Innovative Methods to Analyze and Visualize Protection System Performance

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Outline

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Siemens Grid Software – SI GSW

About Me

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- BE BITS, Pilani, 1989
- English Electric Co. of India (1989 – 1992)
- MS Texas A & M, 1995 (Dr. M. Kezunovic)
- PhD Texas A & M, 2000 (Dr. M. Kezunovic)
- Electrocon International (1999 – 2014)
- Quanta Technology (2014 – 2018)
- Siemens (2018 – Present)

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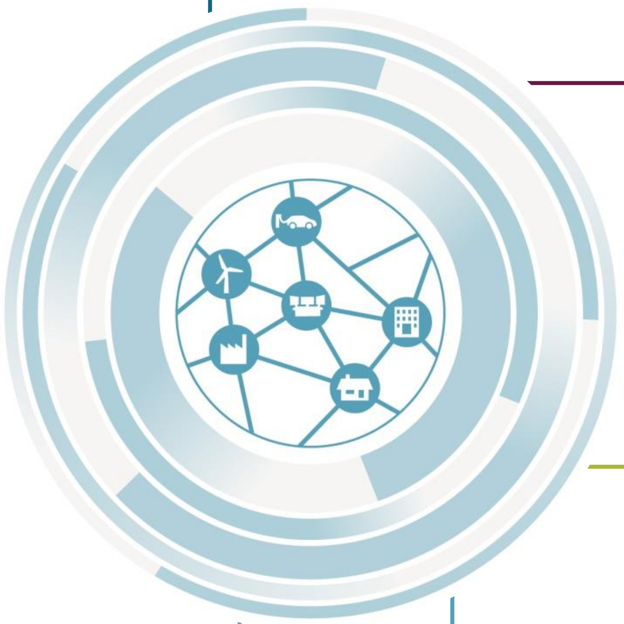
The PSS® Portfolio – More than the sum of its parts



PSS®E
- Transmission operations & planning
- Industry standard for transmission simulation & analysis

PSS®SINCAL
- All-in-one simulation tool for the modeling, analysis, planning, and design of all types of power networks – from high to low voltage

PSS®CAPE
- Computer-Aided Protection Engineering software enabling highly-detailed protection simulation

SIGUARD®
- Grid security solutions comprising of Phasor Data Processor and Dynamic Security Assessment

PSS®MOD
- Enterprise data management and exchange for PSS®E data

PSS®ODMS
- CIM-based transmission network modelling & analysis

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PSS®CAPE Consulting Services

- Developing and validating primary network models
- Developing and validating protection models and preparing them for use in PSS®CAPE
- Developing data interfaces to other programs/systems for interoperability
- Relay settings macros
- Performing protection coordination studies and calculating protection settings for relays for various applications

Protection Sensitivity & Selectivity

Protective Relays and Protection Schemes

- A protection system cannot prevent abnormal conditions such as overloads or faults, but can limit the damage caused by such conditions
- Protective relays are therefore an integral part of the power system and essential for its reliable operation
- With increased penetration of inverter-based resources in transmission system, reliable operation of protection becomes more and more critical in maintaining reliability of the grid
- Main goal of protection
  - Protecting human beings (safety)
  - Preventing/Limiting equipment damage
  - Limiting service disruptions (both from a duration perspective and from a geographic perspective)

Common Terms Associated with Protective Relaying

- Reliability – operate for faults within protection zone, refrain from operating for faults outside zone or in absence of a fault
- Selectivity – isolate only the problem area leaving rest of system intact
- Speed (sensitivity) – isolate as quickly as possible to minimize fault duration
- Simplicity – use most straightforward design for the application
- Economics – benefits should be weighed against costs
- Selectivity and Sensitivity are often at odds with each other

Protection Coordination Studies

Protection Coordination Studies

- Uncover and remove hidden selectivity and coordination issues before they actually occur as relay misoperations
- Evaluate responses of protective relays working together as a system, rather than as simple pairs of relays with a primary – backup relationship
- Challenge the protection system with a large number of fault types, fault locations and system contingencies

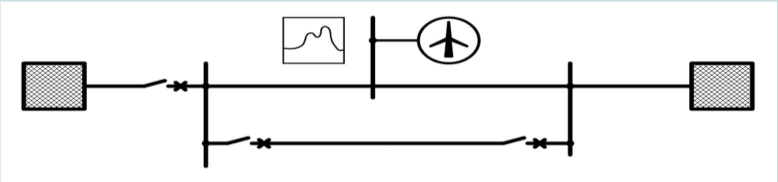
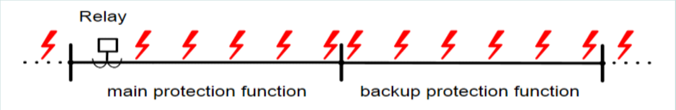
Stepped-Event Simulation

- Quasi time-domain simulation from fault inception until fault clearing
  - Simulate protection system response with a series of steady-state conditions:
  - Apply a fault, evaluate relays and open fastest breaker(s)
  - Reapply fault, re-evaluate relays, open next breaker(s)
  - Continue until fault is cleared or no more relays operate
- Simulate sequential fault clearing
- Detect relay coordination interval and misoperation issues after first breaker operation
- Provides summary reports, and detailed sequence of events operations report

Types of Coordination Problems Found

- Coordination Time Interval (CTI) Violation
  - A backup relay operates too close in time to a primary relay or breaker
  - A backup relay operates too far in time compared to a primary relay or breaker
- Miscoordination
  - A backup breaker opens ahead of, or at the same time as, a primary breaker
- Fault not cleared
  - There was not enough protection available to clear the fault

Automated Protection Coordination Studies

Automated Protection Coordination Studies Consider ALL combinations of operation and fault conditions			
Generation Levels	Variants 2		Are the protection settings suitable for all switching states?
Primary System Contingencies	4		Intermediate infeed and parallel lines cause under-/over-reach of the protection relays. What are the consequences?
Fault locations	3-10		Do the protection settings and protection schemes meet all requirements?
Fault types	3	3-phase, 2-phase, 1-phase faults, conductor interruptions, overloads	Will all faults be detected and cleared?
Fault resistance	1-3	Arc and fault impedances	Is backup protection provided under all circumstances?
Protection System Contingencies	3	Circuit breaker failure Loss of CT or VT (single-point failure)	Are there any risks? How can it be checked?

1000’s of combinations per line are possible – data processing and management challenge

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Automated Protection Coordination Studies

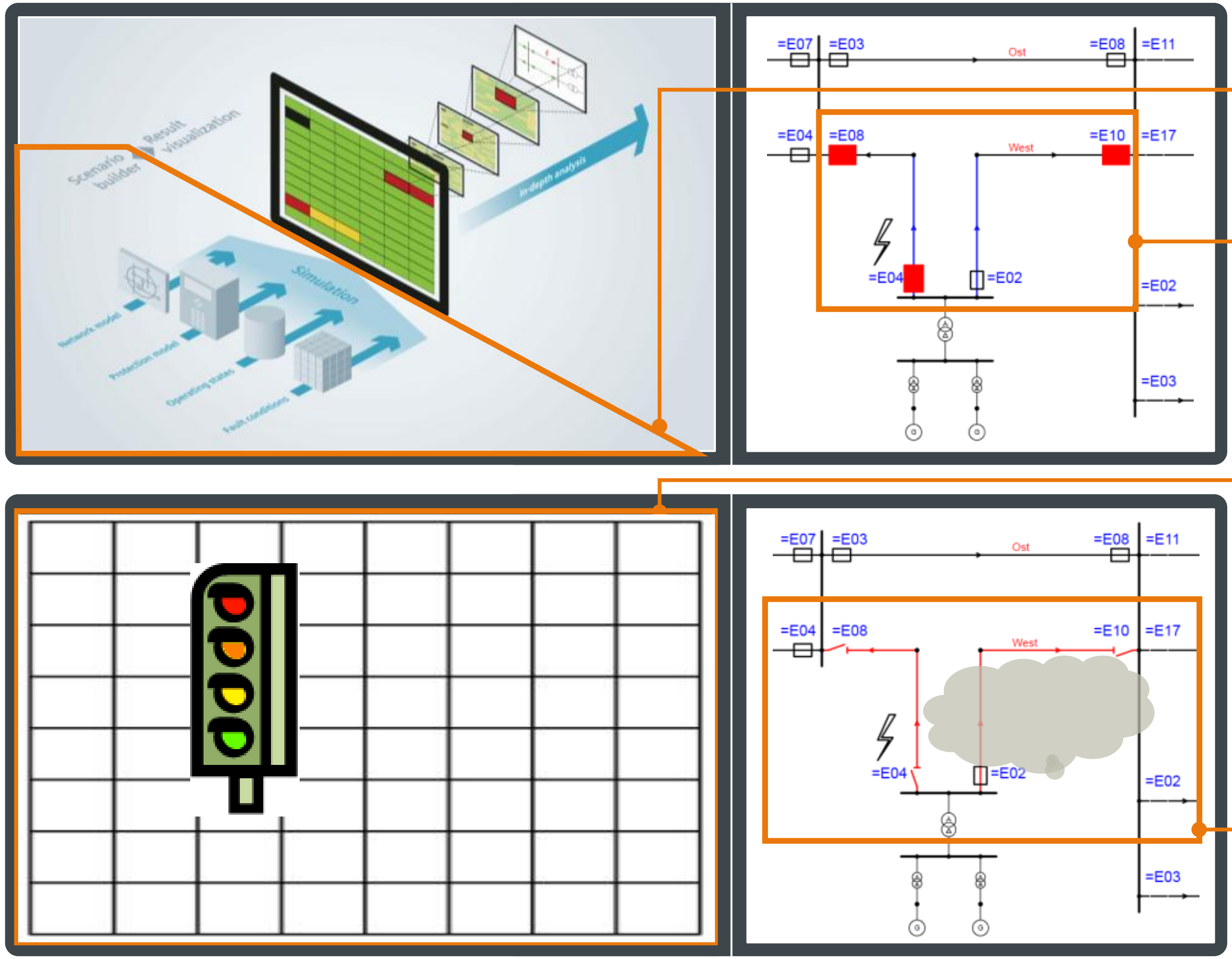
- **Benefits**
  - Optimized system-wide protection coordination
  - Increased system security
  - Higher system utilization
  - Adherence to technical, safety and regulatory standards
  - The high degree of automation enables the efficient handling of complex tasks, and helps saving time and resources

Miscoordination: Backup protection trips; loss of unfaulted equipment

CTI Violation: Backup protection too close in time to primary protection

Fault not cleared: Existing protection not sensitive enough to isolate the fault

Selective operation: Primary protection cleared the fault with adequate selectivity



System-Wide Result Matrix

Scenario builder

Automated system-wide protection simulation

In-depth fault clearing sequence evaluation

Concise result visualization

Weak spot identi-fication by traffic light colors

Impact analysis and mitigation

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System Dynamics in Protection Studies

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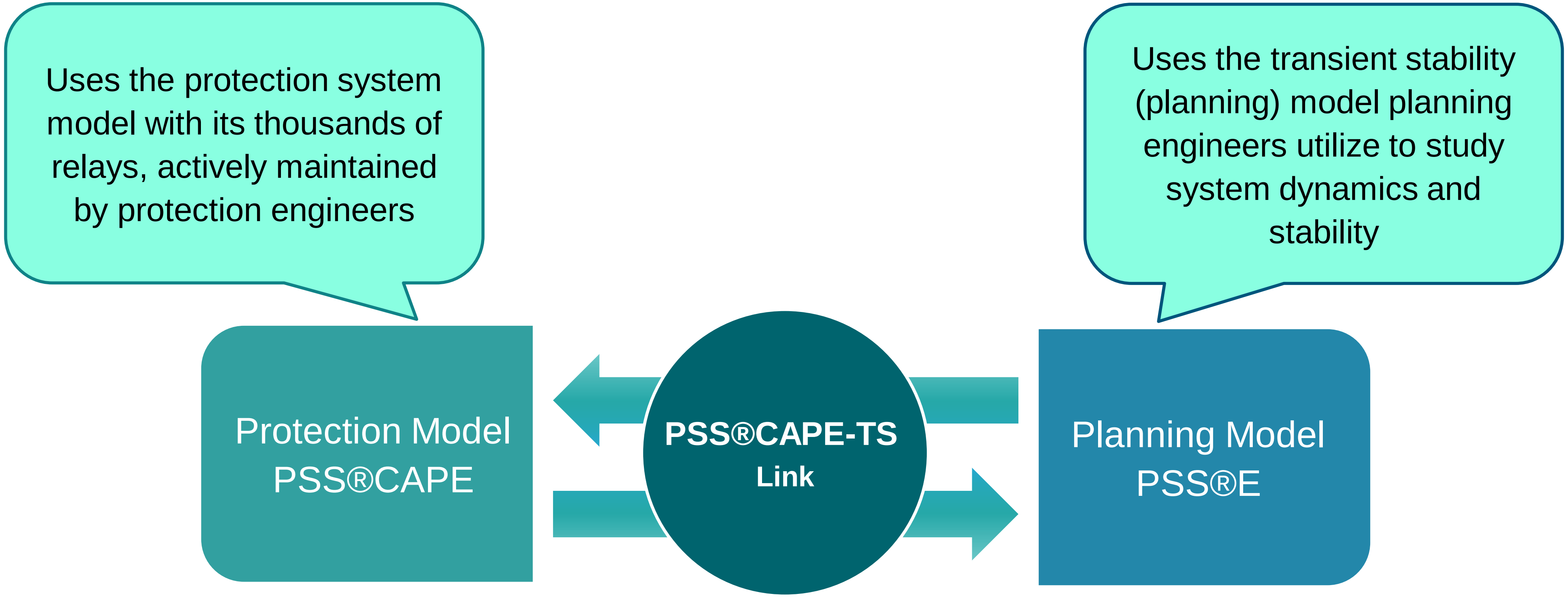
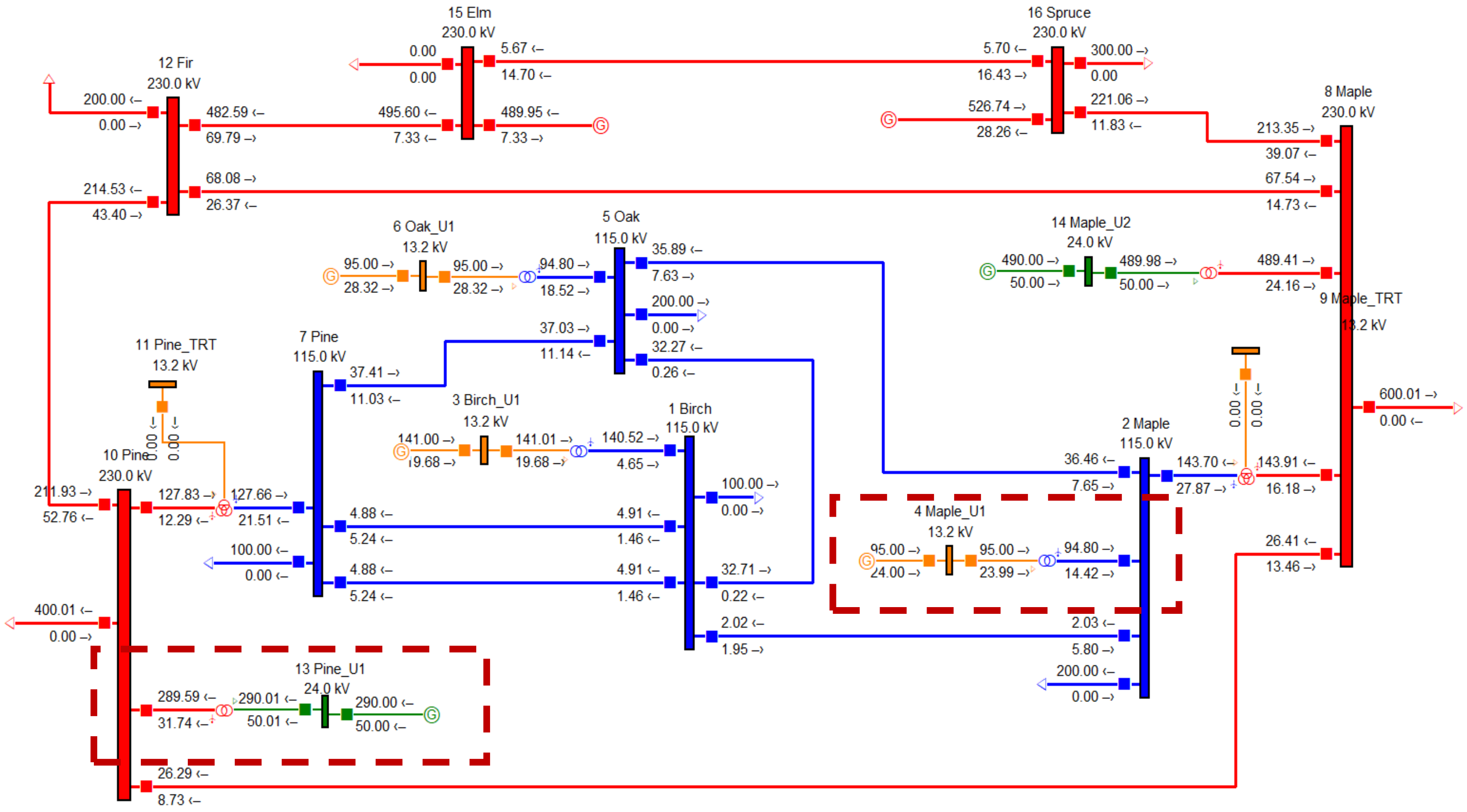
Integrated PSS®CAPE – PSS®E Simulations



Simulates these models together so that interdependence between system dynamics and relay actions can be studied

Original D29 Test System without Renewables

- Total system load demand: 2100 MW



Increasing Penetration of Renewables Reduces Critical Clearing Time

	Renewable Penetration Level	CCT
1	0	0.31 sec
2	~25%	0.24 sec
3	~40%	0.19 sec

Questions and Answers

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