Use of Generic Transmission Constraints in ERCOT

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1. Introduction

In ERCOT, the existing market tools (e.g. Security Constrained Economic Dispatch (SCED), Reliability Unit Commitment (RUC), etc.) are primarily designed to efficiently determine the lowest cost Real-Time system dispatch while adhering to pre- and post-contingency thermal overloads of Transmission Elements. However, there are additional operating limits that must be respected in order to maintain grid reliability. As a result, Generic Transmission Constraints (GTCs) are used to monitor flows between areas of the ERCOT Grid and control those flows using market-based mechanisms in order to maintain stability and other non-thermal reliability limits that would not otherwise be considered in market mechanisms. This translation of non-thermal limits into GTCs, and then the use of market mechanisms to control the GTCs ensures that the stability and other non-thermal constraints on the system are managed in an efficient manner.

This white paper provides an overview of system stability phenomena, the evolution of ERCOT Grid characteristics, identification of GTCs and the use of GTCs to address those stability phenomena and Grid characteristics. It also describes issues related to reliably operating the System within the GTC construct.

2. Background on System Stability

Dynamic studies, which are used to identify most stability limits, require detailed dynamic models of ERCOT Facilities and significant resources and time to conduct the studies. Most GTCs are used in the ERCOT System to maintain stability, therefore, this section provides an overview of the system stability challenges that have been addressed using GTCs. Also, a GTC may be used to constraint different stability issues depending on the system conditions. By describing the types of stability issues, the causes of instability, and options for mitigation, it will become clear that the same underlying conditions, most notably heavily loaded high-impedance transfer paths, tend to exacerbate many of these stability challenges. As such, limited benefit may be realized from mitigation options that address only one aspect of stability.

2.1. Voltage Stability

Voltage stability issues are generally characterized by a lack of sufficient reactive power to maintain acceptable voltage levels. Such conditions are commonly encountered when a load center is importing a large amount of power or a generation pocket is exporting a large amount of power through long transfer paths, which tend to have high aggregate impedance and consume large amounts of reactive power. Generally, there are two types of voltage stability:

- Steady State Voltage Stability: the ability to maintain acceptable voltage levels under normal and outage conditions. Power flow based simulation such as PV analysis without dynamic models is generally used to assess steady state voltage stability. The Voltage Security Assessment (VSAT) application is implemented in ERCOT for real-time operation support.
- Transient/Dynamic Voltage Stability: the ability to maintain acceptable voltage recovery in the first few seconds immediately following system disturbances and return to normal conditions. Dynamic simulation, including models that accurately reflect dynamic response, is required to assess transient/dynamic voltage stability. Currently, dynamic simulation applications like PSS/e and TSAT are used as off-line tools. ERCOT plans to implement Real-Time TSAT to be capable of assessing dynamic stability in the real-time

operation. In the absence of Real-Time TSAT, ERCOT performs off-line dynamic studies to determine dynamic voltage stability limits and apply them in Real-Time operation.

Options for mitigating voltage stability issues include but are not limited to reducing the flow through the high impedance transfer paths, adding sources for reactive compensation (static and/or dynamic devices) and upgrading the transmission grid to reduce network impedance across critical transfer paths. It should be noted that the effectiveness of adding reactive compensation to a system reduces as the system becomes increasingly compensated.

2.2. Angular Stability

Angular stability issues are generally associated with the potential for synchronous generators to lose synchronism with the grid. When a transmission line fault occurs near the generator, low voltage prevents the delivery of power from the generator. Energy that was previously being delivered to the grid accelerates the generator shaft until the fault is cleared and power delivery to the grid can resume. Depending on the fault severity and duration as well as the post-disturbance network connections, the generator may or may not maintain synchronism with the grid. Options for mitigating angular stability issues include but are not limited to reducing flow through high impedance transfer paths, improving protection systems to reduce fault clearing times and transmission upgrades that add outlet paths or reduce post-disturbance network impedance as seen from the generator.

2.3. Oscillatory Stability

Oscillatory stability issues are generally characterized by either a synchronous machine oscillating against the system (local mode) or a group of synchronous machines oscillating against another group of synchronous machines (inter-area mode). When an oscillation occurs, the inverter-based power system devices in the vicinity could be affected and participate in the oscillation. The system is most susceptible to oscillations when there are high power transfers across high impedance paths and relatively weak ties between the components that are participating in the oscillation. Options for mitigating oscillatory stability issues include but are not limited to reducing flow on high impedance transfer paths, adding power oscillation damping (POD) control functions to power system devices[1], and upgrading the transmission grid to reduce network impedance across critical transfer paths.

2.4. Control Stability

Control stability issues are generally associated with the potential for inverter controls to fail under conditions of low system strength, which is often described in terms of a short circuit ratio (SCR). Most IBRs require connection to a strong grid for proper operation. IBRs that experience control instability may exhibit oscillatory behavior and/or trip off. Options for mitigating control stability issues include improving the relative system strength so that voltage is less sensitive to changes in reactive power. This can be accomplished by reducing IBR output, installing devices that contribute fault current (e.g. synchronous condensers), installing dynamic devices to improve voltage control (e.g. SVCs or STATCOMs), and upgrading the transmission grid to reduce network impedance. Advances in IBR technology may allow reliable operation over a wider range of system strength conditions in the future.

[1] In ERCOT, synchronous generating units are required to have power system stabilizers (PSS) which mitigate oscillatory behavior.