Study	What is the study's intent?	What is the output from this study?	When does this study get conducted?	Who conducts this study?
Steady State Impact Study (Load Flow)	Identify new thermal overloads and voltage violations with respect to local, regional, and NERC standards.	Transmission network upgrades to mitigate identified violations	Interconnection studies performed by or in coordination with the interconnecting Transmission Provider / Owner.	Separately: 1) Interconnecting utilities and 2) HVDC Equipment Manufacturer. The HVDC Equipment Manufacturer conducts these studies to ensure that the HVDC solution can meet specific performance requirements while the utilities perform this analysis to ensure secure and reliable operation of their transmission system with the inclusion of the interconnection project.
Short Circuit Impact Study	Identify the minimum and maximum short circuit levels at the points of interconnection. Ensure existing breakers are still within their current breaking capability at increased short circuit levels due to new transmission lines, and additional equipment (e.g. synchronous condensers).	Replacement of substation equipment due to higher short circuit levels.	Interconnection studies performed by or in coordination with the interconnecting utilities.	Separately: 1) Interconnecting utilities and 2) HVDC Equipment Manufacturer. The HVDC Equipment Manufacturer conducts these studies to ensure that the HVDC solution can meet specific performance requirements while the utilities perform this analysis to ensure secure and reliable operation of their transmission system with the inclusion of the interconnection project.
Transient Stability Study (Dynamic Performance)	Identify possible local or widespread instabilities that require mitigation to accommodate the new project. In addition to instabilities, also identifies violations of local, regional and NERC performance standards with respect to things such as under- and over-voltage, transient voltage recovery, frequency, damping of oscillations, etc.	Transmission network upgrades or HVDC control requirements to mitigate identified violations. May also define the need for an overload criteria of the HVDC system or a special protection system	Interconnection studies performed by or in coordination with the interconnecting Transmission Provider / Owner.	Separately: 1) Interconnecting utilities and 2) HVDC Equipment Manufacturer. The HVDC Equipment Manufacturer conducts these studies to ensure that the HVDC solution can meet specific performance requirements while the utilities perform this analysis to ensure secure and reliable operation of their transmission system with the inclusion of the interconnection project.
Reactive Power Scheme Design	Determine reactive power requirements to meet HVDC converter reactive power needs as well as voltage performance criteria and reactive power exchange limits at each point-of-interconnection.	Reactive Power Scheme that meets voltage performance and reactive power exchange requirements.	Detailed HVDC design	HVDC Equipment Manufacturer, potential review by interconnecting utilities to ensure voltage performance and reactive power exchange criteria are met.
Unit Interaction Factor (UIF) – SSR Screening	Identify the potential risk of SSR due to the introduction of the HVDC project.	A list of units/plants that require more detailed analysis of SSR risks.	Interconnection studies performed to develop the control performance requirements in the IA	HVDC Equipment Manufacturer with review by interconnecting utilities.
Fundamental Frequency Overvoltage Study	Ensure utilities' TOV curve requirement is met based on the operation of the HVDC system + filters based on the specific system conditions at each point-of-interconnection.	Identification of size and type of proper dynamic reactive power equipment, if required, to meet voltage performance criteria. This also feeds into the sizing of the surge arrestors in the AC yard of the converter station at each converter station.	Detailed HVDC design	HVDC Equipment Manufacturer with review by interconnecting utilities.

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Filter/PLC Design	Determine background harmonics in existing AC systems and harmonic output from the DC converters.	Filter design that meets performance criteria for system-normal as well as selected outages of nearby transmission facilities, and selected dispatch scenarios of nearby reactive compensation.	Detailed HVDC design	HVDC Equipment Manufacturer with review by interconnecting utilities through a harmonic performance analysis.
DC Filter and Smoothing Reactor	Identify induced harmonic noise and ripple currents from the proposed HVDC project.	Design parameters for the DC Filter/smoothing reactor to limit harmonic noise and reduce DC ripple currents.	Detailed HVDC design	HVDC Equipment Manufacturer
Circuit breakers, DC Switches	Identify expected current breaking requirements.	Determine proper circuit breaker sizes and types.	Detailed HVDC design	HVDC Equipment Manufacturer
Insulation Coordination	Study of the potential over-voltages that can be expected on the electrical equipment at the converter stations based on the specific atmospheric and electrical conditions anticipated.	Identification of placement, size, and type of proper insulation equipment and arresters to meet performance criteria. This study also drives the HVDC converter valve design.	Detailed HVDC design	HVDC Equipment Manufacturer, potential review by interconnecting utilities.
Single Line Diagram, Layout & Seismic Design	Identify and gather environmental constraints, physical space constraints, seismic design requirements, and other site-related data.	Develop a single-line-diagram based on the final equipment set/design. Develop a site layout that conforms to the environmental constraints, electrical design (insulation requirements, etc), and seismic requirements and otherwise meets the requirements of the performance specification.	Detailed HVDC design	HVDC Equipment Manufacturer
Losses Analysis	Identify the actual expected losses based on the final equipment specifications and project design.	Guaranteed loss estimates from the HVDC equipment vendor.	Detailed HVDC design	HVDC Equipment Manufacturer
Audible noise	Identify the audible noise constraints and determine the expected audible noise from the HVDC converter equipment per the final, as-designed equipment.	Audible noise mitigation plan including site layout modification and/or things like noise barriers.	Detailed HVDC design	HVDC Equipment Manufacturer
Radio / TV Interference	Identify the potential for radio and TV interference based on the as-design electromagnetic properties of the equipment set.	Mitigate interference through filtering, layout, barriers, or other mitigation techniques, if necessary.	Detailed HVDC design	HVDC Equipment Manufacturer
Pole overload optimization	Identify the amount of inherent overload capability in each pole of the HVDC project to allow for operation above 50% of project capability during monopolar outages.	A short-term and continuous monopolar rating per-pole.	Detailed HVDC design	HVDC Equipment Manufacturer

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Reliability and Availability	Identify the required reliability and availability requirements as discussed in the performance specification and a means to meet those requirements through equipment sizing and optimization.	Guaranteed Reliability and Availability performance from the HVDC equipment vendors and re-optimization of equipment set to accommodate guarantee.	Detailed HVDC design	HVDC Equipment Manufacturer
Commissioning Plan	Identify the scope of the commissioning study to include a timeline, personnel needs, the types of studies that will be conducted, and the approval process to complete commissioning.	A commissioning plan including the types of tests, outage requirements, timing requirements, test power requirements, identification of required personnel, etc.	Detailed HVDC design	HVDC Equipment Manufacturer, review by interconnecting utilities
Sub-Synchronous Torsional Interaction	Study the final, as-designed HVDC system to determine whether any risks of resonance with nearby generators is present study can be done in two stages, a screening followed by a detailed study if required	Adjustment of control algorithm to prevent operation near resonant points where torsional interactions have the potential to occur.	Detailed HVDC design	HVDC Equipment Manufacturer, review by interconnecting utilities
Stability, Modulation & Frequency Control Interaction with SVC's, STATCOM's and other nearby HVDC systems.	Identify potential power electronic-based equipment near the HVDC Project and identify potential interference/coordination requirements.	Adjustment of control algorithm to accommodate interference from nearby power electronic equipment.	Detailed HVDC design	HVDC Equipment Manufacturer, review by interconnecting utilities