

Subsynchronous Resonance (SSR)   
Study Scope Guideline

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| May 30, 2015 | 1.0 | Original draft | ERCOT System Planning |
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| May 2, 2017 | 2.1 | Minor updates | ERCOT System Planning |
| June 2018 | 2.2 | Minor updates considering nearby generation and request generator-side impedance table | ERCOT System Planning |
| October 2020 | 2.3 | Streamline study scenarios; minor updates | ERCOT System Planning |

Table of Contents

[1 Purpose 4](#_Toc54680623)

[2 General SSR Scope 4](#_Toc54680624)

[2.1 Conventional Generator SSR Studies 4](#_Toc54680625)

[2.2 Inverter Based Resources (IBR): 4](#_Toc54680626)

[3 Study Development 5](#_Toc54680627)

[3.1 Base Case 5](#_Toc54680628)

[3.2 Contingencies 5](#_Toc54680629)

[3.3 Sensitivities 5](#_Toc54680630)

[3.4 Criteria 6](#_Toc54680631)

[4 Modeling Requirements 7](#_Toc54680632)

[5 SSR Countermeasures 7](#_Toc54680633)

[6 Deliverables 7](#_Toc54680634)

Subsynchronous Resonance (SSR) Analysis

# Purpose

The purpose of this document is to serve as a guideline to establish the study scope for the Subsynchronous Resonance (SSR) interactions occurring between Generation Resources and a series capacitor compensated transmission system. If a project is identified to require a SSR study, the designated entity will perform the study to evaluate vulnerability and identify any needed countermeasures.

Both the scope and the final study will be reviewed by the impacted TSP(s), affected RE(s), and ERCOT. This document provides a list of guidelines for the study scope.

# General SSR Scope

## Conventional Generator SSR Studies

The SSR study for conventional generator units should include the following:

* + Induction Generator Effect (IGE)
  + Torsional Interaction (TI)
  + Torque Amplification (TA)
  + Time domain simulations may be required for further investigation and countermeasures development.

## Inverter Based Resources (IBR):

The SSR study for wind, solar, and energy storage units should include the following:

* + Induction Generator Effect (IGE) / Subsynchronous Control Interaction (SSCI)
  + Time domain simulations may be required for further investigation and countermeasure development. Time-domain simulations are generally required for situations where an IBR is radial to a series capacitor within six or fewer outages, and also required for situations where an IBR shows SSR vulnerability for six or fewer outages.

# Study Development

## Base Case

The latest ERCOT Steady State Working Group (SSWG) base cases which include the anticipated system topology based on the projected in-service date of the proposed project should be utilized; use of an alternative case must be technically justified. The study scope should identify the series capacitor(s) of interest.

## Contingencies

The methodology listed below is one possible method of screening to reduce the number of contingencies combinations considered. If the study involves multiple series capacitors, then this process would be repeated for each series capacitor.

* + Begin with the set of contingencies making the generating unit radial[[1]](#footnote-1) to the series capacitor(s) under study. This set is denoted “R”, consisting of N elements.
    - Evaluate radial condition (R) and all combinations of “R+1” tier (with 1 transmission element placed back in service).
    - Evaluate all combinations of “R+2” tier (with 2 transmission elements back in service).
    - Of the R+2 combinations which show SSR vulnerability, study “R+3” combinations (placing a third element back in service).
    - And so forth until no further combinations show SSR vulnerability with respect to the study criteria described in Section 3.4
    - Contingency sets that can concurrently place a generating unit radial to multiple series capacitors should also be evaluated.

## Sensitivities

The following sensitivities should be considered in the study. Additional sensitivities may be included if deemed necessary.

* + - Switched shunt status
    - Series capacitor staging/bypass status when studying synchronous generators
    - Modeling and status of nearby generators
      * Generally required to consider when running time-domain simulations if considered to impact the results
      * Represent using detailed PSCAD (EMT) models
    - Split bus configurations, relaying schemes, or other area-specific concerns as identified by the affected TSP(s) and ERCOT
    - Sensitivity of plant dispatch level, initial reactive power dispatch, and number of units online. For wind and solar and inverter-based generation it is specifically recommended:
      * 100% units online at 100% dispatch at unity power factor
      * 100% units online at 10% dispatch, leading power factor at the POI
      * 100% units online at 10% dispatch, lagging power factor at the POI
      * 50% units online at 20% dispatch
      * For the power factor scenarios, the plant should be initialized close to the ERCOT-obligated 0.95 pf requirement at the POI (measured w.r.t. the PMAX rating)
    - Inadvertent impact of Special Protection Systems(s) or Constraint Management Plans CMP(s) effecting lines or equipment operating at the same voltage as the series capacitors
    - Specifically for Time-Domain (EMT) Simulation:
      * Both fault and faultless outages
      * Vary fault location (near series capacitor versus near generator if electrically distant) and fault type (three phase versus single line-to-ground)
      * Account for varying system impedance (system strength), such as varying status of further away synchronous generators, etc.
      * If generator under study trips, it may be necessary to determine whether the tripping is masking an underlying SSR problem. Rerun the scenario(s) with generator protection disabled, OR, if it is not possible to disable protection, then rerun the scenario(s) with a fictitious MOV/arrestor added to the series capacitor or POI to artificially limit the transient to a level that ensures ride-through.

## Criteria

* + **IGE / SSCI Criteria**
    - When considering the total impedance of the generator[[2]](#footnote-2) and the grid, if the total resistance is negative at a reactance crossover of zero ohms from negative to positive with increasing frequency, then the scenario is considered to have IGE/SSCI vulnerability. Otherwise, the scenario is not considered to be of concern. (Note: An extra margin may be necessary.)
  + **Torsional Interaction (TI)**
    - The sum of electrical damping (De) plus inverse mechanical damping (Dm) resulting in a negative value indicates TI vulnerability. Considering uncertainties associated with the mechanical mode, Dm at +/- 1 Hz of the modal frequency is utilized to compare to De.
  + **Torque Amplification (TA)**
    - Frequency Scan: When considering the total impedance of the generator and the system, a 5% reactance dip occurring within a +/- 3 Hz complement of the modal frequency indicates a potential TA vulnerability.
    - Detailed Analysis: Acceptable Fatigue Life Expenditure (FLE) criterion is less than 50%.
  + **Time Domain Simulation (EMT)**
    - Expectation Project remains online per ERCOT Voltage Ride Through requirements
    - Response should be well-damped with expected real and reactive output.

# Modeling Requirements

* + Provided by TSP
    - If applicable, information regarding series capacitor protection and metal oxide varistor (MOV) circuits and nearby transmission station overvoltage arrestor ratings (recommended when studying interconnections close to series capacitors)
    - Station one-lines, information regarding split bus configurations, stuck breaker contingencies, and bus faults.
    - Contingency conditions to be evaluated for each series capacitor under study.
  + Provided by Interconnecting Entity (IE) or Resource Entity (RE)
    - Conventional Generators
      * Mechanical Data as required by SSR tab in RARF
      * Generator electrical dynamic data
      * If applicable, plant load data and load ratios (PQ, motor, etc.)
      * If applicable, shaft fatigue life expenditure curves (FLE curves)
    - Inverter Based Resources (IBRs) including Wind, Solar, Battery
      * Collection system details
      * Number and type of turbines or inverters
      * Supplemental reactive equipment, e.g., switchable shunts, STATCOMs, and SVCs
      * EMT models of turbines/inverters
  + Provided by ERCOT
    - Review contingencies to be studied and any additional conditions to be evaluated.

# SSR Countermeasures

Where required by the ERCOT specified SSR countermeasure requirement criteria, a follow-up study may be required to demonstrate the effectiveness of the proposed mitigation and/or protection options.

# Deliverables

SSR study report should include the following if applicable:

* Generator size, MVA base, and technology type (e.g. combined cycle, wind, etc.). For IBRs, identify the inverter or turbine name
* Table of spring-mass data and assumed damping for conventional resources
* PSCAD model filename and file date for IBRs
* Screenshot of PSCAD model parameter settings for IBRs
* Identify series capacitors and contingencies being evaluated
* Identify point from which scans are conducted (e.g. POI, low side of GSU, etc)
* Tables of results showing whether certain combinations of contingencies and / or sensitivities are vulnerable
* For IBRs, table of generator-side frequency scan impedances, if available
* Damping plots for conventional plants
* Plots of voltage across series capacitor(s) for Time-Domain simulations
* Plots of POI voltage (RMS and instantaneous) for Time-Domain simulations
* Request to provide PSCAD study case if time-domain simulations were run
* Table of generator-side frequency scan (R,X versus frequency)
  + For convenience, a template for Generator-Side Frequency Scan is provided:  
    

1. “Radial”: A generator is radial to a series capacitor when all of the energy from the generator flows through the series capacitor bank(s). [↑](#footnote-ref-1)
2. For IBRs, when determining generator impedance, the frequency scanning technique may need to take into account the nonlinearity of the generator model and the effect of grid impedance on the generator model. Refer: Ren, Wei; Piwko, Richard; English, Bruce, “[Analysis and Mitigation of Unstable Subsynchronous Oscillations for Renewable Generation Interconnections](http://submissions.mirasmart.com/pesgm2015/Itinerary/TechnicalProgramSubmissionDetail.asp?id=2728),” 2015 IEEE Power and Energy Society General Meeting in Denver. [↑](#footnote-ref-2)