IEEE PES PSRC Report
on
Design and Testing of Selected System Integrity Protection Schemes (SIPS)

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Texas A & M Relay Conference

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WG C15

- The objective of the WG **report** is to provide practical design and testing examples of the selected SIPS for use as references in designing and testing future schemes
- The full report is available at http://www.pes-psrc.org/ (Published Reports)
- This summary covers the followings:
  - Summary of general considerations
  - Brief overview of each selected SIPS

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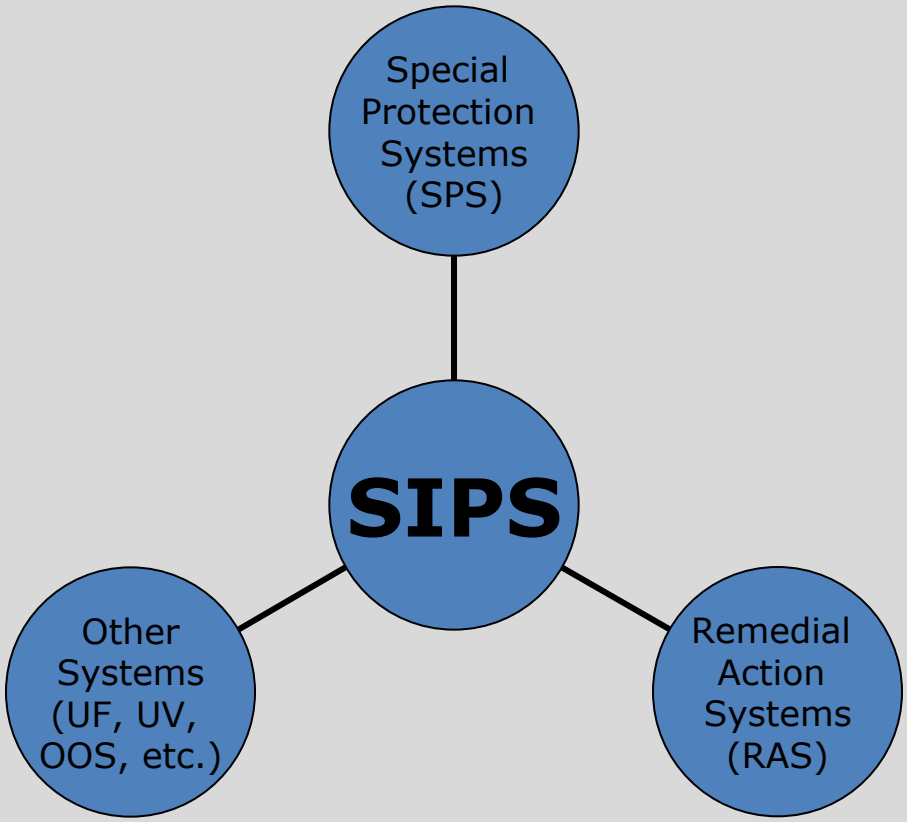
About SIPS

- System Integrity Protection Scheme/System is used to protect the integrity of the power system or strategic portions of the system
  - Provide reasonable countermeasures to slow and/or stop cascading outages caused by several levels of contingencies

- Encompasses a wide range of schemes and systems
  - Remedial Action Schemes (RAS)
  - Special Protection Schemes (SPS)

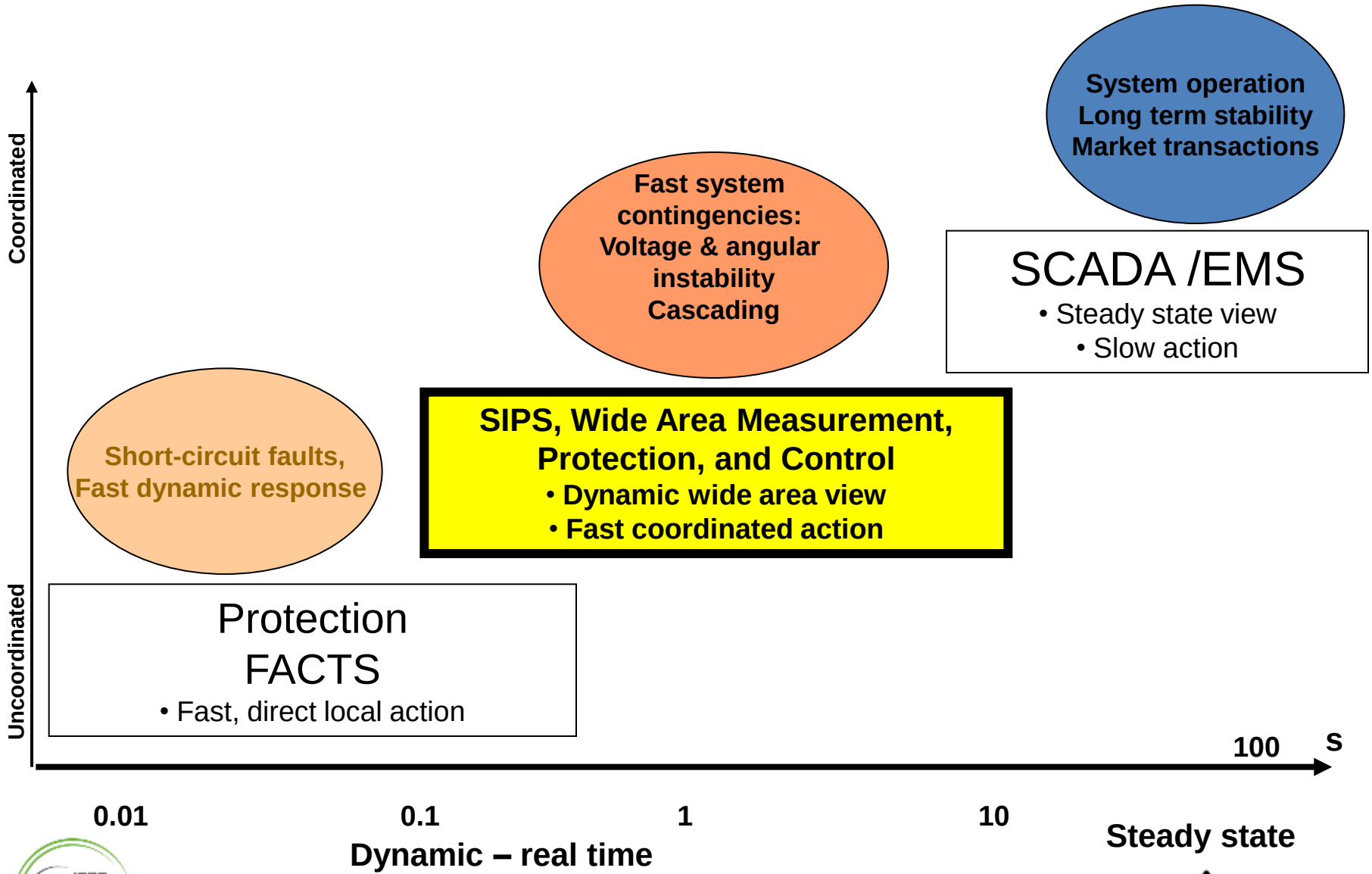
- Design and testing are different from traditional protective relaying schemes / systems

SIPS – System Integrity Protection Schemes



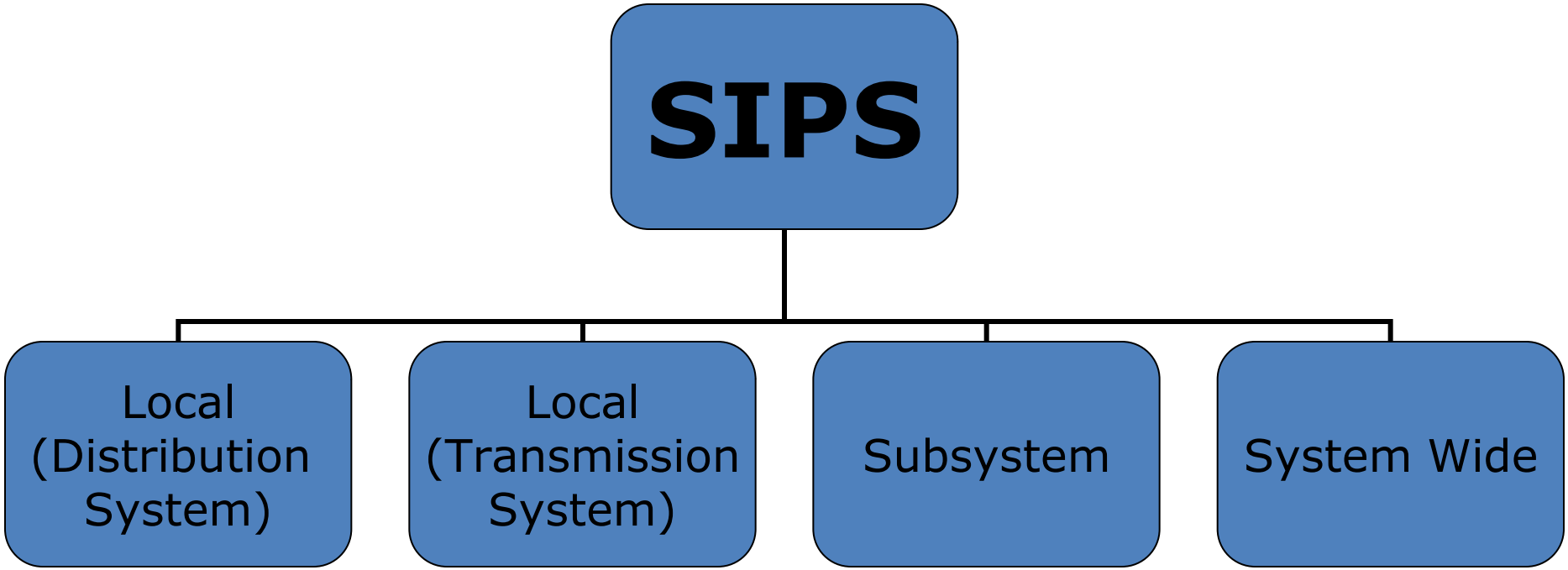
Source: V. Madani, D. Novosel, IREP Bulk Power System Dynamics and Control 2007

Event and Solution Time Scale



Source: V. Madani, D. Novosel, R. King, IIEEE GM - 2007

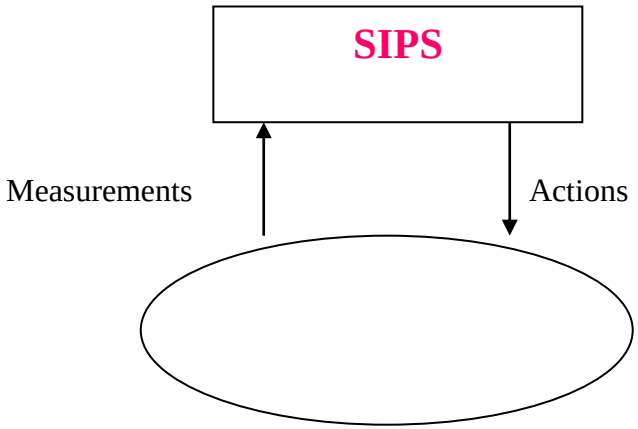
SIPS – Design and Architecture



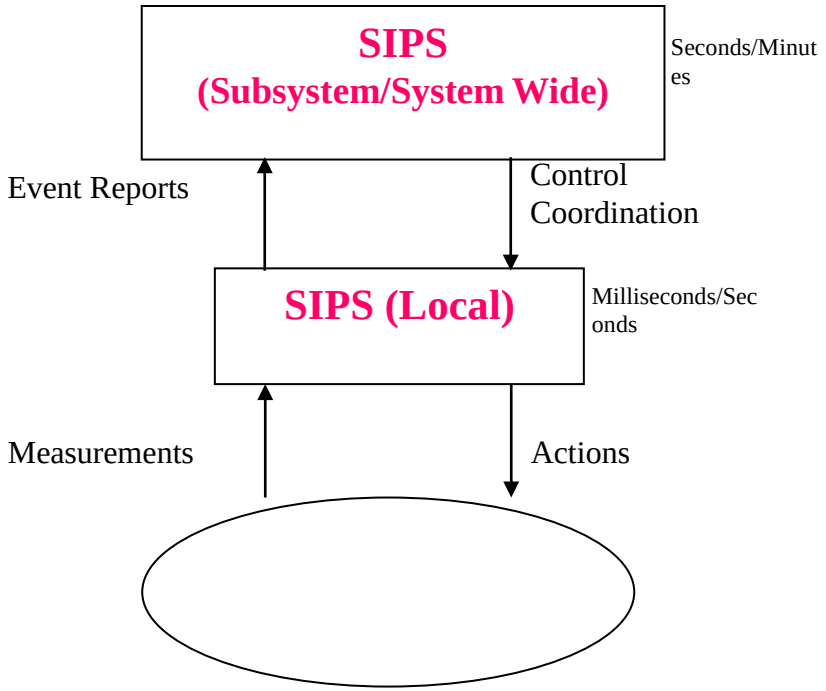
Source: M. Begovic, V. Madani, D. Novosel, IREP Bulk Power System Dynamics and Control 2007

SIPS Classification

- Classification of the scheme architecture
  - ✓ **Based on the scheme function, its purposes, and operating times**
- Two classifications - Flat & Hierarchical



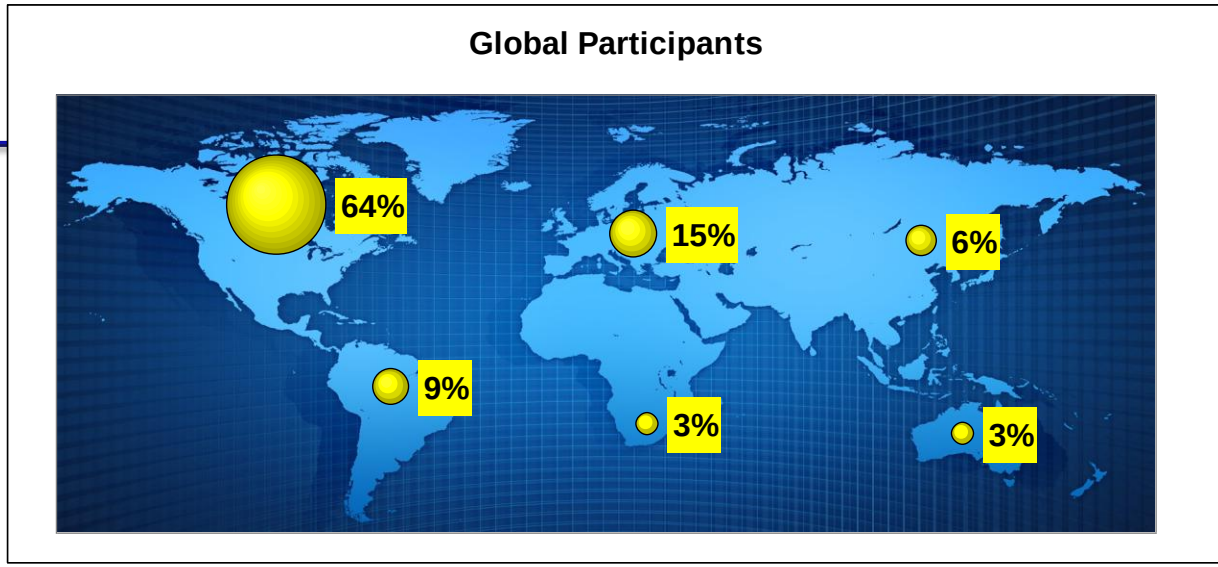
Flat Architecture

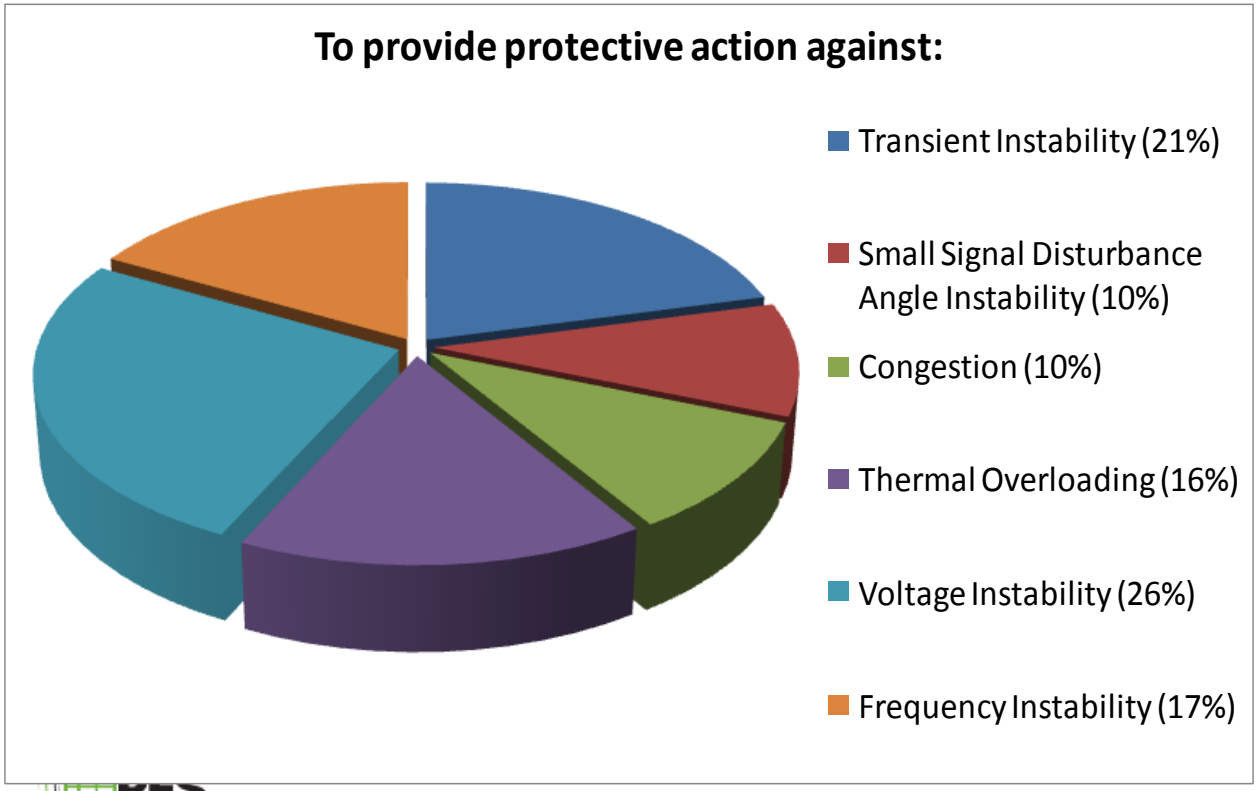


Hierarchical Architecture

Source: IEEE PSRC Global Industry Experiences with SIPS, 2010

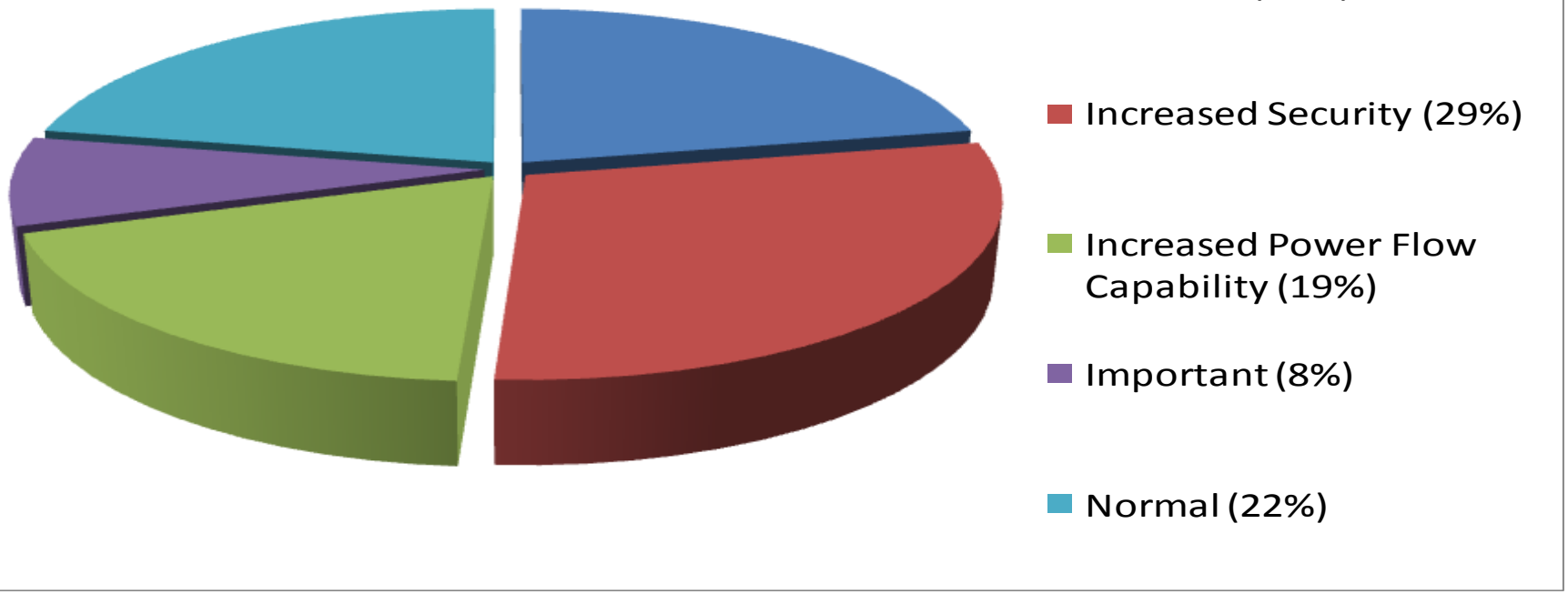
SIPS Purpose
2010 Global Survey





Source: IEEE Transactions on Power Delivery, Vol. 25, October 2012

SIPS Classification



Normal or Normal system improvements (49%) - Three components:
19% Increased Power Flow, 8% Important, 22% Normal

System Security (51%) – Two components:
22% Essential, 29% for Increased Security - At one time was the primary intent of SIPS

Source: IEEE PSRC Global Industry Experiences with SIPS, 2010

WG C15 Report Contents

- General considerations in SIPS design and testing
  - Power system hierarchy
  - Generic SIPS description model
  - Communication requirements
  - Centralized vs. distributed SIPS
  - Redundancy considerations
  - Functional and system SIPS testing
  - Utilities documents
- 5 Examples of Selected SIPS

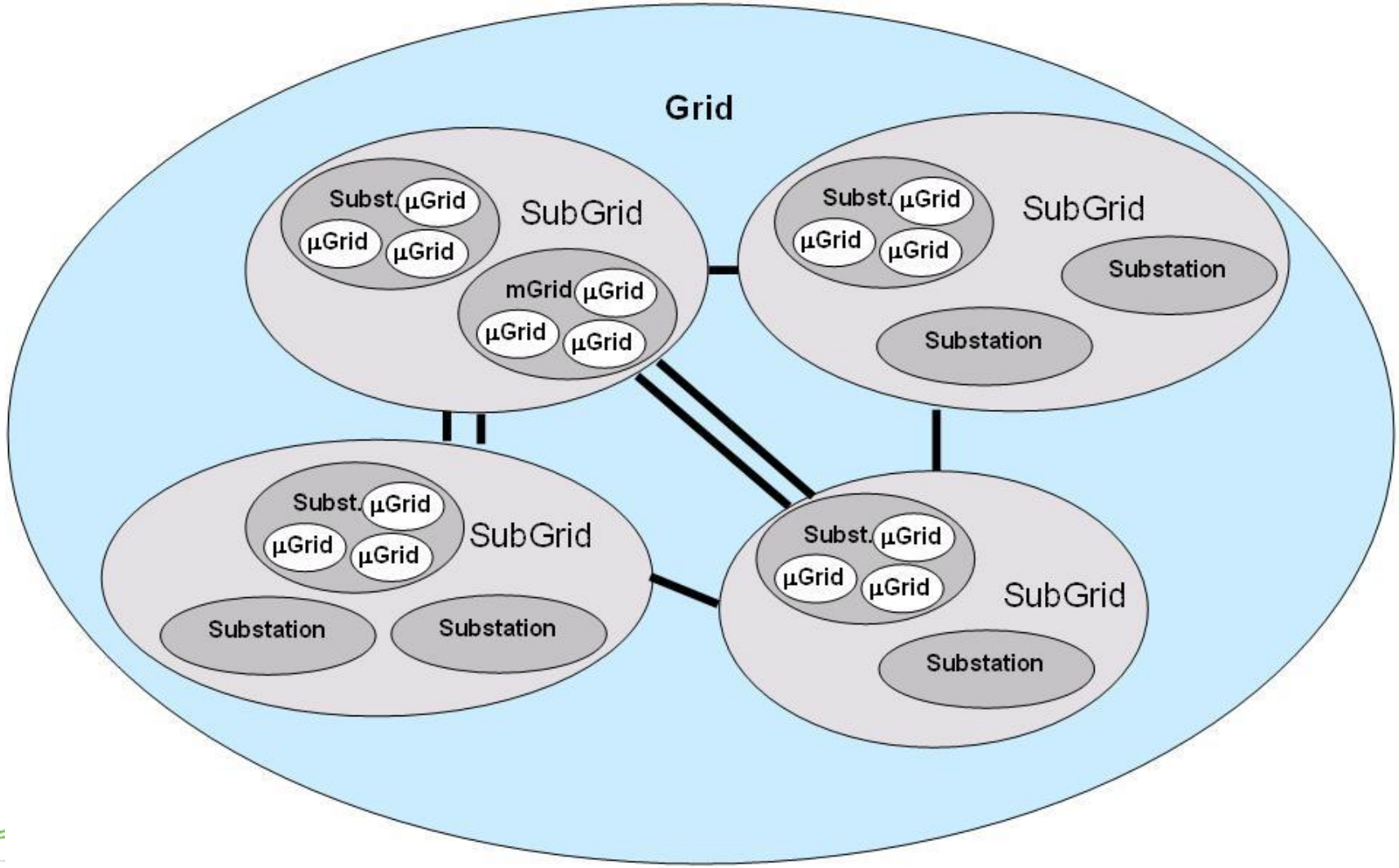
Types of SIPS in Use

- Generator Rejection
- Load Rejection
- Under-Frequency Load Shedding
- Under-Voltage Load Shedding
- Adaptive Load Mitigation
- Out-of-Step Tripping
- Voltage Instability Advance Warning Scheme
- Angular Stability Advance Warning Scheme
- Overload Mitigation
- Congestion Mitigation
- System Separation
- Shunt Capacitor Switching
- Tap-Changer Control
- SVC/STATCOM Control
- Turbine Valve Control
- HVDC Controls
- Power System Stabilizer Control
- Discrete Excitation
- Dynamic Braking
- Generator Runback
- Bypassing Series Capacitor
- Black-Start or Gas-Turbine Start-Up
- AGC Actions
- Busbar Splitting

Details in “Global Industry Experiences With System Integrity Protection Schemes (SIPS)”, available at http://www.pes-psrc.org/ (Published IEEE/PES PSRC and CIGRE Reports)

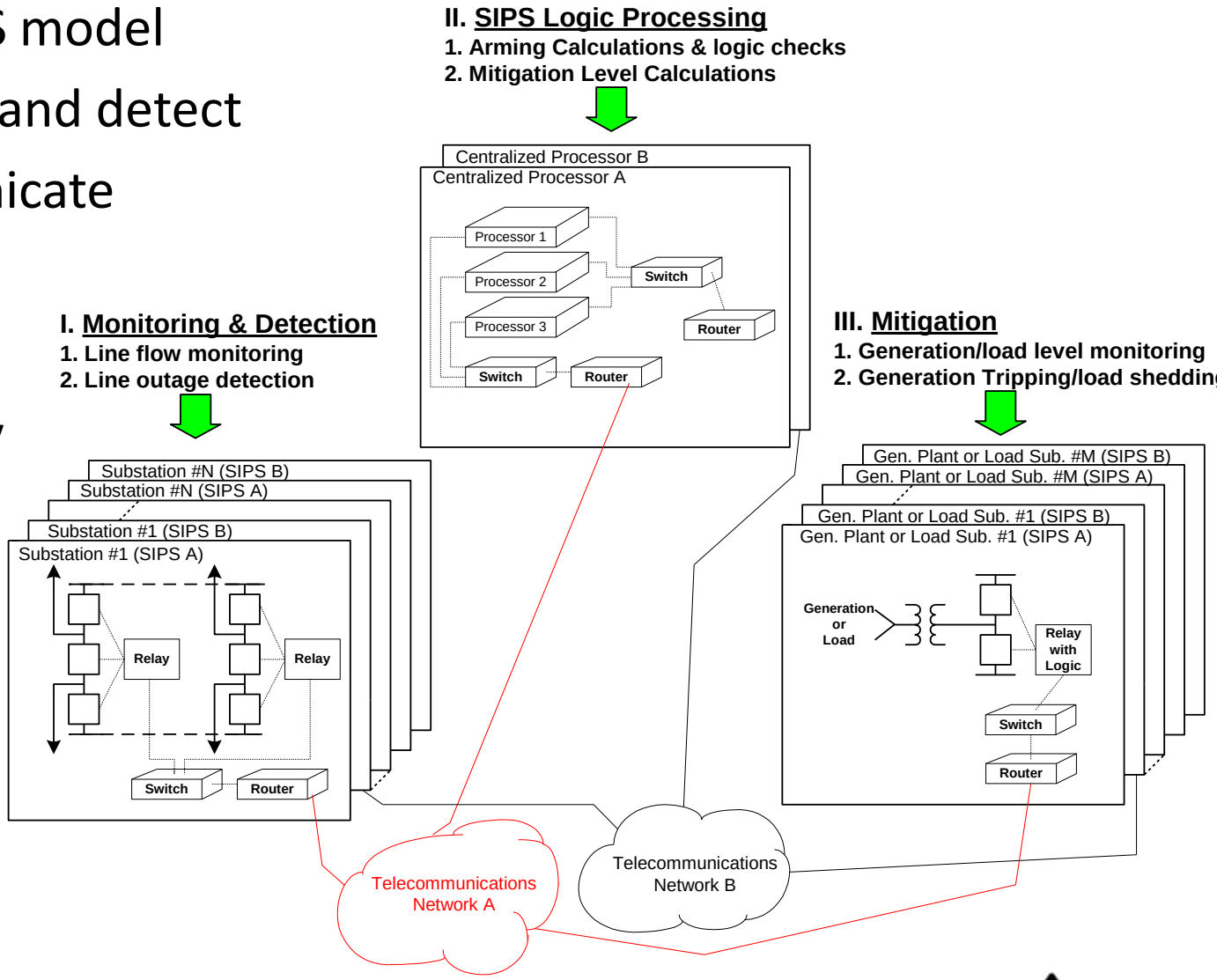
General Considerations in SIPS Design

Grid Hierarchy - highly dependent on location within the Grid.



General Considerations in SIPS Design

- Generic SIPS model
  - Monitor and detect
  - Communicate
  - Decide
  - Mitigate
- Redundancy



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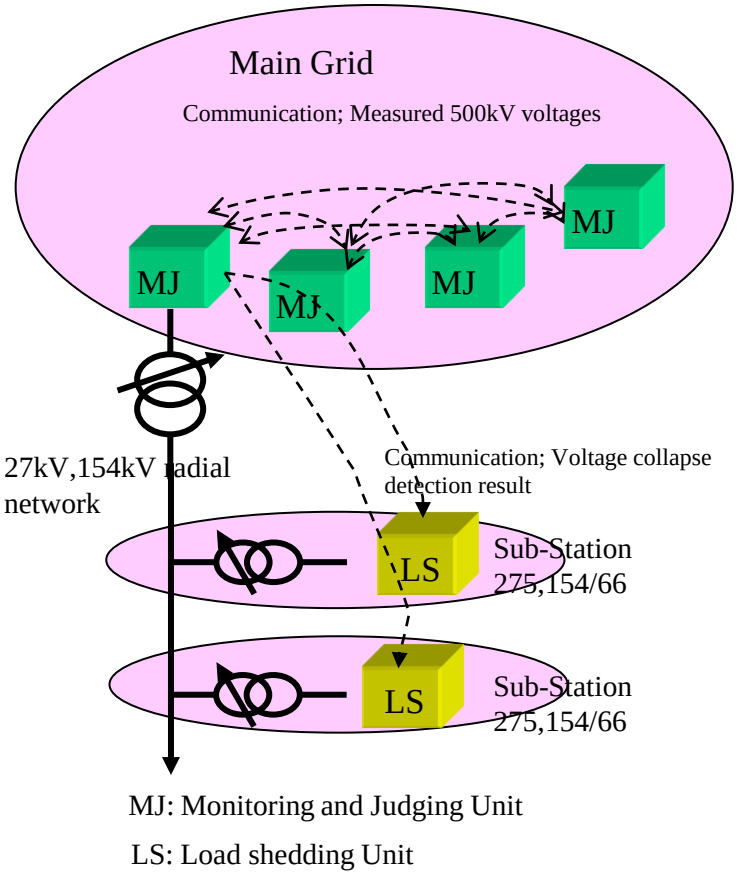
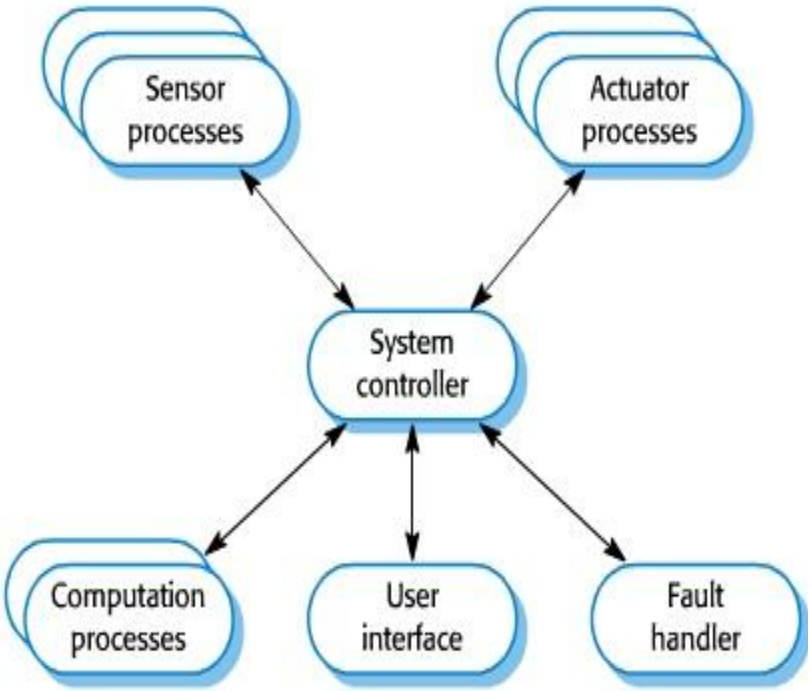
SIPS Design

- Scheme types
  - Event-based
  - Parameter-based
  - Response-based
  - Combination of the above
- Distributed vs. central schemes
  - Combined, scalable, multi-layer approach recommended
- Communication technology to deploy
- Cost of different measures
- Requires coordination of SIPS in the interconnected grid

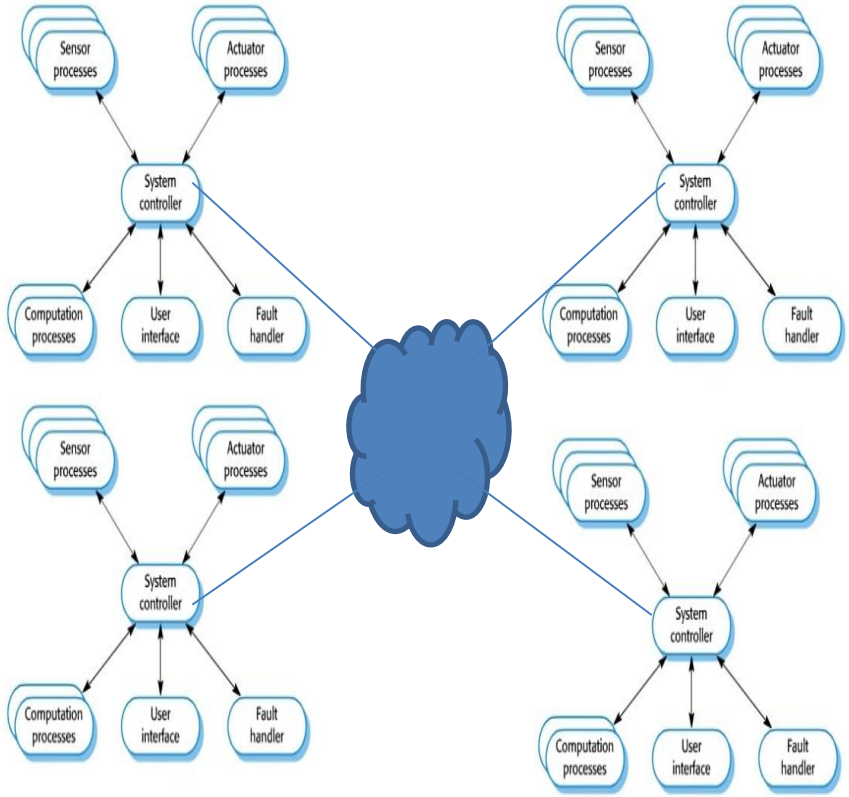


General Considerations in SIPS Design

Centralized

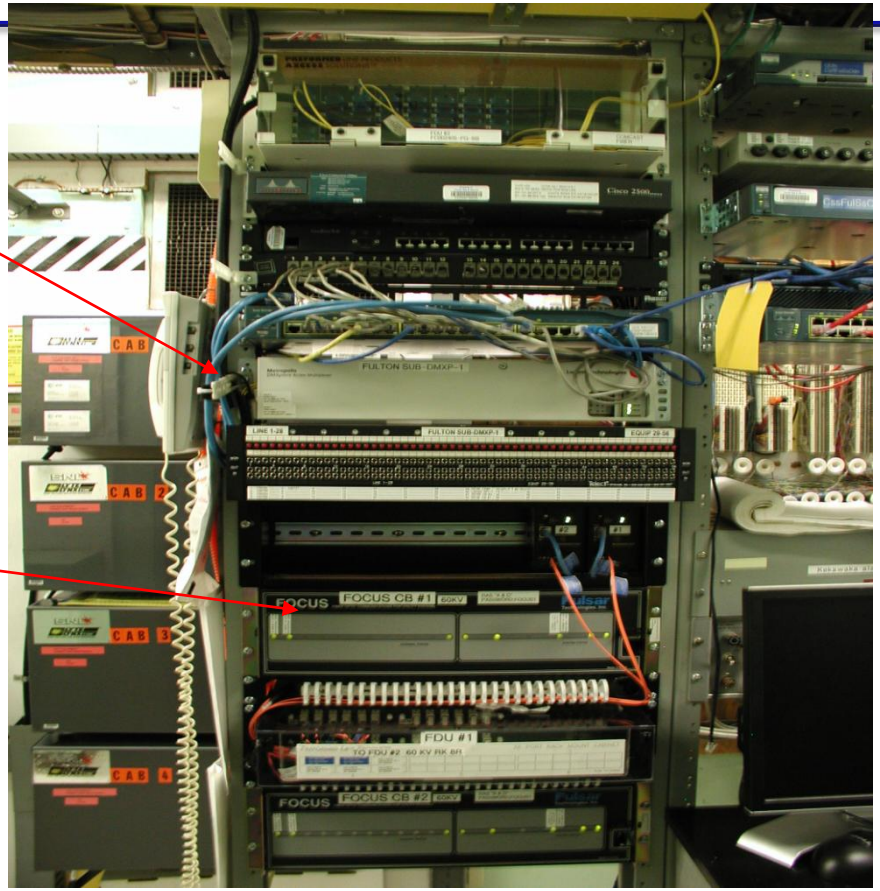


Distributed



General Considerations in SIPS Design

- Communication for SIPS
  - Physical – SONET, T1, Microwave, Lease Line, Fiber, Ethernet, Satellite, Radio
  - Protocols – Internet Protocol, IEC 61850, DNP, Proprietary, Frequency Shift Keying
  - Performance issues – Latency and availability

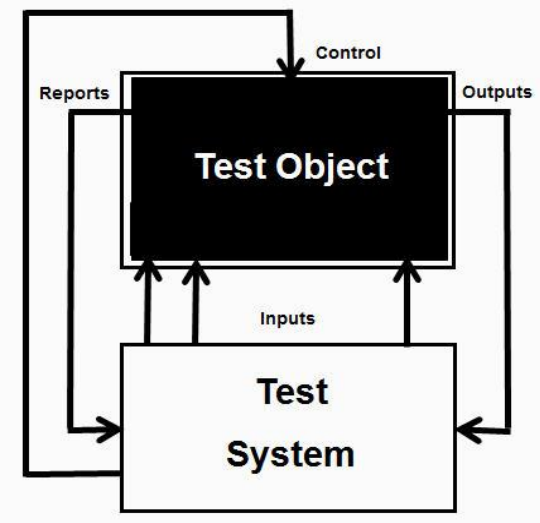


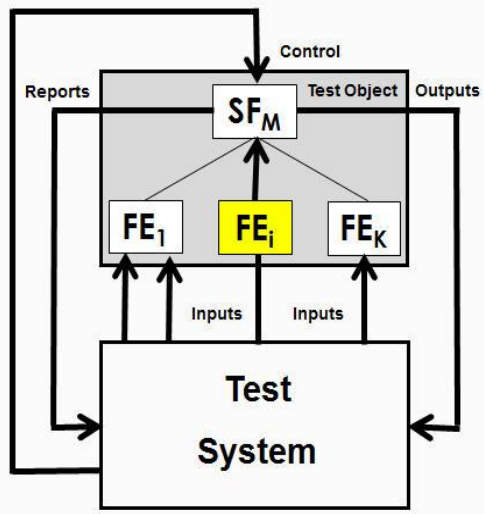
Control signals (e.g. open/close breaker)

Status & measurement (e.g. breaker open, MW)

General Considerations in SIPS Testing

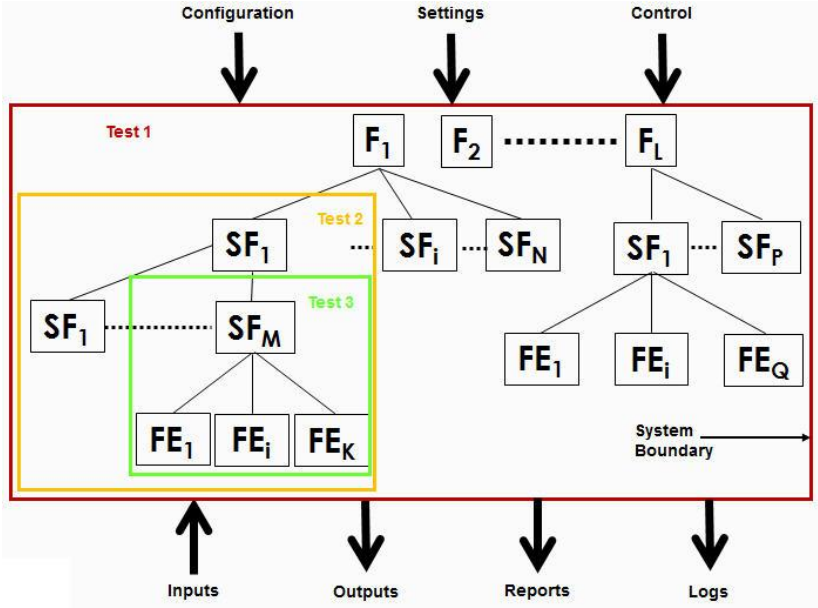
- Functional and system testing of SIPS
  - Functional element testing
  - Integration testing
  - Function testing
  - System testing
- Testing methods
  - Black box testing
    - Functional element testing
    - SIPS Factory Acceptance Testing
    - SIPS Site Acceptance Testing
  - White box testing

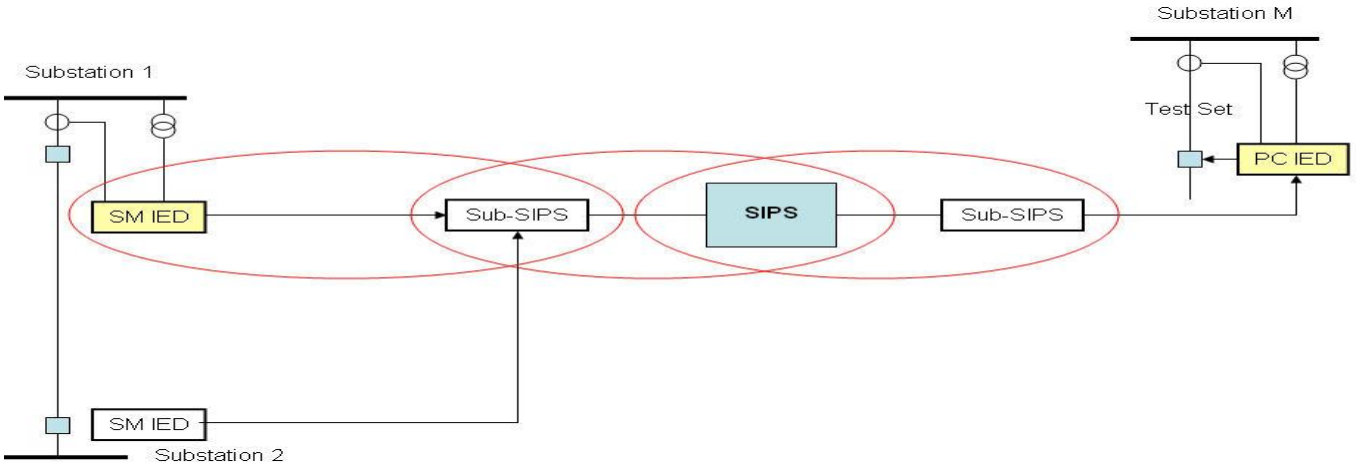




General Considerations in SIPS Testing

- Testing methods (cont.)
  - Top-down testing
  - Bottom-up testing
- Regressing testing
- Device acceptance testing
- Device interoperability testing
- Integration testing





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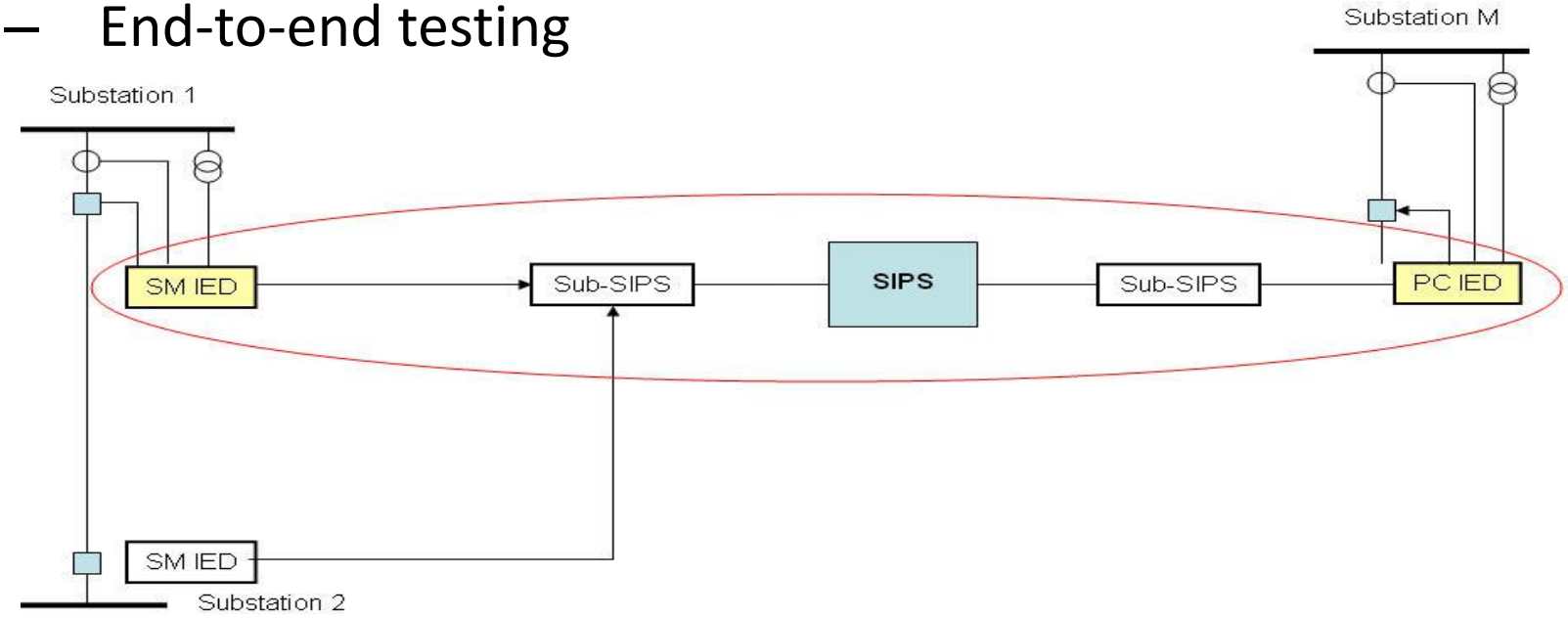
General Considerations in SIPS Testing

- SIPS Factory Acceptance Testing (FAT)
- SIPS Site Acceptance Testing (SAT)
  - End-to-end testing



IEEE Std. C37.233 "Guide for Power System Protection Testing"

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General Considerations in SIPS Design and Testing

- Documents, Standards and Guidelines

  - Regulatory Bodies and Reliability Coordination Authorities
    - Guides/Standards
    - Compliance Requirements

  - Utility Documents
    - Reliability
    - Availability

Generator Rejection Scheme – Design

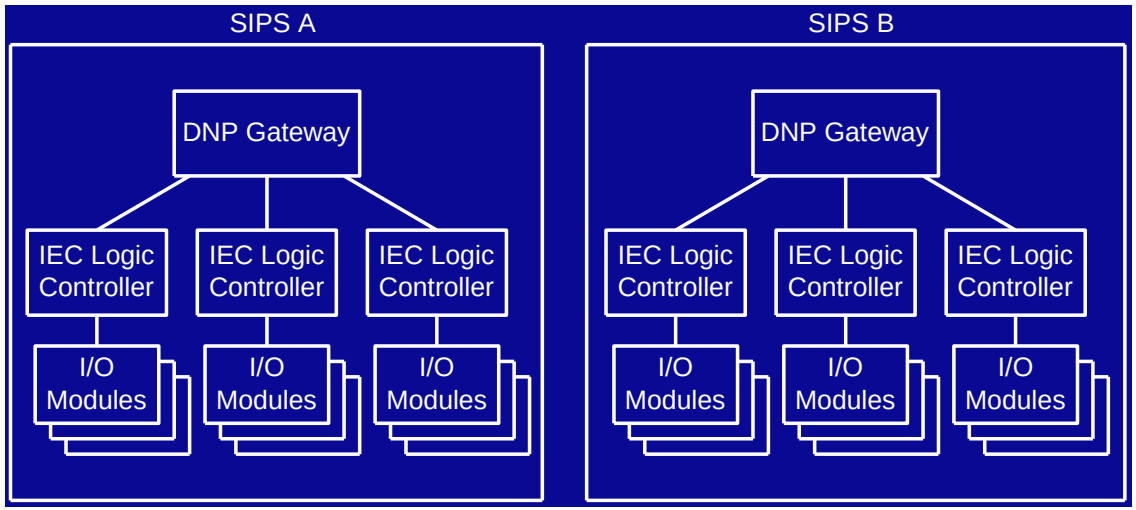
- A remote large 4 unit coal plant with restricted transmission and stability issues for contingencies

- Need generator rejection SIPS to
  - Utilize full capacity of generation
  - Prevent loss of stability under all contingencies

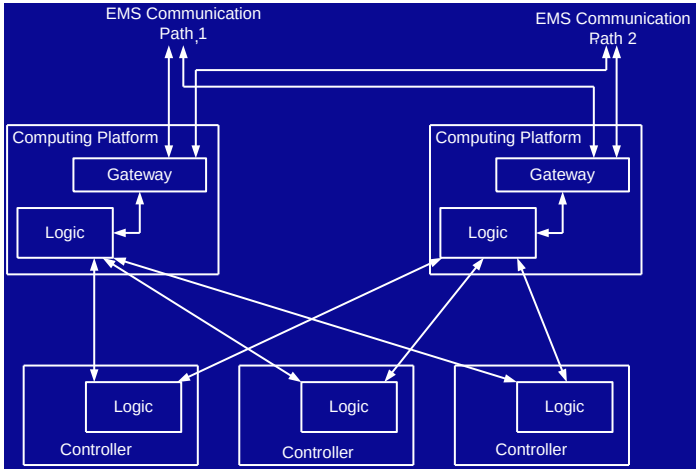
- Generator rejection SIPS requirements
  - Fast corrective actions (5 cycles)
  - SIPS controller must operate < 20 ms

Generator Rejection Scheme – Design

- Scheme architecture/design
  - Balance Security/Dependability
  - 2-of-3 voting, Triple Modular Redundant (TMR)
  - Redundant EMS interface
  - Redundant communication systems



Redundancy



Voting/Communication

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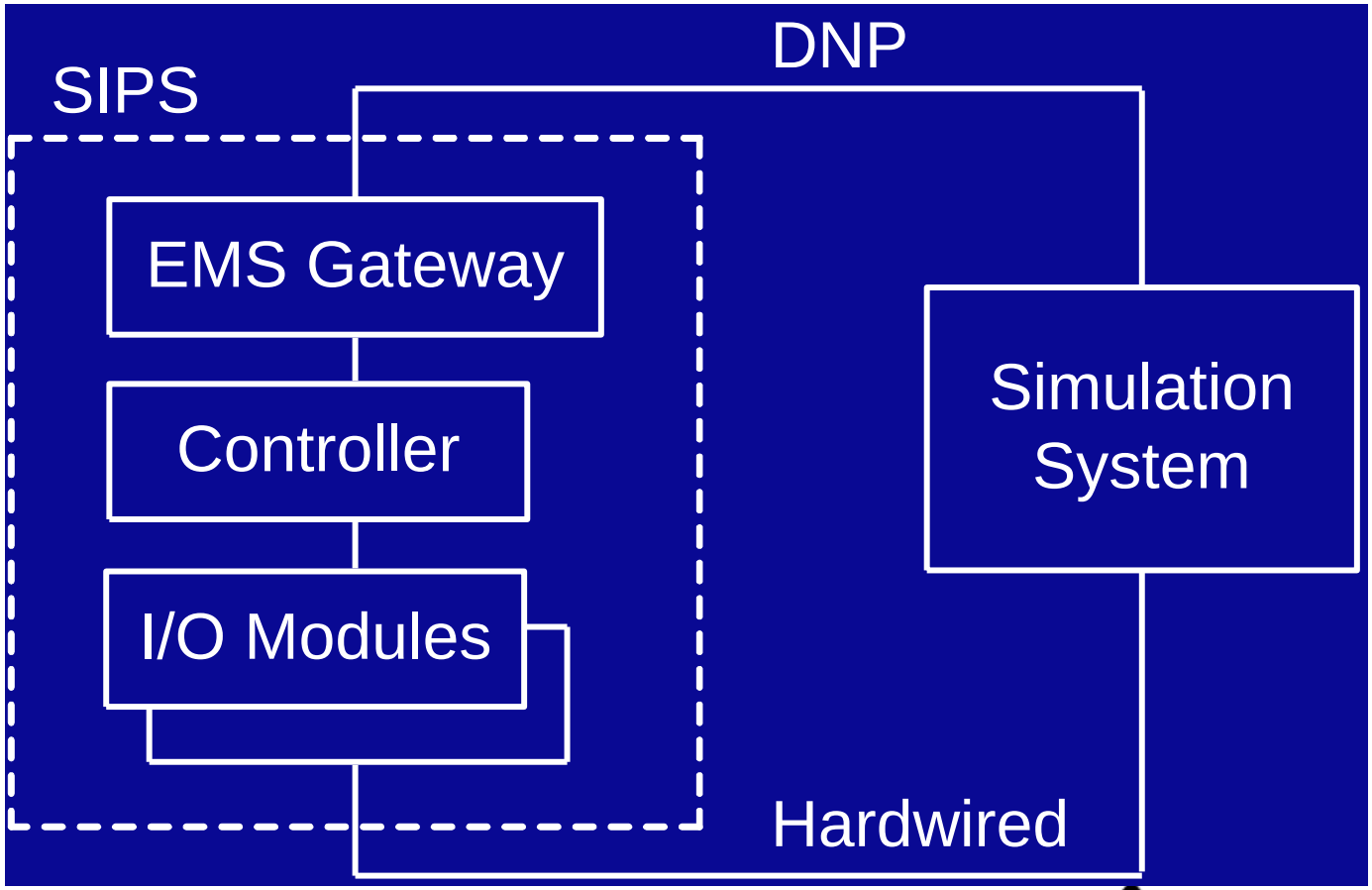
Generator Rejection Scheme - Testing

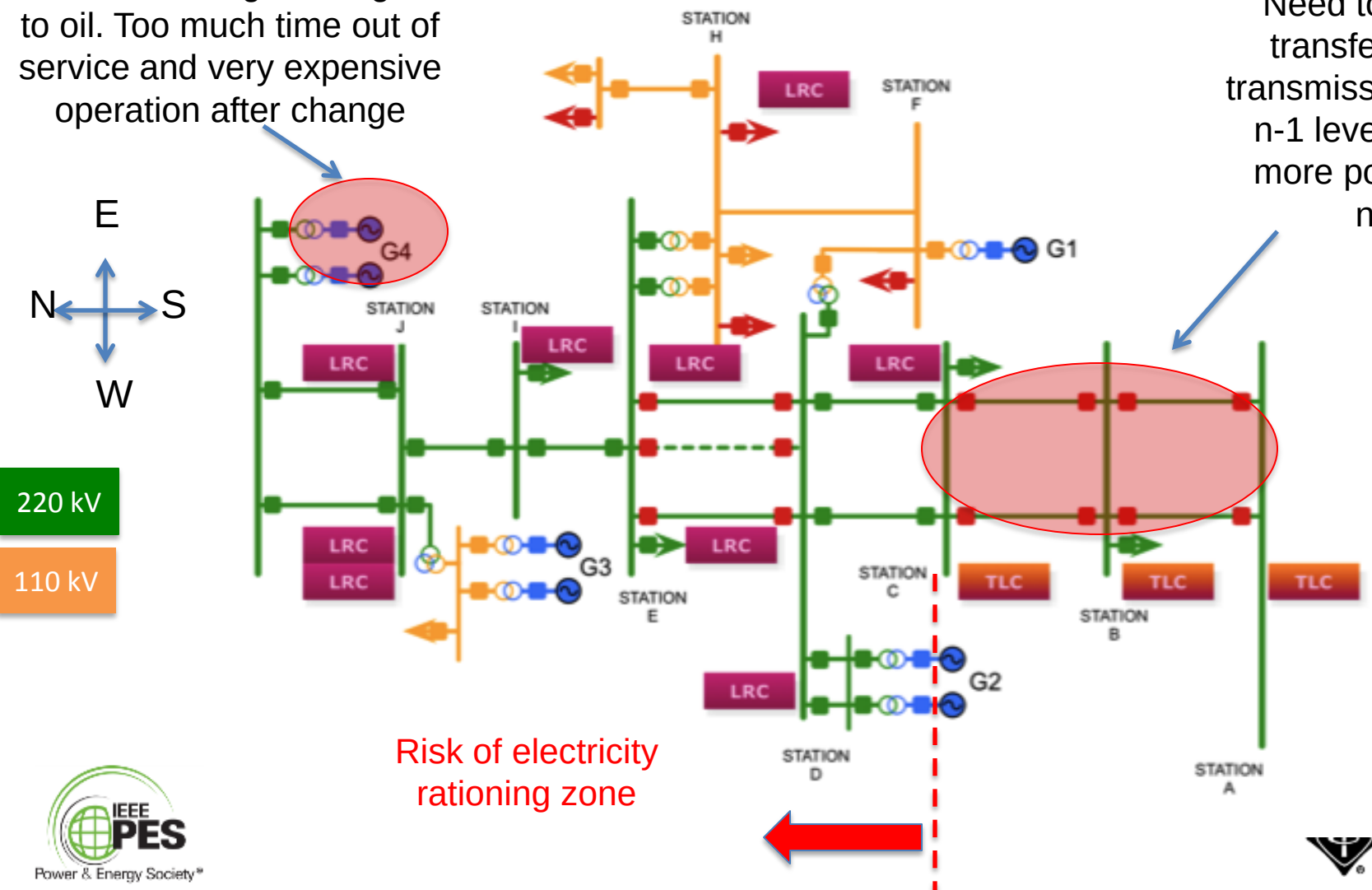
- Testing – Closed-loop testing is important
  - Using a training / playback / testing simulator



Load Rejection Scheme

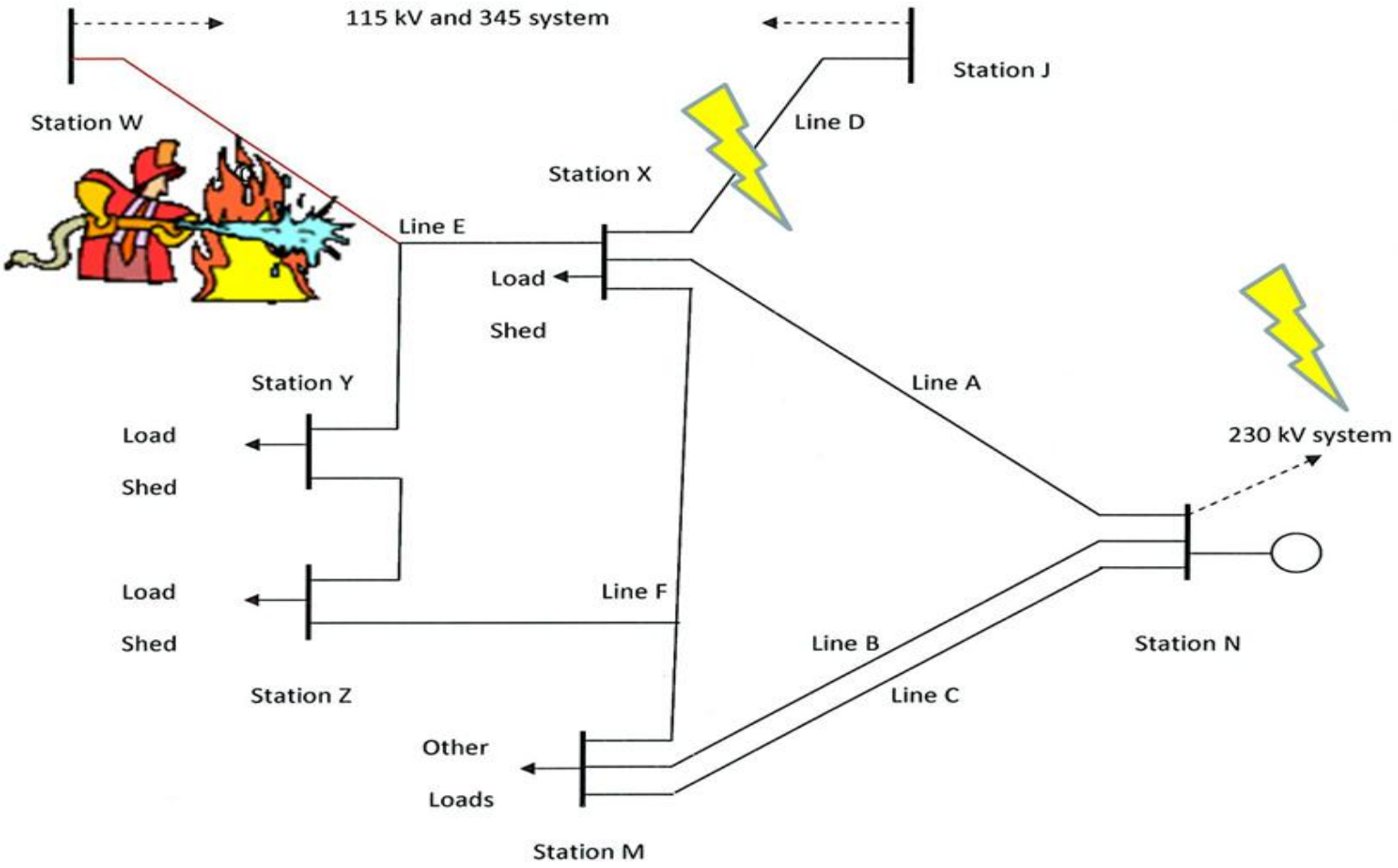
Need to change from gas to oil. Too much time out of service and very expensive operation after change

Need to increase transfers on this transmission line over n-1 level to supply more power to the north



Adaptive Load Mitigation Scheme

The system problem



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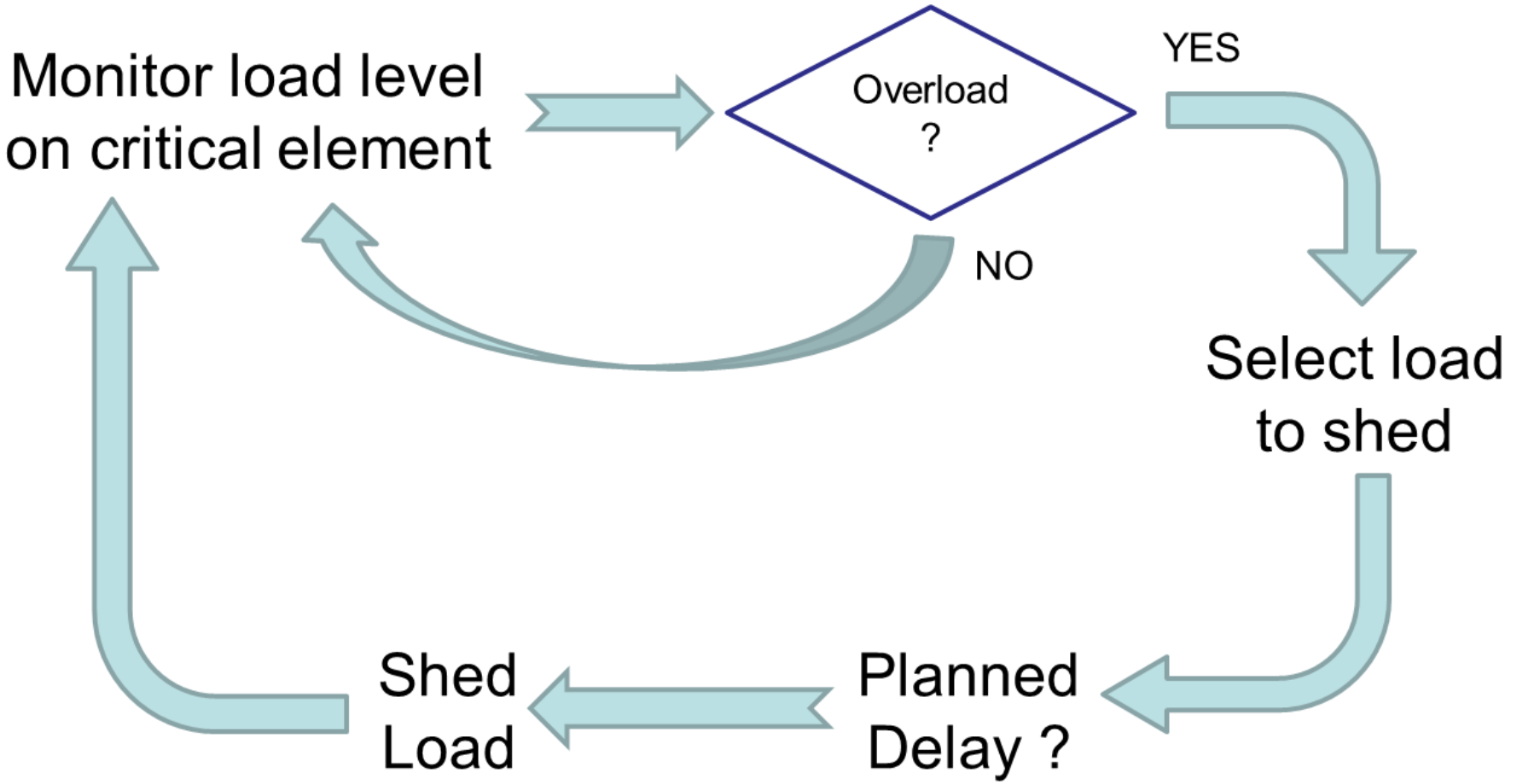
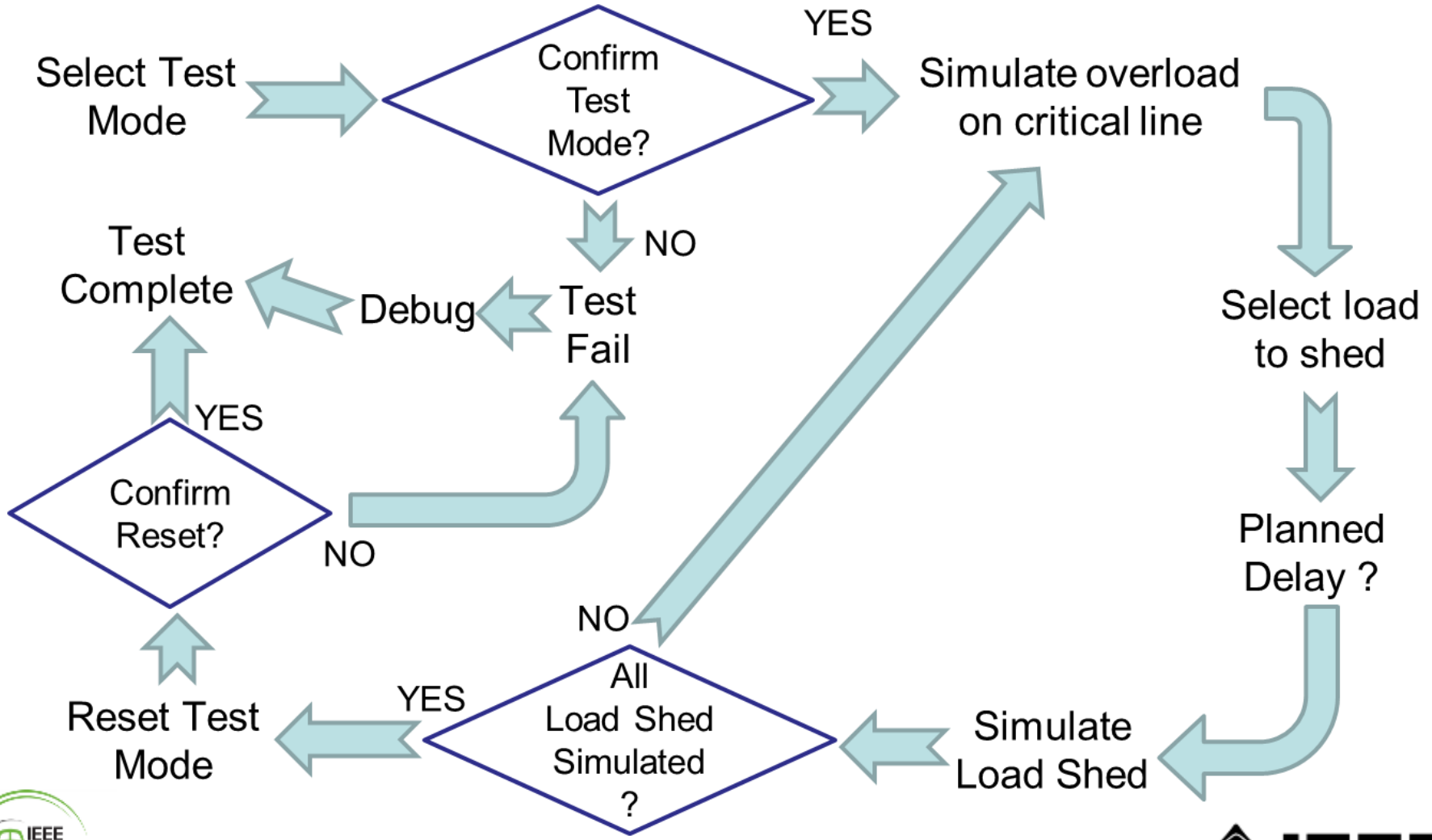
Adaptive Load Mitigation Scheme – Design



Adaptive Load Mitigation Scheme - Testing



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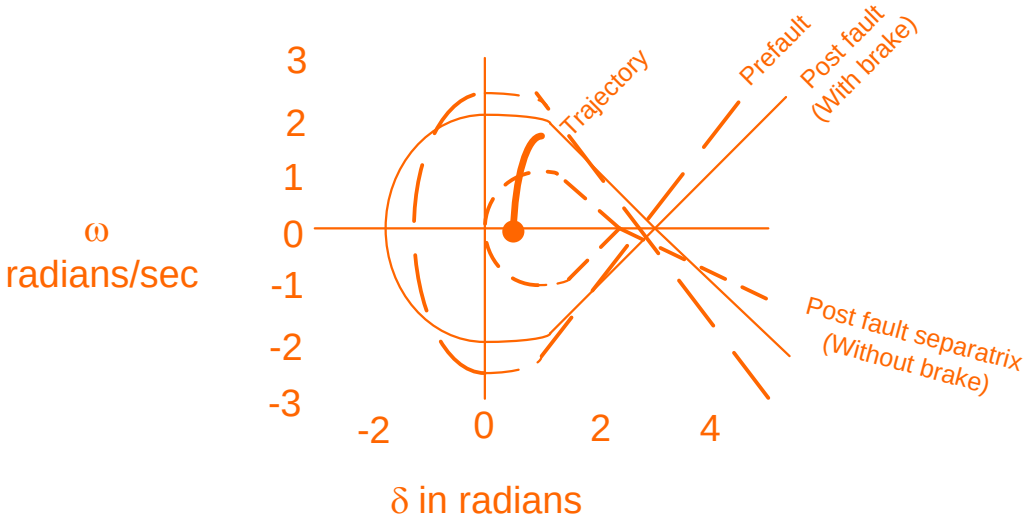
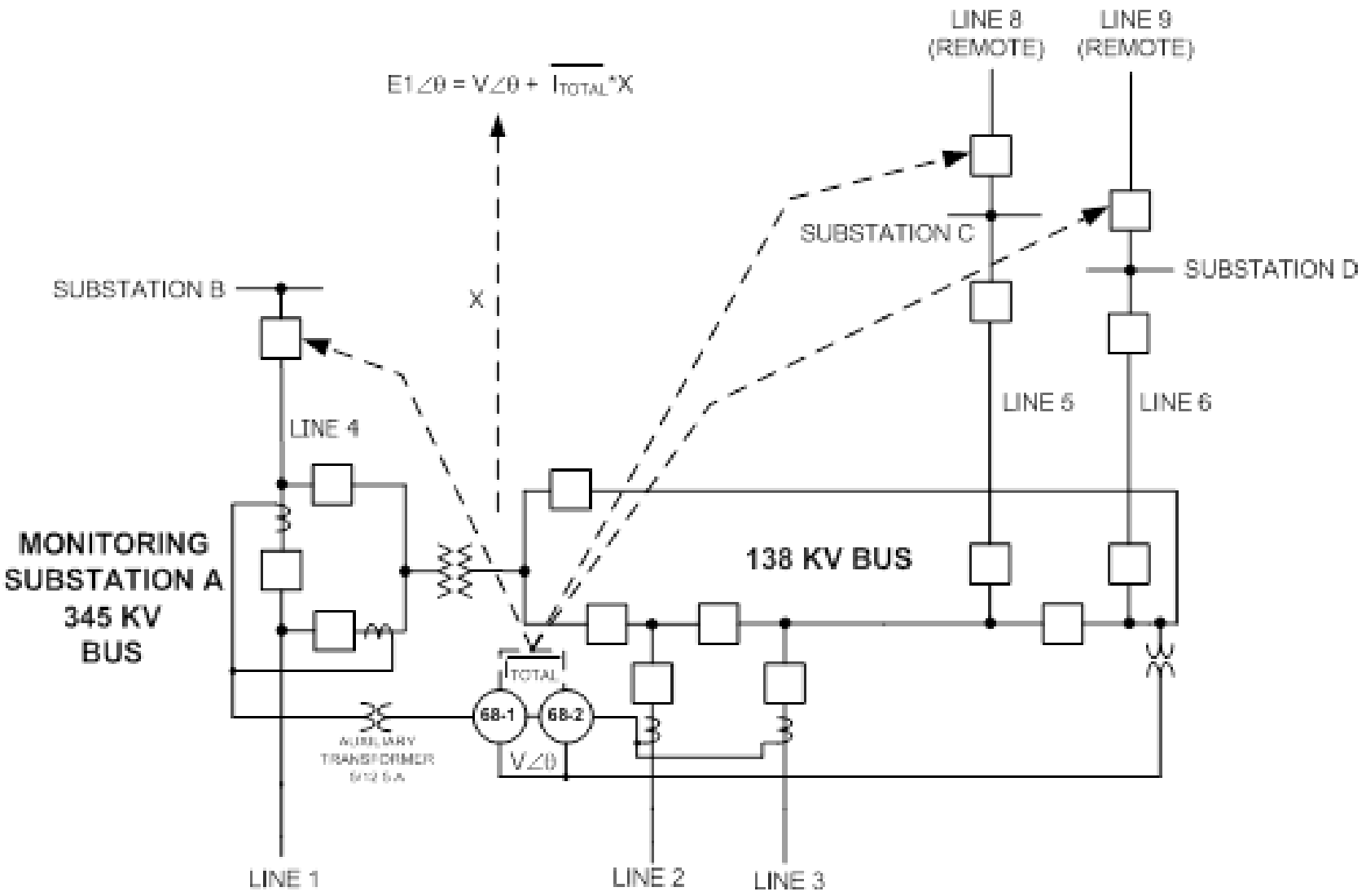
Dynamic Braking Scheme

- Insert 1400MW resistor for 0.5 sec to damp power swing between 50GW systems
- Initiated locally at gen bus AND from remote wide area SIPS controllers
- Inputs = sudden loss of local power transfer with 10% drop in bus voltage OR wide area measurement of multiple line loss OR nearby multi-phase line faults OR loss of remote intertie transfer (5GW or less)
- Augments other SIPS such as gen drop during system export
- EMTP model verifies design parameters and response
- Local relay thermal protection of brake with breaker failure included



System Separation Scheme - Design



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System Separation Scheme - Testing

Types of tests: IEEE Std. C 37.233

- Certification, Acceptance, Type test
- Conformance
- Performance
- Application
- Commissioning
- Maintenance

- **Example of Logic, Proof of Concept Performance**
  - Test logic against many stable and unstable swings
  - Generate COMTRADE files from load flow programs, PSS/E studies.
  - Run the COMTRADE files through the SIPS controllers and devices
  - Results are studied by the transmission planning and protection engineers to verify proper detection and response.

Conclusions and References

- SIPS are intended to protect the integrity of the system to limit the extent large scale system disturbances, cascading failure and even blackouts
  - Require careful design and proper testing to ensure their reliable operation
- Development of set points for arming and triggering requires system studies
- The design and testing of SIPS are highly system dependent
- Multiple tools and methods available to test