IV. Spare Equipment Philosophy for Bulk Electric System Facilities & Interfaces

Spare equipment is critical to the continued integrity of the Bulk Electric System (BES). Failure to maintain adequate spare equipment can lead to unnecessary higher operating costs and unnecessarily long outage times, consequently compromising transmission reliability. Interconnected Transmission Owners (ITOs) need to be able to support any local interconnection agreements. The purpose of this philosophy is to ensure that thought is given to maintaining adequate spare equipment for the BES. Any new facility connecting to the bulk electric system should observe this philosophy.

Equipment critical to the integrity of the grid known to have long lead times should be supported by a spare. Particular focus should be placed on unique “one of a kind” equipment (i.e.: new technology). The expectation is that the ITOs would not be reliant on another party or even the vendor for immediate spare support.

ITOs maintain spare levels consistent with their risk tolerance for contingency events. When electing option to build, an Interconnection Customer (IC) may be required to obtain spare equipment and /or special tooling necessary for operation and maintenance of the equipment in line with ITO spare requirements. Thus, if equipment not normally utilized by the ITO is selected by an IC, then the IC will encounter “but for” costs on the spare equipment and specialty tooling. Contact the ITO for their spare requirements and standard equipment types.

**Overview**

Transmission Owners should be stocking adequate spares in the voltage and ampacity classes necessary to quickly replace any failures of equipment noted below. This document breaks up equipment into three categories based on criticality and lead time for replacement: Major Equipment (the core of this document), Minor Equipment, and common stock items or equipment which generally do not require sparing.

These requirements include but are not limited to the following types of equipment and parts:

* Circuit breakers and parts (compressors, poles, bushings, interrupting media [i.e.: SF6 gas]).
* Power transformers.
* Bushings.
* Surge arresters.
* Relays (electromechanical, solid state and microprocessor).
* Central processing units (CPU), programmable logic controllers (PLC) and circuit boards for communication equipment, substation integration equipment and circuit breakers (if equipped with controlled switching, breaker monitoring, etc.).
* Remote terminal units (RTU).
* Batteries & chargers.
* Standalone potential transformers (PT) and current transformers (CT).
* Station service transformers.
* Critical auxiliary system support components.
  + Automatic Transfer Switches
  + Low Voltage Circuit Breakers (Molded Case, Insulated Case, Power, etc.)
  + MCC Plug In “Buckets”
  + Air Conditioning / Space conditioning equipment
  + Etc.
* Switches and components.
* Line and bus insulators and fittings (connectors, couplings, etc.).
* Underground transmission cables and accessories.
* SF6 equipment and tube (GIB and GIL).
* Overhead transmission structures.
* Communication cabling (fiber optics).
* Capacitor cans & associated specialty transmission capacitor rack equipment.
* Bus (Tube / Pipe, Flat Bar, Angle (UABC), Integral Web, etc.).
* Wire, conductor, and cable.
* Line Traps (with & without power line carrier capability).
* Reactors (Current Limiting and/or Harmonic Filtering)
* Etc.

New facilities should be designed with sufficient land to allow for necessary spare storage and installation, in accordance with applicable regulatory and compliance standards.

Conversations with local authorities and permitting agencies may be necessary to successfully achieve a quick replacement, especially for transportation of large / oversize equipment.

Timing

Target dates within this document assume scenarios where a direct “one for one” replacement (spare) is stocked and available, as noted in the second paragraph. This document further assumes that transportation routes for large equipment are either pre-planned, or able to be permitted and transported in a reasonably short time frame (several days to about two weeks). When additional work or unreasonably long permitting and transportation times are included, restoration times can increase considerably.

Logistics

When major equipment such as a transformer fails during peak season or approaching peak season, TO’s should not hesitate to contact legislators or other state-level contacts to request expedited route analysis and permitting approval, leveraging the fact that large portions of customer load could be adversely impacted.

Collateral Damage

The target dates in this document assume no collateral damage (catastrophic failure of one piece of equipment that damages other equipment, such as transformer fire, expulsive bushing failure, etc.) which could significantly extend repair times. Collateral damage or bridge and road closures cannot be foreseen.

**Major Equipment**

* **Power Transformers (auto transformers, Phase Angle Regulators (PARs), etc.) –** TO’s should have adequate spares and major routes defined so a transformer can be replaced with a target of 30-60 days depending on the transformer size and complexity of the situation. Repair work on firewalls, oil containment/mitigation, modifying transformer foundations, and repair of other collateral damage cannot be anticipated in a spare equipment methodology, and will extend replacement times.
  + **Bushings –** TO’s should target 30 days for power transformer bushings. For each class of power transformers, a minimum of three bushings should be in stock for each type of bushing an entity uses. Additional spares should be maintained with consideration to the total population on a TO’s system, failure rate, etc.
* **Transmission Line Equipment** – the expectation is that a failed or destroyed structure can be replaced (with temporary or permanent structure) in two weeks. This assumes complete failure of a single structure and damage to one structure each on either side of the failed structure. This further assumes reasonable accessibility to the failed structure location and does not account for extreme conditions such as mountainous terrain or river crossings. TO’s should consider having structure parts available, along with conductor of similar or larger size, as well as static wire that may be OPGW. Guy wire and anchors will often be needed to stabilize a temporary structure. The below equipment should be considered when replacing failed transmission structures:
  + **Emergency Structures**
    - **Bypass strategy** – Transmission Engineering departments should have a documented plan to bypass/replace the common structure types on a TO’s system, as well as a materials list. ROW needs to be considered if a bypass plan is invoked.
    - **Emergency Restoration Structures** – contractors and providers exist who stock and construct transmission structures which can be used in a variety of emergency applications and should be considered as a solution where appropriate.
    - Utilities may want to consider a monopole design that would allow for potential long-term utilization. This pole design would be considered for multiple applications (direct embed, bolt on equipment, etc.).
  + **Conductor** – types, sizes, and length, including attachment hardware and splices should be in stock. Consider purchasing reels of longer length than standard to help minimize the number splices or avoid them all together.
  + **OPGW and bare static wire** - types, sizes, and length, including attachment hardware and splices
  + **Guy wire/anchors** – sufficient amount for size and number of structures that will be considered for bypass.
* **Circuit Breakers** – one to two week turnaround is typical for replacement. Transporting spares to a failure location should take a day or two. The relay and control wiring is a major consideration, especially when replacing older equipment with new equipment. Consider Spare breakers that can be “universally” used across a system with respect to not only the breaker rating, but also CT ratio/accuracy/burden, rating factor, control voltage, etc. Consider live tank vs dead tanks needs and stock appropriately. Note this one to two week target does not consider the replacement of foundations, extensive replacement of control wiring, or adjacent equipment such as disconnects, etc.
* **CTs/PTs** (freestanding or steel mounted) – one week turnaround is typical for replacement. Follow the same basic thoughts for Circuit Breakers, such as voltage ratio, common CT ratio, thermal rating factors, burden, etc. Ensure spares are available for all types of equipment across a system.
* **Station Service Transformers** – a one week turnaround is typical for replacement. Most stations have designed redundancies in station service, and can survive a single failure. Consideration for N-1-1 can be catastrophic for station service transformer failures, and provision for a mobile emergency generator connection should be considered in the substation design process. High voltage winding, low voltage winding, Delta/Wye configurations all need to be considered for the various types of transformers across a system. Proper BIL needs to be considered for spares.
* **Underground Cable** –Underground cable spare strategy requires special considerations. TO’s with extensive UG transmission should stock spare cable / spare HPFF transmission parts. TO’s with very little UG transmission may not be able to justify such spare stocks. Unfortunately, this strategy can leave a TO with minimal UG particularly exposed to a cable failure. Ensure enough cable for the longest run. Splice and termination kits should always be stocked spare parts. Consider voltage classes.
  + Spare conduits should always be included in the design, to allow for possible future failures.
  + Solid dielectric cables may develop a permanent set after long periods of storage and may become unusable.
  + High pressure fluid filled cable systems present unique sparing and storage challenges, and equipment lead time is longer than for dielectric cable.
* **Reactors** –
  + **Series reactors** – can be bypassed and consideration for reduced system impedance can be worked to.
    - An air core reactor can be replaced in 1-2 weeks if on site. Oil filled rectors can take considerably longer
    - Due to the size of equipment, especially at higher voltages, moving reactors can take considerable time if they aren’t on site.
    - Oil filled reactors may have special consideration when being replaced with air insulated reactors.
      * These can take years to acquire, allow for long lead times
    - Spares should be stocked for organizations that utilize reactors.
    - Purchasing spares is recommended when designing/building a new reactor installation.
  + **Shunt reactors** –
    - Oil Filled
      * Due to the long lead time for oil filled shunt reactors, there should be careful consideration for having spares available
      * A four to eight weeks turnaround time should be appropriate for replacement. As noted above, transportation can be challenging at higher voltages.
    - Air Core
      * A one to two week turnaround time should be appropriate for replacement.
* **Capacitors** – TO’s should stock enough spare capacitor cans to have a cap bank back online within 5 days.
  + It is expected that racks don’t typically fail as an entire stack.
  + Clean-up from catastrophic failures don’t typically affect replacement times.
  + Ensure adequate fuses are available for individually fused cans.
* **Harmonic Filters**
  + While harmonic filters are comprised of similar capacitor and reactor equipment, consider any specific variations for filters that may be different from traditional reactive equipment.
* **SVCs** – typically have a spare transformer built into the original design
* **STATCOMs** - ???
* **Gas Insulated Switchgear (GIS) and Gas Insulated Bus (GIB) equipment**. (Brett to provide some additional information.)
  + Manufacture support can impact restoration times
    - Typically work is done under the direct supervision of a manufacturer’s representative
    - Rep’s time to site is typically part of a support contract
  + GIB Tube

**Minor Equipment**

The list of equipment below can generally be pulled from stock or from a project under construction. It is expected, as good utility practice, that the equipment below is stocked, and therefore no lead time needs to be considered.

* Surge Arrestors
* Batteries (individual cells or a bank)
  + Battery Trailer – All TO’s should have a portable battery or battery & charger combination, at all appropriate voltages, to maintain station service reliability and redundancy during a failure repair.
* Substation Bus or tubular conductor
* Relays
* Insulators/Fittings/Transmission Line Hardware
* SF6 gas (and/or other insulating gasses)
  + Any TO with SF6 gas breakers is expected to have spare SF6 gas bottles and a gas cart on site or available within a few hours
* Electronics Parts (CPUs, PLCs, RTUs)
* Communication Equipment (Fiber Converters, Ethernet Switches, cellular routers, etc.)

**General items that don’t require sparing**

This section highlights equipment that TO’s should have available through normal business and maintenance activities. Therefore, a specific sparing methodology is not necessary, but this information is provided here for consideration.

* Control cable
* Fiber/cabling: TO’s are expected to have fiber expertise in-house, or have a standing contractual relationship with one or more fiber contractors
* Termination equipment (supply chain issues as seen in 2025)

**Bone Yard of obsolete equipment**- As technology evolves and older-style equipment is removed from a TO’s system, the TO is expected to maintain a ‘boneyard’ of decommissioned equipment up until the last of that style of equipment has been removed from their system. Some examples include:

* Wave Traps
* CB Parts
* Electromechanical Relays
* Electronics Parts (CPUs, PLCs, RTUs)
* Switches/Switch Parts

Alternative Approaches to be considered by TO’s

* Temporary Poles or transmission structures
* Mobile Cap Banks
* Mobile Transformers
* Mobile Battery/Charger Trailers
* Mobile Circuit Breakers
* National spare equipment list for transformers (DOE)

**General notes**

Any TO with a “one-off” (unique equipment existing at only one location) is strongly encouraged to purchase a spare of that unique equipment.

Planning studies may show that unique spares may not be required in specific instances. In these cases, the Planning Study should be referenced in the TO’s Spare Equipment Methodology, and the Planning Study should be refreshed at a minimum once every five years.

When determining storage location(s) for spare equipment, consideration should be given to catastrophic events which could fail both the in-service equipment as well as the spare (collateral damage, flood events, or terroristic attack of an entire substation.)

It is recommended that transportation plans for the largest equipment (transformers, PARs, and EHV circuit breakers and reactors) be reviewed every five years.

Sparing plans (quantity of spares) should be reviewed each time a new BES substation is constructed or each time a new transmission line design is employed. Microsoft Excel provides a Monte Carlo simulation which is a statistically valid method for evaluating quantity of spares and risk levels.

Conducting Transmission restoration tabletop exercises/Readiness exercises can also assist in finding weaknesses in restoration plans and are also a recommended practice.