NUCLEAR POWER PLANT ELECTRICAL ENGINEERING

Offsite Power, Switchyard
and the balance of plant

Non-safety-related electrical engineering for the operating fleet, restarts, uprates, small modular reactors and co-located load — grid interface, switchyard, balance-of-plant distribution and the power system studies the licensing basis rests on.

The safety case is the licensee's. The network it depends on is mostly not safety-related — and that is where an outside electrical engineer earns their place.

The grid, the switchyard, the generator step-up and auxiliary transformers, the non-1E distribution system: nearly the whole path that General Design Criterion 17 depends on is non-safety-related equipment. So is the analysis of it. Keentel Engineering provides that scope — offsite power adequacy and degraded voltage studies, switchyard and protection engineering, balance-of-plant electrical design, grid interface coordination and the study set behind them — working within the licensee's own quality assurance programme rather than around it.

30+	4	4–765 kV	4
YEARS ACROSS TRANSMISSION, GENERATION & SUBSTATIONS	MARKETS — FLEET, RESTART, SMR AND CO-LOCATION	STUDY VOLTAGE RANGE PLANT TO GRID	U.S. OFFICES — TAMPA, AUSTIN, SACRAMENTO, BALTIMORE

SCOPE | Offsite power & grid interface | Switchyard | Balance of plant | Power system studies | SMR & new build | Co-located load

WHERE WE WORK

01
Grid interface
Offsite power adequacy, stability, degraded voltage, transmission coordination.

02
Switchyard
Configuration, protection, relaying, breaker duty, condition and modernization.

03
Plant electrical
GSU and auxiliary transformers, isolated phase bus, non-1E distribution.

04
Studies
Load flow, short circuit, coordination, motor starting, transient stability, arc flash.

05
Modifications
Design packages and technical basis feeding the licensee's change process.

06
New build
SMR and advanced reactor electrical design and grid integration.






START A SCOPE ›› Tell us the plant, the driver and the classification boundary you need respected — we return a scoped fee, a schedule and a clear statement of what sits inside your QA programme.

NSPE | D·U·N·S REGISTERED | IEEE SENIOR MEMBER | BBB ACCREDITED A+

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SAY IT BEFORE THE FIRST MEETING

Where Our Scope Begins and Ends

In this industry an unclear answer about quality classification is disqualifying. Here is ours, in writing, on the second page.

CLASSIFICATION	WHAT IT COVERS	KEENTEL'S POSITION
Safety-related	Structures, systems and components relied on to remain functional during and after design-basis events. Full 10 CFR 50 Appendix B quality assurance, and environmental qualification where applicable	We do not hold our own Appendix B programme and do not act as the Appendix B supplier of record or as a commercial-grade dedicating entity. Where work touches this scope, it is performed **within the licensee's programme** or under an Appendix B prime
Augmented quality	An optional subset of non-safety-related carrying enhanced controls — fire protection under Appendix R, post-accident monitoring, station blackout mitigation, seismic interaction, regulatory commitments	Performed to the licensee's augmented-quality controls, with the licensee's verification and acceptance
Non-safety-related	No safety function and no credible failure impact on safety-related equipment. Commercial-grade treatment. This is most of the switchyard, the generator and its transformers, the isolated phase bus, and the non-1E distribution system	**Our core scope, in our own right.** Design, analysis, studies, specifications and modification packages

How We Actually Work

- **Non-safety-related scope in our own right.** Switchyard, generator step-up and auxiliary transformers, isolated phase bus, non-1E distribution, arc flash, lighting, grounding, cable and generator protection — no Appendix B programme required, and it is the majority of the electrical work at a station.
- **Inside the licensee's quality assurance programme.** Task-order and staff-augmentation work performed to your procedures, with your design verification, checking and approval. The regulation expressly allows a licensee to delegate the execution of programme work while retaining responsibility for the programme — that is the standard route and we are comfortable in it.
- **As a design-input and analysis provider.** Load flow, short circuit, coordination, motor starting, transient stability, degraded voltage and grid adequacy studies delivered as information that the licensee independently verifies and accepts into its own design basis.
- **As a subcontractor to an Appendix B prime** — an architect-engineer, an OEM or a nuclear quality engineering house that performs verification and carries supplier responsibility.

On 10 CFR Part 21

Part 21 reaches consulting services associated with basic components. Because our scope is non-safety-related and we do not dedicate commercial-grade items, those obligations do not attach to our deliverables — and we say so explicitly in the scope of work rather than leaving it ambiguous.

The 50.59 Question

- **The evaluation is the licensee's regulatory act.** A screening or evaluation performed outside a licensee-controlled process has no standing, and we do not present one as if it did.
- **What we produce** is the engineering change package and the technical basis that feeds the screen, together with the safety analysis report markups it requires.
- **Where our people are trained and qualified under your programme**, they can perform the evaluation within it.
- **The trap we watch for.** One of the eight criteria is a departure from a method of evaluation described in the safety analysis report. Replacing the methodology your licensing basis credits — a new load flow method behind degraded-voltage setpoints, for instance — can force a licence amendment. That is a decision to make deliberately at the start of a study, not to discover at the end of one.

Why we lead with this

Because every nuclear client asks it, and because a firm that answers it vaguely is telling you something. Knowing exactly which side of the line a deliverable sits on is part of the competence being purchased.

IF THE SCOPE CHANGES Building a nuclear quality assurance programme to the endorsed consensus standard is a business decision, not a legal barrier. If a client relationship justifies it, the path runs through a programme build and a supplier audit — and we will say so plainly rather than overstate today's position.

THE LEAD CAPABILITY

Offsite Power & the Grid Interface

Criterion 17 is a requirement on the grid, the switchyard and the transformers — almost all of it non-safety-related equipment, all of it analysed with power system engineering.

What the Regulation Requires

- **General Design Criterion 17** requires both an onsite and an offsite electric power system, each with capacity and capability to keep vital functions available. The offsite system needs **two physically independent circuits** from the transmission network, designed and located to minimise the likelihood of simultaneous failure, with one available within seconds after a loss-of-coolant accident.
- **Criterion 18** adds periodic inspection and testing of the full operating sequence, including protection systems and power transfers.
- **The station blackout rule** requires the plant to withstand and recover from a loss of offsite power concurrent with unavailability of onsite emergency AC, for a coping duration driven by source redundancy and reliability, expected loss-of-offsite-power frequency and expected restoration time — with an alternate AC source available within ten minutes removing the coping analysis requirement.
- **Standard Review Plan Chapter 8** sets the acceptance criteria: Section 8.2 for the offsite power system, 8.3.1 and 8.3.2 for onsite AC and DC, and 8.4 for station blackout.

The Branch Technical Positions That Bite

- **Stability of offsite power systems** — the transient and steady-state stability case for the transmission network supplying the plant.
- **Adequacy of station electric distribution system voltages** — the degraded voltage position, and the most consequential analysis in this scope.
- **Allowed outage time extensions** for onsite and offsite power sources — where a risk-informed technical basis is required.
- **Open phase conditions** — the design vulnerability that conventional undervoltage protection does not detect.

THE HIGHEST-VALUE ANALYSIS IN THIS SCOPE

Degraded Voltage

The NRC's current statement of expectations is explicit, and every clause of it is a power system engineering task:

> Degraded voltage relay setpoints derived from voltage calculations based on the **actual plant distribution design**, not generic assumptions

> Calculations that model the offsite circuits **and** the plant distribution system — including **all plant equipment, non-safety-related included**, that can affect voltage supplied to safety-related equipment

> Adequacy demonstrated **at the terminals of each safety-related load**, for both starting and running conditions, across all operating configurations and accident scenarios

> Analysis performed against the **bounding worst-case transmission contingency**, including a unit trip during an accident

The acceptance criterion lands on safety-related terminals. The network being modelled is mostly not.

Open phase — closed as an issue, live as a design feature

A single- or two-phase open on an offsite circuit that undervoltage protection does not see. The generic regulatory action was formally closed in 2023 after the industry installed detection schemes, and a branch technical position now exists for new applications — but the detection scheme, its settings and its interaction with the rest of the protection remain live engineering.

Open Phase

A single open conductor on the offsite supply can leave voltage present and conventional undervoltage protection unpicked, while safety-related loads see an unbalanced supply. The analysis is an unbalanced model of the offsite circuit and the plant distribution system together, followed by detection scheme design and setting.

Allowed Outage Time

Extending the time a source may be out of service needs a technical basis, not an argument — source availability and restoration data, the contingency set that governs the remaining supply, and a defensible statement of what the plant is exposed to for the duration.

Backfeed & Startup

Where the startup path runs backwards through the generator step-up transformer, the offsite power case depends on generator breaker configuration, transformer tap position and switchyard configuration — a set of assumptions worth verifying against the plant as it is operated today.

WHAT WE DELIVER Offsite power adequacy and grid stability studies · Degraded and loss-of-voltage analysis and setpoint basis · Switchyard failure modes and effects analysis · Open phase detection design and settings · Backfeed and startup path analysis · Station blackout coping and alternate AC evaluation support

WHERE THE LICENSING BASIS MEETS THE TRANSMISSION MODEL

NUC-001 & Transmission Coordination

How the Standard Works

- **The plant defines Nuclear Plant Interface Requirements** — the electrical conditions and operational parameters the transmission system must deliver for safe operation and shutdown. These are the bridge between the plant's licensing basis and the grid operator's obligations.
- **The nuclear plant generator operator** provides those requirements in writing to the transmission entities and establishes formal written agreements documenting how they will be implemented.
- **Transmission entities** incorporate them into **planning** analyses and communicate the results, and into **operating** analyses — operating the system to meet them and notifying the plant when the capability to assess conformance is lost.
- **Both parties** coordinate outages and maintenance affecting the requirements, and inform each other of design or operational changes affecting conformance.
- **The agreements themselves** must cover technical requirements, operations coordination, maintenance, communications protocols, training and emergency protocols.
- **Applicability is broad** on the transmission side — operators, owners, planners, service providers, balancing authorities, reliability coordinators, planning coordinators and distribution providers.

Where We Sit

- **Translator between two technical languages.** The plant speaks in design-basis voltages and accident scenarios; the transmission planner speaks in contingency sets and power flow cases. The interface requirements are where those have to reconcile, and they frequently do not.
- **Reconciling study assumptions.** The bounding contingency in your degraded voltage calculation and the contingency set in the transmission planning model should be the same thing. Confirming that they are is a specific, checkable piece of work.
- **Interface requirement development and review** — drafting, technical basis, and review against the current transmission system rather than the one that existed when the requirements were written.
- **Agreement technical content** and the coordination provisions behind it.
- **Change notification support** in both directions — grid changes that affect the plant, and plant changes that affect the transmission entity's analyses.

Where projects get caught

A transmission system that changed materially during a long outage or a shutdown, against interface requirements and a degraded voltage calculation that did not. New generation, retirements, topology changes and new large loads all move the answer. On a restart this is not a formality — it is a re-analysis.

WHAT THE LOSS-OF-OFFSITE-POWER RECORD ACTUALLY SHOWS

- **Frequency is falling.** The published operating experience analysis shows statistically significant decreasing trends in loss-of-offsite-power events during critical operation, and in grid-related events specifically.
- **Switchyard-centred and weather-related events now dominate** both the frequency and the duration of what remains — not grid-wide disturbances.
- **Recovery times are moving the wrong way** for switchyard-centred events and for events occurring during shutdown.
- **Which is the commercial point.** The dominant remaining risk sits in exactly the asset class an outside electrical firm can work on — switchyard protection and relaying, breaker maintenance strategy, storm hardening, and shutdown-risk management.

Requirements register

Each interface requirement traced to the licensing-basis document and the calculation that supports it, so a transmission planner can see what is binding and a plant engineer can see where it came from.

Assumption reconciliation

A side-by-side of the bounding contingency, voltage schedule and source impedance assumed in the plant calculations against what the current transmission planning and operating cases actually contain.

Agreement technical annex

The engineering content behind the written agreement — studies to be performed and by whom, notification thresholds, outage coordination triggers and the re-analysis obligations that follow a grid or plant change.

WHAT WE DELIVER Interface requirement development and technical basis · Reconciliation of plant and transmission study assumptions · Agreement technical content · Transmission change impact assessment · Switchyard reliability and protection improvement programmes

THE EQUIPMENT WE WORK ON

Balance-of-Plant Electrical Scope

SYSTEM	TYPICAL CLASSIFICATION	THE ENGINEERING
Main generator, exciter and generator protection	Non-safety-related	Protection scheme review and settings, capability curve and reactive limits, excitation and voltage regulation, abnormal frequency protection, breaker configuration and backfeed capability
Generator step-up transformer	Non-safety-related, but part of the offsite power path where backfeed is credited	Rating and loading, impedance and tap selection, cooling and thermal capability, protection, spare strategy and long-lead procurement support
Unit auxiliary and startup transformers	Non-safety-related equipment forming part of the preferred power supply — the classic hybrid	Sizing and tap position, voltage regulation across operating modes, and the central role in degraded voltage and open phase analysis
Isolated phase bus	Non-safety-related	Rating, cooling and pressurisation, condition assessment, and failure modes that have historically caused unit trips
Switchyard, breakers, disconnects, instrument transformers, buswork and relaying	Generally non-safety-related, though circuit availability is a technical specification matter — and often owned by the transmission entity	Configuration and failure modes analysis, protection and relaying design and settings, breaker duty, modernisation and obsolescence, remedial action schemes
Non-1E medium and low voltage distribution and load centres	Non-safety-related	The largest single volume of balance-of-plant electrical work — load flow, short circuit, coordination, equipment rating verification and modification design
Non-1E motor control centres and motors	Non-safety-related	Motor starting and voltage dip, protection settings, replacement and obsolescence engineering
Non-1E DC systems, chargers, inverters and uninterruptible supplies	Non-safety-related	Duty cycle development and battery sizing, charger sizing, DC short circuit and voltage drop to the load
Grounding and lightning protection	Generally non-safety-related	Ground grid design and analysis, step and touch potential, lightning protection and surge coordination
Cable systems, raceway and penetrations	Non-safety-related unless fire-protection or 1E-adjacent	Ampacity and derating, routing and separation, condition monitoring and aging management support
Plant and yard lighting	Mostly non-safety-related; fire-protection emergency lighting is augmented quality	Lighting design, emergency lighting battery sizing and coverage verification
Arc flash and electrical safety programme	Non-safety-related — an occupational safety obligation, not a reactor one	Incident energy analysis, labelling, mitigation by settings or configuration, and programme documentation

Classification is the licensee’s determination, not ours

The classifications above are the typical industry position and are shown to describe where our work sits — not to determine anything. The controlling classification for any component is the one in your own design basis and quality assurance programme. We work to the classification you give us, and where a component is safety-related or augmented quality we work inside your programme, to your procedures, with your verification and approval.

NOTE Safety classification is the licensee's determination and varies by plant. The column above reflects the general fleet pattern; we confirm the classification of every item against your own criteria before scoping work on it.

THE ANALYTICAL CORE

The Study Set

The NRC's own guidance enumerates the electrical studies a station is expected to hold. It reads like a scope of work.

Offsite and Grid Interface

- **Steady-state and transient stability analysis** demonstrating that loss of the largest single supply to the grid does not cause complete loss of preferred power.
- **Contingency analysis** for the largest generation loss, the largest load removal and the loss of a critical line.
- **Failure modes and effects analysis of the switchyard** — the systematic search for the single event that takes both offsite circuits.
- **Voltage adequacy across the offsite circuits** under the bounding transmission contingency.
- **Outage history analysis** — frequency, duration and cause data for the offsite supply over an extended period.
- **Backfeed and startup path verification**, including generator breaker configuration.
- **Surge, grounding and lightning protection** for the switchyard and the interface.
- **Underground cable routing and wetted-condition assessment** for the offsite circuits.

One study, two audiences

The same analysis has to satisfy a nuclear reviewer working from the safety analysis report and a transmission planner working from a power flow case. Writing it so both can follow it — and so the assumptions reconcile between them — is most of the skill.

Onsite AC and DC

- **Load flow and voltage regulation** across operating modes, with under and overvoltage protection coordination — the basis of the degraded voltage setpoints.
- **Short circuit analysis** at medium voltage, at 480 volts and at motor control centres, with equipment rating verification.
- **Equipment sizing** — transformers, switchgear, bus and breaker assemblies, batteries, chargers and inverters.
- **Protection and coordination studies** across the distribution system.
- **Motor starting and voltage dip** for large motors and sequenced loading.
- **Insulation coordination, surge and lightning protection.**
- **Power quality** limits, including the effects of digital controls and variable frequency drives.
- **Monitoring and testing capability** — the provisions that make the periodic testing requirement satisfiable.
- **Grounding system design** — station, system and equipment safety grounding.
- **Arc flash incident energy** analysis and the labelling and mitigation that follow.

Platforms

The study set is executed on industry-standard platforms — ETAP and equivalent for the plant distribution system, and transmission-class tools for the grid interface and stability work — with the model, assumptions and results documented for independent verification.

Calculation packages

Written to be reviewed — stated inputs and sources, explicit assumptions with their basis, method, results, and a conclusion a reviewer can check without reconstructing the work.

Models and cases

Native model files, case lists and a change log, so the study can be re-run against next year's configuration rather than re-commissioned from the beginning.

Settings and drawings

Relay setting sheets, coordination curves, one-lines and three-lines, arc flash label schedules, and the marked-up source drawings the results depend on.

The model is the asset, not the report

Most stations hold study reports whose underlying models are either lost, undocumented or several modifications out of date — which is why the next question always costs as much as the last one. We build and hand back the model with the report, documented well enough that your own engineers can re-run it after the next modification, and we say plainly which data came from drawings, which from nameplate and test records, and which from field verification.

HOW THE DELIVERABLE IS STRUCTURED Stated scope and standards · Model description and every assumption written down · Source data provenance · Case list with base, contingency and sensitivity cases · Results with the acceptance criterion beside each number · Equipment rating verification item by item · Findings, exceptions and mitigation options · Calculation records and native model files delivered with the report

MARKET ONE

The Operating Fleet

Power Uprates

- **Three categories.** Measurement uncertainty recapture, typically under two percent; stretch, roughly two to seven percent within the existing design; and extended, up to about twenty percent and requiring major equipment modification.
- **Extended uprates are where the electrical work concentrates** — main generator, generator step-up transformer, isolated phase bus, auxiliary transformers and switchyard thermal limits.
- **The market signal is unusually clear.** Federal policy is targeting several gigawatts of uprate capacity from the existing fleet by the end of the decade, with a dedicated programme and financing behind it — while the regulator's pending-application list has been empty.
- **Which means the front-end studies come first.** Generator capability, transformer and bus rating verification, auxiliary load growth, switchyard thermal limits and protection resetting all precede a licence amendment by a long margin.

Subsequent Licence Renewal

- **Thirteen sites approved to date**, with review durations collapsing — one recent approval came in under twelve months against a policy target of the same.
- **The electrical content is aging management** — cable and connection insulation including inaccessible and underground medium voltage cable, electrical penetration assemblies, metal-enclosed bus and high-voltage insulators.
- **Analysis-driven and largely outside the safety-related boundary** — condition monitoring programme design, cable testing strategy, and the technical basis behind the aging management review.

Modernisation & Obsolescence

- **The median unit is over forty years old.** Analogue protective relays, non-1E switchgear, motor control centre buckets, breakers and cable are aging out across the fleet.
- **Digital protective relay replacement** in the switchyard and non-1E switchgear — settings translation, scheme verification, communications and testing.
- **Switchgear obsolescence** drives like-for-like versus modernisation studies, arc flash re-analysis and coordination re-studies.
- **Non-1E digital upgrades** — plant computer, balance-of-plant control system replacement, and the electrical and interface engineering around safety-related digital work performed by others.

A DISTINCT AND UNUSUALLY ELECTRICAL MARKET

Restarts

Three shut-down units are in various stages of returning to service, with target dates spanning the next several years and federal financing behind them. The work is electrically heavy in a specific way:

- Switchyard and generator step-up recommissioning, and the condition assessment behind it
- Protection scheme re-verification and settings validation after years out of service
- Battery and DC system requalification, and cable condition assessment
- **Degraded voltage re-analysis against a grid that changed during the shutdown** — new generation, retirements and topology changes all move the answer
- Interface requirement and agreement reconstitution with the transmission owner and operator
- Capacity interconnection rights, which have become a critical-path commercial and engineering issue

Where an outside electrical firm typically enters

- Uprate front-end electrical feasibility — what the existing equipment can carry before anything is bought
- Generator step-up and auxiliary transformer rerating and thermal studies
- Switchyard thermal and short-circuit duty verification at the new output
- Auxiliary load growth, load flow and voltage regulation across operating modes
- Protection and coordination re-studies following a rating or configuration change
- Digital relay replacement — settings translation, scheme verification and testing support
- Arc flash re-analysis after switchgear or source impedance changes
- Aging management technical basis for cable, bus, penetrations and insulators

WHAT WE DELIVER Uprate front-end electrical feasibility and rating verification · Aging management technical basis and cable condition programmes · Obsolescence and modernisation studies · Relay replacement settings and scheme verification · Restart electrical recommissioning support · Modification design packages feeding the licensee's change process

MARKET TWO

SMRs & Advanced Reactors

The licensing framework changed in 2026, and with it the electrical design premise that had held since the 1970s.

What Changed

- **A new risk-informed, technology-inclusive licensing framework became effective in 2026**, sitting alongside the two existing pathways rather than replacing them. It is optional, and it eliminates certain prescriptive requirements — including the General Design Criteria themselves.
- **Which matters enormously for electrical design.** Criterion 17's requirement for two independent offsite circuits does not automatically carry over. Offsite power adequacy becomes a performance case an applicant has to make, not a prescription to satisfy.
- **Federal legislation and executive direction** have compressed review schedules, reduced advanced-reactor fee rates and reoriented the regulator's stated mission toward enabling deployment.
- **And it is producing results.** The first commercial non-light-water construction permit in over forty years was approved in early 2026; test and demonstration reactors are under construction; a standard design approval has been issued for an integral pressurised water design; and several construction permit applications are in review.
- **A separate federal authorisation pathway** has taken microreactors to criticality outside the commercial licensing process — a genuinely new regulatory channel, with commercial deployment still requiring the regulator.

What Is Electrically Distinctive

- **Passive designs need DC, not AC.** Safety functions that do not depend on alternating current change the entire premise of the onsite power system, and push the design point toward long-duration battery coping.
- **Multi-module plants raise shared-system questions** that the guidance addressing multi-unit stations was written for two units, not eight or twelve. Shared switchyard, shared station service, shared standby sources, cross-module load sequencing and single-failure treatment across modules are all open design work.
- **The shared switchyard is a common-cause exposure that scales.** A failure modes analysis of the switchyard is already expected; behind it now sit N modules rather than one unit.
- **Load following changes the duty.** Flexible operation drives generator, transformer and auxiliary system duty cycles, protection settings and voltage regulation design that large baseload units never needed.
- **Grid integration behaves differently.** Modularisation changes system inertia and frequency response against one large machine, and electromagnetic transient modelling of these plants for load following and electrical transient analysis is an emerging discipline.
- **Microreactors invert the problem entirely** — island-mode operation, no credited offsite power, black start capability, and interconnection at distribution rather than transmission voltage.

Where we fit on a new build

The switchyard, the grid interconnection, the generator and transformer package, the non-safety distribution system and the whole study set — plus interconnection and transmission planning support, which is our core practice on every other technology we serve.

The offsite power case

Where the prescriptive two-circuit requirement no longer applies automatically, the adequacy of the offsite supply becomes an argument built from transmission data — contingency performance, voltage support, restoration history and common-mode exposure at the site.

Shared-system studies

Station service architecture across modules, sequenced loading, standby source sizing, DC duty cycles for long coping durations, and single-failure treatment where a shared element serves N units.

Interconnection & siting

The grid-side work is the same work every generator faces — queue studies, short circuit and stability, protection at the point of interconnection — with a plant whose licensing basis depends on the answer.

WHAT WE DELIVER Grid interconnection studies and interconnection process support · Switchyard and transmission interface design · Balance-of-plant electrical design · Load following and transient studies · Multi-module shared-system electrical analysis · Site electrical infrastructure for microreactor and behind-the-meter configurations

MARKET THREE

Nuclear & Co-Located Load

Not blocked any more — but channelled into defined transmission service products, with the rules being written market by market right now.

HOW IT UNFOLDED

From Rejected Agreement to Regulated Product

Late 2024 — the regulator rejected an amended interconnection agreement that would have expanded behind-the-meter co-located load at a nuclear station, on cost-allocation and reliability grounds

The deal was restructured, not litigated — to a grid-connected, front-of-meter retail model in which the load pays applicable transmission and distribution charges and the plant's output goes to the market

Early 2025 — a formal proceeding opened on whether the market's tariff for co-located load was just and reasonable

End of 2025 — the tariff was found unjust and unreasonable, with direction to establish **four distinct transmission service options**, revise behind-the-meter generation rules with transition provisions, and report on reliability

2026 — rehearing and compliance proceedings continue to refine the service products

Mid-2026 — the regulator issued show cause orders to **all six organised markets** on large-load integration, including co-location and behind-the-meter generation

Meanwhile the commercial activity has continued regardless — restart power purchase agreements, advanced reactor fleet deals and gigawatt-scale commitments across several technology developers.

The Engineering Questions

- **Point of interconnection design.** Front-of-meter versus behind-the-meter changes metering, protection and ownership of the tie. A tap off the generator lead is a completely different design — and a completely different licensing question — from a new load feeder off the switchyard.
- **The licensing basis interaction.** Any connection that alters the offsite power configuration, adds load that can affect voltage at safety-related buses, or changes the switchyard failure modes analysis engages Criterion 17 and the degraded voltage expectations directly. That is the same study scope described earlier in this document.
- **Loss-of-load transient.** A co-located load that trips instantaneously imposes a full load rejection on the unit; a unit trip strands the load. Both need transient stability analysis and coordinated protection.
- **Capacity interconnection rights** have become a critical-path issue in their own right, including transfers from retired fossil sites to accelerate grid access.
- **Interface requirement implications.** Adding a large co-located load changes the plant's stated requirements on the transmission system and the transmission entity's operating analyses.

Why this is our natural ground

Co-location sits precisely at the intersection of three things we already do: nuclear plant offsite power and degraded voltage analysis; large-load interconnection in the organised markets; and data centre power system design. Very few firms hold all three, and the problem is not solvable from any one of them alone.

The honest caution

The transmission service products, cost allocation rules and behind-the-meter provisions are being rewritten market by market as this is published. Any configuration decision should be re-checked against the current filing rather than against the arrangement a competitor signed last year.

WHAT WE DELIVER Configuration and point-of-interconnection analysis · Load rejection and transient stability studies · Degraded voltage impact assessment · Protection and metering interface design · Interconnection process and market filing technical support · Interface requirement impact assessment

ANALYSIS-HEAVY AND CHRONICALLY UNDER-RESOURCED

Fire Protection Circuit Analysis

The Two Regulatory Tracks

- **Deterministic** — the original appendix applying to plants licensed before 1979, plus plant-specific licence conditions.
- **Risk-informed and performance-based** — the alternative rule incorporating the industry fire protection standard by reference, with its own endorsing guidance. Roughly half the fleet transitioned; the split governs which analysis basis applies.
- **The separation criteria** for redundant shutdown trains in the same fire area: a three-hour rated barrier; twenty feet of horizontal separation free of intervening combustibles with detection and automatic suppression; or a one-hour barrier enclosing one train with detection and suppression.
- **Where separation cannot be met**, alternative or dedicated shutdown capability with independent circuits is required.
- **Emergency lighting** with at least eight hours of battery supply in areas needed for safe shutdown operation and on access routes.

Why this work suits an outside firm

It is analytical in character — cable and raceway tracing, circuit failure mode assessment, coordination verification — even though its conclusions feed a safety-related licensing basis. It is high volume, it is chronically short of resource at licensees, and it is exactly the kind of work performed inside a licensee's programme by qualified outside engineers.

The Circuit Analysis Itself

- **Identify safe shutdown equipment** and the cables and raceways serving it, fire area by fire area.
- **Identify associated circuits of concern** in three classes — **common power supply**, where a fire-induced fault on a non-safety circuit trips the shared supply breaker; **common enclosure**, where non-safety cable shares a raceway with shutdown cable; and **spurious operation**, where hot shorts cause unwanted component actuation.
- **Multiple spurious operations** — the expansion of the analysis to concurrent spurious actuations, and a major driver of transition cost.
- **Circuit failure modes** — hot short including proper-polarity hot shorts in DC circuits, short to ground, and open circuit, with duration and probability treatment.
- **Breaker coordination for fire scenarios** — verifying that the upstream device clears a fire-induced fault before the shared bus is lost. This is ordinary coordination engineering applied to an unusual initiating event.
- **Separation and routing verification** against the criteria, and raceway fire barrier qualification.
- **Remedies are usually electrical** — added isolation, fuses, breaker replacement, separate feeds, re-routing, or operator manual actions with the local disconnect provisions to support them.

What comes out

Safe shutdown equipment and cable lists by fire area, an associated-circuits register, circuit failure mode evaluations, and the coordination and breaker verification that supports the common-power-supply conclusions.

Where it goes wrong

Cable and raceway records that do not match the plant, protective device settings that never got re-verified after a modification, and spurious-operation sets built without the instrumentation and control detail behind them.

How we take it

Inside your programme, to your procedures, with your verification and approval — the standard route for analytical work whose conclusions feed a safety-related licensing basis.

The electrical engineering underneath the fire analysis

Behind every associated-circuit conclusion is ordinary power system work: a short circuit model that establishes available fault current at the postulated fault location, coordination that demonstrates the correct device clears it, breaker and fuse duty that confirms the device can, and cable ampacity and raceway records that establish what is actually in the fire area. That is our core competence applied to a fire protection question — and it is where these analyses most often fail review.

SCOPE NOTE Fire protection engineering, fire modelling and the probabilistic risk assessment elements are performed by qualified fire protection specialists. Keentel provides the electrical circuit analysis, coordination verification and the electrical remedies — coordinated with that scope rather than substituting for it.

THE CONSTRAINT THAT NOW GOVERNS

Long-Lead Equipment Reality

A design recommendation that requires a new generator step-up transformer in 2026 is a recommendation to delay the project by roughly three years.

EQUIPMENT	REPORTED LEAD TIME	WHAT IT MEANS FOR THE ENGINEERING
Generator step-up transformers	Approaching three years, with some high-voltage units reported longer still	The single most schedule-critical item on an uprate, a restart or a co-location project
Large power transformers	Well over two years	Auxiliary and startup transformer replacement has to be planned years ahead of the outage it lands in
High-voltage switchgear	Approaching a year	Switchyard modernisation and obsolescence programmes are procurement-led, not engineering-led
Pricing	Power transformers up substantially since 2019; generator step-up units and circuit breakers up sharply as well	A rerating study that avoids a purchase is worth a large multiple of its own cost

The binding constraints behind these numbers are grain-oriented electrical steel, copper and coil-winding labour — none of which a purchase order solves. Announced North American capacity expansion is real but arrives over years, and extended lead times are widely expected to become the norm rather than a spike.

How We Design Around It

- **Rerating before replacing.** Thermal modelling, cooling upgrades and load-flow-based confirmation that the existing transformer or bus can carry the new duty — the highest-value study on an uprate.
- **Configuration options that avoid a purchase.** Tap changes, impedance and loading redistribution, and operating restrictions traded against capital.
- **Spare and mobile strategy.** What spare exists, whether it fits, and what a mobile arrangement can cover on a critical single-transformer configuration.
- **Procurement specification support.** Getting the specification right the first time, because a change after release to manufacture restarts a queue position rather than a task.
- **Slot confirmation, not quoted lead time.** What belongs on the project schedule is a confirmed manufacturing slot.

The Other Constraint

- **Workforce.** Federal analysis concludes that a substantial expansion of nuclear capacity requires roughly tripling the nuclear workforce, with skilled trades rather than degreed engineers as the binding constraint.
- **Within engineering**, the scarcest sub-segment is power system engineers who can also work inside a licensee's procedures and who understand degraded voltage methodology, circuit analysis and the interface requirements.
- **Which is what we are selling** — scarcity of a specific competence, not hours.

The practical rule

On any uprate, restart or co-location project, ask the transformer question in week one. The engineering answer changes depending on it, and the answer that avoids a new machine is usually available if the question is asked early enough.

What we ask on day one of an uprate, restart or co-location study

Nameplate and test data for the generator step-up, auxiliary and startup transformers, including cooling stages and any prior rerating; the switchyard configuration and equipment ratings as operated today; existing load flow, short circuit and coordination models with their vintage; the current interface requirements and the degraded voltage calculation of record; and the spare and mobile equipment position. Those inputs decide whether the answer is a rerating study or a three-year procurement, and they decide it in the first two weeks rather than the last two.

AS OF August 2026. Lead times and pricing in this section are drawn from public industry reporting and move quickly — they are re-checked against current market data at the start of every engagement rather than carried forward.

THE DESIGN AND REVIEW BASIS

Regulations, Guides & Standards

REFERENCE	WHAT IT GOVERNS	NOTE
10 CFR 50 Appendix A General Design Criteria 17 and 18	Onsite and offsite electric power systems; inspection and testing of them	The foundation of the offsite power case
10 CFR 50.63	Station blackout — coping duration and alternate AC source	Coping analysis avoidable where an alternate source is available within ten minutes
10 CFR 50.65(a)(4)	Risk assessment and management of maintenance activities	Where grid reliability evaluations feed maintenance risk
10 CFR 50.48 and Appendix R	Fire protection; separation criteria, associated circuits, emergency lighting	Alternative risk-informed rule available with its own endorsed standard
10 CFR 50.59	Changes, tests and experiments without prior approval	Endorsed industry guidance including a dedicated appendix for digital modifications
NUREG-0800 Chapter 8 and its branch technical positions	The acceptance criteria for offsite power, onsite AC and DC, and station blackout	Includes offsite stability, distribution voltage adequacy, outage time extensions and open phase conditions
Regulatory Guide 1.32	Criteria for power systems — endorses the current Class 1E power systems standard	Revised 2025
Regulatory Guide on Class 1E protection	Endorses the current protection standard for Class 1E systems and equipment	New guide issued 2025
Regulatory Guide 1.155	Station blackout	Long-standing and still current
Regulatory Guide 1.204	Lightning protection of nuclear power plants	Revised 2024 — directly relevant to switchyard work
IEEE 765	Preferred power supply and its interfaces with the Class 1E system, switchyard and transmission system	Current edition 2022
IEEE 308 / 741 / 384 / 387	Class 1E power systems; their protection; independence of equipment and circuits; standby diesel generator units	All recently revised; the protection and power system standards now carry their own endorsing guides
IEEE 485 / 946	Battery sizing; design of DC power systems for stationary applications	Both current 2020 — and apply equally to non-1E systems
IEEE 242 / 399 / 665 / 666 / 1050 / C37.106 / C62.23	Protection and coordination; system analysis; generating station grounding; auxiliary power systems; instrumentation grounding; abnormal frequency protection; substation surge protection	The working standards behind the balance-of-plant study set
IEEE 1584 and NFPA 70E	Arc flash incident energy and electrical safety in the workplace	An occupational safety obligation rather than a reactor one
NERC NUC-001	Nuclear plant interface coordination between the plant and transmission entities	The contractual and technical bridge to the grid

One point worth flagging: the safety systems criteria standard incorporated by reference in the regulation is an older edition than the current published one, with rulemaking underway to update it. Where a design decision turns on that difference, we confirm which edition governs before proceeding rather than assuming the newest applies.

NOTE Standard designations are shown without version suffixes because editions change, and regulatory guide revisions are noted only where recent. The governing edition, the plant's licensing basis and the licensee's own design criteria control — and are confirmed project by project.

WHO WE WORK FOR AND HOW

Engagement & Capability

WHO COMMISSIONS THIS WORK

Operating licensees	Restart owners	SMR & advanced reactor developers	Data centre & large load developers
Transmission owners at nuclear interfaces	Architect-engineers & Appendix B primes	EPC contractors	OEMs & equipment suppliers
Lenders & technical diligence	Asset managers	Independent power producers	Public power & cooperatives

ENGAGEMENT MODELS

Defined study or design scope

A named deliverable — a degraded voltage calculation, a switchyard failure modes analysis, an arc flash study, a modification package — with a fixed fee and a stated classification boundary.

Within your programme

Task-order or staff-augmentation engineering performed to your procedures, with your verification, checking and approval — the standard route for work adjacent to the safety-related boundary.

Subcontract to a prime

Electrical scope delivered into an architect-engineer, OEM or nuclear quality engineering house that carries supplier responsibility and performs verification.

ENGINEERING PLATFORMS

OUR CLIENTS

How an engagement starts

A short technical call to establish the classification boundary and who holds the quality programme for the deliverable, followed by a written scope that names the deliverable, the inputs we need from you, the software and model basis, the review and approval path, and the classification statement that applies. We would rather spend an hour settling that than discover it at the first review meeting.

START HERE

Four Things and We Can Scope It

The plant — site, unit, vintage and configuration

The driver — uprate, restart, modification, new build or co-located load

The classification — where you need the boundary drawn

The programme — whether we work within yours, or deliver as design input

WHY KEENTEL ENGINEERING

01 Grid-side depth, applied to a nuclear station

Offsite power adequacy, stability, degraded voltage and transmission coordination are our core practice on every technology we serve — and they are where a nuclear plant's electrical exposure actually sits.

02 Explicit about the quality boundary

We state on page two what we do and do not hold, and how we work relative to a licensee's programme. In this industry that is a qualification, not a caveat.

03 Substation and transmission engineers

The switchyard, the transformers, the protection and the studies are our own design practice — not a nuclear specialism bolted onto a generalist firm.

04 We understand the procurement reality

A recommendation that needs a new step-up transformer is a three-year recommendation. We look for the answer that avoids it before we look for the answer that specifies it.

05 P.E.-sealed and defensible

Florida-registered firm (Reg. No. 36853) with multi-state licensure. Written to survive licensee verification, transmission owner and independent engineer review.

06 The co-location problem, from all three sides

Nuclear offsite power, large-load interconnection in the organised markets, and data centre power design sit in one team — which is what the problem actually requires.

PRIMARY AUTHORITIES BEHIND THIS FLYER

NRC regulations. 10 CFR Part 50, including Appendix A General Design Criteria, Appendix B quality assurance criteria and Appendix R fire protection; 10 CFR 50.48, 50.49, 50.59, 50.63, 50.65 and 50.55a; 10 CFR Part 21; and the risk-informed technology-inclusive framework for advanced reactors.

NRC guidance. NUREG-0800 Standard Review Plan Chapter 8 and its branch technical positions; Regulatory Guides 1.28, 1.32, 1.75, 1.81, 1.89, 1.100, 1.128, 1.129, 1.155, 1.164, 1.187, 1.204, 1.205, 1.206, 1.211 and 1.218, and the guide endorsing the current Class 1E protection standard; the regulatory issue summary on adequacy of station electric distribution system voltages; the generic letter on grid reliability and offsite power operability; and the NRC bulletin and subsequent closure on open phase design vulnerability.

Consensus standards. IEEE 308, 323, 344, 384, 387, 485, 603, 741, 765 and 946; IEEE 242, 399, 665, 666, 1050 and 1584; IEEE C37.106 and C62.23; ASME NQA-1 as endorsed for quality assurance; NFPA 70E, NFPA 780 and the fire protection standard incorporated by reference in the alternative rule.

Industry guidance. The endorsed guidance on changes without prior approval and its digital modification appendix; the industry guidance on post-fire safe shutdown circuit analysis; and the industry guidance on commercial-grade dedication as endorsed by the NRC.

Reliability standards. NERC NUC-001, nuclear plant interface coordination.

Operating experience and market data. The NRC operating experience programme analysis of loss-of-offsite-power events; NRC licensing status pages for power uprates and subsequent licence renewal; and public industry reporting on equipment lead times, pricing and workforce.

Regulatory positions, standard editions, project statuses and market data described are current as of August 2026 and are provided for orientation only. Nothing here is legal or regulatory advice. The plant's licensing basis, the governing regulation and guidance, and the licensee's own design criteria and quality assurance programme control.

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