Central Texas Electric Co-op

Harper Substation Distribution Alternative Study

June 27, 2016

Prepared by:
CTEC Engineering Staff

EXECUTIVE SUMMARY

The purpose of this study is to evaluate the viability of system improvement alternatives to meet growing electrical demands on the southwest portion of the Central Texas Electric Cooperative (CTEC) distribution system in the Ingram-Garvin store area south and west of the existing Harper substation. See Appendix A, Exhibit 1. The increasing demand on the electric system, and distribution system territory and topology challenges with regard to the existing Harper substation and its feeders present limited alternatives for distribution service plan options to meet reliability criteria requirements. The Mountain Home substation alternative is the only alternative evaluated that provides a complete, long term solution to the increasing demand and exposure. It should be strategically located in the area from just east of IH 10 west to the intersection of Hwy 41 and Hwy 27 near Mountain Home. CTEC currently owns adequate property on Thrill Hill Rd in Kerr County just east of IH 10.

The study reviews options to satisfy a violation of CTEC's system reliability planning criteria which is presently not being met:

1. To maintain adequate consumer reliability which meets or exceeds present levels, individual feeder loadings will be limited to 6 MW. (CTEC Planning Criteria – Appendix C)

In addition, further study by LCRA TSC is needed to evaluate a violation of LCRA TSC's planning criteria regarding interruption of 20 MW of peak load for a single event.

1. No more than 20 MW of peak load shall be interrupted for a single anticipated event. (LCRA TSC Planning Criteria – Appendix B)

System alternatives considered need to provide long term resolution to both of the criteria violations in order to be viable alternatives.

This study evaluated distribution only alternatives, including a new load serving substation, to correct the two circuits that exceed 6 MW.

INTRODUCTION

Harper Study Area

The Central Texas Electric Cooperative ("CTEC" or the "Cooperative") system study area under evaluation designated as the Harper area is located between the Harper, Texas to the east and Garvin Store, Texas to the South West. It is represented in Exhibit 1 – Harper Existing System, as the area on the southwest part of the system. The existing Harper Substation serves the entire area from north of the city of Harper extending to the southwest along Highway 41 to the North and South of Garvin Store. This feeder is the longest in the CTEC system measuring 41.5 miles from the substation to the end of the feeder.

Reliability issues are reasonable, with outage times averaging approximately 29.92 minutes per meter per year. See Appendix A, Exhibit 4. CTEC has continually upgraded this area with voltage conversions (12.5 KV to 24.9 KV), placing regulators and capacitors at strategic points, pole maintenance, and conductor upgrades.

The area is supplied by a single 69 KV transmission line providing power supply to the Harper and Doss substations, which serve a 12.5 KV and 24.9 KV distribution network comprised of 1,110 miles of distribution circuits.

Growth in Western Gillespie and Kerr county's has increased the electrical demand on the Harper substation, concentrated significant load on one distribution substation, representing approximately 13.3 MW of load during 2015 winter peak conditions, and thus provides exposure to a significant number of CTEC members to a single contingency transmission outage. This load is approximately 7.9% of CTEC's total winter peak load serving obligation. CTEC's peak load is expected to grow from 173 MW in 2016 to 196 MW in 2021 with the bulk of the growing load, approximately 8.3 MW, occurring in the Mountain Home area, which is a significant distance away from the Harper Substation and has no available source for backup with adequate capacity in the event of a power outage.

For a single contingency outage at the Harper substation, local critical assets such as the Harper K-12 Schools and the Harper VFD, would be subject to extended power outages. Prolonged electrical outages would also potentially have an impact on communication tower infrastructure, and economic impacts on local economy functions such as the bank, grocery and feed store, and the growing number of other small businesses servicing the Harper area.

System Planning - Background

CTEC engages in regular system planning studies in accordance with the RUS Guidelines. Although CTEC is no longer an RUS borrower, the Cooperative has committed to continuing to follow two RUS planning processes, (1) Construction Work Plans (Presently in the last year of the 2012-2016 Construction Work Plan), and (2) System Long Range Plan (Presently operating under the 2008 – 2027 System Long Range Plan.) The Construction Work Plans are prepared every 4-5 years and detail specific system improvements required to accomplish the Cooperative's reliability goals. The System Long Range Plan is a strategic document that covers a 20 year strategic system outlook and is a guide in making practical reliability and system development decisions in the interim periods based on load levels.

Both Cooperative system planning processes are prepared utilizing two sets of complementary planning criteria as the basis for engineering the system. First, the document in Appendix C – CTEC Distribution Planning Criteria represents the set of reliability guidelines that have been adopted by the Cooperative for use in making reliable distribution planning engineering decisions. Additionally, the Cooperative participates in a joint transmission planning process with its Transmission Operator – the Lower Colorado River Authority (the Lower Colorado River Authority Transmission Services Corporation "LCRA TSC") for planning necessary transmission and substation improvements as a result of the load growth and distribution planning needs of the Cooperative.

Through a contractual agreement with the LCRA TSC (the "Lease"), the collaborative process, which includes LCRA TSC and other distribution utilities participating in the Lease, seeks to develop system transmission and substation projects for the Central Texas Area to maintain acceptable levels of reliability, meet the growing needs of the system, and optimize engineering and operations expenses. The LCRA TSC Planning Criteria is included in Appendix B.

Planning Criteria Violations

The study discussion below and the alternative's developed is the result of CTEC's planning criteria violations that is the result of continued load growth in the area:

From the CTEC Distribution Planning Criteria:

> Section III, Paragraph C. To maintain adequate consumer reliability which meets or exceeds present levels, individual feeder loadings will be limited as follows: 6 MW for Transition I, 6 MW for Transition II and 7 MW for Transition III.

The application of this criteria to the electric system around the Harper area has precipitated the need for this alternative's study and will be the subject of the remaining discussion of the report.

Harper Area Existing Electric System Discussion

In the winter of 2020, the Harper and Doss substations, which are served by a radial transmission line, are forecast to experience a winter peak of 20,575 KW as shown in Appendix A, Table 1. This demand level violates the 20 MW rule criteria for exposure for a single contingency transmission event. In addition, in 2020, Harper Circuit 3-2 peaks at 6705KW and Circuit 3-3 peaks at 6389 KW, both exceeding the 6 MW per circuit CTEC Planning criteria limit. The CTEC distribution system peaks during the winter due to a preponderance of electric heating throughout the system. Options for transferring loads to other circuits are limited due to the rural nature of the area, with a significant distance between circuits. See Appendix A, Exhibit 1.

ALTERNATIVE ANALYSIS AND DISCUSSION

Alternative 1 - Distribution Only

Objective:

Evaluate a distribution only solution that would keep each circuit loading below the 6MW limit and Harper-Doss radial transmission line below the 20MW limit. A distribution only solution must involve use of new and existing tie lines to existing substations in order to reduce the radial Harper-Doss transmission line load below 20 MW, and achieve circuit loading of less than 6 MW without shifting these problems to other stations and circuits. Some of the 'Distribution Only' solutions require the use of double circuit lines to reduce the load on each distribution circuit.

Projects that call for double circuit lines use the same routes and poles. These projects only achieve a reduction in loading, and do not improve outage exposure because they fail to eliminate single points of failure.

The distribution only solution involves building two new feeder exits at the Harper Sub to relieve excessive load on Circuits 3-2 and 3-3 and a tie line in the Mountain Home area to move load from Harper to Ingram to free up capacity on the Harper-Doss Transmission line.
See Appendix A, Exhibit 2.

Alternative Description

A. Construct a new 24.9 KV circuit to split the existing Circuit 3-1 into an East bound circuit and the City of Harper circuit to the west, new Circuit 3-4. Appendix A, Exhibit 2 – (A)

B. Construct a 24.9 KV tie line to move load from Circuit 3-2 to the East bound part of Circuit 3-1. Exhibit 2 – (B)

C. Construct a 14.4 KV tie line to move load from Circuit 3-2 to the Harper City Circuit 3-4. Exhibit 2 – (C)

D. Construct a new 24.9 KV circuit and double circuit line to split the north part of Circuit 3-3 and west bound part, new Circuit 3-5, of the existing Circuit 3-3. Exhibit 2 – (D)

To reduce excessive loading on the Harper-Doss transmission line:

E. Install (3) 14.4 KV x 7.2 KV distribution type step down transformers between the Wolf Creek and Ingram stations to move load from Ingram Circuit 4-2 to Wolf Creek 19-3. Exhibit 2 – (E)

F. Construct a 24.9 KV .24 mile tie line and rebuild 7.6 miles of 14.4 KV single phase to 24.9 KV three phase, to move load from Harper Circuit 3-2 to Ingram Circuit 4-2. Exhibit 2 – (F).

Findings:

The proposed tie lines and new circuit exits will correct the excessive circuit loading on Harper Circuit 3-2 and Circuit 3-3 through 2034. The proposed load switching to Ingram will reduce the total load on the Harper-Doss transmission line to 18,657 kW in 2020, but the total projected load on this transmission line again exceeds 20 MW in 2023. This will defer additional necessary transmission improvements for only three years due to continued load growth. In addition, line losses in the study area are reduced in 2020 by 910 KW (3.13%) and to 611 KW (1.31%) in 2034.See Appendix A, Table 2.

No additional viable distribution construction options are available for reducing load on the Harper-Doss transmission line. Harper Circuit 3-2 extends to the southwest.

The territory to the north, south and west of the circuit are served by other electric cooperatives, so there is no option for load transfer. This is also true for the west bound part of Harper Circuit 3-3. The northbound part is bordered by the Doss Substation which is also fed by the Harper-Doss transmission line. The east bound part of Circuit 3-1 does connect to the western part of Live Oak Circuit 17-1, but any permanent load transfers to Live Oak forces Circuit 17-1 to prematurely exceed the 6 MW rule.

Alternative 2: Mountain Home Substation

Objective:

Evaluate a solution to the planning criteria violations that includes the construction of a new substation delivery point near Mountain Home to keep circuit loading below the 6MW limit. Please see Appendix A, Exhibits 3A and 3B.

Alternative Description:

The Mountain Home Substation Alternative will require the construction of 4 feeder exits, only one of which requires a tie line.

- Construct a new 24.9 kV load serving substation in the area from Thrill Hill Rd going west to the intersection of Hwy 41 and Hwy 27.
- Construct two circuits, F1 to the northeast and F2 to the southwest from the existing Harper Feeder 2.
- Construct a third circuit, F3 to the south from the existing Ingram Feeder 2
- Construct a fourth circuit, F4 with .5 mile of three phase, double circuit line to the west to tie into the existing Harper Circuit 3-3.
- Install (3) 14.4KV x 7.2 KV Step down transformers on F3 to move load from Ingram Circuit 4-2.

Findings:

Construction of the of the new Mountain Home substation provides a flexible long term solution for each of the planning rule violations. The results of the load switching are shown in the Appendix A, Table 3.

As shown in Table 3, the Harper-Doss transmission loading will stay below 20 MW until 2033. Harper Circuits 3-2 and 3-3 will also stay below 6 MW beyond 2034. The Mountain Home Substation will provide distribution backup to Harper Circuits 3-2 and 3-3, and also Ingram Circuit 4-2. In addition, losses in the study area in 2020 are reduced by 1,024 KW (4.07%) and 1,758 KW (4.30%) in 2034.

Finally, the distribution backup flexibility Alternative 2 provides and the load reduction on the Harper and Ingram distribution circuits result in a preference for Alternative 2 over Alternative 1.

CONCLUSION

This study evaluated two alternatives to address system load growth southwest of Harper, Texas. The load growth and the location of the developing load will exceed the existing system's capacity according to two reliability planning criteria: (1) no more than 20 MW of load interrupted for a single contingency transmission event, and (2) limit circuit loading to less than 6 MW.

Utilizing existing system substations with new distribution circuits, as outlined in Alternative 1, resolves the circuit loading issue but fails to solve the Harper-Doss transmission loading for more than three years.

The Mountain Home substation alternative provides a long term solution to the system growth and reliability needs of CTEC. The Mountain Home substation alternative provides the circuit loading solutions that meet the CTEC reliability planning criteria, provides flexibility for distribution operations, substantially reduces line losses, and also keeps the Harper-Doss transmission line loading below the target 20 MW level until 2031. Based on the study results, the Mountain Home Substation (Alternative 2) is recommended.

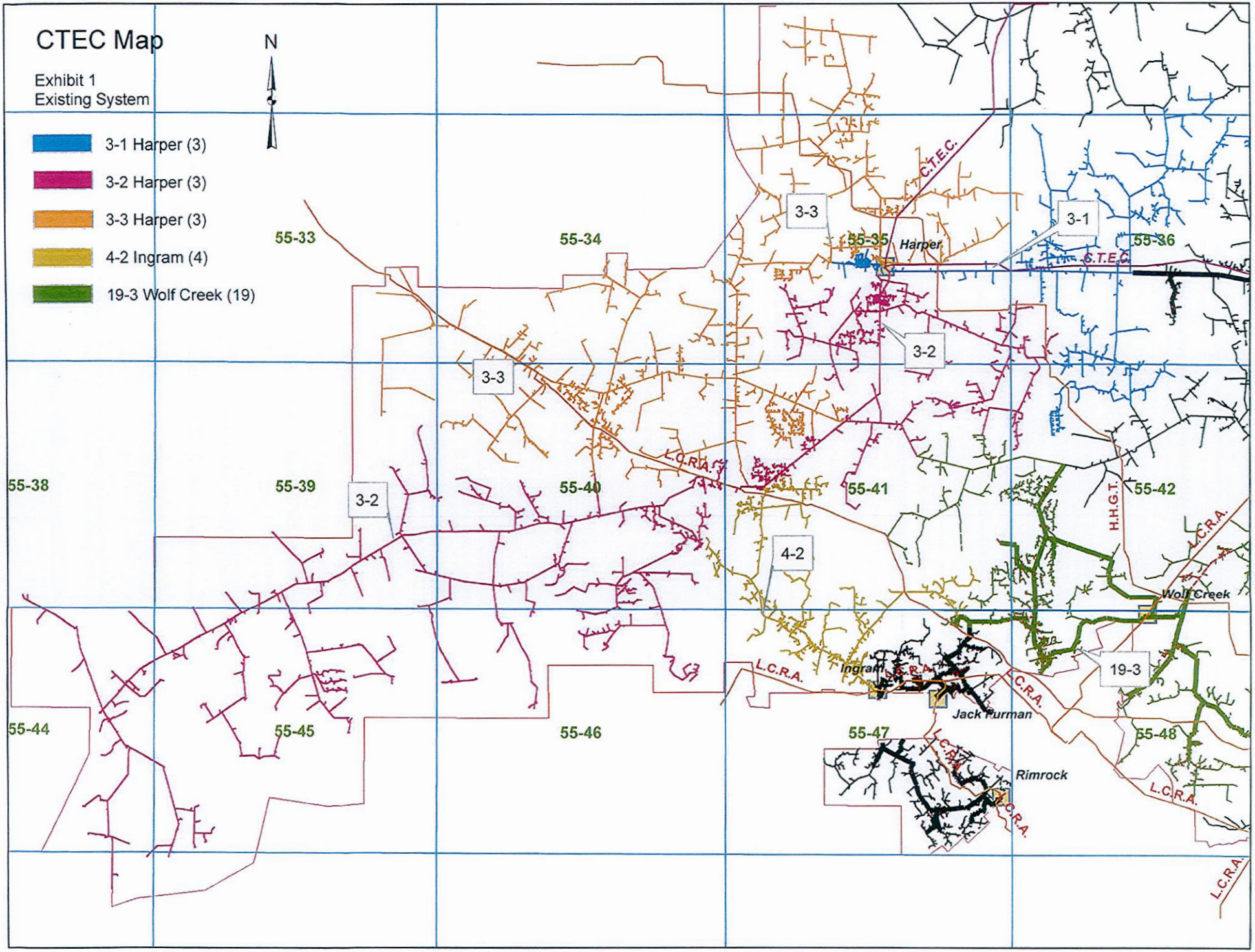
Appendix A

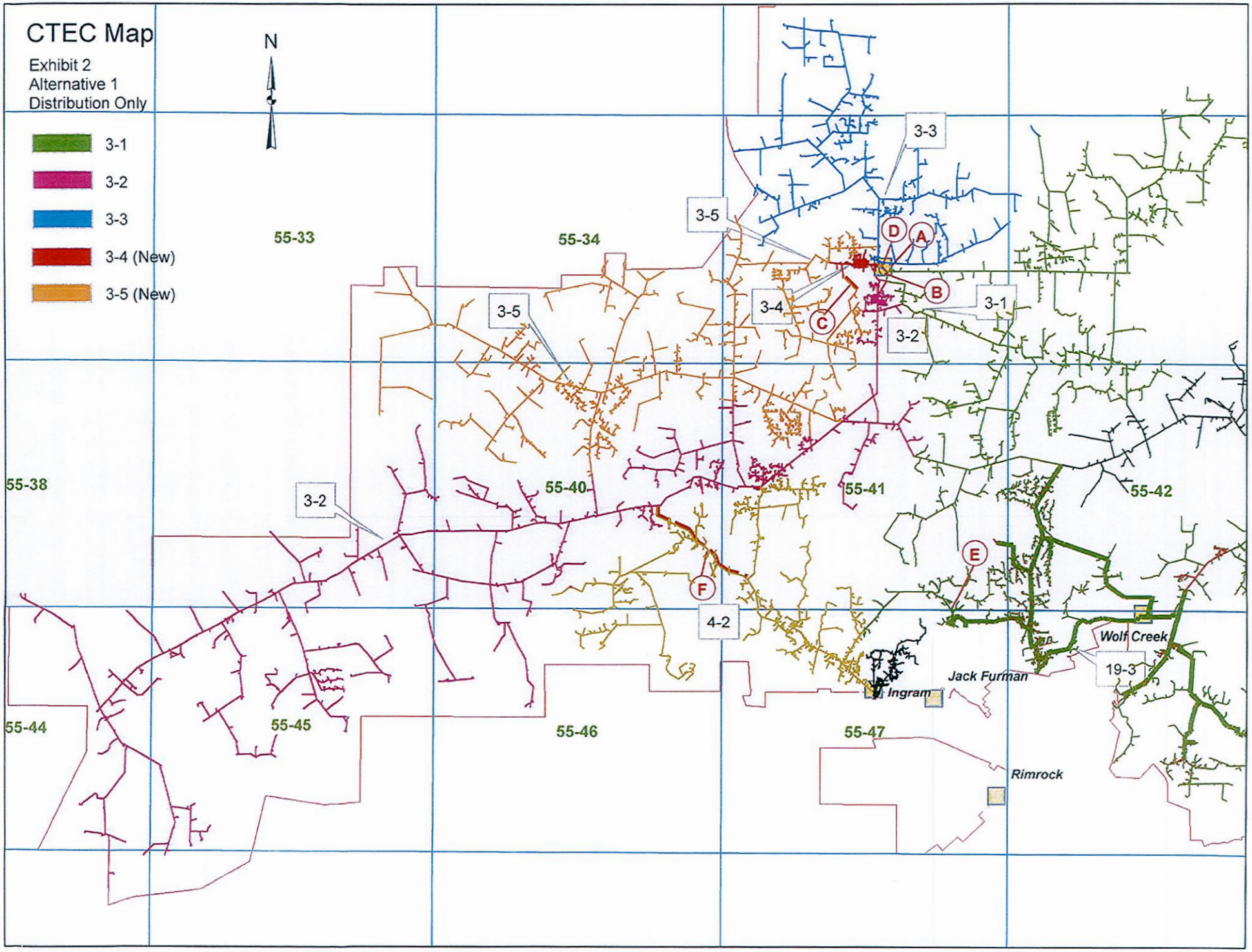
Load Tables and Exhibits

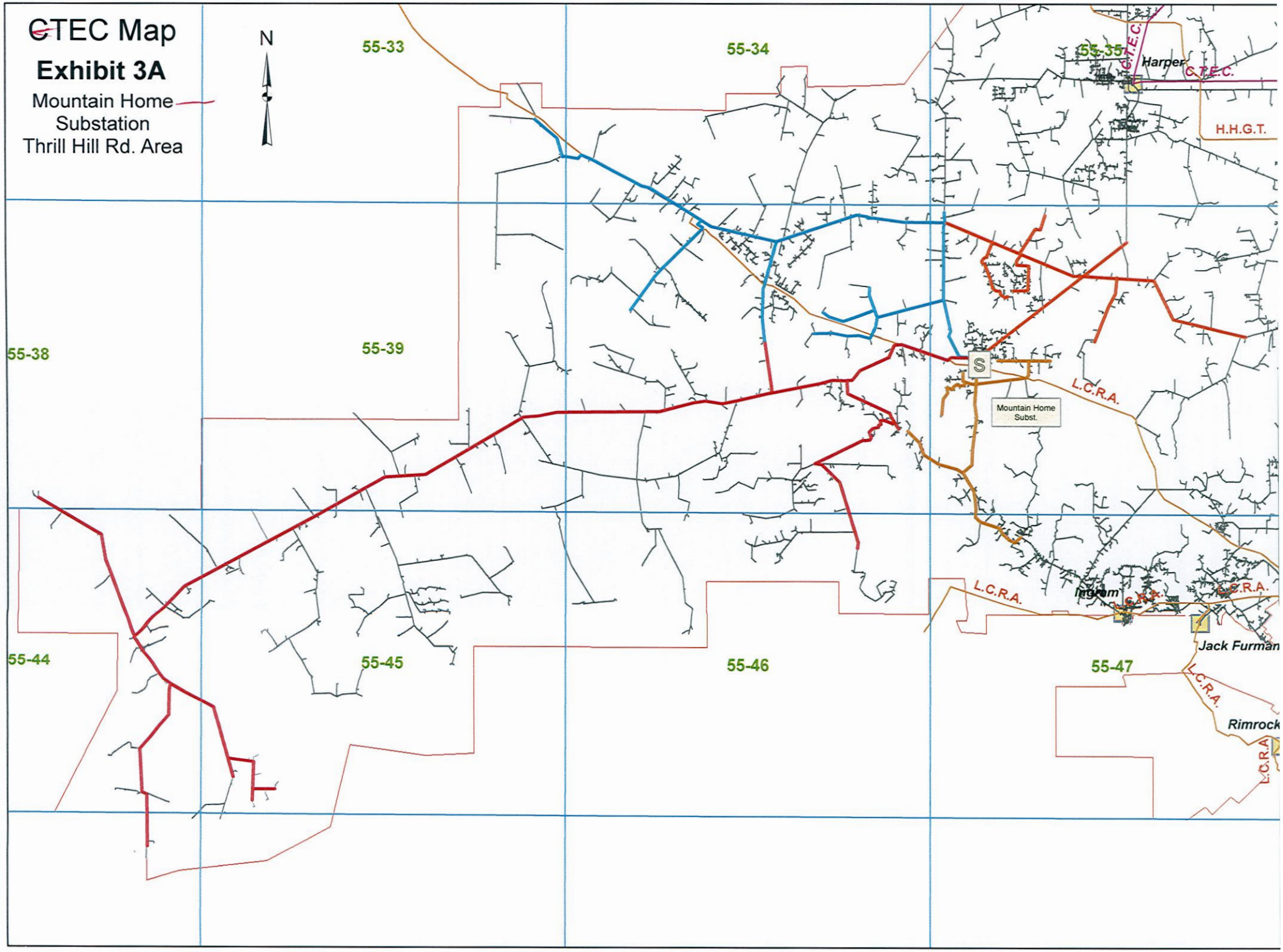
TABLE 1 EXISTING SYSTEM PROJECTIONS												
		Winter		PROJECTED ----------								PROJECTED
	Winter	2014-2015 peak	Feeder %	2015-2016	2016-2017	2019-2020	2020-2021	2023-2024	2026-2027	2029-2030	2030-2031	2034-2035
		3/5/2015										
Harper T1 Peak	3 T1	8019		8339	8671	9750	10138	11400	12818	14413	14987	17523
Feeder 3-1 Peak	3-1	3035	37.0%	3084	3207	3606	3750	4216	4741	5331	5543	6481
Feeder 3-3 Peak	3-3	5171	63.0%	5255	5464	6144	6389	7184	8077	9082	9444	11042
Feeder 1&2 Peak Total		8206										
		3/6/2015										
Harper T2 Peak	3 T2	5329		6100	6216	6579	6705	7096	7511	7949	8101	8737
Feeder 3-2 Peak	3-2	5448										
				14439	14887	16329	16843	18496	20329	22362	23088	26261
Doss T1 Peak	20 T1	3231		3100	3217	3596	3732	4171	4662	5210	5407	6272
LO to Hrpr to Doss 69 KV Total				**17539**	**18105**	**19925**	**20575**	**22667**	**24990**	**27572**	**28495**	**32532**
		3/6/2015										
IngramT1 CTEC Peak	4 T1	5429		5664	5910	6712	7003	7953	9032	10258	10702	12681
Feeder 4-1 Peak	4-1	1875	34.2%	1936	2020	2294	2394	2719	3088	3507	3658	4335
Feeder 4-2 Peak	4-2	3610	65.8%	3728	3890	4417	4609	5234	5945	6751	7044	8346
Feeder 1&2 Peak Total		5485										
		3/6/2015										
Liveoak T1 Peak	17 T1	9011		9203	9399	10013	10226	10894	11606	12363	12627	13738
Feeder 17-1 Peak	17-1	4251	45.8%	4211	4301	4582	4679	4985	5311	5657	5778	6286
Feeder 17-2 Peak	17-2	5039	54.2%	4992	5098	5431	5547	5909	6295	6706	6849	7452
Feeder 1&2 Peak Total		9290										
		3/6/2015										
Wolf Creek T1 Peak	19 T1	12621		12953	13292	14365	14741	15931	17216	18605	19093	21174
Feeder 19-1 Peak	19-1	5575	43.8%	5669	5818	6287	6452	6972	7535	8143	8356	9267
Feeder 19-2 Peak	19-2	3783	29.7%	3847	3948	4266	4378	4731	5113	5526	5670	6288
Feeder 19-3 Peak	19-3	3380	26.5%	3437	3527	3812	3912	4227	4568	4937	5066	5619
Feeder 1, 2, & 3 Peak Total		12738										

TABLE 2											
ALTERNATIVE 1											
DISTRIBUTION ONLY IMPROVEMENTS											
		Winter	2015-2016	2016-2017	2019-2020	2020-2021	2023-2024	2026-2027	2029-2030	2030-2031	2034-2035
Extg	3-1		3084	3207	3606	3750	4216	4741	5331	5543	6481
W/LS	3-1		3084	3207	3606	3250	3654	4109	4620	4804	5617
						(500)	(562)	(632)	(710)	(739)	(864)
Extg	3-2		6100	6216	6579	6705	7096	7511	7949	8101	8737
W/LS	3-2		6100	6216	6579	3877	4103	4343	4596	4684	5052
3-2 transfers load to 3-1, 3-4, and 4-2						(2828)	(2993)	(3168)	(3353)	(3417)	(3685)
Extg	3-3		5255	5464	6144	6389	7184	8077	9082	9444	11042
W/LS	3-3		5255	5464	6144	1576	1772	1993	2240	2330	2724
3-3 transfers load to 3-5						(4813)	(5411)	(6085)	(6842)	(7114)	(8318)
New	3-4					2016	2267	2549	2866	2980	3484
3-4 gains load from 3-1 and 3-2											
New	3-5					4206	4729	5318	5979	6218	7270
3-5 gains load from 3-3											
Doss	20-T1		3100	3217	3596	3732	4171	4662	5210	5407	6272
LO-Hrpr-Doss 69 KV		Extg	17539	18105	19925	20575	22667	24990	27572	28495	32532
LO-Hrpr-Doss 69 KV		W/LS				18657	20697	22972	25512	26423	30419
						(1918)	(1970)	(2018)	(2060)	(2072)	(2113)
Extg	4-2		3728	3890	4417	4609	5234	5945	6751	7044	8346
W/LS	4-2		3728	3890	4417	4751	5396	6128	6960	7261	8604
4-2 transfers load to 19-3 and gains load from 3-2						142	162	183	208	217	258
Extg	19-3		3437	3527	3812	3912	4227	4568	4937	5066	5619
W/LS	19-3		3437	3527	3812	4778	5164	5580	6030	6188	6863
19-3 gains load from 4-2						866	936	1012	1094	1122	1245
Total Load Summary-Existing			24704	25521	28154	29095	32128	35503	39260	40605	46497
Loss Reduction						910	872	822	758	732	611
Loss Reduction %						3.13	2.72	2.32	1.93	1.80	1.31
Alternative 1 Load Summary			24704	25521	28154	28186	31256	34681	38502	39873	45886
	--Planning criteria violations										

Table 3												
Alternative 2												
Moutain Home Substation.												
		Winter	2015-2016	2016-2017	2019-2020	2020-2021	2023-2024	2026-2027	2029-2030	2030-2031	2033-2034	2034-2035
Extg	3-1		3084	3207	3606	3750	4216	4741	5331	5543	6233	6481
Extg	3-2		6100	6216	6579	6705	7096	7511	7949	8101	8573	8737
W/LS	3-2		6100	6216	6579	3055	3232	3420	3619	3688	3906	3981
3-2 transfers to 25-1 & 25-3						(3650)	(3864)	(4090)	(4330)	(4413)	(4667)	(4756)
Extg	3-3		5255	5464	6144	6389	7184	8077	9082	9444	10619	11042
W/LS	3-3		5255	5464	6144	2498	2809	3158	3551	3693	4152	4318
3-3 transfers to 25-1 & 25-4						(3891)	(4375)	(4919)	(5531)	(5751)	(6467)	(6725)
Extg	20-T1		3100	3217	3596	3732	4171	4662	5210	5407	6042	6270
Extg	**LO to Hrpr to Doss 69 KV Total**		**17539**	**18105**	**19925**	**20575**	**22667**	**24990**	**27572**	**28495**	**31467**	**32530**
W/LS	**LO to Hrpr to Doss 69 KV Total**		**17539**	**18105**	**19925**	**13035**	**14428**	**15981**	**17711**	**18330**	**20333**	**21049**
Extg			3100	3217	3596	4609	5234	5945	6751	7044	8000	8346
W/LS	4-2		3100	3217	3596	2759	3134	3560	4044	4219	4789	4996
4-2 transfers to 25-2						(1850)	(2100)	(2384)	(2707)	(2824)	(3211)	(3350)
Mt Home	25-1					1586	1745	1920	2113	2181	2400	2478
25-1 gains load from 3-2 and 3-3												
Mt Home	25-2					1670	1897	2154	2446	2552	2899	3024
25-2 Gains load from 4-2												
Mt Home	25-3					2967	3140	3323	3517	3585	3794	3866
25-3 gains load from 3-2												
Mt Home	25-4					2143	2410	2709	3046	3168	3562	3704
25-4 Gains load from 3-3												
Total Load Summary -- Existing			**20639**	**21322**	**23521**	**25184**	**27901**	**30935**	**34323**	**35539**	**39467**	**40877**
Loss Reduction						**1024**	**1147**	**1287**	**1445**	**1503**	**1690**	**1758**
Loss Reduction %						**4.07**	**4.11**	**4.16**	**4.21**	**4.23**	**4.28**	**4.30**
Mtn. Home Alternative Summary			**20639**	**21322**	**23521**	**24160**	**26754**	**29648**	**32878**	**34036**	**37777**	**39118**


CTEC Map
Exhibit 1
Existing System
N
3-1 Harper (3)
3-2 Harper (3)
3-3 Harper (3)
4-2 Ingram (4)
19-3 Wolf Creek (19)
55-33
55-34
55-35
55-36
55-38
55-39
55-40
55-41
55-42
55-44
55-45
55-46
55-47
55-48
3-1
3-2
3-3
4-2
19-3
Harper
Ingram
Jack Furman
Rimrock
Wolf Creek
C.T.E.C.
L.C.R.A.
H.H.G.T.


CTEC Map
Exhibit 2
Alternative 1
Distribution Only
N
3-1
3-2
3-3
3-4 (New)
3-5 (New)
55-33
55-34
55-38
55-40
55-41
55-42
55-44
55-45
55-46
55-47
3-3
3-5
3-5
3-4
3-1
3-2
3-2
4-2
19-3
A
B
C
D
E
F
Wolf Creek
Jack Furman
Ingram
Rimrock


CTEC Map
Exhibit 3A
Mountain Home Substation
Thrill Hill Rd. Area
N
55-33
55-34
55-35
55-38
55-39
55-44
55-45
55-46
55-47
C.T.E.C.
Harper
H.H.G.T.
S
Mountain Home Subst.
L.C.R.A.
Ingram
Jack Furman
Rimrock

CTEC Map

Exhibit 3B

Mountain Home Substation
Hwy 41 & Hwy 27 Area

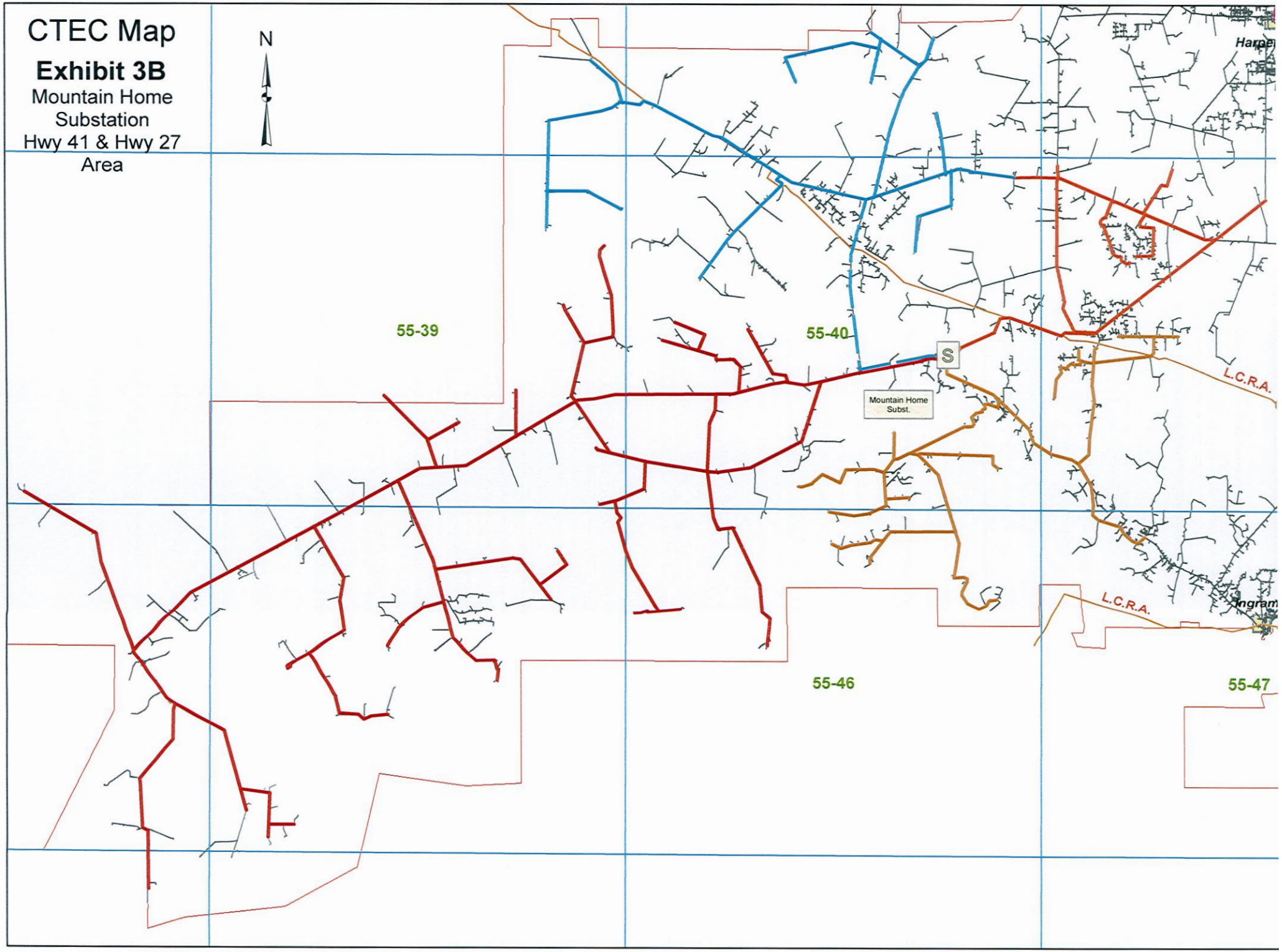


EXHIBIT 4

OUTAGE HISTORY -- HARPER SUB AND CIRCUIT'S 3-2, 3-3

Note: There were no substation or substation transformer outages at Harper Substation from 2010 through 2015.

Year	Total Meters Served	Circuit 3-2		Circuit 3-2		
		Meters Out	Minutes Out	SAIDI	SAIFI	CAIDI
2010	1404	151	14,280	10.17	0.11	95
2011	1418	230	36,660	25.85	0.16	159
2012	1442	1514	150,840	104.60	1.05	100
2013	1453	185	23,280	16.02	0.12	126
2014	1479	124	13,140	8.88	0.08	106
2015	1501	148	22,020	14.67	0.1	149
TOTAL	8697	2352	260,220	29.92	0.27	111

Year	Total Meters Served	Circuit 3-3		Circuit 3-3		
		Meters Out	Minutes Out	SAIDI	SAIFI	CAIDI
2010	997	91	11,460	11.49	0.09	126
2011	1013	107	10,620	10.48	0.11	99
2012	1027	65	5,760	5.61	0.06	89
2013	1055	160	20,940	19.85	0.15	131
2014	1095	150	18,720	17.10	0.14	125
2015	1124	200	34,860	31.01	0.18	174
TOTAL	6311	773	102,360	16.22	0.12	132

Appendix B

LCRA TSC Planning Criteria

Lower Colorado River Authority & Association of Wholesale Customers
TRANSMISSION SYSTEM PLANNING CRITERIA

Original Publication Approved on 01/27/1998
Revision A Approved on 08/24/1999 – Revised Section III.B. System Reliability
Revision B Approved on 10/26/1999 – Revised Section II. Add Table 1
Revision C Approved on 08/27/2002 – Revised Section I –Substation Bus Design Criteria
Revision D Approved 10/17/2005 – Revised Sections E and F

Lower Colorado River Authority & Association of Wholesale Customers
TRANSMISSION SYSTEM PLANNING CRITERIA

I. INTRODUCTION

The Lower Colorado River Authority (LCRA) and the Association of Wholesale Customers (AWC) have adopted this document as the criteria used to maintain an acceptable level of transmission reliability during normal or contingency conditions. The planning criteria are in compliance with Electric Reliability Council of Texas (ERCOT) and North American Electric Reliability Council (NERC) recommended transmission system planning guidelines.

II. STANDARDS

A. Normal Condition

Normal conditions are defined as the state of the power system before any planned or unplanned outage. There are no contingencies assumed for normal conditions. Normal system conditions shall not include the generating capacity of any hydro units within the LCRA control area. During normal conditions, all system equipment limits or impacts shall be within the applicable ratings as defined in Section III of this document.

B. Single Contingency Condition

Single contingency conditions shall include the planned or unplanned outage of one transmission element or generation unit. During single contingency conditions, all system equipment limits or impacts shall be within the applicable ratings as defined in Section III of this document. Single contingency (category B) conditions are summarized in Table 1.

C. Multiple Contingency Condition

Multiple contingency conditions shall include the planned or unplanned outage of multiple transmission elements or generation units. During multiple contingency conditions, all system equipment limits or impacts shall be within the applicable ratings as defined in Section III of this document. The multiple contingency (category C) conditions are summarized in Table 1.

D. Extreme Contingency Conditions

In addition to the normal, single, and multiple contingency condition tests described above and detailed in Table 1, extreme (category D) conditions will also be conducted to ensure that the planned system conforms to the following additional requirements:

1. The contingency loss of a multiple circuit transmission line that is equal to or greater than 0.5 miles in length (either without a fault or subsequent to a normally-cleared non-three-phase fault) with all other facilities normal should not cause a) cascading or uncontrolled outages, b) instability of generating units at multiple plant locations, or c) interruption of service to firm demand or generation other than that isolated by the double-circuit loss, following the execution of all automatic operating actions such as relaying and special protection systems. Furthermore, the loss should result in no damage to or failure of equipment and, following the execution of specific non-automatic predefined operator-directed actions such as re-dispatch, curtailment of interruptible load, or curtailment of unplanned transfers, should not result in applicable voltage or thermal ratings being exceeded.

2. The contingency loss of multiple transmission lines within a common corridor that is equal to or greater than 0.5 miles in length (either without a fault or subsequent to a normally-cleared non-three-phase fault) with all other facilities normal should not cause a) cascading or uncontrolled outages, b) instability of generating units at multiple plant locations, or c) interruption of service to firm demand or generation other than that isolated by the loss of the common corridor, following the execution of all automatic operating actions such as relaying and special protection systems. Furthermore, the loss should result in no damage to or failure of equipment and, following the execution of specific non-automatic predefined operator-directed actions such as re-dispatch, curtailment of interruptible load, or curtailment of unplanned transfers, should not result in applicable voltage or thermal ratings being exceeded. Transmission lines are defined to be within a common corridor if said lines are located in close proximity to each other such that catastrophic failure of one line could cause an outage or failure of another.

Lower Colorado River Authority & Association of Wholesale Customers
TRANSMISSION SYSTEM PLANNING CRITERIA

Table I. Transmission Systems Standards — Normal and Contingency Conditions

Category	Contingencies		System Limits or Impacts				
	Initiating Event(s) and Contingency Component(s)	Components Out of Service	Thermal Limits	Voltage Limits	System Stable	Loss of Demand or Curtailed Firm Transfers	Cascading Outages
A – No Contingencies	All Facilities in Service	None	Normal	Normal	Yes	No	No
B – Event resulting in the loss of a single component.	Single Line Ground (SLG) or 3-Phase (3Ø) Fault, with Normal Clearing: 1. Generator 2. Transmission Circuit 3. Transformer Loss of a Component without a Fault.	Single Single Single Single	Applicable Rating [a] (A/R) A/R A/R A/R	Applicable Rating [a] (A/R) A/R A/R A/R	Yes Yes Yes Yes	No [b] No [b] No [b] No [b]	No No No No
C – Event(s) resulting in the loss of two or more (multiple) components.	SLG Fault, with Normal Clearing: 1. Bus Section 2. Breaker (failure or internal fault)	Multiple Multiple	A/R A/R	A/R A/R	Yes Yes	Planned [d] Planned [d]	No No
	SLG or 3Ø Fault, with Normal Clearing, Manual System Adjustments, followed by another SLG or 3Ø Fault, with Normal Clearing: 3. Category B (B1, B2, B3, or B4) contingency, manual system adjustments, followed by another Category B (B1, B2, B3, or B4) contingency	Multiple	A/R	A/R	Yes	Planned [d]	No
	Fault (non 3Ø), with Normal Clearing: 4. Double Circuit Towerline	Multiple	A/R	A/R	Yes	Planned [d]	No
	SLG Fault, with Delayed Clearing: 5. Generator 6. Transmission Circuit 7. Transformer 8. Bus Section	Multiple Multiple	A/R A/R	A/R A/R	Yes Yes	Planned [d] Planned [d]	No No

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D [e] – Extreme event resulting in two or more (multiple) components removed or cascading out of service	3Ø Fault, with Delayed Clearing (stuck breaker or protection system failure): 1. Generator 2. Transmission Circuit 3. Transformer 4. Bus Section 3Ø Fault, with Normal Clearing: 5. Breaker (failure or internal fault) Other: 6. Loss of two circuits with three or more circuits 7. All transmission lines on a common right-of-way 8. Loss of a substation (one voltage level plus transformers) 9. Loss of a switching station (one voltage level plus transformers) 10. Loss of all generating units at a station 11. Loss of a large load or major load center 12. Failure of a fully redundant special protection system (or remedial action scheme) to operate when required 13. Operation, partial operation, or misoperation of a fully redundant special protection system (or remedial action scheme) for an event or condition for which it was not intended to operate 14. Impact of severe power swings or oscillations from disturbances in another Regional Council.	Evaluate for risks and consequences. • May involve substantial loss of customer demand and generation in a widespread area or areas. • Portions or all of the interconnected systems may or may not achieve a new, stable operating point. • Evaluation of these events may require joint studies with neighboring systems. • Document measures or procedures to mitigate the extent and effects of such events. • Mitigation or elimination of the risks and consequences of these events shall be at the discretion of the entities responsible for the reliability of the interconnected transmission systems.

Footnotes to Table 1.

a) Applicable rating (A/R) refers to the applicable normal and emergency facility thermal rating or system voltage limit as determined and consistently applied by the system or facility owner.

b) Planned or controlled interruption of generators or electric supply to radial customers or some local network customers, connected to or supplied by the faulted component or by the affected area, may occur in certain areas without impacting the overall security of the interconnected transmission systems. To prepare for the next contingency, system adjustments are permitted, including curtailments of contracted firm (non-recallable reserved) electric power transfers.

c) Cascading is the uncontrolled successive loss of system elements triggered by an incident at any location. Cascading results in widespread service interruption which cannot be restrained from sequentially spreading beyond an area predetermined by appropriate studies.

d) Depending on system design and expected system impacts, the controlled interruption of electric supply to customers (load shedding), the planned removal from service of certain generators, or the curtailment of contracted firm (non-recallable reserved) electric power transfers may be necessary to maintain the overall security of the interconnected transmission systems.

e) A number of extreme contingencies that are listed under Category D and judged to be critical by the transmission planning entity(ies) will be selected for evaluation. It is not expected that all possible facility outages under each listed contingency of Category D will be evaluated.

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TRANSMISSION SYSTEM PLANNING CRITERIA

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III. APPLICABLE RATINGS

A. SYSTEM BUS VOLTAGE

The LCRA and AWC transmission system is operated at nominal voltage levels of 345 kilovolts (kV), 138 kV, and 69 kV. The transmission system voltages shall not exceed 105 percent nor fall below 95 percent of nominal voltage during normal conditions (category A). The transmission system voltages shall not exceed 105 percent nor fall below 92 percent of nominal voltage during single, multiple, or extreme contingency conditions (category B, C and D). No single anticipated event shall result in more than a 7 percent voltage swing for three or more substations.

B. SYSTEM RELIABILITY

No more than twenty (20) megawatts (MW) of peak load shall be interrupted for a single anticipated event, except when the single anticipated event is the failure of a single power transformer with a peak load of greater than 20 MW.

1. Reliability to radially supplied station(s), exceeding 20 MW of peak load, shall be addressed by the most technically and economically feasible of the alternatives described below.

    a. Looped transmission service to the radial station may be provided by a separate transmission circuit configuration (separate transmission towers).

    b. Looped transmission service to the radial station may be provided by a double circuit transmission configuration (same transmission towers) from the same source or from multiple sources. If the looped transmission service is from the same source, the transmission source bus must be of a multiple bus construction, and the double circuit to the radial station is terminated on separate buses. Additionally, distribution back-up to support the double circuit supplied station load requirements must be provided. The source(s) of distribution back-up must have the available capacity to support the entire station load without violating emergency loading and voltage levels of the Distribution Planning Criteria. This alternative must include the cost required to limit emergency loading and voltage conditions to within 8 hours.

    c. Limit a radial station load to 20 MW and provide the added capacity requirements from available area stations.

2. Station(s) with looped transmission service, whose peak load exceeds 20 MW, shall be identified as requiring circuit breakers such that the single total interrupted load is 20 MW or less.

3. Any distribution voltage bus that experiences six outages per year or multiple outages totaling more than five hours per year due to failures on the transmission system shall be deemed to have inadequate reliability.

C. CONDUCTOR RATINGS

Planned transmission line loading will be such that National Electrical Safety Code line-to-ground clearances will be maintained for all anticipated normal and contingency conditions (category A, B, C and D). Transmission system power flow shall not exceed 100 percent of the conductor thermal rating.

Conductor thermal ratings are assigned for commonly used transmission conductors as shown in Table 2 below. These conductor ratings are based upon a 93.33° C (200° F) average conductor temperature using coefficients of emissivity and absorptivity of 0.5, a 40.55° C (105° F) ambient temperature, an elevation of 600 feet above sea level, north-south line orientation, 30 degree latitude, 2:00 PM solar conditions, clear atmosphere, and a wind velocity of 2 feet per second normal to the conductor.

TABLE 2 – TYPICAL CONDUCTOR THERMAL RATINGS

Conductor Size	Conductor Ampacity	MVA Rating (69 kV)	MVA Rating (138 kV)	MVA Rating (345 kV)
1/O ACSR	256	31	not used	not used
4/O ACSR	396	47	95	not used
336 ACSR	534	64	128	not used
336x2 ACSR	1068	128	255	not used
477 ACSR	666	81	159	not used
795 ACSR	920	110	220	not used
795x2 ACSR	1840	220	440	1099

1192.5 ACSR	1168	140	279	not used

D. AUTOTRANSFORMER RATINGS

Planned loading on autotransformers, during normal, single, or multiple contingency conditions (category A, B, C, or D) shall be limited to 100 percent of the auto-transformer's maximum megavoltampere (MVA) rating as specified by the manufacturer.

E. STATION EQUIPMENT RATINGS

The criteria for determining the required performance related to station equipment is provided below. At ERCOT's direction and driven by potential congestion, station equipment upgrades may be necessary for performance above and beyond what is required in this criteria.

1. During any new transmission line project, all station equipment related to that line will be designed such that the continuous rating of all station equipment is greater than or equal to the continuous rating of the new line. During any transmission line upgrade project, station equipment related to that line will be upgraded as necessary such that the continuous rating of all station equipment allows for operating conditions described in 2 and 3 below.

2. Station equipment (circuit breakers, circuit switches, wave traps, jumpers, connectors, current transformers, relays, relay settings, etc.) connected in series with the conductor shall be upgraded (independent of a conductor upgrade) if either of the following two conditions are met:

   a. The continuous rating of the station equipment is less than or equal to 50 percent of the continuous rating of the conductor; or

   b. The loading through the station equipment during either Category A or Category B conditions is greater than or equal to 80 percent of the continuous rating of the station equipment.

3. Interrupting duty of station equipment switching devices (circuit breakers and circuit switchers) shall be planned as follows:

   a. The interrupting rating of circuit breakers shall be at least 120 percent of the maximum available close-in fault at the point of application.

b. The interrupting rating of circuit switchers shall be at least 110 percent of the maximum available close-in fault at the point of application.

F. SUBSTATION BUS DESIGN CRITERIA

New Substation Consideration

The ultimate layout for all new 345-kV stations shall be of the ring type, breaker-and-a-half type, or double bus-double breaker type ("improved bus arrangement").

The ultimate layout for all new 138-kV and 69-kV switching stations (i.e. stations with more than two circuits) should allow for an improved bus arrangement where possible.

The type of improved bus arrangement shall be consistent with ultimate plans or potential growth of the substation. The table below lists the accepted improved bus arrangements based on the number of transmission elements connected to the substation. The most cost-effective improved bus arrangement shall be selected.

Transmission Elements*	Accepted Improved Bus Arrangements
Up to Five	1) Ring Bus, 2) Double Bus Double Breaker, or 3) Breaker-and-a-Half
Six-Nine	1) Double Bus Double Breaker, or 2) Breaker-and-a-Half
Ten and Larger	1) Breaker-and-a-Half

*Transmission elements include capacitor banks, generators, lines, and autotransformers.

Improved bus arrangements are required for 138-kV and 69-kV substations meeting the following considerations:

a. Transmission System Considerations

1) The substation includes known plans or has a potential for more than two transmission elements to originate at the substation bus.

2) The substation is located in high load growth or alternative generation corridor.

3) The loss of the entire substation bus causes other elements in the system to reach loading levels above 90 percent of their maximum thermal capacity.

4) The loss of the entire substation bus causes system voltage to fall below acceptable defined limits.

b. Load Considerations

1) Substation includes multiple power transformers totaling more than 60 MW of capacity and without adequate transformer back-up.

2) The loss of the entire substation bus causes outages at multiple substations (substation bus is the only source to radial supplied substation serving more than 10 MW).

Existing Substation Consideration

This design guideline, incorporated into this planning criteria on August 2002, addresses all new projects. For systems existing or under development prior to this date, substation bus requirements shall be reviewed on a case by case basis to establish the need for a more reliable bus arrangement.

As major projects are identified through the annual planning process, consideration to items b) 1 and b) 2 above will dictate the need for retrofitting an existing substation to an improved bus arrangement (e.g. when items a) 1-4 above do not by themselves demonstrate the need). However, feasibility and cost to implement solutions that include improved bus designs shall be a factor in making this determination.

If substation property constraints and associated costs prohibit the expansion of an existing substation to one of an improved bus arrangement, a single bus-single breaker design may be acceptable. However, relocation to another substation site should be considered.

Appendix C

CTEC Planning Criteria

SYSTEM PLANNING CRITERIA

The system planning criteria used in the preparation of the Long Range Plan is based upon CTEC, RUS and ERCOT system planning guidelines. A great deal of emphasis is placed on obtaining an accurate existing system data base on which to base the engineering analysis and system improvement recommendations. Once an accurate system data base has been obtained, a detailed engineering analysis is made of the existing system to determine the system improvements needed to maintain reliable and economic service during the Long Range Plan period. The system improvements recommended are based on the existing system needs with a view towards long range system objectives. Following is a description of the planning criteria used in the preparation of this system planning document.

I. Transmission Planning Criteria

A. Transmission voltages shall be maintained between 105% and 95% of nominal operating voltages for normal operating conditions and at 92% or above during contingency situations involving loss of a transmission facility.

B. Transmission facility loadings will be limited to 85% of the facility MVA ratings for normal operating conditions and 90% for contingency situations. The 15% and 10% margins are used to compensate for weather extremes and lead times associated with transmission system facility upgrades.

C. Fault currents do not exceed 85% of transmission system protective device interrupting ratings.

D. Transmission system power factors maintained between 1.05 and .95 during peak load conditions.

E. No more than 20 MW of peak load shall be interrupted for a single anticipated or unanticipated event to include loss of transmission line, circuit breaker, station bus, etc. Radial stations with more than 20 MW of peak load shall be identified as requiring looped transmission service.

When these transmission planning criteria are not met, an analysis is made to determine the need for transmission system facility upgrades to include:

1. Conversion of existing transmission lines to higher operating voltages and/or larger conductors.

2. Upgrade equipment ratings.

3. Construct new transmission facilities.

II. Substation Planning Criteria

A. Power transformers will be loaded to 85% of their Summer and Winter Normal

MVA Ratings for normal operating conditions. See the Power Transformer Loading Levels table included as page 5-2-5 of this section. An 85% loading criteria is used to compensate for extreme weather conditions and lead times associated with procuring new power transformers.

B. Substations will be expanded to an ultimate 20 MVA power transformer capacity during the planning period. The following substations will be limited to an ultimate of one 20 MVA power transformer during the planning period:

- Ingram (4)
- Rim Rock (11)
- Fredonia (13)
- Streeter (15)

C. Voltage regulators will be loaded to 85% of their MVA rating. The 15% margin is used to compensate for weather extremes and phase unbalance.

D. Hydraulic oil filled reclosers will be loaded to 70% of their continuous current ratings. Electronic reclosers will be loaded to 70% of their continuous current rating.

E. Fault currents do not exceed 85% of interrupting rating of substation protective devices.

When these substation planning criteria are not met, an analysis is made to determine the need for substation system facility upgrades to include:

1. Switching load to adjacent substation areas to relieve facility loading problems.

2. Upgrade equipment ratings.

3. Construct new substation.

III. Distribution System Planning Criteria

A. Single phase distribution voltages on a 120 volt base will be maintained between 126 volts and 118 volts. Three phase main line voltages on a 120 volt base will be maintained between 126 volts and 120 volts.

B. A conductor loading level of 60% of Maximum Ratings will be used as general guideline for optimum conductor loading. See the Conductor Loading Ampacity Levels table included as page 5-2-6 of this section.

C. To maintain adequate consumer reliability which meets or exceeds present levels, individual feeder loadings will be limited as follows: 6,000 kW for Transition I, 6,000 kW for Transition II and 7,000 for Transition III.

D. To allow for proper sectionalizing and phase balance, single phase distribution lines will, in general, be limited to 35 amps.

E. Substations will be expanded to a with additional distribution feeders as needed, with the following feeder quantity limits:

- Ingram (2 feeder max)
- Pitsburg (5 feeder max)
- Rim Rock (2 feeder max)

F. New three-phase lines or three-phase rebuilds will use only 1/0 ACSR or 336.4 MCM ACSR conductors (see Economic Conductor Loading, Exploratory Plan section).

G. New single phase lines or single phase rebuilds will use only #4 ACSR or 1/0 ACSR conductors (see Economic Conductor Loading, Exploratory Plan section),

H. Line equipment loadings, including voltage regulators and step down transformers, will be limited to 85% of their thermal load ratings.

I. Cascaded distribution line voltage regulators will be used in the first and second transition only. Transition three will not have any cascaded distribution line voltage regulators on the distribution system.

J. System power factors will be fixed at 0.98 during peak load conditions.

K. Physical condition of distribution line conductors, poles, etc. is adequate to provide reliable service during the Long Range Plan period. New and replaced poles will use 40 foot Class 5.

L. New three phase and single phase line will be located along improved roads when possible.

When these system planning criteria are not met, the following system improvements are considered:

1. Transfer load to adjacent feeders with surplus capacity when available.

2. Install voltage regulators

3. Increasing line conductor size.

4. Increase equipment ratings.

5. Convert 1Ø lines to 3Ø.

6. Convert 7.2/12.5 kV lines to operation at 14.4/24.9 kV.

7. Construct tie lines to allow switching load to stronger source.

8. Construct new substation.

Power Transformer Ratings
All Ratings are shown in MVA
ANSI/IEEE C57.92-1981

Transformer Cooling Type	Transformer Rating @ 55 °C	Transformer Rating @ 65 °C	Summer Rating			Winter Rating		
			Normal	Maximum	Emergency	Normal	Maximum	Emergency
OA	1		0.9	1	1.4	1.4	1.5	1.8
OA	1.5		1.4	1.5	2.0	2.1	2.3	2.7
OA	2.5		2.3	2.5	3.4	3.4	3.8	4.6
OA	3		2.7	3	4.1	4.1	4.6	5.5
OA	3.75		3.4	3.75	5.1	5.1	5.7	6.9
OA	3.75	4.2	3.8	4.2	5.3	5.4	6.0	7.2
OA	4.5		4.1	4.5	6.1	6.2	6.8	8.2
OA	5		4.5	5	6.8	6.8	7.6	9.2
OA	5	5.6	5.0	5.6	7.1	7.2	8.0	9.6
OA	5	5.75	5.2	5.75	7.3	7.4	8.2	9.8
OA	7.5		6.8	7.5	10.2	10.3	11.4	13.7
OA	7.5	8.4	7.6	8.4	10.7	10.8	12.0	14.4
OA	10		9.0	10	13.6	13.7	15.2	18.3
OA	12.5	14	12.6	14	17.8	18.0	20.0	23.9
OA / FA	2.2 / 2.8		2.5	2.8	3.8	3.6	3.9	4.7
OA / FA	2.5 / 3.125		2.8	3.125	4.2	4.0	4.4	5.3
OA / FA	2.5 / 3.125	2.8 / 3.5	3.2	3.5	4.4	4.3	4.7	5.5
OA / FA	3.75 / 4.687		4.2	4.687	6.3	5.9	6.6	7.9
OA / FA	3.75 / 4.687	4.2 / 5.25	4.7	5.25	6.6	6.4	7.1	8.3
OA / FA	4 / 5		4.5	5	6.8	6.3	7.1	8.4
OA / FA	4.6 / 5.75		5.2	5.75	7.8	7.3	8.1	9.7
OA / FA	5 / 6.25		5.6	6.25	8.4	7.9	8.8	10.5
OA / FA	5 / 6.25	5.6 / 7	6.3	7	8.8	8.5	9.5	11.1
OA / FA	5.6 / 7		6.3	7	9.5	8.9	9.9	11.8
OA / FA	7.5 / 9.375		8.4	9.375	12.7	11.9	13.2	15.8
OA / FA	7.5 / 9.375	8.4 / 10.5	9.5	10.5	13.2	12.8	14.2	16.6
OA / FA		10 / 12.5	11.3	12.5	15.8	15.2	16.9	19.8
OA / FA	10 / 12.5		11.3	12.5	16.9	15.9	17.6	21.0
OA / FA	10 / 12.5	11.2 / 14	12.6	14	17.6	17.0	18.9	22.1
OA / FA	15 / 20	16.8 / 22.4	20.2	22.4	28.2	27.2	30.2	35.4
OA / FA / FA	3.75/4.687/6	4.2 /5.25/6.75	6.1	6.75	8.6	8.0	8.9	10.4
OA / FA / FA	7.5/9.375/12	8.4/10.5/13.5	12.2	13.5	17.3	16.0	17.8	20.8
OA / FA / FA	12/16/20		18.0	20	26.4	24.8	27.6	32.4
OA / FA / FA	12/16/20	13.4/17.9/22.4	20.2	22.4	28.7	26.6	29.6	34.5
OA / FA / FA	13.1/17.5/21.9	14.7/19.6/24.5	22.1	24.5	31.4	29.1	32.3	37.7
OA / FA / FA	15 / 20 / 25	16.8/22.4/28	25.2	28	35.8	33.3	37.0	43.1
OA / FA / FA		20/26.7/33.3	30.0	33.3	42.6	39.6	44.0	51.3
OA / FA / FA	18 / 24 / 30	20.2/26.9/33.6	30.2	33.6	43.0	39.9	44.4	51.7
OA / FA / FA	24 / 32 / 40	26.9/35.8/44.8	40.3	44.8	57.3	53.2	59.1	69.0

All ratings are based upon 70 percent preloading, 8 hour peak loading, and maximum allowable average winding temperature rise except the Summer Maximum Rating, which is limited to the unit's maximum rating as specified by the manufacturer.
All ratings for normal loading are based upon 90 percent of maximum loading.
All ratings for maximum loading are based upon no power transformer loss of life.
All ratings for emergency loading are based upon a one percent power transformer loss of life.
All ratings for summer loading are based upon 40 °C ambient air temperature.
All ratings for winter loading are based upon 0 °C ambient air temperature.
Cooling Types: OA = Self Cooled OA / FA = Forced Air Cooled (one stage of fans) OA / FA / FA = Forced Air Cooled (two stages of fans)
All MVA values are based upon power transformer ratings rather than substation ratings. Substation equipment such as regulators, buses, or fuses may reduce actual ratings.

Conductor Ratings
All Ratings are shown in Amps
IEEE Std. 738-1993

Conductor		Summer Rating		Winter Rating	
Type	Strands	Normal	Emergency	Normal	Emergency
795 ACSR	26 / 7	730	920	1130	1240
477 ACSR	26 / 7	530	670	820	900
336 ACSR	26 / 7	430	530	650	720
4/0 ACSR	6 / 1	320	390	490	530
2/0 ACSR	6 / 1	240	290	360	390
1/0 ACSR	6 / 1	210	250	310	340
2 ACSR	6 / 1	140	170	220	230
4 ACSR	6 / 1	110	130	170	180
795 AAC	37	700	890	1090	1200
477 AAC	19	520	650	800	870
336 AAC	19	410	520	640	690
4/0 AAC	19	310	380	470	520
2/0 AAC	19	230	290	350	380
1/0 AAC	19	200	250	310	330
4/0 CU	19	390	490	600	660
2/0 CU	7	300	360	450	490
1/0 CU	7	260	310	390	420
2 CU	7	190	230	290	310
4 CU	3	150	180	220	240
6 CU	3	110	130	170	180
8 CU	1	80	90	120	120

All ratings are based upon the following constants:

- Wind velocity = 2 feet/second
- Elevation = 600 feet
- Emissivity = 0.5
- Solar Absorptivity = 0.5
- Line Orientation = North-South
- Latitude = 30 $^{\circ}$
- Atmosphere = Clear
- Time of Day = 2:00 PM

All ratings for normal loading are based upon a maximum conductor temperature of 75 $^{\circ}$C.

All ratings for emergency loading are based upon a maximum conductor temperature of 93.3 $^{\circ}$C.

All ratings for summer loading are based upon 40 $^{\circ}$C ambient air temperature.

All ratings for winter loading are based upon 0 $^{\circ}$C ambient air temperature.