DISIS-2020-002

Phase 2 Study Report - Addendum

9/14/2021

This addendum captures the corrections to the DISIS-2020-002 Phase 2 report posted on 8/26/2021 and the additional information requested by the Interconnection Customer(s) at the Phase 2 study report meeting held on 9/2/2021.

The following corrections to DISIS-2020-002 report were identified:

- Section 5.2.4: The ERIS identified for GI-2020-15 is 250MW ~~199.5MW~~
- Section 8.0: The contingent facilities section had incorrect rating for Daniels Park – Priarie3 230kV line.
  Upgrade Daniels Park – Priarie3 230kV line to 756MVA ~~576MVA~~ – ISD under development

Short Circuit Study:

The following additional information regarding breaker duty study methodology and Pre DISIS-2020-002 breaker duty loadings was requested by the Interconnection Customers during the study report meeting.

Modeling: The Short circuit study was performed by modeling a Benchmark Case which represents the system before the DISIS-2020-002. The modeling assumptions for the Benchmark Care are same as Section 4.1 of the Phase 1 DISIS-2020-002 report.

A Study Case was created from the Benchmark Case by modeling the GIRs in the DISIS-2020-002 at their respective POIs, using the modeling data (impedance and configuration information) provided by the Interconnection Customer. All inverter-based generation, including generator step-up transformers, were modeled on an aggregate basis using appropriately scaled generic models at the low side of the main power transformer. In addition, the following Network Upgrades identified from the power flow analysis are modeled in the Study Case.

Table 1 Network Upgrades from DISIS-2020-002 Phase 1

GIRs Sharing the POI	Element	Description

GI-2020- 12/GI-2020-14	Comanche – Daniels Park 345kV line	Terminal Upgrades at Comanche and Daniels Park substations to allow looping of the Comanche – Daniels Park 345kV line into GI-2020- 12/GI-2020-14 345kV Switching Station
GI-2020-12 GI-2020-13 GI-2020-14	Waterton 345/230kV, 560MVA #T2 xfmr	Add second Waterton 345/230kV, 560MVA xfmr
GI-2020-13	Boone – GI-2020-13 230kV line	Uprate line to 394MVA; line conductor is not changed

All connected generating facilities were assumed capable of producing maximum fault current. As such, all generation was modeled at full capacity, whether NRIS or ERIS in the Benchmark Case and the Study case. In addition, where hybrid facilities are included (e.g. solar with battery storage), each technology is modeled as a separate generating resource in CAPE and included at full capacity in the short circuit study, regardless of any limitations to the combined output that would be imposed

Breaker Duty Analysis:

Breaker duty studies were performed on the Benchmark Case and the Study Case, and the results are compared, as shown in Table 2.

Breaker duty studies are conducted using the sub-transient fault analysis. Single and three phase faults are placed at each substation in the system. Each breaker on the PSCo system is modeled by the manufacturer and model number with the catalog characteristics for that breaker and its application, i.e., the relevant standard applying to that breaker's date of manufacture, kA interrupting rating, voltage rating, relay operate time, breaker interrupting time, proximity to generation, etc. The reclosing scheme is not considered in the analysis. The aforementioned factors are used to calculate an X/R factor according to ANSI C37.010-1999, ANSI C37.5-1979, or C37.6-1971. For evaluation of breaker opening by C37.010-1999, applicable to all breakers identified in this study, and with no reclosing and no additional derating, the equivalent current that the breaker is required to interrupt is simply the fault current multiplied by the X/R factor ($I_{breaking}$). This fault current is compared against that breaker's rated interrupting capacity to determine whether the breaker is over-dutied. If it is greater than the breaker's interrupting capacity, it is considered to be over-dutied.

Transmission circuit breakers that were identified as over-dutied (0% margin) in the Benchmark Case are not included. Only breakers that are over-dutied with the addition of the DISIS-2020-

002 GIRs are identified as Network Upgrades. The X/R factor, breaker interrupting capacity, fault current are listed in Table 3 for each over-dutied breaker identified in the study.

In cases where the current resulting from the removal of the GIR resulted in a current reduction at the over-dutied breaker, that cost allocation was set to 0%.

The steps for Breaker duty analysis are shown below.

Step -1: The results of the Benchmark Case and the Study Case are compared and additional breakers that are over-dutied in the Study Case are identified. See Table 2.

Table 2 Over-dutied Breakers Due to Cluster Addition

SUBSTATION	BASE KV	BREAKER NAME
CHEROKEE (PSCO)	230	5043
CHEROKEE (PSCO)	230	5051
CHEROKEE (PSCO)	230	5057
CHEROKEE (PSCO)	230	5058
ARAPAHOE (PSCO)	230	5107
MIDWAY (PSCO)	230	5121
MIDWAY (PSCO)	230	5125
SMOKY HILL (PSCO)	230	5164
SMOKY HILL (PSCO)	230	5166
SMOKY HILL (PSCO)	230	5169
SMOKY HILL (PSCO)	230	5170
SMOKY HILL (PSCO)	230	5171
SMOKY HILL (PSCO)	230	5172
SMOKY HILL (PSCO)	230	5175
SMOKY HILL (PSCO)	230	5177
SMOKY HILL (PSCO)	230	5179
BARR LAKE (PSCO/UPI)	230	5751
BARR LAKE (PSCO/UPI)	230	5752
LOOKOUT (PSCO)	115	9791
LOOKOUT (PSCO)	115	9792
LOOKOUT (PSCO)	115	9794

Step-2: To identify the impact of each GIR, breaker duty studies were re-performed while excluding each individual GIR and associated network upgrade, one at a time. Faults current at each identified over-dutied breaker was used to determine the relative contribution of each GIR and associated network upgrade. The impact of each GIR (which determines the cost allocation) was determined as follows:

$$Allocation\% = \frac{Fault\ Current\ Reduction\ due\ to\ Removal\ of\ GI\ of\ interest}{\sum Fault\ Current\ Reduction, All\ GIs} * 100$$

Where

$Fault\ Current\ Reduction$

$$= (Fault\ Current\ at\ Breaker, All\ GIs\ connected\ )$$

$$- (Fault\ Current\ at\ Breaker, All\ GIs\ connected\ except\ GI\ of\ interest)$$

And,

the Fault Type matches the fault type (3-phase or phase-to-ground) causing the breaker to be overstressed.

Table 3. Cost Allocation of Over-dutied Breakers Due to GIRs in DISIS-2020-002

Substation	Base (kV)	Bkr Name	Bkr. Interr. Rating	Fault Current Before DISIS (kA)	Fault Current with all GIRs connected (kA)	X/R Factor	Ibreaking (XRFACT*Fault Current)	Fault type	GI-2020-12		GI-2020-13		GI-2020-14		GI-2020-15		GI-2020-16		Sum of all reductions (kA)
									Reduction after removing GI (kA)	% of sum of all reductions resulting from removal	Reduction after removing GI (kA)	% of sum of all reductions resulting from removal*	Reduction after removing GI (kA)	% of sum of all reductions resulting from removal	Reduction after removing GI (kA)	% of sum of all reductions resulting from removal	Reduction after removing GI (kA)	% of sum of all reductions resulting from removal	
Cherokee (PSCO)	230	5043	37.6	34.75	35.57	1.06	37.70	3 PH	0.155	20.7%	0.000	0.0%	0.182	24.4%	0.104	13.9%	0.306	41.0%	0.747
Cherokee (PSCO)	230	5051	37.6	34.75	35.57	1.06	37.70	3 PH	0.155	20.7%	0.000	0.0%	0.182	24.4%	0.104	13.9%	0.306	41.0%	0.747
Cherokee (PSCO)	230	5057	37.6	34.75	35.57	1.06	37.70	3 PH	0.155	20.7%	0.000	0.0%	0.182	24.4%	0.104	13.9%	0.306	41.0%	0.747
Cherokee (PSCO)	230	5058	37.6	34.75	35.57	1.06	37.70	3 PH	0.155	20.7%	0.000	0.0%	0.182	24.4%	0.104	13.9%	0.306	41.0%	0.747
Arapahoe (PSCO)	230	5107	31.5	30.97	31.83	1.00	31.83	3 PH	0.220	28.9%	0.006	0.8%	0.258	33.9%	0.067	8.8%	0.211	27.7%	0.762
Midway (PSCO)	230	5121	34.7	31.59	33.82	1.09	36.87	3 PH	0.192	20.4%	0.505	53.8%	0.226	24.1%	0.006	0.6%	0.010	1.1%	0.939
Midway (PSCO)	230	5125	34.7	31.59	33.82	1.09	36.87	3 PH	0.192	20.4%	0.505	53.8%	0.226	24.1%	0.006	0.6%	0.010	1.1%	0.939
Smoky Hill (PSCO)	230	5164	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Smoky Hill (PSCO)	230	5166	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Smoky Hill (PSCO)	230	5169	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Smoky Hill (PSCO)	230	5170	40	38.94	40.43	1.00	40.43	3 PH	0.379	30.2%	0.021	1.7%	0.445	35.4%	0.138	11.0%	0.274	21.8%	1.257
Smoky Hill (PSCO)	230	5171	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Smoky Hill (PSCO)	230	5172	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Smoky Hill (PSCO)	230	5175	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Smoky Hill (PSCO)	230	5177	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Smoky Hill (PSCO)	230	5179	40	39.74	41.35	1.00	41.35	3 PH	0.409	30.8%	0.018	1.4%	0.480	36.2%	0.145	10.9%	0.275	20.7%	1.327
Barr Lake (PSCO/UPI)	230	5751	20	15.75	20.14	1.00	20.14	L-G	0.023	0.5%	0.000	0.0%	0.028	0.6%	0.020	0.5%	4.346	98.4%	4.417
Barr Lake (PSCO/UPI)	230	5752	20	15.75	20.14	1.00	20.14	L-G	0.023	0.5%	0.000	0.0%	0.028	0.6%	0.020	0.5%	4.346	98.4%	4.417
Lookout (PSCO)	115	9791	25	24.73	24.93	1.01	25.18	3 PH	0.050	28.7%	0.000	0.0%	0.059	33.9%	0.015	8.6%	0.050	28.7%	0.174
Lookout (PSCO)	115	9792	25	24.73	24.93	1.01	25.18	3 PH	0.050	28.7%	0.000	0.0%	0.059	33.9%	0.015	8.6%	0.050	28.7%	0.174
Lookout (PSCO)	115	9794	25	24.73	24.93	1.01	25.18	3 PH	0.050	28.7%	0.000	0.0%	0.059	33.9%	0.015	8.6%	0.050	28.7%	0.174

percentage values calculated in the table reflect the breaker cost allocation to each GIR in DISIS-2020-002