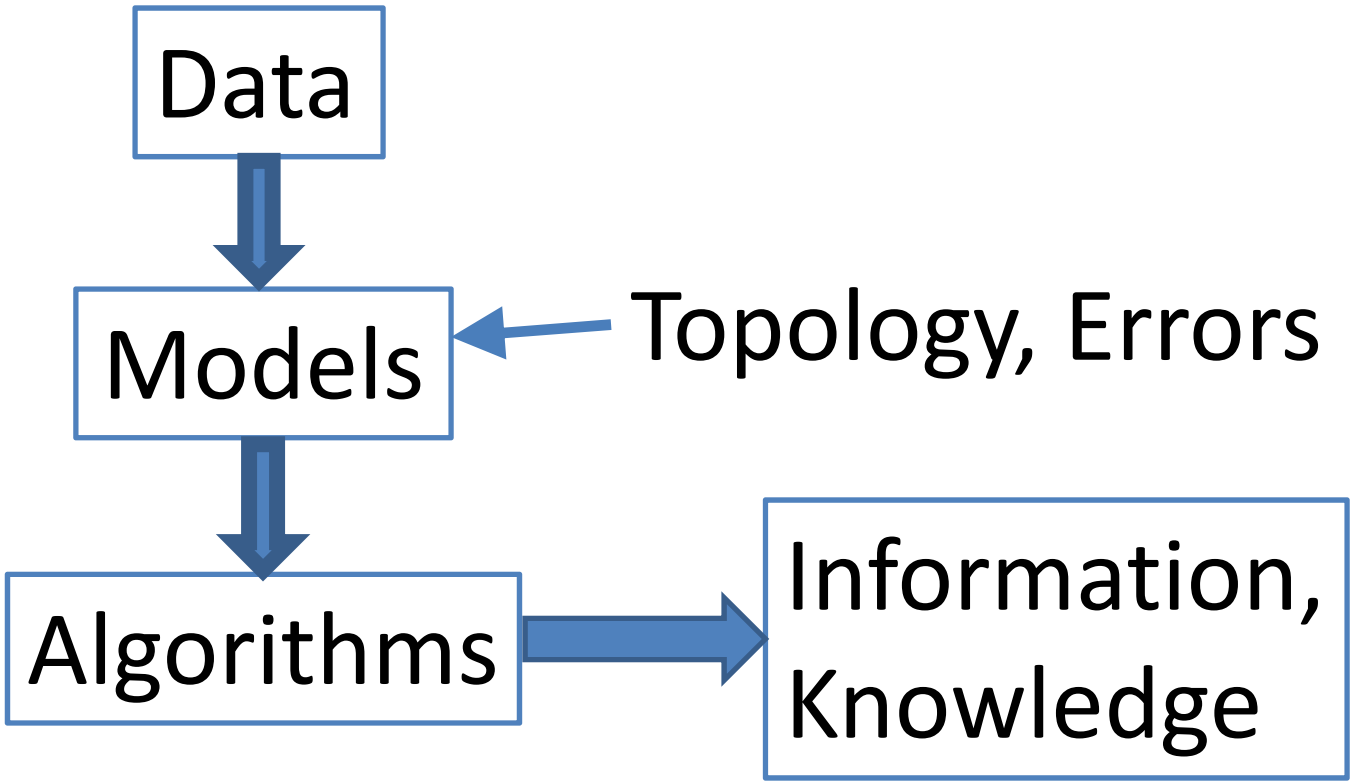
Existing Methods Affecting Resiliency

- Alphabet soup of systems exists today that often organize data, but do not create information from data
- Most of the data gathered today is going into storage and is not being turned into information
- Does data analytics, data integration, integration of databases, or integration of existing systems provide solutions?

Orange & Rockland
a conEdison, inc. company

edd

Data, Models, Algorithms, Information

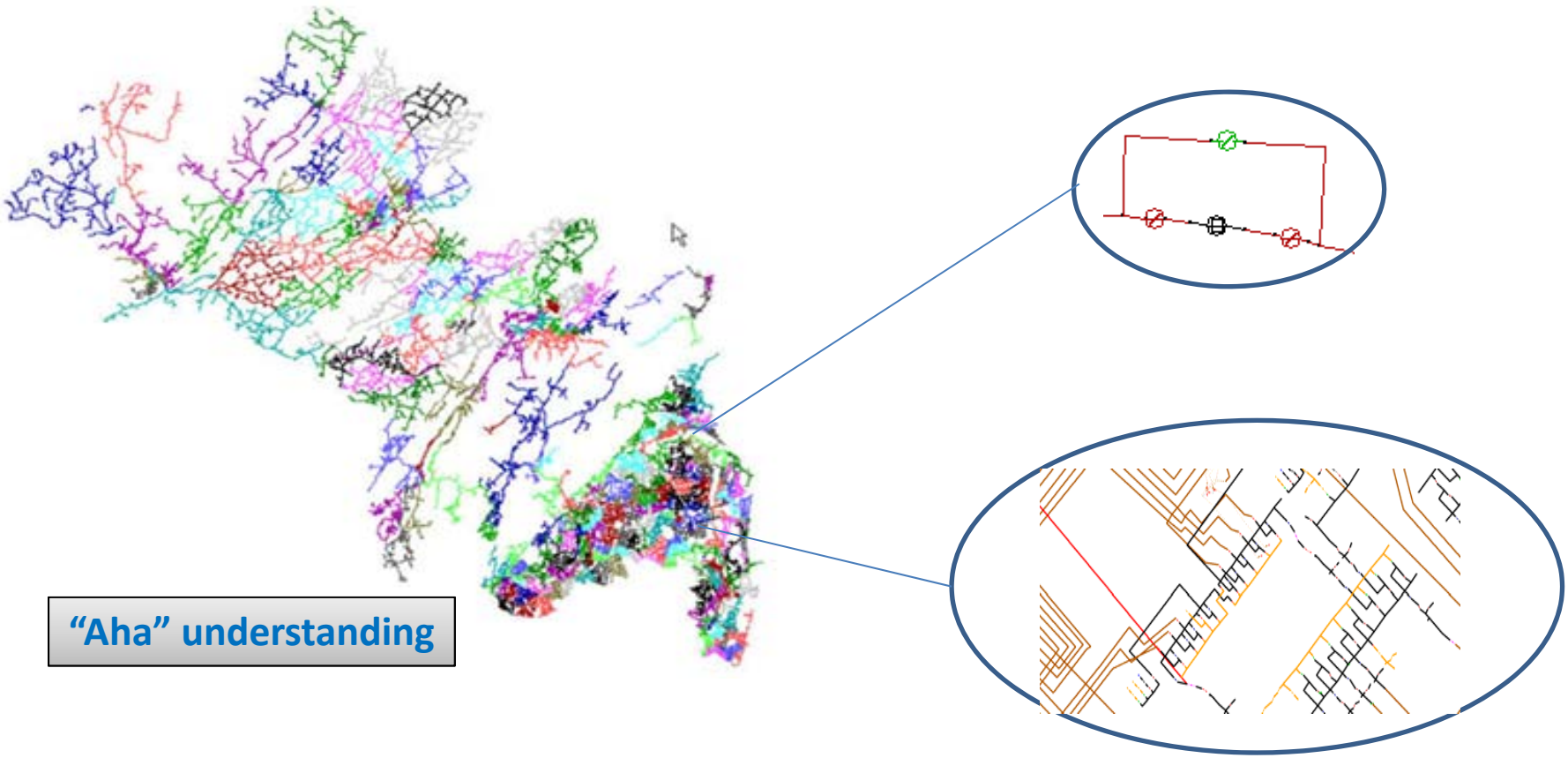


Orange & Rockland
a conEdison, inc. company

edd

Holistic Analysis with ISM

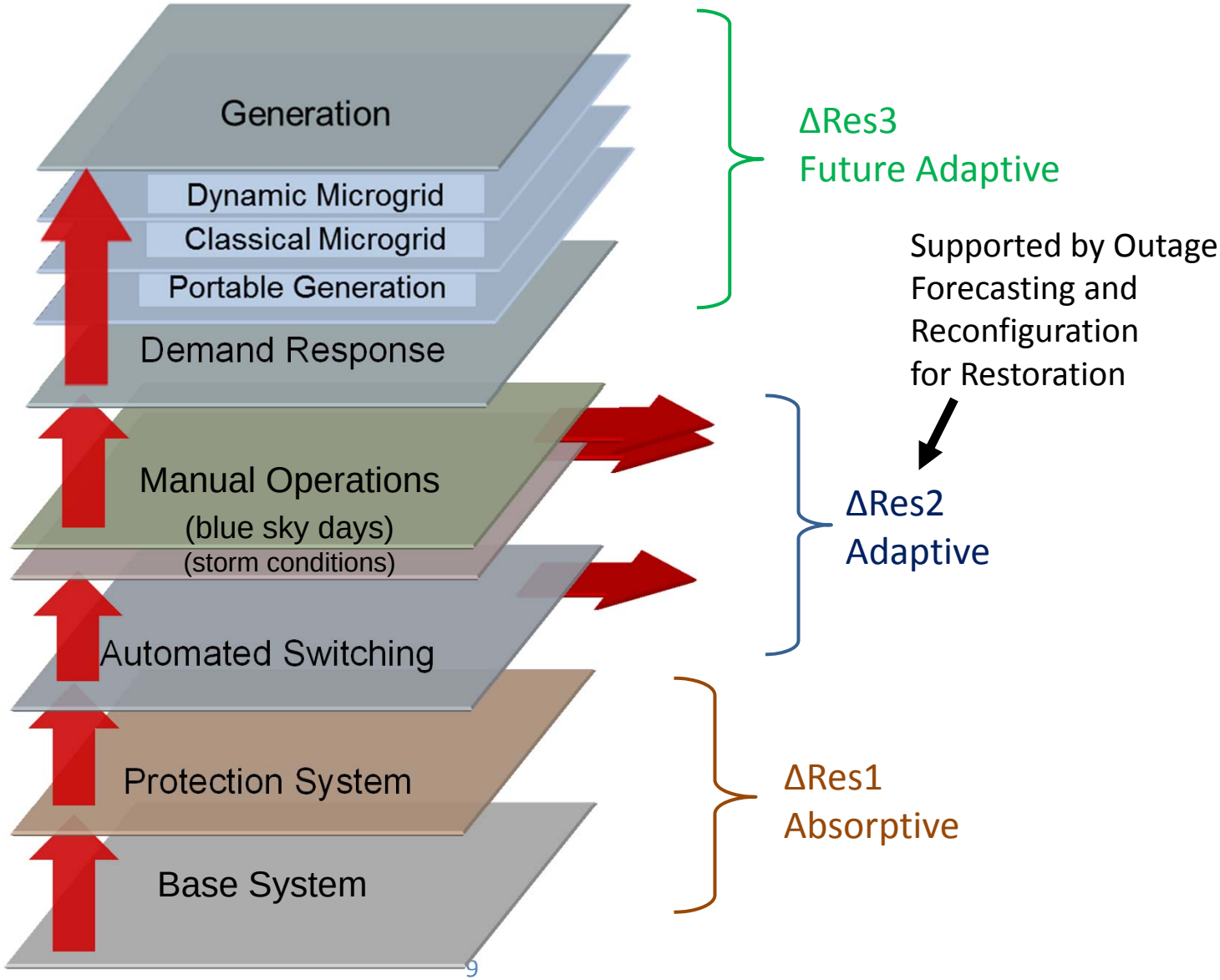
Merge all construction models together, relating all measurements



"Aha" understanding

Use one, detailed, root model for all analysis, from planning to testing to training to real-time analysis and control, maintained in synch with construction models…

Incremental Resiliency Analysis



Current Efforts: Storm Hardening

- Mechanical improvements
  - Larger class equipment poles
  - Larger guy strands and bigger anchor rods
  - High strength construction such as Hendrix spacer cable
- Design improvements
  - Elimination of double circuit pole lines
    - More and longer underground exits to the load pockets
- Operational improvements
  - Enhanced tree trimming

Orange & Rockland
a conEdison, inc. company

edd

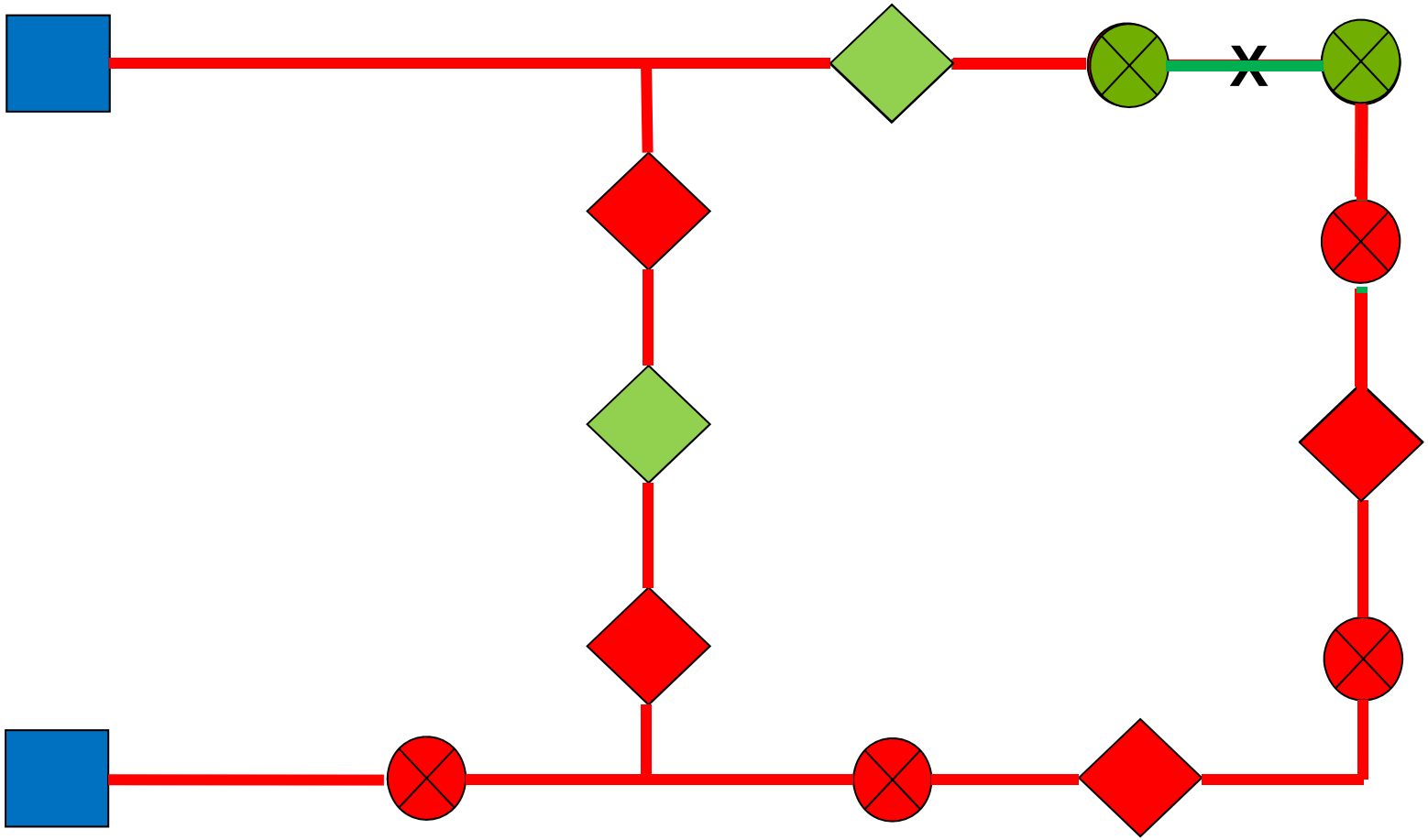
Current Efforts: Automation

- Creation of more automatic loop schemes
- Reduce customer counts between sectionalizing devices
- Implementation of auto-restoration system
  - Model-centric control decisions
- Coordinated volt/var control

Orange & Rockland
a conEdison, inc. company

edd

Auto Restoration



Analysis Efforts

- Integrated System Model
- Planning
  - Monte Carlo reliability analysis
    - Storms
    - Blue sky days
- Real-time storm detection, outage prediction, and crew management
- Real-time automation control
  - Calculate system conditions every SCADA scan
  - Fault location and isolation
  - Reconfiguration for restoration
  - Protection and coordination
  - Coordinated volt/var control
- Security analysis

Orange & Rockland
a conEdison, inc. company

edd

Affecting Restorative Component

- Storm management information
  - Damage prediction
  - Number of outage incidents by type
  - Where outages occur
  - Estimated time to perform switching operations
  - Estimated repair time
  - Estimated restoration time
- Protection system and manual switch design
- Automated switch design and control
- Automated analysis of manual switching operations
- Major storm and emergency preparation
  - Critical loads, missions, restoration based on missions

Orange & Rockland
a conEdison, inc. company

edd

Weather Data for Predicting Outages

- Temperature
- Wind speed
- Lightning intensity and flash density
- Doppler weather radar data
  - Integrate precipitation to determine ground saturation

Orange & Rockland
a conEdison, inc. company

Storm Classifications

STORM CLASSIFICATION AND PARAMETERS

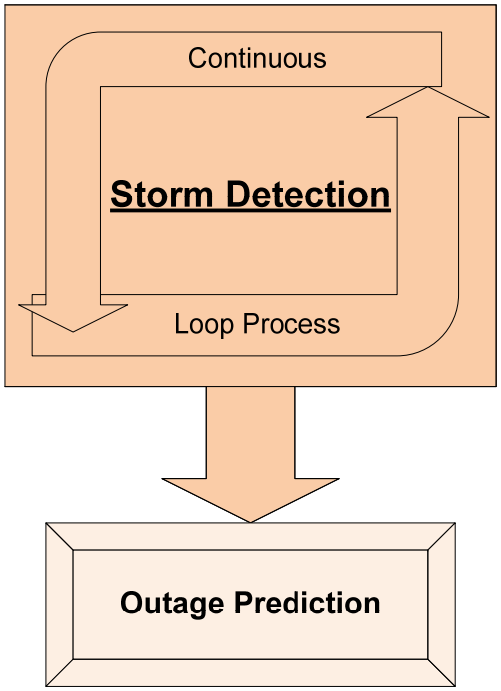
Storm Types and Descriptions	T Range (oF)	Wind Speed (mph)	Average Length (hours)
H: High temperature, no strong wind	MaxT > 80	WS <= 20	56
HS: High temperature, strong wind	MaxT > 80	WS > 20	84
L: Low temperature, no strong wind	MinT < 32	WS <= 20	55
LS: Low temperature, strong wind	MinT < 32	WS > 20	146
M: Moderate temperature, no strong wind	MaxT <= 80 MinT >= 32	WS <= 20	35
MS: Moderate temperature ,strong wind	MaxT <= 80 MinT >= 32	WS > 20	53
MaxT: maximum temperature; MinT: minimum temperature;			

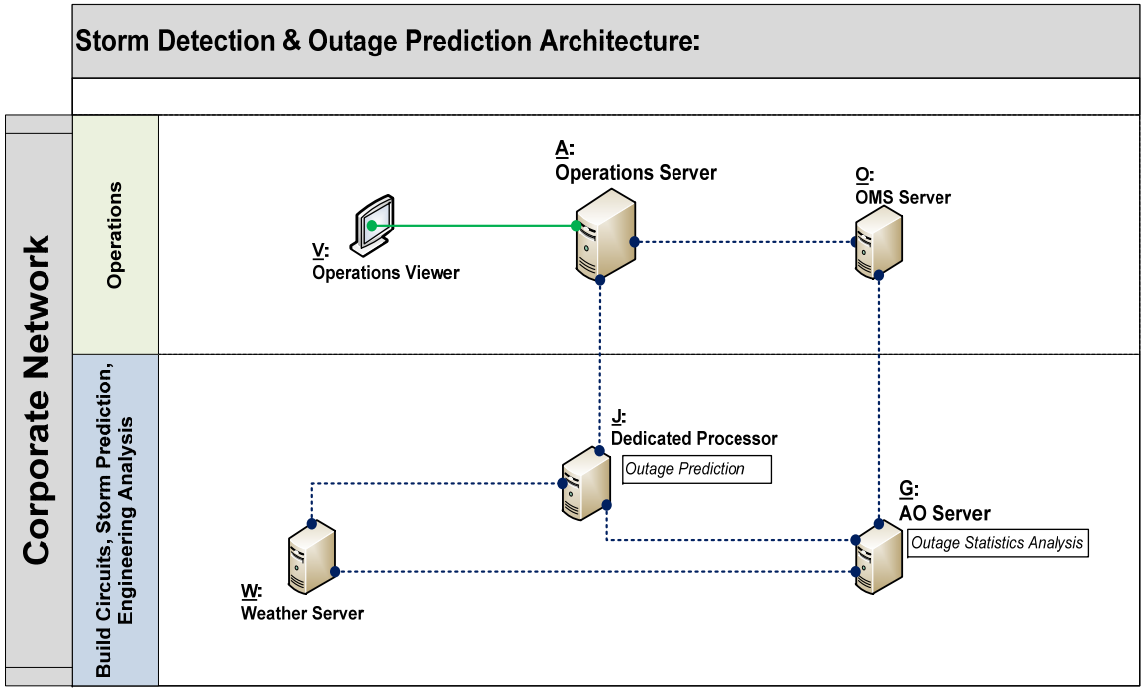
Current Outage Estimation

- Weather conditions (temperature range and maximum wind speed) are used to select curve fit to use of expected outages as a function of the hour of the storm type
- The expected outages are modified every 15 minutes by using error between predicted outages and actual outages to update predicted outages

Orange & Rockland
a conEdison, inc. company

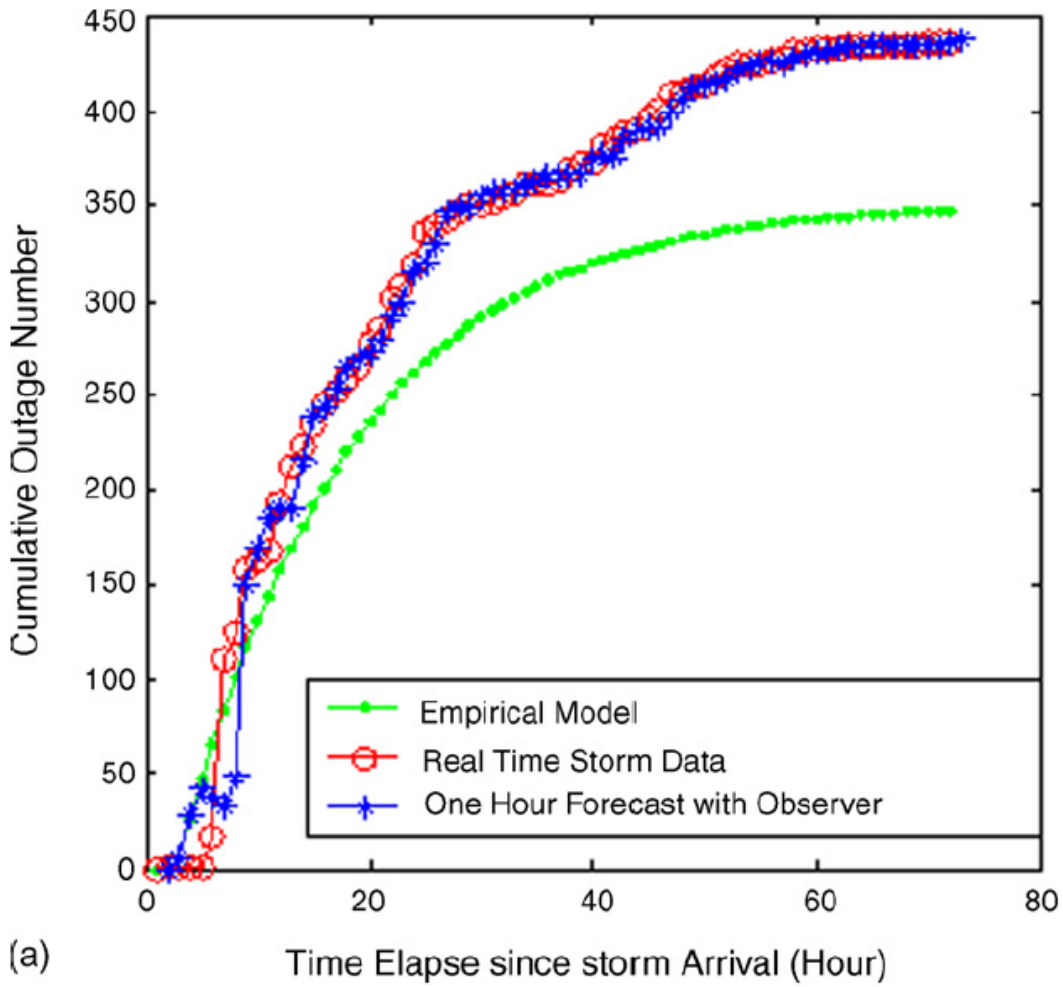
Storm Outage Prediction



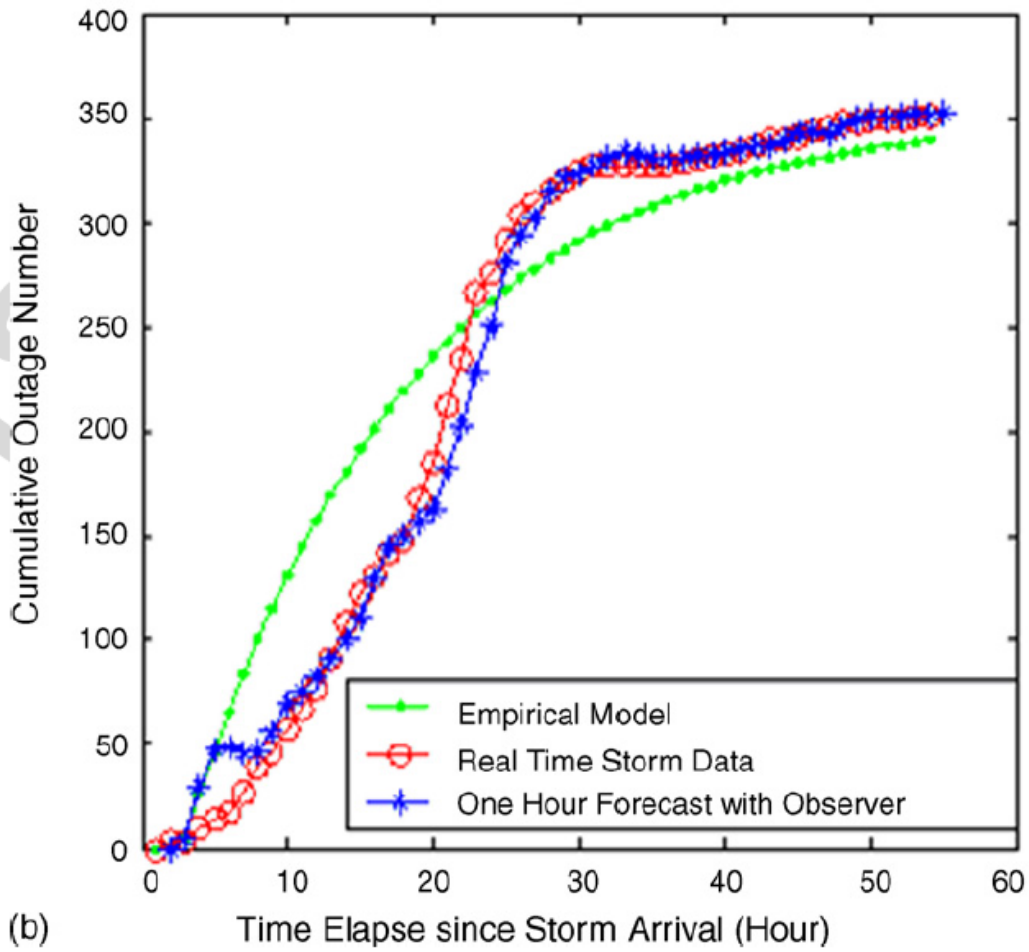


Storm Outage Prediction uses an empirical outage model, along with real time data from the Weather Station and Outage Management Systems, to predict the incident outlook based on worst-case weather conditions. The incident outlook is continually updated, using the latest weather and outage data to provide revised predictions for the operator.

Real-Time Outage Prediction: Normal Storm



Real-Time Outage Prediction: Abnormal Storm



(b)

Modeling of Lightning Outages

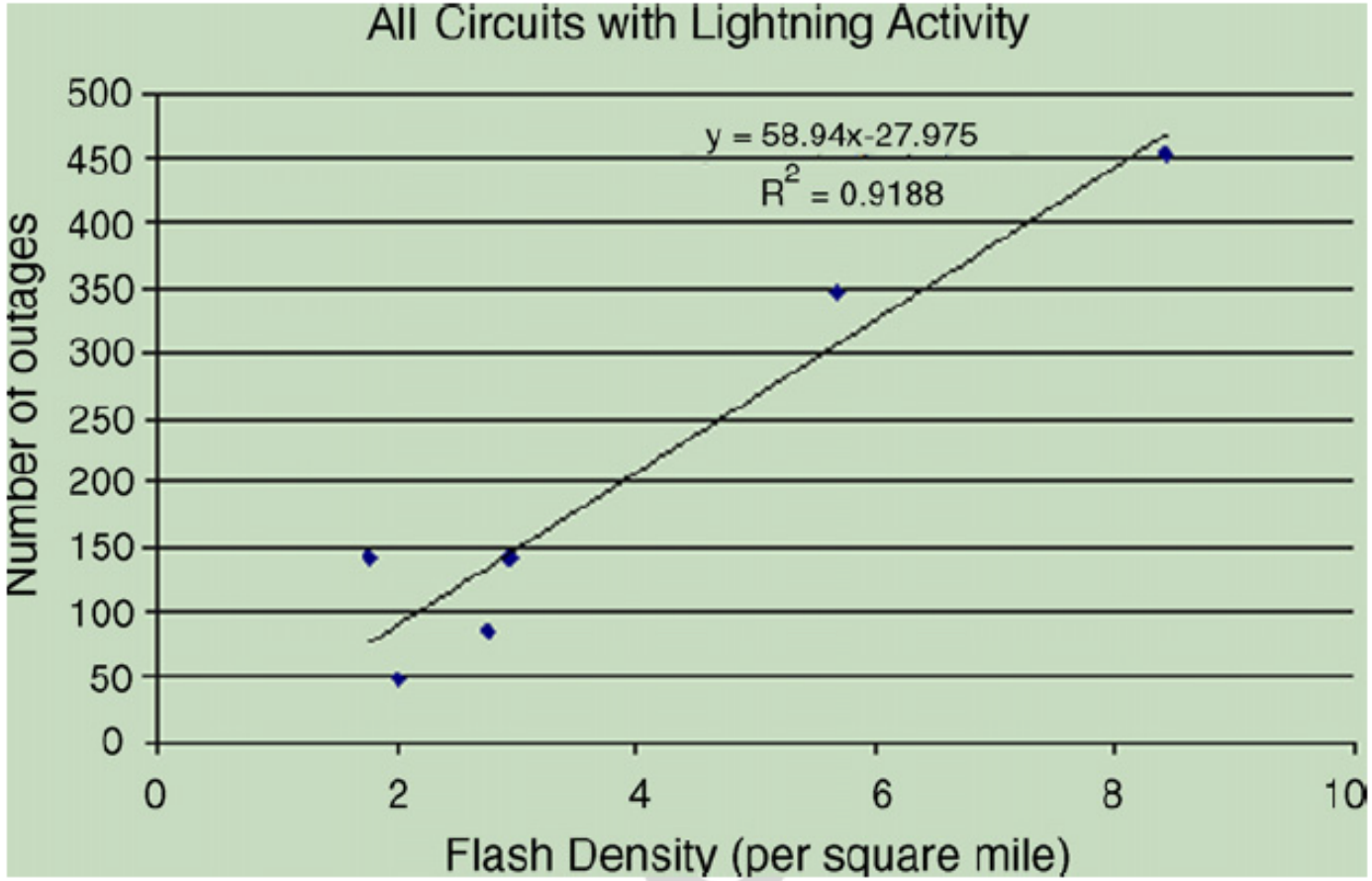


Fig. 10. Number of power outages vs. 10–30 kA flash densities in 200-ft corridor over all circuits with lightning activity.

Monte Carlo Storm Analysis

- Expected failures by equipment type as a function of hour of storm
- Automated, reconfiguration for restoration collaborating with power flow (manual switching or automatic switching or both)
  - Time varying loads (load research, monthly kWHr, hourly kWHr, load growth)
- Crew operation models
  - Numbers of each crew type, what crews can repair what failures, times to operate switches, times to perform repairs by failure type
- Customers and customer types
  - Critical customers and/or critical loads; prioritized missions, which may be groups of critical customers and/or critical loads

Orange & Rockland
a conEdison, inc. company

edd

Failure Distributions for Monte Carlo

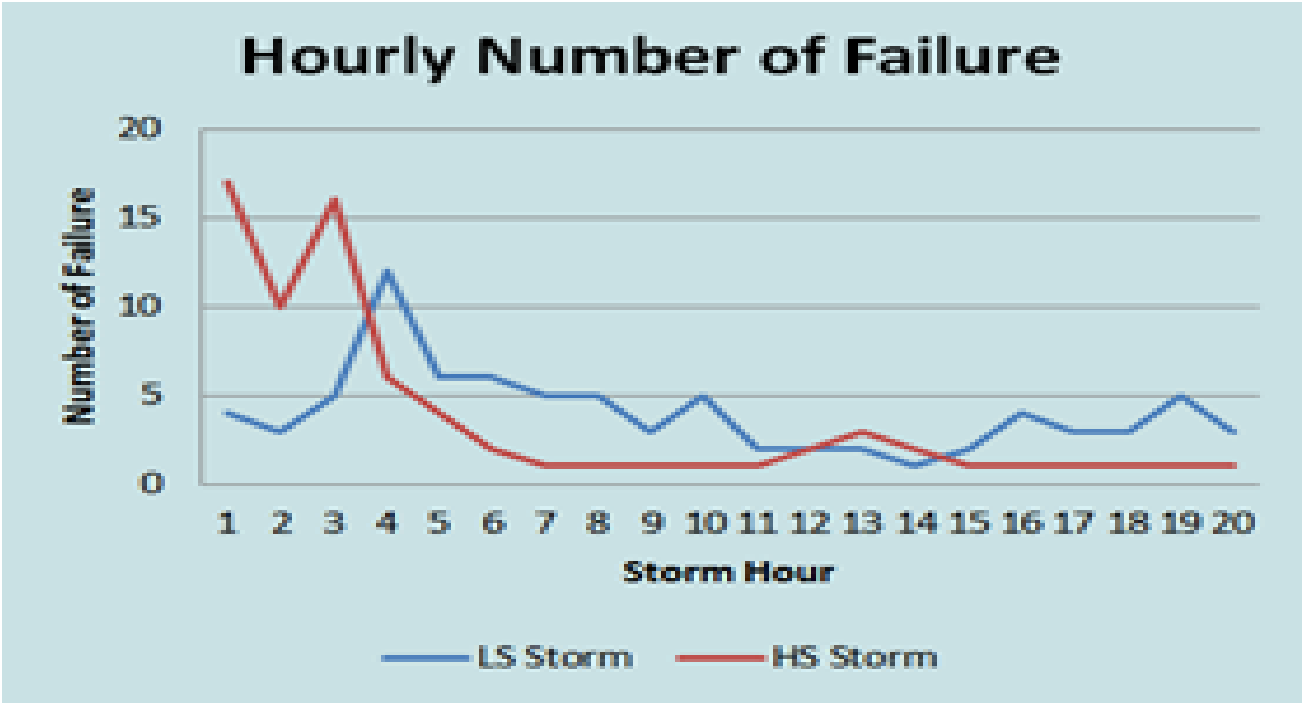
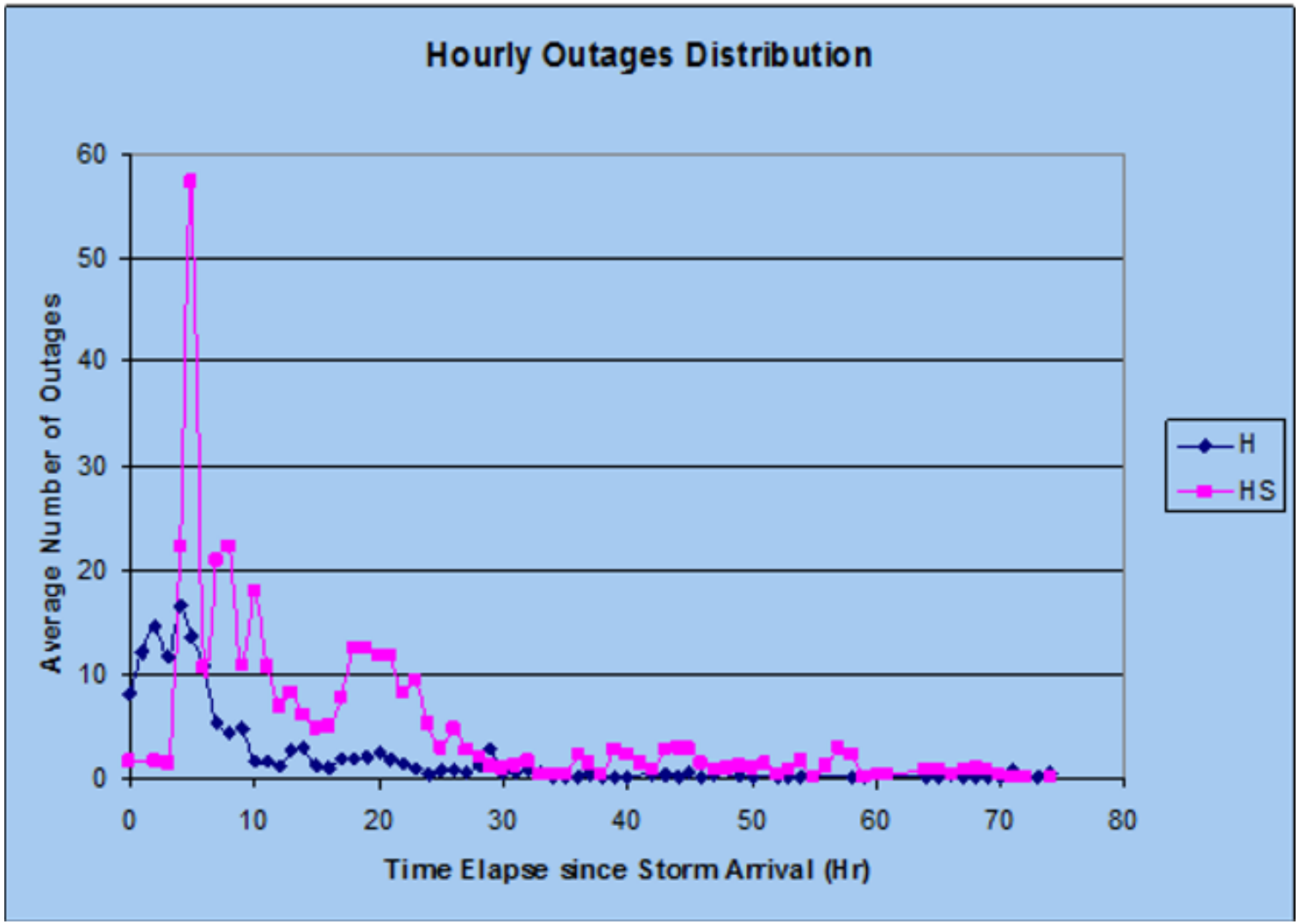
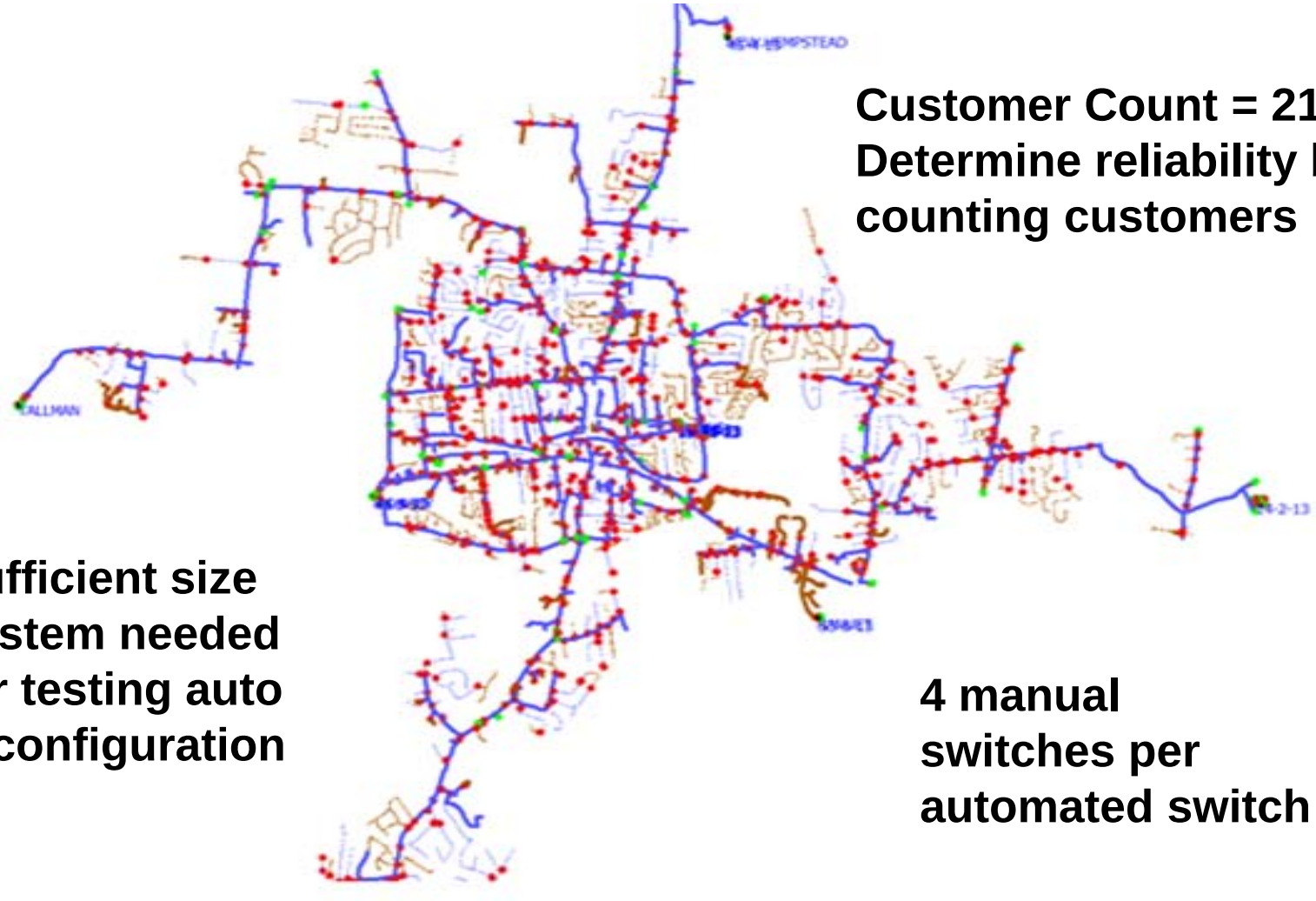


Fig. 3.1. Average Hourly Number of Failures for Low Temperature, Storm Wind (LS) and High Temperature, Strong Wind (HS) Type Storms

Outage Distributions for Monte Carlo



14 Feeder DA Pilot System

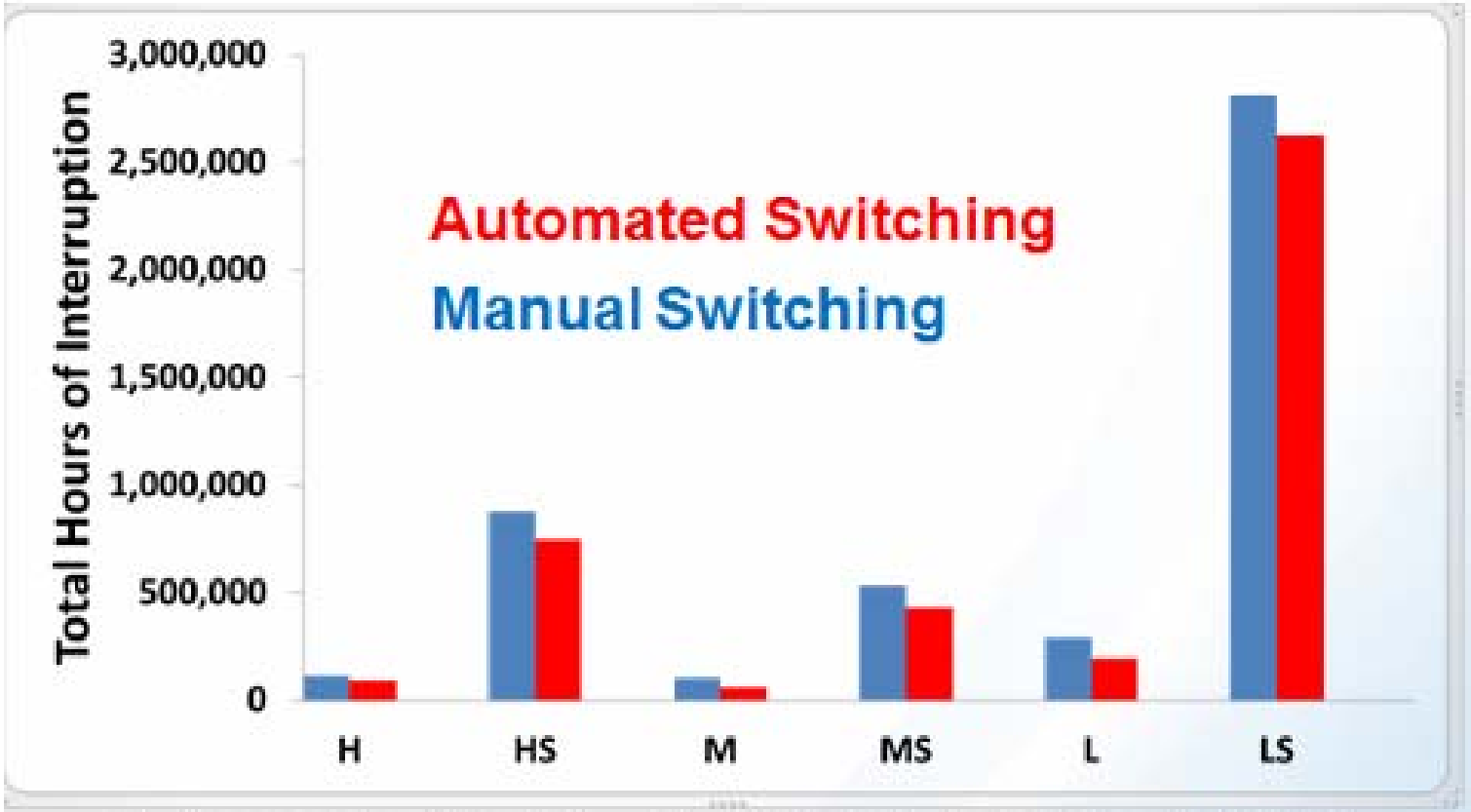


Customer Count = 21,991
Determine reliability by counting customers

Sufficient size system needed for testing auto reconfiguration

4 manual switches per automated switch

Storm Analysis Results



H – (Temperature > 80 degree) *M – (32 degree <= Temperature <= 80 degree)*

L – (Temperature < freezing) *S – (Wind speed > 20 mph)*

SAIDI Improvements

		Manual Circuit		Automated Circuit	SAIDI Improvement
Type of Storm	Average Number of Failure per Storm	Device Switching Hour	Total Customer Outage Time	Total Customer Outage Time	%
H	18	40	113,674	95,859	0.4051
HS	96	213	874,317	745,988	2.9178
M	27	60	103,662	60,925	0.9717
MS	74	168	531,059	431,580	2.2618
L	55	132	301,707	197,353	2.3727
LS	173	403	2,812,471	2,623,756	4.2907

Grid Resiliency for Missions

- Critical customer power loss may be automatically reported at a utility, but generally determining how to restore power is not supported by automated analysis
- Missions and mission critical loads
  - Public safety: live wire down, broken poles, or precariously hanging trees or equipment
  - Critical loads: Major economic impact; Transportation-traffic lights, gas stations, subways, railroads; Fire fighting; Potable water supply; Health services - pharmacies
- ***Including critical customers and missions in ORU ISM enables design and operational algorithms to address emergency management (major storms)***

Orange & Rockland
a conEdison, inc. company

Comparing Alternative Designs

- For a given set of events, Design A is more resilient than Design B if Design A results in better { customer, critical customer, critical load, mission } restoration/resiliency metrics on average than Design B
- Define restoration vector which contains restoration and/or system resiliency metrics that may be used to compare alternatives
- Compare performance from different Monte Carlo runs across different designs against events, using Monte Carlo events from Monte Carlo run on base case system
  - Monte Carlo event performance comparison runs
- Incrementally compare performance of design

Orange & Rockland
a conEdison, inc. company

Resiliency Metrics

- Customers and critical customers outaged after protective device operations
  - Note, critical customers may be grouped by prioritized missions
- Customers and critical customers outaged after auto devices operate
- Customers and critical customers outaged after manual operations
- Total customer outage times

Orange & Rockland
a conEdison, inc. company

Resiliency Metrics with Mission Critical Customers

For event i, for system d, for mission m, calculate

- Number of critical customers outaged when protective devices operate
- Number of critical customers outaged (restored) following operation of automated devices
- Number of critical customers outaged (restored) following operation of each manual device

Orange & Rockland
a conEdison, inc. company

Conclusions

- Resiliency metrics to include components that measure the following resiliency components
  - Absorptive capacity of system
  - Adaptive capacity of system
  - Restorative capacity of system
- Many improvements can be estimated through analysis, but pilot projects are necessary to validate some assumptions that must be made in the analysis

Orange & Rockland
a conEdison, inc. company

edd

Conclusions Continued

- Customer expectations and needs have changed and these need to be modeled as part of any resiliency analysis
- Loads need to be prioritized based on these additional customer requirements and interdependencies
- Systems that are installed to deal with resiliency must have flexibility to rapidly change priorities

Orange & Rockland
a conEdison, inc. company

edd

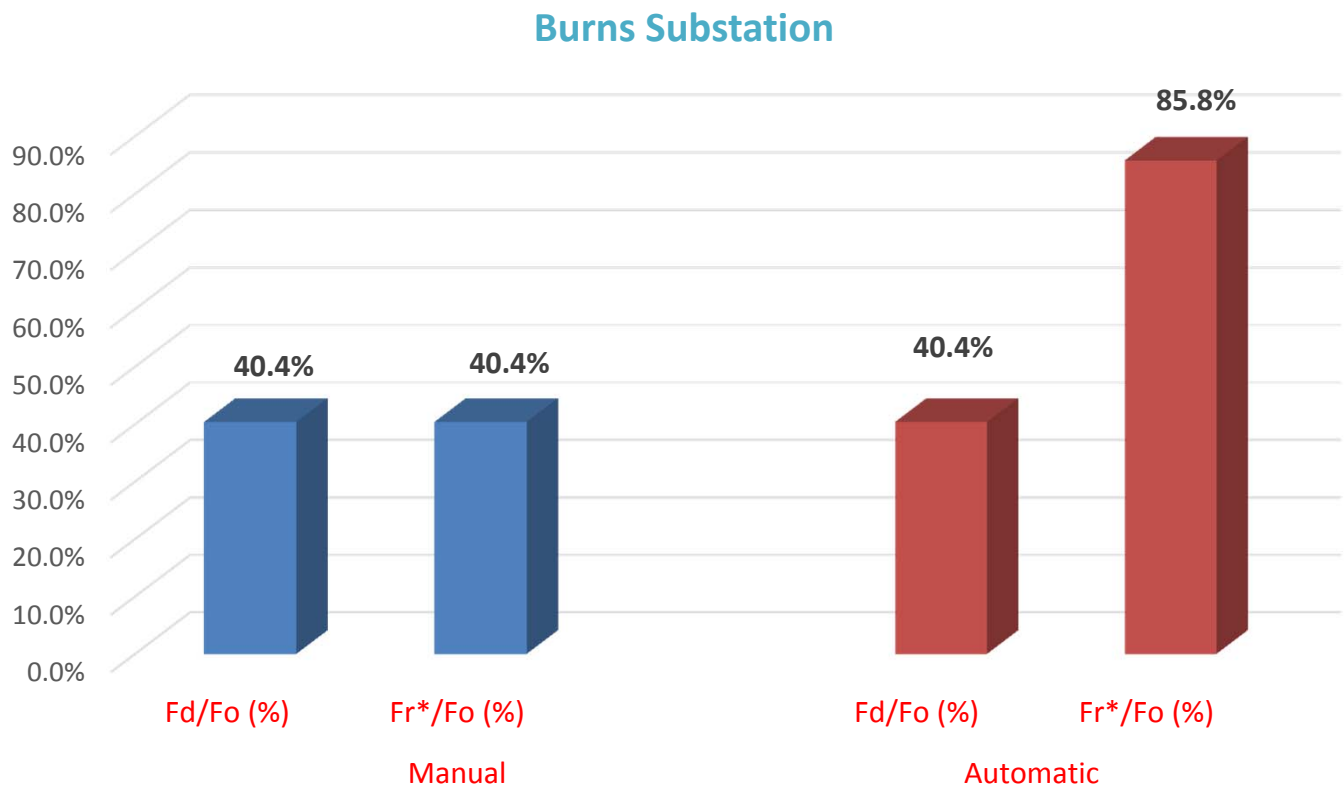
Questions?

Mission Critical Customer Count Definitions

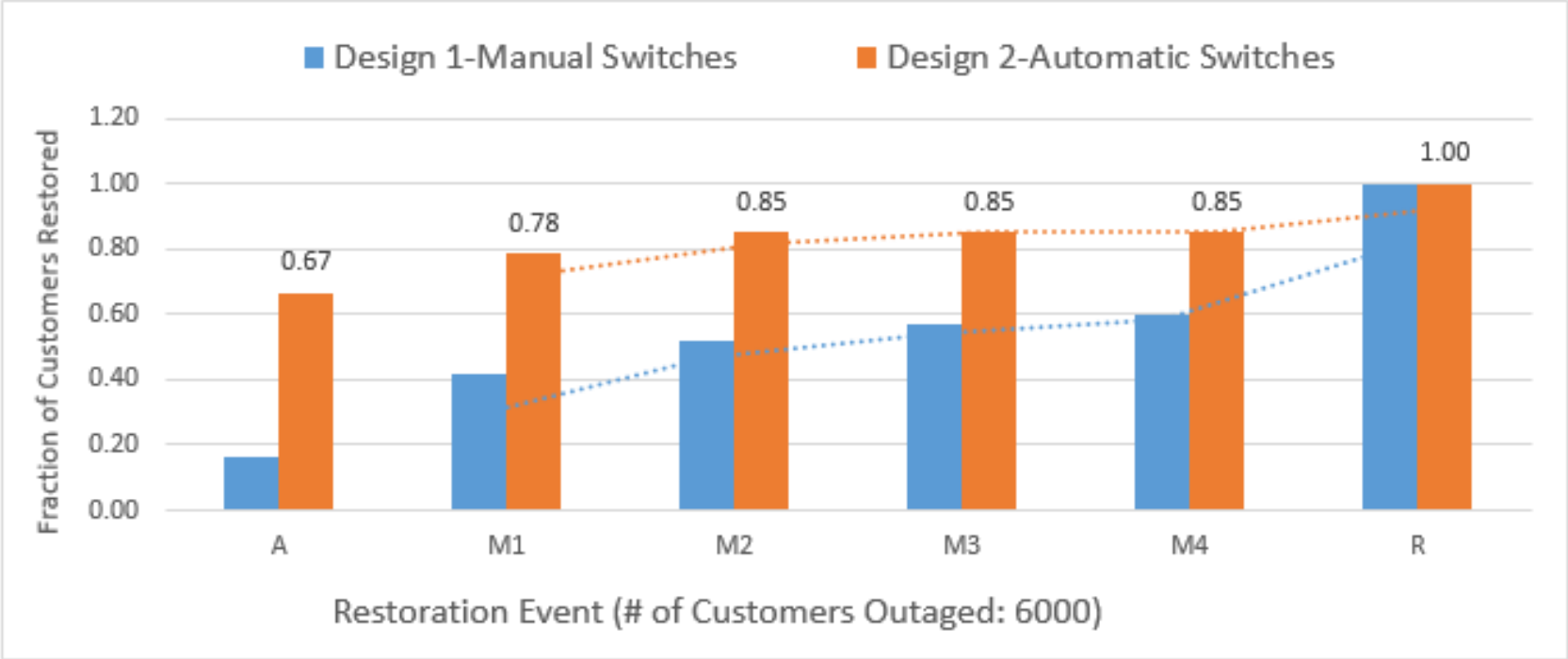
For event i, for system d, for mission m, define

- CC_{OPdmi} = number of critical customers outaged when protective devices operate
- CC_{OAdmi} (CC_{RAdmi})= number of critical customers outaged (restored) following operation of automated devices
- CC_{OMdmio} (CC_{RMdmio}) = number of critical customers outaged (restored) following operation of manual device o

Resiliency Measurement Example



Zoom in on Event i: Fraction of Customers Restored



Restoration Vector

r_{di} = {C_{RAdi}/C_{OPdi} , C_{RMdio}/C_{OPdi} , list(T_{dio}), T_{REPdi} , $CAIDI_{di}$, $TCOH_{di}$, N_F, N_P, N_A, N_{MAN}, N_{MIS}, list(failed equipment), list(protective devices), list(auto switches), list(manual switches), list(crew types), list(crew type repair times), T_{RESdi}, …, list(mission priorities), CC_{RAdmi}/CC_{OPdmi} , list(CC_{RMdmio}/CC_{OPdmi}), $CCAIDI_{dmi}$, $TCCOH_{dmi}$,… ,

o = 1, 2, …, N_M, m = 1, 2, …, N_{MIS}}

Compare performance of alternative designs by plotting restoration vector quantities, such as plotting variable values corresponding to d and/or m against i

Note: ORU capability for blue-sky-days

Customer Count Definitions

- For event i, for system d, define
  - C_{OPdi} = number of customers outaged when protective devices operate
  - C_{OAdi} (C_{RAdi})= number of customers outaged (restored) following operation of automated devices
  - C_{OMdio} (C_{RMdio}) = number of customers outaged (restored) following operation of manual device o

Restoration Vector Definitions

$TCOH_{di}$ = total customer outage hours

$TCCOH_{dmi}$ = total critical customer outage hours

T_{di1} = time required to operate first manual switch measured from protective device(s) operation

T_{dio} = time between operating manual switch o - 1 and manual switch o, o > 1

T_{REPdi} = time to perform repairs measured from time of final manual switch operation

T_{RESdi} = total time required to restore all customer power measured from protective device(s) operation

N_F, N_P, N_A, N_{MAN}, N_{MIS} = count of failed equipment, protective device operations, automated switch operations, manual switch operations, missions, respectively

Calculating $CAIDI_{di}$,$CCAIDI_{dmi}$

($CCAIDI_{dmi}$) $CAIDI_{di}$ = (Critical) Customer average interruption duration interval

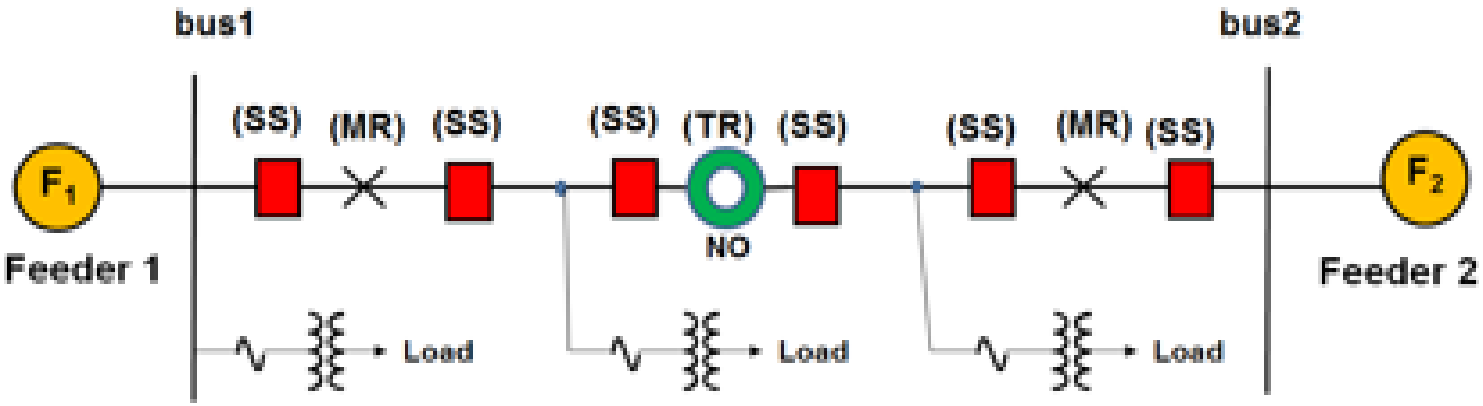
$$CAIDI_{di} = (C_{OAdi} * T_{di1} + \text{sum}(C_{OMdij} * T_{dio} , o = 2 \text{ to } N_M - 1, j = o - 1) + C_{OMdio}(o = N_M) * T_{Rdi}) / C_{OPdi}$$

$$CCAIDI_{dmi} = (CC_{OAdmi} * T_{di1} + \text{sum}(CC_{OMdimj} * T_{dio} , o = 2 \text{ to } N_M - 1, j = o - 1) + CC_{OMdimo}(o = N_M) * T_{Rdi}) / CC_{OPdmi}$$

Restoration Vector Indices

- Subscript d = system “d”, where the performance of different systems will be compared (often base case is d = 1)
- Subscript i = event “i,” defines a set of failures that result in customer power outages
  - 100,000’s of events simulated over many storms/years
- Subscript o = manual switch operation “o,” where for a given event manual switch operations are ordered by index o
- Subscript m = mission “m,” where there may be multiple missions and missions are prioritized

Automated Switch Design



SS: Scada Switch
MR: Midpoint Recloser
TR: Tie Recloser
NO: Normally Open

Use inexpensive, automated switches that do not need to be programmed ….
Model-Centric intelligence covers all scenarios