SMART DISTRIBUTION APPLICATIONS &THEIR INTEGRATION IN A SMART GRID ENVIRONMENT

Presented By:
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July, 2011

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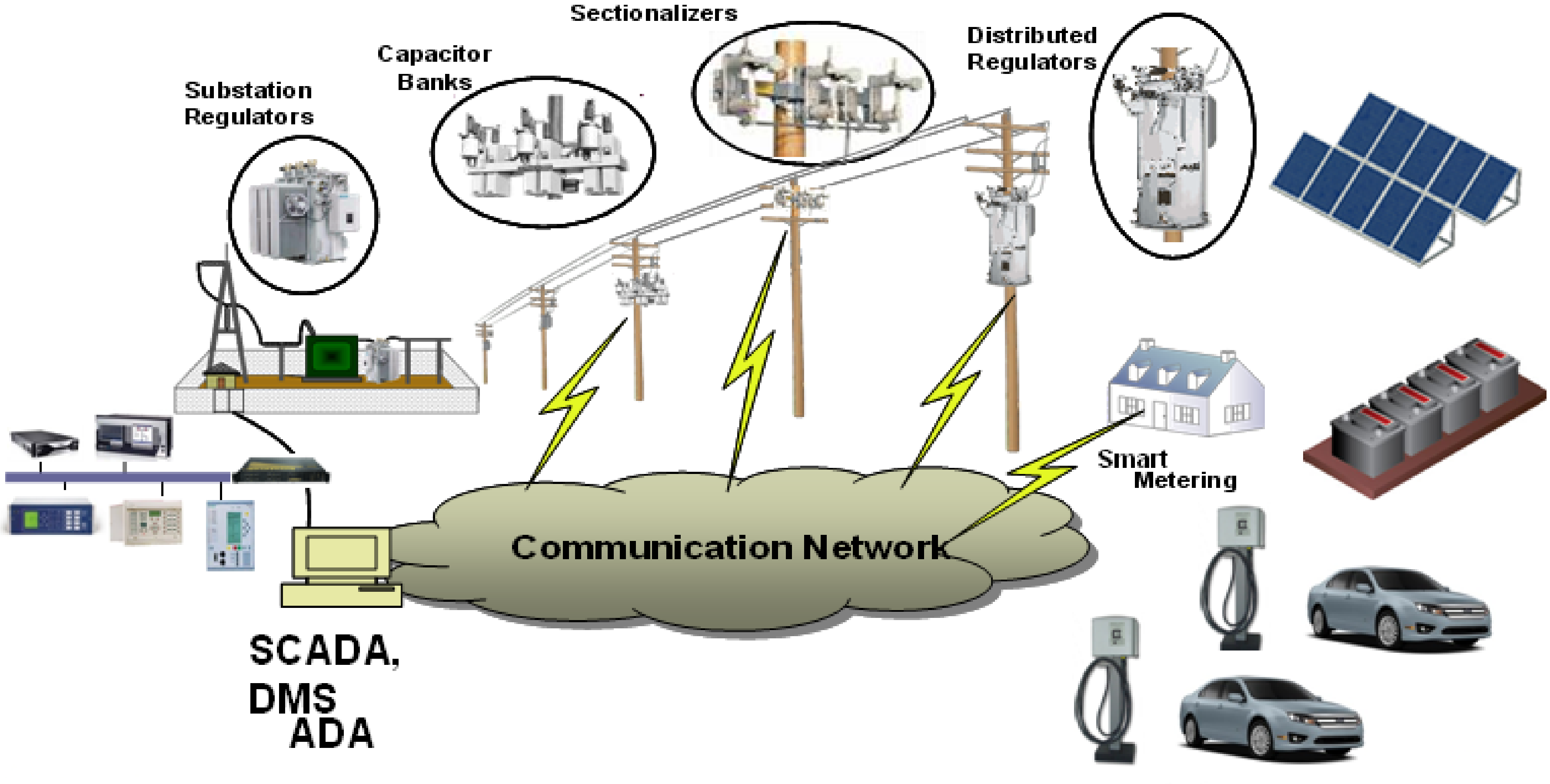

Sectionalizers
Capacitor Banks
Distributed Regulators
Substation Regulators
Smart Metering
Communication Network
SCADA,
DMS
ADA

Key Smart Distribution Applications

- What are the major trends of the day?
- What issues need to be resolved?
- Where should the industry go from here?

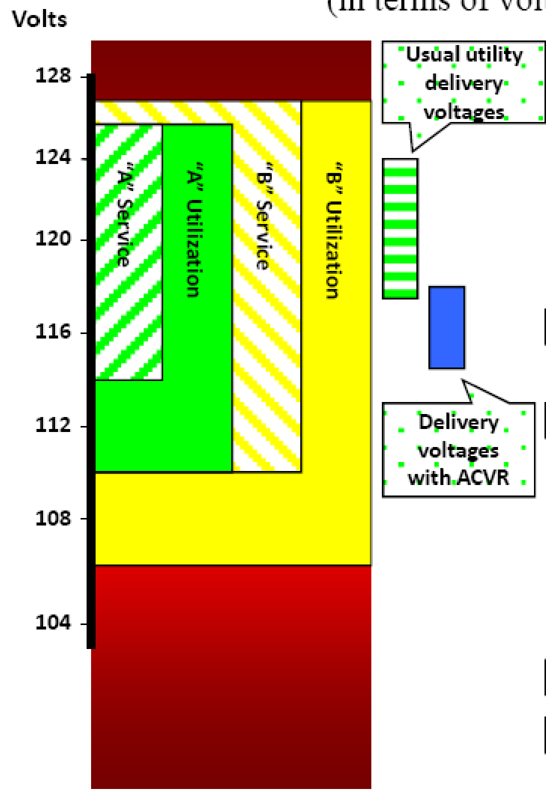
Distribution Voltage Optimization

Major Trend: Many electrical utilities are implementing Conservation Voltage Reduction for demand and energy reduction

- ANSI standards have some flexibility in the allowable delivery voltage
- Distribution utilities typically have delivery voltage in upper portion of the range
- **<u>Concept of CVR:</u> Maintain voltage delivered to the customer in the lower portion of the acceptable range**

Allowable Voltage Range

(in terms of voltages used in homes)



ANSI Standard C 84.1 – 1995 "Electrical Power Systems and Equipment – Voltage Ratings"
[similar to CAN3-C235-83 (R2000)]

Nominal 120 VAC – Range A (Normal Operation)

- **Service Voltage 114 v – 126 v**
  - Voltage at which utility delivers power to home
- **Utilization Voltage 110v – 126 v**
  - Voltage at which equipment uses power
  - Most Motors rated at 115 v
  - Incandescent Lamps rated at 120 v

Nominal 120 VAC – Range B (Out of Normal Operation)

- **Service Voltage 110 v – 127 v**
- **Utilization Voltage 106v – 127 v**

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CVR Benefits Achieved

- **CVR factor** for voltage reduction ranges from 0.65 to 0.7
- **Reduction of electrical demand** ranges from 1.5% to 2.1%
  - Cheap alternative to conventional generation
  - Reduction of total demand by 310 MW (eliminate need for two peak shaving CTs)
  - No carbon or emission offsets needed
- **Reduction of energy consumption** ranges from 1.3% - 2%
- Near **unity power factor**
- Provide **demand response** capabilities
- Decrease sub/feeder **overloading**
- **Reduced** High and Low voltage **complaints**
- Improve Customer voltage quality (**less flicker**).
- Increase customer **end-use appliance life** by 15%.
- **Lower Customer Bills** $16.50/yr

Distribution Voltage Optimization
Key issues and challenges

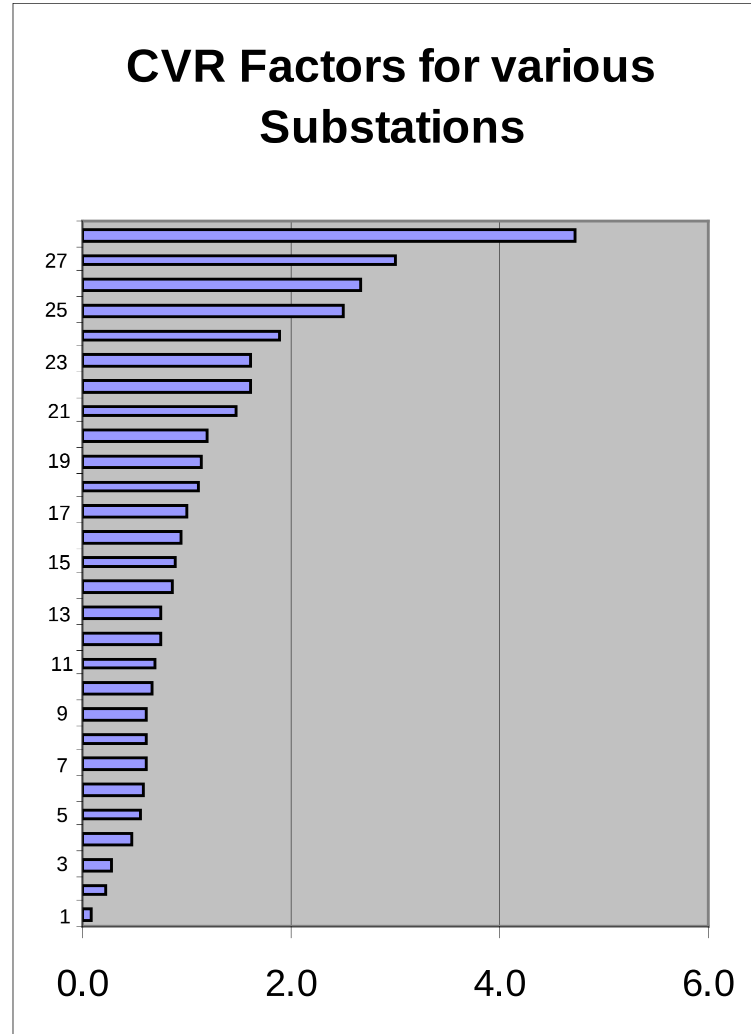
Major Issue: Not all feeders are created equal from a CVR perspective – Benefit varies with load type and feeder characteristics

- Effectiveness measured by CVR factor:

CVR factor = % change in load / % change in voltage

- Average of these results: CVFf = 1.2
- CVRf usually ranges between 0.7 and 0.8

Need ability to determine benefits in advance



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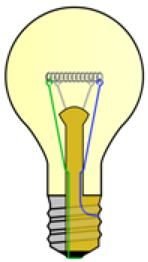
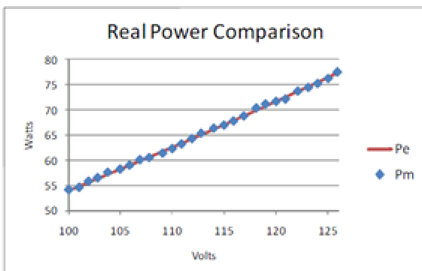
Distribution Voltage Optimization
Key issues and challenges

Major Issue: Will the CVR benefit last long into the future? Or, will the benefits diminish in just a few years?

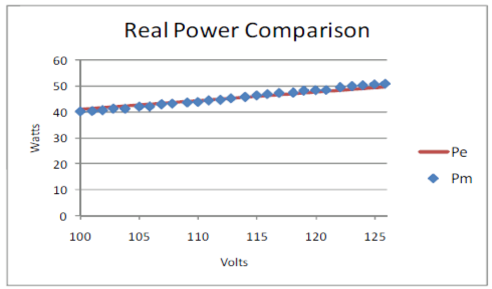
- Some emerging load characteristics don't favor CVR
- Need better understanding of "up and coming" appliances to determine if CVR will provide lasting effects



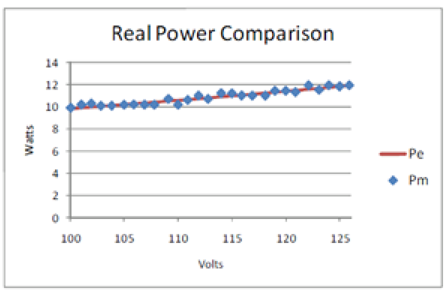
Incandescent Light Bulb (70W)



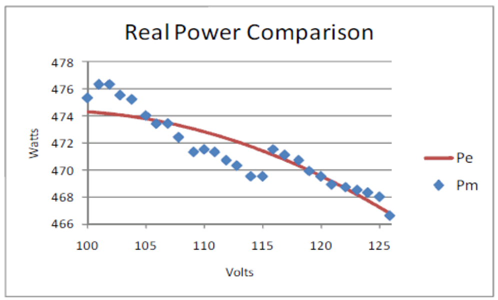
Television (Cathode Ray Tube)



Compact Fluorescent Light (CFL) 13W



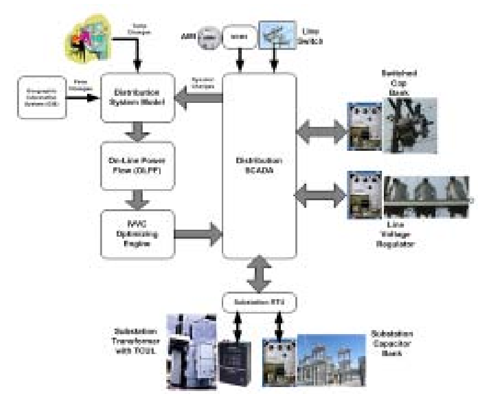
Plasma TV



Distribution Voltage Optimization
Key issues and challenges

Major Issue: What general approach to CVR works best?

- Standalone Voltage regulator and LTC controls with line drop compensation set to “end-of-line” voltage for CVR
- On-Site Voltage Regulator (OVR) for single location voltage regulation
- “Rule-based” DA control of capacitor banks and voltage regulators for CVR with/without voltage measurement feedback from end of line
- “Auto-Adaptive” voltage regulation (e.g. PCS Utilidata “AdatiVolt”, Cooper Power Systems IVVC)
- “Distribution model based” Volt-VAR Optimization



Distribution Voltage Optimization
Key issues and challenges

Major Issue: What general approach to CVR works best?

Characteristic	Standalone Controllers	SCADA "Rule Based"	DMS Model-Based
Maintain Acceptable Voltage	● (red)	● (red)	● (red)
Accommodate Distributed Energy Resources (Hi Penetration)	● (black)	○	● (red)
Accommodate network reconfiguration	● (black)	○	● (red)
Economic	● (red)	○	● (black)
Scalability	● (red)	○	● (black)
Self Monitoring	● (black)	● (red)	● (red)
Operator override capability	● (black)	● (red)	● (red)
Flexible operating strategy	● (black)	○	● (red)
Communication Needs	● (red)	○	● (black)
Produce Optimal results	● (black)	○	● (red)

Distribution Voltage Optimization

Major issue: What infrastructure improvements are needed to effectively implement CVR? Are these infrastructure improvements economically justified

- **Feeder conditioning needed to "flatten" voltage profile** to maximize CVR benefits
- Addition of **fixed and switched capacitor banks**
- Feeder **re-configuration**
- Feeder **phase balancing**
- **Reconductoring**
- Replacement of electromechanical volt-VAR controllers with **Intelligent Electronic Devices (IEDs)**
- Addition of two way **communication facilities**
- Addition of **end-of-line (EOL) metering**

Distribution Voltage Optimization

Major issue: How can AMI assist with effective deployment of CVR? What critical measurements are needed for effective CVR deployment?

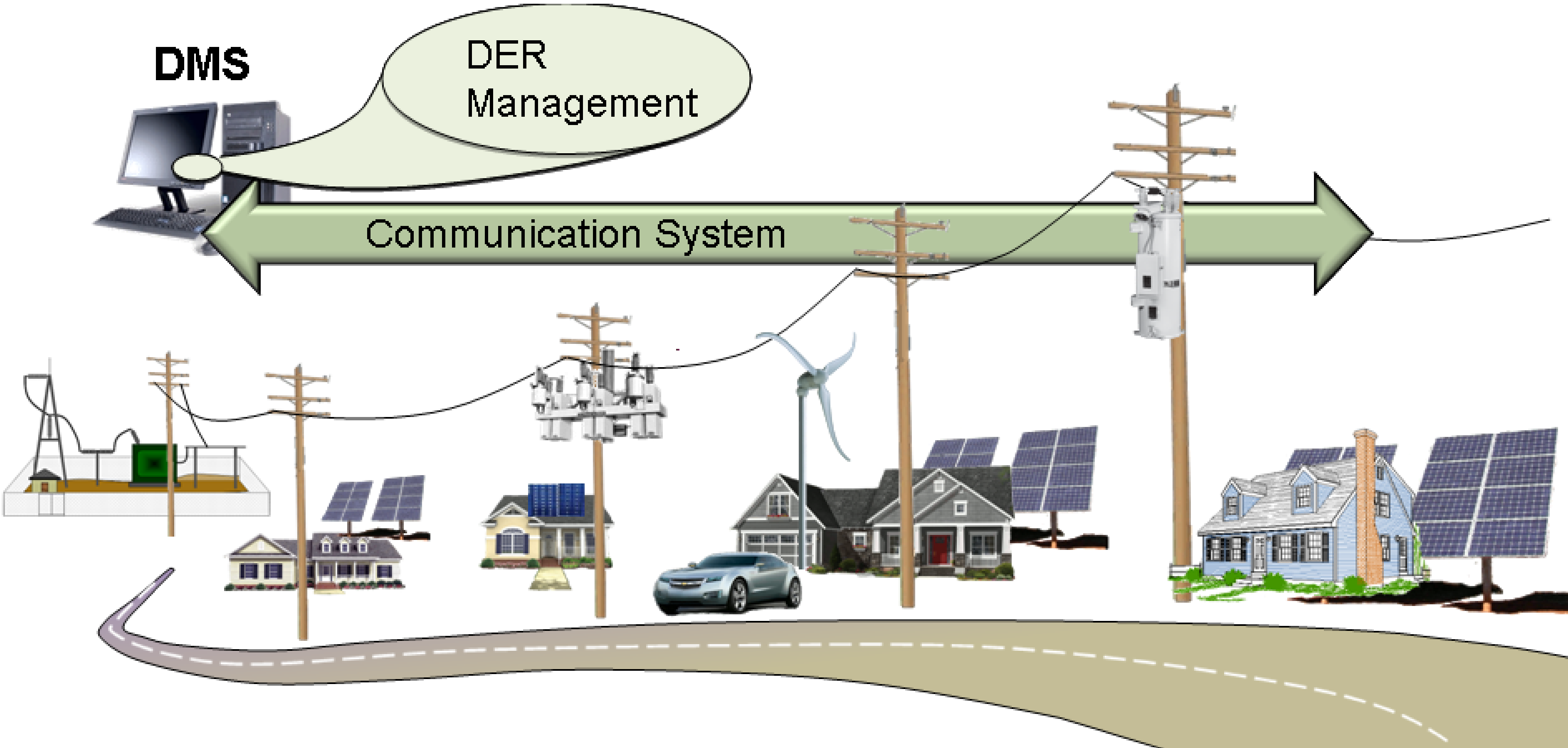
- Need to determine critical voltage measurements for CVR
- Many utilities currently use AMI or bell weather meters for voltage feedback
  - i.e. where are the lowest voltage points at any given time?
  - AMI appears to be an ideal source for providing voltage feedback
    - How many measurements are needed?
    - What locations should be monitored?
    - How often should measurements be taken?
    - Do natural fluctuations in individual measurements affect usability of AMI data

Distribution Voltage Optimization Where should industry go from here?

- **Need ability to predict CVR benefits**
  - Excellent work going on at PNNL, NEETRAC, EPRI and other organizations to model CVR behavior
  - Work being coordinated through IEEE volt-VAR task force
- **Must include distribution voltage optimization (CVR) in distribution planning process**
  - Impact on capacity planning process
  - Design necessary infrastructure improvements
- **Vendors and utilities alike need to gain practical experience with the concept (demonstrations and full-scale deployments)**

Dynamic Volt-VAR Control

Major Trend: Growing need for dynamic voltage control due to variable output from renewable energy resources.



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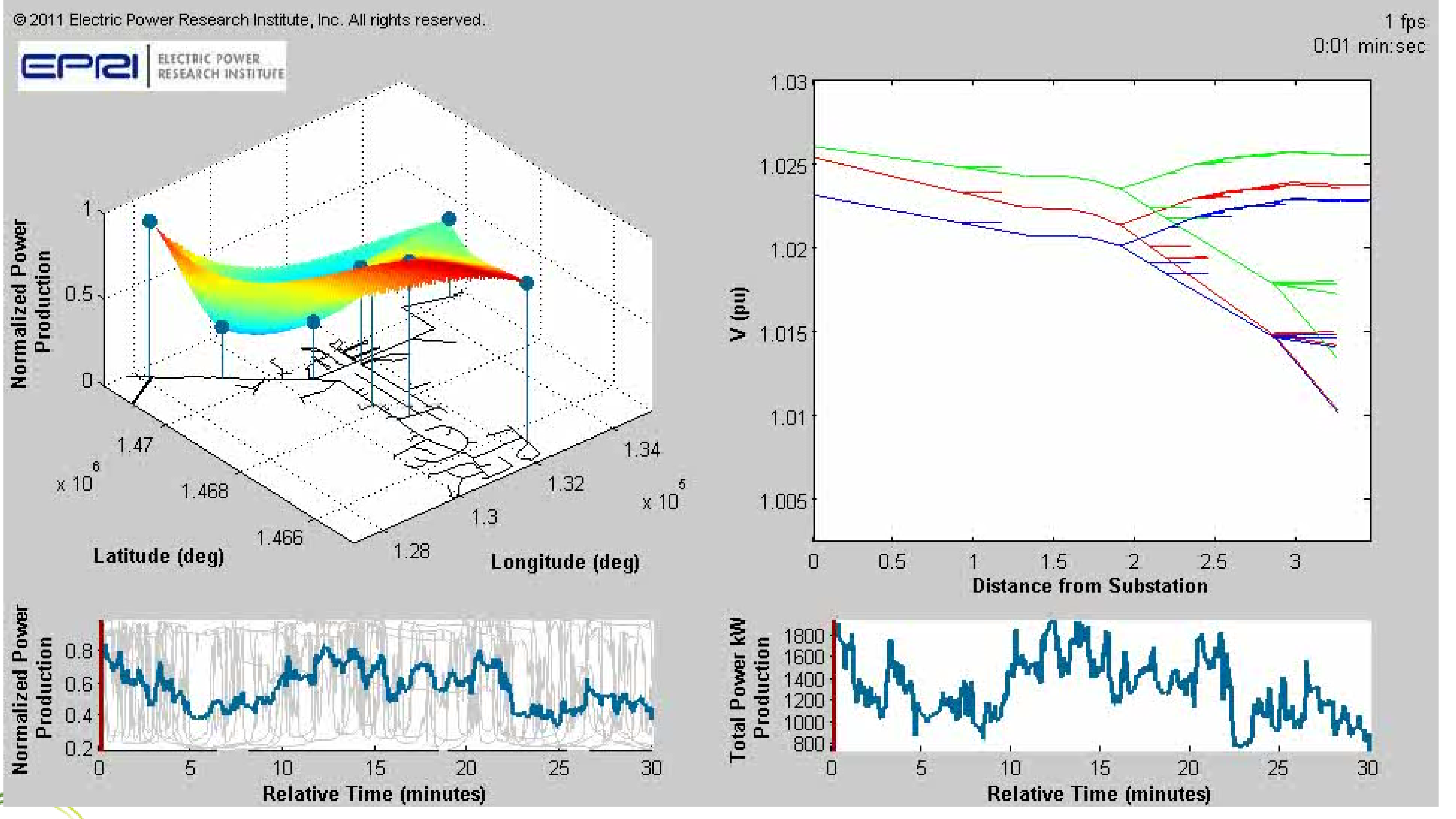


Dynamic Volt/Var Control

Key issue: Need to deal with fluctuations associated with variable power output to prevent customer complaints, excess wear and tear on voltage regulators (LTCs), and other anomolies.

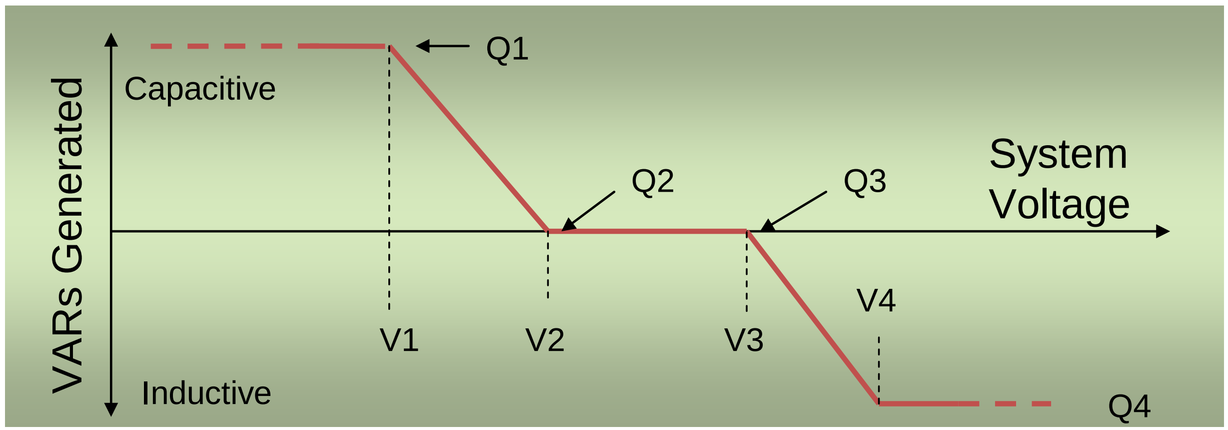
- Solar PV inverters typically operate at unity power factor
- Var control is possible in most applications
  - Inverters have inherent ability to control vars
  - No hardware change required
  - Firmware upgrade only
- VA “Headroom”
  - Data mining of over 40,000 PV installations in CA
  - PV inverters typically sized greater than solar panel
  - 20% margin or “headroom” available in inverters to provide var control
- Some form of communication is needed
  - Vars could be controlled by utility via “broadcast” commands

Dynamic Volt/Var Control

Key issue: Need to deal with fluctuations associated with variable power output to prevent customer complaints, excess wear and tear on voltage regulators (LTCs), and other anomalies.

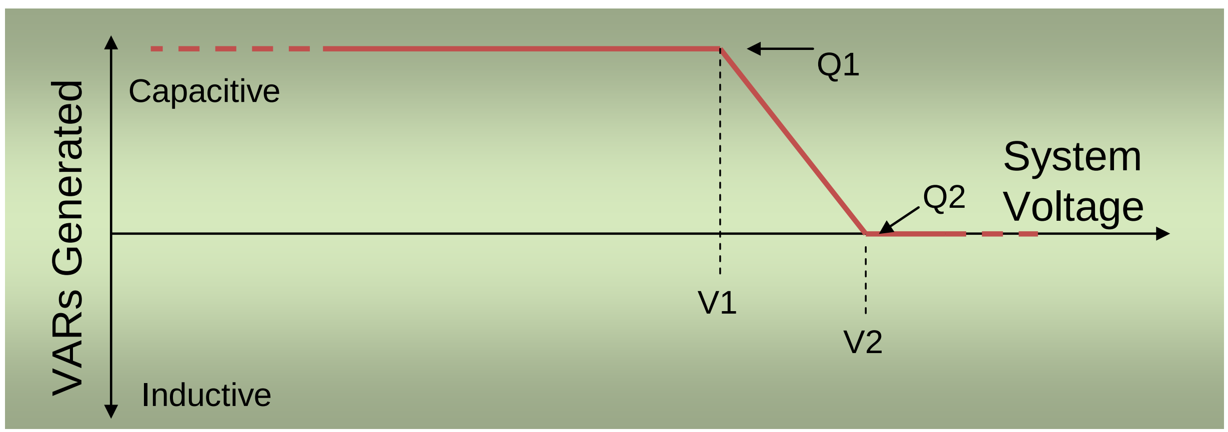
Utility-Defined Curve Shapes

Volt/Var Mode 1 – Normal Regulation



Simple Broadcast

Volt/Var Mode 2 –VAR Support



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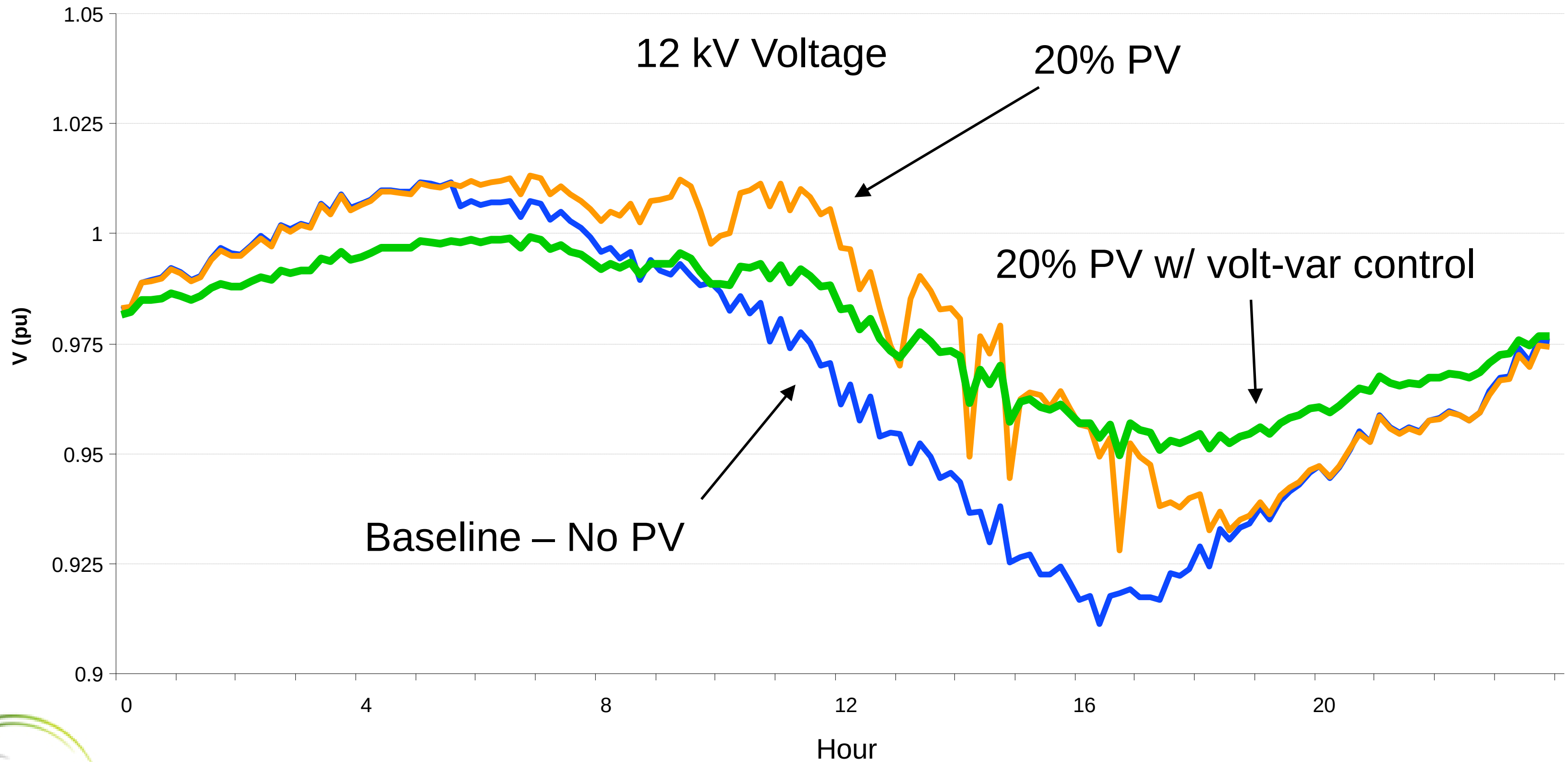
Dynamic Volt/Var Control

Key issue: Need to deal with fluctuations associated with variable power output to prevent customer complaints, excess wear and tear on voltage regulators (LTCs), and other anomalies.

Feeder Medium Voltage Response



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Dynamic Volt/Var Control

Key issue: Restrictive Clause 4.1.1 in IEEE 1547-2003

"The Distributed Energy Resource (DR) shall not actively regulate the voltage at the Point of Common Connection (PCC). The DR shall not cause the Area Electric Power System (EPS) service voltage at other Local EPSs to go outside the requirements of ANSI C84.1-1995, Range A."

addresses the possible impacts of the DR:

- Impact of DR operations on voltage-regulating devices, which may create either a too low, or a too high voltage.
- Voltage imbalance due to single-phase DR
- Intermittent operations of DR, which may result in unacceptable voltage fluctuations and excessive operations of voltage-regulating devices in the Area EPS
- Improper regulation during reverse power flow conditions, which may result in either a too high, or a too low voltage

Dynamic Volt-VAR Control
Where should industry go from here?

- **Continue IEEE 1547.8 WG activities to develop "Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies For Expanded Use of IEEE Standard 1547"**

- **Enhance standard communication protocols (e.g., DNP3) to support broadcast commands to smart inverters.**

- **Add support for smart inverter controls to DMS suite of applications**

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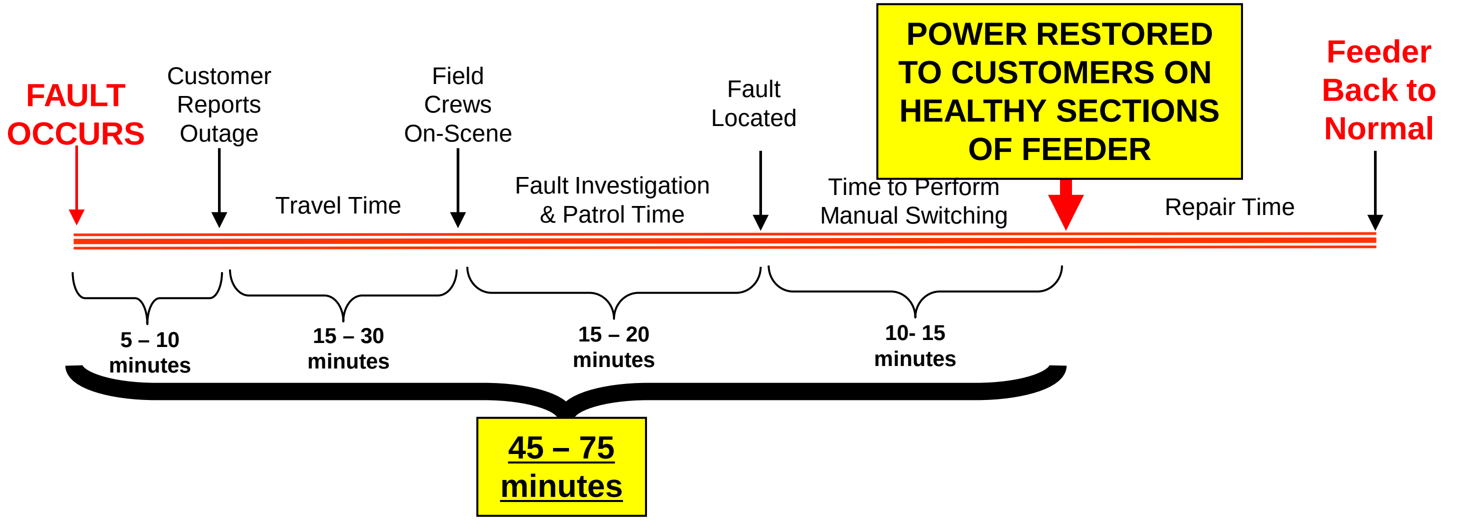
Fault Location Isolation & Service Restoration (FLISR)

Major Trend: Many electrical utilities are implementing FLISR as a means of implementing a "self-healing" grid

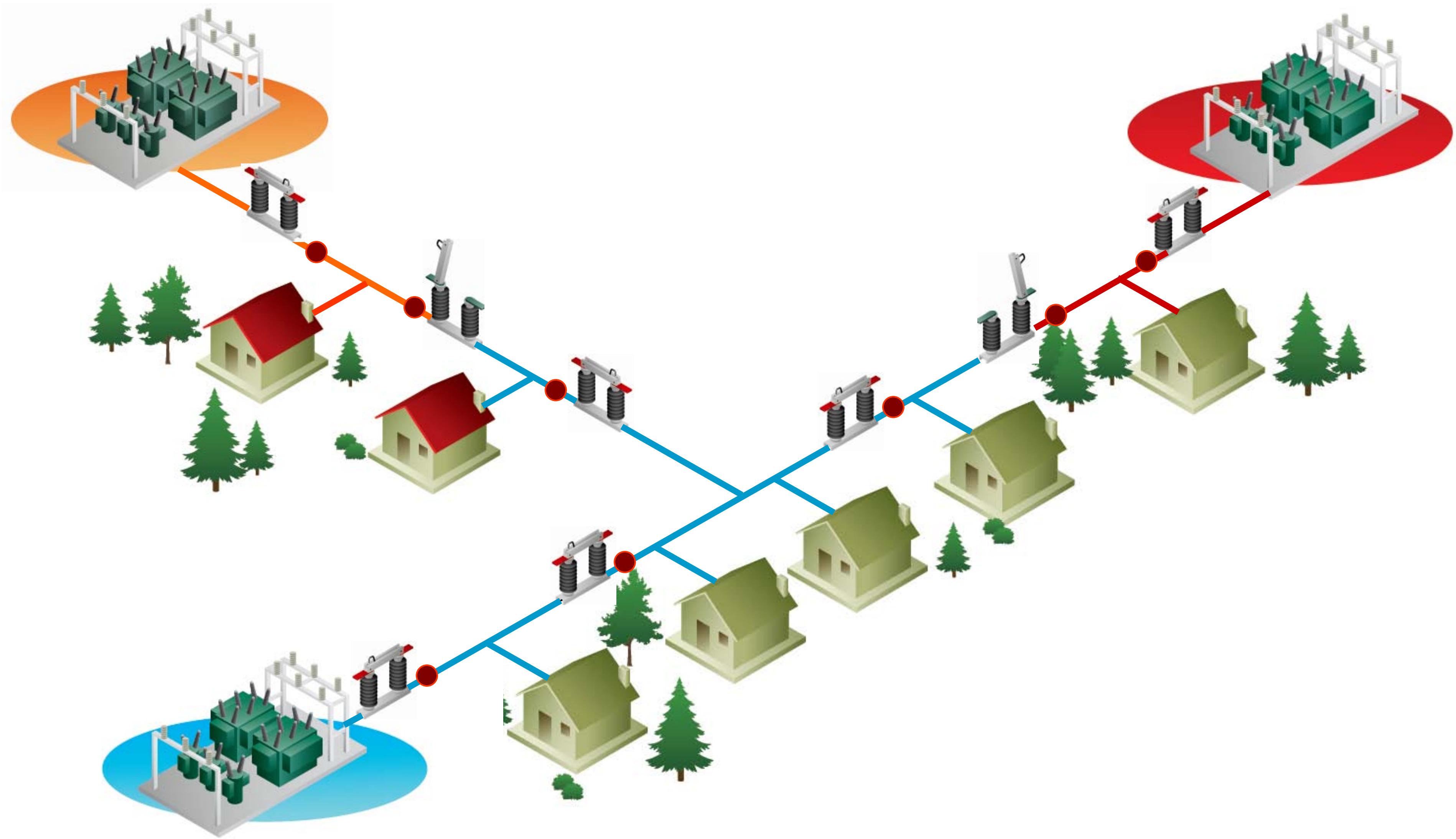
Nature of the Problem

- When a permanent fault occurs, customers on "healthy" sections of the feeder may experience a lengthy outage

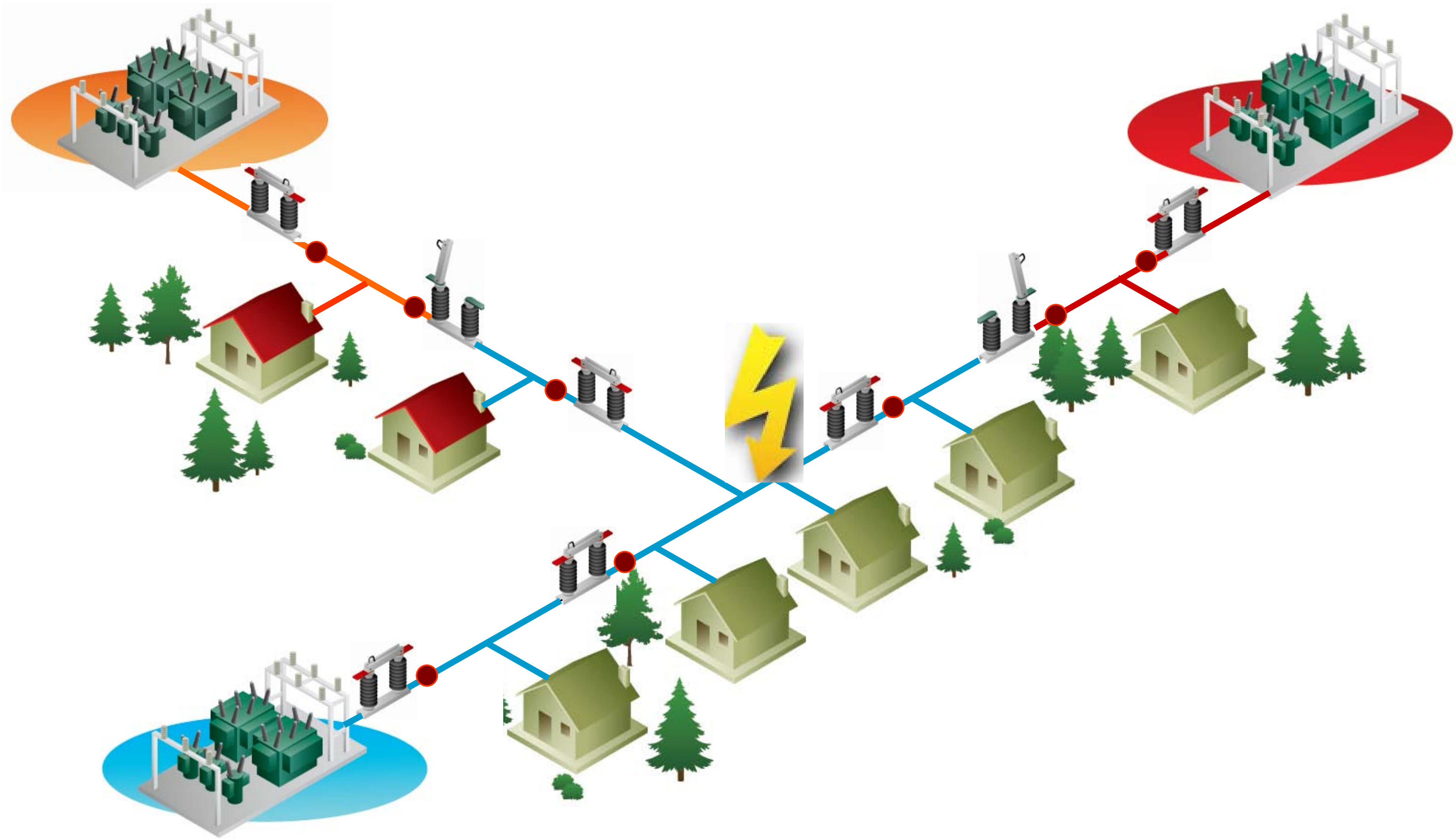


- FLISR provides the means to restore service to some customers before field crews arrive on the scene

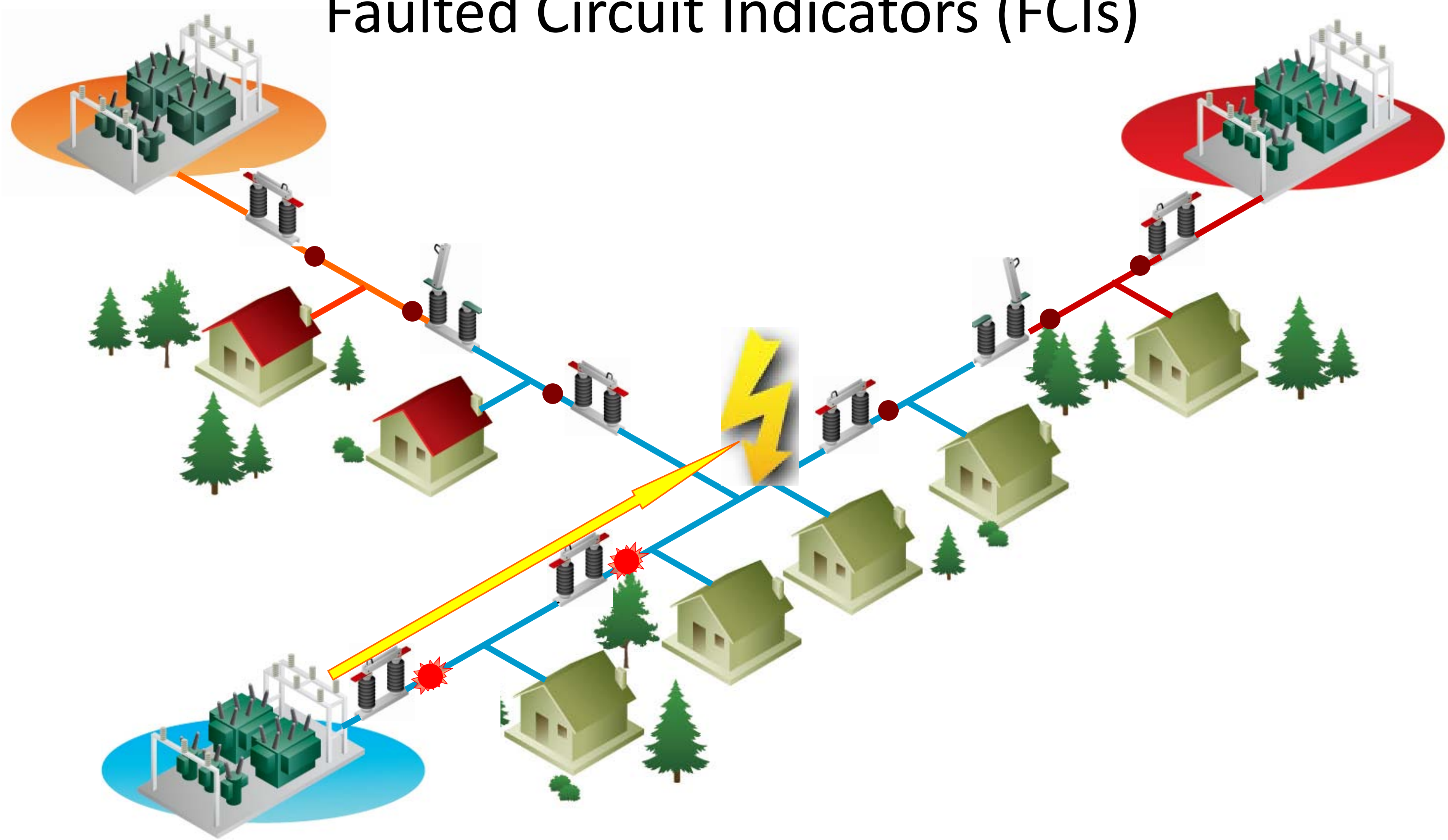
Normal Configuration



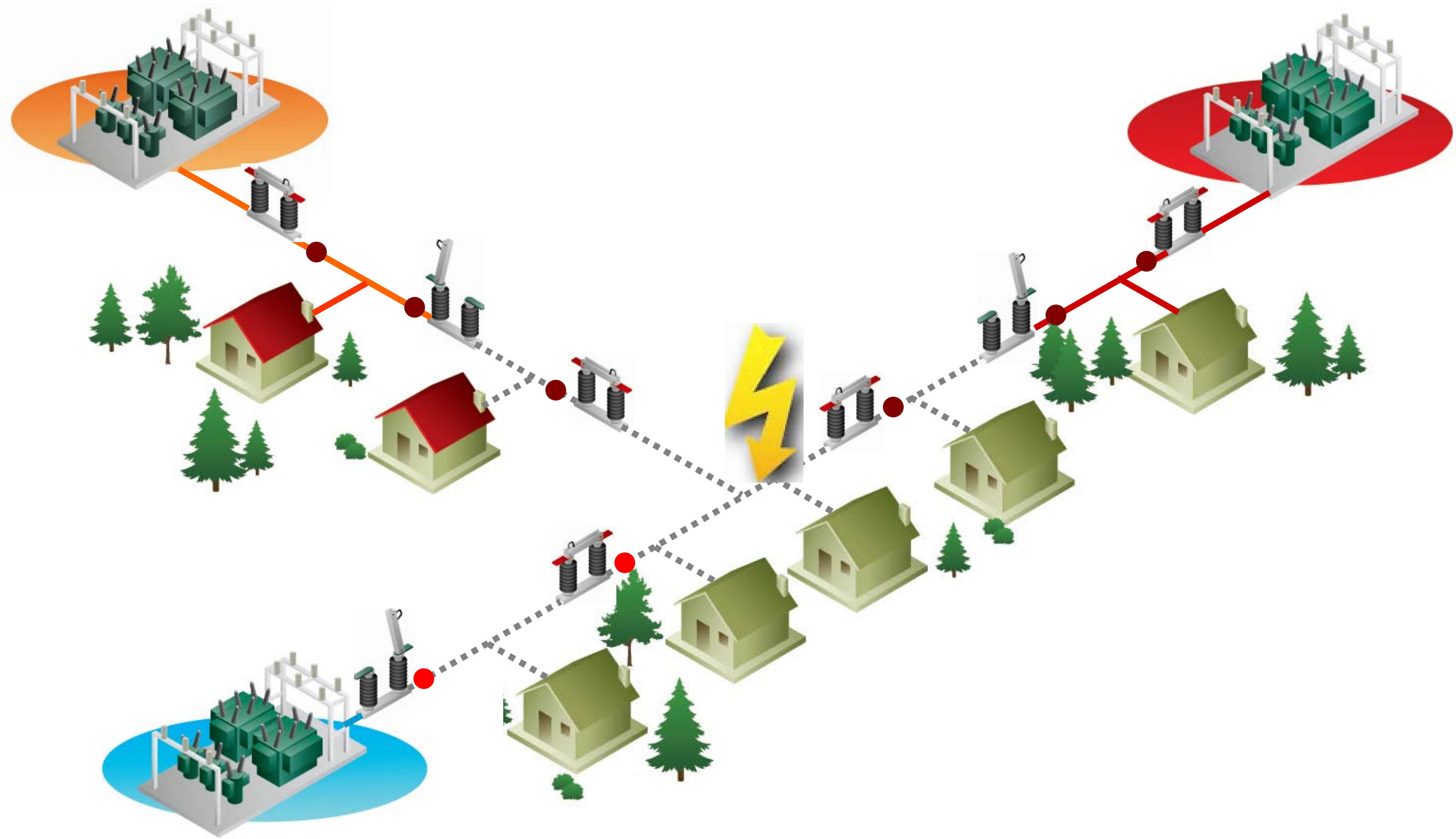
A Fault Occurs



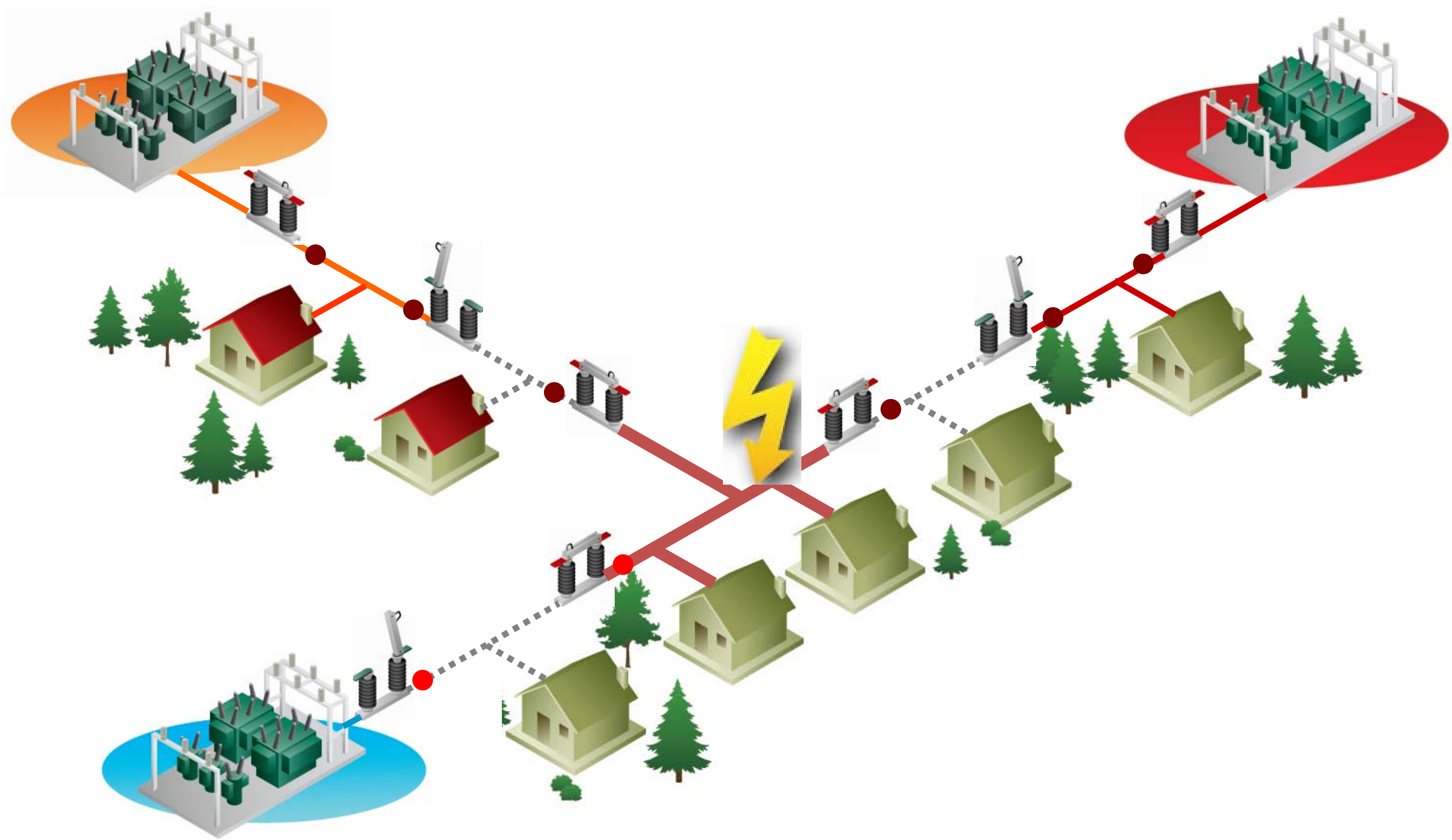
Flow of Fault Current Triggers Faulted Circuit Indicators (FCIs)



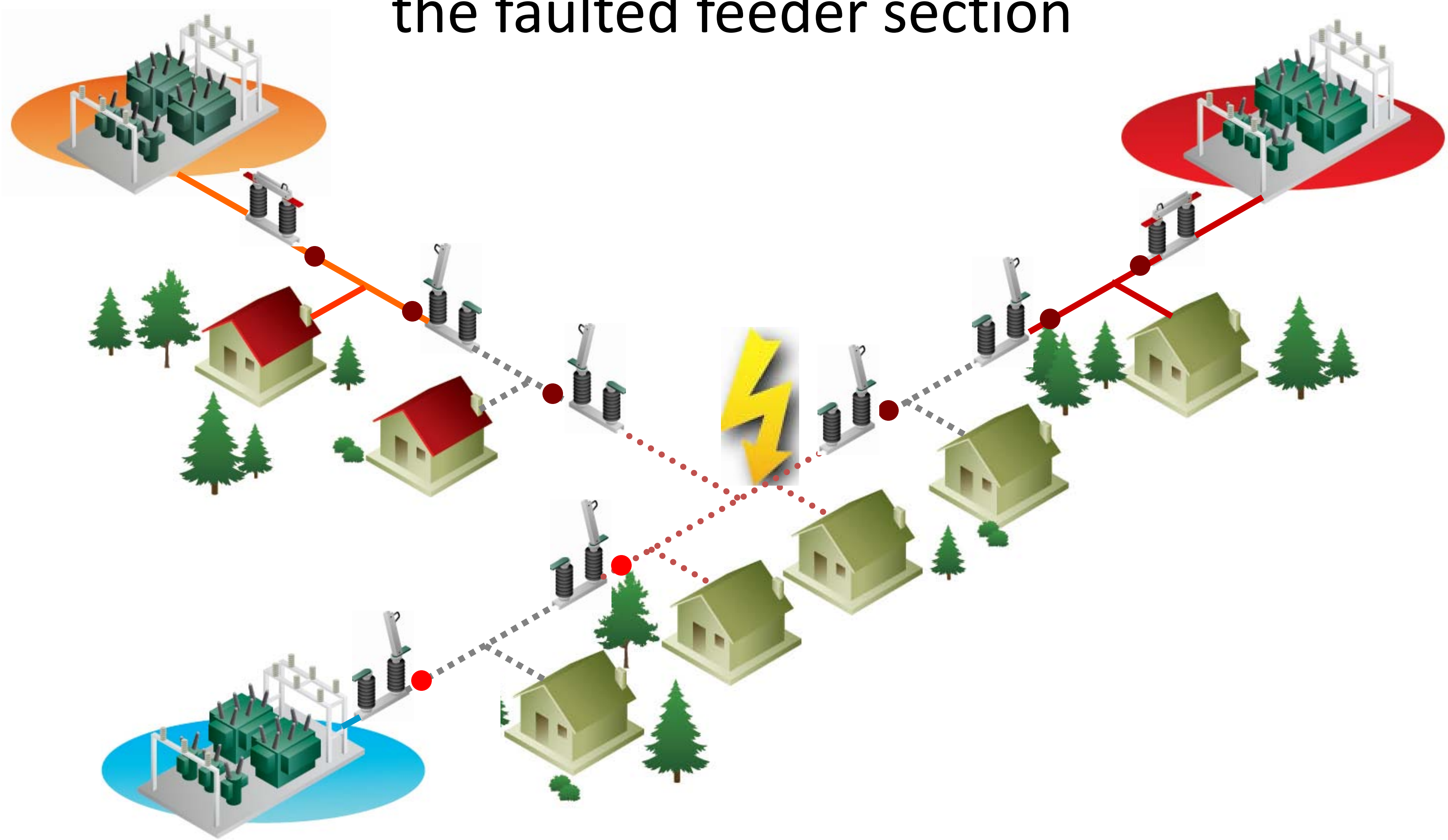
…and trips again (lockout)



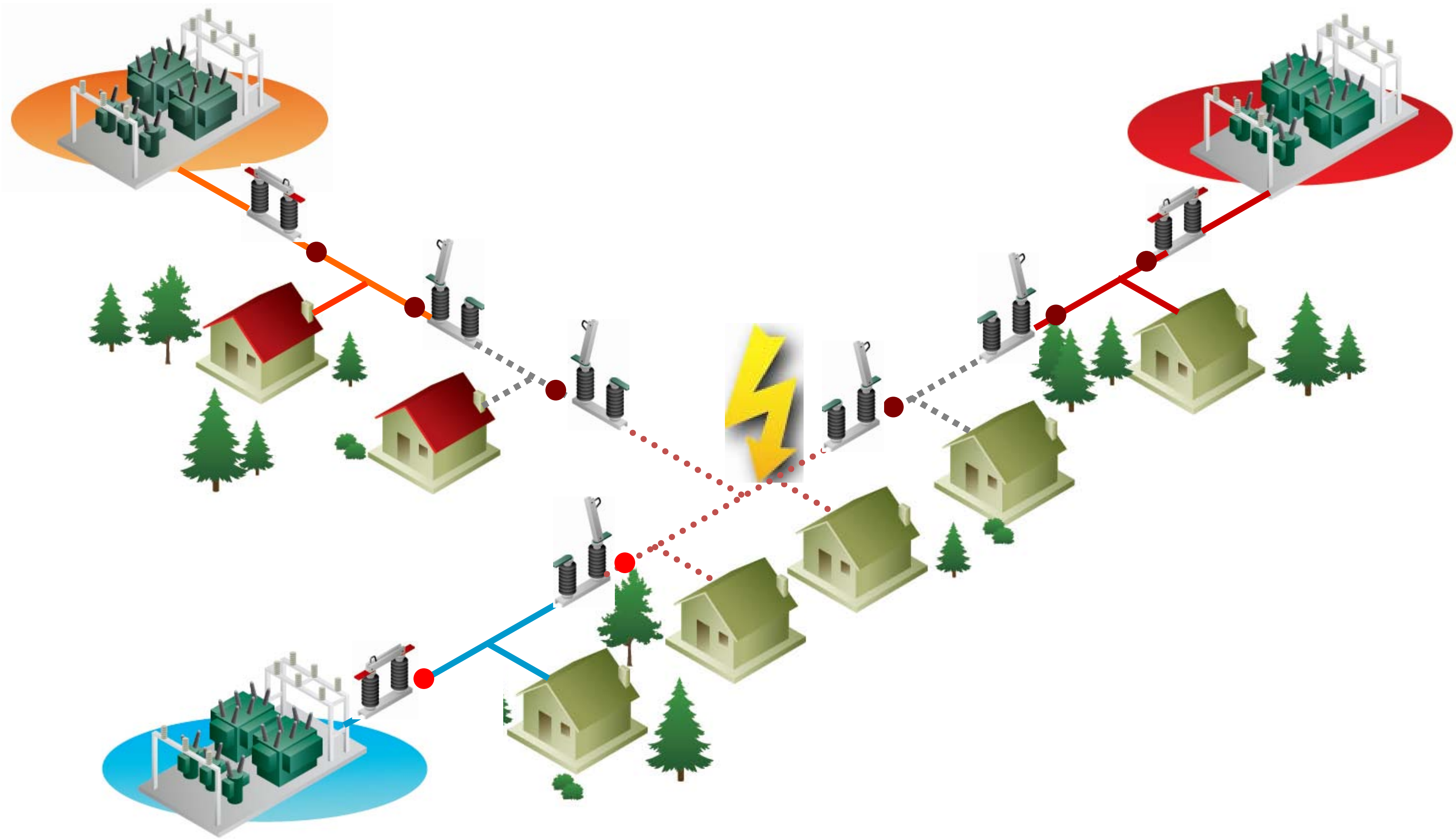
FLISR identifies faulted section by comparing FCIs



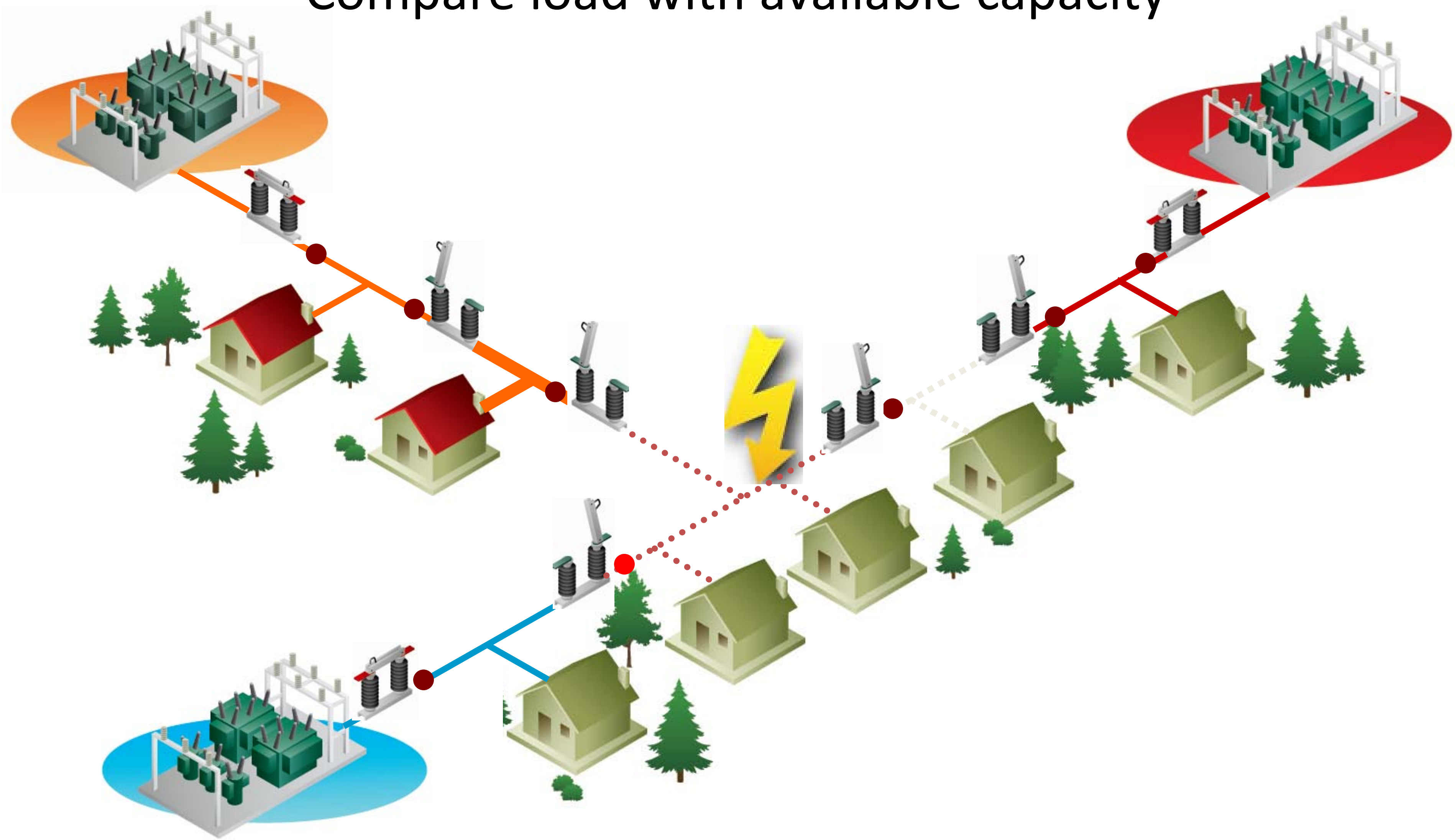
FLISR opens switches to isolate the faulted feeder section



FLISR Triggers Upstream Restoration



Downstream restoration of blinking section
Compare load with available capacity



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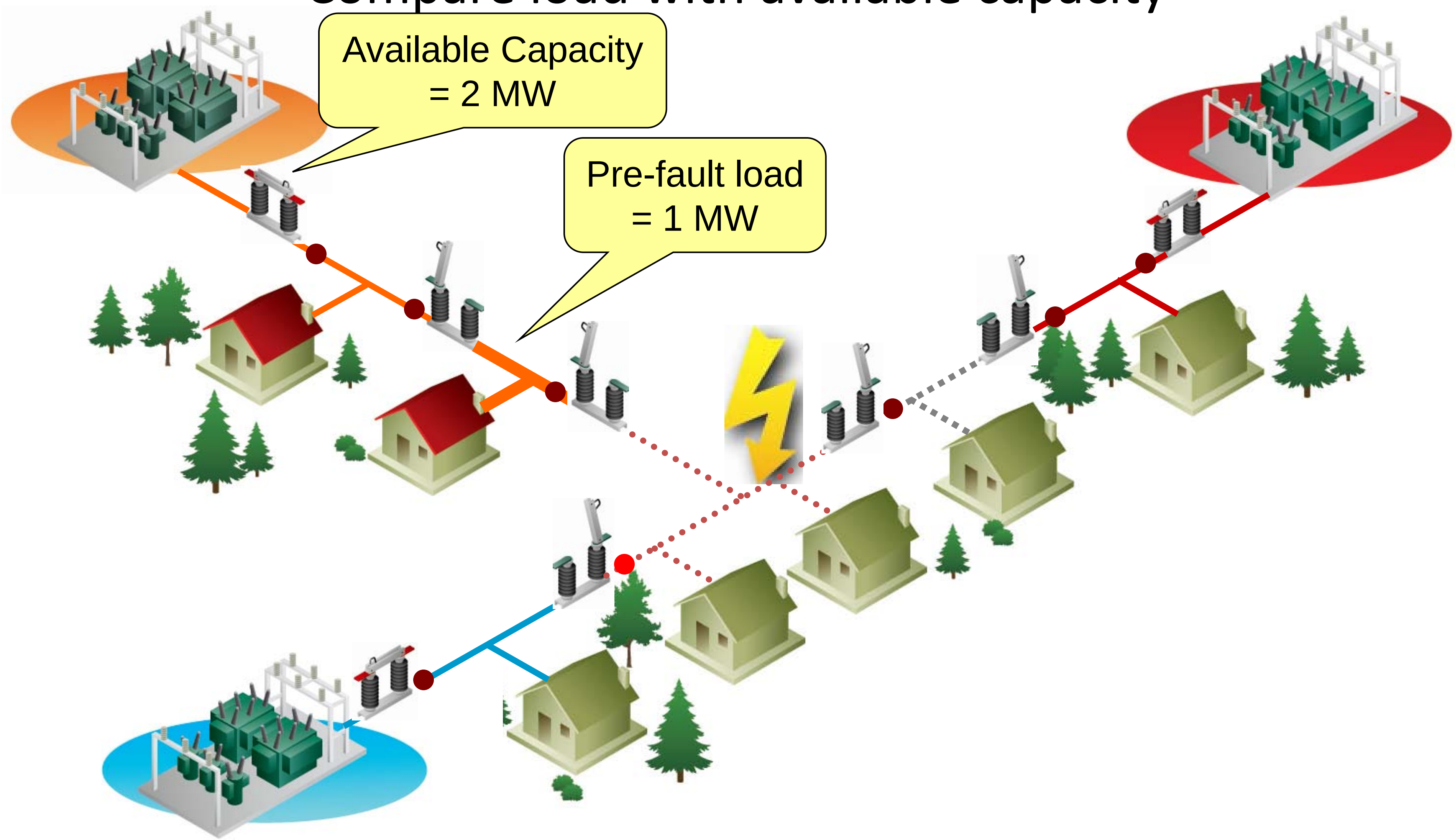
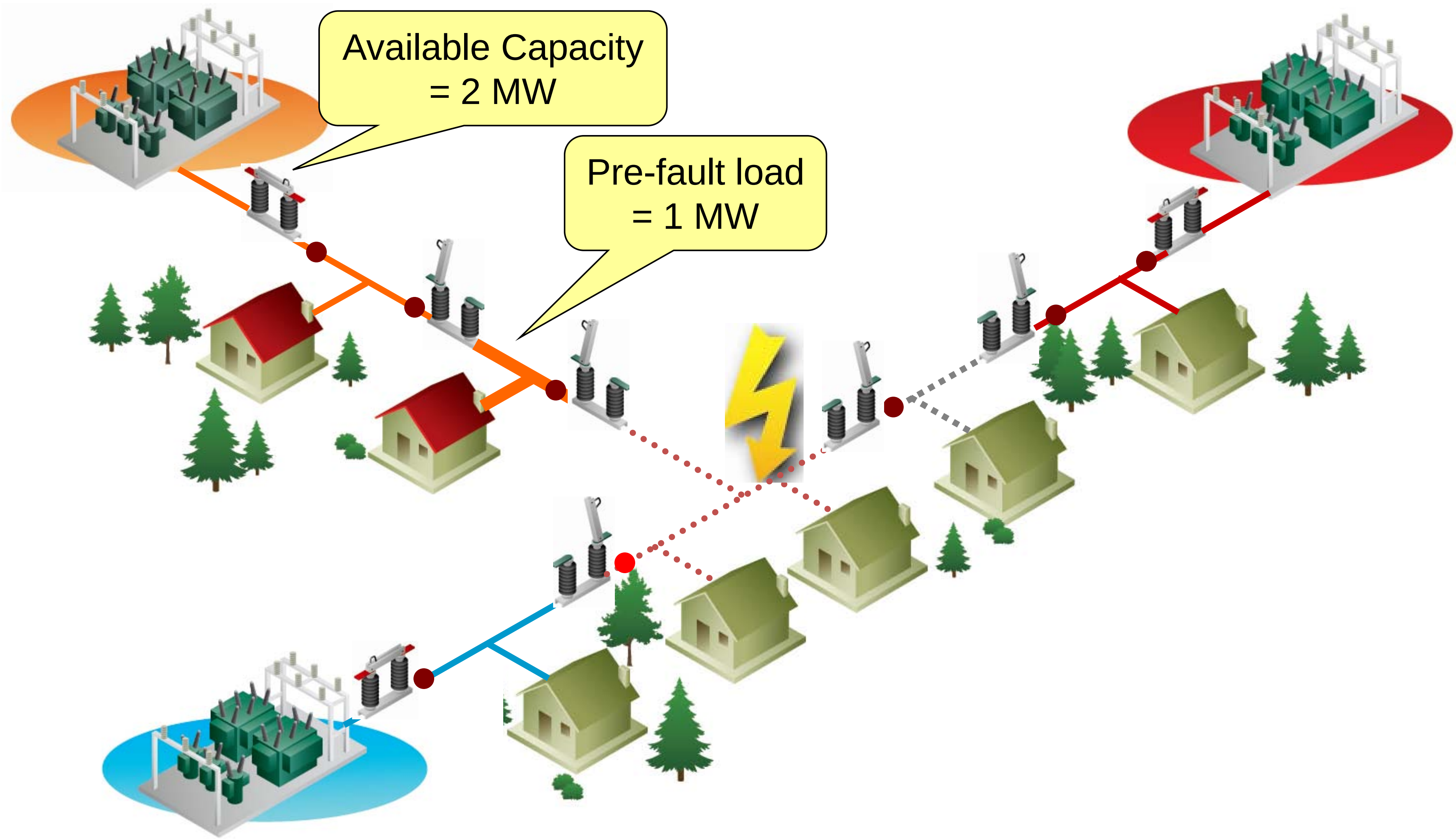
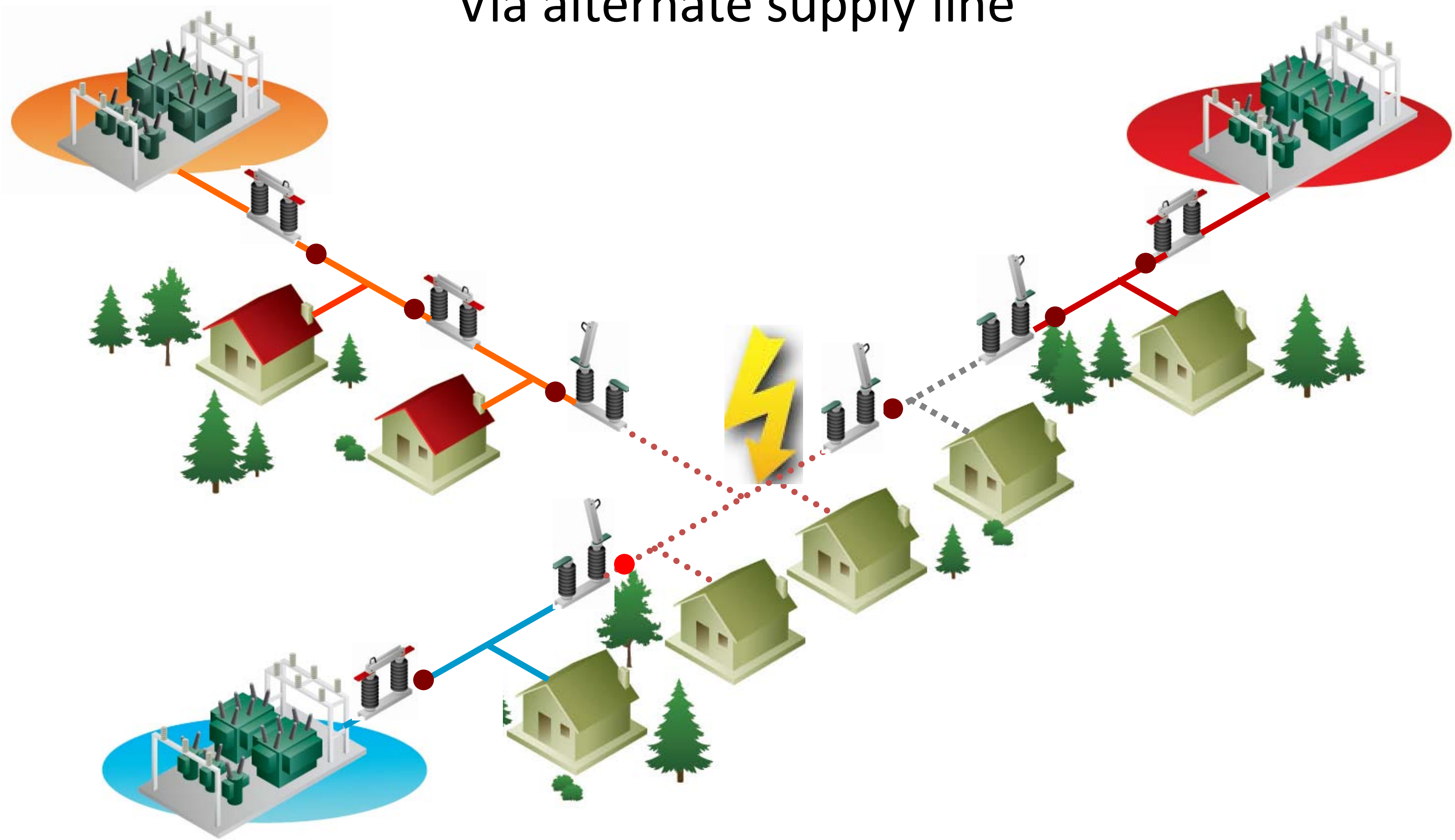


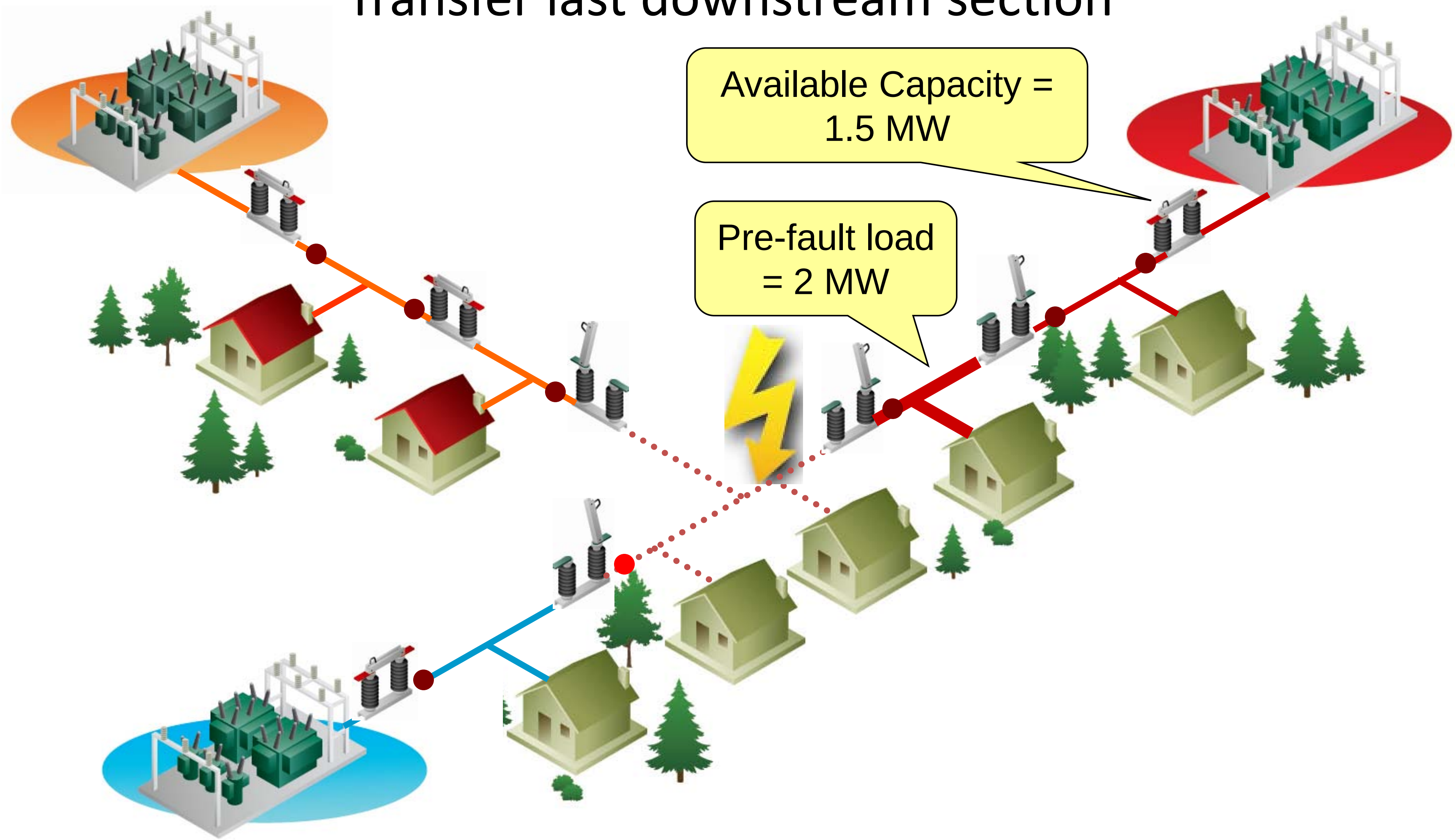
Capability exists, so…



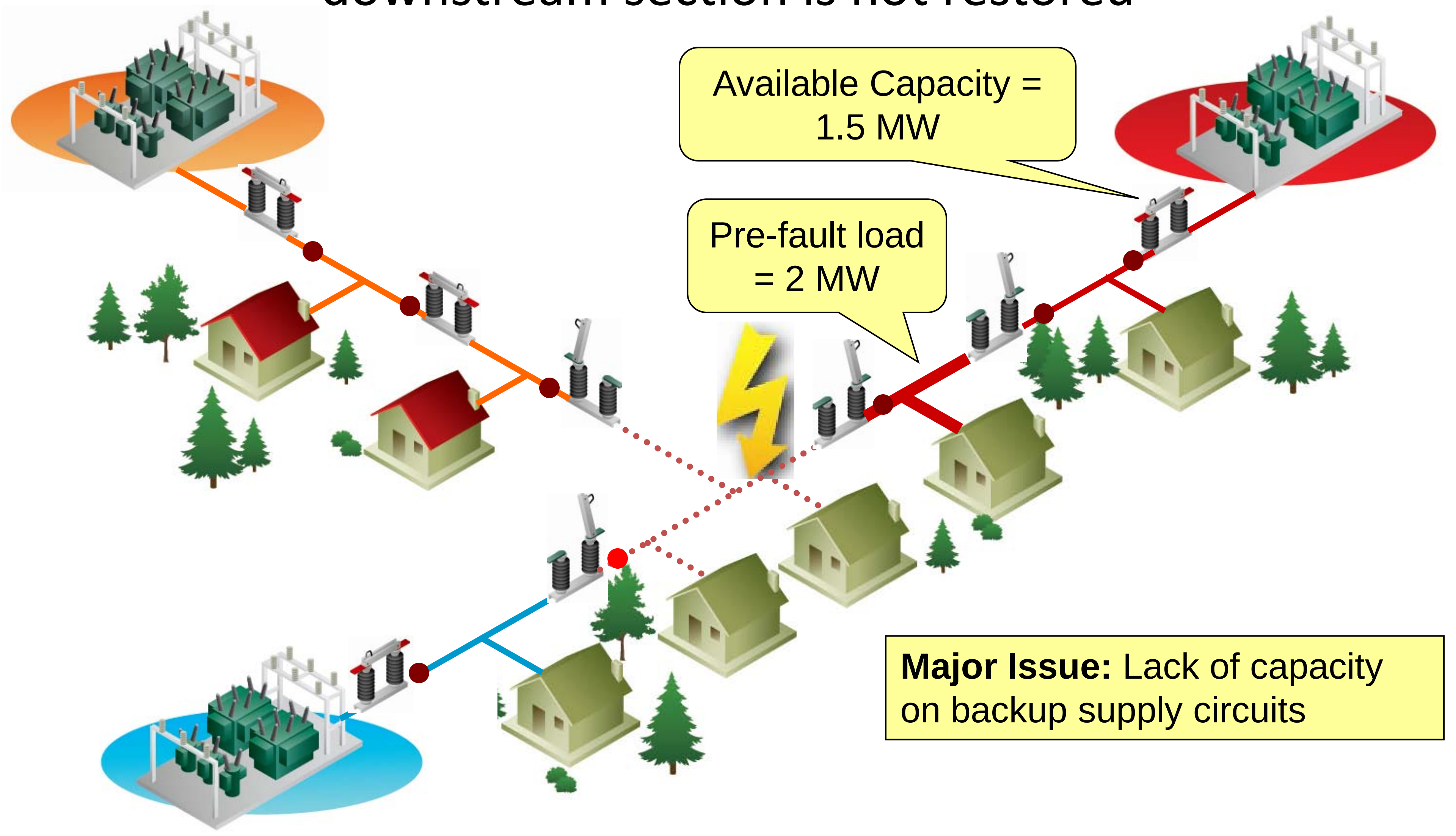
FLISR closes switch to restore service Via alternate supply line



Now FLISR checks for capacity to Transfer last downstream section



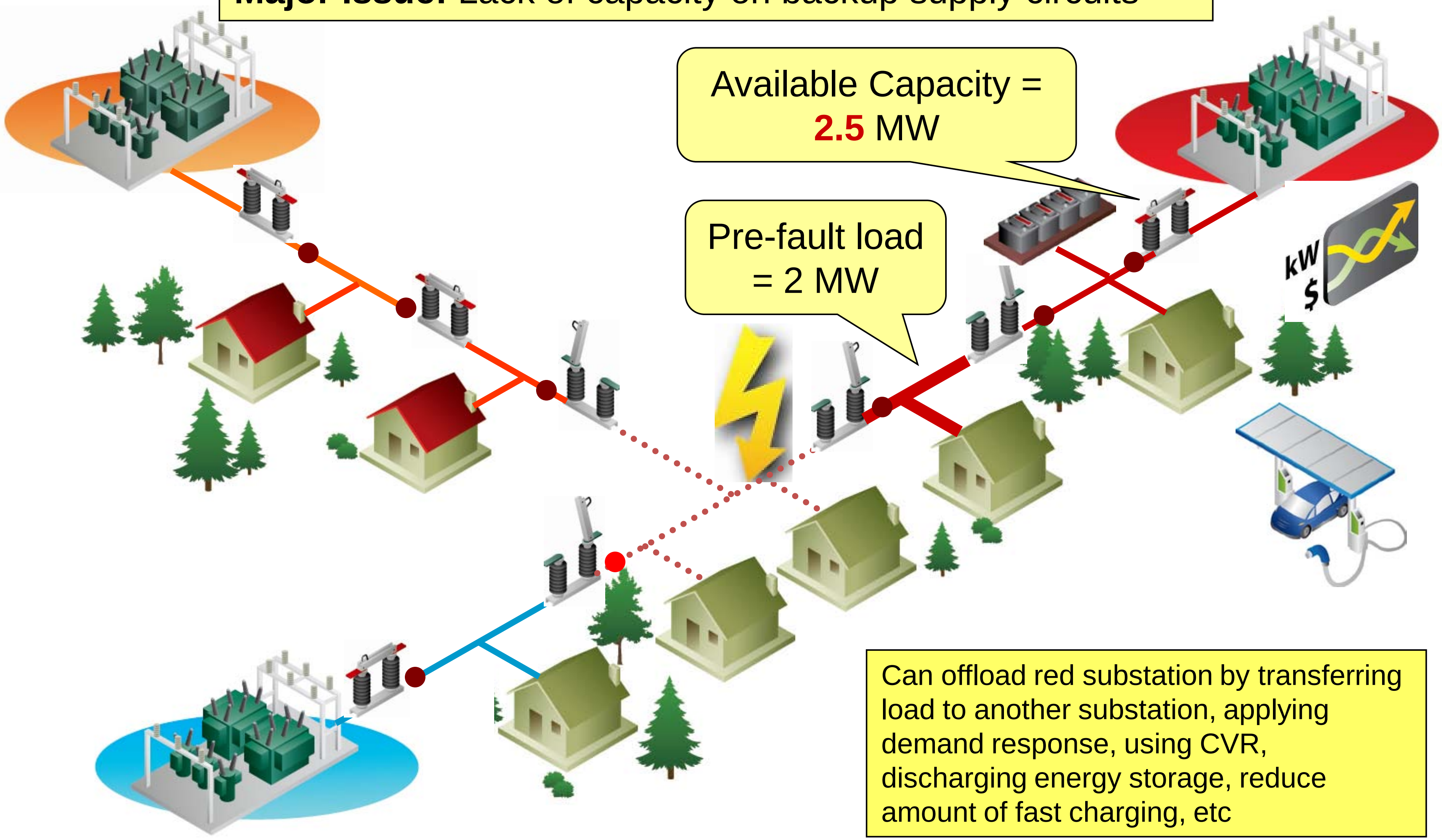
In this case capacity does not exist so downstream section is not restored



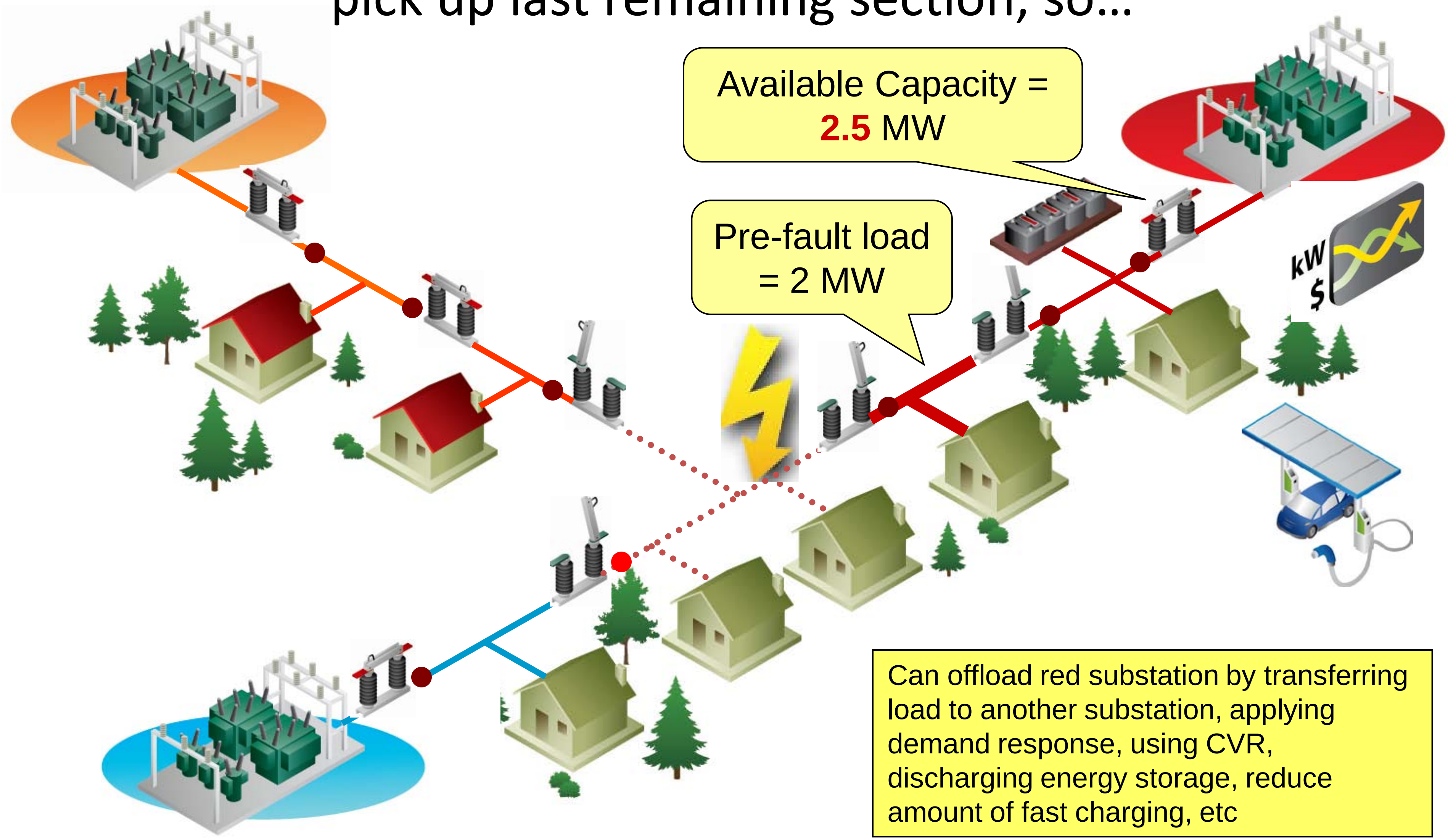
Major Issue: Lack of capacity on backup supply circuits

FLISR: Key issues and challenges

Major Issue: Lack of capacity on backup supply circuits

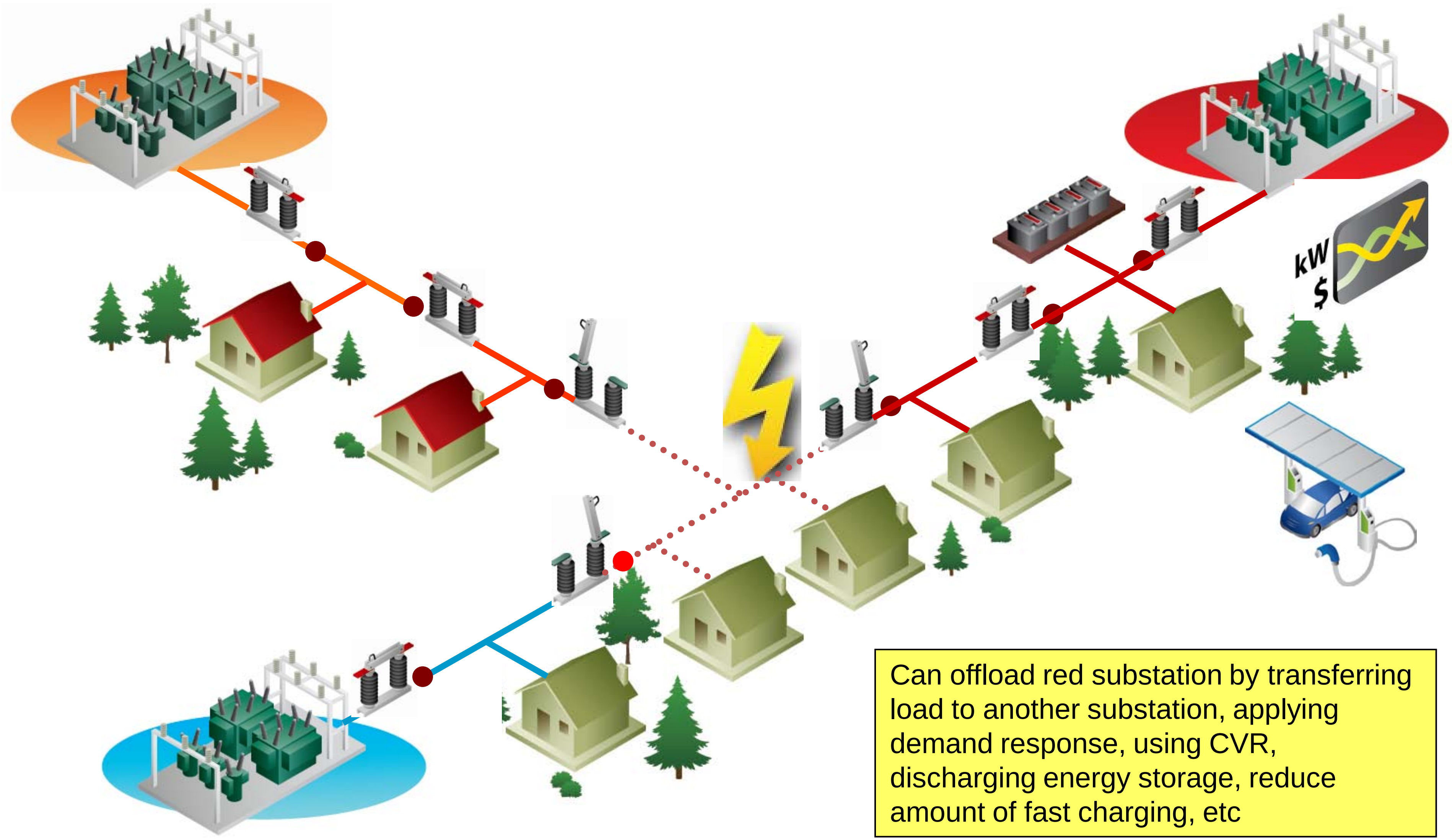


These actions free enough capacity to pick up last remaining section, so…



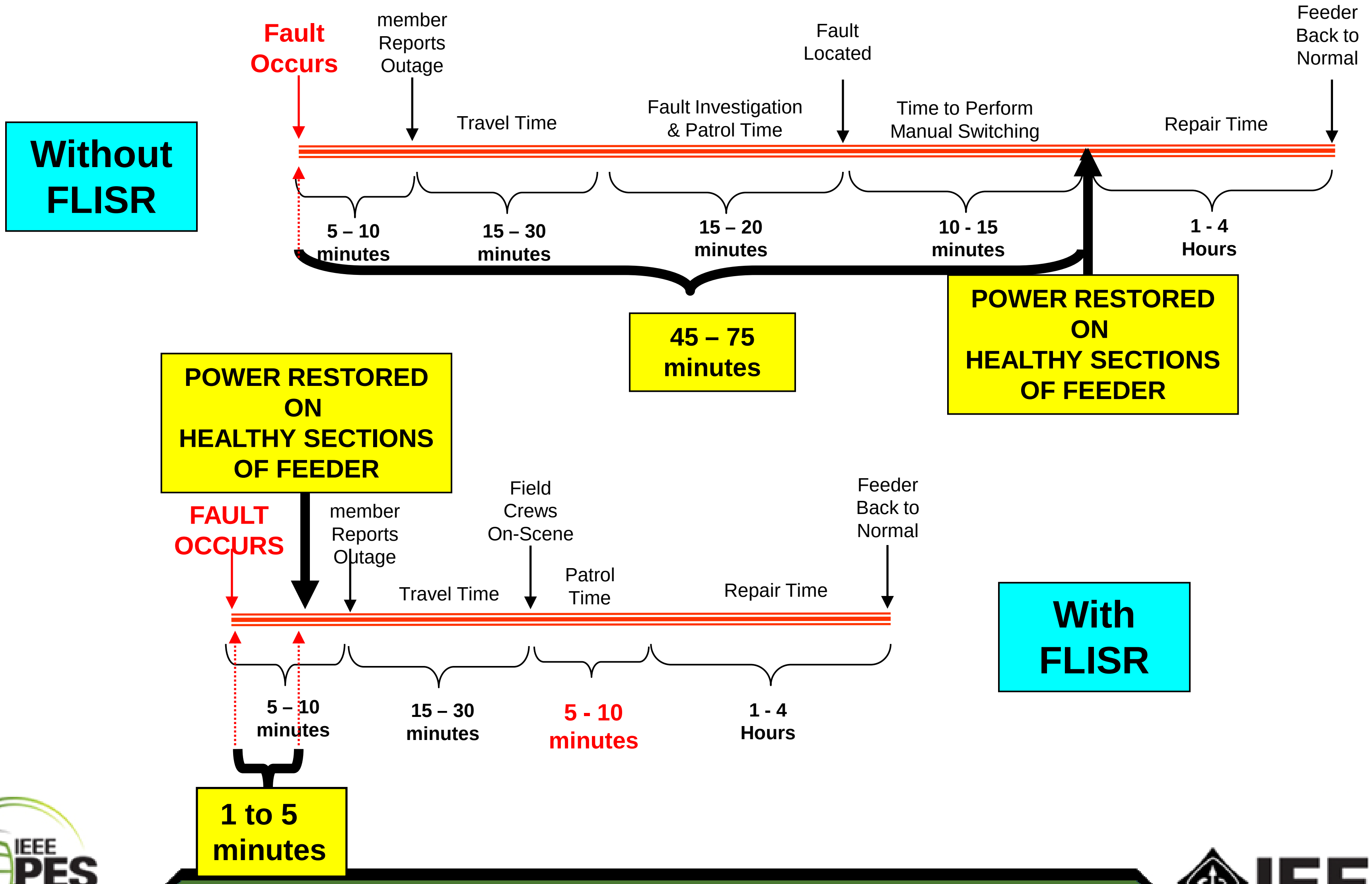
Can offload red substation by transferring load to another substation, applying demand response, using CVR, discharging energy storage, reduce amount of fast charging, etc

Can pick up the last downstream section



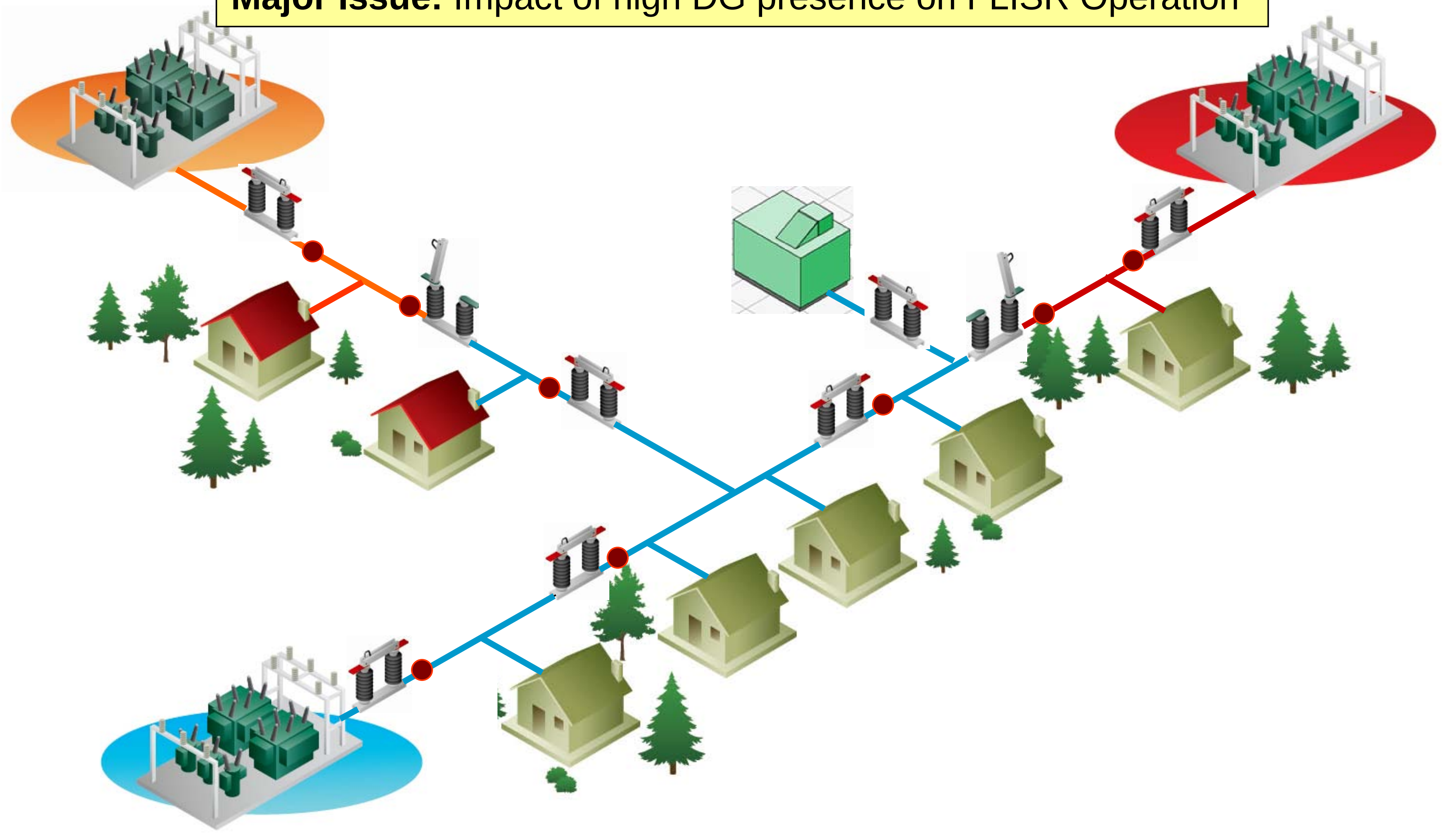
Can offload red substation by transferring load to another substation, applying demand response, using CVR, discharging energy storage, reduce amount of fast charging, etc

Time Line Without and With FLISR



FLISR with large distributed generation present

Major Issue: Impact of high DG presence on FLISR Operation



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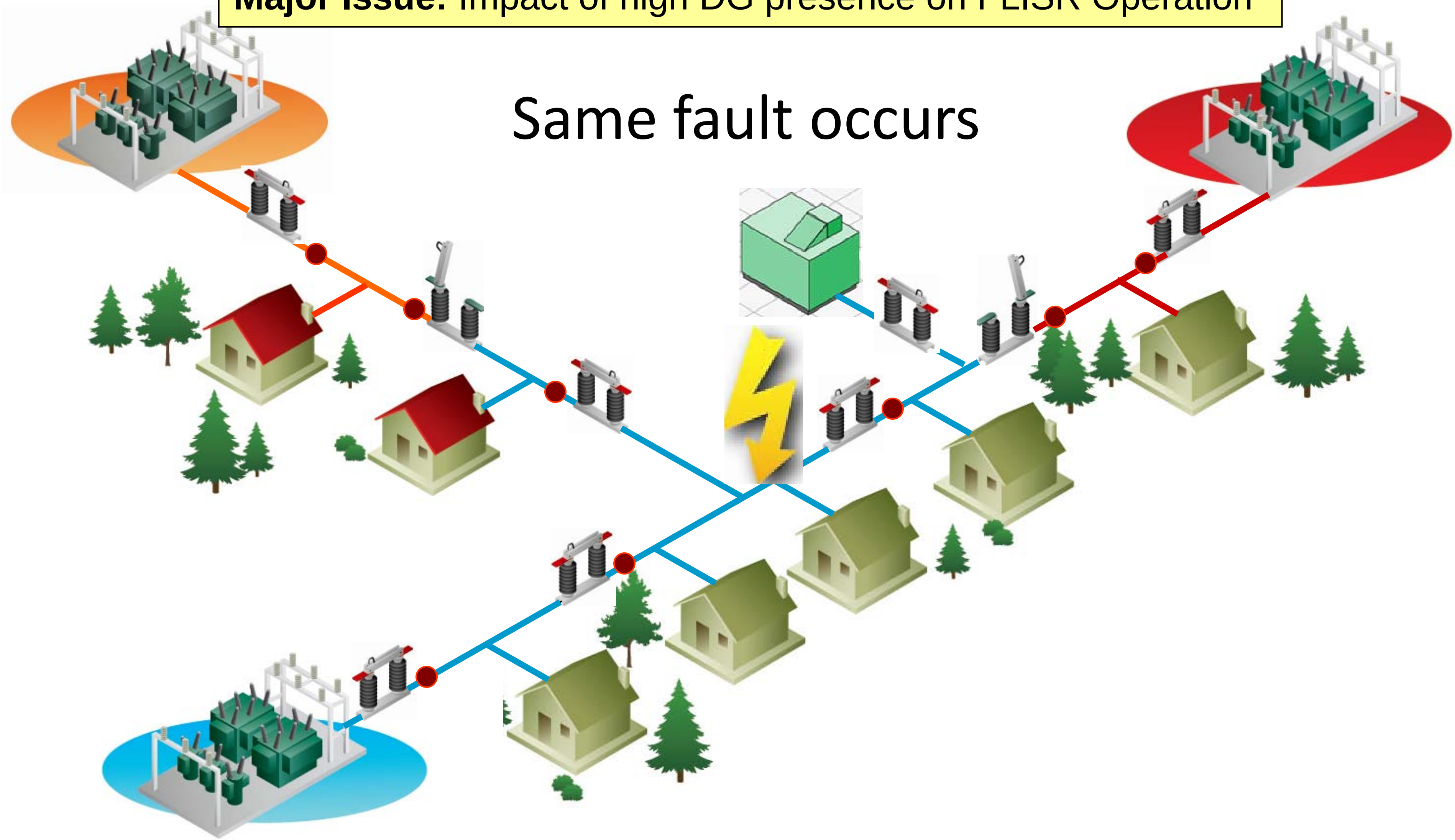

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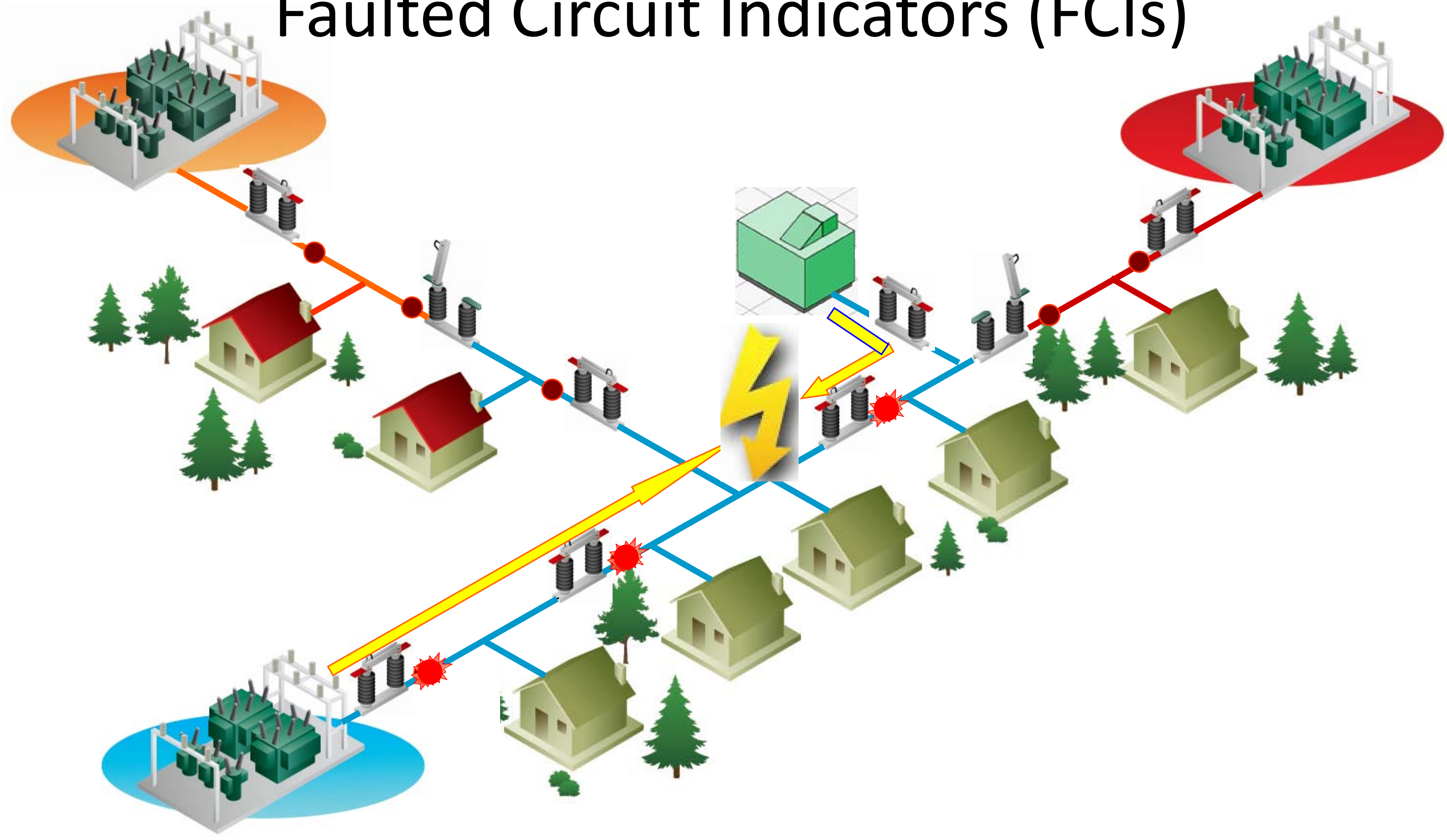
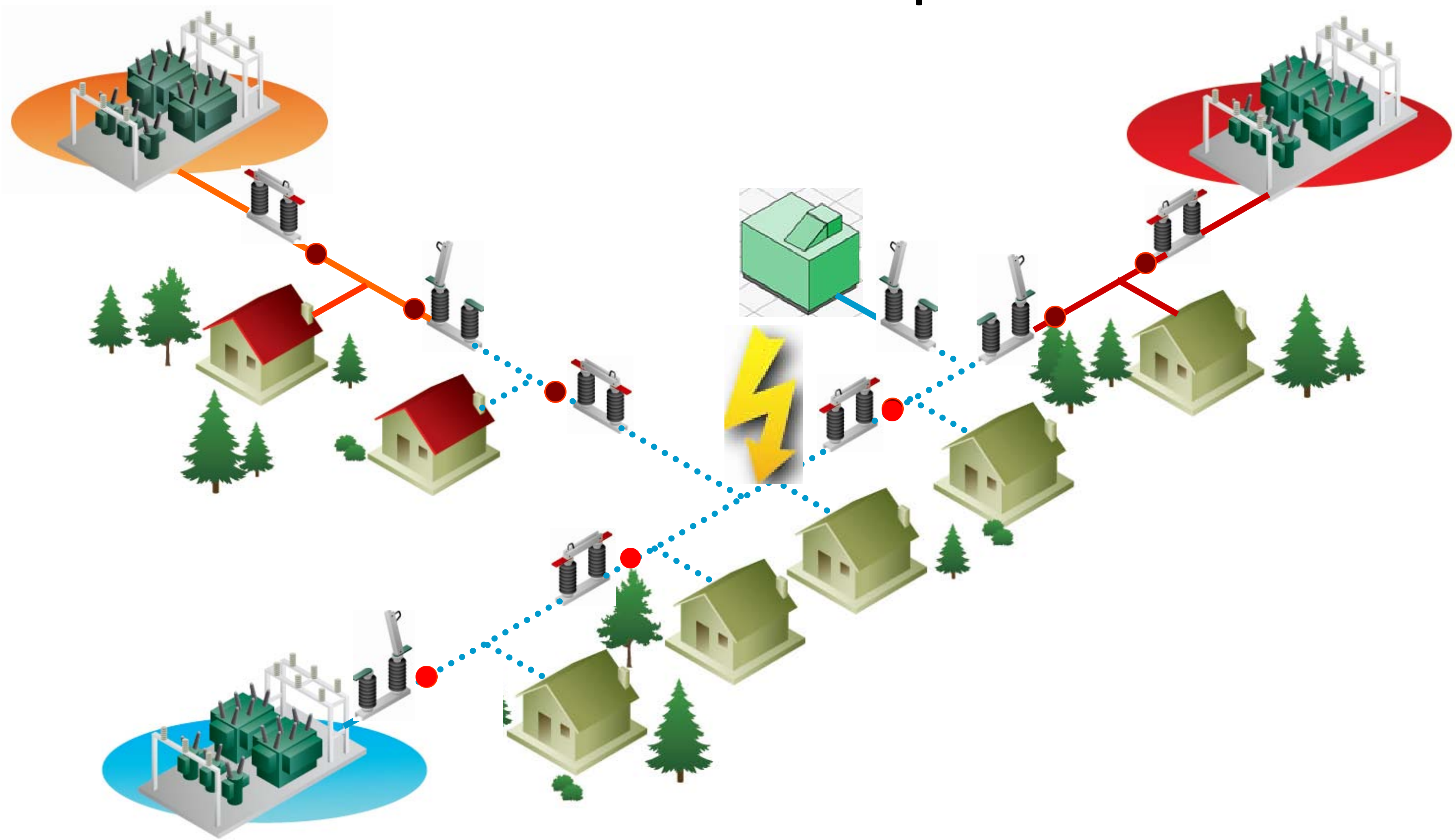
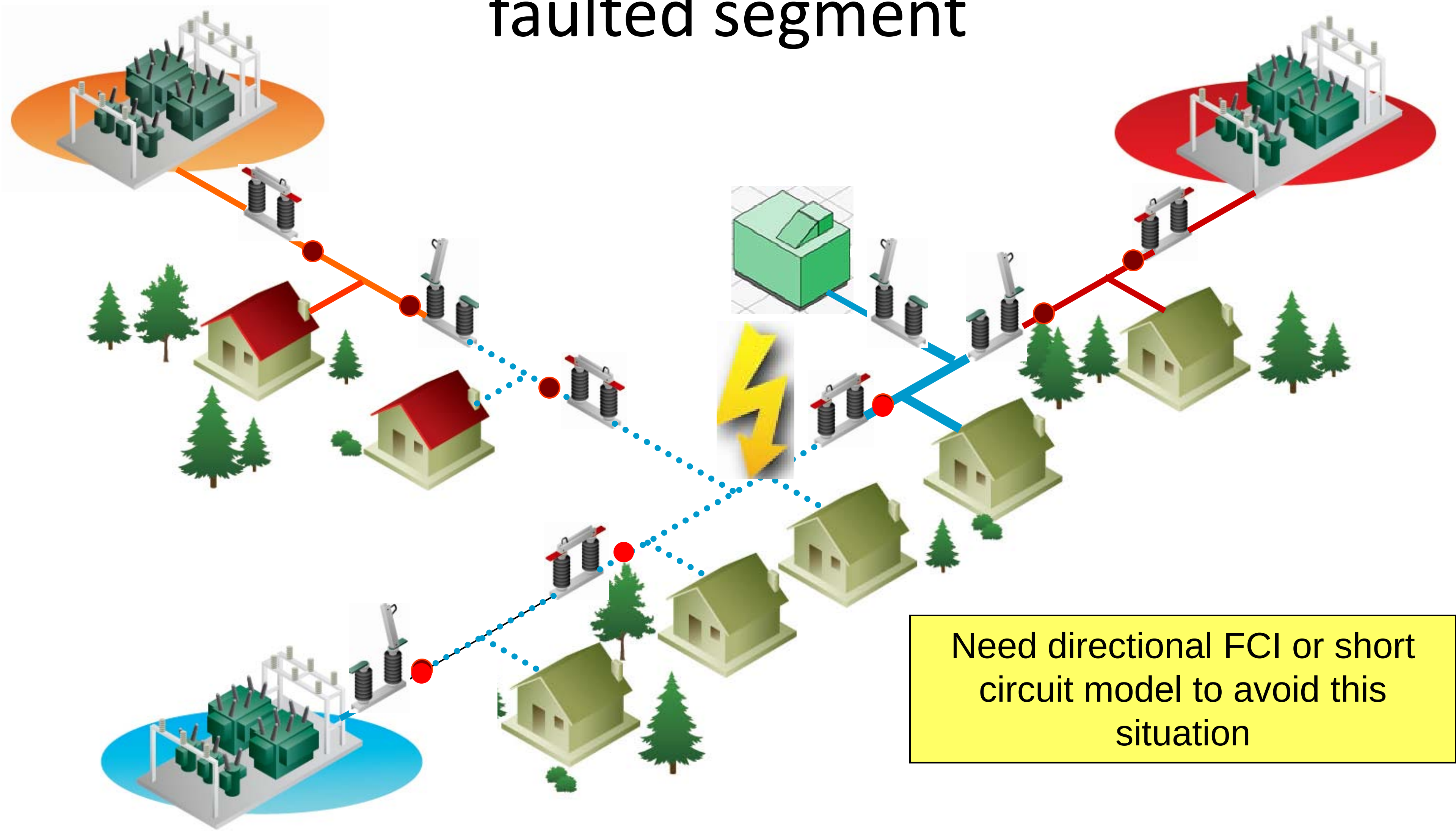


Circuit breaker opens



FLISR analyzes FCIs – incorrectly identifies faulted segment



Need directional FCI or short circuit model to avoid this situation

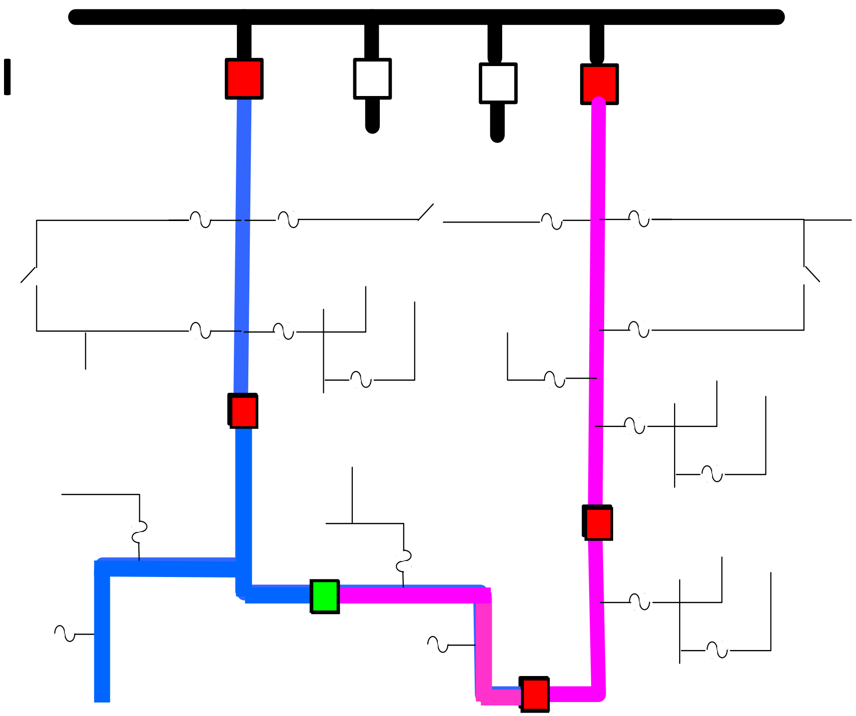
Fault Location Isolation & Service Restoration Where should industry go from here?

- **Incorporate energy storage and possible microgrid in FLISR operation**

- **Develop planning & design criteria for effective FLISR implementation**
  - Availability of backup sources with sufficient capacity
  - Protection system that adapts to feeder reconfiguration
  - Design necessary infrastructure improvements

Optimal Network Reconfiguration

- **Goal: Identify changes in feeder configuration that would improve overall distribution feeder performance and reliability**
  - **optimize topology for steady state operations…**
- **Selectable Operating Objective**
  - **Minimal power and energy losses**
  - **Maximum reliability**
  - **Best load balance**
  - **Best voltage profiles**
  - **Weighted combination of the above**



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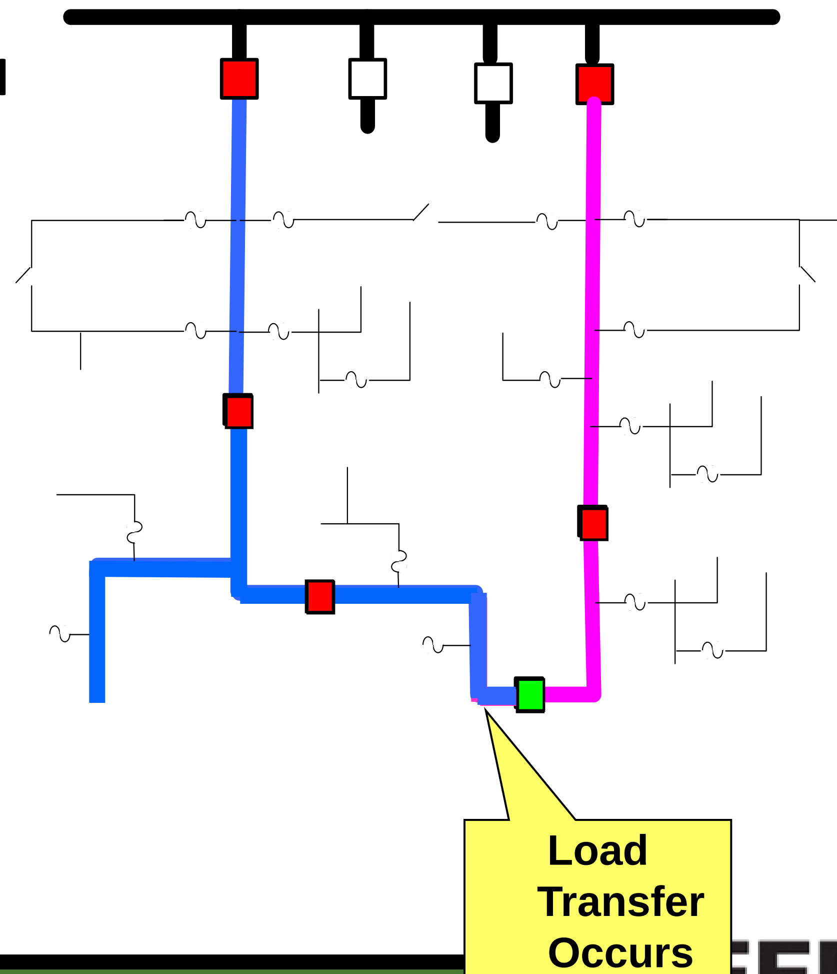
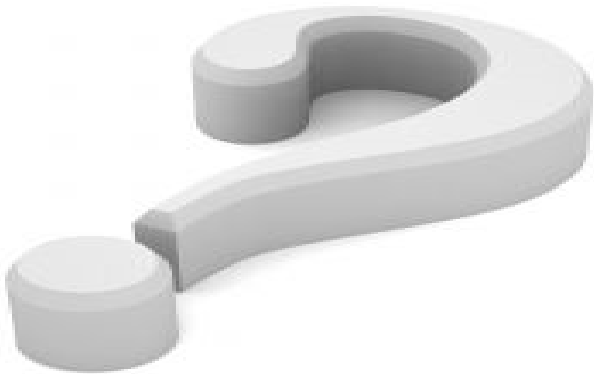


Conclusions

- Advanced distribution applications will play a growing role in managing distribution system operation for improved efficiency, reliability, and performance
- Utilities must have the necessary skills to deal with these new systems:
  - Training/certification of operators
  - New procedures and business processes
  - Maintenance of hi tech systems
  - Growing engineering support in the DSO
- New planning tools and capabilities are needed for smart distribution systems
  - Account for advanced control capabilities,
  - Model impact of DER
  - Real and reactive power forecasting
  - Make sure software supplier vendors are in sync with the needs of planning engineers
- AMI will certainly play a key role in maximizing the benefits
  - improved accuracy and lower operating margins
  - Still some significant issues that need to be addressed such as data throughput and security

Questions and Discussion



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