Intro to Interconnection

An overview of interconnection study processes

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Reliability and Renewables

Grid reliability in North America is a primary objective for any utility or system operator. Every day, planning engineers perform millions of simulations to evaluate the existing and future transmission system to ensure minimal disruption of power delivery to homes, businesses, industrial centers, and other facilities. These analyses help us understand the impacts of not only potential failures of their existing and future infrastructure, but the influence of new devices and facilities on their systems as well. Among the most impactful changes to the grid is new generation, and the energy transition will require substantial new generation to be added to the grid.

All proposed renewable projects are evaluated via an interconnection study process, which evaluates a project's potential impacts on the grid and determines the costs to mitigate those impacts to allow for safe and reliable operation. In this article, we'll discuss these study processes at a high level, and we'll review how utilities and system operators approach studies for new renewable interconnections. The article also explores some of the primary hang-ups that exist in current study processes, and we'll share a few thoughts on how processes could change to address them.

Transmission Planning and the Interconnection Study Process

Transmission planning broadly seeks to understand how both subtle and extensive changes in the grid might present stresses that cause equipment failures or outages, with the goal of identifying and mitigating the scenarios that would most readily affect system reliability. Generally, these impacts entail system voltage violations at substations or along transmission lines, thermal overloading through branch elements, or system collapse scenarios. These planning objectives are achieved through physics-based simulation of some combination of line outages, sudden changes in or losses of generation, and breaker coordination failures at substations, among other types of system events.

Further, not every utility or operator studies the grid in detail beyond their jurisdictional or operational purview, primarily because the financial responsibility and construction authority for mitigations tends to be localized. For instance, a utility in Ohio would not necessarily have the authority to construct new lines or facilities in an Alabama utility's footprint, so there would not typically be a need for the Ohio utility to assess events in Alabama in detail. That said, planning teams will explore stressed operating conditions considering reasonably likely scenarios to gain as accurate a picture as possible of the most probable stress points of the system.

Guidelines for simulating and evaluating the grid can be complicated, but utilities and operators don't set all of these guidelines themselves. The North American Electric Reliability Corporation (NERC) generally sets the rules by which these entities must evaluate their systems. NERC's TPL standards, among others, communicate which types of simulations need to be performed to ensure system reliability, and much of the contents of these standards serve as a basis for renewable generation and storage interconnection studies. They are not the guidelines by which projects are evaluated, but the types of events studied and simulation types align with many aspects of these standards.

A new renewable project undergoing an interconnection study will have its impact evaluated via a comparison of simulations both with and without the project. The system is studied in the footprint of the utility or system operator where the project would interconnect, and an affected systems study component might also be required to evaluate possible influences of the project on neighboring utility or operator footprints. Affected systems studies are also exhaustive simulation analyses, and they require further coordination and communication among many parties to ensure accurate modeling and analysis. These affected system studies and their coordination can cause further delays and uncertainties for all projects.

The most common simulations performed include power flow (or steady-state), transient stability (or dynamics), and short circuit studies. After all of these simulations are performed and results are processed, any outstanding deviation in system reliability due to the project is attributed to its addition to the grid. These deviations are comprised of the types of transmission reliability violations mentioned previously, i.e., substation or line voltage violations, branch thermal loading violations, and system collapse. When violations caused by the project are identified, it is necessary for them to be mitigated, and those mitigations' costs are subsequently assigned (in future articles, we'll outline the specifics of system operator study and cost allocation processes). Common mitigations include shunt and series reactive power compensation, branch upgrades and rebuilds, and new transmission facilities, including high voltage transmission lines. These mitigations are the main result of the study, and their associated costs can make or break the economic viability of a project.

Some utilities and operators evaluate projects one-at-a-time (i.e., a serial process) or in groups of projects (i.e., a cluster-based process). This process repeats for all projects being studied within a particular time frame until the influence of each project has been adequately assessed and any potential upgrades needed to mitigate impacts on system reliability are assigned and cost allocated on a project-relative basis. Following these evaluations, if a project proceeds beyond this evaluation phase, the process typically concludes with the execution of a generator interconnection agreement (GIA) to finalize the project's assigned system upgrade costs and construction schedule specific to the interconnection of the project. After any other due diligence and/or permitting processes are complete, the project and any upgrades enter a construction phase and the project is eventually energized and made commercially operational on the grid.

Observations and Process Improvement Considerations

Transmission planning and interconnection studies are very complex, computationally intensive, and involve many moving parts and parties to execute. The input data for these studies are submitted by many individuals and organizations and can often be inaccurate or incorrect, pre-study model builds require careful consideration of previously studied (i.e., prior-queued) projects and transmission expansion plans, and the study components are typically performed by different teams at a number of organizations. Due to the nature of these processes, the task of performing interconnection studies is time-consuming and not always simple or straightforward. Utility and system operator teams work diligently to process the projects, and coordination on studies with many other entities can take considerable time.

However, interconnection processes also tend to be very manual and reliant on experienced engineers to perform them. Unfortunately, this can lead to long study timelines, lack of transparency and replicability due to judgment calls, and, ultimately, study backlogs. A project entering into a queue today might not be studied for several years. When the manual nature of existing processes is coupled with historic generation expansion, the process can break and create a greater potential for unnecessarily high system upgrade costs. Without more process automation, there will be increased room for error, as well as more disagreement and dispute over study results. This will create additional uncertainty for projects, and fewer projects, that are otherwise good, will be constructed. More attention is being paid to interconnection study processes due to these factors, and there is considerable interest in improving them.

These and other aspects of interconnection studies make them extremely complex and necessarily thorough, but there is opportunity for improvement. Today, there is considerable need to expedite conventionally manual elements of studies through process automation. Examples include reliably and quickly creating study models, performing input data quality checks, and identifying mitigation suggestions, particularly for non-convergent power flow simulations. Further, automation can provide entities beyond utilities and operators (e.g., developers) the ability to easily replicate study results and to better evaluate risk associated with projects' interconnection prior to submission to a queue. At Pearl Street, we're working on products to automate these study processes for utilities and operators, and to help developer decision-making be more automated and less costly to achieve greater portfolio success.

Questions?

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