Standards-enabled Smart Grid for the Future EnergyWeb

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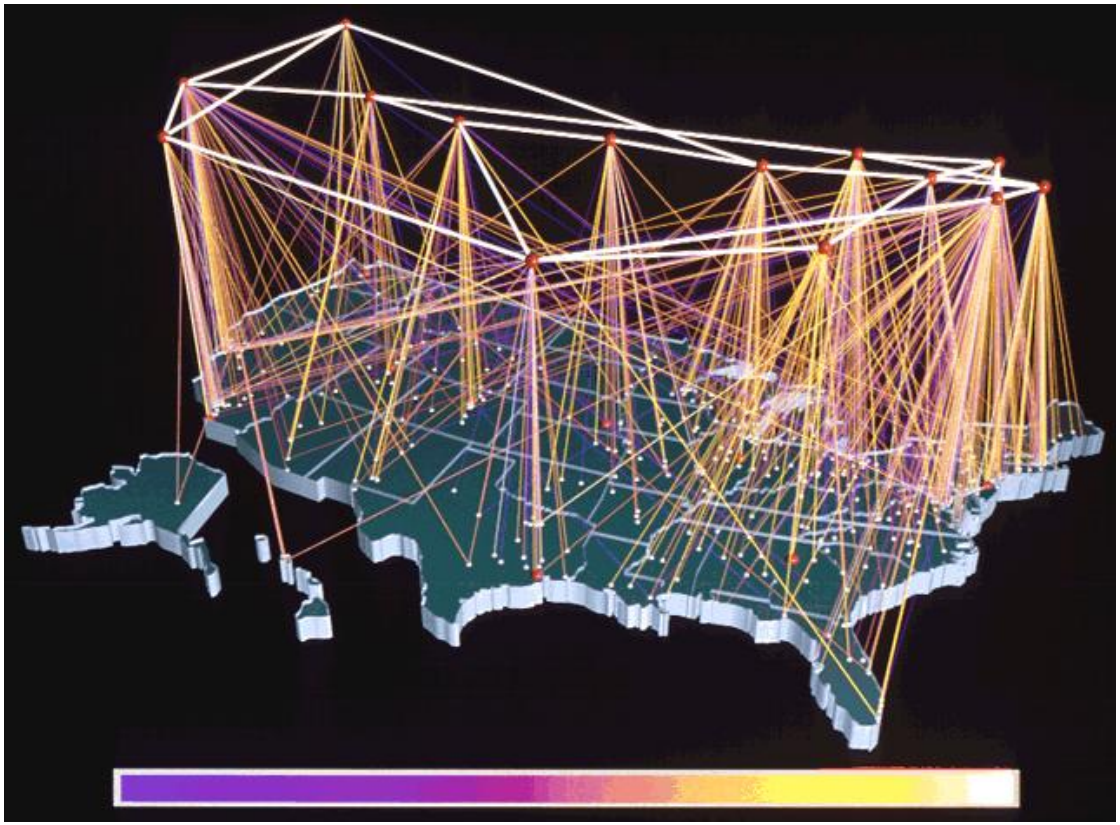
Next Generation Cyber Infrastructure

Vast intelligence network capable of learning to connect distributed sensory input to distributed actions in the real world, **integrated so as to maximize the performance of the global system**

eNetworks = Networked Embedded Control Systems



Future Cyber-Physical Systems: Systems enabled by e-Networks

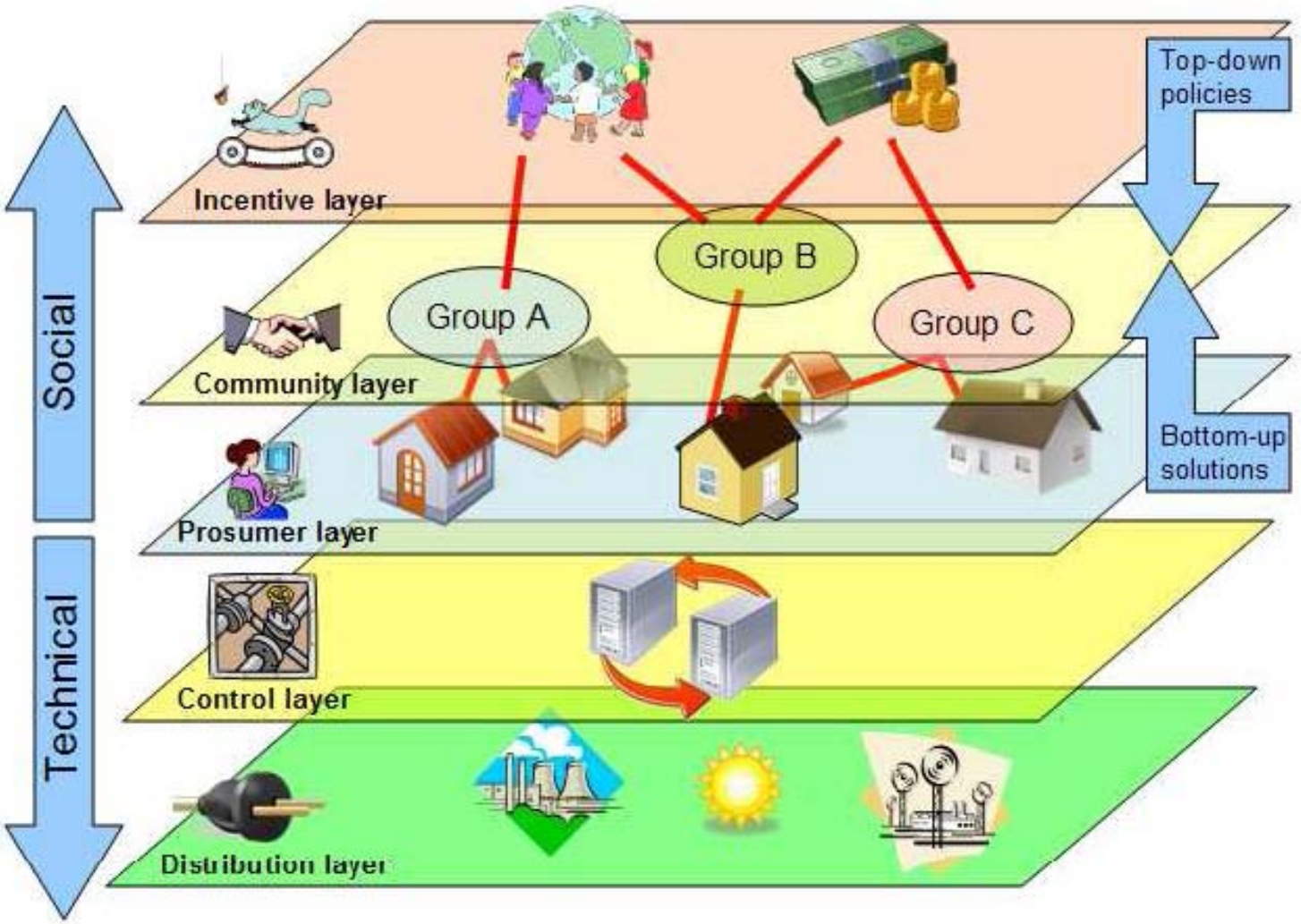
- **Integration** and **networking** of systems across all scales to create a pervasive ICT (Information Communication Technologies) infrastructure applicable in several areas, from intelligent buildings and transportation to effective energy management, intelligent manufacturing, e-Health, e-Commerce…

- **Cyberinfrastructure** – is becoming an artificial nervous system for the entire economy, providing **optimal** integrated management of large critical infrastructures ranging from electric power and water to environment and finances with seamless market interface

Can we apply cyber-physical design approach here?

How to merge intelligent control and power systems expertise ?

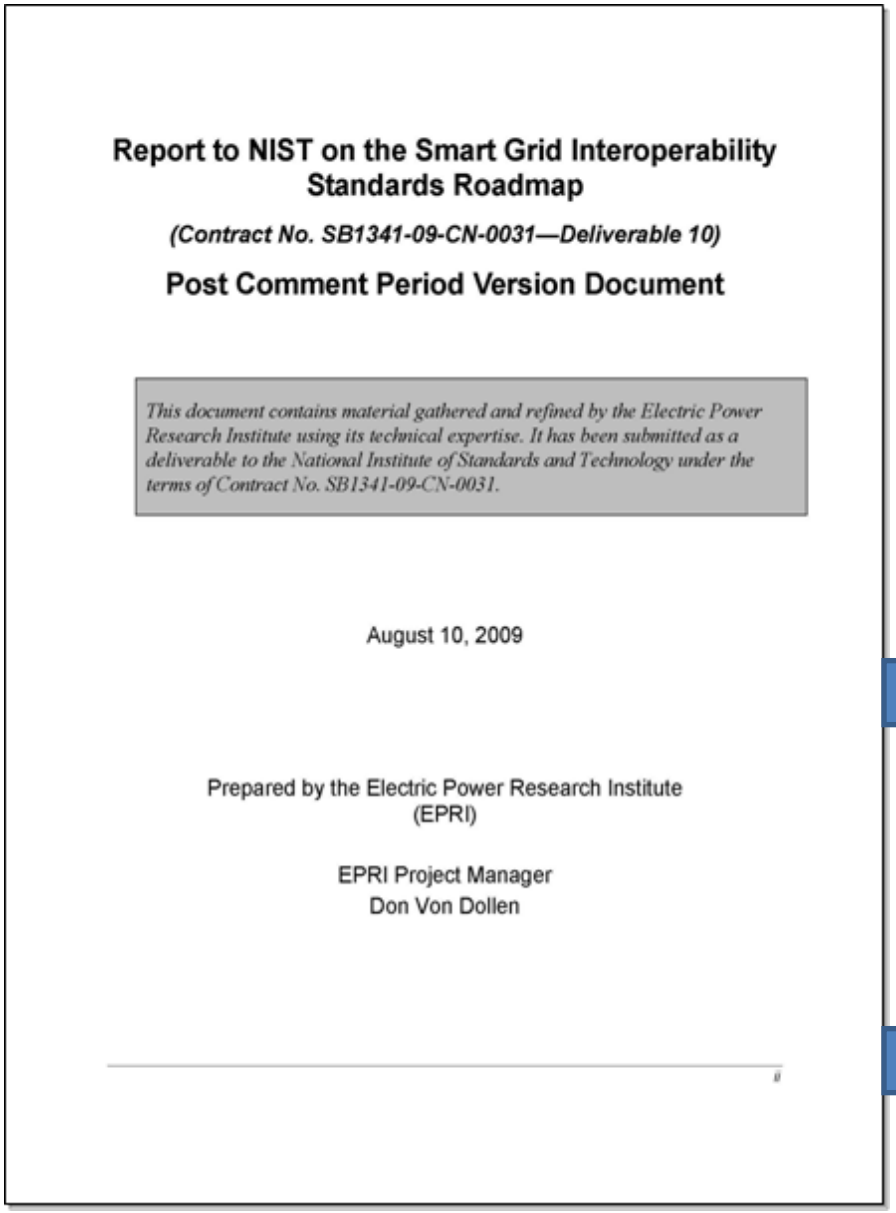
EnergyWeb proposal



Industrial Deployment of Intelligent Control

- It is possible to program controllers with more “intelligent” behaviour ☺
- It is difficult, however, to convince industry to use such controllers ☹
- Standards, norms, design practices ...

Norms about SmartGrid:



Report to NIST on the Smart Grid Interoperability Standards Roadmap

(Contract No. SB1341-09-CN-0031—Deliverable 10)

Post Comment Period Version Document

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August 10, 2009

Prepared by the Electric Power Research Institute (EPRI)

EPRI Project Manager
Don Von Dollen

The Smart Grid ... incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the **device level**.

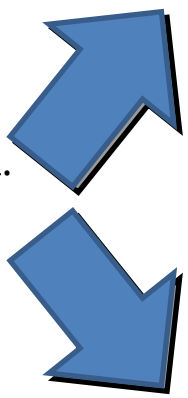
... provides a reliable power supply with fewer and briefer outages, "cleaner" power, and self-healing power systems, through the use of digital information, automated control, and autonomous systems ...

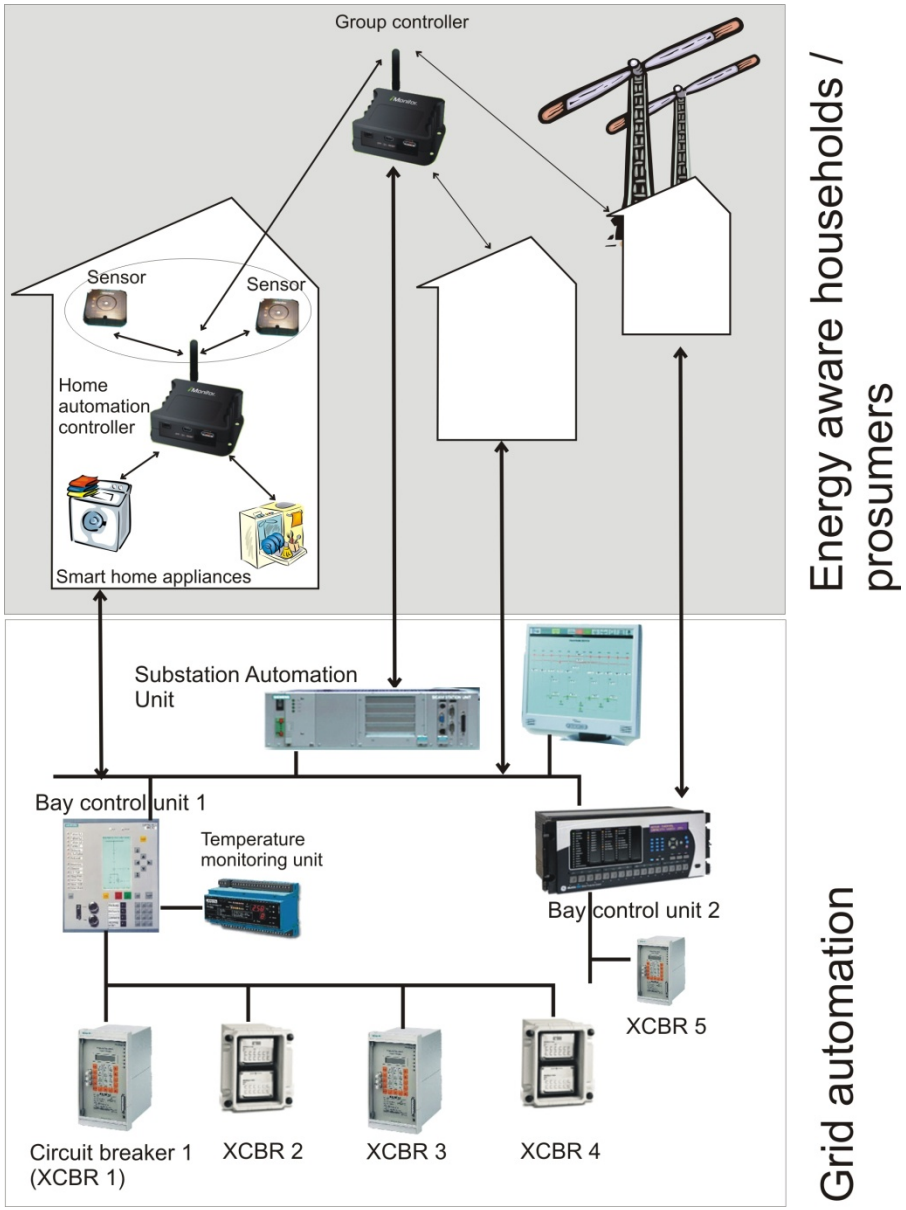
IEC 61499 and IEC 61850 are intended to provide a standardized platform to support Distribution Automation to meet this requirement. ...

Devices enabling EnergyWeb

…

The Smart Grid ... incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand **at the device level**.



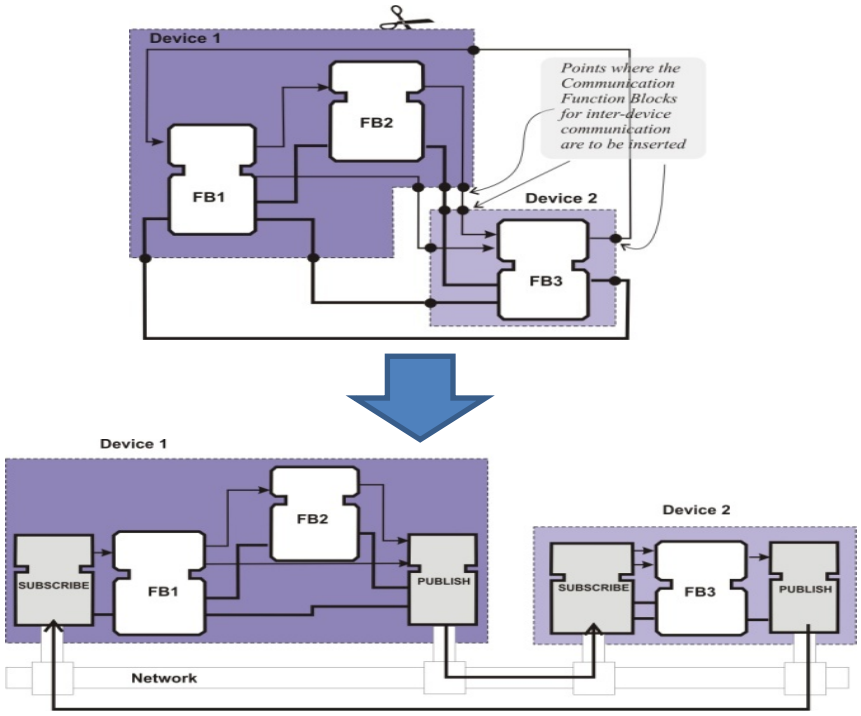


Function Blocks (IEC 61499) and IEC 61850

Function Blocks Architecture

Goal:

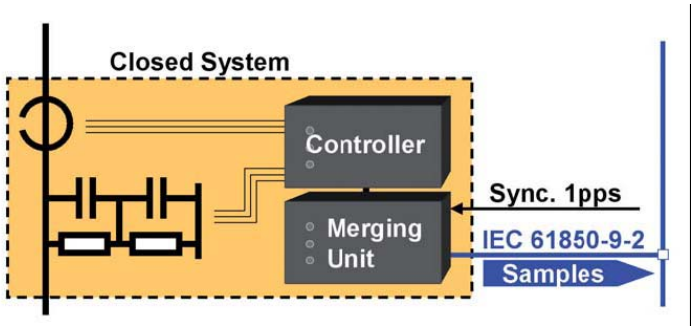
- Intelligence encapsulation & distribution



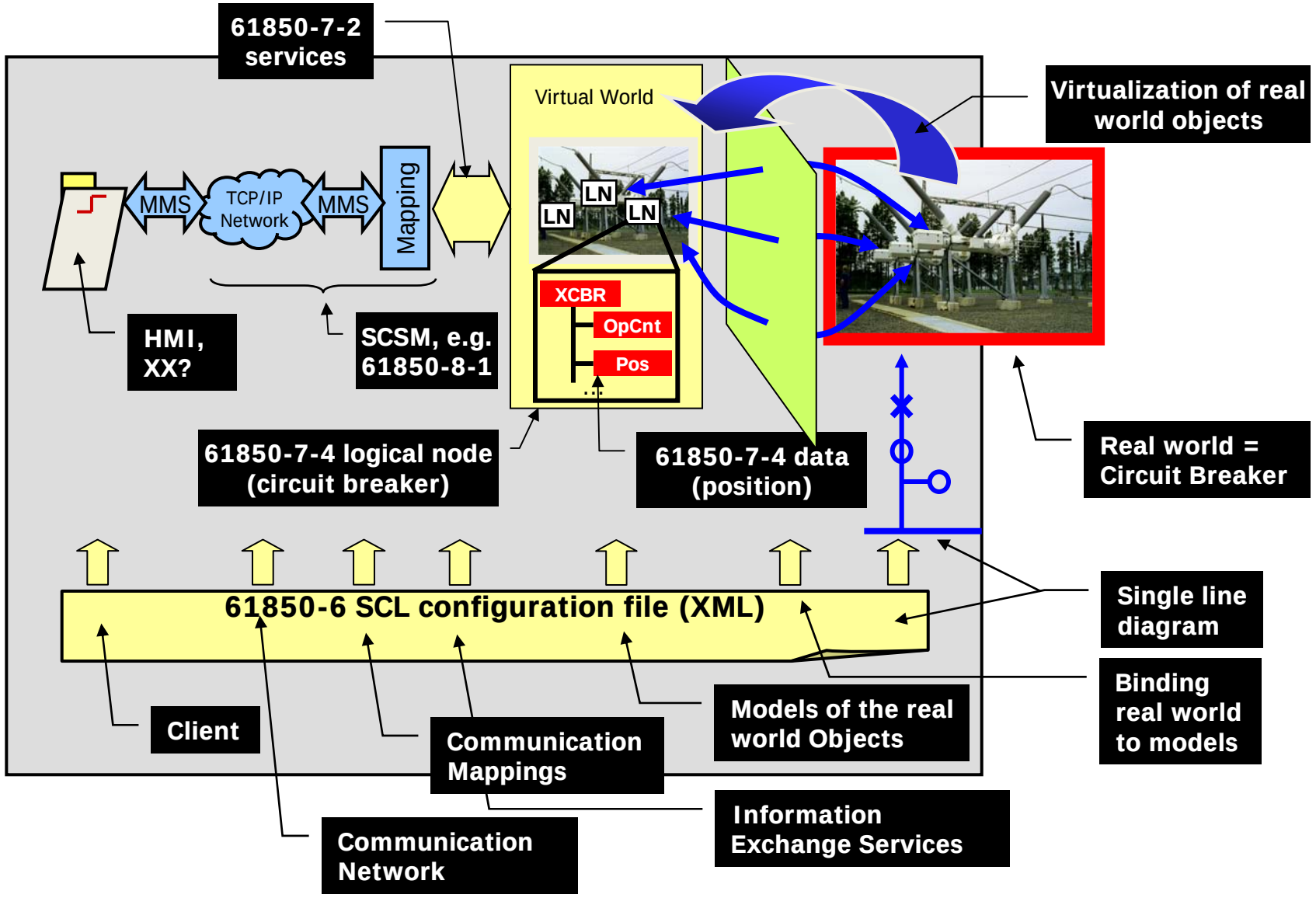
IEC 61850

Goals:

- Communication Networks and Systems in Substations
- Introduce various elements of the power-system-related automation architecture called Substation Automation System (SAS).

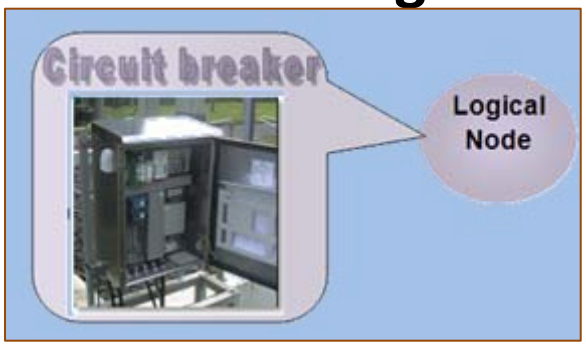


IEC 61850 modeling approach

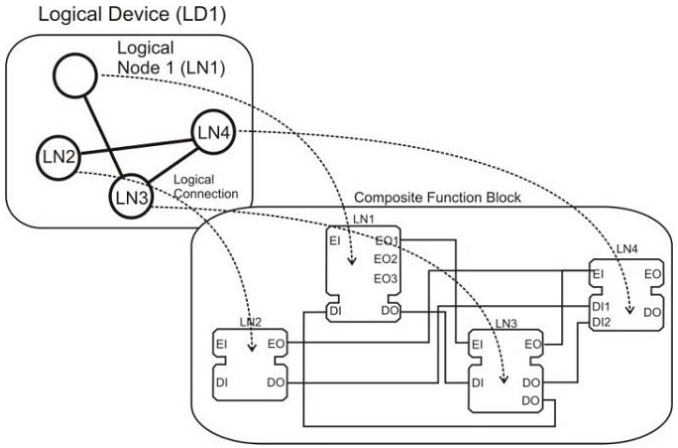


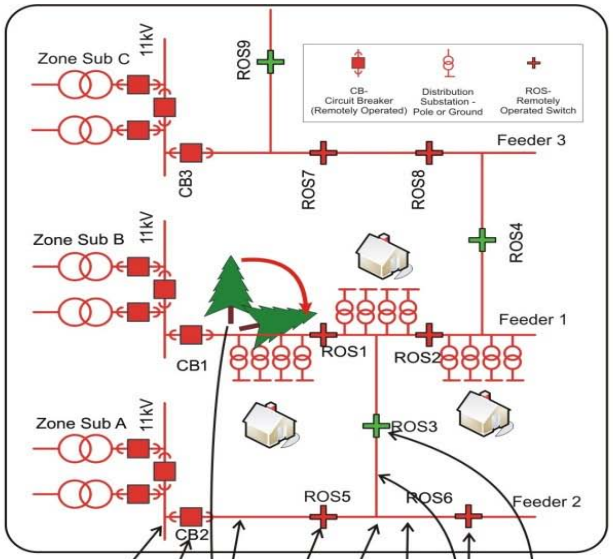
Standards' Harmonisation Strategy

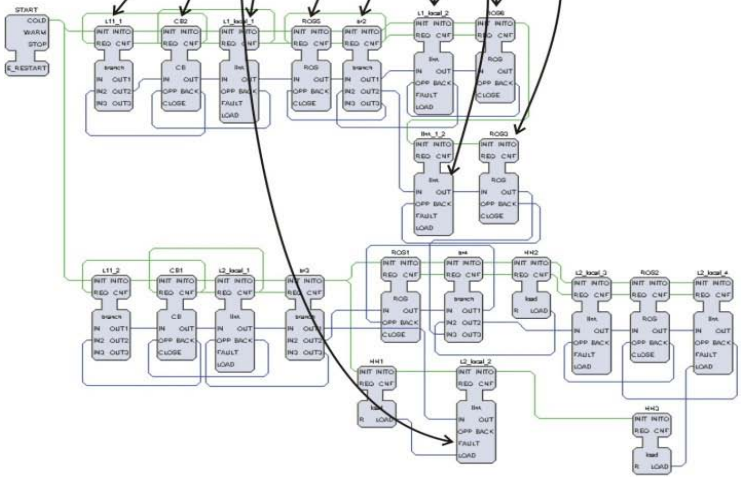
IEC 61850 represents primary devices as Logical Nodes



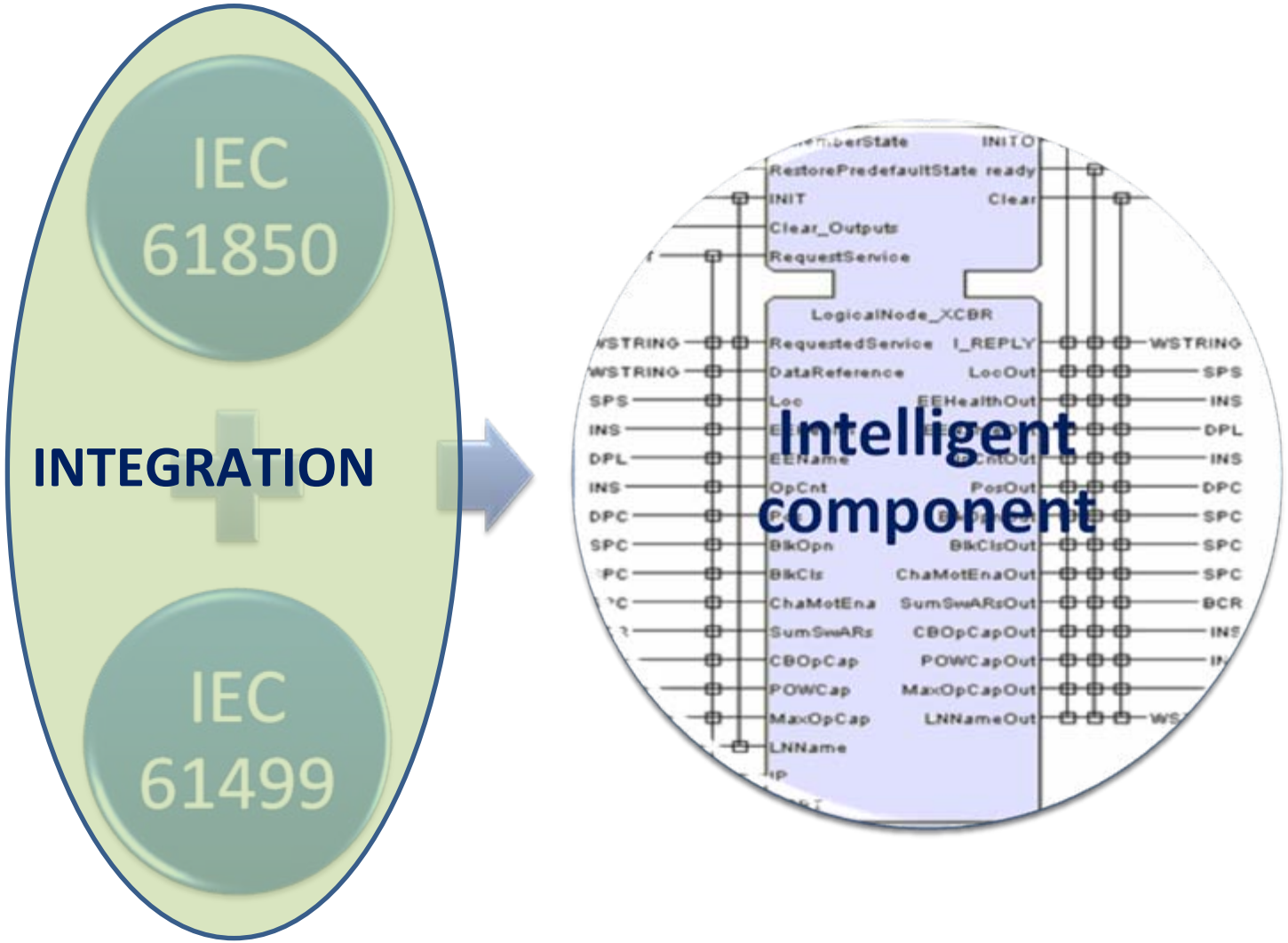
IEC 61499 models LN + Intelligence







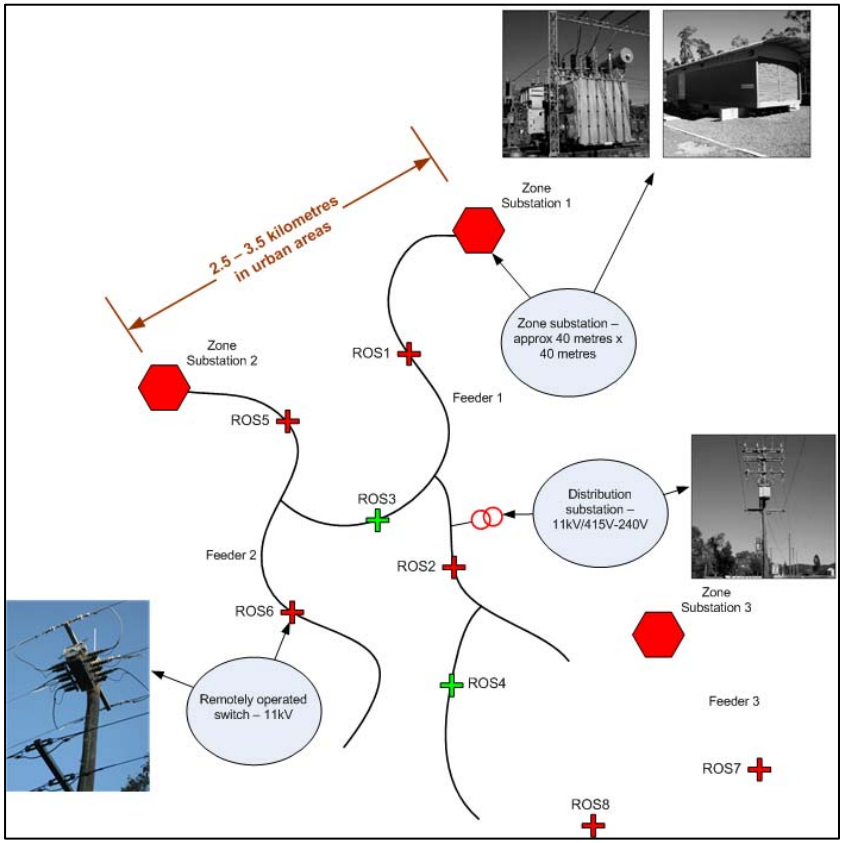
Library of Intelligent Components



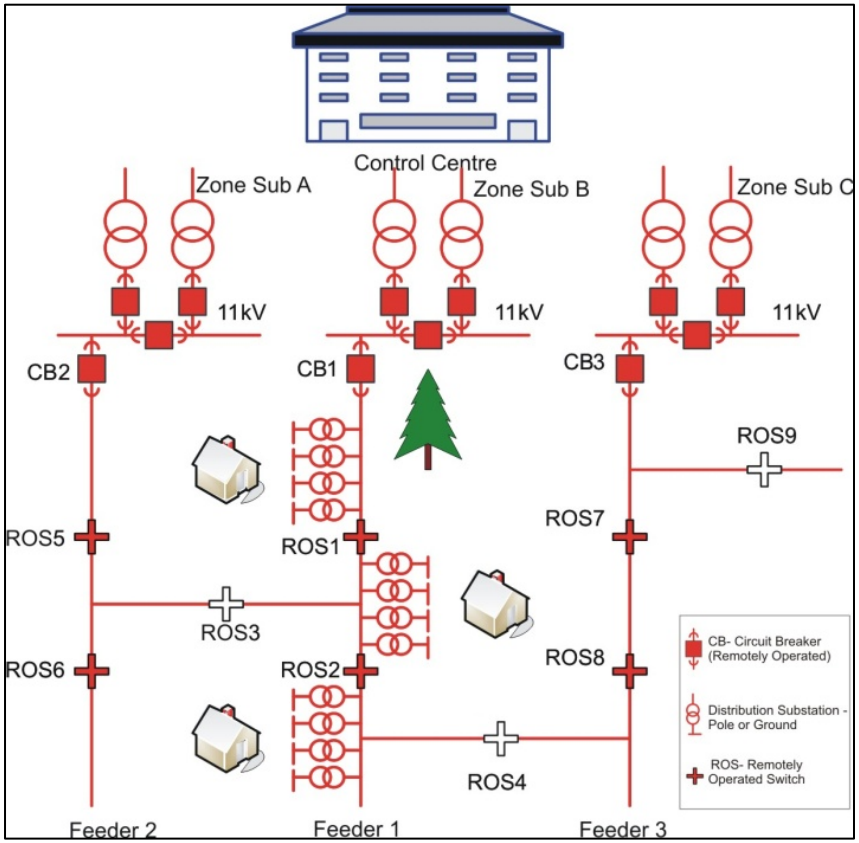
Sample Power Distribution System

We tested our implementation using the following sample power distribution system

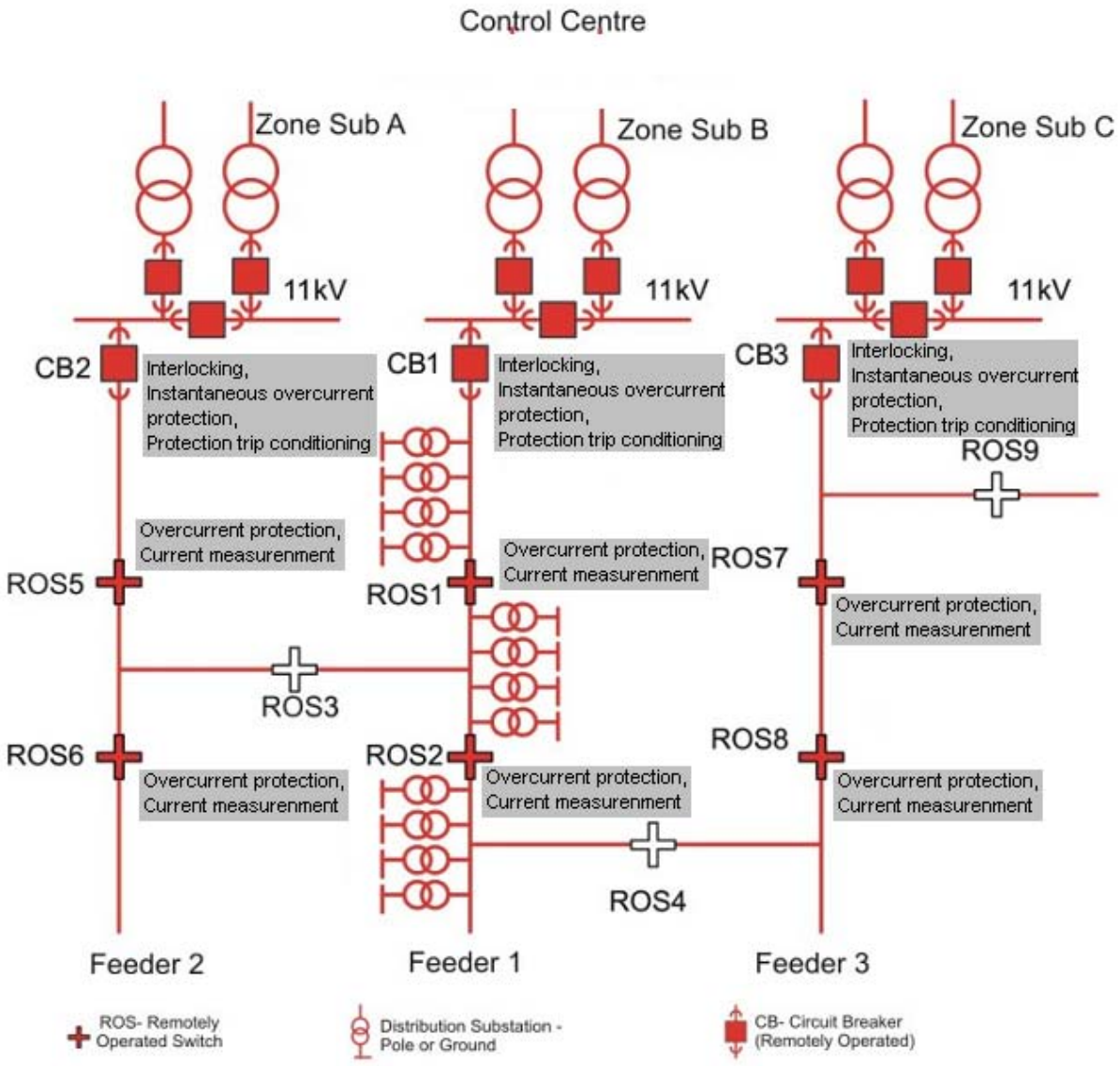
Geographic layout



Schematic layout

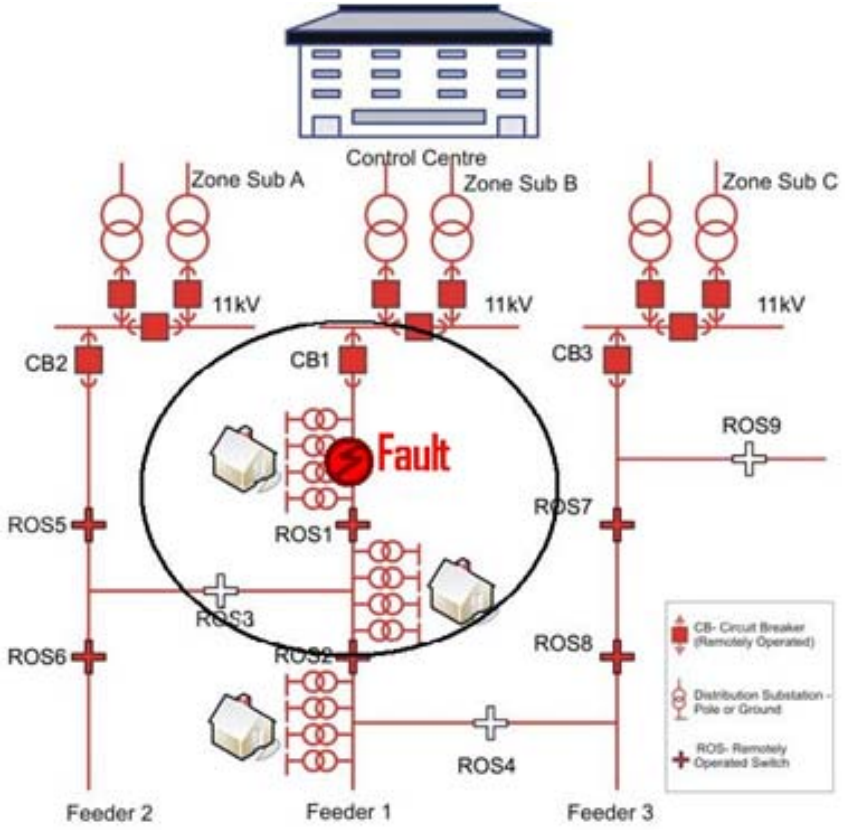


Allocating Functions to Logical Nodes (Collaborating Intelligent Devices)

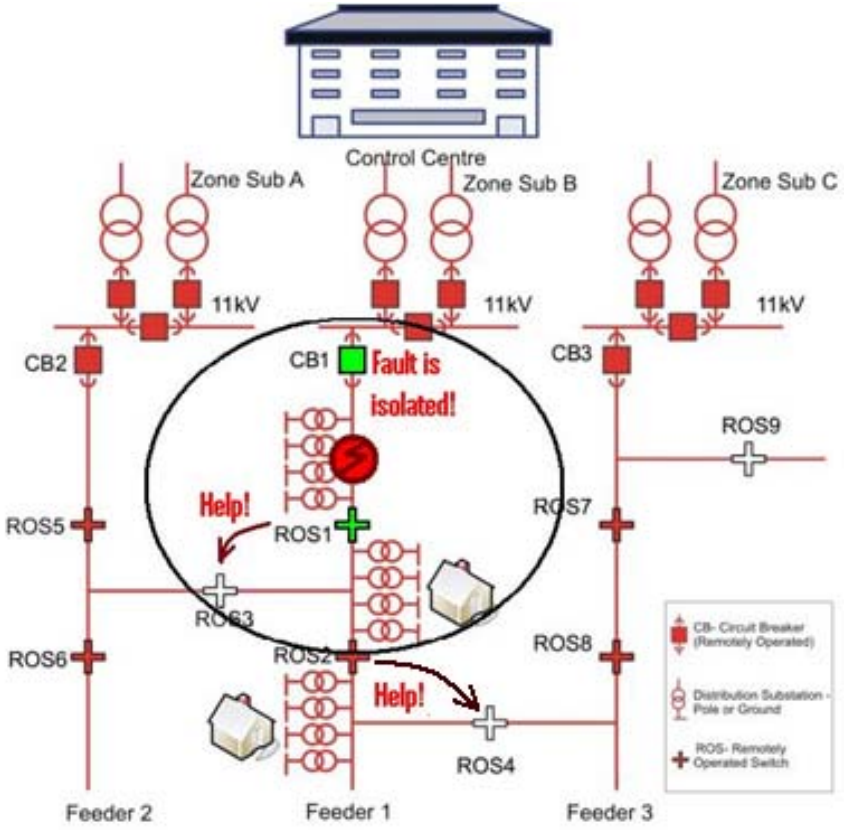


FLISR Scenario Simulation

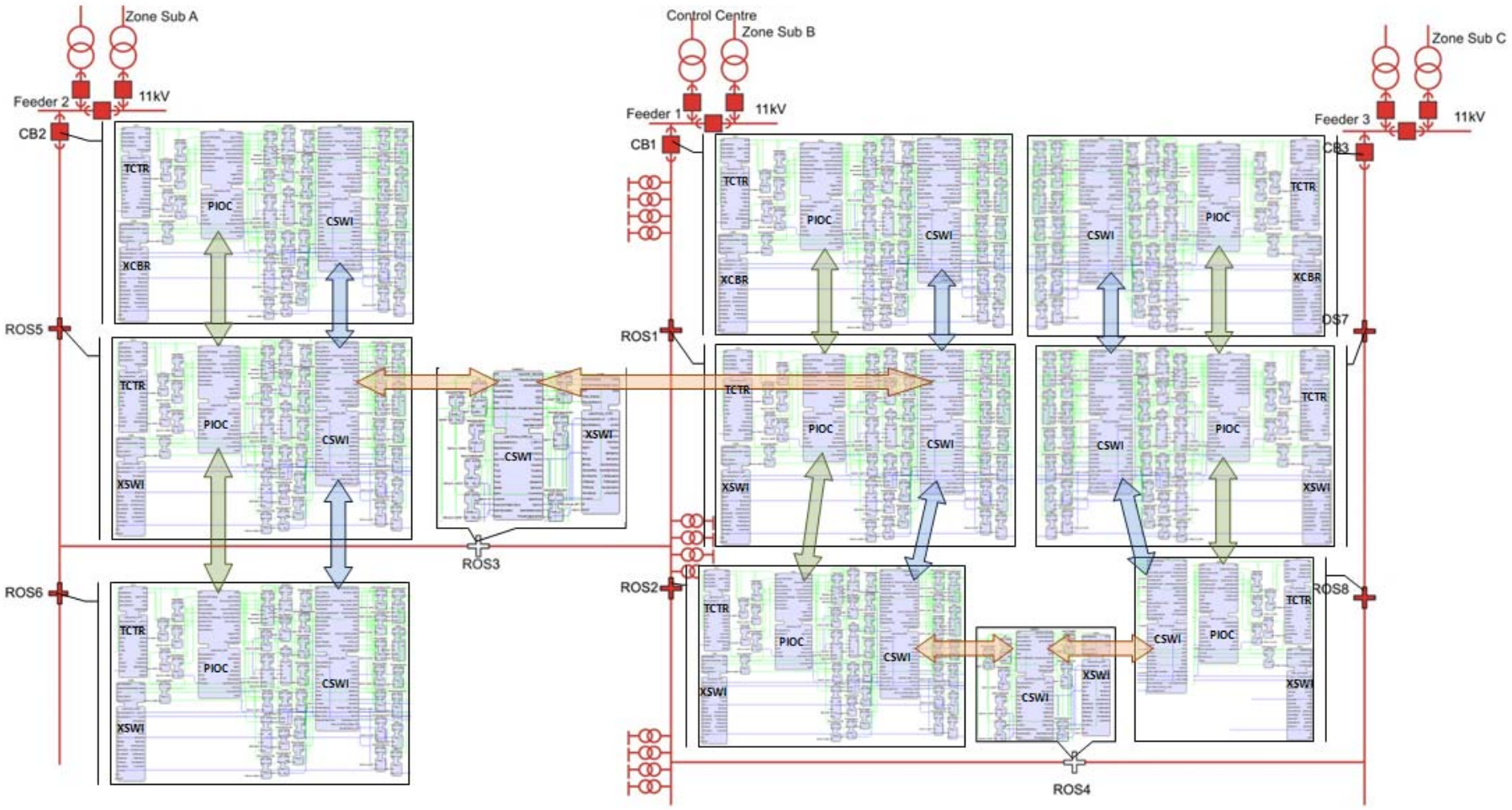
Initial state: Fault occurred



Final State: Power restored

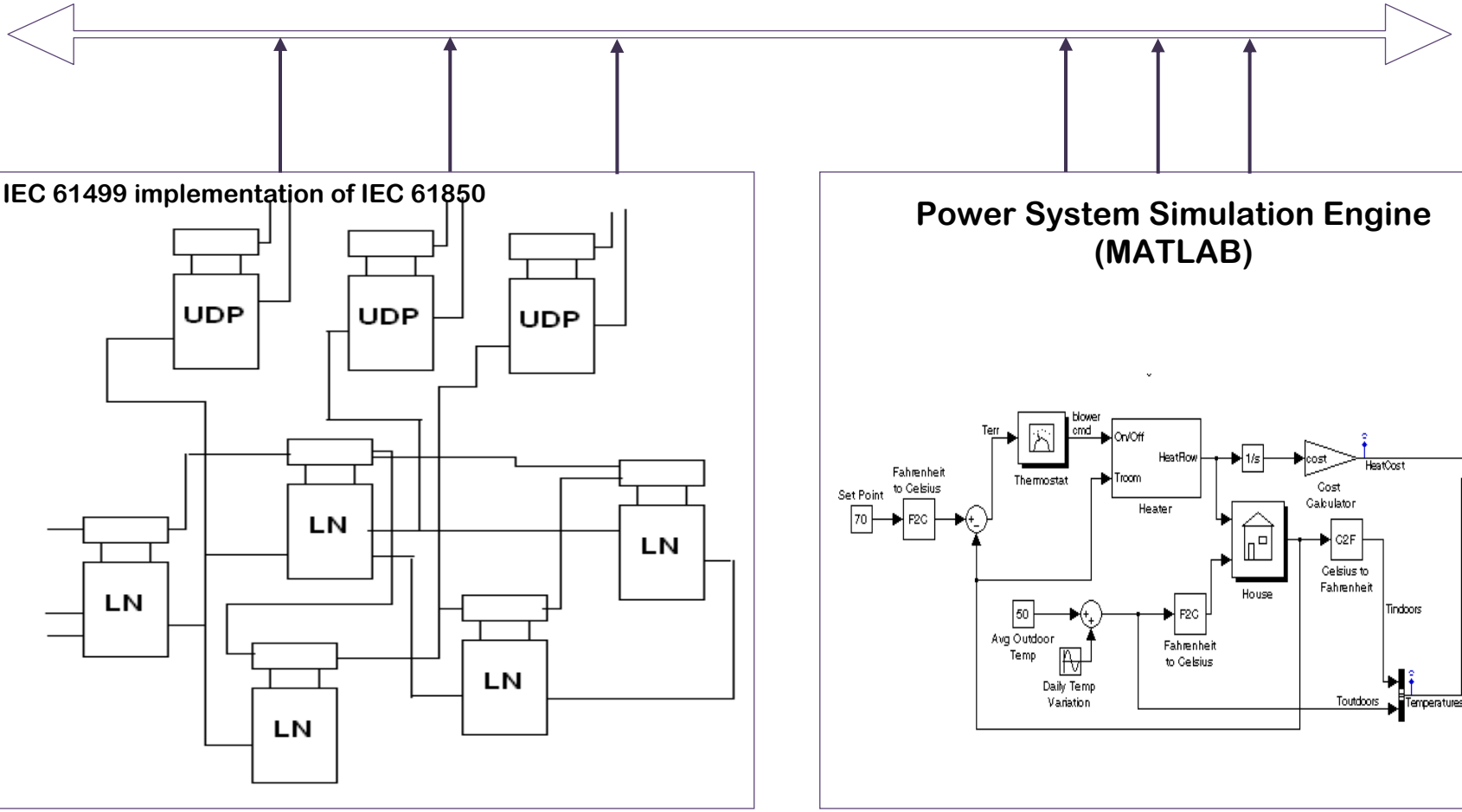


Function Blocks Implementation of LNs

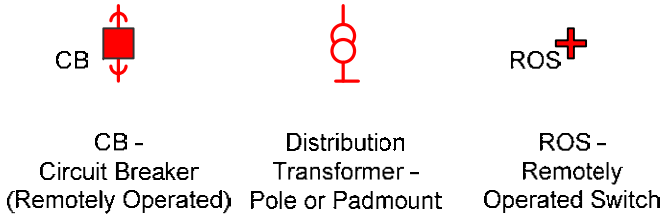


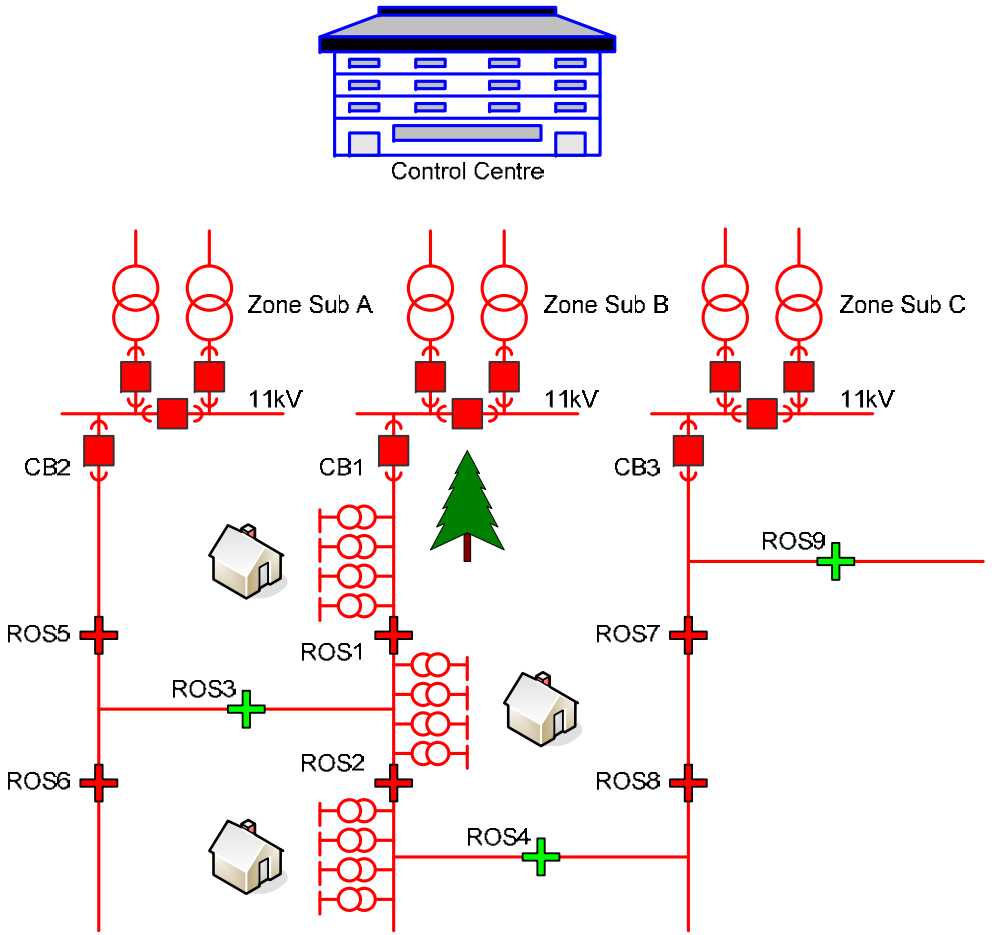
Negotiation flow between LNs in the power distribution network is shown

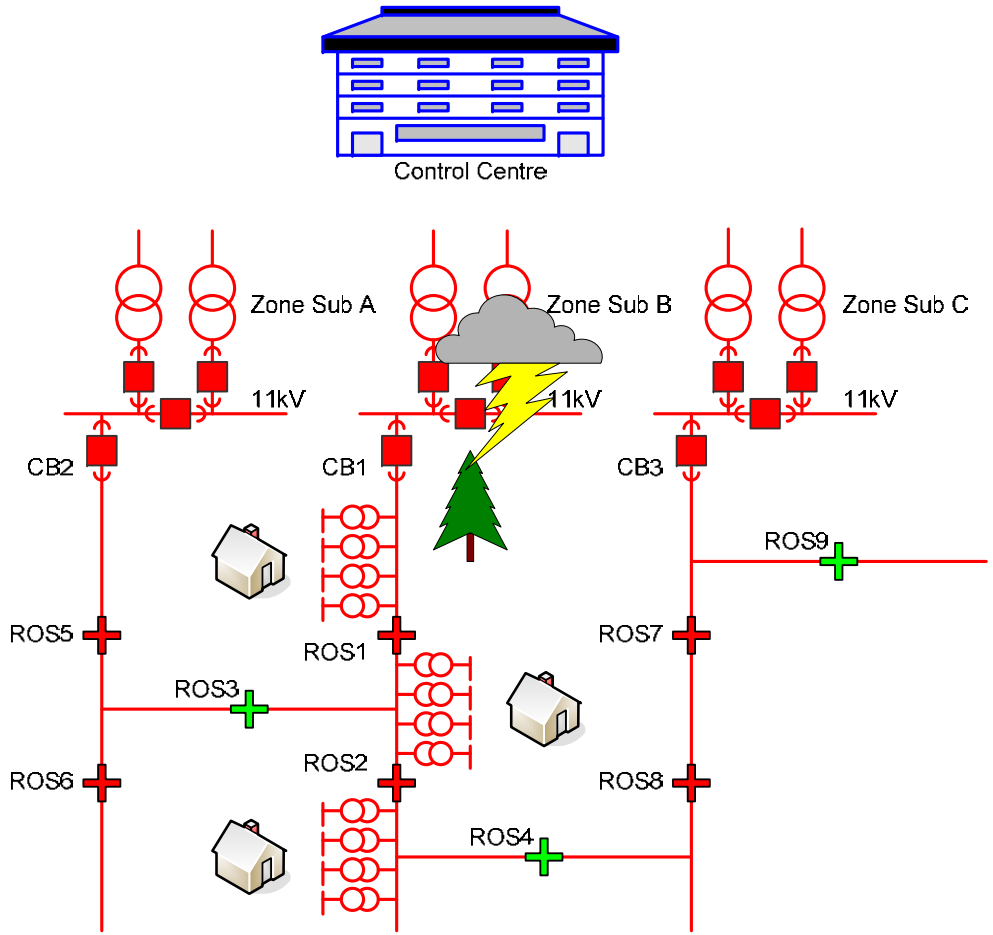
Testbed for Analysis of IEC 61850/IEC 61499 implementation

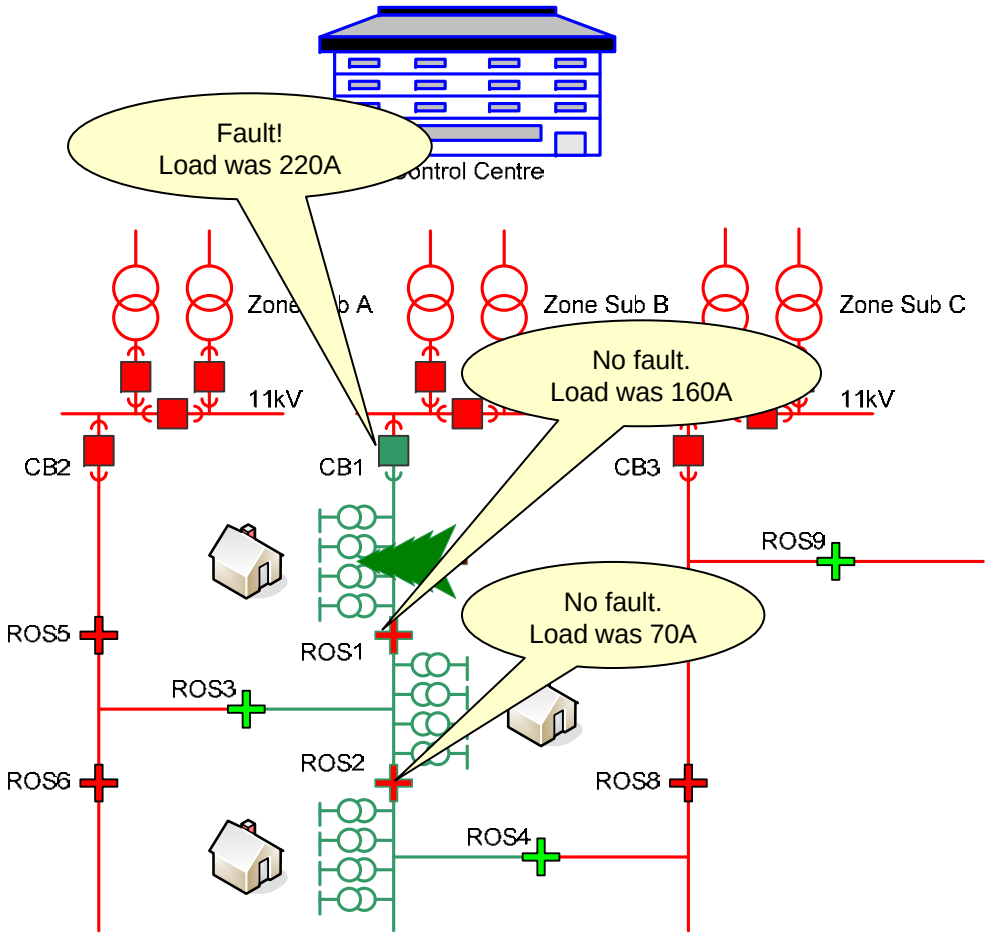


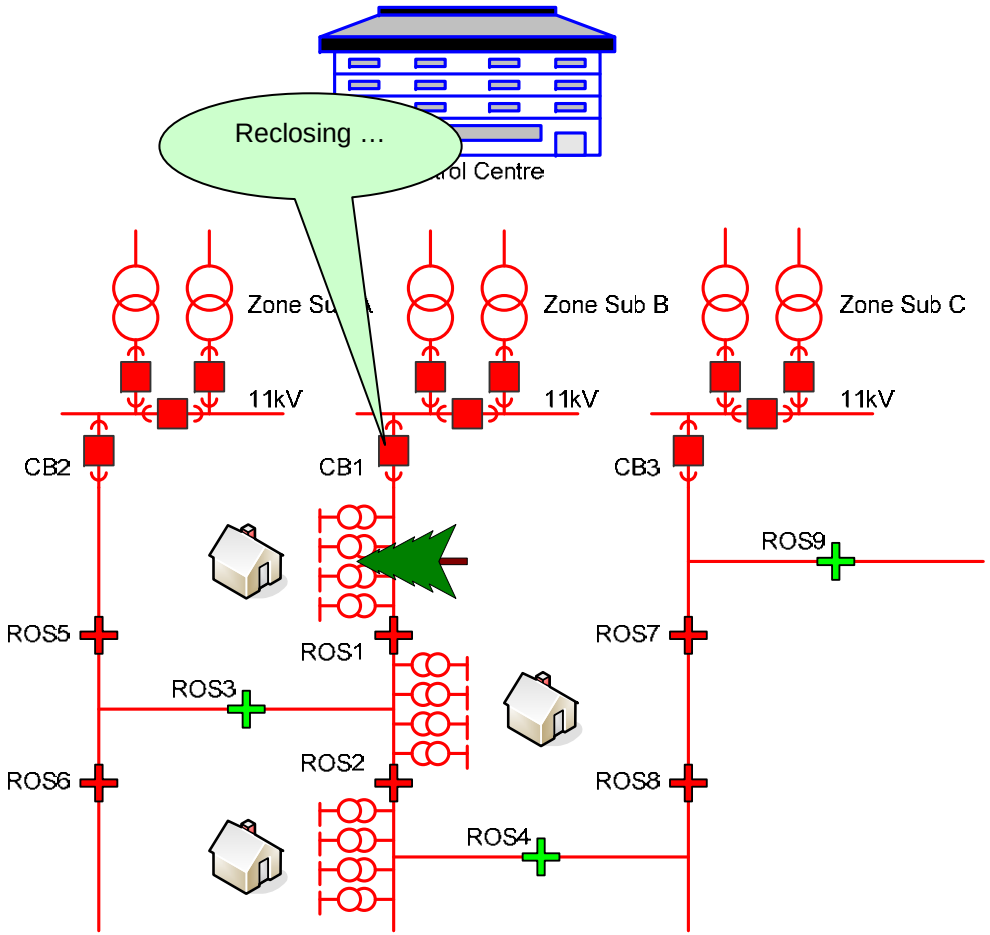
FLISR Scenario Simulation

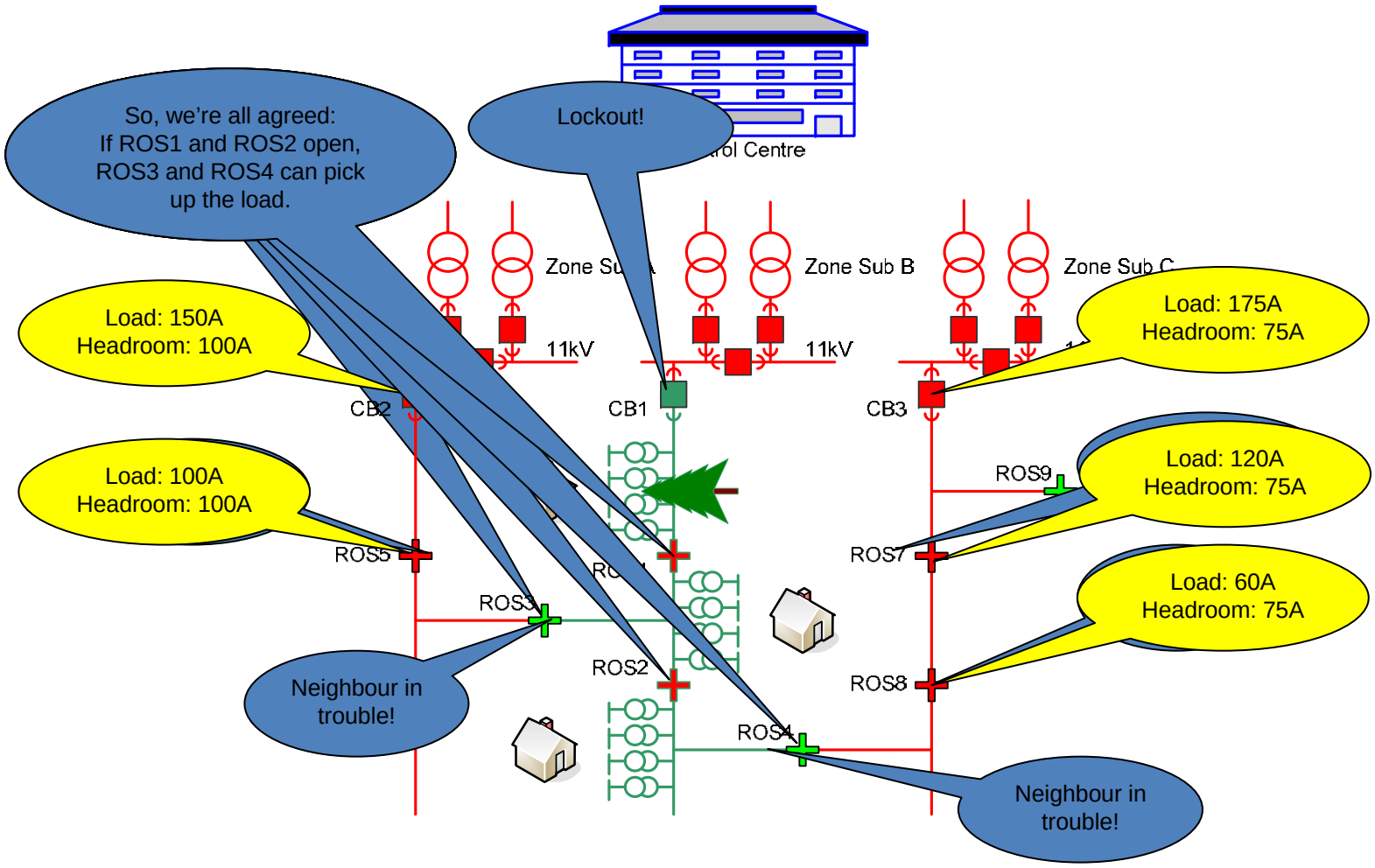


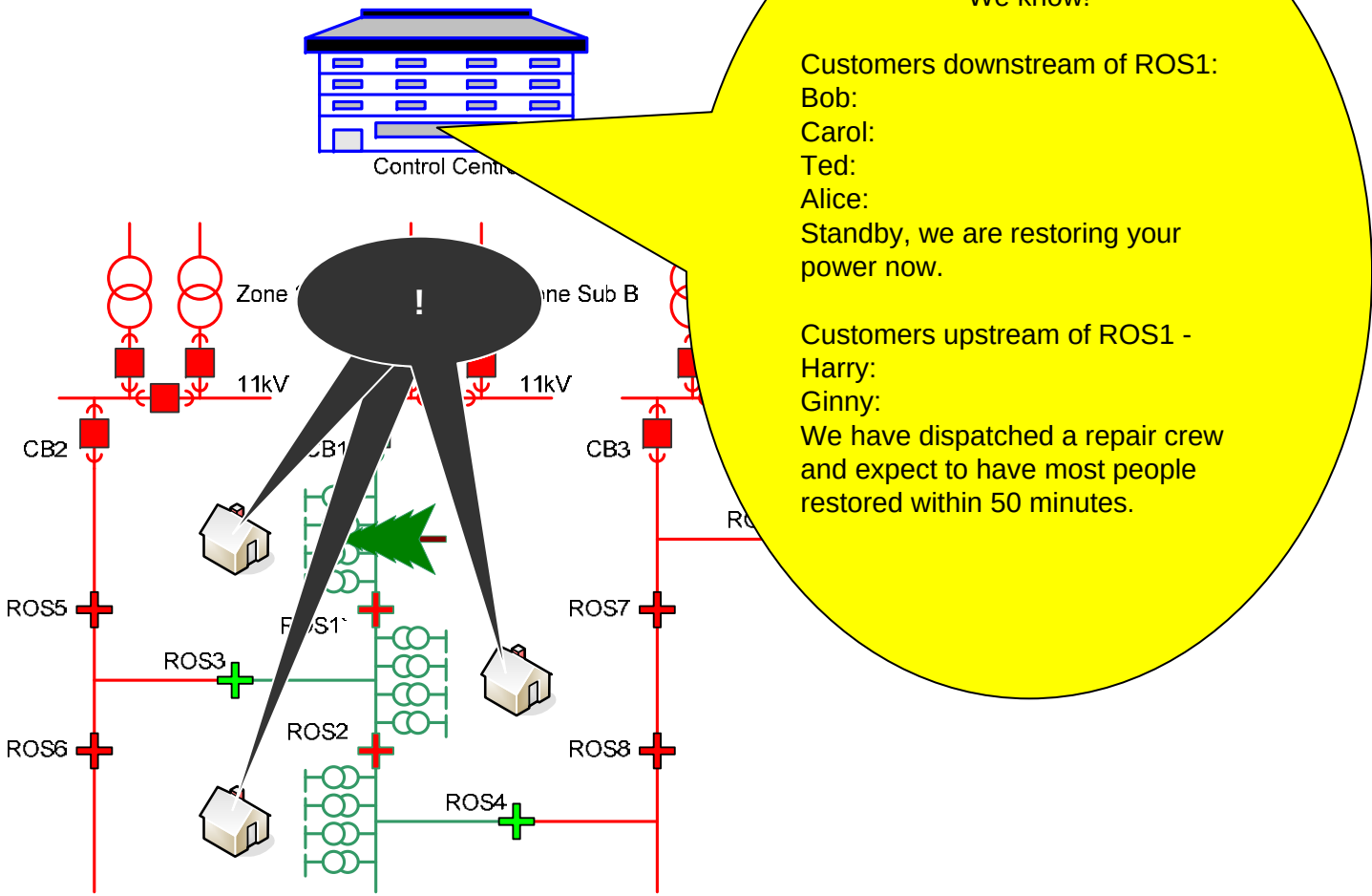


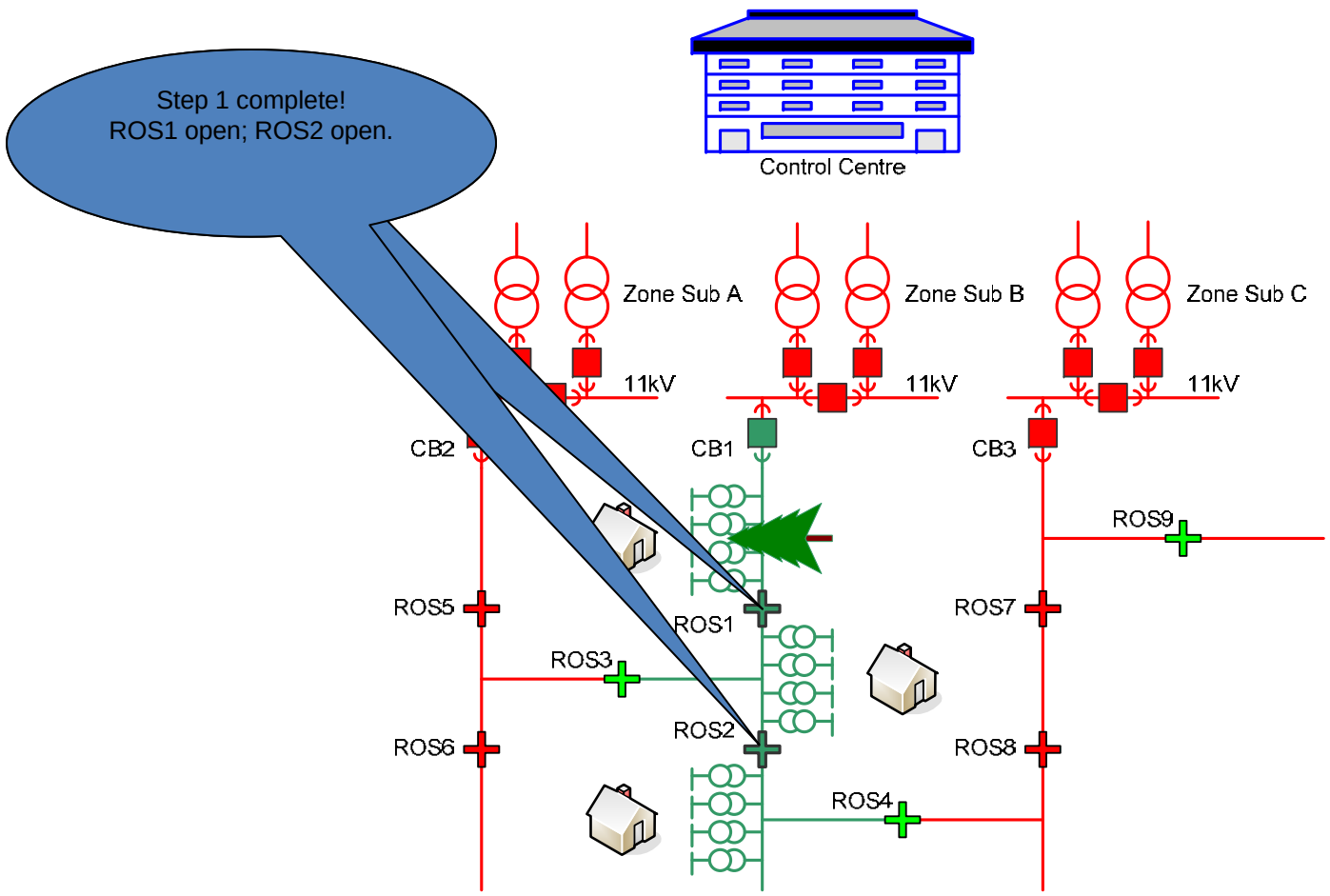

Control Centre
Zone Sub A
Zone Sub B
Zone Sub C
11kV
11kV
11kV
CB2
CB1
CB3
ROS9
ROS5
ROS1
ROS7
ROS3
ROS6
ROS2
ROS8
ROS4

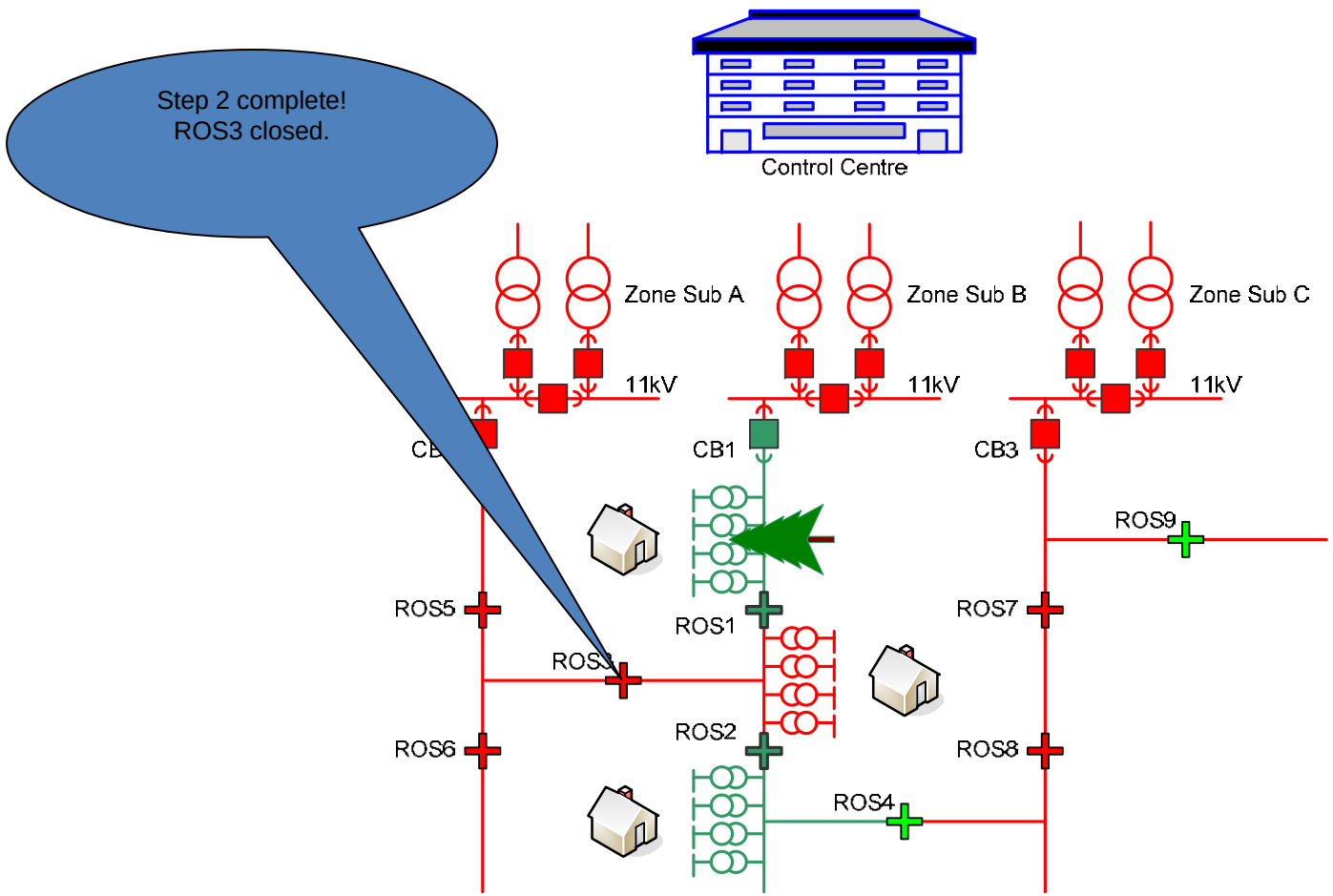

Fault!
Load was 220A
ontrol Centre
Zone Sub A
Zone Sub B
Zone Sub C
No fault.
Load was 160A
11kV
11kV
CB2
CB1
CB3
ROS9
No fault.
Load was 70A
ROS5
ROS1
ROS3
ROS2
ROS6
ROS8
ROS4

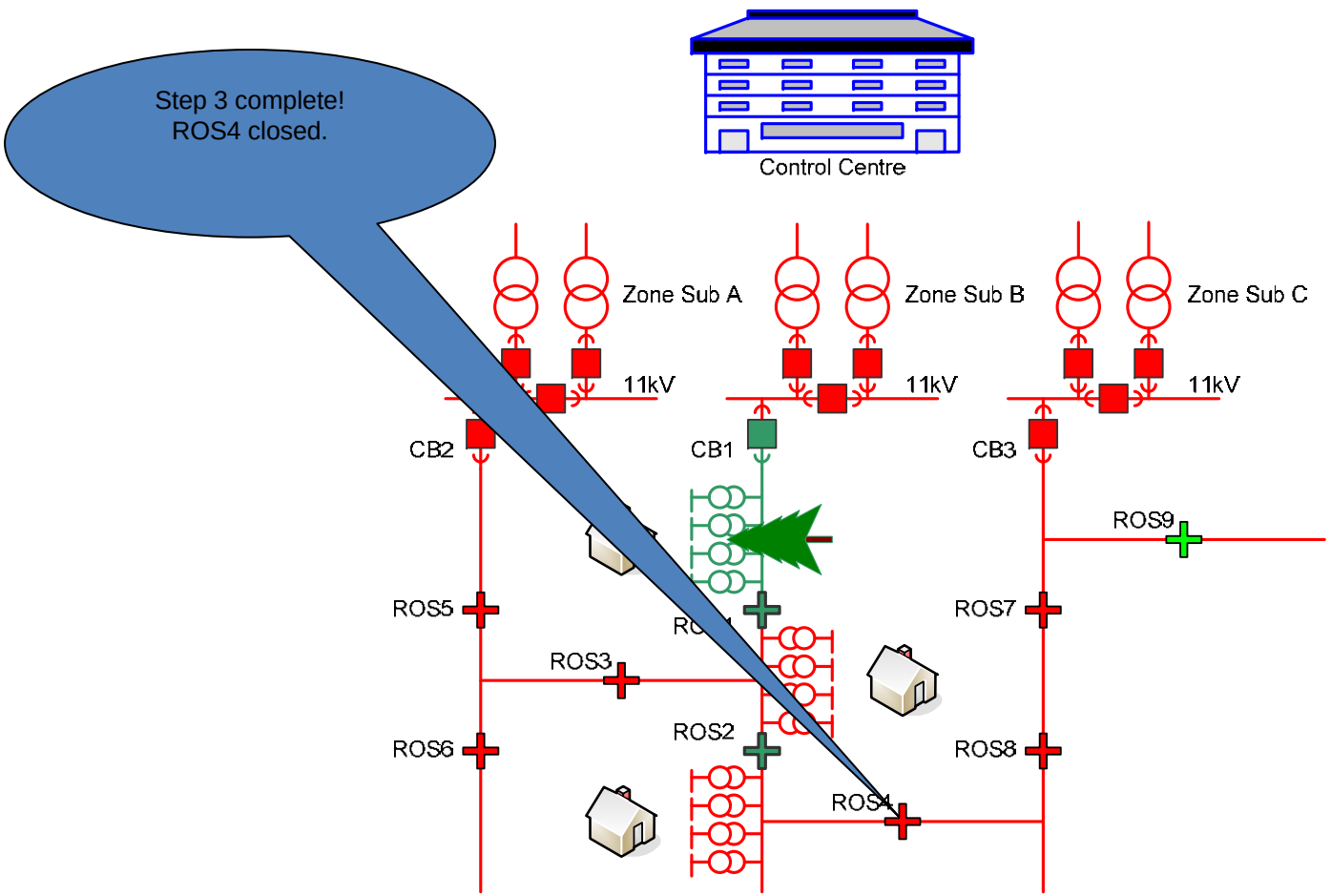

Reclosing …
Zone Sub B
Zone Sub C
11kV
11kV
11kV
CB2
CB1
CB3
ROS9
ROS5
ROS1
ROS7
ROS3
ROS6
ROS2
ROS8
ROS4

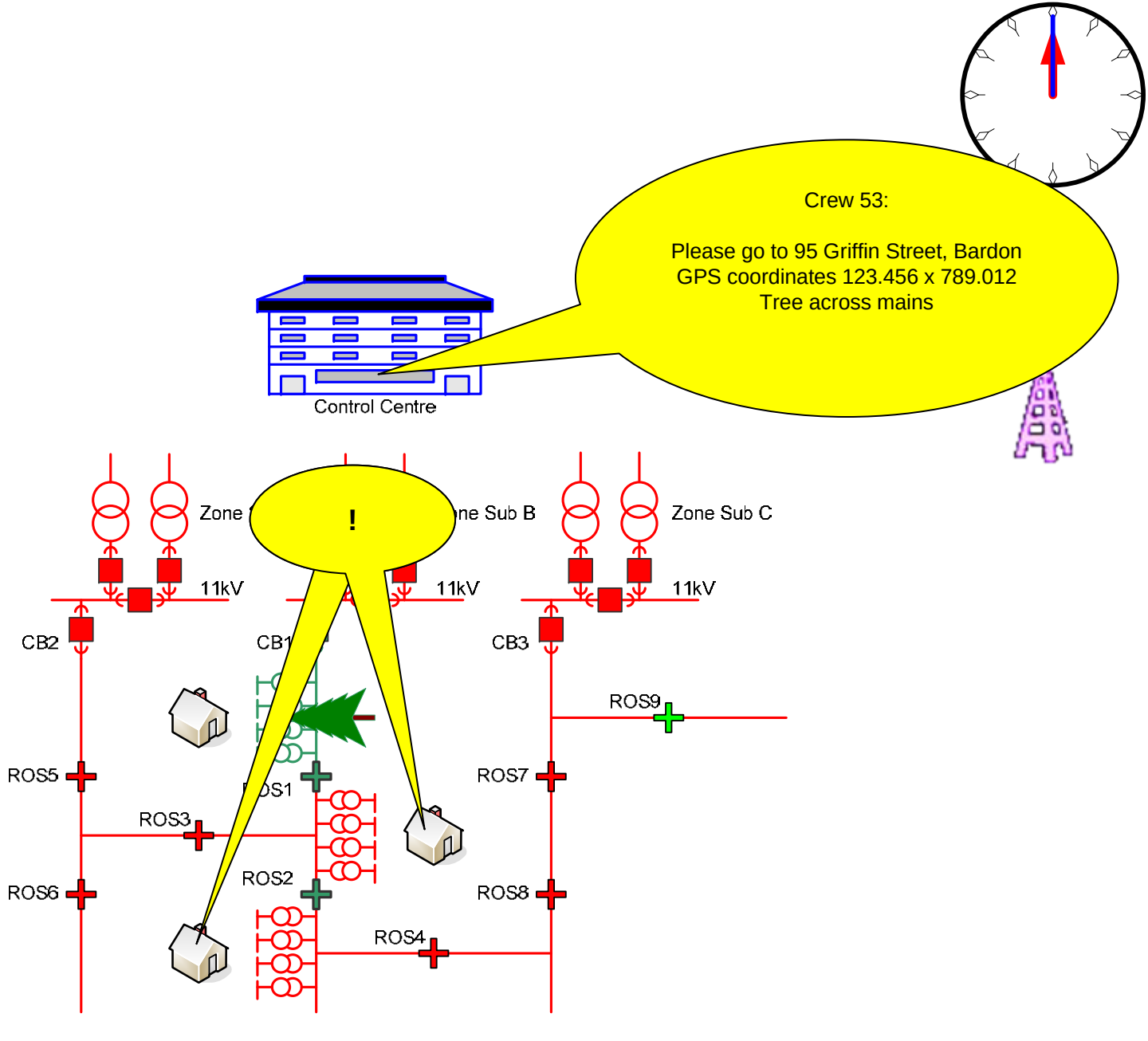

So, we're all agreed:
If ROS1 and ROS2 open,
ROS3 and ROS4 can pick
up the load.
Lockout!
Zone Sub B
11kV
11kV
Load: 150A
Headroom: 100A
Load: 175A
Headroom: 75A
CB2
CB1
CB3
Load: 100A
Headroom: 100A
Load: 120A
Headroom: 75A
ROS9
ROS5
ROS7
ROS3
Load: 60A
Headroom: 75A
ROS2
ROS8
Neighbour in
trouble!
ROS4
Neighbour in
trouble!

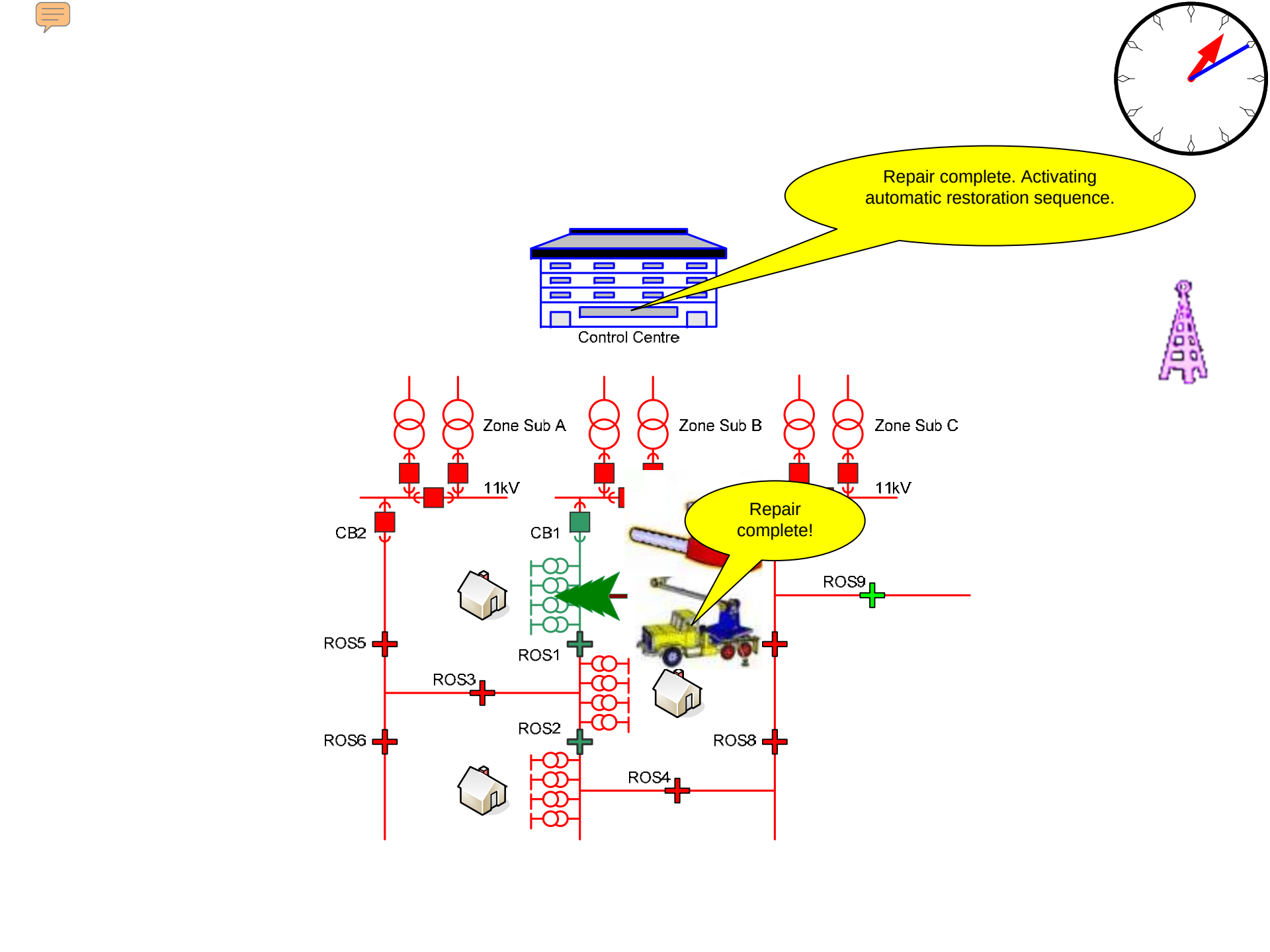

We know!
Customers downstream of ROS1:
Bob:
Carol:
Ted:
Alice:
Standby, we are restoring your power now.
Customers upstream of ROS1 -
Harry:
Ginny:
We have dispatched a repair crew and expect to have most people restored within 50 minutes.
Control Centre
Zone
Sub B
11kV
11kV
CB2
CB3
ROS5
ROS7
ROS3
ROS6
ROS2
ROS8
ROS4

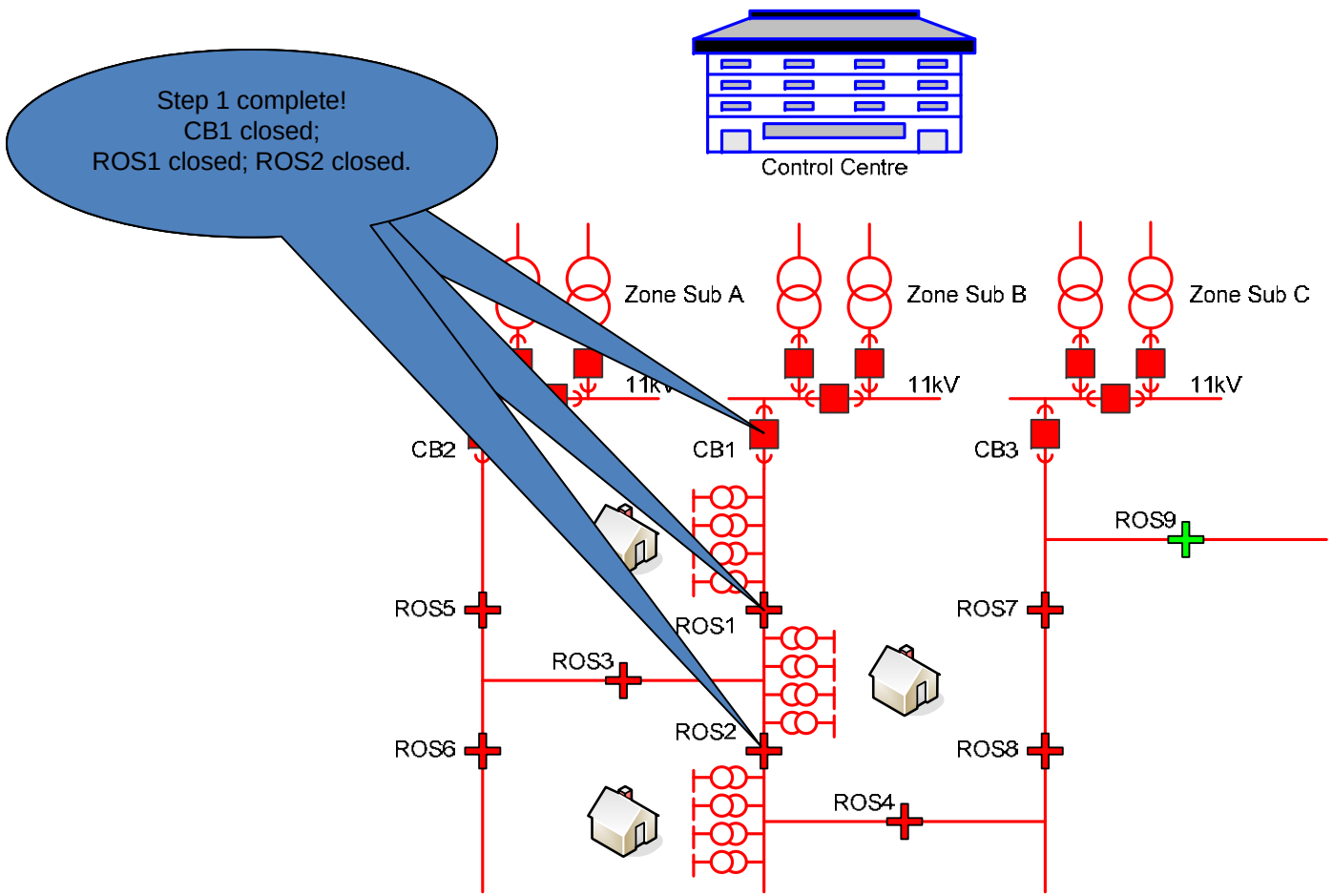

Step 1 complete!
ROS1 open; ROS2 open.
Control Centre
Zone Sub A
Zone Sub B
Zone Sub C
11kV
11kV
11kV
CB2
CB1
CB3
ROS9
ROS5
ROS1
ROS7
ROS3
ROS6
ROS2
ROS8
ROS4

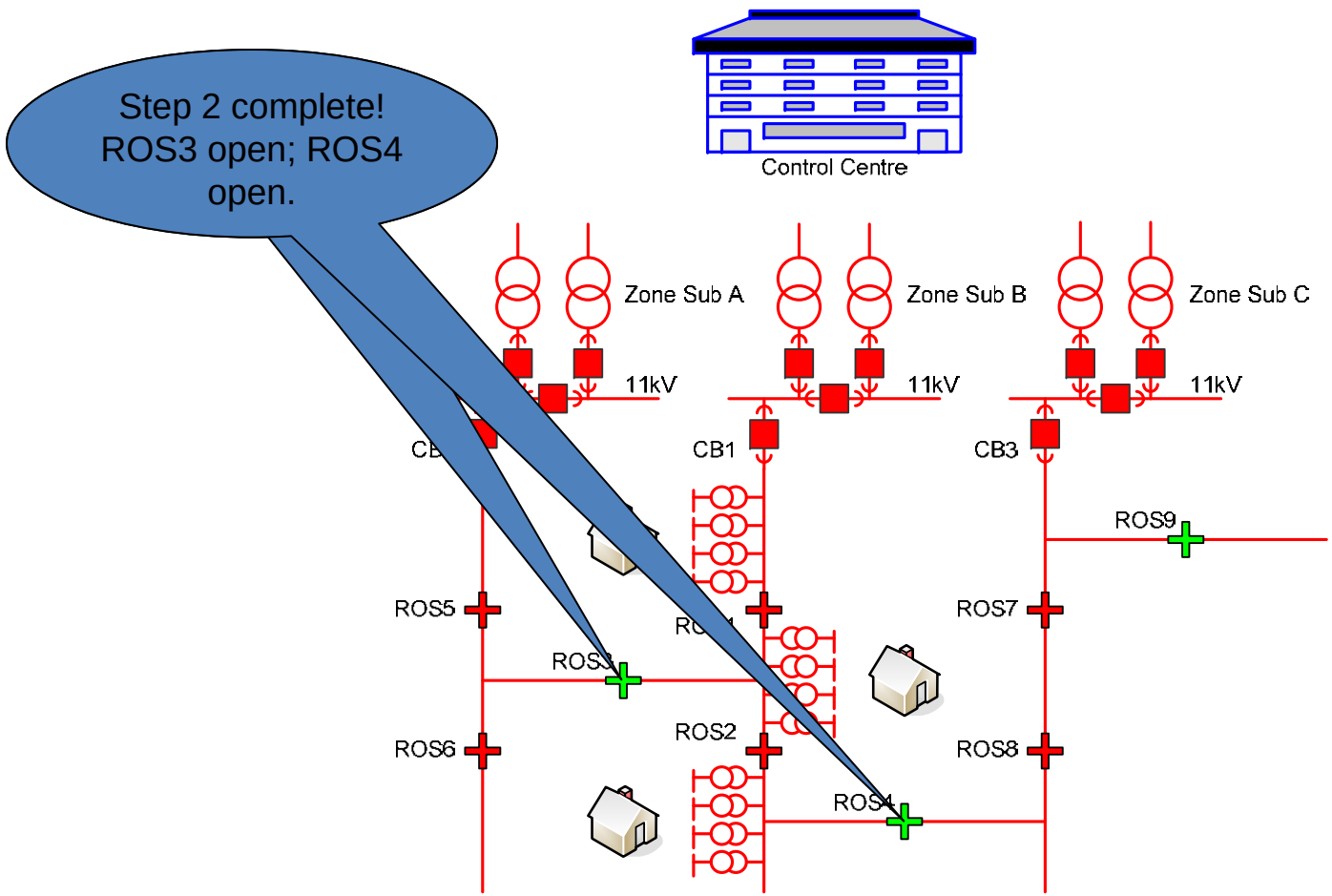

Step 2 complete!
ROS3 closed.
Control Centre
Zone Sub A
Zone Sub B
Zone Sub C
11kV
11kV
11kV
CB1
CB3
ROS1
ROS2
ROS3
ROS4
ROS5
ROS6
ROS7
ROS8
ROS9


Step 3 complete!
ROS4 closed.
Control Centre
Zone Sub A
Zone Sub B
Zone Sub C
11kV
11kV
11kV
CB2
CB1
CB3
ROS9
ROS5
ROS7
ROS3
ROS2
ROS6
ROS8
ROS4

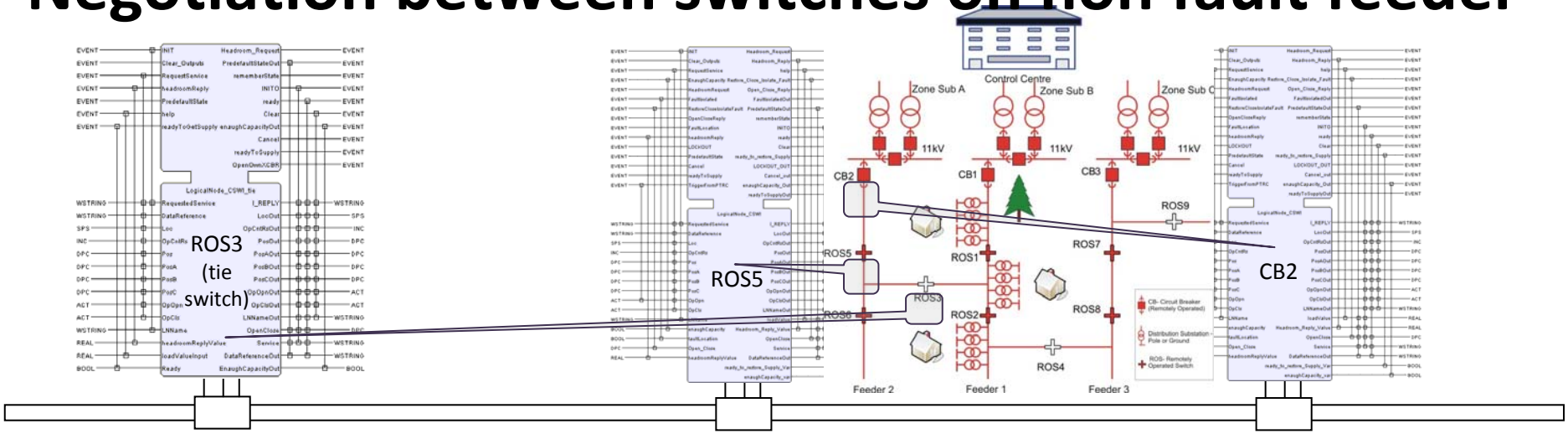

Crew 53:
Please go to 95 Griffin Street, Bardon
GPS coordinates 123.456 x 789.012
Tree across mains
Control Centre
!
Zone Sub C
11kV
CB2
CB3
ROS9
ROS5
ROS7
ROS3
ROS6
ROS2
ROS8
ROS4

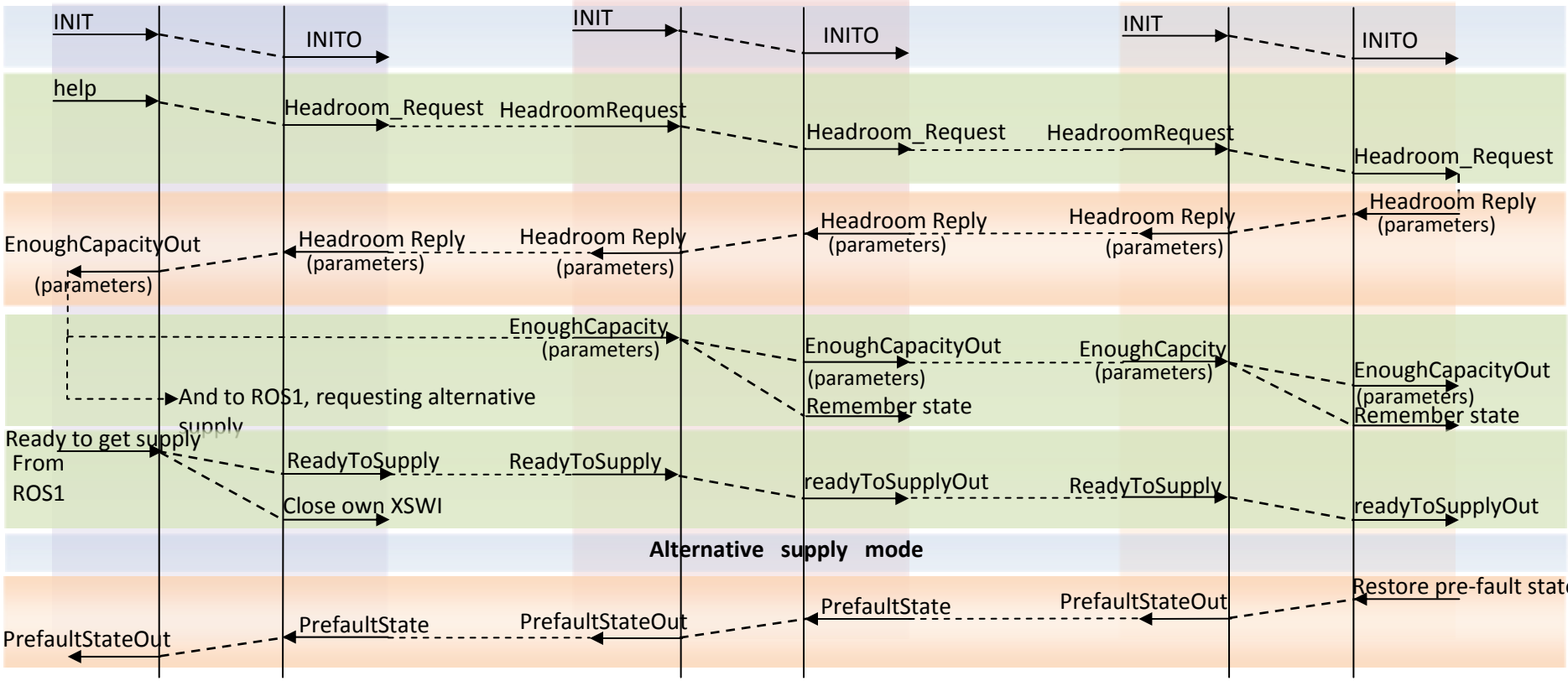

Repair complete. Activating automatic restoration sequence.
Control Centre
Zone Sub A
Zone Sub B
Zone Sub C
11kV
11kV
CB2
CB1
Repair complete!
ROS9
ROS5
ROS1
ROS3
ROS6
ROS2
ROS8
ROS4


Step 1 complete!
CB1 closed;
ROS1 closed; ROS2 closed.
Control Centre
Zone Sub A
Zone Sub B
Zone Sub C
11kV
11kV
11kV
CB2
CB1
CB3
ROS9
ROS5
ROS1
ROS7
ROS3
ROS6
ROS2
ROS8
ROS4


Step 2 complete! ROS3 open; ROS4 open.
Control Centre
Zone Sub A
Zone Sub B
Zone Sub C
11kV
11kV
11kV
CB1
CB3
ROS9
ROS5
ROS7
ROS3
ROS2
ROS6
ROS8
ROS4

Negotiation between switches on non fault feeder





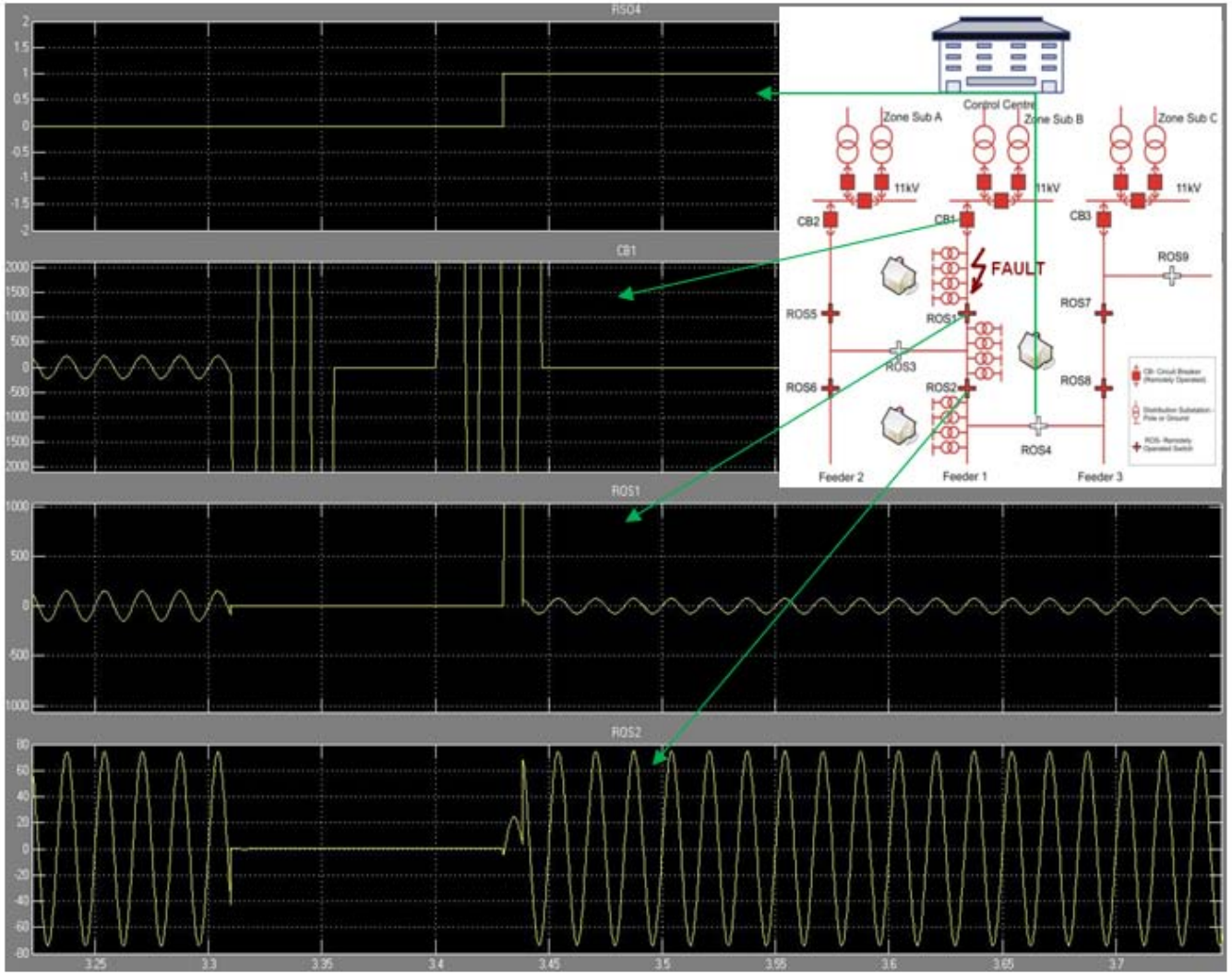
Simulation Results

ROS4

CB2

ROS1

ROS2



FLISR scenario: fault is on CB1 section, supply restored on ROS1 and ROS2 sections

Conclusions

- Cyber-physical approach to the critical infrastructures design is feasible technically and practical in business terms
- Future work:
  - More intelligence in control nodes (for self-organisation)
  - Benchmarking on more complex physical and communication infrastructures
  - Prototypes of devices based on proven commercial platforms and capable of IEC 61850 and Function Blocks