CONCEPT

Power System Stability and Blackout Prevention: Load Shedding, Black Start and Restoration

Power System Stability and Blackout Prevention: Load Shedding, Black Start and Restoration

Introduction:

Power system stability is tested in seconds: a line trip, a lost generator or a slow voltage decline can turn into a wide-area blackout long before operators understand the sequence, and restoration then depends on plans that were rarely drilled. This Core Concept course prepares transmission, generation and control-room staff to read frequency, voltage and rotor angle behaviour, design defence measures such as load shedding, remedial action schemes and controlled islanding, and restart a grid from black start sources. Participants produce a Blackout Risk Review and Restoration Plan for a sample grid.

Course Objectives:

- Classify a disturbance by its frequency, voltage and rotor angle signature and state which operating state the system has entered
- Calculate inertia, droop and reserve effects on frequency nadir after a large infeed loss and check reserve sizing against it
- Assess voltage stability margin from PV and QV curves and plan reactive reserves that prevent long-term voltage collapse
- Design under-frequency and under-voltage load shedding stages, remedial action schemes and islanding boundaries for a transmission network
- Prepare a black start and restoration plan with cranking paths, island resynchronisation and load pickup sequence
- Run restoration drills and review stability margins for grids with a growing share of inverter-based resources

Target Audience:

- Transmission system engineers who carry out operational security, contingency and stability studies
- Control-room dispatchers and shift supervisors who act on alarms, reserves and emergency switching
- Generation engineers responsible for unit frequency response, reactive capability and black start readiness
- Operation planning engineers who prepare outage schedules, defence plans and restoration procedures
- Grid code and system operation specialists who review generator performance and ride-through behaviour

Course Outline:

Day 1: Power System Operation Fundamentals and Security States

- Generation-Load Balance, Economic Dispatch and Control Area Responsibilities
- N-1 Security Criterion and Normal, Alert, Emergency and Restorative Operating States
- Stability Classification into Rotor Angle, Frequency and Voltage Families
- SCADA and EMS Control-Room Displays, State Estimation and Contingency Alarms
- Blackout Anatomy: Initiating Event, Cascade Phase and Collapse Sequence

Day 2: Frequency Control, Inertia and Operating Reserves

- System Inertia, Swing Equation and Rate of Change of Frequency ROCOF
- Governor Droop Response and Primary Frequency Containment Reserve
- Load-Frequency Control, Area Control Error and Secondary Reserve Activation
- Tertiary Reserve Scheduling and Largest Credible Infeed Loss Sizing
- Frequency Nadir and Settling Point Calculation for a Generator Trip

Day 3: Voltage Stability and Reactive Power Management

- Reactive Power Sources: Generator Capability Curves, Capacitor Banks, SVC and STATCOM
- PV and QV Curve Analysis and Loadability Margin to the Nose Point
- On-Load Tap Changer Action and Load Recovery in Long-Term Voltage Collapse
- Overexcitation Limiter Operation and Reactive Reserve Monitoring
- Voltage Control Hierarchy and Reactive Power Dispatch Schedules

Day 4: Rotor Angle Stability and Wide-Area Monitoring Tools

- Power-Angle Curve and Equal Area Criterion for Transient Stability
- Critical Clearing Time and Fault Duration Effects on Synchronism
- Small-Signal Oscillations: Local and Inter-Area Modes and Damping Ratio
- Power System Stabiliser Role and Modal Analysis Output Interpretation
- Phasor Measurement Units and Wide-Area Oscillation Detection Displays

Day 5: Cascading Failures and Major Blackout Lessons: Guided Case Study

- Cascade Mechanisms: Overload Transfer, Hidden Failures and Backup Zone Trips
- Major Interconnection Blackouts as Published Investigation Reports Describe Them
- Vegetation Contact, Situational Awareness and Alarm Handling Gaps in Blackout Sequences
- Event Timeline Reconstruction from Sequence-of-Events and Disturbance Logs
- Week-One Debrief: Frequency, Voltage and Angle Signatures in One Disturbance

Day 6: Defence Plans: Load Shedding, Special Protection Schemes and Islanding

- Under-Frequency Load Shedding Stage Design: Thresholds, Load Blocks and Time Delays
- Under-Voltage Load Shedding Logic for Delayed Voltage Recovery
- Special Protection and Remedial Action Schemes: Generator Tripping and Arming Logic
- Controlled Islanding Boundaries and Separation Point Selection
- Island Frequency and Voltage Control with Limited Generation

Day 7: Black Start Capability, Restoration Strategy and Plan Governance

- Black Start Unit Types: Hydro, Diesel, Open Cycle Gas Turbine and Battery Storage
- Cranking Paths, Energisation Sequences and Overvoltage on Lightly Loaded Lines
- Bottom-Up, Top-Down and Hybrid Restoration with Island Resynchronisation
- Cold Load Pickup, Load Block Sizing and Synchronism Check Criteria
- Black Start Service Procurement, Capability Testing and Restoration Plan Approval

Day 8: Emergency Coordination, Operator Drills and Communication

- Emergency Operating Procedures and Dispatcher Authority During System Emergencies
- Coordination Protocols Between Transmission Operator, Generators and Distribution Utilities
- Restoration Drill Design Using Dispatcher Training Simulator Scenarios
- Critical Load Customer Notification and Public Information Plans
- Post-Event Investigation Reports and Lessons Learned Action Tracking

Day 9: Low-Inertia Grids, Inverter-Based Resources and Resilience Metrics

- Inverter-Based Resource Fault Current Limits and Short Circuit Ratio Assessment
- Grid-Forming Converters, Synchronous Condensers and Fast Frequency Response
- Fault Ride-Through Behaviour and Loss of Distributed Generation in Disturbances
- SAIDI, CAIDI and Unserved Energy Tracking After Major Events
- Stability Margin Dashboard: ROCOF Limits, Reactive Reserve and Minimum Inertia

Day 10: Capstone: Blackout Risk Review and Restoration Plan for a Sample Grid

- Sample Grid Briefing: Network Model, Generation Mix and Critical Contingencies
- Blackout Risk Register Build with Credible Cascade Likelihood and Consequence Scoring
- Defence Plan Check Against Load Shedding Stages, Remedial Schemes and Island Points
- Restoration Plan Drafting: Black Start Sources, Cranking Paths and Load Pickup Order
- Blackout Risk Review and Restoration Plan Presentation and Peer Challenge

Skills You Will Gain:

- Disturbance Signature Analysis
- Frequency Response Assessment
- Reactive Reserve Planning
- Load Shedding Scheme Design
- Controlled Islanding Strategy
- Black Start Sequence Planning
- Restoration Drill Facilitation
- Low-Inertia Grid Assessment

Why Attend This Course:

- Return with a Blackout Risk Review and Restoration Plan built and challenged on a sample grid, ready to adapt to your own network
- Recognise the early frequency, voltage and oscillation signs of a cascade and know which defence action applies
- Rehearse restoration decisions under time pressure in simulated control-room scenarios before a real event demands them
- Compare operating and restoration practice with engineers from utilities, independent generators, industrial networks and system operators

Conclusion:

Blackout prevention rests on knowing how a grid loses stability and having tested plans for both defence and recovery. The first week builds that understanding through operating states, frequency control, voltage stability, rotor angle behaviour and cascade case study. The second week adds what a short course leaves out: load shedding and remedial scheme design, islanding, black start and restoration strategy, emergency coordination and drills, and low-inertia challenges. The final day brings these together in a Blackout Risk Review and Restoration Plan presented for peer challenge.