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

Spare equipment is critical to the continued integrity of thfe 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 shall 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.

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

* Circuit breakers and parts (compressors, poles, bushings, interrupting medium [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;
* Stand alone potential transformers (PT) and current transformers (CT);
* Station service transformers;
* Critical auxiliary system support components;
	+ Automatic Transfer Switches
	+ Battery Chargers
	+ 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;
* Line Traps (with & without power line carrier capability);
* Reactors (Current Limiting and/or Harmonic Filtering); and
* 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.

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 3 categories based on criticality and lead time for replacement.

Conversations with local authorities and permitting agencies may be necessary to successfully achieve a quick replacement.

Need to consider Manpower. Manpower likes to mobilize and work quickly but parts/equipment may not be readily available

Accessibility to damaged equipment is a factor of consideration

Target dates within this document are related to best case scenarios where a direct replacement is being considered. When additional work and transportation are included, restoration times grow considerably in duration.

Major Equipment

* Power Transformers (auto transformers, PARs, etc.) – a TO should have adequate spares and major routes defined so a transformer can be replaced with a target of about 30-60 days depending on the size and complexity of the situation.
	+ Bushings – a 30 day target for power transformer bushings. For each class of power transformers, there should be a minimum of 3 bushings for each type of bushings an entity uses. Additional spares should be maintained with consideration to the total population on a TO’s system, failure rate, etc.
	+ Transportation for large transformers can take very long time.
	+ Work on Firewalls, oil containment/mitigation, etc. will also lengthen replacement times.
* Transmission Line Equipment – the expectation is this can be swapped out in 2 weeks to replace 3 towers, a single structure and maybe the towers on either side. This assumes reasonable accessibility to the failed structure location and does not account for extreme conditions such mountainous terrain or river crossings. Consider having structure parts available, along with conductor of similar or large size, as well as static wire that may be OPGW. Guy wire and anchors will need to be available to maintain structures. 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 your system, as well as a materials list. ROW needs to be considered if a bypass plan is invoked.
		- Lindsey Towers – are a commercially available option for bypass structures and can 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 application. (direct embed, bolt on equipment, etc.)
	+ Conductor – types, sizes, and length, including attachment hardware and splices. Considering purchasing reels of longer length than standard to help minimize the number splices or avoid them all together.
	+ OPGW - types, sizes, and length, including attachment hardware and splices
	+ Static Wire - types, sizes, and length, including attachment hardware and splices
	+ Guy wire/anchors – sufficient amount for size and number of towers that will be considered for bypass. (lots and lots and lots…)
* Circuit Breakers – one-two week turnaround is typical for replacement. Getting spares to a failure location should take a day or two. The relay control wiring is a major consideration, especially when replacing old 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. This does not consider the replacement of foundations, related control wiring, adjacent equipment such as disconnects, etc.
* CTs/PTs – 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. The assumption is that this is freestanding equipment.
* Station Service Transformers – a one week turnaround is typical for replacement. Most stations can survive a single failure. Consideration for N-1-1 can be catastrophic for station service transformer failures. 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 – TBD. Special consideration for UC. Ensure enough cable for the longest run. Splice and termination kits should be available. Consider voltage classes.
	+ Solid dielectric cables may develop a permanent set after sitting for long periods of time and may become unusable.
	+ Typically spare conduits are run to allow for possible future failures.
	+ High pressure fluid filled:
		- Spools need to be rotated to prevent fluid settling per manufacture’s recommendation
		- Typically stored indoors.
		- Lead sheath to cover cable needs to removed when installing
		- Typically a longer lead time for HPFF
	+ Due to the expense and lead times of cables, it is recommended that companies with underground cables consider a sparing philosophy.
		- Cable failure and restoration times should be part of this philosophy.
* Reactors –
	+ Series reactors – can be bypassed and consideration for reduced system impedance can be worked to.
		- An air cooled reactor can be turned around in about a 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 insulated reactors may have special consideration when being replaced with air insulated reactors.
			* These can take years to acquire, allow for long lead times
		- Typically spares should be stocked for organizations that utilize reactors.
		- Purchasing spares is recommended when designing/building a new reactor installation,
	+ Shunt reactors - About a 1-2 week turnaround time should be appropriate for replacement. There can be challenges with transportation. Is there an opportunity to replace a specific coil vs a whole stack? If individual phases, then those are typically easier to replace.
* Capacitor cans (Need more consideration on cap cans vs cap bank) – there should be enough spare cans on a TO’s system to replace failed 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.
	+ Typically non-enclosed???
	+ Ensure adequate fuses are available if necessary.
	+ If a cap bank has filters, ensure adequate filter equipment is available as appropriate.
* 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 below list of equipment can generally can be pulled from stock, a project under construction, or stored in yards. It is expected as good utility practice that the below equipment is stocked, and therefore no lead time needs to be considered.

* Lightning Arrestors
* Batteries (individual cells or a bank)
	+ Battery Trailer – should get through a failure or repair
* Bus, tube
* Relays
* Insulators/Fittings/Transmission Line Hardware
* SF6 gas
	+ SF6 gas
	+ gas handling equipment
* Surge Arrestors
* Power Electronics Parts (CPUs, PLCs, RTUs)
* Communication Equipment (Fiber Converters, Ethernet Switches, cellular routers, etc.)

General items that don’t require sparing

* Control cable
* Fiber/cabling can be replaced by fiber contractors
	+ May want to consider relationship with fiber vendors
* Termination equipment (supply chain issues as seen in 2025)

Bone Yard of obsolete equipment

* Wave Traps
* CB Parts
* Electromechanical Relays
* Power Electronics Parts (CPUs, PLCs, RTUs)
* Switches/Switch Parts (worst case can be jumpered)

Alternative Approaches

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

General notes/Topics/Thoughts

Planning studies may show that unique spares may not be required in specific instances

You can’t stock everything

Storage of equipment

* Batteries on flow charges
* Reels need to be rotated (in place)
* Follow manufacture instructions
* Shelf life of equipment
* Rotate stock

Avoid flood areas for storage

Consider not storing critical spares at the location it will be used, so the spare won’t be compromised with a failure event.

Transportation plans for large equipment,

* How often should this be reviewed?

Timing of reviews (how often do you review your sparing plans)

How often to review stock levels?

Evaluating risk tolerance

Offer guidance on risk in general

Spares need to be available/local/on-site for these timeframes to be achievable

[Internal] Transmission restoration tabletop exercises/Readiness exercises