PACIFICORP

Idaho

2018 Electric System Loss Study

April 2020

PacifiCorp
2018 Electric System Loss Study

Executive Summary

The PacifiCorp's 2018 Electric System Loss Study ("Study") for Idaho presents power loss information on Idaho's power systems. This Study only considers technical losses, or losses affiliated with transmitting electricity over Company equipment and does not consider non-technical losses, such as losses attributable to erroneous metering or theft.

The Study developed estimated losses for each level of the system including; transmission, distribution substations, the primary system, service transformers, the secondary system, services and the retail meter. The Study developed separate demand (kW) and energy (kWh) loss factors for each level of service in the power system.

Since it is impractical to perform detailed line loss calculations for each level of the system for every hour of the year, PacifiCorp selected four hours that broadly represent different conditions on its electric system and conducted power flow analyses at these four hours. The four base cases used in the study were as follows:

Table 1: Power Flow Base Cases

PacifiCorp Load	Percent of Peak	Base Case
10,551 MW	100.0%	July 16,@ 17:00 PPT 2018 (Summer Peak)
8,436 MW	80.0%	February 23, 2018 @ 08:00 PPT (Winter Peak)
6,638 MW	62.9%	October 8, 2018 @ 10;00 PPT (Median)
4,757 MW	45.1%	May 4, 2018, @ 03:00 PPT (Minimum)

To extrapolate the losses from the four base cases to hourly (demand) and annual (energy) losses, two separate second-degree polynomial loss functions for each level of the system were developed – one for winter and one for summer. The total hourly losses for each state and loss category are calculated across the entire year and then, once summed, are divided by the appropriate total load to determine the annual loss percentage for each category. Demand losses are calculated based on the sum of the losses at time of the twelve monthly coincident peaks divided by the sum of load at those same times. The demand loss factors and energy loss factors are shown in Tables 2 and 3.

Table 2: Idaho 2018 Demand and Energy Loss Summary

Voltage Class	Demand Loss Factor	Energy Loss Factor
Transmission	3.816%	3.503%
Primary	8.121%	7.082%
Secondary	9.834%	9.061%

Table 3: Distribution System Losses

Functional Category	Demand Loss Factor	Energy Loss Factor
Dist. Substation Transformers	0.355%	0.715%
Primary Lines	3.950%	2.863%
Service Transformers	1.535%	1.827%
Secondary Lines	0.120%	0.094%
Meters	0.058%	0.058%

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INTRODUCTION

PacifiCorp's 2018 Electric System Loss Study ("Study") for Idaho presents power loss information on Idaho's power systems. This Study only considers technical losses, or losses affiliated with transmitting electricity over PacifiCorp ("Company") equipment and does not consider non-technical losses, such as losses attributable to erroneous metering or theft. Information included in the Study includes an overview of the systems analyzed along with a discussion of the methodology employed. The Appendices provide additional supporting data.

METHODOLOGY

PacifiCorp performed a system loss study on its electric system to determine the amount of demand and energy losses occurring by voltage class level. The Study developed estimated losses for each level of the system including; transmission, distribution substations, the primary system, service transformers, the secondary system, services and the retail meter. The Study developed separate demand (kW) and energy (kWh) loss factors for each level of service in the power system.

Since it is impractical to perform detailed line loss calculations for each level of the system for every hour of the year, PacifiCorp selected four hours that broadly represent different conditions on its electric system and conducted power flow analyses at these four hours. The four base cases used in the study were as follows:

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Subsequent sections provide additional detail regarding the technical analysis necessary to determine the losses for each level of the system for the base case.

High Voltage System

Transmission: To calculate losses on the transmission system, PacifiCorp developed detailed power flow models for the base cases for both the PacifiCorp West (PACW) and PacifiCorp East (PACE) balancing authority areas. PacifiCorp utilized the Siemens PTI

PSS/E power flow software program for power flow studies. Transmission planning relied on Western Electric Coordinating Council (WECC) approved base cases to conduct the system Study, which represents the Bulk Electric System (BES). Detailed system models for the PacifiCorp local area non-BES systems were added to the starting base cases. System loads within each of the PacifiCorp balancing authority areas were scaled to represent the four 2018 snapshot load profiles and generation dispatch was adjusted within each of the four cases to approximate the dispatch observed in those four historic hours. Supporting data and calculations are found in Appendix A.

Distribution System

Distribution Substations: The substation detailed network data was added to the starting WECC approved bases cases in both of the PacifiCorp balancing authority areas. The cases were then tuned and solved. After addition of the detailed network data in the four different base cases, transmission and substation losses were extracted from the base cases. Additionally substation losses were grouped by state jurisdiction. Supporting data and calculations are found in Appendix A.

Primary System: A high level loss ranking of primary distribution system networks was performed in order to develop a sample of primary networks by using their electrical characteristics. Specifically, in order to estimate relative range of losses across many circuits in each state, the customer energy usage (summer peak kWh/day), E, and locational positive sequence resistance (primary R_1) for each customer location were used. From the sample set for each state, several networks near the average E^2R_1 were evaluated to determine whether the distribution model was reasonably accurate, and whether detailed load information (typically SCADA at the breaker) was available. Then three to five of these networks were studied in the CYME power flow application, under base case loading conditions.

The kW and kVAR loss results from each state's sample of power flows were reduced to an average value for each base case, and that average value was then multiplied by the total number of distribution networks within the state to estimate the state's total primary system losses. Supporting data and calculations are found in Appendix B.

Secondary System - Service Transformers, Secondary and Service Conductors: An extract from the Company's GIS database was used to evaluate and classify line transformers and to develop impedance models for the associated secondary and service conductors. A summary of parameters extracted from the Company's GIS database is provided in Table C.1.

Manufacturer test records for line transformers procured between CY2012 and CY2015 were used to determine no-load and load loss values for typical transformer sizes based on class, voltage and kVA rating. Current Company standards for the sizing of secondary

and service conductors were used to develop an impedance model and an associated load loss value for the secondary of each line transformer. Hourly load profile data for the delivery of residential and non-residential load at secondary voltage was used distribute load and calculate losses for each base case.

Retail Meter: PacifiCorp contacted meter manufacturers to determine the losses for those meter models used extensively by PacifiCorp throughout its service territory. PacifiCorp then determined the currently-installed population of each meter model and multiplied the population by the losses, as obtained from the manufacturer. This system-wide total was then allocated to each individual state based on the number of customers located in each state. Supporting data and calculations are found in Appendix D.

APPLICATION OF BASE CASE RESULTS TO HOURLY LOSSES

To extrapolate the losses from the four base cases to hourly (demand) and annual (energy) losses, two loss functions for each level of the system were developed; one for winter and one for summer. Generally, the winter line loss function relies on 2018 loads and losses for three points - winter peak, median and minimum power flow results. The summer line loss function relies on 2018 loads and losses for three points - summer peak, median, and minimum power flow results. In some cases the loss functions rely on two points – peak and minimum power flow results.

Once the loss functions were determined, those loss functions were applied to 2018 actual hourly loads to derive hourly losses. Transmission system losses were derived from PacifiCorp West and PacifiCorp East balancing area hourly loads. Primary losses rely on hourly primary and secondary energy volumes by state as determined by load research studies. Transformer losses and secondary losses rely on hourly secondary energy volumes by state as determined by load research studies. Supporting data and calculations are found in the Appendix E.

Appendix A

Table A.1: PacifiCorp West Power Flow Results

	PACW Total Load (MW)	Transmission Losses (kW)	Transmission Losses (%)
Summer Peak	3,659.7	84,865.1	2.32%
Winter Peak	3,645.3	76,849.0	2.11%
Median Load	2,339.5	54,540.9	2.33%
Minimum Load	1,533.6	46,730.4	3.05%

Table A.2: PacifiCorp East Power Flow Results

	PACE Total Load (MW)	Total Losses (kW)	Total Losses (%)	Transmission Losses (kW)	Distribution Losses ID (kW)
Summer Peak	9,063.0	377,254.0	4.16%	352,903.6	2,159.50
Winter Peak	6,661.4	237,239.9	3.56%	220,050.2	1,435.59
Median Load	6,125.3	185,384.3	3.03%	169,658.7	1,329.32
Minimum Load	5,016.8	141,821.2	2.83%	129,131.1	978.10

Table A.3: Base Case Transmission Loss Results

Location	Condition	Total Load (MW)	Transmission Losses (MW)	Transmission Losses (%)
PACW	Summer Peak	3,659.7	84.9	2.32%
	Winter Peak	3,645.3	76.8	2.11%
	Median	2,339.5	54.5	2.33%
	Minimum	1,533.6	46.7	3.05%
PACE	Summer Peak	9,063.0	352.9	3.89%
	Winter Peak	6,661.4	220.1	3.30%
	Median	6,125.3	169.7	2.77%
	Minimum	5,016.8	129.1	2.57%

Table A.4: Base Case Distribution Substation Power Flow Results

Location	Condition	Total Load (MW)	Substation Losses (MW)
ID	Summer Peak	857.6	2.2
	Winter Peak	570.1	1.4
	Median	527.9	1.3
	Minimum	388.4	1.0

Appendix B

Table B.1: Primary Distribution Screened Network Detail

State	Total Networks	Sampled E^2R_1 Networks (% of Total)	E^2R_1 Average of Sample Set	Detailed Load Flow Networks
ID	168	131 (78%)	493,279,060	3

Table B.2: Base Case Primary Loss Results

State	Condition	Average Network kW Loss	Average Network kVAR Loss	State Total kW Loss	State Total kVAR Loss	State Total kVA Loss
ID	Summer Peak	112.5	125.7	18,897	21,125	28,344
	Winter Peak	51.3	103.6	8,616	17,401	19,417
	Median	8.6	9.2	1,446	1,545	4,472
	Minimum	8.0	8.2	1,336	1,385	4,066

Appendix C

Table C.1: Line Transformer GIS Database Extract

Line Transformer (Parameter)	Parameters Value (ex.)
State	UT, WY, ID, OR, WA, CA
Facility Point Number	Ex: 11302001.0069804
Class	Overhead, Padmount,….
Phase(s) Energized	1,2,3
KVA	25,50,...,2500
Primary Voltage (kV)	7.2,12.47,...14.4,19.9
Secondary Voltage	120/240, 120/208, 277/480,…
No. of Connected Customers	1,2,…10,..
Connected Customer Rate Sch.	Residential, Non-Residential

Table C.2: Secondary Voltage Loads (MW)

State	MWH	Load Factor	Loss Factor	Peak Load	July 16, 2018 at 17:00 PPT	February 23, 2018 at 8:00 PPT	May 14, 2018 at 3:00 PPT	October 8, 2018 at 10:00 PPT
ID	1,812,581	37%	16%	566	497	219	114	157

Table C.3: Non-Residential Secondary Voltage Loads (MW)

State	MWH	Load Factor	Loss Factor	Peak Load	July 16, 2018 at 17:00 PPT	February 23, 2018 at 8:00 PPT	May 14, 2018 at 3:00 PPT	October 8, 2018 at 10:00 PPT
ID	1,112,073	---	---	---	376	97	67	94

Table C.4: Residential Secondary Voltage Loads (MW)

State	MWH	Load Factor	Loss Factor	Peak Load	July 16, 2018 at 17:00 PPT	February 23, 2018 at 8:00 PPT	May 14, 2018 at 3:00 PPT	October 8, 2018 at 10:00 PPT
ID	700,508	48%	25%	165	121	123	46	63

Table C.5: Base Case Service Transformer, Secondary and Service Loss Parameters

Class/State	Sum of Transformer Capacity MVA	Sum of Transformer NLL	Sum of Transformer LL at Full Load	Sum of Secondary Losses LL at Full Load	Sum of Service Losses at Full Load
Non-Residential	**14,706.6**	**24.9**	**135.3**	**0.0**	**70.1**
ID	1,110.0	2.0	10.7	0.0	5.6
Residential	**11,984.5**	**23.9**	**130**	**64.9**	**70.7**
ID	716.3	1.5	8.3	2.3	2.9
Total	**26,691.1**	**48.7**	**265.3**	**64.9**	**140.8**

Table C.6: Base Case Service Transformer, Secondary and Service Loss Results

State	Condition	Transformer Input (MVA)	Transformer NLL (MW)	Transformer LL (MW)	Secondary LL (MW)	Service LL (MW)	Retail Load (MVA)
ID	Summer Peak	528.9	3.4	1.7	0.1	0.8	522.9
	Winter Peak	235.0	3.4	0.4	0.1	0.1	230.9
	Median	169.0	3.4	0.2	0.0	0.1	165.3
	Minimum	123.3	3.4	0.1	0.0	0.0	119.7

Appendix D

Table D.1: Meter Populations and Results

Model	Voltage	Losses (W)	Population	Total Losses (Wh) / Day	Final Losses (MWh) / Day
CENTRON Single Phase	120-240	1.08	1,242,427	32,205,241	32.2
CENTRON Polyphase	120-480	1.35	40,253	1,308,110	1.3
KV2C	120-480	1.15	33,717	930,589	0.9
KV2C	120-480	1.17	5,691	159,803	0.2
KV2C	120-480	2.029	47,342	2,305,366	2.3
I-210+c	240	2.184	605,839	31,755,657	31.8
Total			1,975,269	68,664,767	68.7

Table D2: Meter Loss Results

Location	Customers	Annual Losses (MWh)	Losses (aMW)	Loss Percentage
ID	82,994	1,053	0.1	0.06%
Total	1,975,269	25,063	2.9	0.07%

Appendix E

Table E.1: Loss Functions

		Summer			Winter		
	Level	X^2	X	b	X^2	X	b
PACE	Transmission	0.000008	-0.019110	107.107548	0.000044	-0.300927	647.3062433
PACW	Transmission	0.000008	-0.018491	57.680383	0.000004	-0.003855	45.28459738
ID	Substation	-0.000016	0.013210	-0.390300	-0.000067	0.027641	-1.394837
	Primary	0.000140	-0.033208	2.259246	0.000000	0.136937	-16.384230
	Transformer	0.000007	-0.000106	3.449119	0.000015	-0.002289	3.593100
	Secondary	0.000004	0.000058	-0.002362	0.000010	-0.001678	0.112087