In-Person Class Descriptions (Each Class Is Normally Four-Days Long For 32 CEH)

1. Power System Fundamentals
2. Power System Dynamics
3. NERC Reliability Standards Content & Application
4. Power System Protection For Operations Personnel
5. Dynamics Of Power System Disturbances

Click On The In-Person Class Title To See Details Of That Class

1: Power System Fundamentals In-Person Course Description (32 CEH / 14 Standards)

Learning Objective: Describe & Illustrate Fundamental Concepts Of Electric Power Systems

1. Describe & Illustrate Math Concepts Used In Power System Calculations.
    a. Use & Application Of Fractions Including:
        i. Concepts Of Numerator & Denominator
        ii. Add, Subtract, Multiply & Divide
        iii. Concept Of Lowest Common Denominator
        iv. Concept & Usage Of Ratios & Percentages
    b. Use & Application Of Exponents
        i. Basic Math Using Exponents
        ii. Greek Letter Representation Of Exponents (K, M, G, T, Etc.)
    c. Use Of Square Roots
        i. Explanation Of Square Root Principal
        ii. Power System Square Root Applications Including Square Root Of Three Factor For Conversion Between Phase-To-Phase & Phase-To-Neutral Voltages & Square Root Of Two Factor For Conversion Between RMS & Peak Voltages
    d. Use & Application Of Sine & Cosine Functions
        i. Concept Of An Angle
        ii. Usage & Illustration Of Right Triangles
        iii. Definition Of Sine & Cosine
        iv. Use Of Pythagorean Theorem
        v. Solving Right Triangles For Side Lengths & Angle Values
    e. Concepts Of Vector & Phasor
    f. Introduction To Per-Unit System Of Measurement
        i. Concept Of Per-Unit Measurements
        ii. Conversion Between Per-Unit & Percentage Systems
        iii. Demonstrate Usage Of Per-Unit System For Voltage & Power Flow Value Display Using Power System One-Line With Both Actual & Per-Unit Values For Voltage, Power Flow & Impedance Values
    g. Explanation Of Concept & Usage Of Constant “Pi”
2. Describe & Illustrate Usage Of DC Theory Concepts
    a. Describe Atomic Scale Difference Between Conductor & Insulator
    b. Describe Concept Of Voltage & Illustrate Voltage Sources
    c. Describe & Illustrate Concept Of Electro-Magnetic Induction
        i. Illustrate How Hydro & Steam Prime Movers Serve As Rotation Source For Electro-Magnetic Induction
        ii. Illustrate Development Of AC Voltage & Its Conversion To DC Using Commutator
    d. Describe Concept Of Current & Differentiate Between Conventional Current Flow & Electron Flow
    e. Describe & Illustrate DC Electrical Circuit

f. Describe & Illustrate Usage Of Ohms Law In DC Circuit
g. Describe & Illustrate Usage Of Power & Energy Formulas In DC Circuits
h. Describe & Illustrate Usage Of Kirchhoff's First & Second Laws In DC Circuits
i. Describe & Illustrate Usage Of HVDC Transmission

3. Explain & Illustrate The Usage Of AC Theory Concepts.
    a. Illustrate & Describe Development Of AC Voltage Using Electro-Magnetic Induction
    b. Describe Features Of AC Sine Wave Including Peak Versus RMS Values
    c. Describe & Illustrate Concepts Of Inductance & Inductive Reactance
    d. Briefly Describe How Inductive Coupling Used In Transformers
    e. Describe & Illustrate Concepts Of Capacitance & Capacitive Reactance
    f. Illustrate Effect Of Inductance & Capacitance On Phase Angle Between Voltage & Current
    g. Describe & Illusate Usage Of Impedance & Power Triangles
    h. Use "Pi" Model Of Transmission Line To Explain Presence Of Inductance, Capacitance & Resistance In AC Transmission Lines
    i. Briefly Describe Reactive Power Using Analogies
    j. Describe & Illustrate Concept Of Power Factor
    k. Describe Advantages Of Three-Phase Power System
4. Describe & Illustrate Organizational Structure & Components Of North American Power System
    a. Using Simple Diagram Of Key Components Of Power System Step Through & Describe Typical Power System Arrangement
        i. First Explain Generator Role, Then Transformer, Then Transmission, Then Sub-Transmission, Then Distribution, Etc. All The Way Through To End-User Residential Customer.
    b. Describe & Illustrate How Load Varies Moment To Moment, Hourly, Daily & Seasonally
    c. Describe Load Forcasting Process
    d. Describe & Illustrate The Four NERC Interconnections
    e. Describe Roles Of Organizations Who Administer Power System
        i. Include FERC, NERC, Regional Entities & NAESB
    f. Describe & Illustrate Components & Usage Of Generation System
        i. Purpose Of Rotor, Stator, Prime Mover, Governor, & Exciter
        ii. Use Photographs To Describe Different Types Of Generation Used In Power System
        iii. Explain Concept Of Reliability Must Run (RMR) Generation
    g. Describe & Illustrate Components & Usage Of Transmission System
        i. Purpose & Usage Of Transformers, Switches, Circuit Breakers, Bus-Work, Shunt Capacitors, Shunt Reactors, SVCs, Ground Mats, Transmission Lines, Line Conductors, Insulators, Protective Relaying Components, Instrument Transformers, IEEE Device Numbers, Synchronizing Equipment, UVLS & UFLS

5. Use NERC's Functional Model As Guide To Describe Roles Performed By The Functional Entities Listed In The Functional Model
    a. List, Describe & Where Possible Illustrate The Job Function Of Each Of 18 Entities Listed In NERC's Version 5.1 Functional Model. 18 Functional Entities Include:
        i. Standards Developer
        ii. Compliance Enforcement Entity
        iii. Reliability Assurer
        iv. Reliability Coordinator
        v. Transmission Service Provider
        vi. Planning Coordinator
        vii. Market Operator
        viii. Interchange Coordinator
        ix. Balancing Authority
        x. Transmission Owner
        xi. Generation Operator
        xii. Transmission Operator
        xiii. Transmission Planner
        xiv. Resource Planner
        xv. Generator Owner
        xvi. Load Serving Entity
        xvii. Purchasing Selling Entity
        xviii. Distribution Provider
6. Describe How Transmission Operators, Balancing Authorities & Reliability Coordinators Utilize Tools, Procedures & Real-Time System Data To Operate Power System During Normal & Emergency Conditions.
    a. Briefly Describe & Illustrate How Generation Operations Is Accomplished
        i. Describe & Illustrate How Frequency Is Result Of Balance Between Generation & Load
        ii. Illustrate & Explain Concept Of Inertia
        iii. Describe How Governors Operate
        iv. Describe How AGC Operates
        v. Explain Concept Of Operating Reserve
    b. Briefly Describe & Illustrate How Transmission Operations Accomplished
        i. Describe How TOPs Manage Voltage Control Process
        ii. Describe How TOPs Manage Switching Process
        iii. Describe How RCs & TOPs Operate Within SOLs
        iv. Describe How RCs & TOPs Manage Transmission Congestion
7. Describe How The Power System Is Operated In Emergency Conditions
    a. Describe Common Causes Of Power System Events
    b. Describe How Power Systems Restored After Events
    c. Step Through & Explain Key Points Of 8/14/2013 Eastern Interconnection Event
    d. Step Through & Explain Key Point Of 9/8/2011 Western Interconnection Event
8. List & Briefly Describe The Content Of The Current NERC Reliability Standards
    a. List & Briefly Describe Content Of Current Versions Of NERC Reliability Standards

b. Briefly Describe Following NERC Reliability Standards: BAL-001-2, BAL-002-3, BAL-003-2, BAL-005-1, CIP-002-5.1a, CIP-003-8, CIP-004-6, CIP-005-57, CIP-006-6, CIP-007-6, CIP-008-6, CIP-009-6, CIP-010-4, CIP-011-2, CIP-012-1, CIP-013-2, CIP-014-3, COM-001-3, COM-002-4, EOP-004-4, EOP-005-3, EOP-006-3, EOP-008-2, EOP-010-1, EOP-011-2, FAC-001-3, FAC-002-3, FAC-003-4, FAC-008-5, FAC-010-3, FAC-011-3, FAC-014-2, INT-006-5, INT-009-3, IRO-001-4, IRO-002-7, IRO-006-5, IRO-008-2, IRO-009-2, IRO-010-4, IRO-014-3, IRO-017-1, IRO-018-1(I), MOD-001-1a, MOD-004-1, MOD-008-1, MOD-028-2, MOD-029-2a, MOD-030-3, MOD-025-2, MOD-026-1, MOD-027-1, MOD-031-3, MOD-032-1, MOD-033-2, NUC-001-4, PER-003-2, Per-005-2 (No Course Time Used For Coverage Of PER-005-2), PER-006-1, PRC-003-2, PRC-004-6, PRC-005-1.1b, PRC-005-6, PRC-006-5, PRC-008-0, PRC-010-2, PRC-011-0, PRC-012-2, PRC-017-1, PRC-018-1, PRC-019-2, PRC-023-4, PRC-024-3, PRC-025-2, PRC-026-1, PRC-027-1, TOP-001-5, TOP-002-4, TOP-003-5, TOP-010-1(i), TPL-001-5.1, TPL-007-4, VAR-1-5.1 & VAR-002-4.1

2: Power System Dynamics In-Person Course Description (32 CEH / 21 Standards)

Learning Objective: Describe & Illustrate The Dynamic Behavior Of The Power System Including Frequency Control, Voltage Control & Angle / Voltage Stability

1. Review Fundamental Concepts Of Power System Operations
    a. Describe & Illustrate Fundamental AC Principles & Concepts
        i. Topics Addressed Include Description Of Capacitance, Inductance & Phase Angle, Concept Of Voltage Phase Angle, Capacitive Effects On Transmission Lines & Description Of MW, MVAr, MVA & Power Triangle
    b. Describe & Illustrate Fundamental Concepts Of Generator Operation
        i. Topics Addressed Include Theory Of Electromanetic Induction, Principles Of Construction Of Generators, Illustration & Description Of Types Of Generator Prime Movers Including Steam Turbines, Wind Turbines, Hydro Turbines, Combustion Turbines, Solar Photo-Voltaic, Description & Illustration Of Methods Used To Connect Inverter Based Resources (IBRs) To Interconnection & Description Of Generation Usage By Type In NERC System
    c. Describe & Illustrate Fundamental Principles Of Generator Control Systems
        i. Topics Addressed Include Illustration Of Basic Governor Control System Operation, Basic Excitation Control System Operation & Illustration Of Synchronizing Process
    d. Describe The Purpose & Function Of NERC
        i. Topics Addressed Include Description Of NERC's Jurisdiction, Description Of NERC's Operation & Organization, Explanation Of Need For NERC Standards & Concept Of Markets As Used Within NERC
2. Describe & Illustrate Frequency Control Theory & Describe The Content Of The BAL Series Of Reliability Standards
    a. Describe & Illustrate The Frequency Control Theory Associated With Reliability Standard BAL-001-2 & Evaluate This Standards Impact On System Operations
        i. Topics Addressed Include A Review Of Generation Types Used In The US, The Energy Balance Concept, The Concept Of Inertia, The Load-Damping Concept, Acceptable Frequency Range, Concept & Types Of Operating Reserves, Governor Control Process Including Droop & Deadband, Problems With Step-Response In Governor Deadband, The AGC Process, Constant Frequency, Constant Interchange & Tie-Line Bias AGC Modes, Concepts & Illustration Of CPS-1 & BAAL, The Difference Between Supplemental & Overlap Regulation Services & A Description & Explanation Of The Requirements In BAL-001-2
    b. Describe & Illustrate The Frequency Control Theory Associated With Reliability Standard BAl-002-3 & Evaluate This Standards Impact On System Operations
        i. Topics Addressed Include A Description Of DCS Terminology (Including Most Severe Single Contingency, Balancing Contingency Event, Reportable Balancing Contingency Event, The Application Of The DCS, A Review Of The Contingency Reserve Definition, The Usage & Restoration Of

Contingency Reserve & A Description & Explanation Of Requirements In BAL-002-3

c. Describe & Illustrate The Frequency Control Theory Associated With Reliability Standard BAL-003-2 & Evaluate This Standards Impact On System Operations
    i. Topics Addressed Include A Description Of The Frequency Response Process, The Concept Of An FRSG, The Frequency Bias Concept, The Impact Of Load Damping, Concepts Of FRC, IFRO & FRO, Description Of The Overlap & Supplemental Regulation Services & A Description & Explanation Of The Requirements In BAL-003-2
d. Describe & Illustrate The Frequency Control Theory Associated With Reliability Standard BAL-005-1 & Evaluate This Standards Impact On System Operations
    i. Topics Addressed Include A Description & Demonstration Of The Usage Of The Tie-Line Bias ACE Equation, The Usage Of HVDC With AGC, The Concepts Of Host BA, Dynamic Schedules & Pseudo-Ties & A Description & Explanation Of The Requirements In BAL-005-1
e. Describe & Illustrate The Concepts Of Inadvertent Energy Accounting & Time Error Control & Examine The Details Of The Decay In Frequency Following A Loss Of Generation
    i. Topics Addressed Include A Description Of The Inadvertent Interchange Calculation & Payback Process, The Difference Between Primary & Secondary Inadvertent, Basic Inadvertent Accounting Principles, A Description Of The Time Error Control Process & The Roles Of RCs & BAs, A Description Of Automatic Time Error Control (ATEC) As Used In The WECC, A Description & Explanation Of The Requirements In BAL-004-WECC-3 & A Description Of The Frequency Event Process Including Its Four Different Stages & Four Different Periods.

3. Describe & Illustrate Voltage Control Theory & Practice & Describe The Content Of NERC's Standards With Voltage Control Related Requirements
    a. Describe & Illustrate The Concept Of Reactive Power
        i. Topics Addressed Include An Explanation Of The Concept Of Reactive Power From An Energy Storage Perspective, Illustration Of How Reactive Power Flows, Illustration Of The Usage Of Shunt Capacitors To Compensate Inductive Load & The Derivation & Usage Of A Formula For Transmission System Reactive Power Usage.
    b. Describe & Illustrate The Causes & Effects Of Power System High & Low Voltage
        i. Topics Addressed Include How Transmission Lines Both Use & Produce Reactive Power, An Explanation Of The Surge Impedance Loading (SIL) Concept, Illustration Of How Unscheduled Power Flow Leads To Low Voltage, Illustration Of How Transmission Line Trips Lead To Low Voltage, Explanation Of Why A Shunt Capacitor's MVAr Output Varies With Voltage, Cause & Methods Of Preventing Ferranti Voltage Rise, Explanation Of The GMD Concept & Its Impact On Voltage Control, Description Of The Content Of EOP-010-1: "Geomagnetic Disturbance Operations" & TPL-007-4: "Transmission System Planned Performance For

Geomagnetic Disturbance" As Related To GMDs, The Concept, Impacts & Control Of Harmonics, The Concept Of Sub-Synchronous Resonance (SSR), Description Of Low Voltage Issues When Starting Large Motors, Description & Illustration Of Motor Starting Methods Including Variable Speed Drives, Illustration Of How Point-On-Wave Closing Minimizes Capacitor In-Rush Current & An Explanation Of The Load/Voltage Relationship.

c. Describe & Illustrate How Voltage Control Equipment Is Used To Control Power System Voltage
    i. Topics Addressed Include The Usage Of Shunt & Series Capacitors For Voltage & Impedance Control, Concept Of A Super-Capacitor, Usage Of Shunt (Dry-Type & Oil-Filled) & Series Reactors For Voltage & Impedance Control, Description Of The Design & Operation Of Transformer Tap Changers, Usage Of Transformer Tap Changers For Voltage Control, Usage Of Generators To Both Absorb & Provide MVAr, Description & Illustration Of Various Types Of Excitation Systems, Description & Illustration Of The Usage Of Reactive Capability Curves, Description Of MOD-025-2: "Verification & Data Reporting Of Generator Real & Reactive Power Capability & Synchronous Condenser Reactive Power Capability" Requirements For Creating Accurate Capability Curves, Description Of PRC-024-3: "Frequency & Voltage Protection Settings For Generating Resources" Requirements With Respect To Generator Voltage Disturbance Ride-Through, Description Of PRC-019-2: "Coordination Of Generating Unit Or Plant Capabilities, Voltage Regulating Controls & Protection" Content & Purpose With The Standard's Compliance Represented On A Capability Curve, The Concept & Usage Of Thyrister & IGBT Based Equipment Such As SVCs, STATCOMs, Inverters & HVDC Converters For Voltage Control & The Value Of Dynamic Reactive Reserve For Rapid Response To Voltage Deviations
d. Explain & Illustrate The Content Of Each Of The Requirements Within NERC's Voltage Control Related (VAR Series) Reliability Standards Including:
    i. List, Explain & Illustrate The Content Of Each Of The Six Requirements In VAR-001-5: "Voltage & Reactive Control"
    ii. List, Explain & Illustrate The Content Of Each Of The Six Requirements In VAR-002-4.1: "Generator Operation For Maintaining Network Voltage Schedules"
    iii. List, Explain & Illustrate The Content Of Each Of The Six Requirements In PRC-010-2: "UVLS"

4. Describe & Illustrate Power System Stability Concepts Including Angle Stability & Voltage Stability
    a. Describe & Illustrate The Concepts Of MW & MVAr Flow & Describe The Theory & Operation Of The Equipment Used To Control MW Flow
        i. Topics Addressed Include Meaning & Value Of Voltage Phase Angle Measurement, Utilize Pi Model To Develop Equations For MW & MVAr

Flow, Demonstrate Usage Of Mw & MVAr Flow Equations, Explanation Of Cause Of 30° Shift In Wye-Delta Transformer, Description & Illustration Of How Phase Shifting Transformers (PSTs) Used To Control Voltage Phase Angle & Mw Flow, Description & Illustration Of How Variable Frequency Transformers (VFTs) Used To Control Mw Flow

b. Describe & Illustrate Angle Stability & Angle Instability
    i. Topics Addressed Include Definitions Of Angle Stability & Angle Instability, Description Of How Short Term Frequency Differences Lead To Angle Instability, Use Phasor Diagram To Illustrate Angle Instability, Describe Three Types Of Angle Stability/Instability, Description Of How Angle Stability Limits Determined Using Computer Models Described In MOD-032-1 & MOD-033-2, Description Of How Power-Angle Curves Used To Analyze Angle Stability Of Power System, Description Of Usage Of Swing Equation, Description Of Steady-State Stability & Steady-State Instability Using Power Angle Curves, Description Of Transient Stability & Transient Instability Using Power Angle Curves, Description Of Oscillatory Stability & Oscillatory Instability Using Power Angle Curves, Description Of Content Of TPL-001-5.1 Standard As Relates To Stability Based System Operating Limits, Usage Of Braking Resistors, Usage Of Fast Protection, Usage Of Fast Valving Schemes & Usage Of Out-Of-Step (OOS) Blocking & OOS Tripping Protective Relays & Description Of PRC-026-1 As It Relates To OOS Power Swings, Describe Difference Between Natural & Forced Oscillations, Define & Illustrate Inter-Area & Intra-Area & Local & Intra-Plant Modes Of Oscillations, Describe & Illustrate Concept Of Damping Ratio, Describe & Illustrate How PSS Used To Increase System Damping & Describe WECC's PSS Requirements As Stated In VAR-501-WECC-3.1
c. Describe & Illustrate Voltage Stability, Voltage Instability & Voltage Collapse
    i. Topics Addressed Include Definitions Of Voltage Stability, Voltage Instability & Voltage Collapse, Describe Difference Between Voltage & Angle Stability, Describe & Illustrate Three Types Of Voltage Collapse, Description Of Content Of TPL-001-5.1 Standard As Relates To Voltage Stability-Based System Operating Limits, Explain & Demonstrate Construction Of P-V & V-Q Curves, Interpret Shape & Data Presented In Fictional & Actual P-V & V-Q Curves, Step Through Process Of Voltage Collapse Event Using P-V & V-Q Curves, Describe Impact Of Tap Changers & Generator MVAr Response On Voltage Collapse Scenarios, Describe Value Of Maintaining Adequate Dynamic Reactive Reserve, Describe How UVLS Schemes Can Help Prevent Voltage Collapse & Description Of Content Of PRC-011-0 & PRC-010-2 Standards As Relates To UVLS Programs

3: NERC Reliability Standards Content & Application
In-Person Course Description (32 CEH / 30 Standards)

Learning Objective: List & Describe The Content Of The Current NERC Reliability Standards Emphasizing Those Standards With Real-Time Operational Impact]

1. State The Function Of NERC & Describe NERC's Roles & Responsibilities Within The Power System
    a. Describe The Function Of NERC & NERC 'S Organization, Describe The Roles & Responsibilities Of The Functional Entities As Described In NERC's Functional Model & Glossary Of Terms, State The Purpose & Function Of NAESB, Describe The Difference Between The Bulk Power System (BPS) & Bulk Electrical System (BES), State NERC's Definition Of Reliability & Describe The Purpose Of The Standards Of Conduct
2. Describe & Evaluate The Impact On System Operations Of The BAL Series Of Reliability Standards
    a. Describe The Content Of The Requirements In BAl-001-2 Including The Energy Balance Concept, Load Damping, Acceptable Frequency Range, Concept & Types Of Operating Reserves, Governor Control Process Including Droop & Deadband, AGC Process, Constant Frequency, Constant Interchange & Tie-Line Bias AGC Modes, Inertia, Concepts & Illustration Of CPS-1, CPS-2 & BAAL & The Difference Between Supplemental & Overlap Regulation Services
    b. Describe The Content Of The Requirements In BAL-002-3 Including A Description Of DCS Terminology (Including Most Severe Single Contingency, Balancing Contingency Event & Reportable Balancing Contingency Event), Concept Of An RSG, Application Of The DCS, Contingency Reserve Details & The Usage & Restoration Of Contingency Reserve
    c. Describe The Content Of The Requirements In BAL-003-2 Including A Description Of The Frequency Response Process, Concept Of A FRSG, Frequency Bias Concept, Impact Of Load Damping & The Concepts Of FRM, IFRO & FRO
    d. Describe The Content Of The Requirements In BAL-005-1 Including A Description & Demonstration Of The Usage Of The Tie-Line Bias ACE Equation & The Usage Of HVDC With AGC Control
    e. Describe & Illustrate The Concepts Of Inadvertent Energy Accounting & Time Error Control Including A Description Of The Inadvertent Interchange Calculation & Payback Process, Difference Between Primary & Secondary Inadvertent, Inadvertent Accounting Principles & Describe The Time Error Control Process Including The Roles Of RCS & BAs
3. Describe & Evaluate The Impact On System Operations Of The COM Series Of Reliability Standards
    a. Describe The Content Of The Requirements In COM-001-3 Including The Concept Of & Requirements For Interpersonal Communications
    b. Describe The Content Of The Requirements In COM-002-4 Including The Concept Of An Operating Instruction & Requirements For The Usage Of Three-Way Communications

4. Describe & Evaluate The Impact On System Operations Of The EOP Series Of Reliability Standards
    a. Describe The Content Of The Requirements In EOP-004-4 Including A Description Of NERC's Event Reporting Requirements & NERC's Events Analysis Process
    b. Describe The Content Of The Requirements In EOP-005-3 Including A Description Of The Top's Need For A Restoration Plan, Concept Of A Cranking Path, Concept Of A Blackstart Resource, Explanation Of The Synchronizing Process & A Description Of The Content Of The TOP's System Restoration Plan
    c. Describe The Content Of The Requirements In EOP-006-3 Including A Description Of The RC's Need For A Restoration Plan & The Content Of The RC's Power System Restoration Plan
    d. Describe The Content Of The Requirements In EOP-008-2 Including A Description Of The Requirements For RC, BA & TOP Backup Control Center Functionality
    e. Describe The Content Of The Requirements In EOP-010-1 Including An Explanation Of The GMD Concept, The Impact Of GMDs On The Power System & The Requirements For RC's & TOP's To Mitigate The Effects Of GMDs
    f. Describe The Content Of The Requirements In EOP-011-1 Including A Description Of The Content Of The TOP's & BA's Emergency Operating Plan, The Difference Between Capacity & Energy Emergencies & The Description & Usage Of The Three EEA Levels
5. Describe & Evaluate The Impact On System Operations Of The FAC Series Of Reliability Standards
    a. Describe The Content Of The Requirements In FAC-001-3 & FAC-002-3 Including A Description Of The Need For Facility Connection Requirements & Studies & A Description Of The Items Addressed In NERC's Facility Connection Requirements
    b. Describe The Content Of The Requirements In FAC-003-4 Including An Explanation Of The Need For Vegetation Management Procedures & A Description Of NERCs Vegetation Management Requirements
    c. Describe The Content Of The Requirements In FAC-008-5 Including An Explanation Of The Need For Facility Ratings & A Description Of NERC's Facility Ratings Methodology Requirements
    d. Describe The Content Of The Requirements In FAC-010-3, FAC-011-3 & FAC-014-2 Including A Description Of The Concepts Of SOL, IROL & T_V As Applied In Both The Planning & Real-Time Operations Timeframes
6. Describe & Evaluate The Impact On System Operations Of The INT Series Of Reliability Standards
    a. Describe The Content Of The Requirements In INT-006-5 & INT-009-3 Including A Description Of E-Tag, Illustrate How Interchange Transactions Result In Interchange Schedules, Difference Between Scheduled Path & RTO Scheduling Methods, How Actual Energy Flow Differs From Billed/Scheduled Energy Flow, Concept Of Dynamic Schedules & Pseudo-Ties & Their Tagging Process, Description Of WART's Used In Different Interconnections, Concept Of Ancillary Service, Description Of Four-Step Process (Arrange, Assess, Confirm & Implement) Used To Ensure Interchange Transactions Created In Reliable Manner,

Role Of The BA In Interchange Process, Role Of Transmission Service Provider (TSP) In The Interchange Process, Usage Of HVDC In Interchange Process & How Reliability Entities May Modify Interchange Transactions

7. Describe & Evaluate The Impact On System Operations Of The IRO Series Of Reliability Standards
    a. Describe The Content Of The Requirements In IRO-001-4 Including A Description Of The Role Of The RC In Maintaining A Reliable System & RCs Authority To Issue Operating Instructions
    b. Describe The Content Of The Requirements In IRO-002-7 Including A Description Of The Data & Tools An RC Needs To Do Their Job Function & Need For An RC To Have A Wide Area View
    c. Describe The Content Of The Requirements In IRO-006-5, IRO-006-East-2 & IRO-006-WECC-3 Including A Description Of The Congestion Management Process, TLR Processes Used In Different Interconnections, Usage Of Transmission Distribution Factors, PTDFs, OTDFs & Concept Of A Flowgate
    d. Describe The Content Of The Requirements In IRO-008-2 Including A Description Of The State Estimator, Power Flow & RTCA Tools & Concepts Of Angle Instability, Cascading & Uncontrolled Separation & Concept Of An Operational Planning Analysis
    e. Describe The Content Of The Requirements In IRO-009-2 Including A Description Of The Actions Taken By RC's To Operate Within IROLs
    f. Describe The Content Of The Requirements In IRO-010-3 Including A Description Of The RC's Needs For Data Collection
    g. Describe The Content Of The Requirements In IRO-014-3 Including A Description Of The Need For RC's To Coordinate Operations
    h. Describe The Content Of The Requirements In IRO-017-1 Including A Description Of The Need For RC's To Take The Lead In Coordinating Outages
    i. Describe The Content Of The Requirements In IRO-018-1(i) Including A Description Of The RC's Need To Ensure The Data They Collect For Their Analyses Is High Quality & Difference Between An Operating Plan, Operating Process & Operating Procedure
8. Briefly Describe & Evaluate The Impact On System Operations Of The MOD & NUC Series Of Reliability Standards
    a. Describe The Content Of The Requirements In MOD-001-1a, MOD-004-1, MOD-008-1, MOD-028-2, MOD-029-2a & MOD-030-3 With Respect To The ATC, AFC, TTC & TFC Concepts
    b. Describe The Content Of The Requirements In MOD-025-2, MOD-026-1, MOD-027-1, MOD-031-3, MOD-032-1 & MOD-033-2 With Respect To The Computer Models Created & Used To Simulate Behavior Of Power Systems
    c. Describe The Content Of The Requirements In NUC-001-4 Including A Description Of The Importance Of Documenting Nuclear Plant Interface Requirements (NPIR)
9. Describe & Evaluate The Impact On System Operations Of The PRC Series Of Reliability Standards

a. Describe The Content Of The Requirements In PRC-002-2 Including Describing The IEEE Numbering System, Stating The NERC Definition Of A Protective System & Describing How Different Types Of Disturbance Monitoring Equipment Are Utilized
b. Describe The Content Of The Requirements In PRC-004-6 Including Describing NERC's Protection System Mis-Operation Reporting Requirements
c. Describe The Content Of The Requirements In PRC-005-1.1b & PRC-005-6 Including Describing How Protective Relays, Automatic Reclosing & Sudden Pressure Relays Are Applied, Monitored & Tested & Describe Concepts Of Instrument Transformers & Auxiliary Relays
d. Describe The Content Of The Requirements In PRC-006-5 & PRC-008-0 Including Describing The Purpose & Application Of UFLS Systems
e. Describe The Content Of The Requirements In PRC-010-2 & PRC-011-0 Including Describing The Purpose & Application Of UVLS Systems
f. Describe The Content Of The Requirements In PRC-012-2 & PRC-017-1 Including Describing The Purpose & Application Of RAS
g. Describe The Content Of The Requirements In PRC-019-2 Including Describing The Need For Coordination Of Generator Voltage Regulating Controls & Protection
h. Describe The Content Of The Requirements In PRC-023-4 Including Describing The Need To Ensure That Transmission Protective Relaying Does Not Compromise The Loadability Of The Transmission System
i. Describe The Content Of The Requirements In PRC-024-3 Including Describing NERC Requirements For The Settings Used In Generator Voltage & Frequency Protective Systems
j. Describe The Content Of The Requirements In PRC-025-2 Including Describing The Need To Ensure That Generator Protective Relaying Does Not Compromise The Loadability Of The Generator
k. Describe The Content Of The Requirements In PRC-026-1 Including Describing NERC's Rules For The Application Of Protective Relays That May Respond To Survivable Power Swings
l. Describe The Content Of The Requirements In PRC-027-1 Including Describing The Need For A Protective Relay Coordination Process

10. Describe & Evaluate The Impact On System Operations Of The TOP Series Of Reliability Standards
    a. Describe The Content Of The Requirements In TOP-001-5 Including Describing The Process By Which TOP's & BA's Issue & Receive Operating Instructions, How BA's & TOP's Participate In The Outage Scheduling Process, How TOP's Monitor & Respond To SOL & IROL Exceedances, How TOP's Monitor RAS, How TOP's Conduct Real-Time Assessments & How TOP's Are Dependent On Real-Time Operating Data
    b. Describe The Content Of The Requirements In TOP-002-4 Including Describing How TOP's & BA's Perform Operational Planning Analysis & Create Next-Day Operating Plans

    c. Describe The Content Of The Requirements In TOP-003-4 Including Describing How TOP's Create & Distribute Data Specifications For The Data They Require
    d. Describe The Content Of The Requirements In TOP-010-1(I) Including Describing How TOP's & BA's Perform Their Real-Time Monitoring & Analysis Role & Describe & Illustrate The Different Substation Configurations Used In The BES
11. Describe & Evaluate The Impact On System Operations Of The VAR Series Of Reliability Standards
    a. Describe The Content Of The Requirements In VAR-001-5 Including Describing & Illustrating The MVAr Flow Concept, How TOPs Perform Their Voltage Control Function, How Equipment Is Used To Perform Voltage Control, How TOPs & GOPs Coordinate In The Voltage Control Process, The Concepts Of Rotating & Static Reactive Reserve Sources & The Concepts Of Dynamic & Manual Reactive Reserve Response
    b. Describe The Content Of The Requirements In VAR-002-4.1 Including Describing The Role Of Generators With Respect To Voltage Control, State & Illustrate How The Generator's Excitation System & Voltage Regulator Are Used In The Voltage Control Process, Illustrate The Creation & Usage Of A Generator's Reactive Capability Curve, How GSU Tap Changes Impact The Generator's Ability To Provide & Absorb MVAr & Describe The Concept Of PSS

4. Power System Protection For Operations Personnel
In-Person Course Description (32 CEH / 14 Standards)

Learning Objective: Describe & Illustrate How Power System Protection Is Applied Within The BES, Emphasizing The Power System Operations Perspective

1. Describe The Purpose Of Protective Relaying & List & Define Important Relaying Terms & Concepts Including:
    a. Fundamental Purpose Of Protective Relaying
    b. IEEE's Definition Of Relay & Protective Relay
    c. NERCs Definition Of A Protective Relay System
    d. Purpose & Application Of Protective Relays
    e. Functional Types Of Relays
    f. Quantities & Events Monitored By Protective Relays
    g. Evolution Of Protective Relay Designs From Electro-Mechanical To Todays Microprocessor Numerical
    h. Purpose & Usage Of Relay Targets
    i. Purpose Of & General Types Of Circuit Breakers
    j. ANSI / IEEE Device Numbering System
    k. Usage Of Battery Banks In Protective Relaying
    l. Concept Of A Zone Of Protection
2. Describe The Purpose & Demonstrate The Usage Of The Per-Unit System & Describe The Concepts Of Vectors, Phasors, Synchrophasors & Symmetrical Components:
    a. Purpose Of Per-Unit System
    b. Usage Of Per-Unit Quantities & Formulas
    c. Convert Between Per-Unit, Percent & Ohmic Impedance Values
    d. Usage Of Vectors & Phasors
    e. Purpose & Usage Of North American Synchrophasor Initiative
    f. Purpose & Usage Of Symmetrical Components
3. Describe The Purpose & Illustrate The Usage Of Instrument Transformers, Differential Relays, Over-Current Relays, Distance Relays & Grounding Methods:
    a. Operation Of Instrument Transformers Including CTs, VTs & CCVTs
    b. Application Of Over-Current Relays
    c. Concept Of A Differential Relay
    d. Advantages Of Distance Relays Versus Over-Current Relays
        i. Operation Of Balance Beam Impedance Relay
        ii. Usage Of R-X Diagrams
        iii. How Phase Angles That Occur During Faults Tend To Match Line Impedance Angles
        iv. Difference Between Normal Current Flow & Current Flow During Fault
        v. Difference Between Phase-Fault & Ground-Fault Distance Relays
        vi. How Impedance Based Fault Locator Systems Work
        vii. Usage Of Three-Zone Stepped Distance Protection System
        viii. How Faults On The Transmission System Appear To Distance Relays Using R-X Diagrams

        ix. How Z3 Applications Are Limited By PRC-023-4
    e. Using PRC-027-1 As A Reference, State NERC's Goals For Protective Relay Coordination
    f. Differences Between Ungrounded, High Impedance Grounded, Low Impedance Grounded & Solid Grounded Power Systems
    g. Purpose & Construction Of A Zig-Zag Transformer
4. Describe & Illustrate Transmission Line Protection Concepts Including:
    a. Usage Of Non-Directional Inverse Time Overcurrent Relays To Protect Radial Lines
    b. Coordination Issues Involved In Looped Line Protection
    c. Application Of PRC-023-4 To Transmission Line Protection
    d. Difference Between Primary Backup, Local Backup & Remote Backup
    e. Terminology Used To Classify Pilot Protection Schemes
    f. Telecommunication Methods Used In Pilot Protection
    g. Design & Operation Of The Following Pilot Protection Schemes:
        i. Direct Under-Reaching Transfer Trip (DUTT)
        ii. Permissive Under-Reaching Transfer Trip (PUTT)
        iii. Permissive Over-Reaching Transfer Trip (POTT)
        iv. Directional Comparison Blocking (DCB)
        v. Directional Comparison Un-Blocking (DCUB)
        vi. Line Current Differential (LCD)
    h. How Pilot Schemes Are Impacted By The Requirements In PRC-023-4
5. Describe & Illustrate Generator Protection Concepts Including:
    a. Common Types Of Generators
    b. Hazards Generators Are Typically Protected Against
    c. Describe Features Of Manufacturers Generator Protective Relays
    d. Describe How Generators Are Protected From The Occurrence Of The Following Hazards:
        i. Phase/Ground Faults In Stator
        ii. Ground Faults In Rotor
        iii. Loss Of Field Excitation
        iv. Over & Under Excitation
        v. Motoring
        vi. Synchronizing Issues
        vii. Unbalanced Currents
        viii. Abnormal Frequency Operation
        ix. Breaker Pole Flashover
        x. Delayed Clearing Of System Faults
        xi. Over-Voltage
        xii. O-O-S Operation
        xiii. Field Grounds
    e. IBR Inverters & Collector System Protection
    f. Illustrate Overall Generator Protection Schemes
    g. How PRC-019-2 Requires Coordination Between Generator's MVA Capability, Voltage Regulating Controls & Protective Relaying

h. How PRC-024-3 Restricts Voltage & Frequency Based Generator Protection Settings To Within Allowable Limits
i. How PRC-025-2 Requires Generator Protection Not Limit Loadability Of Generators

6. Describe & Illustrate Transformer, Reactor & Capacitor Protection Concepts Including:
    a. How Following Issues Impact Power Transformer Protection:
        i. Magnetizing In-Rush Current
        ii. Over-Excitation
        iii. CT Saturation
        iv. Different Primary / Secondary Voltage Levels
        v. Phase Shifts
        vi. Transformer Taps
    b. How Power Transformers Are Protected
    c. Application Of A Transformer Differential Relay
    d. How Intentional Fault Switches Are Used In Transformer Protection
    e. How Transformers Are Protected From Occurrence Of Following Hazards:
        i. Dissolved Gas In Oil
        ii. Thermal Damage
        iii. Primary Protection Failure
    f. Describe How Overall Transformer Protection Is Accomplished
        i. How PRC-023-4 Limits The Application Of Overload Protection In Transformers
    g. How Shunt Capacitors & Shunt Reactors Are Protected
7. Describe & Illustrate The Application, Design & Operation Of Bus Differential Relays Including:
    a. How CT Saturation Impacts Bus Differential Protection
    b. Concept Of End-Zone Fault Detection
    c. Operation & Application Of Low Impedance Bus Differential
    d. Operation & Application Of High Impedance Bus Differential
    e. Layout Of Following Substation Bus Configurations & How Differential Relays Are Applied:
        i. Single Bus - Single CB
        ii. Single Bus - Single CB With Bus Sectionalizing CB
        iii. Main & Transfer
        iv. Ring
        v. Breaker-&-A-Half
        vi. Double Bus - Double CB
8. Describe & Illustrate Additional Protection Topics Including:
    a. Review Concept Of Angle Stability
    b. How Impedance Relays Are Used To Detect O-O-S Power Swings
    c. How PRC-026-1 Impacts The Usage Of O-O-S Protection
    d. Purpose & Issues Associated With Automatic Reclosing In High Voltage Transmission System

e. Use Of UVLS Schemes & How UVLA Schemes Are Designed In Accordance With PRC-010-2
f. Use Of UFLS Schemes & How UFLS Schemes Are Designed In Accordance With PRC-06-5
g. Step-Through The NERC Definition Of RAS & Review An Example Of A RAS Application & Describe The Content Of PRC-012-2

5. Dynamics Of Power System Disturbances
In-Person Course Description (32 CEH 13 Standards)

Learning Objective: Using IEEE, FERC, NERC, Regional Entity & Involved Company Disturbance Reports Step Through & Describe The Sequence Of Events During Actual Power System Disturbance Events

1. Step Through & Describe The Sequence Of Events During The 11/9/1965 Disturbance Event In The Northeastern Portion Of The Eastern Interconnection
    a. Description Of The Event Focuses On How The Tools The Industry Has Available Today (Such As RTCA, RSGs, UFLS, Loadability Standards & PSR Procedures Including Designated BSRs) Were Not Widely Available In 1965 & The Consequences Of That Lack Of Tools In A Heavily Stressed System. The Operation Of Z3 Impedance Relays Leading To An Impedance Cascade Is Also Explained & Illustrated.
2. Step Through & Describe The Sequence Of Events During The 2/14/2008 Disturbance Event @ The Huntington Generator In The Western Interconnection
    a. Topics Addressed Include The Importance Of Recovering ACE Following A Generation Loss As Required By BAL-001-2, The Importance Of Recovering Contingency Reserve As Required By BAL-002-3, The Consequences Of Single Points Of Failure In Protection Systems & The Role Of An RC During A Major Disturbance As Stated In IRO-001-4.
3. Step Through & Describe The Sequence Of Events During The 11/09/2016 California ISO Event In The Western Interconnection
    a. Topics Addressed Include How Incorrect Generation Dispatch Orders Resulted In The BA Developing An ACE Of -3,245 MW & Frequency Dropping To 59.83 HZ. Examine This Event From A BAL-001-2, BAL-002-3, IRO-001-4 & IRO-006-5 Perspective.
4. Step Through & Describe The Sequence Of Events During The 8/14/2003 Disturbance Event In The Eastern Interconnection
    a. Topics Addressed Include The Importance Of Accurate System Operator Communications As Required By COM-002-4, The Need For Vegetation Management Rules As Required By FAC-003-4: “Transmission Vegetation Management”, The Importance Of Situational Awareness & The Need For TOPs & RCs To Have Operational Analyses & Real Time Assessment Tools As Mandated By IRO-008-2, The Need For Transmission Loadability Rules As Required By PRC-023-4 & The Mechanics Of An Impedance Cascade, The Need For Each Transmission Operator To Maintain Adequate Dynamic Reactive Reserves As Mandated By VAR-001-5, The Relationship Between Voltage Control & Angle Stability & How This Disturbance Moved The Electric Industry From The Then Existing Operating Policies To Today's Mandatory Reliability Standards.
5. Step Through & Describe The Sequence Of Events During The 7/02/1996 & 8/10/1996 Disturbance Events In The Western Interconnection
    a. Topics Addressed Include The Importance Of Dynamic Reactive Reserves As Stated In VAR-001-5: “Voltage & Reactive Control”, The Need For Accurate

Generator Capability Curves In As Stated In MOD-025-2: “Verification & Data Reporting Of Generator Real & Reactive Power Capability & Synchronous Condenser Reactive Power Capability”, The Mechanics Behind The Formation Of Islands During Disturbances & Illustrate Oscillatory Instability Using Actual Plots Of The 8/10/1996 Transmission Line Flows.

6. Step Through & Describe The Sequence Of Events During The 3/13/1989 Disturbance Event In The Quebec Interconnection
    a. Topics Addressed Include The Concepts Of CMEs, GICs & ESPs, The Purpose & Usage Of The K-Indice & G-Scale, How The Loss Of Key Voltage Control Equipment Led To The Collapse Of The Quebec Power System, How The Salem Nuclear Unit’s GSU Was Damaged Shortly After The Event By GIC Flow, The Content Of EOP-010-1: “Geomagnetic Disturbance Operations”, With Respect To TOP & RC GMD Monitoring Responsibilities & Examine TPL-007-4: “Transmission System Planned Performance for Geomagnetic Disturbance Events”, With Respect To System Planners GMD Preparedness.
7. Step Through & Describe The Sequence Of Events During The 6/25/1998 Disturbance Event In The MAPP (Now MRO) Area Of The Eastern Interconnection
    a. Topics Addressed Include The Importance Of Recovering Rapidly From An IROL Exceedance As Stated In IRO-009-2: “RC Actions To Operate Within IROLs” & TOP-001-5: “Transmission Operations”, The Impact Of The Unexpected Operation Of Reclosing Relays During Disturbance Events & The Importance Of Coordinating OOS Tripping & Blocking Relays.
8. Step Through & Describe The Sequence Of Events During The 6/14/2004 Disturbance Event In The Arizona Area Of The Western Interconnection
    a. Topics Addressed Include The Need To Maintain Protective Relay Components As Required By PRC-005-6: “Protection System, Automatic Reclosing, & Sudden Pressure Relaying Maintenance”, Consequences Of Incorrect Assumptions Of CB Position (Open Versus Closed), The Dangers Associated With Voltage Phase Angle Growth During Extended Faults, The Importance Of Recovering From An IROL Exceedance Within The T_V Value As Described In IRO-009-2: “RC Actions To Operate Within IROLs” & TOP-001-5: “Transmission Operations” As Related To The Overload That Results On WECC’s Path #66.
9. Step Through & Describe The Sequence Of Events During The 2/26/2008 Disturbance Event In The Florida Area Of The Eastern Interconnection
    a. Topics Addressed Include The Consequences Of Protection Engineers & System Operators Intentionally Disabling Primary & Backup Protection, The Impact Of Location Related Differences In Transient Frequency, The Impact Of Frequency Oscillations, The Operation Of Florida’s UFLS Scheme In The Context Of Standard PRC-006-5: “Automatic UFLS” & The Need For Properly Trained TOP & RC System Operators As Stated In PER-003-2: “Operating Personnel Credentials”.
10. Step Through & Describe The Sequence Of Events During The 9/8/2011 Disturbance Event In The Southwest Corner Of The Western Interconnection
    a. Topics Addressed Include The Importance Of Testing & Understanding The Operation Of RAS As Stated In PRC-012-2: “RAS”, The Need For RCs & Their

Responsibility To Act To Maintain Reliability As Required By IRO-001-4: “RC - Responsibilities”, The Cause Of Large Voltage Phase Angles Across Open CBs, The Consequences Of Skipping Steps In Switching Orders & The Purpose Of PRC-023-4: “Transmission Relay Loadability” From A Transformer Loadability Perspective.

11. Step Through & Describe The Sequence Of Events During The Following 10 Disturbance Events That Involved Photo-Voltaic (PV) Inverter Based Resources (IBRs). Topics Addressed Include The Need For Compliance With PRC-024-3 From A Frequency & Voltage Ride-Through Perspective, Compliance With VAR-002-4.1 From A Voltage Support Perspective & Compliance With PRC-027-1 From A Fault Current Supply Perspective.
    a. California Blue Cut Fire Disturbance – 8/16/2016
    b. California Canyon 2 Fire Disturbance – 10/9/2017
    c. California Angeles Forest Disturbance – 4/20/2018
    d. California Palmdale Roost Disturbance – 5/11/2018
    e. California San Fernando Disturbance – July 7, 2020
    f. Texas Odessa Disturbance – 5/9/2021 & 6/26/2021
    g. California Victorville Disturbance – 6/24/2021
    h. California Tumbleweed Disturbance – 7/4/2021
    i. California Windhub Disturbance – 7/28/2021
    j. California Lytle Creek Fire Disturbance – 8/25/2021
12. Step Through & Describe The Sequence Of Events Within The ERCOT, SPP & MISO Systems During The February 2021 Extreme Cold Weather Event
    a. Topics Addressed Include A Description Of The ERCOT, SPP & MISO Power Systems & Their Operations, The Need For Coordination Among RCs As Stated In IRO-014-3, The Performance Of Wind Turbine & Natural Gas Generation During The Event, The Usage Of EEAs (As Stated In EOP-011-2) During The Event, The Recent (10 Year) History Of Extreme Cold Weather In NERC, The Impact Of Cold Weather On Various Types Of Generation, The Use Of Load Shedding To Correct A BA’s ACE, The Use Of Load Shedding To Respond To A Transmission Emergency As Stated In EOP-011-2, The Value Of Interconnections To Neighboring Systems During Generation Shortages & A Review Of The Key Recommendations From The FERC/NERC Report On The February 2021 Cold Weather Outages.