ERCOT Independent Review of Houston Import RPG Project

ERCOT System Planning

Document Revisions

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TABLE OF CONTENTS

1. Executive Summary

The load in the Houston metropolitan area is currently served by the generation in the area and the power imported through 345 kV lines from the north and south into the Houston area (Figure 2.1). Over the past ten years, a significant amount of generation has been retired in the Houston area, while the load in the region continues to grow. The continuous load growth and lack of new generation additions in the load center has resulted in the Houston system relying more on power imports through the existing 345 kV lines into the area. In addition, increasing dependence on power imports causes significant challenges in scheduling a planned outage with a sufficient duration on any of the major 345 kV lines along the Houston import path.

Identifying the reliability need to improve the import capability into Houston, CenterPoint Energy, Lone Star Transmission, and Garland Power & Light and Cross Texas Transmission submitted three different Regional Planning Group (RPG) proposals in July and August 2013. For the three RPG submittals, ERCOT has conducted a combined single independent review and determined that the import paths from the north into Houston are vulnerable to thermal overloads under various contingency conditions by 2018. The review also revealed post-contingency low voltage issues at certain 345 kV buses in the region.

Based on the result of the independent review, ERCOT concludes that transmission reinforcement is needed to meet the reliability criteria under the 2018 summer peak condition. Among various options evaluated, ERCOT prefers Option 4 (new Limestone-Gibbons Creek-Zenith 345 kV double-circuit line) as the best solution for the area and recommends the project to be in-service by 2018. The project will address the reliability need, improve the import capability into Houston, and provide additional benefits to the system in both the near-term and long-term transmission planning horizons.

The project preferred by ERCOT requires

- Construction of a new Limestone-Gibbons Creek-Zenith 345 kV double-circuit line to achieve approximately 2988 MVA of emergency rating for each circuit. The approximate length of the new line is estimated to be 129.9 miles.
- Upgrade of the existing substations at Limestone, Gibbons Creek and Zenith to accommodate the terminations of the new 345 kV line.
- Upgrade of the existing T.H. Wharton-Addicks 345 kV line to achieve at least 1450 MVA of emergency rating (~10.7 miles).

The construction cost for the preferred project is estimated to be approximately $590 million in 2018 dollars. The estimate may vary as the designated providers of the new transmission facilities (CenterPoint Energy, Garland Power & Light and Cross Texas Transmission) perform more detailed cost analysis.

2. Introduction

The Houston metropolitan area is one of the major load centers in Texas, serving more than 25% of the entire load in the ERCOT system. While the load growth in the region is expected to continue, a significant challenge is also anticipated in developing new resources in the increasingly urban area due to restrictions such as air quality standards and site availability inside the city. Historical data indicates that approximately 1,800 MW of new generation has been added in the Houston region over the past ten years (2004 to 2013), while approximately 3,800 MW of generation has been retired over that time. Such continuous load growth and lack of new generation additions in the load center resulted in the Houston system relying more on power imports through the existing 345 kV lines into the area. These issues have been the primary focus of various studies in the past such as the DOE long-term transmission planning study and the annual ERCOT voltage stability study.

Recently, four Transmission Service Providers (TSPs) including CenterPoint Energy (CNP), Lone Start Transmission (LST), and jointly Garland Power & Light and Cross Texas Transmission (GPL & CTT) independently submitted three Regional Planning Group (RPG) proposals, identified a reliability need and proposed new transmission reinforcement to address the need and to improve the import capability into Houston by 2018.

For the three RPG proposals submitted, ERCOT has conducted one combined independent review. ERCOT performed various studies to address the reliability need and identified a best solution that significantly improves the import capability into Houston, which is currently relying on the power import through the existing 345 kV lines:

- Existing import paths from North to Houston
  - Singleton-Zenith 345 kV line #98
  - Singleton-Zenith 345 kV line #99
  - Singleton-Tomball 345 kV line #74
  - Roans Prairie-Bobville-Kuykendahl 345 kV line #75

- Existing import paths from South to Houston
  - Hillje-W.A. Parish 345 kV line #72
  - Hillje-W.A. Parish 345 kV line #64
  - South Texas-W.A. Parish 345 kV line #39
  - South Texas-DOW 345 kV line #18
  - South Texas-DOW 345 kV line #27

Increasing dependence on the power import through the above import paths is also expected to cause significant challenges in scheduling a planned outage with a sufficient duration on any of the 345 kV lines. As the load continues to grow in Houston, it is expected that these outages (forced or planned) will cause significant reliability issues and become increasingly more costly.

The figure below shows the system map of the study area indicating the key 345 kV substations connecting the major import paths into the Houston area.

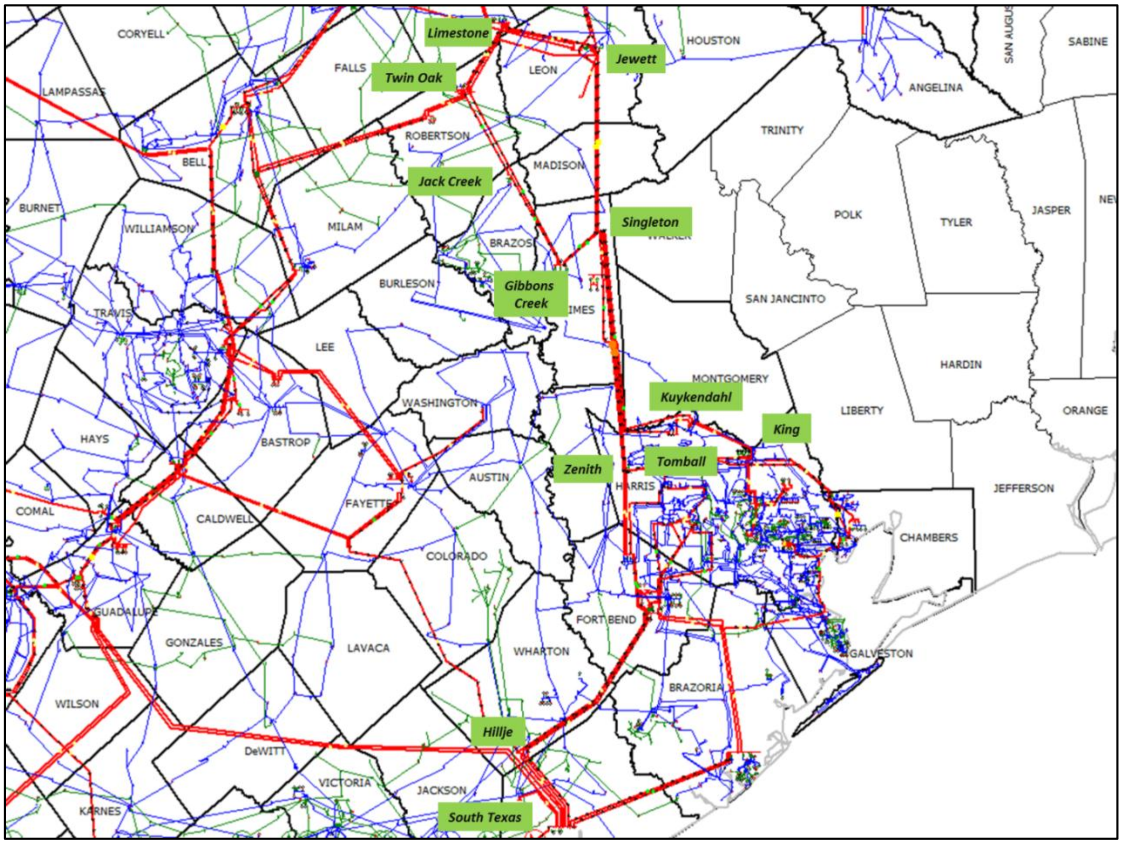

Figure 2.1 System map of study area with key substations

3. Criteria, Study Assumptions and Methodology

ERCOT performed studies under various system conditions to evaluate the reliability need and to find a robust and cost-effective solution from both near-term and long-term transmission planning perspectives. The study criteria, assumption and methodology for the ERCOT independent review are described in this section and are consistent with the NERC reliability standards, ERCOT Protocols, and ERCOT Planning Guide. The study scope and approach was also presented to the RPG at the September 2013 RPG meeting.

3.1 Study Criteria and Monitored Area

The criteria applied for the AC power flow analyses are consistent with the ERCOT Planning Guide 4.1.1.2 and the ERCOT 2013 Regional Transmission Plan (RTP). For the reliability analysis, the following thermal and voltage limits were enforced:

- Rate A under pre-contingency conditions for 60 kV and above transmission lines and transformers with a low side voltage of 60 kV and above

- Rate B under post-contingency conditions for 60 kV and above transmission lines and transformers with a low side voltage of 60 kV and above
- 0.95 pu voltage under pre-contingency conditions for 100 kV and above transmission lines and transformers with a low side voltage of 100 kV and above
- 0.90 pu voltage under post-contingency conditions for 100 kV and above transmission lines and transformers with a low side voltage of 100 kV and above

The area monitored in the study is the system in the ERCOT Coast weather zone and in the East weather zone (electrically close to the Houston metropolitan area).

3.2 Study Assumptions and Methodology

3.2.1 Study Base Case

Two 2018 summer peak cases that were created as part of an ERCOT stakeholder driven process were available for use at the beginning of the study. The first is the 2018 summer peak case from the 2013 Dataset B as developed by the Steady-State Working Group (SSWG) in accordance with the Reliability and Operations Subcommittee approved SSWG Procedure Manual. This is the case that was used by each of the TSPs when developing the results in the three project proposals submitted to the RPG.

The second 2018 summer peak case was developed for use in the ERCOT 2013 RTP. This case started with the SSWG 2018 summer peak case and then modified it in accordance with the 2013 RTP scope and process document which was presented to the RPG for comments. For this analysis, ERCOT elected to use the 2018 RTP summer peak case as the base case as this is the typical practice for independent reviews. As described in later sections of this report, ERCOT also used the SSWG case to perform sensitivities on the analysis.

When the summer peak cases are created by the SSWG or modified by ERCOT for use in the RTP, it is recognized that the load level for each area on the system is set to its non-coincident peak. That is, the load for an area will be set according to the maximum load that area is expected to experience during the summer which may be greater than the load for that particular area when the ERCOT system as a whole reaches its maximum load. Hence, the summed load that is modeled in the base cases when looked at from a system-wide perspective is much greater than the expected ERCOT system-wide load for a given year. Generation, which is provided by the market based on economic considerations, is assumed to be planned to meet the expected ERCOT system-wide load for a given year plus a reserve margin.

In transmission planning analysis the amount of generation available in the base case may not be enough to meet the summed non-coincident peak load of all areas of the system. In order to solve this challenge in the 2013 RTP, ERCOT split the 2018 summer peak case into two study areas, the so-called NW and SE areas. For each study area the load level was set to the forecasted peak load for that area while load outside of the area was scaled down until there was enough generation to meet the load plus an operational reserve of approximately 1375 MW (equal to the largest single unit on the ERCOT system).

In the 2018 SE summer peak case from the 2013 RTP, the load levels for the East, Coast, South Central, and Southern weather zones were set to their forecasted peak load levels. The load levels in the North, North Central, West, and Far West weather zones were set to approximately 85% of the peak load levels from the SSWG base case. ERCOT used 2018 SE summer peak case for the analysis in this review since the Houston area is located within the Coast weather zone and the facilities that were shown to be overloaded in the three RPG project submittals were wholly contained within the East and Coast weather zones.

In order to ensure that the load scaling did not adversely affect the results of the study by disproportionately modeling power flows from the scaled down weather zones to the Coast weather zone, ERCOT analyzed historic weather zone peak data. To do this ERCOT looked at the top ten peak load hours for the Coast weather zone for each of the last three years. For each of the other weather zones ERCOT assessed the percentage of their annual peak for those ten hours and then averaged the results. The data is presented in the below table.

Average % of peak load of each weather zone during the top ten hourly peak load conditions at the Coast Weather Zone							
Year	**East**	**South**	**South Central**	**Far West**	**West**	**North**	**North Central**
2011	97.46%	98.21%	96.38%	93.75%	83.70%	67.86%	93.37%
2012	96.32%	95.58%	96.08%	93.23%	92.93%	78.55%	85.56%
2013	76.77%	98.62%	97.42%	95.81%	78.23%	90.88%	88.81%

The results show that, with the exception of 2013, the East weather zone was near its peak when the Coast weather zone was at its peak. If the 2013 exception were to be taken into account it would likely increase flows along the North to Houston import path. Both the South and South Central weather zones were near their peaks (95% to 98%) when the Coast weather zone was at its peak. In all three years the Far West weather zone was above the assumed 85% loading, however, since the Far West weather zone is electrically far from the Coast weather zone and has a relatively small amount of load this difference is not considered meaningful for this study. Both the West and North weather zones have two years where the average is below the 85% assumption and one year where the average is above the 85% assumption. Therefore, the assumption seems reasonable. In all three years the North Central weather zone was slightly above the 85% assumption, but in 2012 the average was just 0.56% above and 85% can reasonably be assumed to occur.

Based on this analysis ERCOT concluded that the load levels in the 2018 SE summer peak case from the 2013 RTP represent a reasonable variation of load forecast in accordance with Planning Guide Section 4.1.1.1(5)(a), and decided to use the 2018 SE summer peak case as the base case of this ERCOT independent review.

Based on the result of the 2013 RTP studies, several transmission upgrades inside Houston were modeled to create the study case. ERCOT considers these upgrades not relevant to the Houston import project review as the upgrades listed below do not significantly change power flows on the import paths.

- Three new projects were identified in the 2013 RTP for the study area:

- Project to loop Roans Prairie-King into Rothwood 345 kV substation
- Project to upgrade the system in the Katy area, which includes
  - ✓ A new second 345/138 kV transformer at Zenith
  - ✓ A new 138 kV line from Zenith to Franz and reconfiguration of existing 138kV lines in the Katy area
- Project to upgrade the Dickinson-League City 138 kV line

The load level of the Coast weather zone assumed in the 2018 SE study base case is identical to the load level of the same weather zone in the SSWG case. This assumption is consistent with the study scope of the 2013 RTP, and the total load assumed for the year 2018 in the Coast weather zone is 26,355 MW.

Several future generators were modeled in the case based on the model-building requirement in Planning Guide Section 6.9 and the input from stakeholders:

- Future generators modeled online in the study area based on the above ERCOT planning criteria:
  - Deer Park Energy G6, Channel Energy GT3, Deepwater Energy (later cancelled)

- Future generators modeled offline based on the above ERCOT planning criteria and the input from ERCOT stakeholder:
  - A new W.A. Parish unit, Pondera King, Cobisa

3.2.2 Study Methodology

The purpose of the independent review of the Houston import project is first, to determine whether the system in the study area needs transmission reinforcement; and second, if it does, to evaluate options and develop a solution that performs best to meet the reliability criteria under various system conditions. The ultimate goal, if the system needs reinforcement, is to find a best value solution among various options from both system performance and cost perspectives.

To evaluate the reliability need described in the TSP's RPG submittals, ERCOT studied the 2018 study base case by applying the planning criteria in Section 3.1. In addition to the 2018 study base case, ERCOT also performed additional sensitivity studies with and without varying the load levels for all weather zones except the Coast weather zone. The additional studies were done to incorporate the comments from ERCOT stakeholders and to ensure the reliability need also existing in the SSWG case.

Once the reliability need was identified, ERCOT developed a number of options based on the RPG submittals, input from the stakeholders, and past ERCOT studies including the DOE long-term transmission planning study. For the various options developed, ERCOT took a two-step approach to screen and select options for more detailed analyses. First, ERCOT performed a contingency analysis to identify options that mitigate the reliability concerns under the ERCOT N-1 conditions. Then, as a second step, ERCOT studied G-1+N-1 (generator unit outage plus a contingency) conditions for the options that passed the N-1 criteria. If an option addressed the reliability issues under both N-1 and G-1+N-1 conditions, the option was selected for further evaluation.

For the options selected based on the result of the G-1+N-1 analysis, ERCOT performed additional studies to determine the most robust and cost-effective solution that is the best for both the near-term and the long-term (the next 15 years) planning horizons. For each select option, ERCOT conducted a power transfer analysis to evaluate the thermal and voltage stability limits. For transfer analysis, ERCOT gradually scaled up the load in the Coast weather zone, while scaling down the loads in the North, North Central, West and Far West weather zones to balance supply and demand. The purpose of the transfer analysis was to identify additional future upgrades that may be needed for each select option beyond the project in-service year (2018) up to year 2028 and quantify the benefits of each select option from reliability and cost perspectives.

ERCOT also studied the impact of the potential retirement of older generation units (listed in Section 7.3) located inside the Houston area. An AC power flow analysis was performed for each select option using the 2018 study base case with the old units assumed offline. ERCOT also performed a generation reduction analysis to estimate the amount of generation that might be retired without causing any thermal issues on the major import paths. ERCOT compared the system performance of each select option under the potential system conditions.

Severe contingencies such as NERC Category C and D conditions were tested using the 2018 study base case for each of the selected options.

Transmission efficiency was also analyzed for each select option by computing system loss reduction using the 2018 system peak condition.

Although the project discussed in this RPG report is purely driven by reliability need, ERCOT also conducted an economic analysis of each select option using the 2013 RTP economic case developed for study year 2018 in order to compare the relative annual production cost savings of each option.

Finally, ERCOT performed various sensitivity analyses as discussed in Section 8. ERCOT performed a transfer analysis by using a different load-scaling approach to check if there is any significant impact on the result of the transfer analysis (discussed in Section 7.1).

3.2.3 Tools

ERCOT utilized the following software tools for the independent review of the Houston import project:

- PowerWorld version 17 with SCOPF was used for AC power flow analysis
- VSAT and PSAT version 11 were used to perform power transfer analysis
- UPLAN version 8.12.0.9073 was used to perform security-constrained production cost analysis

3.2.4 Contingencies

All NERC Category A and B and ERCOT double circuit contingencies were evaluated for the AC power flow analyses. For G-1+N-1 analysis, the following generator outages were considered to identify the worst G-1 conditions:

- South Texas U1 (1378 MW),
- Cedar Bayou N2 (749 MW),
- Frontier G4 (374 MW),
- Gibbons Creek L1 (470 MW)

In accordance with Planning Guide Section 4, following the outage of a generator (G-1), the system was adjusted (redispatched) before applying the N-1 contingency.

For the power transfer analysis, ERCOT tested roughly 450 contingencies (300 kV and above in Coast, East and South Central weather zone in ERCOT system) using the 2018 study base case. As a result, ERCOT identified 45 key contingencies. These key contingencies were tested for each select option in order to identify future transmission upgrades during the transfer analysis.

For the NERC Category C and D analysis, ERCOT tested 23 severe events selected based on past ERCOT experience and also based on the annual ERCOT stability analysis.

4. Project Need

ERCOT conducted an AC power flow analysis using the 2018 SE study base case. The result indicated the overload of the Singleton-Zenith 345 kV double circuit under N-1 contingency conditions. This issue was aggravated further under G-1+N-1 conditions causing other additional thermal overloads of the import paths and low voltages at certain 345 kV buses in the area.

The result also indicated that the worst G-1+N-1 issues would occur during the outage of South Texas Project (STP) U1. The issues under other G-1+N-1 conditions (i.e. N-1 under Frontier, Gibbons Creek, or Cedar Bayou outage condition) were found to be the subset of the N-1 issues under the STP U1 outage condition (G-1).

The key reliability issues identified in the study are listed below and also illustrated in Figure 4.1. Among various contingencies causing the reliability issues, the worst contingency is the loss of the Singleton-Tomball & Roans Prairie-Bobville 345 kV double circuit.

- Key reliability issues identified under N-1 conditions are
  - Overload (~116.6%) of the Singleton-Zenith 345 kV double circuit
  - Heavy flow (~98.9%) on the Jewett-Singleton 345 kV double circuit

- Key reliability issues under the worst G-1 (STP U1)+N-1 conditions are
  - Overload (~145%) of Singleton-Zenith 345 kV double circuit both under system intact and under contingency conditions
  - Overload (~124%) of Jewett-Singleton 345 kV double circuit

- Overload (~124%) of Jack Creek-Twin Oak 345 kV circuit #1
- Overload (~115%) of Roans Prairie-Bobville-Kuykendahl 345 kV circuit #75
- Overload (~115%) of Gibbons Creek-Twin Oak 345 kV circuit #1
- Overload (~112%) of Gibbons Creek-Singleton 345 kV double circuit
- Overload (~106%) of Gibbons Creek-Jack Creek 345 kV circuit #2
- Overload (~105%) of Singleton-Tomball 345 kV circuit #74
- Low voltage (below 90%) at Tomball, Rothwood, Bobville and Kuykendahl 345 kV buses

More detailed results on the reliability issues are presented in Appendices A and B.

The result of the power flow analysis also showed the overload of the 345/138 kV transformers at DOW substation and certain 138 kV lines inside the Houston area. ERCOT considered these issues as local issues not relevant to the Houston import capability study.

Based on the study result, ERCOT confirmed the reliability need to improve the import capability into Houston.

During the course of the independent review ERCOT provided study updates to the RPG at regularly scheduled monthly RPG meetings and received comments on the study at these meetings. NRG and other stakeholders commented that the load scaling methodology that ERCOT used in the creation of the 2013 RTP base cases may exacerbate the overloads on the North to Houston import pathways. As discussed in Section 3.2.1 of this report ERCOT validated the assumptions used in the study case in response to these comments. In addition ERCOT performed several sensitivities using the latest 2018 summer peak base case built by the SSWG from the 2014 Dataset B which was not available at the beginning of the analysis.

In order to incorporate the comments from the ERCOT stakeholders and ensure that the reliability need exists regardless of the load or generation assumptions used in the 2018 study base case, ERCOT evaluated the following cases (Appendix E has a more detailed description of each case):

Case 1: *2018 SSWG case (2018 SUM1 Final 10/15/2013) with no changes to load or generation*

Case 2: *2018 SSWG case with weather zone load scaled to the highest average percentage load level between 2011 and 2013 when the Coast weather zone was at its peak as presented in section 3.2.1 of this report.*

Case 3: *2018 SSWG case with weather zone load scaled to the average percentage of load level when the Coast weather zone was at its peak in 2013 as presented in section 3.2.1 of this report.*

These cases were evaluated under G-1 (STP U1) + N-1 conditions. As a result of the evaluation, ERCOT found either overloads or heavy flows of the 345 kV lines identified in the 2018 study base case. The details of the results can be found in Appendix F (for Case 1), Appendix G (for Case 2) and Appendix H (for Case 3). The results are summarized in the table below.

Overload Element	Study Case	Case 1	Case 2	Case 3*
Singleton-Zenith double circuit	145%	122%	128%	137%
Roans Prairie-Bobville #75	115%	99%	104%	110%
Bobville-Kuykendahl #75	115%	99%	103%	110%
Jewett North-Singleton #1	124%	93%	99%	106%
Jewett South-Singleton #1	123%	91%	97%	103%
Gibbons Creek-Singleton #75	113%	92%	94%	101%
Gibbons Creek-Singleton #99	113%	92%	94%	101%
Jack Creek-Twin Oak #1	124%	92%	100%	102%
Singleton-Tomball #74	105%	Below 90%	93%	99%
Gibbons Creek-Twin Oak #1	115%	Below 90%	92%	95%
Gibbons Creek-Jack Creek #2	106%	Below 90%	Below 90%	Below 90%

* Low voltage issue (below 90%) at the Tomball 345 kV bus was also found in Case 3 under G-1+N-1 conditions.

The results showed that while overloads were generally less than in the study case, the project need was confirmed in all of the evaluated cases. Based on the results, ERCOT confirmed that the reliability need identified in this section is an imminent issue irrespective of the assumptions used in the 2018 study base case.

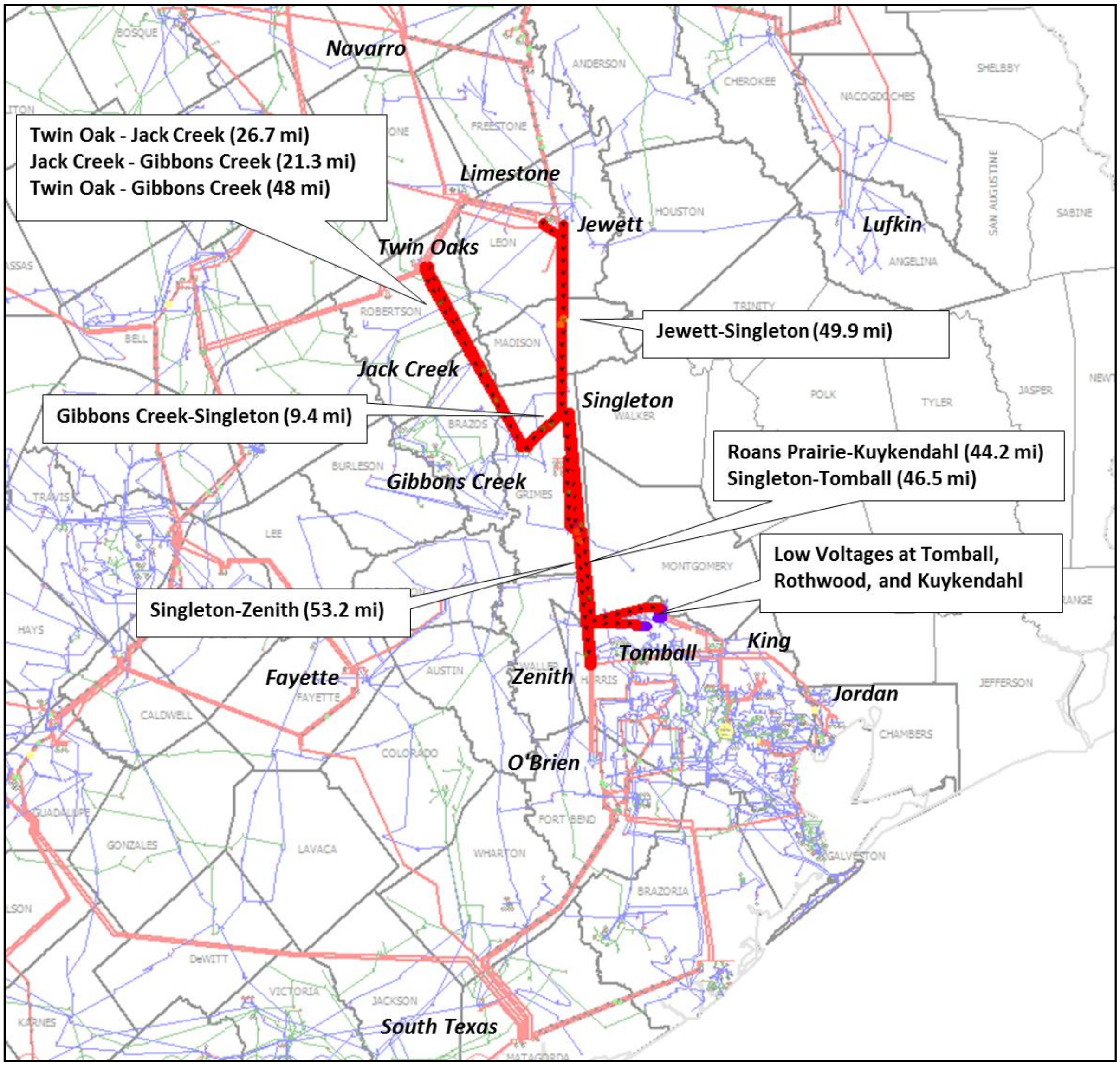

Figure 4.1 Map of system reliability issues related to Houston import capability

Table 4.1 Key thermal overloads identified in 2018 SE Study Base Case under N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	116.6
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	116.6

Table 4.2 Key thermal overloads identified in the 2018 SE Study Base Case under G-1+N-1

Overloaded Element	Percent Loading Under Worst Contingency			
	South Texas G-1	Cedar Bayou G-1	Gibbons Creek G-1	Frontier G-1
Singleton – Zenith 345 kV #98	145.5	136.0	114.2	114.7
Singleton – Zenith 345 kV #99	145.6	136.1	114.2	114.7
Gibbons Creek – Twin Oak Switch 345 kV #1	115.3	107.0	103.1	100.9
Gibbons Creek – Singleton 345 kV #75	112.6	104.7	N/A	N/A
Gibbons Creek – Singleton 345 kV #99	112.6	104.7	N/A	N/A
Jack Creek – Twin Oak Switch 345 kV #1	124.1	115.1	110.9	108.7
Jewett South – Singleton 345 kV #1	123.2	115.5	104.1	109.2
Jewett North – Singleton 345 kV #1	124.1	115.4	102.6	108.7
Roans Prairie – Bobville 345 kV #75	115.7	108.9	N/A	N/A
Bobville – Kuykendahl 345 kV #75	115.4	108.7	N/A	N/A
Gibbons Creek – Jack Creek 345 kV #2	106.1	N/A	N/A	N/A
Singleton – Tomball 345 kV #74	105.6	N/A	N/A	N/A

Table 4.3 Key low voltage issues identified in the 2018 SE Study Base Case under G-1+N-1

Bus Name	Bus Voltage Under Worst Contingency			
	South Texas G-1	Cedar Bayou G-1	Gibbons Creek G-1	Frontier G-1
Tomball 345 kV	0.87	0.89	> 0.90	> 0.90
Bobville 345 kV	0.89	> 0.90	> 0.90	> 0.90
Kuykendahl 345 kV	0.89	> 0.90	> 0.90	> 0.90
Kuykendahl 345 kV	0.89	> 0.90	> 0.90	> 0.90
Rothwood 345 kV	0.89	> 0.90	> 0.90	> 0.90

5. Initial Options

Based on the reliability analysis ERCOT identified that multiple 345 kV lines including Singleton-Zenith, Jewett-Singleton, Jack Creek-Twin Oak, Singleton-Tomball, Gibbons Creek-Singleton and Gibbons Creek-Twin Oak (more than 200 miles of double-circuit 345 kV lines) would overload under either N-1 or G-1+N-1 conditions in 2018. In addition to the overloads, ERCOT also identified other 345 kV low voltage issues under contingency conditions.

ERCOT does not consider upgrading all of the existing 345 kV import lines as a viable option. CNP, the owner of the Singleton-Zenith 345 kV line, estimated that it would take 12 to 18 months to rebuild this line alone. ERCOT's analysis showed that it would not be possible to take any of the lines out of service for construction when load levels in the Houston area are high because the next contingency would place the system at risk of voltage collapse. This would likely lead to high congestion costs because a significant portion of the generation in the Houston area would be required to run during the construction outage in order to maintain system security. Much of this generation is older, less efficient generation that is not typically economic to run in the off peak times when the construction would likely occur. Further, since generators require maintenance outages as well it may not be possible to take all of the required outages for transmission construction and generator maintenance. Since there are over 200 miles of overloaded lines it is not feasible that all of the lines would be rebuilt by 2018. Lastly, the estimated cost (over $700 million) of upgrading all of the lines is more than most of the options studied in this analysis, but would not provide a comparable level of reliability.

ERCOT evaluated twenty-one options to address the identified need and improve the import capability into Houston. All twenty-one options require constructing a new transmission line into Houston area on a new right of way.

Among the options evaluated, three options were preferred by CNP, four options by LST and another three options by GPL & CTT. The remaining options were developed by ERCOT considering new transmission sources from various directions into Houston or modifying certain options from the TSPs. These options are listed in Table 5.1 through 5.4. ERCOT evaluated these options under N-1 and G-1+N-1 conditions. Figure 5.1 shows the system map of the study area overlapped with these options.

Table 5.1 CenterPoint's preferred options

Option ID	CenterPoint Options	Approximate Line Length Modeled in study (mi)
C1	– Construct a new Twin Oak-Zenith 345 kV double circuit	117.0
C2	– Construct a new substation, called Ragan Creek, adjacent to the existing double-circuit 345 kV line running between Gibbons Creek and Jack Creek – Loop the adjacent to the existing double-circuit 345 kV line between Gibbons Creek and Jack Creek into Ragan Creek – Construct a new Ragan Creek-Zenith 345 kV double circuit	69.0
C3	– Construct a new substation, called Ragan Creek, adjacent to the existing double-circuit 345 kV line running between Gibbons Creek and Jack Creek – Loop the adjacent to the existing double-circuit 345 kV line between Gibbons Creek and Jack Creek into Ragan Creek – Construct a new Limestone-Ragan Creek-Zenith 345 kV double circuit	130.2

Table 5.2 Lone Star's preferred options

Option ID	Lone Star Options	Approximate Line Length Modeled in study (mi)
L1	– Construct a new Navarro-Gibbons Creek-Zenith 345 kV double	165.0

	circuit	
L2	– Construct a new Navarro-King 345 kV double circuit	186.0
L3	– Construct a new 500/345 kV substation at Navarro – Install two new 500/345 kV transformers at Navarro – Construct a new 500/345 kV substation at King – Install two new 500/345 kV transformers at King – Construct a new Navarro-King 500 kV double circuit	186.0
L4	– Construct a new Navarro-King 345 kV double circuit with 50% Series Compensation	186.0

Table 5.3 Cross Texas and Garland Power & Light's preferred options

Option ID	Cross Texas & Garland Power and Light Options	Approximate Line Length Modeled in study (mi)
T1	– Construct a new Gibbons Creek-Tomball 345 kV double circuit	50.0
T2	– Construct a new Gibbons Creek-Zenith 345 kV double circuit	60.0
T3	– Construct a new Limestone-Gibbons Creek-Zenith 345 kV double circuit	122.0

Table 5.4 Other options developed by ERCOT

Option ID	ERCOT and Other Options	Approximate Length Modeled in study (mi)
E1	– Construct a new Jewett-King 345 kV double circuit	142.5
E2	– Construct a new Lufkin-Jordan 345 kV double circuit	126.0
E3	– Construct a new Fayette-Zenith 345 kV double circuit	65.6
E4	– Construct a new Fayette-O'Brien 345 kV double circuit	73.9
E5	– Construct a new Jewett-Jack Creek-O'Brien 345 kV double circuit – Loop the existing Twin Oak-Gibbons Creek 345 kV line into Jack Creek	154.6
E6	– Construct a new Jewett-Jack Creek-Zenith 345 kV double circuit – Loop the existing Twin Oak-Gibbons Creek 345 kV line into Jack Creek	134.1
E7	– Construct a new Sandow-Salem-Zenith 345 kV double circuit	113.4
E8	– Construct a new Jewett-Jack Creek-Zenith 345 kV double circuit with 25% Series Compensation	134.1

	– Loop the existing Twin Oak-Gibbons Creek 345 kV line into Jack Creek	
E9	– Construct a new Jewett-Jack Creek-Zenith 345 kV double circuit with 50% Series Compensation – Loop the existing Twin Oak-Gibbons Creek 345 kV line into Jack Creek	134.1
E10	– Construct a new Twin Oak-Zenith 345 kV double circuit with 25% Series Compensation	117.0
E11	– Construct a new Twin Oak-Zenith 345 kV double circuit with 50% Series Compensation	117.0

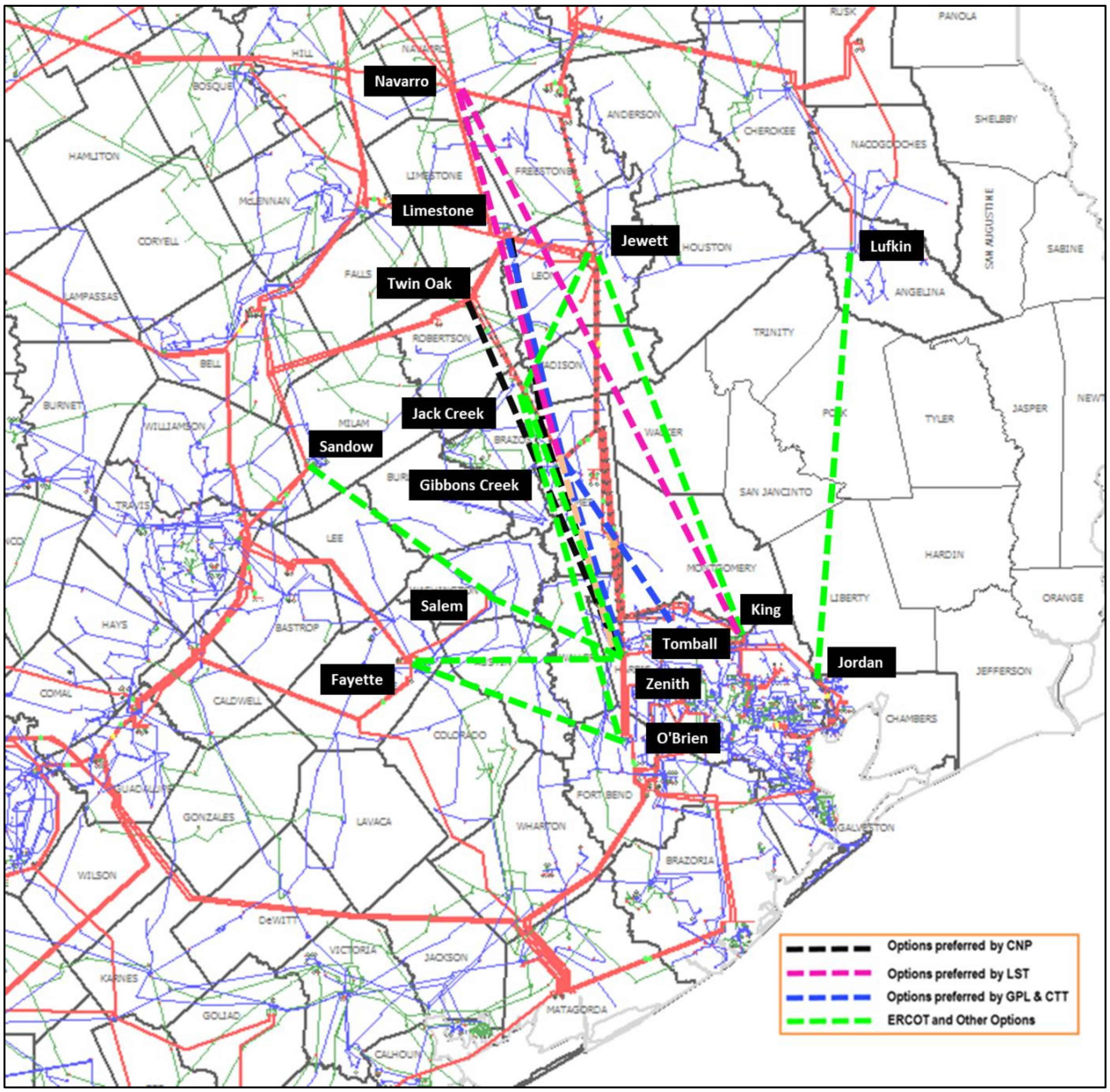

Figure 5.1 System map with initial options

5.1 Result of N-1 and G-1+N-1 Analysis of Each Initial Option

5.1.1 Result of N-1 Contingency Analysis

As described in the study methodology in Section 3, ERCOT tested each option under N-1 contingency conditions by using the 2018 SE study base case to identify options addressing the reliability need under N-1.

Among the initial twenty-one options evaluated, ERCOT found six options that did not meet the N-1 criteria. ERCOT eliminated these six options from further consideration because these options did not address the overload on the existing Houston import paths. ERCOT concluded that the total project cost in 2018 for these six options including the upgrade of existing 345 kV lines along the Houston import path would be significantly higher than other options that resolved all N-1 overloads. In addition, the upgrade of existing 345 kV lines along the Houston import would pose a reliability risk and add significant outage cost. These six options and the reason for the elimination are as follows.

- C2: Ragan Creek-Zenith 345 kV double circuit
  - Overload of Twin Oak-Ragan Creek 345 kV
  - Overload of Jack Creek-Twin Oak 345 kV
  - Heavy flow* on Jewett-Singleton 345 kV

- T1: Gibbons Creek-Tomball 345 kV double circuit
  - Overload of Jack Creek-Twin Oak 345 kV
  - Heavy flow* on Jewett-Singleton 345 kV
  - Heavy flow* on Gibbons Creek-Twin Oak 345 kV

- T2: Gibbons Creek-Zenith 345 double circuit
  - Overload of Jack Creek-Twin Oak 345 kV
  - Heavy flow* on Jewett-Singleton 345 kV
  - Heavy flow* on Gibbons Creek-Twin Oak 345 kV

- E2: Lufkin-Jordan 345 kV double circuit
  - Overload of ~50 miles of 138 kV lines in the Lufkin area

- E3: Fayette-Zenith 345 kV double circuit
  - Overload of Singleton-Zenith 345 kV

- E4: Fayette-O'Brien 345 kV double circuit
  - Overload of Singleton-Zenith 345 kV

*** Note**: Heavy flow means post-contingency loading greater than 95%

Table 5.1.1 Key thermal issues of Option C2 (Ragan Creek-Zenith) under N-1

Thermal Issues	Worst Contingency	Percent Loading
Twin Oak-Ragan Creek 345 kV	Jewett-Singleton 345 kV double circuit	100.0
Jack Creek-Twin Oak 345 kV	Jewett-Singleton 345 kV double circuit	106.9
Jewett North-Singleton 345 kV #1	Jack Creek-Twin Oak 345 kV and Twin Oak-Ragan Creek 345 kV #1	95.1
Jewett South-Singleton 345 kV #2	Jack Creek-Twin Oak 345 kV and Twin Oak-Ragan Creek 345 kV #1	96.8

Table 5.1.2 Key thermal issues of Option T1 (Gibbons Creek-Tomball) under N-1

Thermal Issues	Worst Contingency	Percent Loading
Jack Creek-Twin Oak 345 kV	Jewett-Singleton 345 kV double circuit	102.4
Gibbons Creek-Twin Oak 345 kV	Jewett-Singleton 345 kV double circuit	95.5
Jewett South-Singleton 345 kV #2	Jack Creek-Twin Oak 345 kV and Gibbons Creek-Twin Oak 345 kV	95.7

Table 5.1.3 Key thermal issues of Option T2 (Gibbons Creek-Zenith) under N-1

Thermal Issues	Worst Contingency	Percent Loading
Jack Creek-Twin Oak 345 kV	Jewett-Singleton 345 kV double circuit	104.1
Gibbons Creek-Twin Oak 345 kV	Jewett-Singleton 345 kV double circuit	97.2
Jewett North-Singleton 345 kV #2	Jack Creek-Twin Oak 345 kV and Gibbons Creek-Twin Oak 345 kV	95.2
Jewett South-Singleton 345 kV #2	Jack Creek-Twin Oak 345 kV and Gibbons Creek-Twin Oak 345 kV	96.9

Table 5.1.4 Key thermal issues of Option E2 (Lufkin-Jordan) under N-1

Thermal Issues	Worst Contingency	Percent Loading
Lufkin SS-Lufkin 138 kV	Stryker Creek SES-Lufkin 345 kV	166.11
Nacogdoches SE- Nacogdoches S 138 kV	Stryker Creek SES-Lufkin 345 kV	105.4
Nacogdoches SE- Henry North 138 kV	Stryker Creek SES-Lufkin 345 kV	120.0
Cushing-Gresham Road Switch 138 kV	MT Enterprise-Nacogdoches 345 kV	102.8
Nacogdoches S Tab-Lufkin 138 kV	Stryker Creek SES-Lufkin 345 kV	116.9

Table 5.1.5 Key thermal issues of Option E3 (Fayette-Zenith) under N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	106.0
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	106.0

Table 5.1.6 Key thermal issues of Option E4 (Fayette-O'Brien) under N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	106.7
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	106.7

The remaining fifteen options addressed the N-1 reliability issue and moved to the G-1+N-1 analysis.

5.1.2 Result of G-1+N-1 Contingency Analysis

ERCOT conducted the G-1+N-1 analysis (G-1: STP U1 offline) for the fifteen options that met the N-1 criteria. As a result of the analysis, ERCOT found seven options that did not address the reliability issues under the G-1+N-1 conditions. Although these seven options reduced the contingency loadings on the 345 kV import paths from the north into Houston, there are still overloads or impending overloads on the Singleton-Zenith 345 kV double circuit or the Jewett-Singleton 345 kV double circuit. These seven options are

- C1: Twin Oak-Zenith 345 kV double circuit
  - Heavy flow* on Singleton-Zenith 345 kV
- E1: Jewett-King 345 kV double circuit
  - Overload of Singleton-Zenith 345 kV
- E5: Jewett-Jack Creek-O'Brien 345 kV double circuit
  - Overload of Singleton-Zenith 345 kV
- E7: Sandow-Salem-Zenith 345 kV double circuit
  - Overload of Singleton-Zenith 345 kV
  - Heavy flow* on Jewett-Singleton 345 kV
- L2: Navarro-King 345 kV double circuit
  - Overload of Singleton-Zenith 345 kV
  - Heavy flow* on Jewett-Singleton 345 kV
- L3: Navarro-King 500 kV double circuit
  - Overload of Singleton-Zenith 345 kV
- L4: Navarro-King 345 kV double circuit with 50% series compensation
  - Heavy flow* of Singleton-Zenith 345 kV

*** Note:** Heavy flow means contingency loading greater than 95%

Table 5.2.1 Key thermal issues of Option C1 (Twin Oak-Zenith) under G-1+N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	97.0
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	97.0

Table 5.2.2 Key thermal issues of Option E1 (Jewett-King) under G-1+N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	106.3
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	106.3

Table 5.2.3 Key thermal issues of Option E5 (Jewett-Jack Creek-O'Brien) under G-1+N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	101.7
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	101.7

Table 5.2.4 Key thermal issues of Option E7 (Sandow-Salem-Zenith) under G-1+N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	117.3
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	117.3
Jewett South-Singleton 345 kV	Gibbons Creek-Singleton 345 kV double circuit	98.7
Jewett North-Singleton 345 kV	Gibbons Creek-Singleton 345 kV double circuit	99.4

Table 5.2.5 Key thermal issues of Option L2 (Navarro-King 345) under G-1+N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	112.2
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	112.3
Jewett South-Singleton 345 kV	Gibbons Creek-Singleton 345 kV double circuit	97.7
Jewett North-Singleton 345 kV	Gibbons Creek-Singleton 345 kV double circuit	98.5

Table 5.2.6 Key thermal issues of Option L3 (Navarro-King 500) under G-1+N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	105.3
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	105.4

Table 5.2.7 Key thermal issues of Option L4 (Navarro-King 345 with 50% SC) under G-1+N-1

Thermal Issues	Worst Contingency	Percent Loading
Singleton-Zenith 345 kV #98	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	99.4
Singleton-Zenith 345 kV #99	Singleton-Tomball 345 kV and Roans Prairie-Bobville 345 kV	99.5

6. Description of Options Selected for Further Evaluation

Among the initial twenty-one options, ERCOT found eight options effectively addressing the reliability issues under the N-1 and G-1+N-1 conditions. These eight options are

- E10: Twin Oak-Zenith 345 kV double circuit with 25% series compensation
- E11: Twin Oak-Zenith 345 kV double circuit with 50% series compensation
- C3: Limestone-Ragan Creek-Zenith 345 kV double circuit
- T3: Limestone-Gibbons Creek-Zenith 345 kV double circuit
- E6: Jewett-Jack Creek-Zenith 345 kV double circuit
- E8: Jewett-Jack Creek-Zenith 345 kV double circuit with 25% series compensation
- E9: Jewett-Jack Creek-Zenith 345 kV double circuit with 50% series compensation
- L1: Navarro-Gibbons Creek-Zenith 345 kV double circuit

Due to the injection of the new high voltage transmission source designed in the above options, several additional upgrades were needed to the existing lines located near the termination point(s) of each selected option. The upgrades of the existing lines are listed below:

- For all selected options listed above,
  - Upgrade the T.H. Wharton-Addicks 345 kV line (~10.7 miles)
- For E8 and E9,
  - Upgrade the Jack Creek-Twin Oak 345 kV double circuit (terminal upgrade)
- For L1,
  - Upgrade the Jack Creek-Twin Oak 345 kV line #1 (terminal upgrade)

With the few existing line upgrades included, the select options were updated, renamed, and listed below. The total estimated construction cost[1] provided for each select option is discussed further in Section 7.2, and the details of the estimates can be found in Appendix I.

[1] The line length of new line assumed for the cost estimate includes a 20% of uncertainty added to the straight length of the new line.

- Option 1:
    - Construct a new Twin Oak-Zenith 345 kV double-circuit line with 25% series compensation to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 117 miles.
    - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
    - The estimated cost for Option 1 is approximately $555 million in 2018 dollars.

- Option 2:
    - Construct a new Twin Oak-Zenith 345 kV double-circuit line with 50% series compensation to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 117 miles.
    - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
    - The estimated cost for Option 2 is approximately $572 million in 2018 dollars.

- Option 3:
    - Construct a new Limestone-Ragan Creek-Zenith 345 kV double-circuit line to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 130 miles.
    - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
    - The estimated cost for Option 3 is approximately $610 million in 2018 dollars.

- Option 4:
    - Construct a new Limestone-Gibbons Creek-Zenith 345 kV double-circuit line to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 129.9 miles.
    - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
    - The estimated cost for Option 4 is approximately $590 million in 2018 dollars.

- Option 5:
    - Construct a new Jewett-Jack Creek-Zenith 345 kV double-circuit line to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 128.9 miles.
    - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
    - The estimated cost for Option 5 is approximately $596 million in 2018 dollars.

- Option 6:
    - Construct a new Jewett-Jack Creek-Zenith 345 kV double-circuit line with 25% series compensation to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 128.9 miles.
    - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).

- Upgrade the Jack Creek-Twin Oak 345 kV double-circuit line (terminal upgrade) to achieve 1606 MVA of emergency rating.
- The estimated cost for Option 6 is approximately $617 million in 2018 dollars.

- Option 7:
  - Construct a new Jewett-Jack Creek-Zenith 345 kV double-circuit line with 50% series compensation to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 128.9 miles.
  - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
  - Upgrade the Jack Creek-Twin Oak 345 kV double-circuit line (terminal upgrade) to achieve 1606 MVA of emergency rating.
  - The estimated cost for Option 7 is approximately $629 million in 2018 dollars.

- Option 8:
  - Construct a new Navarro-Gibbons Creek-Zenith 345 kV double-circuit line to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 177.9 miles.
  - Upgrade the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
  - Upgrade the existing Jack Creek-Twin Oak 345 kV circuit #1 (terminal upgrade) to achieve 1606 MVA of emergency rating.
  - The estimated cost for Option 8 is approximately $806 million in 2018 dollars.

The estimates provided for Option 2, Option 3, Option 6 and Option 7 assumed series compensation with a 4000 Amp rating per circuit.

7. Evaluation of Selected Options

As described in the study methodology, ERCOT performed extensive studies to find the most robust and cost-effective solution among the select options. These studies include:

- power transfer analysis (both thermal and voltage stability analysis),
- long-term cost analysis (NPV analysis),
- impact of potential retirement of older generation units inside Houston,
- transmission efficiency in terms of system loss reduction,
- impact of severe events (NERC Category C and D contingency), and
- review of the congestion-related impact.

In this section, ERCOT presents the results of various studies done for each select option, and compares the overall performance of each select option based on the decision metrics in Section 7.8.

7.1 Power Transfer Analysis

Assuming each select option will be in service by 2018, ERCOT performed power transfer analysis (both steady-state thermal and voltage stability analysis) to identify additional future transmission upgrades that might be needed over the next 15 years (up to 2028) to serve the import needs of the Houston area.

Using VSAT and the 2018 SE study base case, ERCOT performed a screening analysis by testing roughly 450 contingencies (300 kV and above) in the Coast, East and South Central weather zones. As a result of the screening analysis, approximately 45 contingencies were found to be significant to the Houston import project study. ERCOT tested these 45 significant contingencies under the worst G-1 condition (STP U1) for each select option in the transfer analysis. ERCOT monitored transmission facilities (100 kV and above) in the Coast weather zone and the vicinity of the entire 345 kV import path into Houston.

For the transfer analysis, ERCOT incrementally scaled the load in the Coast weather zone up to the 2028 load level in order to simulate the continued load growth in the region and to identify what additional thermal issues would occur by 2028 assuming each select option is in-service by 2018.

ERCOT estimated the load level of the year 2028 based on the 2013 ERCOT 90/10 load forecast for 2018 and the 1.3% of annual load growth rate noted in the RPG report submitted by CNP. As demonstrated in Figure 7.1, ERCOT compared the assumed load growth rate against the historical data, and confirmed that it is very close to the historical load growth rate (~1.4%). Thus, ERCOT considered the assumption valid for the power transfer analysis. As shown in the figure, the future load projection estimated for the Coast weather zone is closely aligned with the trend of the historical peak loads of the weather zone.

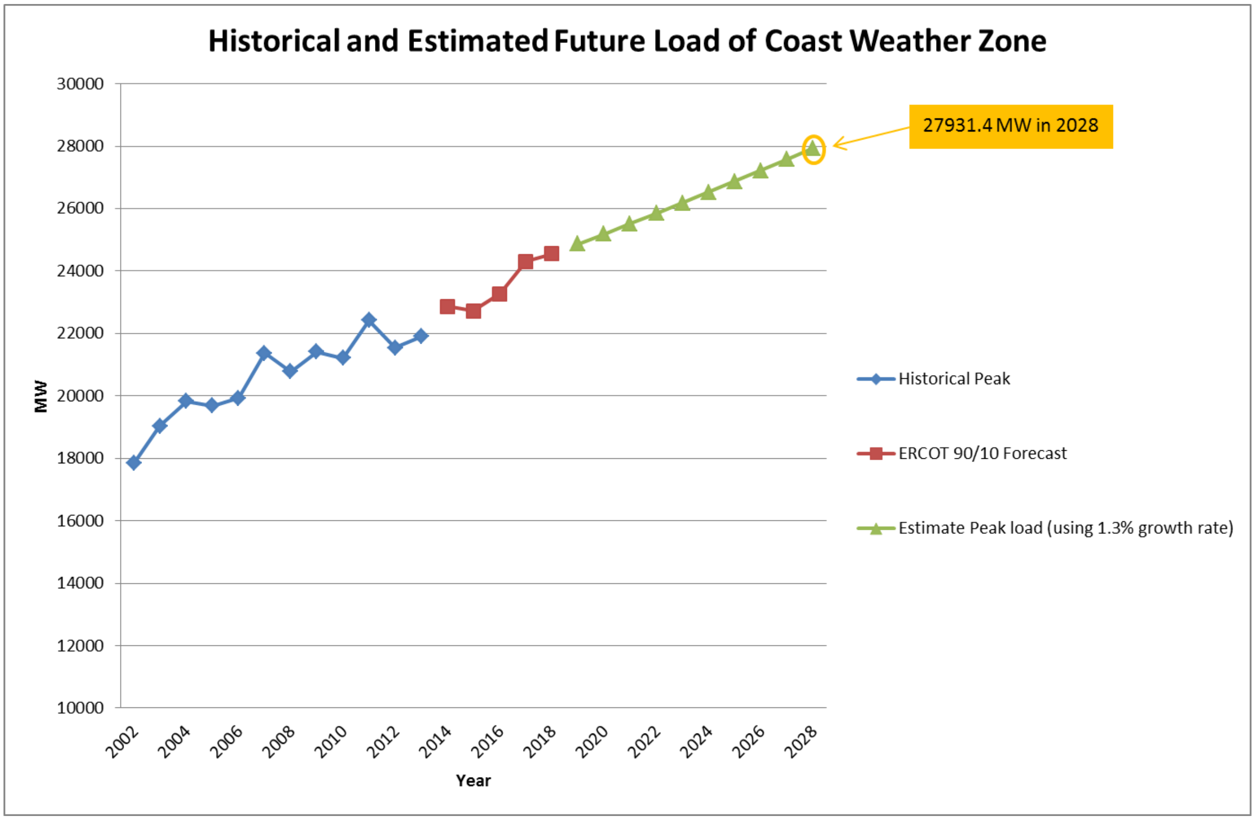

Figure 7.1 Historical load and estimated future load of Coast weather zone

Table 7.1 shows the results of the transfer analysis from a steady-state thermal perspective. The results indicated that some of the major import paths into Houston would need to be upgraded between 2025 and 2028. The result also indicated that the need year of the same line upgrade might vary depending on what option is in service by 2018. As an example, each select option requires the upgrade of the Singleton-Zenith 345 kV double-circuit line in the future, but the upgrade is needed by 2027 under Option 3 and Option 4, and by 2025 under Option 5. Therefore, Option 3 and Option 4 provide a benefit over Option 5 by deferring the need to upgrade the same line by two years. In order to capture such benefit of each select option, ERCOT performed a Net Present Value (NPV) analysis in Section 7.2 by considering not only the construction cost of each select option but also the construction cost of the future transmission upgrades identified in Table 7.1 taking into account the time value of money.

For this analysis ERCOT assumed that the net generation in the Houston area (existing generation plus generation additions minus generation retirements) stayed the same between 2018 and 2028. If more generation were to retire than be added to the area the upgrades identified may need to be accelerated. If more generation were to be added than retired in the area the upgrades identified may be deferred. Future planning analyses will determine the exact timing of upgrades.

Table 7.1 Result of power transfer analysis from a steady-state thermal perspective

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)	

ERCOT also reviewed the performance of each select option from a voltage stability perspective. Figure 7.2 shows the load level of the Coast weather zone at the point of voltage collapse under each select option without any future transmission upgrades. The results indicated that the voltage collapse conditions would occur beyond 2028 under every select option except Option 5.

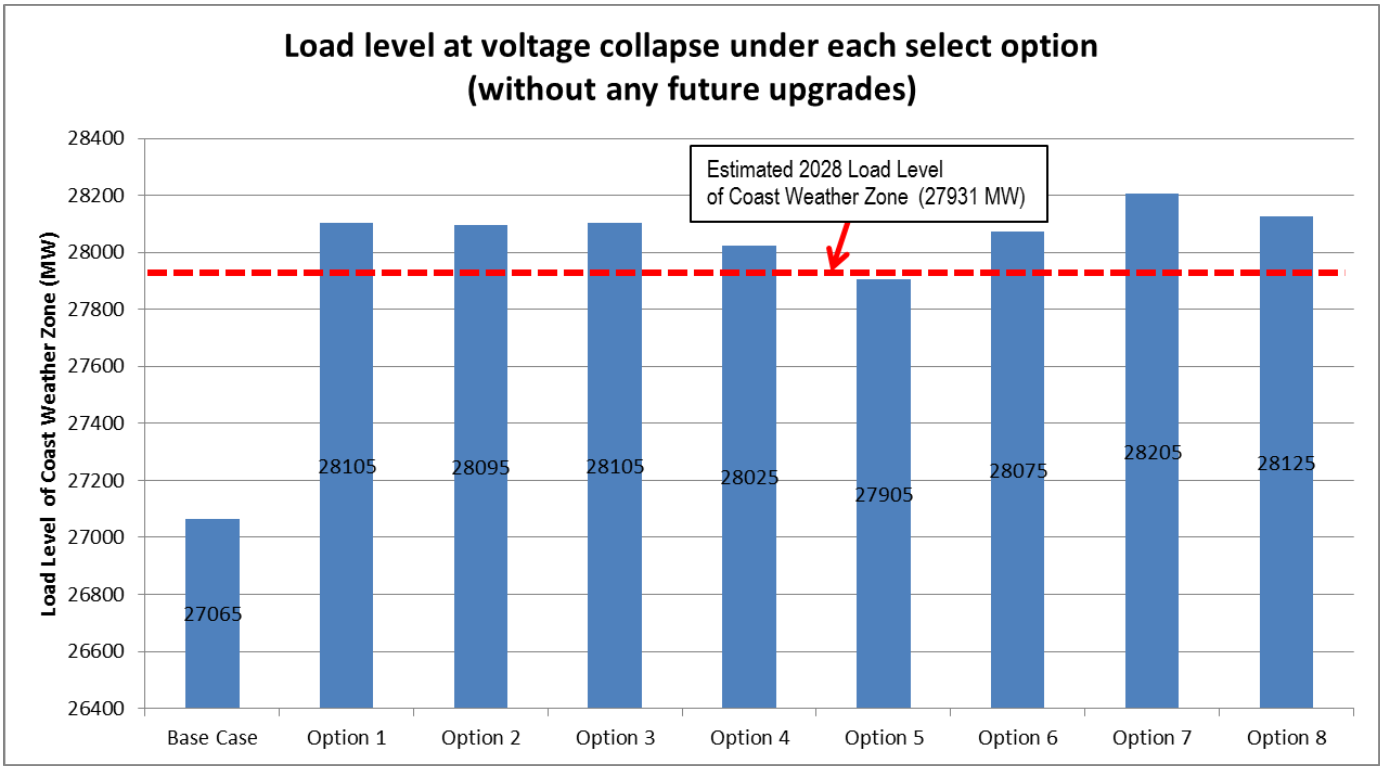

Figure 7.2 Results of power transfer analysis from a voltage stability perspective

7.2 Cost Analysis

This section presents the overall reliability impact of each select option on a NPV basis when considering the potential for Houston import needs out to 2028. For the NPV analysis, ERCOT considered the construction costs of each select option and future transmission upgrades to capture the long-term reliability benefit of each select option. ERCOT assumed 3% of escalation rate[2] and 8% of discount rate[3] to calculate the present value of each set of future upgrades in 2018 dollars, which is associated with each select option.

Based on cost estimates of each select option provided by each TSP, ERCOT found differences in the cost per mile of a new transmission line. CNP and TMPA used approximately $3.78 million per mile and $2.15 million per mile, respectively. Lone Star and Oncor used approximately $1.93 million per mile and $1.83 million per mile, respectively. Among the different cost-per-mileage assumptions for a new line, ERCOT assumed $3.78 million per mile

[2] The 3% escalation rate is consistent with the rate used by TSPs for their cost estimates.
[3] The 8% discount rate is from the report "Update on the ERCOT Nodal Market Cost-Benefit Analysis" prepared by CRA International for the Public Utility Commission of Texas in December 18, 2008, http://www.puc.texas.gov/industry/electric/reports/31600/PUCT_CBA_Report_Final.pdf

for the purpose of comparing the construction cost of each select option in 2018 dollars for the following reasons:

- The project in this report is driven by reliability need, not by economic benefit. Therefore, the cost estimate is not a driver for project justification and is only useful for comparing options.
- An analysis was performed by ERCOT using different cost-per-mileage assumptions ($2.2 mm/mi or combination of $2.15 mm/mi and $3.78 mm/mi) for a new transmission line. The results showed no significant impact in selecting the best solution recommended in this report. The results of the analysis can be found in Appendix D.

Appendix I has more details of the cost estimates of each select option and future upgrades. Shown in Table 7.2.1, the results of the cost analysis were summarized in 2018 dollars. The results of the cost analysis are further discussed in Section 7.8.

Table 7.2.1 Result of NPV analysis

Unit: $ Million

Option	Estimated Cost of Each Select Option (in 2018 dollars)	Net Present Value (NPV) of Estimated Cost of the Set of Future Upgrades (in 2018 dollars)	Overall Cost (in 2018 dollars)
Option 1	554.8	387.0	941.8
Option 2	572.0	390.6	962.6
Option 3	610.2	399.5	1,009.7
Option 4	590.1	383.1	973.3
Option 5	596.3	652.9	1,249.3
Option 6	617.1	419.5	1,036.6
Option 7	629.1	435.2	1,064.4
Option 8	805.9	537.5	1,343.4

Table 7.2.2 Estimated cost of each future upgrade at the potential need year

Unit: $ Million

Option	Construction Cost of Future Upgrades Under Each Option			
	2025	2026	2027	2028
Option 1		279.6	76.5	78.8
Option 2		74.2		375.4
Option 3			416.2	16.4
Option 4			364.5	53.3
Option 5	271.5	123.3		372.7
Option 6		74.2	288.0	130.9
Option 7		74.2		427.5
Option 8		313.8	288.0	

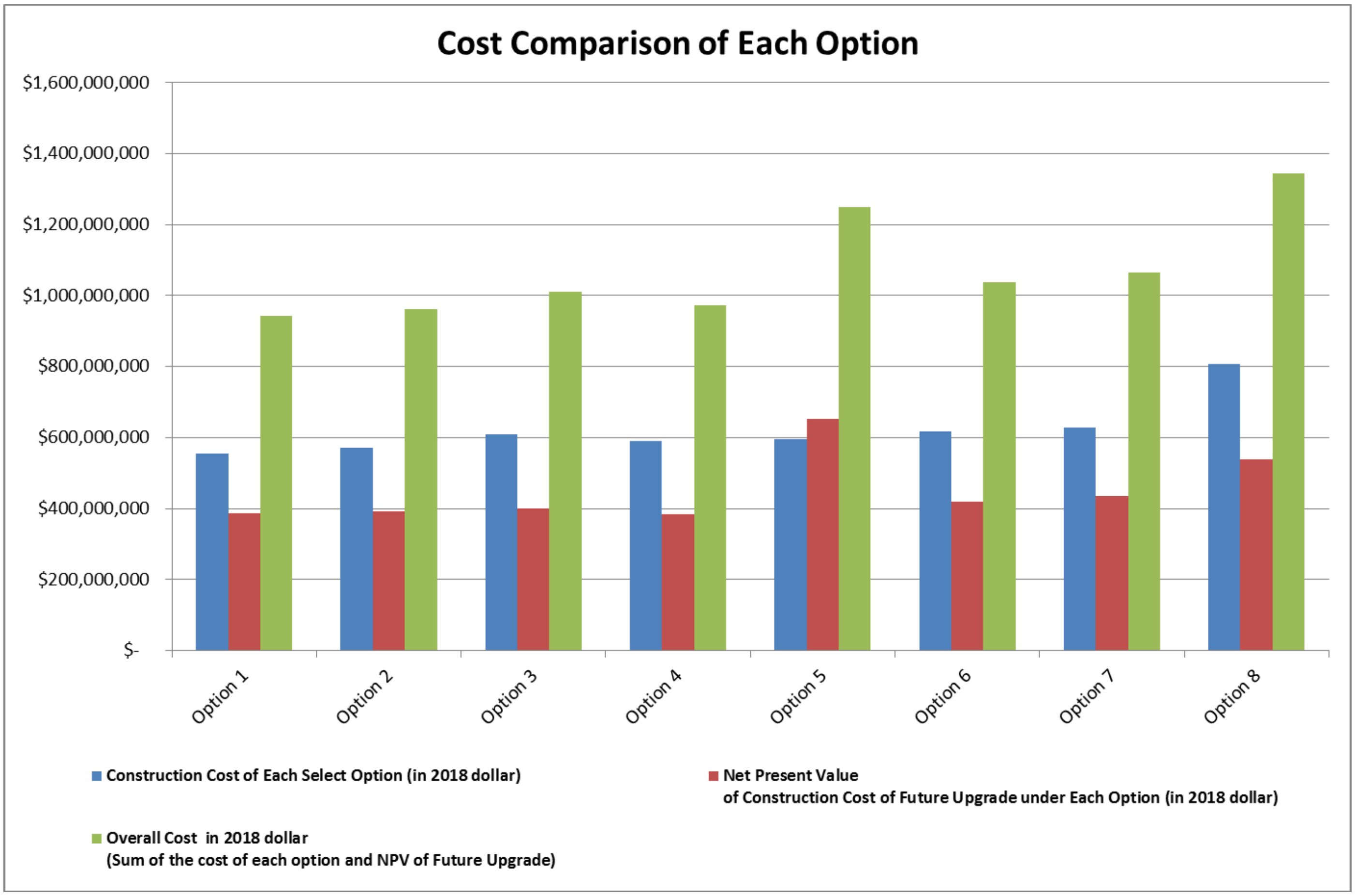

Figure 7.2.1 Cost comparison of each option

7.3 Impact of the Potential Retirement of Older Generation Units inside Houston

Including the Houston area, existing urban load centers in ERCOT rely on legacy generation resources located within the area and power imports from outside of the region to serve their load. Some generation units within the load centers were built approximately fifty years ago. Nearing the end of their useful life, these units are generally less efficient when compared to the overall generation fleet within ERCOT and may be retired relatively sooner than other newer generation units. As pointed out by Luminant Energy in submitted comments, natural gas units of similar vintage throughout ERCOT have retired or mothballed over the last ten years. Examples of these units include Atkins units 4, 5, and 6, Newman unit 5, H.O. Clarke units 1, 2, 3, 4, 5, and 6, J. L. Bates units 1 and 2, Lake Creek unit 2, Lon Hill units 3 and 4, Morgan Creek units 5, 6, 7, and 8, North Lake units 1, 2, and 3, North Texas units 1, 2, and 3, Nueces Bay unit 6, Oak Creek unit 1, P.H. Robinson units 1, 2, 3, and 4, Paint Creek unit 3, Permian Basin units 5 and 6, Rio Pecos units 5 and 6, San Angelo units 1 and 2, Spencer units 4 and 5, Tradinghouse units 1 and 2, Valley units 1, 2, and 3, Tuttle units 3 and 4, and Webster unit 3.

In addition, rapid urbanization has surrounded many of the legacy resources with residential, commercial and industrial development. With increasing urban density and environmental regulations typically it is not as feasible to site generation within a major load center. The siting difficulty is expected to put an increasing demand through the transmission import paths into the Houston area in the future. Furthermore, a new import path into the Houston area may open the market for new, more efficient generation sources to construct outside of the area and sell power by importing into Houston which will introduce additional competition for the legacy generation resources in the area.

To assess the robustness of each select option, ERCOT studied a hypothetical condition for the older generation units inside Houston. Within the Houston area, there are approximately 1939 MW of generation units that will be more than fifty years old by 2018. For the older units shown in Table 7.3.1, ERCOT performed two studies for each select option:

- AC power flow analysis under N-1 conditions with the old units assumed offline
- Generation reduction study using VSAT to compare the amount of generation output that may be retired without causing thermal issues under G-1+N-1 conditions

Table 7.3.1 Generation units more than fifty years old within the Houston area

Generation Unit	(MW)
S.R. Berton GT2	13
S.R. Berton 1	118
S.R. Berton 2	174
S.R. Berton 3	230
S.R. Berton 4	230
T. H. Warton 1	13
W.A. Parish GT1	13
W.A. Parish 1	169
W.A. Parish 2	169
W.A. Parish 3	258
W.A. Parish 4	552
Total MWs for Units fifty Years or more in service	1939

For the AC power flow analysis, ERCOT conducted the N-1 contingency analysis using the 2018 SE study base case with and without each option, assuming all of the old units offline.

The result of the study indicated a number of system issues. The key issues identified in the 2018 SE study base case are

- Under system intact conditions with the units offline,
  - Overload of Singleton-Zenith 345 kV double circuit
  - Overload of Jewett-Singleton 345 kV double circuit
  - Low voltage around Tomball, Kuykendahl, Bobville, and Rothwood

- Under N-1 contingency conditions,
  - Overload of Jewett-Singleton 345 kV double circuit
  - Overload of the bus ties at Twin Oak/Oak Grove
  - Overload of Singleton-Zenith 345 kV double circuit
  - 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 double circuit
  - 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

Based on this analysis, ERCOT found no system problems under system intact conditions and no low voltage issues under N-1 conditions for each of the selected option. Table 7.3.2 shows the result indicating overloads or heavy flows on certain 345 kV lines under N-1 conditions that might still exist even with each option if all of the old units were retired. Among options, Option 3, Option 4 and Option 7 showed no overload issues although a few heavy flow issues on certain 345 kV lines were found under N-1 conditions with the older units offline.

Table 7.3.2 Performance of each select option under N-1 conditions with the older units 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	

ERCOT also performed a generation reduction analysis under G-1+N-1 conditions. Using the 2018 study base case with each select option modeled and with the STP U1 offline (G-1), ERCOT gradually reduced the MW output from the older units using VSAT while testing the G-1+N-1 conditions. Table 7.3.3 shows the result of the generation reduction analysis. As an example, if Option 3 or Option 4 is assumed in service, a thermal overload start to occur when approximately 1000 MW from the older units is retired.

Table 7.3.3 Results of generation reduction study

Option	**Description**	**Approximate MW generation reduction that starts causing overloads 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

7.4 Impact of NERC Category C and D Contingencies

NERC Category C and D contingency conditions are rare events, but the consequences of the events can be severe. To check if each select option provides any benefit to the system under the severe events, ERCOT tested twenty-three NERC Category C and D events selected based on the annual ERCOT voltage stability analysis and knowledge of the system in the area.

Table 7.4.1 shows the result of the analysis, indicating that every option provides better system conditions under the severe events compared to the 2018 SE study base case with no Houston Import project. Particularly, under the NERC Category D events, the number of unsolved contingencies was reduced from six to one under every option. (ERCOT has analyzed the one remaining unsolved contingency in past studies and has taken steps to minimize the likelihood of the occurrence of this event.) This indicates that the new transmission sources designed in each select option will provide significant improvement in the reliability of the system of the area even under the extreme system conditions. It should be noted that the Houston area under-voltage load shedding (UVLS) scheme was not modeled in this analysis.

Table 7.4.1 Impact of NERC Category C and D conditions with each select option

Options	**Number of Unsolved Contingencies (NERC Cat. D)**	**Number of Thermal Overload On 345 kV (115% above)**	**Number of Low Voltage at 345 kV Buses (below 0.9 pu)**
w/o Option	6	6	5
Option 1	1	1	4
Option 2	1	0	3
Option 3	1	0	5
Option 4	1	0	5
Option 5	1	1	6
Option 6	1	0	5
Option 7	1	0	3
Option 8	1	0	5

7.5 System Loss Reduction

When a new transmission line is added to a system, transmission efficiency will be improved due to a decrease in the system impedance and improvement in the system voltage profile. The transmission efficiency improved by a new line can be measured by system loss reduction.

ERCOT performed the system loss analysis with and without each option, using the 2018 SE study base case (summer peak case), in order to capture the benefit of transmission efficiency improved by each select option. The amount of loss reduction is shown in Table 7.5.1 indicating significant loss reduction realized for each of the select options during the peak hour.

Table 7.5.1 System losses reduced by each select option (2018 summer peak condition)

Option	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
System Loss Reduction (MW)	44.7	38.8	47.6	31.2	38.2	44.8	35.0	32.7

7.6 Economic Analysis

Although this RPG project is driven by reliability need, ERCOT also conducted an economic analysis to compare the relative performance of each select option in terms of production cost savings.

Using the 2018 economic case built for the 2013 RTP, ERCOT modeled each select option and performed production cost simulations for the year 2018. The annual production cost under each select option was compared to the option yielding the highest annual production cost in order to obtain a relative annual production cost saving for each option.

As shown in Table 7.6.1, the result indicates that none of the options provides significantly better production cost savings than others.

Table 7.6.1 Relative annual production cost savings (referenced to Option 8)

Unit: $ Million

Option	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Relative Annual Production Cost Savings (referenced to Option 8)	4.3	3.4	3.2	1.7	2.1	2.2	1.7	0.0

7.7 Sub-Synchronous Resonance due to Series Compensation

Four of the eight select options (Option 1, Option 2, Option 6, and Option 7) require series compensation. The series compensation is the capacitor connected in series with a transmission line, used typically to increase power flow by reducing line impedance, to relieve bottlenecks, to increase stability and to reduce voltage variation. However, series capacitors can create a sub-synchronous resonance (SSR) condition in the system under some circumstances, typically when the series capacitor is radially connected to nearby generation. The SSR condition due to a series compensated transmission line may cause damage to the generator shaft and failure of insulation of the windings of the generator. The damage can be extremely costly and require a significant amount of time for repair.

There are existing generators in the area including the conventional units at Gibbons Creek, Twin Oak, Frontier, TNP One, and Limestone that are connected to the major 345 kV import paths. These units may be at risk due to SSR introduced by the series compensation designed in Option 1, Option 2, Option 6 and Option 7. Although no SSR study was performed for the options with series compensation, ERCOT considered the following issues associated with series compensation in comparing each select option:

- Significant time and resources may be needed to perform detailed SSR studies for each generator in the area, which may jeopardize the in-service year of the project. Due to the nature of the study, accurate generator data will be needed for each unit. It may take 3 to 6 months for data gathering, and an additional 6 to 12 months will be needed to complete the SSR studies.

- As mentioned in Section 6, the overall project cost of Option 1, Option 2, Option 6, and Option 7 by TSPs assumed series compensation with a 4000 Amp rating. This cost will increase further for 5000 Amp series compensation if required to match the conductor rating of the new line (5000 Amp conductor).

- Thyristor Controlled Series Capacitors (TCSC) may be used to mitigate the potential SSR issues. The cost of the TCSC will be significantly higher (roughly 1.5 to 5 times more expensive than the fixed series compensation assumed in the given cost estimates).

- Relatively high cost filters may be required to protect area generators from the effects of SSR.

- For Option 1, Option 2, Option 6, and Option 7, the units in the area may become radially connected to a series capacitor under some contingency conditions.

- As pointed out in comments submitted by Edison Mission Marketing and Trading, at the time of this analysis, there were still open policy questions in ERCOT regarding which entities are responsible for paying for SSR mitigation measures when required.

Further discussion of these options with series compensation can be found in Section 7.8.

7.8 Overall Comparison of Selected Options

ERCOT performed various studies to evaluate the options selected as discussed in the previous sections. The results of the studies done for each select option were compared in Table 7.8.1, and summarized as follows:

- All eight selected options addressed the reliability need identified in the 2018 study base case, and met the reliability criteria.
- There are differences in the estimated cost per mile of a new transmission line. ERCOT assumed $3.78 million per mile based on the reasons listed in Section 7.2. The result of the cost analysis indicates:
  - Option 1 as the least cost option, followed by Option 2 and 4.
  - Option 1, followed by Option 2 and Option 4, as the least cost options if the NPV of the future upgrades is considered.
- Except Option 5, each select option performed similarly from a voltage stability perspective. The results indicated that the voltage stability limit exceedance would occur beyond 2028 under every select option except Option 5.
- AC power flow analysis was performed under N-1 conditions with the units 50-years old or older inside Houston assumed offline. As a result of the analysis, potential overloads on certain 345 kV facilities were found under Option 1, Option 2, Option 5, Option 6, and Option 8. Although several heavy flow issues (see Table 7.3.2) were found under Option 3, Option 4 and Option 7, no immediate N-1 overloads on the 345 kV facilities were expected even if the older units inside Houston are assumed to be retired in 2018.
- In addition to the AC power flow analysis, the generation reduction analysis was performed under G-1+N-1 conditions by gradually reducing the MW generation from the older units inside Houston. The results indicated Option 3 and Option 4 as the best performers causing no thermal issues on the 345 kV lines under G-1+N-1 conditions even with significant MW reduction (~1000 MW) from the older units.
- Severe system conditions (NERC Category C and D contingencies) critical to the area were evaluated. The results showed that every select option significantly improved the reliability of the system and equally reduced the number of unsolved events.
- The results of economic analysis indicated no significant difference in the relative annual production cost savings between the options.
- The system loss analysis done using the 2018 peak load condition demonstrated significant system loss reduction under every option resulting in substantial improvement in transmission system efficiency.
- All of the eight select options require new right of way, ranging from 117 miles to 178 miles.
- As discussed in Section 7.7, the series compensation in Option 1, Option 2, Option 6 and Option 7 may introduce potential risk of SSR to the existing conventional thermal units in the area.

Based on the overall comparison above, Options 1 through 4 provided better overall reliability benefits and lower overall project costs compared to the remaining options. Options 1 through 4 performed very similarly in terms of reliability and overall project cost. Although Options 1 and 2 had slightly lower overall costs compared to Options 3 and 4, Options 3 and 4 performed the best under the scenario with the older generation units in the Houston area assumed to be retired. In addition to the reliability benefits, Options 3 and 4 will not cause the potential issues (as discussed in Section 7.7) associated with series compensation required by Options 1 and 2. Therefore, Options 3 and 4 are significantly better options to the system in the area despite the slightly higher project cost.

Based on these overall comparisons, ERCOT narrowed the eight options to Option 3 and Option 4 as the potential solutions to best meet the overall reliability need for the area. The two options are very similar except that Option 3 requires constructing a new 345 kV substation roughly 9 to 10 miles north of the existing Gibbons Creek substation. Between Option 3 and Option 4, ERCOT considers Option 4 as the best alternative for meeting the near-term and future transmission reliability needs in the Houston area based on the comparison of the capital cost estimates of Option 3 and Option 4, and the fact that Option 4 utilizes the existing Gibbons Creek 345 kV substation while Option 3 requires building a new substation. Hence, Option 4 may have slightly less public impact than Option 3.

Table 7.8.1 Overall comparison of each select option

Description	Option 1 (TWZ-25comp-TA)	Option 2 (TWZ-50comp-TA)	Option 3 (LRZ-TA)	Option 4 (LGZ-TA)	Option 5 (JJZ-TA)	Option 6 (JJZ-25comp-TATJ)	Option 7 (JJZ-50comp-TATJ)	Option 8 (NGZ-TATJ)
System Performance (2018) (All options addressed the reliability need)	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria
Capital cost in 2018 dollar ($ Million), (Based on $3.78 million per mile for T-cost)	554.8	572.0	610.2	590.1	596.3	617.1	629.1	805.9
NPV of the set of future upgrades under each option in 2018 dollar ($ Million)	387.0	390.6	399.5	383.1	652.9	419.5	435.2	537.5
Overall cost impact: Sum of the cost of each option and NPV of future upgrades in 2018 dollar ($ Million)	941.8	962.6	1009.7	973.3	1249.3	1036.6	1064.4	1343.4
Voltage stability Analysis (Estimated 2028 load level in Coast zone = 27931 MW)	28105 MW (beyond 2028)	28095 MW (beyond 2028)	28105 MW (beyond 2028)	28025 MW (beyond 2028)	27905 MW (2028)	28075 MW (beyond 2028)	28205 MW (beyond 2028)	28125 MW (beyond 2028)
Performance with the old units offline (AC power flow under N-1)	4 overloads	2 overloads	0 overload	0 overload	6 overloads	2 overload	0 overload	3 overloads
Amount of generation reduction from the old units without causing overload under G-1+N-1 (MW)	900.6	911.1	1061.3	1020.0	400.0	773.8	662.6	652.6
NERC Category C and D performance	Good	Good	Good	Good	Good	Good	Good	Good
Economic Benefit (Relative annual production cost savings in $ million, referenced to Option 8)	4.3	3.4	3.2	1.7	2.1	2.2	1.7	0.0
System Loss Reduction at Peak (MW)	44.7	38.8	47.6	31.2	38.2	44.8	35	32.7
New Right of Way	117 mi	117 mi	130 mi	129.9 mi	128.9 mi	128.9 mi	128.9 mi	177.9 mi
Sub-Synchronous Resonance (SSR) concern	Yes	Yes	No	No	No	Yes	Yes	No

8. Sensitivity Analysis

8.1 Transfer Sensitivity Analysis

Based on the feedback from RPG meetings regarding the load scaling approach assumed in the power transfer analysis in Section 7.1, ERCOT conducted an additional study to check if there would be any significant impact on the results of the power transfer analysis due to a different load scaling approach. ERCOT tested the following two load scaling approaches under N-1 conditions for some of the select options.

- Approach #1: Scaling load down in North, North Central, West and Far West, while scaling load up in the Coast weather zone
- Approach #2: Scaling all load down except the load in Coast weather zone, while scaling load up in the Coast weather zone

As a result, ERCOT found that:

- reliability criteria violations still exist in 2018 regardless of which approach is used and,
- the need for the next set of future upgrades (in the 2025 to 2028 timeframe) may be deferred by one or two years if the all-load-scaling approach (#2) is used. For example, ERCOT found roughly 220~300 MW difference in the transfer capability when the future overload issue on the Singleton-Zenith 345 kV double circuit occurs with each option.

8.2 Non-Transmission Alternative Sensitivity Analysis

A high-level sensitivity analysis was performed to estimate the impact of new future generation or demand response within the Coast weather zone.

To perform this sensitivity the load was scaled down from the base case level in the study case for 2018 in the entire Coast weather zone to mimic the new generation addition or demand response. The results indicated that approximately 1800 MW of new generation and/ or demand response would reduce the G-1 + N-1 overload to 100%. Hence, if a net of 1800 MW of generation were to be added in the Houston area it would defer the need of the project until 2019. However, should this amount of new generation materialize ERCOT would not recommend deferring the project due to the risk of retirement of existing generation within the area as described in Section 7.3. It should be noted that ERCOT cannot compel generation or demand response to locate in a certain area and participate in the ERCOT market. Therefore, ERCOT must plan transmission projects when reliability criteria violations are found.

Since there is currently not a mechanism in ERCOT to call on demand response for a transmission security issue this is not considered a feasible alternative.

9. Conclusion and Recommendation

ERCOT identified a reliability need to increase the Houston import capability by 2018 and based on the independent review selected Option 4 as the preferred option to meet the reliability need.

The following facilities constitute the preferred option:

- Construction of a new Limestone-Gibbons Creek-Zenith 345 kV double circuit to achieve 2988 MVA of emergency rating for each circuit. The line length assumed for the cost estimate is approximately 129.9 miles.
- Upgrade of the substations at Limestone, Gibbons Creek and Zenith to accommodate the terminations of new transmission lines.
- Upgrade of the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles).
- The estimated total cost for Option 4 is approximately $590 million in 2018 dollars. The estimate may vary as the designated providers of the new transmission facilities perform more detailed cost analysis.

9.1 Critical Energy Infrastructure Information (CEII) Considerations *(This section redacted from public version)*

10. Designated Provider of Transmission Facilities

In accordance with the ERCOT RPG Planning Charter and Procedures Section 2.3.4, ERCOT staff is to designate transmission providers for projects reviewed in the RPG. The default providers will be those that own the end points of the new projects. These providers can agree to provide or delegate the new facilities or inform ERCOT if they do not elect to provide them. If different providers own the two ends of the recommended projects, ERCOT will designate them as co-providers and they can decide between themselves what parts of the recommended projects they will each provide.

Both CenterPoint Energy and Texas Municipal Power Agency (TMPA) own endpoints of the new 345 kV transmission line from Limestone to Gibbons Creek to Zenith listed in the project scope of this recommendation. TMPA has delegated their portion of the project to Cross Texas Transmission and Garland Power & Light. Therefore, ERCOT designates CenterPoint Energy, Cross Texas Transmission and Garland Power & Light as co-providers of the new 345 kV transmission line. CenterPoint Energy is the designated provider of the T.H. Wharton-Addicks 345 kV line, Limestone substation, and Zenith substation upgrades. Cross Texas Transmission and Garland Power & Light are the designated providers of the Gibbons Creek substation upgrades.

The designated TSPs have indicated that it is unlikely for the project to be in-service before summer peak of 2018 unless ERCOT designates the project critical to reliability per PUCT Substantive Rule 25.101(b)(3)(D). Since there is a reliability need to have the project in place before summer 2018 ERCOT deems the project critical to reliability.

11. RPG Process of Houston Import Project Review

The following table details significant milestones in the Regional Planning Group review of the project:

Date	Description
7/26/2013	Project proposal submitted by CenterPoint Energy to RPG
7/29/2013	Project proposal submitted by Garland Power & Light and Cross Texas Transmission to RPG
8/16/2013	End of comment period for CenterPoint Energy proposal
8/19/2013	End of comment period for Garland Power & Light and Cross Texas Transmission proposal
8/19/2013	Project proposal submitted by Lone Star Transmission to RPG
8/27/2013	The three project proposals were presented in the RPG meeting by the TSPs
9/9/2013	End of comment period for Lone Star Transmission proposal
9/24/2013	Approach for ERCOT Independent Review of the Houston import project was presented for comment in the RPG meeting
10/22/2013	ERCOT presented and took comments on the results of the 2018 study base case including the reliability need at the RPG meeting
12/17/2013	ERCOT presented the status of the ERCOT Independent Review of the Houston import project at the RPG meeting, which included a list of options under evaluation, the results of various studies (power flow, transfer analysis, impact of older units, NERC C and D contingency analysis, loss analysis and other sensitivity analyses)
11/1/2013	End of project study mode (responses to comments)
1/16/2014	Lone Star submitted late comments concerning the project evaluation to RPG
1/21/2014	ERCOT presented the result of various studies (cost analysis, congestion-related impact analysis, sensitivity analysis, other consideration) at the RPG meeting
1/21/2014	NRG presented comments/concerns with the study assumptions at the RPG meeting
1/30/2014	ERCOT informed RPG of extending the review period to February 20, 2014 in order to review and address the additional comments received from ERCOT stakeholders
2/12/2014	ERCOT sent a response to the Lone Star's January 16 comments to the RPG
2/18/2014	ERCOT addressed the NRG comments/ concerns from the January RPG meeting and presented the final results at the RPG meeting. ERCOT also verbally addressed the Calpine comment/concern at the RPG meeting by referring to the results of the sensitivity analysis presented in the January RPG meeting
2/20/2014	ERCOT posted the independent review

Comments from stakeholders that were received by ERCOT during RPG meetings or formally submitted through the RPG process have been taken into account and included as appropriate in

the analysis presented in this report. The following entities formally submitted comments during the official comment phase for one of the three submitted project proposals:
Bay Area Houston Economic Partnership
Galveston County Economic Alliance
The Woodlands Area Economic Development Partnership
Humble Independent School District
The Economic Development Alliance for Brazoria County
Baytown – W. Chambers County Economic Development Foundation
Galveston Economic Development Partnership
Pearland Economic Development Corporation
City of Waller Economic Development Corporation
Economic Alliance Houston Port Region
City of Houston
Texas Medical Center
Pasadena Second Century Corporation
Tomball Economic Development Corporation
Greater Fort Bend Economic Development Council
Shriners Hospital for Children
Uptown Houston
City of Missouri City, Texas
Calpine
Waller County EDP
NRG Texas Power LLC
Lone Star Transmission
Edison Mission Marketing & Trading
Luminant Energy Company LLC
Texas Industrial Energy Consumers (TIEC)
LCRA Transmission Services Corporation
Cross Texas Transmission (CTT) [and Garland Power & Light]
F to Z Coalition
Oncor Electric Delivery
Mercuria Energy America

12. Appendices

Appendix A: AC Contingency Result of 2018 SE Study Base Case (N-1 analysis)	Houston_Import_BaseCase_N-1.xlsx
Appendix B: AC Contingency Result of 2018 SE Study Base Case (G-1+N-1 analysis)	Houston_Import_BaseCase_G-1_STX_N-1.
Appendix C: AC Contingency Result of 2018 SE Study Base Case with Option 4 (N-1 analysis)	Houston_Import_CTT-LGZ-TA_N-1.xlsx
Appendix D: Result of cost analysis using different cost-per-mileage for new transmission line in each select option	Summary of Cost Analysis using differe
Appendix E: Description of the SSWG Cases, and Summary of the study result	Appendix E.docx
Appendix F: AC Contingency Result of the 2018 SSWG Case 1 (G-1+N-1 analysis)	Contingency Result - Case 1 2018 SSWG (
Appendix G: AC Contingency Result of the 2018 SSWG Case 2 (G-1+N-1 analysis)	Contingency Result - Case 2 2018 SSWG v
Appendix H: AC Contingency Result of the 2018 SSWG Case 3 (G-1+N-1 analysis)	Contingency Result - Case 3 2018 SSWG v
Appendix I: Estimates of selected options and future upgrades in 2018 dollars	Cost Estimates of Selected Options and

