ERCOT NOGRR-124 (HVRT) Compliance Assessment
ERCOT NOGRR-124 Workshop

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January 17, 2014

Agenda

A **ERCOT NOGRR-124 Overview**

B Key Investigation Objectives

C Wind Generation Resource (WGR) Details

D Study Scenarios

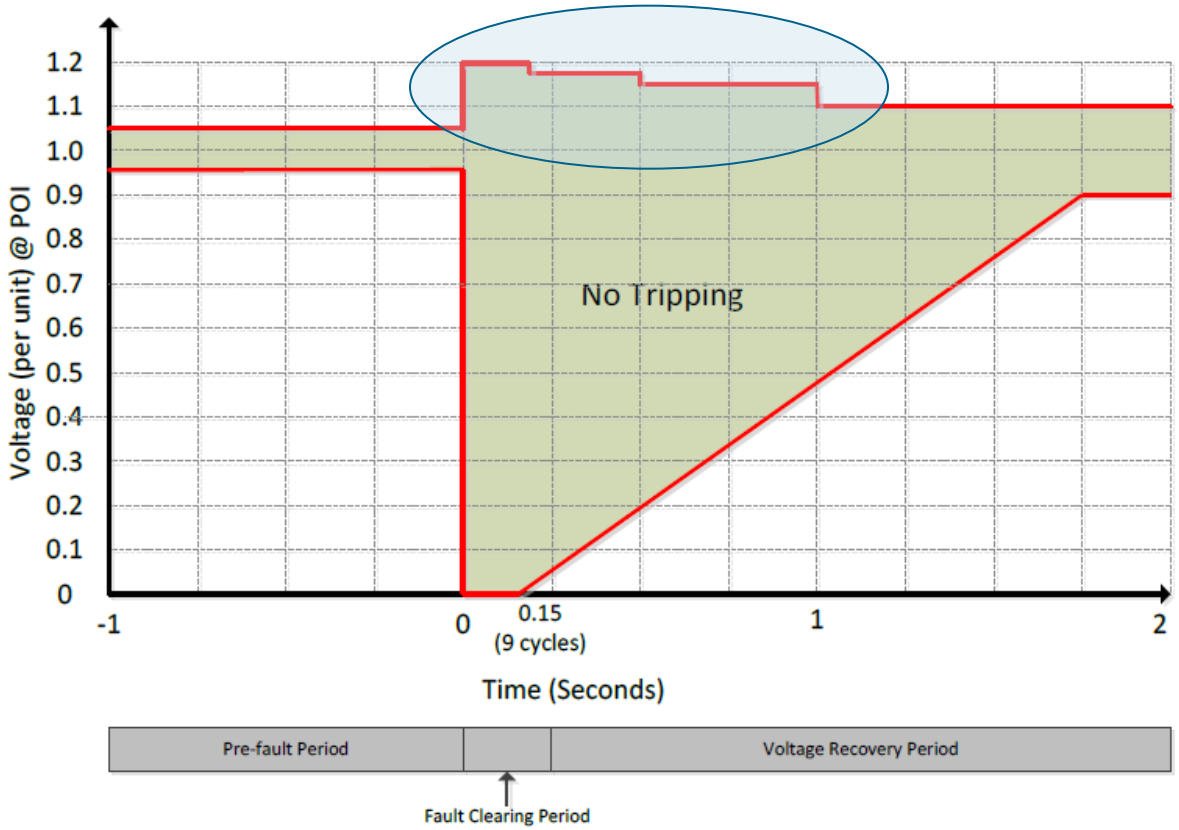
E Dynamic Simulation Results

F Future Investigation

ERCOT NOGRR-124 Overview

- Applicable to all Intermittent Renewable Resources (IRRs) with SGIA executed after August 30, 2013.
  - *"Includes all voltage-related equipment installed or replaced on any such IRR after August 30, 2013 (except for the original equipment installed pursuant to an SGIA executed before August 30, 2013)"*
- Each IRR is required to set generator relays to remain in-service as long as the voltage at the POI is within the boundary of the modified VRT curve
- VRT requirements may be met by the performance of the generators; by installing additional reactive equipment behind the POI; or by a combination of generator performance and additional equipment behind the POI
- Unlike previous HVRT requirement of 1.1 per unit, the NOGRR-124 proposes the following HVRT requirements (as observed at IRR POI):
  - 1.2 per unit for up to 0.2 s
  - 1.175 per unit for up to 0.5 s
  - 1.15 per unit for up to 1s

ERCOT NOGRR-124 Overview



Testing Point	POI Voltage (pu)	Time (sec)
#1	1.2	0.2
#2	1.175	0.5
#3	1.15	1

Proposed High Voltage Ride-Through Boundaries for IRRs (NOGRR-124)

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Key Investigation Objectives

- Evaluate ability of proposed 500 MW WGR connecting in the Panhandle region to comply with the proposed HVRT requirements vis-à-vis NOGRR-124
  - Develop appropriate steady state and dynamic models associated with the WGR campus and turbines thereof
  - Utilize actual ERCOT Dynamics working Group (DWG) dynamic dataset to integrate the relevant WGR model
  - Perform dynamic simulations associated with specific POI over-voltage conditions (with specific magnitude and duration) to assess ability of WGR campus to meet requirements
- Evaluate varying pre-event operational conditions associated with the following:
  - Varying active power dispatch levels
  - Varying VAR output levels vis-à-vis the +/- 0.95 pf requirements at POI per ERCOT requirements
- **Comment on "credible system conditions" to be considered when requesting such HVRT requirements for stakeholder discussion**

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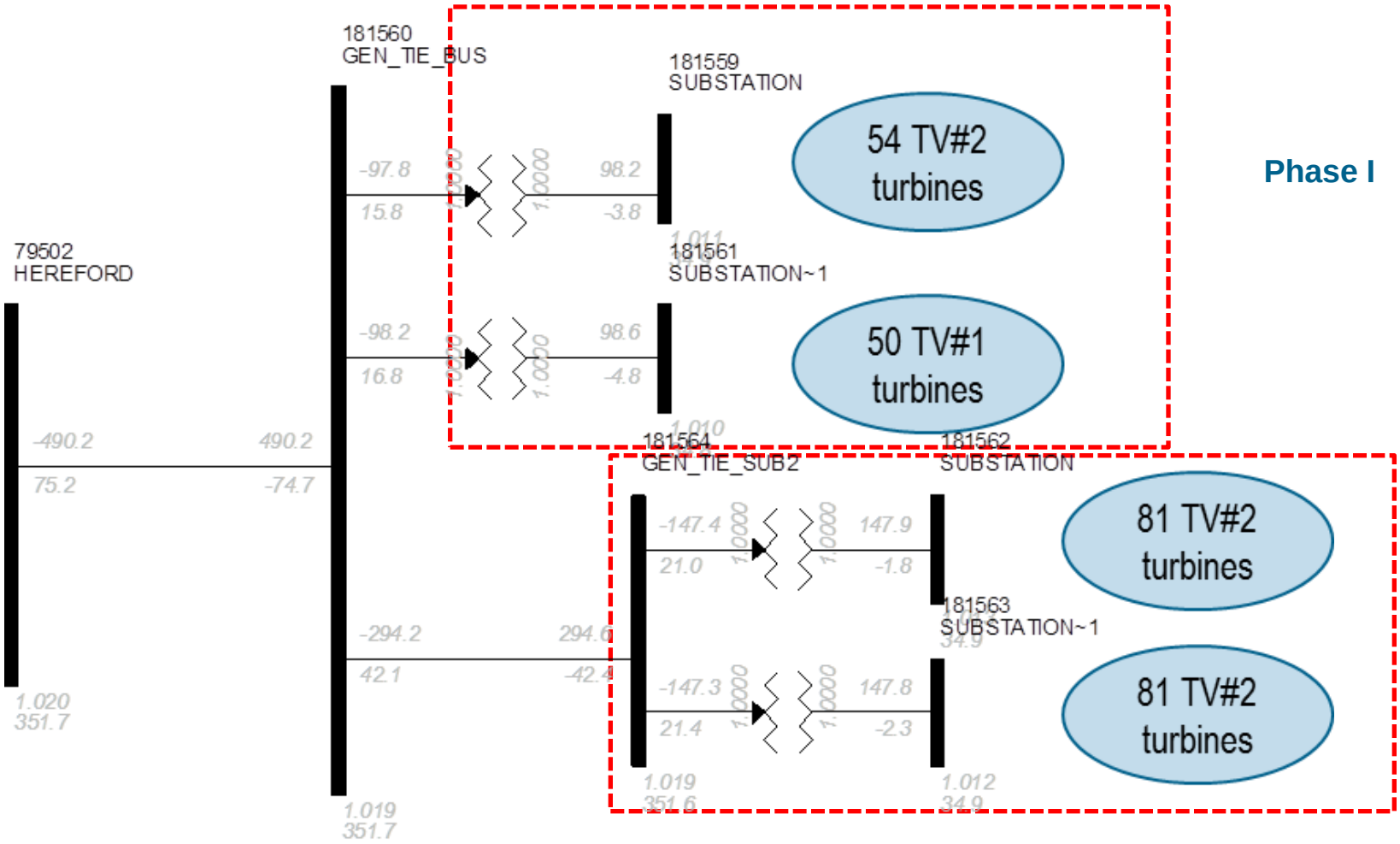
WGR Details

- Project Name: Hereford Wind Project, EDF Renewables
- Project Size: 500 MW
  - Phase I - 199.9MW comprising 50 **Turbine Vendor #1** and 54 **Turbine Vendor #2** wind turbine generators
  - Phase II - 299.7MW comprising **Turbine Vendor #2** wind turbine generators
- Project POI: 345kV Hereford (Windmill) station (Sharyland Utilities)
- Project Modeling Details
  - Detailed collection system model developed for both phases (individual turbines and cable segments modeled based on data provided by EDF)
  - Appropriate modeling of the station transformers and gen tie lines
  - ERCOT FY 2016 High Wind Low Load (HWLL) dynamic dataset utilized for the assessment
  - Entire Hereford project integrated into the ERCOT dynamic dataset
  - 10-sec no disturbance flat start performed to ensure acceptable dynamic initialization

WGR Details



Hereford Wind Farm Single Line Diagram

WGR Details

- Turbine Vendor #1 dynamic model
  - Vendor specific dynamic model utilized
  - Reactive Power/Voltage control: Reactive Power (UPF) control mode
- Turbine Vendor #2 dynamic model
  - Vendor specific dynamic model utilized
  - Reactive Power/Voltage control: Terminal voltage control mode
- Over-voltage relay settings provided below (if terminal voltage exceeds voltage limit for specified (relay + breaker time) duration, turbine expected to trip)

Voltage limit	Relay Time (sec)	Breaker Time (sec)
1.101	1	0.08
1.15	0.5	0.08
1.175	0.2	0.08
1.2	0.1	0.08
1.3	0.01	0.08

Turbine Vendor #2 OV Relay Settings

Voltage limit	Voltage Setting (pu)	Time out (s)
Extreme over voltage 1	1.2	0.08
Extreme over voltage 2	1.25	0.005
Extreme over voltage 3	1.25	0.005
Short term over voltage	1.15	2
Continuous over voltage	1.1	60

Turbine Vendor #1 OV Relay Settings

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Study Scenarios

- Study Scenarios
  - Nine (9) study scenarios developed based on wind dispatch level and pre-event reactive power conditions @ POI
  - Three (3) over-voltage conditions (magnitude/duration) tested for each scenario

Study Scenario #	Dispatch Level (%)	Pre-Event Reactive Power @POI
#1	100	0.95pf Lag
#2	100	unit power factor
#3	100	0.95pf Lead
#4	50	0.95pf Lag
#5	50	unit power factor
#6	50	0.95pf Lead
#7	10	0.95pf Lag
#8	10	unit power factor
#9	10	0.95pf Lead

Study Scenarios, NOGRR-124 Testing Compliance, Hereford Wind Project

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Dynamic Simulation Results

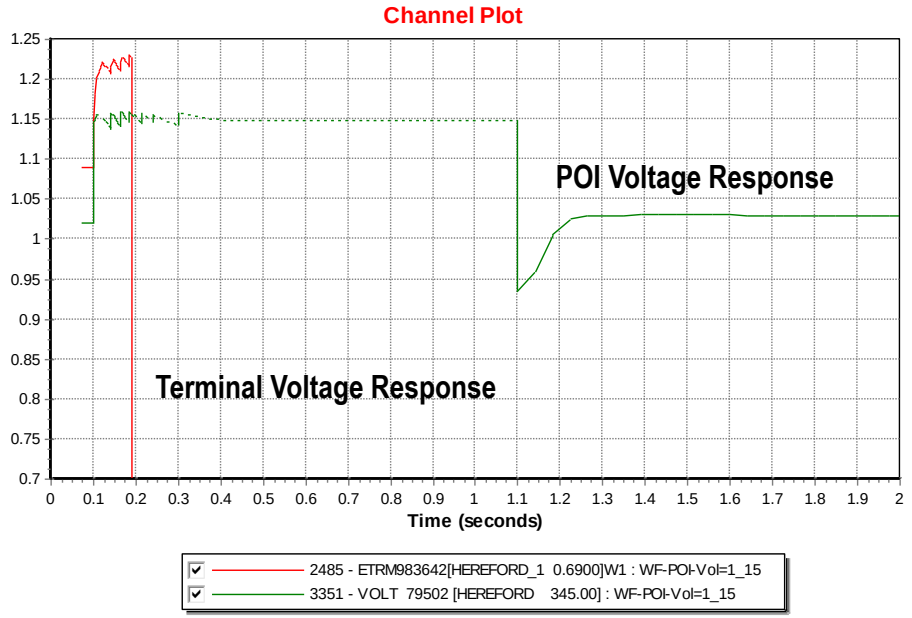
- Pre-event Power Flow
  - Pre-event terminal voltage at the turbine terminals maintained as high as possible (especially under lag conditions) without violating the steady state operation limits.
  - Expected to be one of the worst case scenarios in terms of initial conditions for the NOGRR-124 testing.
  - POI voltage maintained between 1.0 – 1.02 per unit under all the scenarios (reasonable operational voltage profile)

Dispatch Level (%)	P.F.	Q @POI (Mvar)	POI Voltage (pu)	Station Transformer Tap	Turbine Vendor #1				Turbine Vendor #2			
					Q (Mvar, per machine)	Eterm-max	Eterm-min	Eterm-mean	Q (Mvar, per machine)	Eterm-max	Eterm-min	Eterm-mean
100	0.95pf Lag	130.2	1.021	1/1.025	0.406	1.094	1.081	1.088	0.788	1.097	1.075	1.084
100	1.0 pf	2.8	0.993	1	0.000	1.022	1.010	1.016	0.294	1.030	1.030	1.030
100	0.95pf lead	-160.2	1.000	1	-0.583	0.960	0.951	0.955	-0.264	0.973	0.973	0.973
50	0.95pf Lag	160.7	1.019	1.025	0.329	1.061	1.054	1.058	0.632	1.070	1.070	1.070
50	1.0 pf	-1.6	1.007	1	0.000	1.018	1.012	1.015	0.004	1.018	1.018	1.018
50	0.95pf lead	-165	1.024	0.975	-0.329	1.027	1.023	1.025	-0.632	0.990	0.990	0.990
10	0.95pf Lag	154.1	1.020	1.025	0.066	1.031	1.029	1.030	0.551	1.060	1.060	1.060
10	1.0 pf	-0.1	1.008	1	0.000	1.015	1.013	1.014	-0.099	1.005	1.005	1.005
10	0.95pf lead	-161.4	1.024	1/0.975	-0.066	1.023	1.022	1.023	-0.768	0.974	0.970	0.970

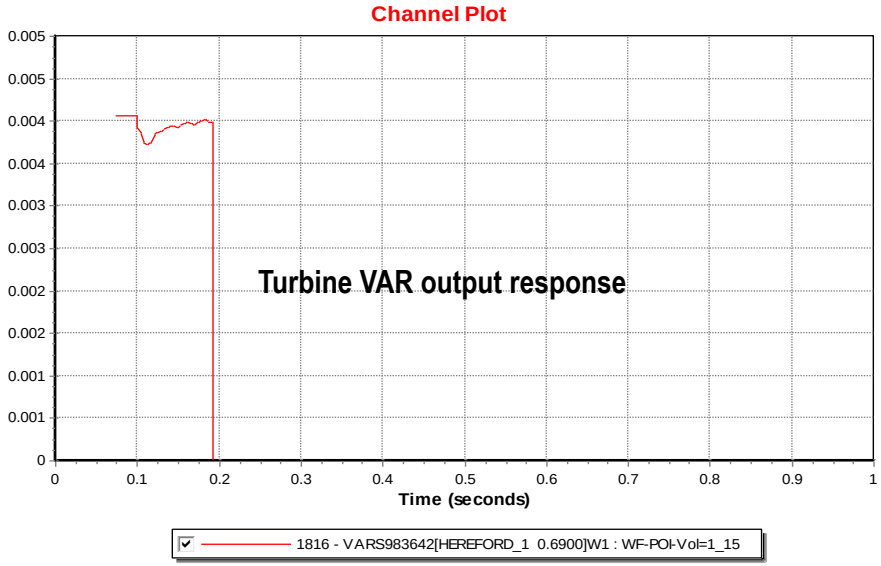
Pre-Event Condition, NOGRR-124 Testing Compliance, Hereford Wind Project

Dynamic Simulation Results

- Dynamic Simulation for HVRT Test
  - Fault based events simulated to evaluate the ability of the campus to ride through the high voltage at POI
  - Varying POI over-voltages (magnitude/duration) to achieve the test scenarios



POI and TV#1Terminal Voltage Response



TV#1 Q Response

HVRT Test Point #3 (1.15pu for 1 second) under Scenario #1 (100% dispatch, 0.95 Lag)

Dynamic Simulation Results

Study Scenario	Dispatch Level (%)	Pre-Event Reactive Power @POI	HVRT Testing Point	HVRT Testing Results	Comments
#1	100	0.95pf Lag	1.15pu - 1sec	Fail	Most of Turbine Vendor #1 machines tripped (Eterm>1.2pu)
#1	100	0.95pf Lag	1.175pu - 0.5sec	Fail	All Turbine Vendor #1 machines tripped (Eterm>1.2pu)
#1	100	0.95pf Lag	1.2pu - 0.2sec	Fail	All Turbine Vendor #1 machines tripped (Eterm>1.25pu)
#2	100	UPF	1.15pu - 1sec	Pass	
#2	100	UPF	1.175pu - 0.5sec	Fail	All Turbine Vendor #1 machines tripped (Eterm>1.2pu)
#2	100	UPF	1.2pu - 0.2sec	Fail	All Turbine Vendor #1 machines tripped (Eterm>1.2pu)
#3	100	0.95pf Lead	1.15pu - 1sec	Pass	
#3	100	0.95pf Lead	1.175pu - 0.5sec	Pass	
#3	100	0.95pf Lead	1.2pu - 0.2sec	Pass	
#7	10	0.95pf Lag	1.15pu - 1sec	Pass	
#7	10	0.95pf Lag	1.175pu - 0.5sec	Pass	
#7	10	0.95pf Lag	1.2pu - 0.2sec	Fail	All Turbine Vendor #1 machines tripped (Eterm>1.2pu)
#8	10	UPF	1.15pu - 1sec	Pass	
#8	10	UPF	1.175pu - 0.5sec	Pass	
#8	10	UPF	1.2pu - 0.2sec	Fail	All Turbine Vendor #1 machines tripped (Eterm>1.2pu)
#9	10	0.95pf Lead	1.15pu - 1sec	Pass	
#9	10	0.95pf Lead	1.175pu - 0.5sec	Pass	
#9	10	0.95pf Lead	1.2pu - 0.2sec	Pass	

Summary Results, NOGRR-124 Testing, Hereford Wind Project (100% and 10% dispatch)

Dynamic Simulation Results

- Key Observations
  - Based on the preliminary test results, the proposed Hereford wind project is **not compliant** with NOGRR-124 (HVRT) requirements under certain operational conditions
    - No tripping of the Turbine Vendor #2 turbine model is observed in all the six (6) HVRT scenarios tested
    - Turbine Vendor #1 OV tripping is observed for several HVRT scenarios related to 0.95 pf Lag and unity power factor conditions
  - **Reactive power control mode** for Turbine Vendor #1 under investigation during dynamic simulation (not power flow setting).
    - TV#2 turbines are observed to be operating in terminal voltage control mode
    - Absorb reactive power to lower the terminal voltage when the POI bus experiences over-voltages simulated during the test.
    - "TV#1 WTGs are not configured for terminal voltage control" per WTG manual.
    - TV#1 WTGs observed to be operating in pre-specified reactive power control mode (as set in power flow) so the terminal voltage will be very high under Lag or unit pf conditions when the POI bus experiences over-voltage

Broader Discussion Points

- Ability of the turbine to provide local/remote voltage control capability/option observed to be an important factor in terms of the campus being able to meet NOGRR-124 requirements
  - Turbines operating in reactive power or pf control mode may not be able to sense the over-voltage at the POI and in case of lagging pf will result in higher voltages on the turbine terminals and trip
- Important to outline **credible pre-event system conditions** under which the NOGRR-124 requirements should be applicable
  - WGRs required to provide +/- 0.95 pf at POI at ERCOT designated voltage profile
  - Such a pre-event operational condition, followed by a fault and a voltage over-shoot (such as Panhandle) may limit the over-all campus capability in meeting NOGRR-124 requirements
- Potential challenges for campuses that employ more than one turbine type
- Specific focus be placed on the practical applicability of NOGRR-124 requirements on weak system conditions
  - Susceptible to larger voltage swings, higher VAR support requirements and probably will pose the stiffest test for NOGRR-124 requirements

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Future Work

- Evaluate ability of voltage control for Turbine Vendor #1 turbines
  - On-going discussions with the vendor
  - Ability to perform local/remote voltage control exists but requires dynamic data modification/augmentations
  - Dynamic set-up associated with such augmentation expected to be site specific
- Re-evaluate conditions of concern with voltage control capability on TV#1 turbine models
- Assess potential complexities in setting voltage control locations/objectives with two turbine vendors within the same campus
  - Terminal voltage control or 34.5kV voltage would probably be the preferred option
  - Prevent any control conflicts and possibility of field issues in case of SCADA communication limitations between the two vendors
- Comment on specific conditions that are observed to pose most limiting conditions on the campus in terms of being able to comply with NOGRR-124

THANK YOU FOR YOUR ATTENTION