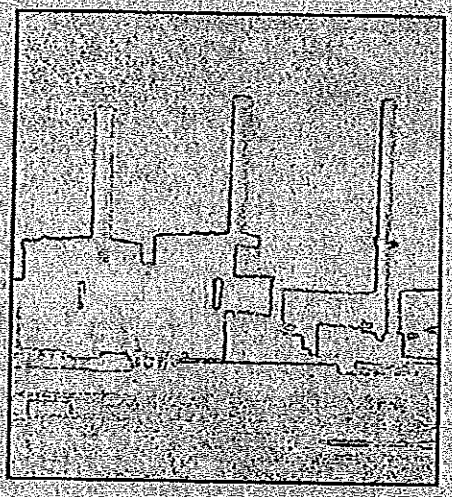
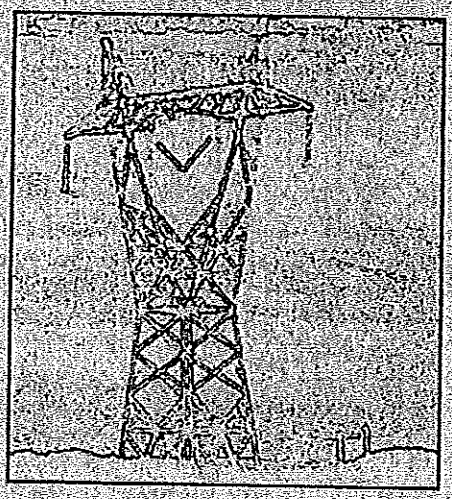
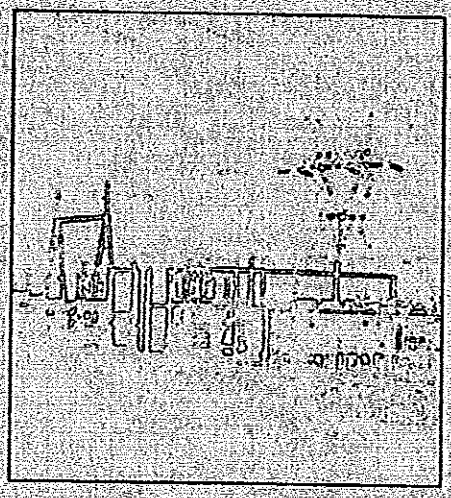






San Luis Valley High Voltage System Study Report

Prepared by Frank R. McElvain

June 1997

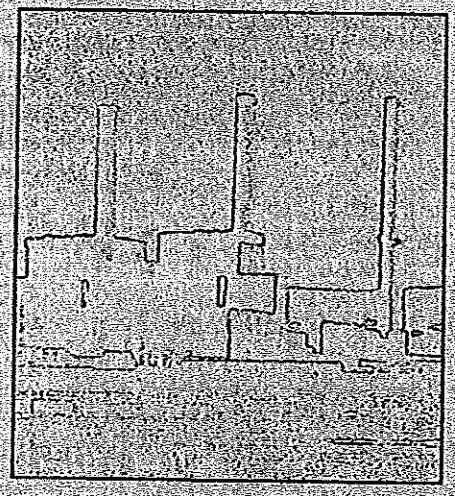
TRI-STATE
GENERATION AND TRANSMISSION
ASSOCIATION, INCORPORATED

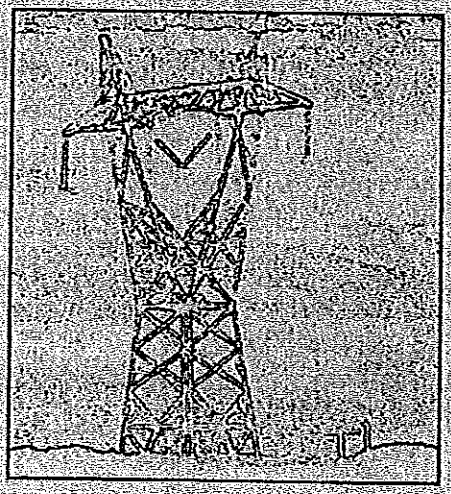
TSGT 000001

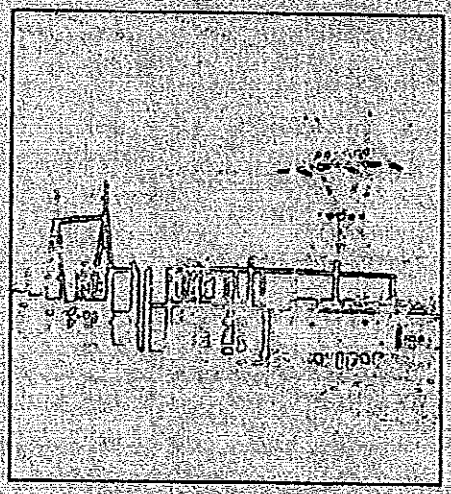
JRD-6

TABLE OF CONTENTS

APPENDICES







San Luis Valley High Voltage System Study Report

Prepared by Frank R. McElvain

June 1997

TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION, INCORPORATED

TABLE OF CONTENTS

APPENDICES

San Luis Valley High Voltage Transmission System
Study Report
May 1997

Executive Summary

This report documents the results of a joint technical study, to assess the capability and adequacy of the existing San Luis Valley High Voltage System to serve future loads in the region. The results of this study indicate that the existing system cannot adequately support 2006 peak loads, and also cannot adequately support existing regional loads during single contingencies.

The San Luis Valley High voltage System is at risk of single contingency voltage collapse, whenever the total regional load exceeds 65 MW. The region's total load presently exceeds 65 MW approximately 15 percent of the time, over the course of a year. The existing coincident peak load in the San Luis Valley was estimated to be 135 MW, and 2006 coincident peak load was estimated to be 144 MW.

The system additions and modifications recommended, based on the single-entity planning concept, to adequately serve a San Luis Valley regional load of at least 144 MW, are listed below. All cost estimates in this report are in 1997 dollars.

1. Construct a San Luis-Walsenburg 230 kV line, add a second San Luis 230-115 kV transformer, and add a second Walsenburg 230-115 kV transformer. This will mitigate single contingency voltage collapse concerns associated with an outage of the Poncha-San Luis 230 kV line. Moreover, these system additions establish a San Luis Valley High Voltage System load serving capability of 163 MW, before the need to address single contingency voltage collapse arises again. The estimated cost to implement this recommendation is $13,902,000. These additions are required as soon as possible, and the costs should be shared by Public Service Company of Colorado and Tri-State Generation & Transmission Association.

   Running the Alamosa Terminal generators improves the single contingency point-of-collapse of the existing San Luis Valley High Voltage System, from 65 MW to 96 MW. However, this is an insufficient solution for load levels in the San Luis Valley, which presently occur.

   The possibility of adding 90-120 MW of generation, at Burro Canyon, is also a viable option to mitigate single contingency voltage collapse in the San Luis Valley. Although not recommended, this option cannot be completely dismissed, and is discussed further on page 14.

2. Add a total of approximately 72 MVAr, of 69 kV capacitors, to the system south of Alamosa. This study indicates that a distribution of 29, 13, and 30 MVAr at Alamosa Steam, Antonito, and Fort Garland, respectively, are required to meet reliability criteria, without the Alamosa Terminal generators on-line. These capacitors help to mitigate the larger-scale single contingency voltage collapse associated with the Poncha-San Luis 230 kV line outage, and will mitigate a smaller-scale, single contingency voltage collapse associated with an outage of the Alamosa Terminal-San Luis 115 kV line.

   Running the Alamosa Terminal generators would allay the single contingency voltage collapse concerns associated with the Alamosa Terminal-San Luis 115 kV line outage. However, the speed of the voltage collapse after the contingency, is unknown, and may be too quick to effectively prevent it by bringing the Alamosa Terminal generators on-line. Even if the Alamosa Terminal generators were operated to anticipate the Alamosa Terminal-San Luis 115 kV line outage, the need for 69 kV capacitors south of Alamosa, is only reduced from a total of 72 MVAr to 46 MVAr.

3. Several load serving transformers in the San Luis Valley exceed their continuous loading capability, at the 144 MW regional load level. The need to replace, augment, or accept the loss-of-life to these transformers, should be reviewed by Public Service Company of Colorado and San Luis Valley Rural Electric Cooperative. The overloaded Public Service Company of Colorado transformers are located at Alamosa Terminal, Fort Garland, Mosca, Poncha, and Romeo substations. The overloaded San Luis Valley Rural Electric Cooperative transformer is located at Stanley substation.

4. The San Luis 115-69 kV transformer overloads during an outage of either the Sargent 115-69 kV transformer or the Alamosa Terminal-San Luis 115 kV line. Adding a second San Luis 115-69 kV transformer provides additional capacity to withstand the Sargent transformer outage, and eliminates concern that a San Luis 115-69 kV transformer single contingency will overload the Ansel-San Luis 69 kV line, until 2005. A second San Luis 115-69 kV transformer is needed as soon as possible. The cost, including circuit breakers, is estimated to be $1,022,000, and is the responsibility of Public Service Company of Colorado and Tri-State Generation & Transmission Association.

5. This study indicates that 10 MVAr of 69 kV capacitors at Del Norte improves the San Luis Valley High Voltage System's voltage profile during the Poncha-San Luis 230 kV line, Rio Grande Tap-Sargent 69 kV line, or Sargent 115-69 kV transformer outages. Public Service Company of Colorado's options are to install the capacitors at an estimated cost of $250,000; or accept the post-disturbance voltage deviation, and bring the Alamosa Terminal generators on-line, to recover to an adequate local voltage profile. Further analysis and implementation is referred to Public Service Company of Colorado.

6. The Ansel-San Luis 69 kV line can overload for several contingencies in the region. The addition of a second San Luis 115-69 kV transformer delays the need to rebuild this line, until approximately 2005. Prior to the addition of a second San Luis 115-69 kV transformer, bringing the Alamosa Terminal generation on-line also effectively mitigates overloading on the Ansel-San Luis line. Rebuilding this line is estimated to cost $720,000; and this cost is the responsibility of Public Service Company of Colorado.

7. The addition of capacitors at Alamosa Steam and Fort Garland will cause high VAr flows on the Alamosa Steam-Mosca-San Luis 69 kV line, during either the Alamosa Steam-Alamosa Terminal 69 kV line outage or the Alamosa Terminal-San Luis 115 kV line outage. This overload can be mitigated by bringing the Alamosa Terminal generation on-line. The possibility that the Alamosa Terminal generation can be brought on-line quickly enough to prevent the overloading should be examined. Since the facilities mentioned in this recommendation are the corporate assets of Public Service Company of Colorado, the details of mitigating this overload are referred to them. The total cost of rebuilding this line with 397.5 MCM conductor would be approximately $2,109,300.

8. The Home Lake-Rio Grande Tap-Sargent 69 kV line overloads during an outage of the Alamosa Terminal-San Luis 115 kV line. Bringing the Alamosa Terminal generation on-line is an effective method to mitigate this overload. The details of addressing this overload are left to Public Service Company of Colorado. The total cost to Public Service Company of Colorado of rebuilding this line is approximately $1,009,900.

9. The Alamosa Terminal 115-69 kV transformer overloads during an outage of the Rio Grande Tap-Sargent 69 kV line. Bringing the Alamosa Terminal generation on-line mitigates this overload. If a second Alamosa Terminal 115-69 kV transformer were added, the cost, including 115 and 69 kV circuit breakers, would be approximately $1,097,000, and it would be Public Service Company of Colorado's expense.

10. Several load serving transformers exceed 80 percent of their continuous rating, at the 144 MW regional load level. These transformers should be monitored for overloading in the future. The Public Service Company of Colorado transformers are located at Del Norte, Home Lake, Rio Grande, and Saguache substations. The San Luis Valley Rural Electric Cooperative transformers are located at Carmel, Center, Hooper, LaGarita, and Plaza substations.

11. Reactors are required during periods of low load. This requirement was not explored in any more detail, other than to determine that voltages are too high, during periods of low loads. Further studies are required to specifically determine the amount of reactors required, and the optimal locations for reactors.

12. Western Area Power Administration's Blue Mesa-Curecanti, Blue Mesa-Skito and Gunnison-Skito 115 kV lines overload during contingencies in the San Luis Valley vicinity. Solutions to these overloads were not pursued, since the facilities are not in the San Luis Valley, and this information is referred to Western Area Power Administration for further analysis.

San Luis Valley High Voltage Transmission System
Study Report
May 1997

Study Objective

The primary objective of this study is to quantify the factors which influence the performance of the San Luis Valley High Voltage System; to determine if the San Luis Valley High Voltage System satisfies all applicable reliability criteria; and to recommend operating and control strategies, system modifications, and additions which will improve system performance and reliability, if required.

A reliable power system will convert energy, from one of naturally available forms, to the electrical form and transport it to points of consumption. Energy is seldom used in the electrical form, but it is converted to other forms such as heat, light, and mechanical energy. The primary benefit for converting energy to the electrical form is that it can be transported and controlled with relative ease, and a high degree of efficiency and reliability.

A properly designed and operated high-voltage transmission system should meet the following fundamental requirements:

1. Meet the continually changing load demand for active and reactive power.
2. Supply energy at minimum cost and least environmental impact.
3. Deliver electricity that meets a minimum standard of quality with regard to constant frequency, constant voltage, and an acceptable level of reliability.

Concerns exist that the San Luis Valley High Voltage System cannot adequately serve regional peak loads during single contingency outage conditions. In addition, no prior record of the completion of a regional joint study exists, so the San Luis Valley High Voltage System is due for a thorough contingency analysis.

The factors that influence the San Luis Valley High Voltage System are as follows (not listed in any particular order):

1. San Luis Valley Load Level
2. San Luis Valley Load Power Factors
3. San Luis Valley Generation Level
4. Tot 5 Power Transfers

Increasing loading on the interconnected transmission system due to increasing customer demands and electric power transfers cause voltage stability and collapse to be a greater concern. Voltage stability and collapse are more accurately assessed by including the effects of various components of customer demand which respond differently to changes in system voltage. Since demand characteristics can have important effects on system performance, two factors were investigated to determine the magnitude of those effects on the San Luis Valley High Voltage System, as follows:

1. The load characteristics modeled in the power flow case
2. The presence of load-serving transformers, with Load Tap Changing (LTC) capability, in the power flow case; with loads modeled on the low side of such transformers

Study Scope

The scope of this study is to identify the facility additions, if any, necessary to develop a system capable of providing reliable electrical service, during single contingency and credible multiple contingency outages, to a regional load level projected for the year 2006, to the geographical region known as the San Luis Valley, in the central part of Southern Colorado. The region is bounded by Highway 50 on the north, the Colorado/New Mexico border on the south, the Sangre De Cristo Mountains on the east, and the San Juan Mountains on the west.

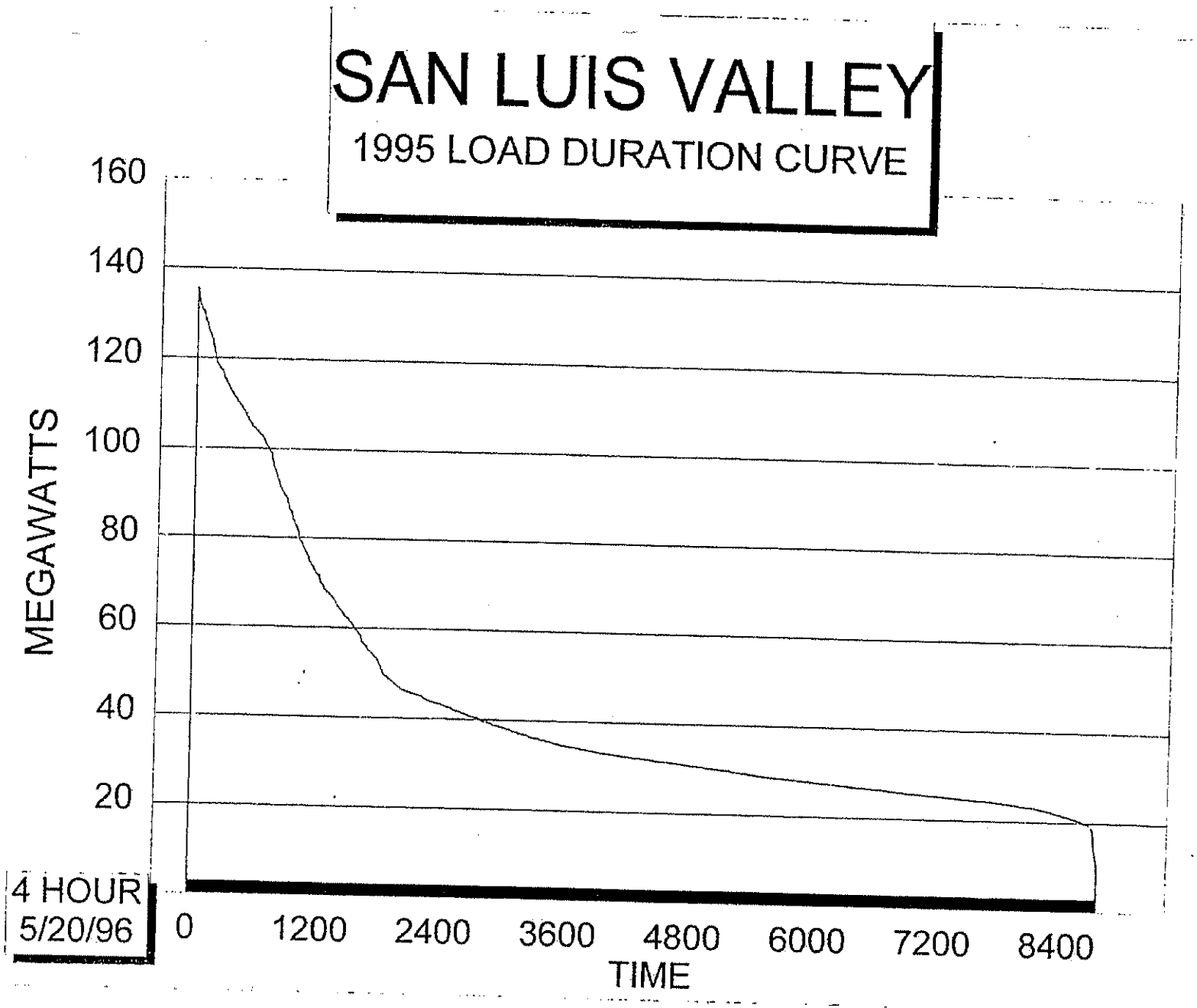
Existing System Demand

The estimated existing system demand for the San Luis Valley High Voltage System is 135 MW. For the purposes of this report, reference to the existing system implies the system as of 1995, and historical peak loads from the summer of 1995. The system facilities have not changed between 1995 and 1997, and 1995 load data was the most recent complete year of load data available, at the beginning of this study.

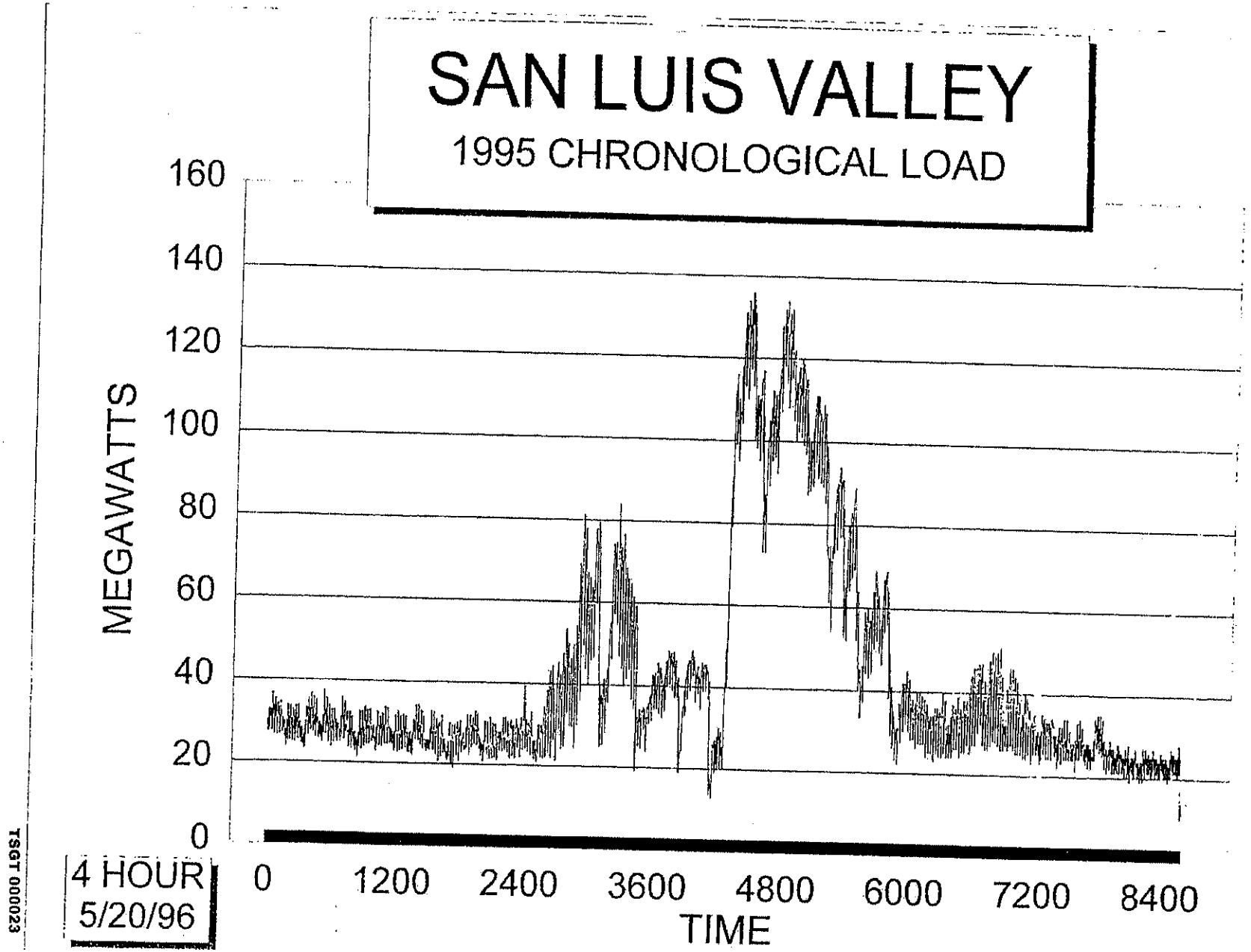
The coincident peak load demand of San Luis Valley Rural Electric Cooperative occurred on July 13, 1995, at 0930. Their load was 59 MW, at that time. Public Service Company of Colorado peak load in the San Luis Valley was estimated to be 76 MW, and it was assumed to coincide with the peak load of San Luis Valley Rural Electric Cooperative.

Therefore, the total coincident peak load in the San Luis Valley was estimated to be 135 MW, on July 13,1995, at 0930. Public Service Company of Colorado's peak load data was shaped to match the load profile of San Luis Valley Rural Electric Cooperative, and the loads were combined. The resultant individual loads are noted in the base case printout, in Appendix A. The resulting load duration curve, and the chronological load profile for 1995 follow, on the next two pages.

The reactive portion of the loads in the region were not completely available at the start of the study. Public Service Company of Colorado did have their VAr loads documented, however, the San Luis Valley Rural Electric Cooperative VAr loads were not initially available. Therefore, the regional power factors were initially treated as a variable in this study. Actual power factor data did become available near the completion of the study, and are documented in the base case printout in Appendix A.


SAN LUIS VALLEY
1995 LOAD DURATION CURVE
MEGAWATTS
160
140
120
100
80
60
40
20
4 HOUR
5/20/96
0
1200
2400
3600
4800
6000
7200
8400
TIME

TSGT 000022



TSGT 0000023

Recommendations

The San Luis Valley High Voltage System has several single contingency reliability concerns that exist under present system operation. The most serious concern for the San Luis Valley High Voltage System, is the risk of voltage collapse, throughout all of the region south of Poncha Switching Station, during an outage of the Poncha-San Luis 230 kV line (or the San Luis 230-115 kV autotransformer), when the total coincident load in the San Luis Valley exceeds 65 MW. The loads in the region exceeded 65 MW approximately 15 percent of the time, in 1995.

Moreover, the San Luis Valley High Voltage System also demonstrates high post-disturbance voltage deviations and overloads for several additional contingency simulations, as well as system normal overloads and low voltages. Bringing the Alamosa Terminal generation, which typically is off, on-line improves system performance, but is insufficient to satisfy reliability criteria, during all single contingencies, particularly the most critical contingency in the region.

The recommendations of this report, to improve system performance to meet reliability criteria, based on the single-entity planning concept, at a coincident regional load level of 144 MW are as follows:

1. To mitigate the risk of single contingency voltage collapse in the San Luis Valley, a San Luis-Walsenburg 230 kV transmission line should be constructed, a second San Luis 230-115 kV, 100 MVA autotransformer should be added, and a second Walsenburg 230-115 kV, 100 MVA autotransformer should be added. The total cost of these system additions, including circuit breakers, is estimated to be $13,902,000. The total cost should be shared by Public Service Company of Colorado and Tri-State Generation & Transmission Association. The voltage collapse risk exists today, whenever regional loads exceed 65 MW (96 MW with the Alamosa Terminal generators on-line), and this system addition is required as soon as possible.

   A second option successfully mitigates the region-wide single contingency voltage collapse concerns for the existing San Luis Valley High Voltage System, at a slightly higher transmission construction cost. This alternative includes a 230 kV transmission line from Burro Canyon to San Luis, with a total of 90-120 MW of generation at Burro Canyon. Although not recommended as a transmission system addition, this option has merit, and should not be dismissed, without considering the merits from a resource perspective. Further discussion of the Burro Canyon Generation option is on page 14.

2. The region south of Alamosa, including Alamosa Steam, Antonito, and Fort Garland substations, requires a total of 72 MVAr, of 69 kV capacitor additions, to meet voltage criteria, with the Alamosa Terminal generation off. This study indicates acceptable performance, with the addition of 29 MVAr at Alamosa Steam, 13 MVAr at Antonito, and 30 MVAr at Fort Garland. These capacitors help to mitigate the larger-scale single contingency voltage collapse associated with the Poncha-San Luis 230 kV line outage, and will mitigate a smaller-scale, single contingency voltage collapse associated with an outage of the Alamosa Terminal-San Luis 115 kV line. The total cost to Public Service Company of Colorado to add 72 MVAr of 69 kV capacitors, is approximately $1,800,000. This voltage support is required as soon as possible.

   Running the Alamosa Terminal generators would allay the voltage collapse concerns associated with the Alamosa Terminal-San Luis 115 kV line outage. However, the speed of the voltage collapse after the contingency, is unknown, and may be too quick to effectively prevent it by bringing the Alamosa Terminal generation on-line. Even if the Alamosa Terminal generators were operated to anticipate the Alamosa Terminal-San Luis 115 kV line outage, the need for 69 kV capacitors south of Alamosa, is only reduced from a total of 72 MVAr to 46 MVAr.

3. Several load serving transformers in the San Luis Valley exceed their continuous loading capability, at the 144 MW regional load level. The need to replace, augment, or accept the loss-of-life to these transformers, should be reviewed by Public Service Company of Colorado and San Luis Valley Rural Electric Cooperative. The overloaded Public Service Company of Colorado transformers are Alamosa Terminal 115-13.8 kV (#2), Alamosa Terminal 115-13.8 kV (#3), Fort Garland 69-25 kV (#3), Mosca 69-13 kV, Poncha 115-25 kV, and Romeo 69-13 kV. The overloaded San Luis Valley Rural Electric Cooperative transformer is Stanley 115-12.5 kV.

4. The San Luis 115-69 kV autotransformer loads to 143 percent and 104 percent, of a 42 MVA rating, during the Sargent 115-69 kV transformer or Alamosa Terminal-San Luis 115 kV transformer outages, respectively. Adding a second San Luis 115-69 kV, 42 MVA autotransformer provides additional capacity to withstand the Sargent transformer outage, and eliminates concern that a San Luis 115-69 kV transformer single contingency will overload the Ansel-San Luis 69 kV line, until 2005. The second San Luis 115-69 kV transformer is required as soon as possible, and is the responsibility of Tri-State Generation & Transmission Association and Public Service Company of Colorado. The cost, including circuit breakers, is estimated to be $1,022,000.