TRANSMISSION AND DISTRIBUTION LOSSES BY RATE GROUP IN VERSANT POWER SERVICE AREA

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1 Executive Summary

This report provides an overview of the determination of electric line losses and the assignment and allocation of those line losses to the various customer groups in the Versant Power service area. The line loss factors applicable to the customer groups will become part of the rate tariff that is used to calculate the invoices for customers and load settlement within Versant Power.

The determination of electric line losses includes the analysis of the electric transmission and distribution systems in the Versant service area. The foundation of the loss studies is the electric meter data that documents the power flowing into the system and the power flowing out of the system that is sold or delivered to its customers. The difference between the two is the total electric loss in the system.

The loss in the electric transmission system is further studied through computer simulations of the system to determine the technical loss associated with the operation of the system. The loss in the electric distribution system is also further studied to determine the technical loss associated with the operation of various components of the electric distribution system including step down transformers, the primary system, distribution transformation and the secondary service connection.

The electric system losses are then assigned to all customers that use the various components of the overall electric system. For example, all customers use the electric transmission system and are accountable to pay for the losses on the transmission system while transmission connected customers do not use the electric distribution system and are not accountable for losses on the electric distribution system.

Customer groups are determined on the basis of the use of various components of the overall electric system and customer groups are made up of one or more Rate Classes. The analysis concluded that the following Loss Factors by Customer Groups for Versant Power in total are:

Table 1 Loss Factors and Percentage Loss on an Annual Basis

Annualized Losses	**Loss Factor - Percentage**			**Annual Loss Factor Table**		
Based on 2021	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	1.764%	1.985%	1.948%	0.98236	0.98015	0.98052
Sub Transmission Sales	2.842%	2.942%	2.862%	0.97158	0.97058	0.97138
Primary Distribution Sales	5.816%	6.241%	5.882%	0.94184	0.93759	0.94118
Secondary Sales	8.797%	9.093%	8.864%	0.91203	0.90907	0.91136

Table 2 Loss Factors and Percentage Loss for the Winter Season

Annualized Losses	Loss Factor - Percentage			Annual Loss Factor Table		
Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	2.448%	2.546%	2.533%	0.97552	0.97454	0.97467
Sub Transmission Sales	3.774%	5.164%	4.146%	0.96226	0.94836	0.95854
Primary Distribution Sales	7.834%	9.009%	8.051%	0.92166	0.90991	0.91949
Secondary Sales	11.715%	12.643%	11.981%	0.88285	0.87357	0.88019

Table 3 Loss Factors and Percentage Loss for the Non Winter Season

Annualized Losses	Loss Factor - Percentage			Annual Loss Factor Table		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	1.434%	1.659%	1.617%	0.98566	0.98341	0.98383
Sub Transmission Sales	2.365%	1.683%	2.250%	0.97635	0.98317	0.97750
Primary Distribution Sales	4.801%	4.642%	4.779%	0.95199	0.95358	0.95221
Secondary Sales	7.308%	7.039%	7.256%	0.92692	0.92961	0.92744

Percentages shown represent the average amount of electrical energy that is lost as it travels from the generation facility to the customer's service connection. These losses shown in the tables are based on the energy delivered.

2 Scope and Background

Versant Power is required to file an Open Access Transmission Tariff (OATT) with the Federal Energy Regulatory Commission (FERC). Versant Power also files a Tariff for approval with the Maine Public Utilities Commission. Versant Power coordinates with the North Maine Independent System Administrator (NMISA) and the ISO – New England for the reliable operation and planning of the electric transmission system. This Report is to assist Versant in filings with the various regulatory authorities to identify and quantify losses in Versants' electric system.

The total loss of electricity in a system is determined by summing all energy inserted into the system and then subtracting all of the energy delivered from the system. The energy inserted into the system includes energy production from electrical generators and imports from neighboring utilities. The energy delivered from the system includes energy sold to customers (metered and unmetered) and exports of electricity to neighboring utilities.

This method relies primarily on data read from electric meters and will be referred to as the Top Down Approach. Most of this data is obtained from revenue class meters, current transformers and potential transformers. When energy sales are small and predictable such as for street lights, energy sales may be based on a calculation instead of meter data.

The Top Down approach provides data as to the total loss but does not provide information as to where in the system loss occurs, when the loss occurs or which customers may be responsible for the causation of the loss. Additional methods are used to determine more information as to the occurrence of electrical loss. The additional methods are referred to as the Bottom Up approach.

The Bottom Up approach includes a number of methods that are described in general in Section 4, and are described in more detail in Section 5 in regards to how they were used in studying the Versant system. As a final reconciliation, the losses determined in the Bottom Up approach must equal the total loss in the Top Down approach.

The determination of losses using the Bottom Up approach will consist of two components, the Technical Loss and the Non-Technical loss. The Technical Loss is determined through calculations and computer simulations that provide information into loss regarding where in the system loss occurs, when the loss occurs and which customers may be responsible for the causation of loss. The Non-Technical loss is a reconciliation factor that is equal to the metered loss determined in the Top Down approach minus the Technical Loss.

The Non-Technical loss are those losses that cannot be determined analytically and may also be referred to as Unaccounted for Energy (UFE).

The following Figure illustrates conceptually the balance of energy, the source of data and the reconciliation. The loss factors and percentage losses presented in the table values include both the Technical Losses and the Non-Technical Losses.

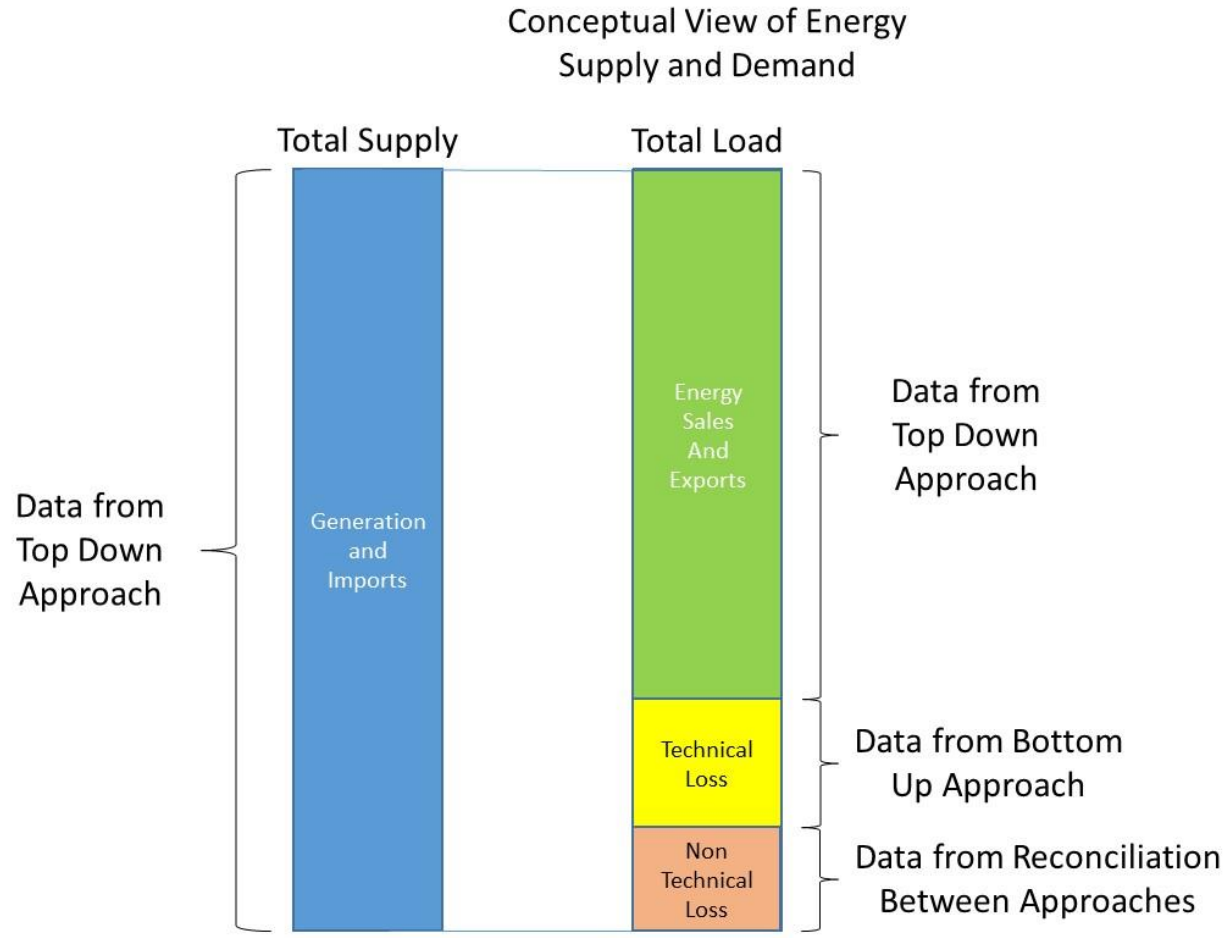


Figure 1 Conceptual Overview of Balance in Energy in an Electric System (not to scale)

3 Versant Power Overview

Versant Power's service is in the State of Maine and is comprised of two service districts – the Bangor Hydro District (BHD) and the Maine Public District (MPD). Each of the two service districts has their own Rate Tariff. This Report considers each of the two service districts individually as well as in total. The following map of the State of Maine show the two service areas. The following map also shows the service area of Versants neighboring utilities of Central Maine Power Company and Eastern Maine Power Cooperative

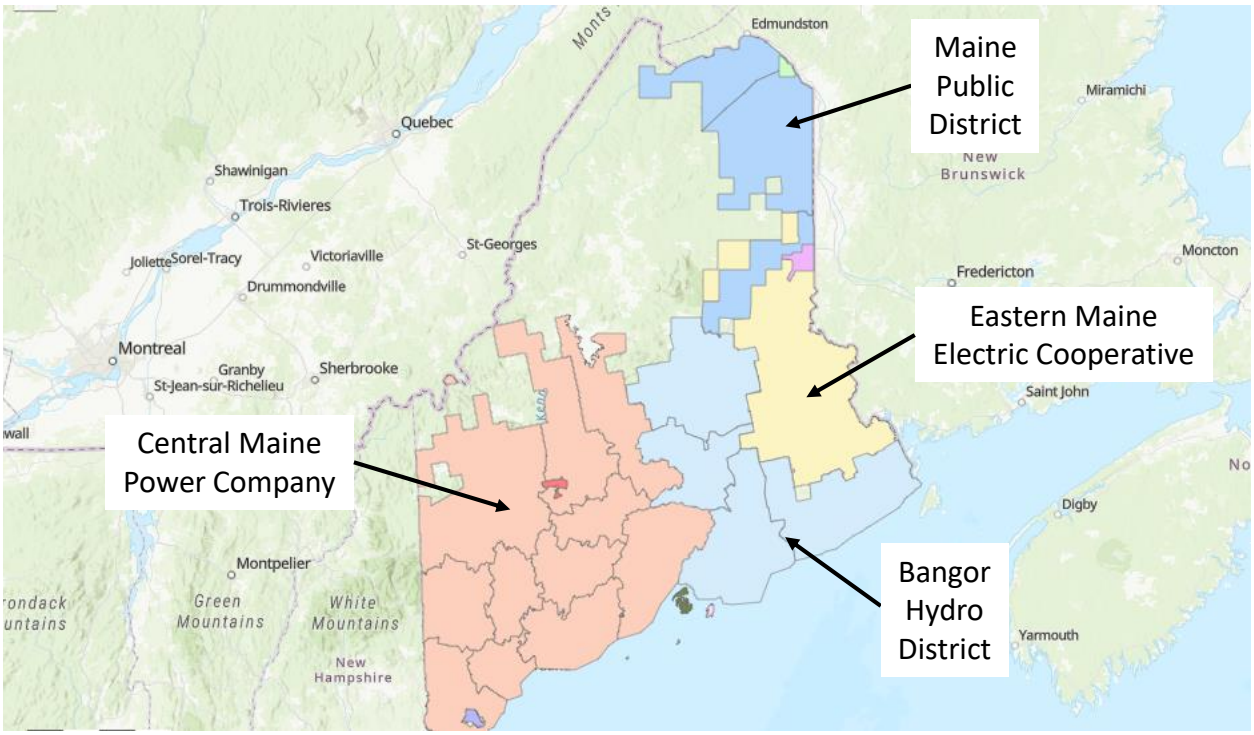


Figure 2 State of Maine Service Areas – Maine Public Utilities Commission

Versant Power provides electric transmission and distribution service to approximately 160,000 customers in the service areas that covers 10,400 square miles. Versant Power has 1,265 miles of transmission lines, 6,090 miles of primary distribution lines and approximately 500 employees. Versant Power delivered a total of 1,493,680 MWh to BHD customers and 507,225 MWh to MPD customers in 2021. Versant has approximately 128,000 residential services, 23,000 commercial services and 128 industrial services. Versant Power was formed from the merger of Bangor Hydro Electric Company and Maine Public Service in January 2014.

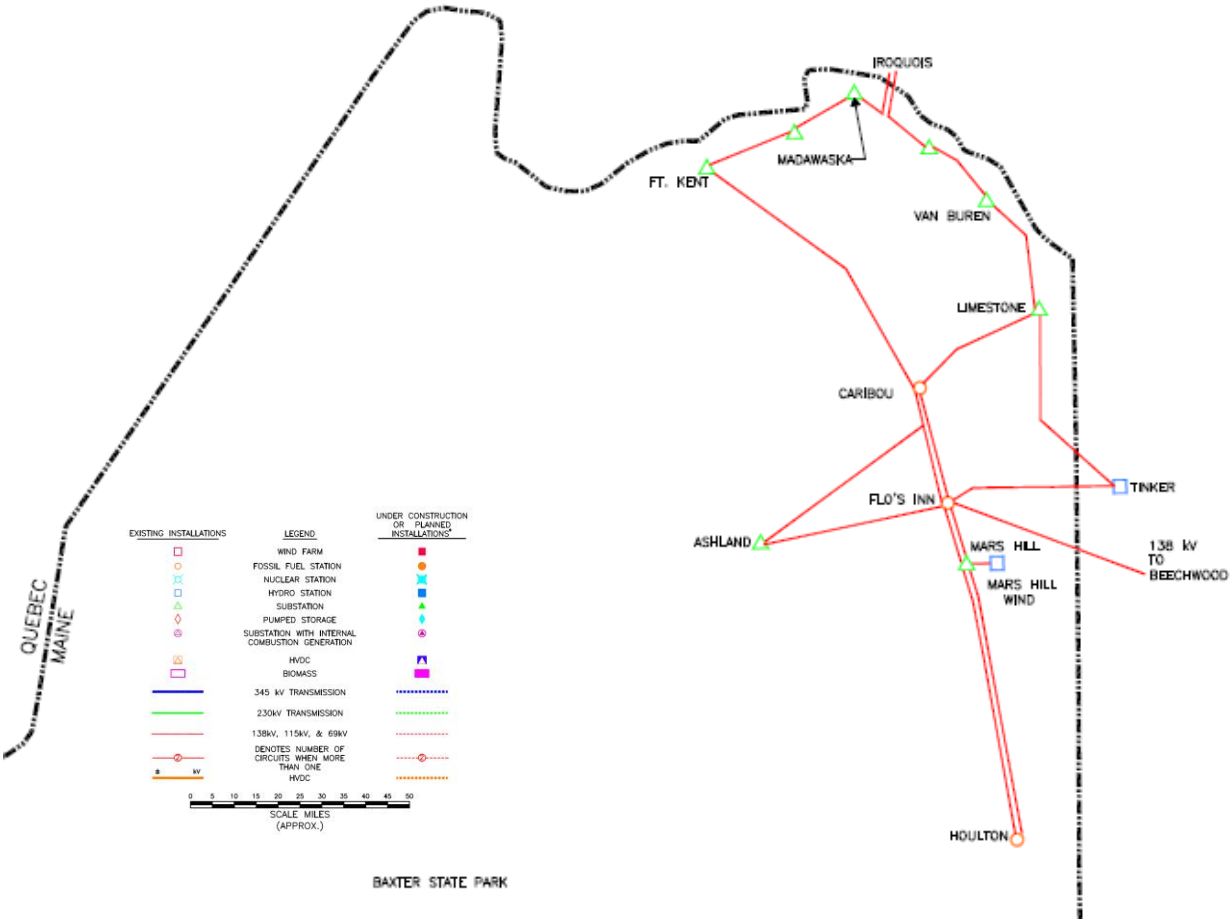


Figure 3 Versant Power – Electric Layout of Maine Public District Service Area - NOR

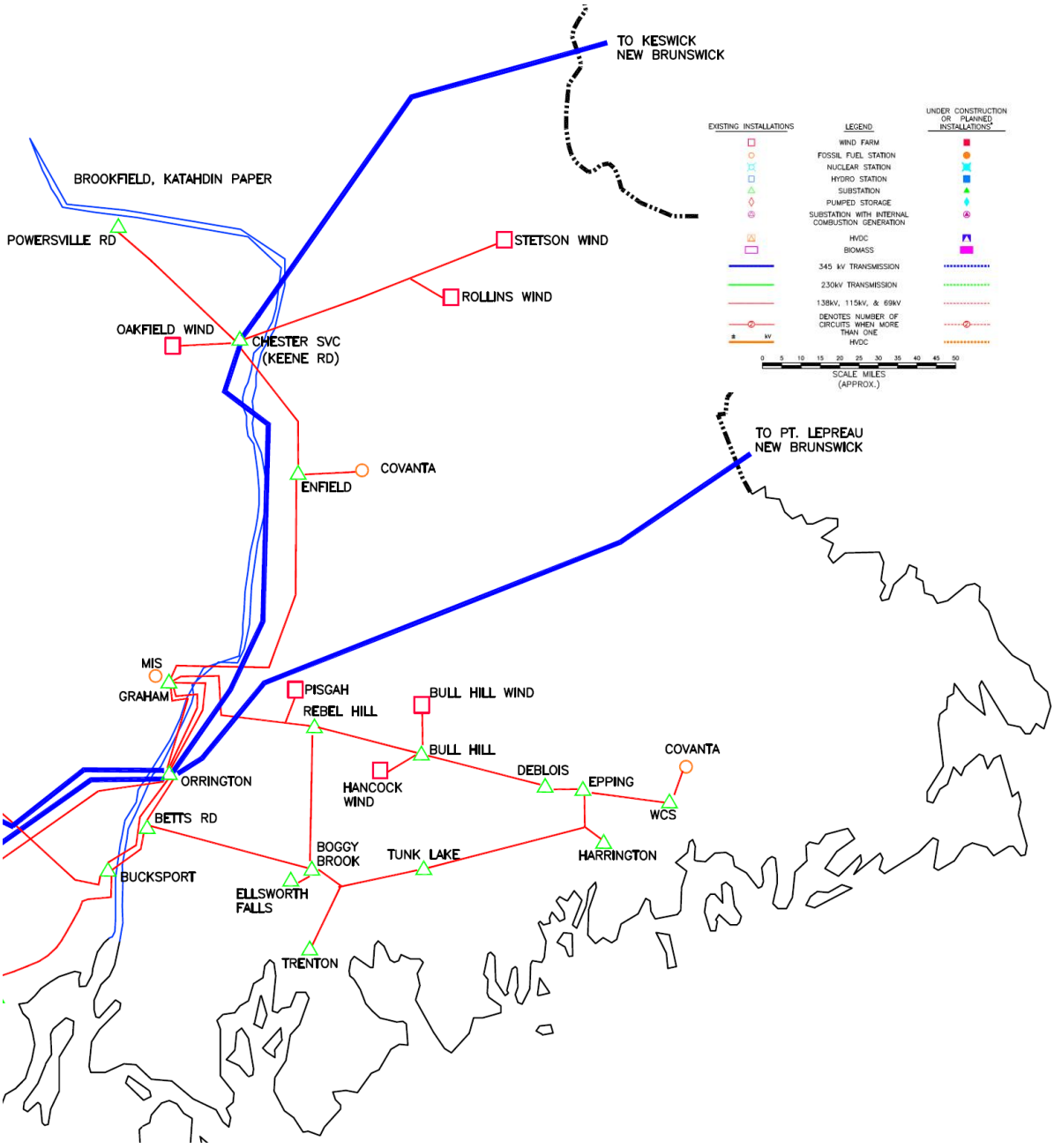


Figure 4 Versant Power – Electric Layout of Bangor Hydro District Service Area - SOR

Figures 3 and 4 are extracted from a larger map from the New England ISO and the full detailed map is shown in Appendix C.

A Block diagram regarding connectivity is shown in Appendix D.

The cost of lost energy is one cost component of all costs that are recovered from the customers through the respective Rate Tariffs. The Bangor Hydro District and the Maine Public District each have

separate Tariffs. Full versions of the Tariffs are available on the Versant Power website at the following URL (as of the date of this report):
VersantPower-BHD-Tariffs-20220701.pdf
VersantPower-MPD-Tariffs-20220801.pdf

The Rate Classes have varying amounts of loss. For example, Residential Service and Street Light Service both include utility owned transformers and secondary cables, and therefore have higher losses than customers such as Transmission Power Service where the utility does not provide transformers and secondaries. Therefore, the following map shows the relationships between the Rate Classes and Customer Groups that are used for determination of loss.

Table 4 Mapping of Sales by Rate Class to Loss Customer Group

BHD Rate Classes	Loss Customer Group
16 Wholesale	Transmission
T1 Transmission	
T1S Transmission	Subtransmission
12 Primary Power	Primary
15 Medium Power Primary	
34 Competitive primary	
01 Residential Service	Secondary
02 Residential Water Heating	
04 General Service	
05 Temporary General Service	
07 Commercial Water Heating	
09 Medium Power Secondary	
11 Residential TOU	
18 Street Lights	
20 Muni Street Lights	
45 Residential Thermal Storage	
47 Residential Heating	
48 Commercial Space Heating	
49 Commercial Space Heating New	
50 Residential Heating New	

MPD Rate Classes	Loss Customer Group
Transmission Power Service - Time of Use	Transmission
Transmission Power Service - Time of Use (Contract)	
Transmission Power Service - Time of Use (Contract)	
Subtransmission Power Service - Time of Use	Subtransmission
Medium Power Service - Primary	Primary
Large Power Service - Primary - Time of Use	
Residential Service	Secondary
Residential Space Heating Rate	
Residential Space Heating Rate (New Installations)	
General Service	
General Service (Non Metered - Flat Rate)	
Municipal Water Pumping Service	
Agricultural Produce Storage Rate	
Snowmaking Rate	
General Service (Contract)	
Medium Power Service - Secondary	
Medium Power Service - Secondary (Contract)	
Large Power Service - Secondary - Time of Use	
Street Lighting Service	
Outdoor Lighting	
Municipal Street Lighting Rate	

Versant Power was instrumental in the preparation for the analysis in this report by providing the required meter data, technical equipment data, SCADA data and technical information regarding the Versant system.

4 Loss Study Overview

Electric energy losses occur whenever electric energy flows through a system. Most of the lost energy manifests through heating of conductors and iron cores. The loss of electric energy is a function of how much electricity is being transported, and the design standards of the electric system. Increased design requirements such as thicker conductors can reduce losses but this comes at an increased capital cost, and there is a tradeoff between capital and operating costs. Utility standards normally consider the tradeoff in costs in the optimization of their systems.

At the highest level, there are two methods to determine loss in a system. The first method is with the use of electrical meters that measure the energy into and out of a system. The difference between the two meter readings is the loss in the system. The second method is the analysis of electrical flow using technical and engineering data to calculate the loss in the component that is being analyzed.

The determination of the total loss on the system is relatively simple because the required meter data is generally readily available. The determination of technical loss on the system is more complex. The determination of technical loss has improved over the years as more meter data becomes available through Supervisory Control and Data Acquisition (SCADA). SCADA is not available on all components of a system, and a hybrid of SCADA and computer simulations are used for the determination of technical loss.

4.1 Transmission System

The main components causing transmission losses are the resistive losses in the conductors in transmission lines and resistive losses in conductors and hysteresis losses in the cores of transformers located in substations.

The Transmission system consists of lines at 345 kV, 138kV, 115 kV and 69 kV and the corresponding substations[1]. The Sub Transmission system consists of 46kV and 34.5 kV and the corresponding substations. There are in total 25 lines at the transmission voltage level and 73 lines at the sub transmission voltage level; many with multiple segments

Transmission line losses are caused by electrical current flowing through the resistance in the conductors. The electrical current (amps) flowing through the conductors is a function of:

- The amount of power flowing in the line,
- The power factor and
- The voltage at which the line is operating.

The resistance (Ohms) of the conductors is a function of:

- The type of conductor and the materials of which it is constructed,
- The size of the conductor,
- The length of the conductor.

The calculation of the heat losses in conductors is shown as follows:

[1] There is a misalignment of FERC defined transmission voltages and VP-MPD rate classes. Transmission in VP-MPD rates includes 69 kV and 44 kV connected customers. Under FERC rules 44kV are sub transmission customers.

$$Loss\ (Watts) = Resistance\ (Ohms)\ \times Current\ (Amps)^2$$

Transformer losses include hysteresis (core magnetizing) and resistive loss in the copper conductor coils. Hysteresis loss is often referred to as no-load loss because this loss is constant, even if there is no load on the transformer. No-load loss does vary with voltage if the transformer is energized at a voltage other than its nominal voltage. The resistive loss in the coils is often referred to as the load loss because the resistive loss is a function of the square of the load on the transformer. Transformer manufacturers provide test data for large transformers, and specifications for small transformers which are used in the determination of losses as follows:

No-load losses are calculated as follows:

$$No\ Load\ Loss\ (NLL) = \frac{NLL_{Test} \times {V_{Actual}}^2}{{V_{Nominal}}^2}$$

Load losses can be calculated as follows:

$$Load\ Loss\ (LL) = \frac{LL_{Test} \times {MW_{Actual}}^2}{{MW_{Nominal}}^2}$$

Versant provided the SCADA data that was available for line voltages and power flows. Transmission line and transformer models were obtained from PSS/E datasets.

PSS/E is the software used in the computer simulations. PSS/E is transmission planning and analysis software owned by Siemens.

4.2 Distribution System

The main components causing distribution losses are the same as in transmission systems. Distribution systems have lower voltage than transmission systems and are configured differently. While transmission systems are typically networks (multiple paths allowing provision of continuous service even when one or more lines are lost from service), distribution systems are typically radial systems (the loss of a component results in an outage for all services downstream of the lost component).
The primary distribution system which is most frequently 12.5 kV, also includes lines at 34.5, 13.2, 8.3 and 4.16 kV feeders. There are a total of 129 distribution feeders in the BHD and 68 distribution feeders in the MPD.

Versant uses CYME software for the planning and analysis modelling of its distribution feeders. CYME models the system at one point in time and may be used to determine the adequacy of the feeder under various forecast conditions. Versant provided the CYME outputs to allow for further analysis.

The CYME outputs were used to determine a Thevenin equivalent resistance for each feeder. This Thevenin resistance is used with hourly SCADA load and voltage data to determine the energy loss over

the year for the Primary Distribution System. CYME models only the primary distribution lines between the transmission system and the step down distribution transformers. The step down distribution transformers and secondaries are modelled separately.

Versant provided a list of distribution step down transformers from its asset management system. Versant also provided specifications for step down transformers that allow for the modelling of losses on the step down transformers. Excel spreadsheets were used to determine the loss on the distribution step down transformers.

Loss on the secondary cables pertains to loss on electric wires between the step down transformers and the customer meters. The loss on secondary cables was determined using Excel spreadsheets and an estimate of the length of and type of secondary cable applicable to each rate class.

4.3 Non-Technical Loss

Following the determination of total loss, and the technical loss, there is a reconciliation for the difference between the two. The difference between the two is referred to as the non-technical loss. Non-technical loss cannot be readily determined by its nature and is calculated as the difference between the total loss and the non-technical loss. The theft of electric energy is generally the largest component of non-technical energy but this will vary from one utility to the next. A general list of the most common forms of non-technical loss include[2]:

- Theft of electric energy,
- Meter error,
- Error in estimates for unmetered service,
- Administrative errors,
- Fraud,
- Loss through contact with vegetation, vehicular or storm damage and lightning,
- Loss through faulty equipment, connections, splices and losses in neutral and ground systems,
- Corona

4.4 Service Provided to Customers

Losses are assigned to customers on the basis of service provided by the utility. For example, where the utility provides a distribution step down transformer, the meter is located at the secondary side of the step down transformer. In this case, the utility incurs energy loss in the transformer and should recover this loss from these customers, where as if the customer is not provided a step down transformer by the utility and the meter is at the primary side of the transformer, the utility does not incur the loss in the transformer and this customer should not be assigned any cost of loss within the transformer (the meter reading already has the customer accountable for this loss).

For residential customers, the meter is typically located on a residence or in a shared utility room, both of which are located some distance from the step down transformer that is typically shared by several customers.

[2] Company use energy was assumed to be billed and cross charged under standard rates.

For street light customers, secondary cables are provided to the street light and power may be provided by a transformer located some distance away and may be shared by other customers, typically residential customers.

For small commercial customers, secondary cables are provided to the meter that is located at the business or in a shared utility room.

For large commercial customers, the meter is located at the secondary side of the step down transformer, and the customer provides their own secondary cables.

For large primary service customers, the meter is located at the primary side of the step down transformer, and the customer provides their own transformer and secondary cables. No loss of transformer or secondary cable is assigned to the large primary service customers.

For transmission and sub transmission connected customers, no distribution losses are assigned or allocated to these customers.

4.5 Distribution Connected Generation

This report is based on the linear flow of energy from the source through the transmission system, the sub-transmission system and through the distribution system.

The total metered energy into the system includes small scale renewable energy facilities that are directly connected to the distribution system. There may also be small scale renewable energy projects connected behind the meter, and the energy production from these projects reduces the metered load at the service. This practice is known as net metering. These projects do not normally generate electricity into the system and are not considered in this study, other than the reduced draw on the system that shows up as a reduction in delivered electricity.

5 Methodology and Results

This section outlines the methods and results of the:

- Top Down approach of total losses on the system,
- Bottom Up approach to determine the technical loss on the system
- Determination of Non-Technical loss through reconciliation between Top Down and Bottom Up approach.

Throughout the analysis there is a recognition of four classes of electrical customers as previously described in Table 4, namely:

1) Transmission
2) Sub transmission
3) Primary Distribution
4) Secondary Distribution

5.1 Total System – Top Down Approach

The total loss on the Versant system was determined for the calendar year 2021. The total energy sales by rate class was summed by Customer Group, and then the Customer Groups are summed to arrive at the total sales. The data is also shown for the Winter and Non Winter seasons.

Table 5 Determination of Total Annual Loss with the Top Down Approach

Total Annual Energy (MWh)			
2021 Annual	BHD (SOR)	MPD (NOR)	Versant (Total)
Generation Production	2,360,262	117,951	2,478,213
Net Tie Line Imports, Wholesale	(747,133)	426,301	(320,832)
2021 Total Energy Inputs	**1,613,129**	**544,252**	**2,157,381**
Transmission Sales	18,756	94,968	113,724
Sub Transmission Sales	97,934	24,357	122,291
Primary Distribution Sales	160,972	29,646	190,618
Secondary Distribution Sales	1,216,018	358,253	1,574,271
2021 Total Energy Sales	**1,493,680**	**507,225**	**2,000,904**
Total Loss	**119,449**	**37,027**	**156,476**
Loss (% of Energy Delivered)	**8.0%**	**7.3%**	**7.8%**

Table 6 Determination of Loss during the Winter Season

Winter Energy (MWh)			
2021 Winter	BHD (SOR)	MPD (NOR)	Versant (Total)
Generation Production	801,844	63,072	864,916
Net Tie Line Imports, Wholesale	(248,518)	186,658	(61,861)
2021 Winter Energy Inputs	**553,325**	**249,730**	**803,055**
Transmission Sales	5,556	38,022	43,578
Sub Transmission Sales	27,986	10,224	38,209
Primary Distribution Sales	52,197	11,854	64,051
Secondary Distribution Sales	413,826	166,070	579,896
2021 Winter Energy Sales	**499,564**	**226,170**	**725,735**
Total Loss	**53,761**	**23,560**	**77,320**
Loss (% of Energy Delivered)	**10.8%**	**10.4%**	**10.7%**
Note: BHD Winter is November through February, MPD Winter is November through March			

Table 7 Determination of Loss during the Non Winter Season

Non Winter Energy (MWh)			
2021 Non Winter	BHD (SOR)	MPD (NOR)	Versant (Total)
Generation Production	1,558,418	56,946	1,615,365
Net Tie Line Imports, Wholesale	(498,615)	239,643	(258,972)
2021 Non Winter Energy Inputs	**1,059,803**	**296,590**	**1,356,393**
Transmission Sales	13,200	56,946	70,146
Sub Transmission Sales	69,949	14,133	84,082
Primary Distribution Sales	108,775	17,792	126,567
Secondary Distribution Sales	802,192	192,183	994,375
2021 Non Winter Energy Sales	**994,115**	**281,054**	**1,275,170**
Total Loss	**65,688**	**15,536**	**81,224**
Loss (% of Energy Delivered)	**6.6%**	**5.5%**	**6.4%**

Losses are generally lower in the Non Winter season indicating the system loading is lighter in the Spring/Fall/Summer than in the Winter.

5.2 Technical Losses, Bottom Up Approach – Transmission System

The electric transmission system provides the function of delivering the electricity from the generators and transmission interconnections to the distribution system for distribution to all of the smaller services. The transmission system may also connect directly to large industrial customers. The electric transmission system generally transmits large volumes of electricity over longer distances.

The transmission system is divided according to voltage into

1) Transmission and
2) Sub-Transmission

5.2.1 Transmission

The electric transmission system includes lines with voltages of 345 kV, 138 kV, 115 kV and 69 kV and the corresponding substations.

Versant uses Siemens PSS/E software to model the system. Transmission line and transformer models from the PSS/E were used to determine the resistances of all major electrical components.

The data from PSS/E were subsequently combined with the 2021 transmission line and substation flow and voltage SCADA data to determine hourly losses on each major system component. Hourly losses are summed for the season or the year to arrive at a total loss for each transmission component. Sum of the losses on all transmission equipment is used together with the energy sales in determining the loss factors.

Losses assumed not to be dependent on the power flow; i.e. transformer magnetizing losses were determined from typical no load test data and nameplate capacity of the transformers for each hour of the year. Transformers were assumed to be energized for the whole year.

Table 8 Transmission System Annual Loss Factor

Transmission System Loss (MWh)	Energy Out of Transmission System			Loss Factor - Transmission		Lost Energy - Transmission		Energy Into the Transmission System		
2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales	18,756	94,968	113,724	1.45%	1.69%	272	1,600	19,028	96,569	115,597
Sub Transmission Sales	98,790	24,551	123,341	1.45%	1.69%	1,433	414	100,223	24,965	125,188
Primary Distribution Sales	166,259	30,700	196,959	1.45%	1.69%	2,412	517	168,671	31,217	199,889
Secondary Distribution Sales	1,285,348	379,519	1,664,867	1.45%	1.69%	18,650	6,396	1,303,998	385,915	1,689,913

The calculation of technical losses occurs on a number of systems that are considered independent for the calculation. The technical losses are built up from the energy delivered to the customer's service entrance. The technical losses from the system closest to the service entrance is calculated and added to the energy that is delivered to determine the total energy into the next system.

Each table has a list of Loss Customer Groups that are correlated to energy sales by Rate Class in Table 4. The Energy Out of the Transmission System is a calculated value based on energy sales by rate class plus technical losses downstream of the Transmission System. The Loss Factor - Transmission is calculated by taking the Lost Energy – Transmission and dividing by the Energy Out of the Transmission System. The

Lost Energy – Transmission is determined by the methods in Section 4 and 5. Finally, the Energy into the Transmission System is determined by the Energy Out of the Transmission System plus the Lost Energy in the Transmission System. These same tables are produced for Annual, Winter and Non Winter and for each of the Transmission, Sub Transmission, Primary Distribution, Distribution Transformers and Secondary Cables.

The energy into the system calculated here is for Technical Loss only and will not match the total energy into the system as shown in the Top Down Approach. In Section 5.4, the Non Technical Losses are determined as the residual between energy in with the Top Down Approach and the energy in with Technical Loss.

Table 9 Transmission System Winter Loss Factors

Transmission System Loss (MWh)	Energy Out of Transmission System			Loss Factor - Transmission		Lost Energy - Transmission		Energy Into the Transmission System		
Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales	5,556	38,022	43,578	1.55%	1.71%	86	650	5,642	38,672	44,314
Sub Transmission Sales	28,217	10,400	38,617	1.55%	1.71%	437	178	28,654	10,578	39,232
Primary Distribution Sales	53,949	12,360	66,308	1.55%	1.71%	836	211	54,784	12,571	67,355
Secondary Distribution Sales	437,721	177,136	614,857	1.55%	1.71%	6,780	3,027	444,502	180,163	624,664

Table 10 Transmission System Non Winter Loss Factors

Transmission System Loss (MWh)	Energy Out of Transmission System			Loss Factor - Transmission		Lost Energy - Transmission		Energy Into the Transmission System		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales	13,200	56,946	70,146	1.40%	1.67%	185	949	13,385	57,895	71,280
Sub Transmission Sales	70,576	14,136	84,713	1.40%	1.67%	989	236	71,566	14,372	85,937
Primary Distribution Sales	112,305	18,316	130,621	1.40%	1.67%	1,574	305	113,879	18,621	132,500
Secondary Distribution Sales	847,608	202,394	1,050,001	1.40%	1.67%	11,880	3,372	859,488	205,766	1,065,254

5.2.2 Sub Transmission

The electric sub-transmission system includes lines with voltages of 46kV and 34.5kV and the corresponding substations.

Losses on sub-transmission system were calculated in a manner identical to that used in calculation of transmission system losses.

Table 11 Sub-Transmission Annual Loss Factor

Sub-Trans System Loss (MWh)	Energy Out of Sub Transmission System			Loss Factor - Sub Trans		Lost Energy - Sub Trans		Energy Into Sub-Transmission System		
2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales	97,934	24,357	122,291	0.87%	0.80%	855	195	98,790	24,551	123,341
Primary Distribution Sales	164,819	30,457	195,276	0.87%	0.80%	1,440	244	166,259	30,700	196,959
Secondary Distribution Sales	1,274,219	376,508	1,650,727	0.87%	0.80%	11,129	3,011	1,285,348	379,519	1,664,867

Table 12 Sub Transmission Winter Loss Factor

Sub-Trans System Loss (MWh)	Energy Out of Sub Transmission System			Loss Factor - Sub Trans		Lost Energy - Sub Trans		Energy Into Sub-Transmission System		
Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales	27,986	10,224	38,209	0.83%	1.73%	231	177	28,217	10,400	38,617
Primary Distribution Sales	53,507	12,150	65,657	0.83%	1.73%	442	210	53,949	12,360	66,308
Secondary Distribution Sales	434,135	174,127	608,262	0.83%	1.73%	3,586	3,009	437,721	177,136	614,857

Table 13 Sub Transmission Non Winter Loss Factor

Sub-Trans System Loss (MWh)	Energy Out of Sub Transmission System			Loss Factor - Sub Trans		Lost Energy - Sub Trans		Energy Into Sub-Transmission System		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales	69,949	14,133	84,082	0.90%	0.02%	628	3	70,576	14,136	84,713
Primary Distribution Sales	111,306	18,312	129,618	0.90%	0.02%	999	4	112,305	18,316	130,621
Secondary Distribution Sales	840,069	202,347	1,042,416	0.90%	0.02%	7,539	47	847,608	202,394	1,050,001

5.3 Technical Losses, Bottom Up Approach – Distribution System

The distribution system provides the function of delivering electricity from the low voltage side of the substations to the customers' meter. As described earlier, there are a variety of different interconnection types or service levels depending on the size and the type of the customer. The large customers may be served with a connection directly to the primary distribution system and a meter on this line. These customers then provide their own transformers and secondary systems. Smaller customers will have Versant provide a transformer with a meter at the low side of the transformer and these customers will provide their own secondary systems. The most common services such as residential services have Versant providing the transformer, secondary cables and then the meter. Each of these connection types will incur different losses on the Versant system as described below.

5.3.1 Substation Step Down Transformers

Substation step down transformers are transformers dedicated to supplying the distribution feeders. The primary of these transformers may be on either transmission or sub-transmission voltage level. Losses for these transformers were determined on an hourly basis using their representation from PSS/E together with voltages and power flows from SCADA. Hourly losses are summed for the season or the year to arrive at a total loss for each transformer.

Losses that are independent of the power flow; i.e. transformer magnetizing losses were determined from typical no load test data and nameplate capacity of the transformers for each hour of the year. Transformers were assumed to be energized for the whole year.

Loss factors are determined by dividing the losses by power flows on the transformers.

Table 14 Substation Step Down Transformer- Annual Loss Factor

Substation Transformer Loss (MWI	Energy Out of Substation Transformer			Loss Factor - Sub Transformer		Lost Energy - Sub Transformer		Energy Into Substation Transformers		
2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales	163,630	29,823	193,453	0.73%	2.12%	1,189	633	164,819	30,457	195,276
Secondary Distribution Sales	1,265,024	368,677	1,633,701	0.73%	2.12%	9,195	7,831	1,274,219	376,508	1,650,727

Table 15 Substation Step Down Transformer-Winter Loss Factor

Substation Transformer Loss (MWI	Energy Out of Substation Transformer			Loss Factor - Sub Transformer		Lost Energy - Sub Transformer		Energy Into Substation Transformers		
Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales	53,121	11,928	65,049	0.73%	1.86%	385	222	53,507	12,150	65,657
Secondary Distribution Sales	431,008	170,944	601,952	0.73%	1.86%	3,127	3,183	434,135	174,127	608,262

Table 16 Substation Step Down Transformer-Non Winter Loss Factor

Substation Transformer Loss (MWI	Energy Out of Substation Transformer			Loss Factor - Sub Transformer		Lost Energy - Sub Transformer		Energy Into Substation Transformers		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales	110,502	17,893	128,395	0.73%	2.34%	804	419	111,306	18,312	129,618
Secondary Distribution Sales	834,001	197,716	1,031,717	0.73%	2.34%	6,068	4,631	840,069	202,347	1,042,416

5.3.2 Primary Distribution System

All distribution connected customers make use of the primary distribution system, while transmission and sub-transmission customers do not make use of this system. Therefore, losses on this system are allocated only to distribution connected customers, primary and secondary.

The primary distribution system losses are a function of the load on the distribution feeder, the conductor type, and the distance that the electricity travels from the source to the customer's service entrance.

Versant uses CYME software to model distribution feeder performance. The CYME model considers one point in time (normally peak load conditions) to calculate the feeder performance at the point in time considered. The outputs of CYME include the feeder load, loss and power factor in the primary conductors. On the basis of the output of the CMYE software, a Thevenin resistance is calculated for the distribution feeder. SCADA data is used for the hourly loads on the feeders. The hourly loads are used together with the Thevenin resistance to determine the loss for each hour. Hourly losses are summed for the season or the year to arrive at a total loss for the primary distribution feeder. The loss is divided by the load to determine the loss factor.

Table 17 Primary Distribution System Annual Loss Factors.

Primary Distribution Loss (MWh)	Energy out of Primary Feeders			Loss Factor - Pri Feeders		Lost Energy - Pri Feeders		Energy Into the Primary Feeders		
2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales	160,972	29,646	190,618	1.65%	0.60%	2,658	177	163,630	29,823	193,453
Secondary Distribution Sales	1,244,473	366,492	1,610,965	1.65%	0.60%	20,551	2,185	1,265,024	368,677	1,633,701

Table 18 Primary Distribution System Winter Loss Factor

Primary Distribution Loss (MWh)	Energy out of Primary Feeders			Loss Factor - Pri Feeders		Lost Energy - Pri Feeders		Energy Into the Primary Feeders		
Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales	52,197	11,854	64,051	1.77%	0.62%	924	74	53,121	11,928	65,049
Secondary Distribution Sales	423,509	169,890	593,399	1.77%	0.62%	7,499	1,054	431,008	170,944	601,952

Table 19 Primary Distribution System Non Winter Loss Factor

Primary Distribution Loss (MWh)	Energy out of Primary Feeders			Loss Factor - Pri Feeders		Lost Energy - Pri Feeders		Energy Into the Primary Feeders		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales	108,775	17,792	126,567	1.59%	0.57%	1,727	101	110,502	17,893	128,395
Secondary Distribution Sales	820,964	196,603	1,017,566	1.59%	0.57%	13,038	1,113	834,001	197,716	1,031,717

5.3.3 Distribution Step Down Transformers

Distribution transformers are provided to all smaller customers with the meter placed downstream of the transformer. This loss factor will apply to all customers who make use of Versant distribution transformers.

Distribution transformers incur energy losses through two ways. The first being losses as electricity flows across the resistance in the copper coils, and these losses may be referred to as copper losses or load losses (this loss is proportional to the square of the load, and if there is no load, there is no copper loss). The second being the loss of energy as the transformer core heats up with the change in magnetic field to induce voltage, and this may be referred to as the iron loss or no load loss (the loss is constant and does not vary with loading on the transformer).

There were a total of 55,141 distribution transformers in the BHD and 15,482 in MPD, for a total of 70,623 transformers. The total capacity associated with these transformers are 984,295 kVA in BHD and 294,220 kVA in MPD. The majority of these transformers have a capacity of less than 50 kVA, with an average capacity of 18 kVA. The smallest transformers have slightly higher losses than larger transformers.

The transformer manufacturer's existing specifications for load losses and no load losses, were applied to the transformers in each of the area's to determine the average distribution transformer loss for each area. The same specifications were used for each area, so any difference in loss is attributable to size

and loading of the transformers. There is insufficient data to determine seasonal loss factors with precision and accuracy, so annual loss factors were used for Distribution Transformers and Secondary Cables.

Table 20 Distribution Transformer Annual Loss Factors

Dist Transformer Loss (MWh)	Energy Out of Dist Transformers			Loss Factor - Dist xformer		Lost Energy - Dist xformer		Energy Into Distribution Transformer		
2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales			-							
Sub Transmission Sales			-							
Primary Distribution Sales			-							
Secondary Distribution Sales	1,222,949	360,295	1,583,244	1.76%	1.72%	21,524	6,197	1,244,473	366,492	1,610,965

Table 21 Distribution Transformer Winter Loss Factors

Dist Transformer Loss (MWh)	Energy Out of Dist Transformers			Loss Factor - Dist xformer		Lost Energy - Dist xformer		Energy Into Distribution Transformer		
Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales			-							
Sub Transmission Sales			-							
Primary Distribution Sales			-							
Secondary Distribution Sales	416,184	167,017	583,201	1.76%	1.72%	7,325	2,873	423,509	169,890	593,399

Table 22 Distribution Transformer Non Winter Loss Factors

Dist Transformer Loss (MWh)	Energy Out of Dist Transformers			Loss Factor - Dist xformer		Lost Energy - Dist xformer		Energy Into Distribution Transformer		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales			-							
Sub Transmission Sales			-							
Primary Distribution Sales			-							
Secondary Distribution Sales	806,765	193,278	1,000,043	1.76%	1.72%	14,199	3,324	820,964	196,603	1,017,566

5.3.4 Distribution Secondary Cables

Small customers such as residential services and street lighting service have secondary cables provided by Versant and the meter is at the end of Versant's secondary cable. The customer is responsible to connect from the meter to their service panel and equipment or house wiring.

As indicated in Section 4.4, only those customers who have secondary cables upstream of the meter, are allocated a portion of losses on the secondary system. There is not sufficient information to determine losses on secondary cables because design standards have changed over time. Therefore, a typical secondary cable design was used where the average secondary cable length is 60 m and a residential load profile was applied to the average residential consumption to determine hourly loss for each hour of the year. The hourly loss is summed and divided by the average residential consumption to arrive at a loss factor of 0.55%. The same method is used to calculate the secondary cable loss for small commercial customers and the loss factor for small commercial customers is 0.58%. The two loss factors are weighted by their percentage of the combined load to arrive at a secondary loss factor of 0.57%. This method was used for both BHD and MPD load.

Table 23 Secondary Cable Annual Loss Factors.

Secondary System Loss (MWh)	Energy Out of Secondary System			Loss Factor - Sec System		Loss of Energy - Sec Sys		Energy Into the Secondary System		
2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales										
Secondary Distribution Sales	1,216,018	358,253	1,574,271	0.57%	0.57%	6,931	2,042	1,222,949	360,295	1,583,244

Table 24 Secondary Cable Winter Loss Factors

Secondary System Loss (MWh)	Energy Out of Secondary System			Loss Factor - Sec System		Loss of Energy - Sec Sys		Energy Into the Secondary System		
Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales										
Secondary Distribution Sales	413,826	166,070	579,896	0.57%	0.57%	2,359	947	416,184	167,017	583,201

Table 25 Secondary Cable Non Winter Loss Factor

Secondary System Loss (MWh)	Energy Out of Secondary System			Loss Factor - Sec System		Loss of Energy - Sec Sys		Energy Into the Secondary System		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	BHD	MPD	BHD	MPD	Versant
Transmission Sales										
Sub Transmission Sales										
Primary Distribution Sales										
Secondary Distribution Sales	802,192	192,183	994,375	0.57%	0.57%	4,572	1,095	806,765	193,278	1,000,043

5.4 Non Technical Loss – Reconciliation

The final step in the Loss and Allocation Study is the reconciliation of Technical Loss with the Total Loss. The Non Technical Loss is the difference between the Total Loss and the Technical Loss. The Non Technical Loss includes factors such as unaccounted for energy (UFE), theft, etc. as described in Section 4.3. The Total Loss from the Bottom Up Approach is divided by the Technical Loss Factor to determine the reconciliation factor. The Technical Loss Factor is prorated up by the reconciliation factor as shown in the following Table.

Table 26 Reconciliation of Annual Total Loss

RECONCILIATION												
Total System Loss (MWh)	Energy Delivered			Loss Factor - Technical Loss			Lost Energy - Technical Loss			Energy Into the Transmission System		
2021	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	18,756	94,968	113,724	1.45%	1.69%	1.65%	272	1,600	1,873	19,028	96,569	115,597
Sub Transmission Sales	97,934	24,357	122,291	2.34%	2.50%	2.37%	2,289	609	2,897	100,223	24,965	125,188
Primary Distribution Sales	160,972	29,646	190,618	4.78%	5.30%	4.86%	7,700	1,571	9,271	168,671	31,217	199,889
Secondary Distribution Sales	1,216,018	358,253	1,574,271	7.24%	7.72%	7.35%	87,980	27,662	115,642	1,303,998	385,915	1,689,913
Total	1,493,680	507,225	2,000,904				98,241	31,442	129,683	1,591,921	538,666	2,130,587
Technical Loss (Total Calculated Lost Energy / Total Energy Delivered)							6.58%	6.20%	6.48%			
Total Loss from Top Down Approach							119,449	37,027	156,476			
Reconciliation Factor Required to Match Total Loss from Top Down Approach							1.216	1.178				

Total System Loss (MWh)	Energy Delivered			Loss Factor - Total Loss			Reconciled to Total Lost Energy			Total Energy In		
2021	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	18,756	94,968	113,724	1.76%	1.98%	1.95%	331	1,885	2,216	19,087	96,853	115,940
Sub Transmission Sales	97,934	24,357	122,291	2.84%	2.94%	2.86%	2,783	717	3,500	100,717	25,073	125,791
Primary Distribution Sales	160,972	29,646	190,618	5.82%	6.24%	5.88%	9,362	1,850	11,212	170,333	31,497	201,830
Secondary Distribution Sales	1,216,018	358,253	1,574,271	8.80%	9.09%	8.86%	106,973	32,576	139,549	1,322,991	390,829	1,713,820
Total	1,493,680	507,225	2,000,904				119,449	37,027	156,476	1,613,129	544,252	2,157,381
							8.00%	7.30%	7.82%			

Table 27 Reconciliation of Winter Loss Factors

RECONCILIATION												
Winter System Loss (MWh)	Energy Delivered			Loss Factor - Technical Loss			Lost Energy - Technical Loss			Energy Into the System		
Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	5,556	38,022	43,578	1.55%	1.71%	1.69%	86	650	736	5,642	38,672	44,314
Sub Transmission Sales	27,986	10,224	38,209	2.39%	3.47%	2.68%	668	354	1,023	28,654	10,578	39,232
Primary Distribution Sales	52,197	11,854	64,051	4.96%	6.05%	5.16%	2,587	717	3,304	54,784	12,571	67,355
Secondary Distribution Sales	413,826	166,070	579,896	7.41%	8.49%	7.72%	30,676	14,092	44,768	444,502	180,163	624,664
Total	499,564	226,170	725,735				34,018	15,813	49,831	533,582	241,984	775,566
Technical Loss (Total Calculated Lost Energy / Total Energy Delivered)							6.81%	6.99%	6.87%			
Total Loss from Top Down Approach							53,761	23,560	77,320			
Reconciliation Factor Required to Match Total Loss from Top Down Approach							1.580	1.490				

Total System Loss (MWh)	Energy Delivered			Loss Factor - Total Loss			Reconciled Lost Energy			Total Energy In		
Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	5,556	38,022	43,578	2.45%	2.55%	2.53%	136	968	1,104	5,692	38,990	44,682
Sub Transmission Sales	27,986	10,224	38,209	3.77%	5.16%	4.15%	1,056	528	1,584	29,042	10,752	39,793
Primary Distribution Sales	52,197	11,854	64,051	7.83%	9.01%	8.05%	4,089	1,068	5,157	56,286	12,922	69,208
Secondary Distribution Sales	413,826	166,070	579,896	11.72%	12.64%	11.98%	48,480	20,996	69,475	462,305	187,066	649,371
Total	499,564	226,170	725,735				53,761	23,560	77,320	553,325	249,730	803,055
							10.76%	10.42%	10.65%			

Table 28 Reconciliation of Non Winter Loss Factors

RECONCILIATION												
Non Winter System Loss (MWh)	Energy Delivered			Loss Factor - Technical Loss			Lost Energy - Technical Loss			Energy Into the System		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	13,200	56,946	70,146	1.40%	1.67%	1.62%	185	949	1,134	13,385	57,895	71,280
Sub Transmission Sales	69,949	14,133	84,082	2.31%	1.69%	2.21%	1,617	239	1,856	71,566	14,372	85,937
Primary Distribution Sales	108,775	17,792	126,567	4.69%	4.66%	4.69%	5,104	829	5,934	113,879	18,621	132,500
Secondary Distribution Sales	802,192	192,183	994,375	7.14%	7.07%	7.13%	57,296	13,583	70,879	859,488	205,766	1,065,254
Total	994,115	281,054	1,275,170				64,202	15,600	79,802	1,058,317	296,654	1,354,971
Technical Loss (Total Calculated Lost Energy / Total Energy Delivered)							6.46%	5.55%	6.26%			
Total Loss from Top Down Approach							65,688	15,536	81,224			
Reconciliation Factor Required to Match Total Loss from Top Down Approach							1.023	0.996				

Total System Loss (MWh)	Energy Delivered			Loss Factor - Total Loss			Reconciled Lost Energy			Total Energy In		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	13,200	56,946	70,146	1.43%	1.66%	1.62%	189	945	1,134	13,389	57,891	71,280
Sub Transmission Sales	69,949	14,133	84,082	2.37%	1.68%	2.25%	1,654	238	1,892	71,603	14,371	85,974
Primary Distribution Sales	108,775	17,792	126,567	4.80%	4.64%	4.78%	5,222	826	6,048	113,997	18,618	132,615
Secondary Distribution Sales	802,192	192,183	994,375	7.31%	7.04%	7.26%	58,622	13,527	72,149	860,814	205,710	1,066,524
Total	994,115	281,054	1,275,170				65,688	15,536	81,224	1,059,803	296,590	1,356,393
							6.61%	5.53%	6.37%			

6 Summary of Results

The analysis concluded that the following Loss Factors by Customer Groups for Versant Power in total are:

Table 29 Loss Factors and Percentage Loss on an Annual Basis

Annualized Losses	Loss Factor - Percentage			Annual Loss Factor Table		
Based on 2021	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	1.764%	1.985%	1.948%	0.98236	0.98015	0.98052
Sub Transmission Sales	2.842%	2.942%	2.862%	0.97158	0.97058	0.97138
Primary Distribution Sales	5.816%	6.241%	5.882%	0.94184	0.93759	0.94118
Secondary Sales	8.797%	9.093%	8.864%	0.91203	0.90907	0.91136

Table 30 Loss Factors and Percentage Loss for the Winter Season

Annualized Losses	Loss Factor - Percentage			Annual Loss Factor Table		
Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	2.448%	2.546%	2.533%	0.97552	0.97454	0.97467
Sub Transmission Sales	3.774%	5.164%	4.146%	0.96226	0.94836	0.95854
Primary Distribution Sales	7.834%	9.009%	8.051%	0.92166	0.90991	0.91949
Secondary Sales	11.715%	12.643%	11.981%	0.88285	0.87357	0.88019

Table 31 Loss Factors and Percentage Loss for the Non Winter Season

Annualized Losses	Loss Factor - Percentage			Annual Loss Factor Table		
Non Winter 2021	BHD	MPD	Versant	BHD	MPD	Versant
Transmission Sales	1.434%	1.659%	1.617%	0.98566	0.98341	0.98383
Sub Transmission Sales	2.365%	1.683%	2.250%	0.97635	0.98317	0.97750
Primary Distribution Sales	4.801%	4.642%	4.779%	0.95199	0.95358	0.95221
Secondary Sales	7.308%	7.039%	7.256%	0.92692	0.92961	0.92744

Percentages shown represent the average amount of electrical energy that is lost as it travels from the generation facility to the service point connected to the grid at the voltage shown. These losses as shown in the tables are based on the energy delivered.

Appendix A – Loss Factor Forms

Losses and loss factors may be expressed in different forms for different purposes. In this report, the losses have generally been represented as percentages that represent the average amount of electrical generation that is lost as it travels from the generation facility to the service point connected to the grid at the voltage level shown. Losses occur due to heat, physical expansion of lines, and other electrical, physical, and thermal means. These percentages are in the range of under 1% for transmission to 10% for secondary voltages, and may vary significantly within this range.

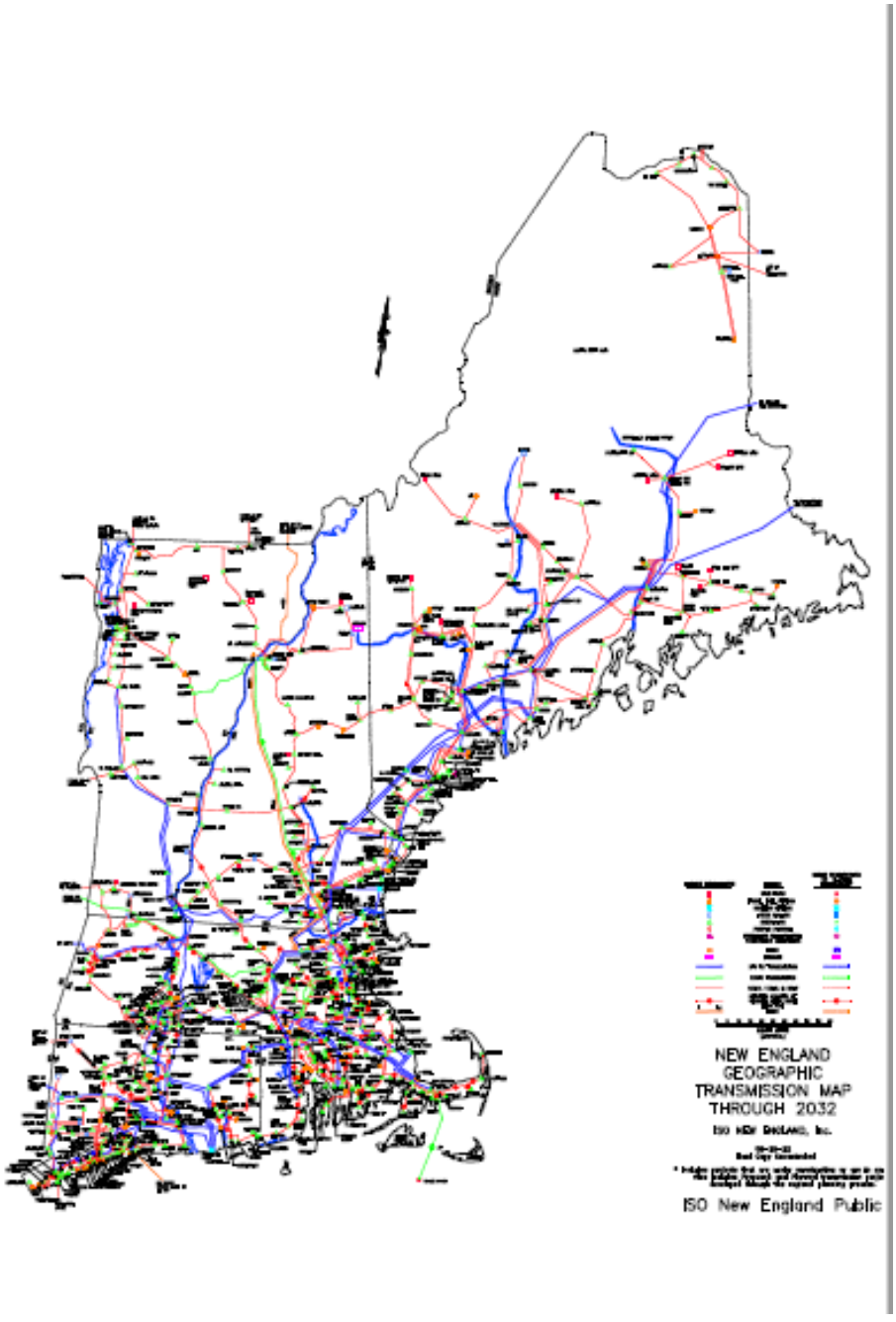
Loss factors used in Versant load settlement are expressed in decimal form, as a number that is slightly more than one. This value represents the amount of generation that needs to be generated (or purchased) in order to deliver one hundred percent to the service point at the voltage level shown. Loss factors are derived from the percentages according to this equation:

Loss Factor = 1 / (loss percentage)

Appendix B–New England ISO Electric Transmission Planning Diagram

The original detailed map can be obtained from the New England ISO at:

[new-england-geographic-diagram-transmission-planning.pdf (iso-ne.com)]



Appendix C–New England Connectivity Block Diagram

The original detailed diagram can be obtained from the New England ISO at:

[Maps and Diagrams (iso-ne.com)]