




PROTECTION CHALLENGES

HOW WILL ENGINEERS KEEP UP WITH ALL OF THE CHANGES?

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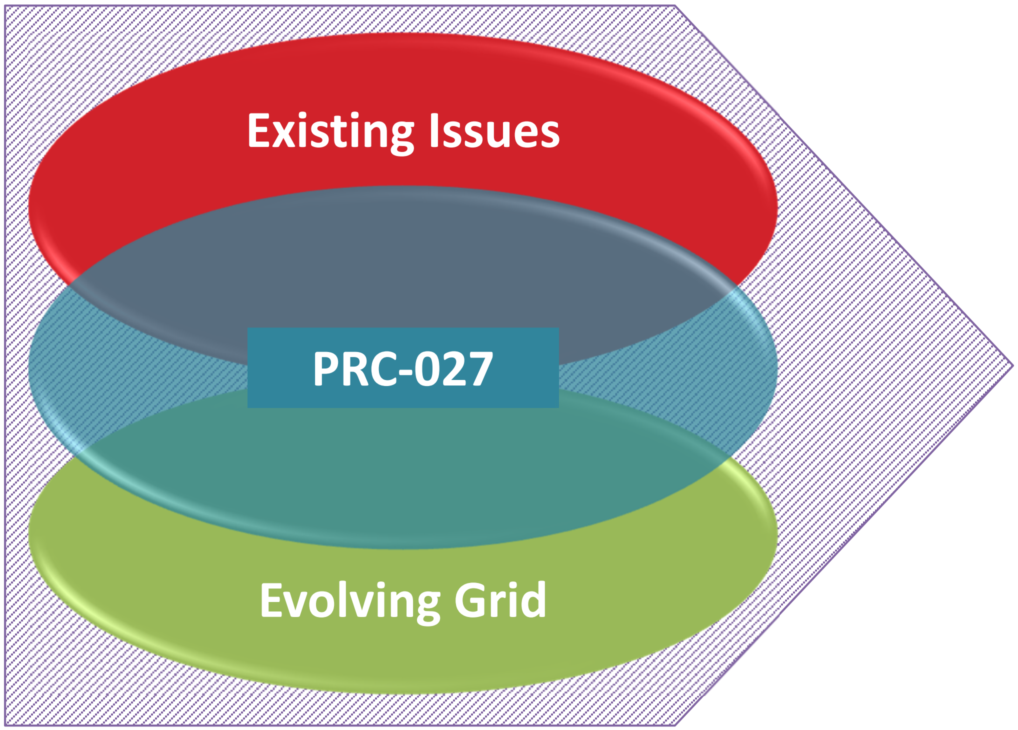
QUANTA TECHNOLOGY

Smart Solutions, Practical Results

Protection Challenges

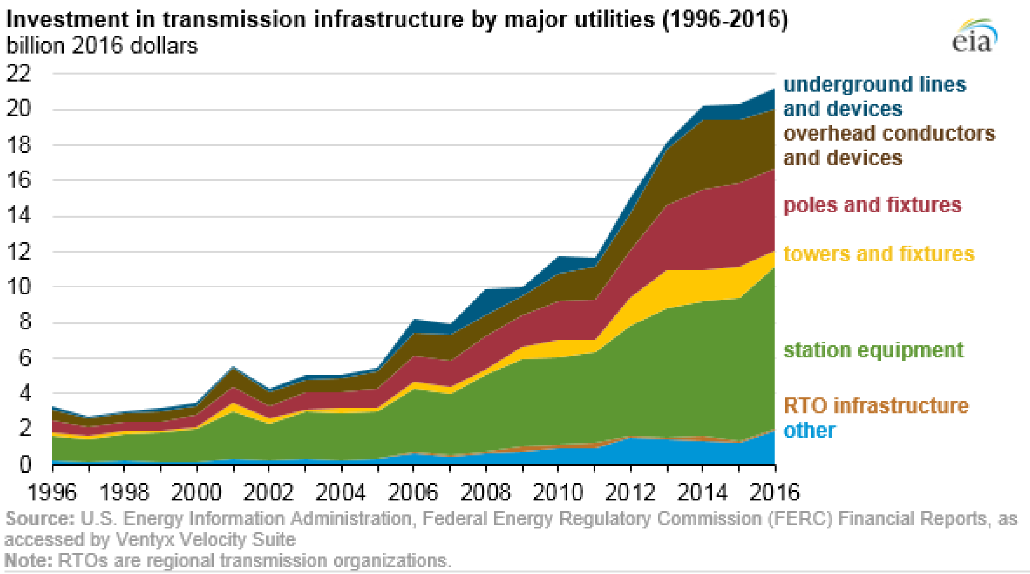


Protection

- Number of resources remaining the same
  - Teams becoming much younger
- Evolution of the power system and PRC-027 will force engineers to review many more scenarios

Evolving Grid

Capital Expansion



Investment doubled since 2008.

EEI estimates growth continued in 2017.

Drivers

- Upgrades
- System hardening
- Improvements to address transmission standards
- Expansion of transmission to integrate renewables

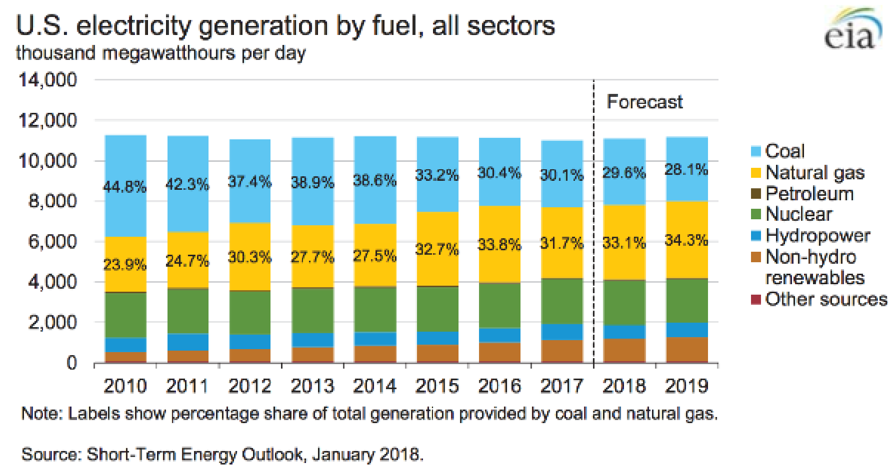
Large transmission projects underway:

- $6.6 BUSD – MISO Multi-Value Portfolio of 17 transmission projects to address reliability and renewable integration concerns.
- $6 BUSD – Energy Gateway to add 2,000 miles of new transmission lines to the WECC to meet demand patterns, strengthen interconnections, and provide access to renewables.
- $4.2 BUSD – Energizing the Future program to replace equipment in the PJM region with smart grid technologies to enhance reliability by preventing or identifying outage locations, meeting load growth, and reinforcing system in light of coal plant closures.
- $1.2 BUSD – Oncor project to upgrade aging infrastructure and build new lines to accommodate electricity usage increases.

Source: ww.eia.gov/todayinenergy

Evolving Grid

Generation Sources



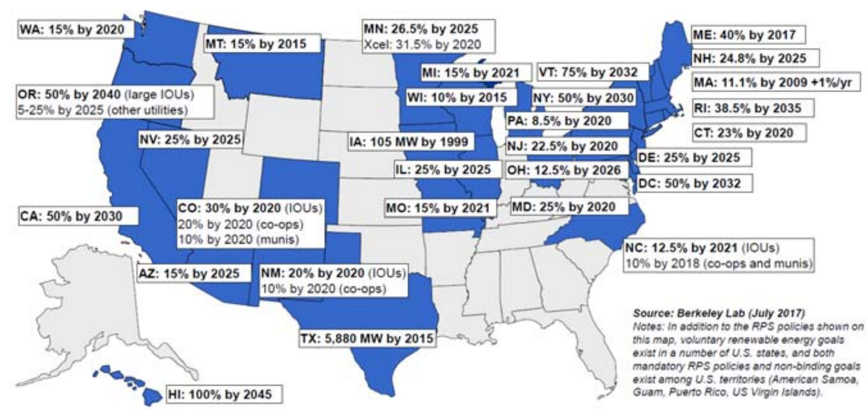
EIA expects gas prices to stay low in 2018, decreasing generation from coal-fired plants. *Credit: EIA*

Change in generation sources:

- Gas generation continues to increase
- Continued retirement of coal plants
- Wind, solar, and hydro exceeded nuclear output for 2 months in 2017
- Nuclear output has remained flat
- RPS increases

2016/2017 Major Renewable Portfolio Standards (RSPs) Revisions:

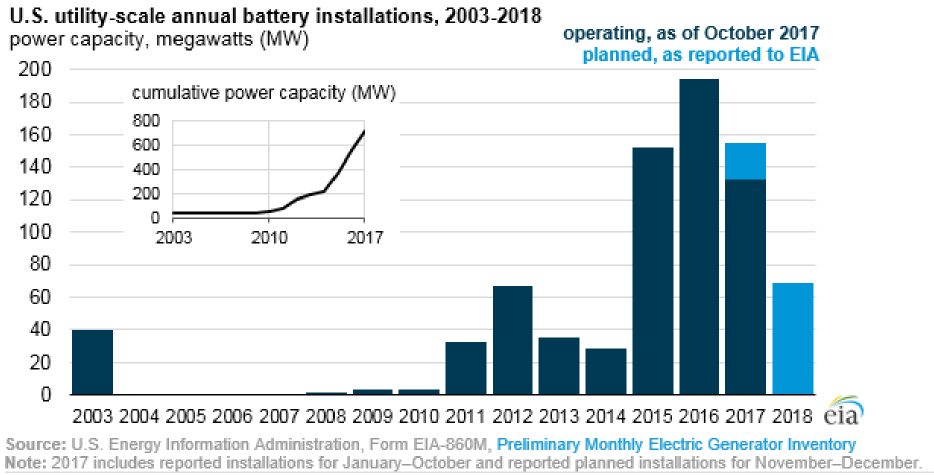
- DC: Increased RPS to 50% by 2032
- IL: Created requirements for new solar and wind
- MA: Created requirements for off-shore wind (1600 MW by 2027) and solar procurement program (1600 MW)
- MD: Increased RPS to 25% by 2020
- MI: Increased RPS to 15% by 2021
- NY: Increased RPS to 50% by 2030
- OR: Increased RPS to 50% by 2040
- RI: Increased RPS to 38.5% by 2035



Source: https://emp.lbl.gov/sites/default/Relays/2017-annual-rps-summary-report.pdf

Evolving Grid

Storage



Applications

- **Balancing grid supply and demand**. Fast-ramping batteries are particularly well suited to provide frequency regulation.
- **Peak shaving and price arbitrage opportunities**. By selling power and discharging during higher price periods, batteries can flatten peaks.
- **Storing and smoothing renewable generation**. Storing excess solar- and wind-generated electricity and supplying it back to the grid or to local loads when needed.
- **Deferring large infrastructure investments**. Provide local power support vs large investments.
- **Reducing end-use consumer demand charges**.
- **Back-up power**. Can be used as part of a microgrid installation.

Expanded deployments of batteries. By 2017, installed 700 MW of utility-scale batteries in the U.S. (0.06% of generation capacity)

Applications

- Power Capacity or Rating in MW for the power produced on a continuous basis
  - PJM - tend to serve power-oriented applications, with larger power capacities but shorter discharge durations
- Energy Capacity in MWh for the total amount of energy that can be stored in or discharged from the batteries
  - CAISO - Utility-scale battery storage systems in California tend to serve energy-oriented applications, with smaller power capacities but longer discharge durations.

Source: https://www.eia.gov/todayinenergy/detail.php?id=34432

Evolving Grids

Issues with Generation Sources

- Fault ride-through
  - Inverter based generation produces limited fault current, and this contribution may be limited to 140 ms for a close-in zero voltage fault. The 140 ms should provide sufficient time for instantaneous primary protection on transmission to clear the fault, provided that the reduced short circuit contribution from DER is sufficient to operate the relay. However, back-up protection, including breaker failure relaying has longer operating time and mitigation such as direct transfer trip from a remote line end may need to be implemented.
- Frequency excursions
  - With increased penetration of inverter based generation, there is a risk for frequency excursions beyond what is experienced today due to less generation/load balance direct control. Implementation of synthetic inertia may alleviate this concern but relay performance should be evaluated for the maximum expected frequency deviation. This has the potential of affecting relays that do not have an adaptive frequency feature and these may need to be replaced by new relays with this feature.

Evolving Grids

Issues with Generation Sources

- Low inertia
  - System stability and power swings become of concern where there could be large blocks of generation being disconnected, resulting in rapid shifts of load flow on major transmission corridors and interconnectors. While these wide area protection issues are best addressed by real time control by synchrophasors or operator control, there may be a need to implement power swing blocking and/or power swing tripping in line protection relays.
  - The fault clearing time requirements will ask for a faster protection operating to maintain stability in the system with a lower inertia. It is assumed that the unit and non-unit protection can met this requirements. The over current coordination interval and the breaker failure times delay used today must be reviewed and revised to meet the future requirements.

Existing Issues

Aspects

- Power system built up over many years
- Industry practices have evolved
- Latent protection issues (i.e., existing problems not yet discovered)

Case Study

Xcel Energy

- Performing numerous system upgrades to its existing transformer and transmission lines
- Several transformer and transmission line additions are also required for Wind Generation outlets
- CAPX2020 project is adding nearly 800 miles of transmission (most of which is 345 kV) crisscrossing the state of Minnesota
- This expansion can create a significant change in system fault currents, resulting in possible over tripping of instantaneous elements and mis-coordination of time delay tripping elements

	kV	Line Count	Region	Total
NSP Region	500	2	318	910
	345	45		
	230	10		
	161	36		
	115	225		
PSCo Region	345	12	262	
	230	127		
	138	4		
	115	119		
SPS Region	345	8	330	
	230	75		
	115	247		

Case Study

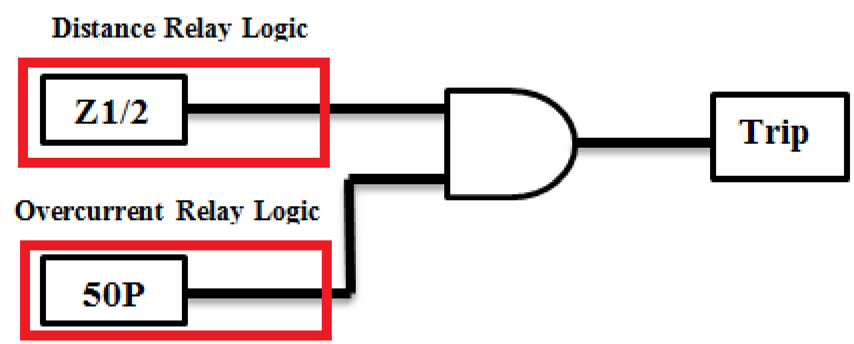
Wide-Area Protection Coordination Study

- Apply different fault types at multiple locations
  - Fault types: SLG, L-L, TPH, DLG (bolted or resistive)
  - Fault locations: Close-In, 10%, 20%, 50%, 80%, 90%, Remote-end
- Check that primary protection operates as expected
  - Check redundant packages (Primary & Secondary) individually
- Evaluate Coordination Time Intervals (CTIs) between primary and back-up elements at each event step
- Flag CTIs that do not meet minimum coordination interval requirements
- Determine if any of the back-up elements might operate ahead of primary protection (mis-op)

Case Study

Example of Findings

- Three-phase faults are applied on a line
- A pair of protection packages, used at both ends of the target line, operate correctly for system normal
- One protection package fails for N-1 contingency when the strongest fault current source at an adjacent line is outaged due to a fault detector setting
- Mis-operation occurs at adjacent line

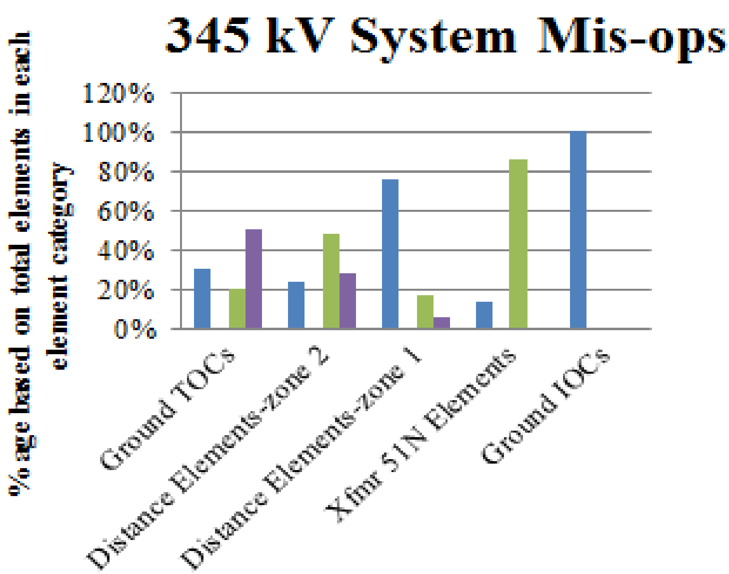


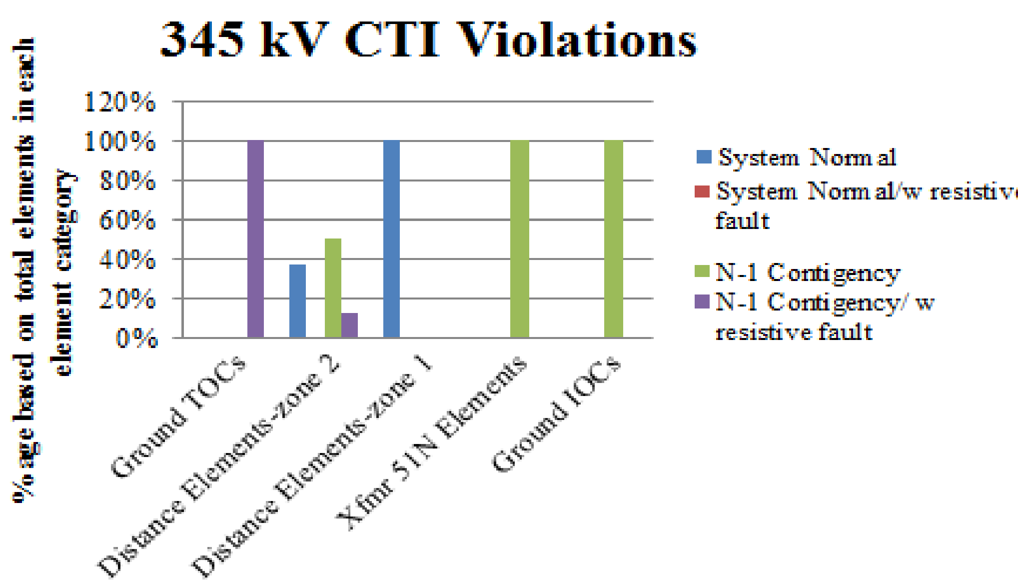
- Supervising FDs don't see the fault because of reduced current with the removal of the strongest fault current source
- By plotting only the distance elements, the problem is not apparent – mho elements show proper operation when plotted graphically
    - Coordination studies must include all supervisory and tripping elements
- Remedy is to lower the fault current pickup to accommodate the worst (least fault current) acceptable operation contingency

Case Study

Example of Findings

- **54** 345-kV Xcel-Energy-owned/partially-owned lines were studied
- **13** lines passed the studies with no major issues
- **41** lines either had unacceptable CTI violations or misoperations or both – only 26% of the flagged violations required immediate attention
- Below is the summary of issues flagged, categorized per relay element type





Case Study

National Grid Saudi Arabia

- Involved major field data collection operation
  - Upwards of 1000 substations
  - More than 120,000 protective relays
  - Over 175 million settings
- Creation of data models in CAPE
- Execution of over a million short-circuit coordination cases
- Review and prioritization of study results
- Implementation of recommendations in the field

PRC-027-1

- **R1**: Establish a process for developing new and revised protection system settings for BES elements such that the protection systems operate in the intended sequence during faults
- **R2**: Where short-circuit fault currents are used to calculate protective relay settings: (Rotating approach – divide up into regions, etc.)
  - **Option 1**: Perform a protection system coordination study in a time interval not to exceed 6 years

    (OR)
  - **Option 2**: Compare present fault current values to an established baseline, and perform a protection system coordination study when the comparison identifies a deviation greater than 15% (6-year interval)
  - **Option 3**: A combination of Options 1 and 2
- **R3**: Develop new protection system settings by following the process established in R1

Process Flow

Develop and Implement Process

- Model Management
- Protection Philosophy
- Review and Q/A Procedure
- Neighboring Utility Information
- Coordination Study Specification

Review System

- Periodic Short-Circuit Fault Current Calculation
- Comparison with Base Case
- Wide Area Coordination Study

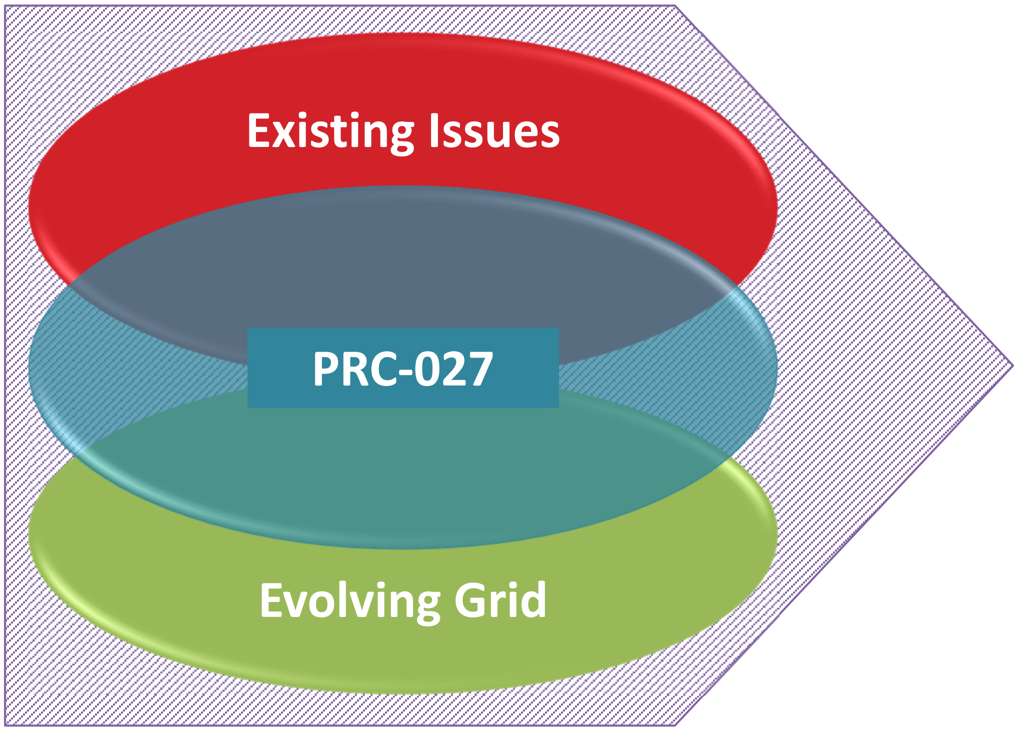
Mitigate and Update

- Analyze Results of Wide Area Coordination Study
- Risk Assessment to Prioritize Protection Settings Issues
- Calculate new Settings and Deploy
- Update Base Case

Impact on Utilities

- Develop procedures and guidelines
  - Short-circuit model management
  - Protection philosophy
  - Coordination study specification
- Determine when a coordination study is required
  - Keep track of short-circuit bus fault current and compare against base case
  - Perform protection coordination studies every 6 years – divide system into regions and rotate the analysis
- Analyze results of wide-area protection coordination studies and provide solutions
  - Risk assessment, calculate new settings to mitigate problems
  - Update the base case

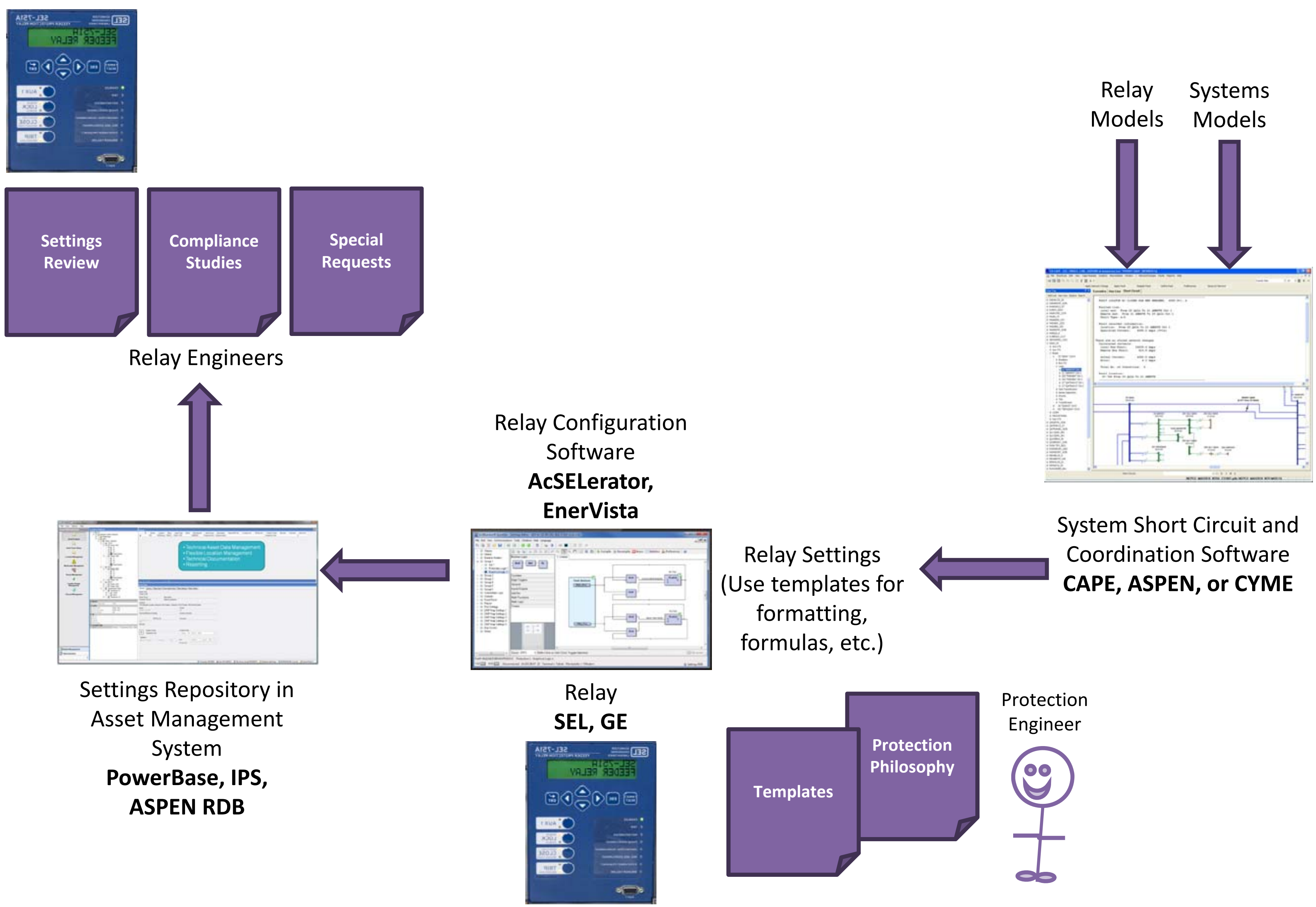
Protection Challenges



Protection Engineering Automation

- Look at how to automate as many tasks as possible to free up protection engineers to focus on key issues

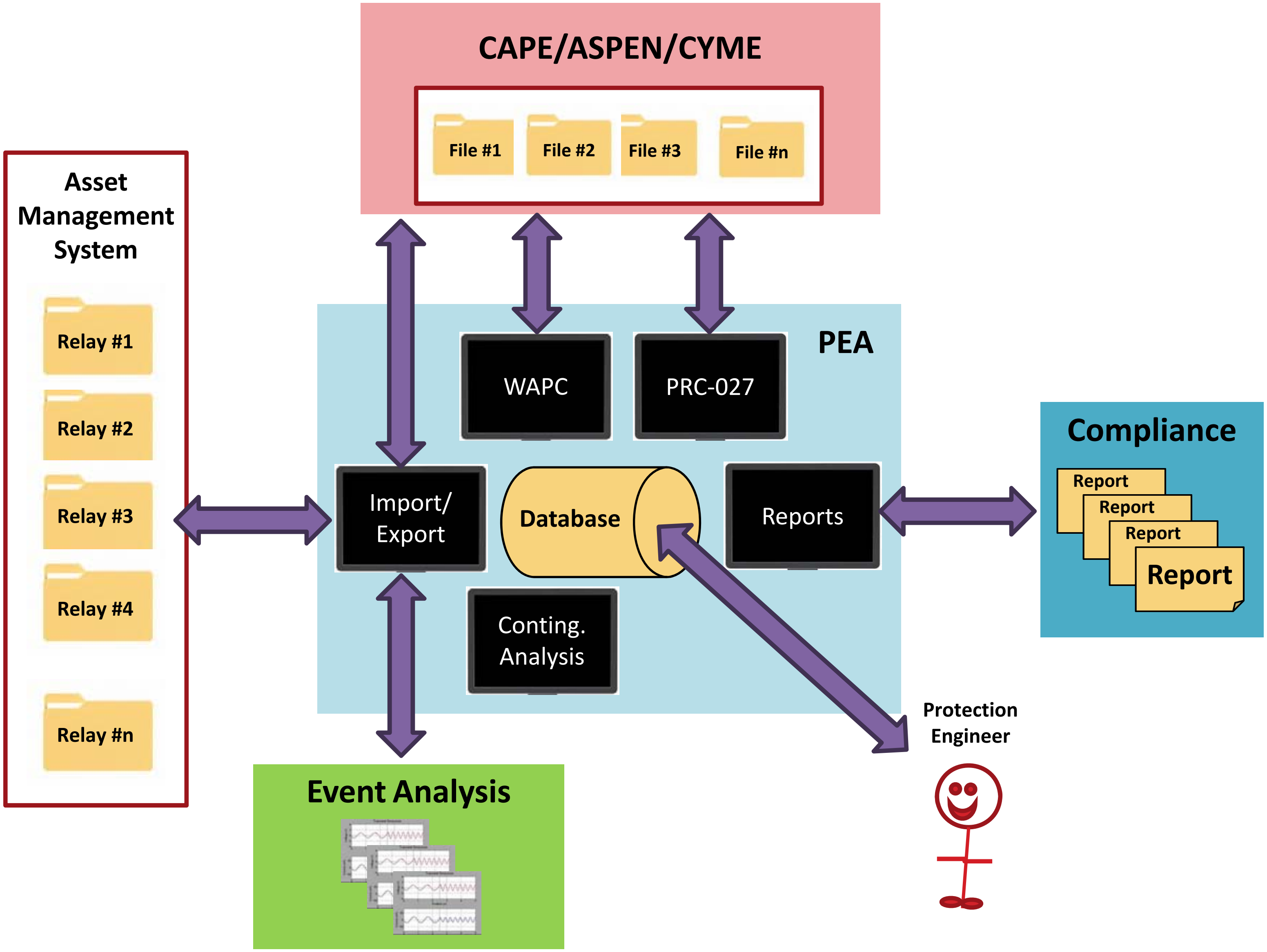
Tools Used by Protection Engineers



Automation

- Drivers
  - Scale of coordination and compliance studies
  - Scale of changes to the grid
  - Number of experienced resources
- Protection Engineering Automation
  - Is being implemented in steps
  - PRC-027 will accelerate the need for automation

Protection Engineering Automation



Automation

- Necessary to accommodate evolving grid
- Improvements in
  - Process
  - Quality
  - Engineer Utilization
- Real Time vs Off-Line Analysis

Thank you!

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