ENERGY CANON

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Abstract

Example

Contents

The Bulk Electric System (BES) MUST maintain frequency and voltage within tolerance under all credible contingencies.

Example: NERC CIP (Critical Infrastructure Protection) 13 mandatory reliability standards (CIP-002 through CIP-014) governing cyber and physical security of BES assets. CIP-002 requires identification and categorization of BES Cyber Systems (High, Medium, Low impact). CIP-007 mandates system security management including patch management, malware prevention, and security event monitoring. N-1 contingency system must survive loss of any single element (generator, transformer, transmission line) without cascading failure. Frequency regulation: 60.000 Hz nominal (North America), ś0.036 Hz (interconnection frequency error), AGC (Automatic Generation Control) dispatches within 4-second scan rate. Voltage regulation: ś5% of nominal at POI (Point of Interconnection). NERC TPL-001-5 (Transmission Planning) requires steady-state and stability analysis for P1-P7 contingency categories. BAL-001-2 (Real Power Balancing Control Performance) CPS1 minimum 100%, CPS2 minimum 90%.

0.1 2. Nuclear Safety

Nuclear facilities MUST implement defense-in-depth with multiple independent barriers and maintain radiation exposure ALARA.

Example: NRC 10 CFR 50 (Domestic Licensing of Production and Utilization Facilities) governs reactor licensing including design basis accidents, emergency core cooling, containment, and technical specifications. 10 CFR 73 (Physical Protection of Plants and Materials) requires armed response force, vehicle barriers, intrusion detection, and Design Basis Threat (DBT) protection. Defense-in-depth: five barriers fuel matrix, fuel cladding, reactor coolant pressure boundary, containment, and exclusion zone. ALARA (As Low As Reasonably Achievable) 10 CFR 20 limits: 5 rem/year total effective dose equivalent (TEDE) for occupational work-

ers, 100 mrem/year for public. NQA-1 (Nuclear Quality Assurance) 18 requirements for quality programs applicable to nuclear facilities (design control, procurement, inspection, test control, corrective action, records, audits). GDC (General Design Criteria) in 10 CFR 50 Appendix A 64 criteria including single failure criterion, redundancy, independence, and testability. PRA (Probabilistic Risk Assessment) core damage frequency target < 1E-4/reactor-year for existing plants, < 1E-5 for new designs.

0.2 3. Metering & Evidence

Energy measurement and substation automation MUST produce tamper-evident, standards-compliant evidence chains.

Example: IEC 61850 (Communication Networks and Systems for Power Utility Automation) defines GOOSE (Generic Object Oriented Substation Event) for < 4ms peer-to-peer trip signaling, MMS (Manufacturing Message Specification) for client-server, SV (Sampled Values) for merging units at 4800 samples/cycle. IEC 62351 (Power Systems Management and Associated Information Exchange Security) Parts 1-14 covering authentication, TLS, role-based access, key management for SCADA/EMS. AMI (Advanced Metering Infrastructure) smart meters with 15-minute interval data, two-way communication, remote connect/disconnect, tamper detection. DLMS/COSEM (Device Language Message Specification / Companion Specification for Energy Metering) IEC 62056 series defining meter data exchange, OBIS (Object Identification System) codes, and security suites (0-2). Revenue metering accuracy: ANSI C12.20 (ś0.2% for Class 0.2, ś0.5% for Class 0.5). Measurement Canada standards for custody transfer metering in gas/oil: ś0.25% for liquid hydrocarbons.

0.3 4. Interconnection

Distributed energy resources MUST meet interconnection standards and grid support requirements at the point of common coupling.

Example: IEEE 1547 (Standard for Interconnection and Interoperability of Distributed Energy Resources) 2018 revision requires voltage regulation (Category A/B/C), frequency ride-through (mandatory operation 57.0-61.8 Hz), voltage ride-through (Category I/II/III), and communication interface (IEEE 2030.5, SunSpec Modbus, DNP3). FERC Order 2222 (2020) enables DER aggregations to participate in wholesale markets through ISOs/RTOs, minimum 100 kW aggregation. Anti-islanding: IEEE 1547 requires ceasing to energize within 2 seconds of island detection, using passive (voltage/frequency shift) and active (impedance measurement, frequency shift) methods. Ride-through requirements: must remain connected during voltage sags to 0.50 p.u. for up to 1.0 second (Category III). IEEE 1547.1 conformance test procedures. UL 1741 SA (Supplement A) smart inverter testing for advanced grid-support functions. FERC Order 828 primary frequency response required for all new generators > 20 MW.

0.4 5. Renewable Integration

Renewable generation MUST comply with equipment standards, grid codes, and curtailment governance to maintain system reliability.

Example: IEC 61400 (Wind Energy Generation Systems) Part 1: design requirements (Class I/II/III/S turbines by wind speed), Part 2: small wind turbines, Part 12: power performance testing, Part 25: communications (using IEC 61850 profiles). IEC 61215 (Terrestrial Photovoltaic Modules Design Qualification) tests including thermal cycling (200 cycles, -40C to 85C), damp heat (1000 hours, 85C/85% RH), mechanical load (5400 Pa front, 2400 Pa rear). IEC 61730 (PV Module Safety) Class A (general) and Class B (restricted access) safety qualification. Grid

codes: ERCOT Nodal Operating Guide (Texas), CAISO tariff (California), EirGrid Grid Code (Ireland) each specifying reactive power capability, ramp rate limits, and forecasting requirements. Curtailment governance: economic curtailment (negative pricing events), reliability curtailment (transmission congestion), and environmental curtailment (bat/bird mitigation hours). Renewable Portfolio Standards (RPS): state-level mandates (California SB 100 100% clean energy by 2045). IEC 62817 solar tracker design qualification.

0.5 6. Market Operations

Energy market transactions MUST follow ISO/RTO market rules with transparent pricing, settlement, and ancillary service procurement.

Example: ISO/RTO markets 7 US ISOs: CAISO, ERCOT, ISO-NE, MISO, NYISO, PJM, SPP. LMP (Locational Marginal Pricing) = energy component + congestion component + loss component, calculated at each node every 5 minutes (real-time) and hourly (day-ahead). Capacity markets: PJM RPM (Reliability Pricing Model), ISO-NE FCM (Forward Capacity Market) 3-year forward procurement. Ancillary services: regulation (AGC responsive, śramp in 4 sec), spinning reserve (10-minute synchronized), non-spinning reserve (10-minute offline), supplemental reserve (30-minute), voltage support (MVAR), black start capability. Demand response: FERC Order 745 DR compensated at LMP when cost-effective. Virtual transactions: financial traders buy/sell at nodes to arbitrage DA/RT price differences. Market monitoring: Independent Market Monitor (IMM) conduct and impact tests, mitigation of market power (offer caps, structural remedies). OATT (Open Access Transmission Tariff) FERC-mandated non-discriminatory transmission service.

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1. Constraints

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MUST:     Cite NERC CIP standard, NRC regulation, or I
MUST:     Distinguish between grid monitoring (observa
MUST NOT: Equate SCADA data acquisition with governanc
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