Attachment A

Competitive Renewable Energy Zones (CREZ) Transmission Optimization Study

ERCOT

System Planning

April 2, 2008

I. Introduction

A. Purpose

In the Interim Order on Reconsideration in Docket 33672 (Interim Order), the Public Utility Commission of Texas (PUCT or Commission) designated five zones as Competitive Renewable Energy Zones (CREZs). These zones are depicted in Figure 1. The PUCT also requested that ERCOT develop transmission plans to provide transfer capacity for wind generation as specified in the four scenarios in Table 1.

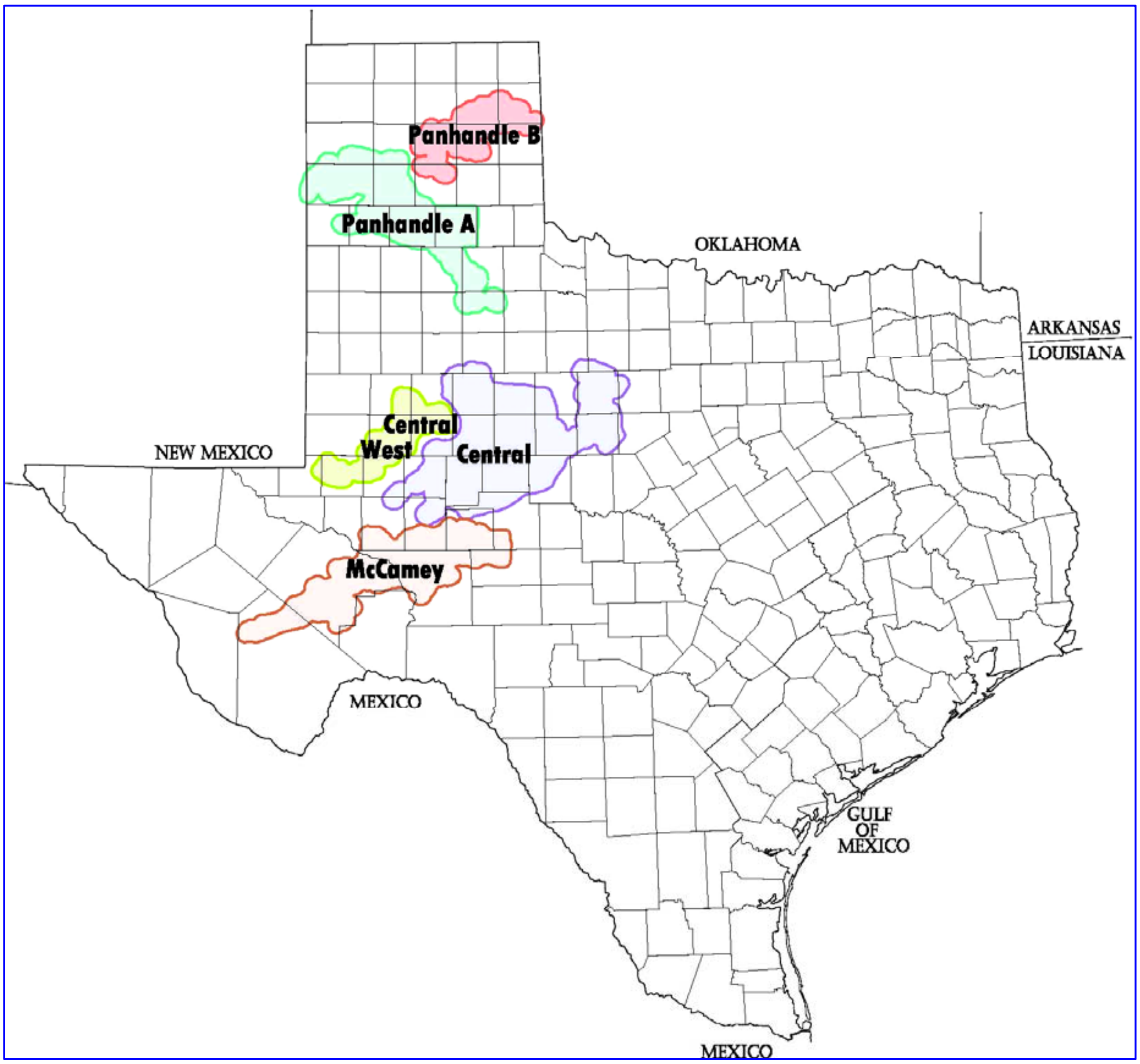


Figure 1: Competitive Renewable Energy Zones

Table 1: MW Tiers for ERCOT CREZ Transmission Optimization Study

	Scenario 1 (MW)	Scenario 2 (MW)	Scenario 3 (MW)	Scenario 4 (MW)
Panhandle A	1,422	3,191	4,960	6,660
Panhandle B	1,067	2,393	3,270	0
McCamey	829	1,859	2,890	3,190
Central	1,358	3,047	4,735	5,615
Central West	474	1,063	1,651	2,051
CREZ Wind Capacity	5,150	11,553	17,956	17,516

In the Interim Order, the Panhandle A region was designated as Zone 2A; the Panhandle B region was designated as Zone 4; the McCamey region was designated as Zone 5/6, the Central region was designated as Zone 9A, and the Central West region was designated as Zone 19. The geographic boundaries of these regions are defined in the Interim Order.

B. Stakeholder Involvement

ERCOT System Planning has maintained a rigorous schedule of open stakeholder meetings, in order to share the ongoing results of this study and to solicit comments and suggestions from interested parties. At the initiation of the study, ERCOT System Planning designated a Task Force of the Regional Planning Group (RPG), named the RPG-CREZ Task Force, and established a mailing list on the ERCOT.com web-site for this task force. Two-hundred seventy-six individuals have registered for this mailing list. Twelve meetings of the RPG-CREZ Task Force have been held over the course of this study. Modeling assumptions, equipment costs, and modeling results have been presented and discussed during these meetings. Input was solicited from existing and potential transmission owners and other market participants. Vendors were invited to join the meetings and discuss the technical capabilities of different transmission technologies, including 765-kV transmission equipment and high voltage direct current (HVDC) equipment. Each of these meetings was attended by 50 or more stakeholders.

C. Issues List

One of the primary topics of discussion at the initial RPG-CREZ Task Force meetings was a list of issues that were raised by ERCOT System Planning staff and by stakeholders. These issues were mostly questions that required resolution prior to the start of analysis of transmission plans. Alternative responses to the various questions were suggested and discussed, and each issue was resolved with general consensus of the stakeholders involved in the RPG-CREZ process. When the issues had been resolved, the list of issues and proposed resolutions to the issues (the Issues List) was submitted into the PUCT CREZ Docket (33672) on November 11, 2007 (document 984).

One of the issues that was discussed was the amount of existing wind generation to include in the base case. As shown in Table 1 above, the Interim Order requested that ERCOT develop sufficient transfer capacity for four levels of new CREZ wind generation. The initial ERCOT CREZ Study, performed in 2006, included 4,850 MW of wind generation located in West Texas in the base case, some of which currently was operational, some of which had signed interconnection agreements with Transmission Service Providers (TSPs), and some of which was at some stage in the ERCOT interconnection process prior to finalization of an interconnection agreement. As described in the Issues List, the base case level of wind generation was updated for the present CREZ Transmission Optimization Study to 6,903 MW of wind generation capacity, which included all of the wind generation facilities that were either operational or had signed interconnection agreements as of the start of the analysis for this study (September 11, 2007). The resulting total amounts of wind in each case, using this amount of base case wind, are shown in Table 2.

Table 2: MW Tiers for ERCOT CREZ Transmission Optimization Study

	Scenario 1 (MW)	Scenario 2 (MW)	Scenario 3 (MW)	Scenario 4 (MW)
CREZ Wind Capacity	5,150	11,553	17,956	17,516
Base Case Wind	6,903	6,903	6,903	6,903
Total Wind	12,053	18,456	24,859	24,419

Another issue that was discussed and included in the Issues List was the appropriate criteria for adequacy of transmission capacity. Previous transmission planning studies for incorporating wind generation in ERCOT indicate that transmission projects that reduce overall wind curtailment due to transmission constraints to approximately 2% of expected wind generation output on an annual basis are generally cost-effective, as that term is applied in ERCOT. As a result, it was decided that a 2%

overall wind curtailment criteria due to transmission congestion was consistent with the Interim Order which instructs ERCOT to "…present to the Commission transmission proposals that provide transfer capacity for the estimated maximum generating capacity per CREZ in the most beneficial and cost-effective way to customers." Using this criterion for wind curtailment, equally effective transmission plans could be compared based on capital cost of system improvements.

It is important to note that this 2% curtailment criterion does not result in transmission solutions in which all wind units will face 2% or less annual curtailment. Rather, in the aggregate, using expected average weather year wind patterns for each wind generation facility, and without including the impacts of transmission line outages, the total wind energy curtailment for each scenario is expected to be approximately 2%. Some wind generation facilities may be curtailed more than 2%; many will be curtailed less. Actual unit curtailments will depend upon the exact locations of CREZ wind generation, day-to-day system operating conditions, and the bidding price for the energy output of the wind generation facilities. Also, there is some inherent wind curtailment in the security-constrained unit-commitment and economic-dispatch model results. Even with no transmission constraints, the model results show about 0.7% of wind energy curtailment.

D. Transmission Equipment Costs

ERCOT facilitated several discussions of estimated transmission equipment costs during RPG-CREZ Task Force meetings. These discussions led to general agreement regarding the planning-level cost estimates of transmission equipment that would be included in transmission plans. These costs are listed in Table 3, and have been used to develop the cost estimates provided in Section III. They are significantly higher than the mid-2006 values that were input into the original ERCOT CREZ Report, primarily because of increased material costs.

The same estimated costs per mile for new transmission lines listed in Table 3 were used throughout the state for this study. However, right-of-way (ROW) costs for new transmission lines will vary across the state. ROW costs will likely be higher in some areas, particularly near and around urban areas. On the other hand, ROW costs may be lower in other areas where many of the additional transmission lines will be required, such as the Panhandle and portions of west Texas.

The planning-level costs of new transmission lines were estimated using straight-line lengths for the purposes of this study. It is likely that, during the routing process for individual transmission lines, the overall length of a line may increase from these straight-line estimates, due to land use and similar considerations.

Table 3: Estimated Costs of Transmission Equipment

Component	Cost ($ Million)
138-KV EQUIPMENT COSTS:	
138-KV NEW CKT./MILE	1.0
138-KV SECOND CKT./MILE	0.25
138-KV RECONDUCTOR/MILE	0.30
138-KV SUBSTATION	10.0
345-KV EQUIPMENT COSTS:	
2-1433 ACSS 345KV SINGLE CKT. ON DOUBLE CKT. TOWERS/MILE	1.5
2-1433 ACSS 345KV DOUBLE CKT. ON DOUBLE CKT. TOWERS/MILE	1.88
2-1590 ACSR 345KV SINGLE CKT. ON DOUBLE CKT. TOWERS/MILE	1.4
2-1590 ACSR 345KV DOUBLE CKT. ON DOUBLE CKT. TOWERS/MILE	1.68
2-959 ACSS/TW 345KV SINGLE CKT. ON DOUBLE CKT. TOWERS/MILE	1.3
2-959 ACSS/TW 345KV DOUBLE CKT. ON DOUBLE CKT. TOWERS/MILE	1.56
345-KV SECOND CKT./MILE	0.4
345-KV RECONDUCTOR/MILE	0.5
SERIES COMP > 100 MILES	30.0
SERIES COMP < 100 MILES	25.0
150-MVAR SHUNT CAPACITOR	6.0
345/138-KV 600MVA AUTO TRANSFORMER	8.0
345/138-KV 800MVA AUTO TRANSFORMER	9.0
Substation - RING BUS 6 - LINE TERMINALS	15.0
Substation - BREAKER & 1/2 > 6 - LINE TERMINALS	25.0
765KV EQUIPMENT COSTS:	
765-KV CKT. COST/MILE	2.6
765-KV COST/SUBSTATION	40.0
765/345-KV AUTO TRANSFORMER	20.0
HVDC COSTS:	
2 x 3,000-MW CONVERTER STATIONS	525.0
345-KV HVDC CKT. COST/MILE	1.05

II. Methodology

A. Overview

The level of complexity associated with developing transmission plans that could integrate the level and distribution of wind generation included in any of the scenarios designated by the Commission in the Interim Order, particularly within the timeframe allotted for the CTO Study, required a novel approach to transmission plan development.

Even at the 12GW level of wind, the wind power must be “picked up” from sites across a broad geographic area and must be “dropped off” onto the existing bulk transmission in a manner that is sufficiently distributed to avoid overtaxing the transmission system around the drop off points. When this large number of potential end points is coupled with the number of new lines that will be required to transmit the amount of installed wind capacity that is included in these scenarios to load that is primarily in the eastern half of the state, the number of transmission solutions that could potentially meet the requirements of the study becomes very large. For the higher scenarios of installed wind capacity specified by the Commission, this complexity grows exponentially.

ERCOT developed an analytical approach to reduce the number of transmission solutions to a number that could be managed and yet would result in full consideration of sufficient plans to ensure that a near-optimal plan for each scenario would be developed. The first step in this approach was to identify a set of fundamentally and significantly different concepts upon which transmission plans would be developed. The intent of developing these significantly different concepts was to force the development of different transmission plans that would span the range of all feasible solutions for CREZ transmission and include all of the different types of solutions that might reasonably be considered.

Once the set of significantly different concepts was identified, the next step was to develop a specific transmission plan for each scenario, based on each significantly different concept, to the point that it was clear which concept resulted in a plan that met the performance requirements for the CREZ transmission for each scenario at the lowest cost. Once it was clear which concept was preferred for each scenario, the next step was to optimize a specific plan based on that preferred concept. Finally, additional analysis was performed to determine what elements of the preferred plan (for scenarios 2, 3 and 4) might be staged to support the level of transmission needed for the lower scenario(s) and to determine what would be required to expand the preferred plans for scenario 1 and 2 to the scenario 3 level, if that became needed in the future.

B. Development of Plan Concepts

A comprehensive list of basic concepts for collecting, transmitting and distributing power from the wind areas to load was formulated. The resulting concepts that were significantly different from one another are:

1) Integrated 345-kV transmission system for wind in west Texas
2) Incremental 345-kV transmission system for wind in west Texas
3) Reduced number of right-of-ways (as compared to the 345-kV concepts) using higher voltage circuits (500 kV or 765 kV)
4) Low impedance backbone or loop around wind areas and/or load centers
5) HVDC circuit(s) to move power to load centers or between load centers, integrated with 345kV upgrades

Each of these concepts would have unique attributes with the potential to help meet the CREZ system requirements, yet each one also would have potential downfalls. By developing full transmission plans based on each of these concepts, and then comparing the resulting plans, the best performing concept could be determined. Then a final transmission plan based on that concept could be optimized, perhaps using specific elements of other concepts to mitigate the downfalls of the best performing concept.

The integrated-system concept would connect the wind generation to the existing system in west Texas as appropriate, and would include supplements to the existing system as necessary to increase the transfer capacity out of west Texas. Of the significantly different plan concepts that were identified, this concept is the most consistent with the current ERCOT system. One potential downfall with the integrated system approach was thought to be that if the new CREZ generation is even indirectly connected to the existing system in west Texas, a small portion of the power from that new generation would flow onto the lower voltage parts of the existing system, causing widespread overloads that would be difficult to resolve. This potential problem led to the concept of an incremental system for wind.

The incremental system concept would result in an “overlay” that is not connected to existing system in west Texas. The incremental system would only have wind generation connected to it and would only connect the existing ERCOT system at the eastern end where the existing 345kV network is more robust (in the DFW area and east of I-35). A potential problem with the “overlay” system is that it would not be as stable as the integrated approach and could require additional transmission facilities to resolve. The question would be whether the cost of resolving the lower voltage system upgrades in the integrated plan or the extra transmission lines needed to achieve a stable system in the incremental plan would result in a lower cost.

While the exact number of new west-to-east 345-kV right-of-ways (ROWs) that would be needed for either the integrated or incremental approach was not known, a preliminary guess was that the theoretical minimum for the Scenario 2 case (for example) would be five new west-to-east 345-kV lines, and more new lines than that minimum number would actually be needed due to as-yet-unknown actual system requirements. This assessment led to the next alternative concept, which was to try to reduce the number of west-to-east ROWs by using higher voltage (e.g. 765-kV) transmission lines for the major west-to-east transfer paths while using 345-kV lines to funnel power from the wind areas to the higher voltage lines and to distribute the power from those lines on their eastern ends.

The higher voltage lines would have a higher capacity, lower impedance and therefore lower losses when compared to a 345-kV line of similar length, with the potential to replace several 345-kV lines with one higher voltage line. The downside to this concept was that these higher voltage lines would be more expensive and have higher substation costs compared to 345-kV lines. The question would be whether the need to provide sufficient transfer capacity while providing system security (must have sufficient parallel transmission capacity such that if any line were to trip open, the lines that remain in service would not overload due to the natural transfer to those lines of the power that had been flowing on the tripped line) would allow the number of ROWs to be reduced enough to make up for the additional cost.

A second concept involving the use of higher voltage lines was also identified. This concept was based on the use of higher voltage loops that would pass through the wind areas, across the state and also loop around several of the larger load areas. It was thought that the previously described reduced ROW plan might have two downfalls: first, that it might require significant 345kV lines to collect the power from the wind areas and also to distribute the power on the eastern end of those lines; and, second, it might not take full advantage of the benefits of moving to the higher voltage lines. The higher voltage loop concept might be able to resolve these issues, but the question would be whether the additional cost of building the loops would be warranted.

The final concept would use one or more high voltage, direct current (HVDC) transmission lines to reduce the number of ROWs that might be needed in the incremental or integrated 345-kV concepts. The properties of an HVDC line are such that the power-flow on the line can be controlled and results in lower losses for an equivalent amount of power transfer, as compared to transmission of the same amount of power on an alternating current (AC) line. The equipment used to convert the power from AC to DC for transmission on the line and then back to AC on the other end of the line is costly, so HVDC lines must typically be several hundred miles long in order to be cost effective. In addition, the

HVDC line cannot be added in isolation; there must be sufficient AC transmission parallel to the HVDC line to handle the power-flow under contingency conditions, and the AC system at both ends of the line must meet certain requirements with respect to how strongly it is connected to the rest of the system.

At different stages in the development of each plan, the potential benefits of developing a hybrid plan, i.e., a plan with characteristics of more than one of the five general concepts, were considered. In this way, the benefits of the selectively adding additional connections to the existing transmission system were considered for plans developed following the “overlay” concept (concept 2) and the benefits of selectively adding 765-kV or HVDC circuits instead of 345-kV lines were considered in plans following both the overlay and integrated concepts (concepts 1 and 2).

C. CREZ Wind Generation Locations

A request was made to all recipients of the RPG-CREZ mailing list for locations of wind generation facilities that were included in the financial testimony submitted as part of PUCT Docket 33672. Responses were received from numerous wind generation developers. These responses were evaluated and a set of likely collection points for CREZ wind generation facilities was developed. In general, these collection points were located amid several facility locations submitted as part of this request.

Although the initial intent was to develop a different set of collection points for each of the four scenarios outlined in the Interim Order, most of the responses from wind developers indicated that they intended to build the same amount of wind generation, in the same locations, regardless of which scenario is selected in the on-going CREZ docket. As a result, one set of locations was developed, and the amount of wind at each location was changed in order to match the totals by zone outlined in the Interim Order.

This set of locations was used to develop the transmission plans that were evaluated as part of this study. Although in the transmission planning model input databases the CREZ wind facilities were directly connected to these connection points, in reality they will likely be connected to a collection hub via a 138-kV or other suitable voltage radial transmission circuit. The exact collection system used to connect individual or groups of wind farms to these connection substations cannot be designed until the precise locations of the wind farms that will connect to these facilities have been determined. The final design will likely be developed at the time that the generation interconnection studies are performed. The present study will include a representative estimate of the cost of these collection facilities.

D. Design Considerations

In very broad terms, each of the plans developed as part of this study has been evaluated on how cost-effectively it is able to collect wind from the five CREZ areas and move that generation to load centers. There are two considerations that have been highly relevant to the design of the transmission plans for the four scenarios. First, a large proportion (approximately 45%) of the new CREZ wind generation is located in the Texas Panhandle (for an illustration of the approximate amounts of wind generation included in Scenario 2, both new CREZ wind generation and existing wind generation, see Figure 2). As power-flows will follow the path of least resistance (in this case, the path of lowest impedance) to load, much of the wind generation from the Panhandle, along with wind generation from the central zone, will tend to flow towards the nearest load center, the Dallas/Fort Worth area.

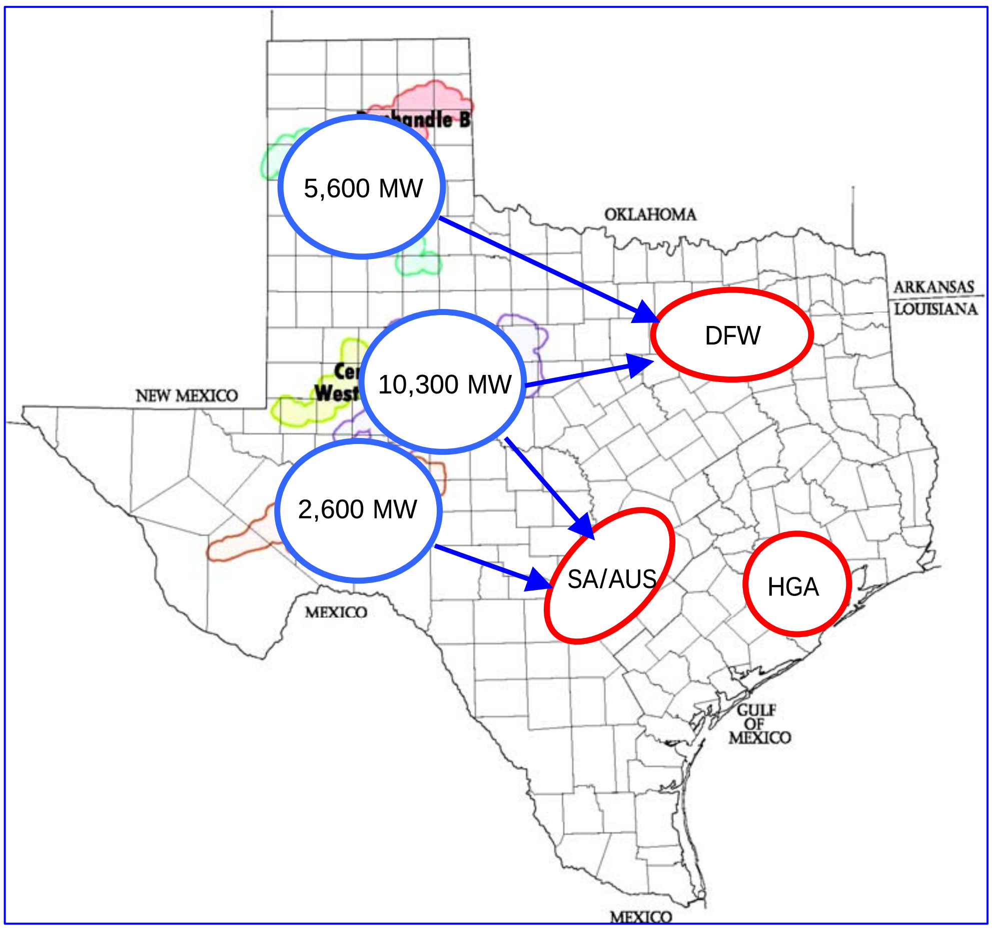


Figure 2: Wind Generation (in Blue) and Load Centers (in Red) in ERCOT for Scenario 2

However, there is not sufficient load in the Dallas/Fort Worth area to reliably accept all of this wind generation. Therefore, one aspect of any successful transmission plan is the capacity to move much of the wind generation from the Central zone, along with some of the wind from the southern Texas Panhandle, to load areas south of Dallas/Fort Worth. In addition, sufficient new pathways are needed so that all of the wind generation from the McCamey area flows towards the east or southeast. This direction of power-flows can be accomplished either through individual circuits leading generally from northwest to southeast, or through a large, low impedance backbone that is capable of allowing large power transfers between the Dallas/Fort Worth areas and the Houston and Austin/San Antonio load centers.

The second consideration results from the fact that both the wind resources and the load centers are distributed over large areas, one in west Texas, the other in east Texas. The load centers in east Texas are already connected by a highly networked transmission system, albeit one that does not provide a significant amount of additional unused capacity. In west Texas, most of the areas in which CREZ wind would be developed are not connected by a strong existing networked transmission system. In some areas, the existing transmission is barely adequate for the wind resources already present (e.g. around McCamey); in some areas the transmission system is designed to serve small rural loads and current wind generation interest already far exceeds existing capacity (e.g., Lamesa and Matador), and in some areas there is no ERCOT transmission at all (e.g. the northern portion of Panhandle A and all of Panhandle B).

As a result, a fundamental question in this study has been what type or types of transmission would be best suited to collect wind generation from scattered locations across much of west Texas, move it hundreds of miles to east Texas (directing much of it away from the Dallas/Fort Worth area), and then redistribute the power-flows to load centers, utilizing any available transmission capacity but without causing significant congestion on the existing transmission system.

E. Modeling Assumptions and Analysis

1. Case Development

The primary tools utilized to develop transmission solutions were PSS/E (version 30) and Powerworld (version 12) for steady-state AC analysis; PSS/MUST (version 8.3) for transfer capacity and contingency analysis; and UPlan (Version 7.4) for security-constrained unit-commitment and economic-dispatch analysis (using a DC approximation to AC power-flows). Dynamic analysis was conducted using PSS/E. Solutions were developed using both steady-state and unit commitment models in parallel. The steady-state models were used to evaluate AC power-flows, while UPlan was used to determine the monthly and annual wind curtailment. By looking at potential solutions using both sets of tools, transmission improvements were developed with an understanding of both real and reactive power flows and the potential for reduction of transmission congestion from changes in generation commitment and dispatch. Plans were developed to meet all applicable NERC and ERCOT reliability criteria related to transmission planning.

The base case for this analysis was derived from the most recent Five-Year Transmission Plan developed by ERCOT System Planning. In UPlan, the 2012 case, with all projects required to serve load reliably, was adjusted to include the incremental amounts of CREZ wind generation specified in the Interim Order, as well as thermal generation that was presented as part of testimony in the CREZ docket. All of the modeling assumptions developed and utilized as part of the evaluation of the 2007 Five-Year Plan were utilized in this study. These assumptions include the following:

- All generation units with signed Interconnection Agreements were included
- All generation units in the Dallas/Fort Worth area without selective catalytic reduction units were assumed to be mothballed
- Delivered price of natural gas to generating units was set to $7/MMBtu
- Some mothballed units were returned to service for cases to maintain a generation reserve margin of at least 12.5%

For more information regarding the ERCOT Five-Year Plan, see the following link:

http://www.ercot.com/news/presentations/2008/35171_ERCOT_2007_Transmission_Constraints_Needs_Report.pdf

As noted in Section II(B), CREZ wind generation locations were determined based on information provided by stakeholders. These locations and generation capacity totals were included in the UPlan case. Wind patterns for each of the units in the UPlan case were developed using AWS Truewind average weather year hourly wind patterns developed as part of the prior ERCOT CREZ Report.

For each of the scenarios, a transmission plan was developed based on each of the five concepts. The development of each plan was a multi-step, iterative process. Beginning with a particular concept and CREZ scenario level of wind, hundreds of variations for endpoints and “trunk” lines between west and east Texas were developed, analyzed, modified and re-analyzed. The process was repeated for each concept for each scenario.

The development and analysis of each plan involved three parts. The first part of the analysis required a simulation of the security-constrained unit commitment and economic dispatch of the ERCOT system for all hours of 2012 using a model that simulates the “real power” flow across the network. This simulation was performed to test whether the transmission plan under consideration was sufficient to result in no more that 2% overall curtailment of the potential energy that could be produced by the aggregate wind generation in the case (based on the typical, hourly wind power production profiles provided by AWS Truewind). In addition, the simulation was used to investigate what transmission elements were limiting the transmission of power by the plan, such that the wind energy curtailment was greater than 2%, requiring further upgrades for the plan to be fully developed.

The second part of the analysis required the simulation in an AC power-flow model of the transmission plan, in order to investigate the modifications needed to maintain voltages on the transmission network within an acceptable range. It is not feasible to analyze every hour of the year in an AC power-flow, so a contingency analysis was performed on three specific hours in the AC power-flow model: the hour with the peak system load; the hour with the minimum loading on new CREZ lines (minimum load in West Texas plus west Texas wind generation) and the maximum transfer of generation from West Texas (maximum wind generation and minimum load in West Texas). These hours were selected as representative of the maximum stress that would be applied to the system from the new CREZ wind and transmission. The generation dispatch and load levels for these three hours were extracted from the security-constrained unit-commitment and economic-dispatch model and were used to develop AC power-flow cases for Scenarios 1 and 2.

The third type of analysis involved the time domain simulation of the performance of the system in the few seconds following different simulated faults on the system to test the plan for angular, voltage and frequency stability. This dynamic stability analysis will be discussed in more detail below.

As each plan was developed and tested through these series of analyses, different optional solutions (for example, adding another line from point A to point B, or instead adding a line from point A to point C) were tested to determine which option resolved any performance deficiencies of the plan at the lowest cost. In some cases, a plan that looked to be the best approach after one step of the analysis might require significant enough modification in the subsequent steps of the analysis that a different plan would be the preferred plan concept for a particular CREZ scenario after all the analyses were completed.

2. Dynamic Stability Modeling

It is necessary to test not only the steady-state performance of the planned power system, but also to test the dynamic performance of the system in the seconds following a fault or other disturbance. The planned system must be sufficient such that it does not reach an operating point that would result in additional disturbances (such as the loss of additional generation or transmission outages) and must be able to recover in a damped manner to an acceptable steady-state operating point. These issues are of particular concern where large amounts of power are transferred over a relatively small number of lines, where a fault and subsequent outage of any line would require significant adjustments of the system (which might be beyond the capability of the system) to reach that stable operating point.

These dynamic analyses require modeling of not only the topology of the grid, but also require modeling of the dynamic response of individual generators and of aggregated electrical loads (motors, lights, etc.) ERCOT maintains a database of these models for existing generators, but it was necessary to assume models for all of the new wind generating units. The model used for these units was the generic Type III Double Fed Induction Generator model developed by Siemens Power Technology Inc., having a protection system that provided the low-voltage ride-through (LVRT) requirements specified in FERC Order 661A.

The maximum transfer case for a particular plan was used for these analyses. Between 150 and 200 dynamic analyses were run per plan, including applying faults at either end of long transmission lines and tripping various generating units. The simulations were run for several seconds and the values of certain bus and machine angles, frequency, and bus voltages were plotted for various locations around the system, as well as the power flows on various key lines. These plots were reviewed to ensure that the disturbance did not result in angular separation, that the voltage performance would not result in the loss of generation, and that the oscillation in any system parameter exhibited a damped response that returned to a steady-state value within several seconds.

3. Modeling Assumptions for Scenarios 3 and 4

As noted in Table 2 (Section I[C]), Scenarios 3 and 4 each include more than 24 GW of wind generation capacity. This amount of wind generation is not likely to be constructed by 2012, the date of the transmission topology base case used for development of transmission plans for scenarios 1 and 2. Therefore, modeling the expected ERCOT grid in 2012 with over 24 GW of wind generation capacity is not consistent with future expectations. Yet modeling generation and load in years beyond 2012 using a security-constrained unit-commitment and economic-dispatch model is not possible as transmission upgrade plans to serve customer load growth beyond 2012 have not been developed.

Plans for Scenarios 3 and 4 can be developed using AC power-flow models, but these models cannot be used to determine the amount of annual wind curtailment. To develop transmission plans for Scenarios 3 and 4 that would provide similar amounts of transfer capacity as those developed for Scenarios 1 and 2, and thus a similar level of overall wind curtailment, the percentage of wind generation during the maximum export hour from scenario 2 was calculated for both CREZ wind (88%) and existing wind (wind generation facilities included in the base case; 55%). The dispatch of thermal units in the maximum export hour and other similar hours in April was also evaluated. A case was built using an AC power-flow model with the amount of wind generation capacity for Scenario 3 and 4 outlined in the Interim Order, placed in the same locations as in scenarios 1 and 2, and set at the same output as a percentage of nameplate capacity as was derived from Scenario 2. Thermal units were committed in the order of decreasing capacity factors for the month of April from the Scenario 2 case. In addition, the minimum load points for both coal units and for cogeneration units were set to no greater than 50%. The total ERCOT load for that day and hour was obtained from the ERCOT Long-Term Load Forecast for the year 2018. Using these inputs, loads and generation were matched and the case was used for development of transmission plans.

4. Substation Location and Design

The results provided in Section III provide potential locations of new substations included in each plan. The substations that connect to the existing transmission infrastructure are also delineated. The locations of new substations are, for the most part, flexible. Potential locations are indicated, but the locations of these facilities can be adjusted, within reason, to suit additional information not available at this time (e.g. actual locations of wind generation facilities that are included in the CREZ allocation process; siting and route selection issues; and future thermal generation development).

In addition to all established substation design practices, the following requirements were assumed for all substation improvements built as part of these CREZ plans:

- Every new substation will be designed in a standard ring-bus or breaker-and-a-half arrangement.
- The expansion of existing substations will include sufficient breakers and protective relays that each new line and each new transformer can be switched out of service independently, no matter how non-standard the arrangement of the existing substation.
- If System Protection and System Planning jointly decide that it will be advantageous to take a select transformer out of service when a particular line trips, the breakers and relays will still be installed to allow independent removal of either the transformer or the line.

The purpose of these two requirements is to prevent the inadvertent creation of any "super-sized" contingencies that stress the system beyond safe operating limits.

5. Existing Wind

Each of the plans presented in this report is designed to provide no more than 2% overall wind curtailment due to transmission congestion. During the development of each plan, the impacts of new transmission circuits on the curtailment of existing and new CREZ wind generation facilities were assessed. Often these impacts varied significantly from facility to facility. In many cases, the least-cost option for reducing overall wind curtailment was to add additional transmission facilities to the plan to change the connection point for an existing wind generation facility. The amount of existing wind generation capacity moved to new connection points is noted in the descriptions of each of the solutions included in Section III. However, additional analysis of these and other system modifications should be conducted as part of the Five-Year Planning process in order to maximize the system benefits relative to the overall costs.

F. Staging and Expandability Analysis

As a part of the development of plans based on the five concepts for each scenario, an analysis was performed to investigate how each plan might be "staged" [1] and how expandable each plan was. To provide information on how a plan might be staged, the portion of that plan which would be needed to provide sufficient transmission capacity for the amount of wind generation in the lower scenarios was identified. As an example, subsets of plans developed for Scenario 3 sufficient to provide transmission capacity for Scenarios 1 and 2 were developed. The expandability of a plan was evaluated by adding transmission infrastructure required to provide transmission capacity for the next higher scenario of wind generation. In expanding each plan, the transmission lines that were included in the original plan were not adjusted as new lines were added.

[1] There was discussion at the RPG CREZ TF meetings that it may not be feasible to build all of the new lines necessary to meet the Scenario 2, 3 or 4 level of wind generation at the same time, and some knowledge of which lines should be built first would be helpful.

III. Results

A. Overview

As described in Section II, the methodology of this study was designed to allow five different types of solutions (and hundreds of individual plans) to be evaluated for each of the four scenarios specified in the Interim Order. The expectation was that different types of solutions would likely be most cost-effective for different scenarios. Initial analyses seemed to bolster this assumption: although a solution consisting solely of 345-kV circuits appeared to be most appropriate for Scenario 1, it appeared unlikely that a 345-kV topology would be cost-effective for Scenario 2 or 3. As Scenario 2 appeared initially to be the level at which a solution other than a collection of 345-kV circuits could be the most cost-effective, plans were developed for this scenario following each of the 5 concepts.

The first solution type that was superseded was the reduced ROW concept. In designing a plan with three or four ROWs from west to east Texas, several large 345-kV loops were required to collect wind generation in west Texas. In addition, an extensive amount of new transmission was required in the immediate vicinity of the new 765-kV substations near the load centers in east Texas. The cost of this extensive amount of new 345-kV circuits in east Texas was greater than the 765-kV backbone that had been developed based on the low-impedance backbone concept. Since the plan based on the low-impedance backbone concept provided all of the benefits that the reduced ROW provided at a lower estimated cost, the analysis of reduced ROW plans was discontinued.

The second concept that was superseded was the incremental 345-kV solution. Under AC power-flow analysis and security-constrained unit commitment and economic dispatch analysis, this type of solution appeared to provide cost-effective and adequate transfer capacity for new wind generation. It was noted that there were some disadvantages with this type of plan, most notably the fact that as there would not be any connections between the existing transmission system and the new transmission system in west Texas, existing wind facilities would not see any benefit from the added transmission. Future planning would be more complicated because there would be two systems that would need to be evaluated for potential upgrades. Also, future changes in the transmission system, most notably changes that connected the two separate west Texas systems (the existing system and the one designed solely for CREZ wind) could actually decrease overall transfer capacity out of west Texas. Even with these disadvantages, the incremental plan was further refined as it appeared to be a cost-effective option.

Following AC contingency analysis, it was determined that numerous additional circuits would be required in order to achieve a stable solution. Although the separation of the incremental plan eliminated the impact of limiting elements on the existing system, it also prevented the incremental plan from gaining stability from interconnection to buses connected to thermal generation and load. As additional circuits were added to this plan to achieve stability, the estimated costs exceeded that of the integrated 345-kV plan, and it was decided to not pursue the incremental plan further. However, much of the analysis that led to the development of the incremental plan was used to develop a new plan, called a hybrid plan, because it was based on both the integrated 345-kV solution and the incremental 345-kV solution.

The reduced-ROW concept was evaluated once more after a 345-kV solution for scenario 2 had been developed and proven to be adequate through steady-state AC contingency analysis. As several additional circuits were added to the 345-kV solution in order to provide adequate capacity for real and reactive flows under all contingencies, an evaluation was conducted to determine if 500-kV or 765-kV circuits could provide the required transmission capacity more cost-effectively. Given the additional costs of 500-kV and 765-kV circuits and autotransformers, it was determined that the cost of the 345-kV solution could not be reduced by incorporating higher-voltage circuits.

Plans based on concepts 1, 4, and 5 were further evaluated for Scenarios 2 and 3. It was recognized from the start of the study that whichever type of solution was most cost-effective for scenario 3 would also likely be selected for scenario 4, as the two scenarios have similar total amounts of wind generation. For scenario 1, a 345-kV solution was developed that was optimized for the Scenario 1 level of generation without consideration of expandability; this plan would be compared with reduced versions of any solutions developed for scenario 2. Analysis of several types of plans continued, along with development of both expanded and reduced versions of each plan (see discussion of staging in Section II[F]), as it was generally considered unlikely that one type of solution would be most cost-effective for scenarios 1, 2, and 3.

When a 345-kV solution for Scenario 2 was found to be stable using transient stability analysis, thus meeting all performance requirements, it became clear that the much more expensive 765-kV solution was not cost-effective for this amount of wind. However, it was still considered likely that a 765-kV solution would be required for scenarios 3 and 4.

Solutions for scenarios 3 and 4 were initially developed primarily using 765-kV equipment based on the low-impedance loop or backbone concept. However, during the staging analysis to determine the expandability of the solution for scenario 2, it was found that adding an HVDC circuit and a few additional 345-kV circuits to the solution for scenario 2 resulted in a significantly lower cost solution for scenario 3 and 4 than any of the 765kV solutions that were based on the low-impedance backbone concept.

Thus, one concept provided the lowest-cost solution for three of the four scenarios, and resulted in a plan that can be implemented at the Scenario 1, 2, or 3 level, and a slightly altered plan that is adequate for scenario 4. The only scenario for which this plan was not the most cost-effective option is scenario 1, for which a smaller and less expandable plan was developed that was less expensive. In the next sections, these plans are described for the four scenarios.

Each of the plan descriptions includes an estimate of the cost of equipment to connect wind generation to the new CREZ facilities. These costs are based on assumptions of average length of transmission lines from the wind facilities to the collection substation (10 miles); average amount of wind generation on each new circuit (400 – 500 MW); and voltage level for lines connecting the wind farms to the collection substation (138-kV or 345-kV).

A figure depicting each plan is provided with the text description. Additional copies of each of these maps, at a higher resolution, are available in separate files.

B. Scenario 1

Two plans are presented for scenario 1. The first plan was designed specifically for the amount of wind generation capacity in this scenario without regard to possible expansion. This solution is presented here because it is the least expensive plan that provides adequate transmission capacity for the amounts and locations of wind generation assumed for this scenario. However, ERCOT is recommending the second plan, which is a subset of the plan developed for scenario 2, if the Commission decides to select Scenario 1 at this time. The second plan can more cost-effectively be expanded in the future to the wind generation levels in Scenarios 2 and 3, even if Scenario 1 is picked now. As such, the second plan will provide a cost-effective pathway for future increases in transmission capacity for wind generation, and will be provide more flexibility for future growth of wind generation capacity both within the CREZ process and through the normal ERCOT interconnection process. This latter consideration is particularly relevant considering that most of the interconnection agreements signed since the CREZ Transmission Optimization study began are located in the Central and Central West zones. While ERCOT has not analyzed the addition of this generation as part of this study, the second plan for Scenario 1 is more robust in these areas, and it is reasonable that it will be better able to handle the additional wind generation in these areas.

1. Plan A

The first plan for Scenario 1 (Plan A) was developed to minimize the cost of the transmission upgrades for the scenario 1 level of wind generation capacity. Because of this, Plan A is less expensive, but has less expansion capacity compared to the second plan that will be presented for Scenario 1, which was initially developed for scenario 2 and scaled back to scenario 1. One of the ways that overall costs are reduced in this plan is the use of 138-kV circuits. These circuits are less expensive to build than 345-kV circuits ($1 million/mile compared to $1.5 million/mile), but they also have a lower rating than 345-

kV circuits, resulting in less capacity on each circuit for connecting additional wind generation. Also, the use of radial circuits in this plan reduces the reliability of the transmission connections between some of the new CREZ wind and the rest of the transmission system. Plan A is depicted in Figure 3. One-line diagrams are provided in Appendix A.

Plan A features a 345-kV loop through the Panhandle connecting to the Oklaunion substation in the north and the new CREZ Central B substation in the south. An additional circuit extends from the Panhandle A-C substation to the new Clear Crossing substation. A radial 138-kV line is used to collect generation from the Panhandle A-B substation through Panhandle A-A to a 345/138-kV autotransformer at the Panhandle A-C substation. From Oklaunion a single-circuit 345-kV line was added to Bowman, as well as a double-circuit 345-kV line to a new station, West Krum. The double-circuit line was continued from West Krum to the existing Anna 345-kV station.

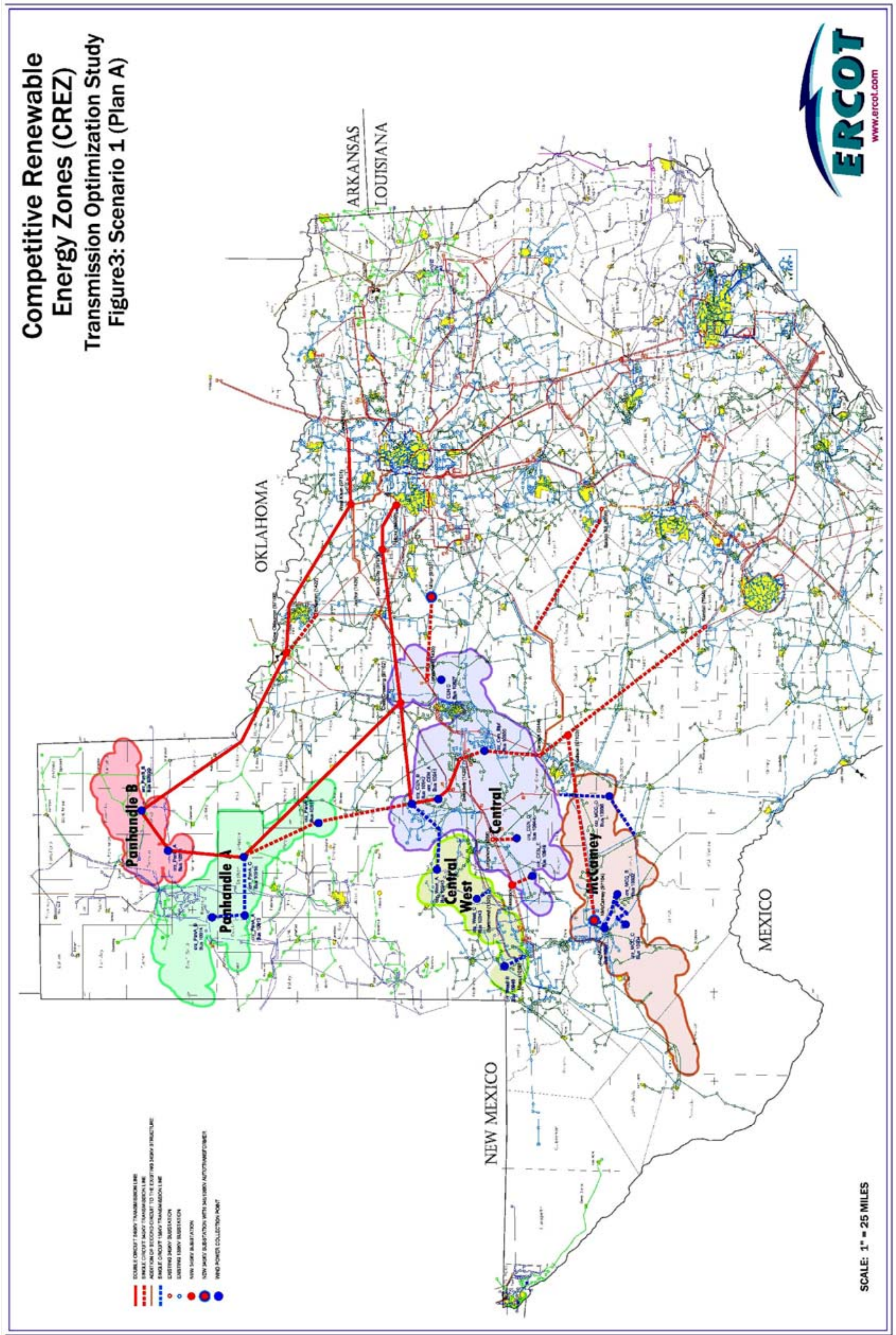
A new double-circuit 345-kV line was added from Central B to the new Clear Crossing station continuing to Jack County and then to a new 345-kV station called Hicks which would be located just east of Eagle Mountain. This line serves as a major trunk line paralleling the existing Morgan Creek to Graham to Fort Worth 345-kV infrastructure. It also serves as the contingency back-up line for the Panhandle generation.

From Central B heading south, a 345-kV line is included to Red Creek, with intermediate connections at the Central A, Tonkawa, Sweetwater, and Central Bluff substations. The purpose of this line was to draw power from the Central area and, to a lesser extent, from the Panhandle to two new 345-kV lines from Red Creek to substations in Central Texas.

The two new 345-kV lines from Red Creek included a circuit to Salado Switch Station and a circuit to Kendall via a new switch station, Edison. The circuit to Salado utilized the available tower position on a portion of the Red Creek to Comanche 345-kV line before cutting east towards Killeen and Salado.

Due to the large amount of existing wind generation connected into the existing Long Creek and Cook Field Road 345-kV substations and the new wind generation proposed for connection at the Central C substation, a 345-kV line was added from Long Creek to the RW Miller power plant with a 345/138-kV autotransformer at the RW Miller substation.

The new CREZ generation in the Central West area was connected with new radial 138-kV lines. The 138-kV line from Central West A to Central B also tied into a reconfigured Willow Valley 138-kV station. The Willow Valley 138-kV station was configured so that the Bull Creek wind plant injected power into the new 138-kV line, but did not inject into the existing system.


Competitive Renewable
Energy Zones (CREZ)
Transmission Optimization Study
Figure3: Scenario 1 (Plan A)
ARKANSAS
LOUISIANA
OKLAHOMA
NEW MEXICO
MEXICO
Panhandle B
Panhandle A
Central
Central West
McCamey
SCALE: 1" = 25 MILES
ERCOT
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The new generation in the McCamey area was all interconnected at the 138-kV level. Most of this was connected using existing 138-kV double-circuit lines that currently have only one circuit in place. Two new exits were added from the McCamey area. First, a 138-kV line was added from Friend Ranch to McCamey D to Twin Buttes. Second, two 345/138-kV autotransformers were added at North McCamey and a 345-kV line was constructed from North McCamey to Edison.

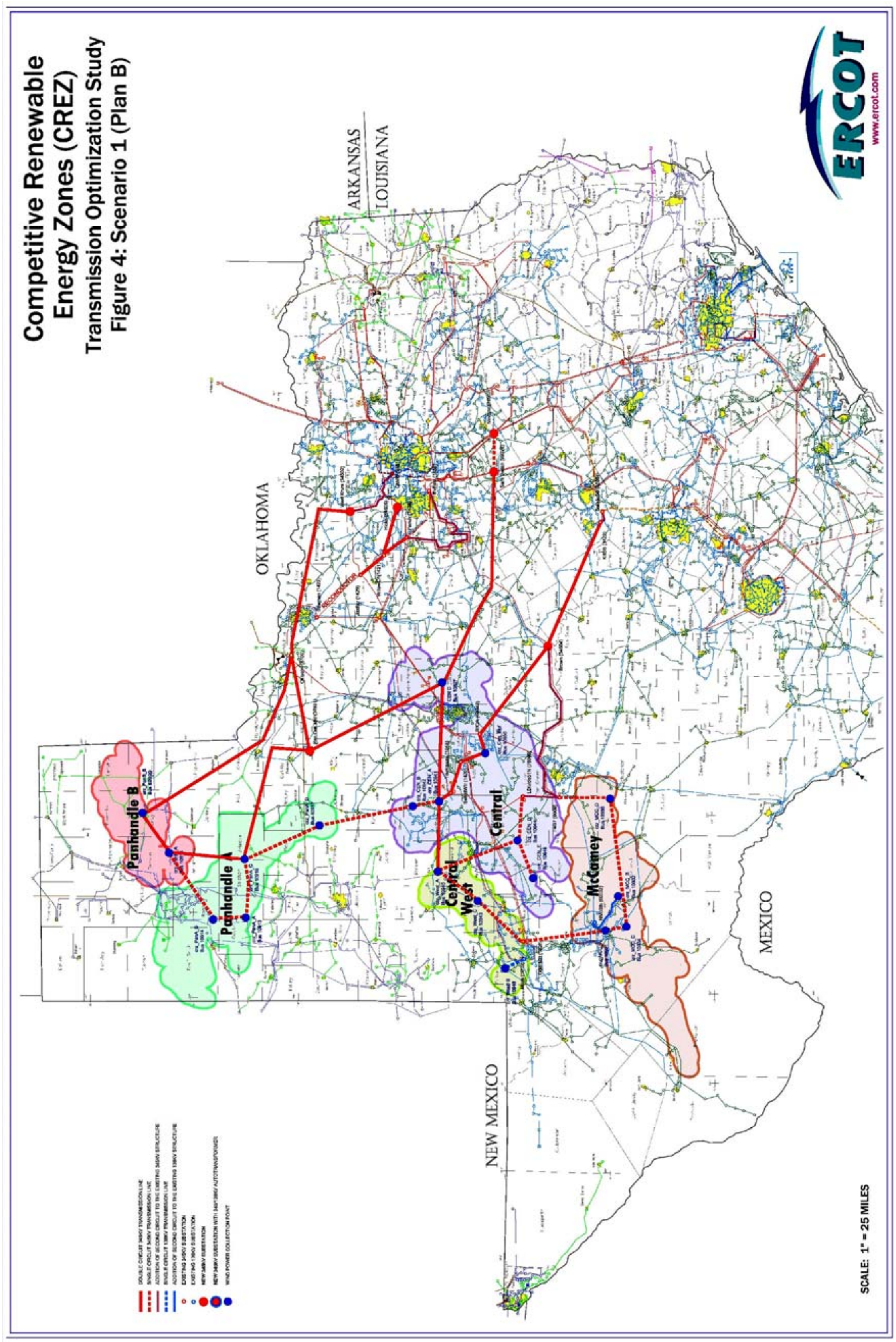
The estimated cost of this plan is $2.95 billion. A list of all circuits and estimated costs for this plan are provided in Appendix B. Based on production-cost modeling, the expected average annual wind curtailment is 1.56%, with a total wind generation of 41,751 gigawatt-hours (GWh). For comparison purposes, the base case, which contains 6,903 MW of wind generation capacity and was built off of the 2012 Five-Year Plan case, had a total wind generation output of 19,903 GWh. In this plan, 180 MW of existing wind generation was moved to a new interconnection location. The average system fuel-cost savings for each megawatt-hour of wind generation was $53/MWh. This plan contains 1,435 miles of new 345-kV right-of-way, and 203 miles of new 138-kV right-of-way. The estimated collection costs for this plan range from $350 million to $410 million.

2. Plan B

The plan depicted in Figure 4 was originally developed using aspects of both the fully integrated plan and the incremental (separated) plan for Scenario 2. The resulting hybrid plan was optimized for Scenario 2 and was shown to be the most cost-effective option for that scenario. A subset of this hybrid plan, adequate for wind levels in Scenario 1, was then developed. Since this plan was initially developed for 18,456 MW of total wind (11,553 MW of new CREZ wind), 345-kV circuits, rather than 138-kV circuits, are used to collect most of the CREZ wind. As such, this plan provides more expansion capacity and reliability for new generation than Plan A.

Plan B has a double-circuit 345-kV loop that extends from Oklaunion up to the Panhandle B zone, then south into the Panhandle A zone, connecting back to Oklaunion. A secondary single-circuit loop extends out to new substations located in the western portion of Panhandle A. An additional line extends from the Oklaunion substation towards a new West Krum substation located north of Dallas/Forth Worth. A new circuit connects the West Krum substation to the existing Carrolton NW substation.

Two circuits run south from the Panhandle to the Central zone, connecting at the Central A substation and at the Central C substation. These two buses are connected via a double-circuit that extends from the Central West zone, through the Central zone, east to new substations, one (Sam Switch) near Hillsboro and one (Navarro) near Corsicana. Both of these new substations would also connect to existing 345-kV circuits.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Energy Zones (CREZ)
Transmission Optimization Study
Figure 4: Scenario 1 (Plan B)
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ARKANSAS
LOUISIANA
OKLAHOMA
NEW MEXICO
MEXICO
Panhandle B
Panhandle A
Central
Central West
McCamey
SCALE: 1" = 25 MILES

From the Central West Zone, a single 345-kV circuit loops southwest to the Odessa/Midland area, down to McCamey, east towards Twin Butte, and north and west back to the West A substation. Two new lines connect to a new substation Brown, near Brownwood: the first, a double-circuit from Central B via Bluff Creek, and the second a new conductor on the existing towers that extend from Twin Butte to Comanche Switch. An additional single-circuit line connects the new Brown substation to the Killeen substation.

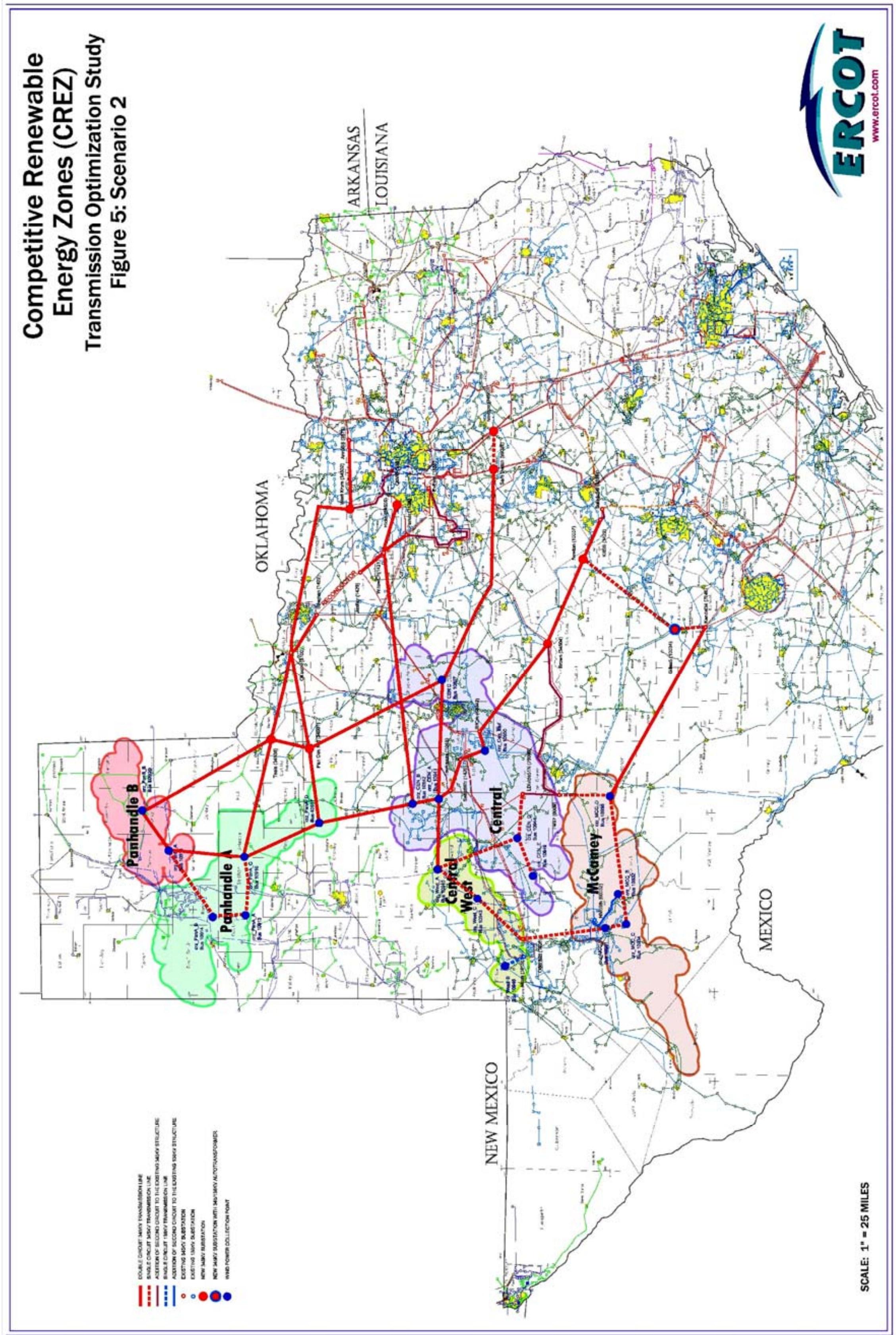
The estimated cost of this plan is $3.78 billion. One-line diagrams depicting this plan are provided in Appendix A. All of the components of this plan are listed in Appendix B. Based on production-cost modeling, the expected average annual wind curtailment is 1.71%, with a total wind generation of 41,689 GWh. In this plan, 820 MW of existing wind generation was moved to a new interconnection location. The average system fuel-cost savings for each megawatt-hour of wind in this scenario was $53/MWh. This plan contains 1,789 miles of new 345-kV right-of-way, and 42 miles of new 138-kV right-of-way. The estimated collection costs for this plan range from $410 million to $530 million.

C. Scenario 2

As noted above, Plan B for Scenario 1 was initially designed for Scenario 2, and was adapted for Scenarios 1, 3, and 4. With the incorporation of two new pathways out of West Texas, several new connections in the Panhandle, and the addition of second circuits on several lines included in Plan B, the Plan depicted in Figure 5 provides adequate capacity for 18,456 MW of total wind generation. Starting with the improvements listed for Plan B, the Scenario 2 plan includes a new bus in the Panhandle (Tesla) which connects the circuit from the Panhandle A C bus to PanOakMid bus and the circuit from Panhandle B B to Oklaunion. An additional circuit connects Panhandle A D to PanOakMid. Also, a new circuit extends from the Central B substation to the existing Willow Creek substation.

Other new circuits in north Texas include a new circuit from Oklaunion to Bowman, and from West Krum to Anna. Towards the south, another addition to this plan is a double-circuit line that extends from the McCamey D substation to the Kendall substation, with an additional circuit connecting the Kendall substation to the Newton substation near Killeen.

The estimated cost of this plan is $4.93 billion. One-line diagrams depicting this plan are provided in Appendix A. All of the components of this plan are listed in Appendix B. Based on production-cost modeling, the expected average annual wind curtailment is 2.31%, with a total wind generation of 64,031 GWh. In this plan, 820 MW of existing wind generation was moved to a new interconnection location. The average system fuel-cost savings for each megawatt-hour of wind in this scenario was $38/MWh. This plan contains 2,334 miles of new 345-kV right-of-way, and 42 miles of new 138-kV right-of-way. The estimated collection costs for this plan range from $580 million to $820 million.


Competitive Renewable
Energy Zones (CREZ)
Transmission Optimization Study
Figure 5: Scenario 2
ARKANSAS
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Panhandle B
Panhandle A
Central
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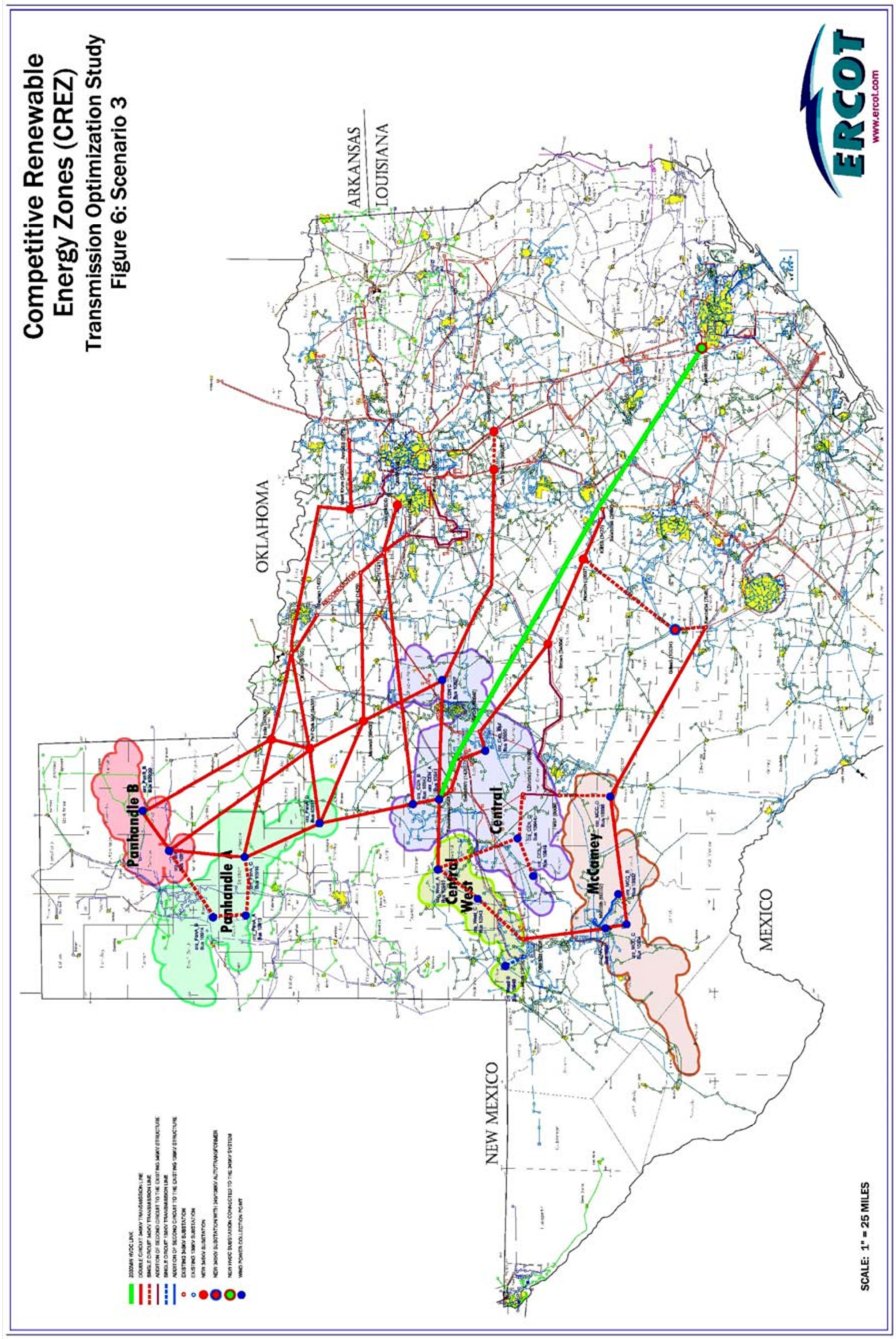
D. Scenario 3

The expansion of the plan developed for Scenario 2 to the wind capacity level specified in Scenario 3 is accomplished by the incorporation of several new circuits in the Panhandle, including a new circuit from Panhandle A C to the Jacksboro substation, and an HVDC circuit from the Central A substation to the Zenith substation located west of Houston. In the plan analyzed for this case, a HVDC circuit with a capacity of 2,000 MW provided sufficient capacity to allow the incorporation of up to 24,859 MW of wind generation. However, the size of this HVDC circuit can be adjusted to better suit system conditions during detailed feasibility studies.

The plan for Scenario 3 is depicted in Figure 6. The estimated cost of this plan is $6.38 billion. One-line diagrams are provided in Appendix A, and the components of this plan are listed in Appendix B. This plan includes 2,634 miles of new 345-kV right-of-way, 42 miles of new 138-kV right-of-way, and 360 miles of new HVDC right-of-way. The estimated collection costs for this plan range from $720 million to $1,030 million. In this plan, 820 MW of existing wind generation was moved to a new interconnection location. Because of the methodology required to develop this plan at the 24GW level, an estimate of the level of wind curtailment, as well as the amount of annual wind output, is not provided.

E. Scenario 4

A plan for Scenario 4 (with 24,429 MW of wind generation capacity) was developed based on the plan designed for Scenario 3 (with 24,859 MW of wind generation capacity). This plan is shown on Figure 7. The primary difference between the plan for Scenario 3 and this plan is the removal of lines connecting generation in Panhandle B. A one-line diagram is provided in Appendix A, and the components of this plan are provided in Appendix B. The estimated cost of this plan is $5.75 billion. This plan includes 2,087 miles of new 345-kV right-of-way, 42 miles of new 138-kV right-of-way, and 360 miles of new HVDC right-of-way. The estimated collection costs for this plan range from $670 million to $940 million. In this plan, 820 MW of existing wind generation was moved to a new interconnection location. Because of the methodology required to develop this plan at the 24GW level, an estimate of the level of wind curtailment, as well as the amount of annual wind output, is not provided.


Competitive Renewable
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Transmission Optimization Study
Figure 6: Scenario 3
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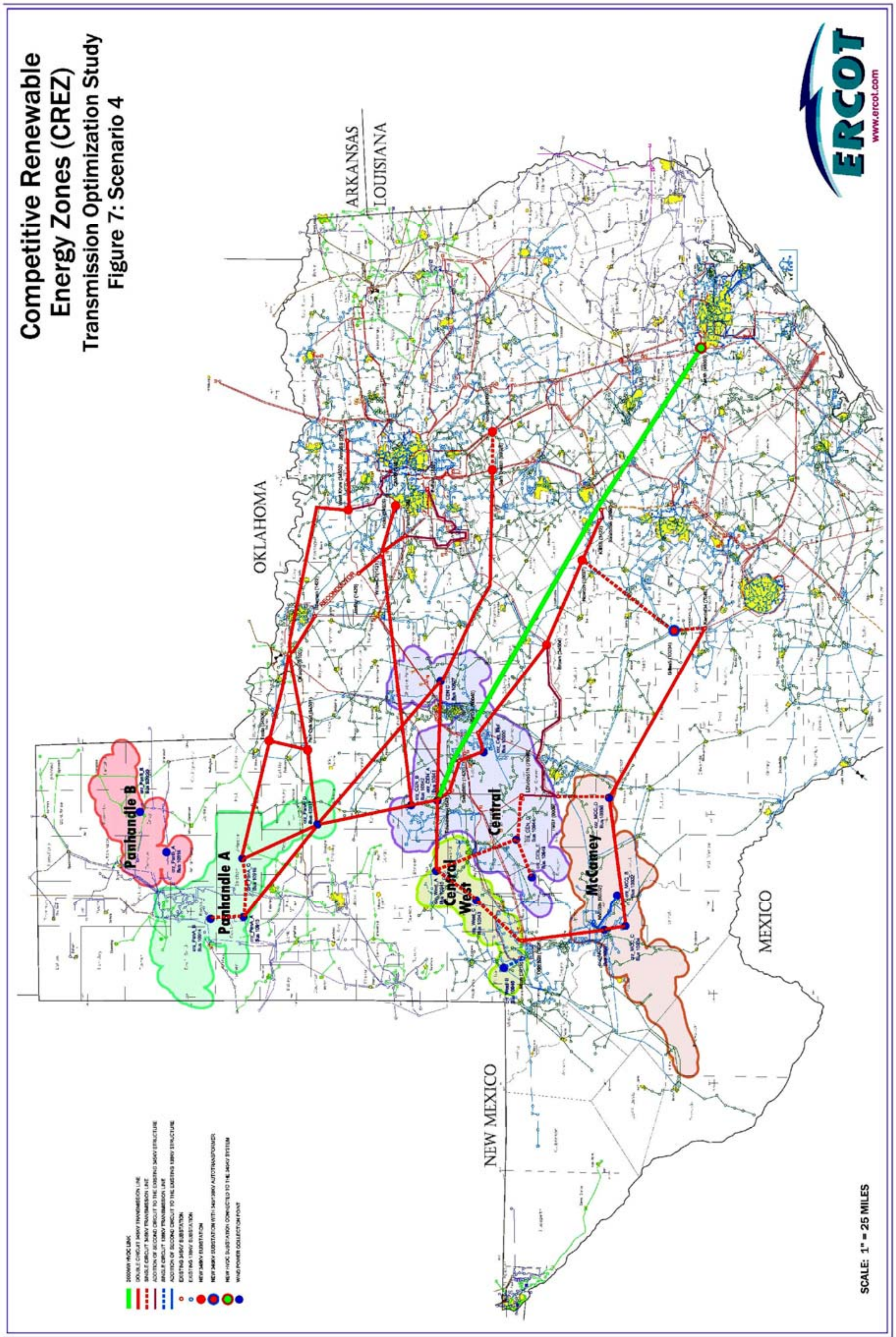
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Figure 7: Scenario 4
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F. Other Options Considered

1. High-Voltage Direct Current

High-voltage direct-current (HVDC) technology was evaluated for incorporation into plans for Scenarios 2, 3, and 4. Due to the cost of the terminal equipment, in order for HVDC to be part of a cost-effective plan when compared to a plan consisting of only new 345-kV circuits, one HVDC pathway must eliminate the need for more than one 345-kV electrical pathway. In addition, due to the proposed rating of the HVDC line (up to 3,000 MW), a significant amount of transmission capacity is required at both end-points of the proposed HVDC line. Finally, there must be sufficient AC transmission capacity that is electrically parallel to the HVDC line to allow the system to remain secure for the loss of the HVDC line. None of the plans developed using HVDC lines for scenario 2 were found to be lower cost than the 345kV plan for Scenario 2 discussed above.

A plan with two HVDC circuits is presented here as an example of the type of results obtained through the analysis of incorporating HVDC circuits into plans for Scenario 2 (see Figure 8). In this plan, the first 3,000-MW HVDC line extends from a proposed Tesla 345-kV substation (located in the southern Texas Panhandle) to the existing Anna 345-kV substation. The distance of this HVDC link is approximately 215 miles. The second 3,000-MW HVDC line extends from the existing Tonkawa 345-kV substation to the existing Venus North 345-kV substation. The distance of this HVDC line is also approximately 215 miles. Evaluation of this system indicated that the following AC circuits could be removed from the proposed solution to achieve the same level of overall wind curtailment as the all-AC solution:

- West Krum – Oklaunion 345-kV circuits 1 & 2
- West Krum – Anna 345-kV circuits 1 & 2
- Willow Creek – Central B circuits 1 & 2
- Central C – Navarro 345-kV circuit
- Central C – Sam Switch 345-kV circuit

Removal of additional AC circuits from this plan resulted in increased wind curtailment above that provided by the all-AC plan for Scenario 2.

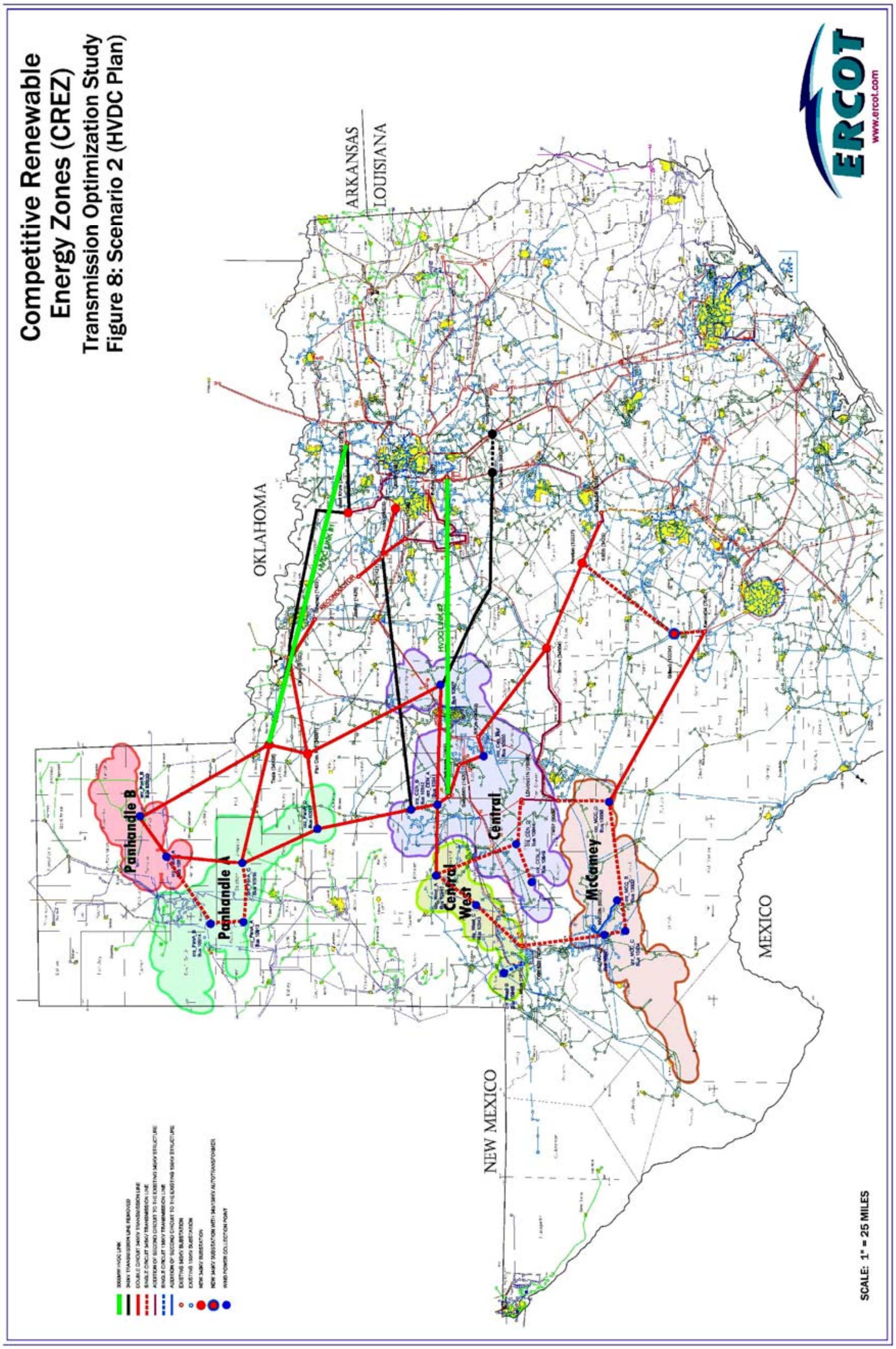
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Figure 8: Scenario 2 (HVDC Plan)
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SCALE: 1" = 25 MILES

The cost of the HVDC equipment, including HVDC line costs (430 miles at $1.05 million/mile), inverters (two pair at $525 million per pair), and additional lines and/or upgrades required for the HVDC installation, was estimated to be $1.56 billion. The savings from eliminating the lines listed above is estimated to be $1.02 billion. The net cost of this plan is $540 million more than the all-AC plan for Scenario 2 presented above.

Other considerations indicate that the HVDC solution may not be as effective as the all-AC solution at this level of wind generation capacity. HVDC technology can be a cost-effective option for transporting power over long distances, yet at this level of wind generation capacity, none of the new proposed AC circuits extend east of the I-35 corridor. As such, transport of wind generation over very long distances was not required. In addition, due to the expensive terminal costs, it is costly to add collection points onto an existing HVDC line. The removal of 345-kV circuits from the plan shown in Figure 8 represents a loss of pathways along which additional wind or thermal generation could be interconnected at a future date.

As such, the analysis concluded that HVDC was not a viable alternative for Scenario 2.

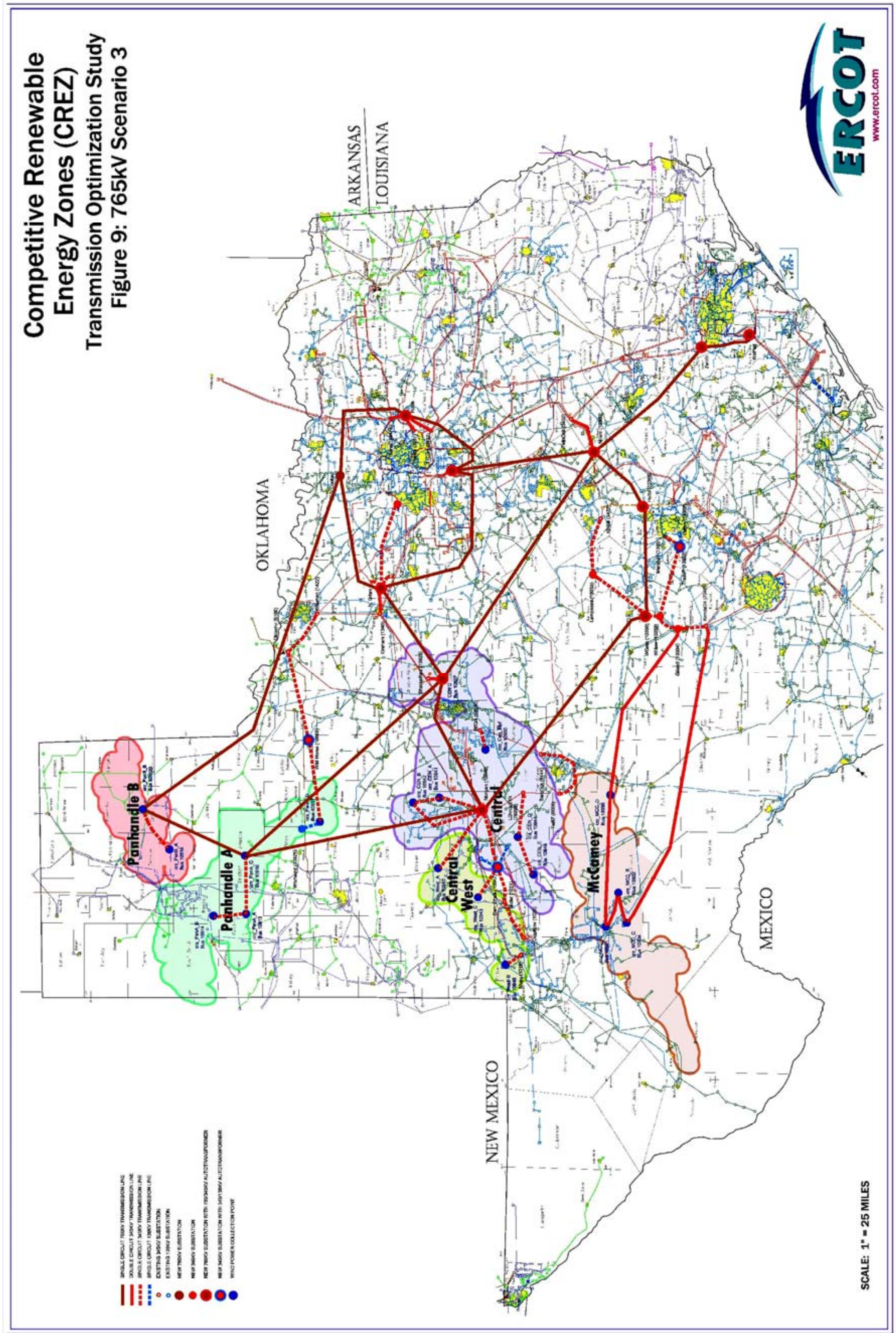
2. 765-kV Plans

As discussed in Section II(B), two of the five initial design concepts for transmission solutions included the use of higher-voltage transmission circuits (either 500 kV or 765 kV). At the start of the analysis it was not known if a stable 345-kV solution could be developed for the levels of wind specified in the Interim Order, such that a 765-kV or 500-kV-based plan might be required to maintain system stability. Preliminary analyses of conductor costs and line ratings indicated that 765-kV circuits would be more cost-effective than 500-kV circuits. As a result, several plans using 765-kV circuits were developed for Scenarios 2 and 3. These plans were several billion dollars higher in cost than the 345-kV-based plans for these scenarios. Once a 345-kV solution for Scenario 2 was shown to be reliable using transient stability analysis, work on the more expensive 765-kV solutions for this scenario was discontinued.

Similar to HVDC circuits, 765-kV circuits provide advantages, both in terms of cost and system reliability, for long-range power-flows. However, as with HVDC, 765-kV circuits also have disadvantages for certain applications. Because of the high potential power-flows on 765-kV circuits, a significant amount of transmission capacity must be present at locations where the 765-kV circuits terminate near load centers. Also, due to the costs of 765-kV substations, it is more expensive to tap into an existing 765-kV circuit to connect new generation (both wind and thermal) sources. Similarly, the higher capacity of each circuit results in a reduced number of total new ROWs, which can be an advantage in areas like east Texas where ROWs are becomingly increasingly harder to site, but can also be a disadvantage in west Texas, where reduced numbers of ROWs can result in fewer possible locations where new generation can be added to the existing transmission system.

Figure 9 depicts one of the 765-kV plans developed for Scenario 3. This plan includes a high-voltage low-impedance backbone from the Dallas area to Houston and to San Antonio, a loop around the Dallas/Fort Worth area, and loops into Panhandle and Central zones. An additional 345-kV loop has been developed to support new wind in the McCamey zone. In most of the scenarios developed, the lack of substations near load centers with sufficient existing transmission capacity led to the use of looped circuits in both the plans developed by ERCOT as well as those submitted by stakeholders. Under contingency, power-flows can move around a closed loop in the other direction to reach the same end-point, whereas each non-looped 765-kV line must terminate at two substations with sufficient transmission capacity. The plan depicted in Figure 9 was originally developed with a single termination point in South Dallas in the place of the loop around the east side of the city. Based on discussions with stakeholders, it was determined that there was no acceptable and feasible location for such a connection point, and, as a result, the 765-kV loop around the east of Dallas was required in order to disperse the power-flows on the high-voltage backbone.

Figure 10 provides a similar plan developed for Scenario 4. Lists of the components from these plans are provided in Appendix B. The total estimated costs of these plans are $9.10 billion for Scenario 3, and $9.42 billion for Scenario 4. In both of these plans, 1,391 MW of existing wind generation was moved to a new interconnection location. The plan for Scenario 3 includes 1,880 miles of new 765-kV right-of-way, 1,435 miles of new 345-kV right-of-way, and 85 miles of new 138-kV right-of-way. The plan for Scenario 4 includes 1,810 miles of new 765-kV right-of-way, 1,660 miles of new 345-kV right-of-way, and 100 miles of new 138-kV right-of-way.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Energy Zones (CREZ)
Transmission Optimization Study
Figure 9: 765kV Scenario 3
OKLAHOMA
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McCamey
SCALE: 1" = 25 MILES
ERCOT
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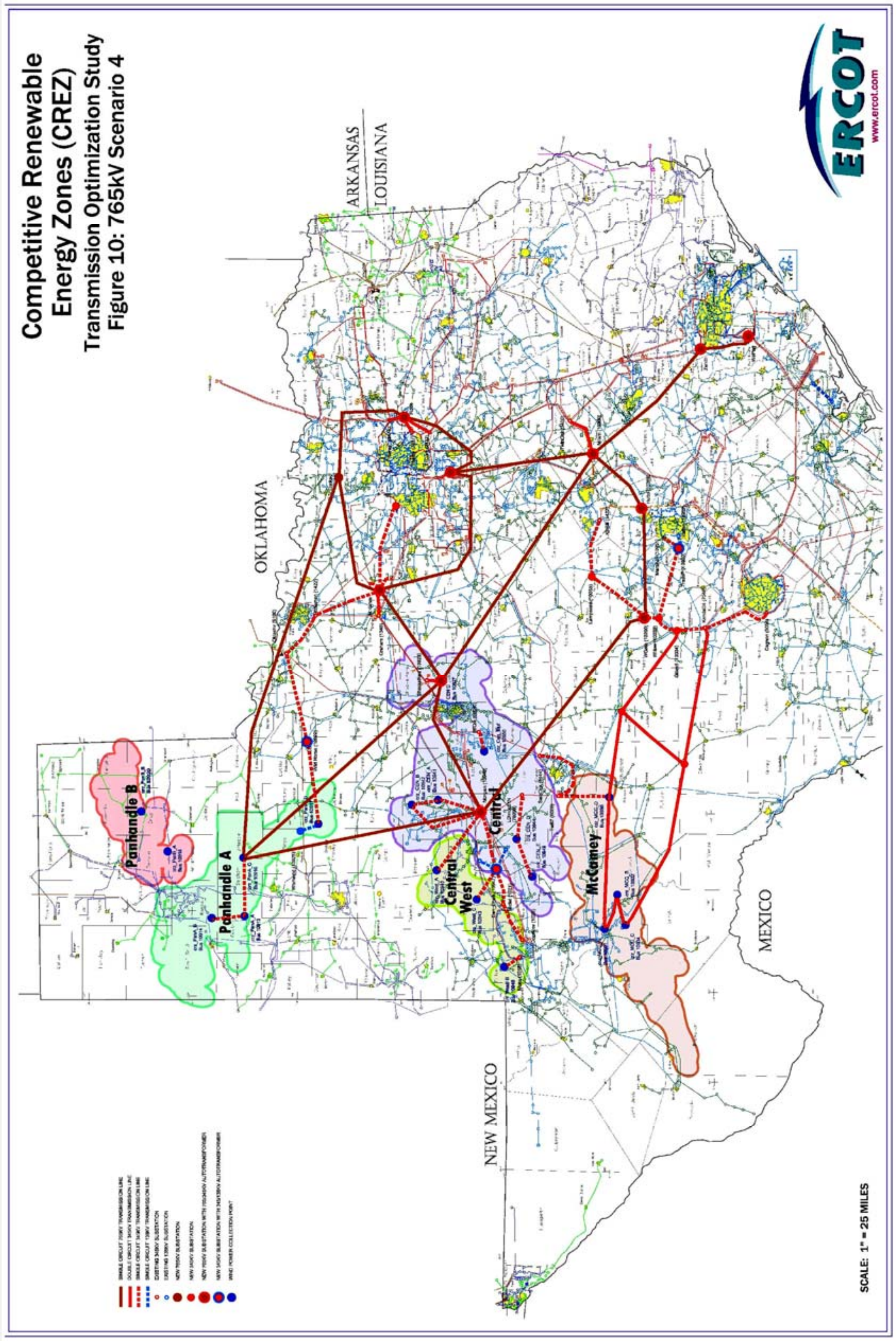
Competitive Renewable
Energy Zones (CREZ)
Transmission Optimization Study
Figure 10: 765kV Scenario 4
OKLAHOMA
ARKANSAS
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Central
Central West
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ERCOT
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SCALE: 1" = 25 MILES

IV. Discussion

A. Feasibility of Alternatives

A significant effort has been made by ERCOT staff and by representatives of TSPs to evaluate the feasibility of the plans submitted in this report. Many of the new substation locations are adjustable based on siting considerations. Most of the connections of new transmission circuits to existing transmission infrastructure appear to be possible to implement, although some of the proposed circuit connections may need to be changed following detailed siting analysis. This is more likely to be required where the proposed circuits connect to substations near large load centers. Additionally, proposed upgrades to existing facilities or the conductor type of new circuits may be adjusted by the TSPs, after consultation with ERCOT System Planning, once they begin detailed engineering analysis, provided that the adjustments do not adversely affect the performance of the plan. TSPs should work with ERCOT System Planning during their siting work for the components of the CREZ transmission plan to ensure that any adjustments due to siting considerations do not adversely impact the effectiveness of the overall transmission solution.

B. Staging of Construction

ERCOT System Planning has designed the transmission plans included in this report to meet the levels of wind generation capacity specified in the Interim Order. By providing subsets of plans for higher scenarios that will provide sufficient transfer capacity for lower scenario levels of wind generation capacity, some guidance regarding how to stage the development of transmission for a desired level of wind has been provided. Due to construction and permitting timing issues, additional staging information may be required by the Commission and its staff. ERCOT System Planning staff will work to provide any additional information requested by the Commission and its staff regarding additional effective subsets of the selected plan.

C. Projects from the Five-Year Plan and Long-Term System Assessment

The Interim Order states that "ERCOT will identify those transmission lines designed to serve the CREZs that are also likely to be required as part of ERCOT's long term system assessment." It is understood that the intent of this request was for ERCOT to delineate those transmission improvements that will likely be recommended for system needs regardless of the CREZ process. As such, ERCOT provides the following list of transmission improvements that have been shown to be recommended, either in the most recent Five-Year Plan or in the Long-Term System Assessment. Some of these improvements are the same as those included in the CREZ plans described in this report, while others are very similar and serve the same purpose.

For the first plan presented for Scenario 1 (optimized for that scenario), the following projects from the Five-Year Plan are the same as or are offset by projects included in this plan:

- New 345-kV circuit from Oklaunion to Bowman (cost estimate: $71 million)
- New 345-kV circuit from Red Creek substation to Killeen substation (cost estimate: $172 million)
- Series Reactor on the Barton to Oran circuit (cost estimate $1 million)

Total cost of similar or offset projects: $244 million.

For the second plan presented for scenario 1 (the subset of the Scenario 2 Plan), the following projects from the Five-Year Plan are the same as or are offset by projects included in this plan:

- New 345-kV circuit from Red Creek substation to Killeen substation (cost estimate: $172 million)
- Addition of a second 450-mva 345/138-kV autotransformer at the Whitney substation (cost estimate: 5 million)

Total cost of similar or offset projects: $177 million

For the plans presented for scenarios 2, 3, and 4, the following projects from the Five-Year Plan are the same as or are offset by projects included in this plan:

- New 345-kV circuit from Red Creek substation to Killeen Substation (cost estimate: $172 million)
- Addition of a second 450-mva 345/138-kV autotransformer at the Whitney substation (cost estimate: 5 million)
- New 345-kV circuit from Oklaunion to Bowman (cost estimate: $71 million)

Total cost of similar or offset projects: $248 million

In addition to these projects that were recommended in the ERCOT 2007 Five-Year Plan, a 345-kV connection from the Kendall substation to the Killeen substation was shown to have long-term benefits in the 2006 ERCOT Long-Term System Assessment. This connection provides a new pathway along the west side of Austin, and has been shown to be beneficial in supporting voltage levels in the Hill Country region. The 345-kV plans for scenarios 2, 3, and 4 originally contained a circuit from the Kendall substation to the Lytton Springs substation, located east of San Marcos. However, due to siting considerations and longer-term system needs, it was recommended that this circuit be replaced by a circuit from the Kendall substation to the Killeen substation. Substituting the Kendall to Killeen line for the Kendall to Lytton Springs line resulted in a similar level of total wind curtailment, and also significantly reduced transmission congestion in the Hill Country region. The estimated cost of this circuit is $159 million.

D. Other Possible Criteria for Selection of Alternatives

The methodology described in this report has been designed to lead to solutions that are reliable and are cost-effective for consumers. Other criteria that could be considered are extensive, and include the flexibility of the plan, the potential for expandability, transmission-siting considerations, equitable distribution of wind generation curtailment and the potential for the plan to meet a distribution of wind generation different from that specified in the Interim Order. The staging information described in Section 3 can be used to evaluate the expandability of each alternative. Each of the plans presented is to some extent flexible, in that substations in the CREZ areas can be moved to locations closest to wind generation facilities that are nominated for inclusion in the CREZ zones. However, each plan is designed for a specific amount of wind in the five zones, as delineated in the Interim Order. If significantly more wind generation capacity is developed in any of the CREZ areas than is specified in the Interim Order, significant wind generation curtailment could result without additional transmission improvements.

As noted in Section 1, the criterion that overall wind curtailment be approximately 2% does not indicate that all wind units experience curtailment less than 2%. Rather, for every solution, some wind generation facilities will be curtailed, while others will not curtailed at all. However, it is likely that the security-constrained unit-commitment and economic-dispatch model used to evaluate these plans cannot accurately predict which units are likely to be curtailed.

The equitable distribution of wind generation curtailment is difficult to evaluate because curtailment is dependent upon the location of new wind generation capacity, prevailing weather patterns, and bid prices of individual wind farms. In some cases, such as for wind generation facilities that have high shift factors on limiting transmission elements, curtailment can be predicted regardless of bid price or the location of new wind generation capacity. However, for most wind generation facilities, it will be necessary to wait until the location of all CREZ wind generation facilities are known before an analysis of which units are likely to be most heavily curtailed can be conducted and the economic system benefits of relieving project-specific curtailment can be quantified. For facilities that are subject to significant curtailment, one potential solution would be to reconnect the facility to a different, less congested transmission circuit. These curtailment evaluations can be conducted on an on-going basis as part of the development of the annual ERCOT Five-Year Transmission Plan.

E. Additional Information Available

As transmission plans described in this document for scenarios 1 and 2 have been evaluated using a security-constrained unit-commitment and economic-dispatch model, information similar to that provided as part of the document "Analysis of Transmission Alternatives for Competitive Renewable Energy Zones in Texas" is available. Examples of these data include: production costs; emissions;

aggregate generator revenue; and wind generation capacity factors. ERCOT focused this Study on the specific questions posed in the Interim Order, but ERCOT can also provide these or similar data at the request of the Commission.

F. Additional Wind Generation

A significant amount of wind generation capacity is currently being evaluated for interconnection into the ERCOT system. Some of this wind generation capacity was included in testimony submitted into the docket for PUCT Case 33672 and thus has been accounted for in the plans described in this report. However, there is still a significant amount of wind generation capacity that, at this time, appears likely to be constructed during the period in which the CREZ transmission plan is being implemented. In fact, since the CREZ Transmission Optimization Study project was started in the fall of 2007, the amount of wind generation capacity that is either existing or has a signed interconnection agreement has grown from 6,903 MW to 9,550 MW. The impact of this additional wind generation capacity on the sufficiency of the selected plan is not known, as it will depend on both the amount of additional wind generation capacity that is constructed and where it is located. In addition, it is not currently known whether this additional generation will ultimately be considered incremental to, part of, or a substitute for the CREZ generation MWs for which the CREZ plans are designed.

Independent of how much wind generation capacity is eventually built in ERCOT, it is widely expected that wind generation capacity will far exceed transmission capacity in west Texas until the transmission circuits developed as part of this CREZ process are completed. In order to reduce the near-term system and market impacts of this congestion, ERCOT System Planning proposes, upon submittal of this CREZ study, to work with stakeholders through the normal Regional Planning Process to develop cost-effective short-term solutions to transmission congestion, and to evaluate the possible economic justification of transmission lines that are included in most or all of the transmission plans presented in this report based on current levels of wind generation (in-service and with signed interconnection agreements) in west Texas.

G. Requirements for Wind Generation

The analysis upon which the plans presented in this report are based necessarily required certain assumptions to be made regarding the characteristics of the additional wind generation that would be added to the system. The models of the additional wind generation used for the dynamic analysis were type-III double-fed induction generators. While this is a reasonable assumption, actual dynamic performance may differ from simulation results if these models are not representative of the actual wind generators constructed. The additional wind generators were assumed to comply with the requirements described in the ERCOT Generation Interconnection Procedure (reactive power capability, power factor, harmonics, etc.) and were assumed to meet the LVRT standards included in

FERC Order 661A. While these requirements are not currently included in the ERCOT Operating Guides, the Guides will need to be revised to include requirements that are equal to or greater than these requirements prior to the installation of large amounts of CREZ generation in order that the performance characteristics of the plans described herein may be achieved.

V. Conclusion

This report presents optimized transmission plans for the four scenarios described in the PUCT Docket 33672 Interim Order. Each of these plans was fully evaluated from using an optimal security-constrained unit-commitment and economic-dispatch model, steady-state AC power flow models, and using full AC power-flow contingency analysis and dynamic stability analysis. These plans represent the most cost-effective, reliable solutions evaluated as part of this analysis.

ERCOT is committed to supporting the CREZ process. Following designation of transmission solutions for CREZ wind generation by the PUCT, ERCOT is prepared to support the PUCT and TSPs in developing additional effective subsets for transmission improvements, and in evaluating changes in the selected plan that are required due to constraints identified during the permitting and siting process.

Appendix A

One-Line Diagrams

Scenario 1: Plan A

Existing Circuit

New Circuit

Upgraded Circuit

Circuits on same towers

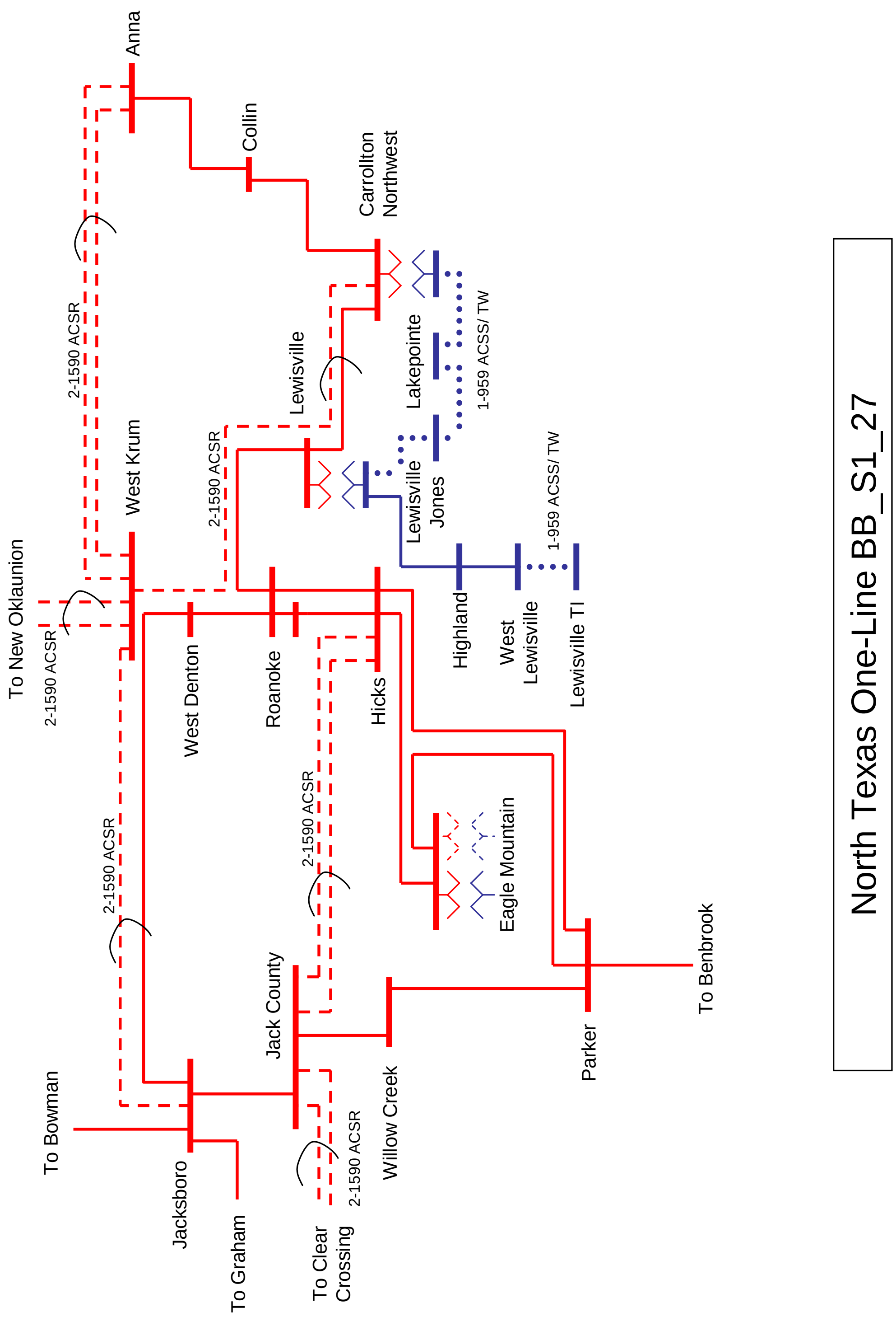
345-kV

138-kV

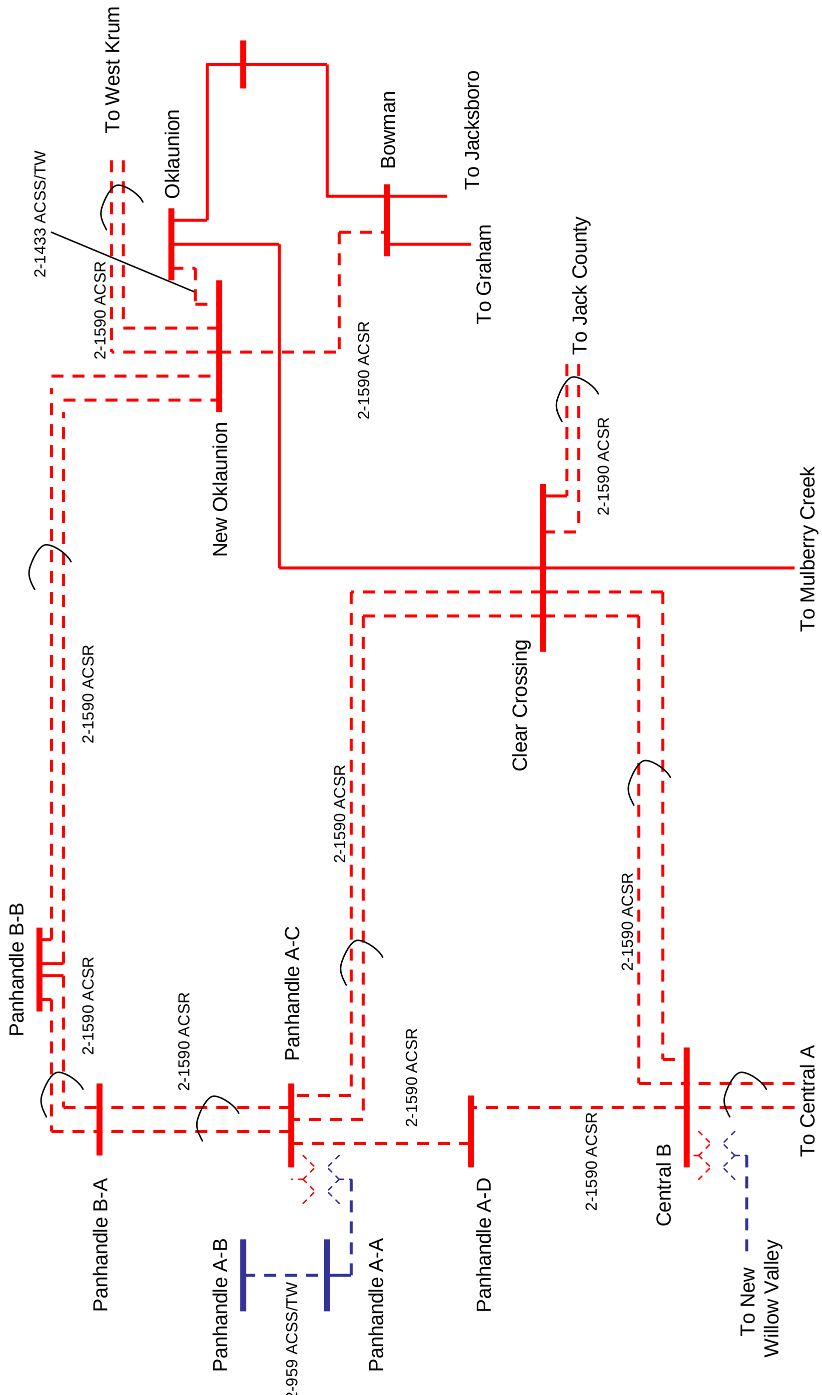
69-kV

Legend

Scenario 1: Plan A

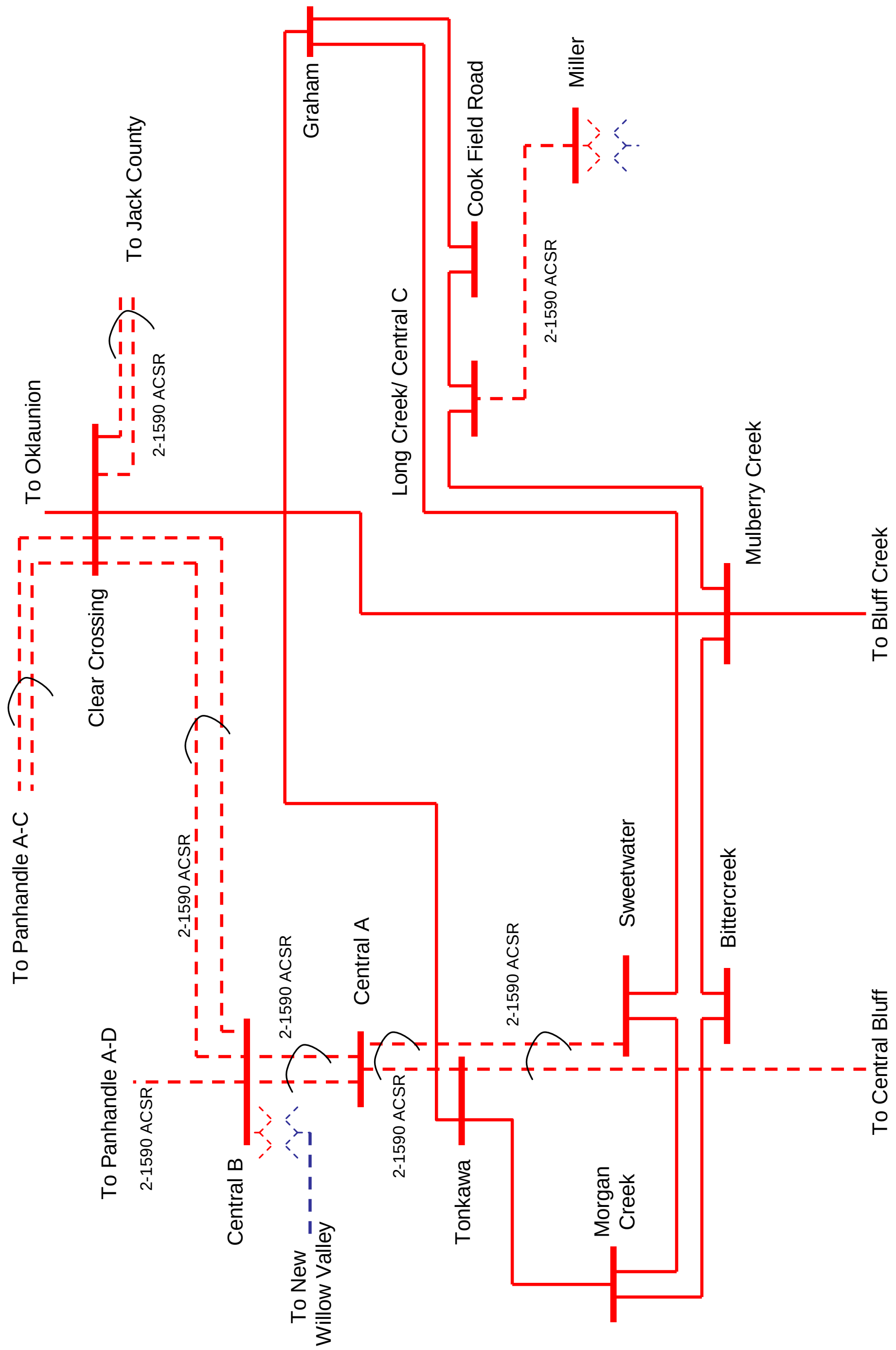


Scenario 1: Plan A



Panhandle One-Line BB_S1_27

Scenario 1: Plan A



CREZ Central-North One-Line BB_S1_27

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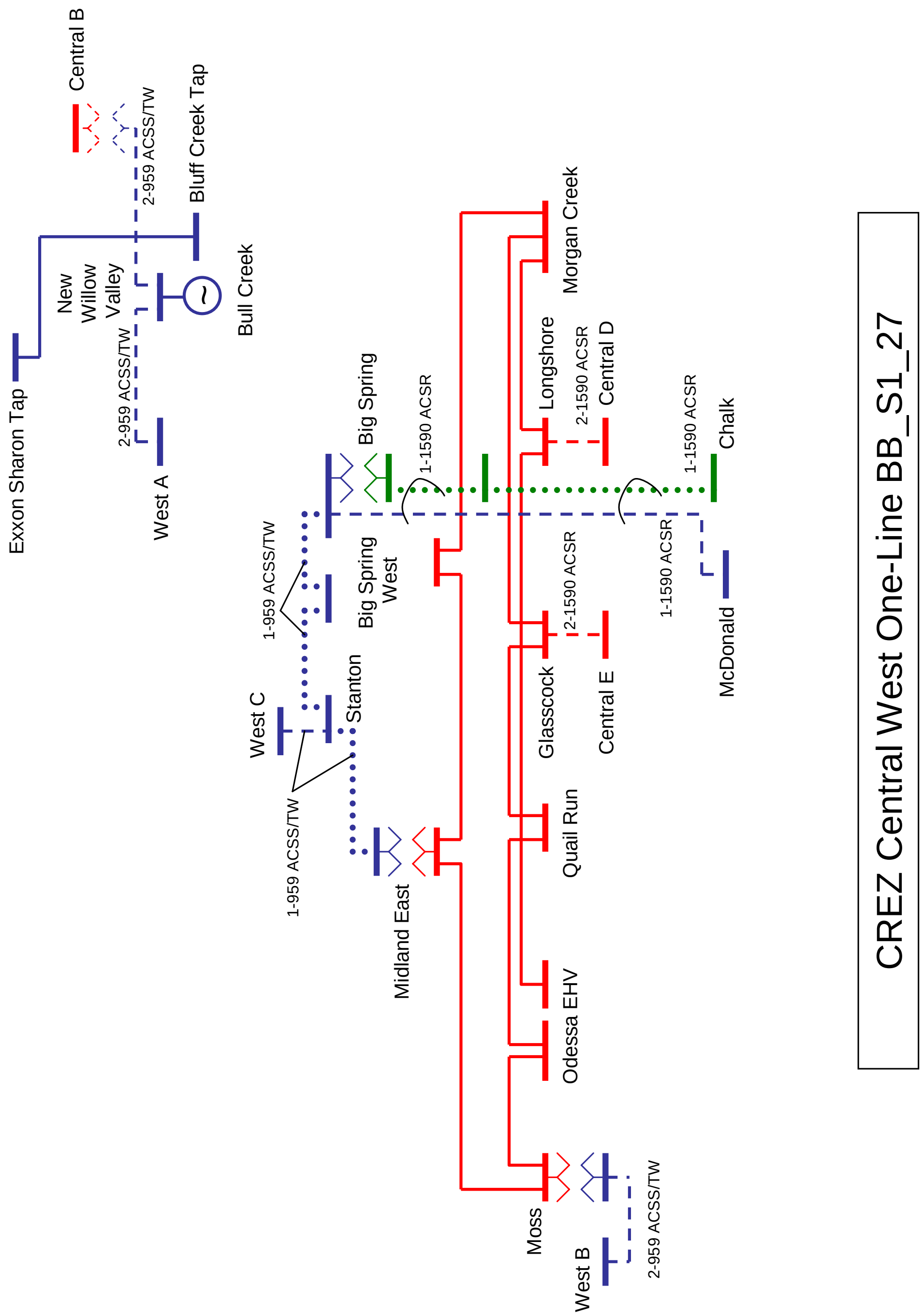
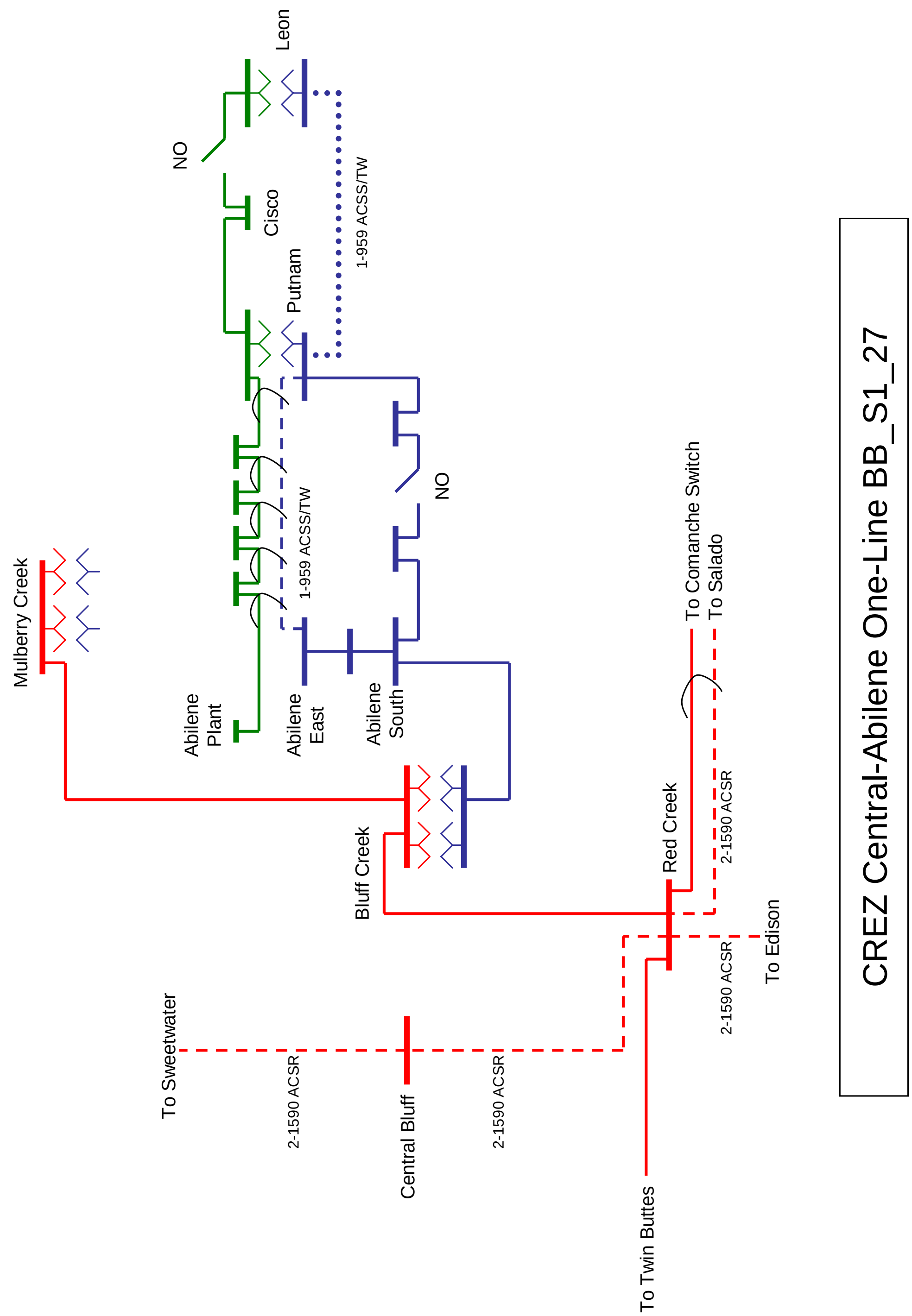
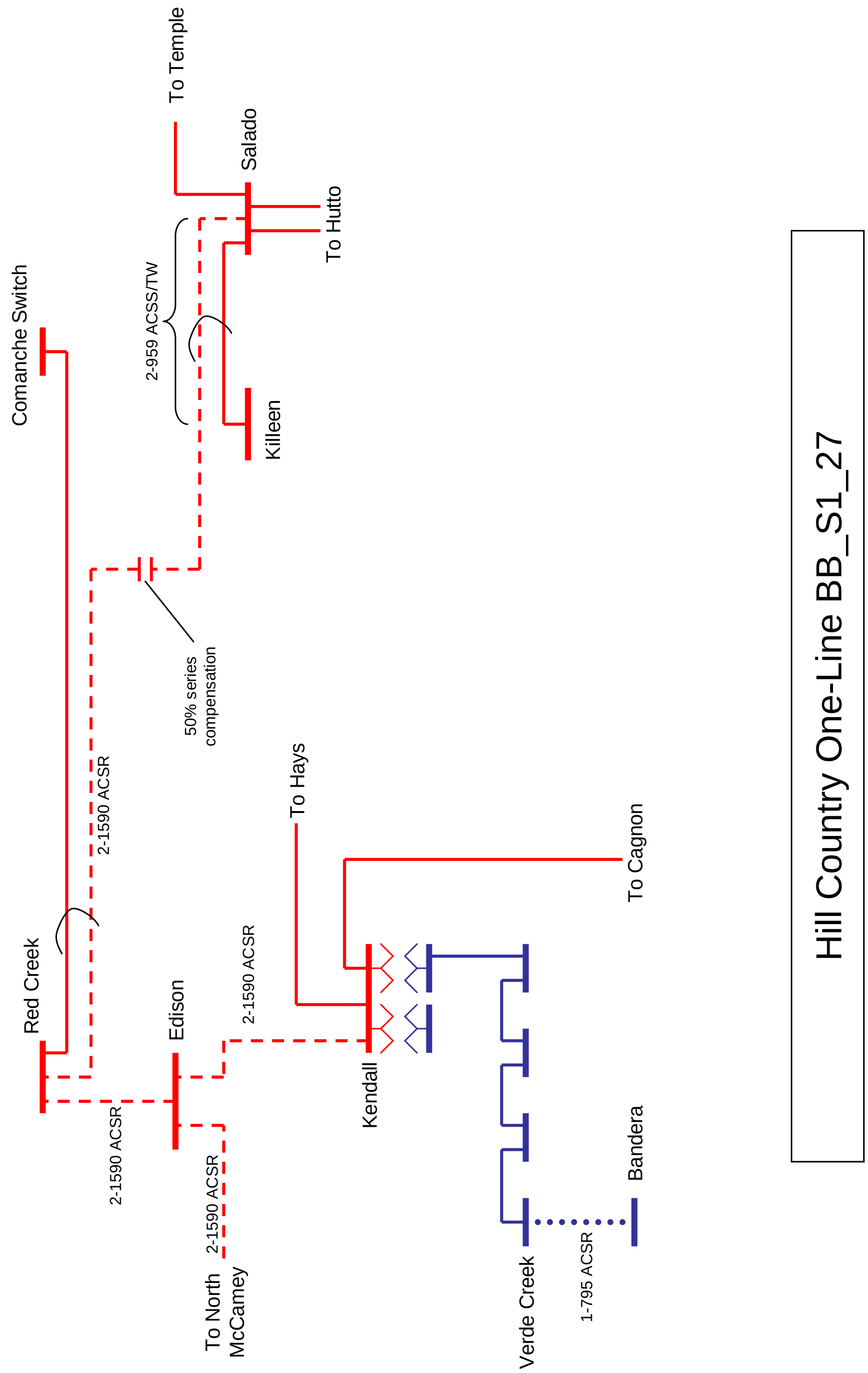


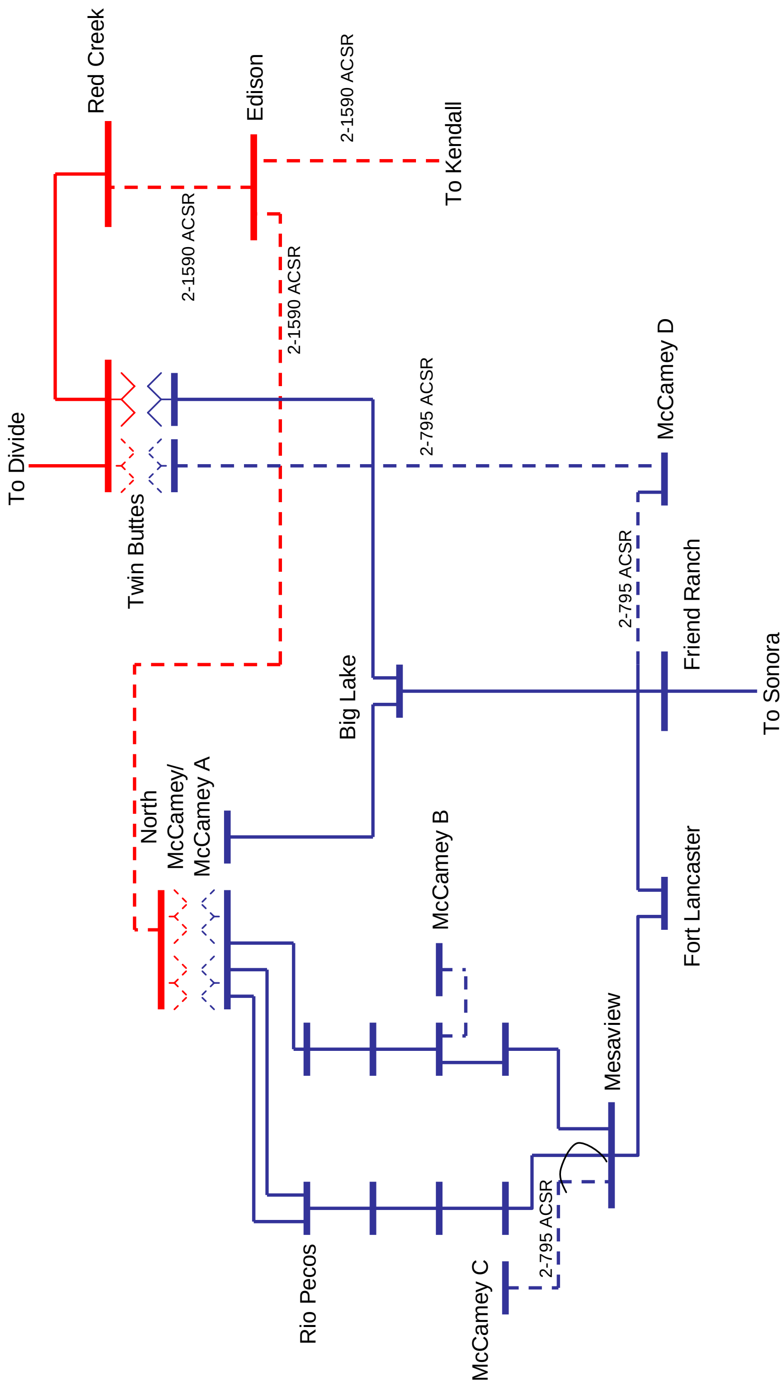
Scenario 1: Plan A



Scenario 1: Plan A



Scenario 1: Plan A



McCamey One-Line BB_S1_27

Scenario 1: Plan B

Existing Circuit

New Circuit

Upgraded Circuit

Circuits on same towers

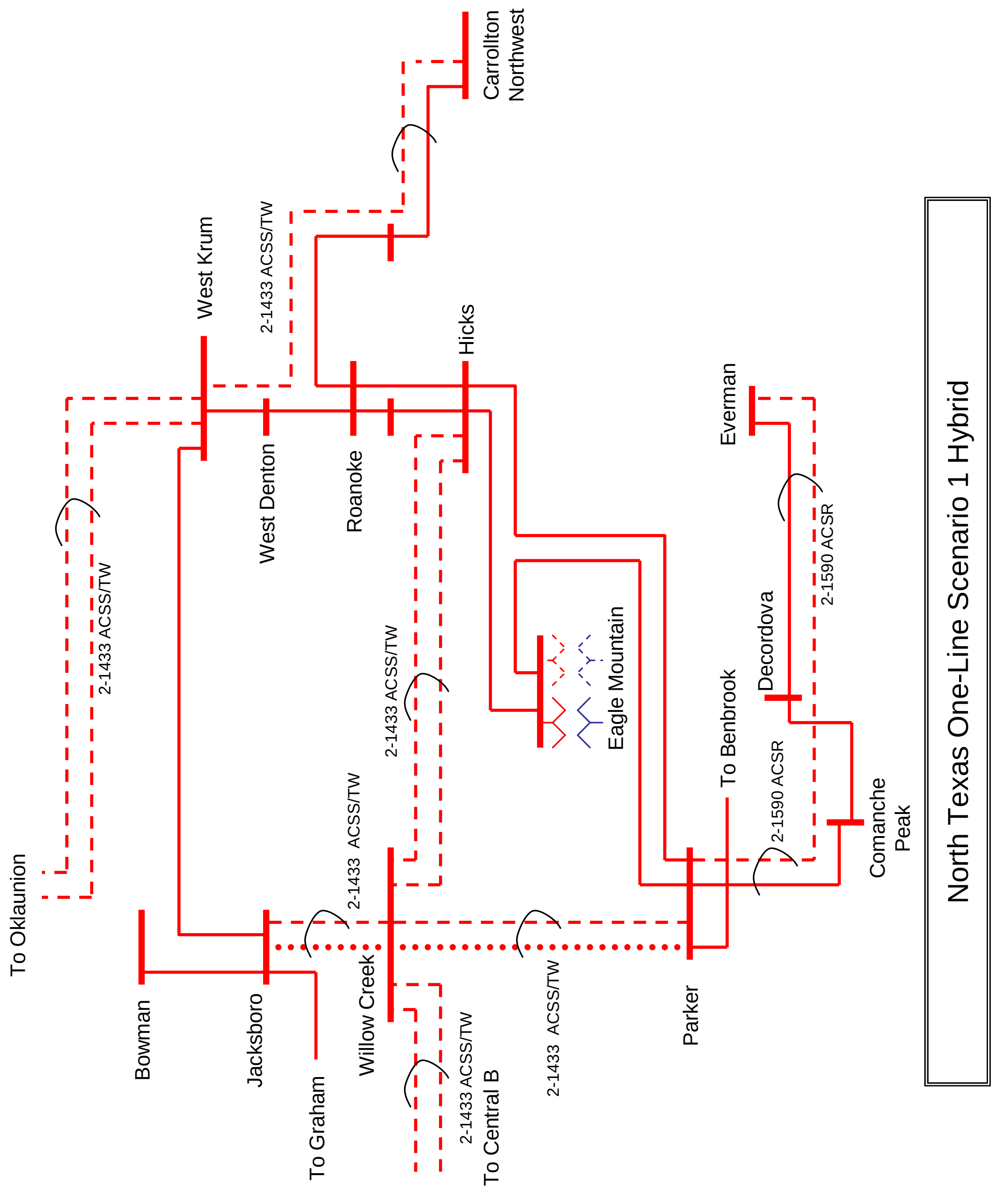
345-kV

138-kV

69-kV

Legend

Scenario 1: Plan B



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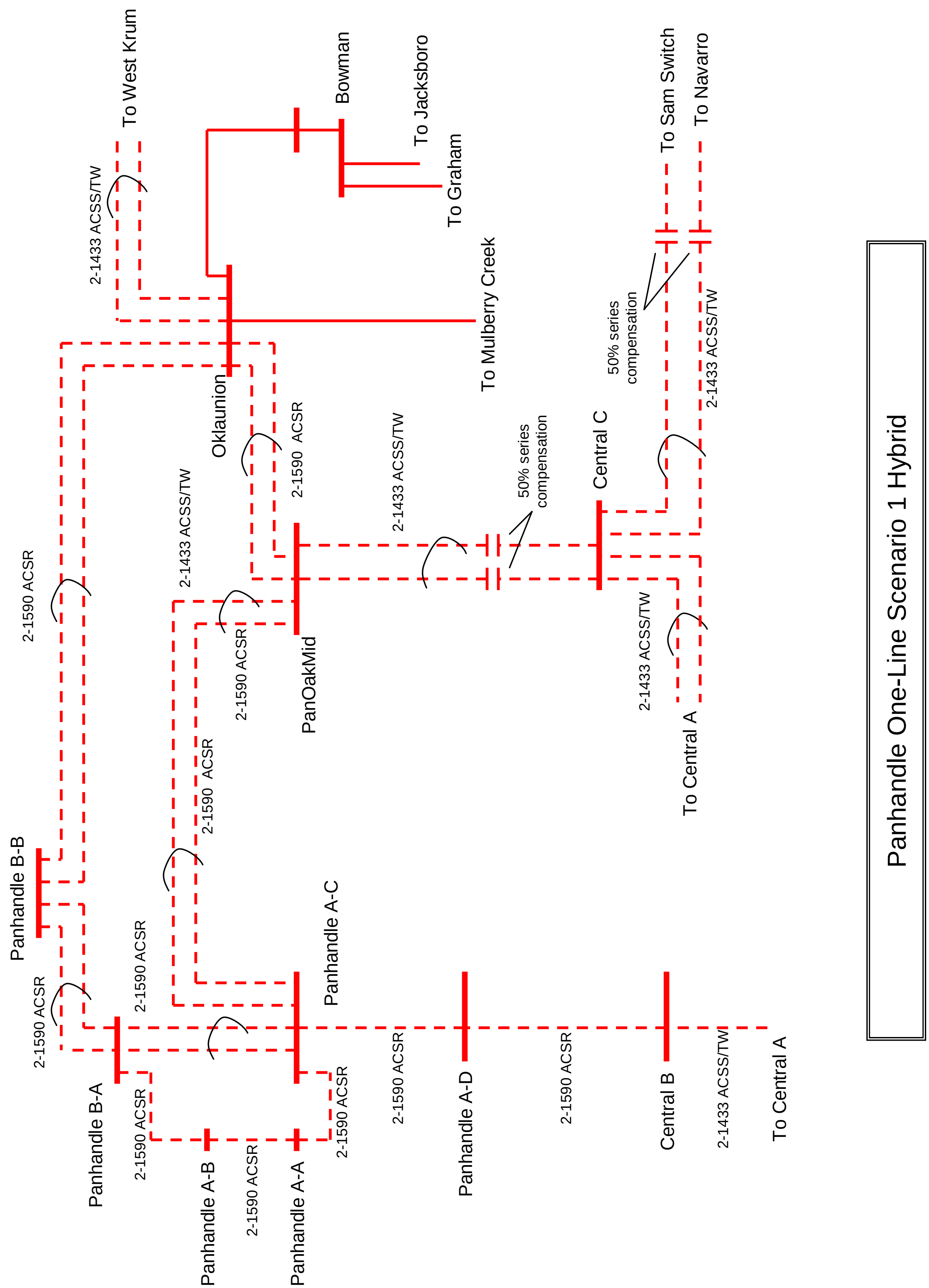

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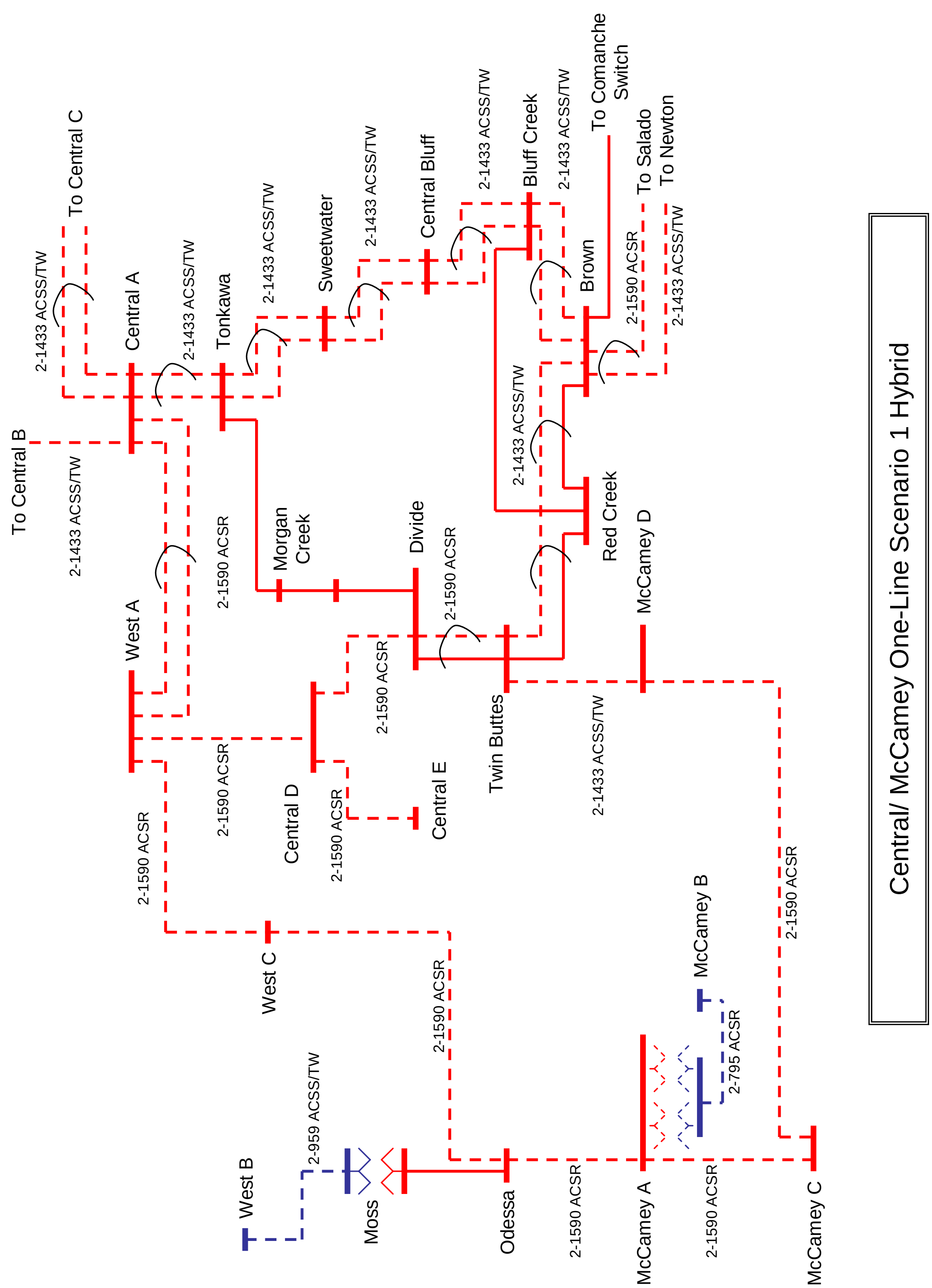

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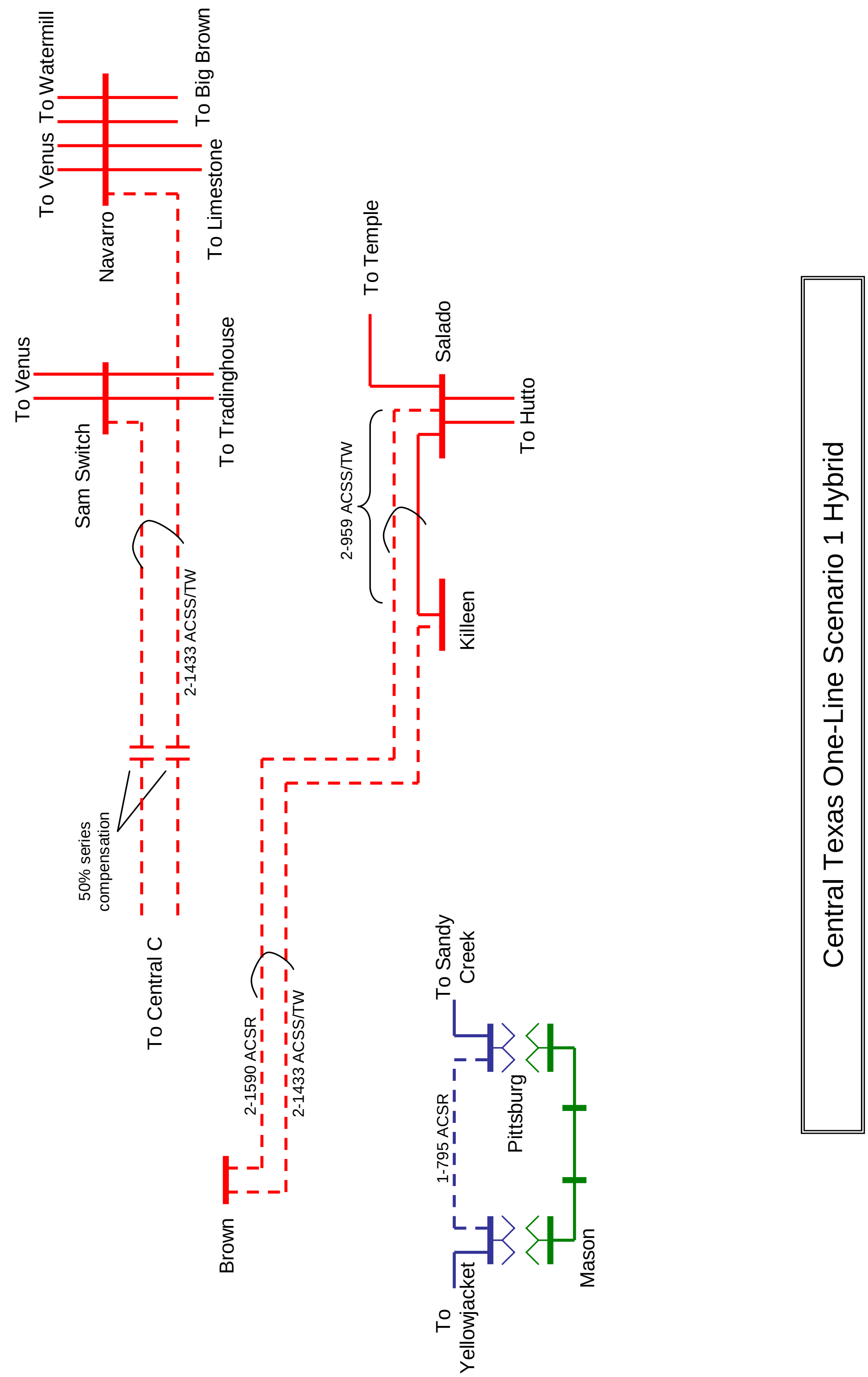
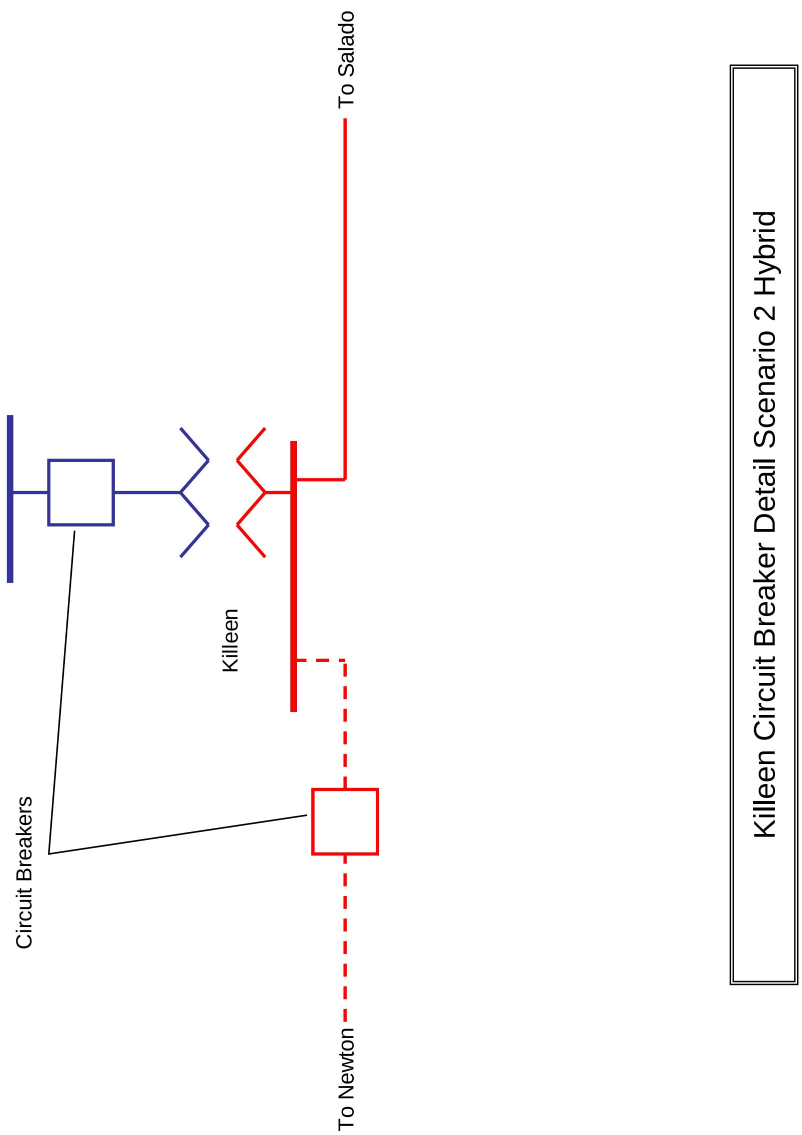


Scenario 1: Plan B



Scenario 2 Plan

Existing Circuit

New Circuit

Upgraded Circuit

Circuits on same towers

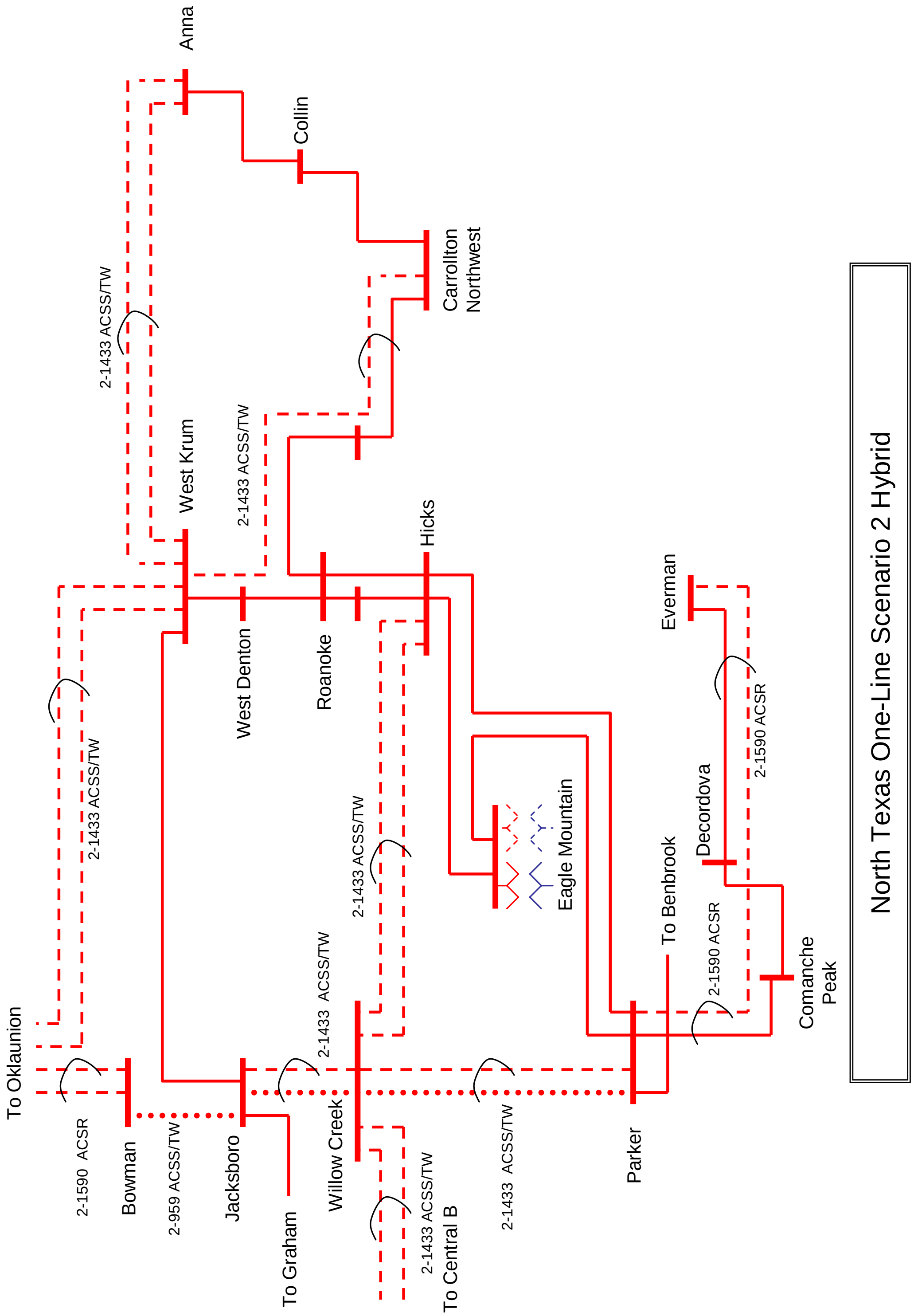
345-kV

138-kV

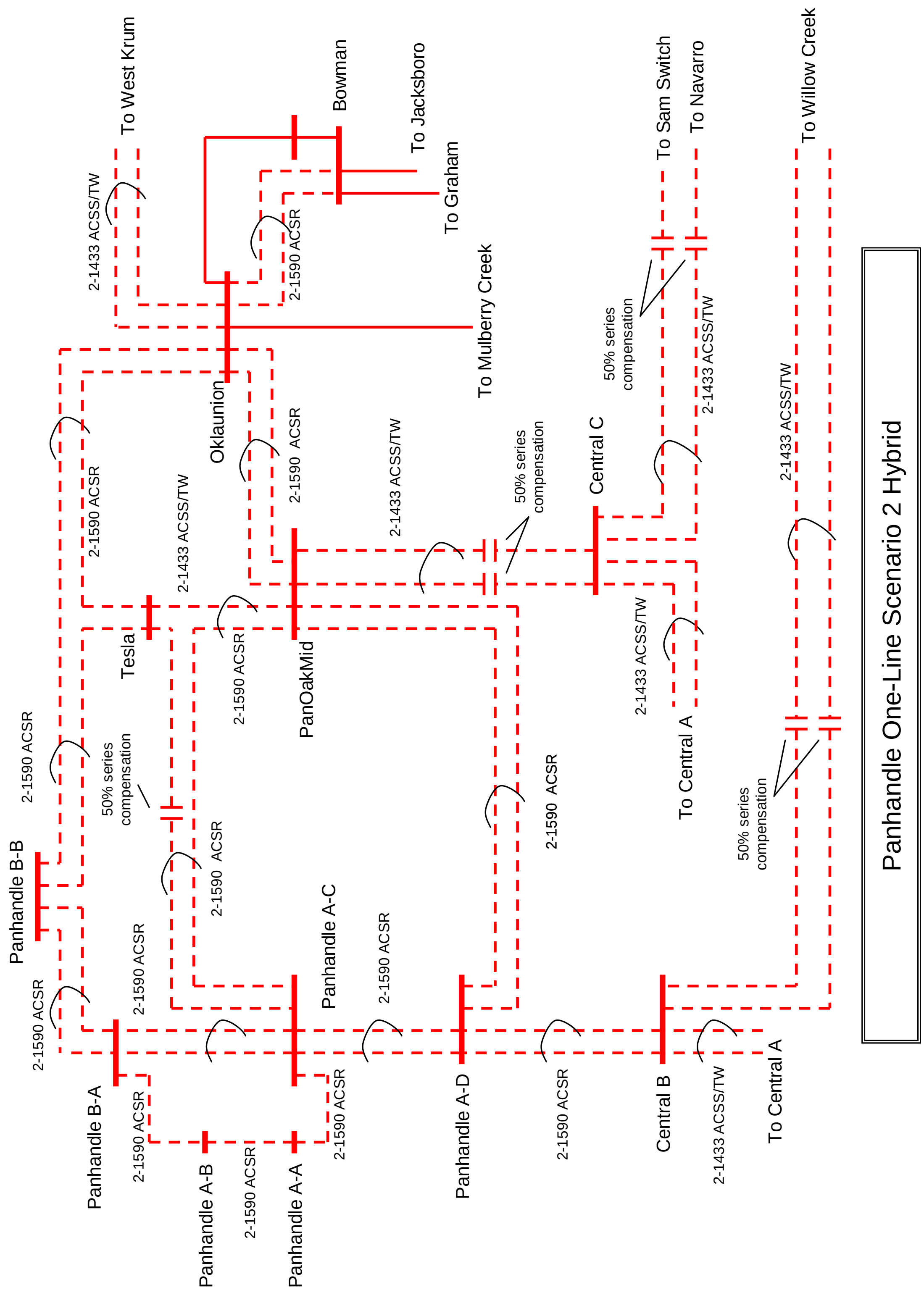
69-kV

Legend

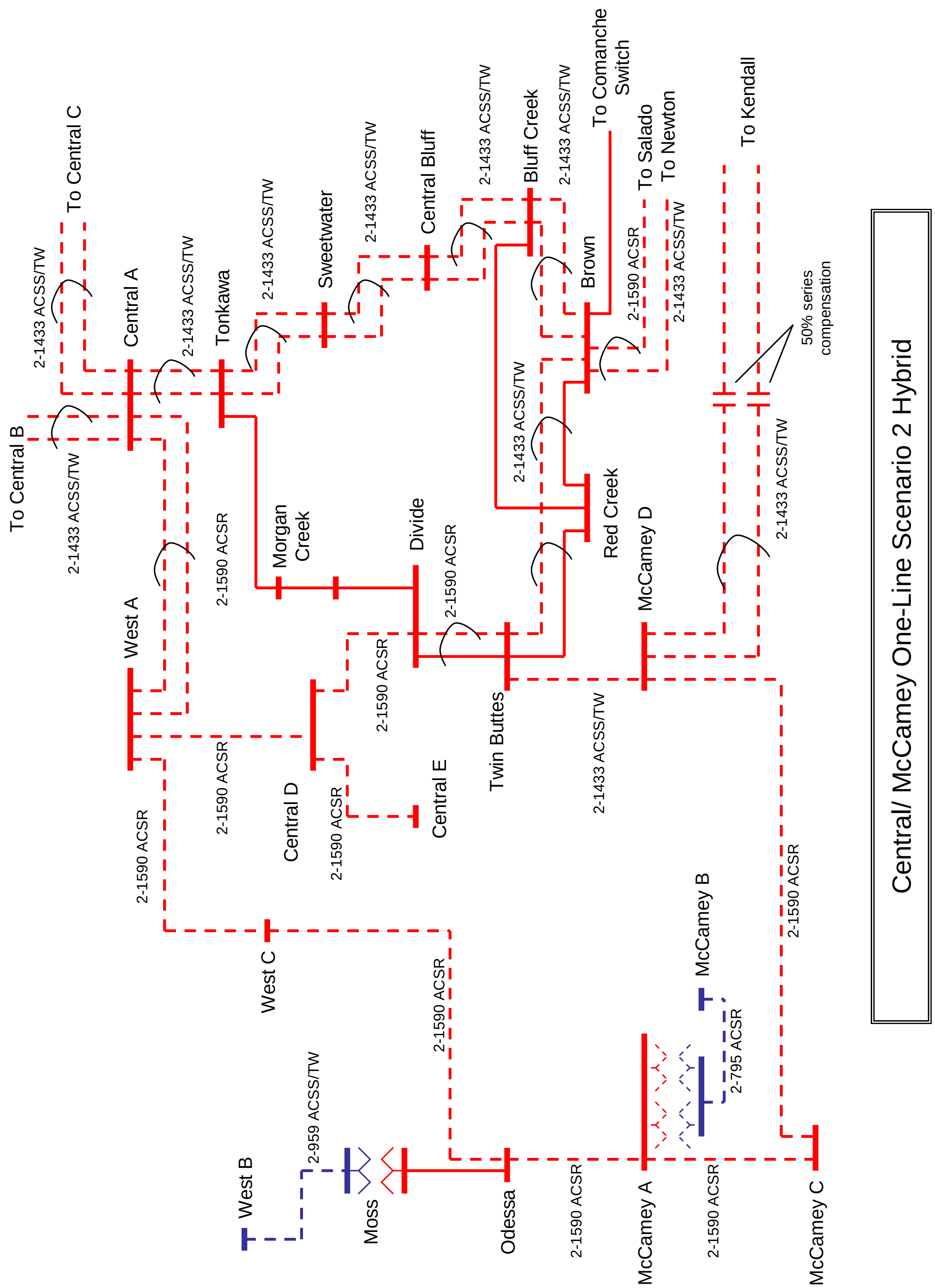
Scenario 2 Plan



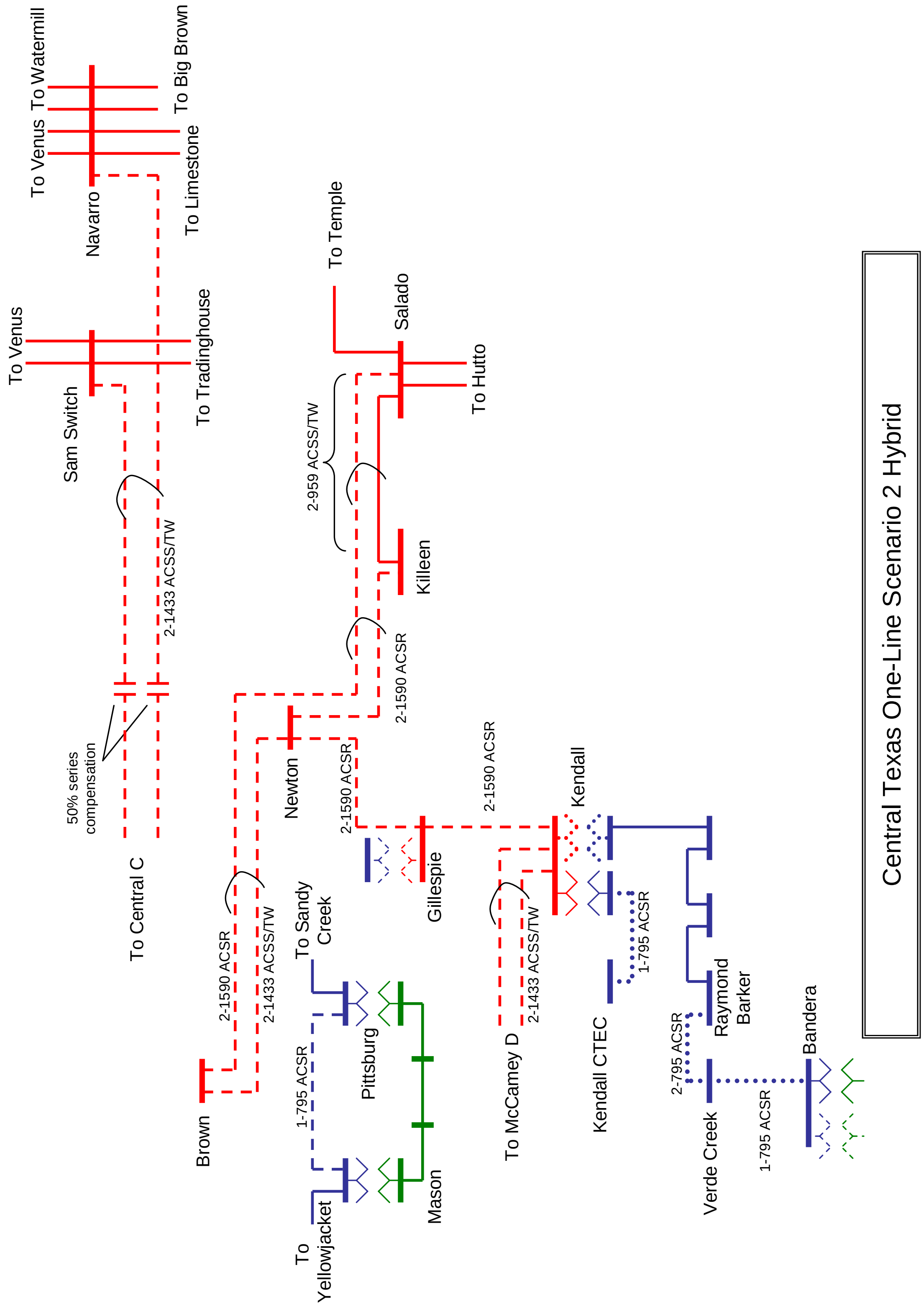
Scenario 2 Plan



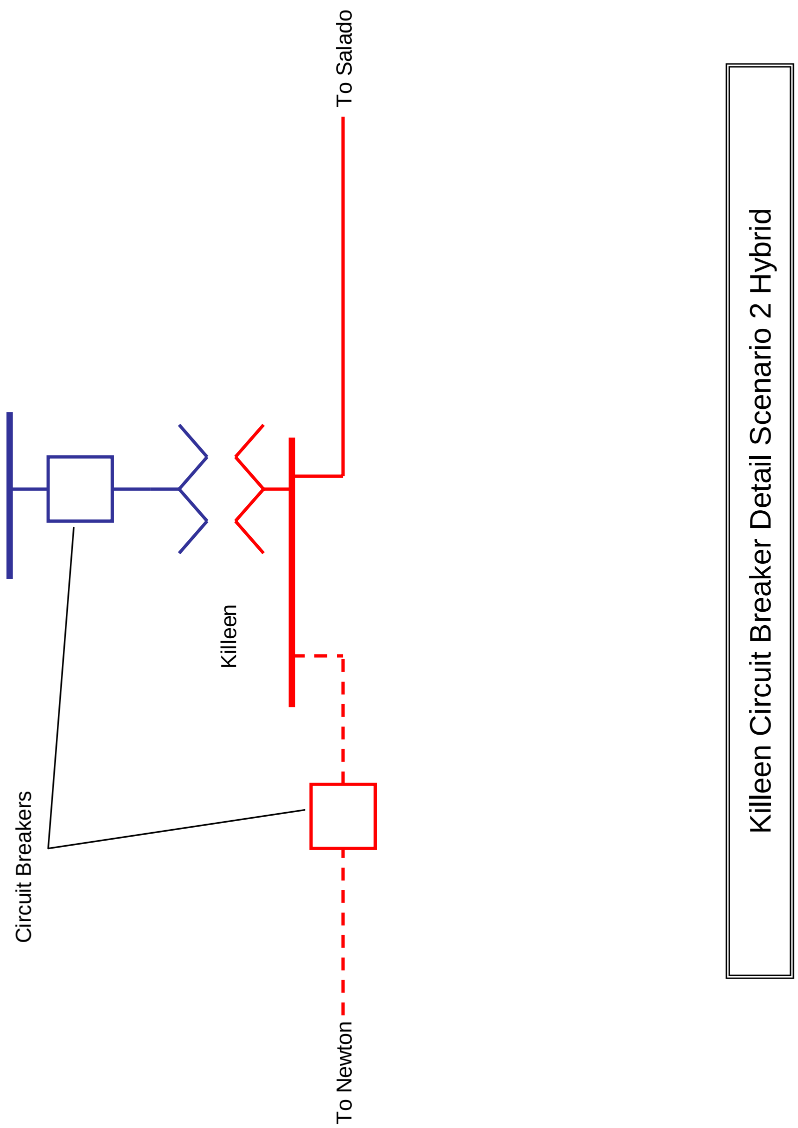
Scenario 2 Plan



Scenario 2 Plan



Scenario 2 Plan



Scenario 3 Plan

Existing Circuit

New Circuit

Upgraded Circuit

Circuits on same towers

345-kV

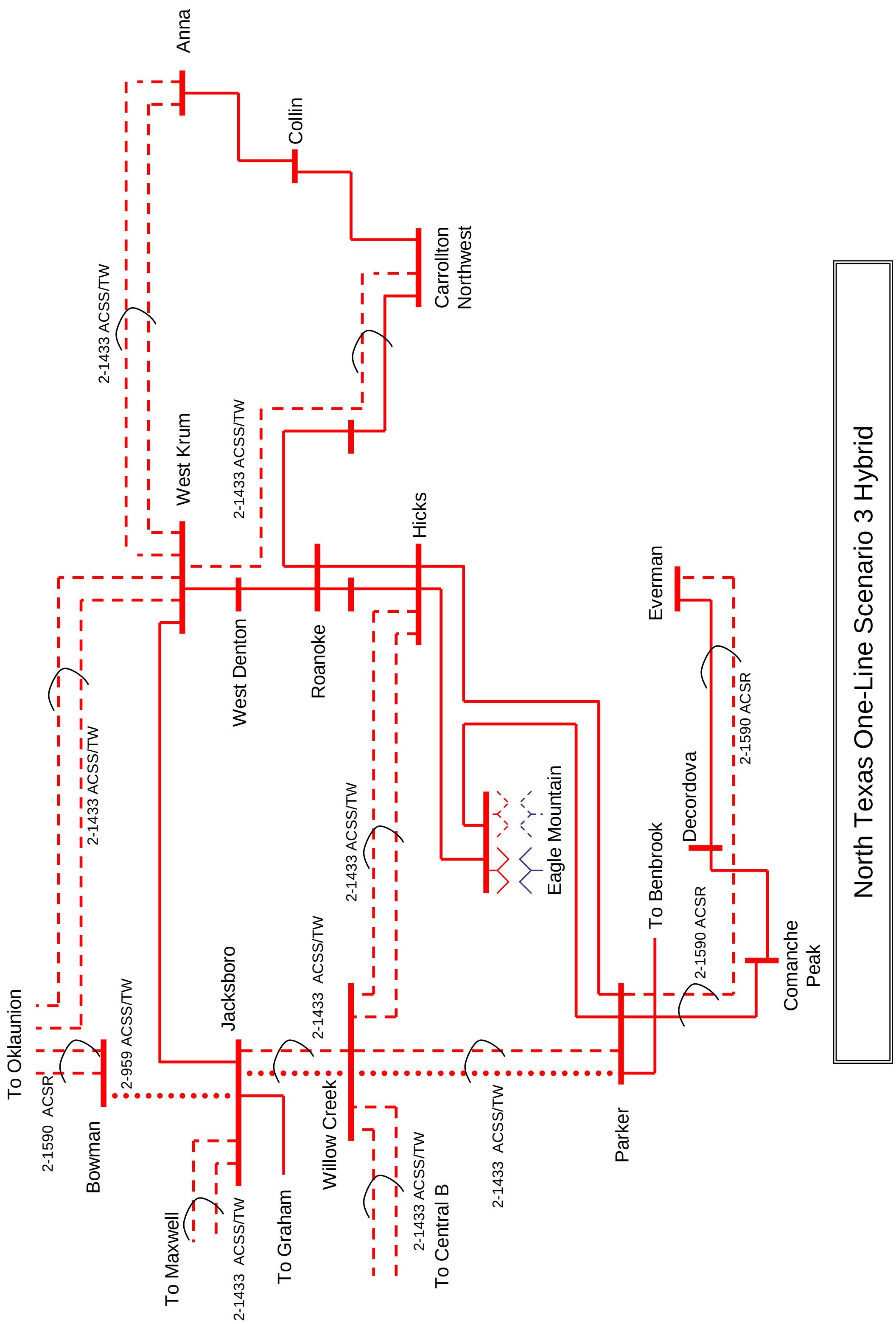
138-kV

69-kV

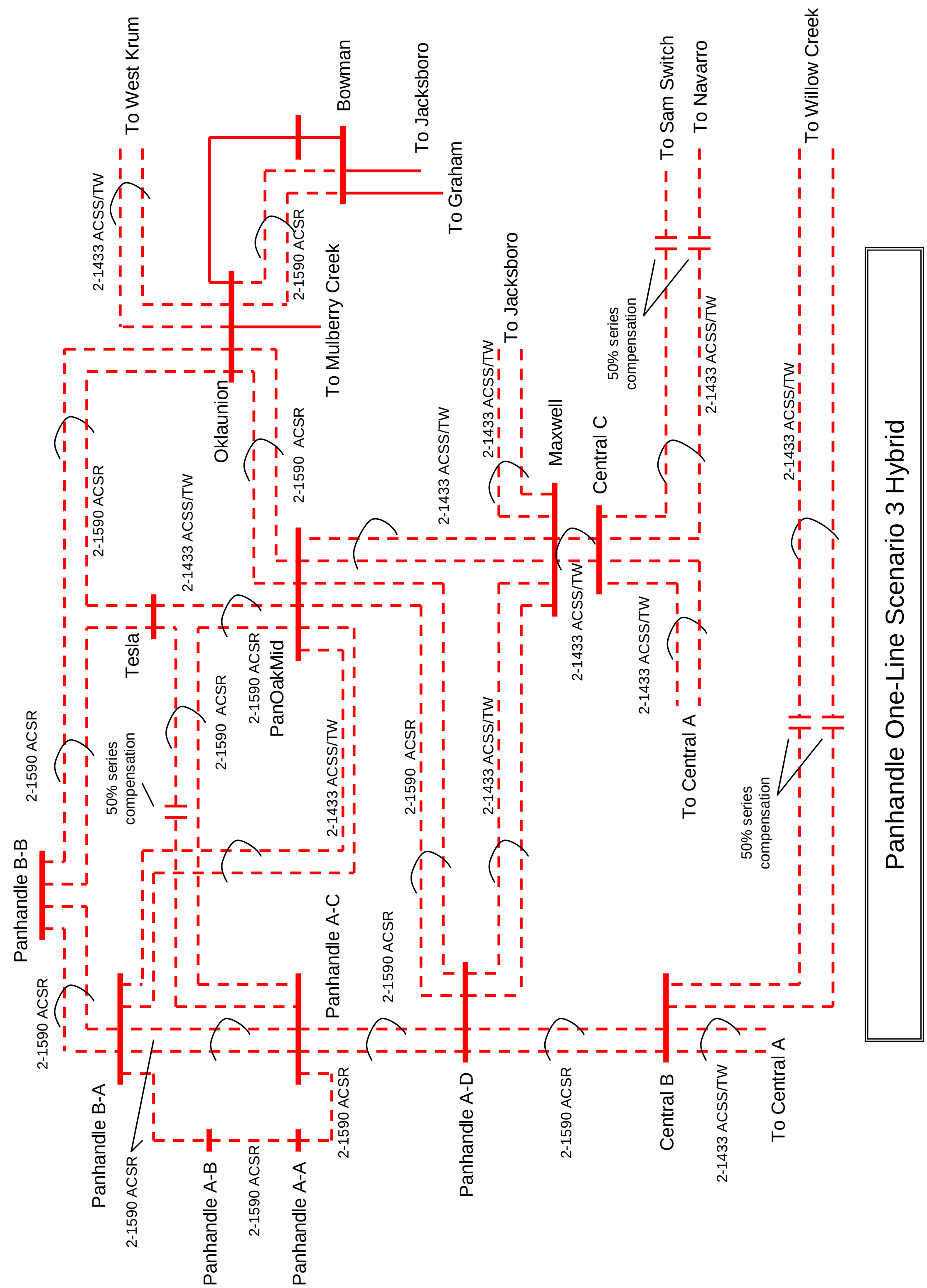
HVDC

Legend

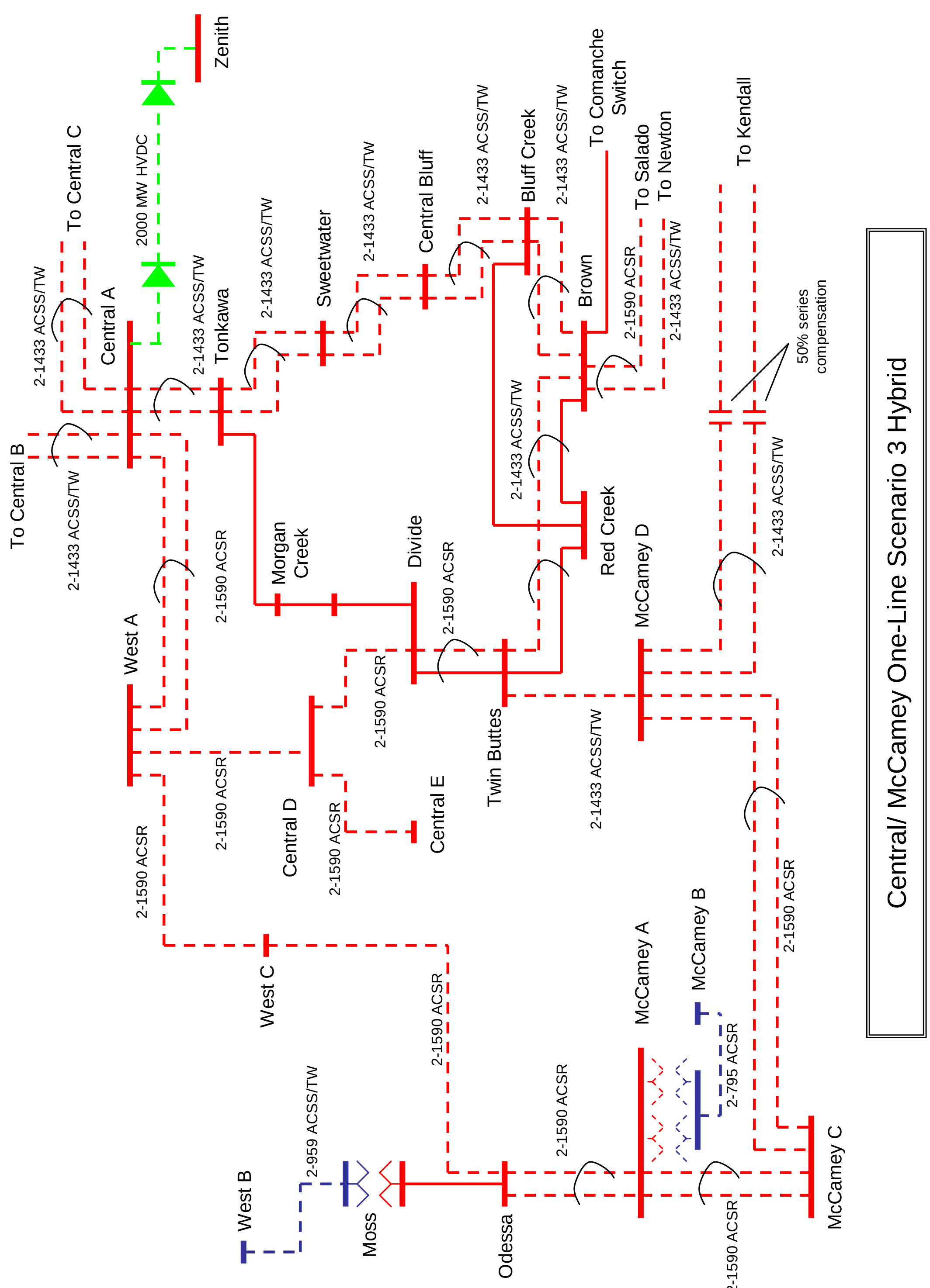
Scenario 3 Plan



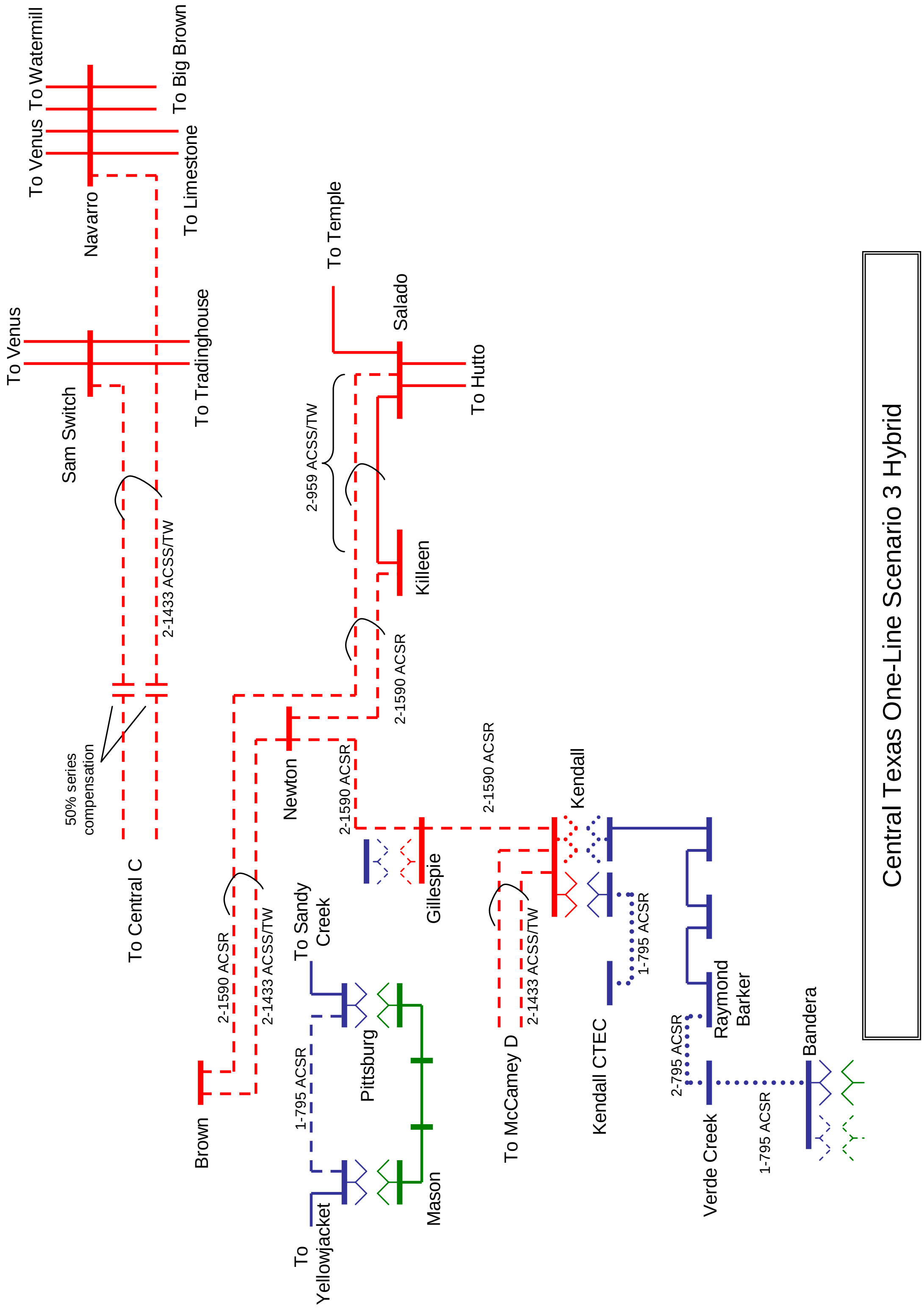
Scenario 3 Plan



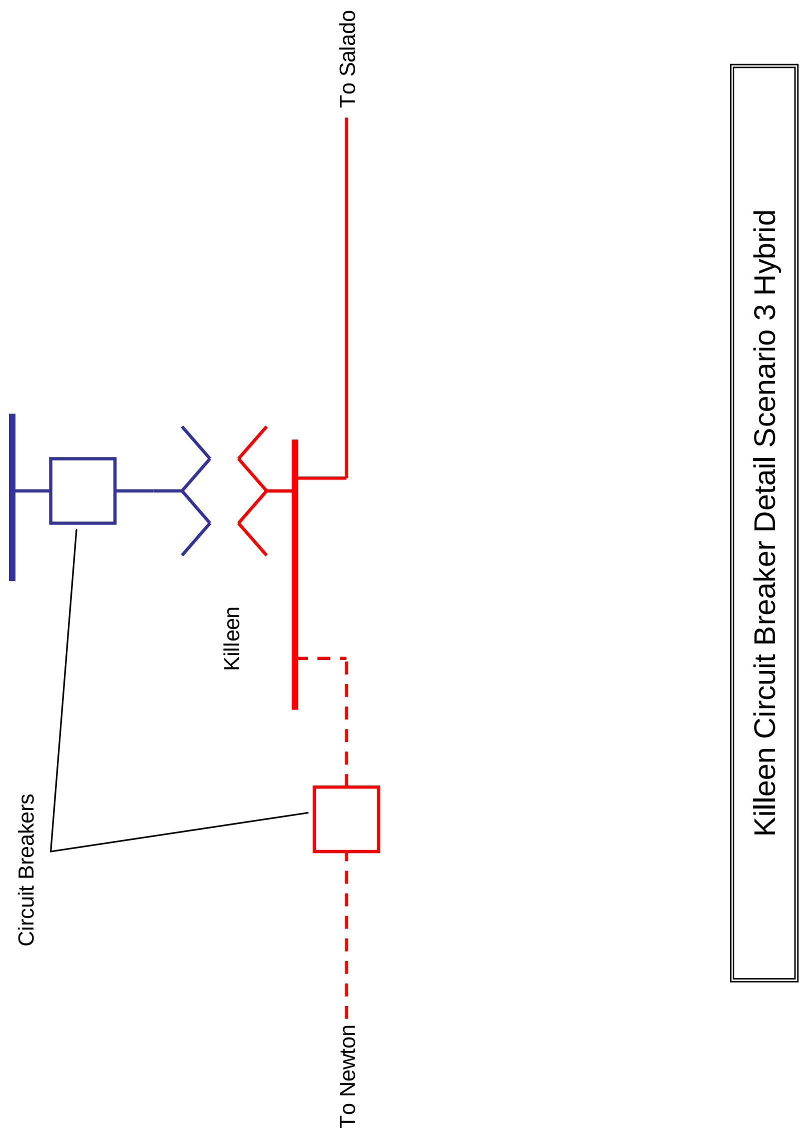
Scenario 3 Plan



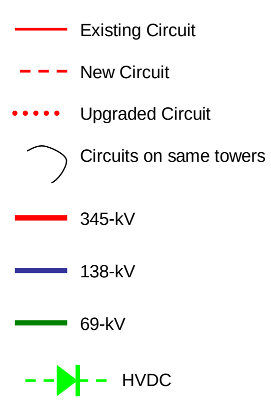
Scenario 3 Plan



Scenario 3 Plan

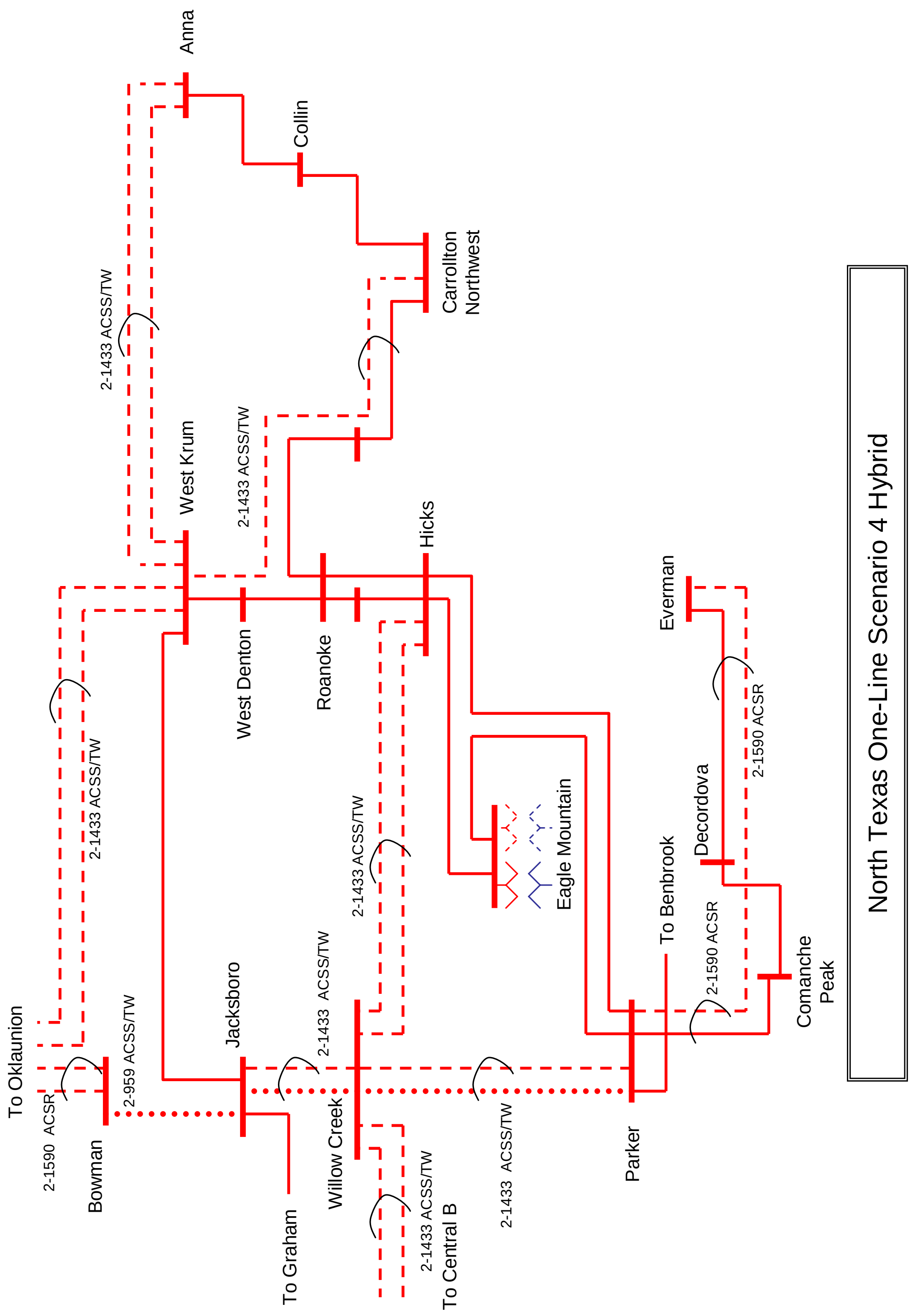


Scenario 4 Plan

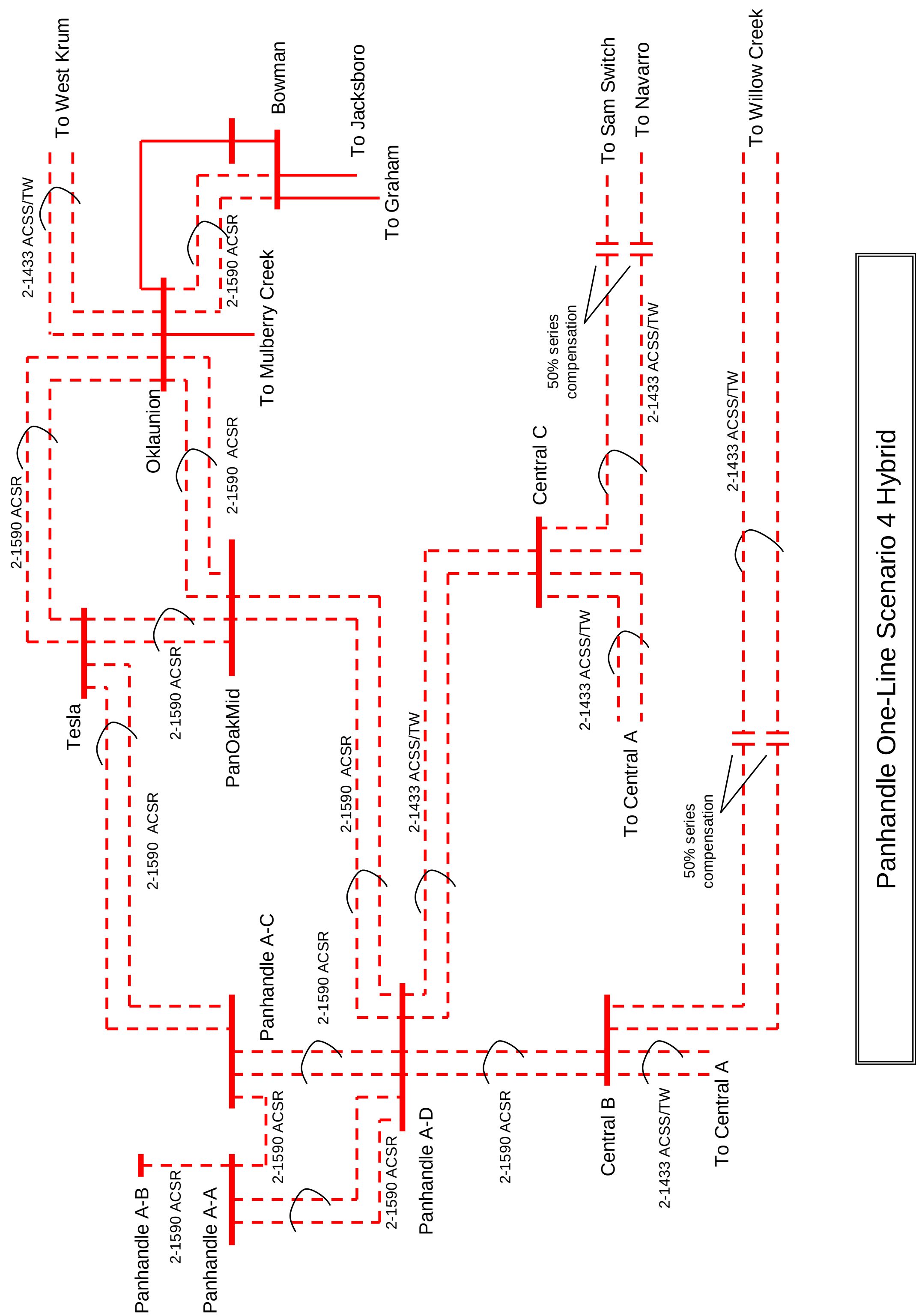


Legend

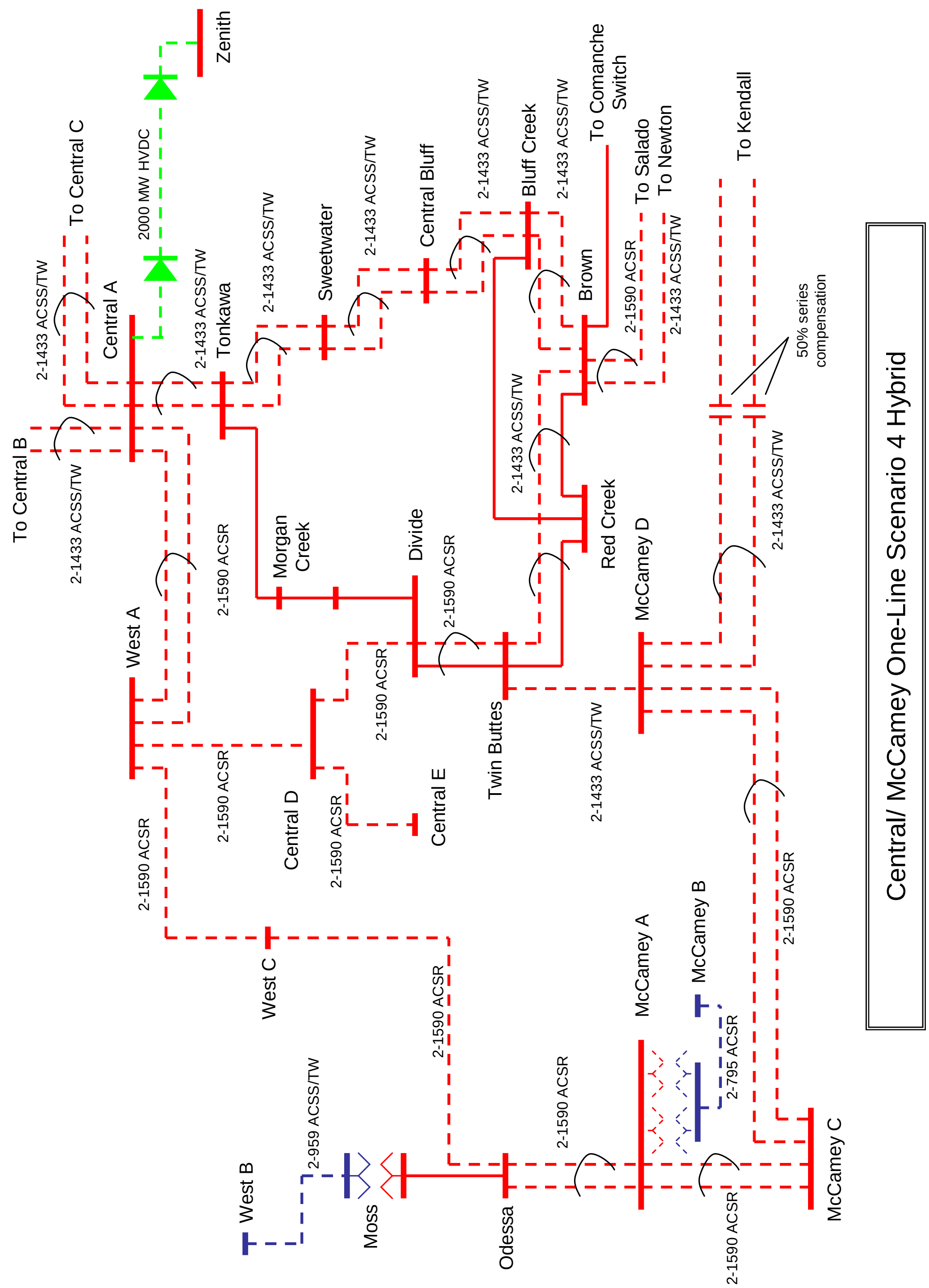
Scenario 4 Plan



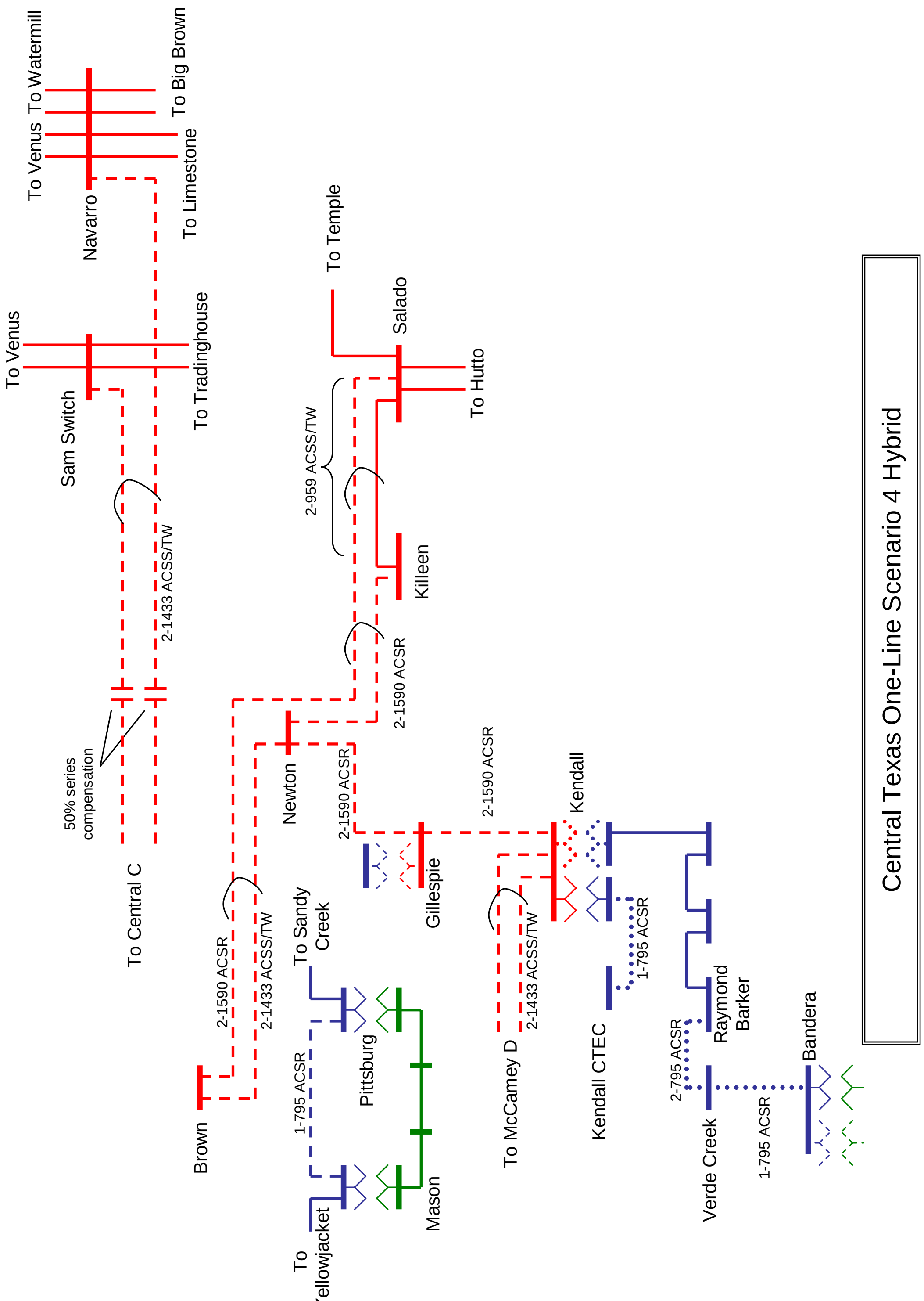
Scenario 4 Plan



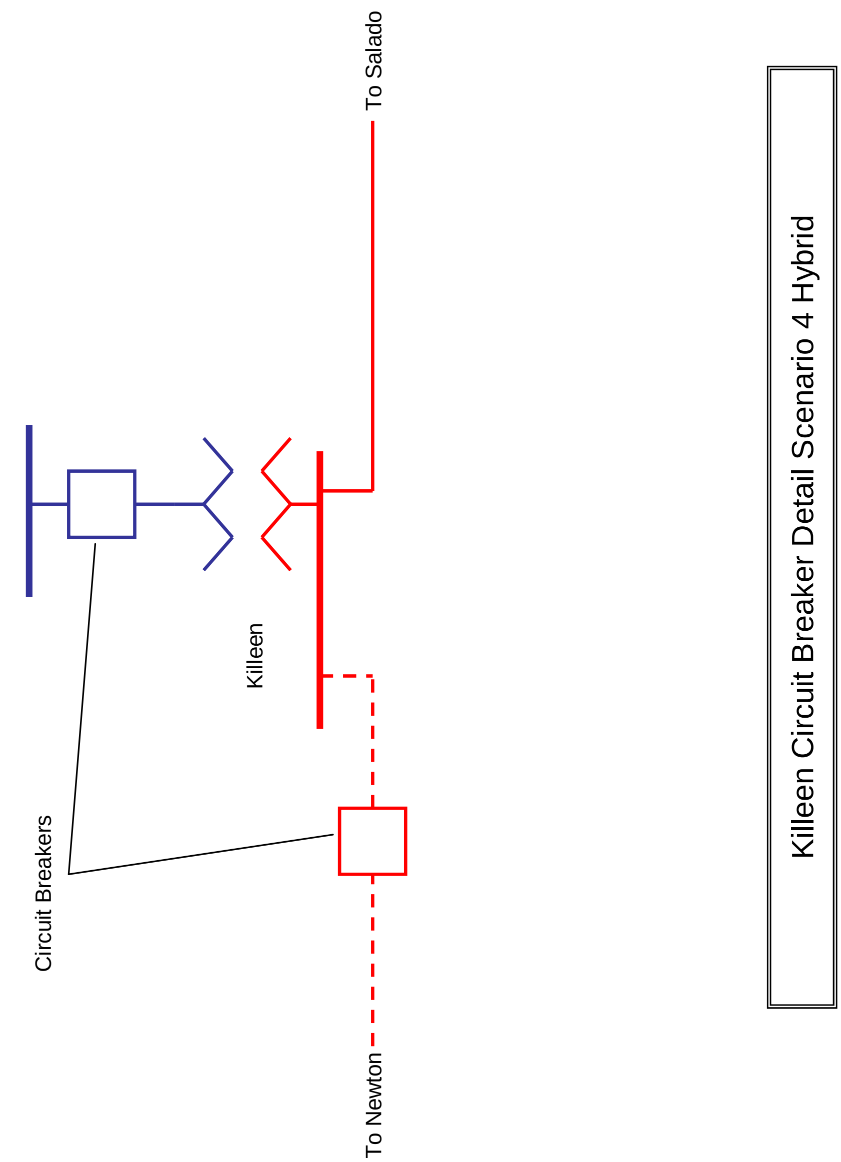
Scenario 4 Plan



Scenario 4 Plan



Scenario 4 Plan



Appendix B

Cost Calculations

COST BREAKDOWN FOR SCENARIO 1 PLAN A

Description	Miles	Conductor	New/ Upgrade Existing	Cost ($M)
West Krum-Anna double circuit 345-kV line	44	2-1590 ACSR	New	73.92
West Krum-Carrollton NW 345-kV line-add second circuit to existing towers	44	2-1590 ACSR	New	17.60
New Oklaunion-West Krum double circuit 345-kV line	119	2-1590 ACSR	New	199.92
West Krum station			New	25.00
Jacksboro-West Krum 345-kV line-add second circuit to existing towers	60	2-1590 ACSR	New	24.00
Reconductor Lewisville-Lewisville Jones-Lakepointe-Carrollton NW 138-kV line	7.7	1-959 ACSS/TW	Upgrade Existing	2.31
Upgrade Highland-West Lewisville 138-kV line	1.64	1-959 ACSS/TW	Upgrade Existing	1.64
Upgrade West Lewisville-Lewisville TI terminal equipment			Upgrade Existing	0.50
New Oklaunion-Oklaunion single circuit 345-kV line (double circuit capable towers)	1	2-1433 ACSS/TW	New	1.50
New Oklaunion-Bowman single circuit 345-kV line (double circuit capable towers)	37.5	2-1590 ACSR	New	52.50
New Oklaunion-Panhandle B-B doulbe circuit 345-kV line	144	2-1590 ACSR	New	241.92
New Oklaunion station			New	25.00
Panhandle B-B-Panhandle B-A double circuit 345-kV line	32	2-1590 ACSR	New	53.76
Panhandle B-A-Panhandle A-C double circuit 345-kV line	50	2-1590 ACSR	New	84.00
Panhandle A-B-Panhandle A-A single circuit 138-kV line	22	2-959 ACSS/TW	New	22.00

COST BREAKDOWN FOR SCENARIO 1 PLAN A (Cont.)

Panhandle A-A-Panhandle A-C single circuit 138-kV line	38	2-959 ACSS/TW	New	38.00
Panhandle A-C Auto (800 MVA)			New	9.00
Panhandle A-C-Clear Crossing double circuit 345-kV line	144	2-1590 ACSR	New	241.92
Panhandle A-C-Panhandle A-D single circuit 345-kV line (double circuit capable towers)	54	2-1590 ACSR	New	75.60
Panhandle A-D-Central B single circuit 345-kV line (double circuit capable towers)	63	2-1590 ACSR	New	88.20
Panhandle A-A Capacitor Bank (2 X 50 MVAR)			New	4.00
Panhandle A-C Capacitor Bank (1 X 150 MVAR)			New	6.00
Add second Eagle Mountain auto (600 MVA)			New	8.00
Hicks station			New	25.00
Eagle Mountain-Hicks-Alliance-Roanoke 345-kV line terminal equipment			Upgrade Existing	2.00
Jack County-Hicks double circuit 345-kV line	45	2-1590 ACSR	New	75.60
Jack County station			New	25.00
Clear Crossing-Jack County double circuit 345-kV line	104	2-1590 ACSR	New	174.72
Central B-Clear Crossing double circuit 345-kV line	68	2-1590 ACSR	New	114.24
Clear Crossing station			New	25.00
West A-New Willow Valley single circuit 138-kV line	25	2-959 ACSS/TW	New	25.00
New Willow Valley-Central B single circuit 138-kV line	29	2-959 ACSS/TW	New	29.00
New Willow Valley station			New	10.00
Central B Auto (600 MVA)			New	8.00
Central B-Central A double circuit 345-kV line	19	2-1590 ACSR	New	31.92

COST BREAKDOWN FOR SCENARIO 1 PLAN A (Cont.)

Central A-Tonkawa double circuit 345-kV line (only one circuit into Tonkawa; one to Sweetwater)	10	2-1590 ACSR	New	16.80
Tonkawa-Sweetwater double circuit 345-kV line (one circuit into Sweetwater; one to Central Bluff)	22	2-1590 ACSR	New	36.96
Sweetwater-Central Bluff single circuit 345-kV line (double circuit capable towers) (circuit from Tonkawa - does not touch Sweetwater)	18	2-1590 ACSR	New	25.20
Central Bluff-Red Creek single circuit 345-kV line (double circuit capable towers)	38	2-1590 ACSR	New	53.20
Central C-RW Miller single circuit 345-kV line (double circuit capable towers)	57	2-1590 ACSR	New	79.80
Miller auto (800 MVA)			New	9.00
Central D-Longshore single circuit 345-kV line (double circuit capable towers)	10	2-1590 ACSR	New	14.00
Central E-Glasscocksingle circuit 345-kV line (double circuit capable towers)	10	2-1590 ACSR	New	14.00
Glasscock Station			New	15.00
West B-Moss single circuit 138-kV line	12	2-959 ACSS/TW	New	12.00
West C-Stanton single circuit 138-kV line (double circuit capable towers)	7	1-959 ACSS/TW	New	7.00
Red Creek-Salado single circuit 345-kV line-half on existing structures-half new ROW built as doulbe circuit capable towers-final 15.2 miles is 2-959 ACSS/TW	190.2	2-1590 ACSR/ 2-959 ACSS/TW	New	171.18
Red Creek-Salado series compensation (50%)			New	25.00
Red Creek-Edison single circuit 345-kV line (double circuit capable towers)	22	2-1590 ACSR	New	30.80

COST BREAKDOWN FOR SCENARIO 1 PLAN A (Cont.)

Edison-Kendal single circuit 345-kV line (double circuit capable towers)	119	2-1590 ACSR	New	166.60
Edison station			New	15.00
North McCamey-Edison single circuit 345-kV line (double circuit capable towers)	128	2-1590 ACSR	New	179.20
North McCamey Autos (2 X 800 MVA)			New	18.00
North McCamey Capacitor Bank (2 X 150 MVAR)			New	12.00
North McCamey station			New	15.00
McCamey C-Mesaview 138-kV line-add second circuit to existing structures	6	2-795 ACSR	New	1.50
Friend Ranch-McCamey D single circuit 138-kV line (double circuit capable towers)	32	2-795 ACSR	New	32.00
McCamey D-Twin Buttes single circuit 138-kV line (double circuit capable towers)	38	2-795 ACSR	New	38.00
Twin Buttes Auto (600 MVA)			New	8.00
Bandera-Verde Creek 138-kV line upgrade	15.4	1-795 ACSR	Upgrade Existing	15.40
Big Spring-Chalk Upgrade	10		Upgrade Existing	10.00
Abilene East-Putnam 138-kV line-add second circuit to exisiting structures	32	1-959 ACSS/ TW	New	8.70
Putnam-Leon 138-kV line upgrade	31	1-959 ACSS/ TW	Upgrade Existing	31.00
Big Spring-Midland E 138-kV line upgrade	45	1-959 ACSS/ TW	Upgrade Existing	45.00
Crane-Arco Tap 138-kV line terminal equipment upgrade			Upgrade Existing	1.00
Sonora-Friend Ranch 138-kV line terminal equipment upgrade			Upgrade Existing	1.00
Fort Stockton-Barilla 138-kV line terminal equipment upgrade			Upgrade Existing	1.00

COST BREAKDOWN FOR SCENARIO 1 PLAN A (Cont.)

Open Potosi-Pecan Bayou 138-kV line	0.00
Open Leon-Cisco 69-kV line	0.00
Open Bradshaw-Winters 69-kV circuit	0.00
Open Rock Springs-Frier 69-kV circuit	0.00
Open Seymour-Bomarton 69-kV circuit	0.00
Lamesa-Bluff Creek Tap 138-kV line terminal equipment upgrade	Underway
Lamesa-Exxon Means Tap 138-kV line terminal equipment upgrade	Underway
Ackerly Vealmoor-Getty Vealmoor 138-kV line terminal equipment upgrade	Underway
Total	**$2,950.11**

Total Scenario 1 Plan A **$2,950.11**

COST BREAKDOWN SCENARIO 1 PLAN B

Description	Miles	Conductor	New/ Upgrade Existing	Cost ($M)
PanOakMid 345kV station			New	15.00
West Krum 345kV station			New	20.00
Hicks 345kV station			New	25.00
Navarro 345kV station			New	30.00
Oklaunion to PanOakMid double circuit 345kV line	62	2-1590 ACSR	New	104.16
Oklaunion to West Krum double circuit 345kV line	106	2-1433 ACSS/TW	New	199.28
Parker to Everman E 345kV line on existing structures	110	2-1590 ACSR	New	30.80
PanhandleA A to PanhandleA C single circuit, double circuit capable 345kV line	56	2-1590 ACSR	New	78.40
PanhandleA A to PanhandleA B single circuit, double circuit capable 345kV line	25	2-1590 ACSR	New	35.00
PanhandleA B to PanhandleB A single circuit, double circuit capable 345kV line	60	2-1590 ACSR	New	84.00
PanhandleA C to PanhandleA D single circuit, double circuit capable 345kV line	56	2-1590 ACSR	New	78.40
PanhandleA D to Central B single circuit, double circuit capable 345kV line	68	2-1590 ACSR	New	95.20
PanhandleB A to PanhandleA C double circuit 345kV line	56	2-1590 ACSR	New	94.08

COST BREAKDOWN SCENARIO 1 PLAN B (Cont.)

PanhandleB B to Oklaunion double circuit 345kV line (One circuit looping into Tesla 345kV bus)	150	2-1590 ACSR	New	252.00
PanhandleB B to PanhandleB A doulble circuit 345kV line	37	2-1590 ACSR	New	62.16
PanhandleA C to PanOakMid double circuit 345kV line (One circuit looping into Tesla 345 bus. Line from Tesla to PanOakMid is 2-1433 ACSS)	105	2-1590 ACSR	New	179.40
PanOakMid to Central C double circuit 345kV line	117	2-1433 ACSS/TW	New	219.96
Rebuild Jacksboro to Willow Creek 345kV as double circuit	18	2-1433 ACSS/TW	Upgrade Existing	33.84
Replace 345kV auto at Kendall			New	8.00
West Krum to Carrolton NW 345kV line on existing structures	60	2-1433 ACSS/TW	New	16.80
Willow Creek to Hicks double circuit 345kV line	31	2-1433 ACSS/TW	New	58.28
Rebuild Willow Creek to Parker 345kV as double circuit	18	2-1433 ACSS/TW	New	33.84
Add 345kV auto at Eagle Mountain			New	8.00
50% compensation on Central C to Navarro/Sam Switch			New	60.00
Open the Seymour to Bomarton 69kV line				0.00
50% compensation on PanOakMid to Central C			New	60.00
50 MVAR Reactive Compensation on PanhandleA C			New	2.00
100 MVAR Cap Bank on PanhandleA C			New	4.00

COST BREAKDOWN SCENARIO 1 PLAN B (Cont.)

50 MVAR Cap Bank on PanhandleA D			New	2.50
50 MVAR Reactive Compensation on PanhandleA D			New	2.00
200 MVAR Cap Bank on PanOakMid			New	9.00
200 MVAR Reactive Compensation on PanOakMid			New	5.50
150 MVAR Cap Bank on Tesla			New	6.00
100 MVAR Reactive Compensation on Tesla			New	3.00
50 MVAR Reactive Compensation on PanhandleB B			New	2.00
50 MVAR Reactive Compensation on PanhandleA B			New	2.00
300 MVAR Cap Bank on Oklaunion			New	11.00
Brown 345kV station			New	15.00
Newton 345kV station			New	20.00
Gillespie 345kV station			New	20.00
Sam Switch 345kV station			New	20.00
Central Bluff to Bluff Creek double circuit 345kV line	6	2-1433 ACSS/TW	New	11.28
Bluff Creek to Brown double circuit 345kV line	75	2-1433 ACSS/TW	New	141.00
Brown to Newton/Salado double circuit 345kV line (Newton line is 2-1433 ACSS/TW and Salado line is 2-1590	50/88	2-1590 & 2-1433 ACSS/TW	New	132.80
Newton to Killeen 345kV line	26	2-1590 ACSR	New	7.28
Central A to Central C double circuit 345kV line	75	2-1433 ACSS/TW	New	141.00

COST BREAKDOWN SCENARIO 1 PLAN B (Cont.)

Central A to Tonkawas double circuit 345kV line	43	2-1433 ACSS/TW	New	80.84
Central A to West A double circuit 345kV line	43	2-1590 ACSR	New	72.24
Central B to Central A single circuit, double circuit capable 345kV line	12	2-1433 ACSS/TW	New	18.00
Central C to Navarro/Sam Switch double circuit 345kV line	168/148	2-1433 ACSS/TW	New	308.24
Central D to Divide single circuit, double circuit capable 345kV line	6	2-1590 ACSR	New	8.40
Central E to Central D single circuit, double circuit capable 345kV line	27	2-1590 ACSR	New	37.80
Add second circuit to existing towers on Divide to Twin Butte	25	2-1590 ACSR	New	7.00
Rebuild Verde Creek to Bandera	16	1-795 ACSR	New	16.00
Mason to Pittsburg 138kV line	18	1-795 ACSR	New	18.00
McCamey C to McCamey D single circuit, double circuit capable 345kV line	75	2-1590 ACSR	New	105.00
McCamey A to Odessa single circuit, double circuit capable 345kV line	50	2-1590 ACSR	New	70.00
McCamey B to North McCamey 138kV line on existing structures	15	2-795 ACSR	New	3.75
McCamey C to McCamey A single circuit, double circuit capable 345kV line	12	2-1590 ACSR	New	16.80
McCamey D to Twin Butte single circuit, double circuit capable 345kV line	31	2-1433 ACSS/TW	New	46.50
Add 2 345kV autos at North McCamey			New	16.00
Close the bus ties at North McCamey bus				0.00

COST BREAKDOWN SCENARIO 1 PLAN B (Cont.)

Sweetwater to Central Bluff double circuit 345kV line	25	2-1433 ACSS/TW	New	47.00
Tonkawas to Sweetwater double circuit 345kV line	18	2-1433 ACSS/TW	New	33.84
Twin Butte to Brown 345kV line on existing structures	106	2-1433 ACSS/TW	New	31.80
West A to Central D single circuit, double circuit capable 345kV line	50	2-1590 ACSR	New	70.00
West A to West C single circuit, double circuit capable 345kV line	25	2-1590 ACSR	New	35.00
West B to Moss single circuit 138kV line	6	2-959 ACSS/TW	New	6.00
West C to Odessa single circuit, double circuit capable 345kV line	43	2-1590 ACSR	New	60.20
Open the Saps to Yellowjacket 138kV line				0.00
Add a 345kV auto at Gillespie			New	8.00
Add 138kV auto at Bandera			New	4.00
Rebuild Kendct to Kendal 138kV line	0.09	1-795 ACSR		0.09
Rebuild Raymond Barker to Verde Creek 138kV line	2	1-795 ACSR		2.00
Add a 345kV auto at Whitney			New	5.00
Rebuild the Goldthwaite to Evant 138kV line		1-795 ACSR	Upgrade Existing	25.00
Open the Rock Springs to Friess Ranch 69kV line				0.00
Open the Fort Stockton to Barilla 69kV line				0.00
Open the Bradshaw to Winters 69kV line				0.00
100 MVAR Reactive Compensation on Gillespie			New	3.00

COST BREAKDOWN SCENARIO 1 PLAN B (Cont.)

150 MVAR Reactive Compensation on Central C			New	4.50
150 MVAR Reactive Compensation on Central B			New	4.50
150 MVAR Reactive Compensation on Brown			New	4.50
100 MVAR Reactive Compensation on Central A			New	3.00
100 MVAR Reactive Compensation on McCamey D			New	3.00
Upgrade terminal equipment on Morgan Creek to Twin Butte 345kV line			Upgrade Existing	3.00
Upgrade terminal equipment on Roanoke to Alliance 345kV line			Upgrade Existing	1.00
Upgrade terminal equipment on both Singleton to Gibbons Creek 345kV lines			Upgrade Existing	2.00
Upgrade terminal equipment on Bowman to Fisher Road 345kV line			Upgrade Existing	1.00
Upgrade terminal equipment on Bowman to Graham 345kV line			Upgrade Existing	1.00
Upgrade Abliene South to Leon 138kV line	66	1-959 ACSS/TW	Upgrade Existing	66.00
Upgrade terminal equipment on Abliene to Mulberry 138kV line			Upgrade Existing	1.00
Eagle Mountain-Hicks-Alliance-Roanoke 345-kV line terminal equipment			Upgrade Existing	2.00
Rebuild Sonora to Hamilton 138kV line	88	1-959 ACSS/TW	Upgrade Existing	88.00
Total Scenario 1 Plan B				**$3,778.96**

COST BREAKDOWN SCENARIO 2

Description	Miles	Conductor	New/ Upgrade Existing	Cost ($M)
PanOakMid 345kV station			New	15.00
West Krum 345kV station			New	20.00
Hicks 345kV station			New	25.00
Tesla 345kV station			New	20.00
Bowman to Oklaunion double circuit 345kV line	37	2-1590 ACSR	New	62.16
Oklaunion to PanOakMid double circuit 345kV line	62	2-1590 ACSR	New	104.16
Oklaunion to West Krum double circuit 345kV line	106	2-1433 ACSS/TW	New	199.28
Parker to Everman E 345kV line on existing structures	110	2-1590 ACSR	New	30.80
PanhandleA A to PanhandleA C single circuit, double circuit capable 345kV line	56	2-1590 ACSR	New	78.40
PanhandleA A to PanhandleA B single circuit, double circuit capable 345kV line	25	2-1590 ACSR	New	35.00
PanhandleA B to PanhandleB A single circuit, double circuit capable 345kV line	60	2-1590 ACSR	New	84.00
PanhandleA C to PanhandleA D double circuit 345kV line	56	2-1590 ACSR	New	94.08

COST BREAKDOWN SCENARIO 2 (Cont.)

PanhandleA D to Central B double circuit 345kV line	68	2-1590 ACSR	New	114.24
PanhandleA D to PanOakMid double circuit 345kV line	37	2-1590 ACSR	New	62.16
PanhandleB A to PanhandleA C double circuit 345kV line	56	2-1590 ACSR	New	94.08
PanhandleB B to Oklaunion double circuit 345kV line (One circuit looping into Tesla 345kV bus)	150	2-1590 ACSR	New	252.00
PanhandleB B to PanhandleB A doulble circuit 345kV line	37	2-1590 ACSR	New	62.16
PanhandleA C to PanOakMid double circuit 345kV line (One circuit looping into Tesla 345 bus. Line from Tesla to PanOakMid is 2-1433 ACSS)	105	2-1590 ACSR	New	179.40
PanOakMid to Central C double circuit 345kV line	117	2-1433 ACSS/TW	New	219.96
Rebuild Jacksboro to Willow Creek 345kV as double circuit	18	2-1433 ACSS/TW	Upgrade Existing	33.84
West Krum to Carrolton NW 345kV line on existing structures	60	2-1433 ACSS/TW	New	16.80
Willow Creek to Hicks double circuit 345kV line	31	2-1433 ACSS/TW	New	58.28
Rebuild Willow Creek to Parker 345kV as double circuit	18	2-1433 ACSS/TW	New	33.84
West Krum to Anna double circuit 345kV line	43	2-1433 ACSS/TW	New	80.84
Add 345kV auto at Eagle Mountain			New	8.00

COST BREAKDOWN SCENARIO 2 (Cont.)

50% compensation on Central B to Willow Creek	New	60.00
Open the Seymour to Bomarton 69kV line		0.00
50% compensation on PanhandleA C to Tesla	New	25.00
50% compensation on PanOakMid to Central C	New	60.00
50 MVAR Reactive Compensation on PanhandleA C	New	2.00
100 MVAR Cap Bank on PanhandleA C	New	4.00
50 MVAR Cap Bank on PanhandleA D	New	2.50
50 MVAR Reactive Compensation on PanhandleA D	New	2.00
200 MVAR Cap Bank on PanOakMid	New	9.00
200 MVAR Reactive Compensation on PanOakMid	New	5.50
150 MVAR Cap Bank on Tesla	New	6.00
100 MVAR Reactive Compensation on Tesla	New	3.00
50 MVAR Reactive Compensation on PanhandleB B	New	2.00
50 MVAR Reactive Compensation on PanhandleA B	New	2.00
300 MVAR Cap Bank on Oklaunion	New	11.00
Navarro 345kV station	New	30.00

COST BREAKDOWN SCENARIO 2 (Cont.)

Brown 345kV station			New	15.00
Newton 345kV station			New	20.00
Gillespie 345kV station			New	20.00
Sam Switch 345kV station			New	20.00
Central Bluff to Bluff Creek double circuit 345kV line	6	2-1433 ACSS/TW	New	11.28
Bluff Creek to Brown double circuit 345kV line	75	2-1433 ACSS/TW	New	141.00
Brown to Newton/Salado double circuit 345kV line (Newton line is 2-1433 ACSS/TW and Salado line is 2-1590	50/88	2-1590 & 2-1433 ACSS/TW	New	132.80
Newton to Killeen 345kV line	26	2-1590 ACSR	New	7.28
Central A to Central C double circuit 345kV line	75	2-1433 ACSS/TW	New	141.00
Central A to Tonkawas double circuit 345kV line	43	2-1433 ACSS/TW	New	80.84
Central A to West A double circuit 345kV line	43	2-1590 ACSR	New	72.24
Central B to Central A double circuit 345kV line	12	2-1433 ACSS/TW	New	22.56
Central B to Willow Creek double circuit 345kV line	168	2-1433 ACSS/TW	New	315.84
Central C to Navarro/Sam Switch double circuit 345kV line	168/148	2-1433 ACSS/TW	New	308.24
Central D to Divide single circuit, double circuit capable 345kV line	6	2-1590 ACSR	New	8.40
Central E to Central D single circuit, double circuit capable 345kV line	27	2-1590 ACSR	New	37.80

COST BREAKDOWN SCENARIO 2 (Cont.)

Add second circuit to existing towers on Divide to Twin Butte	25	2-1590 ACSR	New	7.00
Replace 345kV auto at Kendall			New	8.00
Rebuild Verde Creek to Bandera	16	1-795 ACSR	New	16.00
Mason to Pittsburg 138kV line	18	1-795 ACSR	New	18.00
McCamey C to McCamey D single circuit, double circuit capable 345kV line	75	2-1590 ACSR	New	105.00
McCamey A to Odessa single circuit, double circuit capable 345kV line	50	2-1590 ACSR	New	70.00
McCamey B to North McCamey 138kV line on existing structures	15	2-795 ACSR	New	3.75
McCamey C to McCamey A single circuit, double circuit capable 345kV line	12	2-1590 ACSR	New	16.80
McCamey D to Kendall double circuit 345kV line	137	2-1433 ACSS/TW	New	257.56
McCamey D to Twin Butte single circuit, double circuit capable 345kV line	31	2-1433 ACSS/TW	New	46.50
Add 2 345kV autos at North McCamey			New	16.00
Close the bus ties at North McCamey bus				0.00
Sweetwater to Central Bluff double circuit 345kV line	25	2-1433 ACSS/TW	New	47.00
Tonkawas to Sweetwater double circuit 345kV line	18	2-1433 ACSS/TW	New	33.84

COST BREAKDOWN SCENARIO 2 (Cont.)

Twin Butte to Brown 345kV line on existing structures	106	2-1433 ACSS/TW	New	31.80
West A to Central D single circuit, double circuit capable 345kV line	50	2-1590 ACSR	New	70.00
West A to West C single circuit, double circuit capable 345kV line	25	2-1590 ACSR	New	35.00
West B to Moss single circuit 138kV line	6	2-959 ACSS/TW	New	6.00
West C to Odessa single circuit, double circuit capable 345kV line	43	2-1590 ACSR	New	60.20
50% compensation on Central C to Navarro/Sam Switch			New	60.00
50% compensation on McCamey D to Kendall			New	60.00
Kendall to Gillespie single circuit, double circuit capable 345kV line	18	2-1590 ACSR	New	23.40
Open the Saps to Yellowjacket 138kV line				0.00
Gillespie to Newton single circuit, double circuit capable 345kV line	105	2-1590 ACSR	New	136.50
Add a 345kV auto at Gillespie			New	8.00
Add 138kV auto at Bandera			New	4.00
Rebuild Kendct to Kendal 138kV line	0.09	1-795 ACSR		0.09
Rebuild Raymond Barker to Verde Creek 138kV line	2	1-795 ACSR		2.00
Add a 345kV auto at Whitney			New	5.00
Rebuild the Goldthwaite to Evant 138kV line		1-795 ACSR	Upgrade Existing	25.00

COST BREAKDOWN SCENARIO 2 (Cont.)

Open the Rock Springs to Friess Ranch 69kV line		0.00
Open the Fort Stockton to Barilla 69kV line		0.00
Open the Bradshaw to Winters 69kV line		0.00
100 MVAR Reactive Compensation on Gillespie	New	3.00
150 MVAR Reactive Compensation on Central C	New	4.50
150 MVAR Reactive Compensation on Central B	New	4.50
150 MVAR Reactive Compensation on Brown	New	4.50
100 MVAR Reactive Compensation on Central A	New	3.00
100 MVAR Reactive Compensation on McCamey D	New	3.00
Upgrade terminal equipment on Morgan Creek to Twin Butte 345kV line	Upgrade Existing	3.00
Upgrade terminal equipment on Roanoke to Alliance 345kV line	Upgrade Existing	1.00
Upgrade terminal equipment on both Singleton to Gibbons Creek 345kV lines	Upgrade Existing	2.00
Upgrade terminal equipment on Bowman to Fisher Road 345kV line	Upgrade Existing	1.00
Upgrade terminal equipment on Bowman to Graham 345kV line	Upgrade Existing	1.00

COST BREAKDOWN SCENARIO 2 (Cont.)

Reconductor Bowman to Jacksboro 345kV line	37	2-959 ACSS/TW	Upgrade Existing	9.62
Upgrade Abliene South to Leon 138kV line	66	1-959 ACSS/TW	Upgrade Existing	66.00
Upgrade terminal equipment on Abliene to Mulberry 138kV line			Upgrade Existing	1.00
Eagle Mountain-Hicks-Alliance-Roanoke 345-kV line terminal equipment			Upgrade Existing	2.00
Rebuild Sonora to Hamilton 138kV line	88	1-959 ACSS/TW	Upgrade Existing	88.00
Total Existing System Upgrades				**$4,931.32**

Total Scenario 2 **$4,931.32**

COST BREAKDOWN FOR HYBRID SCENARIO 2 UPGRADE

The following changes were made to Scenario 1 Plan B to arrive at Scenario 2

Start with All Improvements Included in Scenario 1 Plan B and add the following:

Description	Miles	Conductor	New/ Upgrade Existing	Cost ($M)
Tesla 345kV station			New	20.00
West Krum to Anna double circuit 345kV line	43	2-1433 ACSS/TW	New	80.84
Central B to Willow Creek double circuit 345kV line	168	2-1433 ACSS/TW	New	315.84
McCamey D to Kendall double circuit 345kV line	137	2-1433 ACSS/TW	New	257.56
Kendall to Gillespie single circuit, double circuit capable 345kV line	18	2-1590 ACSR	New	23.40
Gillespie to Newton single circuit, double circuit capable 345kV line	105	2-1590 ACSR	New	136.50
PanhandleA D to PanOakMid double circuit 345kV line	37	2-1590 ACSR	New	62.16
Add second circuit PanhandleA C to PanhandleA D 345kV line	56	2-1590 ACSR		22.40
Add second circuit PanhandleA D to Central B 345kV line	68	2-1590 ACSR		27.20
Add a second circuit Central B to Central A 345kV line	12	2-1433 ACSS/TW		4.80
Bowman to Oklaunion double circuit 345kV line	37	2-1590 ACSR	New	62.16
Reconductor Bowman to Jacksboro 345kV line	37	2-959 ACSS/TW	Upgrade Existing	9.62
50% compensation on Central B to Willow Creek			New	60.00
50% compensation on McCamey D to Kendall			New	60.00
50% compensation on PanhandleA C to Tesla			New	25.00
Sum				**$1,167.48**

COST BREAKDOWN FOR HYBRID SCENARIO 2 UPGRADE (Cont.)

Scenario 1 Plan B	$3,778.96
Scenario 2 Upgrade	$1,167.48
Total Scenario 2	**$4,946.44**

COST BREAKDOWN SCENARIO 3

The following changes were made to Scenario 2 to arrive at Scenario 4

Description	Miles	Conductor	New/ Upgrade Existing	Cost ($M)
Maxwell 345kV Switch station			New	20.00
PanhandleB A to PanOakMid double circuit 345kV line	125	2-1433 ACSS	New	235.00
PanhandleA D to Maxwell double circuit 345kV line	75	2-1433 ACSS	New	141.00
Maxwell to Jacksboro double circuit 345kV line	100	2-1433 ACSS	New	188.00
Add 2nd circuit on McCamey D to McCamey C	75	2-1590 ACSR	New	21.00
Add 2nd circuit on McCamey C to McCamey A	12	2-1590 ACSR	New	3.36
Add 2nd circuit on McCamey A to Odessa	50	2-1590 ACSR	New	14.00
2000 MW DC Link from Central A to Zenith (line)	360		New	378.00
2000 MW DC Link from Central A to Zenith (converters)			New	450.00
Total				**$1,450.36**

Scenario 2 Total	$4,931.32
Upgrade to Scenario 3	$1,450.36
Total Scenario 3	**$6,381.68**

COST BREAKDOWN SCENARIO 4

The following changes were made to Scenario 2 to arrive at Scenario 4

Description	Miles	Conductor	New/ Upgrade Existing	Cost ($M)
Remove PanhandleA B to PanhandleB A 345kV line				-84.00
Remove PanhandleB A to PanhandleA C 345kV line				-94.08
Remove PanhandleB B to PanhandleB A 345kV line				-62.16
Remove PanhandleB B to Tesla 345KV line				-176.72
Add 2nd circuit on McCamey D to McCamey C	75	2-1590 ACSR	New	21.00
Add 2nd circuit on McCamey C to McCamey A	12	2-1590 ACSR	New	3.36
Add 2nd circuit on McCamey A to Odessa	50	2-1590 ACSR	New	14.00
2000 MW DC Link from Central A to Zenith (line)	360		New	378.00
2000 MW DC Link from Central A to Zenith (converters)			New	450.00
PanhandleA D to Central C double circuit 345kV line	119	2-1433 ACSS	New	223.72
PanhandleA D to PanhandleA A double circuit 345kV line	85	2-1590 ACSR	New	142.80
Total Upgrades				**$815.92**

Total Scenario 2	$4,931.32
Upgrade to Scenario 4	$815.92
Total Scenario 4	**$5,747.24**

COST BREKADOWN FOR HVDC Scenario 2

Start with the Scenario 2 Plan and make the following changes

Description	Miles	Conductor	New/ Upgrade Existing	Cost ($M)
Remove the following 345KV Lines				
West Krum-Anna double circuit 345-kV line	44	2-1590 ACSR	New	-73.92
New Oklaunion-West Krum double circuit 345-kV line	119	2-1590 ACSR	New	-199.92
Willow Crk. - Crez_Cen double circui 345-kV line	168	2-1590 ACSR	New	-302.40
Crez Central C - Sam Switch 345kv line	148	2-1590 ACSR	New	-266.40
* Crez Central C - Navarro 345kv line	168	2-1590 ACSR	New	-30.00
Crez Central C - Sam Switch 345kv line compensation	n/a		New	-30.00
Crez Central C - Navarro 345kv line compensation	n/a		New	-30.00
Willow Crk. - Crez_Cen double circuit 345-kV line compensation	n/a		New	-60.00
Eliminate Sam Switch/Navarro 345kv substtions	n/a		New	-30.00

* Note: Price reflects Crez Central C - Navarro sharing towers with Crez Central C - Sam Switch for 152 miles then on separate tower structure for 28 miles.

Total				**-$1,022.64**

COST BREKADOWN FOR HVDC Scenario 2 (Cont.)

Add the following components

4-HVDC Converter Stations	n/a	New	1,050.00
2-HVDC Links	430	New	451.50
Upgrade Graham - Parker 345kV line	95	Upgrade	47.50
Upgrade Morgan Crk. - Tonkawas 345kV line	28	Upgrade	14.00
Total			**$1,563.00**

Net Savings with HVDC over Scenario 2 Plan -$540.36

COST BREAKDOWN FOR 765 SCENARIO 3

-	Description	Miles or #	Conductor	New / Upgrade Existing	Cost, $M
	Swisher 765kV substation	1		new	40.00
	765-345kV 1500/2100 MVA autotransformers	3		new	60.00
	Gray 765kV substation	1		new	40.00
	765-345kV 1500/2100 MVA autotransformers	3		new	60.00
	Gray - Cooke 765kV line, 70% compensated	255	6-795 ACSR	new	663.00
	Gray - Swisher 765kV line, 50% compensated	70	6-795 ACSR	new	182.00
	Swisher - Shackleford 765kV line, 60% compensated	155	6-795 ACSR	new	403.00
	Swisher - Morgan 765kV line, 50% compensated	160	6-795 ACSR	new	416.00
	Oklaunion - Wildhorse - Pan_A D 345kV line	110	2-1433 ACSS	new	165.00
	series compensation for the 345kV lines @ 50%	2		new	50.00
	Wildhorse 345-138kV 300 MVA autotransformer	1		new	4.00
	Pan_A D 345-138kV 150 MVA autotransformer	1		new	2.00
	Pan_A D - Whirlwind 138kV line	15	2-795 ACSR	new	15.00
	Pan_A A - Pan_A B 345kV line	30	2-1433 ACSS	new	45.00
	Pan_A A - Pan_A C 345kV line	36	2-1433 ACSS	new	54.00
	Pan_B A - Pan_B B 345kV line	21	2-1433 ACSS	new	31.50
	Cooke 765kV substation, no autotransformers	1		new	40.00

COST BREAKDOWN FOR 765 SCENARIO 3 (Cont.)

Venus 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
NotGram 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
NotGram - Graham double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
NotGram-Hicks 345kV line	60	2-1433 ACSS	new	90.00
Rock 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Rock - Tricorner double-circuit 345kV lines	25	2-1433 ACSS	new	47.00
Rock - Forney double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
Rock - Royse double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
Cooke - NotGram 765kV line, 50% compensated	90	6-795 ACSR	new	234.00
Cooke - Rock 765kV line, 50% compensated	85	6-795 ACSR	new	221.00
NotGram - Venus 765kV line, 50% compensated	135	6-795 ACSR	new	351.00
Rock - Venus 765kV line, 50% compensated	80	6-795 ACSR	new	208.00
Krum substation, no transformers	1		new	15.00
Anna - Krum double-circuit 345kV lines	45	2-1433 ACSS	new	84.60
Jacksboro - Krum - W. Denton 2nd 345kV circuit	72	2-1433 ACSS	new	28.80

COST BREAKDOWN FOR 765 SCENARIO 3 (Cont.)

Bowman - Oklaunion 345kV line	35	2-1433 ACSS	new	52.50
Hicks substation	1		new	15.00
345-138kV 800 MVA autotransformers	2		new	18.00
Hicks - Saginaw double 138kV	10.5		rebuild existing	13.13
Milam 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformer	1		new	20.00
Milam - Hutto 765kV line, 50% compensated	35	6-795 ACSR	new	91.00
Milam - Zenith 765kV line, 50% compensated	100	6-795 ACSR	new	260.00
Milam - Venus 765kV line, 50% compensated	120	6-795 ACSR	new	312.00
Milam - Shackleford 765kV line, 50% compensated	155	6-795 ACSR	new	403.00
Milam - Twin Oak double-circuit 345kV line	25	2-1433 ACSS	new	47.00
Zenith 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
W A Parrish 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Zenith - W A Parrish 765kV line, 50% compensated	40	6-795 ACSR	new	104.00
Salvin - Oasis 345kV line	4	2-1433 ACSS	upgrade existing	6.00
Third 345-138kV 800 MVA autotransformer at T H Wharton	1		new	9.00
Third 345-138kV 500 MVA Dow autotransformer	1		new	8.00

COST BREAKDOWN FOR 765 SCENARIO 3 (Cont.)

West Gate 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Hutto 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Hutto - West Gate 765kV line, 50% compensated	65	6-795 ACSR	new	169.00
West Gate substation, no transformers	1		new	15.00
West Gate - Willow 345kV line	30	2-1433 ACSS	new	45.00
Willow substation	1		new	15.00
345-138kV 800 MVA autotransformers at Willow	2		new	18.00
West Gate - Gillespie 345kV line	30	2-1433 ACSS	new	45.00
345-138kV 800 MVA autotransformers at Gillespie	2		new	18.00
West Gate - Lampasas 345kV line	50	2-1433 ACSS	new	75.00
345-138kV 800 MVA autotransformers at Lampasas	2		new	18.00
Lampasas - Killeen 345kV line	35	2-1433 ACSS	new	52.50
Gillespie - Kendall 345kV line	20	2-1433 ACSS	new	30.00
Willow - Trading Post 345kV line	50	2-1433 ACSS	new	75.00
Trading Post 345-138kV 600 MVA autotransformer	1		new	8.00
Trading Post - Marshall Ford rebuild 138kV line as 345kV	7.6	2-1433 ACSS	rebuild existing	11.40

COST BREAKDOWN FOR 765 SCENARIO 3 (Cont.)

345-138kV 600 MVA autotransformers at Marshall Ford	2		new	16.00
Trading Post - Patton 138kV line	6.5	2-795 ACSR	new	6.50
Gillespie - Willow - Ferguson double-circuit 138kV lines	40	2-795 ACSR	rebuild existing	50.00
Second Bandera - Verde Creek 138kV line	15.4	2-795 ACSR	new	15.40
Third 345-138kV 600 MVA Cagnon autotransformer	1		new	8.00
138-69kV 56 MVA Corona autotransformer	1		upgrade existing	1.00
138-69kV 56 MVA Gillespie autotransformer	1		upgrade existing	1.00
Kendall - Mesa View double-circuit 345kV lines	190	2-1433 ACSS	new	357.20
345kV series compensation @ 50%	2		new	60.00
Mesa View - McCamey B double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
McCamey B - North Mccamey double-circuit 345kV lines	18	2-1433 ACSS	new	33.84
345-138kV 600 MVA auto at North McCamey or Rio Pecos	1		new	8.00
North McCamey - McCamey D double-circuit 345kV lines	85	2-1433 ACSS	new	159.80
345kV series compensation @ 50%	2		new	50.00
McCamey D-(Menard)-Gillespie double-circuit 345kV lines	120	2-1433 ACSS	new	225.60
345kV series compensation @ 50%	2		new	60.00
Fort Stockton - Barrilla 69kV line	16.3	(60 MVA)	rebuild existing	12.23

COST BREAKDOWN FOR 765 SCENARIO 3 (Cont.)

Second Sonora 138-69kV 45 MVA autotransformer	1		new	1.00
Morgan Creek 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	3		new	60.00
Morgan Creek - West Gate 765kV line, compensated 50%	165	6-795 ACSR	new	429.00
Morgan - Central A 345kV line	30	2-1433 ACSS	new	45.00
Morgan Central B 345kV line	40	2-1433 ACSS	new	60.00
Central A - Central B 345kV line	21	2-1433 ACSS	new	31.50
Morgan - West A 345kV line	40	2-1433 ACSS	new	60.00
Morgan - Central Chalk 345kV line	30	2-1433 ACSS	new	45.00
Central Chalk substation	1		new	15.00
345-138kV 600 MVA autotransformer	1		new	8.00
Central Chalk - Big Spring West 138kV line	10	2-795 ACSR	new	10.00
Central Chalk - Forsan tap 138kV line	10	2-795 ACSR	new	10.00
Central Chalk - Midland East 345kV line	40	2-1433 ACSS	new	60.00
Central Chalk - West C 345kV line	30	2-1433 ACSS	new	45.00
Midland East - Odessa 345kV line	30	2-1433 ACSS	new	45.00
Moss - West B 345kV line	15	2-1433 ACSS	new	22.50
Midland East - Stanton - Big SpringWest 138kV line	37.2	2-795 ACSR	new	37.20

COST BREAKDOWN FOR 765 SCENARIO 3 (Cont.)

Big Spring - Big Spring West 138kV line	7.9	2-795 ACSR	new	7.90
Divide - Central D 345kV	20	2-1433 ACSS	new	30.00
Central D - Central E 345kV	42	2-1433 ACSS	new	63.00
Red Creek - Twin Buttes 345kV line, new ROW	40	2-1433 ACSS	new	60.00
Snyder - China Grove 138kV line	14.5	2-795 ACSR	upgrade existing	14.50
Second Divide 345-138kV 270 MVA autotransformer	1		new	4.00
Shackleford 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Shackleford - Morgan 765kV line, 50% compensated	100	6-795 ACSR	new	260.00
Shackleford - NotGram 765kV line, 50% compensated	70	6-795 ACSR	new	182.00
Third 345-138kV 800 MVA Bluff autotransformer	1		new	9.00
Paint substation, no transformers	1		new	15.00
Holder - Cross Plains 138kV line	13	(171 MVA)	new	13.00
Cross Plains 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00
South Bush substation	1		new	10.00
South Bush 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00
Fort Phantom 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00
Abilene East 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00
Lufkin - Tmplinla 138kV line	6	(214 MVA)	upgrade existing	1.80

COST BREAKDOWN FOR 765 SCENARIO 3 (Cont.)

New Blessing - Formosa 138kV line	30	2-795 ACSR	new	30.00
S_McAllen - Mvlasmi - Stewart 138kV line	9.9	(365 MVA)	upgrade existing	9.90
Total				**$9,099.09**

Total 765 Scenario 3 **$9,099.09**

COST BREAKDOWN FOR 765 SCENARIO 4

Description	Miles or #	Conductor	New / Upgrade Existing	Cost, $M
Swisher 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	4		new	80.00
Swisher - Cooke 765kV line, 70% compensated	255	6-795 ACSR	new	663.00
Swisher - Shackleford 765kV line, 60% compensated	155	6-795 ACSR	new	403.00
Swisher - Morgan 765kV line, 50% compensated	160	6-795 ACSR	new	416.00
Oklaunion - Wildhorse - Pan_A D 345kV line	110	2-1433 ACSS	new	165.00
series compensation for the 345kV lines @ 50%	2		new	50.00
Wildhorse 345-138kV 300 MVA autotransformer	1		new	4.00
Pan_A D 345-138kV 150 MVA autotransformer	1		new	2.00
Pan_A D - Whirlwind 138kV line	15	2-795 ACSR	new	15.00
Pan_A A - Pan_A B 345kV line	30	2-1433 ACSS	new	45.00
Pan_A A - Pan_A C 345kV line	36	2-1433 ACSS	new	54.00
Pan_B A - Pan_B B 345kV line	21	2-1433 ACSS	new	31.50
Cooke 765kV substation, no autotransformers	1		new	40.00
Venus 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
NotGram 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
NotGram - Graham double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
NotGram-Hicks 345kV line	60	2-1433 ACSS	new	90.00

COST BREAKDOWN FOR 765 SCENARIO 4 (Cont.)

NotGram - Bowman 345kV line	50	2-1433 ACSS	new	75.00
Rock 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Rock - Tricorner double-circuit 345kV lines	25	2-1433 ACSS	new	47.00
Rock - Forney double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
Rock - Royse double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
Cooke - NotGram 765kV line, 50% compensated	90	6-795 ACSR	new	234.00
Cooke - Rock 765kV line, 50% compensated	85	6-795 ACSR	new	221.00
NotGram - Venus 765kV line, 50% compensated	135	6-795 ACSR	new	351.00
Rock - Venus 765kV line, 50% compensated	80	6-795 ACSR	new	208.00
Krum substation, no transformers	1		new	15.00
Anna - Krum double-circuit 345kV lines	45	2-1433 ACSS	new	84.60
Jacksboro - Krum - W. Denton 2nd 345kV circuit	72	2-1433 ACSS	new	28.80
Bowman - Oklaunion 345kV line	35	2-1433 ACSS	new	52.50
Hicks substation	1		new	15.00
345-138kV 800 MVA autotransformers	2		new	18.00
Reconductor Oklaunion - Fisher 345kV	52	2-959 ACSS/TW	upgrade existing	26.00
Hicks - Saginaw double 138kV	10.5		rebuild existing	13.13
Milam 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformer	1		new	20.00
Milam - Hutto 765kV line, 50% compensated	35	6-795 ACSR	new	91.00
Milam - Zenith 765kV line, 50% compensated	100	6-795 ACSR	new	260.00
Milam - Venus 765kV line, 50% compensated	120	6-795 ACSR	new	312.00

COST BREAKDOWN FOR 765 SCENARIO 4 (Cont.)

Milam - Shackleford 765kV line, 50% compensated	155	6-795 ACSR	new	403.00
Milam - Twin Oak double-circuit 345kV line	25	2-1433 ACSS	new	47.00
Zenith 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
W A Parrish 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Zenith - W A Parrish 765kV line, 50% compensated	40	6-795 ACSR	new	104.00
Salvin - Oasis 345kV line	4	2-1433 ACSS	upgrade existing	6.00
Third 345-138kV 800 MVA autotransformer at T H Wharton	1		new	9.00
Third 345-138kV 500 MVA Dow autotransformer	1		new	8.00
West Gate 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Hutto 765kV substation	1		expand existing	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Hutto - West Gate 765kV line, 50% compensated	65	6-795 ACSR	new	169.00
West Gate substation, no transformers	1		new	15.00
West Gate - Willow 345kV line	30	2-1433 ACSS	new	45.00
Willow substation	1		new	15.00
345-138kV 800 MVA autotransformers at Willow	2		new	18.00
West Gate - Gillespie 345kV line	30	2-1433 ACSS	new	45.00
345-138kV 800 MVA autotransformers at Gillespie	2		new	18.00

COST BREAKDOWN FOR 765 SCENARIO 4 (Cont.)

West Gate - Lampasas 345kV line	50	2-1433 ACSS	new	75.00
345-138kV 800 MVA autotransformers at Lampasas	2		new	18.00
Lampasas - Killeen 345kV line	35	2-1433 ACSS	new	52.50
Gillespie - Kendall 345kV line	20	2-1433 ACSS	new	30.00
Willow - Trading Post 345kV line	50	2-1433 ACSS	new	75.00
Trading Post 345-138kV 600 MVA autotransformer	1		new	8.00
Trading Post - Marshall Ford rebuild 138kV line as 345kV	7.6	2-1433 ACSS	rebuild existing	11.40
345-138kV 600 MVA autotransformers at Marshall Ford	2		new	16.00
Trading Post - Patton 138kV line	6.5	2-795 ACSR	new	6.50
Gillespie - Willow - Ferguson double-circuit 138kV lines	40	2-795 ACSR	rebuild existing	50.00
Second Bandera - Verde Creek 138kV line	15.4	2-795 ACSR	new	15.40
Second Cagnon - Kendal 345kV line	51.5	2-1433 ACSS	new	77.25
Third 345-138kV 600 MVA Cagnon autotransformer	1		new	8.00
138-69kV 56 MVA Corona autotransformer	1		upgrade existing	1.00
138-69kV 56 MVA Gillespie autotransformer	1		upgrade existing	1.00
Edwards 345kV substation, no transformers	1		new	15.00
Kendall - Edwards - Mesa View double-circuit 345kV lines	190	2-1433 ACSS	new	357.20
345kV series compensation @ 50%	4		new	100.00
Mesa View - McCamey B double-circuit 345kV lines	15	2-1433 ACSS	new	28.20
McCamey B - North Mccamey double-circuit 345kV lines	18	2-1433 ACSS	new	33.84
345-138kV 600 MVA auto at North McCamey or Rio Pecos	1		new	8.00

COST BREAKDOWN FOR 765 SCENARIO 4 (Cont.)

North McCamey - McCamey D double-circuit 345kV lines	85	2-1433 ACSS	new	159.80
345kV series compensation @ 50%	2		new	50.00
Menard 345kV substation, no transformers	1		new	15.00
McCamey D - Menard - Gillespie double-circuit 345kV lines	120	2-1433 ACSS	new	225.60
345kV series compensation @ 50%	4		new	100.00
Edwards - Menard double-circuit 345kV lines	65		new	122.20
345kV series compensation @ 50%	2		new	50.00
Menard - Twin Buttes 345kV line	40	2-1433 ACSS	new	75.20
345kV series compensation @ 50%	1		new	25.00
Fort Stockton - Barrilla 69kV line	16.3	(60 MVA)	rebuild existing	12.23
Second Sonora 138-69kV 45 MVA autotransformer	1		new	1.00
Morgan Creek 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	4		new	80.00
Morgan Creek - West Gate 765kV line, compensated 50%	165	6-795 ACSR	new	429.00
Morgan - Central A 345kV line	30	2-1433 ACSS	new	45.00
Morgan Central B 345kV line	40	2-1433 ACSS	new	60.00
Central A - Central B 345kV line	21	2-1433 ACSS	new	31.50
Morgan - West A 345kV line	40	2-1433 ACSS	new	60.00
Morgan - Central Chalk 345kV line	30	2-1433 ACSS	new	45.00
Central Chalk substation	1		new	15.00
345-138kV 600 MVA autotransformer	1		new	8.00
Central Chalk - Big Spring West 138kV line	10	2-795 ACSR	new	10.00
Central Chalk - Forsan tap 138kV line	10	2-795 ACSR	new	10.00

COST BREAKDOWN FOR 765 SCENARIO 4 (Cont.)

Central Chalk - Midland East 345kV line	40	2-1433 ACSS	new	60.00
Central Chalk - West C 345kV line	30	2-1433 ACSS	new	45.00
Midland East - Odessa 345kV line	30	2-1433 ACSS	new	45.00
Moss - West B 345kV line	15	2-1433 ACSS	new	22.50
Midland East - Stanton - Big SpringWest 138kV line	37.2	2-795 ACSR	new	37.20
Big Spring - Big Spring West 138kV line	7.9	2-795 ACSR	new	7.90
Divide - Central D 345kV	20	2-1433 ACSS	new	30.00
Central D - Central E 345kV	42	2-1433 ACSS	new	63.00
Red Creek - Twin Buttes 345kV line, new ROW	40	2-1433 ACSS	new	60.00
Snyder - China Grove 138kV line	14.5	2-795 ACSR	upgrade existing	14.50
Second Divide 345-138kV 270 MVA autotransformer	1		new	4.00
Shackleford 765kV substation	1		new	40.00
765-345kV 1500/2100 MVA autotransformers	2		new	40.00
Shackleford - Morgan 765kV line, 50% compensated	100	6-795 ACSR	new	260.00
Shackleford - NotGram 765kV line, 50% compensated	70	6-795 ACSR	new	182.00
Third 345-138kV 800 MVA Bluff autotransformer	1		new	9.00
Paint substation, no transformers	1		new	15.00
Holder - Cross Plains 138kV line	13	(171 MVA)	new	13.00
Cross Plains 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00
South Bush substation	1		new	10.00
South Bush 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00
Fort Phantom 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00
Abilene East 138-69kV 33.3 MVA autotransformer + LTC	1		new	1.00

Lufkin - Tmplinla 138kV line	6	(214 MVA)	upgrade existing	1.80
New Blessing - Formosa 138kV line	30	2-795 ACSR	new	30.00
S_McAllen - Mvlasmi - Stewart 138kV line	9.9	(365 MVA)	upgrade existing	9.90
Total				**$9,417.74**

Total 765 Scenario 4 **$9,417.74**