Houston Import Project – ERCOT update

RPG Meeting
January 21, 2014

Status of Houston Import Project Review

- ERCOT is conducting the Independent Review to increase the import capability into the Houston area
  - ERCOT presented the reliability need in the October RPG meeting:
    - Thermal overloads of the import paths from North to Houston
    - Low voltages around Bobville, Rothwood, Tomball, and Kuykendahl
    - The worst G-1+N-1 issue occurs when the South Texas U1 is offline
  - Current status:
    - ERCOT has evaluated several options for initial screening and identified eight selected options for detail analysis
    - ERCOT has completed the detail analysis for all eight selected options
    - ERCOT received cost estimates from the TSP for the all selected options and future system upgrades and has completed the cost analysis
    - ERCOT has completed the economic analysis for all select option
    - ERCOT has also completed other sensitivity analysis

Study Base Case

- Total Load in Coast Weather Zone in the 2018 SE case
  - ~ 26,355 MW (CNP load = ~ 22800 MW)
  - The load is identical to the SSWG case load in the Coastal weather zone

- Status of future generators in the study case

  Online:
  - Deer Park Energy G6, Channel Energy GT3,
  - Deepwater Energy,

  Offline:
  - New W.A. Parish unit, Pondera King, Cobisa

Study Approach – Initial Option Evaluation

Initial Options

- Developed based on system problems found, studies done in the past (DOE Long-term planning study), and inputs from TSPs

Study Approach to Screen Initial Options

– N-1 Analysis:
  - AC power flow analysis under N-1 conditions
  - If an option addresses N-1 issue, it moves to the G-1+N-1

– G-1+N-1 Analysis:
  - AC power flow analysis under G-1+N-1 conditions
  - If an option addresses G-1+N-1 issue, it is selected for further evaluation

– Select Options:
  - Options selected for further evaluation
    – Each option that passed G-1+N-1 analysis requires upgrades of certain existing line(s) located near termination point of each option.
    – The existing line upgrade(s) is also assumed as part of each select option

Study Approach – Evaluation of Select Options

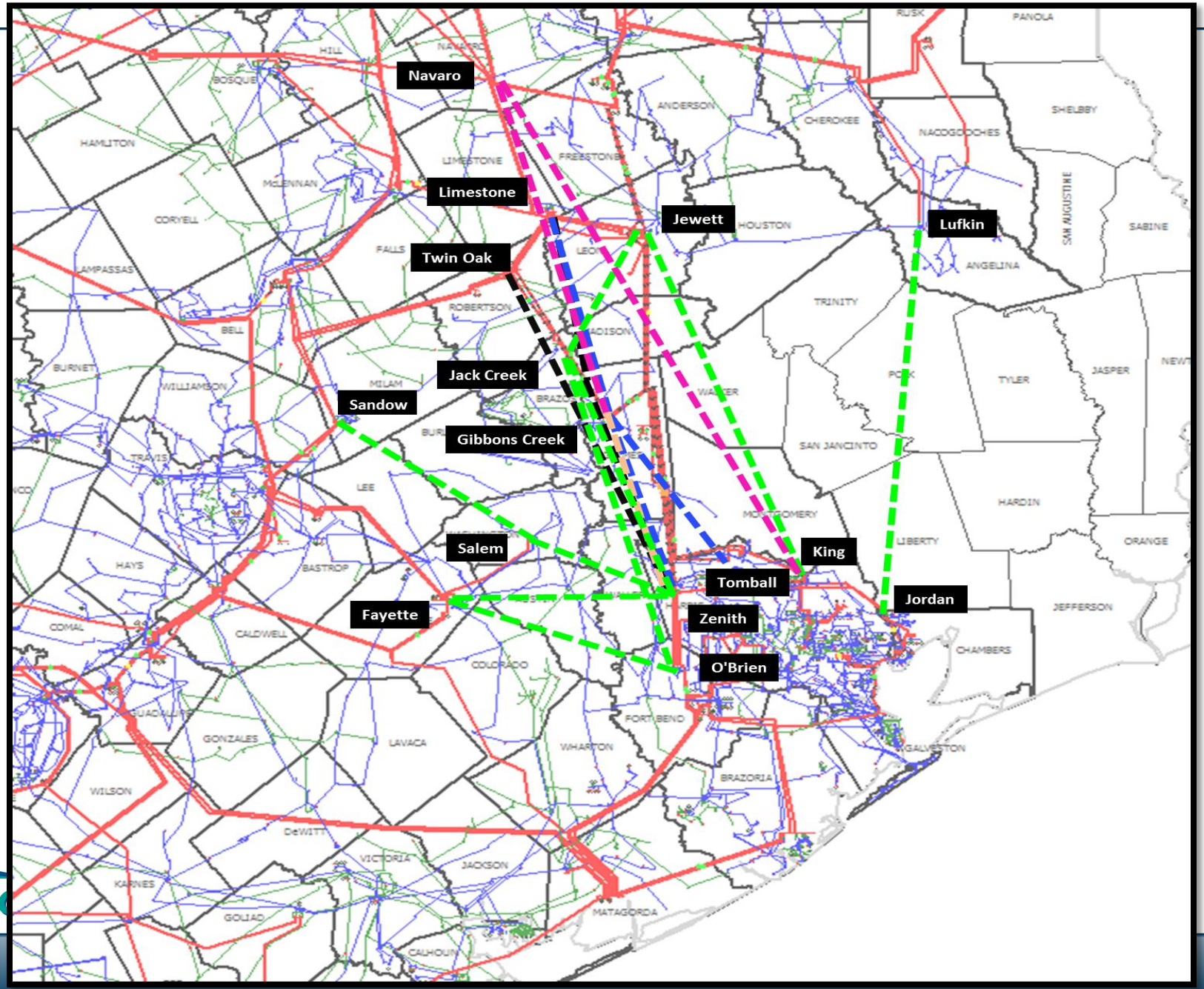
Evaluation of Select Options

- Power transfer capability analysis (including voltage stability)
- Cost Analysis (Present Value Analysis)
- Impact of old generation retirement inside Houston area
- Impact of NERC Category C and D contingencies
- System loss analysis
- Congestion-related impact

Options Evaluated for N-1

ID	CenterPoint Options	Approximate Length (mi)
C1	Twin Oak-Zenith 345 kV double circuit	117.0
C2	Ragan Creek-Zenith double-circuit 345 kV double circuit	69.0
C3	Limestone-Ragan Creek-Zenith 345 kV double circuit	130.2
ID	**Lone Star Options**	**Approximate Length (mi)**
L1	Navarro-Gibbons Creek-Zenith 345 kV double circuit	165.0
L2	Navarro-King 345 kV double circuit	186.0
L3	Navarro-King 500 kV double circuit	186.0
L4	Navarro-King 345 kV double circuit with 50% Series Compensation	186.0
ID	**Cross Texas & Garland Power and Light Options**	**Approximate Length (mi)**
T1	Gibbons Creek-Tomball 345 kV double circuit	50.0
T2	Gibbons Creek-Zenith 345 kV double circuit	60.0
T3	Limestone-Gibbons Creek-Zenith 345 kV double circuit	122.0
ID	**ERCOT and Other Options**	**Approximate Length (mi)**
E1	Jewett-King 345 kV double circuit	142.5
E2	Lufkin-Jordan 345 kV double circuit	126.0
E3	Fayette-Zenith 345 kV double circuit	65.6
E4	Fayette-O'Brien 345 kV double circuit	73.9
E5	Jewett-Jack Creek-O'Brien 345 kV double circuit plus loop Twin Oak-Gibbons Creek into Jack Creek	154.6
E6	Jewett-Jack Creek-Zenith 345 kV double circuit plus loop Twin Oak-Gibbons Creek into Jack Creek	134.1
E7	Sandow-Salem-Zenith 345 kV double circuit	113.4
E6-a	Jewett-Jack Creek-Zenith 345 kV double circuit with 50% or 25% Series Compensation plus Loop Twin Oak-Gibbons Creek into Jack Creek	134.1
C1-a	Twin Oak-Zenith 345 kV double circuit with 50% or 25% Series Compensation	117.0

Map of Options



Result – N-1 Analysis

- Options that did not pass N-1 criteria:
  - **C2: Ragan Creek-Zenith 345 kV**
    - Overload of Twin Oak-Ragan Creek 345 kV, Jack Creek-Twin Oak 345 kV
    - Heavy flow* on Jewett-Singleton 345 kV
  - **T1: Gibbons Creek-Tomball 345 kV**
    - Overload of Jack Creek-Twin Oaks 345 kV
    - Heavy flow* on Jewett-Singleton 345 kV
  - **T2: Gibbons Creek-Zenith 345 kV**
    - Overload of Jack Creek-Twin Oaks 345 kV
    - Heavy flow* on Jewett-Singleton 345 kV
  - **E2: Lufkin-Jordan 345 kV**
    - Overload of ~50 miles of 138 kV lines in the Lufkin area
  - **E3: Fayette-Zenith 345 kV**
    - Overload of Singleton-Zenith 345 kV
  - **E4: Fayette-O'Brien 345 kV**
    - Overload of Singleton-Zenith 345 kV

ERCOT

* Heavy flow: contingency loading greater than 95%

Result – G-1+N-1 Analysis

- Options that did not meet the G-1+N-1 Analysis:
  - **C1: Twin Oak-Zenith 345 kV**
    - ✓ Heavy flow* on Singleton-Zenith 345 kV
  - **E1: Jewett-King 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **E5: Jewett-Jack Creek-O'Brien 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **E7: Sandow-Salem Zenith 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
    - ✓ Heavy flow* on Jewett-Singleton 345 kV
  - **L3: Navarro-King 500 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **L4: Navarro-King 345 kV with 50% series compensation**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **L2: Navarro-King 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
    - ✓ Heavy flow* on Jewett-Singleton 345 kV

ERCOT

* Heavy flow: contingency loading greater than 95%

Selected Option for Further Analysis

- **Eight options selected for further study**
  - Option 1: Twin Oak-Zenith 345 kV with 25% series compensation (~117 miles)
  - Option 2: Twin Oak-Zenith 345 kV with 50% series compensation (~117 miles)
  - Option 3: Limestone-Ragan Creek-Zenith 345 kV (~130.2 miles)
  - Option 4: Limestone-Gibbons Creek-Zenith 345 kV (~122 miles)
  - Option 5: Jewett-Jack Creek-Zenith 345 kV (~134.1 miles)
  - Option 6: Jewett-Jack Creek-Zenith 345 kV with 25% series compensation (~134.1 miles)
  - Option 7: Jewett-Jack Creek-Zenith 345 kV with 50% series compensation (~134.1 miles)
  - Option 8: Navarro-Gibbons Creek-Zenith 345 kV (~165 miles)

- **Few upgrades of existing lines are also included as part of the options**
  - For all options above, upgrade
    - T.H. Wharton-Addicks 345 kV line (~10.7 miles)
  - For Option 6 and 7, upgrade
    - Jack Creek-Twin Oak double-circuit 345 kV line (terminal upgrade)
  - For Option 8, upgrade
    - Jack Creek-Twin Oak 345 kV #1 (terminal upgrade)

- **These select options moved to the next stage for further evaluation.**

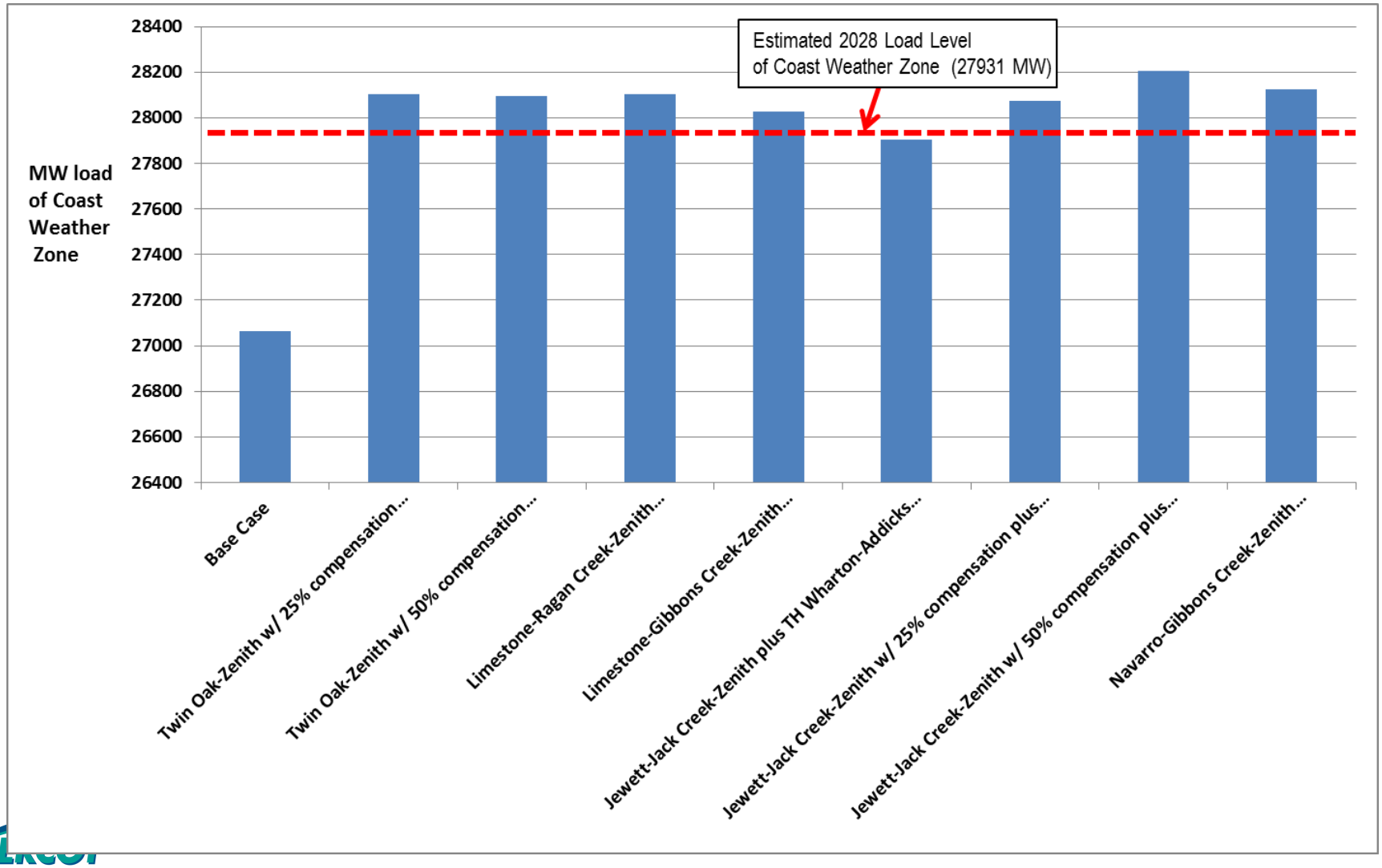
Result of Transfer Capability Analysis (Thermal Overload)

- Performed power transfer analysis and identified future thermal upgrades needed for each option over the next 15 years (2028)

Option		by 2025	by 2026	by 2027	by 2028
Option 1	Twin Oak-Zenith w/ 25% compensation plus TH Wharton-Addicks upgrade		Singleton-Zenith 345 kV (53.2 mi)	Big Brown-Jewett 345 kV (32.8 mi)	Zenith-TH Wharton 345 kV (15.1 mi)
Option 2	Twin Oak-Zenith w/ 50% compensation plus TH Wharton-Addicks upgrade		Big Brown-Jewett 345 kV (32.8 mi)		Singleton-Zenith 345 kV (53.2 mi), Zenith-TH Wharton 345 kV (15.1 mi)
Option 3	Limestone-Ragan Creek-Zenith plus TH Wharton-Addicks upgrade			Singleton-Zenith 345 kV (53.2 mi), Jack Creek-Twin Oak #1 (26.7 mi), Big Brown-Jewett 345 kV (32.8 mi)	Gibbons Creek-Ragan Creek 345 kV (9.6 mi)
Option 4	Limestone-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade			Singleton-Zenith 345 kV (53.2 mi), Big Brown-Jewett 345 kV (32.8 mi)	Jack Creek-Twin Oak #1 (26.7 mi)
Option 5	Jewett-Jack Creek-Zenith plus TH Wharton-Addicks upgrade	Singleton-Zenith 345 kV (53.2 mi)	Big Brown-Jewett 345 kV (32.8 mi), Twin Oak-Jack Creek 345 kV (26.7 mi)		Jewett-Singleton 345 kV (49.9 mi), Zenith-TH Wharton 345 kV (15.1 mi), Gibbons Creek-Singleton 345 kV (9.4 mi), Gibbons Creek-Jack Creek 345 kV (21.3 mi)
Option 6	Jewett-Jack Creek-Zenith w/ 25% compensation plus TH Wharton-Addicks & Twin Oak-Jack Creek upgrade		Big Brown-Jewett 345 kV (32.8 mi)	Singleton-Zenith 345 kV (53.2 mi)	Zenith-TH Wharton 345 kV (15.1 mi), Twin Oak-Jack Creek 345 kV (26.7 mi)
Option 7	Jewett-Jack Creek-Zenith w/ 50% compensation plus TH Wharton-Addicks & Twin Oak-Jack Creek upgrade		Big Brown-Jewett 345 kV (32.8 mi)		Singleton-Zenith 345 kV (53.2 mi), Zenith-TH Wharton 345 kV (15.1 mi), Twin Oak-Jack Creek 345 kV (26.7 mi)
Option 8	Navarro-Gibbons Creek-Zenith plus TH Wharton-Addicks & Twin Oak-Jack Creek upgrade		Jewett-Singleton 345 kV (49.9 mi), Gibbons Creek-Twin Oak & Gibbons Creek-Jack Creek-Twin Oak 345 kV (48 mi)	Singleton-Zenith 345 kV (53.2 mi)	

Result of Transfer Capability Analysis (Voltage Stability)

- MW load level at the point of voltage collapse under each select option <u>without any upgrades</u>
- Voltage collapse occurs beyond 2028 under every option except Option 5



Impact of Old Generator Retirement

- 11 units (total 1939 MW) are more than 50 year old by 2018
  - Sam Bertron G1, G2, G3, G4 and GT2
  - T.H. Warton GT1
  - W.A. Parish G1, G2, G3, G4, and GT1

- Result of AC power flow analysis with all these 50-year old units offline
  - System problems in the 2018 base case either under system intact or N-1 conditions:

    - Under system intact condition with the units offline,
      - Overload of Singleton-Zenith 345 kV line
      - Overload of Jewett-Singleton 345 kV line
      - Low voltage around Tomball, Kuykendahl, Bobville, Rothwood

    - Under N-1 contingency conditions,
      - Overload of Jewett-Singleton 345 kV line
      - Overload of the bus ties at Twin Oak/Oak Grove
      - Overload of Singleton-Zenith 345 kV line
      - Overload of Gibbons Creek-Twin Oak 345 kV line
      - Overload of Jack Creek-Twin Oak 345 kV line
      - Overload of Gibbons Creek-Singleton 345 kV line
      - Overload of Roans Prairie-Bobville-Kuykendahl 345 kV line
      - Heavy flow on Singleton-Tomball and Gibbons Creek-Jack Creek 345 kV line
      - Low voltages at 15 345-KV buses and 38 138-kV buses in Houston area

Impact of Old Generator Retirement

- Result of AC power flow analysis with each option:
  - ✓ No system problem under system intact condition
  - ✓ No low voltage issues under N-1 condition
  - ✓ Table below shows overload and heavy flow issues under N-1 conditions when the old units are offline

Elements	Jewett S-Singleton 345 kV line #1	Jewett N-Singleton 345 kV line #1	Twin Oak-Oak Grove 345 kV bus tie	Twin Oak 345 kV bus tie	Singleton-Zenith 345 kV line #98	Singleton-Zenith 345 kV line #99	Gibbons Creek-Twin Oak 345 kV #1	Gibbons Creek-Jack Creek 345 kV #2	Jack Creek-Twin Oak 345 kV #1	Jack Creek-Twin Oak 345 kV #2
Option 1			Overload	Overload	Overload	Overload				
Option 2			Overload	Overload						
Option 3			Heavy flow	Heavy flow	Heavy flow	Heavy flow			Heavy flow	
Option 4			Heavy flow	Heavy flow	Heavy flow	Heavy flow				
Option 5			Overload	Overload	Overload	Overload			Overload	Overload
Option 6			Overload	Overload	Heavy flow	Heavy flow				
Option 7			Heavy flow	Heavy flow					Heavy flow	Heavy flow
Option 8	Overload	Overload	Heavy flow	Heavy flow	Heavy flow	Heavy flow	Overload	Heavy flow	Heavy flow	

Impact of Old Generator Retirement

- Result of generation reduction analysis:
  - ✓ Tested G-1+N-1 while reducing the output from the old units
  - ✓ Estimated total MW output that can be reduced from the old unit under each select option without causing any thermal issues

Option	Description	Approximate MW generation reduction that starts causing overload under G-1+N-1
Option 1	Twin Oak-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade	900.6
Option 2	Twin Oak-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade	911.1
Option 3	Limestone-Ragan Creek-Zenith plus TH Wharton-Addicks upgrade	1061.3
Option 4	Limestone-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade	1020.0
Option 5	Jewett-Jack Creek-Zenith plus TH Wharton-Addicks upgrade	400.0
Option 6	Jewett-Jack Creek-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	773.8
Option 7	Jewett-Jack Creek-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	662.6
Option 8	Navarro-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	652.6

Impact of NERC Category C and D

- Tested 23 severe events (NERC Cat. C and D contingencies) based on the past study and knowledge of the system

Options	Description	# of Unsolved Contingencies (NERC Cat. D)	Thermal Overload 345 kV 115% above	Low Voltage At 345 kV Buses (below 0.9 pu)
	Base Case	6	6	5
Option 1	Twin Oak-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade	1	1	4
Option 2	Twin Oak-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade	1	0	3
Option 3	Limestone-Ragan Creek-Zenith plus TH Wharton-Addicks upgrade	1	0	5
Option 4	Limestone-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade	1	0	5
Option 5	Jewett-Jack Creek-Zenith plus TH Wharton-Addicks upgrade	1	1	6
Option 6	Jewett-Jack Creek-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	1	0	5
Option 7	Jewett-Jack Creek-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	1	0	3
Option 8	Navarro-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	1	0	5

System Loss Reduction

- System losses with each option modeled in the 2018 summer peak study case were compared to the base case
- In every option, significant loss reduction is expected

Option	Option 1 (TWZ-25%COMP-TA)	Option 2 (TWZ-50%COMP-TA)	Option 3 (LRZ-TA)	Option 4 (LGZ-TA)	Option 5 (JJZ-TA)	Option 6 (JJZ-25%COMP-TATJ)	Option 7 (JJZ-50%COMP-TATJ)	Option 8 (NGZ-TATJ)
System Loss Reduction (MW)	44.7	38.8	47.6	31.2	38.2	44.8	35	32.7

Sensitivity Analyses for Transfer Study

- A sensitivity analysis was performed using the latest SSWG case
  - Case used: As-built 2014 SSWG Data Set B 2018 base case
  - Results confirmed overload on Singleton-Zenith 345 kV double circuit line under the G-1+N-1 condition

- Power transfer analysis using different load scaling approach
  - Power transfer analysis was performed for certain options under N-1 conditions using the following two load scaling approaches:
    1) Scaling load down in North, North Central, West and Far West
    2) Scaling all load down except the load in Coast Weather Zone
  - The result indicates that:
    - There are reliability criteria violations in 2018 regardless of which approach is used
    - The need identification for the next set of upgrades may be deferred by a year or two if the all-load-scaling (#2) approach is used
      - For example, roughly 220~300 MW difference in the transfer capability, when the future overload issue on the Singleton-Zenith double-circuit 345 kV line occurs with each option

Cost Analysis

- Methodology and Assumptions:

  - ✓ In addition to the cost of each select option, the cost of each future upgrade (up to 2028) was also considered to capture the long-term reliability benefit of each select option.

  - ✓ Overall cost associated with each select option was calculated.

Overall cost = Construction cost* of each select option +
NPV† of construction cost** of future upgrades

* the construction cost of each select option in 2018 dollar.

** the future value of each future upgrade, estimated by using 3% inflation rate.

† 8% discount rate was used to calculate the NPV (in 2018 dollar) of the set of future upgrades under each select option.
(Reference of discount rate: www.puc.texas.gov/industry/electric/reports/31600/PUCT_CBA_Report_Final.pdf)

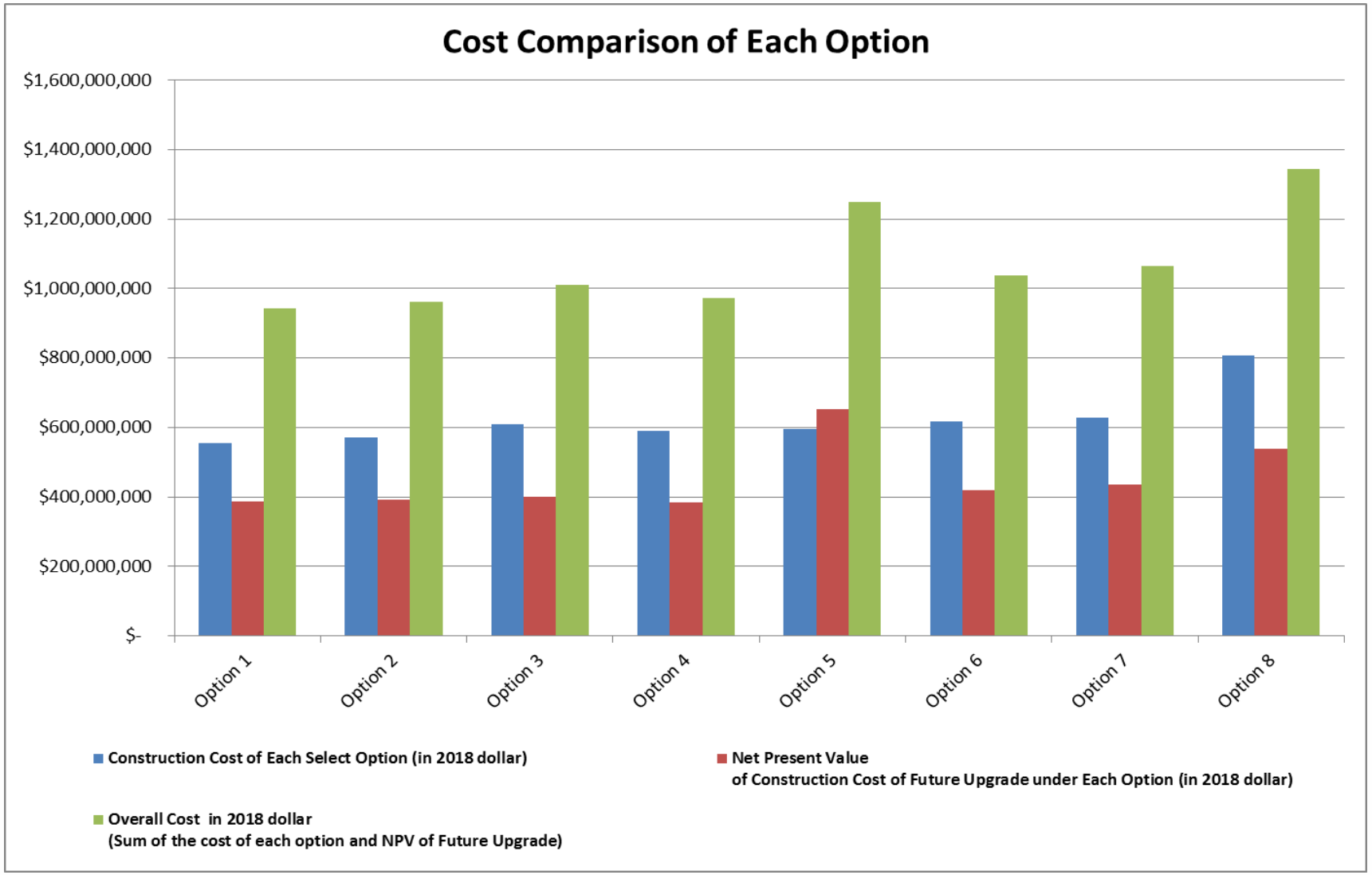
Result of Cost Analysis

Unit: $ Million

Option	Construction Cost * of Each Select Option (in 2018 dollar)	Net Present Value (NPV) of Construction Cost of the Set of Future Upgrades (in 2018 dollar)	Overall Cost (in 2018 dollar)
Option 1 (TWZ-25%)	554.8	387.0	941.8
Option 2 (TWZ-50%)	572.0	390.6	962.6
Option 3 (LRZ)	610.2	399.5	1,009.7
Option 4 (LGZ)	590.1	383.1	973.3
Option 5 (JJZ)	596.3	652.9	1,249.3
Option 6 (JJZ-25%)	617.1	419.5	1,036.6
Option 7 (JJZ-50%)	629.1	435.2	1,064.4
Option 8 (NGZ)	805.9	537.5	1,343.4

* $ 3.78 million-per-mile was assumed for T-line portion of the cost. ERCOT performed sensitivity analysis using different cost-per-mile assumption. No significant impact was found in selecting a best solution.

Result of Cost Analysis



Economic Analysis

- Although the Houston Import RPG review is purely driven by reliability need, ERCOT also performed an economic analysis for the year 2018 using the 2018 economic case.

- Relative annual production cost of each option was obtained by comparing the annual production cost of each option against the option with the highest annual production cost.

Unit: $ Million

Option	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Production cost savings	4.3	3.4	3.2	1.7	2.1	2.2	1.7	0.0

Other Sensitivity Studies

Study using the as-built SSWG case

- A sensitivity analysis was performed using the latest SSWG case
  - ✓ Case used: As-built 2014 SSWG Data Set B 2018 base case (built on 10/15/2013)
    - ✓ No changes to SSWG load (no scaling done to weather zone)
    - ✓ No changes to SSWG generation
  - ✓ As a result of the AC power flow analysis under G-1+N-1, ERCOT found
    - Overload of Singleton-Zenith double circuit (122%)
    - Roans Prairie-Bobville #75 (99%)
    - Bobville-Kuykendahl #75 (99%)
    - Jewett North-Singleton #1 (93%)
    - Jewett South-Singleton #1 (91%)
    - Gibbons Creek-Singleton #75 (92%)
    - Gibbons Creek-Singleton #99 (92%)
    - Jack Creek-Twin Oak #1 (92%)

Other Sensitivity Studies

Adding a 10-Ohm Series Reactor on the Singleton to Zenith 345 kV

- An AC power flow analysis was performed for the Jewett-King 345 kV double circuit option with a series reactor assumed on the Singleton-Zenith 345 kV double circuit.
  - ✓ Significant contingency loading (~98%) still exist on the Singleton-Zenith 345 kV double circuit, close to overload even with the series reactor assumed along with the Jewett-King 345 kV option
  - ✓ Similar approach can be applied to each select option. Thus, it will provide no impact on relative performance of each select option

- ERCOT also tested the series reactor with the Twin Oak-Zenith option as a sensitivity check
  - ✓ AC contingency analysis showed no overload on the Singleton-Zenith 345 kV double circuit
  - ✓ However, power transfer analysis showed that voltage collapse would occur even before 2028

Impact of new Generation in Houston Area

- High level sensitivity analysis was performed to estimate the impact of new future generation with in the coast weather zone
  - ✓ The load was scaled down in the entire coast weather zone (below the base case level) to mimic the new generation addition
  - ✓ Results indicate that approximately 1800 MW of new generation would reduce the G-1 + N-1 overload to 100%.

Potential issues to consider for Options with Series Compensation

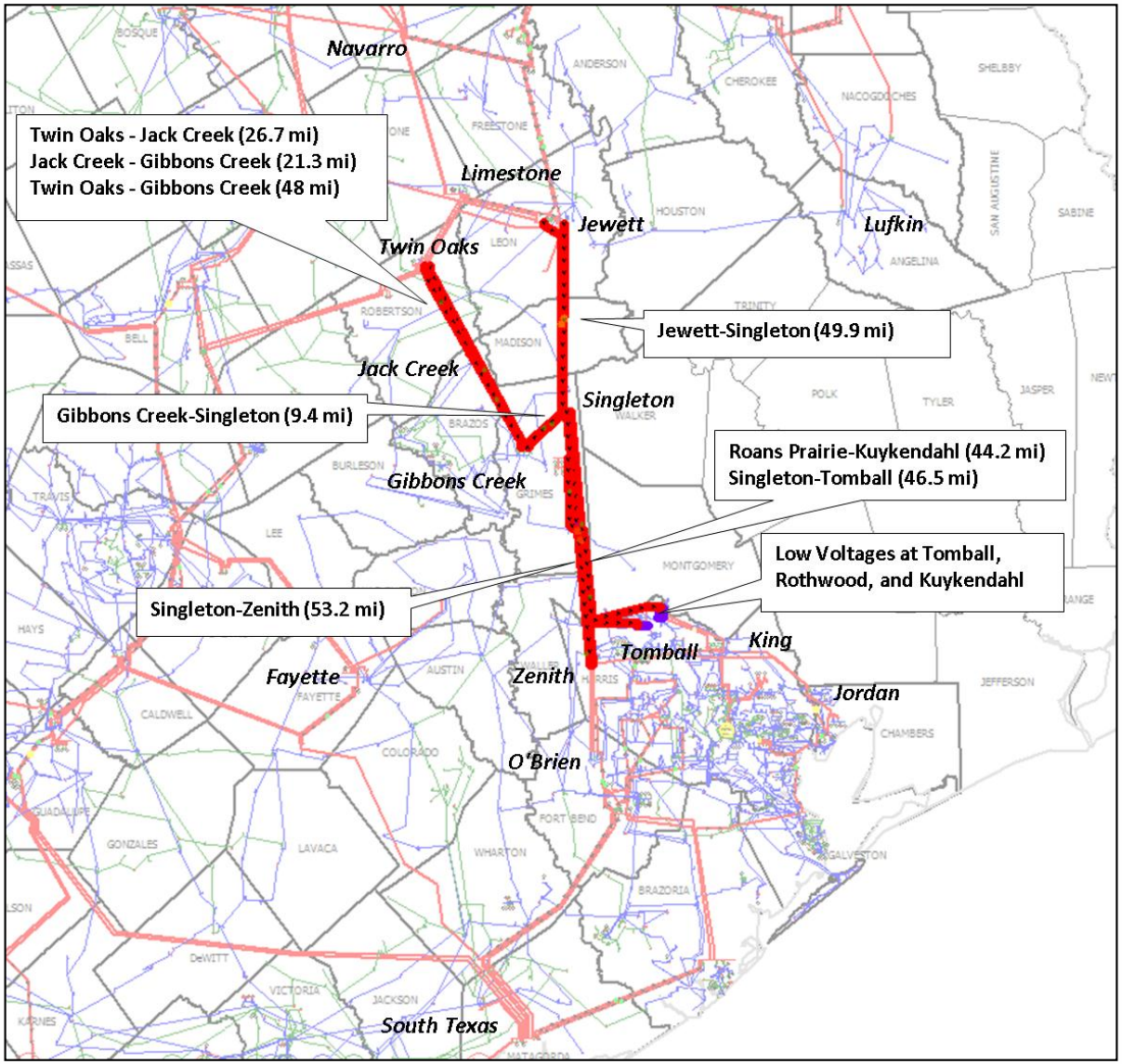
- ✓ Conventional units in the area may be at risk due to Sub-Synchronous Resonance (SSR) introduced by the series compensation (SC) in Option 1, Option 2, Option 6 and Option 7
- ✓ Based on the past study experience, relatively higher chance of having SSR issue at the conventional units under a lower depth of contingency conditions (i.e. less than N-3 could result in some units connected radially to the SC)
- ✓ Significant time and resources will be needed to perform detail SSR studies for each generator in the area (3~6 months of data gathering, 6 to 12 months for SSR study)
- ✓ Overall project cost for the 5000 Amp SC (same as the line rating) will be higher compared to the 4000 Amp SC rating included in the current estimate
- ✓ Thyristor Controlled Series Capacitors (TCSC) may be used to mitigate the potential SSR issues. The cost will be significantly higher(1.5 to 5 times)
- ✓ Currently, there is no policy existing in ERCOT regarding series compensation

Next Step

- ERCOT will review additional feedback provided by Stakeholders
- Prepare the final report with ERCOT recommendation
- Present ERCOT recommendation to TAC and ERCOT Board of Directors endorsement

Questions?

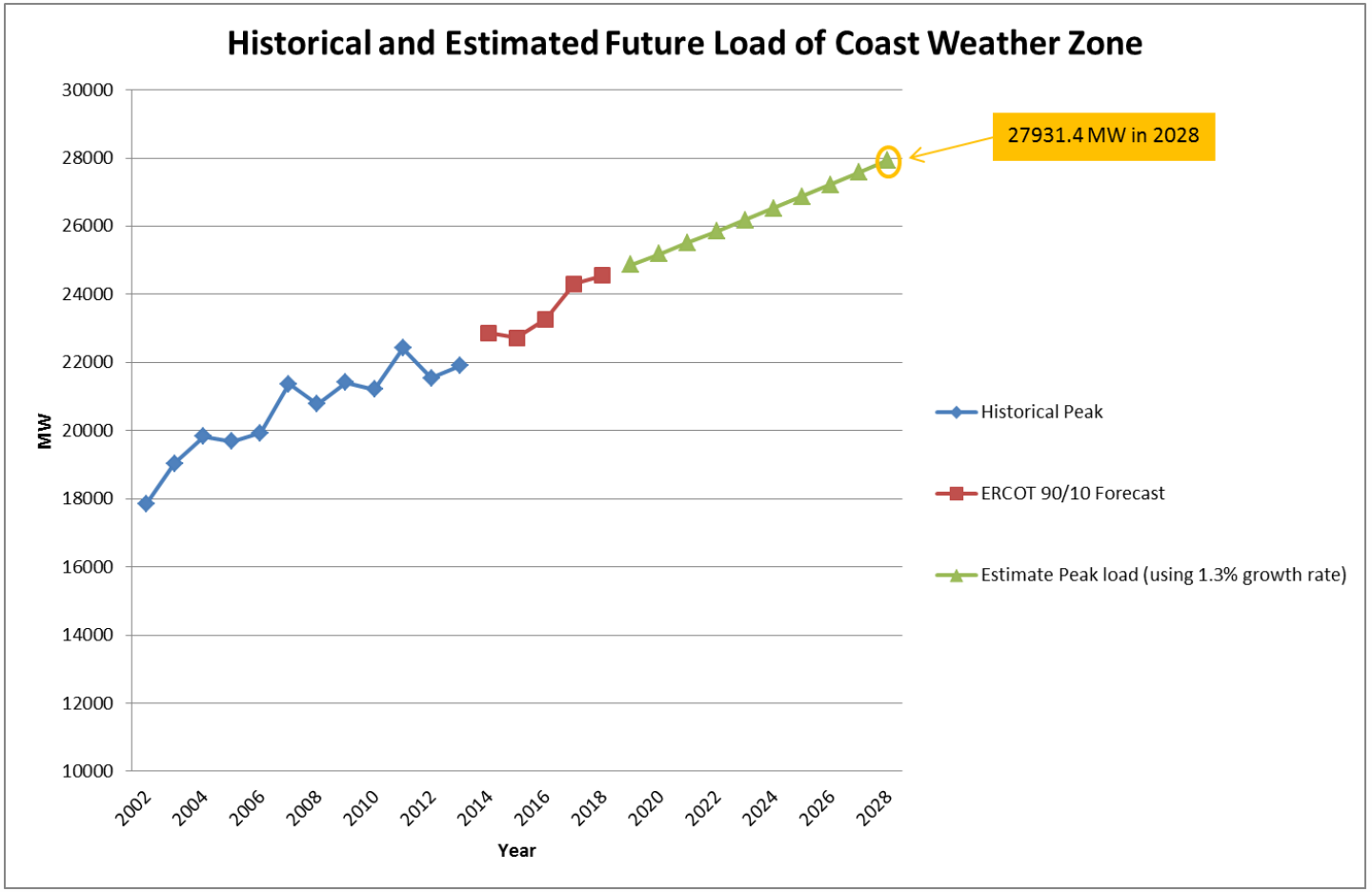
Appendix 1. Map of System Problems



(The Worst G-1 Condition = South Texas U1, 1375 MW)

Appendix 2. Future Load (Coast WZ) Assumed for Study

- Estimated load in Coast Weather Zone for the year 2028
  - 1.3 % of annual load growth rate was used from 2018 to 2028
  - Roughly 27931 MW of load in 2028



Appendix 3. Cost Analysis Using Different Cost-Per-Mileage

Ranking if $2.2 mm/mi used for T-line cost	Construction Cost of Each Select Option in 2018 dollar	Net Present Value of Construction Cost of the set of Future Upgrade in 2018 dollar	Total Reliability Impact in 2018 dollar (Cost of Option + Cost of Potential Future Upgrades)
Option 1	$339,396,785	$386,990,789	$ 726,387,574
Option 4	$351,005,049	$383,144,654	$ 734,149,704
Option 2	$356,605,049	$390,597,601	$ 747,202,650
Option 3	$364,243,959	$399,464,064	$ 763,708,023
Option 6	$376,882,114	$419,524,370	$ 796,406,484
Option 7	$388,932,768	$435,242,033	$ 824,174,801
Option 5	$356,136,904	$652,947,369	$1,009,084,273
Option 8	$478,411,731	$537,495,476	$1,015,907,207

Ranking if $3.78 mm/mi used for T-line cost	Construction Cost of Each Select Option in 2018 dollar	Net Present Value of Construction Cost of the set of Future Upgrade in 2018 dollar	Total Reliability Impact in 2018 dollar (Cost of Option + Cost of Potential Future Upgrades)
Option 1	$554,769,900	$386,990,789	$ 941,760,689
Option 2	$571,977,900	$390,597,601	$ 962,575,501
Option 4	$590,141,093	$383,144,654	$ 973,285,747
Option 3	$610,220,900	$399,464,064	$1,009,684,964
Option 6	$617,075,011	$419,524,370	$1,036,599,381
Option 7	$629,126,011	$435,242,033	$1,064,368,044
Option 5	$596,330,011	$652,947,369	$1,249,277,380
Option 8	$805,912,093	$537,495,476	$1,343,407,569

Ranking if Hybrid (2.15 & 3.78 mm/mi) approach is used	Construction Cost of Each Select Option (in 2018 dollar)	Net Present Value of Construction Cost of Future Upgrade under Each Option (in 2018 dollar)	Total Reliability Impact in 2018 dollar (Sum of the cost of each optio and NPV of Future Upgrade)
Option 1 (TWZ 25%)	$553,700,190	$386,990,789	$ 940,690,980
Option 6 (JJZ 25%)	$531,161,785	$419,524,370	$ 950,686,155
Option 2 (TWZ 50%)	$570,908,455	$390,597,601	$ 961,506,056
Option 4 (LGZ)	$588,936,779	$383,144,654	$ 972,081,433
Option 7 (JJZ 50%)	$543,212,439	$435,242,033	$ 978,454,472
Option 3 (LRZ)	$602,358,854	$399,464,064	$1,001,822,918
Option 8 (NGZ)	$586,767,919	$537,495,476	$1,124,263,396
Option 5 (JJZ)	$510,416,576	$652,947,369	$1,163,363,945