AEP Protection & Control Design Standards

CREZ System Protection & Control Scheme Development

American Electric Power
AEP P&C Design Standard: Design Modules (DM)

Concept: Modular approach to standardize P&C design for each protection zone

DM06: UHV Transmission Line Protection

DM01: UHV Transformer Protection

DM07: Transmission Line Protection

DM81: Transmission CB Protection/Control

DM17: Transmission Cap Bank Protection and Control

DM16: Transmission Bus Protection

DM21: Distribution Transformer and LV Bus Protection and Control

DM22: Distribution Feeder Protection and Control
Example - DM21: Distribution Transformer and LV Bus Protection and Control

- One Line Diagrams
- Design Notes
- Drawings (Panel Front View, Schematic and Wiring)
- Relay Setting Templates
- Relay Setting Summary Form
- Relay Logic Diagrams
- Standard CID Panels

Total 13 Design Modules
AEP Standard P&C Design Modules (Cont.)

Design Module Index

- Design Module 01 - UHV/EHV Transformer Protection
- Design Module 02 - Subtransmission Transformer Protection
  - DM 02.01 - Subtransmission Transformer w/HS Line MOS, w/HS Switcher, with or without LS CBs
  - DM 02.02 - Subtransmission Transformer w/HS Breaker and Half, Optional HS MOS (No Restoration), with
  - DM 02.03 - Subtransmission Transformer w/HS MOS, with or without LS CBs
- Design Module 06 - UHV Transmission Line Protection
- Design Module 07 - HV Transmission Line Protection - Gen. 2.5
  - DM 07.01 - HV Transmission Line with System 1 DCB & System 2 Step Distance (GE D60, SEL 421)
  - DM 07.02 - HV Transmission Line with System 1 DCB, DTT & System 2 Step Distance (GE D60, SEL 421)
  - DM 07.03 - HV Transmission Line with System 1 DCB, DTT & System 2 DCB (GE D60, SEL 421)
- Design Module 08 - HV Transmission Line Protection - Gen. 2.5
- Design Module 09 - Subtransmission Line Protection - Gen. 2.5
- Design Module 10 - Subtransmission Line Protection - Gen. 2.5
- Design Module 16 - Transmission Bus Protection
- Design Module 17 - Transmission Capacitor Bank Protection
- Design Module 21 - Distribution Transformer and LV Bus Protection
- Design Module 22 - Distribution Feeder and Capacitor Bank Protection
- Design Module 51 - Metering
- Design Module 61 - SCADA, DMS, Communication
- Design Module 66 - DFR, Data Repository, Automation
- Design Module 81 - CB Control and Mechanisms - Gen. 2.5
- Relay Firmware - GE
- Relay Firmware - SEL
### Station Standard (SS) Guides: Base for Design Modules

| SS-451001 | AEP Protection Requirements For Connecting to AEP Transmission Grid |
| SS-451002 | Windfarm Protection Guide |
| SS-451005 | Station IED Settings Management Process |
| SS-451010 | Protective Relay Setting Guide |
| SS-451011 | AEP Relay Reference Manual |
| SS-451015 | Protection & Control Equipment Rating Guide |
| SS-451018 | Protection System Coordination Guide |
| SS-451019 | Procedure for Calculating and Utilizing Protective Relay Loadability Relay |
| SS-451101 | Station Alarm Application Guide |
| SS-451104 | Station Misc Alarm Annunciator Setting Guide |
| SS-451105 | C30 Application Guide |
| SS-451106 | Universal Pnl Alarm Disable Procedure |
| SS-451107 | Gen2.0 765KV T Line C30 Relay |
| SS-451301 | AEP Disturbance Monitoring Equipment Guidelines |
| SS-462001 | Distribution Transformer Relaying Guide |
| SS-463200 | SEL 351R_Cooper Retrofit |
| SS-465011 | Distribution Cross-Tripping Schemes Application Guide |
| SS-470000 | Automatic Equipment Investigation Reporting Guideline |
| SS-472001 | 0 SEL351 Transmission Breaker Application Guide Eastern AEP |
| SS-472002 | Breaker Control Replacement Guideline |
| SS-473001 | AEP Planning Guide for Single-Phase EHV Equipment 0603 |
| SS-473101 | Transformer Protection T35 Application Guide |
| SS-473102 | EHV 3 Phase Transformer Relay Application Guide |
| SS-473103 | EHV Single Phase Transformer Relay Application Guide |
| SS-473104 | Gen2.1 Subtransmission XFMR Relay App Guide |
| SS-473105 | Gen2.0 Transformer T35 Relay |
## Catalogue Identity (CID) Based Standard Panel Design

### CID: 0077828007

**0077828007 0802HV421_S**  
LINE ABCD, SYSTEM 2 MIRROR BITS, SEL-421  
SCHEMATIC DIAGRAM

**0077828007 0802HVCMB_F**  
PANEL pnr, LINE ABCD RELAY SYSTEM 1 CURRENT DIFF & SYSTEM 2 MIRRORED BITS  
FRONT VIEW

**0077828007 0802HVCMB_W**  
PANEL pnr, LINE ABCD RELAY SYSTEMS 1 & 2  
WIRING DIAGRAM

**0077828007 0802HVCTPT_S**  
LINE ABCD CURRENT & POTENTIAL CIRCUITS  
SCHEMATIC DIAGRAM

**0077828007 0802HL90_S**  
LINE-ABCD SYSTEM 1 CURRENT DIFFERENTIAL & SYSTEM 2 MIRRORED BITS, L90  
SCHEMATIC DIAGRAM

### Customized Panels vs CID Panels

<table>
<thead>
<tr>
<th>Year</th>
<th>CID Panels</th>
<th>Customized Panels</th>
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<td>2011</td>
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### Bar Chart

- **CID Panels**
- **Customized Panels**
AEP Standard P&C Design Highlights

- System 1 and 2 Relaying Schemes for Transmission
- Redundancy for Bulk Electric System (BES)
- Two Relay Vendors
- Substation Automation Based on Modern IED’s
- IEC61850, Station Data Repository (SDR), etc.
- Reliability Oriented
- Human Performance Improvement
- Efficiency Improvement
- Evolving Standards
AEP Standard P&C Design Highlights (Cont.)

- Line Protection: Communication-aided High Speed Schemes for above 100kV, Dual High Speed for above 200kV
  - High Speed Schemes: DCB, POTT, 87L, DTT

- Separate CB Control relay - Reclosing and CB Failure Prot.

- Bus Protection: Low / High Impedance 87B, Bus 1-Shot for LV Stations

- Transformer Protection: Overall 87T, 87T, Lead 87, Overcurrent, Sudden Pressure, etc.
CREZ : Competitive Renewable Energy Zone

Competitive Renewable Energy Zones (CREZ)
Docket No. 35665
Attachment A
CREZ: Challenges to Protection and Control

- Renewable Energy
- Interconnection
- Redundancy
- Parallel Lines
- Impact of Series Capacitors
- Impact of ShuntReactors
- Communication and NERC-CIP Compliance
- Reactive Power Control
- Other Issues
Wind Farm Low Voltage Ride Through Requirement

- 0.65pu for 18 cycles
- 0.45pu for 9 cycles

NO TRIP ZONE
CREZ Challenge 2: Interconnection

- Interconnection with 6x TSP’s
- Each has its own P&C philosophy and standards
- Changes to existing standards
- Common Goal: System Reliability
Full Redundancy Requirements

- AC Current Source
- AC Voltage Source
- Protective Relay
- Communication Channel
- DC Circuitry
- Auxiliary Trip Relay
- Breaker Trip Coil
- Station DC Source

"Transmission protection systems shall provide redundancy such that no single protection system component failure would prevent the interconnected transmission systems from meeting the system performance requirements" - NERC
CREZ Challenge 4: Parallel Long Lines

- Zero sequence coupling induces false information to relays
- 21G / 67G Overreach or Underreach
- Current Reversal
- Voltage Inversion

\[ \text{Relay sees fault in wrong direction} \]
Non-linearity caused by series capacitor and MOV
Voltage inversion and current inversion
Distance relay over-reaching or under-reaching
Sub-synchronous resonance (SSR)
Sub-synchronous Control Interaction (SSCI)

A zero seq. network example
CREZ Challenge 6: Shunt Reactor

- Energizing or reclosing may result in large DC current offset.
- Trip right after closing may cause line breaker failure.
**CREZ Challenge 7: Shunt Reactor Switching**

- Interrupting inductive current leads to TRV
- CB Switching: Stressful to reactor, turn-to-turn overvoltage
- RLSwitcher: Good for switching but cannot interrupt fault

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**Interrupter Voltage (TRV)**

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**Reactor Current**

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</table>

- Reactor voltage with high frequency
- Fast rise TRV
High speed protection is relying on fiber channel
Redundancy is relying on self-healing SONET ring
Who owns the communication channel for interconnection?
CREZ Challenge 9: Other Issues

- High Transient Recovery Voltage (TRV)
- Induced Voltage and Current - Potential Risks for Maintenance Personnel
- Mitigation of SSCI and SSR
Full Redundancy
- Dual High Speed Primary Protection
- Redundant Communication Channels Using SONET
- Dual Battery Systems, etc.

Optical Fiber-based Current Differential Protection (87L)

Auto-reclosing Schemes

Coordinate the Series Capacitor Protection and Control

Comprehensive Shunt Reactor Control Scheme

Secured Breaker Failure Protection Scheme

State-of-art Relays
Line Differential Protection (87L)

- Simple in Principle: Compare Currents In & Out
- Highly Sensitive and Dependable for Internal Faults
- Highly Secure Against External Faults
- Relying on Good Communication Channel

![Diagram of Line Differential Protection (87L)]
<table>
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<th>PLC-based schemes</th>
<th>Optical fiber-based 87L</th>
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87L Channels – Self Healing SONET Rings

- 87L-1
- 87L-2

Multiplexer

87L Relay

D1
D2

A1
A2

B1
B2

C1
C2

OPGW
- OPGW is shared, SONET ring is NOT
Auto-reclosing Schemes

- Reclose for 1LG faults only
- Single shot, ~30 cycles dead time
- Leader / Follower Scheme:
  - Leader CB tests for hot bus / dead line condition
  - Follower CB reclosing under sync-check condition
- Shunt compensated Line: Anytime the line is de-energized, isolate the shunt reactor.
- Series compensated Line: Bypass series capacitors prior to line CB reclosing
- Series Capacitor Flashover: Automatically isolate the platform before reclosing the line CB
Series Compensated Line Protection & Control

- Faults on the line: Bypass SC before reclosing
- Faults within SC zone: Isolate SC before reclosing
Shunt Compensated Line Protection Schemes

- Faults on the line: Trip CBs and RLSwitcher
- RLSwitcher Failure: Pause reclosing until MOS is open
- Faults within shunt reactor zone: Trip all CBs & MOS, DTT to remote CBs, Delayed trip to RLSwitcher
CREZ & AEP Standards Development

- Enhance the Standards Library
  - Line Protection Using State-of-art Technology
  - Dual DC Battery System Design
  - Shunt Reactor Schemes Enhancement
  - Series Compensated Line Schemes
  - Breaker Control Enhancement
  - Drop-in Control House Design
  - etc.

- Addressing Future needs
  - BES Reliability
  - NERC Standards Compliance

- Human Performance Improvement
Current State of CREZ Projects in AEP/ETT

- Riley North - South 345kV station has 19 breakers, 8 lines, 4x 50MVAR shunt reactors and 2x shunt capacitors. Part of the station was in-service around May 2011.

- Tesla 345kV station has 17 breakers, 8 lines, 4x 50MVAR shunt reactors, 2x 130.9 MVAR shunt capacitors, 2x (-50 to +150 MVAR) SVCs. The construction is ongoing. The Drop-In Control House will be delivered to the site in October, 2011. Planned In-service date is October 2012.

- The majority of the equipment will be in-service the later part of 2012 through 2013.
Questions?