BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION

IN THE MATTER OF SOUTHWESTERN PUBLIC SERVICE COMPANY'S APPLICATION FOR: (1) REVISION OF ITS RETAIL RATES UNDER ADVICE NOTICE NO. 312; (2) AUTHORITY TO ABANDON THE PLANT X UNIT 1, PLANT X UNIT 2, AND CUNNINGHAM UNIT 1 GENERATING STATIONS AND AMEND THE ABANDONMENT DATE OF THE TOLK GENERATING STATION; AND (3) OTHER ASSOCIATED RELIEF, **SOUTHWESTERN PUBLIC SERVICE COMPANY,** **APPLICANT.**	))))))))))))))))))	**CASE NO. 22-00286-UT**

DIRECT TESTIMONY

of

DUANE J. RIPPERGER

on behalf of

SOUTHWESTERN PUBLIC SERVICE COMPANY

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GLOSSARY OF ACRONYMS AND DEFINED TERMS

Acronym/Defined Term	**Meaning**
2021 Loss Study	SPS's Transmission and Distribution System Loss Evaluation Study
2022 Radial Line Study	Study to identify radial line segments existing on SPS's transmission system
Commission	New Mexico Public Regulation Commission
Feeders	Primary voltage distribution main lines
FERC	Federal Energy Regulatory Commission
kV	Kilovolts
LP&L	Lubbock Power & Light
MWh	Megawatt hour
OATT	Open Access Transmission Tariff
PUCT	Public Utility Commission of Texas
Resources	Energy supplies (generation sources)
RFP	Rate Filing Package
Sales	Energy deliveries to loads on the SPS system
SPS	Southwestern Public Service Company, a New Mexico corporation
Study Period	January 1, 2021 through December 31, 2021
T&D	Transmission and Distribution

LIST OF ATTACHMENTS

<u>**Attachment**</u>	<u>**Description**</u>
DJR-1	2021 Loss Evaluation Study Explanatory Document (*Non-native format*)
DJR-2	2021 Loss Study Excel Workbook (*Filename:* DJR-2.xlsx)
DJR-3	2022 Radial Line Study Excel Workbook (*Filename:* DJR-3.xlsx)

Case No. 22-00286-UT
Direct Testimony
of
Duane J. Ripperger

I. WITNESS IDENTIFICATION AND QUALIFICATIONS

Q. Please state your name and business address.

A. My name is Duane J. Ripperger. My business address is 790 South Buchanan Street, Amarillo, Texas 79101.

Q. On whose behalf are you testifying in this proceeding?

A. I am filing testimony on behalf of Southwestern Public Service Company, a New Mexico Corporation ("SPS") and wholly-owned electric utility subsidiary of Xcel Energy Inc.

Q. By whom are you employed and in what position?

A. I am employed by Xcel Energy Services Inc. as Manager, Regional Transmission Initiatives.

Q. Please briefly outline your responsibilities as Manager, Regional Transmission Initiatives.

A. I am responsible for supporting the implementation of strategic transmission priorities. These priorities include the planning for large transmission projects, support of transmission-related regulatory and legislative activities, and the implementation of evolving technologies on the transmission grid.

Q. Please describe your educational background.

A. I earned a bachelor's degree in Electrical Engineering from Iowa State University and a master's degree in Engineering Management from the University of Colorado.

Q. Please describe your professional experience.

A. I have 38 years of extensive experience in the electric utility industry through various engineering and management positions. I have held positions in distribution engineering, electrical operations, Transmission and Distribution ("T&D") planning, asset management, and most currently in Transmission project planning and Transmission-related regulatory and legislative matters.

Q. Do you hold a professional license?

A. Yes. I am currently licensed as a Professional Engineer in New Mexico, Texas, and Colorado.

Q. Are you a member of any professional organizations?

A. Yes. I am a senior member of the Institute of Electrical and Electronics Engineers.

Q. Have you filed testimony before any regulatory authorities?

A. Yes. I filed testimony with the New Mexico Public Regulation Commission ("Commission") on behalf of SPS regarding the 2016 System Loss Study and the

2017 Radial Line Study in Case No. 17-00255-UT, SPS's 2017 New Mexico base rate case. I have also filed testimony with the Public Utility Commission of Texas ("PUCT") on behalf of SPS regarding transmission capital additions in Docket No. 46877, SPS's 2017 proceeding to adjust its Transmission Cost Recovery Factor; the 2016 System Loss Study and the 2017 Radial Line Study in Docket No. 47527, SPS's 2017 base rate case; impacts to the SPS system of the Sharyland Utilities/Lubbock Power and Light ("LPL") Certificate of Convenience and Necessity applications for new transmission lines in Docket Nos. 48909 and 49151; and system loss factors in SPS's case to reconcile fuel and purchased power costs in Docket No. 53034. Additionally, I filed affidavit testimony with the Federal Energy Regulatory Commission ("FERC") regarding a filing by the Southwest Power Pool, Inc. in FERC Docket No. ER18-2358-000; and Loss Factors Applicable to SPS Wholesale Customers in FERC Docket No. ER19-911-000.

II. ASSIGNMENT AND SUMMARY OF CONCLUSIONS

Q. What is your assignment in this proceeding?

A. First, I discuss SPS's 2021 Transmission and Distribution System Loss Evaluation Study ("2021 Loss Study") conducted for the period January 1, 2021 through December 31, 2021 ("Study Period"). The 2021 Loss Study explanatory document is provided as Attachment DJR-1; and Appendices A – Q to the 2021 Loss Study, in native format, are provided in Attachment DJR-2.

Second, I discuss SPS's 2022 Radial Line Study ("2022 Radial Line Study"), including a description of the study and an explanation of its results. The 2022 Radial Line Study is provided, in native format, as Attachment DJR-3 to my testimony.

Finally, I co-sponsor Rate Filing Package ("RFP") Schedules M-3 and P-9.

Q. Please provide a brief summary of your testimony regarding the 2021 Loss Study.

A. The 2021 Loss Study was conducted using the methodology most recently approved by the Commission in Case No. 17-00255-UT.[1] The 2021 Loss Study is

[1] *In the Matter of Southwestern Public Service Company's Application for Revision of its Retail Electric Rates Pursuant to Advice Notice No. 272*, Case No. 17-00255-UT, Final Order Adopting Recommended Decision with Modifications at 2 (Sep. 5, 2018), *adopting in relevant part* Recommended Decision at 181 (Jun. 29, 2018).

a valid calculation of SPS's losses at multiple voltage levels, which correspond to voltages on the T&D systems at which electric service is provided to customers.

During the Study Period, SPS's energy supplies ("Resources") totaled 32,466,434 megawatt hours ("MWh"), and its energy deliveries ("Sales")[2] were 30,652,284 MWh. The difference between these Resources and Sales (1,814,151 MWh) were SPS's actual system losses for the Study Period. The 2021 Loss Study used engineering principles to calculate the energy losses at specific voltage levels, resulting in total calculated losses of 1,813,929 MWh. Thus, there is only a 222 MWh (or 0.01%) difference between the calculated and actual energy losses for the Study Period.

The following Table DJR-1 compares data and the resulting energy loss factors from the 2021 Loss Study to the four previous loss studies. As a percentage of SPS's total Resources, actual system energy losses were slightly lower at 5.59% in the 2021 Loss Study as compared to 6.03% in the 2016 Loss Study.

[2] "Sales" means the sum of the energy SPS sold to customers and the energy delivered to interconnections with other utilities at the points the energy left the SPS transmission and distribution systems.

Table DJR-1
Comparison of 2021 Loss Study Data and Results to the Four Previous Loss Studies

Subject	2021 Loss Study	2016 Loss Study	2012/2013 Loss Study	2008/2009 Loss Study	2006 Loss Study
Total Resources, MWh	32,466,434	31,758,276	32,964,320	29,707,136	27,821,080
Total Sales, MWh	30,652,284	29,843,731	31,142,401	27,867,115	26,091,693
Actual Losses, MWh	1,814,151	1,914,545	1,821,919	1,840,020	1,729,387
Overall Loss Percentage	5.59%	6.03%	5.53%	6.19%	6.22%
Calculated Losses, MWh	1,813,929	1,948,827	1,836,997	1,829,126	1,694,750
Calculated Losses as % of Actual Losses	99.99%	101.79%	100.83%	99.41%	98.00%
Undeterminable Losses, MWh	222	-34,282	-15,079	10,894	34,637
Peak Load, MW	5,605	6,003	6,079	5,456	5,598
Loss Level 1: Generation Energy Loss Factor	1.000000	1.000000	1.000000	1.000000	1.000000
Loss Level 2: Backbone Transmission Energy Loss Factor	1.025762	1.029633	1.025158	1.024427	1.027036

Subject	2021 Loss Study	2016 Loss Study	2012/2013 Loss Study	2008/2009 Loss Study	2006 Loss Study
Loss Level 3: Sub-Transmission Energy Loss Factor	1.031784	1.035919	1.032914	1.032089	1.034426
Loss Level 4: Primary Distribution Energy Loss Factor	1.096228	1.105898	1.099263	1.112001	1.103775
Loss Level 5: Distribution Secondary Transformers Energy Loss Factor	1.11657	1.125047	1.118223	1.130411	1.114705
Loss Level 6: Distribution Secondary and Service Lines Energy Loss Factor	1.12008	1.128389	1.121893	1.134348	1.119737
Composite Energy Loss Factor for Loss Levels 5 and 6	1.118598	1.126935	1.120217	1.132439	1.114705

Q. Please provide a brief summary of your testimony regarding the 2022 Radial Line Study.

A. The 2022 Radial Line Study was conducted in accordance with the settlement methodology set forth in FERC Docket No. ER08-313 and implemented under Attachment AI of the Southwest Power Pool Open Access Transmission Tariff

("OATT"). The 2022 Radial Line Study, which is Attachment DJR-3 to this testimony, provides an accurate summary of SPS's radial lines and their corresponding Actual Installed Costs and Net Book Values as of June 30, 2022. Table DJR-2 provides a summary of the key New Mexico results of the 2022 Radial Line Study.

Table DJR-2
Summary of 2022 Radial Line Study Results

Number of New Mexico Radial Lines Serving Wholesale Customers	8
Net Book Value of New Mexico Radial Lines Serving Wholesale Customers	$1,794,496
Number of New Mexico Radial Lines Serving SPS Retail Customers	101
Net Book Value of New Mexico Radial Lines Serving SPS Retail Customers	$39,817,436

Q. Were Attachments DJR-1 through DJR-3 prepared by you or under your direct supervision and control?

A. Yes.

Q. Were the RFP schedules that you co-sponsor prepared by you or under your direct supervision and control?

A. Yes.

Q. Do you incorporate the RFP schedules that are co-sponsored by you into your testimony?

A. Yes.

III. 2021 LOSS STUDY

Q. What topic do you discuss in this section of your testimony?

A. In this section of my testimony, I discuss the 2021 Loss Study, which provides loss factors that SPS witness Richard M. Luth uses in his New Mexico retail class cost of service study to calculate jurisdictional allocators.

A. Discussion of 2021 Loss Study and Equipment Losses

Q. Why is SPS filing an updated loss study in this proceeding?

A. SPS is filing the 2021 Loss Study for two major reasons. First, pursuant to the Unopposed Stipulation in SPS's most recent Texas rate case (PUCT Docket No. 51802),[3] SPS committed to perform an updated loss study for the 2021 calendar year and file that loss study with the PUCT no later than December 31, 2022.

Second, as discussed at Section III.B. below, there have been several significant changes to the SPS T&D systems since the 2016 Loss Study was filed in New Mexico in Case No. 17-00255-UT. Even in the absence of the PUCT Docket No. 51802 stipulation requirements, SPS would have needed to perform an

[3] *Application of Southwestern Public Service Company for Authority to Change Rates*, PUCT Docket No. 51802, Unopposed Stipulation at 7 (Jan. 26, 2022), *adopted by* Order at 13, Findings of Fact 103-106 (May 20, 2022).

updated Loss Study in order to determine the impact of these system changes on system losses. Prior to planning for the current New Mexico rate case, SPS had already decided to perform the 2021 Loss Study using calendar year 2021 to provide a year of operating data with the Sagamore wind project in service.

Q. What are electric system losses?

A. As electrical current flows from generation sources to customers' loads, it passes through wires and transformers that have an inherent resistance to the flow of electricity. This electrical resistance causes some of the energy flowing in the system to be converted to heat, energy which is, thereby, "lost." Total actual energy losses are the difference between the electrical energy injected into the T&D system and the electrical energy that was either sold to customers or delivered to exit points on the utility's T&D systems. For example, if a utility generates 1,000 MWh of energy and experiences overall losses of 6%, it will deliver only 940 of the 1,000 MWh of energy generated. The 60 MWh difference between the amounts generated and delivered to customers are the T&D actual losses. Such losses are an inherent characteristic of a properly functioning electrical system and are unavoidable.

Q. In your example, would each customer cause the utility to lose 6% of the energy generated?

A. No, not generally, and not on SPS's system. In order for electricity to reach a residential customer, it typically flows from the generator through bulk transmission lines and related autotransformers, then through transformers at a distribution substation, then through primary distribution lines, then through a pole top transformer, then through a secondary distribution line from the pole top transformer to a pole behind the residence, and finally through a service line from the pole to the meter on the side of the house. At each step, losses are incurred to serve the residential customer.

By contrast, to reach an industrial customer taking service at 230 kilovolts ("kV"), the electricity flows only from the generator through some bulk transmission lines, and possibly through a 345/230-kV autotransformer. None of the losses incurred at distribution substations, primary distribution lines, distribution transformers, secondary lines, and service lines are experienced in serving this industrial customer taking service at 230-kV. Thus, in general, customers taking service at higher voltages cause fewer losses to be incurred than do customers taking service at lower voltages. On SPS's system, customers take service at multiple voltages ranging from 230,000 volts to 120 volts.

Q. Do utilities in general, and SPS in particular, have meters installed at each step in the electrical flow described above so that losses at each Loss Level can be measured?

A. No. In general and on SPS's system, billing-class meters exist at generators, at locations where SPS's transmission lines interconnect with transmission lines of other utilities, and at points of delivery to customers. Thus, SPS can use meters to accurately measure the total electrical energy placed on its T&D system, whether from generators located within or outside its system, and the total energy Sales. The difference between total Resources and total Sales is the actual energy loss incurred.

Given that meters do not exist at each Loss Level at which losses are incurred, a loss evaluation study is performed to quantify, through engineering analysis and calculations, the power and energy losses that occurred at the different Loss Levels on the T&D system during the Study Period. The calculated loss values for each Loss Level are used with the undeterminable losses (discussed later) to assign the proper portion of actual energy losses to Loss Level 2 through Loss Level 6 discussed below.

Q. What physical circuit elements of SPS's electrical system were analyzed in the 2021 Loss Study?

A. The circuit elements analyzed were the transmission lines, the transmission autotransformers, the distribution substation transformers, the distribution primary feeder circuits, the distribution line transformers, and the distribution secondary and service lines.

Q. You stated that the 2021 Loss Study calculates losses at several Loss Levels. Please identify the Loss Levels and circuit elements contained in each Loss Level.

A. Loss Level 1 is the generator and generator step-up transformer, and no losses are calculated at this level because the Backbone Transmission (Loss Level 2) is considered the delivery point of the electricity from the generator. Loss Levels 2 through 6 and the circuit elements in each Loss Level are identified below.

Loss Level 2 – Backbone Transmission

- Bulk transmission lines (345-kV, 230-kV, and 115-kV); and
- Autotransformers (345/230-kV, 345/115-kV, and 230/115-kV and the four autotransformers used to connect static var compensators to the transmission system).

<u>Loss Level 3 – Sub-Transmission</u>

- 69-kV transmission lines; and
- Autotransformers (115/69-kV).

<u>Loss Level 4 – Distribution Primary</u>

- Distribution substation transformers fed from the transmission system; and
- Primary Distribution Lines ("feeders") operating at voltages from 33-kV through 2.4-kV.

<u>Loss Level 5 – Distribution Secondary Transformers</u>

- Primary Distribution Transformers in the field.

<u>Loss Level 6 – Distribution Secondary and Service Lines</u>

- Secondary distribution lines running from Loss Level 5 transformers to other poles or service points and service lines running to the customers' premises.

The losses at Loss Levels 5 and 6 are combined to create composite "Distribution Secondary" demand and energy loss factors.

Q. Where are transmission level losses discussed in the 2021 Loss Study?

A. The circuit elements (i.e., lines and transformers) of the transmission system are identified in Section 1.1 of Attachment DJR-1, and the process for calculating losses for each type of transmission circuit element is discussed in Sections 2 through 5.

Appendix M of Attachment DJR-2 presents a summary of losses for each type of circuit element at all T&D Loss Levels.

Energy losses by Loss Level are stated in Appendix O of Attachment DJR-2 in the column labeled "kWh Loss by Level" and Loss Levels 2 and 3 are the transmission voltage Loss Levels.

Losses for individual transmission circuit elements are tabulated in Appendices E, F, and G of Attachment DJR-2.

The summary results of the transmission powerflow studies are in Appendix N of Attachment DJR-2.

Q. Where are distribution level losses discussed in the 2021 Loss Study?

A. The circuit elements (i.e., lines and transformers) of the distribution system are identified in Section 1.1 of the Attachment DJR-1, and the process for calculating losses for each type of circuit element is discussed in Sections 6 through 9.

Appendix M of Attachment DJR-2 presents a summary of losses for each type of circuit element at all T&D Loss Levels.

Energy losses by Loss Level are stated in Appendix O of Attachment DJR-2 in the column labeled "kWh Loss by Level" and Loss Levels 4, 5, and 6 are the distribution voltage Loss Levels.

Losses for individual distribution circuit elements are tabulated in Appendices I, J, K, and L of Attachment DJR-2.

B. 2021 Loss Study Methodology and Data

1. *Methodology*

Q. Please describe the methodology used to evaluate the transmission system losses.

A. For peak demand losses, the 2021 summer peak was modeled with powerflow studies and the losses by circuit element were tabulated and grouped by voltage category. Any demand loss contribution due to no-load losses was also calculated. For energy losses, the Study Period was divided into four time segments consisting of whole months, and average loads were computed for each time segment. Powerflow studies calculated the losses for each circuit element for the average load during each of the four time segments. The months included in each time segment are identified in Appendix A of Attachment DJR-2.

Q. What are "no-load losses"?

A. Whenever a transformer is energized, a relatively small loss occurs even during hours when no load current is passing through the transformer. These losses are referred to as "no-load losses." Since transformers are typically energized every hour of the year, no-load losses must be calculated for every hour of the year for every transformer in order to accurately model the total losses incurred for each transformer.

Q. Please describe the methodology used to determine distribution losses.

A. Peak demand and energy losses were calculated for the elements in the distribution system and accumulated based on a typical representation of SPS's distribution system. Losses were calculated for the distribution substation transformers, the primary feeders, the secondary system (including distribution transformers), and the service lines to the customers. The annual energy loss was determined by calculating annual energy loss per distribution element and summing up the total energy loss. Similarly, demand losses were determined on each component of the distribution system and aggregated.

Q. In performing the 2021 Loss Study, did SPS use the same methodology and analytical powerflow tool used in the 2016 Loss Study?

A. Yes. The methodology used in the 2021 Loss Study is the same as was used in the 2016 Loss Study. The powerflow studies on the transmission system were performed using the same computer software package that SPS has used since 1998 and that SPS used for the 2016 Loss Study.

Q. Is it appropriate to perform a loss evaluation study over a period shorter than 12 months?

A. In general, no. The loss evaluation study must correlate energy generated and purchased for customers with Sales to those customers. SPS bills some customers every regular business day of each month. Customers are usually billed once per month; however, the billing period start and end dates do not always respect the calendar month boundary. The billing period may cover part of a previous calendar month or may only cover part of the current month, with no overlap into a previous month. When all Sales are totaled and compared to that billing month's generation and power purchases, there will be a difference, which may be a positive or a negative number. This difference does not necessarily reflect the actual losses incurred on the T&D system during this billing month. This precludes doing a loss evaluation study for a short period of time.

Q. How does using a study period of at least 12 months aid in preparing a loss study?

A. By using a longer study period, such as one year, the effects of the different customer billing cycles are minimized. In addition, the loss factors for a loss study performed over a one-year period will account for the differences in system losses during all four seasons of that year.

Q. Did the 2021 Loss Study consider losses of customers operating their own T&D systems?

A. No. SPS evaluated losses up to the customers' meters, but not beyond, because SPS does not incur the losses that occur beyond the customers' meters.

Q. Was there any change in the treatment of wholesale transactions with entities outside of SPS's service area?

A. No. The same net metering approach used in the 2006, 2008/2009, 2012/2013, and 2016 Loss Studies was used in the 2021 Loss Study.

2. *Changes to the SPS T&D System since the 2016 Loss Study*

Q. Were there any changes in the data you used to calculate losses in the 2021 Loss Study as compared to the 2016 Loss Study?

A. Yes, there are always many changes in data from one loss study to the next. Changing the Study Period changes much of the data, including generation amounts, power purchases, peak load, powerflow case results, Sales data, miles of T&D lines, customer meter counts, etc. The updated data are reflected in the 2021 Loss Study appendices in Attachment DJR-2.

The SPS T&D systems modelled in the 2021 Loss Study have experienced five major changes since the 2016 Loss Study. These changes had a significant impact on power flows on the T&D systems, and thus warranted performing an updated loss study. The major T&D system changes are as follows:

- SPS added 1,220 MW of wind generation to its system, including both the installation of the Hale and Sagamore SPS-owned wind farms and purchased power agreements for the output from the Bonita I and II wind farms. This additional generation, and other renewable generation connected directly to the SPS system, significantly affects power flows by injecting power into the transmission system at different locations than in the past.

- LP&L moved approximately 470 MW of its former 640 MW peak load from the SPS region of the Southwest Power Pool grid to the ERCOT grid on approximately June 1, 2021. This decrease in load had a significant effect on transmission line flows. The remaining LP&L load was served by the SPS T&D systems throughout the Study Period.

- Customer loads in southeast New Mexico have continued to increase significantly over time since the 2016 Loss Study. The majority of the growth in this region is related to increased oil field activity and related services. Significant T&D facilities have been installed to provide service to these new customer loads. Changes in the size and location of customer loads also changes the power flows on the T&D systems.

- SPS has continued to expand its 345-kV network of transmission lines, from 905 miles in 2016 to 1263 miles in 2021. These 345-kV transmission lines act as super-highways for power flow, which reduces the amount of power that flows on the 230-kV and 115-kV transmission lines.

- Changing patterns of power delivery on SPS's system continues as SPS's wholesale customers transition from power provided from SPS to power procured from other wholesale providers and additional generation resources have been added to the SPS T&D system that do not serve SPS's wholesale or retail customers.

C. 2021 Loss Study Results

Q. What are the results of the 2021 Loss Study?

A. Total actual losses for the Study Period were 1,814,151 MWh, and the losses calculated by the 2021 Loss Study's engineering analysis were 1,813,929 MWh. The difference between these two values is called the Undeterminable Losses, which totaled 222 MWh or 0.01% of the actual losses. See Appendix M of Attachment DJR-2, line no. 32 for total actual energy losses, line no. 31 for total calculated energy losses, and line no. 33 for Undeterminable Energy Losses.

Q. Can you determine the reason for the 222 MWh difference between the losses calculated in the 2021 Loss Study and the actual losses incurred?

A. No. Undeterminable Losses are equal to the total actual losses minus the total calculated losses. The 222 MWh of Undeterminable Losses cannot be assigned to any particular cause. A loss evaluation study is an engineering analysis of losses attributable to average electrical loadings of particular components of the T&D system. There is always a difference between the actual and calculated losses, which can be positive or negative, between the results of a computer analysis using average loads and the actual losses experienced.

Q. Are Undeterminable Losses taken into account in determining loss factors?

A. Yes. The loss factors are based on actual losses during the Study Period. Thus, the Undeterminable Losses, whether positive or negative, are assigned to the circuit elements for which losses have been calculated in the study based on the ratio of each circuit element's calculated losses to the total of all calculated losses. The results of this allocation process appear in Appendix M of Attachment DJR-2 in the "Calculated Energy Losses Adjusted to Actual Losses, MWh" column. The total for this column matches the total actual energy losses on line no. 65 of Appendix A in Attachment DJR-2.

Q. How does the amount of Undeterminable Losses in the 2021 Loss Study compare to that found in SPS's previous loss studies?

A. Undeterminable Losses, as a percent of total actual losses, is 0.01% in the 2021 Loss Study as compared to 1.79% in the 2016 Loss Study, both of which are within a reasonable bandwidth of the results in prior loss studies. Table DJR-3 compares the Undeterminable Losses in the 2021 Loss Study with the same data from the previous four loss studies prepared by SPS.

Table DJR-3
Comparison of Undeterminable Losses with Previous Loss Studies

	2021 Loss Study Losses (MWh)	**2016 Loss Study Losses (MWh)**	**2012/2013 Loss Study Losses (MWh)**	**2008/2009 Loss Study Losses (MWh)**	**2006 Loss Study Losses (MWh)**
Total Actual Losses (App. M)	1,814,151	1,914,545	1,821,919	1,840,020	1,729,387
Calculated Losses (App. M)	1,813,929	1,948,827	1,836,997	1,829,126	1,694,750
Undeterminable Losses (App. M)	222	-34,282	-15,079	10,894	34,637
Undeterminable Losses as a percent of Total Actual Losses	0.01%	-1.79%	-0.83%	0.59%	2.00%

As described in the previous question, the Undeterminable Losses are allocated to each of the circuit elements based on the ratio of each circuit element's calculated losses to the total of all calculated losses, resulting in the adjusted calculated energy losses being equal to the total actual energy losses. This ensures that the loss factor for each Loss Level represents its appropriate portion of the total actual energy losses. Using the energy loss factors calculated in the 2021 Loss Study, customers only pay for the actual energy losses that occurred on the SPS T&D systems in 2021.

D. Calculation of Loss Factors

Q. What are loss factors?

A. An energy loss factor is simply a number, which when multiplied by a given amount of Sales, yields the amount of energy that must be generated to produce the Sales amount. If, for example, losses at a specific voltage level are 10%, then 100 MWhs have to be generated to yield 90 MWh of Sales. Thus, the loss factor at that level is 1.1111 (i.e., 90 MWh sold x 1.1111 loss factor = 100 MWh generated).

Q. Have you calculated loss factors based on the results of the 2021 Loss Study?

A. Yes. The loss factors were calculated in the same manner as in previous loss studies. The energy and demand loss factors for each SPS rate class are shown in Appendix Q of Attachment DJR-2. Loss factor derivation is discussed in Section 11 of Attachment DJR-1.

Q. How do the 2021 loss factors compare to those of previous loss studies?

A. The loss factors resulting from the 2021 Loss Study are comparable to those of previous loss studies. However, the loss factors resulting from the 2021 Loss Study are slightly lower than those resulting from the 2016 Loss Study. A comparison of the 2021 energy loss factors to those of previous loss studies is presented in Table DJR-4 below.

Table DJR-4
Comparison of 2021 Energy Loss Factors to Previous Loss Studies

Loss Level	2021 Energy Loss Factors	2016 Energy Loss Factors	2012/2013 Energy Loss Factors	2008/2009 Energy Loss Factors	2006 Energy Loss Factors
1: Generation	1.000000	1.000000	1.000000	1.000000	1.000000
2: Backbone Transmission	1.025762	1.029633	1.025158	1.024427	1.027036
3: Sub-Transmission	1.031784	1.035919	1.032914	1.032089	1.034426
4: Primary Distribution	1.096228	1.105898	1.099263	1.112001	1.103775
5: Distribution Secondary Transformers	1.11657	1.125047	1.118223	1.130411	1.114705
6: Distribution Secondary and Service Lines	1.12008	1.128389	1.121893	1.134348	1.119737
Composite Loss Factor for Loss Levels 5 and 6	1.118598	1.126935	1.120217	1.132439	1.118078

A comparison of the 2021 demand loss factors to those of previous loss studies is presented in Table DJR-5 below.

Table DJR-5
Comparison of 2021 Demand Loss Factors to Previous Loss Studies

Loss Level	2021 Demand Loss Factors	2016 Demand Loss Factors	2012/2013 Demand Loss Factors	2008/2009 Demand Loss Factors	2006 Demand Loss Factors
1: Generation	1.000000	1.000000	1.000000	1.000000	1.000000
2: Backbone Transmission	1.020732	1.023667	1.026174	1.030610	1.026172
3: Sub-Transmission	1.026867	1.030961	1.035392	1.040605	1.035186
4: Primary Distribution	1.110806	1.131015	1.127359	1.156872	1.126222
5: Distribution Secondary Transformers	1.142271	1.161769	1.158647	1.188431	1.142593
6: Distribution Secondary and Service Lines	1.147022	1.166539	1.164118	1.193903	1.149273
Composite Loss Factor for Loss Levels 5 and 6	1.145441	1.164833	1.161975	1.191800	not calculated

Q. Will SPS revise the loss factors applied for determining the monthly Fuel and Purchased Power Cost Adjustment Clause if the Commission approves the new loss factors in this rate case?

A. Yes.

IV. 2022 RADIAL LINE STUDY

Q. What topic do you discuss in this section of your testimony?

A. I discuss the 2022 Radial Line Study. This study reflects the SPS system as of June 30, 2022 and is provided as Attachment DJR-3. This study provides the basis for the direct jurisdictional allocation of the costs of particular radial line segments, as discussed in the direct testimony of SPS witness Stephanie N. Niemi.

Q. Is SPS using the same methodology for completing the 2022 Radial Line Study as it used in the 2020 Radial Line Study presented in its most recent previous base rate case, Case No. 20-00238-UT?

A. Yes. The methodology used to complete both studies was the same.

Q. What is the source for the methodology used to complete the 2022 Radial Line Study?

A. The methodology for the 2022 Radial Line Study was prescribed in FERC Docket No. ER08-313 *et al.* and implemented under Attachment AI of the Southwest Power Pool OATT. The settlement in that docket provided definitions, required study components, and the basic methodology as to how the radial line study would be performed.

Q. Please summarize the results of the 2022 Radial Line Study.

A. The results of the 2022 Radial Line Study are summarized in Table DJR-6.

Table DJR-6
Summary of 2022 Radial Line Study Results

State	Number of Wholesale Radial Lines	Net Book Value of Wholesale Radial Lines	Number of SPS Retail Radial Lines	Net Book Value of SPS Retail Radial Lines
New Mexico	8	$1,794,496	101	$39,817,436
Texas	55	$9,566,984	131	$60,435,482
Oklahoma	2	$1,028	0	0
Kansas	0	0	0	0
Total	65	$11,362,508	232	$100,252,918

Q. Does this conclude your pre-filed direct testimony?

A. Yes.

BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION

IN THE MATTER OF SOUTHWESTERN PUBLIC SERVICE COMPANY'S APPLICATION FOR: (1) REVISION OF ITS RETAIL RATES UNDER ADVICE NOTICE NO. 312; (2) AUTHORITY TO ABANDON THE PLANT X UNIT 1, PLANT X UNIT 2, AND CUNNINGHAM UNIT 1 GENERATING STATIONS AND AMEND THE ABANDONMENT DATE OF THE TOLK GENERATING STATION; AND (3) OTHER ASSOCIATED RELIEF,	)	**CASE NO. 22-00286-UT**
SOUTHWESTERN PUBLIC SERVICE COMPANY,	)	
APPLICANT.	)	

VERIFICATION

On this day, November 18, 2022, I, Duane J. Ripperger, swear and affirm under penalty of perjury under the law of the State of New Mexico, that my testimony contained in Direct Testimony of Duane J. Ripperger is true and correct.

/s/ Duane J. Ripperger
Duane J. Ripperger

Southwestern Public Service Company

2021 Loss Evaluation Study

Explanatory Document

Study Period of January – December 2021

SPS Transmission Planning
Xcel Energy Services, Inc.

June 2022

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1.0 Overview

This report discusses an evaluation of transmission and distribution (T&D) system losses for the 12 month period of January – December 2021 (2021 Study Period). This evaluation was designed to be as introspective as technically practical and provide a significant level of confidence in determining the electrical losses on the Southwestern Public Service (SPS) T&D systems. This evaluation determines actual losses and then uses engineering principles to calculate both demand and energy losses at specific voltage levels.

SPS operates an electrical system consisting of 345-kV, 230-kV, 115-kV and 69-kV transmission lines and a distribution system with lines operating at 33-kV to 2.4-kV. The system spans a large 52,000 square mile area from the Oklahoma panhandle through the Texas panhandle and into eastern and southeastern New Mexico. SPS owns generation on both 230-kV and 115-kV busses throughout this area. Since 2009, SPS and other power producers have installed significant amounts of wind and solar generation within the SPS boundary. Most of this generation is connected at transmission voltage levels with the balance being connected at distribution primary voltage levels.

The scope of this study was to determine the demand and energy losses for the following components:

Transmission System Components:

- Generation Unit Main Transformers
- Transmission Lines
- Autotransformers

Distribution System Components:

- Distribution Substation Transformers
- Distribution System Lines, including Primary, Secondary and Service Lines
- Distribution Line Transformers

The losses related to these elements of the power system are frequently seen in accounting reports as "Unaccounted For Energy." The purpose of this study is to determine actual losses and then specifically assign those losses by the components identified above for the 2021 Study Period.

The losses incurred by customer-operated transformers, transmission systems and distribution systems are not considered in this study. Additionally, losses occurring in auxiliary busses at power plants are not considered in this study.[1] Also, losses related to the generator step-up transformers are not included since net generation is recorded at the high voltage side of these transformers where they connect to the transmission system.

The analysis of losses requires consideration of both demand losses and energy losses. The demand losses are typically measured in megawatts (MW), kilowatts (kW), or watts (W). The energy losses are measured in megawatt-hours (MWh), kilowatt-hours (kWh), or watt-hours (Wh). Certain components of the energy losses are present even though there is very low electrical load current passing through the device. An example of this is the magnetizing current and related losses in a transformer. When a transformer is energized, these losses will occur. Power flow through the transformer will increase the losses in the transformer, but even in the absence of any power flow, the transformer will experience what is referred to as “no-load losses” simply because it is energized.

To provide a basis for the calculations in this study, input data was gathered for the T&D systems. This data and associated calculations are shown in the appendices of Attachment DJR-RD-2(CD). All references in this document to a specific appendix are found in Attachment DJR-RD-2(CD). Each appendix corresponds to a section of the total loss calculation or provides data used in other appendices. The calculation of transmission losses employs highly detailed electrical models of the transmission system, using actual values for the transformers and lines in the field that cause losses at the

[1] Auxiliary busses are distribution busses which provide internal power plant distribution service for internal power plant equipment (i.e. water wells, internal plan equipment, plant controls, pumps, etc.).

transmission level. Actual counts and data on transformers and lines does not exist for all the distribution system, however. Actual system values are used where available and engineering approximations are used where actual data is not available. These approximations are noted in the discussion.

1.1 Loss Levels

Losses in the T&D systems are grouped in six Loss Levels. These Loss Levels are:

- Loss Level 1 – Generation
- Loss Level 2 – Backbone Transmission
- Loss Level 3 – Sub-Transmission
- Loss Level 4 – Primary Distribution
- Loss Level 5 – Secondary Distribution Transformers
- Loss Level 6 – Secondary Distribution Lines

Losses are not calculated at Level 1 because the power flowing into the transmission system is metered at the point of delivery to the transmission system. Losses in the other levels are composed of the following categories of physical equipment:

- Loss Level 2 – Backbone Transmission
  - 345-kV, 230-kV and 115-kV Transmission Lines
  - 345/230-kV, 345/115-kV, and 230/115-kV Autotransformers
- Loss Level 3 – Sub-Transmission
  - 69-kV Lines
  - 115/69-kV Autotransformers
- Loss Level 4 – Primary Distribution
  - Distribution Substation Transformers
  - Distribution Primary Feeder Lines (33-kV to 2.4-kV lines)
- Loss Level 5 – Secondary Distribution Transformers
  - Distribution Line Transformers
- Loss Level 6 – Secondary Distribution Lines
  - Distribution Secondary and Service Lines

Transmission losses are those at Loss Levels 2 and 3. Losses attributable to distribution facilities are those calculated for Loss Levels 4, 5 and 6. In setting loss factors for rate classes, the losses calculated at levels 5 and 6 are combined and a composite loss factor is calculated.

A summary of the losses calculated in the 2021 Loss Evaluation Study are shown in Appendix M and the rate class loss factors derived from the study are shown in Appendix Q.

1.2 Calculation of Actual System Losses

Appendix A contains the calculation of actual system losses measured in MWh for the total T&D systems based on 2021 Study Period operating data. The general definition of actual losses is the difference between the total energy injected into SPS's system by generation resources and the total energy deliveries supplied to customers and other companies. The total Resources categories shown in Appendix A are discussed below.

> **Total SPS System Resources** – these Resources include the metered output of SPS-owned generating plants and SPS interconnections with other electric companies outside of the SPS system boundary. The interconnections with other electric companies include the metered physical flows at all interchange tie points with the Southwest Power Pool (SPP) and the Western Electric Coordinating Council (WECC). Wherever SPS's transmission system interconnects with the transmission systems of other electric companies in the SPP or WECC, meters exist, and data are captured to determine the energy flowing either into or out of SPS's system boundary. The net flows into or out of the SPS system at these boundaries account for any purchases made from, or sales made to, entities outside the SPS system boundary. In addition, if third parties enter into a sale and purchase transaction and SPS's transmission system is used to deliver power, the net metered flows at SPS's boundaries will reflect the use of the transmission system by recording the corresponding inflow or outflow. This process of calculating the net flows into or out of SPS's system is referred to as "net metering."

SPS Thermal Firm Purchased Power

- Borger Energy Associates – SPS purchases energy pursuant to the contracts with Borger Energy Associates

- Lea Power Partners – SPS purchases energy pursuant to the contracts with Lea Power Partners, LLC.

- Sid Richardson (Tokai Carbon) and Orion Engineered Carbons (DeGau) – SPS purchases relatively small amounts of energy from these entities pursuant to firm QF Standard Purchase Agreements.

SPS Renewable Firm Purchase Power – these are energy purchases from renewable sources that have firm network transmission service.

Golden Spread Electric Cooperative Generation – Golden Spread Electric Cooperative (GSEC) owns the Mustang Plant near Denver City, Texas, and the Antelope and Elk Stations located near Abernathy, Texas. GSEC also purchased the output of the Panhandle Wind Ranch. Since the GSEC generation is within SPS's boundary, its generation must be included in total area Resources to prevent an under-statement of Resources due to the net metering process described above.

Lea County Electric Cooperative (LCEC) Generation – This renewable and fossil generation is connected to LCEC's 115-kV transmission line from SPS Hobbs Plant to SPS Denver City Substation.

Farmers' Electric Cooperative (FEC) Generation – This renewable generation is connected to FEC's transmission system and the value reported is the excess generation above FEC's load that flows back onto the SPS transmission system.

Export Renewables – The output of these renewable resources was scheduled or purchased by other companies outside of the SPS boundary.

SPS Non-Firm Purchased Power – The output of these renewable resources was purchased by SPS and flowed onto the SPS transmission system.

SPP Market – Renewables and Lubbock Power & Light (LP&L) Thermal – These renewable and LP&L resources located within SPS's boundary provided power over SPS's transmission lines to the SPP Energy Market. Like GSEC's generation, this generation must be included in SPS's total resources to prevent an under-statement of resources due to the net metering process described above. Note that the City of Lubbock and LP&L moved their generators and high voltage transmission system from the SPP electric grid to the Electric Reliability Council of Texas grid in June 2021, so this LP&L generation can no longer supply power to the SPS system. LP&L generation did generate on the SPS system from January through May of 2021. This generation was located within the LP&L network and no SPS losses were attributable to this power.

The total of the Resources described above is the "Total On-System Resources" value shown on line 59 that was available on SPS's system for serving customer load within its system boundary.

Total Deliveries shown on line 62 consists of all retail sales, all full requirements wholesale sales within the system boundary, and all deliveries to Golden Spread load points within the system boundary.

The Total Actual Losses value shown on line 65 represents the actual losses experienced during the 2021 Study Period. Total Actual Losses are calculated by subtracting the Total Deliveries from the Total Resources. This Total Actual Losses value will be used to calculate the loss factors by Loss Level (voltage level) as described above.

SPS's Total System Loss percentage for the 2021 Study Period is shown on line 66. This value is derived by dividing Total Actual Losses by Total Resources.

The Net Output to Lines by Load Segment Period values shown on lines 69-73 are the sums of monthly Total Resources values shown on line 59 for the months contained in each load segment period. The determination of load segment periods is discussed in Section 3.1 and the Net Output to Lines by Load Segment Period data are used in determining transmission line losses in Section 4.3.

1.3 Distribution Connected Generation Sources

Appendix B contains a list of distribution-connected resources that deliver power directly onto the SPS distribution system at Primary Loss Level 4. These resource values are used in the calculation of losses on the distribution system, specifically in Appendices I and J – Distribution Substation Transformers and Distribution Feeder Line Loss.

2.0 Generation Step-Up Transformer Losses

Losses attributable to these transformers are included in station power and are not included as a part of this study.

3.0 Transmission System Loss Analysis

To calculate the transmission line and autotransformer losses, it is necessary to perform powerflow studies at different average system load levels throughout the year. The average system loading levels must be determined before these studies can be done. The load represented in these studies is a composite of SPS retail load, GSEC and other wholesale loads within the SPS system boundary. Any sales or purchases of energy that either originated in or was received into the SPS system boundary are also included in the calculations. These include any through transactions that flow power from east to west or west to east across the SPS system between the eastern and western grids to capture any transmission losses due to those transactions.

The average of SPS's daily minimum and maximum load values is used as the daily average load. Then the corresponding values for the same hours for tie line flows. LP&L load, and wind and solar generation are similarly averaged to obtain daily average values. Graphs are created for the daily minimum and maximum load values and the daily average load values to be analyzed. These graphs are shown in Appendix D – System Load Graphs.

3.1 Segment Derivation

Powerflow analysis is used to determine some of the component losses on the transmission system. Powerflow analysis provides loss data on the transmission lines and transformers for one specific load level. Since the load levels change across the SPS system during the year, the 2021 Study Period is broken up into different segments of months that have a similar average load levels. As described above, the daily minimum and maximum load values are averaged to provide a daily average load value. The next step is to produce a daily average load graph. The Average MW Load Analysis graph is shown in Appendix D – System Load Graphs. This graph shows the daily average load values plotted for the 2021 Study Period. Next, the 2021 Study Period is broken into groups of whole months with the goal to minimize the sum of the errors between the average load values to be used in the study and the actual daily average load. This optimization process results in the determination of groups of whole month periods or "segments" and the corresponding average load value for those segments that minimize the calculated error. The segment boundaries are required to fall on whole calendar months because the data is based on a calendar month. These segments, consisting of whole months, are modeled in the powerflow program using the average load values for each segment to calculate transmissions losses for that segment. For the 2021 Study Period, the best fit to model the loads for the 12 months was a four segment model. The sum of the errors in the 2021 Study Period is -0.0024% as shown in Appendix D - System Load Data. The segment values determined from this analysis were:

Segment 1:	January - February	3,674 MW
Segment 2:	March - April	3,736 MW
Segment 3:	May - September	4,077 MW
Segment 4:	October - December	3,472 MW

The average load per segment, number of days in each segment, and other values used in the analysis are shown on the chart in Appendix D - System Load Data.

3.2 Powerflow Loss Calculations

Once the segment loads have been determined, the powerflow analysis is performed. The average segment load values determined above are used for the load levels in the powerflow studies. Powerflow cases are performed on each of the load segments under study. The generation patterns are changed in each segment to best represent the mix of generators typically on-line at that time of the year. A peak powerflow case is also prepared, which analyzes the system losses at the hour of the system peak.

The powerflow program used to perform studies is Power Technologies Inc.'s PSS/E program. Once the powerflows have been completed, the transmission losses are summarized for the SPS system. The loss values for each transmission element and voltage class are tabulated for the peak hour case and for each segment period. The summary of these losses is shown in Appendix N. These losses represent the loss value for that element for each segment time period. These values are then used to determine the total transmission line and autotransformer losses.

Excluded from the loss calculations are transmission-voltage systems that are not owned by SPS but reside inside SPS's boundary and modelled in SPS's powerflow program. These include systems owned by Lea County Electric Cooperative, Farmers' Electric Cooperative, and Lubbock Power and Light.

4.0 Transmission Line Losses

Demand and energy losses on transmission lines consist of corona losses, insulator losses, and losses caused by power flow through the transmission lines. These losses are calculated by transmission voltage level in Appendix E – Transmission Line Losses.

4.1 Transmission Line Corona and Insulator Losses

Transmission systems have losses due to corona and insulator leakage. Corona loss occurs when the voltage gradient near the conductor surface exceeds the breakdown strength of the surrounding air. Insulator leakage is the small current that flows across the surface of the insulators attached to the electric conductor. The Transmission Line Reference Book published by Electric Power Research Institute contains information on determining the representative losses associated with corona and insulator leakage. Using that reference, losses per mile for each transmission voltage level were determined and entered in the "kW Losses Per Mile of Transmission Line" column. Transmission line mileage was obtained from the Federal Energy Regulatory Commission (FERC) Form 1 data. The demand loss due to corona and insulator leakage (Appendix E, "Total Demand Losses, MW" column) is calculated by multiplying the kW loss per mile for a specific voltage level times the miles of transmission operating at that voltage and then dividing that product by 1,000 to yield a MW loss result. The energy loss is the demand loss times the number of hours in the Study Period. For 345-kV transmission lines, for example, the corona and insulator demand loss of 2.343 MW in Appendix E is the rounded value of this equation: (2.343 kW loss/mile x 1262.83 miles) ÷ 1,000. The annual energy loss (25,919 MWH) for these same elements is the product of 2.96 MW (the unrounded value from the previous equation) x 8,760 hours in the 2021 Study Period.

4.2 Transmission Line Demand Losses

The losses caused by power flow though transmission lines are shown in Appendix E in the section labeled "Transmission Line Demand Losses." The peak demand losses were calculated in the peak powerflow study by transmission voltage as shown in in Appendix N.

4.3 Transmission Line Energy Losses

The energy losses caused by power flow though transmission lines are shown in Appendix E in the section labeled "Transmission Line Energy Loss by Segment." The energy loss for the transmission lines at each voltage level is determined by using the demand losses calculated in the powerflows for each of the four load segments. The segment loads are listed in Appendix E along with the net output of energy to the transmission system during that particular segment. This energy value was determined in Appendix A and is labeled "Net Output to Lines By Load Segment Period." The Net Output to Lines by Load Segment Period is the amount of generated and purchased energy injected into the transmission system to serve load during that period as shown in Appendix A. Energy losses for transmission lines by voltage for a specific segment period is calculated using the equations below.

$$\text{Segment Loss Factor} = \frac{\text{Segment Loss for Transmission Element, MW}}{\text{Segment Load, MW}} \quad (4.3.1)$$

$$\text{Segment Losses} = \text{Segment Loss Factor} \times \text{Segment Output to Lines, MWh} \quad (4.3.2)$$

The powerflows calculate the demand loss for each segment. Dividing the segment demand loss by the segment load produces an energy loss factor. Multiplying this energy loss factor by the Segment Output to Lines produces the energy loss for that element in that segment. The energy loss values for the 2021 Study Period are simply the sum of the energy loss values in each segment and are shown in Appendix E.

5.0 Transmission Autotransformer Losses

SPS's transmission system autotransformers reduce voltage from one transmission voltage to a lower transmission voltage. The high side and low side autotransformer voltages are typically written as "345/230," "230/115" and "115/69," and the autotransformers are grouped by the high side voltage. Every autotransformer that was used on SPS's transmission system during the 2021 Study Period is identified in Appendix G. The losses related to transmission autotransformers are separated into two categories, load losses and no-load losses.

5.1 Transmission Autotransformer Load Losses

Transmission autotransformer load losses are calculated in Appendix F. Load losses in autotransformers are the losses that are incurred when the autotransformer is actively converting power from a higher input voltage to a lower output voltage. These losses increase as the amount of power being converted in the autotransformer increases. The demand and energy load losses were calculated using the same methodology as transmission line losses. The demand component was calculated for each voltage level of autotransformers from the summer peak powerflow study, summarized in Appendix N. This study provided the MW losses for the autotransformers based on the loading at the peak time of the year. These losses are shown by voltage class of autotransformers in Appendix F under the section heading "Transmission Autotransformer Demand Load Losses." A segment loss factor for each time segment was calculated by dividing the MW Loss by the Segment Load in Appendix F. The autotransformer energy losses for each time segment were calculated by multiplying the segment loss factor by the Segment Output to the Lines for that segment. This produces the energy losses by voltage level for each segment. The data needed to make these calculations and the results are shown in Appendix F. The equations used to obtain these energy losses for the autotransformers are the same as Equations 4.3.1 and 4.3.2 above.

5.2 Transmission Autotransformer No Load Losses

Transmission autotransformer no load losses are calculated in Appendix G. No load losses in autotransformers are the losses associated with magnetizing the windings of the transformer, which enables the transformer to convert power from a higher voltage to a lower voltage. These losses exist both when the transformer is only energized and when it is energized and carrying load, so these losses are being incurred every hour of the 2021 Study Period as all the transformers are presumed to be in use throughout the 2021 Study Period. No load losses can be compared to a gasoline powered automobile idling. The automobile is consuming gasoline even though it is not moving and not providing the transportation function. Both the no load demand and energy losses are calculated from each transformer's no load loss value. This no load loss value is measured on each transformer when it is manufactured and provided to the purchaser as part of the operational characteristics specific to that transformer. The no load demand losses are the sum of the no load loss values in Watts for each autotransformer by voltage level and divided by 1,000 to convert the units to kilowatts. The no load energy losses are the sum of the no load loss value in Watts for each transformer by voltage level multiplied by the number of hours in the 2021 Study Period and divided by 1,000,000 to convert the units to megawatt-hours. The calculations are shown in Appendix G.

All the losses discussed to this point are transmission level losses. The losses discussed in the following sections 6 through 9 are losses at the distribution level.

6.0 Distribution Substation Transformer Losses

Distribution substation transformers are those transformers that reduce the transmission voltage, *e.g.*, 69-kV, to a distribution voltage, such as 33-kV, 22-kV or 12.5-kV. The data for each distribution substation transformer are in listed in Appendix I. When available, manufacturer's data were used to calculate losses. When manufacturer's data were not available for a specific transformer, data for a similar transformer were used.

Column J provides codes indicating the source of transformer capacity ratings and loss data. The meanings of these codes used in this field are as follows:

R – the capacity rating was verified from manufacturer's data

L – the loss value was verified from manufacturer's data

E – the loss value was estimated

There are many transformers connected to SPS's system that are either owned by a specific customer or have metering or other arrangements to reflect the billing on the high side of the transformer, *i.e.*, before losses are incurred. These transformers are excluded from the loss calculations in Appendix I and may be excluded from Appendix I's list of transformers because SPS does not incur the losses associated with these transformers (the losses are borne by the customer leasing or owning the transformer). In some situations, only a portion of a transformer's capacity is leased, and thus, only a portion of the losses associated with that transformer should be excluded. These transformers are identified by the letter "E" in column K of Appendix I, and the percentage of losses to be excluded is stated in column P. The letter "I" in column K means that 100% of the transformer's losses are included in the loss calculations.

6.1 Distribution Substation Transformer Demand Losses

The demand losses associated with distribution substation transformers have two components. The first component is the magnetizing current losses (no load losses) that are present anytime the transformer is energized. The second component is the load loss for the transformer incurred when power flows through the transformer. Manufacturer's test report data (when available) was used to determine the no load losses and the full load losses when the transformers were loaded to their nominal MVA ratings (Appendix I, column E). Loading of transformers at their nominal MVA rating is referred to in Appendix I as "full load" but this label does not mean that the transformers have no additional capacity. The maximum MVA loading for each transformer is listed in Appendix I, column F. As evidenced by the differences between the values in columns E and F of Appendix I, many transformers can handle loads well in excess of their nominal full load ratings. The no-load demand losses and nominal full load demand losses for each transformer are shown in Appendix I, columns G and H respectively, and totaled for the entire system near the bottom of spreadsheet.

It was assumed for the purposes of this study that the distribution transformers were operating at their nominal MVA ratings at the time of the system peak. This assumption was reasonable, conservative, and necessary. The T&D systems are designed to handle the system's peak load and have additional capacity available in case peak load is greater than forecasted. As can be expected, system load has grown since most of these transformers were originally sized and installed. Thus, at the time of system peak, it is likely that many transformers operated somewhere between their nominal and maximum MVA ratings. Thus, basing losses upon only the nominal MVA loading, as SPS has done, is conservative. Using this assumption was necessary since manufacturers typically provide test data only for losses at the transformer's nominal MVA rating.

6.2 Distribution Substation Transformer Energy Losses

Transformer energy losses also have two components. The first is the no-load energy losses, which occur during every hour of the 2021 Study Period as described previously. Referring to Appendix I, these no load energy losses were calculated by multiplying the no-load demand losses in Watts from manufacturer's test data, column G, by the number of hours in the 2021 Study Period, and then dividing by 1,000,000 to calculate the no load losses in MWh as shown in column M.

The full load energy losses required the calculation of a Load Factor that represents the percent of loading of the distribution substation transformers based on each transformer's nominal MVA rating. The load factor assigned to the distribution substation transformers is shown in Appendix I, column L.

The load factor for the 2021 Study Period is defined as:

$$\text{Load Factor} = \frac{\text{Total Study Period Energy Delivered}}{\text{Max. Demand} \times \text{Hours in Study Period}} \qquad (6.2.1)$$

The following equation was used to calculate the 2021 Study Period full load energy losses:

$$\text{Losses} = \text{Full Load Loss} \times \text{Hours in Period} \times \text{Load Factor} \ / \ 1{,}000{,}000 \qquad (6.2.2)$$

The results of this calculation are shown in Appendix I, column N.

The load factor calculated using formula 6.2.1 is not a pure load factor, such as might be found for a particular rate class. Rather, it represents the composite mix of all customer loads served from Loss Level 4. The demand and energy values used in this load factor calculation come from Appendices B and H and this data comes from rate analysis of the different customer classes on SPS's system. Using the monthly demand peaks and monthly energy deliveries in Appendix H, a composite load is developed which represents the desired substation class load. With the summed energy and demands, the load factor is calculated. These energy and demands are adjusted to account for the generation located on the distribution system as summarized in Appendix B. The annual load factor for primary distribution, Loss Level 4, is shown in Appendix I in cell C312.

6.3 Accounting for Generation Connected to Loss Level 4 – Primary

The section "Demand on Primary Distribution Feeder Lines" shows the calculated load at Loss Level 4 – Distribution Primary. The 36.00 MW adjustment shown on line 318 is the coincident wind and solar primary generation on the distribution primary system from Attachment B at system peak hour, which reduces the power flow through the distribution substation transformers and the primary feeder lines. Note that the Load Factor formula 6.2.1 above also accounts for the demand and energy output of the generation connected to the primary distribution system per the calculation shown in cell C312 in Appendix I. The power supplied by the generation that is connected to the distribution primary voltage level is expected to remain in the distribution primary voltage level and not flow into the transmission voltage levels.

6.4 Calculation of Load at Each Feeder Line Voltage Level

The load at each feeder line voltage level is calculated in the Primary Distribution Feeder Summary Information section of Appendix I. The loading on 33-kV feeder lines, for example, is calculated by determining the ratio of the total nominal MVA of transformers connected to 33-kV feeders (153.30 MVA on line 324) to the adjusted nominal MVA of all distribution substation transformers (3,377.78 on line 324) and then multiplying that ratio by total loading on all distribution feeders (line 319). Thus, for 33-kV feeder lines, the calculated loading is: (153.30/3,377.78) x 2,229.52 MW = 101.19 MW. This value appears at line 325, column C of Appendix I. From this value, the load on transformers with no feeder lines (line 326) is subtracted to yield the load on 33-kV feeder lines, which appears on line 329. Line 327 shows data on total numbers of feeder lines at each voltage level and line 328 shows the number of feeder lines after excluding the portions of transformers that are leased to customers.

7.0 Distribution Primary Feeder Line Losses

The primary distribution system (Level 4 in the loss study) includes the distribution lines (feeders) that transport power from the distribution substation to the distribution line transformers near each customer. The losses associated with these primary distribution feeders are calculated on Appendix J. At the top of Appendix J, the distribution demand and energy are summarized for Loss Levels 4 through 6 for the 2021 Study Period. They are broken out by Loss Levels and represent the demand and energy for each Loss Level of the distribution system. These values shown are derived from Appendix H and will be used throughout the distribution loss calculations. On lines 2 and 13, the demand and energy values are offset by the distribution-connected generation as summarized in Appendix B.

Losses are calculated for the 573.46 feeders operating at 6 nominal distribution voltage levels (33-kV, 22-kV, 13.2-kV, 12.5-kV, 4.16-kV and 2.4-kV). There are 588 feeders connected to the transformers (Appendix I, line 327), but some feeders are connected to transformers whose capacity is shared with customers. Thus, the number of feeders at each voltage level has been reduced in proportion to the nominal MVA of substation transformers at each voltage level leased by customers. The percentage of each transformer's excluded capacity is shown in column P of Appendix I. This process produces fractional feeders that are used to calculate primary distribution feeder losses.

7.1 Distribution Primary Feeder Line Demand Losses

The number of feeder lines and load at each distribution voltage level are derived from lines 328 and 329, respectively, of Appendix I.

The Feeder Line Current, in amps, is:

$$\text{Feeder Current} = \frac{\text{Feeder Load}}{(\sqrt{3}) \times \text{ Feeder Voltage}} \qquad (7.1.1)$$

The Feeder Loss, in watts, for a given voltage level is:

$$\text{Feeder Loss} = 3 \text{ x } (\text{Feeder Current})^2 \text{ x Resistance x Total Feeder Length} \qquad (7.1.2)$$

The length and conductor sizes of each feeder varies considerably, which affects the feeder line's resistance to power flows. The typical conductor size and material for a voltage class was determined by selecting the most common conductor size and material based on the total mileage of each conductor size and material in the three-phase portions of the feeders for a particular distribution voltage class. The average feeder length was determined by sorting the feeders by voltage and dividing the sum of the lengths of the three-phase portions of the feeders by the number of feeders in each voltage range. These results are used in the feeder loss calculations in Appendix J. The total kW demand loss for a given voltage level is obtained by multiplying the demand loss per mile determined above by the total miles of feeder line for the given voltage level. These results are shown in column J in rows 24-30.

7.2 Distribution Primary Feeder Line Energy Losses

These losses were calculated by multiplying the demand energy loss for the entire load served via the primary feeder lines by the hours in the study year and by the loss factor for the entire distribution load. The load factor is determined in Appendix J from the Total Primary Demand and the Total Energy. Note that the Total Primary Demand and Energy have been offset by the distribution primary connected generation from Appendix B. The Loss Factor is determined by the following equation:[2]

$$\text{Loss Factor} = (0.3 \times \text{Load Factor}) + (0.7 \times (\text{Load Factor})^2) \qquad (7.2.1)$$

Thus, the energy losses over the year are determined by the following equation:

$$\text{Loss} = \text{Demand Loss} \times \text{Hours in Study Period} \times \text{Loss Factor} \qquad (7.2.2)$$

8.0 Distribution Line Transformer Losses

Appendix K contains the loss calculations for distribution line transformers, which corresponds to Loss Level 5. The number of meters and transformers are actual counts derived from SPS's records. The meters per transformer data is derived by dividing the number of single-phase and three-phase meters by the number of single-phase and three-phase transformer installations respectively. In calculating losses, it is necessary to distinguish between single phase transformers, which serve single-phase meters used primarily by residential and small commercial customers, and three-phase transformers, which serve three-phase meters used primarily by commercial customers.

8.1 Distribution Line Transformer Demand Losses

Based on consultation with distribution system engineers, typical transformer sizes were chosen as a 25 KVA for single phase meters and 100 KVA for three phase meters. The transformer loss data at no load and full load for both sizes are listed in Appendix K. The average load per meter is developed by taking the demand served and dividing by the number of meters. Then the loss per transformer is developed by taking the load per meter and calculating the losses proportionally to the load served by the transformer and its full load rating. The total demand loss is calculated by multiplying the number of

[2] Westinghouse Electric Corporation, Distribution Systems, 1965, page 28.

transformers by each no-load and full-load loss component. The no-load and load demand losses per typical transformer are shown in Appendix K on lines 29 and 30.

8.2 Distribution Line Transformer Energy Losses

The energy losses were calculated by using the demand energy loss for the distribution line transformers and multiplying by the loss factor of the load served through the distribution transformers and by the number of hours in the 2021 Study Period. The load factor is determined from data in Appendix K using the Total Secondary Distribution Transformer Demand and the Total Secondary Distribution Transformer Energy. The Loss Factor is determined from equation 7.2.1. Thus, the losses over the 2021 Study Period are determined by the following equation.

$$\text{Energy Losses} = \text{Demand Loss} \times \text{Hours in Study Period} \times \text{Loss Factor} \qquad (8.2.1)$$

9.0 Distribution Secondary Losses

The distribution secondary losses are determined in Appendix L and consist of secondary line losses and service line losses. Service to single phase meters was modeled as one single phase meter taking service directly from each single phase distribution line transformer with the balance of the other single phase meters being served from secondary distribution lines. Secondary lines are the lines that typically run from a pole top distribution line transformer to another pole that has no transformer. From that second pole, a service line runs to the customer's premises. Service to three phase meters was modeled as each three phase meter being served directly from a three phase transformer with only a service line (no secondary line).

To determine the single phase secondary line losses, it was determined that the typical secondary conductor was 60 feet of 1/0 ACSR conductor serving the single phase meters not served directly from the transformer. As noted earlier, only single phase meters are modeled to be served through secondary and service lines whereas three phase meters are modeled to be served directly from the transformers through a service line.

9.1 Distribution Secondary Line Demand Losses

The number of calculated single phase meters on each secondary line is shown on line 16. The current value of the single phase loads on one secondary line is calculated by multiplying by the total number of single phase meters served from secondary lines by the demand for one single phase meter and dividing by 0.24-kV. The loss, in watts, on a secondary line was determined by the following equation:

$$\text{Demand Loss} = (2 \times I^2 \times R) \qquad (9.1.1)$$

Multiplying this secondary loss value by the total number of secondary lines yields the total demand loss for all the distribution secondary lines.

9.2 Distribution Service Line Demand Losses

It was determined that the typical service line to a single phase meter consisted of 65 feet of #2 triplex service cable and the typical service line to a three phase meter consisted of 30 feet of #1/0 quadraplex service cable. The current values of the loads for both types of services are calculated and then the losses are calculated using the following equations:

$$\text{Loss} = 2 \times I^2 \times R \text{ , for single phase meters and} \qquad (9.2.1)$$

$$\text{Loss} = 3 \times I^2 \times R \text{ , for three phase meters} \qquad (9.2.2)$$

The total demand loss for single phase and three phase services was determined by multiplying the demand loss per service by the number of meters, which is shown in Appendix K.

9.3 Distribution Secondary and Service Line Energy Losses

The energy losses were calculated by adding the demand loss of both the Secondary Lines and Service Lines and multiplying by the number of hours in the 2021 Study Period and by the loss factor of the load served by Secondary and Services. The load factor is determined from data in Appendix L using the total demand and energy for Loss Levels 5 and 6 and the total hours in the Study Period. The Loss Factor is determined from equation 7.2.1. The losses over the Study Period are determined by the following equation:

Energy Losses = Demand Loss x Hours in Study Period x Loss Factor (9.3.1)

The results of this calculation are shown in Appendix L.

10.0 Summary of the Loss Study

Appendix M summarizes the results of all the loss calculations discussed previously. The power system elements for which losses are determined are:

Transmission Lines
Transmission Autotransformers
Distribution Substation Transformers
Distribution Primary Feeder Lines
Distribution Primary Line Transformers
Distribution Secondary and Service Lines

Line 31 shows the total of the loss values calculated by the study, labeled as "Total Calculated Losses." Line 32, labeled "Total Actual Energy Losses from App. A," is the actual energy losses described in Section 1.2 of this report. The difference in energy loss values between the results of this study and the actual losses is shown on line 33 as "Undeterminable Energy Losses". Typically, the results from a loss study will be within a few percentage points, plus or minus, of the actual losses. For the 2021 Study Period, the Total Calculated Losses are 0.01% lower than the actual losses. ***It should be noted***

that nowhere in this study is the actual loss value used to force the loss study to produce a calculated loss value equal to the actual loss value.

The results of this study are used to determine loss factors for the different rate classes. To do this, the calculated losses must be adjusted to match the actual losses; therefore, the Undeterminable Losses on line 33 must be allocated to Loss Levels 2 through 6. Each category of energy losses is allocated a portion of the Undeterminable Losses equal to the ratio of that category's calculated losses to Total Determined Losses in MWh. For example, under the column heading "Calculated Energy Losses Adjusted to Actual Losses", the value for Transmission Lines – 345-kV on line 2, which is 132,343 MWh, is determined by: 132,327 MWh (line 2 Calculated Energy Losses) x (1,814,151 MWh Total Actual Losses / 1,813,929 MWh Total Calculated Losses).

The values in Appendix M under the column headings "Total Demand Losses, MW" and "Total Energy Losses, MWh" are used in the development of the Loss Level and rate class loss factors.

11.0 Loss Factor Derivation

Appendices O and P contain the calculations of the Loss Level energy and demand loss factors from summary data in Appendix M. The loss factors for each Loss Level are determined by starting with the total Resource input to the system at the Generation Level, Loss Level 1. This value is the starting point for these two appendices. Using Energy Loss Factors in Appendix O as an example, starting in the column titled "kWh Flow into Loss Level" on line 5 for Loss Level 2, the kWh Flow Into Loss Level 2 is equal to the kWh Flow Into Loss Level 1 minus the "kWh Loss by Level" for Level 1 and minus the "kWh Sales for Loss Level" for Loss Level 1. This calculation is done for each Loss Level, with the result that all energy losses and deliveries have been subtracted from the Total Resources with a result of zero. This means that all energy deliveries and losses have been assigned to a Loss Level. Energy Loss Factors are calculated for each Loss Level as shown in the column titled "Loss Factor to Gross Up to Generation."

The process of calculating the Demand Loss Factors in Appendix P is similar to the process described for calculating the Energy Loss Factors in Appendix O. The calculation starts with the system peak demand for the Study Period and is reduced by the Total Demand Losses from Appendix M for that Loss Level and the demand calculated for the load from Appendix H for that Loss Level. After the demand calculations in Load Level 6 are completed, a small amount of remaining demand may result. This small amount of remaining demand may exist because the difference between the actual and calculated demands are not allocated to all the Loss Levels like the "Undeterminable Energy Losses" are. Unlike energy, not all demand is metered with billing class metering when it is delivered to the customer. Therefore, it is not known if this remaining demand was actually load or losses. In order to not affect demand losses positively or negatively, this small remaining demand is not assigned to the load or to the losses.

The energy and demand loss factors are calculated in Appendices O and P where by Loss Level, and a composite Loss Factor for Loss Levels 5 and 6 is also calculated since the losses in these Loss Levels are associated with several Rate Classes as shown in Appendix Q.

Appendix Q shows the Demand and Energy Loss Factors for the different Rate Classes. The demand and energy loss factors in Appendix Q were all calculated in Appendices O and P and shown with the appropriate Rate Classes in Appendix Q. The composite loss factors calculated in Appendices O and P are used for all Rate Classes identified as Loss Levels 5 and 6 in Appendix Q.

Attachment DJR-2 is provided

in electronic format

Attachment DJR-3 is provided

in electronic format